KINETICS Noise Control

SEISMIC DESIGN MANUAL

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Member VISCMA
(Vibration Isolation and Seismic Control Manufacturers Association)

Forward

An industry leader, Kinetics Noise Control has engineered and manufactured vibration isolation, noise control products and seismic restraint systems for over 40 years. With the advent of recent changes to the building codes, in particular with respect to a building's ability to survive seismic events, there is a new focus on the proper design, application and installation of equipment restraint componentry.

To address this need, Kinetics Noise Control has taken a more active role in the development of new restraint devices that are more effective than those produced by the industry in the past. In conjunction with the development of hardware, this manual has been published as an aid to project specifiers, architects, engineers, and installation contractors.

The primary focus of this manual is to offer a guide to meeting the different requirements specified in the various building codes in ways that are more easily understood than in the original code format. The key to the manual is its ability to link both code and project requirements to products and design solutions with a minimum of effort.

Often raised questions and frequently encountered field problems are addressed in the earlier segments of this manual. Prior to designing or installing a restraint system, those parties involved should read and become familiar with these sections. A full understanding of them will allow an installation to move ahead smoothly with a minimum of difficulty.

Interpretations of code language are included for areas in which there is often confusion. Because this manual is focused on the restraint of equipment, large segments of the existing code language intended to address items beyond the scope of the mechanical system, and generally not of interest to those using this manual, have been reduced to a more manageable size.

Piping and duct restraint is covered in detail because of the high level of input and guidance needed at the field level. Addressed in this section are piping, conduit and ducting systems, cable and strut restraint arrangements, and various anchorage systems.

This manual was written to allow the user to maintain compliance with SMACNA to the maximum extent possible. When there are areas where safe, functional systems can be installed at a lower cost or level of effort than is dictated by the SMACNA guidelines, these are pointed out as possible options. It is not the intent of this manual to be fully SMACNA compatible, however, and when SMACNA is specified the end user should obtain and reference their manual as well.

Also included in this manual are guidelines for determining the level of restraint required and the quantity of restraint components needed for various pieces of equipment in various locations. Different types of restraints are identified with explanations as to which ones might be the most appropriate for particular situations and why.

Design and sizing information for interfacing items such as anchorage components and housekeeping pads are addressed as well.

Kinetics Noise Control Qualifications

In addition to a staff of non-licensed Engineers, Kinetics Noise Control employees include eight licensed Professional Engineers, including three with PhD's and four with Master's degrees. Kinetics Noise Control holds and maintains P.E. licenses in over 30 seismically active or high wind probability states, as well as portions of Canada.

In addition, Engineers from Kinetics Noise Control participate at the national level in the following organizations: BSSC (Building Seismic Safety Council), ASCE (American Society of Civil Engineers), FEMA (Federal Emergency Management Agency), ACI (American Concrete Institute), ASHRAE (American Society of Heating, Refrigeration and Air-conditioning Engineers) - TC-2.6 (Sound and Vibration), TC-2.7 - (Seismic Restraint), ASHRAE/ANSI Standard 171 Development - (Testing Standards for Seismic Devices) and VISCMA (Vibration Isolation and Seismic Control Manufacturers Association).

Kinetics Noise Control has been an active supporter and a leader in developing tools to aid contractors and designers in designing and specifying appropriate restraint devices. Recent accomplishments include authorship of the ASHRAE 2003 HVAC Applications Handbook's Seismic chapter and generation and presentation of several papers on seismic subjects for ASHRAE at the national level and many more at the local chapter level. Kinetics Noise Control supported the development of FEMA's (3) pocket seismic installation guides at both the basic drafting and oversight levels and has authored papers for VISCMA publication, clarifying IBC code provisions.

Kinetics Noise Control offers extensive practical experience in both design and application. Combined, the licensed Professional Engineers of Kinetics Noise Control have a total of over 200 years of experience in the design of components and systems and of this, over 125 years is directly linked to seismic, vibration and sound control systems.

Kinetics Noise Control is an innovative company. Working over the broadest range of markets of anyone in our industry, Kinetics has designed and provided solutions to a large variety of problems or situations. Some of the markets served include:

HVAC Equipment and Piping	Molded Elastomeric Components
Industrial Vibration Systems	Mobile Equipment Applications
MRI Scanners/Electron Microscopes	Acoustic Test Chambers
Architectural Noise Separation	Pipe Flexes
Interior Wall Treatments	Riser System Support
Rigid and Curtain Wall Enclosures	Seismic Restraint Systems
Whole Building Isolation	Bomb Blast Mitigation
Tuned Mass Damping Systems	Rail Isolation Systems
Duct Silencers	Coordinate Measuring Machines
Jet Engine Testing Silencers	Dynamometers

In developing solutions to these and other design challenges, Kinetics Noise Control and/or its employees hold, or have pending, 16 patents. Of these, seven are directly linked to seismic restraint, vibration, and sound control systems.

About the Authors

Paul Meisel, PE, Vice President of Engineering, currently maintains P.E. licenses in ten states. Mr. Meisel has been with Kinetics for over 12 years and prior to that was involved in the design of mining equipment for 17 years. He is an active member of ASHRAE and the author of the ASHRAE 2003 Handbook Seismic Restraint chapter. He is a past member of FEMA's BSSC TS-8 (Restraint of Non-structural Components) Task Group. Mr. Meisel is a regular speaker at ASHRAE functions and the author of two ASHRAE publications related to seismic restraint issues. Mr. Meisel holds or has pending four patents, three directly related to the vibration and seismic control industry.

Richard Sherren, MS, PE, Chief Mechanical Engineer, currently maintains licenses in ten states. Mr. Sherren has been with Kinetics for three years and prior to that worked as an engineering consultant for five years and in the design of heavy construction and mining equipment for 17 years. He is an active member of ASHRAE and a past instructor of college-level engineering, management and CAD courses. Mr. Sherren is a member of ASHRAE committees TC 2.7 (Seismic Restraint) and SPC-171 (Testing of Seismic Restraint Devices). He is author of a paper issued through VISCMA on the interaction between internal and external isolation systems on packaged air handling systems. Mr. Sherren has pending one patent on an innovative method for the seismic restraint of equipment.

Scott Campbell, PhD, PE, Chief Civil/Structural Engineer, currently maintains licenses in seven states. Dr. Campbell has been with Kinetics for three years and has been involved in design, teaching, and research in dynamics for over 18 years. Specializing in nonlinear analysis of structures, a significant amount of the work that Dr. Campbell has done throughout his career has been in the field of blast and seismic design. He is an active member of ASHRAE, ASCE, and ACI and is a current member of FEMA's BSSC TS-8 (Restraint of Non-structural Components). In line with his specialty, Dr. Campbell is also the author of numerous papers and presentations on nonlinear analysis and design for seismic, blast, and vibratory loads.

David Meredith, MS, PE, Export Manager. Mr. Meredith has held his current position since 1994 and is responsible for the design of custom noise and vibration control systems sold by the company. He is also responsible for export sales and marketing, working with the company's overseas sales offices. Prior to assuming his current duties, Mr. Meredith was Chief Engineer for the company. He joined Kinetics Noise Control in 1978 and has recently presented papers and technical lectures at seminars sponsored by the Society of Manufacturing Engineers (Nashville), the International Conference on Structural Dynamics, Vibration, Noise and Control (Hong Kong) and InterNoise '96 (Liverpool, U.K.). Mr. Meredith is a member of the American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc. (ASHRAE), the Acoustical Society of America (ASA), and the Institute of Noise Control Engineers (INCE).

Interpretation of this Publication

Referenced in this publication is information on various Codes and Standards provisions, design and installation procedures and guidelines for satisfying these Codes and Standards. The included information was carefully developed using sound engineering principles to meet these guidelines: however, the final authority and responsibility as to specific design, installation, approval and/or Code interpretations addressed herein rests with the engineer or architect responsible for the specific design. Kinetics Noise Control, Inc., and all contributors to this publication assume no liability for the specific installation of its products or the design, application, approval or interpretation of the requirements or guidelines contained in this publication. It is recommended that all users of this publication, under all circumstances, consult with competent design professionals as well as applicable federal, state, local and contract regulations on requirements for specific installations.

Reprint Permission & Restrictions

Amendments and Updates

Kinetics Noise Control reserves the right to periodically update this document as well as to offer formal interpretations as questions arise. Prior to using this document it is the responsibility of the user to verify that the segment being used is the latest release. Updates can be found on the web at www.kineticsnoise.com.

Proprietary Products

This manual assumes the use of Proprietary Products as provided by Kinetics Noise Control or otherwise identified herein. As not all components have equal capacities, Kinetics Noise Control cannot support or authorize the use of materials that are not under the direct control of Kinetics. Any liability that may result from the application of this manual to materials procured from other sources is not the responsibility of Kinetics Noise Control or its employees.

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HOW TO USE THIS MANUAL
(Overview of Chapter Contents)

This Manual is organized into 2 major sections, *Design and Application Guidelines* and *Product Details*. The *Design and Application Guidelines* segment is intended to provide the user with practical guidance for installation and sizing of Seismic Restraint components. The *Product Details* segment identifies various products and their features, functions and benefits for use in various applications.

It is important to recognize that not all portions of this Manual will be of interest or even of practical use to most users. Instead Architects, Designers, Structural Engineers, HVAC or Plumbing Contractors, Inspectors and/or Code officials will likely be keyed into specific areas relating to their particular field of interest. To that end, the Manual includes adequate redundancy within the Chapters to allow each one to (as much as possible) stand individually.

As an aid to the user, the following section offers general guidance as to what is in each chapter of the manual. When confronted with a design issue or installation problem, the first step of researching a solution would be to quickly review the summaries below. From this, the segment of the manual appropriate to the issue at hand can be identified and a further data can be located quickly and easily.

Section D
Design and Application Guidelines

The Design and Application section is broken into several chapters, each dealing with a somewhat different subject area. Below you will find a listing of these Chapters and immediately after the listing, there is a summary of the material in each Chapter.

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Kinetics Seismic Engineering (D1)

The first chapter (D1) addresses in detail the Design Analysis of Seismic restraint systems as performed by Kinetics Noise Control. The chapter is Analytical in nature and will be of considerably more interest to Designers and Engineers in reviewing the design details of the project than it will be to installation contractors.

Discussed are the items addressed by Kinetics Noise Control in a standard analysis, the items excluded, input information required and interpreting the output.

Purpose, Extent and Limitations of Analysis (D1.1)

This document describes details of exactly what a Seismic Analysis performed by Kinetics Noise Control addresses, what it does not address and why there are limitations. It also indicates the information required from other parties to generate a successful installation and why these independent parties must be involved.

Referenced Standards (D1.2)

This document identifies the various codes and standards used to compile this manual and used as a basis for the calculations and recommendations offered by Kinetics Noise Control.

Overview of the Analytical Methods Used (D1.3)

This segment briefly goes through the procedures used by Kinetics Noise Control to determine the distribution of Seismic loads from the effective center of mass of the restrained system to the various restraint locations. It is not an all-inclusive “cookbook” and as such, does not provide detailed computation instructions. It is intended as an overview to aid in the understanding of the process for Engineers and other design professionals.

Static versus Dynamic Modeling Techniques (D1.4)

This is a commentary on the Pros and Cons of Static versus Dynamic modeling of equipment restraint systems. Appropriateness for various types of applications will also be addressed.

Required Calculation Input (D1.5)

In order to obtain appropriate output from an Analysis, the proper input data is necessary. Listed here is the material needed by Kinetics Noise Control to perform an accurate analysis. Also discussed here are what input data is mandatory and where assumptions can be made to expedite the analytical process. Of necessity, any assumptions made will be conservative. This paper also addresses the potential impact that these assumptions can have on the overall design of the restraint system.

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Understanding Standard Calculation Output (D1.6)

The bulk of Kinetics Noise Control performed calculations are done using a proprietary program that yields standardized output. This paper guides the reader through the output document identifying the locations on the document where input parameters are identified as well as how to understand the output results and how to apply this to “real world” applications.

Understanding Non-Standard Calculation Output (D1.7)

Because not all equipment can be fit into a configuration that can be handled by the proprietary analysis program listed above, this segment will address analyses for various “non-standard” equipment arrangements. Identified are the input and output parameters that must appear in some format to ensure that all appropriate factors are addressed as well are the proper output factors that must be present to ensure selection of the appropriate restraint components.

General Qualifications and Disclaimer (D1.8)

This is simply a copy of the Standard Kinetics Noise Control Seismic disclaimer appropriate for all seismic calculations performed by Kinetics Noise Control. It identifies in detail the extent of the analysis performed by Kinetics Noise Control and it employees. It also lists factors that are beyond the scope of the Kinetics Noise Control analysis and which must be addressed by others.

Seismic Building Code Review (D2)

The second chapter (D2) addresses various Building Codes and details of their requirements. Every attempt has been made in this section to weed out portions of the various codes that are not appropriate for the restraint of non-structural components and mechanical equipment and to convert the remainder of the language into something that can be more easily understood.

This chapter will be of interest to designers, specifiers, estimators and others who are looking to identify areas where seismic restraint is or is not required.

Understanding the IBC Code (D2.1)

This document is a rewording of the 2000 IBC Code focussing on non-structural components and simplified to make it more readily understood by the typical user. It includes references back to the IBC document should anyone reading the section be interested in the exact verbiage in the code.

Pipe Restraint Requirements (IBC) (D2.2)

Pipe restraint requirements as defined by the 2000 IBC code are addressed in detail in this document. This does not include any sizing or installation guidance. It simply defines those pipes that require restraints and those that for one reason or another, can be exempted from this requirement.

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Duct Restraint Requirements (IBC) (D2.3)

Duct restraint requirements as defined by the 2000 IBC code are addressed in detail in this document. Again it does not include any sizing or installation guidance. It simply defines those ducts that require restraints and those that for one reason or another, can be exempted from this requirement.

Pipe Restraint Requirements (SBC, BOCA) (D2.4)

Pipe restraint requirements as defined by both 1997 SBC and the 1996 BOCA codes are addressed in detail in this document.

Duct Restraint Requirements (SBC, BOCA) (D2.5)

Duct restraint requirements as defined by both 1997 SBC and the 1996 BOCA codes are addressed in detail in this document.

Pipe Restraint Requirements (97UBC) (D2.6)

Pipe restraint requirements as defined by the 1997 UBC code is addressed in detail in this document.

Duct Restraint Requirements (97UBC) (D2.7)

Duct restraint requirements as defined by the 1997 UBC code is addressed in detail in this document.

Evaluating Seismic Requirements in Specs (D2.8)

This paper addresses the IBC, UBC, SBC, BOCA and TI-809-04 Requirements. It is an overview document intended to offer insight to estimators and others interested in roughly determining what componentry may be needed to meet Seismic requirements for particular Projects.

National Building Code of Canada Requirements (D2.9)

Non-structural design issues required by the 1995 Canadian Building Code are collected and identified in this document.

Other Referenced Standards (OSHPD, VISCMA, SMACNA) (D2.10)

An overview of other commonly identified standards and design guides are referenced in this paper. These are discussed without going into significant detail on any of them, but do offer the reader some other references and points of view.

Product/Design Overview (D3)

The third chapter of this manual (D3) is more practically oriented than the previous chapters. It is geared toward identifying problems and issues routinely encountered in the field and offers guidance and/or recommendations for resolving them with minimal effort. This section offers the most value if read early in a project as many of the

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recommendations impact design or installation philosophies that once set, can be difficult to modify. It is recommended reading for any group involved in locating, supporting or installing mechanical systems in structures.

10 Biggest Seismic Problems Dealt with by Contractors (D3.1)

This document identifies 10 items that routinely cause problems for installation contractors. Included are identification of the problems as well as alternate less costly designs and possible solutions if the problems are unavoidable.

Cables vs Struts for Ceiling Mounted Pipe/Duct/Conduit Restraint (D3.2)

This is a cautionary document intended only as a warning that Cable and Strut restraint systems behave very differently and different rules must be applied. More detail is available in the Piping, Duct and Conduit sections of the manual.

When to Use Combination Isolator/Restraints (D3.3)

Benefits of using combination Isolator/Restraint components and common applications are addressed here from a design standpoint.

When to Use Separate Isolator/Restraints (D3.4)

Benefits of using separate Isolator/Restraint components and common applications are reviewed from a design standpoint.

High Capacity Restraint Configurations (D3.5)

As the codes have changed and required restraint capacities have increased, older more conventional restraint designs have been found to be insufficient for many applications. This section is an overview of the issues faced when selecting restraints for the more severe applications found today and what avenues are open to optimize the installation.

Hybrid Isolator/Restraints (FMS) (D3.6)

In an effort to provide a more suitable restraint system better tailored to current requirements, KINETICS Noise Control has developed the FMS family of Isolator/Restraints. These components can be mixed and matched to provide a broad range of capacities. In addition, they can be used either as separate restraints or in combined isolator/restraint applications. This section addresses the uses and benefits of the FMS components for many potential applications.

Roof Mounted Equipment Applications (D3.7)

Roof mounted equipment applications have always involved challenges not experienced with indoor applications. These range from wind and weather considerations to variations in structural attachment. Because new code requirements have greatly increased the design force levels at the roof, the design for these applications has become more complicated. This section offers an overview of what is involved.

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Applying Restraint Capacity Ratings (D4)

Chapter D4 of this manual provides a significant level information with regard to the selection of appropriately sized, Seismically rated components for particular applications. Differences between the ASD and LRFD rating systems are addressed as well as how to read, understand and interpret the Seismic rating charts which accompany each Seismic component submittal.

This Chapter includes information critical to anyone involved in making decisions relating to sizing or locating restraints in the field, particularly with regard to piping, duct or conduit installations. The installation of restraints on these systems often requires that design decisions be made in the field. This is the result of issues relating to access, modifications, inaccurate drawing details or a myriad of other reasons that result in the initial drawings not matching the installation. Understanding this information will allow the user to safely size restraints if alternate restraint components or locations are found to be necessary.

The section is recommended reading for Design Professionals or any group responsible for sizing or evaluating the appropriateness of particular restraint devices.

ASD (Applied Stress Design) vs LRFD (Load Resistance Factor Design) (D4.1)

Older Codes have historically used ASD values when sizing components. New Codes have switched to LRFD. When evaluating ratings, all load and capacity data must be converted into the same units or the resulting mismatch can invalidate the analysis. This paper discusses the differences between the two and when a conversion is required to properly size components.

Horizontal/Vertical Seismic Load Capacity Envelopes (Constant) (D4.2)

The most common way of expressing the Seismic Capacity of a Restraint or seismically rated isolator is with a Horizontal/Vertical load capacity chart. This Section explains these charts and how to use them.

Horizontal/Vertical Seismic Load Capacity Envelopes (Variable) (D4.3)

In some combination Isolator/Restraint devices, the supported load affects the seismic rating. Depending on the load or the device, it could increase or decrease the restraint capacity. Charts used to evaluate these kinds of restraints are slightly different than the charts mentioned above and this section explains them and their application.

Force Class (for Hanging Piping, Ductwork, Conduit and Equipment) (D4.4)

Because of the significant number of variables involved, rating cable and strut restraint systems are typically more complicated that rating conventional stand alone restraints. In an effort to simplify sizing these components, Kinetics Noise

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Control has developed the "Force Class" Rating System. In it, A restraint location is assigned a "Force Class" load requirement (I-VI) based on Seismic Zone, Code, Length of Run, Weight per foot of suspended system and Location in the structure. Hardware is also assigned a "Force Class" capacity based on Size, Anchorage and Worst case geometry. These values are such that a "Force Class" I component can generate sufficient capacity to with stand a "Force Class" I Load. It is then a simple matter to select components appropriate to the load. This section describes in detail and provides necessary data to use this system. It is of critical interest to those involved in evaluating pipe, duct or conduit restraint systems.

Force Class Load Determination Table (Sample) (D4.5)

A Sample "Force Class" load rating Table is presented in this document. As these are customized for each installation, this example cannot be used for design without being tailored to the application in question, but if offers a typical example of what might be encountered in practice.

Maximum Restraint Spacing, Run Offset and Drop Length (D4.6)

This is a collection of Tables that allow a user to quickly select appropriate maximum spacing for both lateral and axial restraints as well as determine allowable unrestrained drop lengths maximum allowable offsets. It is appropriate for piping, ductwork and conduit.

Hanger Rod, Strut and Stiffener Tables (D4.7)

When subjected to Seismic Loads (either in Strut of Cable restrained system) Uplift forces are generated in hanger rods. Depending on the magnitude of the force and the length and diameter of the hanger rod, a rod stiffener is often required. This section provides guidance as to how big a stiffener to use and when it is needed.

Cable and Anchorage Ratings (D4.8)

"Force Class" ratings for and application information for various Cable and Cable Anchorage Components are addressed in this section.

Force Class Examples (D4.9)

This section works through some typical "Force Class" applications and sample problems.

Floor & Wall Mounted Equipment (D5)

Design information relative to the anchorage of floor mounted equipment, whether hard mounted or isolated, or wall mounted equipment is provided in this Chapter (D5). Offered are both a technical review of the issues involved as well as more practical installation considerations and options.

This section is recommended reading for Design Professionals or any group responsible

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for sizing or evaluating the appropriateness of particular restraint devices.

Floor Mounted Section

Floor Mounted Equipment Primer (D5.1.1)

This section provides a technical overview of the forces encountered by all floor mounted equipment in seismic applications.

Forces Transferred between Equipment and Restraints (D5.1.2)

A summary of the details relating to the interface between Floor mounted equipment and the restraint is addressed in this document. Items such as impact and load sharing for different restraint arrangements are discussed.

Attachment of Equipment to Restraints (D5.1.3)

In some cases, the direct connection between equipment and restraint is obvious. In others it is not. Issues that need to be understood relative to this connection are highlighted in this paper.

Attachment of Restraints to the Structure (D5.1.4)

There is a wide range of structures to which restraints can be attached. Variations in these structures as well as in the restraints, can significantly impact the capacity of the system.

Oversized Baseplate Section

Oversized Baseplates – How they work and why to use them (D5.2.1)

When connecting to concrete, the brittle nature of the concrete requires that the load capabilities of the hardware be significantly de-rated. As a result, the restraint device normally has considerably more capacity than does the connection. In these cases, an adapter plate can significantly increase the capacity of the system.

Oversized Baseplates – Capacities and Selection Guide (D5.2.2)

This section offers guidance on selecting an appropriate oversized baseplate for a given application.

Wall Mounted Section

Forces Transferred between Wall Mounted Equipment and Restraints (D5.3.1)

The addition of gravity loads increases the requirements for restraint hardware in wall mounted equipment. A brief review of the appropriate factors is addressed in this document.

Attachment of Wall Mounted Equipment to Structure (D5.3.2)

As wall structures are frequently very different from ceiling or floor construction, the

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detail of equipment attachment must also be adapted. This section addresses this interface.

Curb Mounted Equipment (D6)

Design information relative to the connection of curb mounted equipment, whether hard mounted or isolated, is provided in this Chapter (D6). It offers a technical review of curbs and equipment/curb interfaces as well as more practical installation considerations.

This chapter is recommended reading for Design Professionals or any group responsible for sizing or evaluating the appropriateness of curbs and curb mounted restraint devices and curbs themselves. The is also more practical guidance as to how to increase the capacity of non-seismically rated curb assemblies.

Seismic Forces Acting on Curb Mounted Equipment (D6.1)
This section provides a technical overview of the forces encountered by curb mounted equipment in seismic applications.

Sheet Metal Curb Section

Basic Primer for Sheet Metal Curbs (D6.2.1)
An overview of curbs and curb issues is the key goal of this document. It offers the reader a basic understanding of the issues involved.

Attachment of Equipment to Sheet Metal Curbs (D6.2.2)
Making structural connections to sheet metal structures is often difficult. It is the intent of this paper to offer make the reader aware of key factors needed to have a successful installation.

Transferring Seismic Forces through Sheet Metal Curbs (D6.2.3)
Methods of increasing the seismic capacity of unrated sheet metal curbs are addressed in this document.

Attachment of Sheet Metal Curbs to the Building Structure (D6.2.4)
Similar to the equipment connection, making structural connections to sheet metal structures is often difficult. It is the intent of this paper to offer make the reader aware of key factors needed to securely anchor curbs to the supporting structure.

Limitations of Sheet Metal Curbs in Seismic Applications (D6.2.5)
Guidance as to when a sheet metal curb may be appropriate and when it isn't is covered in this paper.

Rules for Using Sheet Metal in Seismic Applications (D6.2.6)
This document is a summary of the previous (D6.2) documents in this chapter

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offering basic guidance without going into detail.

Structural Curb Section

Basic Primer for Structural Curbs (D6.3.1)
An overview of curbs and curb issues is the key goal of this document. It offers the reader a basic understanding of the issues involved.

Attachment of Equipment to Structural Curbs (D6.3.2)
Access, weatherproofing, and secure attachment all make connecting equipment to curbs more difficult than it would be in an interior environment It is the intent of this paper to offer make the reader aware of key factors needed to have a successful installation.

Transferring Seismic Forces through Structural Curbs (D6.3.3)
Methodologies used to maximize the seismic capacity of structural curbs are addressed in this document.

Attachment of Structural Curbs to the Building Structure (D6.3.4)
Because of the long narrow footprint of each of the curb walls, making structural connections to the parent structure is often difficult. It is the intent of this paper to offer make the reader aware of key factors needed to securely anchor curbs to the supporting structure.

Limitations of Structural Curbs in Seismic Applications (D6.3.5)
Guidance as to when structural curbs are suitable and when they are not, are covered in this paper.

Rules for Using Structural Curbs in Seismic Applications (D6.3.6)
This document is a summary of the previous (D6.3) documents in this chapter offering basic guidance without going into detail.

Piping Systems (D7)

This section comprehensively addresses the restraint of Piping systems for seismic applications. It is extremely practical in nature. It avoids the basic sizing of components (which is explained in Chapter D4) and focuses on layout, hardware arrangements, installation options and other issues critical to the installation contractor. Addressed in the section are floor mounted, suspended and vertically oriented systems.

This chapter is recommended reading for Installation contractors, design support for contractors and field inspection personnel.

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Seismic Forces Acting on Piping Systems (D7.1)

This section provides a brief overview of the forces encountered by piping systems exposed to seismic forces and how they generate loads in restraint systems.

Basic Primer for the restraint of Piping (D7.2)

This section addresses different kinds of piping systems, variations between them and provides some general direction in getting started with a restraint plan.

Pros and Cons of Struts versus Cables (D7.3)

While Struts and Cables are often used to perform the same restraint function and because they appear similar to the casual observer, there are significant differences between them that need to be accounted for in the field. This section addresses these issues.

Layout Requirements for Pipe Restraint Systems - Definitions and Locations (D7.4.1)

The basic installation "Rules" for the appropriate restraint of piping systems along with basic definitions of terms used in later sections of this manual make up this section of the manual.

Ceiling Supported Pipe Restraint Arrangements (D7.4.2)

Illustrated here are widely ranging options for the installation of both lateral and axial restraint arrangements acceptable for use on piping systems. Isolated, non-Isolated, single pipe and multiple trapezed pipes are all addressed in this section.

Floor or Roof supported Pipe Restraint Arrangements (D7.4.3)

This section is similar to the one above except that it covers piping that is supported from below, either on floors or for roof mounted applications.

Pipe Restraint Arrangements for Vertical Piping Runs (D7.4.4)

The focus on this section is risers or other vertical runs of piping. Support and restraint arrangements and guidelines for these kinds of applications are addressed in detail in this segment.

Axial Restraint of Steam and High Temp Piping (D7.4.5)

Because of expansion/contraction issues, the axial restraint of steam and other high temperature piping systems can be extremely difficult. This section addresses these areas and includes recommendations to resolve these issues.

Attachment Details - Transferring Forces (D7.5.1)

A key element in the effectiveness of a restraint is the details of the connection. Basic parameters required to ensure that these connections are appropriate for seismic applications are included in this paper.

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Attachment Details – Cable Clamps (D7.5.2)

There are several end connection details that are suitable for cable restraints. Both appropriate and inappropriate connections are identified in this section along with proper installation techniques.

Attachment Details – Piping Attachment (D7.5.3)

The connection between the cable or strut and a piping system can be accomplished in a wide variety of ways and through the use of a wide variety of hardware. A wide variety of acceptable arrangements applicable to a broad variety of possible applications are shown and discussed in this section.

Attachment Details – Attachment to Structure (D7.5.4)

Similar to the connection between the cable or strut and a piping system is the connection between the cable or strut and the structure. Cautions are required to ensure that the structure is not weakened by the connection and that the connection is adequate to transfer the design load. As in the section above, this segment illustrates a wide variety of acceptable arrangements that can accomplish this feat.

Non-Moment Generating Connections (D7.5.5)

Under some conditions, restraints can be avoided if the pipe hanger rod is fitted with a "Non-Moment" generating connection. Additional input on this subject is available in this section.

Connection options for Awkward Situations (D7.6)

Virtually every application will have situations where the basic connection arrangements won't fit or simply are not suitable. This section illustrates several typical "Awkward" situations and offers guidance on possible configurations to incorporate restraints in these areas.

Ductwork (D8)

This section comprehensively addresses the restraint of Ductwork for seismic applications. It is extremely practical in nature. It avoids the basic sizing of components (which is explained in Chapter D4) and focuses on layout, hardware arrangements, installation options and other issues critical to the installation contractor. Addressed in the section are floor mounted and suspended systems.

This chapter is recommended reading for Installation contractors, design support for contractors and field inspection personnel.

Seismic Forces Acting on Ductwork (D8.1)

This section provides a brief overview of the forces encountered by ductwork exposed to seismic forces and how they generate loads in restraint systems.

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Basic Primer for the restraint of Ductwork (D8.2)

This section addresses different kinds of duct systems, variations between them and provides some general direction in getting started with a restraint plan.

Pros and Cons of Struts versus Cables (D8.3)

While Struts and Cables are often used to perform the same restraint function and because they appear similar to the casual observer, there are significant differences between them that need to be accounted for in the field. This section addresses these issues.

Layout Requirements for Duct Restraint Systems - Definitions and Locations (D8.4.1)

The basic installation "Rules" for the appropriate restraint of duct systems along with basic definitions of terms used in later sections of this manual make up this section of the manual.

Ceiling Supported Duct Restraint Arrangements (D8.4.2)

Illustrated here are widely ranging options for the installation of both lateral and axial restraint arrangements acceptable for use on Ductwork. Isolated, non-Isolated, single and multiple trapezed ducts are all addressed in this section.

Floor or Roof supported Duct Restraint Arrangements (D8.4.3)

This section is similar to the one above except that it covers ductwork that is supported from below, either on floors or for roof mounted applications.

Attachment Details - Transferring Forces (D8.5.1)

A key element in the effectiveness of a restraint is the details of the connection. Basic parameters required to ensure that these connections are appropriate for seismic applications are included in this paper.

Attachment Details – Cable Clamps (D8.5.2)

There are several end connection details that are suitable for cable restraints. Both appropriate and inappropriate connections are identified in this section along with proper installation techniques.

Attachment Details – Duct Attachment (D8.5.3)

The connection between the cable or strut and a duct can be accomplished in a wide variety of ways and through the use of a wide variety of hardware. A wide variety of acceptable arrangements applicable to a broad variety of possible applications are shown and discussed in this section.

Attachment Details – Attachment to Structure (D8.5.4)

Similar to the connection between the cable or strut and the ductwork is the connection between the cable or strut and the structure. Cautions are required to

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ensure that the structure is not weakened by the connection and that the connection is adequate to transfer the design load. As in the section above, this segment illustrates a wide variety of acceptable arrangements that can accomplish this feat.

Non-Moment Generating Connections (D8.5.5)

Under some conditions, restraints can be avoided if the duct support hanger is fitted with a “Non-Moment” generating connection. Additional input on this subject is available in this section.

Connection options for Awkward Situations (D8.6)

Virtually every application will have situations where the basic connection arrangements won’t fit or simply are not suitable. This section illustrates several typical “Awkward” situations and offers guidance on possible configurations to incorporate restraints in these areas.

Electrical Distribution Systems (D9)

This section comprehensively addresses the restraint of Conduit and Cable Trays for seismic applications. It is extremely practical in nature. It avoids the basic sizing of components (which is explained in Chapter D4) and focuses on layout, hardware arrangements, installation options and other issues critical to the installation contractor.

Addressed in the section are floor mounted and suspended systems.

This chapter is recommended reading for Installation contractors, design support for contractors and field inspection personnel.

Seismic Forces Acting on Conduit and Cable Trays (D9.1)

This section provides a brief overview of the forces encountered by electrical distribution systems exposed to seismic forces and how they generate loads in restraint systems.

Basic Primer for the restraint of Cable Trays & Conduit (D9.2)

This section addresses different kinds of Distribution systems, variations between them and provides some general direction in getting started with a restraint plan.

Pros and Cons of Struts versus Cables (D9.3)

While Struts and Cables are often used to perform the same restraint function and because they appear similar to the casual observer, there are significant differences between them that need to be accounted for in the field. This section addresses these issues.

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Layout Requirements for Electrical Distribution Restraint Systems - Definitions and Locations (D9.4.1)

The basic installation "Rules" for the appropriate restraint of conduit and cable trays along with basic definitions of terms used in later sections of this manual make up this section of the manual.

Ceiling Supported Conduit/Tray Restraint Arrangements (D9.4.2)

Illustrated here are widely ranging options for the installation of both lateral and axial restraint arrangements acceptable for use on Electrical Distribution systems.

Floor supported Conduit/Tray Restraint Arrangements (D9.4.3)

This section is similar to the one above except that it covers conduit and cable trays that are supported from below, typically in floor mounted applications.

Attachment Details - Transferring Forces (D9.5.1)

A key element in the effectiveness of a restraint is the details of the connection. Basic parameters required to ensure that these connections are appropriate for seismic applications are included in this paper.

Attachment Details – Cable Clamps (D9.5.2)

There are several end connection details that are suitable for cable restraints. Both appropriate and inappropriate connections are identified in this section along with proper installation techniques.

Attachment Details – Conduit/Tray Attachment (D9.5.3)

The connection between the cable or strut and conduit or cable trays can be accomplished in a wide variety of ways and through the use of a wide variety of hardware. A wide variety of acceptable arrangements applicable to a broad variety of possible applications are shown and discussed in this section.

Attachment Details – Attachment to Structure (D9.5.4)

Similar to the connection between the cable or strut and the distribution system is the connection between the cable or strut and the structure. Cautions are required to ensure that the structure is not weakened by the connection and that the connection is adequate to transfer the design load. As in the section above, this segment illustrates a wide variety of acceptable arrangements that can accomplish this feat.

Non-Moment Generating Connections (D9.5.5)

Under some conditions, restraints can be avoided if the conduit support is fitted with a "Non-Moment" generating connection. Additional input on this subject is available in this section.

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Connection options for Awkward Situations (D9.6)

Virtually every application will have situations where the basic connection arrangements won't fit or simply are not suitable. This section illustrates several typical "Awkward" situations and offers guidance on possible configurations to incorporate restraints in these areas.

Suspended Equipment (D10)

This section comprehensively addresses the restraint of Suspended Equipment in seismic applications. It is extremely practical in nature. It avoids the basic sizing of components (which is explained in Chapter D4) and focuses on layout and hardware issues.

This chapter is recommended reading for Installation contractors, design support for contractors and field inspection personnel.

Seismic Forces Acting on Suspended Equipment (D10.1)

This section provides a brief overview of the forces encountered by suspended equipment exposed to seismic forces and how they generate loads in restraint systems.

Basic Primer for the restraint of Suspended Equipment (D10.2)

This section addresses different kinds of by suspended equipment, variations between them and provides some general direction in getting started with a restraint plan.

Pros and Cons of Struts versus Cables (D10.3)

While Struts and Cables are often used to perform the same restraint function and because they appear similar to the casual observer, there are significant differences between them that need to be accounted for in the field. This section addresses these issues.

Suspended Equipment - Definitions and Locations (D10.4.1)

Basic installation "Rules" along with basic definitions of terms used in later sections of this manual make up this section of the manual.

Suspended Equipment Arrangements (D10.4.2)

Illustrated here are a wide range of options for the installation of Restraints suitable for use on suspended equipment.

Attachment Details - Transferring Forces (D10.5.1)

A key element in the effectiveness of a restraint is the details of the connection. Basic parameters required to ensure that these connections are appropriate for seismic applications are included in this paper.

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Attachment Details – Cable Clamps (D10.5.2)

There are several end connection details that are suitable for cable restraints. Both appropriate and inappropriate connections are identified in this section along with proper installation techniques.

Attachment Details – Suspended Equipment (D10.5.3)

The connection between the cable or strut and the equipment can be accomplished in a wide variety of ways and through the use of a wide variety of hardware. A wide variety of acceptable arrangements applicable to a broad variety of possible applications are shown and discussed in this section.

Attachment Details – Attachment to Structure (D10.5.4)

Similar to the connection between the cable or strut and the suspended equipment is the connection between the cable or strut and the structure. Cautions are required to ensure that the structure is not weakened by the connection and that the connection is adequate to transfer the design load. As in the section above, this segment illustrates a wide variety of acceptable arrangements that can accomplish this feat.

Connection options for Awkward Situations (D10.6)

Virtually every application will have situations where the basic connection arrangements won't fit or simply are not suitable. This section illustrates several typical "Awkward" situations and offers guidance on possible configurations to incorporate restraints in these areas.

Architectural Element Restraint Design and Applications (D11)

Most projects include a significant number of non-structural architectural elements that under some conditions require restraint as well. This section relates specifically to vibration-isolated elements and restraint requirements for them.

The most likely audience for this section would be Architects and Structural Engineers responsible for the integrity of the structure.

Floating Floor Restraint Design (D11.1)

This section addresses the basic parameters required to ensure the performance of a floating floor restraint system. Internal forces in the slab as well as appropriate restraint techniques are addressed.

Floating Floor Perimeter Restraint (D11.1.1)

Pros and cons of perimeter restraints are covered in detail in this section.

Floating Floor Internal Restraints (D11.1.2)

In many cases perimeter restraint is either not possible or impractical. For these

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cases internal restraint elements are needed. Information on appropriate internal restraints is available in this section.

Isolated Ceiling Restraint Design (D11.2)

This section addresses the basic parameters required to ensure the performance of an isolated-ceiling restraint system.

Isolated Ceiling Perimeter Restraint (D11.2.1)

Pros and cons of perimeter restraints are covered in detail in this section.

Isolated Ceiling Internal Restraints (D11.2.2)

In many cases perimeter restraint is either not possible or impractical. For these cases internal restraint elements are needed. Information on appropriate internal restraints is available in this section.

Isolated Wall Restraint Design (D11.3)

This section addresses the basic parameters required to ensure the performance of an isolated-ceiling restraint system.

Isolated Walls Restrained at the Top and Bottom (D11.3.1)

Pros and cons of perimeter restraints are covered in detail in this section.

Isolated Wall Internal Restraints (D11.3.2)

In many cases top and bottom restraint is either not possible or impractical. For these cases internal restraint elements are needed. Information on appropriate internal restraints is available in this section.

Kinetics Seismic Specification (D12)

Recommended long format Specifications

Long Form Specification (D12.1)

Comprehensive long form specifications as appropriate for inclusion in contract documents.

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HOW TO USE THIS MANUAL
(Overview of Chapter Contents)

Section P
Product Details

The Product Detail section is broken into several chapters, each dealing with different Seismically related products. Below you will find a listing of these Chapters and immediately after the listing, there is a summary of the material in each Chapter.

Seismic Mounting Brackets (P1)

The first Product Section includes information on standard attachment brackets used by Kinetics Noise Control for the direct attachment of hard or pad mounted equipment to structures. Both Geometrical and capacity data is included for each component.

General Description (P1.1)

A general description of these items is provided along with information on recommended applications.

Floor Mounted Equipment

Submittal Data (KSMS) (P1.2.1)

Design information and installation information on the KSMS (Equipment Attachment) mounting clip is provided in this section.

Submittal Data (KSMG) (P1.2.2)

Design information and installation information on the KSMG (Isolation Pad

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Mounted Equipment) mounting clip is provided in this section.

KSMS and KSMG Locating Guide (P1.2.3)

Standard orientation and placement information for KSMS and KSMG clips can be found in this segment.

Curb Mounted Equipment

Submittal Data (KSMF) (P1.3.1)

Design information and installation information on the KSMF (Mushroom Fan mounting clip) is provided in this section.

Submittal Data (KSCM-1) (P1.3.2)

Design information and installation information on the KSCM-1 (Curb Mounting Kit 1 (1 piece)) Equipment mounting clip is provided in this section.

Submittal Data (KSCM-2) (P1.3.3)

Design information and installation information on the KSCM-2 (Curb Mounting Kit 2 (2 piece)) Equipment mounting clip is provided in this section.

Submittal Data (KSCV) (P1.3.4)

Design information and installation information on the KSCV (Curb Mounted Vertical Restraint Kit) Equipment restraint clip is provided in this section.

Submittal Data (KSVR) (P1.3.5)

Design information and installation information on the KSVR (Sheet Metal Curb Reinforcement Kit) is provided in this section.

Clip Selection Information

Selection Information (P1.4)

General component selection guidance for the above listed hardware is offered in this document.

FMS Isolators and Restraints (P2)

With the advent of higher restraint capacity requirements in the field, Kinetics Noise Control has developed the FMS modular isolator/restraint family. These restraints have many features that are new and different in the marketplace and can offer significant benefits to the user. This Chapter addresses this isolator/restraint in detail.

The FMS will be of interest to anyone attempting to restrain extremely heavy equipment, equipment in seismically active areas and/or equipment that is going to be attached to concrete.

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General Description (P2.1)

A general description of the FMS, it's features, functions, benefits as well as practical applications are provided in this section.

FMS Restraint Data

FMSAA Restraint Submittal Data (P2.2.1)

FMSAA Submittal and Design information data is provided in this section.

FMSA Restraint Submittal Data (P2.2.2)

FMSA Submittal and Design information data is provided in this section.

FMSB Restraint Submittal Data (P2.2.3)

FMSB Submittal and Design information data is provided in this section.

FMSC Restraint Submittal Data (P2.2.4)

FMSC Submittal and Design information data is provided in this section.

FMSD Restraint Submittal Data (P2.2.5)

FMSD Submittal and Design information data is provided in this section.

FMSE Restraint Submittal Data (P2.2.6)

FMSE Submittal and Design information data is provided in this section.

FMSF Restraint Submittal Data (P2.2.7)

FMSF Submittal and Design information data is provided in this section.

FMSG Restraint Submittal Data (P2.2.8)

FMSG Submittal and Design information data is provided in this section.

FMS Spring Coil Data

FMS 1" Deflection "A" Coil Isolator Data (P2.3.1)

Data for 1" deflection coils used in conjunction with the FMS Restraint ranging in capacity from 35 to 1600 lb is illustrated in this document.

FMS 1" Deflection "C" Coil Isolator Data (P2.3.2)

Data for 1" deflection coils used in conjunction with the FMS Restraint ranging in capacity from 250 to 14,000 lb is illustrated in this document.

FMS 2" Deflection Coil Isolator Data (P2.3.3)

Data for 2" deflection coils used in conjunction with the FMS Restraint ranging in capacity from 100 to 18,000 lb is illustrated in this document.

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FMS 4" Deflection Coil Isolator Data (P2.3.4)

Data for 4" deflection coils used in conjunction with the FMS Restraint ranging in capacity from 100 to 23,200 lb is illustrated in this document.

FMS Restraint Selection Information (P2.4)

Seismic ratings and technical application data for use on FMS type Isolators.

FMS Load Spreader Plate Data (P2.5)

This section addresses application data for FMS restraints fitted with oversized baseplates.

FMS Installation Instructions (P2.6)

Comprehensive Installation Instructions for the FMS Isolators and Restraints can be found in this segment of the chapter.

FHS, FLS and FLSS Seismic Isolators (P3)

Design and selection data for the FHS, FLS and FLSS lines of Seismically rated Isolators are available here. These older isolators are used commonly throughout the industry.

Data here is of interest to specifiers, installation contractors and design professionals involved in the restraint selection process.

General Description (P3.1)

A general description of the FHS, FLS and FLSS isolators begins this chapter. Their features, functions, benefits as well as practical applications are provided in this section.

FHS Restraint Submittal Data (P3.2.1)

Design information and capacity information for the FHS Isolator line is provided in this section.

FLS Restraint Submittal Data (P3.2.2)

Design information and capacity information for the FLS Isolator line is provided in this section.

FLSS Restraint Submittal Data (P3.2.3)

Design information and capacity information for the FLSS Isolator line is provided in this section.

FLS, FLSS, FHS Selection Information (P3.3)

Design Selection and guidance information to be used in conjunction the FHS, FLS and FLSS Isolators are summarized in this document.

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FHS, FLS and FLSS Load Spreader Plates (P3.4)
Load Spreader Plates and the resulting increase in performance for concrete anchorage applications are addressed in this section.

FHS, FLS and FLSS Installation Instructions (P3.5)
Comprehensive Installation Instructions for the FHS, FLS and FLSS Isolators can be found in this segment of the chapter.

KRMS and RQ Elastomeric Seismic Isolators (P4)

Design and selection data for the KRMS and RQ lines of Seismically rated Isolators/Mounts are available here.

Data here is of interest to specifiers, installation contractors and design professionals involved in the restraint selection process.

KRMS General Description (P4.1.1)
A general description of the KRMS Isolator begins this chapter. Their features, functions, benefits as well as practical applications are provided in this section.

RQ General Description (P4.1.2)
Descriptive information and specifications on the RQ Isolators are addressed here.

KRMS Restraint Submittal Data (P4.2.1)
Design information and capacity information for the KRMS Isolator line is provided in this section.

RQ Seismic Mount Submittal Data (P4.2.2)
Design information and capacity information for the RQ Mount family is provided in this section.

KRMS and RQ Selection Information (P4.3)
Design Selection and guidance information to be used in conjunction the KRMS and RQ Isolators/Mounts are summarized in this document.

KRMS and RQ Load Spreader Plates (P4.4)
Load Spreader Plates and the resulting increase in performance for concrete anchorage applications are addressed in this section.

KRMS and RQ Installation Instructions (P4.5)
Comprehensive Installation Instructions for the KRMS and RQ Isolators/Mounts can be found in this segment of the chapter.

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HS Series Seismic Restraints (P5)

Design and selection data for the HS lines of Seismic Restraints/Snubbers are available here.

Data here is of interest to specifiers, installation contractors and design professionals involved in the restraint selection process.

General Description (P5.1)

A general description of the HS-2 and HS-5 Restraint/Snubbers begins this chapter. Their features, functions, benefits as well as practical applications are provided in this section.

HS-2 Restraint/Snubber Submittal Data (P5.2.1)

Design information and capacity information for the HS-2 Restraint/Snubber is provided in this section.

HS-5 Restraint/Snubber Submittal Data (P5.2.2)

Design information and capacity information for the HS-5 Restraint/Snubber family is provided in this section.

HS-2 and HS-5 Selection Information (P5.3)

Design Selection and guidance information to be used in conjunction the HS-2 and HS-5 Restraint/Snubbers are summarized in this document.

HS-2 and HS-5 Load Spreader Plates (P5.4)

Load Spreader Plates and the resulting increase in performance for concrete anchorage applications are addressed in this section.

HS-2 and HS-5 Installation Instructions (P5.5)

Comprehensive Installation Instructions for the HS-2 and HS-5 Restraint/Snubbers can be found in this segment of the chapter.

ESR / KSR / KSCR Seismically Rated Roof Curbs (P6)

Design and selection data for the ESR / KSR and KSCR Seismically rated Isolation curbs or curb isolation rails are available here.

Data here is of interest to specifiers, installation contractors and design professionals involved in the restraint selection process.

General Description (P6.1)

A general description of the ESR / KSR and KSCR begins this chapter. Their

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features, functions, benefits as well as practical applications are provided in this section.

ESR Restraint Submittal Data (P6.2.1)
Design information and capacity information for the ESR Isolation Curb is provided in this section.

KSR Isolation Rail Submittal Data (P6.2.2)
Design information and capacity information for the KSR Curb-top Isolation Rail is provided in this section.

KSCR Curb Submittal Data (P6.2.3)
Design information and capacity information for the KSCR Isolation Curb is provided in this section.

ESR / KSR / KSCR Selection Information (P6.3)
Design Selection and guidance information to be used in conjunction the KRMS and RQ Isolators/Mounts are summarized in this document.

ESR Load Spreader Plates (P6.4)
Load Spreader Plates and the resulting increase in performance for concrete anchorage applications are addressed in this section.

ESR / KSR / KSCR Installation Instructions (P6.5)
Comprehensive Installation Instructions for the ESR / KSR / KSCR Curb Systems can be found in this segment of the chapter.

Cable and Wire Rope Restraints (P7)

Design and selection data for a wide range of Cable restraint kits and hardware is included in this section.

Data here is of interest to specifiers, installation contractors and design professionals involved in the restraint selection process.

General Description (P7.1)
A general description of the tradeoffs and benefits of the various different cable arrangements begins this chapter. Their features, functions as well as practical applications are provided in this section.

Fixed Length Cable Kits (Swaged End) Submittal Data (P7.2.1 through P7.2.6)
Design and capacity information for the wide range of cable hardware kits offered by Kinetics Noise Control is provided in these sections.

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Bulk Length Cable Kits (Not Swaged) Submittal Data (P7.3.1 through P7.3.7)
Design and capacity information for the wide range of cable hardware kits offered by Kinetics Noise Control is provided in these sections.

Cable Anchorage Kits Submittal Data (P7.4.1 through P7.4.4)
Design and capacity information for the wide range of cable hardware kits offered by Kinetics Noise Control is provided in these sections.

Cable Restraint Selection Information (P7.5)
Design Selection and guidance information to be used in conjunction the various cable kits are summarized in this document.

Cable Restraint Installation Instructions (P7.6)
Comprehensive Installation Instructions to be used in conjunction the various cable kits can be found in this segment of the chapter.

Other Hardware Required for use with Suspended Equipment (P8)

Proper restraint design for many suspended equipment applications requires the use of additional hardware "accessory" items. Design and selection data for these components is included in this section.

Data here is of interest to specifiers, installation contractors and design professionals involved in the restraint selection process.

General Description (P8.1)
A general description of these pieces of hardware and their function are provided in this section.

KHRC-A (Rod Stiffener Clamps for Angles) Submittal Data (P8.2.1)
Design information is provided in this section.

KHRC-P (Rod Stiffener Clamps for Pipe) Submittal Data (P8.2.2)
Design information is provided in this section.

KCHB (Pipe Clevis Internal Brace) Submittal Data (P8.2.3)
Design information is provided in this section.

KSCA (Cable/Strut Attachment Bracket) Submittal Data (P8.2.4)
These components are included in many of the cable kits, but are also available separately. Design information is provided in this section.

KSUA (Cable Attachment Bracket) Submittal Data (P8.2.5)
These components are included in many of the cable kits, but are also available

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separately. Design information is provided in this section.

KSCC (Cable/Strut Attachment Bracket) Submittal Data (P8.2.6)
These components are included in many of the cable kits, but are also available separately. Design information is provided in this section.

Cable Hardware Selection Information (P8.3)
Design Selection and guidance information to be used in conjunction the various suspended equipment hardware components are summarized in this document.

Cable Hardware Installation Instructions (P8.4)
Comprehensive Installation Instructions to be used in conjunction the various hardware components can be found in this segment of the chapter.

Restraint Components for Architectural Elements (P9)

In acoustically or vibration sensitive buildings, often significant non-structural elements are used to prevent the transfer of noise or vibration. These components require restraint in seismically prone areas. Design and selection data for hardware to be used to accomplish this task are included in this section.

Data here is of interest to specifiers, architects, installation contractors and design professionals involved in the restraint selection process.

General Description (P9.1)
A general description of these pieces of hardware and their function are provided in this section.

FFR-1 (Embedded Restraint for Jack-up Floating Floors) Submittal Data (P9.2.1)
Design information is provided in this section.

FFR-2 (Embedded Restraint for Roll-Out Floating Floors) Submittal Data (P9.2.2)
Design information is provided in this section.

Perimeter Pads (Perimeter Restraint for Floating Floors) Submittal Data (P9.2.3)
Design information is provided in this section.

KSWC (Ceiling Cable Restraint Kit) Submittal Data (P9.3.1)
Design and capacity information for the KSWC cable kit offered by Kinetics Noise Control is provided in this section.

PSB (Embedded Wall Restraint) Submittal Data (P9.4.1)
Design information is provided in this section.

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IPRB (Top of Wall Restraint Angle) Submittal Data (P9.4.2)
Design information is provided in this section.

KSWB (Seismically Rated Wall Mounting Isolation Clip Submittal Data (P9.4.3)
Design information is provided in this section.

Selection Information (P9.5)
Design Selection and guidance information to be used in conjunction the various hardware components listed above are summarized in this document.

Installation Instructions (P9.6)
Comprehensive Installation Instructions to be used in conjunction the various hardware components can be found in this segment of the chapter.

Anchor Bolts and Attachment Hardware (P10)

Design and selection data for Seismically Rated Anchorage hardware used by Kinetics Noise Control makes up this section.

Data here is of prime interest to installation contractors and design professionals involved in the restraint selection process.

General Description (P10.1)
A general description of the anchorage hardware used by Kinetics Noise Control is provided in this section.

KCAB (Wedge type Anchor Bolt) Submittal Data (P10.2.1)
Design information is provided in this section.

KUAB (Undercut type Anchor Bolt) Submittal Data (P10.2.2)
Design information is provided in this section.

TG Grommets (Anchor Bolt Adapter Grommets) Submittal Data (P10.2.3)
Design information is provided in this section.

Selection Information

KCAB Anchor Selection Information (P10.3.1)
Design Selection and guidance information to be used in conjunction the various anchors are summarized in this document.

KUAB Anchor Selection Information (P10.3.2)
Design Selection and guidance information to be used in conjunction the various anchors are summarized in this document.

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Installation Instructions (P10.4)

Comprehensive Installation Instructions to be used in conjunction the various anchor types can be found in this segment of the chapter.

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SECTION D1.0 – TABLE OF CONTENTS

D1.0 – Kinetics Seismic & Wind Engineering

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PURPOSE, EXTENT, AND LIMITATIONS OF A SEISMIC OR WIND ANALYSIS

1.1.1 – Purpose:

The primary purposes for Kinetics Noise Control's seismic and wind analysis for equipment, piping, duct work, and electrical distribution systems are to;

1. Indicate to the architect, structural engineer, and building owner that the seismic and/or wind restraint components were selected to meet the design force requirements of the code in force for the building project.
2. For an analysis that has been signed and sealed by one of Kinetics' professional engineers, the seal and signature give confidence that the calculations have been reviewed and approved by an individual that is knowledgeable with the code provisions, restraint products, and the project parameters as presented to Kinetics Noise Control.
3. Provide the installing contractors with some guidance in locating and anchoring the seismic and/or wind restraints.

1.1.2 – Extent of the Analysis:

The seismic and/or wind analyses that are performed by Kinetics Noise Control cover only the components that are supplied specifically by Kinetics Noise Control. The analysis extends only from the mounting point on the equipment, pipe, duct, or electrical distribution system to the attachment point on the building structure. The analysis ***does not*** extend to the equipment, pipe, duct, electrical distribution system, or the building structure.

The analysis performed by Kinetics Noise Control will cover the following items.

1. The design seismic and/or wind loads acting on the equipment, pipe, duct, or electrical distribution system based on the provisions of the prevailing building code.
2. The strength and suitability of the Kinetics Noise Control restraint products to withstand the code based design seismic and/or wind loads.
3. Potential suitable attachment methods and/or hardware for Kinetics Noise Control's products to the building structure.

The ability of the equipment, pipe, duct, electrical distribution system and the building structure to resist the code based design seismic and/or wind loads imposed upon them is the responsibility of others. Kinetics Noise Control does not have adequate knowledge of the building structure, equipment structure, or the construction of the pipe, duct, and electrical distribution systems, and therefore must defer to the engineers of record for those structures and systems.

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1.1.3 – Limits of the Analysis:

The analysis performed by Kinetics Noise Control is a code based static analysis. It does not account for any dynamic effects than may be required by various specifications, jurisdictional requirements, codes, or Unified Facilities Criteria. Further discussion of Static vs. Dynamic analysis will be covered in Section D1.4 of this manual.

Kinetics Noise Control's analytical procedures assume that the equipment being restrained is rigid. While this is true for most HVAC equipment, there may be some pieces of equipment that are highly flexible, or compliant, that may behave quite differently than what would be expected from the results of the analysis. The manufacturer of the equipment must evaluate the response of their equipment to the design seismic and/or wind force with the restraints attached to the locations indicated by Kinetics Noise Control's analysis.

The analytical procedures used by Kinetics Noise Control also assume that the building structure where the restraints are to be attached is rigid. No attempt has been made to account for the strength and rigidity of the building structure to which Kinetics' products are being attached. Only the Structural Engineer of Record has the capacity to evaluate the suitability of the building structure to resist the expected design seismic and/or wind loads being imposed on the structure by the equipment, pipe, duct, or electrical distribution systems. It is also the responsibility of the Structural Engineer of record to provide a suitable building structure to which these restraints may be attached.

Finally; the analysis performed by Kinetics Noise Control assumes that Kinetics' products will be installed exactly per the installation instructions and submittal drawings. Installations that do not conform to the installation instructions and submittal drawings are not certified under the analysis. Post installation walk through inspections of restraint installations may not reveal hidden inconsistencies with the installation instructions and submittal drawings. It is the responsibility of the installing contractor, and in some cases an independent inspector hired by the building owner, to ensure full compliance with the installation instructions and submittal drawings.

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2. ASCE/SEI 7-02 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400; 2002.
3. ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400; 2005.
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5. 2011 ASHRAE Handbook – HVAC Applications; American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc, 1791 Tullie Circle, N.E., Atlanta, GA 30329.
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OVERVIEW OF ANALYTICAL METHODS USED

D1.3.1 – Introduction & Assumptions:

The analytical methods that are used are defined by the assumptions made in order to carry out the calculations. The methods used by Kinetics Noise Control for seismic and wind analysis are based on the following assumptions.

1. A static analysis is performed on the non-structural component (equipment, pipe, duct, or electrical distribution system) using code based design seismic and wind loads. Dynamic load effects are taken into account through application factors specified by the code for the various classifications of non-structural components.

2. The non-structural component being analyzed is rigid.

3. The design seismic loads are applied at the center of gravity of the non-structural component, and the design wind loads are applied at the centroid of the projected area of the non-structural component normal to the direction of the wind.

4. Since the direction of the seismic wave front and the direction of the wind are not known, the worst case direction resulting in the highest loads being applied to the restraints will be used.

D1.3.2 – Load Analysis:

The primary objective of the seismic and wind analysis is to obtain the reaction loads at the restraints that are due to the design seismic and wind loads. In some cases, the reaction loads due to the seismic and wind loads a will depend on the dead weight distribution of the non-structural component. Other load types are horizontal shear load, imbalanced shear load, overturning, and vertical uplift load. The actual reaction loads at the restraints may be due to a combination of these load types. The results used by Kinetics Noise Control will be due to the worst case combinations at each restraint point.

D1.3.2.1 – Dead Weight Load Distribution:

A non-structural component is shown in three views in Figure D1.3-1 below.

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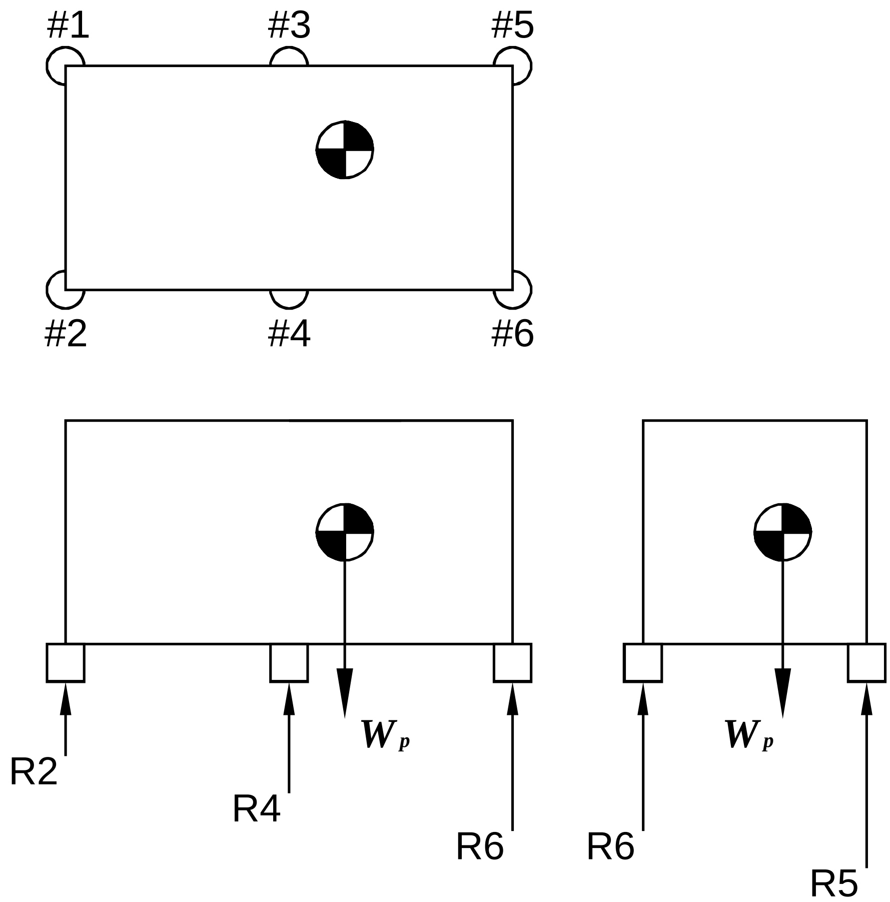
Figure D1.3-1; Dead Weight Distribution for a Non-Structural Component



Where:

R_i = the dead weight reaction loads at supports #1 thru #2.

W_p = the dead weight of the non-structural component.

Kinetics Noise Control has developed and algorithm that will estimate the dead weight load reaction at each support point on a non-structural component based on its proximity to the center of gravity of the component in the plan view.

D1.3.2.2 – Shear Load Analysis:

The distribution of shear reaction loads on a non-structural component due to a horizontal force applied at the center of gravity with the center of gravity located at the geometric center of the restraint array is shown in Figure D1.3-2.

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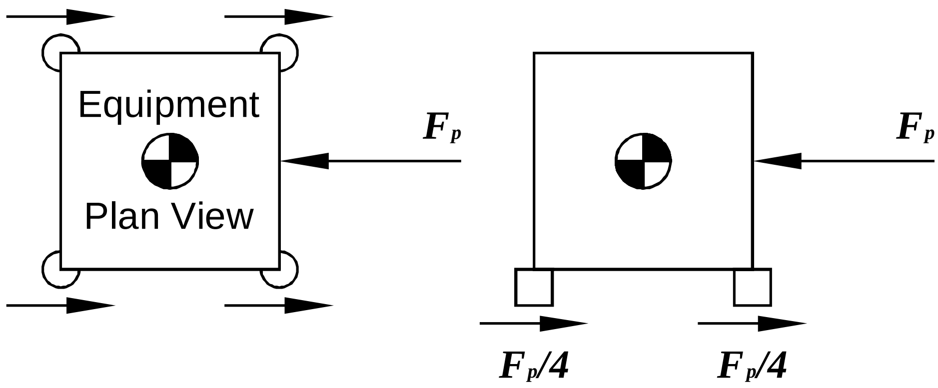
Figure D1.3-2; Distribution of Horizontal Shear Reaction Loads



Where:

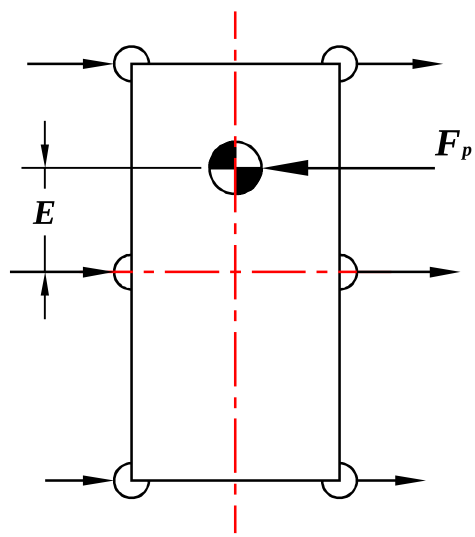
F_p = the horizontal design force.

The simplest case is when the center of gravity of the component is located in the geometric center of the restraint array when viewed in plan. The horizontal shear reactions will be resolved such that the load is equally shared between the restraints.

D1.3.2.3 – Imbalanced Shear Load Analysis:

Shown in Figure D1.3.3 is the plan view of a component with an imbalanced shear load.

Figure D1.3-3; Imbalanced Shear Load Reactions



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Where:

E = the offset, eccentricity, of the center of gravity from the geometric center of the restraint array.

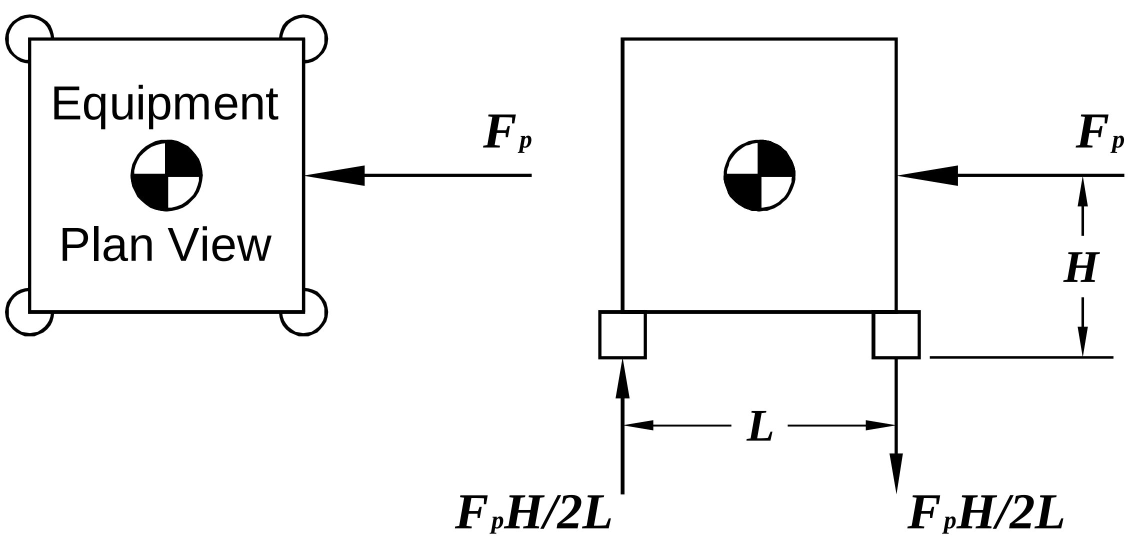
The center of gravity of a component is almost never located at the geometric center of the restraint array. When the horizontal design load is applied at the center of gravity of the equipment, the shear reaction loads will be distributed to the restraints as a function of the dead weight load distribution described in Section D1.3.2.1. Thus the restraints closest to the center of gravity will show the highest shear reaction loads, and those furthest away will shown the lowest shear reaction loads.

Seismic loads are applied to a component at its center of gravity. Wind loads are applied to the component at the centroid of the projected area of the component normal to the direction of the wind, which usually lies along a line of action that passes through the geometric center of the restraint array. So, this load case will not normally apply to wind analysis. The shear reaction loads in a wind analysis will almost always be evenly distributed among the restraints.

D1.3.2.4 – Overturning Load Analysis:

The simplest case where reaction loads resist a horizontal overturning load is shown in Figure D1.3-4. Here the horizontal load is applied to the center of gravity which is coincident with the geometric center of the restraint array. The center of gravity in this case is at an elevation that is higher than the restraint level. Note that the case modeled in Figure D1.3-4 is a seismic load case. The same effect will occur for a wind load applied at the centroid of the projected area of the component which is normal to the direction of the wind.

Figure D1.3-4; Overturning Load Reactions



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In this case, the overturning reactions are a function of the height of the center of gravity, or the centroid of the area with respect to the restraints, and the distance separating the restraints.

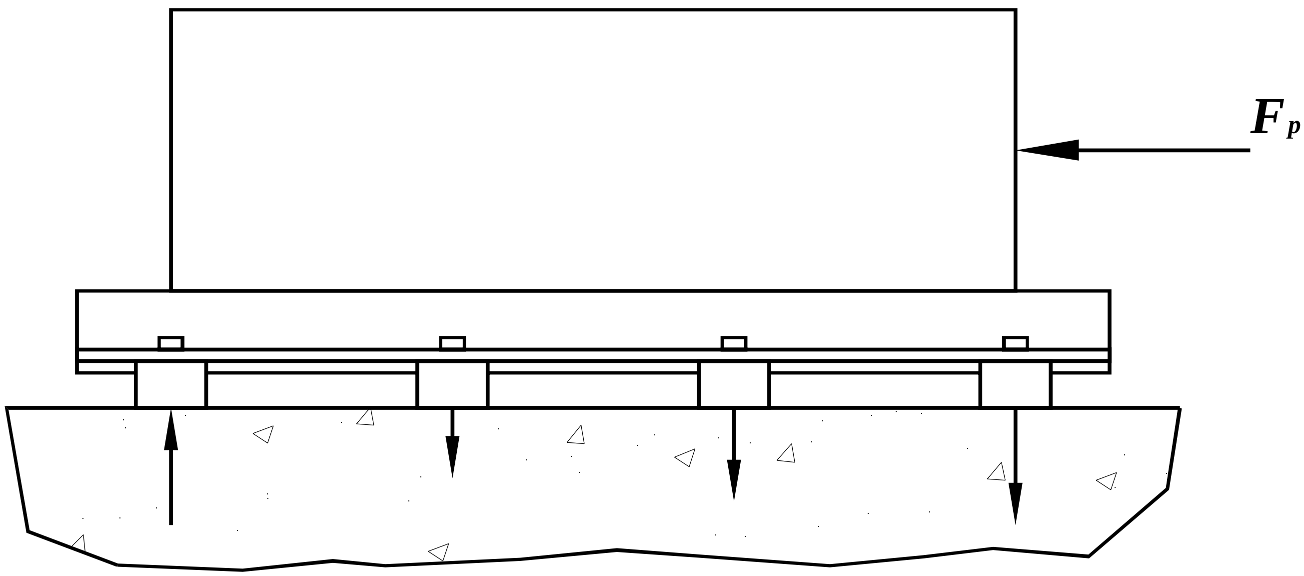
Where:

L = the distance between restraints.

H = the elevation of the horizontal load application point relative to the restraints.

When non-structural components have more than four restraints, the number of points that can be considered to share the overturning reaction load will be a function of the clearance that is in the restraints. Some types of restraints are designed to function without clearance. Figure D1.3-5 shows a non-structural component whose restraints do not have any clearance, and being acted upon by a horizontal load.

Figure D1.3-5; Multiple Restraints with No Clearance



In this case all of the restraints would be engaged and share the load in some fashion dependent upon the geometry and dead weight load distribution. The most common type of installation that exhibits this behavior is a component that is bolted rigidly to the supporting structure.

When the non-structural component is to have vibration isolation, the seismic or wind restraints used will have clearance designed into them to allow the component to float freely on the isolation springs. This clearance is rather small compared to the size of the component. Typically it is limited by industry standard practice to ±0.25 inch. Figure D1.3-6 illustrates a non-structural component with restraints that have built in clearance.

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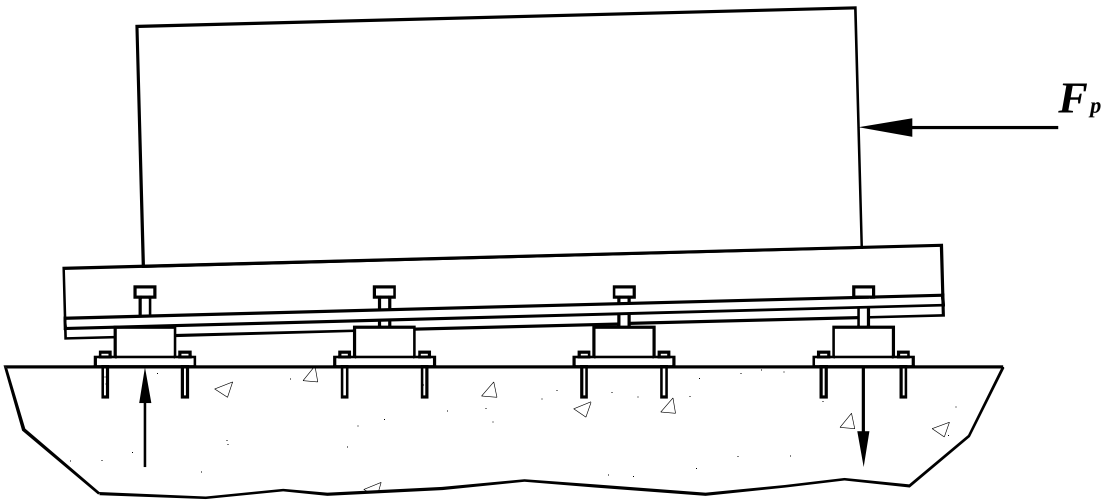
Figure D1.3-6; Multiple Restraints with Clearance

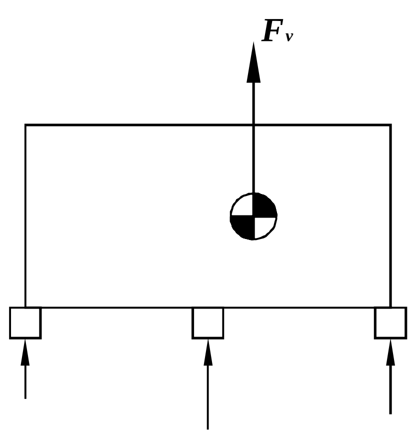


There may be cases where the clearance in the restraints is such that all or most could be engaged and share the load. But, the most conservative way to look at the system is that the end restraints are the only ones engaged as shown in Figure D1.3-6. This is the approach used by Kinetics Noise Control when performing seismic and wind analysis for restraints that are known to have built in clearances.

D1.3.2.5 – Code Based Uplift Forces:

The latest versions of the International Building Code require that a prescribed design uplift force be applied to the non-structural components. For seismic applications, this force is applied to the center of gravity of the component as shown in Figure D1.3-7, and the loads will be distributed to the restraints based on their proximity to the center of gravity.

Figure D1.3-7; Code Based Design Uplift Force for Seismic



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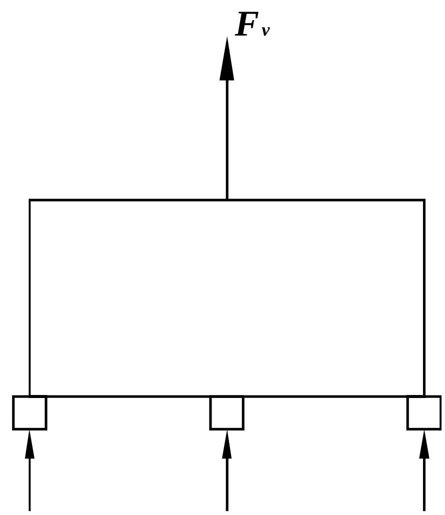
For wind applications, the design uplift force is applied to the centroid of the projected area normal to the direction of the wind as shown in Figure D1.3-8. Here the load will be equally distributed to the restraints.

Figure D1.3- 8; Code Based Design Uplift Force for Wind



Where:

F_v = the code based uplift design force.

D1.3.3 – Direction of Load Application:

How the loads are applied to a non-structural component, as mentioned before, depends on whether the analysis is for seismic events or wind events. Seismic loads are applied to the center of gravity of the component. Whereas the wind loads are applied at the centroid of the projected area of the component that is normal to the direction of the wind.

D1.3.3.1 – Seismic Loads:

When a seismic analysis is performed on a component, the direction from which the seismic loads will come is not known. It is therefore necessary to determine the worst case overturning load at each restraint point based on the seismic load coming from any possible direction. Figure D1.3-7 helps to illustrate this problem.

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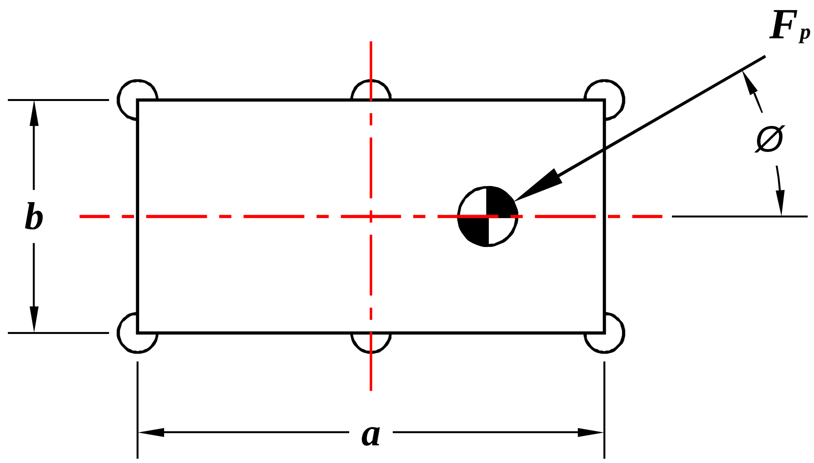
Figure D1.3-9: Seismic Load Application

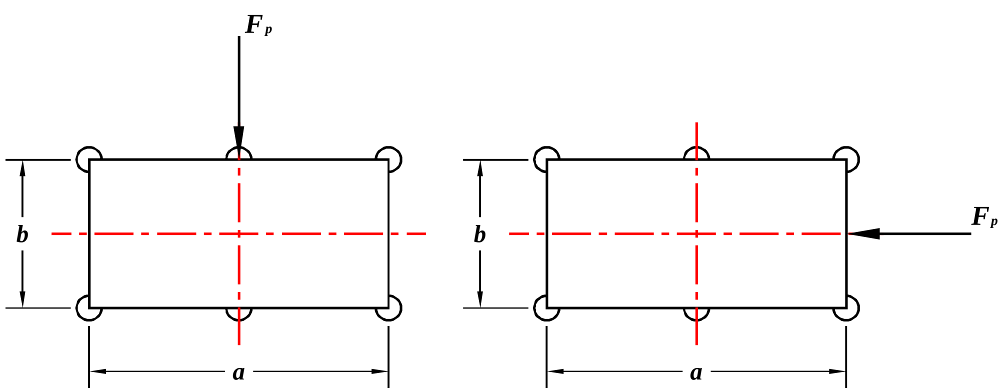


The algorithm developed by Kinetics Noise Control will increment the design horizontal seismic load 360° around the Center of Gravity, as shown in Figure D1.3-9, in 1° increments. For each position of the seismic load, the overturning load for each restraint point is computed. The worst case load at each restraint point is used in the analysis. This method of analysis is also described in the ASHRAE Handbook[1].

D1.3.3.2 – Wind Loads:

As with the seismic analysis, the direction of the wind relative to the component is never known. Figure D1.3-5 illustrates the loading conditions that are applied to components for wind analysis.

Figure D1.3-10; Wind Load Application



[1] 2007 ASHRAE Handbook – HVAC Applications; American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc, 1791 Tullie Circle, N.E., Atlanta, GA 30329; Chapter 54.

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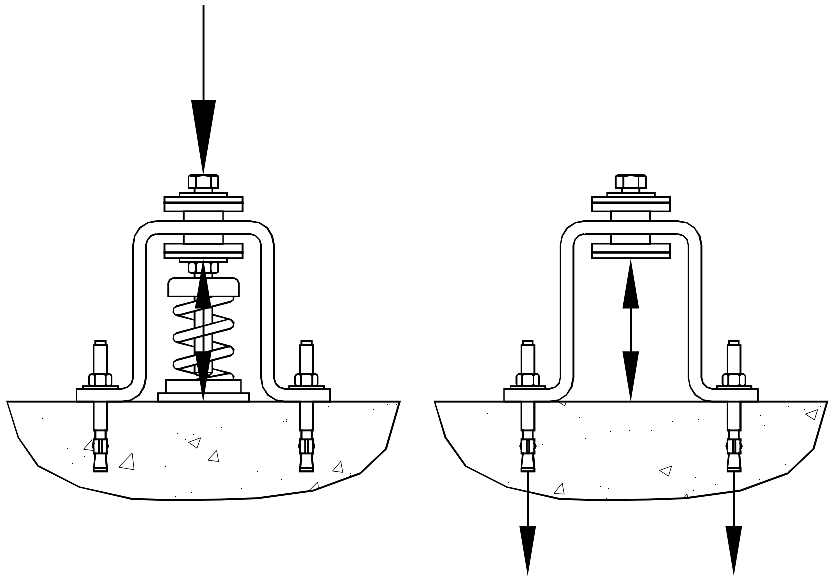
For wind loadings, Kinetics Noise Control's method of analysis applies the design wind load parallel to both the minor and major axes of the component as shown above in Figure D1.3-10. The worst case loads at each restraint point will be used in the analysis.

D1.3.4 – Open vs. Contained Spring Isolator/Restraints:

D1.3.4.1 – Open Spring Isolator/Restraints:

One of the major issues when analyzing anchor forces has to deal with whether the isolator/restraint system has open springs, of contained springs. An example of an open spring isolator/restraint is shown in Figure D1.3-11.

Figure D1.3-11; Open Spring Isolator/Restraint



With an open spring isolator/restraint, the spring sits directly on the floor. The dead weight load supported by the system goes directly through the spring to the floor. When an isolator is installed beneath a component, it is adjusted, the leveling nut is turned to compress the spring until enough force is built up in the spring to lift, or float, the component. This has some serious consequences for the loads imposed on the anchors. If there is an uplift force, then the spring force is transmitted through the housing to the anchors adding to the uplift force itself. Thus, the anchors will be subjected to not only the reaction loads due to a seismic or wind event, but also to the forces locked up in the spring.

D1.3.4.2 – Contained Spring Isolator/Restraints & Separate Restraints (Snubbers):

A contained spring isolator/restraint is shown in Figure D1.3-12.

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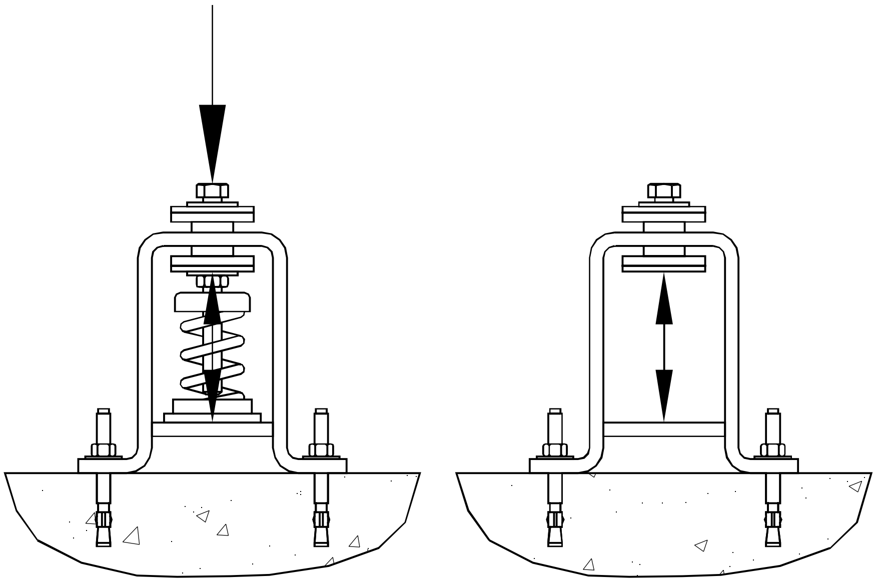
Figure D1.3-12; Contained Spring Isolator/Restraint



With a contained spring isolator/restraint, the spring is completely supported by the housing of the isolator/restraint. When the spring is unloaded due to uplift of the component being supported, all of the spring forces are "contained" within the structure of the housing with out being transferred to the anchors. Thus, in this case, the anchors are subjected only to the reaction loads due to seismic or wind events.

The phenomenon associated with open springs also occurs when free standing springs are used with separate restraints, or snubbers. A component is shown in Figure D1.3-13 mounted on a base with separate free standing springs and restraints under normal conditions.

Figure D1.3-13; Separate Free Standing Springs & Restraints under Normal Load Conditions

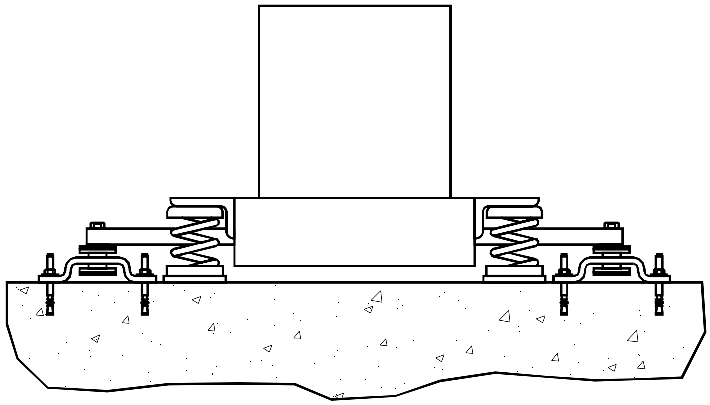


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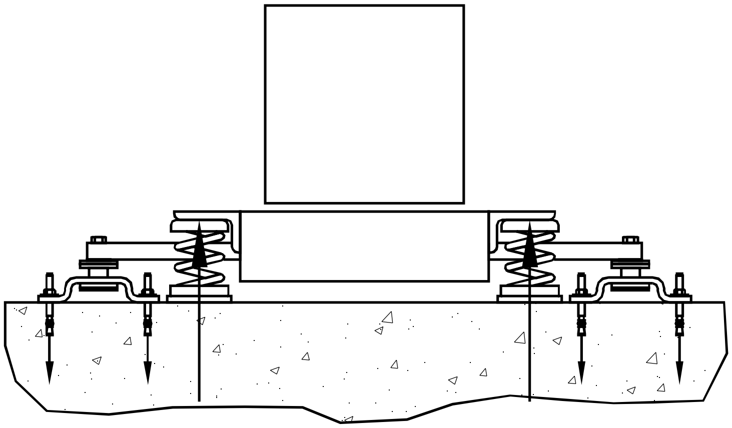
Figure D1.3-14 shows what happens when an uplift load condition on the component occurs. As the load moves component upward, the restraints engage, and because the springs can not fully relax, the load stored in them is transferred to the anchors in for the restraints. Thus, this arrangement behaves like an open spring isolator/restraint.

Figure D1.3-14; Separate Free Standing Springs & Restraints under Uplift Load Conditions



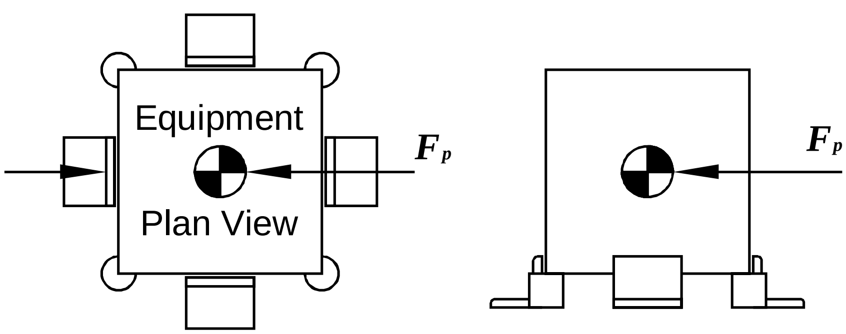
D1.3.5 – Snubbers:

Snubbers will be either uni-directional, acting in only one direction, or multi-directional, operating in two or three directions.

D1.3.5.1 – Uni-Directional Snubbers:

When uni-directional snubbers are used, at least four snubbers are required to completely restrain the non-structural component. They are generally placed around the non-structural component space 90° to each other. This arrangement is shown in Figure D1.3-15. Typically, only one, or at most two, snubbers will be active during an event. Also, this type of snubber can not be used when uplift forces are present.

Figure D1.3-15; Uni-Directional Snubbers



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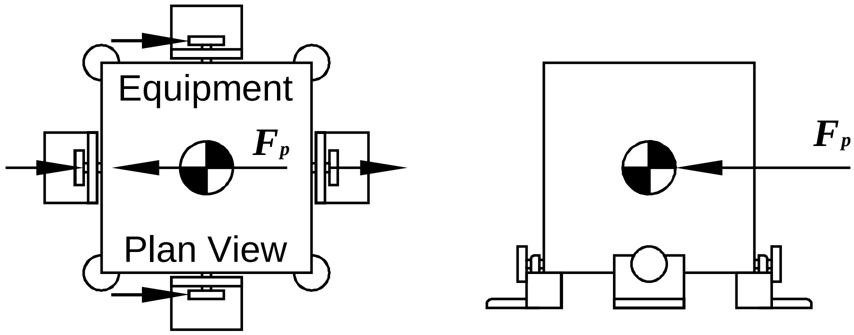
D1.3.5.2 – Multi-Directional Snubbers:

Multi-directional snubbers can carry loads in more than one direction as shown in Figure D1.3-16 below.

Figure D1.3-16; Multi-Directional Snubbers



With multi-directional snubbers, the reaction loads may be shared by all of the snubbers. Also, 3-axis multi-directional snubbers should be used when there is the potential for uplift forces. Because, all of the snubbers can share the reaction load, multi-directional snubbers may have reduced size and anchorage requirements when compared to the uni-directional snubbers that would be applied to the same component.

D1.3.6 – Restraint Analysis:

The analysis algorithm used by Kinetics Noise Control will compute the reaction loads at the restraint location. The actual seismic/wind restraints are usually supported by a structure that transmits the reaction loads at the restraints to the building structure. Kinetics Noise Control analyzes the restraint supporting structure in the following way.

1. In both horizontal directions to get a worst case limiting, allowable, horizontal load.

2. In the vertical direction, up and down, to get a worst case limiting, allowable, vertical load.

3. Equal combined and vertical loads in the worst case horizontal and vertical cases to get a worst case limiting, allowable, combined load.

These three load cases are plotted together to generate an allowable load envelope for the restraint and its supporting structure. The horizontal and vertical restraint reactions computed by using Kinetics Noise Control's algorithm can be plotted on this same charted. If the reaction load points fall beneath the allowable restraint envelope the restraint will be suitable for that application. If, on the other hand, the reaction load points fall above the allowable restraint envelope, the restraints will not be suitable for that application.

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STATIC vs. DYNAMIC ASSESSMENT OF SEISMIC RESTRAINT SYSTEMS

D1.4.1 – Introduction:

There are three basic formats to analyze or test seismic restraint systems, static, quasi dynamic and dynamic. The information produced by each format and the costs associated with each, are radically different. Static analysis and testing is the oldest and most common method. It has been used in the past to both determine the allowable load capacity for a restraint, and to certify that restraint for a particular application. Quasi dynamic testing is a newer method used to determine the allowable load capacity for a restraint and would be used in conjunction with a static analysis to certify the adequacy of a component for a particular application. Dynamic analysis and testing is most often used to qualify a piece of equipment that must remain functional at the conclusion of a seismic event. The basic formats and their applicability for particular tasks will be discussed in this document.

D1.4.2 – Static Analysis and Testing:

Static analysis and testing both rely on the application of constant non-fluctuating loads. Static analysis and testing are the easiest and quickest to perform. Both will be discussed below.

D1.4.2.1 – Static Analysis:

The static analysis for determining the allowable load capacity of a restraint is done using the classical methods of engineering mechanics, and more-or-less follows these steps.

1. In the course of a static analysis, it is assumed that the components that make up the restraint device are stiff enough to be assumed to be rigid and that no plastic deformation occurs.

2. The force and moment balances are set up algebraically using the classical methods of engineering mechanics based on the geometry of the restraint.

3. The critical sections of the restraints are determined.

4. The forces and moments at these critical sections in terms of the geometry and applied loads are determined as algebraic functions.

5. These forces and moments are used to set up equations for the stresses at the critical sections.

6. Limits on the stresses allowed at the critical sections are determined based on the various material properties and prevailing design standards, ASD or LRFD.

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7. These limiting stress values are substituted into the stress equations from step 5, and the equations are solved for the applied loads acting on the restraint.

Three sets of static analyses are performed in the following manner to completely define the capacity of the restraint.

1. An analysis looking at loads on both of the principal horizontal axes (or on a worst case combined axis) to get a worst case limiting, allowable, horizontal load.

2. An analysis looking at the vertical direction, up and down, to get a worst case limiting, allowable, vertical load.

3. An analysis that uses equal combined and vertical loads in the worst case horizontal and vertical cases to get a worst case limiting, allowable, combined load.

4. A deration factor is applied to the computed values both to add a safety factor and to compensate for the effects of dynamic impacts.

The results from these three load cases are plotted together on a chart to generate an allowable load envelope for the restraint and its supporting structure.

The static analysis for sizing and certifying the seismic restraints for a particular project is also carried out using the methods of classical mechanics. A model of the non-structural component is set up assuming that the component is a rigid body. The reactions due to the code based design forces are applied to the equipment and reactions at the restraints are determined using the methods outlined in Section D1.3 of this manual. The horizontal and vertical reactions are plotted on the chart with the allowable load envelope for the restraint being considered. If the reaction load points fall beneath the allowable restraint envelope the restraint will be suitable for that application. If, on the other hand, the reaction load points fall above the allowable restraint envelope, the restraints will not be suitable for that application.

It should be noted that additional factors are included in code based load equations to further counter the variances that occur between dynamically loaded equipment of different types as compared to statically loading the same equipment.

D1.4.2.2 – Static Testing:

Restraint components are often statically tested to determine the allowable load that can be placed on them. The allowable load will be based on either yielding failure of the restraint, or its ultimate failure depending on the restraint type and its intended use. ASHRAE[1] has developed a standard method of test based on static loading that may be applied to seismic restraints. This test method will produce the maximum horizontal, vertical and combined equal horizontal and vertical

[1] ANSI/ASHRAE Standard 171-2008 – Method of Testing Seismic Restraint Devices for HVAC&R Equipment; American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329; www.ashrae.org

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loads that will produce failure in the restraint components. A separate organization such as VISCMA[2] would then publish a rating procedure based on the method of test that would define the allowable horizontal, vertical and combined equal horizontal and vertical loads that may be safely applied to the restraint components. From these values an allowable load envelope for the restraint can be plotted and utilized in the same manner described in Section D1.4.2.1 above.

Static testing per a method similar to that published by ASHRAE fits well with using the code base seismic design forces. This is because the code based seismic design forces are static forces that have been modified to account for not only the various seismic parameters such as ground motion, soil type, and building occupancy, but also dynamic effects such as flexibility, fragility, and resonance effects of the equipment.

If the maximum reaction loads to the code based design horizontal and vertical loads for a non-structural component for a particular job are known, static testing may also be used to qualify a restraint for that project. The method of test published by ASHRAE could be modified to evaluate a single load in each horizontal and vertical direction to see if the restraint meets the code based load requirements.

D1.4.3 – Quasi Dynamic Testing (This is a test procedure only and should not be confused with an analysis):

New procedures have been developed based on testing and rating standards currently in use by the fire piping industry. In an effort to better assess the impact of dynamic loads on restraint devices and to come up with a procedure that will actually produce a rating “value” for a particular restraint component instead of a simple “pass/fail” rating, a quasi-dynamic process is being used.

In this case, a cyclic load of gradually increasing amplitude is applied to a component along the same set of axes as would be done for the static test. The component is monitored for failure and when the failure is noted, a peak load is determined that is slightly less than the peak load at failure. This then is used as the basis for the rating.

D1.4.4 – Dynamic Analysis and Testing:

D1.4.4.1 – Dynamic Analysis:

Dynamic analysis is normally performed with the aid of a computer program written specifically to allow the user to model the type of structure under consideration. Different types of programs are required to model components made up of a few parts, such as a restraint component, and many parts, such as a building structure. This implies that in order to completely qualify a part for an application using dynamic analysis, one might require at least two different types of dynamic modeling programs. This document will refer to the programs and models that deal with a few parts as small scale programs and models, and those that deal with many parts as large scale programs and models.

[2] Vibration Isolation and Seismic Controls Manufacturers Association – www.viscma.com

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In order to qualify a restraint component for a given application, a large scale model would need to be created and run using a large scale program to obtain the reactions at the restraint component. Then a small scale detail model of the restraint component would need to be created and run using a small scale program to determine the stresses that would be generated in the restraint component for the applied inputs.

The inputs for a dynamic analysis program that models earthquake effects would be the load spectrum of the design earthquake for the project location. This load spectrum is specified in the version of ASCE 7 that corresponds to the prevailing version of the IBC; see Section D2.1.1 of this manual. The load spectrum found in ASCE 7 is a composite of several earthquake spectra from events that have occurred in southern California.

The use of dynamic analysis to assess the performance of seismic restraints is limited in several ways.

1. The analysis will apply only to one particular case, and so would need to be performed nearly on a project by project and an installation by installation basis.
2. In order to be as accurate as required, the structure of the building and the non-structural component would need to be modeled. This involves the acquisition of a lot more information than is normally available to the suppliers of seismic restraints.
3. A great deal of time and effort will be required to create the necessary computer models.
4. Many runs would be required to generate allowable load capacity envelope data that is easily generated with static analysis.
5. The load spectrum of the design earthquake will have the same frequency content for each geographical location in the United States. To account for different locations, the magnitude of the force will be increased or reduced to account for the increased or reduced seismic risk. This can not accurately predict the results from an earthquake in every location. The frequency content of a typical earthquake spectrum for Los Angeles, CA. will be significantly different than that for say St. Louis, MO, which will be different than that for Charleston, SC.

D1.4.4.2 – Dynamic Testing:

Dynamic testing is predominantly used to qualify, certify, equipment and other designated seismic systems that are intended for use in Occupancy Category IV, Seismic Use Group III, buildings, see Section D2.1.2.2 of this manual. This type of test must be performed on a shake table to AC156[3]. Here, as with the dynamic analysis, there is a design earthquake load spectrum that is used for input to control the shake table. The spectrum used for AC156 is very similar, If not identical, to that specified in ASCE 7. This type of test has special issues that accompany it.

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[3] AC156 – Acceptance Criteria for Seismic Certification by Shake-Table Testing of Nonstructural Components; ICC Evaluation Service, LLC, A subsidiary of the International Code Council; Effective November 1, 2010, www.icc-es.org

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1. This test will qualify equipment and components for a particular design earthquake, and also those of a lesser magnitude.

2. If the test is performed by an equipment or component manufacturer to act as a general qualification of their product up to a certain design earthquake, the test will not account for the effects due to the flexibility and dynamics of the building structure.

3. There are not many shake tables of the type and size required to perform these tests on large HVAC components. Therefore, getting time scheduled for these tests is difficult.

4. The tests are extensive, and therefore very expensive.

5. Only one sample is tested. This does not account for the variability in the manufacturing processes and materials employed in the production of the component.

6. The results from the test are pass or fail. This test produces no useful capacity envelope data that can be used to extend the results to other projects.

D1.4.4 – Summary:

Dynamic analysis and testing do have their place in the design of seismic systems and components. They are most useful in verifying equipment and restraint selection and performance for highly critical facilities in very high seismic areas, such as hospitals in southern California. They are not very useful or practical for the selecting seismic restraint components for the vast majority of building projects in the country; this includes hospitals in places such as New York City, Buffalo, Charleston, Columbus, and etc.

However, the short comings of dynamic assessment of equipment and restraints must be recognized.

1. The spectrum of the design earthquake is based on earthquakes of a particular type occurring in a particular geographical location.

2. To properly account for the dynamic effects of a particular isolator/restraint design, the isolator/restraints specified for the equipment would need to be dynamically assessed with the equipment.

3. Dynamic assessment, either by analysis or test, does not necessarily account for the dynamic properties of the structure supporting the equipment.

For the majority of the building projects in this country static analysis and testing or the more current quasi-dynamic testing using the code based design seismic forces will produce reliable results in the selection and qualification of restraint devices. The results from these methods maybe applied uniformly across the country with the aid of the code based application factors and

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design force equations described in Section D2.1.8 of this manual. Static and quasi-dynamic assessment of equipment and restraints provides convenient and universally applicable method.

1. They allow a restraint capacity envelope to be generated for each restraint device.

2. The equipment may be analyzed using the well recognized techniques of classical engineering mechanics with code based design seismic forces that account for the dynamic effects and fragility of the equipment.

3. Dynamic testing has been performed at the University of Buffalo, State University of New York[4 5]. These tests were partially sponsored by ASHRAE through TC 2.6 to get a better idea of how the equipment and restraints are affected during a seismic event. The isolator/restraints were designed to allow design parameters that control the performance of the restraints to be changed between test runs to evaluate the effectiveness of the restraints and the effects on the equipment. The results of these tests will help the writers of ASCE 7 to more accurately assign the proper application factors to various types of equipment and components.

For nearly all applications therefore, static analysis and testing or quasi-dynamic testing allow seismic restraints to be quickly selected and qualified. Dynamic analysis and testing have their place in qualifying seismic restraints for a few very critical applications, and for aiding in the design of new restraint devices and the selection of code based application factors.

[4] Fathali, Saeed and Filiatrault, André; Experimental Seismic Performance Evaluation of Isolation/Restraint Systems for Mechanical Equipment – Part 1: Heavy Equipment Study; MCEER – University of Buffalo, State University of New York, Red Jacket Quadrangle, Buffalo, NY 14261 http://mceer.buffalo.edu, Technical Report MCEER-07-0007

[5] Fathali, Saeed and Filiatrault, André; Experimental Seismic Performance Evaluation of Isolation/Restraint Systems for Mechanical Equipment – Part 2: Light Equipment Study; MCEER – University of Buffalo, State University of New York, Red Jacket Quadrangle, Buffalo, NY 14261 http://mceer.buffalo.edu, Technical Report MCEER-07-0022

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REQUIRED CALCULATION INPUT FOR THE IBC

D1.5.1.1 – Introduction:

There are certain pieces of information that are absolutely required in order to perform an analysis of a non-structural component for the purpose of selecting and certifying restraint components for a particular application. Some of the required information has its basis in the building code that is in force for the project. This code related information is discussed in detail in Sections D2.1 and D2.2 of this manual. However, they will be given a cursory discussion in this section to make clear their need in the analysis, selection and certification process for the seismic and wind restraints. Other pieces of the required information are related to the building itself.

Kinetics Noise Control has published a Seismic/Wind Checklist for the IBC and UFC 3-310-04, UFC 3-310-04 references IBC 2003. This document lists the basic information that is required to allow Kinetics Noise Control to accurately analyze the non-structural component, select the proper restraint components, and certify their suitability to the application. This section will discuss in detail the items on this checklist. A copy of this check list is shown in Figure D1.5.1-1.

D1.5.1.2 – Project Name:

The exact project name helps Kinetics keep the information straight within the office. It also helps the customer maintain proper organization of the seismic and wind data. These issues are code related and will have extra scrutiny especially if the project is a federal, state, or military facility.

D1.5.1.3 – Project Location:

The project location is critical since the magnitude of the design forces for both seismic and wind are dependent on the geographical location of the project. Both address and ZIP Code are helpful.

D1.5.1.4 – Code Year of Issue:

The code year in force will affect the following areas in a seismic or wind analysis.

1. The magnitude of the seismic and wind force will vary depending on the code year in force in the projects jurisdiction.
2. The exemptions that apply to non-structural components vary by the code year.
3. Anchorage requirements depend on the code year in force.

Any analysis that is used for certifying the suitability of the restraints for a particular application will carry the seal and signature of a registered professional engineer, and thus it becomes a legal document for the project. So, the calculations must be performed per the proper code to maintain the legality of any certification for the project.

This is generally found on the first page of the structural drawings, or in the specification.

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Figure D1.5.1-1; Kinetics Seismic/Wind Checklist for IBC and UFC 3-310-04

KINETICS Noise Control SEISMIC/WIND WORKSHEET (For IBC and UFC 3-310-04 only)

GENERAL DATA: (All items (except noted) in this box must be completed)

Project Type ○New Project ○Previous Project | **Basis of Building Code** ○U.S. ○Canadian | Note: This document must be **completed** before Kinetics will generate a Certification. Note that the Seismic and Wind parameters identified below can be found on the first sheet of the structural drawing documents.

Project Name [ ] Purchase Order # [ ] Date: [ ]

Project Address: Street # [ ] Street Name: [ ] Street Type: [ ] Country: [ ]

State Code [ ] City [ ] Zip Code (US only): [ ]

IBC Code Year of Issue: ○ 2006 ○ 2009 ○ 2012 ○ Other Other Specify: [ ]

If State Code Based on the IBC is referenced: **Enter** State: [ ] **AND** Effective Year: [ ]

Seismic Design Category (if specified): ○ A ○ B ○ C ○ D ○ E ○ F ○ Not in Spec

Specified Seismic Acceleration Parameter Values: **Enter** (S_{DS} [ ] S_{D1} [ ]) **OR** (S_S [ ] S_1 [ ]) **OR** Compute from ZipCode

Specified Soil Type: (Provide detail data on soil conditions if E or F is selected.)

○ A (Hard Rock) ○ B (Rock) ○ C (Dense Soil/Soft Rock) ○ D (Stiff Soil) ○ E (Soft Soil) ○ F (Other-Back fill, etc)

Occupancy Category: ○ I,II (Storage) ○ III (Typical) ○ IV (Critical)

Roof Elevation (from grade): **Enter** [ ] ○feet ○Meters **AND** [ ] Floors

Minimum Seismic Acceleration "G" Factors: **Enter** [ ] Horizontal **AND** [ ] Vertical **OR** ☐ Not Specified

Minimum Specified Safety Factor: [ ] (If applicable this number is found in the Specs, if not leave it at 1.0)

Max diameter of exempted Hazardous Piping: ☐ N/A **Enter** ☐ Per Code **OR** (Ip = 1.0) [ ] Inches **AND** (Ip = 1.5) [ ] Inches

Max area of exempted Ductwork: ☐ N/A **Enter** ☐ Per Code **OR** (Ip = 1.0) [ ] Sq Ft **AND** (Ip = 1.5) [ ] Sq Ft

Exposure: ○ Interior Only ○ B Urban/Suburban ○ C Flat, Open Hurricane Zone ○ D Flat, Open Non-Hurricane Zone

Project Wind Speed: [ ] MPH

Other Special Requirements* [ ]

***Attach only the portions of the Spec that are pertinent to this order** (10 mb maximum size limit)

Include a copy of the PO (10 mb maximum size limit)

Equipment Data

#	Tag	Qty	(1.0) Standard	(1.5) Critical, Hazardous, Life Safety	Operating Weight (lbs.)	Equipment Elevation (Floor #)	Mounted to Floor or Suspended	Desired Isolator Type (or Non-Isolated [in blue]) * See Note Below	Attached to: Steel/Concrete/Wood Structure	Indoor or Outdoor	
1			○	○							Browse...
2			○	○							Browse...
3			○	○							Browse...
4			○	○							Browse...
5			○	○							Browse...
6			○	○							Browse...
7			○	○							Browse...
8			○	○							Browse...
9			○	○							Browse...
10			○	○							Browse...
11			○	○							Browse...
12			○	○							Browse...
13			○	○							Browse...

* If Isolated with hangers KNC will assume that restraint is by cables.

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D1.5.1.5 – Specified Seismic Design Category:

This helps Kinetics Noise Control determine if seismic restraint is required for a project. If seismic restraint is required, the Seismic Design Category will define which components may be exempt from the need for seismic restraint. This parameter is listed on the first page of the structural drawings.

D1.5.1.6 – Specified Seismic Acceleration Parameter Values:

These are the acceleration values that are used to determine the design seismic forces. Of particular interest to Kinetics Noise Control are the values for S_S and S_{DS}. These values are listed on the first page of the structural drawings as they are used by the structural engineer to determine the Seismic Design Category for the building.

D1.5.1.7 – Building Use & Nature of Occupancy:

How a building is to be used is very important. The use of the building determines the level of restraint that will be required for the components in the building. For IBC 2000 and 2003 this is indicated by the Seismic Use Group. This parameter varies from Seismic Use Group I to III, with Seismic Use Group III being the most stringent. For IBC 2006 and 2009, the building use is indicated by the Occupancy Category, which varies from Occupancy Category I to IV. Occupancy Category IV will apply to the most critical facilities. A more detailed discussion of Seismic Use Group and Occupancy Category may be found in Section D2.1.2.2 of this manual. The Seismic Use Group and Occupancy Category are always to be found on the first sheet of the structural drawings.

D1.5.1.8 – Site Class or Soil Type:

This parameter indicates the type of geology which underlies the project. It affects the design value for the acceleration parameter for non-structural components which is S_{DS}. The Site Class will vary from A to F, with A being the best possible Site Class and F being the worst. The value of S_{DS} will be the lowest for Site Class A and the highest for Site Class F. See Section D2.1.2.3 of this manual for an explanation of the Site Class. As before, this parameter is indicated on the first sheet of the structural drawings.

D1.5.1.9 – Roof Elevation:

This is required for computing both the seismic and wind design forces that will be acting on the non-structural components. For seismic design forces, the higher up in the building the components are located the higher the forces, see Section D2.1.8.2 of this manual. For the design wind loads, the taller the building the higher the wind loads acting on the component, see Section D2.2.3 of this manual. It can be entered as a distance in feet or meters, or it can be expressed as the number of floors in the building.

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D1.5.1.10 – Exposure Category:

In the checklist this is indicated simply as Exposure. It will be B, C, or D depending on the terrain surrounding the building. This is listed on the first sheet of the structural drawings and is critical for calculating the design wind loads that will be acting on the equipment or other non-structural components.

D1.5.1.11 – Project Wind Speed (Design Wind Speed):

This will vary depending on the geographical location of the project. It is found, again, on the first sheet of the structural drawings. This is often specified at a higher value than is required by the code, so it is important to obtain it directly from the structural drawings. It is used to compute the design wind loads acting on the component.

D1.5.1.12 – Maximum Seismic Acceleration "G" Factors:

Frequently horizontal and vertical "G" factors are specified for a project to ensure that a certain margin of safety is maintained, or to account events other than seismic such as bomb blast. These are normally found in the specification for the building. They can be buried in the specification section for the particular trade, or under the section for seismic restraint. Typically these "G" factors will have values that are similar to the following.

1. 0.5 G Horizontal and 0.33 G Vertical

2. 1.00 G Horizontal and 0.67 G Vertical for Life Safety Components

It is critical that the specifications be scanned for these "G" factors. They can greatly increase the cost of restraining the components. There are times when seismic restraint would not be required for the project at all per the code, but these specified "G" factors will supersede the code.

D1.5.1.13 – Minimum Specified Safety Factor:

Depending on whether the restraint is rated based on yield or ultimate, Kinetics Noise Control has built-in Safety Factor of 1.67:1 or 2:1 respectively with regard to the allowable values used to select and certify the restraint for a particular application. The Safety Factors listed in Kinetics' documentation are with respect to the allowable loads for the restraint. Occasionally, there will be a requirement for a certain minimum Safety Factor for seismic load application. This is becoming more-and-more frequent with the advent of designing for anti-terrorism. This requirement may be either on the first sheet of the structural drawings, or in the seismic portion of the specification. It is absolutely critical that presence of these Safety Factors be determined and the communicated to Kinetics Noise Control. Typically these Safety Factors have values of 2:1 or 4:1. The use of an additional Safety Factor can double or quadruple the cost of any required restraint components.

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D1.5.1.14 – Maximum Permitted Diameter of Unrestrained Hazardous Pipe:

Occasionally certain standards are specified that will supersede the pipe size limit for exemption found in the code. Any deviation from the code will be noted in the specification.

D1.5.1.15 – Maximum Permitted Area of Unrestrained Ductwork:

Different duct standards will allow or disallow the exemption of duct from the need for seismic restraint based on its cross-sectional area. The specification will indicate which standards apply to the project and/or which duct sizes are exempt.

D1.5.1.16 – Equipment Data:

The information listed in this table is critical to selecting the best possible restraint for the application.

1. **Tag** – Keeps the equipment straight and correlates the calculation and restraint selection to the customer's designations.
2. **Qty** – Lets Kinetics Noise Control know how many typical components are to be covered under one calculation.
3. **Critical, Hazardous, Life Safety, or Standard** – Helps Kinetics determine the Component Importance Factor if it is not listed by the Engineer of Record.
4. **Operating Weight** – Required to determine the design seismic forces.
5. **Equipment Location in Structure** – Required to determine the design seismic force.
6. **Is it Over 10 HP** – Equipment over 10 Hp total may require the use of special anchors per the code.
7. **Mounted to Floor or Suspended** – Determines the type of restraints required.
8. **Desired Isolator Type or Non-Isolated** – Helps Kinetics select the proper product for the application.
9. **Attached to Steel/Concrete/Wood Structure** – Required to select the proper anchorage hardware.
10. **Indoors or Outdoors** – Will indicate whether wind loading is an issue, and permits the proper selection of anchorage hardware.

D1.5.1.17 – Signature & Date:

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This is important to Kinetics Noise Control and their authorized representatives. It is important that someone connected with the project that has access to the most recent revisions of the structural drawings and specifications fill out this checklist. This will ensure that the latest information is used to select and certify the restraint devices and protect all concerned from liability.

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UNDERSTANDING STANDARD IBC CERTIFICATION OUTPUT

D1.6.1.1 – Introduction:

There are two basic formats for Kinetics Noise Control's standard certification output. One format deals with the seismic analysis and the certification of the restraints to meet the seismic requirements of the code. The other format deals with the wind analysis and the certification that the restraint components meet that portion of the code. With each certification, there is a sheet that contains an installation summary of the restraints and the attachment hardware. The two certification formats and the installation summary will be discussed in detail in this section.

The certifications are printed as LRFD forces as the default method. However, the certifications may be printed out as ASD forces upon request.

D1.6.1.2 – Kinetics Seismic Certification Sheet (A):

D1.6.1.2.1 – Input Data:

The first page of the standard seismic certification output is shown in Figure D1.6.1-1 on the next page. At the very top of the page are three pieces of information.

1. **KNC PO** – This is found in the upper left hand corner of the page. Sometimes this will be referred to as the KNC number. It is a 5 digit number that identifies the project in the computer system. All of the calculations, drawings, and other correspondence reference this number.

2. **Tag** – The tag information is found in the upper right hand corner of the page. This identifies the actual piece of equipment being certified.

3. **(A)** – Indicates the page. If an oversized base plate is required for an isolator, there will be a (B) and (C) page to the certification. The (B) page will be the certification for the isolator with an oversized base plate, and the (C) page will be a manufacturing drawing for the oversized base plate.

The top line inside the border is the project and representative information; refer to the information enclosed in the rectangle in Figure D1.6.1-2. From left to right;

1. **Project Name** – The project name. This typically corresponds to the name submitted by the representative

2. **Representative** – The name of the authorized representative of Kinetics Noise Control.

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3. **P.O. Number** – The representative's purchase order number. This is included as the projects are usually tracked through the representative's computer system via the purchase order number.

Figure D1.6.1-1; First Page of Kinetics Standard Seismic Certification Output – Sheet (A)

P-B-1 THRU 4

KNC PO: 76816 **KINETICS SEISMIC CERTIFICATION** **(A)**

Input Data

Project:	KALEIDA HEALTH	Representative:	M. SCHILLER	P.O. Number:	1519
Date:	11-25-2013	Code Used:	2003IBC	Min Horiz G:	.00 (LRFD)
Equip Type:	END SUCT. PUMP	Tag:	P-B-1 THRU 4	Min Vert G:	.00 (LRFD)
Installation Type:	Vibration isolated <= 1/4" Gap Standard			Bolted G (ASD)	.13/.04 (H/V)
Site Class:	D (1.568)			Conc Ancs(ASD):	.17/.04 (H/V)

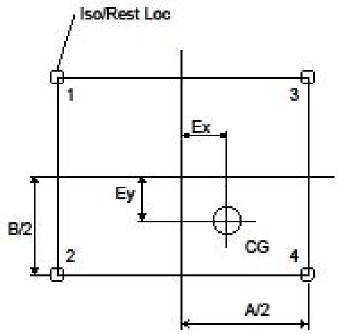
Data used is derived from Customer input, others are responsible to verify the accuracy of this data.

Wt(lb): 3327 Elev-Roof/Equip: 100/0 ft

Geometry (in):

Ap:	2.50	Ss/Sds:	0.290/0.303
Ip:	1.50	Rp s/c:	2.50/2.50
A:	74.50	B:	34.50
ex:	7.45	ey:	3.45

Hgt (CG to Restraint): 2.55



Restraint Data

Total Number of Restraints: 4

Restraints/Side on Lg Axis: 2

Restraints/Side on Sht Axis: 2

Restraint Type: FHS

Loc 1:	2-100/1600	Loc 2:	2-100/1600
Loc 3:	2-100/1600	Loc 4:	2-100/1600

Output Data (ASD) (Contact KNC to get LRFD Values)

Cert Loads Bolted (Seismic) (lb)	Loc 1	Loc 2	Loc 3	Loc 4
Static Load (- is Down)	-532	-798	-798	-1198
Max Uplift Load at Loc (S/C):	31/36	38/43	38/43	48/53
Max Horiz Load at Loc (S/C):	68/88	102/132	102/132	153/198
Max Download at Loc (S/C):	-40/-45	-51/-56	-51/-56	-68/-73

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4
Restraint SF if Welded to Steel	39.13	26.53	26.53	17.66
Restraint SF if Through Bolted	39.13	26.53	26.53	17.66
Anc SF/Failure Mode (Ductile/Brittle)	4.29 (D)	2.90 (D)	2.90 (D)	1.96 (D)
Anchor Size/Qty	3/8" CC /2	3/8" CC /2	3/8" CC /2	3/8" CC /2
Anchor Embedment Req'd	2"	2"	2"	2"
Attachment Bolt Size/Qty	5/8" A307 /2	5/8" A307 /2	5/8" A307 /2	5/8" A307 /2

If welded, the bracket corners (4 Locs) each require 2.75 linear inches of .38 weld.

Note: Bolt Safety Factors based on the capacity of Type A307 hardware
or anchors to handle tensile loads after all horizontal loads are accounted for.
Min Edge Distance - See Anchor Data Sheet
Safety Factors listed as 100 indicate 100 or greater
For a detailed summary of how these loadings were derived, contact KINETICS NOISE CONTROL, Inc.

KNC certifies that the seismic/wind isolation and or restraint system described on this sheet is adequate to resist the certification loads specified herein. The use of hardware other than that provided by KNC voids this certification.

This certification addresses the load path from the equipment point connection to the connection point of the structure. Others must verify the ability of the equipment or structure to resist these loads. See also the included disclaimer. Certification void if disclaimer and Certification Cover Sheet not included. In connection with this certification and the application of the certification design loads to the project ,KINETICS NOISE CONTROL, Inc guarantees that we will use that degree of care and skill ordinarily excercised under similar conditions by reputable members of our profession to determine restraint loadings and Safety Factors based on customer supplied input data. No other warranty, expressed or implied, is made or intended. 11/22/2013

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Figure D1.6.1-2; Project and Representative Information

P-B-1 THRU 4

KNC PO: 76816 KINETICS SEISMIC CERTIFICATION (A)

Input Data

Project: KALEIDA HEALTH Representative: M. SCHILLER P.O. Number: 1519

Referring to Figure D1.6.1-3, the next partial line down the page, left hand side, has the following data from left to right.

1. **Date** – The date the certification was performed.
2. **Code Used** – This is the model code that is indicated for the project.

Figure D1.6.1-3; Date and Code

KNC PO: 76816 KINETICS SEISMIC CI

Input Data

Project: KALEIDA HEALTH Representative: M. SCHILLER
Date: 01-25-2011 Code Used: 2003IBC

The line immediately below the date on the left hand side of the page, shown in Figure D1.6.1-4, contains equipment data.

1. **Equip Type** – This identifies the equipment as a pump, cooling tower, air handling unit, chiller, and etc.
2. **Tag** – The tag information is repeated here.

Figure D1.6.1-4; Equipment Type and Tag

KNC PO: 76816 KINETICS SEISMIC CEI

Input Data

Project: KALEIDA HEALTH Representative: M. SCHILLER
Date: 01-25-2011 Code Used: 2003IBC
Equip Type: END SUCT. PUMP Tag: P-B-1 THRU 4

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The line directly below the Equip Type is the **Installation Type**, see Figure D1.6.1-5.

Figure D1.6.1-5; Installation Type

Date: **01-25-2011** Code Used: **2003IBC**
Equip Type: **END SUCT. PUMP** Tag: **P-B-1 THRU 4**
Installation Type: **Vibration isolated <= 1/4" Gap Standard**

The **Installation Type** is referring to the general descriptions of equipment, isolation, and restraints. These descriptions are tied to the component types specified in Tables D2.1.8-1, D2.1.8-2, D2.1.8-3, and D2.1.8-4 in Section D2.1.8 of this manual. The program uses the **Installation Type** to select the application factors to be used to compute the design seismic loads.

Immediately below the **Installation Type**, is the **Site Class**, sees Figure D1.6.1-6.

Figure D1.6.1-6; Site Class

Equip Type: **END SUCT. PUMP** Tag: **P-B-1 THRU 4**
Installation Type: **Vibration isolated <= 1/4" Gap Standard**
Site Class: **D (1.568)**

The **Site Class** is a piece of information required to compute the design seismic forces, See Sections D1.5.1 and D2.1.2.3 of this manual. This numerical value changes as the Stie Class varies from A to F. The number **(1.568)** is the value of F_a interpolated from Table D2.1.2-4 of this manual. It will vary from project site to project site. If the value of the **Site Class** is not given to Kinetics Noise Control, it will be assumed to be **D**, which is the code specified default value.

On the right hand side of the form directly below the **P.O. Number**, are the minimum specified horizontal and vertical acceleration factors, refer to Figure D1.6.1-7. These are not code based values. They usually appear in the seismic portion of the specification.

Figure D1.6-7; Minimum Specified Horizontal and Vertical Accelerations

FCU-1, 3 & 4
TIFICATION (A)

P.O. Number: **3129-J853**
Min Horiz G: **.50** (LRFD)
Min Vert G: **.33** (LRFD)

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1. **Min Horiz G** – This is the minimum specified horizontal acceleration used for the entire project. It will supersede the code derived horizontal acceleration if it exceeds that value. Shown in Figure D1.6.1-7 is a typical value for this specification. For Life Safety systems it might be increased to 1.0. If there is no specified value, it will be set to zero.

2. **Min Vert G** - This is the typical minimum specified horizontal acceleration used for the entire project. It will supersede the code derived horizontal acceleration if it exceeds that value, which it generally will. Shown in Figure D1.6.1-7 is a typical value for this specification. For Life Safety systems it might be increased to 0.67. If there is no specified value, it will be set to zero.

Immediately below the minimum acceleration factor lines are two lines that indicate the actual code based acceleration acting on the mass of the component, see Figure D1.6.1-8.

Figure D1.6.1-8; Code Derived Accelerations Acting on the Component.

Min Horiz G:	.00	(LRFD)
Min Vert G:	.00	(LRFD)
Bolted G (LRFD)	.18/.06	(H/V)
Conc Ancs(LRFD):	.24/.08	(H/V)

1. **Bolted G (LRFD or ASD)** – In Equation D2.1.8-1 in Section D2.1.8 of this manual, this value is the combination of all of the factors that multiply the weight of the component, W_P. These values apply to components that are to be bolted or welded to the structure. The values $.18/.06\ (H/V)$ refer to the horizontal and vertical accelerations respectively.

2. **Conc Ancs (LRFD or ASD)** – In Equation D2.1.8-1 in Section D2.1.8 of this manual, this value is the combination of all of the factors that multiply the weight of the component, W_P. These values apply to the evaluation of the anchors embedded in structural concrete. Some codes require that the forces acting on components anchored to concrete be increased to select the concrete anchors. This accounts for the fact that the concrete is a brittle material, and that its properties are not always well known. The values $.24/.08\ (H/V)$ refer to the horizontal and vertical accelerations respectively.

The next section below the **Bolted G (LRFD)** and **Conc Ancs (LRFD)** contains application information supplied by the customer, or representative dealing with the equipment and the location, shown in Figure D1.6.1-9 below. This figure is for restrained only with no isolation, or for isolators and restraints on the same centers.

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Figure D1.6.1-9; Application Information Derived from Customer Supplied Inputs – Isolators and Restraints on the Same Centers

	Bolted G (LRFD)	.18/.06	(H/V)
	Conc Ancs(LRFD):	.24/.08	(H/V)

Data used is derived from Customer input, others are responsible to verify the accuracy of this data.

Wt(lb):	3327	Elev-Roof/Equip:	100/0 ft
	Geometry (in):		
Ap:	2.50	Ss/Sds:	0.290/0.303
Ip:	1.50	Rp s/c:	2.50/2.50
A:	74.50	B:	34.50
ex:	7.45	ey:	3.45
Hgt (CG to Restraint):	2.55		

1. **Wt(lb/kg)** – The operating weight of the component in pounds or kilograms.
2. **Elev-Roof/Equip** – The elevation of the roof and the elevation of the equipment attachment in feet or meters.
3. **Ap** – The component amplification factor for the equipment from Tables D2.1.8-1, D2.1.8-2, D2.1.8-3, and D2.1.8-4 in Section D2.1.8 of this manual. It is derived from the **Installation Type**.
4. **Ss/Sds** – Ss is the mapped short period spectral acceleration for the project location, and Sds is the design short period spectral acceleration for the project location. One can be determined from another using the F_a data associated with the **Site Class**.
5. **Ip** – The Component Importance Factor which has a value of either 1.0 or 1.5. This is provided by the customer. If none is provided, Kinetics Noise Control will assume that it has a value of 1.5.
6. **Rp** – The response modification factor for the equipment from Tables D2.1.8-1, D2.1.8-2, D2.1.8-3, and D2.1.8-4 in Section D2.1.8 of this manual. This is also obtained by using the **Installation Type**.
7. **A** – The spacing between the end most isolator/restraints on one side in the direction of the long axis of the equipment. If there are more than two restraints on each long side, Kinetics Noise Control assumes that the restraints are repetitively spaced between the two end most restraints.
8. **B** – The spacing between the end most isolator/restraints on one side in the direction of the short axis of the equipment. If there are more than two restraints on each short side, Kinetics

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Noise Control assumes that the restraints are repetitively spaced between the two end most restraints as with the previous case.

9. **ex** – The location of the equipment center of gravity along the long axis of the equipment relative to the geometric center of the restraint array. If the actual location of the center of gravity is not provided to Kinetics Noise Control a value for it will be assumed based on the component type, IF not obvious, it will be assumed to have the value of **ex=0.1A**.

10. **ey** – The location of the equipment center of gravity along the short axis of the equipment relative to the geometric center of the restraint array. If the actual location of the center of gravity is not provided to Kinetics Noise Control a value for it will be assumed based on the component type. If not obvious, it will be assumed to have the value of **ey=0.1B**.

11. **Hgt (CG to Restraint)** – This is the vertical location of the equipment center of gravity relative to the restraint. If this is not provided, Kinetics Noise Control will typically assume that this is equal to one half of the equipment height. However, for concrete inertia bases this will be assumed to be lower than one half of the total height.

If the equipment is supported on isolators, and the restraints are not on the same centers as the isolators, this section with application information will be as shown in Figure D1.6.1-10. All of the definitions are the same as above except for the following.

1. **A** – This is now the spacing between the end most isolators on one side in the direction of the long axis of the equipment.

2. **B** - This Is now the spacing between the end most isolators on one side in the direction of the short axis of the equipment.

3. **a** – The spacing between the end most restraints on one side in the direction of the long axis of the equipment.

4. **b** - The spacing between the end most restraints on one side in the direction of the short axis of the equipment.

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Figure D1.6.1-10; Application Information Derived from Customer Supplied Inputs – Isolators and Restraints on the Different Centers

	Bolted G (LRFD)	.45/.06	(H/V)
	Conc Ancs(LRFD):	.59/.08	(H/V)

Data used is derived from Customer input, others are responsible to verify the accuracy of this data.

Wt(lb):	1250	Elev-Roof/Equip:	24/24 ft
	Geometry (in):		
Ap:	2.50	Ss/Sds:	0.290/0.303
Ip:	1.00	Rp s/c:	2.00/2.00
A:	76.27	B:	38.02
a:	74.75	b:	36.50
ex:	1.00	ey:	-6.00
Hgt (CG to Restraint):			22.00

D1.6.1.2.2 – Restraint Data:

D1.6.1.2.2A – Four Isolator/Restraints on the Same Centers:

Below the section with the application information is a **Restraint Data** section that outlines the types and number of restraints used. This section has several different formats which will be covered here. Figure D1.6.1-11 is for a component that has four isolator/restraints on the same centers.

Figure D1.6.1-11; Four Isolator/Restraints on the Same Centers

Restraint Data			
Total Number of Restraints:			4
Restraints/Side on Lg Axis:			2
Restraints/Side on Sht Axis:			2
Restraint Type:	FHS		
Loc 1:	2-100/1600	Loc 2:	2-100/1600
Loc 3:	2-100/1600	Loc 4:	2-100/1600

1. **Total Number of Restraints** – This is, of course, the total number of restraints in the array.

2. **Restraints/Side on Lg Axis** – The number of restraints acting on each long side. For the case above, the restraints are mounted on the long sides of the component.

3. **Restraints/Side on Sht Axis** – The number of restraints acting on each short side. Even though the restraints are mounted on the long sides of the component, when the component is viewed from the short side, there appears to be two restraints.

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4. **Restraint Type** – This specifies the Kinetics Noise Control model designation for the restraints used.

5. **loc 1, loc 2, loc 3, and loc 4** – These represent the four principle isolator/restraint locations and specify which Kinetics Noise Control product is used at that location. These are typically close to the four corners of the component.

D1.6.1.2.2B – More Than Four Isolator/Restraints on the Same Centers:

Figure D1.6.1-12 portrays a situation where there are more than four isolator restraints on the same centers.

Figure D1.6.1-12; More Than Four Isolator/Restraints on the Same Centers

Restraint Data

Total Number of Restraints:			10
Restraints/Side on Lg Axis:			5
Restraints/Side on Sht Axis:			2
Restraint Type:	FHS		
Loc 1:	1-250/2200	Loc 2:	1-250/2200
Loc 3:	1-250/2200	Loc 4:	1-250/2200
Smallest Restraint of other Loc:			1-250/2200

When more than four restraints are present, the line labeled **Smallest Restraint of other Loc** will indicated the smallest, weakest, restraint in the central area located between **Loc 1** and **Loc 3**, and between **Loc 2** and **Loc 4**.

D1.6.1.2.2C – Floor/Roof Mounted Non-Isolated Component:

When the component is floor or roof mounted, and non-isolated, the **Restraint Data** will be as shown in Figure D1.6.1-13 below.

Figure D1.6.1-13; Floor/Roof Mounted Non-Isolated Component

Restraint Data

Total Number of Restraints:	10
Restraints/Side on Lg Axis:	5
Restraints/Side on Sht Axis:	2
Restraint Type:	Solid - Floor Mtd

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Note that the **Restraint Type** simply says **Solid-Floor MTD**. It will be assumed that the same anchor type will be used in all locations.

D1.6.1.2.2D – Suspended Component with Four Restraint Cables:

For a suspended component, the Restraint Data section will be as shown in Figure D1.6.1-14.

Figure D1.6.1-14; Suspended Component with Four Restraint Cables

Restraint Data			
Total Number of Restraints:		**4**	
Restraints/Side on Lg Axis:		**2**	
Restraints/Side on Sht Axis:		**2**	
Restraint Type:	**Cable - Suspended**		
Loc 1:	**1 x 2mm**	Loc 2:	**1 x 2mm**
Loc 3:	**1 x 2mm**	Loc 4:	**1 x 2mm**

For this case, the **Restraint Type** is **Cable-Suspended**. Each restraint is identified by **Number of Cables x Cable Size (1 x 2mm)**. If more than four cables are to be used, the count will be eight, and each **Loc** will have a callout similar to **(2 x 1/4)**.

D1.6.1.2.2E – Wall Mounted Non-Isolated Component:

For a non-isolated wall mounted application, the **Restraint Data** will be as shown in Figure D1.6.1-15.

Figure D1.6.1-15; Wall Mounted Non-Isolated Component

Restraint Data			
Total Number of Restraints:		**4**	
Restraints/Side on Hor Axis:		**2**	
Restraints/Side on Vert Axis:		**2**	
Restraint Type:	**Solid**		
Loc 1:	**A307 Bolt**	Loc 2:	**A307 Bolt**
Loc 3:	**A307 Bolt**	Loc 4:	**A307 Bolt**

The **Restraint Type** is specified as **Solid** and the type of mounting hardware is indicated at each **Loc (A307 Bolt)**. The mounting hardware can be bolts, anchors, lag screws, or a type of toggle bolts.

D1.6.1.2.2F – Restraint Data for the ESR:

For the Kinetics Model ESR type restraint, the Restraint Data will appear as shown in Figure D1.6.1-16.

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A line is added above the **Restraint Data** indicating the **Overall Curb Height** and the number of bottom cross-braces (**# X-Braces**) that need to be in the curb to meet the seismic and wind force requirements. The **Restraint Type** is **ESR**. There are no specific listings for the various **Loc**s because each **Loc** has the same **Restraint Type**.

Figure D1.6.1-16; Restraint Data for the ESR

Overall Curb Height / # X-Braces:	**25.25 / 1**
Restraint Data	
Total Number of Restraints:	**6**
Restraints/Side on Lg Axis:	**3**
Restraints/Side on Sht Axis:	**2**
Restraint Type: **ESR-C**	

D1.6.1.2.2G – Restraint Data for the KSR:

The format for the Restraint Type for the Model KSR is the same as that for the ESR, see Figure D1.6.1-17.

Figure D1.6.1-17; Restraint Data for the KSR

Restraint Data	
Total Number of Hor Restraints:	**6**
Hor Restraints/Side on Lg Axis:	**1**
Hor Restraints/Side on Sht Axis:	**2**
Restraint Type: **KSR**	

D1.6.1.2.2H – Restraint Data for KSRs & ESRs with Island Supports:

Occasionally KSRs and ESRs come equipped with island supports beneath the condenser end of the unit. This allows the condensate to drain directly to the roof and either evaporate or run down the roof drains. It eliminates the need for complicated full perimeter curbs with drain pans. With the island support, the KSR or ESR will not be pull perimeter curbs, and the condenser end of the equipment will be supported by two Kinetics Noise Control Model FLSS isolator/restraints. The FLSS isolator/restraint is attached to the island support and the island support is anchored to the roof forming the load path for those restraints. The Restraint Data for the island support is shown, along with some of the Input Data in Figure D1.6.1-18, from Sheet (A) for the island support.

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Figure D1.6.1-18; Restraint Data for an Island Support

Data used is derived from Customer input, others are responsible to verify the accuracy of this data.

Wt(lb): **11065** Elev-Roof/Equip: **13/13 ft**

Geometry (in):

Ap:	**2.50**	Ss/Sds:	**1.500/1.000**
Ip:	**1.00**	Rp s/c:	**2.00/2.00**
A:	**347.00**	B:	**91.58**
ex:	**-8.00**	ey:	**1.00**

Hgt (CG to Restraint): **36.50**

Restraint Data

Total # of Island Restraints:	**2**
Restraints/Side on Lg Axis:	**1**
Restraints/Side on Sht Axis:	**2**
Restraint Type:	**FLSS**

Loc 1:	**Curb**	Loc 2:	**Curb**
Loc 3:	**1-250:3500**	Loc 4:	**1-250:3500**
Other Restraints			**Curb**

When selecting the isolator/restraints for the island support, the full weight of the unit and the center of gravity location is used. Kinetics Noise Control has a procedure that will estimate the number of isolator/restraints that would be needed to support the unit if no curb were present. The isolator/restraints are selected based on the weight being carried at **Loc 3** and **Loc 4** and the seismic force being resisted, and are displayed with the appropriate location For **Loc 1**, **Loc 2**, and **Other Restraints**, the **Curb** is listed as the support and restraint.

The Restraint Data for the curb portion is shown in Figure D1.6.1-19, and is taken from Sheet (A) for the curb. Also, in this figure, a portion of the Input Data is shown for clarity. Notice that the full weight of the unit is not considered for this portion of the calculation, but only the weight that is directly supported by the curb. Also, the center of gravity location along the long axis of the component is not considered as it was used to size the isolator/restraints for the island support. This Restraint Data section is the same as that above for the ESR in Section D1.6.1.2.2F above. If the curb had been a Model KSR, the Restraint Data would be the same as described in Section D1.6.1.2.2G above.

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Figure D1.6.1-19; Restraint Data for the Curb

Data used is derived from Customer input, others are responsible to verify the accuracy of this data.

Curb Wt(lb):**7898** Elev-Roof/Equip: **13/13 ft**

Geometry (in):

Ap:	**2.50**	Ss/Sds:	**1.500/1.000**
Ip:	**1.00**	Rp s/c:	**2.00/2.00**
A:	**269.76**	B:	**91.58**
ex:	**0**	ey:	**1.00**

Hgt (CG to Restraint): **36.50**

Overall Curb Height / # X-Braces: **20.25 / 2**

Restraint Data

Total Number of Restraints:	**8**
Restraints/Side on Lg Axis:	**4**
Restraints/Side on Sht Axis:	**2**
Restraint Type:	**ESR**

D1.6.1.2.2I – Restraint Data for Snubbers:

When snubbers are used, they are placed on different centers, locations, than the isolators. Typically they are placed in the central portion of the sides. Figure D1.6.1-20 shows the Restraint Data for Kinetics Noise Control Model HS-1 snubbers. Note that there is one snubber located on each side. The HS-1 is a uni-directional snubber, so one is required on each side for each direction. Other snubbers are multi-directional, and may be placed differently.

Figure D1.6.1-20; Restraint Data for Snubbers

Restraint Data

Total Number of Restraints:	**4**
Restraints/Side on Lg Axis:	**1**
Restraints/Side on Sht Axis:	**1**
Restraint Type:	**HS1,**

Loc 1:	**HS-1-2000**	Loc 2:	**HS-1-2000**
Loc 3:	**HS-1-2000**	Loc 4:	**HS-1-2000**

1.6.1.2.3 – Installation Sketch:

The installation sketch is located to the left of the **Restraint Data**. There are many permutations and combinations for this sketch. Several examples will be presented in this section. This is by no means and exhaustive compilation of all of the possible versions.

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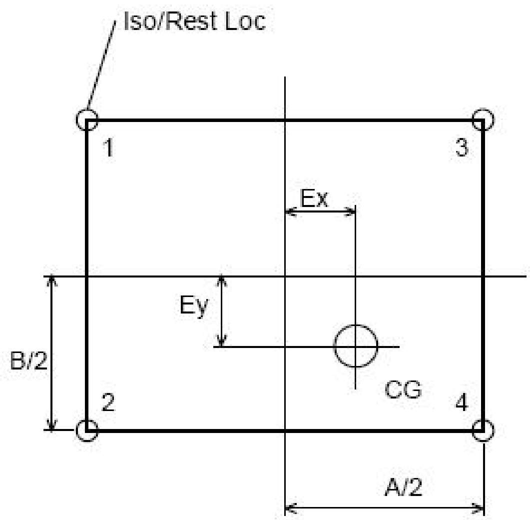
1.6.1.2.3A – Basic Installation Sketch for Four Isolator/Restraints:

The basic installation sketch for four isolator/restraints is shown in Figure D1.6.1-21.

Figure D1.6.1-21; Basic Installation Sketch for Four Isolator/Restraints



From the **Restraint Data** section for the locations, **Loc 1**, **Loc 2**, **Loc 3**, and **Loc 4**, are indicated in the installation sketch as **1**, **2**, **3**, and **4** respectively. The dimensions **A** and **B** from the application Information derived from the customer supplied data are shown on the installation sketch as the location of the center of the restraint array, **A/2** and **B/2** respectively. The center of gravity is indicated relative to the geometric center of the restraint array by **Ex** and **Ey**. These are related to the center of gravity locations in the application information as; **Ex=ex** and **Ey=ey**.

1.6.1.2.3B – Installation Sketch with More Than Four Isolator/Restraints:

When there are more than four isolator/restraints, the installation sketch is shown in Figure D1.6.1-22. Note, this will apply to isolator restraints such as Kinetics Model FHS, FLSS, FTS, FMS, ESR, KSMS, and etc.

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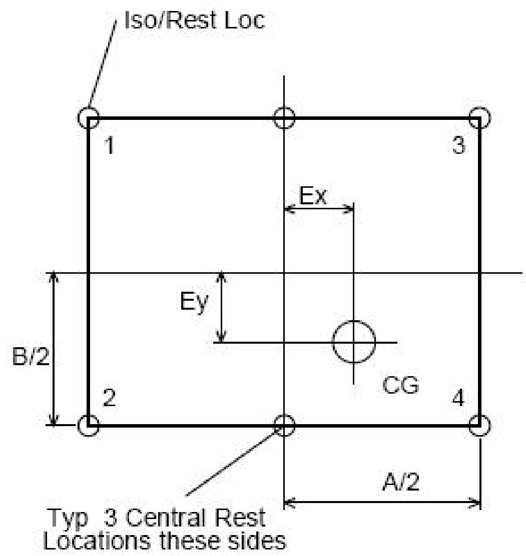
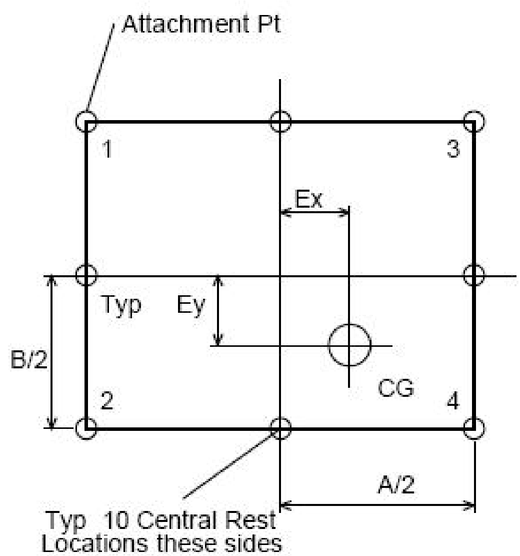
Figure D1.6.1-22; Installation Sketch with More Than Four Isolator/Restraints



In this sketch there is a leader pointing to the central restraint location and a note that reads; **Typ x Central Rest Locations these sides**. The **x** will be the number of central restraints between the end restraints on each opposite side; in this case **x** is **3**. If there are more than two restraint locations on the short axis side, the installation sketch looks like Figure D1.6.1-23.

Figure D1.6.1-23; Installation Sketch with more than Two Isolator/Restraints on Both the Long and Short Axis Sides



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1.6.1.2.3C – Installation Sketch for Suspended Components:

The two basic installation sketch formats for suspended components are shown in Figures D1.6.1-24 and D1.6.1-25. In each case the restraint cables are shown oriented 90° to each other.

Figure D1.6.1-24; Basic Installation Sketch #1 for Suspended Components

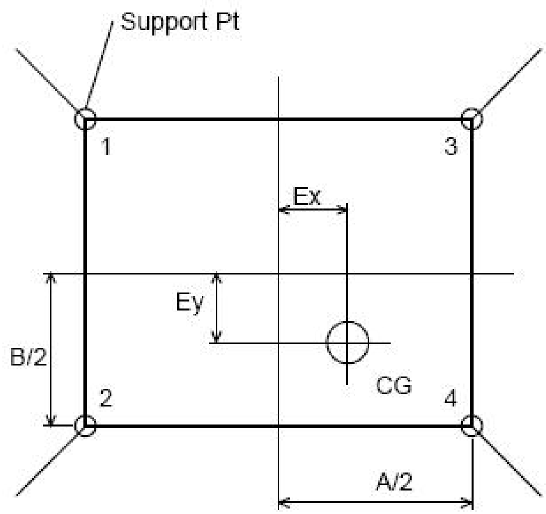
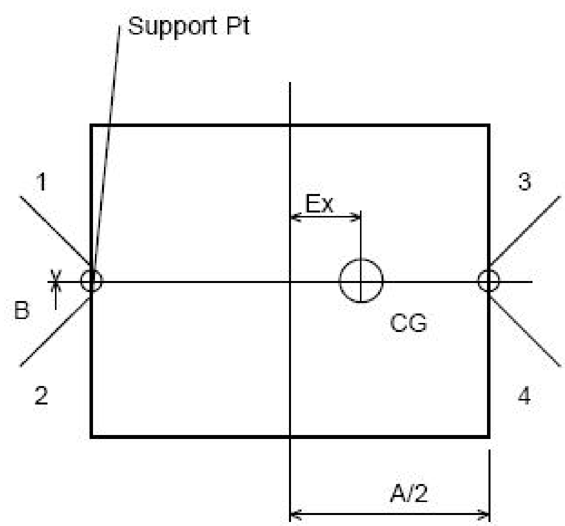


Figure D1.6.1-25; Basic Installation Sketch #2 for Suspended Components



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1.6.1.2.3D – Installation Sketch for KSR, KSCR, and Snubbers:

Snubbers, such as Kinetics Model HS-1 and HS-5, and the Kinetics Model KSR and KSCR are restraint devices that are intended to operate on centers, or locations, that are different than the isolators. An installation sketch for snubbers is shown in Figure D1.6.1-26.

Figure D1.6.1-26; Installation Sketch for Snubbers on Different Centers than the Isolators

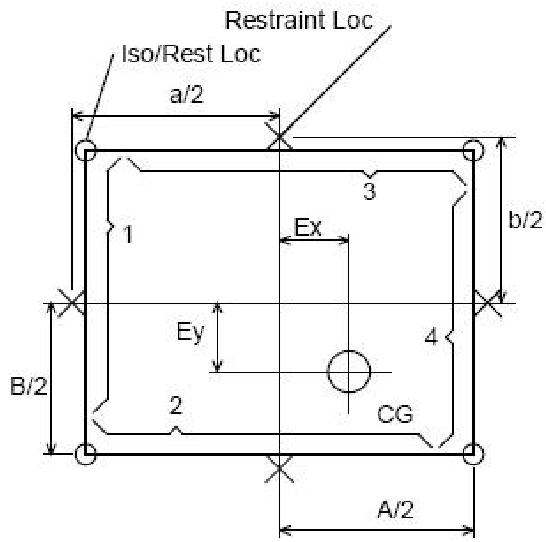
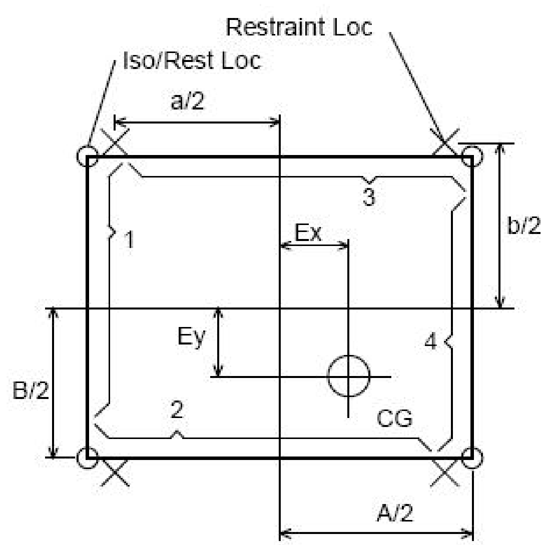


Figure D1.6.1-27; Installation Sketch for the Model KSR and KSCR



Note that the restraints are shown in the center of the sides. This is the proper and most efficient location for a snubber type restraint that is not coincident with the isolators. The sides of the

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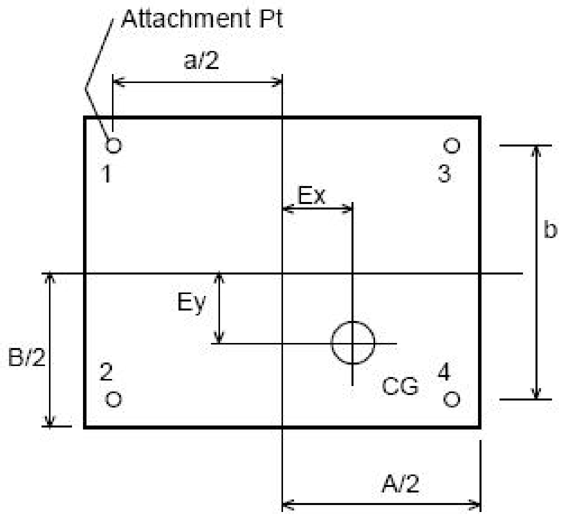
equipment are labeled **1** through **4**, indicating the restraint locations. The installation sketch for the Model KSR is slightly different as seen in Figure D1.6.1-27. In this case, the restraints are shown in the corners which are the optimum location for this type of restraint device.

1.6.1.2.3E – Installation Sketch for Wall Mounted Components:

The installation sketches for wall mounted components have a different appearance, see Figure D1.6.1-28. Note that **a** and **b** denote the anchorage locations, and **A** and **B** are dimensions the outside envelope of the component that touches the wall.

Figure D1.6.1-28; Typical Installation Sketch for Wall Mounted Components



1.6.1.2.3F – Installation Sketch for Island Supports:

The Installation sketch for an island support with a curb from Sheet (A) for the island support is shown in Figure D1.6.1-29.

The island support is indicated by the box shape on the right with locations **3** and **4** shown. The image on the left is shown as an ESR. If the curb were to be a KSR, then that image would appear as that shown in Figure D1.6.1-27. Note that **A/2** is shown to the centerline of the island support. Figure D1.6.1-30 is the installation sketch for a curb with an island support from Sheet (A) for the curb. Here the focus is on the image of the curb, and **A/2** is defined to the last set of isolators on the curb. Again, if the curb section were a KSR, the image would appear as shown in Figure D1.6.1-27.

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Figure D1.6.1-29; Installation Sketch for an Island Support with a Curb

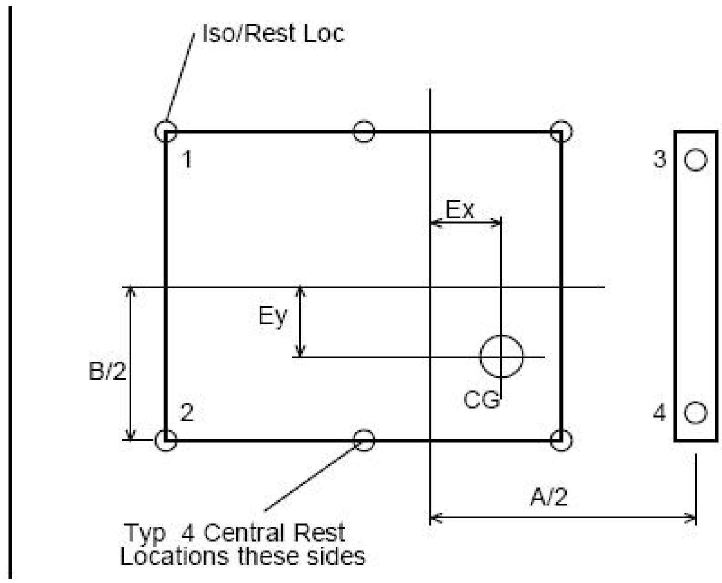
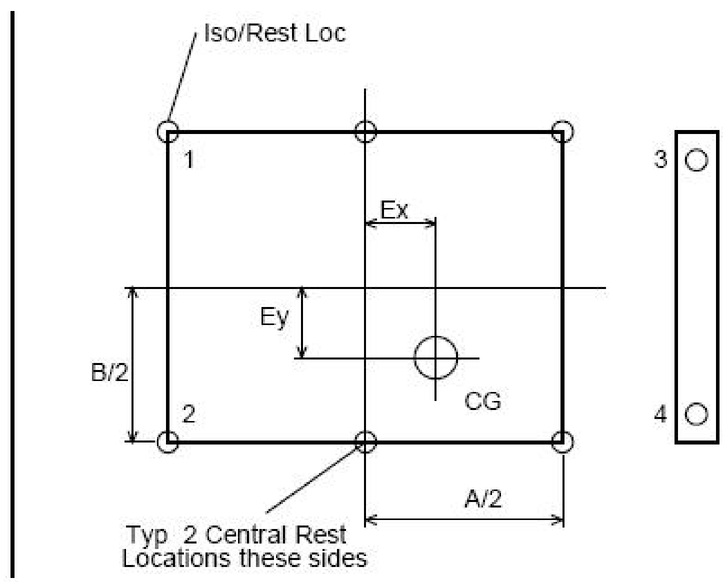


Figure D1.6.1-30; Installation Sketch for a Curb with an Island Support



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D1.6.1.2.4 – Output Data:

The output data section is composed of four areas. First is a summary of the loads that are being applied to the supports and restraints. Second is a summary of the performance of the selected restraints under the applied loads. Also in this section is a discussion of alternate attachment methods that may be used. Fourth are listed brief disclaimers indicating the limits of the analysis and Kinetics Noise Control's liability.

Looking first at the top of the output section, Figure D1.6.1-31 shows the results of the force analysis.

Figure D1.6.1-31; Results of the Force Analysis for Four Restraint Locations

Output Data (LRFD) Cert Loads Bolted (Seismic) (lb)	Loc 1	Loc 2	Loc 3	Loc 4
Static Load (- is Down)	-532	-798	-798	-1198
Max Uplift Load at Loc (S/C):	54/70	68/89	68/89	90/117
Max Horiz Load at Loc (S/C):	97/126	145/189	145/189	218/283
Effective Crnr Wt (- is Down)	-480	-719	-719	-1078

In all cases, loads that are (-) act downward. The loads are printed out in columns under the headings of **Loc 1**, **Loc 2**, **Loc 3**, and **Loc 4**. These correspond to the four primary restraint location indicated in the installation sketch. When the isolators and restraints are coincident, in the same housing, these locations will be indicated at the corners of the component.

1. **Static Load (- is Down)** – This is the estimated static dead load at each restraint location based on the center of gravity information.

2. **Max Uplift Load at Loc (S/C)** – This is the vertical restraint reaction at the restraint locations indicated. **(S/C)** indicates the design value for the anchorage calculation based on whether the restraint is attached to the building structural steel or to concrete. **S** is for steel attachment and **C** is for concrete attachment.

3. **Max Horiz Load at Loc (S/C)** – This is the horizontal reaction at the restraint locations indicated. **(S/C)** has the same meaning as before.

4. **Effective Crnr Wt (- is Down)** – This is the effective corner weight. Kinetics Noise Control assumes that all of the component weight is distributed to the corner isolator/restraints relative to the position of the center of gravity. When more than four restraints are employed, the restraints that have built in clearances that are positioned toward the center of the component will not usually will not be engaged when overturning forces are present, see Section D1.3.2.4 of this manual. Instead, only the outermost restraints will be engaged and thus resist the overturning forces. The use of effective corner weights will assure that the active restraints are properly loaded to resist the overturning forces and moments.

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If there are more than four restraint locations, the results of the force analysis will be as shown in Figure D1.6.1-32. Notice that there is a column marked **Other.** This column represents the most highly loaded restraint other than the four primary restraints identified by **Loc 1** through **Loc 4**. Also note that there is no effective corner weight listed. Any dead load weight associated with this restraint has been redistributed to the nearest corner(s) per the center of gravity location.

Figure D1.6.1-32; Results of the Force Analysis for More Than Four Restraint Locations

Output Data (LRFD) Cert Loads Bolted (Seismic) (lb)	Loc 1	Loc 2	Loc 3	Loc 4	Other
Static Load (- is Down)	-861	-861	-1033	-1033	-1863
Max Uplift Load at Loc (S/C):	-530/-229	-530/-229	-820/-513	-820/-513	-956/-739
Max Horiz Load at Loc (S/C):	358/465	358/465	430/558	430/558	775/1007
Effective Crnr Wt (- is Down)	-1537	-1537	-1845	-1845	

When an island support is used with a Kinetics Noise Control Model ESR or KSR, the Output Data section has a different appearance. On Sheet (A) for the island support, the Output Data looks like Figure D1.6.1-33.

Figure D1.6.1-33; Output Data for an Island Support

Output Data (LRFD) Cert Loads Bolted (Seismic) (lb)	Loc 1	Loc 2	Loc 3	Loc 4
Static Load (- is Down)	Curb	Curb	-1549	-1618
Max Uplift Load at Loc:			1407	1317
Max Horiz Load at Loc:			2324	2427
Effective Crnr Wt (- is Down)			-2323	-2427

Data is shown for **Loc 3** and **Loc 4** which are the locations for the island support. Loc 1 and Loc 2 are marked as being part of the curb section. Figure D1.6.1-34 shows the Output Data for the curb portion form Sheet (A) for the curb when and island support is used.

Figure D1.6.1-34; Output Data a Curb with an Island Support

Output Data (LRFD) Loads Generated by Wind (lb)	Loc 1	Loc 2	Loc 3	Loc 4	Other
Static Load (- is Down)	-644	-673	Island	Island	-1346
Max Uplift Load at Loc:	1627	1550			997
Max Horiz Load at Loc:	1363	1363			1363
Effective Crnr Wt (- is Down)	-1739	-1816			

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Here **Loc 1**, **Loc 2**, and **Other** have the Output Data displayed indicating that they are part of the curb section. **Loc 3** and **Loc 4** are marked as belonging to the island support with their Output Data being displayed on Sheet (A) for the island support. If the curb consisted of a KSR, or a four pedestal ESR, there would not be a column for **Other**.

1.6.1.2.5 – Performance Data:

The next section down the page deals with the performance of the selected restraint components. The performance is defined by the use of a Safety Factor (**SF**) that is defined with respect to the allowable loads permitted for the restraint components recommended by Kinetics Noise Control. This Safety Factor is with respect to the allowable restraint load envelope established by Kinetics Noise Control for the restraint product being recommended and certified. This process of generating the allowable restraint load envelope is discussed in Section D1.4.2 of this manual. If the restraint is rating is based on the yield of the material, then the limits are based on eight tenths of yield. If the restraint rating is based on testing or the ultimate strength of the material, the limits are one half of the maximum tested value, or one half of ultimate.

1.6.1.2.5A – Performance Data for Floor/Roof Mounted Isolator/Restraints – FHS, FLSS, FLS, FTS, and FMS:

Figure D1.6.1-35 shows this portion of the output for a component restrained using a seismic isolator such as a Kinetics Model FLSS or FHS. Again, the Safety Factors are listed by **Loc**. Safety Factors that exceed 1.00 are acceptable as they are computed with respect to the allowable load envelopes which will have built in Safety Factors of either 1.67:1 or 2.0:1 depending on whether they are with respect to yield or ultimate respectively.

Figure D1.6.1-35; Performance of Isolator/Restraints as Indicated by Safety Factors

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4
Restraint SF if Welded to Steel	**39.13**	**26.53**	**26.53**	**17.66**
Restraint SF if Through Bolted	**39.13**	**26.53**	**26.53**	**17.66**
Anc SF/Failure Mode (Ductile/Brittle)	**4.29 (D)**	**2.90 (D)**	**2.90 (D)**	**1.96 (D)**
Anchor Size/Qty	**3/8" CC /2**	**3/8" CC /2**	**3/8" CC /2**	**3/8" CC /2**
Anchor Embedment Req'd	**2"**	**2"**	**2"**	**2"**
Attachment Bolt Size/Qty	**5/8" A307 /2**	**5/8" A307 /2**	**5/8" A307 /2**	**5/8" A307 /2**

If welded, the bracket corners (4 Locs) each require 2.75 linear inches of .38 weld.

Note: Bolt Safety Factors based on the capacity of Type A307 hardware
or anchors to handle tensile loads after all horizontal loads are accounted for.
Min Edge Distance - See Anchor Data Sheet
Safety Factors listed as 100 indicate 100 or greater

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1. **Restraint SF if Welded to Steel** – This is the Safety Factor of the restraint and the attachment if the restraint is welded to the building structural steel. Typically this applies also to the restraint components themselves. Kinetics Noise Control designs their restraints to have maximum capacity when welded to the building's structural steel.

2. **Restraint SF if Bolted to Steel** – This is the Safety Factor if the restraint is bolted to the building structural steel. This value is based on ASTM A307 hardware. So, this number represents just the attachment. The restraint would typically have a higher Safety Factor.

3. **Restraint SF if Anchored to Concrete** – This is the attachment Safety Factor if the restraint has been anchored to the building concrete. The (D) or (B) designate the type of analysis performed. (B) indicates that with the anchor parameters given the anchor failure mode does not qualify as a ductile connection and a brittle analysis was performed. If (D) is listed, the failure mode can be considered to be ductile.

4. **Anchor/Attachment Bolt Size/Qty** – This is the size and quantity of concrete anchors or bolts required to attach the restraint to the building. There will also be some indication of the type of anchor being used. **Wdg** indicates a standard wedge type anchor that has not been approved for use in cracked concrete. If there is a **CC** designation, the anchor is a wedge type anchor approved for use in cracked concrete and will have an ICC-ESR number. If the designation is **Adh** then the anchor is an adhesive anchor that has been rated for use in cracked concrete and will have an ICC-ESR number. Finally, if the designation is **Unc**, the anchor is an undercut wedge type anchor rated for use in cracked concrete and will have an ICC-ESR number.

5. **Min Anchor Embedment Req'd** – Concrete anchors require a certain minimum embedment within the concrete to produce the required load capacity. This value is the minimum required per the ICC-ESR.

Below this is a sentence that indicates that, if the isolator/restraint is to be welded to structural steel, specifies where weld is to be located, the minimum length of each weld, and the minimum size of the weld to be used. Next is information relative to the anchors or bolts that may be used to attach the isolator/restraint to the building.

16.1.2.5B – Performance Data for Non-Isolated Floor/Roof Mounted Components:

Figure D1.6.1-36 shows the performance section of the output where the component has been solid mounted, non-isolated, with either concrete anchors or bolts to the building structure. No vibration isolation is considered in this output.

Minimum Anchor Size – Kinetics Noise Control will calculate the minimum anchor size of the type indicated to resist the applied loads at each location. The location marked **Other** is the worst case condition of all the central anchors locations. In this example, the anchors recommended are adhesive type anchors as indicated by **Adh** to the right of the anchor size.

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Min Anchor Embedment Req'd – This is the minimum anchor embedment depth in the concrete to achieve the required allowable loads for the anchors.

Anchor Safety Factor if in Concrete – This is the safety factor of the recommended anchor with respect to its allowable values as derived from the ICC-ESR per ACI 318 Appendix D.

Min Steel Attachment Bolt Size – This is the minimum bolt size required to resist the loads at any one given location. This selection is based on UNC ASTM A307 hardware.

Bolt Safety Factor is Attached to steel – This is the Safety Factor of the bolted to steel attachment configuration based on the yield strength of ASTM A307 material.

Figure D1.6.1-36; Performance of Anchors or Bolts as Indicated by Safety Factors

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4	Other
Minimum Anchor Size	**3/8"CC**	**3/8"CC**	**3/8"CC**	**3/8"CC**	**3/8"CC**
Min Anchor Embedment Req'd	**2"**	**2"**	**2"**	**2"**	**2"**
Anc SF/Failure Mode (Ductile/Brittle)	**5.39 (D)**	**3.61 (D)**	**3.60 (D)**	**2.41 (D)**	**1.21 (D)**
Min Attachment Bolt Size	**#10 / 1/4"**	**#10 / 1/4"**	**#10 / 1/4"**	**1/4"**	**3/8"**
Through Bolt Safety Factor	**2.02**	**1.35**	**1.35**	**1.56**	**1.76**

If welded, each anchor point requires 1.25 linear inches of .12 weld.
Kinetics Adhesive or KUAB Undercut anchors must be used for equipment over 10 HP
Note: Bolt Safety Factors based on the capacity of Type A307 hardware
or anchors to handle tensile loads after all horizontal loads are accounted for.
Min Edge Distance - See Anchor Data Sheet
Safety Factors listed as 100 indicate 100 or greater

If Mult Hardware sizes indicated, use the largest at all Locations

Below the performance data for the anchors and bolts by Safety Factor is a sentence that specifies the amount and size of a weld required to replace each anchor and/or bolt. Next is information relative to the anchors or bolts that may be used to attach the isolator/restraint to the building.

16.1.2.5C – Performance Data for the KSR and KSCR:

Figure D1.6.1-37 shows the performance output for a Model KSR. Each of the four locations in this case refers to the four sides of the curb. The straps and horizontal restraints are listed separately because they are two different components. They are not combined in a single entity like the FHS or FLSS.

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Figure D1.6.1-37; Performance of KSR Restraints as Indicated by Safety Factors

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4
Vert Straps per Side / FS	**Not Req**	**1 Strap/24.4**	**Not Req**	**Not Req**
Horiz Safety Factor	**4.12**	**1.53**	**2.94**	**3.92**

The equivalent of (1) 1/4 " Fastener per Restraint
is required to connect the equip to the top rail.

The connection between the curb and the roof deck is to be made with a minimum of (10) #10 Screws on each of the short sides and (15) #10 screws on each of the long sides. or the equivalent to resist the above listed loads. Analysis of curb components not manufactured by KNC are the responsibilty of others.

Note: Bolt Safety Factors based on the capacity of Type A307 hardware or anchors to handle tensile loads after all horizontal loads are accounted for.

Vert Straps per Side / FS – This shows the number of vertical straps per side to resist the uplift forces or overturning moments, and the safety factor **FS** that is associated with that number of straps.

Horiz Safety Factor – This indicates the performance of the horizontal leaf type restraints. The safety factor published is for all of the restraints on a given side.

Below the Safety Factor information for the KSR is a paragraph that tells the size and number of bolts required to hold the unit on the top rail of the KSR. The paragraph below this one is a hardware list that gives the installing contractor some idea of the hardware requirements for attaching the curb to the roof deck. At the bottom of this section is a note that describes the bolts to be used.

16.1.2.5D – Performance Data for the ESR:

The performance data for a Kinetics model ESR attached to structural steel is shown below in Figure D1.6.1-38. The ESR pedestal location designations are the same as those used for floor mounted isolator/restraints such as the FHS or FLSS.

Top Bolt Weld Failure – This is the safety factor for the weld between the top rail of the ESR and the bolt that connects it to the restraint system.

Bracket Bending Failure – This is the safety factor of the ESR housing.

Base Attachment Weld Failure – This is the safety factor for the weld between the housing and the base plate.

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Figure D1.6.1-38; Performance of an ESR Attached to Steel as Indicated by Safety Factors

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4	Other
Top Bolt Weld Failure	15.10	13.93	14.65	13.50	6.83
Bracket Bending Failure	13.96	12.96	13.58	12.59	100.00
Base Attachment Weld Failure	20.96	19.33	20.34	18.74	100.00
I-Beam Hgt Extension Weld FS	5.13	4.73	4.98	4.59	100.00
Bolt FS Attached to steel	4.92	4.56	4.79	4.43	21.19
Min Bolt Size, Attach to Steel	0.625	0.625	0.625	0.625	0.625
Anchors/Bolts per Pedestal	3	3	3	3	3

For full Restraint Capacity, (1) 1/2" Or (2) 3/8" Cap screws are required
per Pedestal to connect the equipment to the top curb rail.

If ESR is Welded, Ignore Bolt Data, Bolt Safety Factors and O'Size Baseplate Reqmt
Weld required is a min 6 in. long by 1/4 in. weld for both sides of the pedestal
with a min 3 in. long x 1/4 in. weld at each pedestal end.

Safety Factors listed as 100 indicate 100 or greater

I-Beam Hgt Extension Weld FS – If the ESR has an extended height, the extension will be via a piece of I-beam welded to the bottom of the ESR base plate. There will be another base plate welded to the bottom of the I-beam. This safety factor applies to the weld between the I-beam and the bottom base plate.

Bolt FS Attached to Steel – This is the safety factor for the bolts that are attaching the ESR pedestals to the building structure. The safety factor is based on ASTM A307 bolt material.

Min Bolt Size, Attach to Steel – The bolts required for attaching the ESR Pedestal to the building steel.

Anchors/Bolts per Pedestal – Shows how many bolts or anchors would be required per ESR pedestal.

Below the **Anchors/Bolts per Pedestal** there are two lines that detail the number and size for the bolts required per pedestal to attach the unit to the ESR top rail. These bolts must be minimum ASTM A307 material. The three lines below this details the weld size and length required to weld attach the pedestal to the building structural steel in lieu of the 5/8" ASTM A307 bolts.

The performance data for a Kinetics model ESR attached to structural concrete is shown below in Figure D1.6.1-39.

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The first four items are the same as they were for the ESR that was attached to structural steel.

Anchor FS in Normal Concrete – The anchor factor of safety in minimum 3,000 psi normal-weight concrete.

Anchor Size in Normal Concrete – The recommended anchor size for use in minimum 3,000 psi normal-weight concrete.

Min Embedment – The embedment depth required to achieve the required strength to produce the safety factor listed above.

Figure D1.6.1-39; Performance of an ESR Attached to Steel as Indicated by Safety Factors

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4	Other
Isolator Hsg or Weld Failure	7.93	7.34	7.70	7.12	3.68
Restraint Stud Failure	13.38	12.77	13.15	12.54	6.83
Std Base Anc SF/Mode(Ductl/Britl)	1.28 (D)	1.19 (D)	1.24 (D)	1.16 (D)	1.52 (D)
OSize Base Anc SF/Mode(Ductl/Britl)	n.a.	n.a.	n.a.	n.a.	n.a.
Anchor Size in Std Base	5/8"	5/8"	5/8"	5/8"	5/8"
Concrete / Anchor Type	Nrml / KCCAB	Nrml / KCCAB	Nrml / KCCAB	Nrml / KCCAB	Nrml / KCCAB
Min Embedment	4"	4"	4"	4"	4"
Anchors/Bolts per Pedestal	3	3	3	3	3
Oversize Baseplate Req'd	No	No	No	No	No

For full Restraint Capacity, (1) 1/2" Or (2) 3/8" Cap screws are required
per Pedestal to connect the equipment to the top curb rail.

Note: Bolt Safety Factors based on the capacity of Type A307 hardware
or anchors to handle tensile loads after all horizontal loads are accounted for.
Min Edge Distance - See Anchor Data Sheet
Safety Factors listed as 100 indicate 100 or greater

Anchors/Bolts per Pedestal – This indicates how many anchors are required per pedestal to achieve the factor of safety listed above, **3** for standard pedestals and **4** for oversized base plates.

Oversize Baseplate Req'd – If and Oversized Base plate is required, **Yes**, will be indicated at each pedestal location, otherwise, **No**, will be indicated.

16.1.2.5E – Performance Data for an ESR or KSR with an Island Support:

As mentioned earlier, island supports are special cases of curb type supports and restraints with a floor mounted isolator/restraint. Figure D1.6.1-39 shows the performance Data for the isolator/restraints for an island support, taken from Sheet (A) for the island Support.

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Restraint SF if Welded to Steel – This is the safety factor of the isolator/restraint used for the island if welded to the island support.

Restraint SF if Bolted to Steel – This is the safety factor of the isolator/restraint used for the island if bolted to the island support.

Attachment Bolt Size/Qty – This is the size and number of ASTM A307 UNC bolts required per isolator/restraint.

Figure D1.6.1-40; Performance Data for an Island Support

Calculated Restraint Safety Factors (Must be greater than or equal to 1)	Loc 1	Loc 2	Loc 3	Loc 4
Restraint SF if Welded to Steel			**3.97**	**3.76**
Restraint SF if Bolted to Steel			**3.97**	**3.76**
Attachment Bolt Size/Qty			**0.625 /4**	**0.625 /4**

Normally the isolator/restraints are factory installed to the island support. Note that **Loc 1** and **Loc 2** do not have any Performance Data associated with them.

Taken from Sheet (A) for the curb, the Performance Data will look like that shown in Figure D1.6.1-41.

Figure D1.6.1-41; Performance Data for a Curb with an Island Support

Calculated Restraint Safety Factors (Must be greater than or equal to 1)	Loc 1	Loc 2	Loc 3	Loc 4	Other
Top Bolt Weld Failure	**5.57**	**5.74**			**5.80**
Bracket Bending Failure	**4.22**	**4.22**			**53.12**
Base Attachment Weld Failure	**8.39**	**8.48**			**80.29**
Bolt FS Attached to steel	**1.92**	**1.93**			**14.40**
Min Bolt Size, Attach to Steel	**0.625**	**0.625**			**0.625**
Anchors/Bolts per Pedestal	**3**	**3**			**3**

For full Restraint Capacity, (1) 1/2" Or (2) 3/8" Cap screws are required per Pedestal to connect the equipment to the top curb rail.
If ESR is Welded, Ignore Bolt Data, Bolt Safety Factors and O'Size Baseplate Reqmt
Weld required is a min 6 in. long by 1/4 in. weld for both sides of the pedestal with a min 3 in. long x 1/4 in. weld at each pedestal end.

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The curb depicted in Figure D1.6.1-41 is a Kinetics Model ESR. The Performance Data will be as described in Section 16.1.2.5D above. **Loc 3** and **Loc 4** are blank as they refer to the island support.

16.1.2.5F – Performance Data for the KSMS and KSMG:

The performance data for Kinetics Models KSMS and KSMG will have a format like that shown in Figure D1.6.1-42 below.

Figure D1.6.1-42; Performance Data for KSMS and KSMG

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4	Other
Restraint SF if Welded to Steel	**5.54**	**5.08**	**3.47**	**3.17**	**1.64**
Restraint SF if Bolted to Steel	**5.54**	**5.08**	**3.47**	**3.17**	**1.64**
Restraint SF if Anchored to Concrete	**1.67**	**1.56**	**1.22**	**1.17**	**1.00**
Anchor/Attachment Bolt Size/Qty	**0.375 CC /1**	**0.375 CC /1**	**0.375 CC /1**	**0.375 CC /1**	**0.375 CC /1**
Min Anchor Embedment Req'd	**2"**	**2"**	**2"**	**2"**	**2"**

If welded, each bracket end requires 1.75 linear inches of .18 weld.

Restraint SF if Welded to Steel – This is the safety factor if the KSMS is welded to the building structural steel. It is also the safety factor of the restraint itself. The KSMG ***is not*** to be welded to the building structural steel because it is isolated from the building by a neoprene pad. This line would indicate the bracket factor of safety.

Restraint Safety Factor if Bolted to Steel – These devices may also be bolted to the building structural steel. This is the safety factor if bolted to the building steel using ASTM A307 bolts.

Restraint SF if Anchored to Concrete – This is the safety factor if attached to the building structural concrete using the type of anchor indicated in the next line. The concrete is assumed to be minimum 3,000 psi normal-weight concrete.

Anchor/Attachment Bolt Size/Qty – The first item is the anchor or bolt size in inches followed by the anchor designation. If there is a **CC** designation, the anchor is a wedge type anchor approved for use in cracked concrete and will have an ICC-ESR number. If the designation is **Adh** then the anchor is an adhesive anchor that has been rated for use in cracked concrete and will have an ICC-ESR number. Finally, if the designation is **Unc**, the anchor is an undercut wedge type anchor rated for use in cracked concrete and will have an ICC-ESR number. The second item is the number of anchors or bolts required for each KSMS or KSMG.

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Below this is a line that specifies the size and length of the weld required to anchor the KSMS to the building structure. **Note:** ***The KSMG is an isolated version of the KSMS and <u>is not</u> to be welded to the building structural steel. For the KSMG this line would not appear on the Kinetics Seismic Certification Sheet.***

16.1.2.5G – Performance Data for Wall Mounted Components:

For wall mounted components that are through bolted to the wall structure, the performance data will appear as shown in Figure D1.6.1-43.

Min Steel Attachment Bolt Size – This gives the minimum ASTM A307 bolt required at each location to resist the seismic and dead loads of the component.

Bolt Factor of Safety if Attached to steel – This is the factor of safety with respect to the allowable limit for the bolt size and material specified above.

The paragraph directly below the **Bolt Factor of Safety if Attached to steel** line gives the welding equivalent for the specified ASTM A307 bolts.

Figure D1.6.1-43; Performance Data for a Wall Mounted Component – Bolted to the Structure

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4
Min Steel Attachment Bolt Size	**1/4**	**1/4**	**1/4**	**1/4**
Bolt Safety Factor if Attached to steel	**11.20**	**8.48**	**7.51**	**5.43**

If welded, each anchor point requires 1.25 linear inches of .12 weld.
Seismically rated anchors must attach to poured or grout filled masonry walls
Note: Bolt Safety Factors based on the capacity of Type A307 hardware
to handle tensile loads after all horizontal loads are accounted for.

If Mult Hardware sizes indicated, use the larg-est at all Locations

Other types of wall attachments will indicate the type of fastener used to attach the component to the wall. An example of this type is shown in Figure D1.6.1-44.

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Figure D1.6.1-44; Performance Data for a Wall Mounted Component

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4
Minimum Anchor Size	**3/8 Tgl**	**3/8 Tgl**	**3/8 Tgl**	**3/8 Tgl**
Min Anchor Embedment Req'd	**n.a.**	**n.a.**	**n.a.**	**n.a.**
Anchor Safety Factor if in Concrete	**4.47**	**4.48**	**3.12**	**2.70**
Min Steel Attachment Bolt Size	**1/4**	**1/4**	**1/4**	**1/4**
Bolt Safety Factor if Attached to steel	**11.20**	**8.48**	**7.51**	**5.43**

Min Anchor Size – This is the minimum fastener size required to meet the seismic and dead load requirements. The next three letters indicate the type of fastener that is to be used.

Tgl – This is a toggle bolt. It is intended for use in hollow masonry units and through steel studs.

Adh – Indicates an Adhesive type anchor. There are two types used for wall mounted equipment. One is for use in hollow masonry units and the other for use in 3,000 psi normal-weight concrete.

Wdg – This refers to a standard wedge type anchor, one that is not pre-qualified for use in cracked concrete. This type of anchor is for use in the grout filled concrete masonry units.

Lag – Indicates the use of a lag screw. It is intended for use in structural wood members; see Appendix A7.3 for guidelines in using lag screws.

CC – This is a concrete anchor that has been pre-qualified for use in cracked concrete. These are used in poured normal-weight concrete walls.

16.1.2.5H – Performance Data for Suspended Components:

Typical performance data for a suspended component with four supports and four restraint cables is shown in Figure D1.6.1-45.

Minimum Anchor Size – Indicates the minimum nominal anchor size for each location. The initials **CC** indicate that wedge type concrete anchors that have been pre-qualified for use in cracked concrete are required. The initials **Wdg** would indicate standard wedge type anchors requiring a minimum embedment of 8 times the nominal anchor diameter.

No of Anchors per Bracket – Indicates the number of anchors per bracket at each location.

Min Anchor Embedment Req'd – This is the minimum anchor embedment required to obtain the rated capacity of the anchors.

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Figure D1.6.1-45; Performance Data for a Suspended Component – Four Supports

Cable Restraint and Anchorage Requirements

	Loc 1	Loc 2	Loc 3	Loc 4
Minimum Anchor Size	**3/8 CC**	**3/8 CC**	**3/8 CC**	**3/8 CC**
No of Anchors per Bracket	1	1	1	1
Min Anchor Embedment Req'd	**2"**	**2"**	**2"**	**2"**
Anchor Safety Factor if in Concrete	**3.12**	**3.07**	**3.40**	**3.47**
Min Bolt size, Attach to Steel	**1/4**	**1/4**	**1/4**	**1/4**
No Bolts/Brkt, Attach to Steel	1	1	1	1
Bolt Safety Factor if Attached to steel	**3.49**	**3.43**	**3.81**	**3.88**
Hanger Rod Compressive Load (lbs)	**163**	**152**	**152**	**135**
Cable Safety Factor	**1.47**	**1.44**	**1.60**	**1.64**

If welded, use a .63 long .12 weld each side of bracket. 30 to 60 deg cable angle permitted.

Note: Bolt Safety Factors based on the capacity of Type A307 hardware or anchors to handle tensile loads after all horizontal loads are accounted for.

Min Edge Distance - See Anchor Data Sheet

If Mult Hardware sizes indicated, use the larg-est at all Locations

Anchor Factor of Safety if in Concrete – indicates the factor of safety of the anchor with respect to the allowable loads if installed in 3,000 psi normal-weight concrete.

Min Bolt Size, Attach to Steel – If the brackets are to be attached to the building structural steel, this is the minimum nominal bolt size required. It is based on the use of ASTM A307 UNC bolts.

No Bolts/Brkt, Attach to Steel – This is the number of bolts required per bracket to achieve the required capacity of the brackets are to be attached to steel.

Bolt Factor of Safety if Attached to steel – the factor of safety with respect to the allowable loads for an ASTM A307 bolt of the specified minimum size to attachment o the building structural steel.

Hanger Rod Compressive Load (lbs) – This is the net compressive reaction load in the hanger rod due to the horizontal seismic loads. It is used to select the hanger rod stiffener and specify the proper number of clamps to be used.

Cable Safety Factor – The factor of safety of the restraint cables with respect to the allowable tension load.

The first line of the paragraph below the performance data gives welding instructions for attaching the brackets to the building structural steel as an option to the use of bolts.

If there are only two supports with four restraint cables, the performance data section will look like Figure D1.6.1-46 below.

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Figure D1.6.1-46; Performance Data for a Suspended Component – Two Supports

Cable Restraint and Anchorage Requirements

	Loc 1	Loc 2	Loc 3	Loc 4
Minimum Anchor Size	**3/8 CC**	**3/8 CC**	**3/8 CC**	**3/8 CC**
No of Anchors per Bracket	**1**	**1**	**1**	**1**
Min Anchor Embedment Req'd	**2"**	**2"**	**2"**	**2"**
Anchor Safety Factor if in Concrete	**17.47**	**17.47**	**17.47**	**17.47**
Min Bolt size, Attach to Steel	**1/4**	**1/4**	**1/4**	**1/4**
No Bolts/Brkt, Attach to Steel	**1**	**1**	**1**	**1**
Bolt Safety Factor if Attached to steel	**19.55**	**19.55**	**19.55**	**19.55**
Hanger Rod Compressive Load (lbs)	**13**	**13**	**2**	**2**
Cable Safety Factor	**16.50**	**16.50**	**16.50**	**16.50**

Note: For Equip hanging on 2 supports, restraints must be attached to the equipment at its vertical CG.

If welded, use a .63 long .12 weld each side of bracket. 30 to 60 deg cable angle permitted.

Note: Bolt Safety Factors based on the capacity of Type A307 hardware or anchors to handle tensile loads after all horizontal loads are accounted for.

Min Edge Distance - See Anchor Data Sheet

If Mult Hardware sizes indicated, use the largest at all Locations

Note that everything is the same as the performance data for a component with four supports except the line directly beneath the **Cable Safety Factor**. This line indicates that when the component has only two supports, that the restraint cables must be attached to the component at its vertical center of gravity location.

D1.6.1.3 – Kinetics Seismic Certification Sheet (B):

A typical Certification Sheet (B) is shown in Figure 1.6.1-47. Sheet (B) of the output is generated for floor mounted isolator/restraints when the anchored to concrete safety factors for the standard base plates are less than 1.0. This sheet applies to Kinetics Models FHS, FLS, FLSS, FTS, and FMS. The program selects a square oversized base plate with four anchor holes, and four concrete anchors that will yield a factor of safety for attachment to concrete that is greater than or equal to 1.0, which is the standard format for both the Kinetics Seismic and Wind Certification Sheets (B). Some project specifications require a much higher minimum factor of safety. In these cases the programs used by Kinetics Noise control have the input option to account for higher minimum factors of safety.

There are standard base plate sizes with standard holes. If the program selects anchors that are smaller than the standard hole size in the plate, the clearance in the holes must be taken up with a Kinetics Model TG grommet, grout/epoxy, or a washer plate welded over the hole with the proper clearance hole for the specified anchor.

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Figure D1.6.1-47; Second Page of Kinetics Standard Seismic Certification Output – Sheet (B)

P-12A1

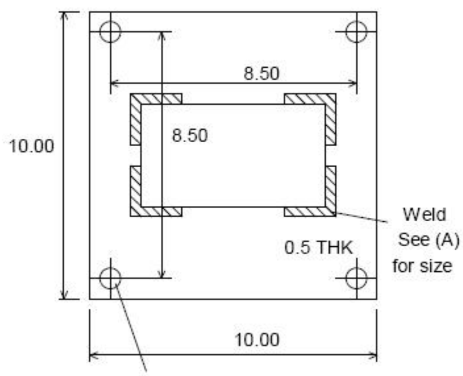
KNC PO: 83578

KINETICS SEISMIC CERTIFICATION (B)

Input Data

Project: **Kidney Care** Representative: **Mark Schiller** P.O. Number: **1547**
Date: **03-07-2011** Code Used: **2003IBC** Min Horiz G: **.00** (LRFD)
Equip Type: **PUMP ON CIB** Tag: **P-12A1** Min Vert G: **.00** (LRFD)
Installation Type: **Vibration isolated <= 1/4" Gap Standard** Bolted G (LRFD) **.60/.07** (H/V)
Site Class: **B (1)** Conc Ancs(LRFD): **.78/.09** (H/V)

BasePlate Dimensions



Data used is derived from Customer input, others are responsible to verify the accuracy of this data.

Wt(lb): **9040** Elev-Roof/Equip: **30/30 ft**

Geometry (in):

Ap:	**2.50**	Ss/Sds:	**0.500/0.333**
Ip:	**1.50**	Rp s/c:	**2.50/2.50**
A:	**85.50**	B:	**45.50**
ex:	**7.00**	ey:	**2.50**

Hgt (CG to Restraint): **12.00**

Restraint Data

Total Number of Restraints: **4**
Restraints/Side on Lg Axis: **2**
Restraints/Side on Sht Axis: **2**
Restraint Type: **FHS**
Loc 1: **1-250/2200** Loc 2: **1-250/2200**
Loc 3: **1-2465/3500** Loc 4: **1-2465/3500**

Output Data (LRFD)

Certification Loads (Seismic) (lb)	Loc 1	Loc 2	Loc 3	Loc 4
Static Load	**-1682**	**-2098**	**-2341**	**-2919**
Max Uplift Load at Loc (S/C):	**-592/-315**	**-938/-653**	**-1141/-851**	**-1623/-1321**
Max Horiz Load at Loc (S/C):	**1009/1312**	**1259/1637**	**1405/1826**	**1752/2277**

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4
Anchor Size Required / Qty	**0.375 CC /4**	**0.375 CC /4**	**0.375 CC /4**	**0.375 CC /4**
Min Anchor Embedment Req'd	**2"**	**2"**	**2"**	**2"**
Anchor Safety Factor in Concrete	**7.04**	**5.65**	**4.96**	**3.75**

For Restraint Locations (Loc 1, etc), see Sheet A

Adapter plates are not provided as part of the standard package. They can be purchased from KNC or provided by the contractor involved in the installation
(Note: Anchor Safety Factors based on the capacity of Type A-307 hardware to handle tensile loads after all horizontal loads are accounted for.
Min Edge Distance - See Anchor Data Sheet
Safety Factors listed as 100 indicate 100 or greater

For a detailed summary of how these loadings were derived, contact KINETICS NOISE CONTROL, Inc.

KNC certifies that the seismic/wind isolation and or restraint system described on this sheet is adequate to resist the certification loads specified herein. The use of hardware other than that provided by KNC voids this certification.

This certification addresses the load path from the equipment point connection to the connection point of the structure. Others must verify the ability of the equipment or structure to resist these loads. See also the included disclaimer. Certification void if disclaimer and Certification Cover Sheet not included. In connection with this certification and the application of the certification design loads to the project ,KINETICS NOISE CONTROL, Inc guarantees that we will use that degree of care and skill ordinarily excercised under similar conditions by reputable members of our profession to determine restraint loadings and Safety Factors based on customer supplied input data. No other warranty, expressed or implied, is made or intended. 03/04/2011

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The performance data listed below the force data will reflect the use of four anchors per isolator/restraint for the oversized base plate. The size of the anchors to be used is selected by the program to optimize the cost/performance of the anchorage. As mentioned earlier, the anchor selected by the program may be much smaller than the clearance holes in the base plate. Some method of dealing with the excess clearance between the anchor and the hole must be employed to prevent potential impact loads on the anchor. Each submittal package will have a document (ANC-1) that presents pertinent installation data for the anchors provided by Kinetics Noise Control. This document explains the various methods that may be used to take up the excess clearance in the anchor holes in the oversized base plates. The rest of the information in the performance data will be very similar to that presented on Sheet (A).

D1.6.1.4 – Kinetics Wind Certification Sheet (A):

A typical Kinetics Wind Load Certification Sheet (A) is shown below in Figure D1.6.1-48. This particular certification sheet is for a Kinetics Noise Control Model KSR. Part of the Input Data section format will change significantly, while the Installation Sketch, Output Data and Performance Data will maintain the same format as that for the Seismic Certification Sheet (A). The part of the Input Data format that has changed from that of the Seismic Certification Sheet A is shown below in Figure D1.6.1-49.

Wind Pres (H/V) – These are the design wind pressure values determined per the applicable code that will act on the component, and they are given in pounds per square foot. The first number is the horizontal design pressure, and the second number is the design uplift pressure. 2000 IBC and 2003 IBC require only a horizontal design wind pressure, and so the second number for these code versions will be **0**. 2006 IBC and 2009 IBC strongly recommend that uplift forces be accounted for in doing wind restraints calculations. ASCE 7-10 which will form the basis for the wind provisions of 2012 IBC will require that uplift be considered for roof top components.

Wt(lb) & Elev and Roof/Equip – These have the same meaning as used for the Seismic Certification Sheet (A).

Length – This is the overall length of the component.

Width – This is the overall width of the component.

Height – This is the overall height of the component.

a & b – These have the same meaning as for the Seismic Certification Sheet (A).

Center Hgt of Area – This is the height of the centroid of the area exposed to the horizontal wind as measured from the restraints.

Hgt (CG to Restraint) – This has the same meaning as for the Seismic Certification Sheet (A).

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The Output Data and Performance Data sections for the Wind Certification Sheet (A) will be identical to those of the Seismic Certification Sheet (A).

D1.6.1.5 – Kinetics Wind Certification Sheet (B):

As with the Seismic Certification, a Sheet (B) of the output is generated for floor mounted isolator/restraints when the anchored to concrete safety factors for the standard base plates are less than 1.0. This sheet applies to Kinetics Models FHS, FLS, FLSS, FTS, and FMS. Everything will be the same for the Wind Certification Sheet (B) as it was for the Seismic Certification Sheet (B) except for the portion of the Input Data that is described in Figure D1.6.1-49 as being particular to the Wind Certification Sheet.

Figure D1.6.1-48; Input Data Specific to the Kinetics Wind Certification

Wind Pres (H/V): **43.3/26.0 PSF**

Data used is derived from Customer input, others are responsible to verify the accuracy of this data.

Wt(lb): **5750** Elev-Roof/Equip: **16/16 ft**

Geometry (in):

Length:	**232.75**	Width:	**90.63**
Height:	**77.00**		
a:	**220.40**	b:	**76.90**
Center Hgt of Area:			**38.50**
Hgt (CG to Restraint):			**38.50**

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Figure D1.6.1-49; First Page of Kinetics Standard Seismic Certification Output – Sheet (A)

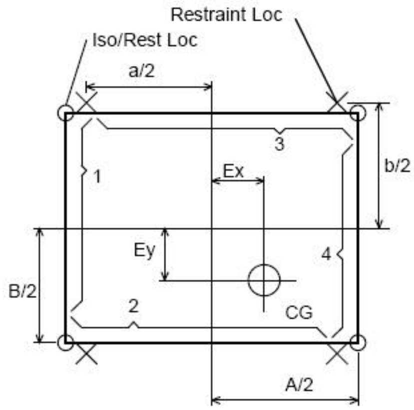
RTU-4

KNC PO: 84042

KINETICS WIND LOAD CERTIFICATION (A)

Input Data

Project: **AIKEN YMCA** Representative: **TRS** P.O. Number: **W110209A**
Date: **03-07-2011** Code Used: **2006IBC**
Equip Type: **AIR HANDLER** Tag: **RTU-4**
Installation Type: **Vibration isolated <= 1/4" Gap Spring Suprtd Sys** Wind Pres (H/V): **43.3/26.0 PSF**



Data used is derived from Customer input, others are responsible to verify the accuracy of this data.

Wt(lb): **5750** Elev-Roof/Equip: **16/16 ft**

Geometry (in):

Length: **232.75** Width: **90.63**
Height: **77.00**
a: **220.40** b: **76.90**
Center Hgt of Area: **38.50**
Hgt (CG to Restraint): **38.50**

Restraint Data

Total Number of Hor Restraints: **28**
Hor Restraints/Side on Lg Axis: **5**
Hor Restraints/Side on Sht Axis: **9**
Restraint Type: **KSR**
Loc 1: Loc 2:
Loc 3: Loc 4:

Output Data (LRFD)

Loads Generated by Wind (lb)	Loc 1	Loc 2	Loc 3	Loc 4
Static Load per Restrnt(- is Down)	-1329	-1522	-1353	-1546
Total Uplift per Vert Restraint:	2439	1542	1542	2439
Load per Horiz Restraint:	479	336	336	479
Effective Crnr Wt (- is Down)	-1092	-1282	-1290	-1513

Calculated Restraint Safety Factors (Must be greater than or equal to 1)

	Loc 1	Loc 2	Loc 3	Loc 4
Vert Straps per Side / FS	1 Strap/1.1	4 Straps/1.2	4 Straps/1.2	1 Strap/1.1
Horiz Safety Factor	1.34	1.90	1.90	1.34

The equivalent of (1) 1/4 " Fastener per Restraint is required to connect the equip to the top rail.

The connection between the curb and the roof deck is to be made with a minimum of (21) #10 Screws on each of the short sides and (31) #10 screws on each of the long sides. or the equivalent to resist the above listed loads. Analysis of curb components not manufactured by KNC are the responsibilty of others.

Note: Bolt Safety Factors based on the capacity of Type A307 hardware or anchors to handle tensile loads after all horizontal loads are accounted for.

For a detailed summary of how these loadings were derived, contact KINETICS NOISE CONTROL, Inc.

KNC certifies that the seismic/wind isolation and or restraint system described on this sheet is adequate to resist the certification loads specified herein. The use of hardware other than that provided by KNC voids this certification.

This certification addresses the load path from the equipment point connection to the connection point of the structure. Others must verify the ability of the equipment or structure to resist these loads. See also the included disclaimer. Certification void if disclaimer and Certification Cover Sheet not included. In connection with this certification and the application of the certification design loads to the project ,KINETICS NOISE CONTROL, Inc guarantees that we will use that degree of care and skill ordinarily excercised under similar conditions by reputable members of our profession to determine restraint loadings and Safety Factors based on customer supplied input data. No other warranty, expressed or implied, is made or intended. 03/04/2011

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D1.6.1.6 – Installation Summary:

The Installation Summary is a sheet that pulls together most of the information that the contractor will need to make sure that the right restraints are being installed in the proper way. The Installation Summary is in no way a detailed set of installation instructions. These are provided elsewhere in the submittal.

At the top of the sheet the **KNC PO** number and the **TAG** information are displayed. Below the **Installation Summary** heading is the general project specific input data form the top of the Seismic and/or Wind Sheet (A). Below this is the data is arranged as follows.

Equipment Weight and Geometric Data Assumed

Weight (lb) – This is the equipment weight in pounds.

Elev in Bldg (ft) – This is the attachment elevation within the building of the component as measured from grade.

Geometry (in)

Span Between Restraints

a – This is the span between the end most restraints on each long side.

b – This is the span between the end most restraints on each short side.

Restraint Data

Total Number of Restraints – This is as it implies the total number of restraints to be applied to the component.

Restraints/Side on "A" Axis – This is the number of restraints on each long side of the component.

Restraints/Side on "B" Axis – This is the number of restraints on each short side of the component.

Restraint Type – This is the type of restraint that is to be applied to the component.

To the right of the **Restraint Data** is an installation sketch showing how the restraints are to be applied to the component. This sketch is intended to be an aid to the contractor in visualizing the application of the recommended restraints. Below the **Restraint Data** and the installation sketch are two sections that detail the anchorage of the restraints to the building structure.

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Figure 1.6.1-50; Typical Installation Summary Sheet

KNC PO: 83578 TAG: P-12A1

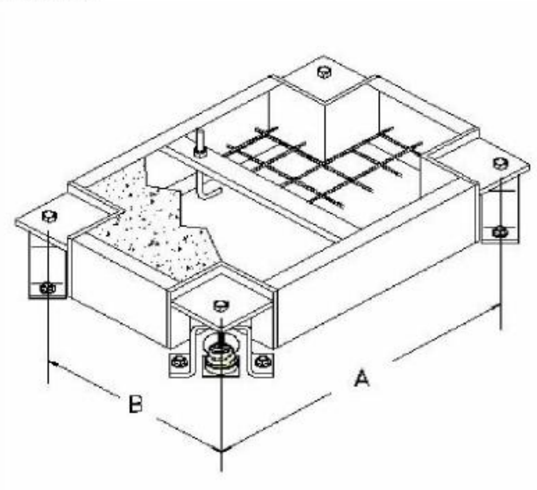
INSTALLATION SUMMARY

Project: **Kidney Care** Representative: **Mark Schiller** P.O. Number: **1547**
Date: **03-07-2011** Code Used: **2003IBC** Performed by: **SY**
Equip Type: **PUMP ON CIB** Building Height: **30 ft**
Installation Type: **Vibration isolated <= 1/4" Gap Standard**

Equipment Weight and Geometric Data Assumed
Weight (lb): **9040**
Elev in Bldg (ft): **30**

Geometry (in)
Span Between Restraints
a: **85.50**
b: **45.50**

Restraint Data
Total Number of Restraints: **4**
Restraints/Side on "A" Axis: **2**
Restraints/Side on "B" Axis: **2**
Restraint Type: **FHS**



Seismic Anchorage Hardware
Concrete Anchor Data
Quantity of Anchors per Tag: **16**
Anchor Bolt Type: **KCCAB**
Min Anchor Size (All Locs): **0.375 "**
Min. Embedment Depth: **2 "**
Min. Edge Distance: **4.38 "**
Min. Anchor Spacing: **6 "**

Through Bolt Data
Quantity of Bolts per Tag: **8**
Bolt Dia (All Locations): **0.75 in**
Min Bolt Grade: **A307**

Data used to perform this analysis was provided by others, If not obvious, Mounting arrangements were projected, It is the responsibility of others to verify that the data used to create this analysis reflects the actual installation configuration. Inaccurate input information or alternate mounting arrangements void the accuracy of this analysis.

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Seismic Anchorage Hardware

Concrete Anchor Data

Quantity of Anchors per Tag – This tells how many anchors are required for the entire component. This is important if oversized base plates are required with isolator/restraints that normally require only two anchors. Where several similar tags are being restrained, this allows the contractor to properly allocate the anchors to each tag before installation begins.

Anchor Bolt Type – This will indicate the type of concrete anchor required by Kinetics Noise Control model.

Min Anchor Size (All Locs) – This is the minimum anchors size required at each location in order to achieve the performance indicated on the Seismic and/or Wind Certification Sheets (A) and (B).

Min Embedment Depth – This is the required effective embedment depth needed to achieve the performance indicated on the Seismic and/or Wind Certification Sheets (A) and (B). Note that the actual pilot hole drill depth may be deeper than this value. Refer to the submittal sheet for the recommended anchors or ANC-1 in the submittal package.

Min Edge Distance – This is the minimum distance from any free edge in order for the recommended anchors to have their full rated capacity.

Min Anchor Spacing – This is the minimum distance between adjacent anchors in order for the recommended anchors to have their full rated capacity. Note that many of Kinetics Noise Control's isolator/restraints and oversized base plates may have anchor spacings that are closer than this value. The anchor capacities have been appropriately de-rated when computing their capacities in conjunction with the isolator/restraints and oversized base plates.

Through Bolt Data

Quantity of Bolts per Tag – Again; this will be the number of bolts that will be required if the isolator/restraints are to be through bolted to the structure.

Bolt Dia (All Locations) – The minimum nominal bolt size required at each location to achieve the performance indicated on the Seismic and/or Wind Certification Sheets (A) and (B).

Min Bolt Grade – This indicates the minimum material specification for the bolts to be used in order to achieve the performance indicated on the Seismic and/or Wind Certification Sheets (A) and (B).

The Installation Summary for suspended components is greatly different than that for floor, roof, or wall mounted components. An example of an Installation Summary for a suspended piece of equipment is shown in Figure 1.6.1-51 below. Below the section specifying the **Seismic**

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Anchorage Hardware, there are several sections pertaining specifically to the restraint of suspended components.

Cable Data (Cable Restrained)

Quantity of Cable Assy's per Tag – This tells the contractor how many restraint cables will be required per component.

Min. Cable Size – This is the minimum restraint cable size required to meet the Performance Data listed on the Seismic and/or Wind Certification Sheets (A) and (B).

Permitted Cable Angles – This is the range of cable installation angles that are permitted to meet the Performance Data listed on the Seismic and/or Wind Certification Sheets (A) and (B). The cable installation angle is measured from the horizontal. The typical range of allowable installation angles for the restraint cables is 30° to 60°.

Hanger Rod Data (Cable Restrained)

Peak Tensile Load – This is the maximum expected tensile load in any of the hanger rods supporting the component.

Peak Compression Load (LRFD) – This is the net compressive reaction load in the hanger rod due to the horizontal seismic design force.

Minimum Rod Size – The minimum hanger rod size required to support the dead weight load of the component.

Anchor Selection – This will indicate whether an anchor that has been pre-qualified for use in cracked concrete is required to support the dead weight load of the component, and who will be providing the anchors.

Maximum Length before a Rod Stiffener is Required – This is the maximum Unbraced hanger rod length that can be tolerated before a hanger rod stiffener is required to prevent buckling of the rod under the **Peak Compression Load (LRFD)**. This value will help the contractor determine whether they need rod stiffeners or not.

Maximum Hanger Rod Length with Rod Stiffeners

This table is provided as a guide to assist the contractor in selection the proper rod stiffener for the application. The columns will be discussed below from left to right across the page.

Stiffener Material – This column recommends standard rolled structural angles that are compatible with the **Minimum Rod Size**, and the available model KHRC rod stiffener clamps from Kinetics Noise Control.

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Max Length – This is the maximum hanger rod length that can be stiffened, or braced, with the recommended angle size under the **Stiffener Material** column.

Max Clip Spacing – This is the maximum spacing for the recommended Kinetics Noise Control model KHRC rod stiffener clips.

Number of KHRC Clips – This will tell the contractor how many Kinetics Noise Control model KHRC rod stiffener clips to order per hanger rod.

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Figure 1.6.1-51; Typical Installation Summary Sheet for Suspended Components

KNC PO: 83134 TAG: EF-C01

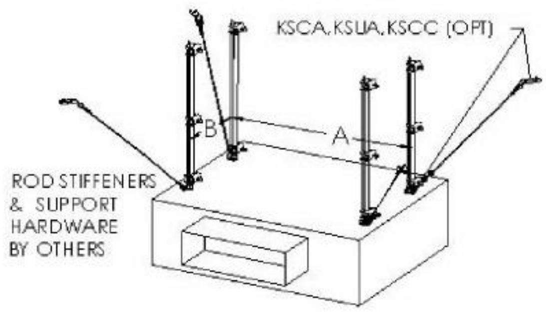
INSTALLATION SUMMARY

Project: **JENNERSVILLE** Representative: **J.A. BROWN** P.O. Number: **3182-J875**
Date: **01-27-2011** Code Used: **2006IBC** Performed by: **SY**
Equip Type: **DUCT BLOWER** Building Height: **30 ft**
Installation Type: **Hard Mounted Air-side HVAC**

Equipment Weight and Geometric Data Assumed
Weight (lb): **110**
Elev in Bldg (ft): **30**

Geometry (in)
Span Between Restraints
a: **24.00**
b: **11.75**

Restraint Data
Total Number of Restraints: **4**
Restraints/Side on "A" Axis: **2**
Restraints/Side on "B" Axis: **2**
Restraint Type: **A307 Grade Bolt**



Seismic Anchorage Hardware

Concrete Anchor Data
Designed for through bolted attachment only

Through Bolt Data
Quantity of Bolts per Tag: **4**
Bolt Dia (All Locations): **0.25 in**
Min Bolt Grade: **A307**

Cable Data (Cable Restrained)
Quantity of Cable Assy's per Tag **4**
Min. Cable Size: **2mm**
Permitted Cable Angles: **30-60 degrees from Horizontal**

Hanger Rod Data (Cable Restrained)
Peak Tensile Load: **50 lbs**
Peak Compression Load(LRFD): **22 lbs**
Minimum Rod Size: **3/8 in**
Anchor Selection: **Non-Seismic, By Others**
Maximum Length before a Rod Stiffener is Required: **46 in**

Maximum Hanger Rod Length with Rod Stiffeners

Stiffener Material	Max Length	Max Clip Spacing	Number of KHRC Clips
1 x 1 x .12 Angle	149 in	102 in	3
1.5 x 1.5 x .25 Angle	365 in	102 in	5
2 x 2 x .25 Angle	569 in	102 in	7
2.5 x 2.5 x .25 Angle	803 in	102 in	9
2.5 x 2.5 x .5 Angle	1095 in	102 in	12

Data used to perform this analysis was provided by others, If not obvious, Mounting arrangements were projected, It is the responsibility of others to verify that the data used to create this analysis reflects the actual installation configuration. Inaccurate input information or alternate mounting arrangements void the accuracy of this analysis.

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UNDERSTANDING NON-STANDARD IBC CERTIFICATION OUTPUT

D1.7.1.1 – Introduction:

At times there will be component applications that can not be adequately modeled using the standard computation program(s) developed by Kinetics Noise Control. This section is intended to present the minimum output information that should be expected in a certification document that does not follow the standard format outlined in Section D1.6.1 of this manual.

The component certification will also include the input data for the project and the component that was provided to Kinetics Noise Control by others. The end recipient of the certification should take the time to verify that the project and component information provided to Kinetics Noise Control is current and correct. Occasionally project and component information will change over the course of the project. Project specification can be amended, and component selections can change subject to cost and availability. Incorrect input data will result in an invalid certification.

D1.7.1.2 – Echoed Input Data:

Typically, the following input data will be contained in the certification. The actual order in which it occurs may be different from that presented below.

D1.7.1.2.1 – General Echoed Input Data:

1. **KNC PO number:** This may also be referred to as the KNC number. It is the internal tracking number used by Kinetics Noise Control and there is a separate particular KNC number for each project. It is the basic reference number that links of the certifications, calculations, and drawings for a particular project together.

2. **Project Name:** This is the name given to the project by the end customer. It helps link all certifications, calculations, and drawings together in the customer's frame of reference.

3. **Date:** This will be the date on which the certification was performed. It helps organize the certifications, calculations, and drawings chronologically.

4. **TAG:** This is the component reference provided by the end customer. This is what ties the certification, calculation, and drawings to the customers project records.

5. **Occupancy Category:** This indicates the building use and is part of the information required to determine the level of detail required for seismic and wind restraints.

6. **Component Weight:** This is needed to calculate the design seismic load acting on the component and the overturning loads for the seismic and wind analysis.

7. **Mean Roof Height of the Building:** This is required to calculate both the seismic and wind design loads acting on the component.

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8. **The Center of Gravity of the Component:**

D1.7.1.2.2 –Echoed Input Data for Seismic Certifications:

1. **Site Class:** This indicates the type of soil upon which the project is being constructed. It is used to calculate the design short period acceleration for non-structural components, and to determine the level of detail required for seismic restraints.

2. S_S **or** S_{DS}**:** S_{DS} is the short period design acceleration that is used to compute the design horizontal seismic force. If S_S is given, then the Site Class will be required to compute the value for S_{DS}.

3. a_P**:** This is the component amplification factor. It is a measure of how close the natural frequency of the component and the natural frequency of the building are expected to be.

4. R_P**:** This is the response modification factor. It is an indication of how fragile, brittle, the component and its supports are expected to be.

5. I_P**:** This is the component importance factor. It will be either 1.0 or 1.5, and is assigned by the design professional of record responsible for the component to be restrained.

6. **Minimum Horizontal & Vertical Gs:** Project specifications will occasionally list a minimum horizontal and vertical acceleration level expressed in terms of a fraction or multiple of gravity. This is intended to assure that the components are restrained to an acceptable factor of safety.

D1.7.1.2.3 – Echoed Input Data for Wind Certifications:

1. **Exposure Category:** This is an indication of how many obstructions the terrain surrounding the project site is expected to have.

2. **Design Wind Speed 3 second Gust:** This is the wind speed used to calculate the design horizontal wind pressure acting on the component, and the design uplift pressure acting on the component if required by the code in force for the project.

3. **Overall Component Length:** This is used to calculate the design horizontal and uplift wind forces acting on the component.

4. **Overall Component Width:** This is also used to calculate the design horizontal and uplift wind forces acting on the component.

5. **Overall Component Height:** This is used to compute the design horizontal wind forces acting on the component.

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D1.7.1.3 – Calculation Output:

The minimum output that should be offered to the end customer as a result of the seismic and/or wind analysis is as follows.

1. **Isolator/Restraint Selection:** The isolator/restraints selected for the component should be specified along with a submittal drawing showing the number of restraints used, restraint locations, and the restraint configuration.
2. **The Design Seismic and/or Wind Loads:** These will be the design seismic and wind loads as calculated based on the code provisions.
3. **The Maximum Horizontal and Vertical Loads at the Restraints:** These will be based on the worst case seismic and/or wind loads, and component/restraint geometry.
4. **Confirmation of Restraint Capacity and Adequacy:** This is usually indicated with a Factor of Safety with respect to the allowable loads for the restraint device.
5. **For Anchorage to Concrete:**
   a. **Anchor Type:** Wedge, Undercut, Adhesive, or Screw Type.
   b. **Minimum Anchor Size:**
   c. **Minimum Required Embedment:**
   d. **Oversized Base Plates Required:** Yes or No
   e. **Number of Anchors to be Used for Each Restraint Device:**
6. **For Bolting to Steel:**
   a. **Minimum Bolt Size:**
   b. **Minimum Bolt Grade:**
   c. **Number of Bolts Required per Restraint Device:**
7. **For Welding to Steel:**
   a. **Minimum Weld Size:**
   b. **Minimum Weld Length:**
   c. **Minimum Weld Material Grade:**

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D1.7.1.4 – General Assumptions and Disclaimer:

A document that outlines the general assumptions used for the analysis, and a disclaimer will accompany each submittal package. Assumptions particular to the individual calculations will be noted in the body of the analysis. The general assumptions are those that are made in order to proceed with the analysis and normally deal with the seismic and wind parameters that apply to the project as a whole. The disclaimer covers exactly those things for which Kinetics Noise Control can be held responsible in the analysis and certification. It is worth while to read both the general assumptions and the general disclaimer to be sure proper project specific data is being used, and that the certification meets the requirements of the project specifications.

D1.7.1.5 – Signed and Sealed Cover Sheet:

There will be a cover sheet for the calculation package that is project specific. It will list the following information.

1. **The Date:** This is the calculations were performed or reviewed.
2. **The Project Name:**
3. **The Project Location:**
4. **The KNC Number:**
5. **The Tags**: These are the equipment tags included in the calculations
6. **Special Notes:** Occasionally special application notes are required for certain tags to alert the engineer of record that issues must be addressed.
7. **The Kinetics Noise Control Professional Engineer:** This is the design professional employed by Kinetics Noise Control.
8. **The State of Licensure of the Professional Engineer:**
9. **The License Number of the Professional Engineer:**
10. **The Expiration Date of the Professional Engineer's License**:

Below this information will be a block containing the seal and signature of the Kinetics Noise Control registered professional engineer who performed or reviewed the calculation. This cover sheet serves as the certification document provided by Kinetics Noise Control guaranteeing that the products selected for use on the project for the listed tags will meet the seismic and/or wind provisions of the code in force for the project.

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SEISMIC AND WIND CERTIFICATION – GENERAL ASSUMPTION AND DISCLAIMER

D1.8.1 – Introduction:

All Seismic and Wind Certifications performed by Kinetics Noise Control, Inc and/or its associates, unless clearly stated otherwise in the body of that certification document, will be performed in accordance with the assumptions and disclaimers identified here in. If key information is not provided to Kinetics Noise Control that affects the attachment of, the size or the quantity of restraint components specified for this project, any required additional analysis or revisions to the hardware provided will be considered to be a change in scope and costs will be assessed accordingly.

D1.8.2 – Loads Considered:

The loads considered in this certification are limited to those forces described in the seismic portion of the code and/or that portion of the specification and project documents appropriate to the project *as provided to Kinetics Noise Control*. If Kinetics Noise Control is not otherwise informed, the most recent version of the appropriate code as listed on the IBC code adoption website will be used. Because equipment can be indoors or may be addressed by other means, wind will not be considered during the analysis unless it is specified to be included in the seismic certification request (note that there is no extra charge for performing a wind analysis *at the same time as a seismic analysis is performed*). Wind loads will be determined based on the following: 1) if included in the provided documentation, the documented value will be used, 2) If not in the spec, but the project site is known, wind speed will be drawn from the wind maps published in the appropriate code and 3) In the absence of a specified value or a known project location, Kinetics Noise Control will use the equivalent of ~45 psf (2,155 Pa) as a wind load requirement. If this is not adequate, it is the responsibility of the Design Professional of Record to notify Kinetics Noise Control.

D1.8.3 – Extent of the Certification:

This certification applies only to those components provided by Kinetics Noise Control. It does not extend to the building structure, equipment, or pipe/duct and their supports.

D1.8.4 – Equipment Data:

The equipment weight, geometry and CG data used to perform the certification have been provided to Kinetics Noise Control by others, no attempt has been made by Kinetics Noise Control to verify its accuracy and it is up those providing the information to do so. Where CG data is not provided, associates of Kinetics Noise Control will attempt to make reasonable, yet conservative estimates as to the magnitude of any imbalance although it must be recognized that the direction of the imbalance is often unknown. Unless the equipment orientation is obvious from the diagram in the certification document, it should be assumed that the orientation is not known.

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Under these conditions, the worst case restraint, attachment and/or anchorage selection indicated for any particular location must be used for all locations.

D1.8.5 – Equipment Durability:

Kinetics Noise Control and its associates make no representations as to equipment durability and its ability to survive a seismic event and remain functional.

D1.8.6 – Installation:

Where detailed installation procedures are not addressed in documentation provided by Kinetics Noise Control, all seismic hardware and components must be installed in conformance with FEMA 412, 413, and 414, Installing Seismic Restraints for Mechanical Equipment, Installing Seismic Restraints for Electrical Equipment, and Installing Seismic Restraints for Pipe and Duct respectively. Free copies or these documents are available from FEMA (1-800-480-2520) or through Kinetics Noise Control.

D1.8.7 – Equipment, Restraint, and Component Attachment Holes:

For seismic restraint, it is necessary that any attachment bolts positioned in the path between the equipment to be restrained and the building structure, be a tight fit with their mating holes (The hole is to be not more than 1/8" (3 mm) in diameter larger than the attachment bolt). In the case of Kinetics Noise Control supplied restraint components, attachment safety factors are based on hardware properly sized to mate with components. In the case of directly attached equipment, the hardware and components provided by Kinetics Noise Control are the minimum required to withstand the seismic loading. If attachment holes in the equipment exceed the recommendation above, the attachment hole is to be sleeved or grouted to bring its effective diameter down to not more than 1/8" (3 mm) larger than the attachment hardware used.

D1.8.8 – Anchor Capacity and Edge Distances:

All anchor allowable loads are based on ICC – ES test data for hardware provided by Kinetics Noise Control and assume full listed anchor embedment in 3,000 psi (20,684 kPa) (minimum) concrete and a minimum spacing between the anchor centerline and the edge of the slab into which it is sunk in accordance with the included anchorage data provided by Kinetics Noise Control. Under some conditions as noted in the calculations, "Undercut" or "Adhesive" type anchors may be required.

D1.8.9 – Stamps

Stamped documents are intended to support the Engineer of Record on the project. If the project is located in an area for which Kinetics does not have a valid PE license, the documents will be signed and sealed by a Licensed Professional Engineer in the State of Ohio. This practice is intended solely to indicate that an individual knowledgeable in the field of seismic restraint has reviewed the document and that the selected components are certified to have adequate capacity

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to resist the anticipated seismic or wind load condition as set forth by the code requirements for the project. It is not intended to imply that the licensee is legally empowered to practice in the jurisdiction of the project.

D1.8.10 – General:

Kinetics Noise Control, Inc. and its associates guarantee that we will use that degree of care and skill ordinarily exercised under similar conditions by reputable members of our profession to determine restraint and/or attachment safety factors based on customer supplied input data. No other warranty, expressed or implied is made or intended.

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SIGNED & SEALED COVER SHEET

D1.9.1 – Introduction:

Every seismic and/or wind certification that is submitted by Kinetics Noise Control will have a cover sheet that has been signed and sealed by an engineer licensed in the project's jurisdiction or in the state of manufacture of the product (Ohio, USA/Ontario, Canada). This cover sheet is intended to be the official certification letter for the restraint products in the submittal. A typical cover sheet is shown in Figure D1.9-1 on the next page.

D1.9.2 – Project Information:

At the top of the sheet is the basic project information as listed below.

1. **Date:** This is the date that the calculations were performed and/or reviewed by the design professional.
2. **Project:** This is the project for which the calculations were preformed. This name will be that used by the end customer to help link the certification to the proper job.
3. **Location:** This will be the city and state/province/country where the project is located. This will help any reviewer to corroborate the data used for the certification
4. **KNC Number:** This is the Kinetics Noise Control internal identification number for the project. It helps Kinetics Noise Control to tie all of the certifications, calculations, and data for a given project together. It is the reference number that should be supplied to Kinetics Noise Control or their authorized representatives when corresponding with Kinetics Noise Control on a particular project or requesting project information on that project.

D1.9.3 – Tags:

This is a list of the equipment or components for which seismic and/or wind calculations have been performed, and therefore have been provided with certified restraint components.

D1.9.4 – Reviewer Information:

Below the Tag information will be the information that pertains to the Kinetics Noise Control Design Professional that performed and/or reviewed the calculations for the Tags listed.

1. **Reviewed By:** This is the design professional engaged by Kinetics Noise Control that performed and/or reviewed the calculations for the equipment and component tags listed.
2. **Registration:** This is the state/province in which the design professional engaged by Kinetics Noise Control is licensed.

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Figure D1.9-1; Cover Sheet

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KINETICS RESTRAINT COMPONENT CERTIFICATION

Date: April 15, 2011

Project: Hospital

Location: Somewhere, OH

KNC Number: xxxxx

Tags:

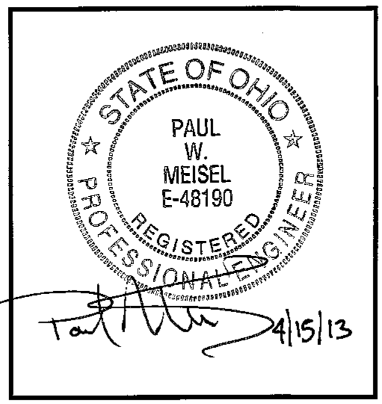
Reviewed By: Paul Meisel — Registration: State of Ohio

License Number: E-48190 — Expiration Date: 12/31/2013

This packet contains certifications of Kinetics Noise Control restraint products tailored to the specific load conditions indicated on the individual certification documents. Unless indicated otherwise on the attached documents, the basis of the certification is code minimum requirements. Load and equipment data has been drawn from information provided to Kinetics Noise Control by our client. Where required input data was not provided, Kinetics Noise Control will attempt to extract data from publicly available mapped data, however it remains the responsibility of those with full access to the project data to verify that the loads used, as well as the equipment and installation conditions are consistent with the system as certified. Any significant deviations from the conditions identified in these documents including equipment substitutions, relocations, mounting arrangements, special load conditions, etc will void this certification.

It is critical to note that this certification covers only those hardware items which have been <u>provided</u> by Kinetics Noise Control. It does not extend to global or localized stresses in the building/supporting structure, the equipment, or where relevant, piping/ductwork and their suspension components.

This document and all documents referenced above have been sealed in the name of Kinetics Noise Control, Inc, by the listed Professional engineer. The Seal is either for the jurisdiction of the project or if the reviewing engineer is not licensed in that jurisdiction, from the State of manufacture of the components. The seal represents only that components have been selected to meet the requirements of ASCE 7 and IBC as indicated in the project requirements. Any specialized Professional Engineering services desired for this project are beyond the scope of Kinetics Noise Control. In conjunction with these certifications, Kinetics Noise Control, Inc guarantees only the use of that degree of care and skill ordinarily exercised under similar conditions by reputable members of our profession. No other warranty, expressed or implied, is made or intended.



3. **License Number:**

4. **Expiration Date:** For the license of the design professional engaged by Kinetics Noise Control.

D1.9.5 – Disclaimer:

Below the reviewer information is a disclaimer which is basically a synopsis of the Seismic and Wind Certification – General Assumptions and Disclaimer discussed in Section D1.8 of this manual. This disclaimer is contained in the certification document in case the certification is separated from the body of the submittal which contains the General Assumptions and Disclaimer. This disclaimer indicates exactly what Kinetics Noise Control's certification will cover, and what it will not cover. It also contains some of the basic assumptions that were made in performing the calculations leading to the certification.

D1.9.6 – Seal and Signature:

Adjacent to the disclaimer is a block which will contain the seal and signature of the design professional that performed and/or reviewed the calculations. Also, the date of the seal and signature will be recorded in this block. Note that this date may not correspond with the date listed above in the project information. This is because there may be a delay between when the calculations were performed and when the design professional reviewed, signed, and sealed the cover sheet.

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SECTION D2.0 – TABLE OF CONTENTS

D2.1 – Understanding Seismic for IBC

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D2.2 – Understanding Wind for IBC

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D2.3 – Understanding Seismic for NBCC

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D2.4 – Understanding Wind for NBCC

D2.5 – UFC Seismic, Wind, & Antiterrorism

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IBC SEISMIC

D2.1.1 – Introduction:

The purpose of this section is to provide design professionals, contractors, and building officials responsible for the nonstructural components (MEP – Mechanical, Electrical, and Plumbing) with the information and guidance required to ensure that the seismic restraints required for a specific project are selected and/or designed, and installed in accordance with the provisions code. This guide will be written in several easily referenced sections that deal with specific portions of the code.

This guide is based on the International Building Code (IBC). The 2000 IBC and the 2003 IBC are very similar, and in fact are almost identical. When they are referenced in this section, it will be as 2000/2003 IBC. The 2006 IBC and 2009 IBC are also nearly identical, and will be referenced in the section as 2006/2009 IBC. The latest version of the IBC is dated 2012 and is substantially different from the previous versions, particularly in respect to the attachment of components to concrete. The seismic provisions for all of the versions of the IBC for nonstructural components are found in ASCE 7. The IBC version with its corresponding ASCE 7 reference is shown in Table 2.1.1-1.

Table D2.1.1-1; IBC & ASCE 7 References

INTERNATIONAL BUILDING CODE YEAR (IBC)	ASCE 7 VERSION	ASCE 7 SEISMIC NON-STRUCTURAL COMPONENTS CHAPTER
2000	98	9
2003	02	9
2006	05	13
2009	05	13
2012	10	13

Since all versions of the IBC are still currently adopted by various states, they will all be discussed and covered in this section.

The following References are used throughout Section D2.1.

1. 2007 ASHRAE HANDBOOK – Heating, Ventilating, and Air-Conditioning Applications; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E. Atlanta, GA 30329, 2007; Chapter 54 Pp 54-11 and 54-12.

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2. 2000 International Building Code; International Code Council, 5203 Leesburg Pike, Suite 708, Falls Church, Virginia, 22041-3401; 2000.

3. ASCE 7-98 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapter 9.

4. 2003 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2002.

5. ASCE/SEI 7-02 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapter 9.

6. 2006 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2006.

7. 2009 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2009.

8. ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapters 1, 2, 11, 13, 20, and 21.

9. 2012 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2012

10. ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400; 2010, Chapters 1, 2, 11, 13, 20, 21, 22 and 23.

11. Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary – Appendix D; American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331.

12. SMACNA, Seismic Restraint Manual – Guidelines for Mechanical Systems 3rd Edition; Sheet Metal and Air Conditioning Contractors' National Association, Inc., 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209; March, 2008.

The selection and installation of the proper seismic restraints for non-structural components requires good coordination with the design professionals and contractors involved with the building project. A good spirit of cooperation and coordination is especially required for projects that have been designated as essential facilities, such as hospitals, emergency response centers, police and fire stations. Coordination between the various design professionals and contractors

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will be a constant theme throughout this section. This coordination is vital for the following reasons.

1. The seismic restraints that are installed for a system can and will interfere with those of another unless restraint locations are well coordinated.

2. The space required for the installed restraints can cause problems if non-structural walls need to be penetrated, or other non-structural components are in the designed load path for the restraints.

The building end of the seismic restraints must always be attached to structure that is adequate to carry the code mandated design seismic loads. It is the responsibility of the structural engineer of record to verify this.

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REQUIRED BASIC PROJECT INFORMATION

D 2.1.2.1 Introduction:

As with any design job, there is certain basic information that is required before seismic restraints can be selected and placed. The building owner, architect, and structural engineer make the decisions that form the basis for the information required to select the seismic restraints for the mechanical and electrical systems in the building. This information should be included in the specification and bid package for the project. It also should appear on the first sheet of the structural drawings. For consistency, it is good practice to echo this information in the specification for each building system, and on the first sheet of the drawings for each system. In this fashion, this information is available to all of the contractors and suppliers that will have a need to know.

D2.1.2.2 Building Use – Nature of Occupancy (Section 1.5) [Section 1.5] {Section 1.5}[1]:

How a building is to be used greatly affects the level of seismic restraint that is required for the non-structural components. In 2012 IBC, the building use will be defined by Risk Category. In the 2006/2009 IBC the building use is defined through the Occupancy Category, which ranges from I to IV. Occupancy Category I is applied to buildings where failure presents a low hazard to human life. At the other end of the range, Occupancy Category IV is applied to buildings which are deemed to be essential. In 2012 IBC, the building use will be defined by Risk Category. The Risk Categories are assigned in exactly the same way as the Occupancy Categories in 2006/2009 IBC. In the first two versions of the IBC (2000/2003), the building use was defined though the Seismic Use Group which varied from I to III. Table 1-1 of ASCE 7-98/02 and ASCE 7-05 describes which types of buildings are assigned to which Occupancy Category. Table D2.1.2-1 below summarizes the information found in Tables 1-1 and 9.1.3 of ASCE 7-98/02, Table 1-1 of ASCE 7-05, and Table 1.5-1 of ASCE 7-10, and ties the Seismic Use Group from the previous versions of the IBC to the Occupancy Category. The nature of the building use, or its Occupancy Category, is determined by the building owner and the architect of record.

D2.1.2.3 Site Class – Soil Type (Sections 9.4.1.2.1, 9.4.1.2.2) [Section 11.4.2 & Chapter 20] {Section 11.4.2 & Chapter 20}:

The Site Class is related to the type of soil and rock strata that directly underlies the building site.

The Site Class ranges from A to F progressing from the stiffest to the softest strata. Table D2.1.2-2 lists the various Site Classes and their corresponding strata.

Generally the structural engineer is responsible for determining the Site Class for a project. If the structural engineer's firm does not have a geotechnical engineer on staff, this job will be

[1] References in brackets (Section 1.5), [Section 1.5], and {Section 1.5} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 respectively.

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contracted to a geotechnical firm. The Site Class is determined in accordance with the references stated above from ASCE 7-98/02, ASCE 7-05, and ASCE 7-10. The site profile is normally obtained by drilling several cores on the property. If there is insufficient information concerning the soil properties, then the default Site Class D is assigned to the project.

Table D2.1.2-1; Building Use vs. Occupancy Category, Risk Category, & Seismic Use Group (Table 1-1, Table 9.1.3), [Table 1-1], {Table 1.5-1}

SEISMIC USE GROUP 2000/2003 IBC	OCCUPANCY CATEGORY 2006/2009 IBC	RISK CATEGORY 2012 IBC	BUILDING USE
I	I	I	Buildings and other structures whose failures would pose a significant risk to human life.
	II	II	Buildings and other structures not listed in Occupancy/Risk Categories I, III, and IV or Seismic Use Groups II and III.
II	III	III	Buildings and other structures whose failure would pose a significant risk to human life, cause a significant economic impact, or cause mass disruption in the day-to-day life of civilians.
III	IV	IV	Buildings or other structures that are essential for post disaster recovery, whose failure would pose a substantial hazard to the community, or are used to process, store, or dispose of hazardous materials.

Table D2.1.2-2; Site Class vs. Soil Type (Table 9.4.1.2) [Table 20.3-1] {Table 20.3-1}

SITE CLASS	SOIL TYPE
A	Hard Rock
B	Rock
C	Very Dense Soil & Soft Rock
D	Stiff Soil (Default Site Class)
E	Soft Clay Soil
F	Liquefiable Soils, Quick Highly Sensitive Clays, Collapsible Weakly Cemented Soils, & etc. These require site response analysis.

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D2.1.2.4 Mapped Acceleration Parameters (Sections 9.4.1.2.4 & 9.4.1.2.5) [Sections 11.4.3 & 11.4.4 and Chapters 21 & 22] {Sections 11.4.3 & 11.4.4 and Chapters 21 & 22}

The United States Geological Survey, USGS, has mapped all of the known fault lines in the United States and its possessions. They have assigned ground level acceleration values to each location based on the Maximum Considered Earthquake, MCE, for two earthquake periods, 0.2 sec and 1.0 sec, at 5% damping. The mapped values are listed in terms of %g, where 1g is 32.2 ft/sec^2, 386.4 in/sec^2, 9.8 m/sec^2. The long period values are generally applied to the buildings and other structures since they react more strongly to the long period excitation due to their relatively high mass and low stiffness. The code specifies the use of short period values when evaluating non-structural components, which include pipe and duct, as they respond more strongly to the short period excitation due to their relatively low mass and high stiffness.

The Mapped Acceleration Parameters are available in ASCE 7-98/02 for 2000/2003 IBC, ASCE 7-05 for 2006/2009 IBC and ASCE 7-10 for 2012 IBC, or may be obtained from the USGS cataloged by ZIP Code. The short period Mapped Acceleration Parameter is usually denoted as S_S and the Long period Mapped Acceleration Parameter is denoted as S_1. Note that the values for S_S and S_1 may be different for 2000/2003 IBC, the 2006/2009 IBC or the 2012 IBC. Be sure the correct values are being used for the code that is in force in your jurisdiction.

<u>Special Note:</u> For the purpose of making preliminary estimates, the long and short period mapped acceleration parameters for selected U. S. cities are given in Table D2.1.2-3 (the values for 2012 IBC have not been published at this time as indicated by TBP on Table D2.1.2-3). For the U. S. cities please refer to the data compiled by the USGS by ZIP CODE. For international locations, local geological assessments should be sought from reputable sources at that location.

The Site Class information is then used to determine the Design Spectral Acceleration Parameters, S_{DS} and S_{D1}, for the short and long period MCE respectively. Eq D2.1.2-1 and Eq D2.1.2-2 may be used to estimate the Design Spectral Acceleration Parameters.

$$S_{DS} = \frac{2}{3} F_a S_S$$ **Eq D2.1.2-1 (9.4.1.2.4-1) [11.4-3] {11.4-3}**

And

$$S_{D1} = \frac{2}{3} F_v S_1$$ **Eq D2.1.2-2 (9.4.1.2.4-2) [11.4-4] {11.4-4}**

Where:

F_a = the short period Site Coefficient which is listed in Table D2.1.2-4. The values for F_a which correspond to values of S_S that fall between those listed in Table D2.1.2-4 may be obtained through linear interpolation.

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F_v = the long period Site Coefficient which is listed in Table D2.1.2-5. The values for F_v which correspond to values of S_1 that fall between those listed in Table D2.1.2-5 may be obtained through linear interpolation.

S_{DS} = the Design Short Period Spectral Acceleration Parameter which has been corrected for the Site Class.

S_{D1} = the Design Long Period Spectral Acceleration Parameter which has been corrected for the Site Class.

S_S = the Mapped Short Period Acceleration Parameter for the MCE @ 5% damping.

S_1 = the Mapped Long Period Acceleration Parameter for the MCE @ 5% damping.

If not otherwise listed for the project, the structural engineer should be contacted for the values of S_{DS} and S_{D1}. These values are not only required to determine the design accelerations, but also to determine the Seismic Design Category for the building, which will be discussed next.

D2.1.2.5 Seismic Design Category (Section 9.4.2.1) [Section 11.6] {Section 11.6}:

This parameter is of great importance to everyone involved with non-structural components. The Seismic Design Category to which a building has been assigned will determine whether seismic restraints are required or not, and if they qualify for exemption, which non-structural components may be exempted, and which will need to have seismic restraints selected and installed. The non-structural components within a building will be assigned to the same Seismic Design Category as the building itself. There are six Seismic Design Categories, A, B, C, D, E, and F. The level of restraint required increases from Seismic Design Category A through F. Up through Seismic Design Category D, the Seismic Design Category to which a building or structure is assigned is determined though the use of Tables D2.1.2-6 and D2.1.2-7.

To determine the Seismic Design Category both the Long (S_{D1}) and Short (S_{DS}) Period Design Response Acceleration Parameter must be determined. The most stringent Seismic Design Category, resulting from the two acceleration parameters, will be assigned to the project.

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Table D2.1.2-3; Mapped Acceleration Parameters for Selected U.S. Cities 2000/2003 IBC, 2006/2009 IBC, & 2012 IBC (TBP)

STATE, CITY	ZIP CODE	S_S			S_1		
		00	06	12	00	06	12
AL							
Birmingham	35217	0.33	0.31	0.27	0.12	0.10	0.11
Mobile	36610	0.13	0.12	0.11	0.06	0.05	0.06
Montgomery	36104	0.17	0.16	0.14	0.08	0.07	0.08
AR							
Little Rock	72205	0.48	0.50	0.41	0.18	0.16	0.17
AZ							
Phoenix	85034	0.23	0.19	0.18	0.07	0.06	0.06
Tucson	85739	0.33	0.29	0.28	0.09	0.08	0.08
CA							
Fresno	93706	0.76	0.78	0.95	0.30	0.29	0.34
Los Angeles	90026	1.55	2.25	2.78	0.60	0.83	0.99
Oakland	94621	1.98	1.97	2.27	0.87	0.77	0.95
Sacramento	95823	0.59	0.64	0.70	0.23	0.25	0.30
San Diego	92101	1.61	1.62	1.26	0.86	0.82	0.49
San Francisco	94114	1.50	1.61	1.64	0.86	0.82	0.76
San Jose	95139	2.17	1.60	1.50	0.78	0.60	0.60
CO							
Colorado Springs	80913	0.18	0.22	0.19	0.06	0.06	0.07
Denver	80239	0.19	0.21	0.18	0.06	0.06	0.06
CT							
Bridgeport	06606	0.34	0.27	0.21	0.09	0.06	0.07
Hartford	06120	0.27	0.24	0.18	0.09	0.06	0.07
New Haven	06511	0.29	0.25	0.19	0.08	0.06	0.07
Waterbury	06702	0.29	0.25	0.19	0.09	0.06	0.07
FL							
Ft. Lauderdale	33328	0.07	0.06	0.05	0.03	0.02	0.03
Jacksonville	32222	0.14	0.14	0.11	0.07	0.06	0.06
Miami	33133	0.06	0.05	0.05	0.02	0.02	0.02
St. Petersburg	33709	0.08	0.07	0.06	0.04	0.03	0.03
Tampa	33635	0.08	0.07	0.06	0.03	0.03	0.04
GA							
Atlanta	30314	0.26	0.23	0.19	0.11	0.09	0.09
Augusta	30904	0.42	0.38	0.30	0.15	0.12	0.12
Columbia	31907	0.17	0.15	0.13	0.09	0.07	0.08
Savannah	31404	0.42	0.43	0.33	0.15	0.13	0.13
IA							
Council Bluffs	41011	0.19	0.18	0.15	0.09	0.08	0.08
Davenport	52803	0.13	0.13	0.11	0.06	0.06	0.07
Des Moines	50310	0.07	0.08	0.07	0.04	0.04	0.05
ID							
Boise	83705	0.35	0.30	0.31	0.11	0.10	0.11
Pocatello	83201	0.60	0.63	0.57	0.18	0.19	0.18

STATE, CITY	ZIP CODE	S_S			S_1		
		00	06	12	00	06	12
IL							
Chicago	60620	0.19	0.17	0.14	0.07	0.06	0.07
Moline	61265	0.14	0.14	0.12	0.06	0.06	0.07
Peoria	61605	0.18	0.18	0.15	0.09	0.08	0.08
Rock Island	61201	0.13	0.13	0.11	0.06	0.06	0.07
Rockford	61108	0.17	0.15	0.13	0.06	0.06	0.06
Springfield	62703	0.27	0.29	0.22	0.12	0.11	0.11
IN							
Evansville	47712	0.82	0.72	0.62	0.23	0.21	0.22
Ft. Wayne	46835	0.17	0.15	0.12	0.06	0.06	0.06
Gary	46402	0.18	0.16	0.13	0.07	0.06	0.07
Indianapolis	46260	0.18	0.19	0.16	0.09	0.08	0.09
South Bend	46637	0.12	0.12	0.10	0.06	0.05	0.06
KS							
Kansas City	66103	0.12	0.13	0.12	0.06	0.06	0.07
Topeka	66614	0.19	0.17	0.15	0.06	0.05	0.06
Wichita	67217	0.14	0.14	0.11	0.06	0.05	0.06
KY							
Ashland	41101	0.22	0.19	0.16	0.09	0.07	0.08
Covington	41011	0.19	0.18	0.15	0.09	0.08	0.08
Louisville	40202	0.25	0.25	0.21	0.12	0.10	0.11
LA							
Baton Rouge	70807	0.14	0.12	0.11	0.06	0.05	0.06
New Orleans	70116	0.13	0.11	0.10	0.06	0.05	0.06
Shreveport	71106	0.17	0.15	0.13	0.08	0.07	0.07
MA							
Boston	02127	0.33	0.28	0.22	0.09	0.07	0.07
Lawrence	01843	0.38	0.33	0.25	0.09	0.07	0.08
Lowell	01851	0.36	0.31	0.24	0.09	0.07	0.08
New Bedford	02740	0.26	0.22	0.18	0.08	0.06	0.06
Springfield	01107	0.26	0.23	0.18	0.09	0.07	0.07
Worchester	01602	0.27	0.24	0.18	0.09	0.07	0.07
MY							
Baltimore	21218	0.20	0.17	0.14	0.06	0.05	0.06
ME							
Augusta	04330	0.33	0.30	0.24	0.10	0.08	0.08
Portland	04101	0.37	0.32	0.25	0.10	0.08	0.08
MI							
Detroit	48207	0.12	0.12	0.10	0.05	0.04	0.05
Flint	48506	0.09	0.09	0.08	0.04	0.04	0.05
Grand Rapids	49503	0.09	0.09	0.08	0.04	0.04	0.05
Kalamazoo	49001	0.12	0.11	0.09	0.05	0.05	0.05
Lansing	48910	0.11	0.10	0.09	0.04	0.04	0.05

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Table D2.1.2-3 Continued; Mapped Acceleration Parameters for Selected U.S. Cities 2000/2003 IBC, 2006/2009 IBC, & 2012 IBC (TBP)

STATE, CITY	ZIP CODE	S_S 00	S_S 06	S_S 12	S_1 00	S_1 06	S_1 12
MN							
Duluth	55803	0.06	0.06	0.05	0.02	0.02	0.02
Minneapolis	55422	0.06	0.06	0.05	0.03	0.03	0.03
Rochester	55901	0.06	0.06	0.05	0.03	0.03	0.04
St. Paul	55111	0.06	0.06	0.05	0.03	0.03	**003**
MO							
Carthage	64836	0.16	0.17	0.15	0.09	0.08	**0.09**
Columbia	65202	0.19	0.21	0.18	0.10	0.09	0.10
Jefferson City	65109	0.22	0.23	0.21	0.11	0.10	0.10
Joplin	64801	0.15	0.16	0.14	0.08	0.08	**0.09**
Kansas City	64108	0.15	0.13	0.12	0.06	0.06	0.07
Springfield	65801	0.21	0.22	0.21	0.10	0.10	0.11
St. Joseph	64501	0.12	0.12	0.10	0.05	0.05	0.06
St. Louis	63104	0.59	0.58	0.44	0.19	0.17	0.17
MS							
Jackson	39211	0.19	0.20	0.17	0.10	0.09	0.09
MT							
Billings	59101	0.16	0.17	0.16	0.06	0.07	0.07
Butte	59701	0.74	0.65	0.60	0.21	0.20	0.18
Great Falls	59404	0.29	0.26	0.22	0.09	0.09	0.08
NE							
Lincoln	68502	0.18	0.18	0.14	0.05	0.05	0.05
Omaha	68144	0.13	0.13	0.11	0.04	0.04	0.05
NV							
Las Vegas	89106	0.64	0.57	0.50	0.19	0.18	0.17
Reno	89509	1.36	1.92	2.12	0.50	0.77	0.73
NM							
Albuquerque	87105	0.63	0.59	0.49	0.19	0.18	0.15
Santa Fe	87507	0.62	0.54	0.52	0.19	0.17	0.16
NY							
Albany	12205	0.28	0.24	0.19	0.09	0.07	0.08
Binghamton	13903	0.19	0.17	0.13	0.07	0.06	0.06
Buffalo	14222	0.32	0.28	0.21	0.07	0.06	0.06
Elmira	14905	0.17	0.15	0.12	0.06	0.05	0.06
New York	10014	0.43	0.36	0.28	0.09	0.07	0.08
Niagara Falls	14303	0.31	0.28	0.21	0.07	0.06	0.06
Rochester	14619	0.25	0.21	0.17	0.07	0.06	0.06
Schenectady	12304	0.28	0.24	0.19	0.09	0.09	0.08
Syracuse	13219	0.19	0.18	0.15	0.08	0.06	0.07
Utica	13501	0.25	0.22	0.18	0.09	0.07	0.07
NC							
Charlotte	28216	0.35	0.32	0.24	0.14	0.11	0.10
Greensboro	27410	0.26	0.23	0.18	0.11	0.08	0.09

STATE, CITY	ZIP CODE	S_S 00	S_S 06	S_S 12	S_1 00	S_1 06	S_1 12
Raleigh	27610	0.22	0.21	0.16	0.10	0.08	0.08
Winston-Salem	27106	0.28	0.24	0.19	0.12	0.09	0.09
ND							
Fargo	58103	0.07	0.08	0.06	0.02	0.02	0.02
Grand Forks	58201	0.05	0.06	0.05	0.02	0.02	0.02
OH							
Akron	44312	0.18	0.17	0.16	0.06	0.05	0.06
Canton	44702	0.16	0.14	0.13	0.06	0.05	0.06
Cincinnati	45245	0.19	0.18	0.15	0.09	0.07	0.08
Cleveland	44130	0.20	0.19	0.17	0.06	0.05	0.06
Columbus	43217	0.17	0.15	0.12	0.07	0.06	0.07
Dayton	45440	0.21	0.18	0.15	0.08	0.07	0.08
Springfield	45502	0.26	0.21	0.17	0.08	0.07	0.07
Toledo	43608	0.17	0.16	0.13	0.06	0.05	0.06
Youngstown	44515	0.17	0.16	0.17	0.06	0.05	0.06
OK							
Oklahoma City	73145	0.34	0.33	0.26	0.09	0.07	0.08
Tulsa	74120	0.16	0.16	0.14	0.07	0.07	0.07
OR							
Portland	97222	1.05	0.99	0.99	0.35	0.34	0.43
Salem	97301	1.00	0.80	0.93	0.4	0.34	0.44
PA							
Allentown	18104	0.29	0.26	0.20	0.08	0.06	0.07
Bethlehem	18015	0.31	0.27	0.21	0.08	0.07	0.07
Erie	16511	0.17	0.16	0.16	0.05	0.05	0.06
Harrisburg	17111	0.23	0.20	0.15	0.07	0.05	0.06
Philadelphia	19125	0.33	0.27	0.21	0.08	0.06	0.06
Pittsburgh	15235	0.13	0.13	0.11	0.06	0.05	0.06
Reading	19610	0.30	0.26	0.20	0.08	0.06	0.06
Scranton	18504	0.23	0.20	0.16	0.08	0.06	0.06
RI							
Providence	02907	0.27	0.23	0.18	0.08	0.06	0.07
SC							
Charleston	29406	1.60	2.19	1.71	0.45	0.56	0.59
Columbia	29203	0.60	0.55	0.42	0.19	0.15	0.15
SD							
Rapid City	57703	0.16	0.17	0.13	0.04	0.04	0.05
Sioux Falls	57104	0.11	0.11	0.09	0.04	0.03	0.04
TN							
Chattanooga	37415	0.52	0.46	0.38	0.14	0.12	0.13
Knoxville	37920	0.59	0.53	0.43	0.15	0.12	0.13
Memphis	38109	1.40	1.40	1.04	0.42	0.38	0.37
Nashville	49503	0.09	0.09	0.08	0.04	0.04	0.05

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Table D2.1.2-3 Continued; Mapped Acceleration Parameters for Selected U.S. Cities 2000/2003 IBC, 2006/2009 IBC, & 2012 IBC (TBP)

STATE, CITY	ZIP CODE	S_S			S_1		
		00 03	06 09	12	00 03	06 09	12
TX							
Amarillo	79111	0.17	0.18	0.16	0.05	0.04	0.05
Austin	78703	0.09	0.08	0.07	0.04	0.03	0.04
Beaumont	77705	0.12	0.10	0.09	0.05	0.04	0.05
Corpus Christi	78418	0.10	0.08	0.07	0.02	0.02	0.02
Dallas	75233	0.12	0.11	0.10	0.06	0.05	0.05
El Paso	79932	0.37	0.33	0.31	0.11	0.11	0.10
Ft. Worth	76119	0.11	0.11	0.09	0.06	0.05	0.05
Houston	77044	0.11	0.10	0.08	0.05	0.04	0.04
Lubbock	79424	0.10	0.11	0.08	0.03	0.03	0.04
San Antonio	78235	0.14	0.12	0.09	0.03	0.03	0.03
Waco	76704	0.10	0.09	0.08	0.05	0.04	0.05
UT							
Salt Lake City	84111	1.82	1.71	1.50	0.78	0.09	0.55
VA							
Norfolk	23504	0.13	0.12	0.10	0.06	0.05	0.05
Richmond	23233	0.32	0.25	0.22	0.09	0.06	0.07
Roanoke	24017	0.30	0.26	0.20	0.10	0.08	0.08
VT							
Burlington	05401	0.47	0.40	0.37	0.13	0.10	0.11
WA							
Seattle	98108	1.56	1.57	1.54	0.54	0.54	0.59
Spokane	99201	0.38	0.40	0.34	0.09	0.11	0.12
Tacoma	98402	1.24	1.22	1.31	0.40	0.42	0.06
D.C.							
Washington	20002	0.18	0.15	0.12	0.06	0.05	0.05
WI							
Green Bay	54302	0.07	0.06	0.06	0.03	0.03	0.04
Kenosha	53140	0.14	0.12	0.10	0.05	0.05	0.06
Madison	53714	0.12	0.11	0.09	0.05	0.04	0.05
Milwaukee	53221	0.12	0.11	0.09	0.05	0.05	0.05
Racine	53402	0.13	0.12	0.10	0.05	0.05	0.05
Superior	54880	0.06	0.06	0.05	0.02	0.2	0.02
WV							
Charleston	25303	0.21	0.19	0.15	0.08	0.07	0.07
Huntington	25704	0.23	0.20	0.16	0.09	0.07	0.08
WY							
Casper	82601	0.38	0.39	0.30	0.08	0.08	0.08
Cheyenne	82001	0.19	0.20	0.19	0.06	0.05	0.06

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Table D2.1.2-4; Short Period Site Coefficient, F_a (Table 9.4.1.2.4a) [Table 11.4-1] {Table 11.4-1}

SITE CLASS	MAPPED MCE SHORT PERIOD SPECTRAL RESPONSE ACCELERATION PARAMETER				
	S_S≤0.25	S_S=0.50	S_S=0.75	S_S=1.00	S_S≥1.25
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	These values to be determined by site response analysis.				

Table D2.1.2-5; Long Period Site Coefficient, F_v (Table 9.4.1.2.4b) [Table 11.4-2] {Table 11.4-2}

SITE CLASS	MAPPED MCE LONG PERIOD SPECTRAL RESPONSE ACCELERATION PARAMETER				
	S_1 ≤ 0.10	S_1 = 0.20	S_1 = 0.30	S_1 = 0.40	S_1 ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	These values to be determined by site response analysis.				

For Occupancy/Risk Categories I, II, or III (Seismic Use Group I or II) structures, if the Mapped Spectral Response Acceleration Parameter is greater than or equal to 0.75, $S_1 \geq 0.75$, then the structure will be assigned to Seismic Design Category E. For Occupancy/Risk Category IV (Seismic Use Group III) structures, if the Mapped Spectral Response Acceleration Parameter is greater than or equal to 0.75, $S_1 \geq 0.75$, then the structure will be assigned to Seismic Design Category F. To ensure consistency, the Seismic Design Category should be determined by the structural engineer.

Table D2.1.2-6; Seismic Design Category Based on the Short Period Design Response Acceleration Parameter (Table 9.4.2.1a) [Table 11.6-1] {Table 11.6-1}

VALUE OF S_{DS}	OCCUPANCY/RISK		
	I or II	III	IV
S_{DS} < 0.167	A	A	A
0.167 ≤ S_{DS} < 0.33	B	B	C
0.33 ≤ S_{DS} < 0.50	C	C	D
0.50 ≤ S_{DS}	D	D	D

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Table D2.1.2-7; Seismic Design Category Based on the Long Period Design Response Acceleration Parameter (Table 9.4.2.1b) [Table 11.6-2] {Table 11.6-2}

VALUE OF S_{D1}	OCCUPANCY/RISK		
	I or II	III	IV
S_{D1} < 0.067	A	A	A
0.067 ≤ S_{D1} < 0.133	B	B	C
0.133 ≤ S_{D1} < 0.20	C	C	D
0.20 ≤ S_{D1}	D	D	D

D2.1.2.6 Summary:

The following parameters will be required by the design professionals having responsibility for non-structural components in a building, and should be determined by the structural engineer of record.

1. Occupancy/RIsk Category (or Seismic Use Group for 2000/2003 IBC): This defines the building use and specifies which buildings are required for emergency response or disaster recovery.
2. Seismic Design Category: This determines whether or not seismic restraint is required.
3. Short Period Design Response Acceleration Parameter (S_{DS}): This value is used to compute the horizontal seismic force used to design and/or select seismic restraints required.

These parameters should be repeated in the specification and drawing package for the particular system, mechanical, electrical, or plumbing, in question.

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COMPONENT IMPORTANCE FACTOR

D2.1.3.1 Introduction:

MEP components and systems are categorized in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 as non-structural components. There are just two values for the Component Importance Factors for non-structural components, 1.0 and 1.5, which are not directly linked to the importance factor for the building structure. The Component Importance Factor is designated as I_P in the body of the code. All non-structural components must be assigned a component importance factor. The design professional that has responsibility for the MEP system in question is also responsible for assigning the Component Importance Factor to that system.

D2.1.3.2 Criteria for Assigning a Component Importance Factor (Sections 9.6.1 and 9.6.1.5) [Section 13.1.3] {Section 13.1.3}[1]:

For non-structural components, the Component Importance Factor (I_P) assigned to the components shall be determined as follows.

1. If the MEP system is required to remain in place and function for life-safety purposes following and earthquake the Component Importance Factor assigned to the non-structural component shall be 1.5. Some examples of this type of system would be;

    a. Fire sprinkler piping and fire suppression systems.

    b. Smoke removal and fresh air ventilation systems.

    c. Systems required for maintaining the proper air pressure in patient hospital rooms to prevent the transmission of infectious diseases.

    d. Systems that maintain proper air pressure, temperature, and humidity in surgical suites, bio-hazard labs, and clean rooms.

    e. Medical gas lines.

    f. Steam lines or high pressure hot water lines.

2. If the non-structural component contains or is used to transport hazardous materials, or materials that are toxic if released in quantities that exceed the exempted limits a Component Importance Factor of 1.5 shall be assigned to that component. Examples are as follows.

    a. Systems using natural gas.

[1] References in brackets (Sections 9.6.1 and 9.6.1.5), [Section 13.1.3], {Section 13.1.3} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009, and 2012 IBC respectively.

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b. Systems requiring fuel oil.

c. Systems used to exhaust laboratory fume hoods.

d. Boilers, furnaces and flue systems.

e. Systems that are used to ventilate bio-hazard areas and infectious patient rooms.

f. Chemical or by-product systems which are required for industrial processes.

3. If the non-structural component is in or attached to a building that has been assigned to Occupancy/Risk Category IV (Seismic Use Group III), i.e. essential or critical facilities, and is required for the continued operation of that facility following an earthquake, then a Component Importance Factor of 1.5 shall be assigned to that component. Hospitals, emergency response centers, police stations, fire stations, and etc. fall under Occupancy/Risk Category IV (Seismic Use Group III). The failure of any system could cause the portion of the building it serves to be evacuated and unusable would cause that system and its components to be assigned a Component Importance Factor of 1.5. Even the failure of domestic water lines can flood a building and render it uninhabitable. So, all of the items listed above under items 1 and 2 would apply to facilities in Occupancy/Risk Category IV (Seismic Use Group III).

4. If the non-structural component that is located in or attached to an Occupancy/Risk Category IV (Seismic Use Group III) facility and its failure would impair the operation of that facility, then a Component Importance Factor of 1.5 shall be assigned to that component. This implies that any non critical non-structural component that is located above a non-structural component with a Component Importance Factor of 1.5 must be assigned a Component Importance Factor of 1.5, or otherwise supported in a fashion that the more critical system would not be damaged.

5. All non-structural components that are not covered under items 1, 2, 3, or 4 may be assigned a Component Importance Factor of 1.0.

D2.1.3.3 Summary:

The Component Importance Factor is very important to the designer responsible for selecting and certifying the seismic restraints for a non-structural component. This factor is a direct multiplier for the horizontal seismic design force, which shall be discussed in a later section. The Component Importance Factor will also be a key indicator as to whether a particular component will qualify for an exemption or not. If a Component Importance Factor has not been assigned, the designer responsible for selecting the seismic restraints must assume that the Component Importance Factor is equal to 1.5. If the non-structural component could actually be assigned a Component Importance Factor of 1.0, this could result in a large increase in the size and number of restraints required along with a corresponding increase in the cost for the system.

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It is in the best interest of the design professionals responsible for the non-structural components to properly assign the Component Importance Factor to those components. The Component Importance Factor for each non-structural component should be clearly indicated on the drawings that are distributed to other design professionals, contractors, suppliers, and building officials.

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GENERAL EXEMPTIONS AND REQUIREMENTS

D2.1.4.1 Introduction:

The International Building Codes (IBC's) allow certain exemptions to be made for MEP (Mechanical, Electrical, and Plumbing) components and other non-structural components from the need for seismic restraint. These exemptions are based on the Seismic Design Category, the Component Importance Factor, the size, the weight, and the vertical location within the building of the components.

There are further general provisions in the IBC pertaining to MEP components and other non-structural components that must be acknowledged at the outset of a project. These are provisions ranging from the upper bound size for a component to the component certifications and documentation required.

This section will present the general exemptions for MEP components and other non-structural components and discuss the general requirements that apply to them.

D2.1.4.2 Exemptions for Seismic Design Categories A and B (Sections 9.6.1-1 & 9.6.1-3) [Sections 13.1.4-1 & 13.1.4-2] {Sections 11.7, 13.1.4-3, & 13.1.4-4}[1]:

MEP components that are located in or on buildings that have been assigned to Seismic Design Categories A and B, and other non-structural components that have been assigned to Seismic Design Category B, are exempt from the requirements for seismic restraints. These two exemptions point out the need for having the correct seismic deign in formation for the project available to all of the design professionals and contractors during the bidding stage of the project. Being able to use these exemptions can save the contractors as much as 10% to 15% in their costs.

For example, a critical piece of information required at the outset is the Site Class. If the Site Class has not been determined by a qualified geotechnical engineer, then Site Class D must be assumed. The resulting combination of the mapped acceleration parameters and soil profile of Site Class D may force the project to be assigned to Seismic Design Category C which in turn forces the requirement for seismic restraints. If instead the Site Class had been determined to be Site Class B by a qualified geotechnical engineer, then the project may have been found to fall into Seismic Design Category A or B, thus eliminating the need for seismic restraints for the nonstructural components.

[1] References in brackets (Section 9.6.1-1 & 9.6.1-2) [Section 13.1.4-1 & 13.1.4-2], {Sections 11.7, 13.1.4-3, & 13.1.4-4} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, ASCE 7-12 respectively, which forms the basis for the seismic provisions in 2000/2003 IBC and 2006/2009 IBC, 2012 IBC respectively.

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D2.1.4.3 Exemptions for Seismic Design Category C (Section 9.6.1-4) [Section 13.1.4-3] {Section 13.1.4-5}:

MEP components that have been assigned to Seismic Design Category C, and that have also been assigned a Component Importance Factor of 1.0, are exempt from the requirements for seismic restraints. In this case it is very important that the design professionals responsible for the various MEP components assign the correct Component Importance Factors to those systems and components. If no Component Importance Factor is assigned, the installing contractor should prudently assume that the Component Importance Factor is equal to 1.5, and provide restraints for that system or component. This is particularly true of duct runs where it is very likely that the ventilation components may also be required for smoke control.

It is also critical to know which MEP systems and components have a component Importance Factor of 1.0 and which ones have a Component Importance Factor of 1.5. To the extent possible, those with Component Importance Factors equal to 1.5 should be installed above those with Component Importance Factors equal to 1.0 in order to reduce the over all number of restraints needed for the project.

D2.1.4.4 Exemptions for Seismic Design Categories D, E, and F

D2.1.4.4.1 ASCE 7-98/02 and ASCE 7-05 (Sections 9.6.1-5 and 9.1.6-6) [Sections 13.1.4-4 and 13.1.4-5] also ASCE 7-10, IBC 2012 with special conditions indicated in line item 3 below:

There are basically three exemptions that apply here.

1. MEP components that:
    a. Are in Seismic Design Categories D, E, and F.
    b. Have a Component Importance Factor equal to 1.0,
    c. Have flexible connections between the components and all associated duct, piping, conduit.
    d. Are mounted at 4 ft (1.22 m) or less above a floor level.
    e. And weigh 400 lbs (181 kg) or less.
2. MEP components that:
    a. Are in Seismic Design Categories D, E, and F.
    b. Have a Component Importance Factor equal to 1.0.
    c. Have flexible connections between the components and all associated duct, piping, conduit.

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d. And weigh 20 lbs (9.1 kg) or less.

3. MEP distribution systems that:

   a. Are in Seismic Design Categories D, E, and F.

   b. Have a Component Importance Factor equal to 1.0.

   c. Have flexible connections between the components and all associated duct, piping, conduit.

   d. And weigh 5 lbs/ft (2.6 kg/m) or less.

   (Note: In ASCE 7-10 and IBC 2012, there are no exemptions for Plumbing. Plumbing

   consists of all non HVAC related water piping and includes Drain, Waste and Vent Piping.)

No Seismic restraint is required for MEP components in Seismic Design Categories D, E, or F if all of the following criteria apply.

1. The Component Importance Factor is $I_P = 1.0$.

2. The MEP component is positively attached to the structure.

3. Flexible connections are used between the MEP component and any associated services, and either of the following apply;

   a. The component weighs 400 lb (181 kg) or less and has a center of mass located 4 ft (1.22 m) or less above the floor level.

   b. The component weighs 20 lb (9.1 kg) or less or, in the case of a distributed system, 5 lb/ft (2.3 kg/m).

D2.1.4.4.2 ASCE 7-10 (Sections 9.6.1-5 and 9.1.6-6) [Sections 13.1.4-4 and 13.1.4-5]:

D2.1.4.5 "Chandelier" Exemption (Section 9.6.3.2) [Section 13.6.1] {Section 13.6.1}:

This exemption applies to light fixtures, lighted signs, ceiling fans, and other components that are not connected to ducts or piping and which are supported by chains or other wise suspended from the structure by a method that allows the component to swing freely. These components will require no further seismic support provided that all of the following conditions are met.

1. The design load for these components shall be equal to:

   a. 3.0 times the operating load, applied as a gravity design load, for 2000/2003 IBC.

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b. 1.4 times the operating weight of the component acting downward with a simultaneous horizontal load that is also equal to 1.4 times the operating weight for 2006/2009 IBC and 2012 IBC. The horizontal load is to be applied in the direction that results in the most critical loading and thus the most conservative result.

2. The component shall not impact other components, systems, or structures as it swings through its projected range of motion.

3. The connection to the structure shall allow a 360° range of motion in the horizontal plane. In other words, this must be a "free swinging" connection.

D2.1.4.6 Component Size Relative to the Building Structure (Section 9.6.1) [Section 13.1.5] {Section 15.3.1}:

MEP components are treated as non-structural components by the code. However, if the MEP component is very large relative to the building it must be treated as a nonbuilding structure, which has a completely different set of design issues. For 2000/2003 IBC, If the weight of the MEP component is greater than or equal to 25% of the combined weight of the MEP Component and the supporting structure, the MEP component must be treated as a nonbuilding structure per Section 9.14 of ASCE 7-98/02. For 2006/2009 IBC, if the weight of the nonstructural component is greater than or equal to 25% of the effective seismic weight of the building as defined in Section 12.7.2 of ASCE 7-05, then that component must be classified as a nonbuilding structure and designed accordingly. For 2012 IBC, this provision is found in Section 15.3.1 of ASCE 7-10. Here it states that when the weight of the nonbuilding structure is less than 25% of the combined effective seismic weights of the nonbuilding structure and its supporting structure the nonbuilding structure will be treated like a non-structural component where the forces are determined in accordance with ASCE 7-10 Chapter 13.

When might this apply? This applies to very large pieces of MEP equipment such as large cooling towers, and the very large air handling units that are placed on the roofs of buildings employing lightweight design techniques. The structural engineer of record will have a value for the effective seismic weight of the building. This must be compared to the operating weight of the MEP component in question.

D2.1.4.7 Reference and Accepted Standards (Sections 9.6.1.1 and 9.6.1.2) and Reference Documents [Section 13.1.6] {Section 13.1.6}:

Typically reference standards, acceptance standards, and reference documents are other publications that will provide a basis for earthquake resistant design. Examples of reference documents currently in existence would be the SMACNA Seismic Restraint Manual, listed in Section 1.0 Introduction of the guide, and NFPA 13. These documents may be used with the approval of the jurisdiction having authority as long as the following conditions are met.

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1. The design earthquake forces used for the design and selection of the seismic restraints shall not be less that those specified in Section 9.6.1.3 of ASCE 7-98/02 and Section 13.3.1 of ASCE 7-05 and ASCE 7-10, which is also covered in Section 8.0 of this guide.

2. The seismic interaction of each MEP or non-structural component with all other components and building structures shall be accounted for in the design of the supports and restraints.

3. The MEP or other non-structural component must be able to accommodate drifts, deflections, and relative displacements that are defined in ASCE 7-05 and ASCE 7-10. This means that flexible connections for pipe, duct, and electrical cables for MEP components are in general, a good idea to prevent damage if the MEP component, and/or the pipe, duct, and electrical cables that are attached to it are unrestrained.

4. The MEP or other non-structural component anchorage requirements is not to be less than those covered in Section 13.4 of ASCE 7-10.

D2.1.4.8 Allowable Stress Design (Sections 2.3 and 2.4) [Sections 2.3, 2.4, and 13.1.7] {Sections 2.3, 2.4, and 13.1.7}:

Reference documents that use allowable stress design may be used as a basis for the design and selection of seismic restraints. However, the design earthquake loads determined in accordance with Section 9.6.1.3 of ASCE 7-98/02 and Section 13.3.1 of ASCE 7-05 and ASCE 7-10 must be multiplied by 0.7.

D2.1.4.9 Submittals and Construction Documents (Sections 9.6.3.6, 9.6.3.15 and A.9.3.4.5) [Sections 13.2.1, 13.2.5, 13.2.6, and 13.2.7] {Sections 13.2.1, 13.2.5, 13.2.6, and 13.2.7}:

Projects that require seismic restraints for MEP systems and components will require project specific certification that the design of the seismic restraints selected for the MEP systems and their components will meet the code, specification, or details which ever is most stringent. This certification is to be provided both in the submittals and in the construction documents.

For the submittal of seismic restraints and supports, the certification may be satisfied by one of the following means.

1. Project and site specific designs and documentation that are prepared and submitted by a registered design professional. Please note that a specific discipline is not mentioned regarding the registered design professional that is responsible for the design and signing and sealing of the documentation. However, it should be noted that certain states and local jurisdictions do specify a discipline for the registered design professional responsible for signing and sealing the documentation.

2. Manufacturer's certification accompanying the submittal the restraints are seismically qualified for the project and site. The certification may be made in any one of three ways as detailed below.

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a. Analysis – this is typical for the seismic restraints used for MEP systems and components. Manufacturers of these seismic restraint devices will normally have families of the various types of restraint devices that have different seismic force capacity ranges. The manufacturer will perform an analysis to determine the project and site specific seismic design loads, and then analyze the MEP system and/or components to determine the required restraint capacities at the restraint attachment points to the system and/or components. The proper restraint will be selected from the manufacturer’s standard product offering, or a special restraint may be designed and built for the application. The manufacturer’s certification will include a statement signed and seal by a registered design professional that the restraint devices will meet the appropriate code, specification, and/or details.

b. The manufacturer of the restraint devices may have them tested in accordance with ICC-ES AC 156 as outlined in Sections 9.6.3.6 and A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.5 of ASCE 7-05 and ASCE 7-2012. They will then provide a signed and sealed certification document stating that the restraint devices will provide adequate protection for the MEP system and components.

c. Experience data per the requirements in Sections 9.6.3.6 and A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.6 of ASCE 7-05 and ASCE 7-10. This is not a normal avenue for a manufacturer of seismic restraint devices to use to certify their products as being fit for a specific project. In using this method, the manufacturers would incur a great deal of liability.

Section A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.7 of ASCE 7-05 and ASCE 7-2012 indicates that seismic restraints for MEP systems and components will require construction documents that are prepared and, signed and sealed by a registered design professional. Frequently, the submittal package provided by the manufacturer of the seismic restraints will also have enough information to fulfill this requirement.

The registered design professional mentioned above needs to be one with knowledge and experience in force analysis, stress and analysis, and the proper use of steel, aluminum, elastomers, and other engineering materials in the design of force resisting systems. There are several disciplines that may fulfill these requirements such as, structural engineers, civil engineers, and mechanical engineers involved in the area of machine design.

D2.1.4.10 Equipment Certification for Essential Facilities (Sections 9.6.3.6, 9.6.6.15, and A9.3.4.5) [Sections 13.2.2, 13.2.5, and 13.2.6] {Sections 13.2.2, 13.2.5, and 13.2.6}:

MEP components for buildings that have been assigned to Seismic Design Categories C, D, E, and F and have designated seismic systems that must remain functional will require certification. Designated seismic systems are those whose failure has the potential to cause loss of life or loss of function for buildings that were deemed essential for recovery following an earthquake. Typically essential facilities are those that have been assigned to Occupancy Category IV, see Section 2.2 of Section D2.0. For these types of systems, certification shall be provided as follows.

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1. For active MEP systems and components that must remain functional after an earthquake shall be certified by the supplier or manufacturer as being operable after the design level earthquake for the project site based on:

    a. Shake table testing such as that specified in ICC-ES AC 156 as described in Section A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.5 of ASCE 7-05 and ASCE 7-10. Evidence of compliance is to be submitted to the jurisdiction having authority and the design professional of record for approval.

    b. Experience or historical data as outlined in Sections 9.6.3.6, 9.6.3.15 and A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.6 of ASCE 7-05 and ASCE 7-10. This experience data is to come from a nationally recognized procedures and data base that is acceptable to the authority having jurisdiction. The substantiated seismic capacities from the experience data must meet or exceed the specific seismic requirements for the project. As in a. above evidence of compliance will need to be submitted to the design professional of record, and the jurisdiction having authority for approval.

2. MEP systems and components that contain hazardous materials must be certified as maintaining containment of the hazardous materials following an earth quake. Evidence of compliance must be submitted to the design professional of record and the jurisdiction having authority for approval. This certification may be made through:

    a. Analysis.

    b. Approved shake table testing specified in Section 9.6.3.6 of ASCE 7-98/02 and Section 13.2.5 of ASCE 7-05 and ASCE 7-10.

    c. Experience data as described in Section 9.6.3.6 of ASCE 7-98/02 and Section 13.2.6 of ASCE 7-05 and ASCE 7-10.

D2.1.4.11 Consequential or Collateral Damage (Section 9.6.1) [Section 13.2.3] {Section 13.2.3}:

The potential interaction of the MEP systems and components with surrounding systems, components or building structures must be considered when locating and restraining the MEP systems and components. The failure of an MEP system or component that has been assigned a Component Importance Factor equal to 1.0 must not cause the failure of an MEP system or component that has been assigned a Component Importance Factor equal to 1.5. This goes back to the issue of assigning a Component Importance Factor of 1.5 to MEP systems or components with a Component Importance Factor of 1.0 whose failure would cause the failure of a system or component with a Component Importance Factor of 1.5.

D2.1.4.12 Flexibility of Components and their Supports and Restraints (Sections 9.6.1 and 9.6.1.2) [Section 13.2.4] {Section 13.2.4}:

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All MEP systems and components that are constructed of normal engineering materials will have a certain amount of flexibility, or springiness. So how these systems and components behave during an earthquake will greatly affect their performance and survivability. The system or component could have a flexibility that would put it to resonance with the building and/or the earthquake, in which case the displacements and stresses in the system would be much larger than expected. Conversely the flexibility of the system or component could be such that it was not in resonance with either the building or the earthquake. In this case, the displacements and stresses may be much lower than a code based analysis would indicate. Therefore, the code indicates that the flexibility of the components and their supports be considered as well as the strength of the parts to ensure that the worst cases are considered.

D2.1.4.13 Temporary or Movable Equipment {Section 13.1.4-2}:

Only 2012 IBC addresses temporary and moveable equipment. This would include temporary air handlers, air conditioners, boilers, air purification systems, and etc. that have been brought in to handle the load during an outage, or other event. Section 13.1.4-2 of ASCE 7-10 exempts all temporary or movable equipment from the need for seismic restraint.

D2.1.4.14 Summary:

The exemptions and requirements outlined in this section are intended to assist the MEP design professionals and contractors in planning their project contribution efficiently. Also, they help define the limits of responsibility for each MEP design profession and trade.

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EXEMPTIONS FOR PIPING SYSTEMS

D2.1.5.1 Introduction:

The exemptions that apply specifically to piping are covered in Section 9.6.3.11.4 of ASCE 7-98/02 and Section 13.6.8 of ASCE 7-05 AND ASCE 7-10. The provisions of this section do not cover elevator system piping which is covered in Section 9.6.3.16 of ASCE 7-98/02 and Section 13.6.10 of ASCE 7-05 and ASCE 7-10. The piping considered in this section is assumed to be high-deformability piping. This implies pipes made from ductile materials that are joined by welding, brazing, or groove type couplings, similar to VICTAULIC, or groove type couplings, where the grooves in the pipe have been roll formed rather than cut. Limited deformability piping on the other hand, would be pipes made of ductile materials that are joined by threading, bonding, or the use of groove type couplings where the grooves in the pipe have been machine cut. Low deformability piping would be comprised of pipes made from relatively brittle materials such as cast iron, PVC, CPCV, or glass. Also not covered in this section is fire protection piping. Fire protection piping will be covered in a separate publication.

D2.1.5.2 The 12″ Rule (9.6.3.11.4-c) [Section 13.6.8-1] {Section 13.6.8-2}[1]:

No restraints will be required for piping that meets the requirements of the 12″ Rule for the entire piping run. The 12″ Rule will be said to apply to a piping run if:

1. The piping is supported by rod hangers.

    a. For single clevis supported pipe, all of the hangers in the piping run are 12 in. (305 mm) or less in length from the top of the pipe to the supporting structure.

    b. For trapeze supported pipe, all of the hangers in the piping run are 12 in. (305 mm) or less in length from the top of the trapeze bar to the supporting structure.

2. For 2000/2003 IBC The hanger rods and their attachments are not to be subjected to bending moments. For 2006/2009 IBC the hangers are to be detailed to avoid bending of the hangers and their attachments. This statement very is ambiguous. It does not clearly define the phrase “significant bending”, and leaves it up to the design professional responsible for the piping system, or worse, the contractor responsible for installing the piping system. The past practice by SMACNA and other recognized authorities in the industry to call for the connection between the hanger and the supporting structure to be “non-moment generating”. This means that the connector must be one that allows the piping run to swing freely on its hangers without introducing a bending moment in the hanger. 2012 IBC has clarified this

[1] References in brackets (9.6.3.11.4-c) [Section 13.6.8-1] {Section 13.6.8-2} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 IBC respectively.

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situation by stating that rod hangers are to be "equipped with swivels, eye nuts, or other devices to prevent bending in the rod".

3. There must be sufficient space around the piping run to accommodate the expected motion of the pipe as it sways back and forth with the earthquake motion in the building.

4. Connections between the piping and the interfacing components must be designed and/or selected to accept the full range of motion expected for both the pipe and the interfacing component.

D2.1.5.3 Single Clevis Supported Pipe in Seismic Design Categories A and B (Sections 9.6.1-1 and 9.6.1-3) [Sections 13.1.4-1 and 13.1.4-2] {Sections 11.7 and 13.1.4-4}:

No seismic restraints are required for piping in building assigned to Seismic Design Categories A and B. This is implied in ASCE 7-05 for Seismic Design Category A by the general exemptions found in Section 13.1.4-1 and 13.1.4-2. For ASCE 7-10, it is specified in Section 11.7.

D2.1.5.4 Single Clevis Supported Pipe in Seismic Design Category C (Sections 9.6.1-1 and 9.6.3.11.4-d2) [Sections 13.1.4-3 and 13.6.8-2b] {Sections 13.1.4-5 and 13.6.8.3-2a}:

1. For single clevis supported piping in buildings assigned to Seismic Design Category C for which the Component Importance Factor is equal to 1.0, no seismic restraint is required.

2. For piping in Buildings assigned to Seismic Design Category C, for which the Component Importance Factor is equal to 1.5, and for which the nominal size is 2 in. (51 mm) or less; no seismic restraint is required.

D2.1.5.5 Single Clevis Supported Pipe in Seismic Design Categories D, E, and F (Sections 9.6.3.11.4-d1 and 9.6.3.11.4-d3) [Sections 13.6.8-2a and 13.6.8-2c] {Sections 13.6.8.3-3b and 13.6.8.3-3c}:

1. For single clevis supported piping in buildings assigned to Seismic Design Categories D, E, and F, for which the Component Importance Factor is equal to 1.5, and for which the nominal size is 1 in. (25 mm) or less; no seismic restraint is required.

2. For single clevis supported piping in buildings assigned to Seismic Design Categories D, E, and F, for which the Component Importance Factor is equal to 1.0, and for which the nominal size is 3 in. (76 mm) or less; no seismic restraint is required.

Special Note: ***For 2012 IBC the exemptions described in Sections D2.1.5.4 and D2.1.5.5 above do not apply to piping having*** $R_P \leq 4.5$ ***per ASCE 7-10 Section 13.6.8.3-3. Plumbing piping will fall under this category for 2012 IBC because it has been given an*** $R_P = 2.5$ ***in Table 13.6-1. Per ICC, All Drain, Waste and Vent piping is to be considered to be plumbing.***

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D2.1.5.6 Exemptions for Trapeze Supported Pipe per VISCMA Recommendations {Section 13.6.8.3-1}:

Neither ASCE 7-98/02 nor ASCE 7-05 specifies how the piping is to be supported. The point is that many pipes of the exempted size may be supported on a common trapeze bar using hanger rods of the same size as would be specified for a single clevis supported pipe. Keep in mind that the purpose of the seismic restraints is to make sure the pipe moves with the building. The amount of force that the hanger rod must carry will be a direct function of the weight of pipe being supported. It is apparent that there must be some limit to how much weight a trapeze bar can support for a given hanger rod size before seismic restraint is required. VISCMA (Vibration Isolation and Seismic Control Manufacturer's Association) has investigated this issue and makes recommendations in a paper, *Seismic Exemptions for Suspended Trapeze Supported pipe – IBC 2006/ASCE7-05 (SUMMARY)*, which is published on their web site, www.viscma.com.

2012 IBC contains language that directly deals with trapeze supported pipe exemptions. This is found in ASCE 7-10 Section 13.6.8.3-1. For piping that falls within the limits discussed above in Sections D2.1.5.4 and D2.1.5.5, the trapeze assembly will be exempt if the piping supported by the trapeze bar is less than 10 lb/ft (4.5 kg/m).

D2.1.5.7 Summary:

The exemptions and allowances outlined in this section can, with careful planning save a lot of time and money. They may also mean the difference between making a profit on a project and breaking even, or worse, losing money. In order to take proper advantage of these exemptions, the Seismic Design Category to which the project has been assigned must be known. This is readily available from the structural engineer. Also, the design professional who is responsible for the piping system must assign an appropriate Component Importance Factor to the system.

As a sidebar to the previous statement, it should be noted that the specification for the building may increase the Seismic Design Category in order to ensure an adequate safety margin and the continued operation of the facility. This is a common practice with schools, government buildings, and certain manufacturing facilities. Also, the building owner has the prerogative, through the specification, to require all of the piping systems to be seismically restrained. So, careful attention to the specification must be paid, as some or all of the exemptions in this section may be nullified by specification requirements that are more stringent than those provided by the code.

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EXEMPTIONS FOR HVAC DUCTWORK

D2.1.6.1 Introduction:

The 2000/2003/2006/2009/2012 IBC have some general exemptions that apply to HVAC ductwork based on Component Importance Factor and the size of the duct. At present, there are not as many exemptions for ductwork as there are for piping. The number of exemptions for ductwork changed with SMACNA being dropped as a reference document in the 2003/2006 IBC. This will be discussed below in the appropriate section.

Note: For 2012 IBC, the exemptions for ductwork that are to be discussed do not apply if the duct is designed to carry toxic, highly toxic, or flammable gases or used for smoke control.

D2.1.6.2 The 12″ Rule (Section 9.6.3.10-a) [Section 13.6.7-a] {Section 13.6.7-1b}[1]:

No seismic restraints will be required for ductwork with a Component Importance Factor equal to 1.0 that meets the requirements of the 12″ Rule for the entire run of ductwork. The 12″ Rule is said to apply to a run of ductwork if:

1. The HVAC ducts a suspended for hangers that are 12″ (305 mm) or less in length for the entire run of ductwork. This is usually measured from the supporting structure to the top of the trapeze bar that is supporting the ductwork.

2. The hangers have been detailed and constructed in order to avoid significant bending of the hanger and its attachments. As with the 12″ rule applied to piping, the industry generally interprets this to mean that the connection of the hanger to the structure must be "non-moment generating", or free swinging. For 2012 IBC ASCE 7-10 plainly states that, hanger rods must be "equipped with swivels to prevent inelastic bending of the hanger rod".

Section 1613.6.8-1 of 2009 IBC allows the 12″ Rule to be applied to ductwork having a Component Importance Factor equal to 1.5.

ASCE 7-10 and 2012 IBC will also allow the 12″ Rule to be applied to ductwork having a Component Importance Factor equal to 1.5.

D2.1.6.3 Size Exemption (Section 9.6.3.10-b) [Section 13.6.7-b] {Section 13.6.7-2}:

For 2000/2003/2006 IBC, no seismic restraints are required for ductwork with a Component Importance Factor equal to 1.0 if the cross-sectional area is less than 6 ft^2 (0.557 m^2). There is no specific exemption for ducts whose Component Importance Factor is equal to 1.5. However, 2000

[1] References in brackets (Section 9.6.3.10-a) [Section 13.6.7-a] {Section 13.6.7-1b} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 IBC respectively.

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IBC has the SMACNA; Seismic Restraint Manual – Guidelines for Mechanical Systems 2nd Edition[2] directly referenced in Section 1621.3.9 as meeting the lateral bracing requirements of the code, does allow the exemption of duct with a cross-sectional area of less than 6 ft^2 (0.557 m^2) exemption to be made for all ductwork regardless of its Component Importance Factor. For 2003/2006 IBC, there are no exemptions for ductwork with a Component Importance Factor equal to 1.5. They simply state that; “HVAC duct systems fabricated and installed in accordance with a standards approved by the authority having jurisdiction shall be deemed to meet the lateral bracing requirements of this section (of the code)”. This statement does open the door to permitting the SMACNA Seismic Restraint Manual to be used as a standard, thus permitting the 6 ft^2 (0.557 m^2) exemption.

Section 1613.6.8-2 of 2009 IBC allows the 6 ft^2 (0.557 m^2) exemption to be made for all ductwork with a Component Importance Factor of 1.5 as well as ductwork whose Component Importance Factor is equal to 1.0.

ASCE 7-10 and 2012 IBC will also allow the 6 ft^2 (0.557 m^2) exemption to be made for all ductwork regardless of the Component Importance Factor that has been assigned to it. Also, there is a weight limit assigned to this exemption in ASCE 7-10 of 17 lb/ft (7.7 kg/m) or less. So, the duct work is exempt if has either a cross-sectional area of less than 6 ft^2 (0.557 m^2) or a weight of 17 lb/ft (7.7 kg/m) or less.

D2.1.6.4 Trapeze Supported Ductwork {Section 13.6.7-1a}:

In this section, there is a new exemption for trapeze supported duct that is independent of the Component Importance Factor. Trapeze supported ductwork that weighs less than 10 lb/ft (4.5 kg/m) is exempt from the need for seismic restraint.

D2.1.6.5 Restraint Allowance for In-Line Components (Section 9.6.3.10) [Section 13.6.7] {Section 13.6.7}:

This allowance deals with components, such as fans, heat exchangers, humidifiers, VAV boxes, and the like, that are installed in-line with the ductwork. Components that have an operating weight of 75 lbs (334 N) or less may be supported and laterally, seismically, braced as part of the duct system. Where the lateral braces, seismic restraints, have been designed and sized to meet the requirements of ASCE 7-98/02 Section 9.6.1.3 or ASCE 7-05/10 Section 13.3.1. The following requirements will also apply to these components.

1. At least one end of the component must be hard, rigidly, attached to the ductwork. The other end may have a flex connector or be open. The flex connected, or open end, of the component must be supported and laterally braced. This requirement is not mentioned as part of ASCE 7-98, -02, -05, or -10, but is a requirement that is born out of common sense.

[2] SMACNA; Seismic Restraint Manual – Guidelines for Mechanical Systems 2nd Edition; Sheet Metal and Air Conditioning Contractors’ National Association, In.; 4201 Lafayette Center Drive, Chantilly, VA 20151-1209

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2. Devices such as diffusers, louvers, and dampers shall be positively attached with mechanical fasteners.

3. Unbraced piping and electrical power and control lines that are attached to in-line components must be attached with flex connections that allow adequate motion to accommodate the expected differential motions.

D2.1.6.6 Summary:

As with the piping exemptions these exemptions and allowances, with careful planning, can save the contractor and the building owner a great deal of effort and money. There is also a great advantage to petition the local building authority to allow the SMACNA Seismic Design Manual to become a reference document for the project. This will allow the exemptions spelled out in the SMACNA Seismic Design Manual to be utilized to best advantage

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EXEMPTIONS FOR ELECTRICAL

D2.1.7.1 Introduction:

The equipment exemptions mentioned in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 are actually implied exemptions that are stated as requirements. The exemptions for electrical distribution systems are better defined at least in ASCE -05 and ASCE -10. This section is an attempt to more fully define these provisions for the design professional responsible for the design of the electrical components and distribution systems, and also for the installing contractor who is responsible for bidding and installing the restraints.

D2.1.7.2 "Implied" Blanket Exemption Based on Component Importance Factor I_P (Section 9.6.3.14) [Sections 13.6.4 and 13.6.5] {Sections 13.6.4 and 13.6.5}[1]:

Section 9.6.3.14 of ASCE 7-98/02 states that;

"Attachments and supports for electrical equipment shall meet the force and displacement provisions of Sections 9.6.1.3 and 9.6.1.4 and the additional provisions of this Section. In addition to their attachments and supports, electrical equipment designated as having $I_P = 1.5$, itself, shall be designed to meet the force and displacement provisions of Sections 9.6.1.3 and 9.6.1.4 and the additional provisions of this Section."

In this statement, there really are no implied exemptions for electrical equipment, except that if the supports for the equipment have been designed by the manufacturer to meet the seismic load requirements with the specified mounting hardware, no further analysis and restraint will be required.

In Section 13.6.4 of ASCE 7-05 and ASCE 7-10, the text reads as follows.

"Electrical components with I_P greater than 1.0 shall be designed for the seismic forces and relative displacements defined in Sections 13.3.1 and 13.3.2 …."

ASCE 7-05 Section 13.6.5 states the following;

"Mechanical and electrical component supports (including those with $I_P = 1.0$) and the means by which they are attached to the component shall be designed for the forces and displacements determined in Sections 13.3.1 and 13.3.2. Such supports including structural members, braces, frames, skirts, legs, saddles, pedestals, cables, guys, stays, snubbers, and tethers, as well as elements forged or cast as part of the mechanical or electrical component."

[1] References in brackets (Section 9.6.3.14) [Sections 13.6.4 and 13.6.5] {Sections 13.6.4 and 13.6.5} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, 2012 IBC respectively.

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ASCE 7-05 and ASCE 7-10 Section 13.6.4 implies that electrical components that have been assigned a Component Importance Factor equal to 1.0, regardless of the Seismic Design Category to which they have been assigned, will not require seismic restraints beyond the attachment provisions normally included with the component, provided that a qualified component is selected. This means that if the component has four mounting feet with holes for Φ3/8″ mounting hardware, then the component should be attached to the structure with four Φ3/8″ bolts, or anchors. Beyond that nothing further is required.

However, ASCE 7-05 Section 13.6.5 insists that the supports must be designed to withstand the code mounted forces and displacements. So, as with ASCE 7-98/02 this is not a general blanket exemption. The manufacturer of the component must be able to certify that the supports designed as part of the component will withstand the seismic requirements for the project using hardware of the appropriate size and strength.

So, while additional analysis and restraint may not be required for electrical components with $I_P = 1.0$, the supports for this equipment must be designed by the manufacturer with sufficient strength to meet the code mandated requirements. After this the design professional of record for a project and the contractor may provide attachment hardware of the appropriate type, size, and strength, as recommended by the manufacturer of the equipment, without doing any further analysis, or providing any further restraint.

While this sounds rather “wishy-washy”, it’s really not. If the manufacturer of the equipment and its supports certifies that is was design to handle accelerations in excess of the design acceleration for the project, then it may be exempted from the need for further seismic restraint or analysis.

D2.1.7.3 Conduit Size Exemption [13.6.5.5-6a] {13.6.5.5-2}:

There are no specific size exemptions for electrical conduit in 2000/2003 IBC, ASCE 7-98/02. However, 2006/2009 IBC and ASCE 7-05, and 2012 IBC and ASCE 7-10 do have exemptions for electrical conduit. They seem to follow the exemptions, in terms size, that are used for piping. Therefore, it is reasonable to use the exemptions in 2006/2009/2012 IBC for 2000/2003 IBC since it is the most recent version, and takes into account any new testing or analysis.

For 2006/2009 IBC and ASCE 7-05, and 2012 IBC and ASCE 7-10, seismic restraints are not required for conduit that has been assigned a Component Importance Factor equal to 1.5, and whose trade size is 2.5 in. (64mm) or less. When sizing and selecting restraints for electrical conduit, that the weight per linear foot of conduit varies greatly depending on the exact type of conduit being used. Also, when computing the total weight per foot of the conduit plus the cabling, it standard practice to assume that there will be ~40% copper fill for the cabling.

D2.1.7.4 Trapeze Supported Electrical Distribution Systems [13.6.5.5-6b] [13.6.5.6-1a]:

As with conduit, no specific exemptions for trapeze supported electrical distribution systems exist in 2000/2003 IBC, ASCE 7-98/02. However, an exemption is allowed under 2006/2009 IBC and ASCE 7-05, and 2012 and ASCE 7-10. It makes sense to argue for the use of this exemption in

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2000/2003 IBC as well. The exemption matches the weight limits proposed for trapeze supported pipe in Section 5.6 of this guide.

No restraints are required for conduit, bus ducts, or cable trays (termed in ASCE 7-10 as raceways) that are supported on trapeze bars, that have been assigned a Component Importance Factor equal to 1.5, and that have a total weight that is 10 lb/ft (4.5 kg/m) or less. This total weight includes not only the conduit, bus duct, or cable trays, but also includes the trapeze bars as well. In ASCE 7-10, there is no Component Importance Factor stated, so this will apply to both a Component Importance Factor of 1.0, and 1.5 for 2012 IBC.

D2.1.7.5 The 12″ Rule {Section 13.6.5.6-1b}:

In ASCE 7-10, the 12″ Rule has been applied to electrical raceways (conduit, bus ducts, or cable trays. The raceway run will be exempt fro the need for seismic restraints if every hanger supporting the raceway run is 12 in (305 mm) or less in length from the raceway attachment point to the supporting structure. If hanger rods are used to support the raceway, they must be equipped with swivels to prevent inelastic bending of the hanger rod.

D2.1.7.5 Summary:

All of the implied exemptions above are made without regard for the Seismic Design Category to which the building has been assigned. Further, a complete reading of the project specification is in order to ensure that these exemptions have not been negated by the wishes of the building owner.

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SESIMIC DESIGN FORCES

D2.1.8.1 Introduction:

The code based horizontal seismic force requirements for MEP systems and components are either calculated by the seismic restraint manufacturer as a part of the selection and certification process, or may be determined by the design professional of record for the MEP systems under consideration.

This is an informational section. It will discuss the code based horizontal seismic force demand equations and the variables that go into them. This discussion will provide a deeper understanding for the designer responsible for selecting the seismic restraints for MEP systems and their components and the nature of the seismic forces and the factors that affect them.

D2.1.8.2 Horizontal Seismic Design Force (Section 9.6.1.3) [Section 13.3.1] {Section 13.3.1}[1]:

The seismic force is based on the mass, or weight, of the MEP component and as such is applied to the MEP component at its center of gravity. Keep in mind that the earthquake ground motion moves the base of the building first. Then the motion of the building will accelerate the MEP component through its supports and/or seismic restraints. The horizontal seismic force acting on an MEP component will be determined in accordance with Equation 9.6.1.3-1 of ASCE 7-98/02 and Equation 13.3-1 of ASCE 7-05 and ASCE 7-10.

$$F_P = \frac{0.4 a_P S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{z}{h}\right)$$ **Eq D2.1.8-1 (9.6.1.3-1) [13.3-1] {13.3-1}**

ASCE 7-98/02, -05, and -10 define an upper and lower bound for the horizontal force that is to be applied to the center of gravity of a component. The horizontal seismic force acting on an MEP component is not required to be greater than;

$$F_P = 1.6 S_{DS} I_P W_P$$ **Eq D2.1.8-2 (9.6.1.3-2) [13.3-2] {13.3-2}**

And the horizontal seismic force acting on an MEP component is not to be less than;

$$F_P = 0.3 S_{DS} I_P W_P$$ **Eq D2.1.8-3 (9.6.1.3-3) [13.3-3] {13.3-3}**

Where:

[1] References in brackets (Section 9.6.1.3) [Section 13.3.1] {Section 13.3.1} refer to sections and/or tables in ASCE 7-98/02, ASCE 7-05, and ASCE7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 IBC respectively.

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F_P = the design horizontal seismic force acting on an MEP component at its center of gravity.

S_{DS} = the short period design spectral acceleration.

a_P =the component amplification factor. This factor is a measure of how close to the natural period of the building the natural period of the component is expected to be. The closer the natural period of the component is to that of the building, the larger a_P will be. Conversely, the further the natural period of the component is away from that of the building, the smaller a_P will be. Typically a_P will vary from 1.0 to 2.5, and is specified by component type in ASCE 7-98, -02, -05, and -10 and is listed in Tables D2.1.8-1, D2.1.8-2, D2.1.8-3, and D2.1.8-4 respectively.

I_P = the component importance factor which be either 1.0 or 1.5.

W_P = the operating weight of the MEP system or component that is being restrained.

R_P = the response modification factor which varies from 1.25 to 5.0 in ASCE 7-98, 1.5 to 5.0 in ASCE 7-02, and 1.50 to 12.0 in ASCE 7-05 and -10 by component type. This factor is a measure of the ability of the component and its attachments to the structure to absorb energy. It is really a measure of how ductile or brittle the component and its attachments are. The more flexible, ductile the component and its supports and/or restraints are the larger R_P will be. And conversely, the more brittle and inflexible the component and its supports and/or restraints are, the smaller R_P will be. The values are specified by component type in Table D2.1.8-1 for ASCE 7-98, Table D2.1.8-2 for ASCE 7-02, Table D2.1.8-3 for ASCE 7-05, and Table D2.1.8-4 for ASCE 7-10.

z = the structural attachment mounting height of the MEP component in the building relative to the grade line of the building.

h = the average height of the building roof as measured from the grade line of the building.

The $\mathbf{0.4}$ factor was introduced as a modifier for S_{DS} as a recognition that the MEP components inside the building would react more strongly to the long period earthquake ground motion than to the short period motion. The $\mathbf{0.4}$ factor brings the design level acceleration for the MEP components more in line with the design level acceleration that is applied to the building structure itself.

The $\left(1+2\frac{z}{h}\right)$ term in Equation D2.1.8-1 is recognition of the fact that all buildings and structures become more flexible as they increase in height. That is they are much stiffer, stronger, at the foundation level than the roof. Since the ground motion from an earthquake enters the building structure at the foundation level, the actual accelerations imparted an MEP component will be greater the higher in the building they are attached. A building may be likened to a vertically mounted cantilever beam that is being shaken by the bottom. It is a vibrating system that will have

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a certain natural period that is, in a general fashion, based on its mass and stiffness. If the natural period of the building is at, or close too, the earthquake period, the motion of the building could be extreme. This was the case in the Mexico City earthquake of September 19, 1985.

The horizontal seismic design force must be applied to the component along it's least resistant axis. This is likely not one of the primary axes. The horizontal seismic design force must also be applied in conjunction with all of the expected dead loads and service loads. The idea here is that the horizontal seismic design force is to be applied in the direction that causes the highest stress in the supports and restraints, and thus produces the most conservative results. Load combination equations are provided in the various versions of the IBC that indicate all of the various load considerations that must be addressed.

D2.1.8.3 Vertical Seismic Design Force (Sections 9.5.2.7 and 9.6.1.3) [Sections 12.4.2.2 and 13.3.1] {Sections 12.4.2.2 and 13.3.1}:

The MEP component, its supports, and its restraints must also be designed for a vertical seismic design force that acts concurrently with the horizontal seismic design force. This vertical seismic design force must be directed such that it also produces the highest stress in the supports and restraints, thus producing the most conservative result. This vertical seismic design force is defined as follows.

$$F_V = \pm 0.2 S_{DS} W_P$$ **Eq D2.1.8-4 (9.5.2.1-1/-2) [12.4-4] {12.4-4}**

Where:

F_V = the vertical seismic design force.

D2.1.8.4 The Evolution of a_P and R_P Factors (Sections 9.6.1.3 and 9.6.3.2 and Table 9.6.3.2) [Sections 13.3.1 and 13.6.1 and Table 13.6-1]:

The a_p and R_p factors represent respectively the dynamic response of the attachment method and the durability level of the restrained piece of equipment. The component amplification factor (a_p) increases the seismic force for conditions where the looseness in the mounting system can create pounding or where the attachment can possibly resonate with the motion generated by a seismic event. This number will increase as the attachment becomes more resilient.

The component response modification factor (R_p) is a measure of how much energy the restrained component along with its supports and attachments can absorb without sustaining crippling damage. A common term used throughout the HVAC industry for this factor is the fragility level. For R_p = 1.0 the component is extremely fragile. For R_p = 12.0, on the other hand, the component would be very robust.

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The values for a_P and R_P are assigned by the ASCE 7 committee based on accumulated experience throughout the building industry. The evolution of these factors may be traced through Tables D2.1.8-1; D2.1.8-2, D2.1.8-3, and D2.1.8-4 which represent 2000 IBC, ASCE 7-98; 2003 IBC, ASCE 7-02; 2006/2009 IBC, ASCE 7-05; and 2012 IBC, ASCE 7-10 respectively. The different values for the same items in the three tables indicate the lack of knowledge and understanding concerning these components throughout the industry. Only time, experience, and shake table testing will produce true usable values for a_P and R_P.

D2.1.8.5 LRFD versus ASD: (Sections 2.3 and 2.4) [Sections 2.3, 2.4 and 13.1.7] {Sections 2.3, 2.4 and 13.1.7}:

This topic was briefly touched upon in Section D2.1.4.8 of this guide. However, more should be said about it in this section dealing the design seismic forces that will be applied to the MEP components. The Civil and Structural Engineering community has adopted the LRFD, Load Resistance Factor Design, philosophy. With this design philosophy the factors controlling the serviceability of the structure as assigned to the design loads. ASD, Allowable Stress Design, is the design philosophy which preceded LRFD. In ASD, the factors controlling the serviceability of the structure are assigned to the yield strength or to the ultimate strength of the material. Traditionally the factors controlling the serviceability of the structure have been known as the Safety Factors, or Factors of Safety.

The forces calculated using Equations D2.1.8-1, D2.1.8-2, D2.1.8-3, and D2.1.8-4 will have magnitudes that correspond to LRFD. Many standard components such a concrete anchors, bolts, screws, and etc. will have their capacities listed as ASD values. Components whose capacities are listed as ASD values may be compared to the LRFD results from Equations D2.1.8-1 through D2.1.8-4 by multiplying the ASD values by 1.4.

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Table D2.1.8-1; Component Amplification and Response Modification Factors for 2000 IBC (Table 9.6.3.2)

MECHANICAL & ELECTRICAL COMPONENT[2]	a_P [3]	R_P [4]
General Mechanical Equipment	-----	-----
Boilers and furnaces.	1.0	2.5
Pressure vessels on skirts and free-standing.	2.5	2.5
Stacks & cantilevered chimneys	2.5	2.5
Other	1.0	2.5
Piping Systems	-----	-----
High deformability elements and attachments (welded steel pipe & brazed copper pipe).	1.0	3.5
Limited deformability elements and attachments (steel pipe with screwed connections, no hub connections, and Victaulic type connections).	1.0	2.5
Low deformability elements and attachments (iron pipe with screwed connections, and glass lined pipe).	1.0	1.25
HVAC Systems	-----	-----
Vibration isolated.	2.5	2.5
Non-vibration isolated.	1.0	2.5
Mounted-in-line with ductwork.	1.0	2.5
Other	1.0	2.5
General Electrical	-----	-----
Distributed systems (bus ducts, conduit, and cable trays).	2.5	5.0
Equipment.	1.0	2.5
Lighting fixtures.	1.0	1.25

[2] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers, and the horizontal seismic design force shall be equal to $2F_P$.
[3] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P=1.0 is to be applied to equipment that is rigid or rigidly attached. A value of a_P=2.5 is to be applied to equipment regarded as flexible or flexibly attached.
[4] A value of R_P=1.25 is to be used for component anchorage design with expansion anchor bolts, shallow chemical anchor, shall low deformability cast in place anchors, or when the component is constructed of brittle materials. Shallow anchors are those with an embedment depth to nominal diameter ratio that is less than 8.

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Table D2.1.8-2; Component Amplification and Response Modification Factors for 2003 IBC (Table 9.6.3.2)

MECHANICAL & ELECTRICAL COMPONENT[5]	a_P [6]	R_P
General Mechanical Equipment	-----	-----
Boilers and furnaces.	1.0	2.5
Pressure vessels on skirts and free standing.	2.5	2.5
Stacks and cantilevered chimneys.	2.5	2.5
Other	1.0	2.5
Piping Systems	-----	-----
High deformability elements and attachments (welded steel pipe & brazed copper pipe).	1.0	3.5
Limited deformability elements and attachments (steel pipe with screwed connections, no hub connections, and Victaulic type connections).	1.0	2.5
Low deformability elements and attachments (iron pipe with screwed connections, and glass lined pipe).	1.0	1.5
HVAC Systems	-----	-----
Vibration isolated.	2.5	2.5
Non-vibration isolated.	1.0	2.5
Mounted-in-line with ductwork.	1.0	2.5
Other	1.0	2.5
General Electrical	-----	-----
Distribution systems (bus ducts, conduit, and cable trays).	2.5	5.0
Equipment	1.0	2.5
Lighting fixtures.	1.0	1.5

[5] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers. If the maximum bumper/snubber clearance, or air gap, is greater than 1/4 in., the horizontal seismic design force shall be equal to $2F_P$. If the maximum bumper/snubber clearance, air gap, is less than or equal to 1/4 in., the horizontal seismic design force shall be taken as F_P.

[6] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P=1.0 is to be applied to equipment that is rigid or rigidly attached. A value of a_P=2.5 is to be applied to equipment regarded as flexible or flexibly attached.

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Table D2.1.8-3; Component Amplification and Response Modification Factors for 2006/2009 IBC [Table 13.6-1]

MECHANICAL AND ELECTRICAL COMPONENTS	a_P [7]	R_P [8]
Air-side HVAC – fans, air handlers, and other mechanical components with sheet metal framing.	2.5	6.0
Wet-side HVAC – boilers, chillers, & other mechanical components constructed of ductile materials.	1.0	2.5
Engines, turbines, pumps compressors, and pressure vessels not supported on skirts.	1.0	2.5
Skirt supported pressure vessels.	2.5	2.5
Generators, batteries, transformers, motors, & other electrical components made of ductile materials.	1.0	2.5
Motor control cabinets, switchgear, & other components constructed of sheet metal framing.	2.5	6.0
Communication equipment, computers, instrumentation and controls.	1.0	2.5
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	2.5	3.0
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	1.0	2.5
Lighting fixtures.	1.0	1.5
Other mechanical & electrical components.	1.0	1.5
Vibration Isolated Components & Systems	-----	-----
Components & systems isolated using neoprene elements & neoprene isolated floors with elastomeric snubbers or resilient perimeter stops	2.5	2.5
Spring isolated components & systems & vibration isolated floors closely restrained with elastomeric snubbing devices or resilient perimeter stops.	2.5	2.0
Internally isolated components or systems.	2.5	2.0
Suspended vibration isolated equipment including in-line duct devices & suspended internally isolated components.	2.5	2.5
Distribution Systems	-----	-----
Piping in accordance with ASME B31, this includes in-line components, with joints made by welding or brazing.	2.5	12.0
Piping in accordance with ASME B31, this includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	6.0
Piping & tubing that is not in accordance with ASME B31, this includes in-line components, constructed with high deformability materials with joints made by welding or brazing.	2.5	9.0
Piping & tubing that is not in accordance with ASME B31, this includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	4.5
Piping & tubing of low deformability materials, such as cast iron, glass, or non-ductile plastics.	2.5	3.0

[7] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P=1.0 is to be applied to components that are rigid or rigidly attached. A value of a_P=2.5 is to be applied to components regarded as flexible or flexibly attached.

[8] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers. If the maximum bumper/snubber clearance, or air gap, is greater than 1/4 in., the horizontal seismic design force shall be equal to $2F_P$. If the maximum bumper/snubber clearance, air gap, is less than or equal to 1/4 in., the horizontal seismic design force shall be taken as F_P.

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Ductwork, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0
Ductwork, including in-line components, constructed of high or limited deformability materials, with joints made by means other than welding or brazing.	2.5	6.0
Duct work constructed of low deformability materials such as cast iron, glass, or non-ductile plastics.	2.5	3.0
Electrical conduit, bus ducts, rigidly mounted cable trays, & plumbing.	1.0	2.5
Suspended cable trays.	2.5	6.0

Table D2.1.8-4; Component Amplification and Response Modification Factors for 2012 IBC {Table 13.6-1}

MECHANICAL AND ELECTRICAL COMPONENTS	a_P [9]	R_P [10]
Air-side HVAC – fans, air handlers, and other mechanical components with sheet metal framing.	2.5	6.0
Wet-side HVAC – boilers, chillers, & other mechanical components constructed of ductile materials.	1.0	2.5
Engines, turbines, pumps compressors, and pressure vessels not supported on skirts.	1.0	2.5
Skirt supported pressure vessels.	2.5	2.5
Generators, batteries, transformers, motors, & other electrical components made of ductile materials.	1.0	2.5
Motor control cabinets, switchgear, & other components constructed of sheet metal framing.	2.5	6.0
Communication equipment, computers, instrumentation and controls.	1.0	2.5
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	2.5	3.0
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	1.0	2.5
Lighting fixtures.	1.0	1.5
Other mechanical & electrical components.	1.0	1.5
Vibration Isolated Components & Systems	-----	-----
Components & systems isolated using neoprene elements & neoprene isolated floors with elastomeric snubbers or resilient perimeter stops	2.5	2.5
Spring isolated components & systems & vibration isolated floors closely restrained with elastomeric snubbing devices or resilient perimeter stops.	2.5	2.0
Internally isolated components or systems.	2.5	2.0
Suspended vibration isolated equipment including in-line duct devices & suspended internally isolated components.	2.5	2.5

[9] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P=1.0 is to be applied to components that are rigid or rigidly attached. A value of a_P=2.5 is to be applied to components regarded as flexible or flexibly attached.

[10] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers. If the maximum bumper/snubber clearance, or air gap, is greater than 1/4 in., the horizontal seismic design force shall be equal to $2F_P$. If the maximum bumper/snubber clearance, air gap, is less than or equal to 1/4 in., the horizontal seismic design force shall be taken as F_P.

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Distribution Systems	-----	-----
Piping in accordance with ASME B31, this includes in-line components, with joints made by welding or brazing.	2.5	12.0
Piping in accordance with ASME B31, this includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	6.0
Piping & tubing that is not in accordance with ASME B31, this includes in-line components, constructed with high deformability materials with joints made by welding or brazing.	2.5	9.0
Piping & tubing that is not in accordance with ASME B31, this includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	4.5
Piping & tubing of low deformability materials, such as cast iron, glass, or non-ductile plastics.	2.5	3.0
Ductwork, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0
Ductwork, including in-line components, constructed of high or limited deformability materials, with joints made by means other than welding or brazing.	2.5	6.0
Duct work constructed of low deformability materials such as cast iron, glass, or non-ductile plastics.	2.5	3.0
Electrical conduit and cable trays	2.5	6.0
Bus ducts	1.0	2.5
Plumbing	1.0	2.5

D2.1.8.6 Summary:

This section has provided an insight into the way in which the seismic design forces for MEP systems and components are to be computed. It is generally not necessary for a designer to actually run the computations for the seismic design forces. These forces are normally computed by the manufacturer of the seismic restraint devices as part of the selection and certification process to ensure that the proper components are selected per the code and the specification.

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ANCHORAGE OF MEP COMPONENTS TO THE BUILDING STRUCTURE

D2.1.9.1 Introduction:

The anchorage, or attachment, of the MEP components and their seismic restraints to the building structure has always been a gray area generally left to the installing contractor with little or no guidance from the design professionals responsible for the MEP systems or the building structure. ASCE 7 does give some general guidance for the making these attachments. However, the design professionals involved with the MEP systems and the building structure must share the responsibility for ensuring the adequacy of these attachments. This section will cover the guidance provided to the design professionals of record in ASCE 7.

D2.1.9.2 General Guidelines for MEP Component Anchorage (Section 9.6.1.6 and 9.6.3.4) [Section 13.4] {Section 13.4 and Section 13.4.1}[1]:

1. The MEP component, its supports, and seismic restraints must be positively attached to the building structure without relying on frictional resistance generated by the dead weight of the component. The following are some of the acceptable ways and means of attachment.

    a. Bolting

    b. Welding

    c. Post installed concrete anchors

    d. Cast in place concrete anchors

2. There must be a continuous load path of sufficient strength and stiffness between the component and the building structure to withstand the expected seismic loads and displacements. This means that when cable restraints are used for distributed MEP systems, the cables can not bend or wrap around any other component or structure in a straight line path between the component and the structure.

3. The local areas of the building structure must be designed with sufficient strength and stiffness to resist and transfer the seismic restraint forces from the MEP systems and components to the main force resisting structure of the building. It is at this point that the design professional of record, and the installing contractor for the MEP system must work closely with the structural engineer of record to make sure that the intended anchorage points for the MEP system seismic restraints have sufficient capacity.

[1] References in brackets (Sections 9.6.1.6 and 9.6.3.4) [Section 13.4] {Section 13.4} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 IBC respectively.

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Special Notes:

1. **The design documents need to contain enough information pertaining to the attachments to allow a design professional to verify the compliance with the code.**

2. **In ASCE 7-10 Section 13.4.1, the design forces and displacements are to be determined according to Sections 13.3.1 and 13.3.2 as in previous versions except that $R_P \leq 6.0$. Thus, the design forces for certain pipe and duct systems will be higher than what would be indicated from using the R_P values found in Table 13.6-1of ASCE 7-10.**

D2.1.9.3 Anchorage in (Cracked) Concrete and Masonry (Section 9.6.1.6) [Section 13.4.2] {Section 13.4.2.1 and Section 13.4.2.3}:

1. Anchors for MEP component seismic restraints and supports are to be designed and proportioned to carry the least of the following:

   a. A force equal to 1.3 times the seismic design forces acting on the component and its supports and restraints.

   b. The maximum force that can be transferred to the anchor by the component and its supports.

2. $R_P \leq 1.5$ will be used to determine the component forces unless:

   a. The design anchorage of the component and/or its restraints is governed by the strength of a ductile steel element.

   b. The design of post installed anchors in concrete used for the anchorage of the component supports and restraints is prequalified for seismic applications according to ACI 355.2.

      i. Anchors that have been prequalified per AC 193[2] (ACI 355.2) will have an ICC-ES ESR Report issued for that anchor stating the fact that it is suitable for seismic applications for the current version of IBC. It will also give the allowable loads, embedments, and edge distances pertinent to the allowable loads.

      ii. Anchors from different manufacturers may not be directly substituted on a one-to-one basis. Each manufacturer will have a different design that will have different allowable loads when tested under AC 193 (ACI 355.2). The allowable loads for equivalent anchor sizes may be radically different.

[2] AC 193 is the Acceptance Criteria used by ICC ES to evaluate and pre-qualify the concrete anchors for use in cracked concrete. It is base directly on ACI 355.2.

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c. The anchor is designed in accordance with Section 14.2.2.14 of ASCE 7-05.

For 2000 IBC, ASCE 7-98, the "cracked" concrete anchors are not required, and standard post installed wedge type anchors may be used for seismic restraint as long as there is an ICC Legacy report stating that the anchors may be used in seismic applications. For 2003 IBC, ASCE 7-02, there are no specific statements in ASCE 7-02 that require the use of "cracked" concrete anchors in seismic applications. However, ASCE 7-02 Section 9.9 adopts ACI 318-02 as a reference document. ACI 318-02 specifies that the post installed anchors meet ACI 355.2 and "are required to be qualified for moderate or high seismic risk zone usage." ACI 355.2 is the test standard by which post installed anchors are to be pre-qualified for seismic applications in cracked concrete. So, by inference, "cracked" concrete anchors should also be used for 2003 IBC. However, that has not yet been widely enforced since few if any post installed anchors had been qualified to this standard before 2006/2009 IBC was issued.

There are new and special wrinkles for concrete anchors in ASCE 7-10 which will be picked up by 2012 IBC. ASCE 7-10 Section 13.4.2.1 requires the concrete anchors to be designed per ACI 318 Appendix D. ACI 318-08 Section D.3.3.4 specifies that the anchors must be designed such that their failure is to be governed by a ductile steel element. So, the ductile steel element needs to fail before the concrete fails. The intent of the code is to prevent an unpredictable brittle failure in the concrete by having a predictable ductile failure in the steel of the anchor. There is an alternative to this requirement in ACI 318-08 Section D.3.3.6 which requires that, instead of the ductile failure in the steel of the anchor, that the allowable strength of the anchors may be reduced by 60%. This will create problems throughout the industry for MEP contractors who must use post installed concrete anchors to attach the restraints for MEP components to the building structure because the standard offering of wedge type anchors, typically, do not meet the ductility requirement of the code. To meet the requirement of the code, the steel element must have an elongation of at least 14% and a reduction in area of at least 30%. It may be possible to achieve this with adhesive type post installed anchors, but not in all cases. The result is that more anchors will be required to attach the restraints to the building than before. This means more "real estate" will be required for each anchor point.

Masonry anchors are now discussed more fully in ASCE 7-10 Sections 13.4.2.2 and 13.4.2.3. ASCE 7-10 Section 13.4.2.2 requires that the design of masonry anchors be per TMS 402/ACI 503/ASCE5, and that the design be governed by the failure of a ductile steel element or that the allowable strength of the anchor be reduced by 60%. Also, ASCE 7-10 Section 13.4.2.3 requires that the anchors used in masonry be prequalified for seismic applications per approved qualification standards (which do not yet exist). This will cause problems with application and inspection when 2012 IBC is implemented. There will be no acceptance criteria for pre-qualifying anchors for seismic applications in masonry, and thus, no pre-qualified anchors with an ICC-ESR.

D2.1.9.4 Undercut Anchors (Section 9.6.3.13.2-c) [Section 13.6.5.5-5] {Section 13.6.5.5-5}:

For both 2000 IBC, ASCE 7-98, and 2006/2009 IBC, ASCE 7-05, post installed expansion, wedge, anchors may not be used for non-vibration isolated mechanical equipment rated over 10 hp (7.45

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kW). However, post installed undercut expansion anchors may be used. Also, because they are not specifically prohibited, adhesive anchors may be used.

For 2003 IBC, ASCE 7-02, post installed expansion, wedge, anchors may not be used for non-vibration isolated mechanical equipment. However, post installed undercut expansion anchors are permitted. Again, adhesive anchors may be used because they are not specifically prohibited.

ASCE 7-10 Section 13.6.5.5-5 simply states that anchors used for non-vibration isolated equipment rated over 10 Hp (7.45 kW) are to be qualified per ACI 355.2 (AC 193). The requirement for undercut wedge anchors is removed.

D2.1.9.5 Prying of Bolts and Anchors (Section 9.6.1.6.3) [Section 13.4.3] {Section 13.4.3}:

The design of the attachment of the MEP component supports and restraints must take into account the mounting conditions such as eccentricity in the supports and brackets, and prying of the bolts or anchors.

D2.1.9.6 Power Actuated or Driven Fasteners (Section 9.6.1.6.5) [Section 13.4.5] {Section 13.4.5}:

Power actuated or driven fasteners, such as powder shot pins, may not be used for tensile load applications in Seismic Design Categories D, E, and F unless specifically approved for this application.

The language in ASCE 7-10 Section 13.4.5 has been made more restrictive. Power actuated fasteners in concrete or steel are not to be used sustained tension loads or brace (seismic restraint) applications in Seismic Design Categories D, E, or F unless they have been approved for seismic applications. Power actuated fasteners are not to be used in masonry unless approved for seismic applications.

D2.1.9.7 Friction Clips (Section 9.6.3.13.2-b) [Section 13.4.6] {Section 13.4.6}:

Friction clips may not be used to attach seismic restraints to the component or the building structure. A typical example would be the attachment of a cable restraint to a structural beam with a standard beam clamp. A beam clamp with a restraint strap or safety strap, capable of resisting the applied seismic load that will ensure that the clamp will be prevented from walking off the beam may be used.

ASCE 7-10 Section 13.4.6 has clarified the application of friction type clips for attaching seismic restraints to the building structure. They are not to be used for supporting sustained loads as well as seismic loads in Seismic Design Categories D, E, or F. The implication is that they can be used for seismic loads alone. C-type beam and large flange clamps can be used for hangers if they are equipped with safety straps. In all cases the bolts providing the clamping force that generates the friction load must be equipped with lock nuts or the equivalent to prevent the loosening of the threaded connections.

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D2.1.9.8 Summary:

Attachment of the MEP components and their seismic restraints to the building structure is of the utmost importance to maintaining the building function following an earthquake. It is the responsibility of the design professionals of record for the MEP systems to work with the structural engineer of record and the architect of record for the building to ensure that the anchorage points for the MEP component supports and restraints have been properly designed to transfer the design seismic loads as well as any other dead weight and service loads.

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IBC Wind

D2.2.1 - Introduction:

The need for the seismic restraint of equipment has been well recognized for many years. It even appears in most specifications. The need for the wind restraint of exposed roof top equipment, however, has been largely ignored. It very seldom appears as a specification item, and when it does it is placed in an obscure portion of the specification, almost as an after thought. Hurricane Katrina and the other recent hurricanes in Florida and the Gulf of Mexico have focused FEMA's attention on the ability of roof top equipment to withstand forces generated by high wind events. Of particular interest are the attachments of the equipment to the building structure. This paper will center on the different versions of the International Building Code (IBC), which are based on the wind provisions of ASCE 7, and how they apply to the wind loads acting on roof top equipment. Table 2.2.1-1 shows the IBC code year along with its ASCE 7 reference version.

Table D2.2.1-1; IBC & ASCE 7 Wind Load References

INTERNATIONAL BUILDING CODE YEAR (IBC)	IBC WIND LOAD SECTION	ASCE 7 VERSION	ASCE 7 WIND LOAD CHAPTER FOR ROOFTOP EQUIPMENT
2000	1609	98	6
2003	1609	02	6
2006	1609	05	6
2009	1609	05	6
2012	TBD	10	29

The following references are used throughout Section D2.2

1. 2000 International Building Code; International Code Council, 5203 Leesburg Pike, Suite 708, Falls Church, Virginia, 22041-3401; 2000.

2. ASCE 7-98 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapter 9.

3. 2003 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2002.

4. ASCE/SEI 7-02 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapter 9.

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5. 2006 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2006.

6. 2009 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2009.

7. ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapters 1, 2, 11, 13, 20, and 21.

8. 2012 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; ***Not Yet Published***.

9. ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400; 2010, Chapters 1, 2, 11, 13, 20, 21, 22 and 23.

10. Reinhold, Timothy A.; "Wind Loads and Anchorage Requirements for Rooftop Equipment"; ASHRAE Journal March 2006, www.ashrae.org.

When applying wind restraints to rooftop equipment, it is important to keep the following things in mind.

1. Wind loads are a real and constant threat in all locations in the country.

2. In many cases the wind loads acting on a piece of rooftop equipment will be more severe than the seismic loads.

3. There must be a continuous load path between the rooftop equipment and the building structure.

4. The building structure must be strong enough to carry, not only the dead weight of the equipment, but also carry the design wind loads calculated according to the code provisions.

5. Design calculations and submittals for wind restraints must be forwarded to the Structural Engineer of Record for evaluation and approval.

6. For curb mounted equipment, not only must the equipment be properly attached to the curb, but the curb itself must be properly attached to the building structure that supports it.

7. The restraint types used for isolated equipment may cause the isolation to be "shorted out", or ineffective, for extended periods of time during low to moderate wind conditions.

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CODE OVERVIEW & BASIC INFORMATION

D2.2.2.1 – Introduction

IBC code years 2000 thru 2009 have been published and are current. IBC 2012 has not yet been published. However, ASCE 7-10 has been published and will, no doubt, form the basis of the wind load requirements for IBC 2012. IBC 2000 and 2003, ASCE 7-98 and -02, are, for all intents and purposes, the same in regards to wind loading. They do not specifically mention equipment, and only have provisions for horizontal wind loads. IBC 2006, ASCE 7-05, is similar to IBC 2000 and 2003, but it does specifically mention equipment in a new section (Section 6.5.15.1), and it recommends consideration of wind generated uplift forces acting on the equipment in the Commentary (Page 300). IBC 2012 will have entirely new language and structure as pertains to wind loads. ASCE 7-10 has broken the wind load section up into 6 new chapters. As seen in Table D2.2.1-1, Chapter 29 deals specifically with roof top equipment. Also, the basic 3 second gust wind speeds are being increased significantly, by 30 mph.

D2.2.2.2 – Wind Restraint for Rooftop Equipment

For all current published versions of the IBC, 2000 thru 2009, Sections 1609.1 and 1609.1.1 require that all parts of buildings and structures be designed to withstand the minimum wind loads prescribed by the version of ASCE 7 that corresponds to the IBC code year in force. Section 1609.1 also states that wind loads acting on rooftop equipment may not be reduced through the shielding effects of other structures. These sections of the IBC will impact rooftop equipment in the following ways.

1. It requires that all exposed, outside, equipment and their attachment to the building structure be designed to resist the code mandated wind loads.

2. Barrier walls, screens, parapets, overhangs, and other shielding structures can not be counted on to protect exposed, outside, equipment. The equipment and its attachments to the structure must be designed to withstand the full force of the code mandated wind loads.

D2.2.2.3 – Building Classification for Wind Design:

The magnitude of the design wind loads will depend on the classification and use of the building. The basic building classifications have remained the same over the various versions of the IBC and ASCE 7. However, the designations of those classifications have changed over the various versions of the code. Table D2.2.2-1 shows how the building classifications have changed over the years, and is based on Table 1-1 of ASCE 7-98/-02, Table 1-1 of ASCE 7-05, and Table 1.5-1 of ASCE 7-10.

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Table D2.2.2-1; Building Use vs. Building Category, Occupancy Category, and Risk Category

BUILDING CATEGORY 2000/2003 IBC	OCCUPANCY CATEGORY 2006/2009 IBC	RISK CATEGORY 2012 IBC	BUILDING USE
I	I	I	Buildings and other structures whose failures would pose a significant risk to human life.
II	II	II	Buildings and other structures not listed in Occupancy/Risk Categories I, III, and IV or Seismic Use Groups II and III.
II	III	III	Buildings and other structures whose failure would pose a significant risk to human life, cause a significant economic impact, or cause mass disruption in the day-to-day life of civilians.
III	IV	IV	Buildings or other structures that are essential for post disaster recovery, whose failure would pose a substantial hazard to the community, or are used to process, store, or dispose of hazardous materials.

Building, Occupancy, or Risk Category is assigned by the Architect and/or structural engineer and is specified on the first sheet of the structural drawings.

D2.2.2.4 – Basic Wind Speed & Wind Importance Factor:

The Basic Wind Speed is used to compute the design wind loads that are applied to the rooftop equipment. For IBC 2000/2003 the Basic Wind Speed for each location in the United States is given in Figures 6-1 and 6-1a through -1c of ASCE 7-98/-02. Notice that for the bulk of the United States, the Basic Wind Speed is 90 mph. This wind speed corresponds to a Category 1 hurricane. Coastal areas have much higher basic wind speeds that increase with decreasing distance to the coast. For IBC 2006/2009, the basic wind speeds are given in Figures 6-1 and 6-1A through 6-1C of ASCE 7-05. The values shown on these maps did not change from those for ASCE 7-98/-02.

For IBC 2000/2003/2006/2009, the building classification is accounted for through the use of a Wind Importance Factor. The Wind Importance Factor is matched to the building classification by Table 6-1 of ASCE 7-98/-02/-05, which is repeated in Table D2.2.2-2 below.

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Table D2.2.2-2; Importance Factors for Wind Based on Building Occupancy
ASCE 7-98/-02/-05 Table 6-1

BUILDING, OCCUPANCY, OR RISK CATEGORY	NON-HURRICANE PRONE REGIONS AND HURRICANE PRONE REGIONS WITH $V = 85 - 100\ mph$ AND ALASKA	HURRICANE PRONE REGIONS WITH $V > 100\ mph$
I	0.87	0.77
II	1.00	1.00
III	1.15	1.15
IV	1.15	1.15

As will be seen in a later Section D2.2.3 of this manual, the Wind Importance Factor will be a direct multiplier of the calculated wind load based in the Basic Wind Speed.

In ASCE 7-10, all of this has changed dramatically. The Basic Wind Speeds are now found in Figures 26.5-1A through -1C. The Wind Importance Factor has been eliminated. The Basic Wind Speed will now be a function of the Risk Category that has been assigned to the building. From this point forward; this manual will deal only with Risk Category III and IV buildings. Most of the buildings that require large pieces of rooftop equipment will fall into one of these two Risk Categories. For Risk Category III and IV buildings, the Basic Wind Speeds have all been increased by 30 mph. So now, the bulk of the United States will have a Design Wind Speed of 120 mph, which corresponds to a Category 3 hurricane. The design wind loads are a function of the square of the Basic Wind Speed, so it may be expected that the design wind loads will increase dramatically across the board.

D2.2.2.5 – Exposure Categories:

The Exposure Category takes into account the surrounding terrain and structures. This is generally assigned to the building by the structural engineer and is listed on the first sheet of the structural drawings. Table D2.2.2-3 will help with understanding the assignment of the Exposure Category to a particular building, and is based on Section 6.5.6 of ASCE 7-98/-02/-05 and Section 26.7 of ASCE 7-10. Exposure Category A was dropped with ASCE 7-02, and will not be included in Table D2.2.2-3.

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Table D2.2.2-3; Importance Factors for Wind Based on Building Occupancy ASCE 7-98/-02/-05 Section 6.5.6 and ASCE 7-10 Section 26.7

BUILDING, OCCUPANCY, OR RISK CATEGORY	SURROUNDING TERRAIN & STRUCTURES
B	Urban and Suburban areas, wooded areas, or other terrain with many closely spaced obstructions of single family dwelling size or larger.
C	Open terrain with scattered obstructions generally 30 ft or less in height; including flat open country, grasslands, and all water surfaces in hurricane-prone regions.
D	Fat unobstructed areas and water surfaces outside hurricane-prone regions; includes smooth mud flats, salt flats, and unbroken ice.

D2.2.2.6 – Mean Roof Height:

The design wind loads acting on the rooftop equipment will depend on the mean roof height of the building on which the equipment is setting. Generally speaking, the design wind loads increase with increasing roof height. So, it is critical that the actual roof height at the equipment mounting location be determined. This should be available from both the architectural drawings and the structural drawings.

D2.2.2.7 – Summary

The basic pieces of information that are required to determine the design wind loads on a piece of equipment are as follows.

1. The Building, Occupancy, or Risk Category; which is available from the first sheet of the structural drawings.
2. The Basic Wind Speed; this may be determined from the figure listed in Section D2.2.2.4 for the various versions of IBC and ASCE 7, or may be available from the first sheet of the structural drawings.
3. The Exposure Category; which is available from the first sheet of the structural drawings.
4. Mean roof height at the equipment mounting location; this may be found in the structural drawings or the architectural drawings.

Wind loads must be taken seriously. They are a real and constant threat to the building envelope integrity. For the bulk of the country the design wind speeds will be equivalent to either a Category 1 hurricane, IBC 2000/2003/2006/2009, or a Category 3 hurricane, IBC 2012. The fact that rooftop equipment and their attachments must be designed to meet these wind loads is not usually spelled out in the specifications for the various trades and disciplines as are the seismic

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design requirements. However, the code does require that rooftop equipment and its attachments to the building be designed to meet these wind loads.

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Evolution of Design Wind Loads

D2.2.3.1 – Introduction:

Over the various versions of ASCE 7, the design wind loads acting on rooftop equipment have gone from being very ambiguous and difficult to calculate to being fairly well defined and straightforward. The purpose of this section will be to cover the equations and constants that apply to wind loads acting on rooftop equipment and standardized worst case load values for differing conditions.

D2.2.3.2 – Velocity Pressure:

This parameter is common to all versions of ASCE 7 in one of two forms. For ASCE 7-98/-02/-05, it is expressed as Equation 6-13 in ASCE 7-98, Equation 6-15 in ASCE 7-02, and Equation 6-15 in ASCE 7-05, and is shown below in Equation D2.2.3-1.

$$q_z = 0.00256 K_z K_{zt} K_d V^2 I$$ **Eq 2.2.3-1**

Where:

q_z = the velocity pressure at height z of the centroid of the area being impacted (psf). In this section it will be evaluated at the mean roof height of the building, and z will be taken to be the mean roof height at the equipment mounting location.

K_z = the velocity pressure exposure coefficient.

K_{zt} = the topographic factor.

K_d = the wind directionality factor.

V = the Design Wind Speed.

I = the Wind Importance Factor, see Table D2.2.2-2

For ASCE 7-10, the velocity pressure is defined in Equation 29.3-1, and show below in Equation D2.2.3-2. Notice that the only difference is that the Wind Importance Factor has been removed.

$$q_z = 0.00256 K_z K_{zt} K_d V^2$$ **Eq 2.2.3-2**

D2.2.3.2.1 – Velocity Pressure Exposure Coefficient:

The value of this parameter is defined in Tables 6-5 and 6-4 of ASCE 7-98, Tables 6-3 and 6-2 of ASCE 7-02/-05, and Tables 29.3-1 and 26.9-1 of ASCE 7-10. For the purposes of this analysis the

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equations listed in Note 1 of the tables will be used to compute the values for K_{zt} rather than trying to use tabulated data. The equation used in this section will be;

$$K_z = 2.01\left(\frac{z}{z_g}\right)^{\frac{2}{\alpha}} \text{ Where } 15 \le z \le z_g$$ **Eq 2.2.3-3**

Where:

z = the mean roof height of the building at the equipment mounting location (ft) and $z = 15$ for mean roof heights less than 15 ft.

The constants z_g and α are defined in Table 6-4 of ASCE 7-98, Table 6-2 of ASCE 7-02/-05, and Table 26.9-1 of ASCE 7-10 and are repeated below in Table D2.2.3-1 for convenience.

Table D2.2.3-1; Constants by Exposure Category for Computing K_z

EXPOSURE CATEGORY	α	z_g (FT)
B	7.0	1200
C	9.5	900
D	11.5	700

D2.2.3.2.2 – Topographic Factor:

This factor accounts for the wind speed-up effect that occurs when wind flows over a hill of an escarpment. It is defined by Equation 6-1 and Figure 6-2 of ASCE 7-98, Equation 6-3 and Figure 6-4 of ASCE 7-02/-05, and Equation 26.8-1 and Table 26.8-1 of ASCE 7-10. The values are the same over all four version of ASCE 7. Rarely are the exact topographic conditions surrounding a building site known to the suppliers of restraints for rooftop equipment. So, for the purposes of making a reasonable estimate of the design wind loads it will be assumed that;

$$K_{zt} = 1.0$$

D2.2.3.2.3 – Wind Directionality Factor:

This factor accounts for how the wind strikes the object, whether the wind can strike the object from only one direction, or whether it can strike the object from any direction. It allows for a reduction in the magnitude of the design wind loads to account for the reduced probability that the highest winds will strike the equipment from the worst possible direction. The values for this factor

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are given in Table 6-4 of ASCE 7-98/-05, Table 6-6 of ASCE 7-02, and Table 26.6-1 of ASCE 7-10. Timothy Reinhold in his ASHRAE Journal paper "Wind Loads and Anchorage Requirements for Rooftop Equipment", see Section D2.2.1 of this manual for the reference, recommends that the Wind Directionality Factor be given the following Value for rooftop equipment.

$$K_d = 0.85$$

This is the value given in the ASCE 7 tables listed above that is applied most frequently to objects that can be struck by the wind from any direction.

D2.2.3.3 – IBC 2000 & 2003 (ASCE 7-98 & -02):

The equation for the design wind load for ASCE 7-98 and ASCE 7-02 is found in Section 6.5.13 which is titled "Design Wind Loads on Open Buildings and Other Structures". In ASCE 7-98 the equation used is Equation 6-20, and in ASCE 7-02 it is 6-25. Both equations are identical and are shown below.

$$F = q_z G C_f A_f \qquad \textbf{Eq D2.2.3-4}$$

Where:

F = the horizontal design wind load (lbs).

G = the gust effect factor.

C_f = the net force coefficient.

A_f = the projected area normal to the wind (ft^2).

For the purposes of this manual it will be more convenient to express the design wind load as a design wind pressure. In this way the manual will be more generically applicable. So, then Equation D2.2.3-4 will have the following form.

$$p_h = q_z G C_f \qquad \textbf{Eq D2.2.3-5}$$

Where:

p_h = the horizontal design wind pressure (psf).

D2.2.3.3.1 – Gust Effect Factor:

The gust effect factor takes into account the turbulence and the resilience of the structure, and there are procedures for calculating the gust effect factor. However, the code provides only one

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value for rigid structures in Section 6.5.8.1 of ASCE 7-98/-02, and this is the value that has typically been used for rooftop equipment.

$$G = 0.85$$

There is some thought that the gust effect factor should be higher than 0.85, say on the order of 1.0 or 1.1, for roof top equipment since the equipment is small enough to be completely enveloped by a wind gust. However, there was no research available at the time ASCE 7-02 was published to allow a recommendation to be made on an acceptable value for the gust coefficient. Therefore, for ASCE 7-98/-02, the gust coefficient will remain at a value of 0.85.

D2.2.3.3.2 – Net Force Coefficient:

The net force coefficient is determined form Table 6-10 of ASCE 7-98 and Table 6-19 of ASCE 7-02. Most rooftop equipment is square or rectangular. Kinetics Noise Control performs its calculations with the wind acting on the gross diagonal area. The worst case for a square, rectangular, unit with the wind acting along the diagonal will produce a value for the net force coefficient of;

$$C_f = 1.5$$

This will also cover all of the cases of round rooftop stacks.

D2.2.3.3.3 – Design Wind Pressures for IBC 2000 & 2003:

Table D2.2.3-2 presents horizontal design wind pressures based on the equations and values for the various coefficients and factors given above. These design wind pressures are for Category III and IV buildings where $I = 1.15$.

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Table D2.2.3-2; Design Horizontal Wind Pressures on Rooftop Equipment for IBC 2000 & 2003 Category III & IV Buildings

Building Height (ft)		15	30	45	60	100	200
Design Wind Speed (mph)	Exposure Category	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)
85	B	13.2	16.1	18.1	19.7	22.8	27.8
	C	19.6	22.6	24.7	26.2	29.2	33.8
	D	23.7	26.8	28.7	30.2	33.0	37.3
90	B	14.9	18.1	20.3	22.1	25.5	31.1
	C	21.9	25.4	27.6	29.4	32.7	37.8
	D	26.6	30.0	32.2	33.9	37.0	41.8
100	B	18.3	22.4	25.1	27.2	31.5	38.4
	C	27.1	31.3	34.1	36.3	40.4	46.7
	D	32.9	37.1	39.8	41.8	45.7	51.6
110	B	22.2	27.0	30.4	33.0	38.2	46.5
	C	32.8	37.9	41.3	43.9	48.9	56.5
	D	39.8	44.9	48.1	50.6	55.3	62.4
120	B	26.4	32.2	36.1	39.2	45.4	55.3
	C	39.0	45.1	49.2	52.2	58.1	67.3
	D	47.3	53.4	57.3	60.2	65.8	74.3
130	B	31.0	37.8	42.4	46.0	53.3	65.0
	C	45.8	53.0	57.7	61.3	68.2	79.0
	D	55.6	62.7	67.2	70.7	77.3	87.2
140	B	35.9	43.8	49.2	53.4	61.8	75.3
	C	53.1	61.4	66.9	71.1	79.1	91.6
	D	64.4	72.7	78.0	82.0	89.6	101.1
150	B	41.3	50.3	56.5	61.3	70.9	86.5
	C	60.9	70.5	76.8	81.6	90.9	105.1
	D	74.0	83.4	89.5	94.1	102.9	116.0

D2.2.3.4 – IBC 2006 & 2009 (ASCE 7-05):

The design wind load for ASCE 7-05 is described in Sections 6.5.15 and 6.5.15.1. The basic equation specified for computing the design wind load is identical to that used in ASCE 7-98/-02, and is shown in Equation D2.2.3-4. However, it is to be modified for the mean roof height of the building at the mounting location for the rooftop equipment. The factor used to modify Equation D2.2.3-4 for building heights less than or equal to sixty feet varies from 1.9 down to 1.0 in a linear fashion based on the size of the equipment relative to the building size. Since the overall building dimensions are not always known, the maximum value of 1.9 will be used in this manual as a worst case condition. Timothy Reinhold's ASHRAE Journal paper, see Section D.2.2.3-1 of this manual, recommended that Equation D2.2.3-4 be increased by a factor of 1.6 for buildings over sixty feet in height. Thus, the equations used to determine the horizontal design wind loads for ASCE 7-05 will be as follows.

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$F = 1.9 q_z G C_f A_f$ For $z \le 60'$ **Eq D2.2.3-6**

And;

$F = 1.6 q_z G C_f A_f$ For $z > 60'$ **Eq D2.2.3-7**

Expressing Equations D2.2.3-6 and D2.2.3-7 as horizontal design wind pressures as in the previous section will lead to;

$p_h = 1.9 q_z G C_f$ For $z \le 60'$ **Eq D2.2.3-8**

And;

$p_h = 1.6 q_z G C_f$ For $z > 60'$ **Eq D2.2.3-9**

The values for the gust effect factor G and the net force coefficient C_f will remain the same as those for ASCE 7-98/-02.

In the commentary of ASCE 7-05 (page 300) there is a strong recommendation to include uplift loads in the design of the attachments for rooftop equipment. No guidance is given in this version of the code as to how the uplift forces should be calculated. Timothy Reinhold in his ASHRAE Journal paper cited in Section D2.2.1 of this manual recommends the following form for the equations to compute the uplift design wind force acting on the rooftop equipment.

$F_v = 1.9 q_z G C_p A$ For $z \le 60'$ **Eq D2.2.3-10**

And;

$F_v = 1.6 q_z G C_p A$ For $z > 60'$ **Eq D2.2.3-11**

Where:

F_v = the uplift design wind load (lbs).

C_p = the external pressure coefficient.

A = the horizontal projected area of the rooftop equipment (ft^2).

Expressing Equations D2.2.3-10 and D2.2.3-11 as horizontal design wind pressures as in the previous section will lead to;

$p_v = 1.9 q_z G C_p$ For $z \le 60'$ **Eq D2.2.3-12**

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And;

$p_v = 1.6 q_z G C_p$ For $z > 60'$ **Eq D2.2.3-13**

Where:

p_v = the vertical, uplift, design wind pressure (psf).

D2.2.3.4.1 – External Pressure Coefficient:

The value for this coefficient is to be found in ASCE 7-05 Table 6-6. It will be assumed that the roof slope is less than or equal to 10° and that the wind is acting normal to the roof ridge. The values listed for C_p are negative because the act outward away from the roof. By convention the negative sign will be dropped in this manual, and the uplift design wind load will be assume to always act upward away from the roof surface. Then; the value for the external pressure coefficient will be taken to be;

$C_p = 0.9$

D2.2.3.4.2 – Design Wind Pressures for IBC 2006 & 2009:

Table D2.2.3-3 presents horizontal and uplift design wind pressures based on the equations and values for the various coefficients and factors given above. These design wind pressures are for Category III and IV buildings where $I = 1.15$.

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Table D2.3.3-3; Horizontal & Uplift Design Wind Pressures on Rooftop Equipment for IBC 2006 & 2009 – Occupancy Category III & IV Buildings

Building Height (ft)		15		30		45		60		100		200	
Design Wind Speed (mph)	Exposure Category	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)
85	B	25.2	15.1	30.7	18.4	34.5	20.7	37.4	22.4	36.4	21.9	44.4	26.7
	C	37.2	22.3	43.0	25.8	46.9	28.1	49.8	29.9	46.7	28.0	54.0	32.4
	D	45.1	27.1	50.9	30.5	54.6	32.8	57.4	34.5	52.9	31.7	59.6	35.8
90	B	28.2	16.9	34.4	20.6	38.6	23.2	41.9	25.2	40.9	24.5	49.8	29.9
	C	41.7	25.0	48.2	28.9	52.5	31.5	55.8	33.5	52.3	31.4	60.6	36.3
	D	50.6	30.4	57.1	34.2	61.2	36.7	64.4	38.6	59.3	35.6	66.8	40.1
100	B	34.8	20.9	42.5	25.5	47.7	28.6	51.8	31.1	50.4	30.3	61.5	36.9
	C	51.5	30.9	59.5	35.7	64.9	38.9	68.9	41.3	64.6	38.8	74.8	44.9
	D	62.5	37.5	70.5	42.3	75.6	45.4	79.5	47.7	73.1	43.9	82.5	49.5
110	B	42.2	25.3	51.4	30.8	57.7	34.6	62.6	37.6	61.0	36.6	74.4	44.6
	C	62.3	37.4	72.0	43.2	78.5	47.1	83.4	50.0	78.2	46.9	90.5	54.3
	D	75.6	45.3	85.2	51.1	91.5	54.9	96.2	57.7	88.5	53.1	99.8	59.9
120	B	50.2	30.1	61.2	36.7	68.7	41.2	74.6	44.7	72.6	43.6	88.6	53.1
	C	74.1	44.5	85.7	51.4	93.4	56.0	99.2	59.5	93.0	55.8	107.7	64.6
	D	89.9	54.0	101.5	60.9	108.9	65.3	114.5	68.7	105.3	63.2	118.8	71.3
130	B	58.9	35.3	71.8	43.1	80.6	48.4	87.5	52.5	85.3	51.2	103.9	62.4
	C	87.0	52.2	100.6	60.4	109.6	65.8	116.4	69.9	109.2	65.5	126.3	75.8
	D	105.5	63.3	119.1	71.4	127.8	76.7	134.3	80.6	123.6	74.2	139.5	83.7
140	B	68.3	41.0	83.2	49.9	93.5	56.1	101.5	60.9	98.9	59.3	120.5	72.3
	C	100.9	60.5	116.7	70.0	127.1	76.3	135.0	81.0	126.6	76.0	146.5	87.9
	D	122.4	73.4	138.1	82.9	148.2	88.9	155.8	93.5	143.4	86.0	161.7	97.0
150	B	78.4	47.0	95.6	57.3	107.3	64.4	116.5	69.9	113.5	68.1	138.4	83.0
	C	115.8	69.5	134.0	80.4	145.9	87.5	155.0	93.0	145.4	87.2	168.2	100.9
	D	140.5	84.3	158.5	95.1	170.1	102.1	178.8	107.3	164.6	98.8	185.7	111.4

D2.2.3.5 – IBC 2012 (ASCE 7-10):

ASCE 7-10 does count for the wind effects on rooftop equipment in Sections 29.5 and 29.5.1. Section 29.5.1 deals with buildings whose mean roof height is sixty feet or less, and Section 29.5 covers buildings whose mean roof height is greater than sixty feet.

D2.2.3.5.1 – Buildings with $h \le 60'$:

For buildings whose mean roof height is sixty feet or less, the horizontal design wind load is given by ASCE 7-10 Equation 29.5-2.

$$F_h = q_h \left(GC_f\right) A_f \text{ For } h \le 60' \qquad \textbf{Eq D2.2.3-14}$$

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Where:

F_h = the horizontal design wind load (lbs).

q_h = the velocity pressure evaluated at the mean roof height (psf). For the purposes of this manual this value will be computed as q_z using Equation D2.2.3-2.

(GC_f) = 1.9 for rooftop equipment. This is allowed to vary in a linear fashion from 1.9 for equipment that is small compared to the size of the building to 1.0 for equipment that is approaching the same size as the building. IN this manual it will be taken as 1.9 for a worst case.

The uplift design wind load is given by ASCE 7-10 Equation 29.5-3.

$F_v = q_h (GC_r) A_r$ For $h \leq 60'$ **Eq D2.2.3- 15**

Where:

(GC_r) = 1.5 for rooftop equipment. Here again this is allowed to vary in a linear fashion from 1.5 for equipment that is small compared to the size of the building to 1.0 for equipment that is approaching the same size as the building. I this manual the worst case value of 1.5 will be used.

A_r = the horizontal projected area of the rooftop equipment (ft2).

The design loads presented in Equations D2.2.3-14 and D2.2.3-15 may be expressed as design pressures as follows.

$p_h = q_h (GC_f)$ For $h \leq 60'$ **Eq D2.2.3-16**

And;

$p_v = q_h (GC_r)$ For $h \leq 60'$ **Eq D2.2.3- 17**

D2.2.3.5.2 – Buildings with $h > 60'$:

For buildings whose mean roof height exceeds sixty feet, the neither the code nor the commentary mentions an uplift design wind load requirement. For buildings whose mean roof height exceeds sixty feet no design uplift wind load will be considered, and the horizontal design wind load is given by Equation 29.5.1 of ASCE 7-10.

$F = q_z GC_f A_f$ For $h > 60'$ **Eq D2.2.3-18**

And the horizontal design wind pressure is;

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$$p_h = q_z G C_f \text{ For } h > 60'$$ **Eq D2.2.3-19**

For this manual, the value of q will be evaluated using Equation D2.2.3-1 at the mean roof height of the building. The values of G and C_f will be as before for ASCE 7-98/02/05.

D2.2.3.5.3 – Design Wind Pressures for IBC 2012 (ASCE 7-10):

The design wind pressures for IBC 2012 (ASCE 7-10) are presented below in Table D2.2.3-4. Note that there are no vertical uplift pressures listed for mean roof heights exceeding sixty feet. This table reflects the 30 mph increase across the board in design wind loads.

Table D2.2.3-4; Design Wind Pressures on Rooftop Equipment for IBC 2012 (ASCE 7-10) Risk Category III & IV Buildings

Building Height (ft)		15		30		45		60		100		200	
Design Wind Speed (mph)	Exposure Category	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v [a] (psf)	Horz Press p_h (psf)	Vert Press p_v [a] (psf)
115	B	31.4	24.8	38.3	30.2	43.0	34.0	46.7	36.9	36.3	0.0	44.2	0.0
	C	46.4	36.6	53.7	42.4	58.5	46.2	62.1	49.1	46.4	0.0	53.7	0.0
	D	56.3	44.5	63.5	50.2	68.2	53.8	71.7	56.6	52.6	0.0	59.3	0.0
120	B	34.2	27.0	41.7	32.9	46.8	37.0	50.8	40.1	39.5	0.0	48.1	0.0
	C	50.5	39.9	58.5	46.2	63.7	50.3	67.7	53.4	50.6	0.0	58.5	0.0
	D	61.3	48.4	69.2	54.6	74.2	58.6	78.1	61.6	57.2	0.0	64.6	0.0
130	B	40.2	31.7	49.0	38.6	55.0	43.4	59.7	47.1	46.3	0.0	56.5	0.0
	C	59.3	46.8	68.6	54.2	74.7	59.0	79.4	62.7	59.3	0.0	68.7	0.0
	D	72.0	56.8	81.2	64.1	87.1	68.8	91.6	72.3	67.2	0.0	75.8	0.0
140	B	46.6	36.8	56.8	44.8	63.7	50.3	69.2	54.6	53.7	0.0	65.5	0.0
	C	68.8	54.3	79.6	62.8	86.7	68.4	92.1	72.7	68.8	0.0	79.6	0.0
	D	83.5	65.9	94.2	74.4	101.1	79.8	106.2	83.9	77.9	0.0	87.9	0.0
150	B	53.5	42.2	65.2	51.5	73.2	57.8	79.4	62.7	61.7	0.0	75.2	0.0
	C	79.0	62.3	91.4	72.1	99.5	78.6	105.7	83.5	79.0	0.0	91.4	0.0
	D	95.8	75.7	108.1	85.4	116.0	91.6	122.0	96.3	89.4	0.0	100.9	0.0
160	B	60.8	48.0	74.2	58.5	83.3	65.7	90.4	71.4	70.2	0.0	85.6	0.0
	C	89.8	70.9	104.0	82.1	113.2	89.4	120.3	95.0	89.9	0.0	104.0	0.0
	D	109.0	86.1	123.0	97.1	132.0	104.2	138.8	109.6	101.8	0.0	114.8	0.0
170	B	68.7	54.2	83.7	66.1	94.0	74.2	102.0	80.6	79.2	0.0	96.6	0.0
	C	101.4	80.1	117.4	92.7	127.8	100.9	135.8	107.2	101.5	0.0	117.4	0.0
	D	123.1	97.2	138.9	109.6	149.0	117.6	156.7	123.7	114.9	0.0	129.6	0.0
180	B	77.0	60.8	93.8	74.1	105.4	83.2	114.4	90.3	88.8	0.0	108.3	0.0
	C	113.7	89.8	131.6	103.9	143.3	113.1	152.2	120.2	113.8	0.0	131.6	0.0
	D	138.0	109.0	155.7	122.9	167.1	131.9	175.6	138.7	128.8	0.0	145.3	0.0
190	B	85.8	67.7	104.6	82.6	117.4	92.7	127.5	100.6	99.0	0.0	120.7	0.0
	C	126.7	100.0	146.6	115.7	159.7	126.1	169.6	133.9	126.8	0.0	146.7	0.0
	D	153.8	121.4	173.5	136.9	186.1	146.9	195.7	154.5	143.5	0.0	161.9	0.0
200	B	95.0	75.0	115.9	91.5	130.1	102.7	141.2	111.5	109.7	0.0	133.7	0.0
	C	140.4	110.8	162.4	128.2	176.9	139.7	188.0	148.4	140.5	0.0	162.5	0.0
	D	170.4	134.5	192.2	151.7	206.2	162.8	216.8	171.2	159.0	0.0	179.4	0.0

a. ASCE 7-10 does not require uplift for rooftop euipment on buildings over 60' in height.

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D2.3.3.6 – Summary:

1. The design wind loads increased greatly across the board between IBC 2000/2003 and IBC 2006/2009. The design wind loads also increased between IBC 2006/2009 and IBC 2012. However, the increase was smaller for the lower brackets of the Design Wind Speed, and the increase was much greater at the higher brackets of the Design Wind Speed.

2. IBC 2006/2009 saw the addition of a design uplift load requirement in the commentary of ASCE 7-05. For IBC 2012 this design uplift load requirement is specified in the body of the code in ASCE 7-10 in Chapter 29. For IBC 2006/2009 the uplift load requirement was not limited to a mean roof height of sixty feet or less. For IBC 2012, the design uplift load requirement applies only to buildings whose mean roof height is sixty feet or less.

3. The design wind pressures given in Tables D2.2.3-2, D2.2.3-3, and D2.2.3-4 may be used to ***estimate*** the wind loadings on rooftop equipment in order to make preliminary selections of wind restraint devices. The actual selection of the restraint devices must be reviewed and approved by Kinetics Noise Control and the Structural Engineer of Record.

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NBCC-OBC SEISMIC

D2.3.1 – Introduction:

The purpose of this guide is to provide design professionals, contractors, and building officials responsible for the MEP, Mechanical, Electrical, and Plumbing, with the information and guidance required to ensure that the seismic restraints required for a specific project are selected and/or designed, and installed in accordance with the code provisions. This guide will be written in several easily referenced sections that deal with specific portions of the code.

This guide is based on the National Building Code of Canada 2005 (NBCC 2005). The NBCC 2005 appears to be very different in the formulation of the design forces than the previous NBCC 1995 version. This document will be based entirely on the newer NBCC 2005 version.

1. National Building Code of Canada 2005; Canadian Commission on Building and Fire Codes and National Research Council of Canada, 1200 Montreal RD, Ottawa, ON K1A 9Z9 Chapter Division B – Part 4 Structural Design.

The selection and installation of the proper seismic restraints for MEP systems requires good coordination with the design professionals and contractors involved with the building project. A good spirit of cooperation and coordination is especially required for projects that have been designated as post-disaster buildings, such as hospitals, emergency response centers, police and fire stations. Coordination between the various design professionals and contractors will be a constant theme throughout this guide. This coordination is vital for the following reasons.

1. The seismic restraints that are installed for a system can and will interfere with those of another unless restraint locations are well coordinated.

2. The space required for the installed restraints can cause problems if non-structural walls need to be penetrated, or other MEP components are in the designed load path for the restraints.

3. The building end of the seismic restraints must always be attached to structure that is adequate to carry the code mandated design seismic loads. It is the responsibility of the structural engineer of record to verify this.

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REQUIRED BASIC PROJECT INFORMATION

D2.3.2.1 – Introduction:

As with any design job, there is certain basic information that is required before seismic restraints can be selected and placed. The building owner, architect, and structural engineer make the decisions that form the basis for the information required to select the seismic restraints for the pipe and duct systems in the building. This is information that should be included in the specification and bid package for the project. It also should appear on the first sheet of the structural drawings. For consistency, it is good practice to echo this information in the specification for each building system, and on the first sheet of the drawings for each system. In this fashion, this information is available to all of the contractors and suppliers that will have a need to know.

D2.3.2.2 – Building Use-Nature of Occupancy [Sentence 4.1.2.1][1]:

How a building is to be used greatly affects the level of seismic restraint that is required for the MEP (Mechanical, Electrical, and Plumbing) components. In the NBCC 2005 the building use is defined through the Importance Category, which ranges in four stages from Low to Post-Disaster. Table D2.3.2-1 below summarizes the information found in Tables 4.1.2.1 of the NBCC 2005. The nature of the building use, or its Occupancy Category, is determined by the building owner and the architect of record.

D2.3.2.3 – Site Class-Soil Type [Sentences 4.1.8.4.(2) and 4.1.8.1.(3)]:

The Site Class is related to the type of soil and rock strata that directly underlies the building site.

The Site Class ranges from A to F progressing from the stiffest to the softest strata. Table D2.3.2-2 lists the various Site Classes and their corresponding strata.

Generally the structural engineer is responsible for determining the Site Class for a project. If the structural engineer's firm does not have a geotechnical engineer on staff, this job will be contracted to a geotechnical firm. The site profile is normally obtained by drilling several cores on the property. Unlike the U. S. building codes, there is no published default Site Class that may be that can be substituted for the actual Site Class that is determined from soils testing performed at the actual project location.

[1] References in brackets [Sentence 4.1.2.1 and Table 4.1.2.1] apply to sections, tables, and/or equations in the National Building Code of Canada 2005.

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Table D2.3.2-1; Importance Category vs. Building Use and Occupancy [Table 4.1.2.1]

IMPORTANCE CATEGORY	BUILDING USE OR NATURE OF OCCUPANCY
Low	Buildings whose failure will present a low direct or indirect hazard to human life ➢ Low human occupancy buildings where structural collapse is unlikely to cause injury or other serious consequences. ➢ Minor storage buildings and structures.
Normal	Buildings not listed as Importance Category Low, High, or Post-Disaster.
High	Buildings which are likely to be used in Post-Disaster situations as shelters, which will include the following building types: ➢ Elementary, middle, or secondary schools. ➢ Community centers. Manufacturing and storage facilities which contain toxic, explosive, or hazardous materials in sufficient quantities to pose a hazard to the public is released, such as: ➢ Petrochemical facilities. ➢ Fuel storage facilities ➢ Manufacturing and storage facilities for dangerous goods.
Post-Disaster	Buildings and structures which are designated as essential facilities which include but are not limited to: ➢ Hospitals, emergency treatment facilities, and blood banks. ➢ Emergency response facilities, fire, rescue, ambulance, and police stations, housing for emergency response equipment, and communications facilities including radio and television, unless exempted by the jurisdiction having authority). ➢ Power generating stations and sub-stations. ➢ Control centers for air land and marine transportation. ➢ Water treatment, storage, and pumping facilities. ➢ Sewage treatment facilities and buildings or structures required for national defense.

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Table D2.3.2-2; Site Class vs. Soil Type [Table 4.1.8.4A]

SITE CLASS	SOIL TYPE
A	Hard Rock
B	Rock
C	Very Dense Soil & Soft Rock
D	Stiff Soil
E	Soft Soil
F	Liquefiable Soils, Quick Highly Sensitive Clays, Collapsible Weakly Cemented Soils, & etc. These require site-specific evaluation.

D2.3.2.4 – Spectral Response Acceleration Value at 0.2 Second [Sentence 4.1.8.4.(1) and Table C-2]

The Spectral Response Acceleration Values at 0.2 Second, which are denoted as $S_{a(0.2)}$, have been determined for selected location in Canada and documented in the Canadian Journal of Civil Engineering, Volume 10, Number 4, pp 670-680, 1983. These values for selected location in Canada are presented in Table C-2 of the NBCC 2005, and are repeated for convenience below in Table D2.3.2-3

D2.3.2.5 – Importance Factor for Earthquake Loads [Sentence 4.1.8.5 and Table 4.1.8.5]:

The Importance Factor for Earthquake Loads (I_E) for the building is assigned based on the Importance Category of the building. It may be prudent to request both the assigned Importance Category and the Importance Factor for Earthquake Loads. The Importance Factor for Earthquake Loads may be specified more stringently than the Importance Category of the building would indicate in order to artificially provide increased protection for the building and its contents. The Importance Factor for Earthquake Loads is assigned as shown in Table D2.3.2-4

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Table D2.3.2-3; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
British Columbia	------	Masset	0.53	Langley	1.10
100 Mile House	0.28	McBride	0.27	New Westminster	0.99
Abbotsford	0.92	Mcleod Lake	0.18	North Vancouver	0.88
Agassiz	0.67	Merrit	0.32	Richmond	1.10
Alberi	0.75	Mission City	0.93	Surrey (88 Ave & 156 St.)	1.10
Ashcroft	0.33	Montrose	0.27	Vancouver	0.94
Beatton River	0.12	Nakusp	0.27	Vancouver (Granville & 41 Ave)	0.88
Burns Lake	0.12	Nanaimo	1.00	Vernon	0.27
Cache Creek	0.33	Nelson	0.27	***Victoria Region***	------
Campbell River	0.62	Ocean Falls	0.38	Victoria (Gonzales Hts.)	1.20
Carmi	0.28	Osoyoos	0.28	Victoria (Mt. Tolmie)	1.20
Castlegar	0.27	Penticton	0.28	Victoria	1.20
Chetwynd	0.24	Port Alberni	0.75	Williams Lake	0.28
Chilliwack	0.73	Port Hardy	0.43	Youbou	1.00
Comox	0.66	Port McNeill	0.43	**Alberta**	------
Courtenay	0.65	Powell River	0.67	Athabasca	0.12
Cranbrook	0.27	Prince George	0.13	Banff	0.24
Crescent Valley	0.27	Prince Rupert	0.38	Barrhead	0.12
Crofton	1.10	Princeton	0.42	Beaverlodge	0.13
Dawson Creek	0.12	Qualicum Beach	0.82	Brooks	0.12
Dog Creek	0.32	Quesnel	0.27	Calgary	0.15
Duncan	1.10	Revelstoke	0.27	Campsie	0.12
Elko	0.27	Salmon Arm	0.27	Camrose	0.12
Fernie	0.27	Sandspit	0.56	Cardston	0.18
Fort Nelson	0.12	Sidney	1.20	Claresholm	0.15
Fort St. John	0.12	Smith River	0.52	Cold Lake	0.12
Glacier	0.27	Smithers	0.12	Coleman	0.24
Golden	0.26	Squamish	0.72	Coronation	0.12
Grand Forks	0.27	Stewart	0.30	Cowley	0.20
Hope	0.63	Taylor	0.12	Drumheller	0.12
Kamloops	0.28	Terrace	0.34	Edmonton	0.12
Kaslo	0.27	Tofino	1.20	Edson	0.15
Kelowna	0.28	Trail	0.27	Embarras Portage	0.12
Kimberley	0.27	Ucluelet	1.20	Fairview	0.12
Kitimat Plant	0.37	***Vancouver Region***	------	Fort MacLeod	0.16
Kitimat Townsite	0.37	Burnaby (Simon Fraser Univ.)	0.94	Fort McMurray	0.12
Lilooet	0.60	Cloverdale	1.00	Fort Saskatchewan	0.12
Lytton	0.60	Haney	0.97	Fort Vermilion	0.12
Mackenzie	0.23	Ladner	1.10	Grande Prairie	0.12

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Alberta	------	Humboldt Bay	0.12	Selkirk	0.12
Habay	0.12	Island Falls	0.12	Spit Lake	0.12
Hardisty	0.12	Kamsack	0.12	Steinbach	0.12
High River	0.15	Kindersley	0.12	Swan River	0.12
Hinton	0.24	Lloydminster	0.12	The Pas	0.12
Jasper	0.24	Maple Creek	0.12	Virden	0.12
Keg River	0.12	Meadow Lake	0.12	Winnipeg	0.12
Lac la Bishe	0.12	Melfort	0.12	**Ontario**	------
Lacombe	0.12	Melville	0.12	Ailsa Craig	0.16
Lethbridge	0.15	Moose Jaw	0.12	Ajax	0.22
Manning	0.12	Nipawin	0.12	Alexandria	0.68
Medicine Hat	0.12	North Battleford	0.12	Alliston	0.17
Peace River	0.12	Prince Albert	0.12	Almonte	0.58
Pincher Creek	0.19	Qu' Appelle	0.12	Armstrong	0.12
Ranfurly	0.12	Regina	0.12	Arnprior	0.64
Red Deer	0.12	Rosetown	0.12	Atikokan	0.12
Rocky Mountain House	0.15	Saskatoon	0.12	Aurora	0.19
Slave Lake	0.12	Scott	0.12	Bancroft	0.26
Stettler	0.12	Strasbourg	0.12	Barrie	0.16
Stony Plain	0.12	Swift Current	0.12	Beaverton	0.16
Suffield	0.12	Uranium City	0.12	Belleville	0.26
Taber	0.12	Weyburn	0.23	Belmont	0.20
Turner Valley	0.15	Yorktown	0.12	Big Trout Lake	0.12
Valleyview	0.12	**Manitoba**	------	CFB Borden	0.16
Vegreville	0.12	Beausejour	0.12	Bracebridge	0.18
Vermilion	0.12	Boussevain	0.12	Bradford	0.18
Wagner	0.12	Churchill	0.12	Brampton	0.26
Wainwright	0.12	Dauphin	0.12	Brantford	0.24
Wetaskiwin	0.12	Flin Flon	0.12	Brighton	0.25
Whitecourt	0.12	Gimli	0.12	Brockton	0.40
Wimborne	0.12	Island Lake	0.12	Burk's Falls	0.21
Saskatchewan	------	Lac du Bonnet	0.12	Burlington	0.36
Assiniboia	0.17	Lynn Lake	0.12	Cambridge	0.22
Battrum	0.12	Morden	0.12	Campbellford	0.23
Biggar	0.12	Neepawa	0.12	Cannington	0.17
Broadview	0.12	Pine Falls	0.12	Carleton Place	0.52
Dafoe	0.12	Portage la Prairie	0.12	Cavan	0.20
Dundurn	0.12	Rivers	0.12	Centralia	0.14
Estevan	0.15	Sandilands	0.12	Chapleau	0.12

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Ontario	------	Grimsby	0.40	Mattawa	0.51
Chatham	0.20	Guelph	0.21	Midland	0.15
Chesley	0.13	Guthrie	0.16	Milton	0.30
Clinton	0.13	Haileybury	0.29	Milverton	0.15
Coboconk	0.18	Haldimand (Caledonia)	0.34	Minden	0.19
Cobourg	0.24	Haldimand (Hagersville)	0.29	Mississauga	0.31
Cochrane	0.21	Haliburton	0.21	Mississauga (Port Credit)	0.32
Colborne	0.24	Halton Hills (Georgetown)	0.25	Mitchell	0.14
Collingwood	0.14	Hamilton	0.33	Moosonee	0.15
Cornwall	0.67	Hanover	0.13	Morrisburg	0.63
Corunna	0.14	Hastings	0.23	Mount Forest	0.15
Deep River	0.66	Hawkesbury	0.65	Nakina	0.12
Deseronto	0.27	Hearst	0.12	Nanticoke (Jarvis)	0.26
Dorchester	0.19	Honey Harbour	0.15	Nanticoke (Port Dover)	0.23
Dorion	0.12	Hornepayne	0.12	Napanee	0.28
Dresden	0.18	Huntsville	0.20	New Liskeard	0.29
Dryden	0.12	Ingersoll	0.19	Newcastle	0.22
Dunnville	0.35	Iroquois Falls	0.21	Newcastle (Bowmanville)	0.21
Durham	0.14	Jellicoe	0.12	Newmarket	0.19
Dutton	0.20	Kapuskasing	0.14	Niagara Falls	0.41
Earlton	0.26	Kemptville	0.60	North Bay	0.29
Edison	0.12	Kenora	0.12	Norwood	0.22
Elmvale	0.15	Killaloe	0.48	Oakville	0.35
Embro	0.18	Kincardine	0.12	Orangeville	0.18
Englehart	0.25	Kingston	0.30	Orillia	0.16
Espanola	0.12	Kinmount	0.19	Oshawa	0.21
Exeter	0.14	Kirkland Lake	0.24	Ottawa	0.66
Fenelon Falls	0.18	Kitchener	0.19	Owen Sound	0.13
Fergus	0.18	Lakefield	0.20	Pagwa River	0.12
Forest	0.14	Lansdowne House Leamington	0.20	Paris	0.22
Fort Erie	0.40	Lindsay	0.18	Parkhill	0.15
Fort Erie (Ridgeway)	0.39	Lion's Head	0.15	Parry Sound	0.16
Gananoque	0.31	London	0.18	Pelham (Fonthill)	0.40
Geraldton	0.12	Lucan	0.16	Pembroke	0.66
Glencoe	0.19	Maitland	0.41	Penetanguishene	0.15
Goderich	0.12	Markdale	0.14	Perth	0.39
Gore Bay	0.12	Markham	0.22	Petawawa	0.66
Graham	0.12	Martin	0.12	Peterborough	0.20
Gravehurst (Muskoka Airport)	0.17	Matheson	0.22	Petrolia	0.16

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Ontario	------	Temagami	0.30	Beauport	0.60
Pickering (Dunbarton)	0.23	Thamesford	0.18	Bedford	0.60
Picton	0.26	Thedford	0.14	Beloeil	0.67
Plattsville	0.18	Thunder Bay	0.12	Brome	0.42
Point Alexander	0.66	Tillsonburg	0.20	Brossard	0.68
Port Burwell	0.21	Timmins	0.17	Buckingham	0.68
Port Colborne	0.38	Timmins (Porcupine)	0.19	Campbell's Bay	0.67
Port Elgin	0.12	***Toronto (Metropolitan)***	------	Chambly	0.67
Port Hope	0.23	Etobicoke	0.26	Chicoutimi	0.62
Port Perry	0.19	North York	0.24	Chicoutimi (Bagotville)	0.63
Port Stanley	0.20	Scarborough	0.24	Chicoutimi (Kenogami)	0.62
Prescott	0.44	Toronto	0.26	Coaticook	0.41
Princeton	0.20	Trenton	0.25	Contrecoeur	0.66
Raith	0.12	Trout Creek	0.25	Cowansville	0.48
Rayside-Balfour (Chelmsford)	0.14	Uxbridge	0.19	Deux-Montagnes	0.68
Red Lake	0.12	Vaughan (Woodbridge)	0.24	Dolbeau	0.31
Renfrew	0.63	Vittoria	0.21	Drummondville	0.50
Richmond Hill	0.22	Walkerton	0.13	Farnham	0.59
Rockland	0.66	Wallaceburg	0.18	Fort-coulonge	0.67
Sault Ste. Marie	0.12	Waterloo	0.19	Gagon	0.12
Schreiber	0.12	Watford	0.16	Gaspé	0.22
Seaforth	0.14	Wawa	0.12	Gatineau	0.68
Simcoe	0.22	Welland	0.40	Gracefield	0.62
Sioux Lookout	0.12	West Lorne	0.20	Granby	0.48
Smith Falls	0.42	Whitby	0.21	Harrington-Harbour	0.12
Smithville	0.40	Whitby (Brooklin)	0.20	Harve-St-Pierre	0.33
Smooth Rock Falls	0.19	White River	0.12	Hemmingford	0.68
South River	0.23	Wiarton	0.12	Hull	0.68
Southhampton	0.12	Windsor	0.18	Iberville	0.66
St. Catharines	0.41	Wingham	0.13	Inukjuak	0.12
St. Mary's	0.16	Woodstock	0.19	Joliette	0.63
St. Thomas	0.20	Wyoming	0.15	Jonquiére	0.62
Stirling	0.25	**Québec**	------	Kuujjuaq	0.12
Stratford	0.16	Acton-Vale	0.45	Kuujjuarapik	0.12
Strathroy	0.17	Alma	0.59	La-Malbaie	2.30
Sturgeon Falls	0.23	Amos	0.17	La-Tuque	0.29
Sudbury	0.15	Asbestos	0.37	Lac-Mégantic	0.40
Sundridge	0.22	Aylmer	0.67	Lachute	0.64
Tavistock	0.17	Baie-Comeau	0.66	Lennoxville	0.38

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Québec	------	Richmond	0.38	**New Brunswick**	------
Léry	0.70	Rimouski	0.63	Alma	0.27
Loretteville	0.63	Rivière-du-loup	1.10	Bathhurst	0.41
Louisevilee	0.63	Roberval	0.43	Campbellton	0.39
Magog	0.38	Rock-Island	0.42	Chatham	0.41
Malartic	0.21	Rosemère	0.68	Edmundston	0.41
Maniwaki	0.66	Rouyn	0.20	Fredericton	0.39
Masson	0.66	Salaberry-de-Valleyfield	0.69	Gagetown	0.34
Matane	0.68	Schefferville	0.12	Grand Falls	0.42
Mont-Joli	0.62	Senneterre	0.20	Moncton	0.30
Mont-Laurier	0.66	Sept-Îles	0.37	Oromocto	0.36
Montmagny	0.89	Shawinigan	0.58	Sackville	0.25
Montréal Region	------	Shawville	0.67	Saint John	0.34
Beaconsfield	0.69	Sherbrooke	0.37	Shippagan	0.34
Dorval	0.69	Sorel	0.65	St. Stephen	0.66
Laval	0.68	St-Félicien	0.31	Woodstock	0.41
Montréal	0.69	St-Georges-de-Cacouna	0.98	**Nova Scotia**	------
Montréal-Est	0.68	St-Hubert	0.68	Amherst	0.24
Montréal-Nord	0.69	St-hubert-de-Temiscouata	0.64	Antigonish	0.19
Outremont	0.69	St-Hyacinthe	0.59	Bridgewater	0.23
Pierrefonds	0.69	St-jean	0.69	Canso	0.24
St-Lambert	0.69	St-Jérôme	0.64	Debert	0.22
St-Laurent	0.69	St-Jovite	0.63	Digby	0.26
Ste-Anne-de-Bellevue	0.69	St-Nicolas	0.59	Greenwood (CFB)	0.25
Verdun	0.69	Ste-Agathe-des-Monts	0.59	***Halifax Region***	------
Nicolet (Gentilly)	0.64	Sutton	0.44	Dartmouth	0.23
Nitchequon	0.12	Tadoussac	0.84	Halifax	0.23
Noranda	0.20	Témiscaming	0.59	Kentville	0.24
Percé	0.20	Thetford Mines	0.35	Liverpool	0.24
Pincourt	0.69	Thurso	0.63	Lockeport	0.26
Plessisville	0.45	Trois-Rivières	0.64	Louisburg	0.22
Port-Cartier	0.46	Val-d'Or	0.22	Lunenburg	0.23
Povungnituk	0.22	Varennes	0.68	New Glasgow	0.18
Québec City Region	------	Verchères	0.67	North Sydney	0.19
Ancienne-Lorette	0.60	Victoriaville	0.43	Pictou	0.18
Levis	0.58	Ville-Marie	0.33	Port Hawkesbury	0.21
Québec	0.59	Waterloo	0.41	Springhill	0.24
Sillery	0.58	Windsor	0.36	Stewiacke	0.22
Ste-Foy	0.59	------------------------------	------	Sydney	0.20

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Nova Scotia	------	Echo Bay / Port Radium	0.12
Tatamagouche	0.19	Fort Good Hope	0.15
Truro	0.21	Fort Providence	0.12
Wolfville	0.25	Fort Resolution	0.12
Yarmouth	0.23	Fort Simpson	0.12
Prince Edward Island	------	Fort Smith	0.12
Charlottetown	0.19	Hay River	0.12
Souris	0.15	Holman	0.12
Summerside	0.19	Inuvik	0.12
Tignish	0.22	Mould Bay	0.35
Newfoundland	------	Norman Wells	0.51
Argentia	0.18	Rae-Edzo	0.12
Bonavista	0.17	Tungsten	0.51
Buchans	0.15	Yellowknife	0.12
Cape Harrison	0.24	**Nunavut**	------
Cape Race	0.20	Alert	0.12
Channel-Port aux Basques	0.15	Arctic Bay	0.18
Corner Brook	0.14	Arviat / Eskimo Point	0.18
Gander	0.16	Baker Lake	0.12
Grand Bank	0.18	Cambridge Bay	0.12
Grand Falls	0.15	Chesterfield Inlet	0.16
Happy Valley-Goose Bay	0.15	Clyde River	0.50
Labrador City	0.12	Coppermine	0.12
St. Anthony	0.15	Coral Harbour	0.24
St. John's	0.18	Eureka	0.33
Stephenville	0.14	Iqaluit	0.13
Twin Falls	0.12	Isachsen	0.40
Wabana	0.12	Nottingham Island	0.24
Wabush	0.12	Rankin Inlet	0.12
Yukon	------	Resolute	0.35
Aishihik	0.26	Resolution Island	0.44
Dawson	0.54	------------------------------	------
Destruction Bay	0.73	------------------------------	------
Snag	0.61	------------------------------	------
Teslin	0.19	------------------------------	------
Watson Lake	0.45	------------------------------	------
Whitehorse	0.22	------------------------------	------
Northwest Territories	------	------------------------------	------
Aklavik	0.18	------------------------------	------

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Table D2.3.2-4; Importance Factor for Earthquake Loads by Importance Category [Table 4.1.8.5]

IMPORTANCE CATEGORY	IMPORTANCE FACTOR FOR EARTHQUAKE LOADS I_E
Low	0.8
Normal	1.0
High	1.3
Post-Disaster	1.5

D2.3.2.6 Summary:

The following parameters will be required by the design professionals having responsibility for MEP systems in a building, and should be determined by the structural engineer of record.

1. Importance Category: This defines the building use and specifies which buildings are required for emergency response or disaster recovery.
2. Spectral Response Acceleration Value at 0.2 Second: This is used to determine the actual Lateral Design Seismic Force.
3. Importance Factor for Earthquake Loads: This is a numerical value that translates the building usage into the Lateral Design Seismic Force used to design and/or select seismic restraints for non-structural components. This value used in conjunction with the Spectral Response Acceleration Value at 0.2 Second will determine whether seismic restraints are required for non-structural components or not.

These parameters should be repeated in the specification and drawing package for the particular system, mechanical, electrical, or plumbing, in question.

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DESIGN SESIMIC FORCES

D2.3.3.1 – Introduction:

The code based horizontal seismic force requirements for MEP systems and components are either calculated by the seismic restraint manufacturer as a part of the selection and certification process, or may be determined by the design professional of record for the MEP systems under consideration.

This is an informational section. It will discuss the code based horizontal seismic force demand equations and the variables that go into them. This discussion will provide a deeper understanding for the designer responsible for selecting the seismic restraints for MEP systems and their components and the nature of the seismic forces and the factors that affect them.

D2.3.3.2 – Lateral Design Seismic Force [Sentence 4.1.8.17.(1)][1]:

The seismic force is a mass, or weight, based force, and as such is applied to the MEP component at its center of gravity. Keep in mind that the earthquake ground motion moves the base of the building first. Then the motion of the building will accelerate the MEP component through its supports and/or seismic restraints. The lateral seismic force acting on an MEP component will be determined in accordance with the following set of equations from NBCC 2005.

$$V_P = 0.3 F_a S_{a(0.2)} I_E S_P W_P \quad \textbf{Eq D2.3.3-1}$$

Where:

V_P = the Lateral Design Seismic Force

F_a = the acceleration based site coefficient. Values for this coefficient are given in Table D2.3.3-1 based on the site class. Linear interpolation between these values is permitted.

I_E = the Importance Factor for Earthquake Loads for the building. See Section D2.3.2.5 of this manual.

S_P = the horizontal force factor for the non-structural component and its anchorage to the building.

W_P = the weight of the non-structural component.

The value for S_P is computed in the following fashion.

[1] References in brackets [Sentence 4.1.8.17.(1)] apply to sections, tables, and/or equations in the National Building Code of Canada 2005.

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$$S_P = \frac{C_P A_r A_x}{R_P}$$ **Eq D2.3.3-2**

Where:

C_P = the seismic coefficient for mechanical and electrical equipment. These values are given per component category in Table D2.3.3-2.

A_r = the response amplification factor used to account for the type of attachment of the mechanical or electrical component to the building listed by component category in Table D2.3.3-2.

A_x = the amplification factor at the elevation of the component attachment point in the building. It is used to account for the increasing flexibility of the building from grade level to roof level.

R_P = the element or component response modification factor listed by component category in Table D2.3.3-2.

A_x is computed as follows.

$$A_x = \left(1 + 2\frac{h_x}{h_n}\right)$$ **Eq D2.3.3-3**

Where:

h_x = the elevation of the attachment point to the structure of the non-structural component.

h_n = the elevation of the roof line.

The values for S_P must remain within the following limits.

$$0.7 \le S_P \le 4.0$$ **Eq D2.3.3-4**

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Table D2.3.3-1; Acceleration Based Site Coefficient, F_a [Table 4.1.8.4]

SITE CLASS	SPECTRAL RESPONSE ACCELERATION VALUE AT 0.2 SECOND (LINEAR INTERPOLATION IS PERMITTED)				
	$S_{a(0.2)} \leq 0.25$	$S_{a(0.2)} = 0.50$	$S_{a(0.2)} = 0.75$	$S_{a(0.2)} = 1.00$	$S_{a(0.2)} \geq 1.25$
A	0.7	0.7	0.8	0.8	0.8
B	0.8	0.8	0.9	1.0	1.0
C	1.0	1.0	1.0	1.0	1.0
D	1.3	1.2	1.1	1.1	1.0
E	2.1	1.4	1.1	0.9	0.9
F	These values to be determined by site response analysis.				

D2.3.3.3 – Basis of Design for NBCC 2005 [Sentences 4.1.3.1.(1a), 4.1.3.2.(4), 4.1.3.2.(6), 4.1.3.2.(7), and 4.1.3.2.(8) and Table 4.1.3.2]:

The design of seismic restraints in the NBCC 2005 is based on the Ultimate Limit State. This limit state is used for design when life safety is at issue to prevent building or system collapse. This design basis along with the prescribed loads for earthquake design will produce results which are consistent with LRFD design techniques. Therefore; LRFD allowable loads may be used for the design and selection of seismic restraints for MEP components.

D2.3.3.4 – Summary:

This section has provided an insight into the way in which the seismic design forces for MEP systems and components are to be computed. It is generally not necessary for a designer to actually run the computations for the seismic design forces. These forces are normally computed by the manufacturer of the seismic restraint devices as part of the selection and certification process to ensure that the proper components are selected per the code and the specification.

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Table D2.3.3-2; Seismic Coefficient, Response Amplification Factor, and Response Modification Factor NBCC 2005 [Table 4.1.8.17]

CATEGORY	NON-STRUCTURAL COMPONENT	C_P	A_r	R_P
7	Suspended light fixtures with independent vertical support	1.00	1.00	2.50
11	Machinery, fixtures, equipment, ducts, and tanks (including contents):	-----	------	------
	That are rigidly connected.	1.00	1.00	1.25
	That are flexible or flexibly connected.	1.00	2.50	2.50
12	Machinery, fixtures, equipment, ducts, and tanks (including contents) containing toxic or explosive materials, materials having a flash point below 38°C or firefighting fluids:	-----	------	------
	That are rigidly connected.	1.50	1.00	1.25
	That are flexible or flexibly connected.	1.50	2.50	2.50
13	Flat bottom tanks (including contents) that are attached directly to the floor at or below grade within a building.	0.70	1.00	2.50
14	Flat bottom tanks (including contents) that are attached directly to the floor at or below grade within a building that contain toxic or explosive materials, materials that have a flash point below 38°C or firefighting materials.	1.00	1.00	2.50
15	Pipes, ducts, cable trays (including contents)	1.00	1.00	3.00
16	Pipes, ducts, cable trays (including contents) containing toxic or explosive materials.	1.50	1.00	3.00
17	Electrical cable trays, bus ducts, conduits.	1.00	2.50	5.00
18	Rigid components with ductile material and Connections.	1.00	1.00	2.50
19	Rigid components with non-ductile material or Connections.	1.00	1.00	1.00
20	Flexible components with ductile material and Connections.	1.00	2.50	2.50
21	Flexible components with non-ductile material or Connections.	1.00	2.50	1.00

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GENERAL EXEMPTIONS AND REQUIREMENTS

D2.3.4.1 – Introduction:

The National Building Code of Canada has limited exemptions for MEP components written in to it. The SMACNA Seismic Restraint Manual – Guidelines for Mechanical Systems, 2nd Edition with Addendum No. 1, 1998; is not directly referenced in the NBCC. Therefore, it is safe to assume that any exemptions in the SMACNA manual that have been previously taken are no longer allowed.

There are, however, some general exemptions for MEP components which will be covered in this section. Along with the exemptions, this section will the requirements for flexible/flexibly connected (isolated) components, direction of seismic design force application, structural connections, deflections, transfer of seismic forces to the building structure, and hanger rods for MEP components.

D2.3.4.2 - General Acceleration Based Exemption for MEP Components [Sentences 4.1.8.1, and 4.1.8.17.(2)][1]

Sentence 4.1.8.1 is a general exemption for building, and also applies to those buildings that have been assigned to the Importance Category classified as Post Disaster. The deflections and loads due to earthquake motion as specified in Sentence 4.1.8.17, do not apply to MEP Components when $S_{a(0.2)} \leq 0.12$. Under this condition seismic restraints will not be required for MEP components.

The next general exemption is found in Sentence 4.1.8.17.(2) and applies to buildings that have been assigned to Importance Categories Low, Normal, and High. Section D2.3.3 of this manual covered the seismic design forces specified by the NBCC. The basic acceleration term multiplying the weight (mass) of the MEP component is $I_E F_a S_{a(0.2)}$. This term includes the importance of the building, the effects of the ground upon which the project is being built, and the expected horizontal acceleration produced by the design earthquake for the project location. This general exemption for MEP components is based on the value of this term. If $I_E F_a S_{a(0.2)} < 0.35$, then MEP components that fall into categories 7 through 21 in Table D2.3.3-2 of this manual do not require seismic restraint for buildings assigned to Importance Categories Low, Normal, and High.

[1] References in brackets [Sentence 4.1.8.17.(2)] apply to sections, tables, and/or equations in the National Building Code of Canada 2005.

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D2.3.4.3 – "Chandelier" Exemption [Sentence 4.1.8.17.(13)]

This exemption does not read exactly as the companion exemption in the International Building Code (IBC); see Kinetic's Guide to Understanding IBC Seismic for MEP, Section D2.1.4.5. So, for clarity it will be directly quoted below.

> Isolated suspended equipment and components, such as pendant lights, may be designed as a pendulum system provided that adequate chains or cables capable of supporting 2.0 times the weight of the suspended component are provided and the deflection requirements of Sentence 4.1.8.17.(11) are satisfied.

D2.3.4.4 – Isolated vs. Rigidly Connected Components [Sentence 4.1.8.17.(4)]:

The NBCC basically says that MEP components that can be defined by Categories 11 and 12 in Table D2.3.3-2 of this Guide are to be treated as flexible/flexibly connected (isolated) components. If, however, the fundamental period of the component and its connections to the building structure can be shown to be less than or equal to 0.06 second, it mat be treated as though it were a rigid or rigidly connected component.

D2.3.4.5 – Design Horizontal Seismic Load Application [Sentence 4.1.8.17.(7)]:

The design horizontal seismic loads are to be applied in the direction the results in the most critical loading for the MEP component and its attachment to the structure. This will ensure that the most conservative design and selection of seismic restraints for the MEP component has been made.

D2.3.4.6 – Connection of MEP Components to the Building Structure [Sentence 4.1.8.17.(8)]:

Connections for the MEP components to the building structure must be designed to resist gravity loads, meet the requirements of Sentence 4.1.8.1 of the NBCC, and also satisfy the following additional requirements.

1. Friction due to gravity loads may not be used to resist seismic forces.
2. The $\boldsymbol{R_P}$ value for non-ductile fasteners such as adhesives, powder shot pins, and other power actuated fasteners must be taken as 1.0.
3. Shallow embedment anchors, shallow expansion, chemical, epoxy, or cast-in-place, are those whose embedment depth to nominal diameter ratio is less than 8:1. For these types of anchors the value for $\boldsymbol{R_P}$ shall be taken as 1.5.
4. Drop in anchors and power actuated fasteners, such as powder shot pins, are not to be used in tensile applications.

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D2.3.4.7 – Lateral Deflections of MEP Components [Sentence 4.1.8.17.(10)]:

The lateral deflections based on design horizontal seismic force specified the Sentence 4.1.8.17.(1), see Section D2.3.3 of this manual, need to be multiplied by a factor of R_P / I_E to yield more realistic values for the anticipated deflections. The values of R_P and I_E are used to artificially inflate the loads to ensure the selection of seismic restraints and attachments that will meet the Post-Disaster criteria.

D2.3.4.8 – Transfer of Seismic Restraint Forces [Sentence 4.1.8.17.(11)]:

This provision is intended to engender co-operation between the MEP design professionals and the structural engineering professionals. It is basically saying that the MEP components and their attachments to the building structure must be designed in such away that they do not transfer any loads to the structure that were not anticipated by the structural engineer. This means that the MEP design professionals must inform the structural engineer of the anticipated dead loads and seismic restraint forces at the restraint attachment points as soon as the MEP component selections have been finalized. Conversely, the structural engineer needs to make him or her self available to the MEP design professionals to work out issues surrounding the seismic loads and the attachment points for the seismic restraints used for the MEP components.

D2.3.4.9 – Seismic Restraints for Suspended MEP Components & Hanger Rods [Sentence 4.1.8.17.(12)]:

The seismic restraints for suspended MEP equipment, pipes, ducts, electrical cable trays, bus ducts, and so on, must meet the force and displacement conditions of Sentence 4.1.8.17, and be designed in such away that they do not place the hanger rods in bending.

D2.3.4.13 - Summary:

The exemptions and requirements outlined in this section are intended to assist the MEP design professionals and contractors in planning their project contribution efficiently. Also, they help define the limits of responsibility for each MEP design profession and trade.

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UFC ANTI-TERRORISM

D2.5.1 – Introduction:

The United States Department of Defense has developed a set of standards for the design of new and existing buildings. These are called Unified Facilities Criteria (UFC). For seismic and wind restraint, and antiterrorism provisions for nonstructural components are found in three separate UFC documents which are listed below.

1. UFC-3-310-04 Dated 22 June 2007 Including Change Dated 01 May 2012 SESISMIC DESIGN FOR BUILDINGS.

2. UFC-3-301-01 Dated 27 January 2010 STRUCTURAL ENGINEERING.

3. UFC-4-010-01 Dated 8 October 2003 Including Change Dated 22 January 2007 DoD MINIMUM ANTITERRORISM STANDARDS FOR BUILDINGS.

These documents are available via the internet. They may be down loaded in PDF format by "GOOGLING" the UFC number.

This document will deal with each of the sub-headings one at a time. Antiterrorism will be the first sub-heading discussed since it seems to show up in specifications more often than the other two. Also, the provisions for restraint in the antiterrorism standard will "trump" those of the seismic design standard if the design acceleration level for the seismic design falls below that required for the antiterrorism standard.

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UFC-4-010-01 ANTITERRORISM

D2.5.2 - UFC-4-010-01:

Only one Section B-4.5 – **Standard 20. Equipment Bracing** of this document will apply to the restraint of MEP (Mechanical, Electrical, and Plumbing) components. It is quoted in its entirety below.

Mount all overhead utilities and other fixtures weighing 14 kilograms (31 pounds) or more (excluding distributed systems such as piping networks that collectively exceed that weight) to minimize the likelihood that they will fall and injure building occupants. Design all equipment mountings to resist forces of 0.5 times the equipment weight in any horizontal direction and 1.5 times the equipment weight in the downward direction. This standard does not preclude the need to design equipment mountings for forces required by other criteria such as seismic standards.

Piping, ductwork, cable trays, conduit, and bus bars appear to be exempt from the provisions of this standard. The reasoning appears to be that distributed systems such as these will have many hangers supporting them. Equipment, on the other hand, will have only four or perhaps six hangers. Losing one or two hangers in a distributed system would not be likely to bring down the entire system, whereas, losing one or two hangers on a piece of equipment would pretty much guarantee that it would fall.

Some specifications do impose the provisions of this standard on piping and ductwork. In these cases the following items need to be considered.

All hangers and their anchors will need to be evaluated for the increased vertical loads mandated by this standard. That is the deadweight of the pipe or duct plus 0.5 times the deadweight of the pipe or duct.

The hanger spacing and the restraint spacing may need to be reduced to protect the pipe or duct from the increased vertical and horizontal loads mandated by this standard.

The first sentence of the standard indicates that it applies only to overhead equipment and fixtures. These components will need to be braced to resist 0.5 time the deadweight of the equipment (0.5 G) horizontally in any direction and 0.5 times the deadweight of the equipment plus the deadweight of the equipment (1.5 G total) in the downward direction. The second sentence says that ***all*** equipment must be braced to this standard. However the 1.5 G total downward would seem to indicate that only suspended equipment and fixtures are covered under this standard. So, a clear interpretation of that provision will need to come from the specification and/or the Engineer of Record.

In many buildings where UFC 4-010-01 is specified, seismic restraint of MEP components may not be required by the building code. This horizontal restraint requirement of this standard will “trump” the seismic restraint requirements of the code up to the point where the code requirements exceed the 0.5 G horizontal load specified by this standard. A careful reading of the

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specification will be needed to obtain the proper interpretation of this standard for a project, and to see what if any components have been made exempt from the provisions of this standard.

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UFC-3-310-04 SEISMIC DESIGN & UFC-3-301-01 STRUCTURAL ENGINEERING

D2.5.3.1 – Introduction

This standard is a replacement for TI 809-04 and TI 809-05. It adopts the seismic design provisions of 2003 IBC and ASCE 7-02, with some modification. This standard is meant to work in conjunction with UFC 3-301-01 Structural Engineering. UFC 3-301-01 has adopted the provisions of 2006 IBC and ASCE 7-05. Some of the provisions of ASCE 7-02 in UFC 3-310-04 have been replaced by the provisions of ASCE 7-05. If this seems confusing, it is. This document will attempt to cover the provisions that apply to MEP components and concisely as possible.

D2.5.3.2 – Building Occupancy:

UFC 3-301-01 uses Occupancy Category to classify buildings and structures in a manner similar to 2006 IBC. However, it adds a fifth occupancy category for national strategic military assets. These are buildings that are considered to be irreplaceable and must be kept functioning at all costs. The example given was National Missile Defense facilities. UFC 3-310-04 still uses the Seismic Use Group (SUG) to classify buildings and structures. It adds a fourth SUG that corresponds to the fifth Occupancy Category of UFC 3-301-01. Occupancy Category and SUG will be defined below. For detailed examples of each refer to UFC 3-301-01 Table 2-2.

1. SUG I (Occupancy Categories I & II) – Buildings and other structures that represent a low hazard to human life in the event of failure.

2. SUG II (Occupancy Category III) – Buildings and other structures that represent a substantial hazard to human life or represent a significant economic loss in the event of failure.

3. SUG III (Occupancy Category IV) – Buildings and other structures designed as essential facilities.

4. SUG IV (Occupancy Category V) – Facilities designed as national strategic military assets.

D2.5.3.3 – Design for Wind Loads:

The design for wind loading of exterior exposed MEP components will be per 2003 IBC and ASCE 7-02. The 3-sec gust design wind speed may be found in UFC 3-301-01 Table E-1 for installations in the United States, its territories, and possessions. For facilities located outside the United States, its territories, and possessions, the 3-sec gust design wind speed may be found in UFC 3-301-01 Table F-1. The Wind Importance Factor, I_W, will depend on the Occupancy Category of the building or structure as shown in Table D2.5.3-1.

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Table D2.5.3-1; Wind Importance Factor per Occupancy Category

OCCUPANCY CATEGORY	SUG	WIND IMPORTANCE FACTOR
I	I	0.87
II	I	1.00
III	II	1.15
IV	III	1.15
V	IV	1.70

D2.5.3.4 – SUG I, II, & III Buildings & Structures:

The seismic and wind restraint design for MEP components appears to be Identical to the provisions specified in 2003 IBC and ASCE 7-02. So, the process of selecting, sizing and quoting seismic and wind restraints for these facilities will be identical to that of similar civilian buildings and structures.

Be sure to check the specification for the facility to see if UFC 4-010-01 has been listed. It may well require restraints for buildings that would not normally require seismic restraint for MEP components. For those buildings that would normally need seismic restraints, the size and cost of the restraints may be increased by the requirements of UFC 4-010-01.

Exemptions per Seismic Design Category would appear to apply to UFC 3-310-04. However, check the specification to see if particular exempts are allowed or disallowed.

D2.5.3.5 – SUG IV Buildings & Structures:

As mentioned before, these facilities are national strategic military assets that are required to function at all costs. As such, they are subjected to more rigorous design and analysis. Components inside these facilities are broken down into three categories.

1. Mission-Critical Level 1 (MC-1) – These are components that are critical to the mission of the facility and must be operational immediately following the maximum considered earthquake. They must be certified as being such per 1621.1.9 of Appendix B of UFC 3-310-04.

2. Mission-Critical Level 2 (MC-2) – These are components that are allowed to sustain minor damage and would be repairable within three days with parts that are stocked at or near the facility.

3. Non-mission Critical Components (NMC) – These are components that can incur damage during the maximum considered earthquake.

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These designations apparently replace the Component Importance Factor that would normally be assigned to the MEP components in the facility.

The seismic forces specified for MC-1, MC-2 MEP components in ASCE 7-02 do not apply to SUG IV facilities. The response spectrum, acceleration, is computed using ASCE 4-98, and the actual forces are computed per equation E-15 of UFC 3-310-04. The seismic forces for the NMC MEP components are calculated using the normal equations found in ASCE 7-02.

Quoting restraints for SUG IV facilities will require close coordination with the Structural Engineer of Record, and the Architect of Record to ensure that the proper designation is assigned to each component and that the proper seismic parameters are transmitted to Kinetics Noise Control.

Carefully reading the specification will indicate whether any exemptions may be applied to piping and ductwork. Also the specification will indicate whether additional safety factors will be required.

D2.5.3.6 – Ground Acceleration Values:

The values of S_S and S_1 for installations that lie within the United States may be obtained form Table E-2 of UFC 3-301-01, and for installations that lie outside the United States, the values for S_S and S_1 may be obtained from Tables F-2 and G-1 of UFC 3-301-01. These values should also be available in the specification and on the first sheet of the structural drawing package. In the provisions for SUG III & IV buildings more stringent values for S_S and S_1 may be required.

D2.5.3.7 – Component Importance Factor:

For SUG I, II, and III facilities, the Component Importance Factor is assigned to MEP components, unless UFC 3-310-04 Appendix D is used for the design of an SUG III facility. The Component Importance Factor will be either 1.0 or 1.5 similar to 2003 IBC. If Appendix D is used for the design of SUG III facilities, no Component Importance Factors will be assigned to MEP components. This is because the acceleration factors used to compute the seismic forces are 1.5 times greater than those normally used for 2003 IBC. So, if Appendix D is referenced for the design of an SUG III facility treat all components as if they had a Component Importance Factor equal to 1.5.

As seen in Section D2.5.3.5 of this document, SUG IV facilities will not have Component Importance Factors assigned to the MEP Components.

D2.5.3.8 – SMACNA:

SMACNA is directly referenced in UFC 3-310-04. However, it is the new SMACNA seismic manual that is referenced.

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ANSI/SMACNA 001-2008 Seismic Restraint Manual, Guidelines for Mechanical Systems 3rd Edition; Sheet Metal and Air Conditioning Contractors' National Association, 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1219.

This has consequences for the engineers and contractors since this version of the SMACNA manual does not allow the 6 ft^2 exemption for ducts assigned a Component Importance Factor of 1.5. Thus for SUG III & IV buildings there will be no exemptions for ductwork, and everything will need to be restrained. Again, it is important to check the specification to see if it will allow the size exemptions for ductwork.

D2.5.3.9 – Inspections:

Walk-down inspections are required for all MEP components in all SUG III and IV facilities as well as all facilities assigned to Seismic Design Categories D, E, and F, prior to facility commissioning. The inspectors are to be registered design professionals who are familiar with the construction and installation of MEP components. The selection of these inspectors must be approved by the headquarters of the authorizing design agency. While this inspection is to be carried out a special selected team of design professionals, representatives from Kinetics Noise Control may be required to participate per the specification. Therefore, any quotations to supply restraints should include the cost of time and travel to cover the inspection(s).

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UFC ANTITERRORISM

D2.5.4 – Summary:

1. UFC 4-010-01 (Antiterrorism) appears to apply only to equipment. Piping and ductwork are excluded. Check the specification to see if piping and ductwork have been included under the provisions of this UFC, occasionally they are.

2. UFC 4-010-01 mentions suspended equipment, and then states that all equipment is to be braced. Check the specification to see if floor and roof mounted equipment is included for consideration.

3. UFC 4-010-01 requires that equipment be braced to withstand 0.5 G in any horizontal direction and 1.5 G total in the downward direction. This requirement will "trump" the seismic provisions of UFC 3-310-04 up to the point where they exceed 0.5 G.

4. UFC 3-301-01 (Structural Engineering) Table 2-2 defines the Building Occupancy Categories used in the UFC standards. A new Building Occupancy Category (V) has been established; see Section 3.1 of this document.

5. UFC 3-301-01 (Structural Engineering) Table E-1 will give the 3-sec gust design wind speed for facilities in the United States, its territories, and possessions. While Table F-1 will give the 3-sec gust design wind speed for facilities outside the United States, its territories, and possessions.

6. UFC 3-301-01 (Structural Engineering) Table E-2 will give the seismic data for facilities in the United States, its territories, and possessions.

7. UFC 3-301-01 (Structural Engineering) Tables F-2 and G-1 will give the seismic data for facilities outside the United States, its territories, and possessions.

8. UFC 3-310-04 (Seismic Design) is based on the provisions of 2003 IBC (ASCE 7-02).

9. UFC 3-310-04 (Seismic Design) establishes a new Seismic Use Group (SUG), see Section D2.5.3.1 of this document.

10. For SUG I, II, and III facilities, the seismic restraint of MEP components is carried out in a manner similar to 2003 IBC (ASCE 7-02). The exception would be if the design of an SUG III facility was specified as using UFC 3-310-04 Appendix D, see section D2.5.3.7 of this document.

11. SUG IV facilities will require special consideration and design for the seismic restraints for MEP components. Contact Kinetics Noise Control before quoting the seismic restraints for a facility designate as SUG IV or Occupancy Category V.

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12. It is important to obtain and read the specification for all Department of Defense facilities or other facilities that reference UFC 4-010-01 or UFC 3-310-04.

    a. The specifications will indicated the exact design standards being employed.

    b. The specifications may increase the requirements beyond the UFC standards. They may require that UFC-4-010-01 be applied to floor and roof mounted equipment, and also to piping and ductwork. They specifications may also increase the minimum safety factor, sometimes to 3:1 or even 4:1. This will significantly affect the number and size of restraints required.

    c. The specification will indicate whether representatives from Kinetics Noise Control are to participate in the mandated walk-down inspections of SUG III and IV facilities. Also, walk-down inspections appear to be required for all facilities assigned to Seismic Design Categories D, E, and F. Quotations to supply seismic restraints to these projects must include the cost of time and travel for the inspections.

    d. Finally, the specifications may indicate the exemptions that will apply to piping, ductwork and electrical distribution systems.

13. Note that the Wind Importance Factor for Occupancy V facilities has been raised to 1.7, which means that more restraint is required for exposed outside equipment.

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SECTION D3.0 – TABLE OF CONTENTS

D3.0 – Product/Design Overview

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THE BIGGEST PROBLEMS CONTRACTORS HAVE WITH RESTRAINTS

D3.1.1 – General:

<u>Problem No. 1 – Knowing When Restraint is Required:</u>

Section D2.1 of this manual covers the requirements for the various code years of the International Building Code (IBC). All of the states have adopted some version of the IBC. If the project in question has been assigned to Seismic Design Category A all of the non-structural components, architectural, mechanical, and electrical components, are exempt from the need for seismic restraint. If the Project has been assigned to Seismic Design Category B by, the mechanical and electrical components will not require seismic restraint. If the project is assigned to Seismic Design Category C, D, E, or F, some of all of the mechanical and electrical components will require seismic restraint; see Sections 2.1.4, 2.1.5, 2.1.6, and 2.1.7 of this manual.

Section D2.4 of this manual covers the requirements of the National Building Code of Canada (NBCC) and the Ontario Building Code (OBC). In general, if the 0.2 second period ground acceleration value for the project is less than 0.12; seismic restraint will be required for the non-structural components, mechanical, electrical, and plumbing components. There are no exemptions in the NBCC or the OBC. However, the specifications may spell out certain components and sizes that may be exempted from the need for seismic restraint.

Section D2.2 of this manual covers the wind provisions of the IBC for roof top equipment and components. Any equipment or components that are on the roof will need restraint of some type. Barrier walls and wind screens may not be used to reduce or eliminate the need for wind restraint.

Section D2.5 of this manual covers the requirements for restraint specified the Unified Facilities Criteria published by the DoD. The seismic and wind restraint requirements are similar to those spelled out in the IBC. However, there is a document, UFC-4-010-04, that deals with antiterrorism. In this document any suspend piece of equipment that weighs more than 31 lbs (14 kg) will require restraint to 0.5 G horizontal and 1.5 G total vertically down, this includes the dead weight of the component.

D3.2 – Anchorage Issues:

<u>Problem No. 2 – Equipment Location in the Building:</u>

The earthquake motion and the forces that the restraints must resist will increase as one moves up through the building. As far as the code is concerned, the total height of the building is not as important as the elevation of the equipment attachment relative to the mean roof height. The IBC and the NBCC/OBC recognize this with a factor that increases the design seismic forces in a linear fashion from a value of 1.0 at and below grade to 3.0 at the roof line.

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This means that the contractor, who is generally responsible for obtaining the seismic restraints, will need more and/or larger restraints on the upper floors or roof of the building than in the basement. It is obvious that restraining equipment and components on the upper floors and roof of a building may be more expensive than restraining the same objects in the basement of the building. The contractors usually rely on the manufacturers of the seismic restraints to select and certify the restraint product for their projects. Unless information on the mean roof height above grade and the attachment elevation of the equipment or components is provided by the contractor, Kinetics Noise Control must assume that the equipment or components are attached to the roof of the building. This is a worst case assumption which will ensure that the right size and number of restraints are specified for each piece of equipment or component. The upshot of all of this is, the contractors can make sure they have the most economical restraint arrangements by providing accurate mean roof elevation and component attachment elevation to Kinetics Noise Control at the outset of the project.

Problem No. 3 – Anchorage to Concrete:

Anchorage of seismic restraints to concrete presents some unique and often serious problems. The major problem is that by the time the contractor is requesting the seismic restraint selection from Kinetics Noise Control; the concrete has been designed, specified, and often poured. That leaves very little room for Kinetics to recommend the appropriate anchorage. In lieu of being able to control the design of the concrete, Unless it is indicated otherwise, Kinetics Noise Control selects anchors based on the following parameters.

1. The concrete is normal-weight concrete with a density of 150 lbs/ft^3.

2. The concrete has a minimum compressive strength of 3,000 psi.

3. The minimum, or critical, edge distance in any direction as published in the Kinetics Noise Control anchor capacity data in Section P10 of this manual in maintained for each anchor. This edge distance is the one that will lead to a failure in the steel of the anchor before concrete fails.

4. When anchors are used to hard mount equipment and components to concrete, the minimum, or critical anchor spacing listed in the anchor capacity data published by Kinetics Noise Control in Section P10 of this manual must be maintained in order to maintain the maximum published anchor capacity.

5. The minimum concrete thickness for the recommended anchors as published in Section P10 of this manual will be maintained in all cases. This minimum concrete thickness includes the standard effective embedment for the anchor, any over drill requirement for the pilot hole, and the proper amount of cover over the end of the anchor to prevent moisture intrusion. It should be noted here that Kinetics Noise Control chooses the standard effective embedment depth for the manufacturer's published ICC-ESR data. Other standard embedments may produce acceptable results, but will need to be evaluated by the Structural Engineer of Record.

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The effective embedment depth of the anchors in the concrete controls the capacity of the anchors. The 2000 and 2003 IBC and the NBCC/OBC require that the concrete anchors have an effective embedment depth that is equal to eight times the nominal anchor diameter, or use a greatly increased design horizontal seismic force. This will lead to the use of larger and/or more anchors. The 2006, 2009, and 2012 IBC codes do not have this restriction. However, the requirements for embedment depth published in the ICC-ESR for the anchors must be followed.

The 2000, 2003, 2006, and 2009 IBC do not allow standard wedge type anchors to be used for equipment that has a total of 10hp or greater on board. In this case either undercut type wedge anchors or adhesive anchors must be used. The undercut wedge type anchors are expensive, and require a great deal more labor to install than do standard wedge anchors. The adhesive anchors work well except in environments where the operating temperatures will normally exceed 100 °F for extended periods of time. This requirement for the undercut or adhesive anchors for equipment with 10 hp or greater on board has been lifted in 2012 IBC.

The isolator/restraints provided by Kinetics Noise Control and other manufacturers have been designed to maximize their performance when bolted or welded to structural steel. Thus the anchor hole locations in the isolator/restraint base plates may not optimize the performance of the concrete anchors, and additional capacity may be required. Typically the concrete anchor capacity increase is achieved through the use of an oversized base plate, see Sections D5.2.1 and 5.2.2 of this manual. The oversized base plate allows for the use of larger anchors, and spreads the anchor centers out far enough that maximum rated anchor capacity can be achieved. ***Please note***; pay attention to the submittal data issued with the recommended isolator/restraints to be sure that the recommended edge distance for the concrete anchors in the oversized base plate is maintained in all directions.

Where concrete of insufficient strength or thickness is provided, the only clear alternative will be to drill clear through the slab, and use through bolts, nuts and fish, spreader, plates. This solution is generally unacceptable because it penetrates a roof slab and compromises the roof integrity, or it leaves bolts showing which may be unsightly and/or cause interference.

The 2012 IBC will require that all concrete anchorage be designed per ACI 318 Appendix D which will require the failure of a ductile steel element at a force level below that required to fail the concrete. The alternative will be either a 2.5 increase in the design loads acting on the anchors, or a 60% reduction in the capacity of the concrete anchors. Unless the concrete anchor manufacturers redesign their products, or the code relaxes the requirements for concrete anchors, more and/or larger anchors will be required to attach equipment and components to concrete in building structures.

Problem No. 4 – Concrete Housekeeping Pads, Curbs, and Piers:

If concrete housekeeping pads are used, they must;

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1. Be either dowled to the structural slab, or be a monolithic pour with the structural slab. This is to prevent the housekeeping pad from shifting position relative to the rest of the building during an earthquake, and breaking pipe, duct, and electrical connections.

2. Be steel reinforced to have enough strength to transmit the seismic loads from the equipment to the building structure, and to not be broken up into rubble under the earthquake motion.

3. Be normal-weight concrete with a standard density of 150 lbs/ft^3.

4. Have a minimum compressive strength of 3,000 psi.

5. Have a minimum concrete thickness that is compatible with the anchors specified by Kinetics Noise Control

6. Be large enough to provide the required edge distance in all directions for the anchors specified by Kinetics Noise Control and also any oversized base plates that may be required to achieve the necessary capacity.

Concrete curbs and piers represent an enormous headache. They are typically designed and poured before Kinetics is approached to select restraints and anchors. The design of concrete curbs and piers almost never;

1. Takes into account the size and configuration of the isolator/restraints that are to be mounted on them.

2. Leaves enough edge distance for the concrete anchors required to attach the isolator/restraints to the curb or pier to resist the design seismic and wind loads. This often means that a special steel frame must be fabricated to encapsulate part or the entire top of the concrete curb or pier so that the anchors can be installed along the sides rather than the top of the curb.

D3.3 – Equipment Issues:

Problem No. 5 – Equipment Durability and Interfacing Support Members:

For designated seismic systems in essential facilities, the IBC requires that the durability of the equipment be certified by the manufacturer of the equipment. It must continue to function after an earthquake that is equal to the design level for the project location. It is becoming more common for this certification must be performed by shake table testing. The usual testing protocol is ICC AC156.

Interfacing support members must have sufficient strength and stiffness to transfer the earthquake and wind loads from the equipment to the isolator/restraints. Unless these are being designed and manufactured by Kinetics Noise Control, Kinetics can not comment on their suitability for a particular application. If Kinetics Noise Control does provide the interfacing support members,

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Kinetics can not guarantee the performance of the equipment structure. That must be by the equipment manufacturer. Kinetics can only certify that the interfacing support members meet the force requirements of the code in force for the project.

Problem No. 6 – Restraint of Tall, Narrow Floor/Roof Mounted Equipment:

Tall, narrow pieces of equipment are difficult to restrain, and all the more so if they are isolated. The restraint points at the floor or roof are relatively close together when compared to the elevation of the center of gravity, seismic loads, or the center of pressure, wind loads. This produces very large overturning moments which will require very large vertical forces at the restraint points. While restraints might be sized to properly resist these vertical loads, the frame of the equipment most likely has not been so designed.

There are several design schemes that can be employed to restrain equipment that is tall and narrow.

1. Restrain the equipment rigidly to a wall, and loosely at the base to keep the base from kicking out.

2. Fabricate a frame to which the equipment would be mounted, and adequately brace the equipment to the frame. The frame is used to spread the restraint points out reducing the vertical forces required to resist the overturning moment.

3. Attach the equipment to an inertia base to lower the center of gravity and spread the restraint points out.

4. Limit the lateral motion of the equipment with cable restraints. The cables should be attached to the equipment somewhere above the center of gravity/pressure, and anchored to the floor or roof.

Problem No. 7 – Adequate Attachment Locations on Equipment:

Frequently the equipment to be restrained does not have adequate attachment location possibilities. This can be due to a number of reasons.

1. The equipment base rails are inaccessible for attaching the required isolator/restraints.

2. The equipment base rails or attachment points are constructed from a material that is not compatible with galvanized or painted steel restraint components normally used. Some of these materials are aluminum and fiber reinforced plastics.

3. There are times when there are no base rails, and the restraints would need to be attached to the sheet metal panels of the equipment. This is undesirable because the panels were not designed to take concentrated loads, and the restraints may block access to maintenance doors and panels.

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D3.4 – Distribution System Issues – Pipe, Duct, Conduit, and Cable Trays:

All of the following issues are covered fully in the **Kinetics Pipe & Duct Seismic Application Manual** which is available from www.kineticsnoise.com. Throughout the rest of this manual, the Kinetics Pipe & Duct Application Manual will be referred to as the Pipe & Duct Manual.

Problem No. 8 – Room for Restraints:

The most frequent issue relative to suspended distribution systems is that there is almost never enough room for running the seismic restraints from the suspended distribution components to the building structure. Most of this interference comes from adjacent distribution system components that have been installed by other trades. It is typical procedure for the distribution systems to be installed first, and then the seismic restraints for those systems are installed at a later date. During the intervening time other trades are installing their systems. By the time the restraints are to be installed there are many components in the way making it difficult if not impossible to properly install the seismic restraints. This issue is discussed in Sections I1.0 and I2.0 of the Pipe & Duct Manual.

It is sometimes necessary to be very creative with the restraints and their installation. Some of the various restraint schematics normally used for suspended distribution are found in Sections I3.0, I4.0, and I7.0 of the Pipe & Duct Manual.

Problem No. 9 – Mixing Cable and Strut Type Restraints:

It is important that cable type restraints and strut type restraints are not used on the same run of a suspended distribution system. It has to do with the way the two different types of restraints load the pipe, duct, conduit, or other distribution component. For example, if all of the restraints on a run were to be cable type restraints, and an interference issue required the use of a strut type restraint for one location, all of the restraints in that run would need to be changed to struts.

Problem No. 10 – Problems with Strut Type Restraints:

Cables are the preferred type of restraints. This is because they are small and easily routed past other components. ***Note: cable restraints must not touch any other component or the building structure along their path from the components being restrained and the attachment point to the structure.*** Also, cable restraints are preferred because they apply only compressive reaction loads to the hanger rods.

Strut type restraints, on the other hand, will induce tension reaction loads in the hangers in addition to the dead weight of the component. There are cases when the tensile reaction loads from the struts can equal or exceed the dead weight load of the component. If struts must be used for a particular run, the hangers and hanger attachments to the building must be reevaluated to see if they have enough capacity to carry the additional tension loads. Also, struts are more difficult to route past other components. See Section I7.0 of the Pipe & Duct Manual for additional information regarding the application of strut type restraints.

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Problem No. 11 – Rod Stiffeners:

Rod stiffeners may be required for hanger rods that are small in diameter and/or relatively long. Also, they are more often required when the distribution components are supported by a trapeze bar. They are required only at the seismic restraint locations, and are used to carry the net compressive reaction loads from the seismic restraints to prevent the buckling of the hanger rod. Section I8.0 of the Pipe & Duct Manual will provide some guidance on when rod stiffeners may be required, and how to apply them. The actual sizing of the rod stiffeners is discussed in Section S8.0 of the Pipe & Duct Manual. There is also a web based tool on Kinetics' web site that will assist in determining whether rod stiffeners are required for a particular location, sizing the stiffener, and recommending the number of clamps required.

Problem No. 12 – Implementing the 12″ Rule:

The 12″ Rule is defined in Sections S4.0 and S12.0 of the Pipe & Duct Manual. Basically any pipe or duct that is suspended within 12 inches of the supporting structure, and is supported by non-moment generating, free swinging, hangers does not require seismic restraint provided that the pipe or duct can swing freely without striking another object or the building, and that any interfaces with equipment are designed to tolerate the expected motion. There are some issues that must be dealt with when trying to implement the 12″ Rule.

1. The trade(s) that are on site first have the best opportunity to implement the 12″ Rule. The best and most cost effective way to use the 12″ Rule is by plan. The MEP coordinator should decide which system will give the building owner the most benefit from utilizing the 12″ Rule, and then schedule that trade in to the job first making sure they follow the guidelines for implementing the 12″ Rule completely.

2. Each and every hanger location on a run must meet the requirements for the 12″ Rule or the entire run must be restrained.

3. Non-moment generating, free swinging, connections between the hangers and the structure must be used at each hanger location.

4. The distribution system components must be free to swing without contacting any other components or the building structure.

5. Interfaces, connections, with equipment must be designed to accommodate the expected relative motion between the pipe or duct and the equipment.

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Problem No. 13 – Small Duct Exemptions:

The SMACNA Seismic Restraint Manual 2nd Edition[1] allows all ducts with a cross-sectional area of 6 ft^2 or less to be exempt regardless of the Component Importance Factor. The SMACNA Seismic Restraint Manual 3rd Edition[2] only allows this exemption for Duct with a Component Importance Factor of 1.0. 2000 IBC directly references the SMACNA Seismic Restraint Manual 2nd Edition, so the 6 ft^2 or less exemption will apply regardless of the Component Importance Factor. 2003 and 2006 IBC do not allow the 6 ft^2 or less exemption for duct whose Component Importance Factor is 1.5. However, 2009 and 2012 IBC will allow the 6 ft^2 or less exemption regardless of the Component Importance Factor.

Problem No. 14 – Restraint of Hot & Cold Pipes:

Pipes that undergo significant expansion or contraction from installation state to operational state present unique problems for seismic restraint designers and installers. Wherever a longitudinal restraint is placed, an anchor is created. If anchors already exist on a run of pipe, placing the longitudinal restraint anywhere but the anchor location will place the pipe in tension or compression which can be sever enough to either fail the pipe, or fail the restraints. How to handle hot and cold piping is discussed and illustrated in Sections S9.0 and I3.0 of the Pipe & Duct Manual.

[1] SMACNA; Seismic Restraint Manual – Guidelines for Mechanical Systems 2nd Edition; Sheet Metal and Air Conditioning Contractors' National Association, Inc., 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209; March, 1998.

[2] SMACNA; Seismic Restraint Manual – Guidelines for Mechanical Systems 3rd Edition; Sheet Metal and Air Conditioning Contractors' National Association, Inc., 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209; March, 2008.

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CABLES vs. STRUTS IN SEISMIC RESTRAINT APPLICATIONS

Cable and strut restraints perform the same function in very different ways. Cable restraints are often called tension only braces. Because of their flexible nature, they can carry loads only in tension. So, for each direction being restrained, two cables are required located 180° apart. And, to completely restrain a component, four cables are required located 90° apart Struts, on the other hand, are referred to as rigid braces. They are capable of carrying both tension and compression loads. For each direction being restrained, only one strut is required. To completely restrain a component two struts spaced 90° apart are required.

Cables represent a more flexible and easily installed restraint system. Even though four cables are needed to fully restrain a component, it is generally easier to route the cables past any adjacent components to achieve a clear load path from the component to the building structure. Cables are light weight and can be easily cut to a proper length while at the restraint location. Struts, on the other hand, being rigid may prove difficult to route past other component. Also, struts are heavy and inflexible. Generally they must be cut on the ground, and perhaps more than one try may be required in certain instances.

When the equipment, pipe, or duct must be isolated, it is not good practice to use strut type restraints. The struts are rigid by definition which will "short circuit" the isolation. Cable type restraints are more flexible which will lead to better isolation performance.

Both types of restraints will place the hanger rod in compression. The cable restraints will ***only*** place the hanger rod on compression. The strut restraint will place the hanger rod in compression, and then in tension as the component being restrained tries to swing back and forth. This is a serious draw back of the strut type restraints. They can place additional tension loads on the hanger rod beyond the dead weight load of the component. Any hanger rod design and selection of its attachment to the structure must be sized to include the tensile reaction loads due to the design horizontal seismic force.

Occasionally, a component was designed to be restrained with cables, but an unforeseen interference required a strut type restraint to be used. In this case, the following practices ***must*** be used.

1. All restraints on this component must be changed to struts. If the component is a run of pipe, duct, conduit, or cable tray, all of the restraints on that run must be converted to struts. This is because they behave completely differently than the cables, and the reaction loads on the equipment and hangers are different.

2. All of the hanger rods and their attachments must be re-evaluated for the increased tensile loads due to the seismic reactions from the struts. If they are undersized, they must be changed. If the hanger rods are attached to concrete, the anchors used for the attachment must be prequalified per ACI 355.2 (ICC-AC193) for use in cracked concrete, and have an

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ICC-ESR stating they are suitable for applications in Seismic Design Categories C, D, E, or F. This is because with the tensile component due to the struts, the hanger rod and its attachment are part of the seismic load path.

This is detailed more thoroughly in Sections S8.0 and I7.0 of the Pipe & Duct Manual.

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ISOLATOR/RESTRAINTS – COMBINED OR SEPARATE

D3.3.1 – Introduction:

In the world of vibration isolation and seismic restraint for floor mounted equipment, there are two routes that may be taken.

1. **Combination Isolator/Restraints:** Where the restraint component is incorporated in the same housing as the isolation component.

2. **Separate Isolators and Restraints:** Where the restraint component and isolation component are self contained separate entities.

Whether combination isolator/restraints or separate isolators and restraints are to be used will depend on the application. For highly sensitive isolation applications, when the vibration consultant is concerned about the restraints shorting out the isolation, the isolators and restraints are installed as separate stand alone devices. However, when the application does not highly sensitive to occasional shorting of the isolation, the combined isolator/restraints will generally be the most cost effective. Normally, isolator/restraints require less floor space than the separate isolators and restraints, and they are usually more cost effective since they can be combined into a single package.

D3.3.2 – Combination Isolator/Restraints:

Combination isolator/restraints are devices that incorporate the vibration isolation function and the seismic/wind restraint function in one device. Kinetics Noise Control manufactures several types of these combination isolator/restraints. All of the combination isolator/restraints have three axis restraint capabilities.

1. **Model FHS:** This is a post type isolator with one spring coil, and one leveling bolt assembly. The leveling bolt assembly serves three purposes; levels the equipment, is part of the restraint, and is tapped for a bolt to attach the equipment to the isolator/restraint. The restraint is a three axis restraint. This product is detailed in Section P3.2.4 of this manual.

2. **Model FLS, FLSS, FTS, Titan:** These are plate type isolator/restraints with one or more spring coil sets and leveling bolts. The top plate of the isolator restraint is flat with through holes that will allow the equipment to be bolted or welded to the isolator/restraint. These devices are detailed in Sections P3.2.2, P3.2.1, and P3.2.3 of this manual respectively.

3. **Model FMS:** This is a hybrid isolator/restraint. It combines the best of both the isolator/restraints and the separate isolators and restraints. The restraint portion can be used by itself or in conjunction with a freestanding isolator. The freestanding isolator can be combined with the restraint as part of the assembly, or it can be completely separate from the **FMS** restraint. For more details for the **FMS** system, see Section P2 of this manual.

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4. **Model KRMS:** This is a neoprene isolator/restraint. This type of isolator can be used for floor, walls, and ceiling mounted equipment because it is basically a zero clearance isolator/restraint, see Sections P4.1 and 4.2.1 of this manual.

5. **Model ESR, KSR, KSCR, HD-KSR, Kinetics Curb, MegaCurb:** These are roof curbs that incorporate isolators and restraints in the same package. The Model **ESR** has pedestals that operate as combined isolator/restraints, see Sections P6.1 and P6.2.1 of this manual. The Model **KSR** and **KSCR** have isolators and restraints that are separate, but that share the same supporting members, see Sections P6.1, P6.2.2, and P6.2.3 of this manual. The **Kinetics Curb** also has separate isolators and restraints, but is has zero clearance horizontal restraints, see Sections P6.1 and P6.2.4 of this manual. The HD-KSR is fitted with independent high capacity restraints in each corner and optional restraints on the sides, see Sections P6.1 and P6.2.5 of this manual. The MegaCurb is a High Wind/High Seismic structural steel curb fitted with modular spring/isolator elements, see Sections P6.1 and P6.2.6 of this manual.

D3.3.3 – Separate Isolators and Restraints:

When separate isolators and restraints are specified, the Kinetics Noise Control Model **FDS** isolator is used. This is a free standing coils spring isolator sitting on a neoprene high frequency barrier. The restraint devices normally used with the freestanding isolators are described below.

1. **Single Axis Snubbers – Model HS-1:** The **HS-1** snubber, restraint, only acts against a horizontal force in one direction. A piece of equipment would require at least one Model **HS-1** on each side to be fully restrained. This restraint ***does not*** accommodate any uplift load conditions. See Section P5.2.1 of this manual for a complete description of this product.

2. **Two Axis Snubbers – Model HS-2:** The **HS-2** snubber, restraint, acts against a horizontal force in any horizontal direction. A piece of equipment to be restrained using the **HS-2** would require at least two of these devices on opposite sides. This restraint also ***does not*** accommodate any uplift load conditions. See Section P5.2.2 of this manual for a complete description of the **HS-2**.

3. **Three Axis Snubbers – Model HS-5 and FMS:** Both of these snubbers, restraints, act against forces in any horizontal and vertical direction, and so may be used for uplift load conditions. See Section P5.2.3 of this manual for a complete description of the HS-5, and Section P2 of this manual for a description of the **FMS** product line.

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ROOF MOUNTED EQUIPMENT APPLICATIONS

D3.7.1 – Introduction:

Mounting equipment to the roofs of buildings and other structures and properly restraining it against the design seismic and wind forces has always required special attention. The roof structure of most buildings contains the lightest and weakest structural components of the building. This is because it is at the top of the building and does not carry the dead weight loads that the lower levels of the structure do. Also, the roof structure may be designed to carry the dead weight load of the roof top equipment, but it is designed to carry it as a distributed load rather than line loads or point loads.

D3.7.2 – Point Loads from Isolator/Restraints:

Many times for isolated equipment, the dead weight loads are transferred to the roof structure as point loads. Almost always, the seismic restraint loads are transferred to the roof structure as point loads. This creates a problem for the design professional charged with designing the restraint for a piece of roof top equipment because the roof structure may not be sufficient to handle the point loads generated by the restraints.

Restraints can produce concentrated loads of several types.

1. **Horizontal Loads:** The horizontal loads produce localized shear of the roof structure, and concentrated loads at anchor and bolt holes.

2. **Vertical Loads:** The vertical loads can be either downward or upward. Downward reactions from the restrains would add to the dead weight load if combination isolator restraints were used. The vertical loads tend to put the structural members in bending.

3. **Moment Loads:** Due to the fact that the restraints have some structure to them, the horizontal seismic and wind loads are not applied to the surface of the structure. They are applied at some distance above the surface of the structure. This means that there will be a moment that must be resisted at the interface between the restraint and the structure. Depending on the type of structural elements that are used, this moment will be either a bending moment or a torsional moment.

It is critical, especially in lightweight and/or long span structures, that the structural engineer of record takes these expected point loads from the restraints and isolators into account when designing the building structure. Lack of proper coordination can lead to a building structure that is inadequate to resist the design seismic and wind loads prescribed by the code. This will leave the contractor and the design professional responsible for the restraint design holding the bag at the time the building is to be commissioned.

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D3.7.3 – Main Structural Elements:

For large pieces of roof top equipment such as cooling towers, air handlers, and packaged roof top units, the main structural elements of the roof need to be placed beneath the equipment to give it proper support, and to transfer the restraint reactions due to the design seismic and wind loads. Failure to do so can leave a significant portion of the equipment load cantilevered out over unsupported roof deck; which can lead to failure of the deck and a loss of roof integrity.

When the large piece of equipment is to be isolated, it important for the supporting roof structure to be stiff enough to not only support the equipment, but also to allow the equipment isolation to properly adjusted. In cases where the roof structure is not stiff enough, the when the adjusting screws of the isolators are turned down to increase the load on the springs and lift the equipment, the isolators will push the roof structure down rather than lifting the equipment. Here the isolation has been rendered useless. Also, this situation can lean to a failure of the roof deck and a loss of roof integrity. This is most often a problem when the roof structure is of lightweight and/or long span construction.

D3.7.4 – Concrete Roof Decks, Housekeeping Pads, Curbs, & Piers:

Due to the nature of roof structures there is an increasing desire to use lightweight concrete poured over a metal deck for the roof. This presents several serious problems.

1. Not all concrete anchors that have been prequalified per ACI 355.2 are rated for use in lightweight concrete.
2. The design strength of lightweight concrete is significantly less than normal-weight concrete of the same compressive strength.
3. Typically the concrete thickness is insufficient to generate the full rated strength of the anchors that are to be used.
4. The lightweight concrete deck is for all intents and purposes un-reinforced and not necessarily well bonded to the metal decking that supports it. Therefore, the probability of breaking pieces out of the roof deck during a severe seismic or wind event is very real.

The anchorage of large pieces of roof top equipment can not be an afterthought. If the roof deck is to be concrete, either concrete of the proper type, strength, and thickness must be provided to resist the design seismic and wind forces, or a steel structure penetrating the concrete and attaching directly to the structural steel of the building must be provided. Both of these options involve the efforts of the structural engineer of record in conjunction with the engineer of record for the piece of equipment that is to be attached to the roof.

If however, the concrete deck is not adequate to carry the required seismic and wind loads through the use of post installed anchors, the only viable option may be through bolting the

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isolator/restraints to the roof deck. This involves drilling through the concrete deck then using bolts, nuts, and large washer plates on the underside of the deck to distribute the load.

Large penetrations in a concrete roof deck must be treated with special care. There must be enough distance from the inner most anchors of the roof curbs or the base plates of the isolator/restraints to the edge of the penetration to allow the full rated capacity of the specified anchors to be developed. As much as is practical, should be kept away from the interior edge of the roof curbs or the base plates of the isolator/ restraints by at least 12 inches.

Occasionally, concrete housekeeping pads are used for roof top equipment. These concrete housekeeping pads on the roof must be;

1. Doweled to the roof structure or a continuous pour with the roof structure.

2. Normal-weight concrete of minimum 3,000 psi compressive strength.

3. Steel reinforced to resist the design seismic and wind reaction loads applied to it.

4. Thick enough to accept the embedment for the required anchors.

Concrete curbs and piers pose special issues all their own. Normally the curbs and piers have already been poured before the isolator/restraints have been selected. This means that there is a strong probability that the tops of the curbs and piers do not match the width of the isolator/restraint base plate, nor will they allow enough edge distance for the concrete anchors to generate their full rated capacity rendering the restraint system to be inadequate. In such cases special steel “caps” will need to be provided that extend far enough over the sides of the curb or pier to allow proper anchorage to be developed. The isolator/restraints are then welded to the steel “caps”. Alternately, the structural engineer of record can design the anchorage of the isolator/restraints to the curb or pier.

D3.7.5 – Metal Roof Decking:

Attaching restraint bearing roof curbs and isolator/restraints directly to metal roof decking is not generally a good idea. The only exceptions would be if the equipment along with the design seismic and wind forces were small. Then, the proper number of fasteners would be required to attach the curbs or isolator/restraints to the metal deck so that failure of an individual fastener is not likely. Also, the structural engineer of record will need to make sure that the sheets of metal decking are properly attached to the building structural steel and to each other to resist the additional seismic and wind loads that would be imposed by the equipment through the curb or isolator/restraints.

For larger pieces of equipment and/or higher design seismic and wind loads the curb and isolator/restraint connection should be made directly to the building structural steel supporting the metal roof decking. This will alleviate the problems associated with the metal deck not being stiff enough to carry the seismic and wind loads to the building structure.

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D3.7.6 – Isolated Roof Top Equipment & Isolation Performance:

The restraints in most roof curbs and other isolator/restraint devices have a certain amount of built in clearance that allows for placement errors and free vertical movement of the spring support equipment. The only isolator/restraint devices that do not have this built in clearance are the Model KSR, KSCR, Kinetics Curb, and KRMS. In roof top applications, the isolator/restraints with built in clearance have the problem of having partially shorted out isolation when the wind blows. The wind will cause the equipment to move sideways and engage the horizontal restraints. Even a relatively light wind can bring the restraints into engagement. So, a periodic loss of isolation efficiency for isolated roof top equipment must be expected.

Roof top equipment that is exposed in any fashion to the wind will require restraint. Even equipment that is surrounded barrier walls will need restraint because the enclosure is open at the top and exposed to the effects of the wind. This is a code driven requirement that is explained in Section D2.2.2 of this manual. This means that all isolated roof top equipment will suffer some deterioration in isolation efficiency when the wind blows.

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SECTION D4.0 – TABLE OF CONTENTS

D4.0 – Applying Restraint Capacity Ratings

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ASD (Allowable Stress Design) vs. SD (Strength Design)

D4.1.1 – Introduction:

In the past, the relationship between Strength Design (SD) loads and Allowable Stress Design (ASD loads has been relatively straight forward, and was defined by;

$P_U = \alpha P_A$ [1] **Eq D4.1-1**

Where:

P_U = the load expressed as a SD value.

P_A = the load expressed as an ASD value.

α = the factor used to convert ASD values to SD Values.

In general for most cases dealing with the seismic restraint of nonstructural components the value of α has been defined to be;

$\alpha = 1.4$ [2] **Eq D4.1-2**

In cases where the components see only earthquake loads, such as some instances for concrete anchors and other fasteners, the value of α has been permitted to be;

$\alpha = 1.1$ [3] **Eq D4.1-3**

If the SD design values are to be converted to ASD allowable values, this practice amounts to inflating the allowable loads by roughly 1/3. This was a standard practice under the UBC 97 building code for components such as concrete anchors, but has since been deemed to be inadequate for designing seismic anchorage for 2006/2009/2012 IBC.

The ICC has issued a memorandum[4] outlining the procedure for computing the value of α for each application based on the definition of the α factor above, the load condition being used for the design of the nonstructural component, and its anchorage. The purpose of this section is to

[1] Quimby, T. Bartlett; A Beginner's Guide to ASCE7-05, www.bgstructuralengineering.com, 08/02/2008, Chapter2
[2] ASCE 7-10 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Graham Bell Drive, Reston, Virginia, 20191; 2010, Section 13.1.7
[3] ES Report ESR-1917 Re-issues September 1, 2007; HILTI KWIK BOLT TZ CARBON AND STAINLESS STEEL ANCHORS IN CONCRETE; ICC Evaluation Service, Inc., www.icc-es.org, Pg 3 of 14
[4] Gerber, Brian C.; *Clarification on the use of the Conversion Factor* α *to convert Strength Design (SD) to Allowable Stress Design (ASD)*, ICC Evaluation Service, Inc., www.icces.org, January 20, 2009

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develop a range of values for α as they relate to the design and anchorage of seismic and wind restraints for nonstructural members.

D4.1.2 – Seismic Loads Not Supported by the Restraints:

The controlling SD load case is found in ASCE 7-10 Section 2.3.2 (7);

$$P_U = 0.9D + 1.0E$$ **Eq D4.1-4**

Where:

D = the dead load.

E = the earthquake load.

The controlling load case for ASD from ASCE 7-10 Section 2.4.1 (8) is;

$$P_A = 0.6D + 0.7E$$ **Eq D4.1-5**

Now let;

$$D = nP_T$$ **Eq D4.1-6**

And;

$$E = (1-n)P_T$$ **Eq D4.1-7**

Where:

P_T = the total load.

n = the percentage of the total load that is made up of the dead load.

Substitute Equations D4.1-6 and D4.1-7 into Equations D4.1-4 and D4.1-5 to obtain the following expressions.

$$P_U = 0.9(nP_T) + 1.0[(1-n)P_T] = (1-0.1n)P_T$$ **Eq D4.1- 8**

And;

$$P_A = 0.6(nP_T) + 0.7[(1-n)P_T] = (0.7-0.1n)P_T$$ **Eq D4.1-9**

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Now, substitute the results from Equations D4.1-8 and D4.1-9 into Equation D4.1-1 and solve for α .

$$(1-0.1n)P_T = \alpha(0.7-0.1n)P_T$$

From which;

$$\alpha = \frac{1-0.1n}{0.7-0.1n}$$ **Eq D4.1-10**

It is important to note from Equation D4.1-10 that if the dead load of the equipment is very small compared to the earthquake load such that $n \to 0$, then the value of α will be;

$$\alpha = \frac{1}{0.7} = 1.43$$ **Eq D4.1-11**

This is the value for α that is specified in ASCE 7-10 Section 13.1.7. If on the other hand the dead load of the equipment is very large relative to the earthquake load so that $n \to 1$, the value of α will be;

$$\alpha = \frac{1-0.1}{0.7-0.1} = \frac{0.9}{0.6} = 1.50$$ **Eq D4.1-12**

The effective working range for α is;

$$1.43 \le \alpha \le 1.50$$ **Eq D4.1-13**

In order to have on value for α that will cover all of the possibilities, it is prudent to choose $\alpha = 1.5$ for the load case where the restraints and/or anchorage do not support the dead load of the equipment.

D4.1.3 – Seismic Loads Supported by the Restraints:

As in the preceding section, this analysis will begin with the controlling load cases. The controlling SD load case for the dead load being supported by the restraints and/or their anchors is found in ASCE 7-10 Section 2.3.2 (5).

$$P_U = 1.2D + 1.0E + L + 0.2S$$ **Eq D4.1-14**

Where:

S = the snow load.

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L = the live load.

For ASD, the controlling load case is found in ASCE 7-10 Section 2.4.1 (6b).

$$P_A = D + 0.75L + 0.75(0.7E) + 0.75S \quad \textbf{Eq D4.1-15}$$

For this case, both $S = 0$ and $L = 0$. Here, as before, Equations D4.1-6 and D4.1-7 will be used. Substitute these into Equations D4.1-14 and D4.1-15.

$$P_U = 1.2(nP_T) + 1.0[(1-n)P_T] = (1+0.2n)P_T \quad \textbf{Eq D4.1-16}$$

And;

$$P_A = nP_T + 0.75[0.7(1-n)P_T] = (0.525 + 0.475n)P_T \quad \textbf{Eq D4.1-17}$$

Substitute Equations D4.1-16 and D4.1-17 into Equation D4.1-1, and solve for α.

$$(.525 + 0.475n)P_T = \alpha(0.7 + 0.3n)P_T$$

This will lead to;

$$\alpha = \frac{1+0.2n}{0.575+0.475n} \quad \textbf{Eq D4.1-18}$$

Using Equation D4.1-18, the limits of this application may be examined. As $n \to 0$, the dead load will be small compared to the earthquake load, and the value of α will be;

$$\alpha = \frac{1}{0.575} = 1.74 \quad \textbf{Eq D4.1-19}$$

When $n \to 1$, the dead weight loads far exceed the earthquake loads, and the value of α will be;

$$\alpha = \frac{1+0.2}{0.575+0.475} = \frac{1.2}{1.05} = 1.14 \quad \textbf{Eq D4.1-20}$$

For this case, the effective working range for α is;

$$1.14 \le \alpha \le 1.74 \quad \textbf{Eq D4.1-21}$$

In order to cover all of the possible load combinations with one value, $\alpha = 1.74$.

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D4.1.4 – Wind Loads Not Supported by the Restraints:

The controlling load case for SD is given in ASCE 7-10 Section 2.3.2 (6).

$$P_U = 0.9D + 1.0W$$ **Eq D4.1-22**

The controlling load case for ASD is ASCE 7-10 Section 2.4.1 (7).

$$P_A = 0.6D + 0.6W$$ **Eq D4.1-23**

Where:

W = the wind load.

As with the seismic analysis in the preceding two sections, let;

$$D = nP_T$$ **Eq D4.1-6**

And;

$$W = (1 - n)P_T$$ **Eq D4.1-24**

Substitute Equations D4.1-6 and D4.1-24 into Equations D4.1-22 and D4.1-23.

$$P_U = 0.9(nP_T) + 1.0[(1 - n)P_T] = (1 - 0.1n)P_T$$ **Eq D4.1-25**

And;

$$P_A = 0.6(nP_T) + 0.6[(1 - n)P_T] = 0.6P_T$$ **Eq 4.1-26**

Substitute Equations D4.1-25 and D4.1-26 into Equation D4.1-1 and solve for α.

$$(1 - 0.1n)P_T = \alpha(0.6P_T)$$

$$\alpha = \frac{1 - 0.1n}{0.6}$$ **Eq 4.1-27**

For the limit analysis, as the dead load comprises a smaller and smaller portion of the total load, $n \to 0$, and;

$$\alpha = \frac{1}{0.6} = 1.67$$ **Eq 4.1-28**

When the dead load makes up the vast majority of the total load, $n \to 1$, and

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$$\alpha = \frac{1+0.1}{0.6} = 1.83$$ **Eq 4.1-29**

In order for a single value of α to cover the entire range of load combinations between the dead load and the wind load, its value would need to be $\alpha = 1.83$.

D4.1.5 – Wind Loads Supported by the Restraints:

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From ASCE 7-10 Section 2.3.2 (4) the load combination for SD is found.

$$P_U = 1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$$ **Eq D4.1-30**

Where:

L_r = the live roof load.

R = the rain load.

ASCE 7-10 Section 2.4.1 (6a) provides the ASD load combination.

$$P_A = D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$$ **Eq D4.1-31**

In the above equations, $L = L_r = S = R = 0$. Substitute Equations D4.1-6 and D4.1-24 into Equations D4.1-30and D4.1-31 to yield the following results.

$$P_U = 1.2(nP_T) + 1.0[(1-n)P_T] = (1-0.2n)P_T$$ **Eq D4.1-32**

And;

$$P_A = nP_T + 0.75[0.6(1-n)P_T] = (0.45+0.55n)P_T$$ **Eq D4.1-33**

Substitute Equations D4.1-32 and D4.1-33 into Equation D4.1-1 and solve for α.

$$(1-0.2n)P_T = \alpha(0.45+0.55n)P_T$$

$$\alpha = \frac{1-0.2n}{0.45+0.55n}$$ **Eq D4.1-34**

As $n \to 0$, the wind load is dominant, and;

$$\alpha = \frac{1}{0.45} = 2.22$$ **Eq D4.1-35**

When $n \to 1$; the dead load becomes dominant, and;

$$\alpha = \frac{1-0.2}{0.45+0.55} = 0.80$$ **Eq D4.1-36**

The effective range for α will be;

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$0.80 \leq \alpha \leq 2.22$ **Eq D4.1-37**

In order to cover all of the potential load combinations with one value, $\alpha = 2.22$.

D4.1.6 – Summary:

The results of the preceding analysis for all four cases are summarized below in Table D4.1-1.

Table D4.1-1; Range of values of α for Seismic and Wind Loadings

LOAD CASE	α FOR $N=0$[5]	α FOR $N=1$[6]
For Seismic Loads When Floor & Ceiling Mounted Components are Not Supported by the Restraints	1.43	1.50
For Seismic Loads When Floor Ceiling, and Wall Mounted Components are Supported by the Restraints	1.74	1.14
For Wind Loads When Floor & Ceiling Mounted Components are Not Supported by the Restraints	1.67	1.83
For Wind Loads When Floor Ceiling, and Wall Mounted Components are Supported by the Restraints	2.22	0.80

When converting the ASD values to SD values, or visa versa, it is prudent to use the largest value for α since the exact percentage of the total load assigned to the dead load is not normally known.

[5] When $n=0$, the total load is made up of either the earthquake or the wind component.
[6] When $n=1$, the total load is made up of the dead weight component.

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HORIZONTAL/VERTICAL SEISMIC LOAD CAPACITY ENVELOPES (CONSTANT)

All seismically rated restraints that resist both horizontal and vertical loads and that are provided by Kinetics Noise Control represent their seismic capacity with a load envelope diagram. The capacities shown conform to ASD (Applied Stress Design) methodology. The vertical axis of the diagram is the vertical capacity of the restraint. The horizontal axis of the diagram is the horizontal capacity of the restraint. The area in between represents the maximum capacity for applications that have combined vertical and horizontal load components. Most applications involve combination of these forces. For restraints that resist horizontal loads only, a single number identifies their capacity.

For all seismic restraints and for most seismically rated isolators, the seismic capacity is independent of the load that the isolator might support. In some cases, however, the load being supported by the isolator can increase of decrease its seismic rating. This section addresses only those isolators where the restraint capacity is unaffected by the load.

Note: The load supported does not impact the capacity of most seismically rated isolators. Any seismically rated component that has its capacity illustrated as in the diagrams below are of the "constant" capacity type. If the seismic rating is load sensitive, the capacity diagrams will be more complex. Refer to section D4.3 for more information on these and on how to use the load diagrams appropriate to them.

On most diagrams, there are two curves. One represents the capacity of the restraint when through bolted and/or welded. This can also be assumed to be the capacity limit of the restraint device itself.

The other curve indicates the capacity of the restraint if bolted to concrete. This rating is based on standardized anchor conditions such as normal embedment depths, 3000 psi normal weight concrete and edge distances adequate to ensure that breakout is not a failure mode. These factors can be used for 2009 and earlier IBC codes as long as the standardized conditions are met. For later codes (2012 IBC). All anchor evaluations are required to be conducted on a case by case basis. In these cases, the anchor curves can be used as a guide, but a full evaluation is still required by the code. Note that the anchored capacity will always be equal to or less than the through bolted capacity. It should be noted that the concrete anchorage capacity can increase up to the limit of the through bolted capacity with the addition of optional oversized base plates and significantly larger anchors.

In some cases, a "family" of isolators or restraints may be identified on the same diagram. If this is the case, each curve will be labeled as to which family member it represents and where appropriate, both anchored to concrete and through bolted values will be shown.

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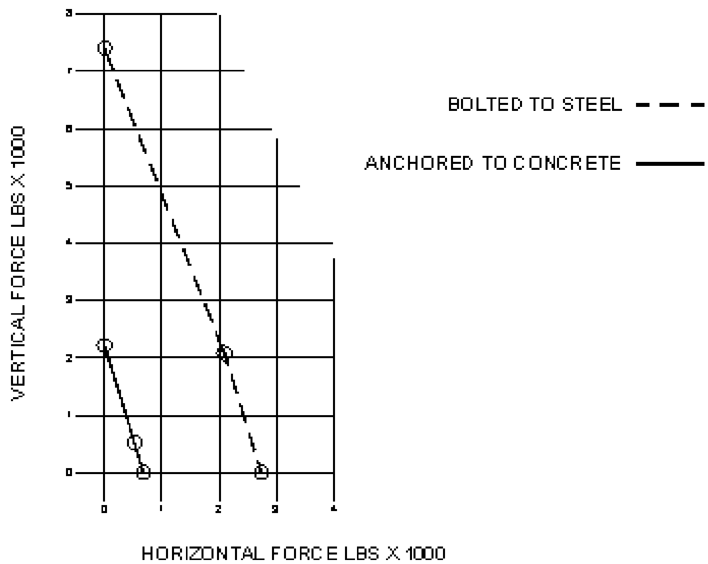
In addition, not all components are intended to be anchored to concrete. If it is not appropriate for the given component, no associated curve will be published for it.

A typical set of curves is shown below.

Figure D4.4-1; Restraint Capacity Chart



To use the diagram, the required capacity at the various restraint (or attachment) points for the application must be known (or computed). There are a number of ways to obtain these values. Some of these can be fairly simple but give very conservative values. Some are more complicated, but may substantiate the use of lower capacity attachment hardware. As part of a standard seismic analysis for given piece of equipment, Kinetics Noise Control provides these values for particular applications. The ASHRAE Handbook offers guidance on alternate ways of computing these forces and there could well be other ways to do it that result in reasonable answers.

Some caution must be exercised though, as it is not as simple as dividing the total seismic force by the number or isolators to get a force per isolator (See also Section D1.3 of this manual).

Once the vertical and horizontal restraint capacity necessary has been determined using ASD design practices, these values should be plotted on the diagram using the vertical force component for the y-variable and the horizontal force component for the x-variable. Shown below is a diagram with capacity requirement of 3500 lb vertical and 750 lb horizontal plotted on it. For our purposes, we will assume that the parameters used to calculate these values are "through bolted" parameters. (When using these charts, because the actual computed load requirement can vary depending on whether the final connection is to steel or concrete, it is critical to ensure that the load requirement used is appropriate to the anchorage type being

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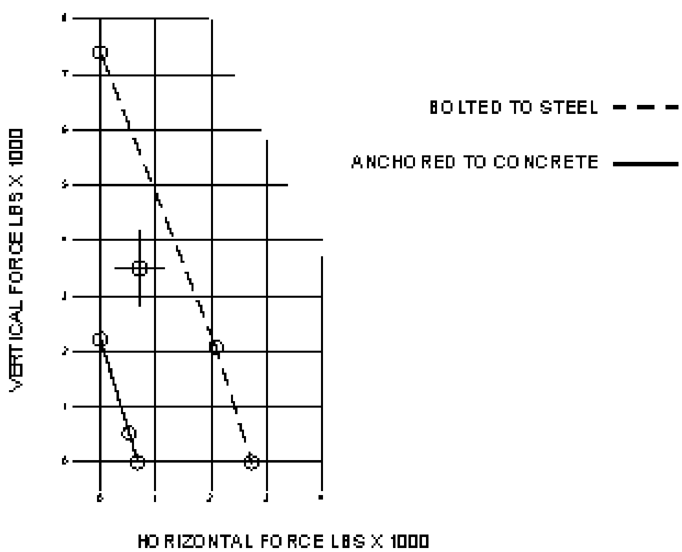
considered. [Concrete anchorage forces compares to concrete allowables and through bolted forces compare to bolted allowables])

Note that the point falls between the "Anchored to Concrete" and "Bolted to Steel" curves. Because the point is inside the "Bolted to Steel" curve, this indicates two things. 1) The restraint itself is adequate for the application and, 2) if the application involves through bolting the restraint to the structure, the restraint can be successfully applied "as is".

If the point had fallen outside of the "Bolted to Steel" curve, the restraint device would have been inadequate in size for the application and a restraint with higher capacity would have to be selected.

If the force had been computed using "Anchored to Concrete" parameters, because the point falls outside of the anchored to concrete curve, it indicates that if connecting to concrete using post installed anchors, the restraint cannot be used "as is". Since it does fall inside the "Bolted to Steel" curve however, it indicates that it could be fitted with an oversized baseplate and more (or larger) anchor bolts. If this oversized baseplate is sized to resist these forces, it offers a viable attachment option. Details on selecting an adequate oversized baseplates can be found in the Floor and Wall Mounted Equipment Chapter, Section D5.2.

Figure D4.4-2; Restraint Capacity Chart with Load Point



If the point had fallen inside of the "Anchored to Concrete" curve, the restraint could have been used "as is" in the anchored to concrete application.

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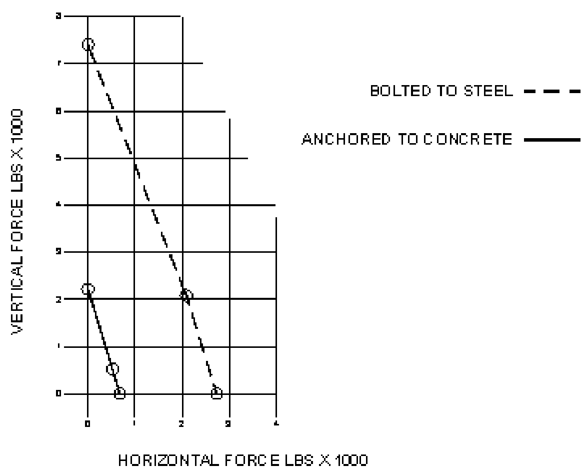
HORIZONTAL/VERTICAL SEISMIC LOAD CAPACITY ENVELOPES (VARIABLE)

All seismically rated restraints that resist both horizontal and vertical loads and that are provided by Kinetics Noise Control represent their seismic capacity with an ASD Based load envelope diagram as indicated in the previous section. In some cases involving combined isolation and restraint devices however, the supported load can significantly impact the lateral, vertical or combined capacity. This requires the creation of a special load diagram appropriate to the specific load being supported.

Once developed, the vertical axis of the diagram indicates the vertical capacity of the restraint and the horizontal axis of the diagram is the horizontal capacity of the restraint in the same manner as does the "Constant" load capacity envelope. (See also D4.2)

Figure D4.3-1; Typical "Constant" capacity Envelope

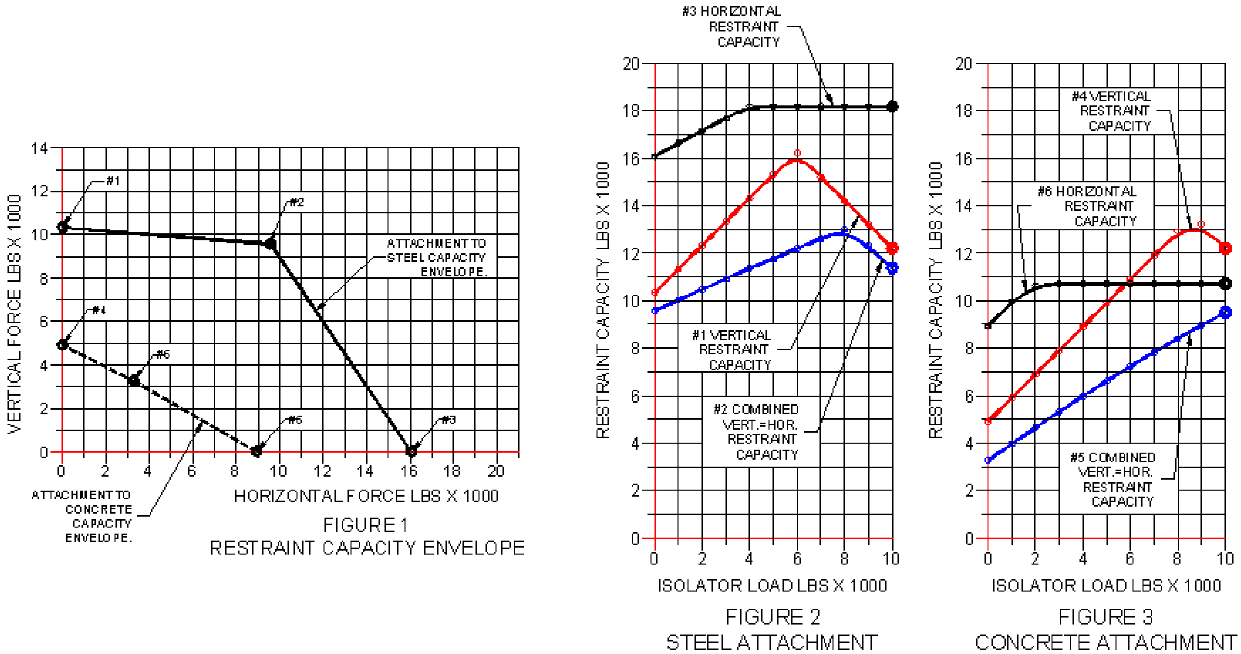


In general, when working with a restraint that has "Variable" load capacity, increases in the supported load will make restraints more stable (and resistant to lateral loads) and will increase the applied force necessary to overcome gravity forces (and increase their effectiveness in dealing with uplift loads).

If the seismically rated isolator, however, is designed with a cantilever element that transfers the load from both the spring and the snubber to the supported piece of equipment, the actual stress in the component is the resultant of these two factors. As the supported load increases, the maximum restraint load will decrease and vice versa. This relationship is typically linear and needs to be taken into account when sizing the restraint component.

If the restraint being used is of the "Variable" capacity type, it will be obvious from the load envelopes provided. Instead of the single graph illustrating the "Constant" capacity curve as shown above, there will be 3 separate graphs as shown below.

Figure D4.3-2; Typical "Variable" capacity Envelope



It should be noted on the Variable load envelope set of graphs, that Figure 1 (the one on the left) is similar to the graph for the "Constant" capacity case. This envelope represents the capacity of the restraint if it does not support any weight. (When it is used as a restraint only and not as an isolator.)

If the restraint bears weight, a new envelope must be created. This is accomplished using the following procedure:

1)To generate the seismic restraint capacity envelope for a particular load condition, first determine the static load on the isolator element.

2)Refer to Figure 2 or 3 depending on whether the restraint is to be through-bolted (Steel Attachment) or anchored to concrete (Concrete attachment). Locate the above static load on the "X" axis and determine the horizontal restraint capacity rating by reading the intersecting "Y" axis value from the appropriate curve (#3 or #6).

3)Plot this point on the horizontal axis of the restraint envelope graph.

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4)Similarly determine and plot the vertical restraint rating drawn from curve #1 or #4 on the vertical axis of the restraint envelope graph.

5)Repeat for the combined rating (curve #2 or #5) and plot it at the location where both the vertical and horizontal force equal this value.

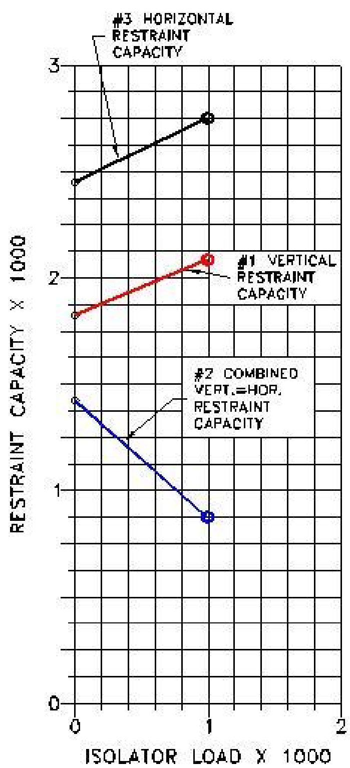
6)Connect the above points to generate the performance envelope for the restraint under the particular load condition.

Example

Assume we have a seismically rated restraint that supports 600 lb and we want to derive a restraint capacity curve for it.

Using the sample graph below, we can see that the horizontal capacity with a 600 lb support load is 2650 lb (Curve #3), The vertical capacity is 2000 lb (Curve #1) and the combined capacity is 1100 (Curve #2).

Figure D4.3-3; Sample Graph



Plotting these values on the Restraint Capacity Envelope curve, we produce a curve that looks like the dashed line shown on the following page.

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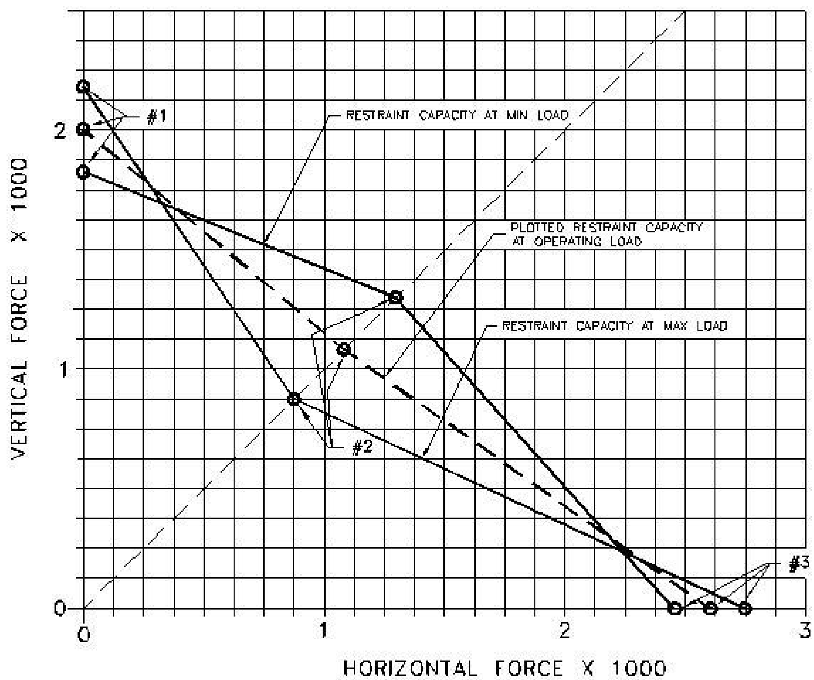
Also shown on this diagram is the unloaded restraint curve and added is a curve indicating the capacity for this particular restraint if it were to be loaded to the maximum (1000 lb.)

At this point, the curve can be applied in the same manner as the constant capacity envelope addressed in the previous section of the manual.

Figure D4.3-4; Generated Seismic Load Capacity Envelope



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QuakeLoc SEISMIC SWAY BRACING SYSTEM

D4.4.1 - Introduction

The Kinetics QuakeLoc seismic sway bracing system is a tension only bracing system designed to maintain the position of non-structural components to the structure during seismic events. QuakeLoc cable assemblies are mounted in opposing pairs to resist horizontal forces applied to non-structural components. These cable pairs mount both longitudinally and transversely to the components to maintain the components position in all directions.

QuakeLoc bracing systems designed per these guidelines do not guarantee adequacy of the existing structures to withstand the loads induced by the seismic attachments. It is the responsibility of the structural engineer or record to verify that the structure is capable of resisting any and all loads added to the structure as a result of the use of the QuakeLoc sway bracing system. The project engineer and installer shall determine the placement and installation of braces according to these guidelines and in compliance with all applicable codes.

This bracing system is intended for use on internal building components only. The QuakeLoc system is not intended as a sway brace for fire sprinkler system piping. Loads restrained are limited to seismic loads and do not include loads due to wind, thermal expansion, pressure, fluid dynamics, etc.

D4.4.2 - Restraint Spacing Rules

Rule 1. Typical seismic restraint spacing for transverse and longitudinal restraints are listed in table D4.4.2-1 below.

Typical Seismic Restraint Spacing, Table D4.4.2-1

TYPICAL SEISMIC RESTRAINT SPACING		
TRANSVERSE SEISMIC RESTRAINT SPACING S_T (FT.)	LONGITUDINAL SEISMIC RESTRAINT SPACING $\boldsymbol{S_L}$ (FT.)	COMMENTS ON MAXIMUM ALLOWABLE RESTRAINT SPACINGS
10	10	Maximum Allowable Spacing for Low Deformability (Brittle) Piping.
10	20	Other Optional Spacing Used to Extend the Useful Range of Application for Specific Restraints.
15	30	

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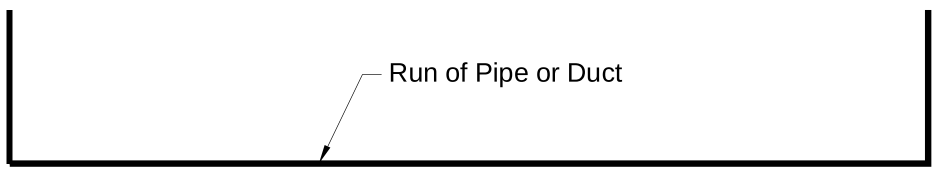
20	40	Maximum Allowable Restraint Spacing for Hazardous Gas Piping.
30	60	Maximum Allowable Restraint Spacing for Ductwork.
40	80	Maximum Allowable Restraint Spacing for HVAC & Plumbing Piping.

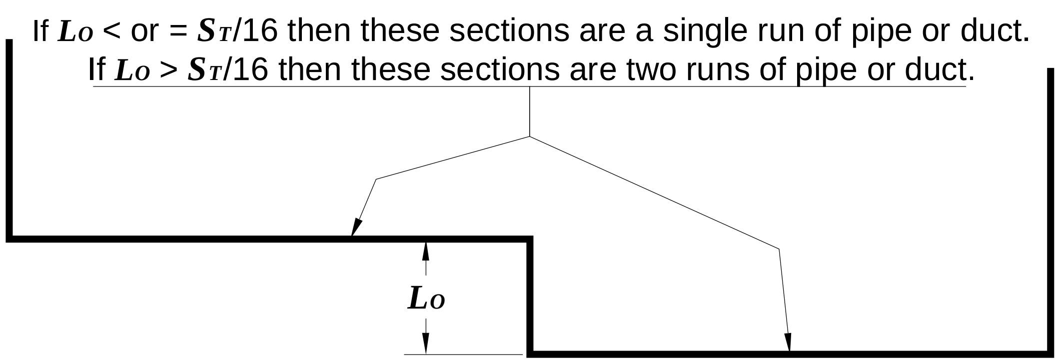
Rule 2. Seismic restraint spacings are to be applied to nominally straight sections of pipe or duct between bends called runs. . Each run will have two transverse and one longitudinal restraint, however if the run length is less than half the maximum transverse restraint spacing, only one transverse would be required.

Definition of a "Run" of Pipe or Duct, Figure D4.4.2-1



Rule 3. A run of pipe or duct may include a jog of less than 1/16 of the maximum allowable transverse seismic restraint spacing for the pipe or duct being restrained. A jog is a short offset in the run of pipe or duct. See figure D4.4.2-2 below. If the jog is greater than 1/16 of the maximum allowable transverse seismic restraint spacing, then the jog as well as the two primary sections of the run must be treated as independent pipe or duct runs. (for example, if $S_T = 40\,ft$ the $L_o \leq 40/16 = 2.5\,ft = 30in$)

Permissible Jog in a "Run" of Pipe or Duct, Figure D4.4.2-2



RULE 4. General longitudinal seismic restraint spacing (S_L) rules:

a. See table D4.4.2-1 for maximum seismic restraint spacing.

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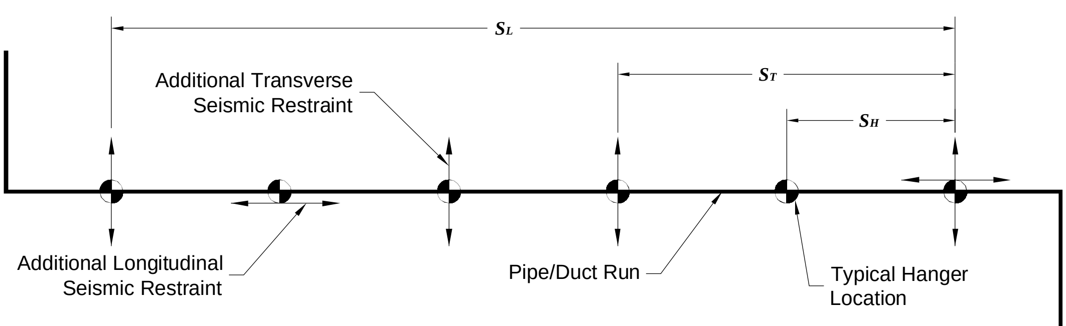
b. Maximum longitudinal seismic restraint spacing, S_L, should not exceed twice the maximum allowable transverse seismic restraint spacing, $S_L \le 2S_T$, unless independently analyzed by a qualified individual.
c. If the run length is greater than the maximum longitudinal seismic restraint spacing, additional longitudinal restraints may be required to reduce the distance between longitudinal restraints to be equal to or less than the maximum spacing for longitudinal restraints.
d. Longitudinal seismic restraints maybe placed anywhere along the run, but must be within 4in of a pipe or duct hanger location.
e. Longitudinal restraints shall be mounted +/- 10° to the longitudinal axis of component.

RULE 5. General transverse seismic restraint spacing (S_T) rules:

a. See table D4.4.2-1 for maximum seismic restraint spacing.
b. Transverse seismic restraints are to be located at or with in 4in of pipe or duct hanger location.
c. If run is over half the maximum allowable transverse seismic restraint spacing and less than or equal to the maximum allowable transverse seismic restraint spacing in length, each straight run of pipe or duct must have a transverse seismic restraint at each end of the run.
d. If the run is longer than the maximum allowable for transverse seismic restraints, additional transverse seismic must be added until the distance between transverse seismic restraints is less than the maximum.
e. If the run is under half of the maximum allowable spacing for transverse seismic restraint, only one transverse seismic restraint is required anywhere along the run.
f. Transverse restraint to be mounted perpendicular to the component within +/- 10°

Maximum Restraint Spacing, Figure D4.4.2-3



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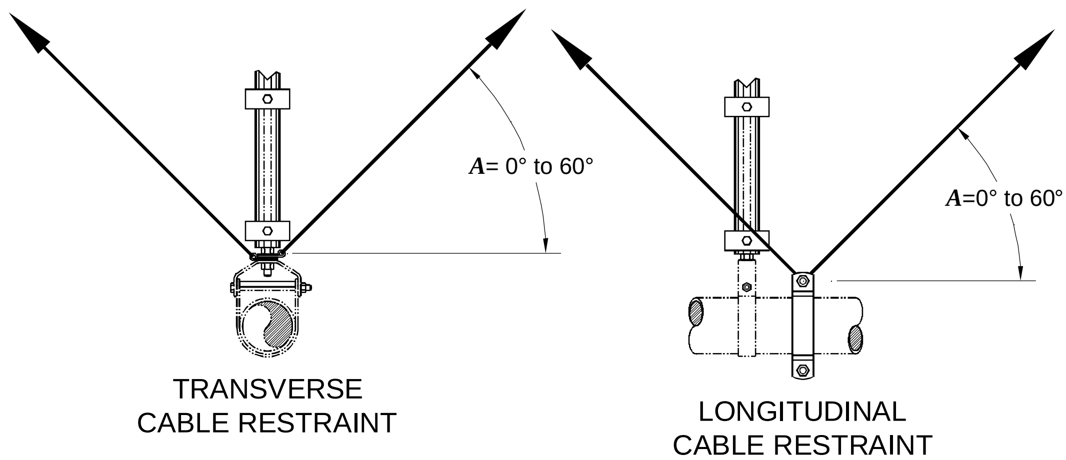
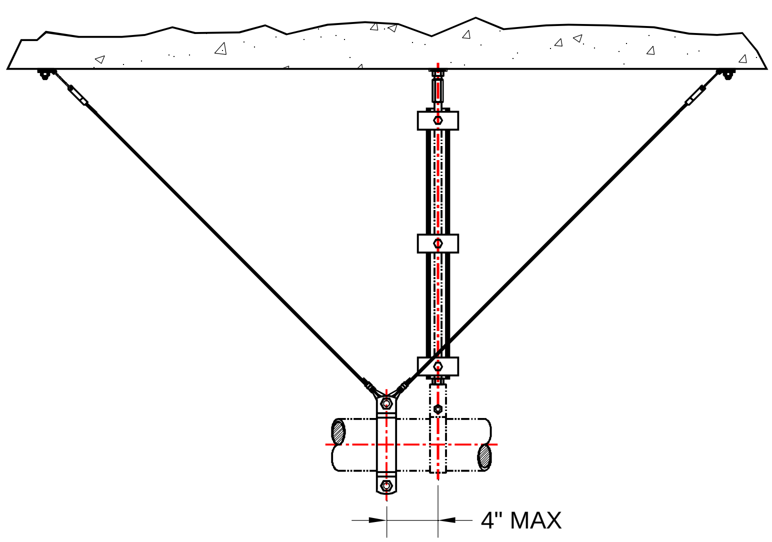
Rule 6. For QuakeKit cable restraints, the installation angle A may be between 0° and 60° as measured from the horizontal. See figure D4.4.2-4.

Permitted Range of Restraint Cable Installation Angles, Figure D4.4.2-4



Rule 7. Longitudinal seismic restraints for single clevis hung pipe must be attached directly to the pipe in a manner similar to that shown in figures D4.4.2-5 and D4.4.2-6. The seismic restraints maybe attached to the pipe using a pipe clamp as shown in figure D4.4.2-5.

Longitudinal Restraint Connection Overview, Figure D4.4.2-5



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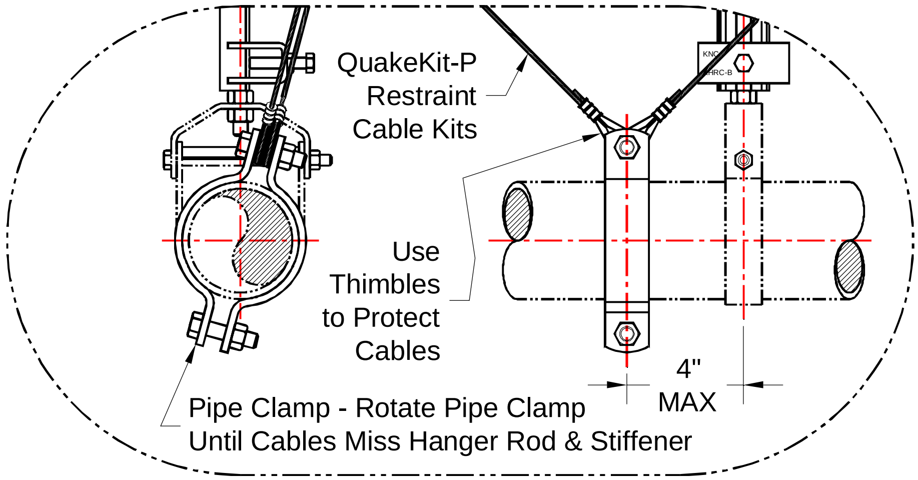
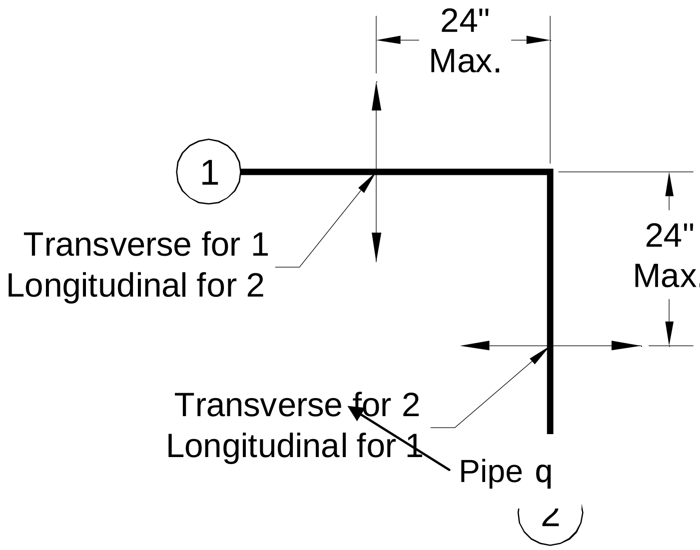
Longitudinal Restraint Connection Detail, Figure D4.4.2-6



Rule 8. Where smaller pipes branch off from larger pipes, the seismic restraints on the smaller pipe **cannot** be used as seismic restraints for the larger pipe.

Rule 9. Transverse seismic restraints located within 24in of a 90° bend can serve as the longitudinal restraint for the other leg.

Corner Restraints Doing "Double Duty", Figure D4.4.2-7



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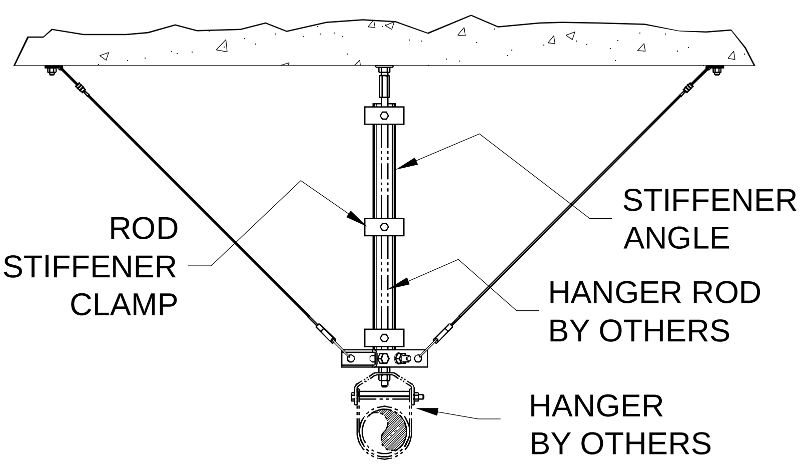
Rule 10. The hanger rods used at seismic restraint locations must be a rigid member, such as all-thread rod capable of resisting compressive loads without buckling. Spring isolated hangers are permitted as long as they comply with Rule #12.

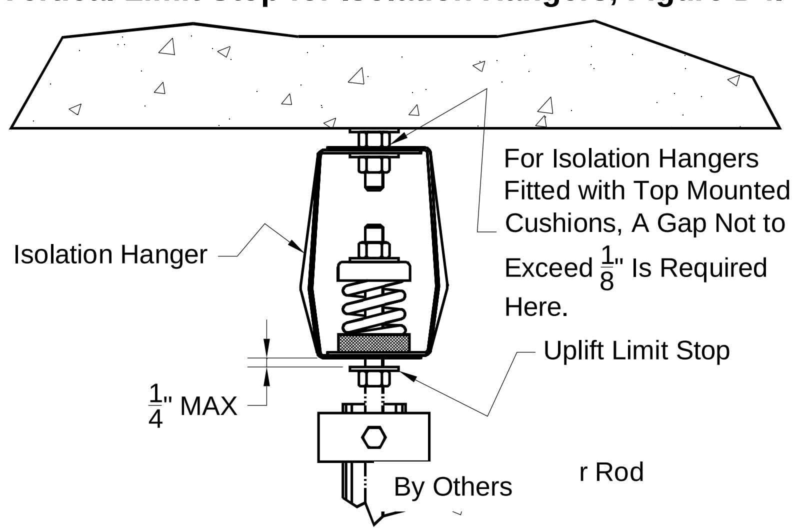
Rule 11. For hanger rods which are long or small in diameter, rod stiffeners may need to be added to prevent buckling. If deemed necessary, only the hanger rod at or near the seismic restraint locations will require stiffeners. No stiffeners are required on hangers used purely for support.

Rod Stiffener, Figure D4.4.2-8



Rule 12. For isolated pipe or duct, the hanger rods at seismic restraint locations must be located close to structure and be fitted with uplift limit stops as shown in figure D4.4.2-9 to allow the compressive reaction loads to be transferred to the building structure.

Vertical Limit Stop for Isolation Hangers, Figure D4.4.2-9



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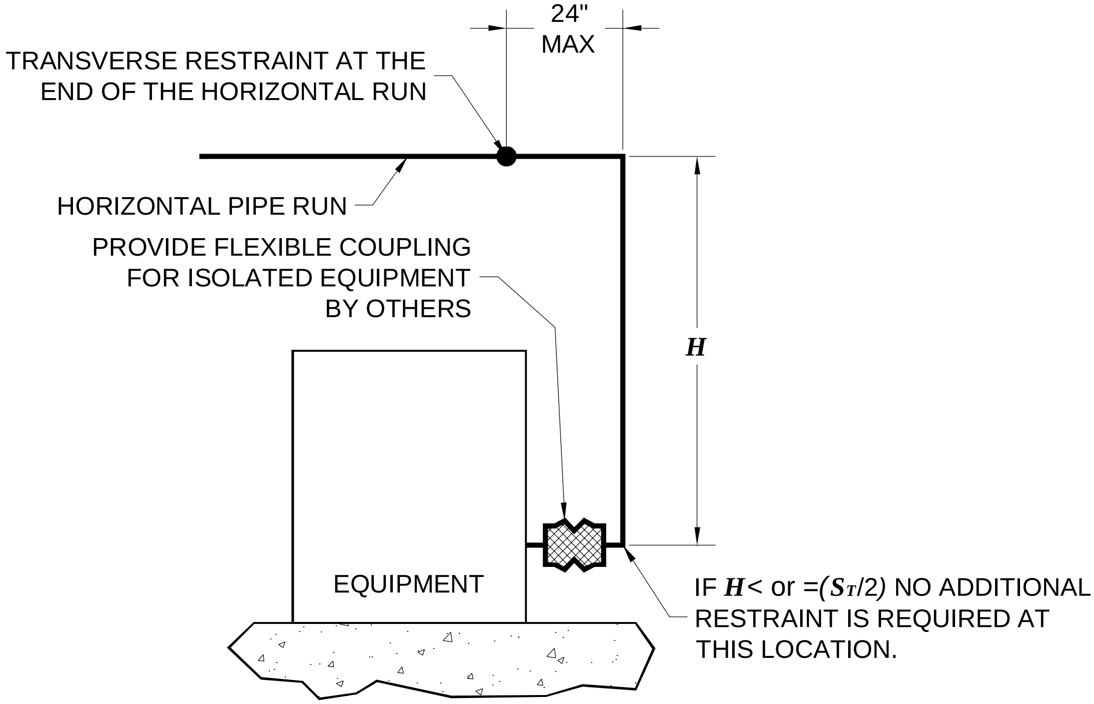
Rule 13. For vertical drops to equipment a flexible coupling will be required to account for relative motion between the piping and the equipment. If the pipe or duct drop is less or equal to half of the transverse seismic restraint spacing, $H \le S_T / 2$, seismic restraints are not required for the drop, provided that there is a transverse seismic restraint within 24" of the top elbow of the drop. If, however, the drop is greater than half the transverse seismic restraint spacing, the bottom of the drop will need to be restrained to structure with a "4-way" restraint to limit horizontal movement in all directions.

Drops and Restraints for Piping/Ducts under S_T/2 in Length, Figure D4.4.2-10



Rule 14. For code based exemptions to these rules refer to **ASCE/SE 7-10 section 13**.

The example below shows a portion of a cold water piping system with seismic restraints applied. The table lists the pipe run, length of the run based on maximum allowable restraint spacing and the rules that apply to the application of seismic restraints for that run of pipe.

Typical Application Example, Table D4.4.2-2

Run	Run Length based on max spacing	Rule

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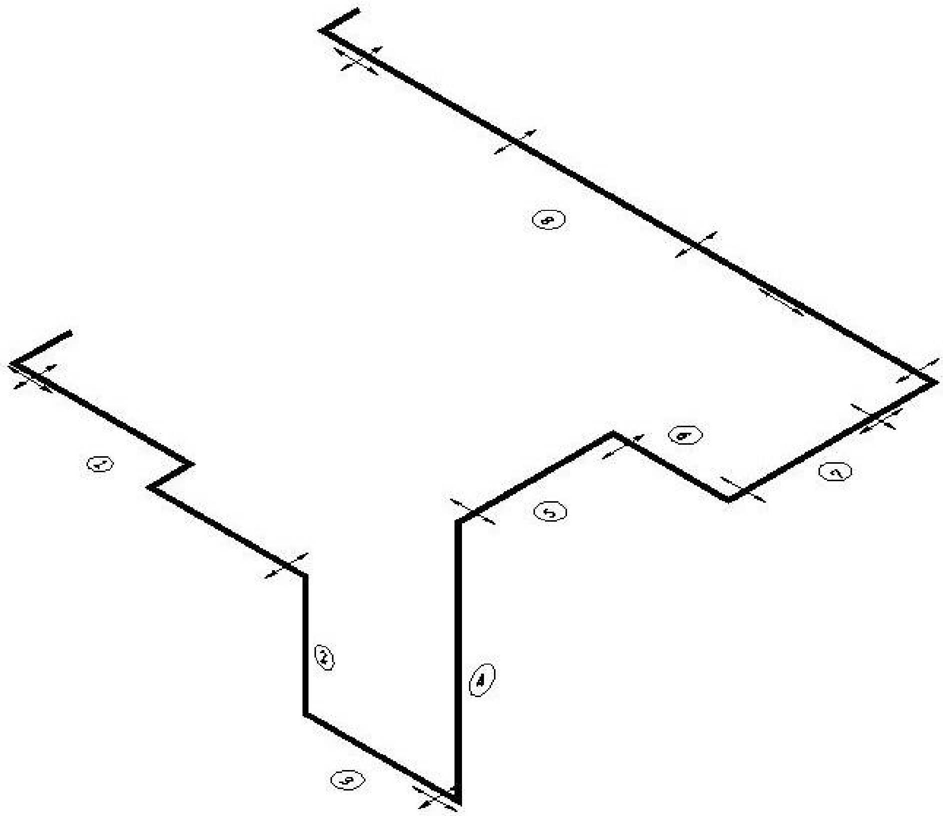
1	S_T	2,3,5c
2	$<S_T/2$	13
3	$<S_T/2$	2, 5e
4	$>S_T/2$	13
5	$<S_T/2$	2,5e,9
6	$S_T/16<$ run $< S_T/2$	3,9
7	$>S_T/2$	2, 5c
8	$> 2\ S_L$	4c, 5d

Application Example Sketch, Figure D4.4.2-11



D4.4.3 - Seismic Horizontal Force Factor

The horizontal force generated by pipes and ducts during a seismic event determines the size of the restraint required. The horizontal force can be calculated using the equation identified in

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Section D2.1.8 of this manual. For the purposes of this chapter, the equation can be re-written as:

$$G = \frac{0.4 a_p S_{DS} I_p}{R_p}\left(1 + 2\frac{z}{h}\right)$$

where all the factors that modify the component operating weight (W_p) can be combined into one factor (G). This variable (G) would be the factor applied to the operational weight which yields the horizontal seismic force factor. This resulting output force generated be this equation would yield an LRFD based value.

G shall be between the following limits

$$0.3 S_{DS} I_p \leq G \leq 1.6 S_{DS} I_p$$

Substituting G into the seismic horizontal force equation the equation becomes:

$$F_p = G W_p$$

D4.4.4 Restraint Cable Size and Anchorage Selection Procedure

1. Determine restraint spacing for transverse and longitudinal restraints in accordance to spacing rules section D4.4.2.

2. Determine the weight per foot of pipe or duct being restrained. This weight includes weight of content, insulation, lining, etc in addition to the pipe or duct weight. The weight per foot of individually supported, water filled, insulated standard pipe is identified on the graph directly. For multiple components on a trapeze, the weights of all components must be summed.

3. Select the appropriate "Maximum Cable and Anchor Capacities" graph from figures D4.4.4-1 through D4.4.4-6. Based on the structural attachment condition.

4. Using the appropriate "Maximum Cable and Anchor Capacities" graph, find the weight being restrained associated with the restraint being evaluated.

    A. For single supported pipe or duct.

        a. Determine the length of the span of pipe or duct that will be restrained by the restraint of interest. This is typically the restraint spacing.

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b. Find the restraint span as indicated above on the lower vertical axis of the graph*.

c. Project a horizontal line to intersect with the diagonal line* for the weight per foot being restrained from step 2.

d. From this point, project a vertical line up to the left horizontal axis to find the weight restrained by the restraint being evaluated.

B. For trapeze hangers.

a. Determine the length of the span of pipe or duct that will be restrained by the restraint of interest. This is typically the restraint spacing.

b. Find the restraint span as indicated above on the lower vertical axis of the graph*.

c. Project a horizontal line to intersect with the diagonal line* for the total weight per foot of the items being supported on the trapeze from step 2.

d. From this point, project a vertical line up to the left horizontal axis to find the total weight being restrained on the trapeze restraint being evaluated.

5. Determine horizontal seismic force.

A. Project a line vertically upward into the left quadrant of the graph from the weight found above to the required G factor diagonal line* determined in section D4.4.3.

B. From this point project horizontally to the upper vertical axis to find the horizontal seismic force on the restraint being evaluated.

6. Sizing cables and anchors

A. Project horizontal line from the seismic force axis into the upper right quadrant of the graph to the angle of installation*.

B. Cable and anchor sizes shown above this point are acceptable for this application.

* Linear interpolation is permitted

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C. If no acceptable anchors are found to be above the installation angle, seismic force point, the restraint span must be reduced. This is true even if a cable capacity is above the point listed.

D. If the point falls above a listed cable capacity, and below a listed anchor capacity, the capacity will be limited to that of the cable.

E. If no cable or anchor capacities are identified as being above the installation angle, seismic force point, the restraint span must be reduced.

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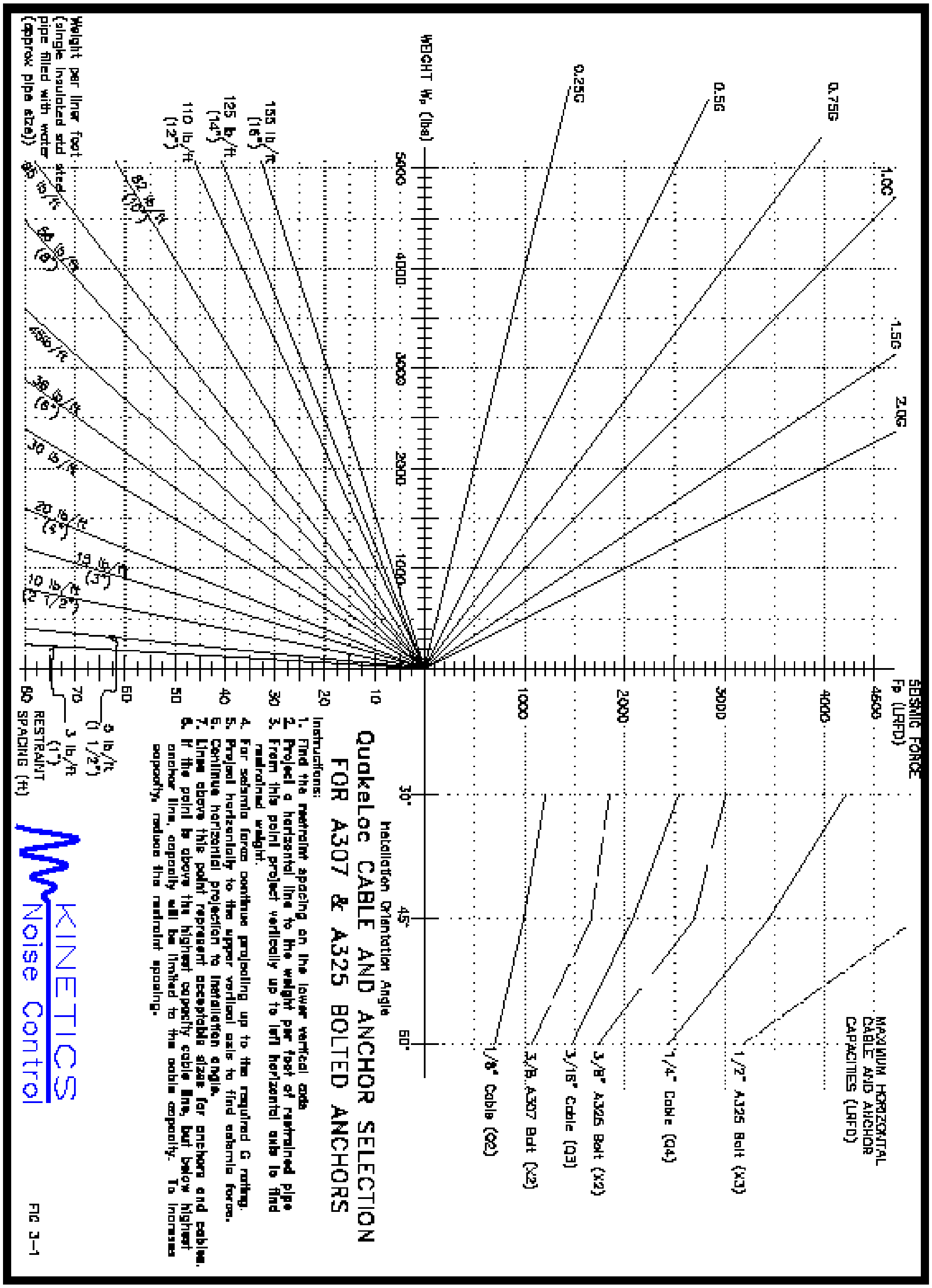
Through Bolt Selection Chart, Figure D4.4.4-1



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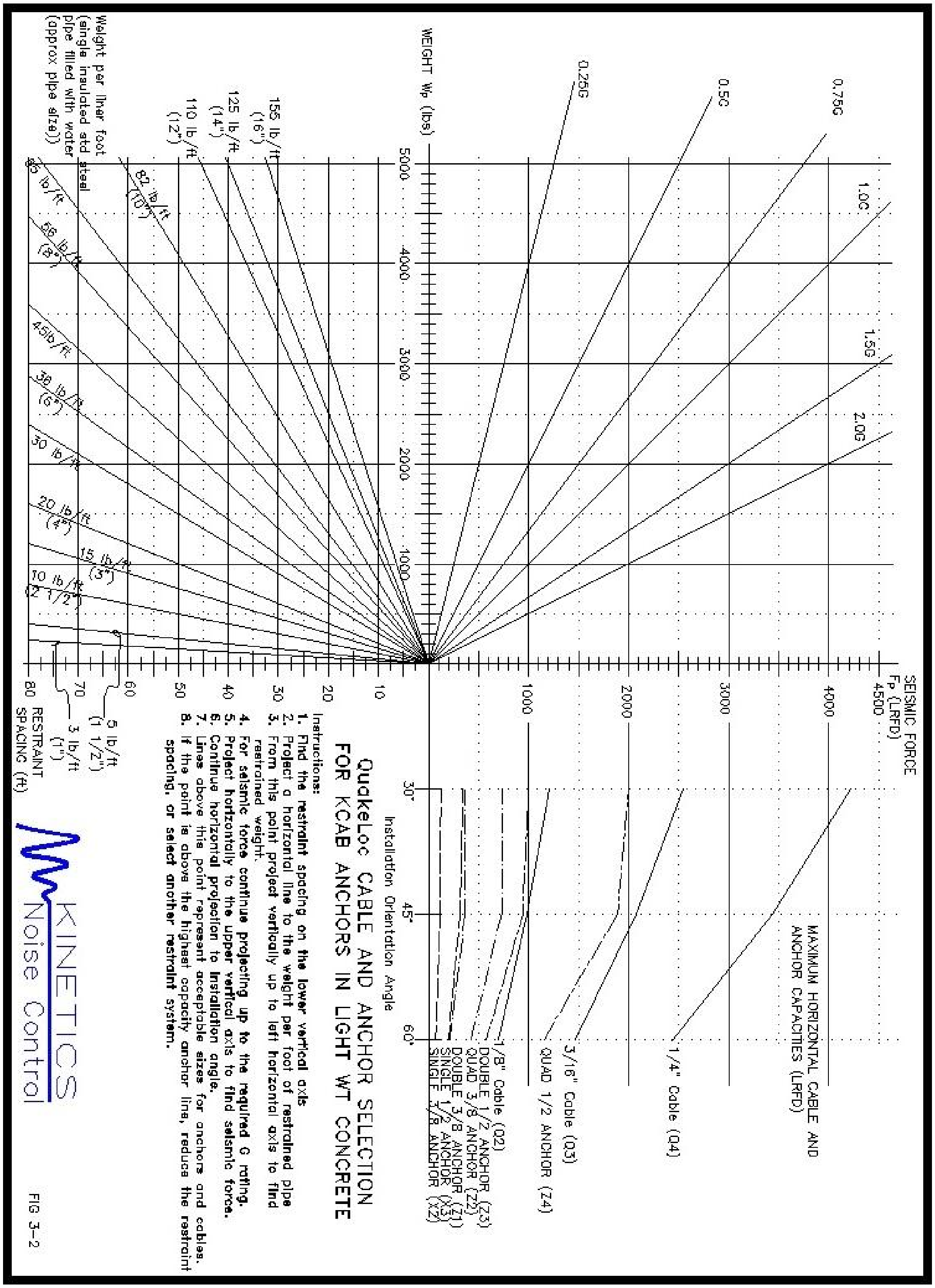
KCAB Anchors/Lightweight Concrete Selection Chart (Not IBC Compliant), Figure D4.4.4-2



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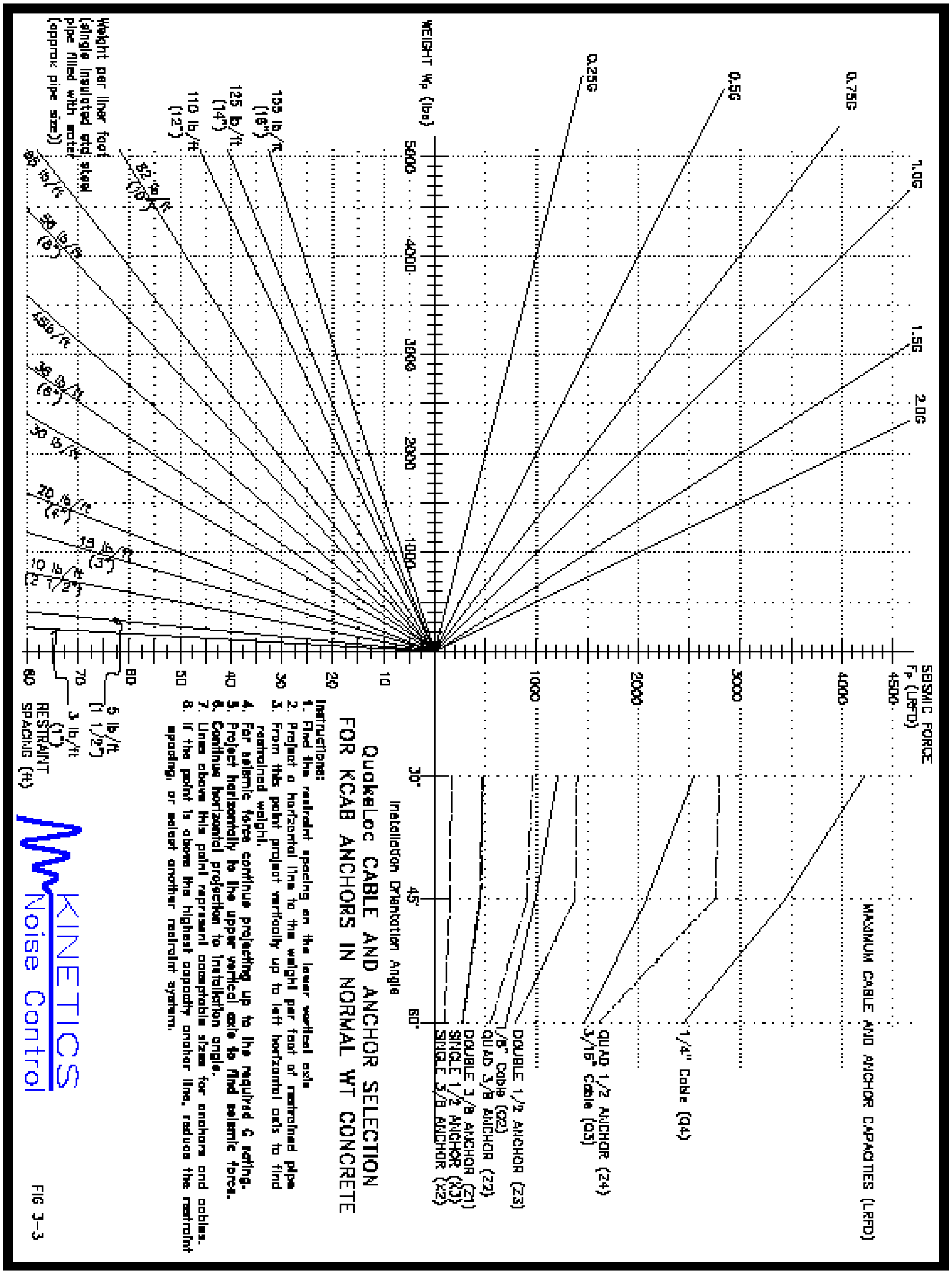
KCAB Anchors/Normal Weight Concrete Selection Chart (Not IBC Compliant), Figure D4.4.4-3



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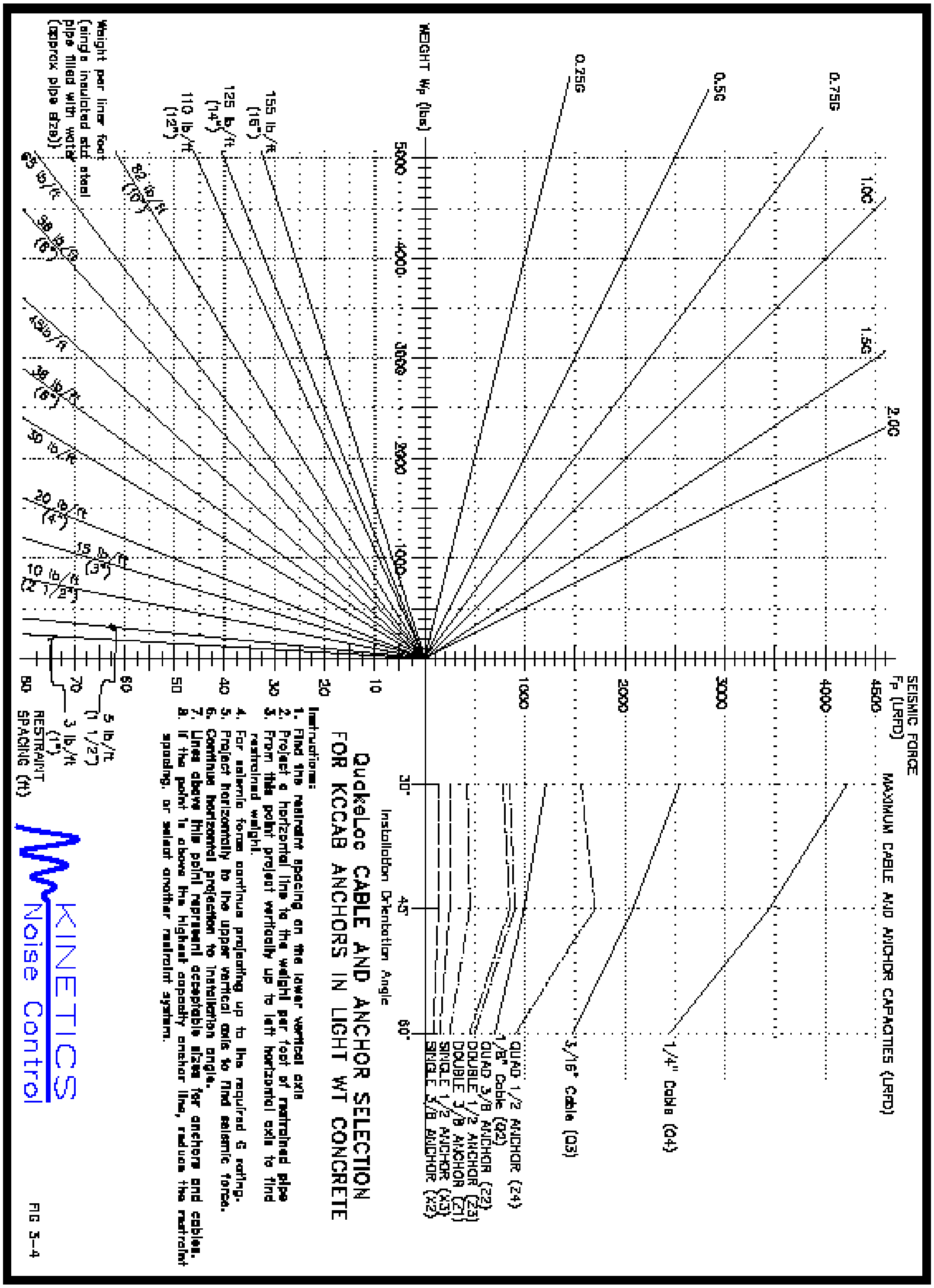
KCCAB Anchors/Lightweight Concrete Selection Chart, Figure D4.4.4-4



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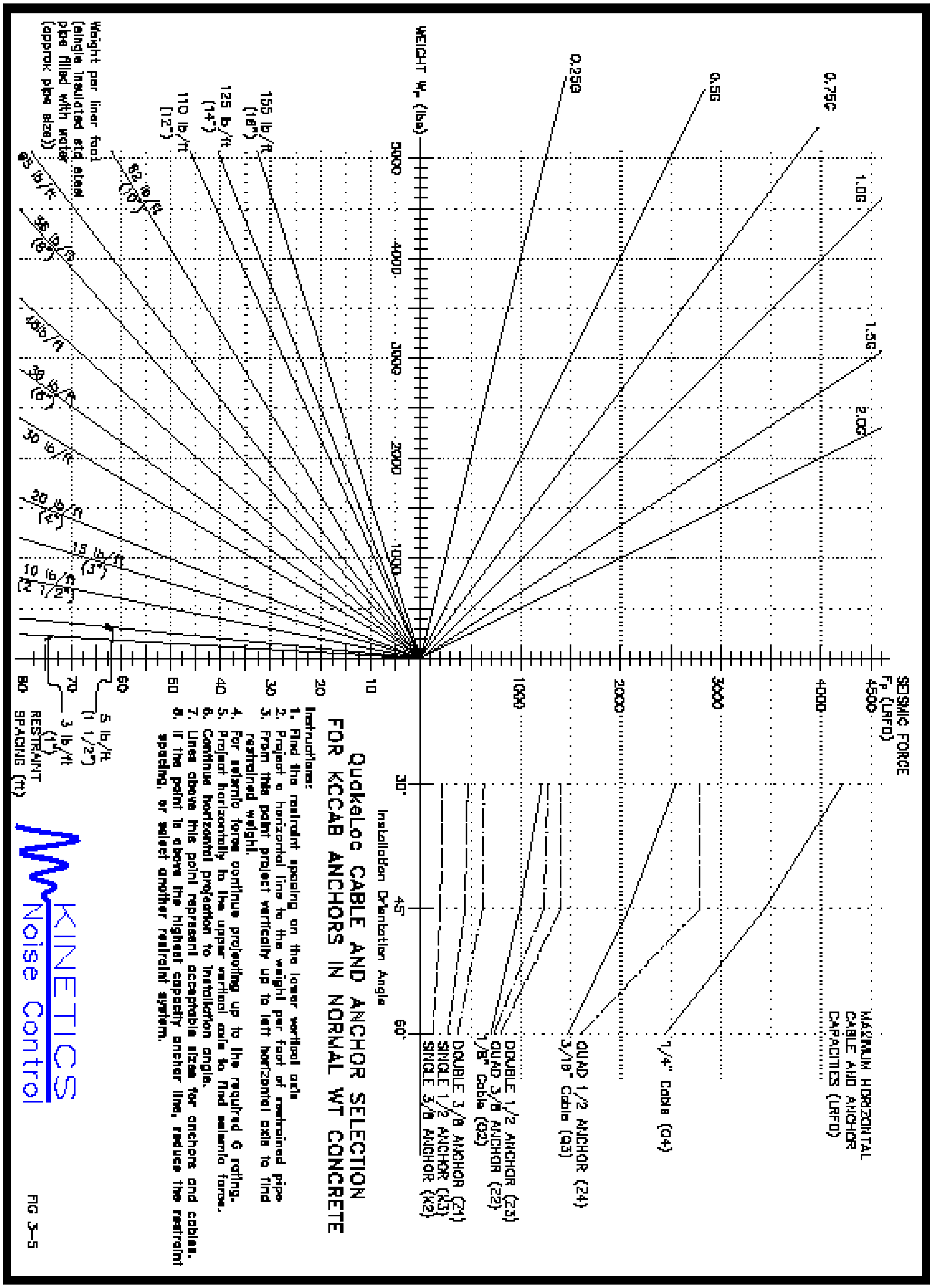
KCCAB Anchors/Normal weight Concrete Selection Chart, Figure D4.4.4-5



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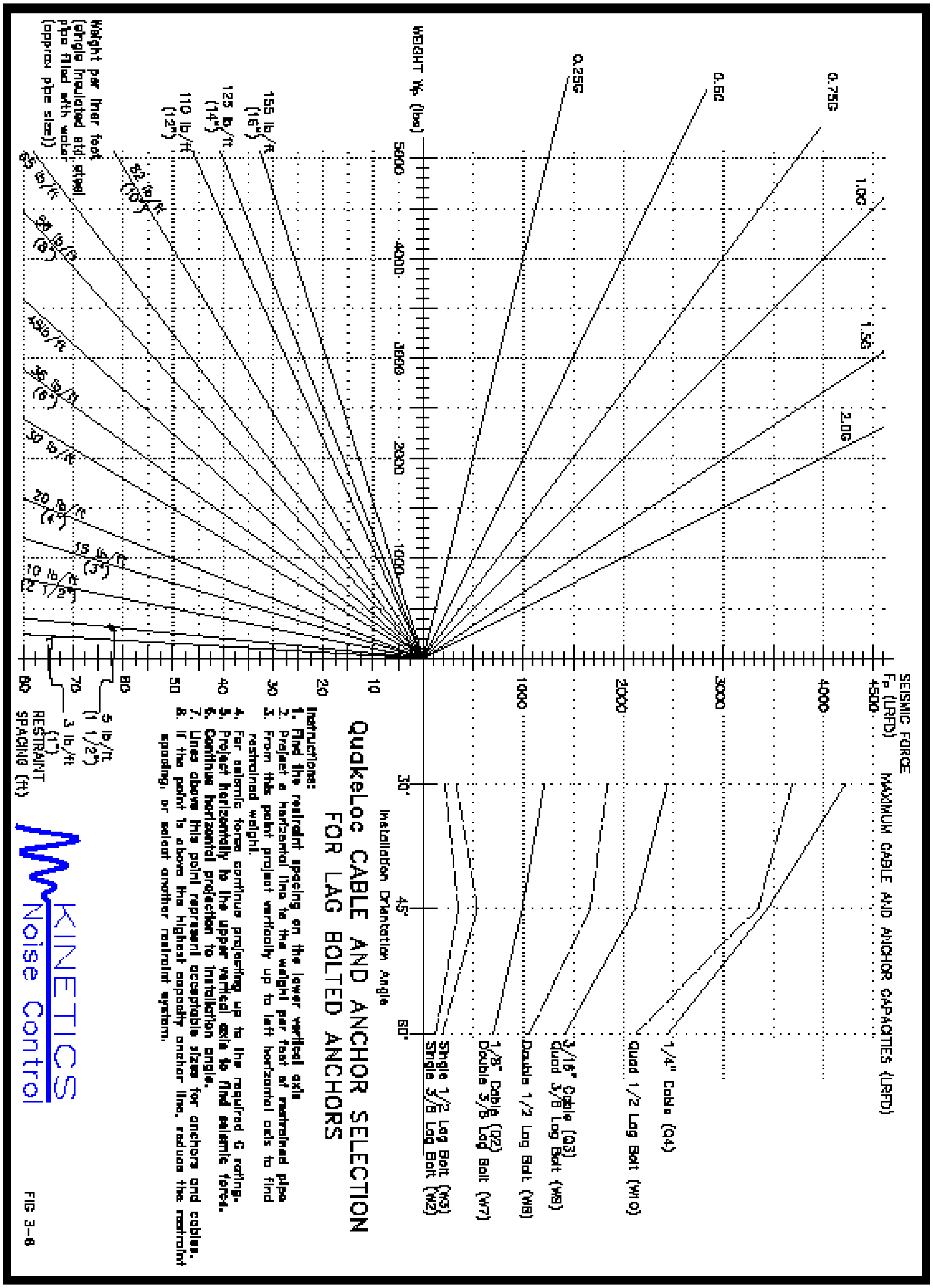
Lag Screw Attached Selection Chart, Figure D4.4.4-6



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D4.4.5 - Cable and Attachment Codes

The table below gives a reference for the codes used in the capacity graphs for cable selection. Q designates a QuakeLoc kit and the size of the cable. X designates either a single bolt or post installed concrete wedge anchor. Z's designate the use of a over-sized base plate with multiple post installed concrete wedge anchors. Finally, W's designate lag screws to be used for attachment to wood.

Cable Restraint Component Codes, Table D4.4.5-1

Code	Designation	Size
Q2	Quakekit	1/8" cable
Q3	Quakekit	3/16" cable
Q4	Quakekit	1/4" cable
X2	Bolt or Anchor	3/8"
X3	Bolt or Anchor	1/2"
Z1	Anchors	2x 3/8"
Z2	"	4x 3/8"
Z3	"	2x 1/2"
Z4	Anchors	4x 1/2"
W2	Lag Screw	3/8"
W3	"	1/2"
W7	"	2x 3/8"
W8	"	2x 1/2"
W9	"	4x 3/8"
W10	Lag Screw	4x 1/2"

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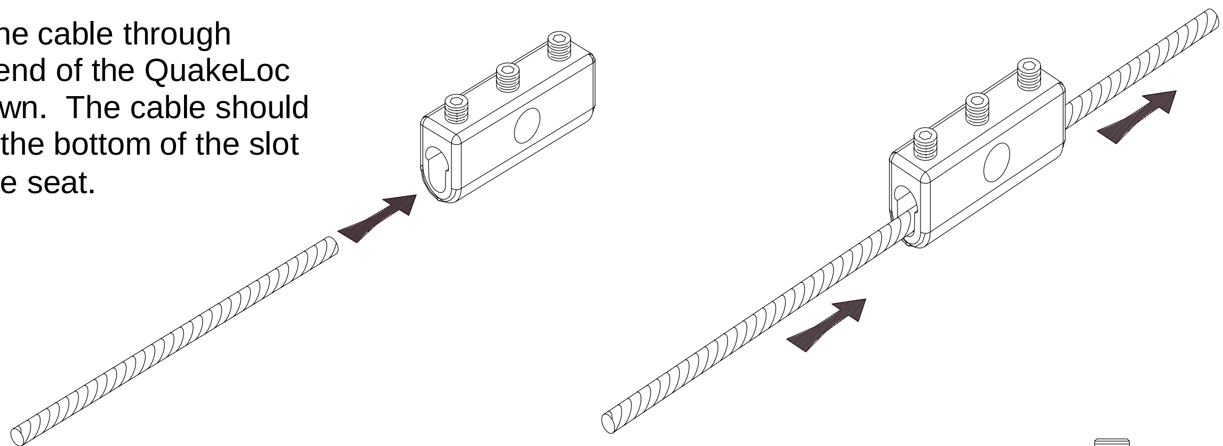
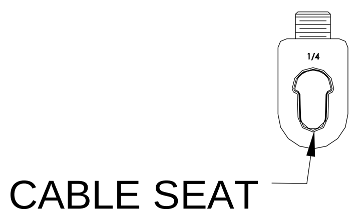
D4.4.6 QuakeLoc Assembly Procedure

Tools Required: Torque Wrench with Hex Bit Socket:
1/8” Hex (1/8” QuakeLoc), 5/32” Hex (3/16” QuakeLoc), 3/16” Hex (1/4” QuakeLoc).

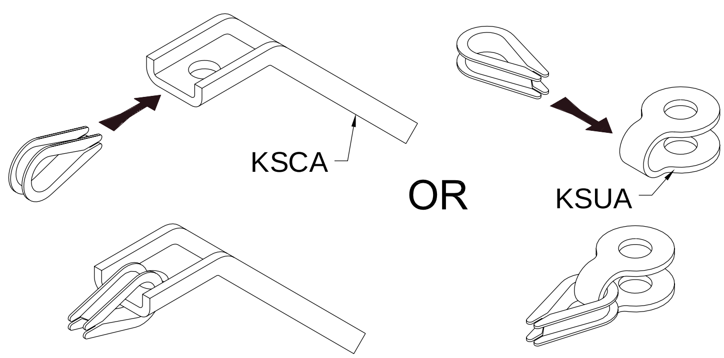
1) Feed the cable through either end of the QuakeLoc as shown. The cable should rest in the bottom of the slot or cable seat.





2) Place a cable thimble through the KSCA or KSUA attachment bracket.

QuakeKit-D cable restraint kits contain KSUA brackets only.



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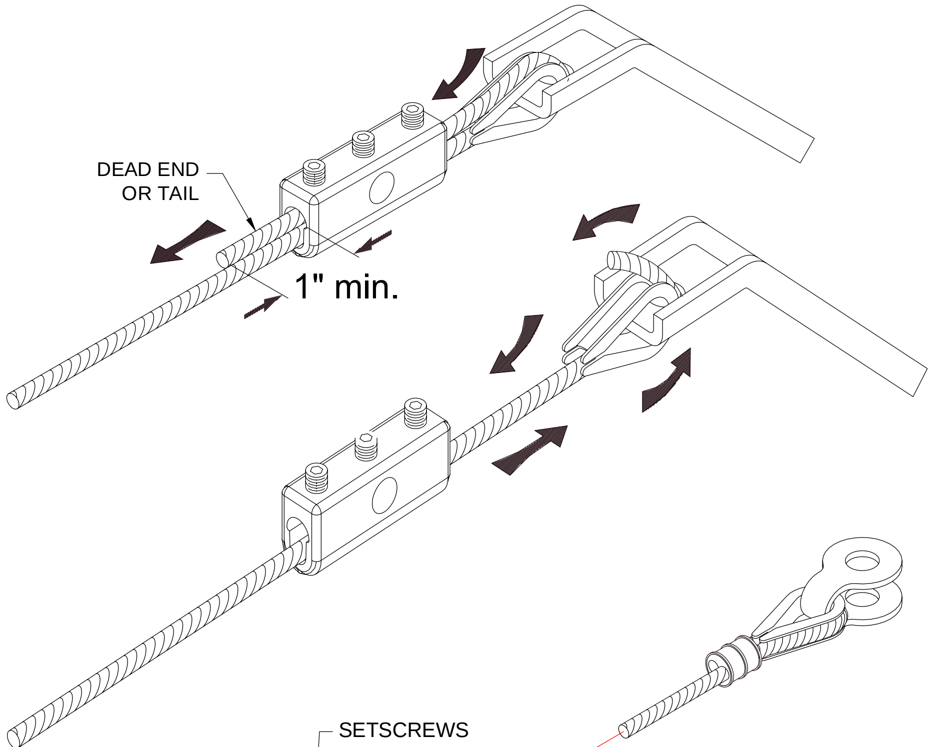
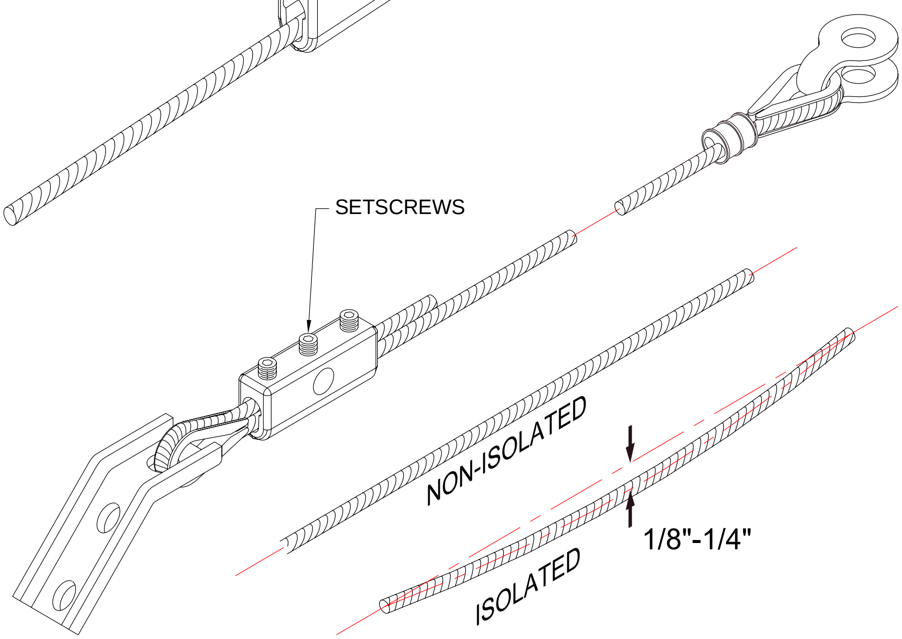
3) Loop cable through attachment bracket and thimble then feed back through the QuakeLoc so that setscrews compress the cable dead end. Bring QuakeLoc snug against thimble.



4) Remove slack from the cable. If isolated, the cables should be left slightly loose to prevent transfer of vibrations into the structure. (Slightly loose can be defined as having approx. 1/8" to 1/4" of visible sag in the cable. 1/8" for cable lengths under 2 ft and ¼" for longer cables.



5) Tighten all setscrews finger tight to hold cable in place.

6) Fully seat the setscrews by using a tool to torque the setscrews to the appropriate torque for the size of cable. Start with the setscrew closest to the loop, and work out to the "tail" end of cable.

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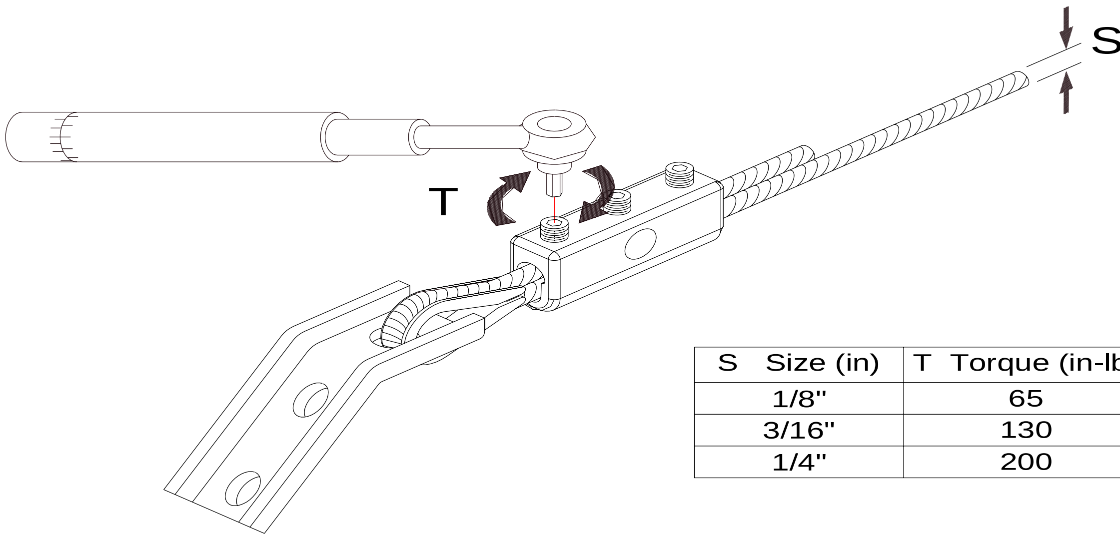

S Size (in)	T Torque (in-lb)
1/8"	65
3/16"	130
1/4"	200

(Top of screw will be slightly below top of housing when properly torqued)

7) Installation is now complete.

D4.4.7 – QuakeLoc Kit Attachment to Structure

D4.4.7.1 – KSCA Brackets – Basic Sizes & Installation:

The Kinetics Noise Control Model KSCA bracket was originally designed to be a part of a clamp assembly that would allow the restraint cables to be attached to hanger rods. However, over time, the KSCA bracket has proven to be useful for attaching the restraint cables to the building structure. The KSCA bracket as part of a bolted or anchored structural attachment is shown in Figures D4.4.7-1, D4.4.7-2, D4.4.7-3, D4.4.7-4 and D4.4.7-5. Notice in Figure D4.4.7-5, that the single hole beyond the bend is used for attaching the cable to the bracket. A thimble will be needed in this loop to prevent damage to the cable. A QuakeKit seismic restraint cable kit consists of two 1/8", 3/16" or ¼" restraint cables with a loop swaged on one end, two KSCA attachment brackets, two Kinetics provided end connectors, two Kinetics Model KSUA attachment brackets (which will be described in detail in the Section D4.4.9) and ½" mounting hardware. Prior to attaching restraints to the structure, the Engineer of Record should review the proposed method of attachment as well as the projected loads and grant his approval.

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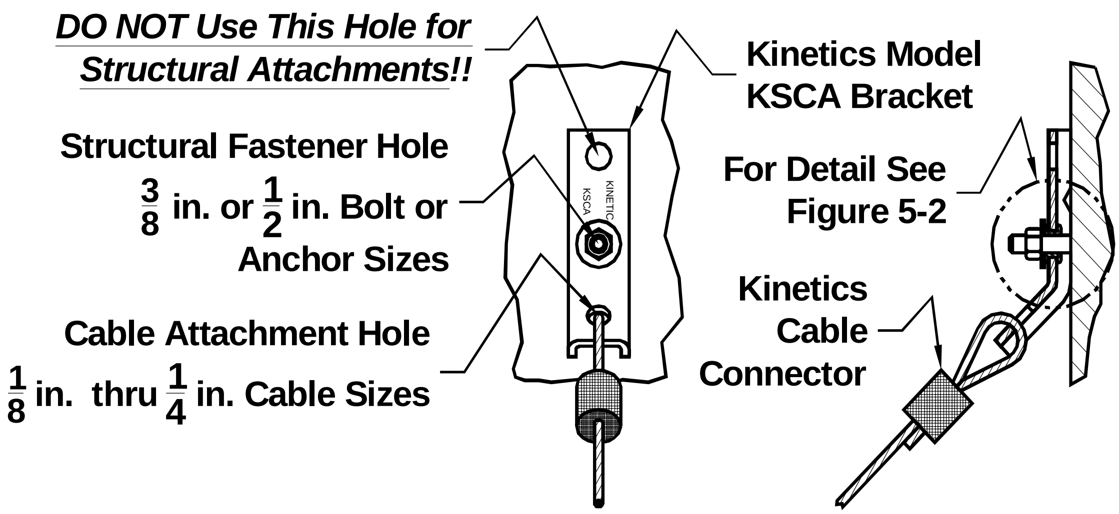
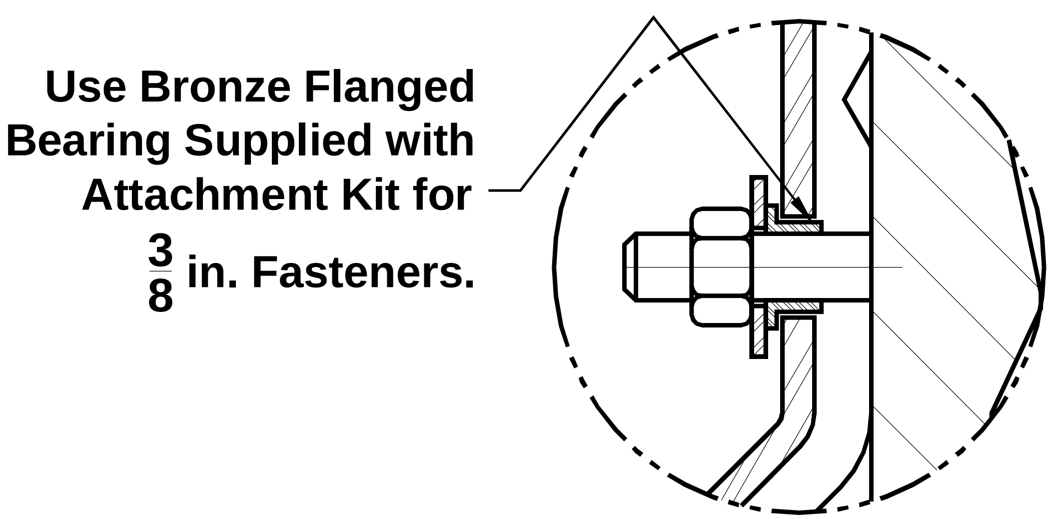
General Information on Attaching the KSCA Bracket to Structure, Figure D4.4.7-1



Detail of KSCA Bracket When Used with Smaller Bolts/Anchors, Figure D4.4.7-2



D4.4.7.2 – KSCA Brackets – Attachment to Steel:

KSCA brackets are most easily attached to structural steel by welding, see Figures D4.4.7-3 and D4.4.7-4. Figure D4.4.7-5 which shows the KSCA bracket attached to structural steel AISC W, M, S, or HP shapes without welding.

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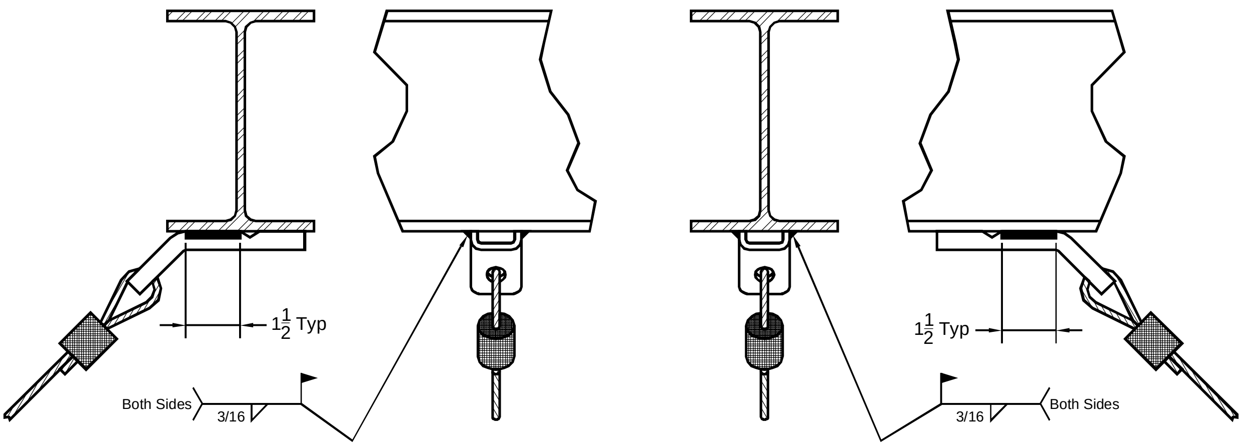
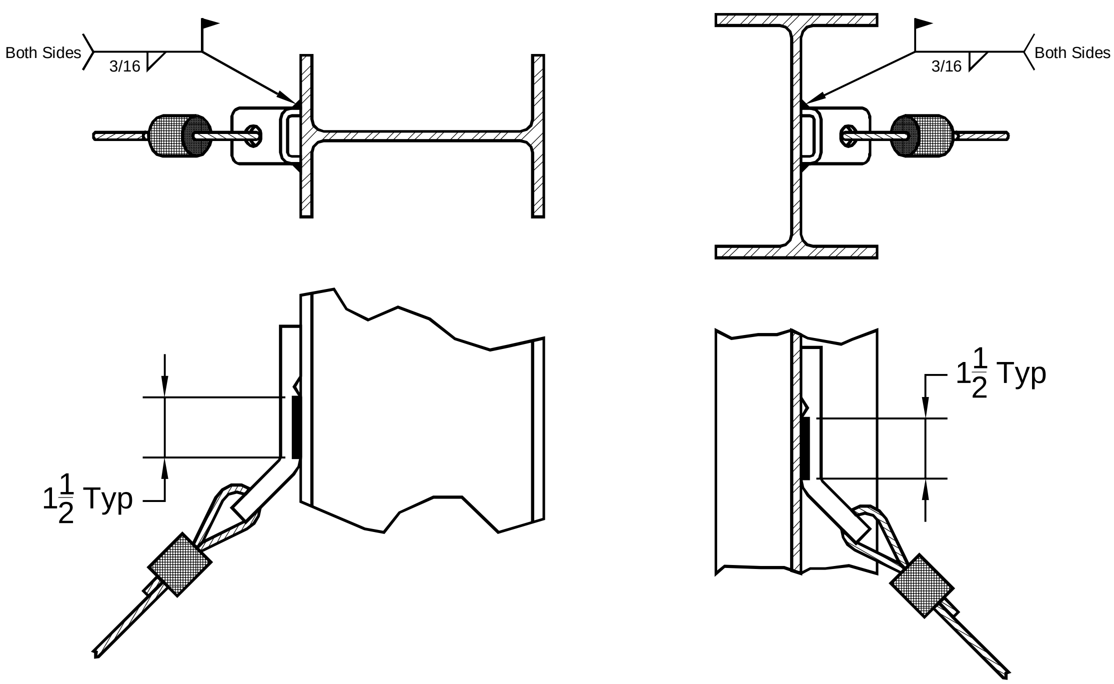
KSCA Bracket Attachment to Steel (Horizontal Orientation), Figure D4.4.7-3



KSCA Bracket Attachment to Steel (Vertical Orientation), Figure D4.4.7-4



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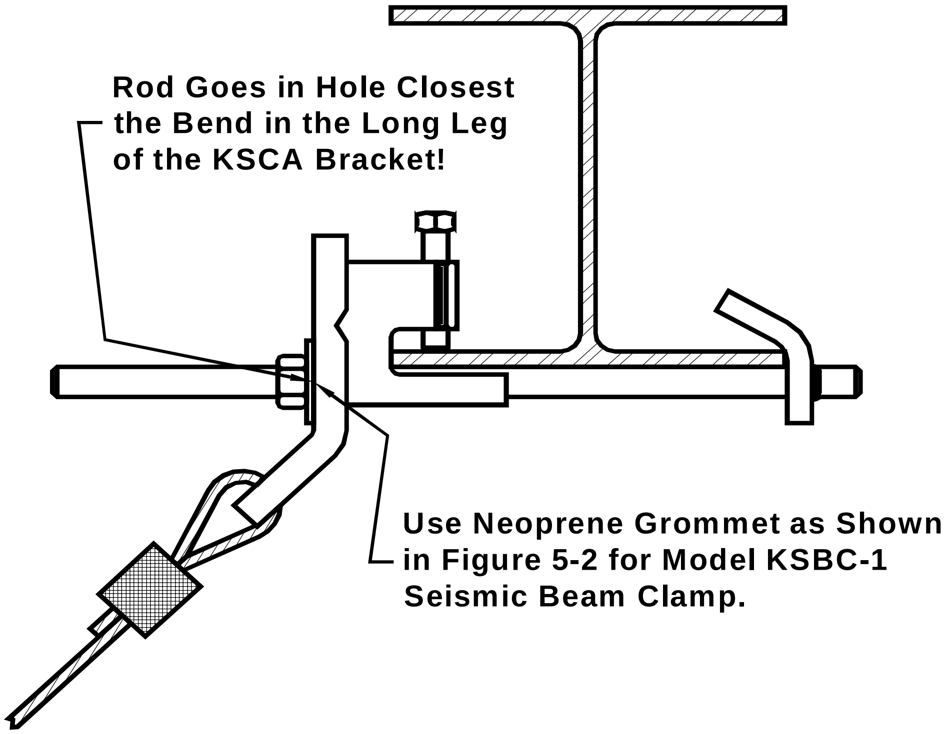
KSCA Bracket Attachment Using a KSBC (Seismic Beam Clamp), Figure D4.4.7-5



D4.4.7.3 – KSCA Brackets – Attachment to Concrete:

KSCA brackets should not be attached directly to light weight concrete. This is due to the fact that the contact area of a KSCA bracket is small enough that the light weight concrete may be crushed when tightening the fasteners. This will lead to the bracket being loose and increased shock loads during an earthquake. KSCA brackets may be attached directly to normal weight concrete as shown in Figure D4.4.7-6. All concrete anchor recommendations in this report are based on the Kinetics recommended KSCC.

There may be certain instances where a single anchor with a KSUA bracket or a KSCA bracket will not have enough capacity. Then the KSCAZ2, two concrete anchor, and KSCAZ4, four concrete anchor, kits may be used, shown in Figures D4.4.7-7, D4.4.7-8, 5-9, and D4.4.7-10.

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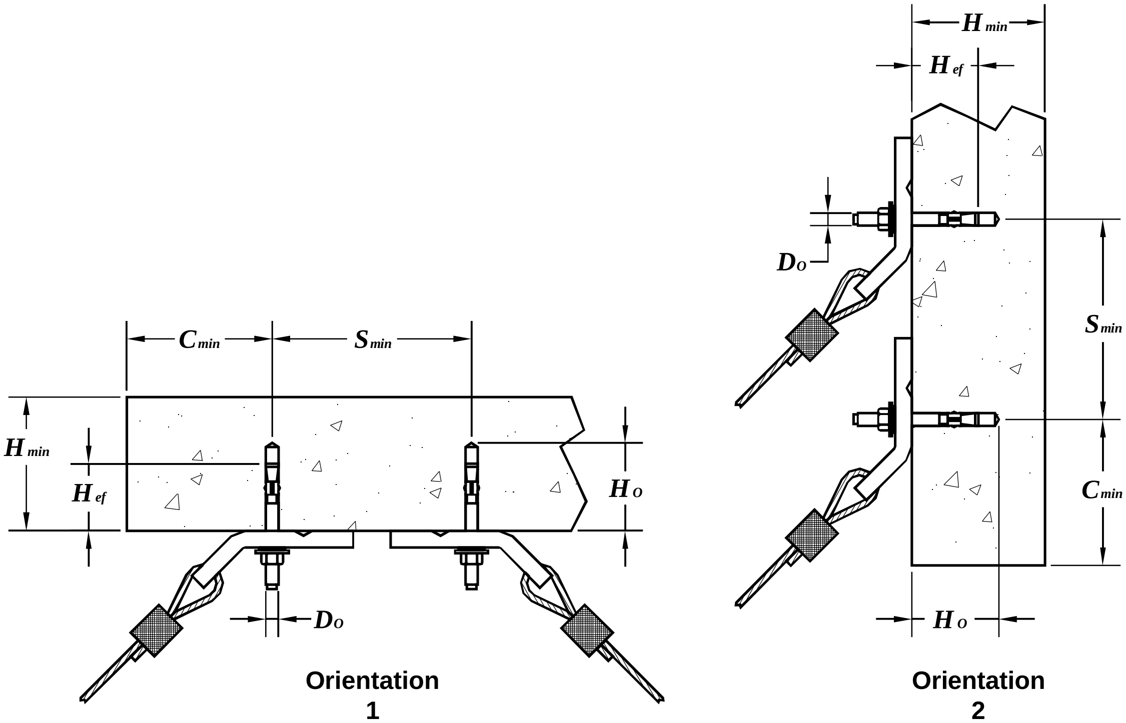
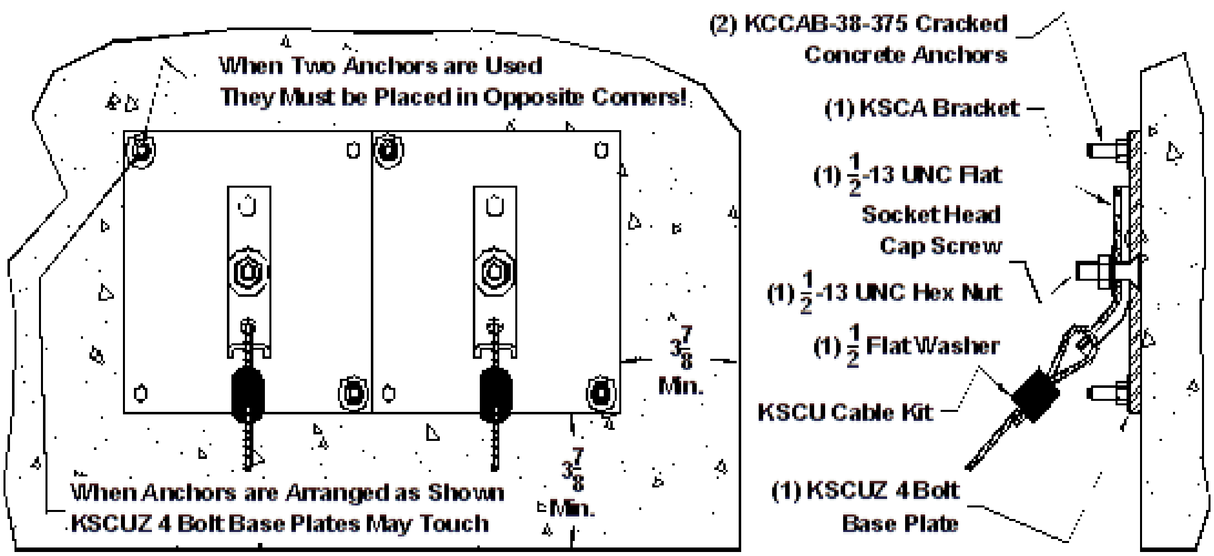
Typical KSCA Bracket Installation in Normal Weight Concrete, Figure D4.4.7-6



Orientation 1

Orientation 2

Model KSCAZ2 Attachment Kit to Concrete Using the KSCA Bracket – (2) 3/8 Anchors, Figure D4.4.7-1



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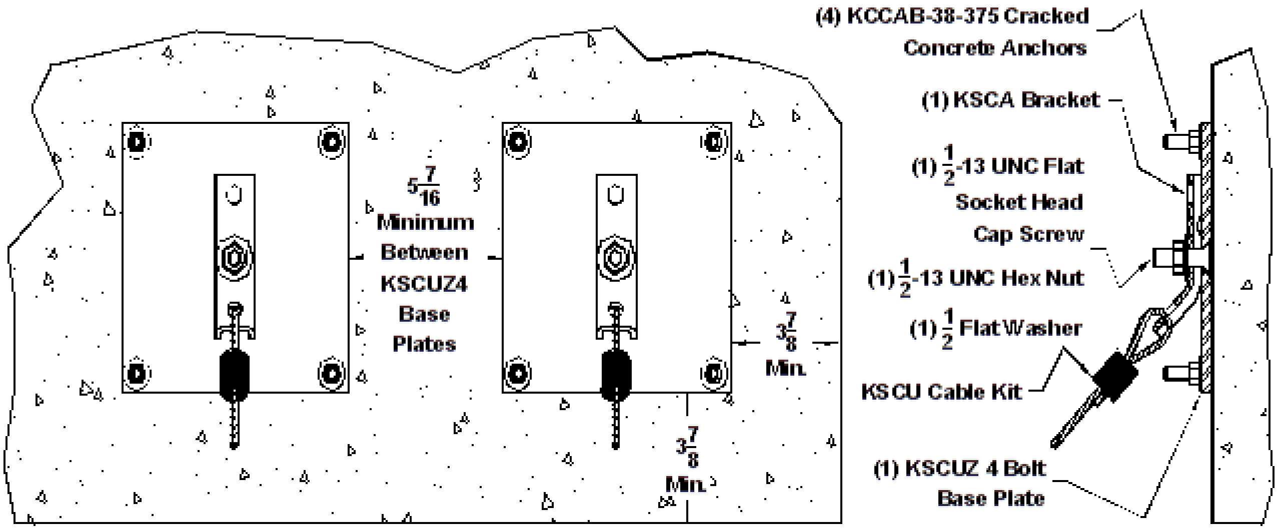
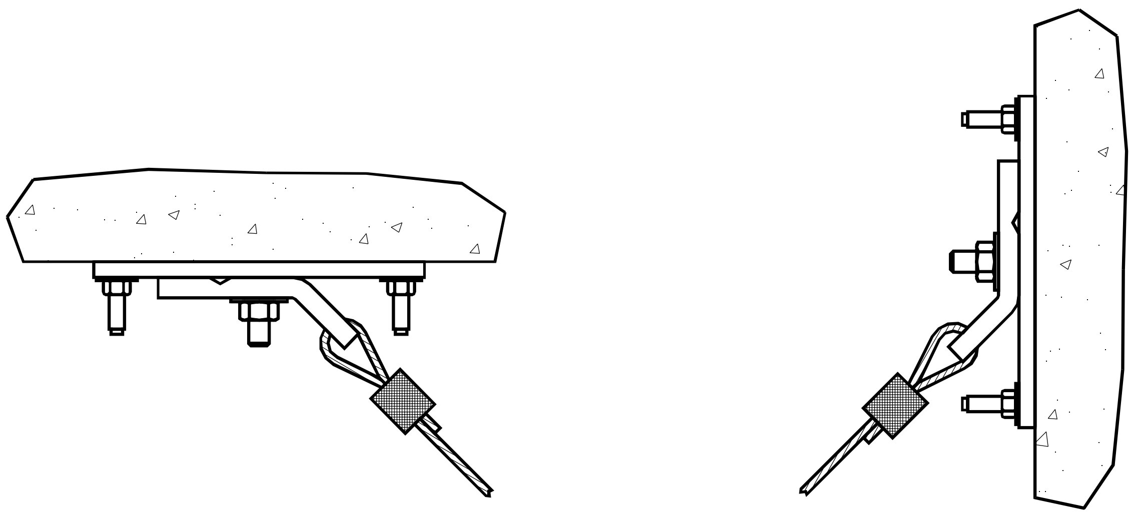
Model KSCAZ4 Attachment Kit to Concrete Using the KSCA Bracket – (4) 3/8 Anchors, Figure D4.4.7-2;



Models KSCAZ2 and KSCAZ4 Concrete Attachment Kits for KSCA Brackets in Orientation 1 and Orientation 2, Figure D4.4.7-3



Orientation 1

Orientation 2

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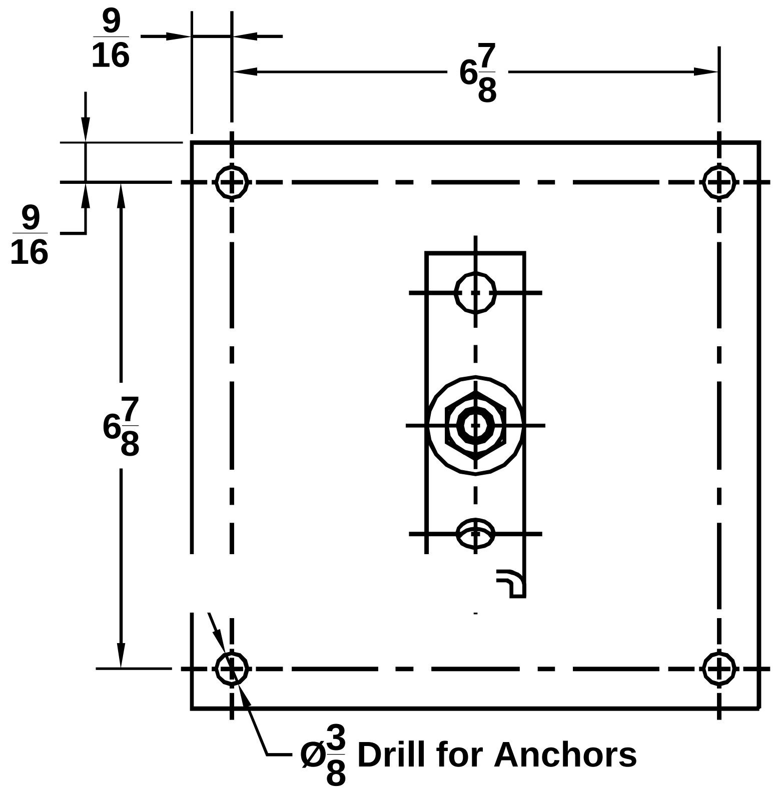
Anchor Hole Drill Template for Models KSCAZ2 and KSCAZ4, Figure D4.4.7-4



D4.4.8 – KSCA Brackets – Attachment to Wooden Structures

Attachment of seismic or wind restraints to a wooden structure requires careful coordination with the building structural engineer. While wooden structures tend to perform better during an earthquake than their concrete, masonry, or sometimes even steel counterparts, individual restraint attachments and point loads can adversely affect the strength and performance of the building structure. This is because the location of grain irregularities, knots, splits and checks cannot be controlled. The building structural engineer can indicate the proper locations and load capacity limits for each restraint attachment type and location. Figure D4.4.8-1 and Table D4.4.8-1 show the typical installation dimensions that will apply to lag screw attachments.

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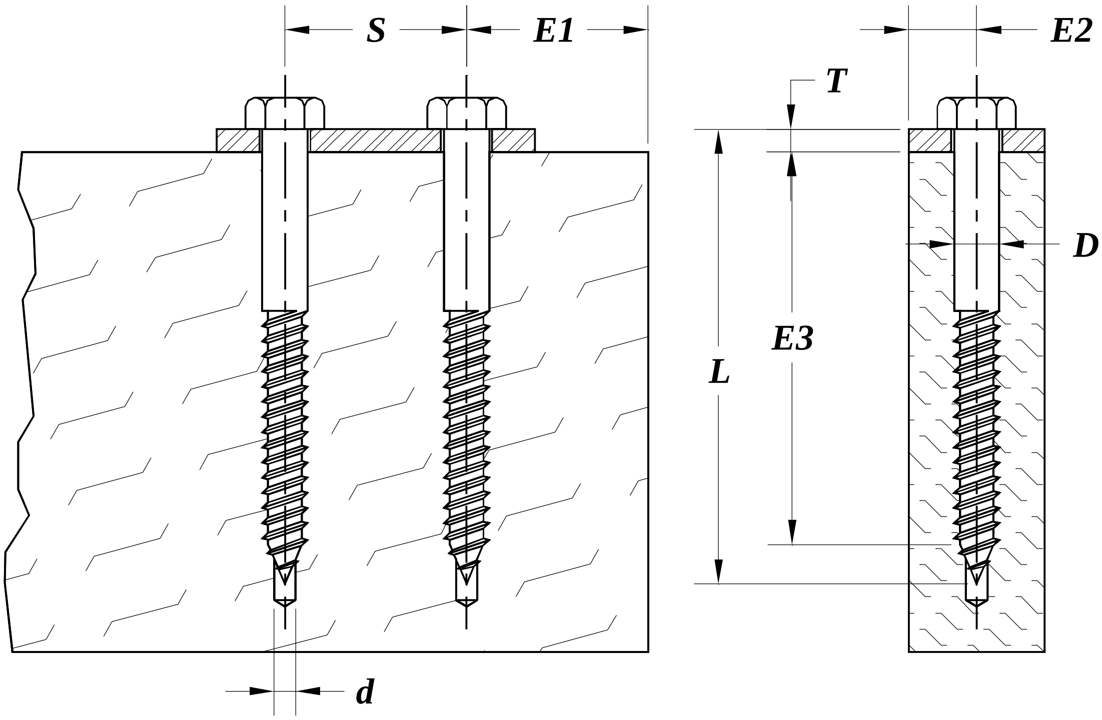
Figure D4.4.8-5 Typical Lag Screw Installation Dimensions, Figure D4.4.8-6



Lag Screw and Through Bolt Installation Data for Model KSCU Restraint Cable Kits, Table D4.4.8-1

LAG SCREW & THROUGH BOLT SIZE *D* (IN)	LAG SCREW PILOT HOLE SIZE *D* (IN)		SCREW & BOLT MINIMUM SPACING *S* (IN)	SCREW & BOLT MINIMUM END DISTANCE *E1* (IN)	SCREW & BOLT MINIMUM EDGE DISTANCE *E2* (IN)	LAG SCREW EMBEDMENT DOES NOT INCLUDE SCREW POINT *E3* (IN)
	Soft Wood	Hard Wood				
3/8	3/16	1/4	1-1/2	1-1/2	9/16	3
1/2	15/64	21/64	2	2	3/4	4

KSCA brackets installed in Orientation 1 to structural wood are shown in Figure D4.4.8-2 for a lag screw attachment and Figure D4.4.8-3 for a through bolted attachment. ***KSCA brackets used from attachment to wood applications will require steel backer plates beneath the KSCA bracket to prevent damage to the wood!***

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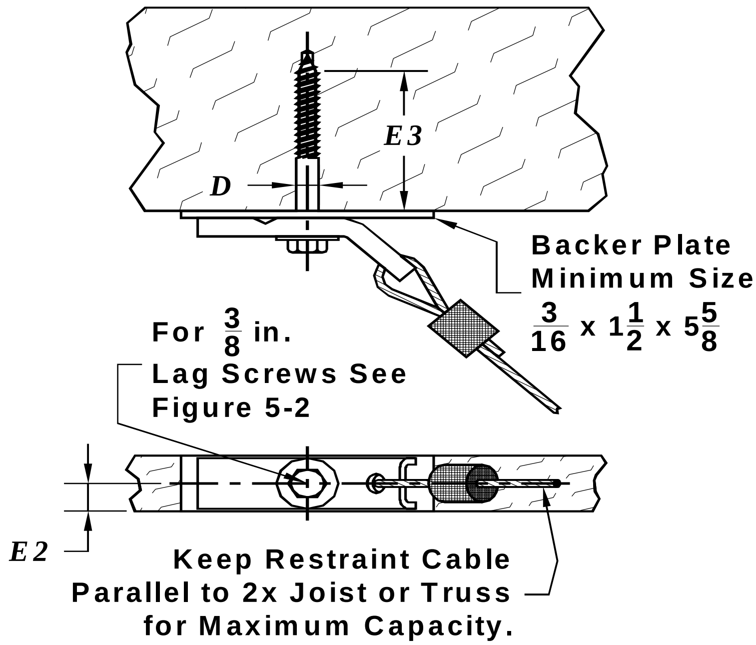
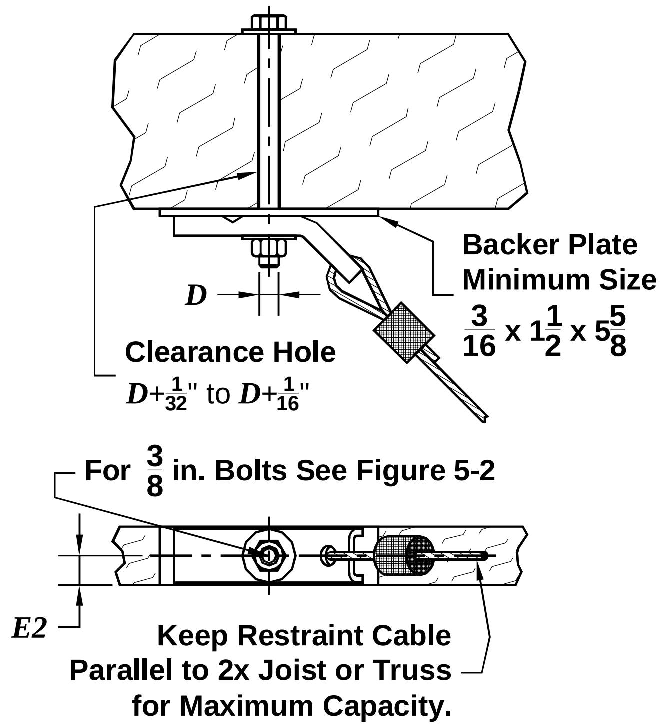
KSCA Attached to Wood in Orientation 1 Using a Lag Screw, Figure D4.4.8-2



KSCA Attached to Wood in Orientation 1 Using a Through Bolt, Figure D4.4.8-3



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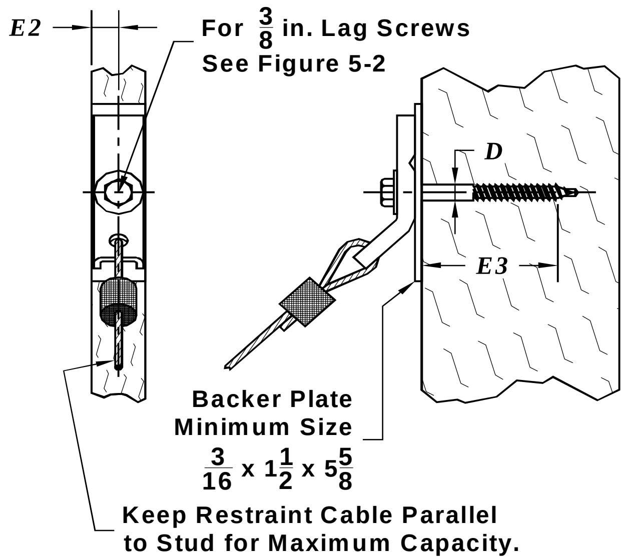
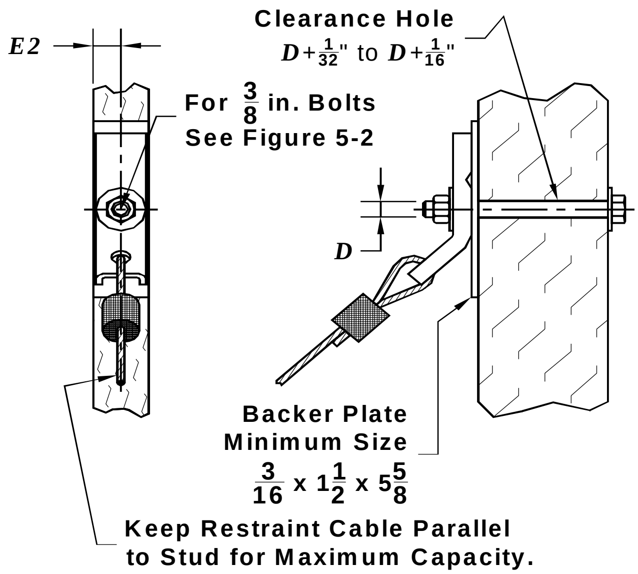
Special Note: Seismic and wind restraints are not to be attached to the end grain of structural wood!!

KSCA brackets installed in Orientation 2 to structural wood are shown in Figure D4.4.8-4 for a lag screw attachment and Figure D4.4.8-5 for a through bolted attachment.

KSCA Attached to Wood in Orientation 2 Using a Lag Screw, Figure D4.4.8-4



KSCA Attached to Wood in Orientation 2 Using a Through Bolt, Figure D4.4.8-5



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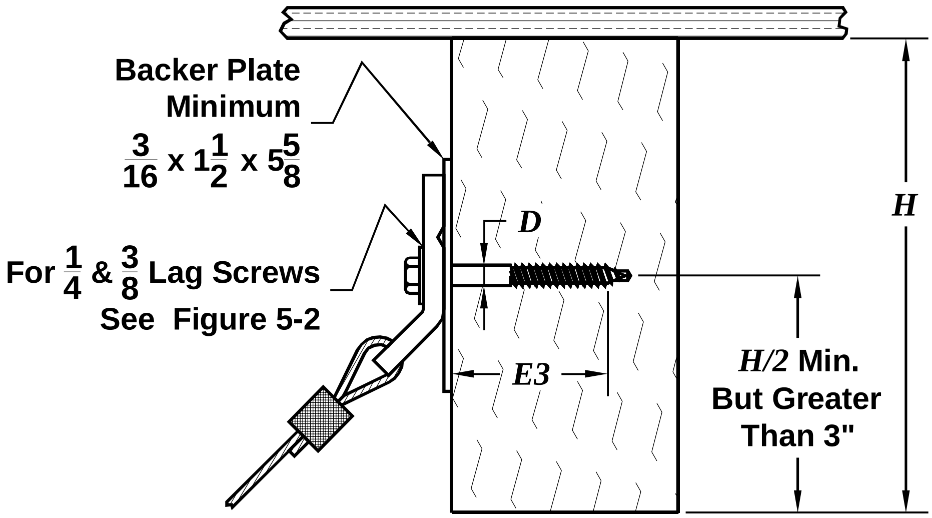
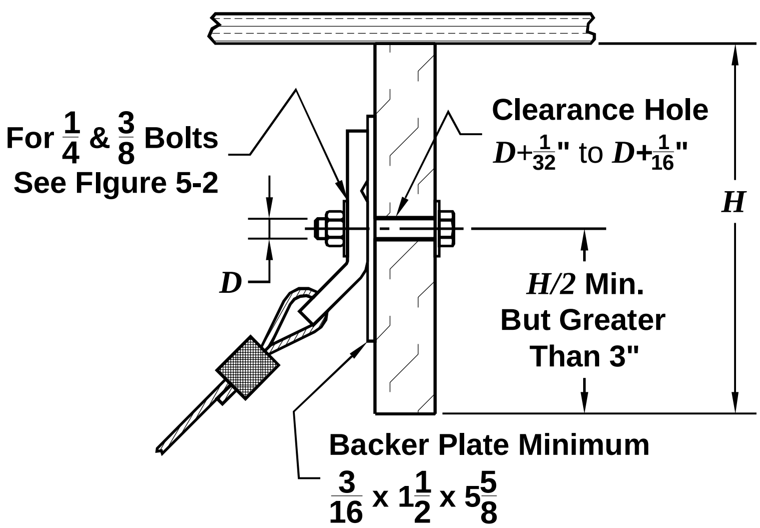
The KSCA bracket may be attached to the sides of wooden joists and beams in Orientation 2 as shown in Figure 5-16 for lag screw attachment and Figure 5-17 for through bolt attachment.

KSCA Attached to a Wooden Joist or Beam in Orientation 2 Using a Lag Screw, Figure D4.4.8-6



KSCA Attached to a Wooden Joist or Beam in Orientation 2 Using a Through Bolt, Figure D4.4.8-7



The KSCAZ2 and KSCAZ4 attachment kits will allow the KSCA bracket to be mounted to a wooden structural member using two or four lag screws. Figures D4.4.8-8 and D4.4.9-9 show the KSCAZ2 and KSCAZ4, respectively, mounted to a wooden column.

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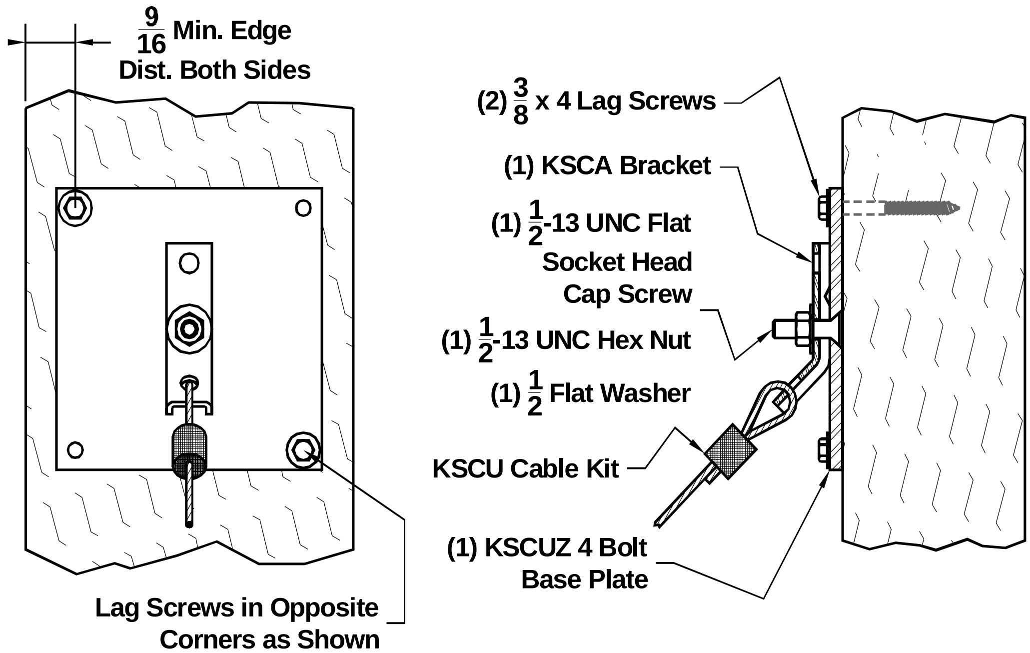
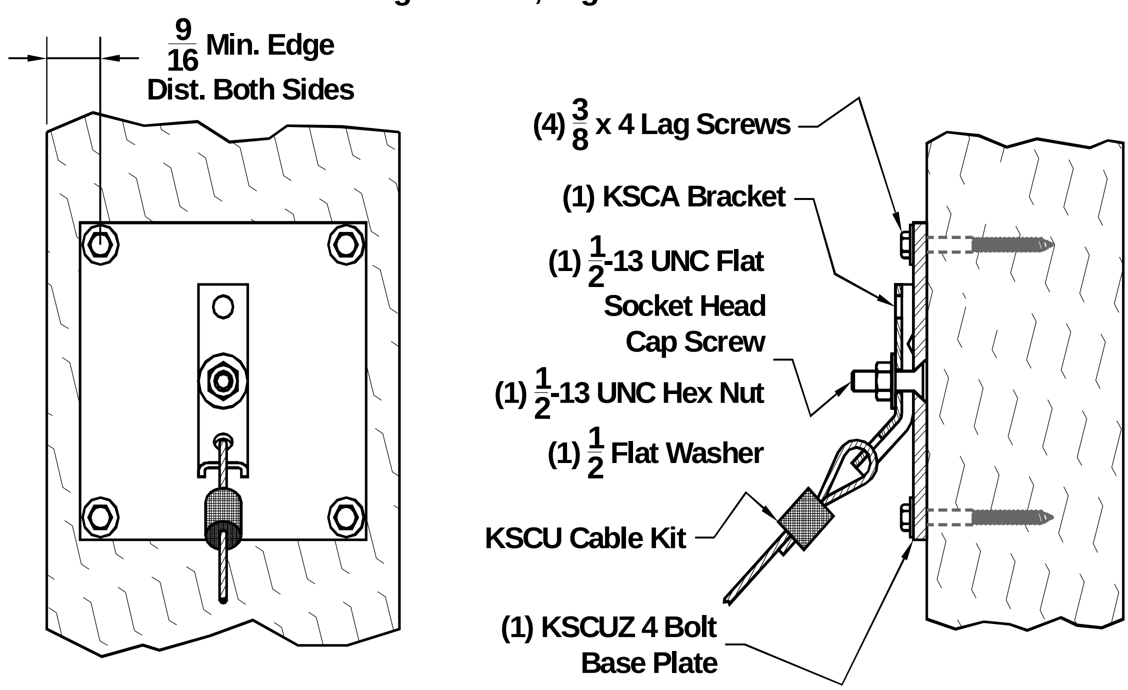
Model KSCAZ2 Attachment Kit to a Wooden Column Using the KSCA Bracket – (2) 3/8 Lag Screws, Figure D4.4.8-8



Model KSCAZ4 Attachment Kit to a Wooden Column Using the KSCA Bracket – (4) 3/8 Lag Screws, Figure D4.4.8-9



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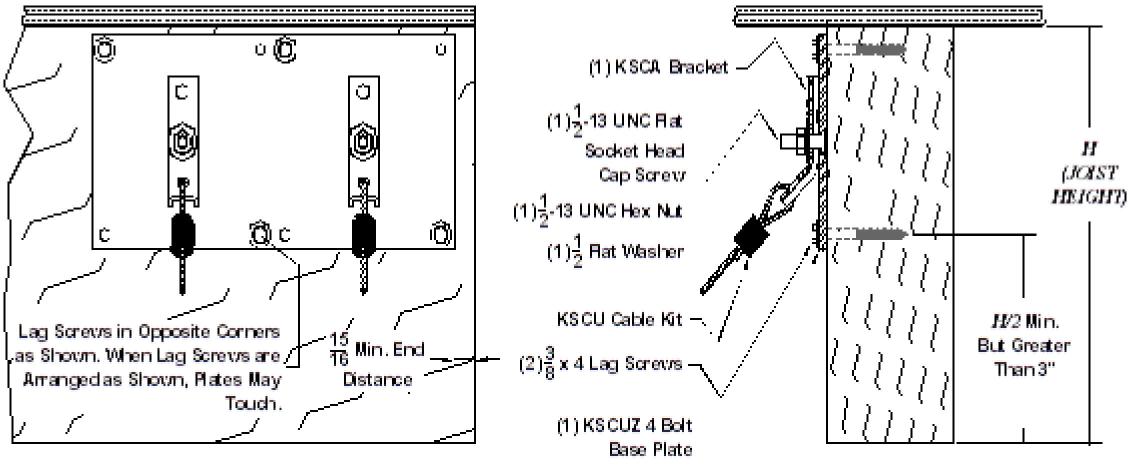
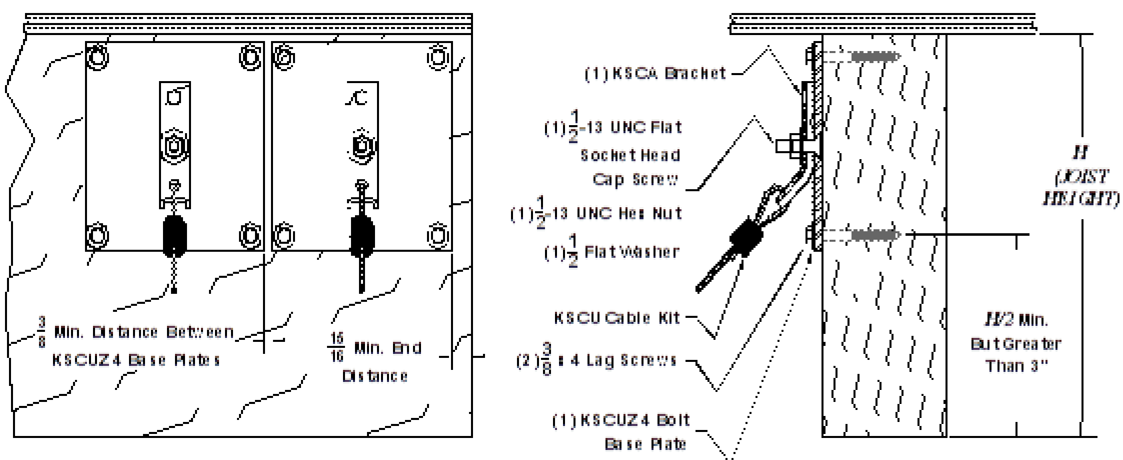
The KSCAZ2 and KSCAZ4 attachment kits may also be used to attach multiple KSCA brackets to wooden structural beam using two or four lag screws. Figures D4.4.8-10 and D4.4.8-11 show the KSCAZ2 and KSCAZ4, respectively, mounted to a wooden beam.

Model KSCAZ2 Attachment Kit to a Wooden Beam Using the KSCA Bracket – (2) 3/8 Lag Screws, Figure D4.4.8-10



Model KSCAZ4 Attachment Kit to a Wooden Beam Using the KSCA Bracket – (4) 3/8 Lag Screws, Figure D4.4.8-11



D4.4.9 – KSUA Brackets – Basic Sizes & Installation

Kinetics Noise Control provides several different attachment brackets that can be used for making the structural attachment for the seismic cable restraints. Figure D4.4.9-1 shows the

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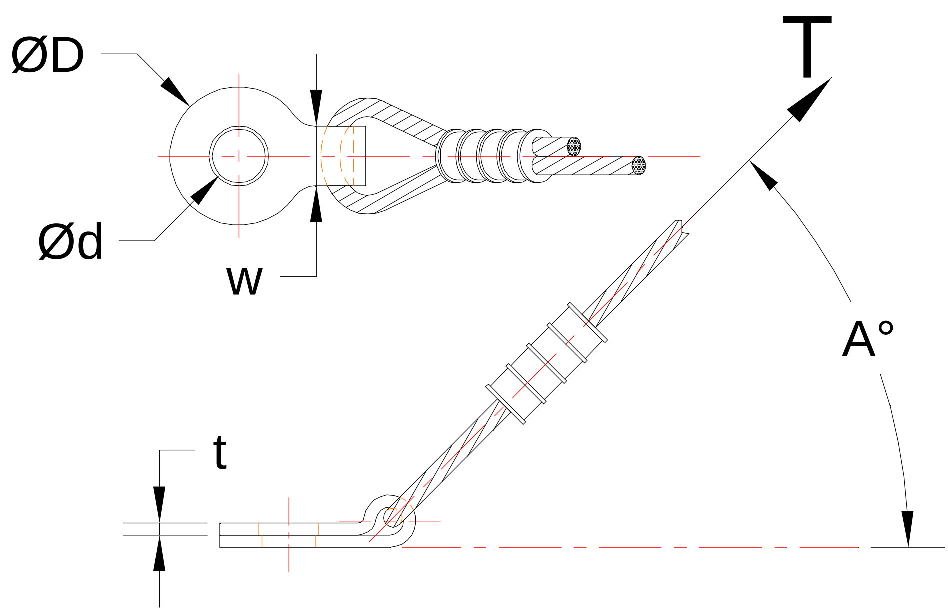
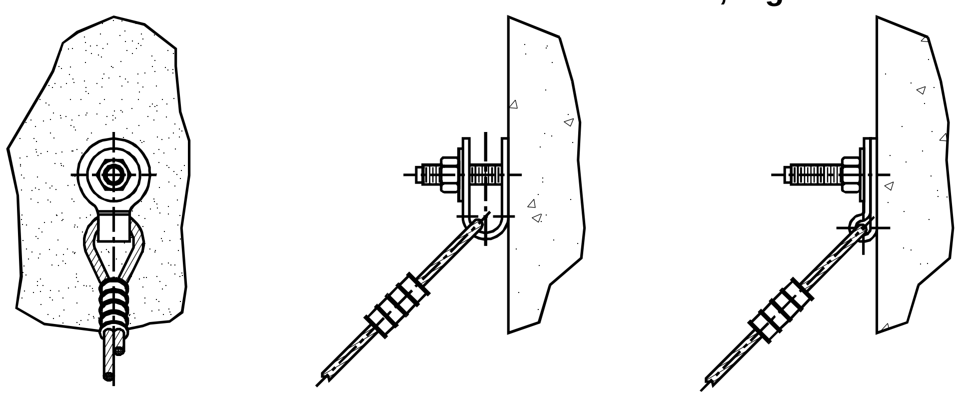
KSUA-2 bracket supplied with QuakeLoc Kits. The KSUA-2 bracket comes pre-installed with thimble in the swaged loop end of all sizes of QuakeLoc cables.

Kinetics Noise Control Model KSUA Seismic Restraint Cable Attachment Brackets, Figure D4.4.9-1



Primarily, the KSUA attachment brackets are used with the Kinetics Noise Control Model KSCU and QuakeKit Seismic Restraint Cable Kits.

Installation of Model KSUA Attachment Bracket, Figure D4.4.9-2



View #1
Front
KSUA - Installed

View #2
Side
KSUA - Open

View #3
Side
KSUA - Closed

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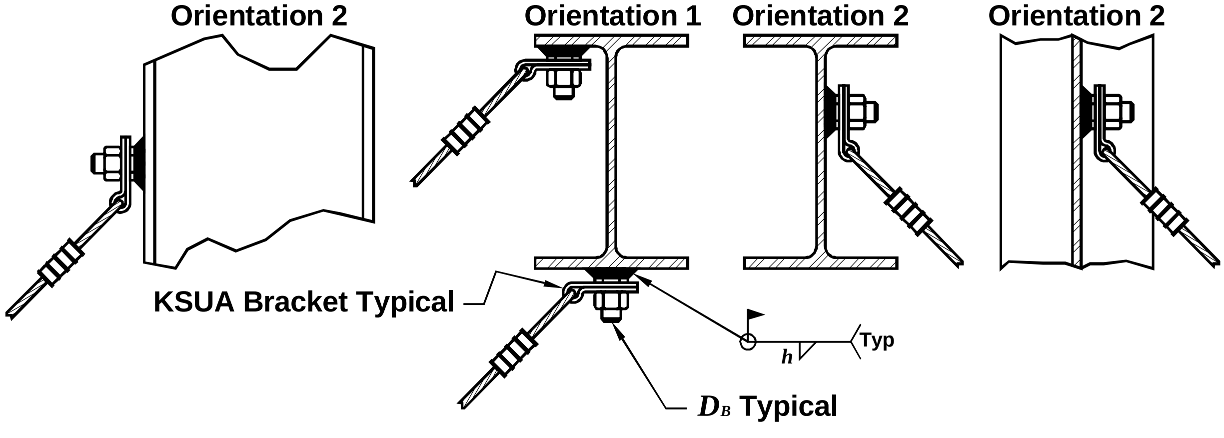
In addition to the KSUA attachment bracket pre-installed in the swaged loop end of the restraint cable, the KSUA bracket can also be used on the QuakeLoc end of the cable where the loop is made along with a thimble. Figure D4.4.9-2 shows the basic installation of the KSUA brackets. The particular installation shown is for attachment to the building structural concrete, although the basic procedure is the same regardless of whether the bracket is being attached to structural steel, concrete, or wood.

1. The open KSUA bracket is placed over the fastener, with (for a 3/8" anchor) or without (for a 1/2" anchor) a flat washer, and the nut is run down finger tight on the bracket. See View #2 Side KSUA – Open in Figure D4.4.9-2 above.
2. Tighten the nut with a wrench to the proper torque specified for the fastener being used. The two legs of the KSUA bracket should be squeezed shut as shown in View # 3 Side KSUA – Closed as shown in Figure D4.4.9-2. Squeezing the legs of the KSUA bracket shut will form a loop for the restraint cable. The cable should be loose and free to move inside the loop of the KSUA bracket.

D4.4.9-1 – KSUA Brackets – Attachment to Steel:

In general, attaching the KSCU seismic restraint cable kits to structural steel will maximize the capacity of the KSCU restraint installation. Figure D4.4.9-3 and Table D4.4.9-1 illustrate how the KSUA bracket may be welded to structural steel. A rolled structural W shape is shown; however, this scheme may be applied to any structural shape with the ***approval of the building structural engineer***. An ASTM A325 bolt of the proper size is located on the structural steel and welded as shown in Figure D4.4.9-3. Then the cable and KSUA bracket are installed a described in Section D4.4.6.

Welding KSUA Brackets to Structural Steel, Figure D4.4.9-3



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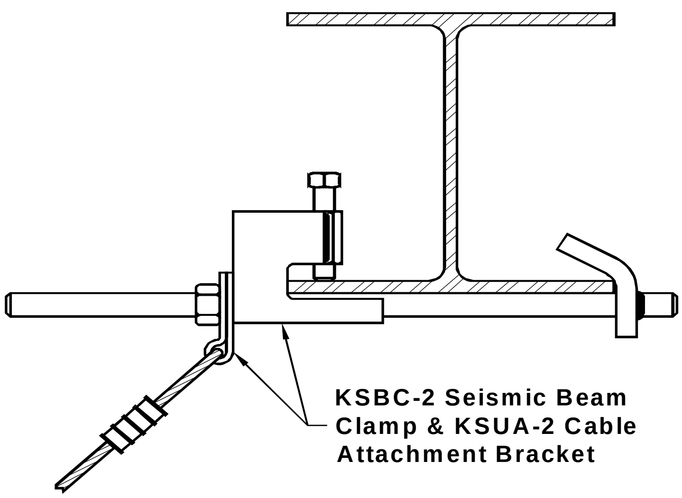
Bolt and Weld Size for KSUA Bracket Weld Attachment to Structural Steel, Table D4.4.9-1

KSUA BRACKET	BOLT SIZE D_B	WELD SIZE H (IN)
KSUA-1	3/8-16 UNC	3/16
KSUA-2	1/2-13 UNC	1/4

Kinetics Noise Control offers Models KSBC-1 and -2 Seismic Beam Clamps that may be used to attach the KSUA brackets to structural steel AISC W, M, S, or HP shapes without welding. This method of attachment to structural steel is shown in Figure 5-25. Here also, the use of the seismic beam clamps to attach the KSUA brackets to the structural steel ***must be approved by the building structural engineer***.

Using Model KSBC Seismic Beam Clamps to Attach KSUA Brackets to Structural Steel, Figure D4.4.9-4



KSUA Brackets may be attached to steel open web joists as shown in Figures D4.4.9-5 and D4.4.9-6. These structural elements are normally designed to be as efficient as possible which means that they are designed to carry primarily vertical loads, and frequently have little capacity beyond the code mandated loads. As a result, if seismic restraints for pipe and duct are to be attached to these open web steel joists, ***it is absolutely necessary for the building structural engineer to approve each attachment point***.

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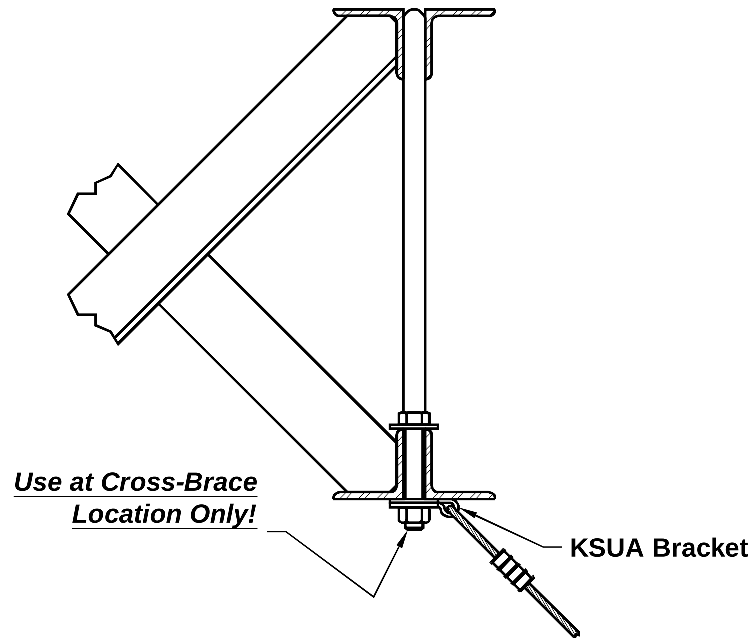
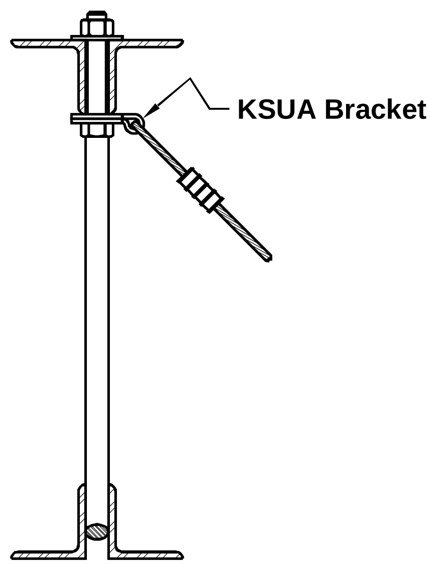
Attaching KSUA Brackets to Cross-Braced Open Web Steel Joists, Figure D4.4.9-5



Attaching KSUA Brackets to Un-Braced Open Web Steel Joists, Figure D4.4.9-6



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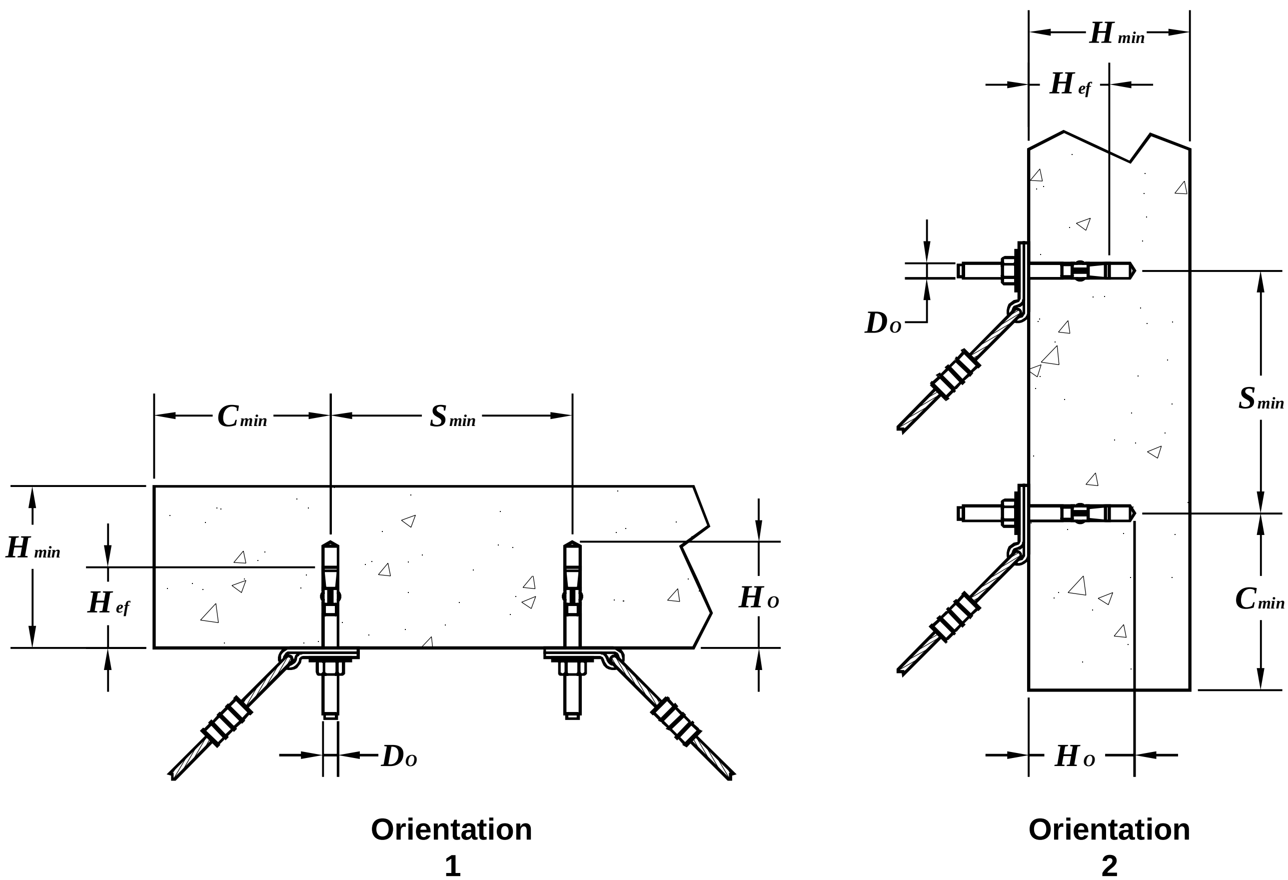
D4.4.9-2 – KSUA Brackets – Attachment to Concrete:

The typical attachment of seismic cable restraints to concrete using KSUA brackets is shown in Figure D4.4.9-7. This installation is based on the use of Kinetics recommended KCCAB concrete anchors. The installation dimensions and instructions listed appendix D are the minimum required to achieve the listed capacities in appendix C for the QuakeKit Seismic Restraint Cable Kits. Figure D4.4.9-8 shows a KSUA bracket attached to concrete which has been poured over a corrugated metal deck.

Typical KSUA Bracket Installation in Concrete, Figure D4.4.9-7



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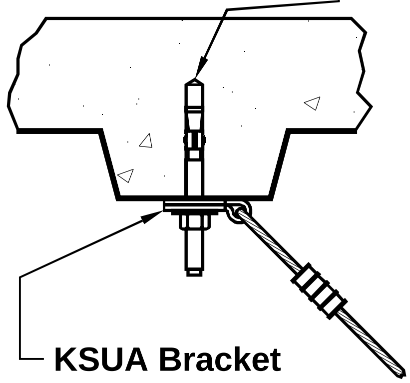
KSUA Bracket Attached to Concrete Poured on Corrugated Metal Decking, Figure D4.4.9-8



D4.4.10 - Hanger Rod Stiffeners

Using cable restraints such as the QuakeLoc series always creates an upward vertical force into the hanger rod when the cable restrains the component from moving in a horizontal direction as shown in figure D4.4.10-1 below. The vertical force, results from one of the cable restraints always being in tension. This force only applies at locations where a seismic restraint attaches to a component hanger. All other hangers only support the hanging weight of the component and are not subject to this additional upward vertical force.

The vertical force from the tension in the cable restraint can be found from the formula below.

$$F_v = F_P Tan(A)$$

While this upward vertical force will not increase the load on the hanger rod due to the weight of the pipe or duct being supported, it could place the hanger rod in compression and cause it to buckle. Buckling is a condition that causes catastrophic failure in long slender columns. Buckling risk depends on the compressive load, hanger rod size and length.

The use of rod stiffeners protects the hanger rod from a buckling failure. A stiffener in the form of equal length leg steel angles attached to the hanger rod increases the rod resistance to buckling. The stiffener acts with the hanger rod to resist the upward compressive force from the cable restraint. If found to be necessary, rod stiffeners need only be fitted to hanger rods attached to or in the immediate vicinity of seismic restraints.

Compression Forces Generated in Hanger Rod, Figure D4.4.10-1

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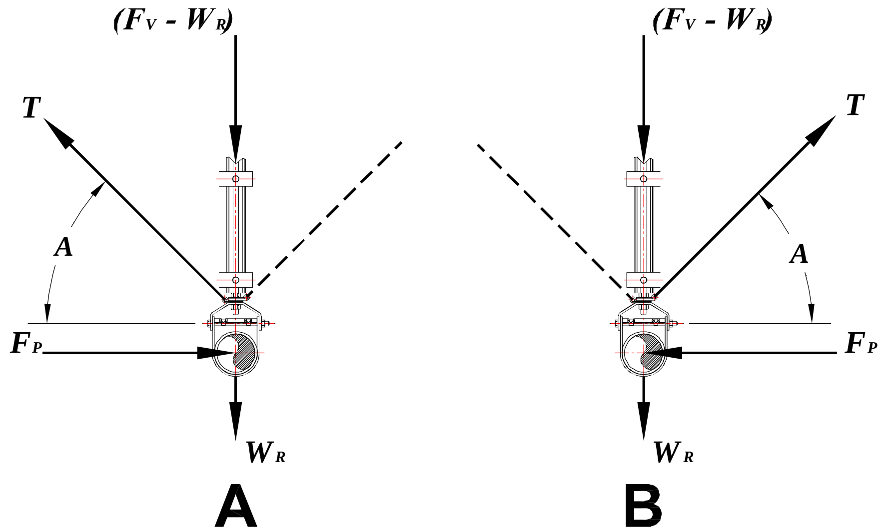
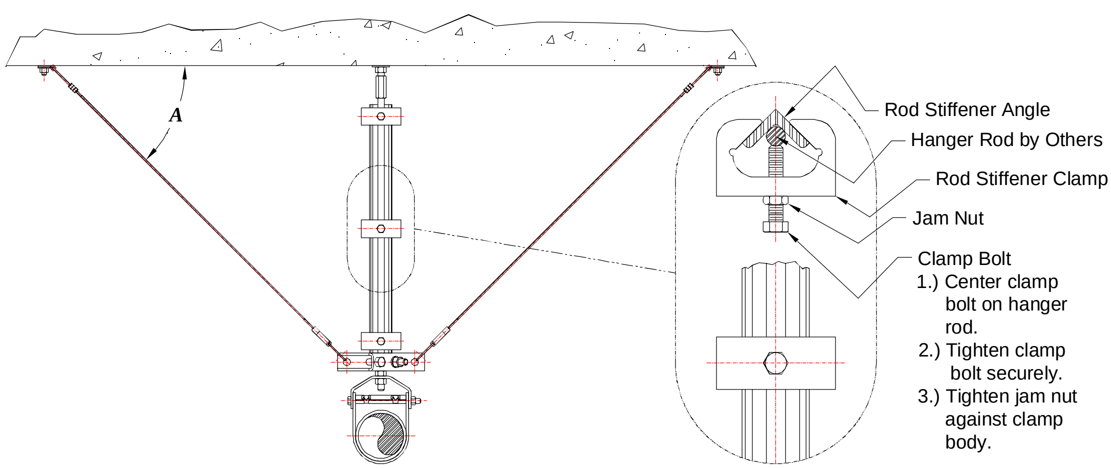


Typical Hanger Rod Stiffener Installation, Figure D4.4.10-2



Kinetics Noise Control Model KHRC-B Hanger Rod Stiffener Clamp, Figure D4.4.10-3

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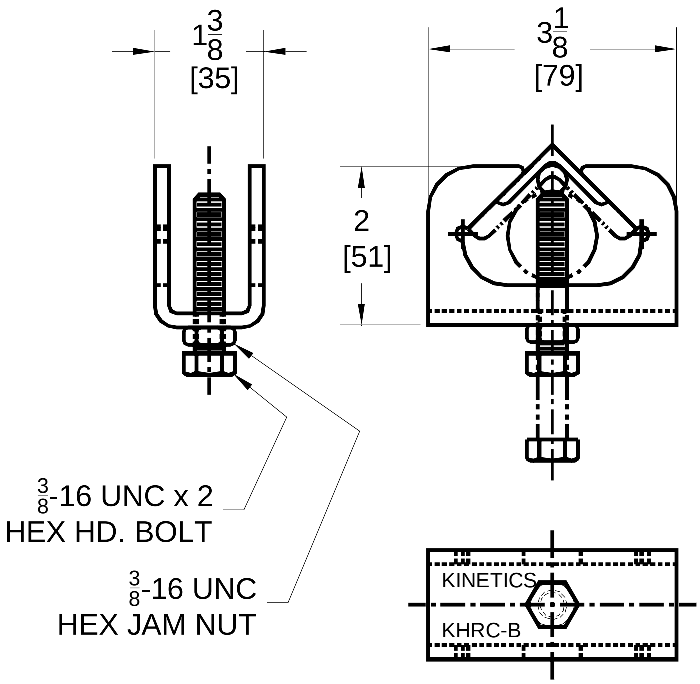
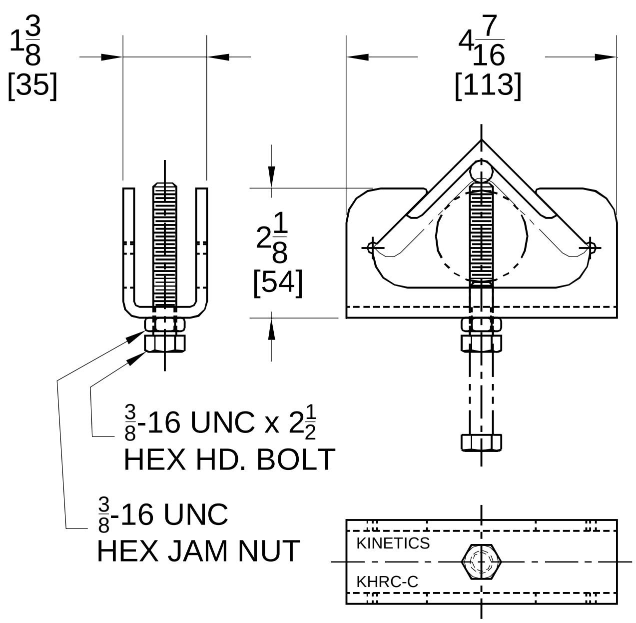


RANGE OF STIFFENER ANGLES	
AISC STANDARD	METRIC
1 x 1 x 1/8	25 x 25 x 3
1-1/4 x 1-1/4 x 1/4	30 x 30 x 5
1-1/2 x 1-1/2 x 1/4	40 x 40 x 6

RANGE OF HANGER RODS	
INCH STANDARD	METRIC STANDARD
3/8	M10
1/2	M12
5/8	M16
3/4	M20
7/8	M22
1	M24
1-1/8	M30

Kinetics Noise Control Model KHRC-C Hanger Rod Stiffener Clamp, Figure D4.4.10-4



RANGE OF STIFFENER ANGLES	
AISC STANDARD	METRIC
1-3/4 x 1-3/4 x 1/4	45 x 45 x 6
2 x 2 x 1/4	50 x 50 x 6
2 x 2 x 3/8	50 x 50 x 8
2-1/2 x 2-1/2 x 1/4	60 x 60 x 6

RANGE OF HANGER RODS	
INCH STANDARD	METRIC STANDARD
3/8	M10
1/2	M12
5/8	M16
3/4	M20
7/8	M22
1	M24
1-1/8	M30
1-1/4	M36

D4.4.11 – Hanger Rod Stiffener Selection and Clamp Requirement Procedure

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1. Determine spacing of hanger rods, transverse restraints and longitudinal restraints
2. Determine weight per foot of pipe or duct being restrained including any insulation, liner and content. (w_p)
3. Use the “Hanger rod vertical compressive load” graph figure D4.4.11-1 to find the upward vertical load being placed on the hanger rod.
   A. Weight supported by hanger rod W_R
      a. Find the hanger spacing on the lower vertical axis of the graph
      b. Project a horizontal line for the hanger spacing to the diagonal weight per foot line. (W_f)
      c. From this intersection, project a vertical line up to the left horizontal axis to find the weight being supported by the hanger. W_R
      d. For evenly loaded trapeze bars, the hanger rod carries only half of the supported weight. If the load is offset to one side, proportion the weight accordingly and set W_R equal to the lighter of the 2 supported weights.

   B. Vertical compressive load applied to the hanger by the restraint. F_V
      a. Find the restraint spacing on the lower vertical axis of the graph.
      b. Project a horizontal line for the restraint spacing to the diagonal weight per foot line.
      c. From this intersection, project a vertical line up to the required G factor.
      d. From this point, project a horizontal line to the line for the restraint installation angle.
      e. From this intersection, project a vertical line down to the right horizontal axis to find vertical component of the restraint force. F_V .
      f. For trapeze hung components the hanger rod will still carry the full vertical compressive load.

   C. Subtract the weight supported by the hanger from the vertical component of the restraint force to find vertical force being placed on the hanger rod.

      Single hung Trapeze hung (Evenly Loaded)

      $V_F = F_V - W_R$ $V_F = F_V - W_R/2$

      If the result is 0 or a negative number, the weight hanging for the hanger rod is equal to or greater than the vertical component of the restraint force, so no stiffener rod will be required.

4. If uplift is present, determine if stiffener is required
      a. On the appropriate “Hanger Rod Buckling” graph (figure D4.4.11-2, D4.4.11-3 & D4.4.11-4) identify the vertical compressive force found above in step 3C on the vertical axis of the graph.
      b. Locate the hanger rod length L on the horizontal axis of the graph.
      c. Find the curve for the hanger rod size on the graph
      d. If the intersection of the vertical force and rod length is below the hanger rod size line, no stiffener will be required.

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e. If the intersection of the vertical force and hanger rod length is on or above the hanger rod size curve, a stiffener will be required.
f. On trapeze hung components, stiffeners are required only on hanger rods that are attached to the restrained end of the trapeze bar. If restraints are fitted to both ends of the trapeze, stiffeners are to be fitted on both ends as well.

5. Find acceptable rod stiffeners
   a. On the "Stiffener Buckling" graph (figure D4.4.11-5) identify the vertical compressive force from step 3C above on the vertical axis of the graph.
   b. Locate the hanger rod length on the horizontal axis of the graph.
   c. Find the intersection of the vertical compressive force and hanger rod length on the graph.
   d. Any stiffener identified by a capacity line that is above this point will make an acceptable hanger rod stiffener.

6. Determine number and spacing of stiffener rod clamps

   a. Using the appropriate "Maximum Stiffener Clamp Spacing" graph (figures D4.4.11-6, D4.4.11-7 & D4.4.11-8), find the vertical force V_F from step 3C on the vertical axis of the graph.
   b. Project a horizontal line to intersect with the hanger rod size curve being used.
   c. Project a vertical line down to the he horizontal axis of the graph to find the maximum distance between stiffener clamps. S_{SC}
   d. Find the number of stiffener clamps N_{SC} by dividing the hanger rod length L by the maximum distance between stiffener clamps S_{SC} and add 1. Round this number up to the next whole number to find the number of stiffener clamps required.

$$N_{SC} = \left(\frac{L}{S_{SC}}\right) + 1$$

   e. Stiffener clamps are to be evenly spaced along the length of the hanger rod. This length can be found by subtracting 1 from the number of clamps required and then dividing the hanger rod length by this number.

$$Stiffener\_clamp\_spacing = \frac{L}{N_{SC} - 1}$$

Hanger Rod Compression Chart, Figure D4.4.11-1

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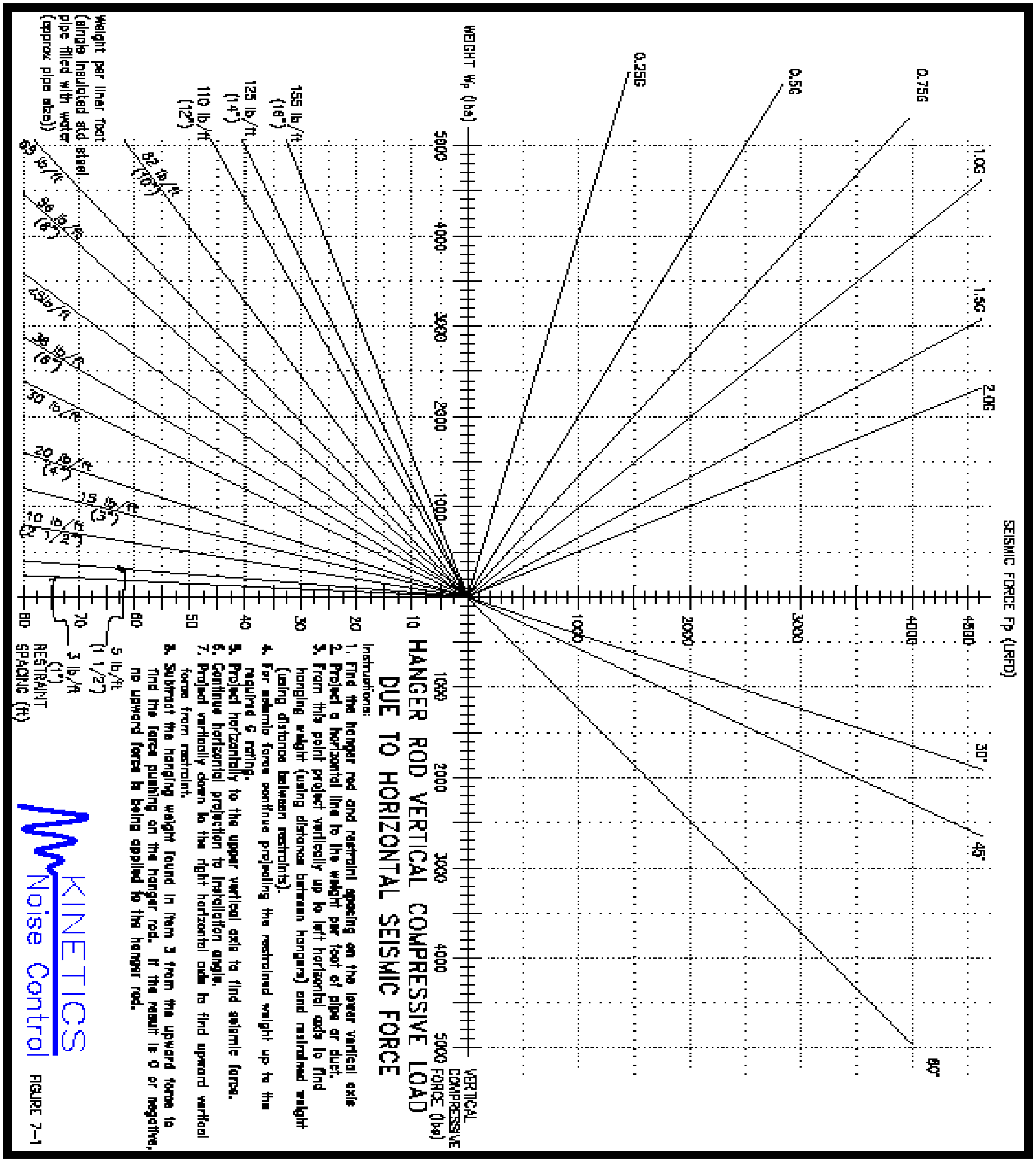
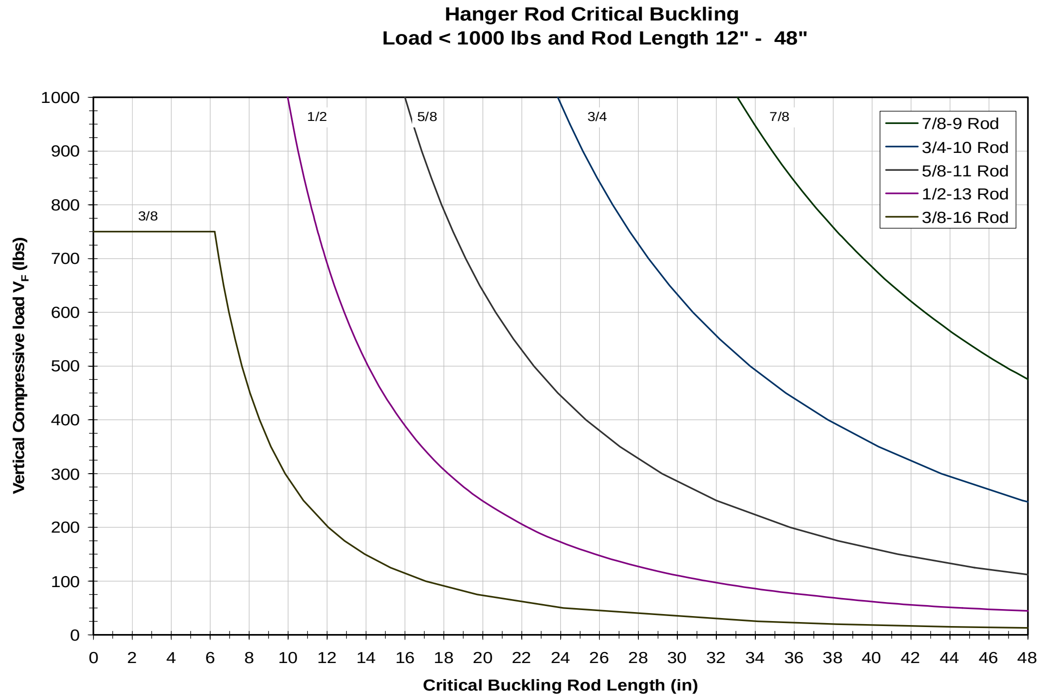
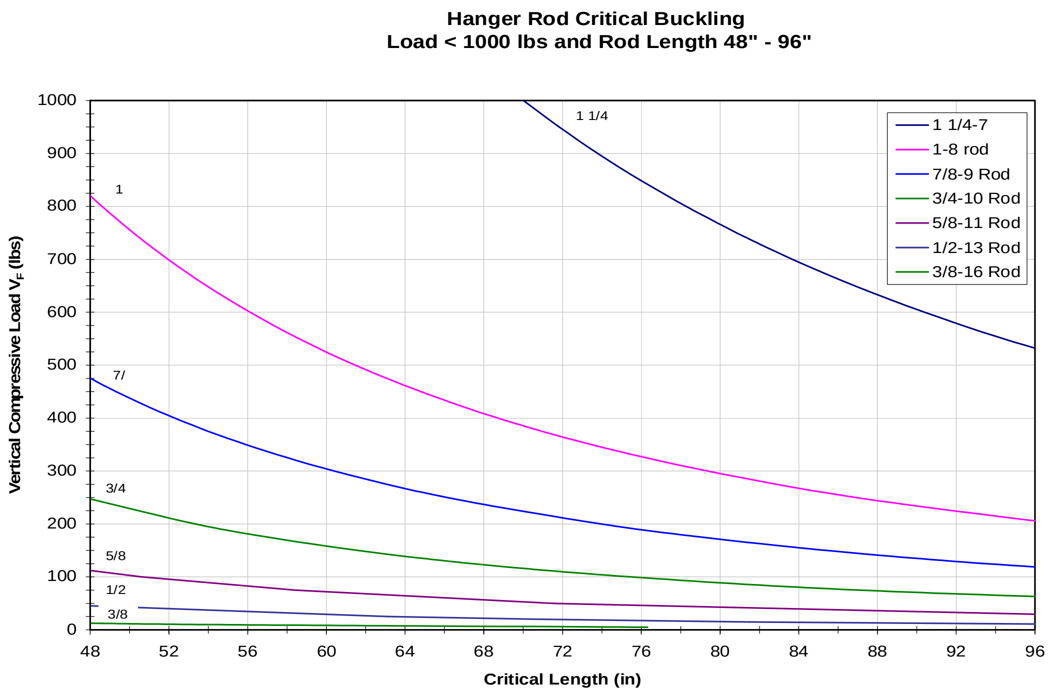


Rod Bucking < 1000 lb, < 48" Lg Chart, Figure D4.4.11-2



Rod Bucking < 1000 lb, 48”< Lg < 96” Chart, Figure D4.4.11-3



Rod Bucking > 1000 lb, 6”< Lg < 72” Chart, Figure D4.4.11-4

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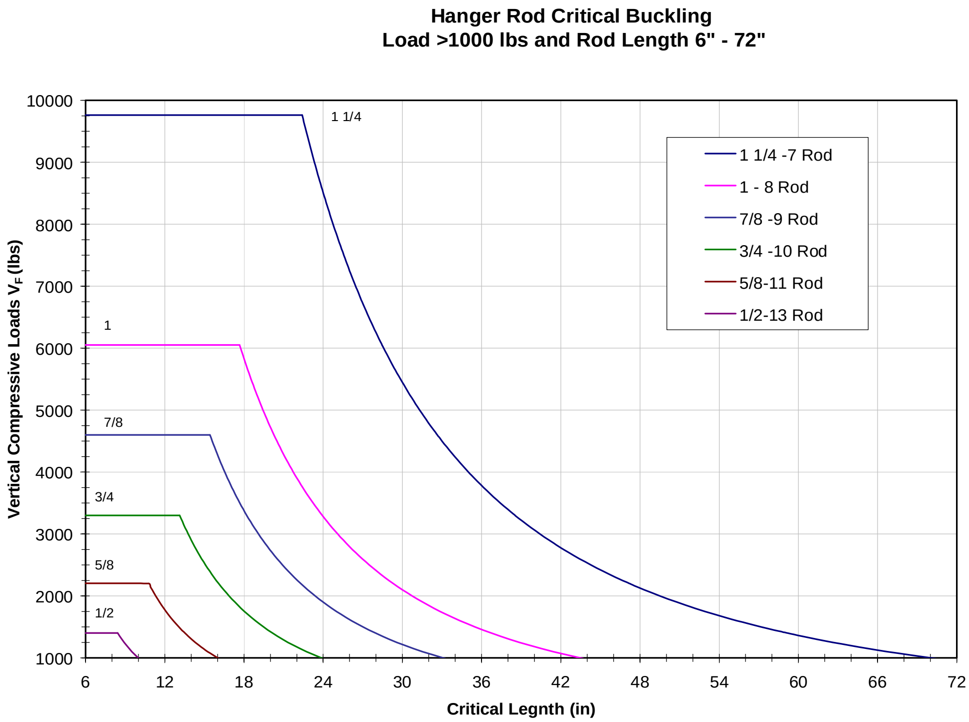
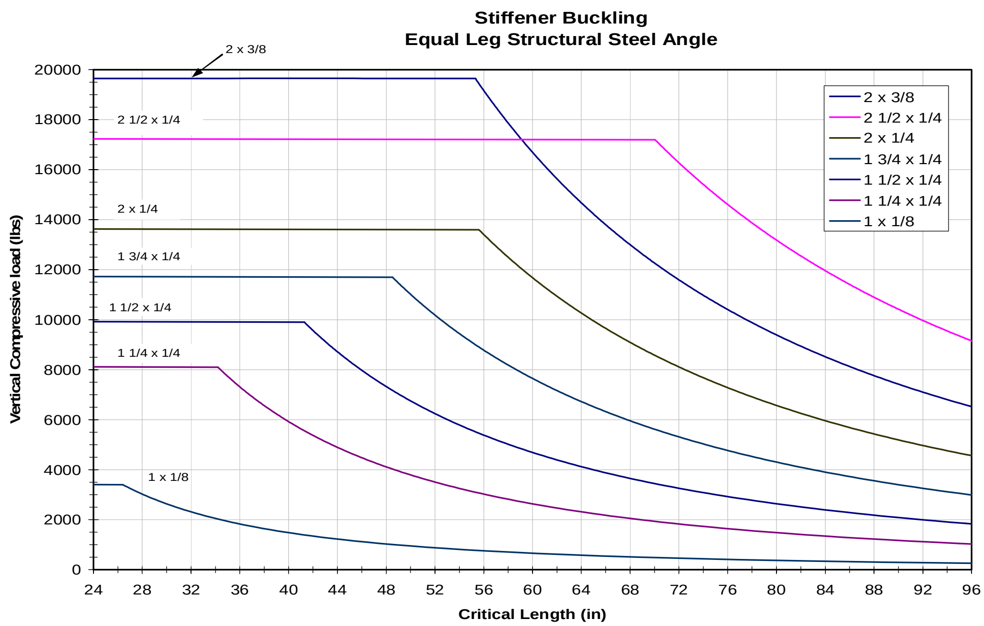


Angle Stiffener Bucking > 1000 lb, 6"< Lg < 72" Chart, Figure D4.4.11-5



Maximum Stiffener Clamp Spacing < 1000 lb, 12" < Lg < 48" Chart, Figure D4.4.11-6

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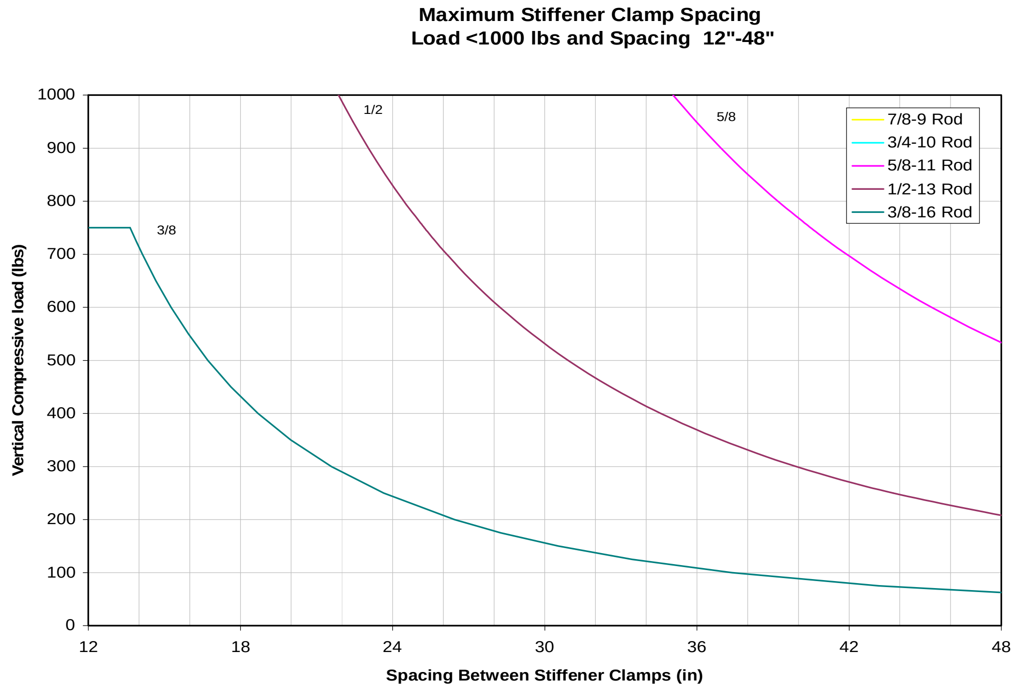
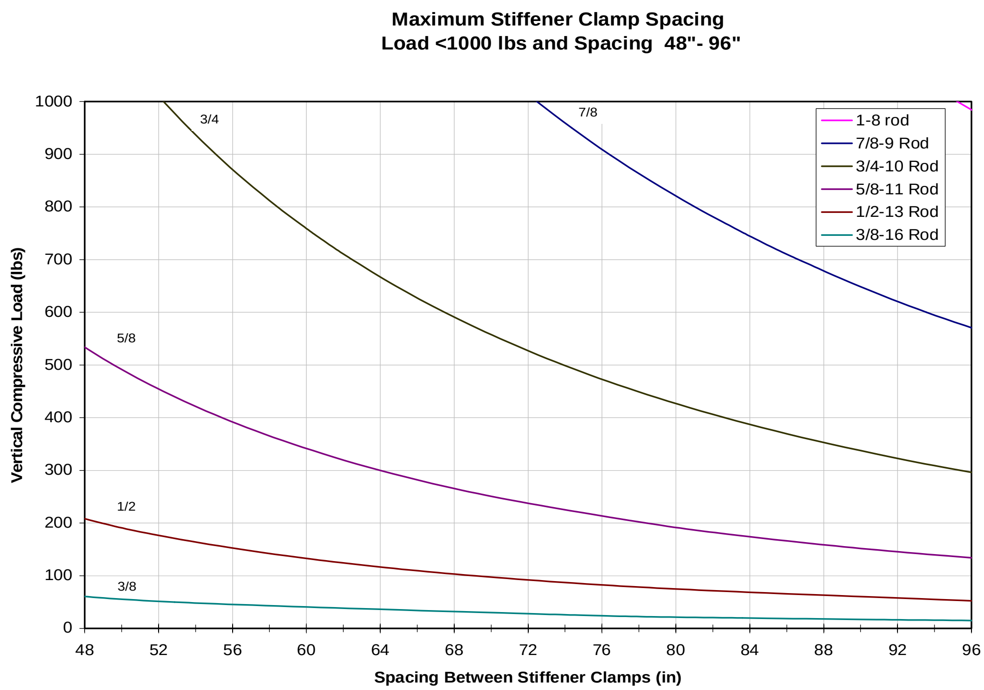


Maximum Stiffener Clamp Spacing < 1000 lb, 48”< Lg < 96” Chart, Figure D4.4.11-7



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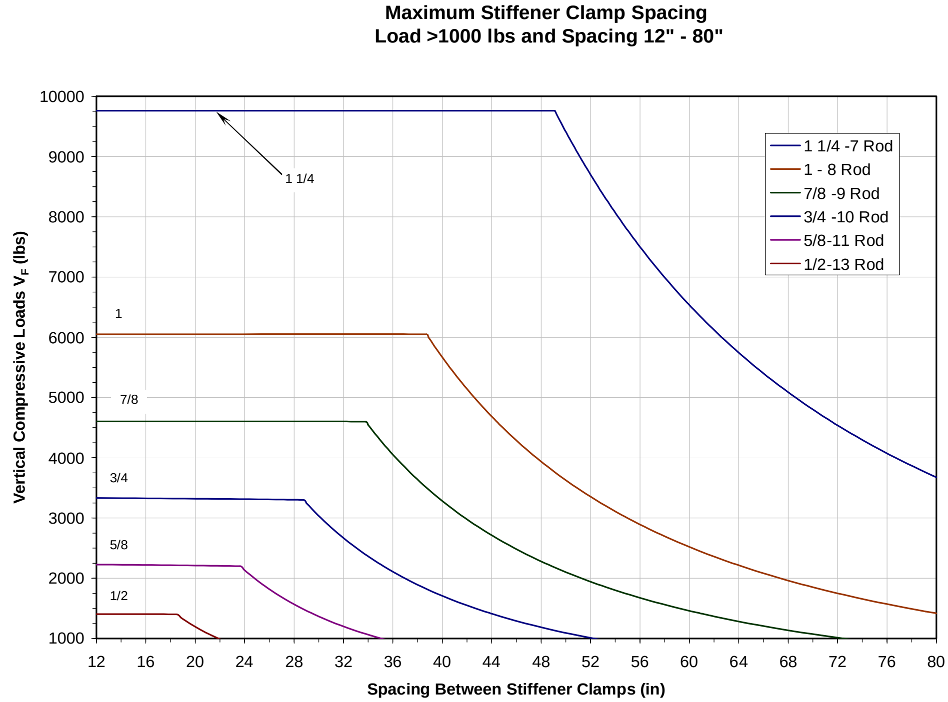
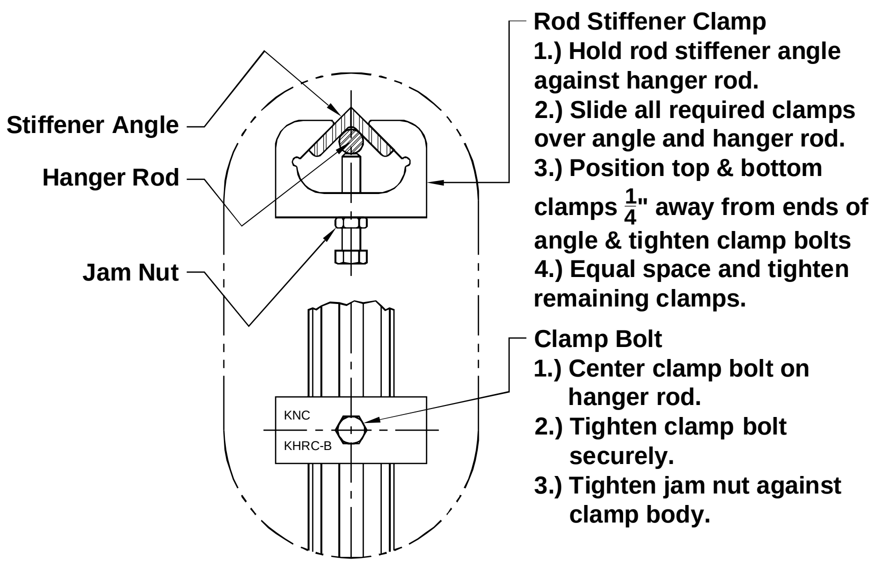
Maximum Stiffener Clamp Spacing > 1000 lb, 12”< Lg < 80” Chart, Figure D4.4.11-8



D4.4.12 – Hanger Rod Stiffener Installation Details

Below are shown typical arrangements for pipe and duct supports with properly installed rod stiffeners.

Stiffener Installation Section, Figure D4.4.12-1



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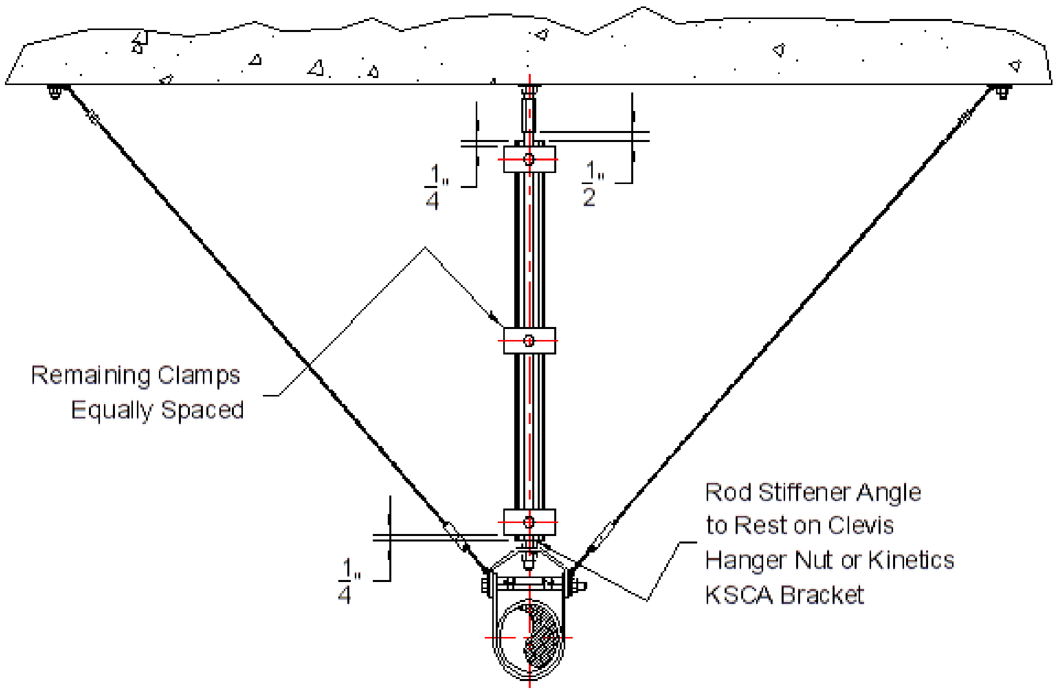
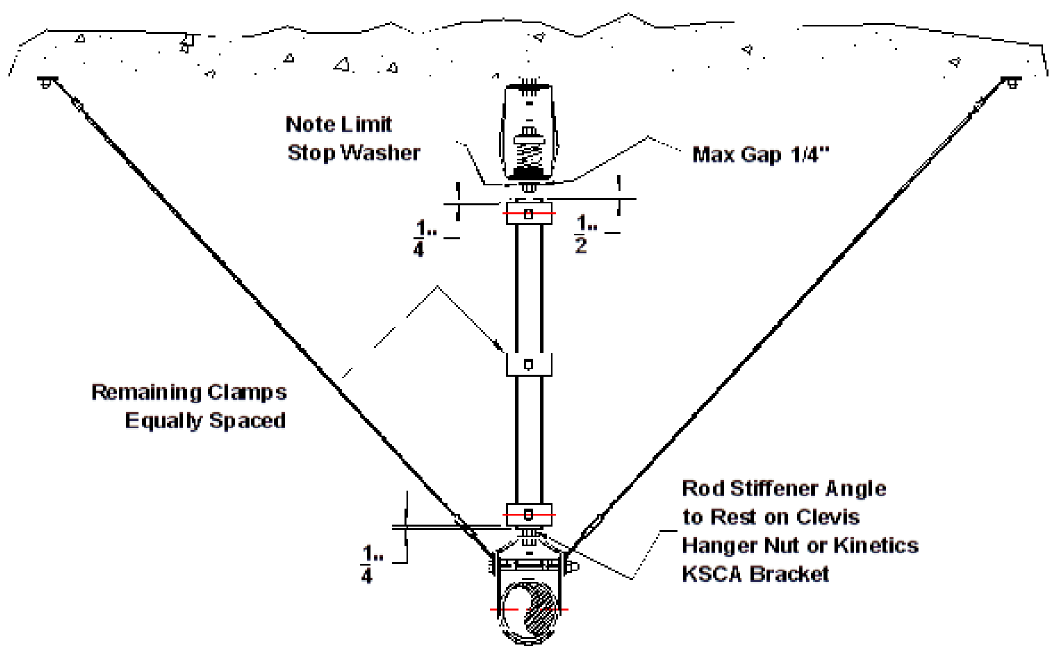
Non-Isolated Single Hung Pipe Arrangement, Figure D4.4.12-2



Isolated Single Hung Pipe Arrangement, Figure D4.4.12-3



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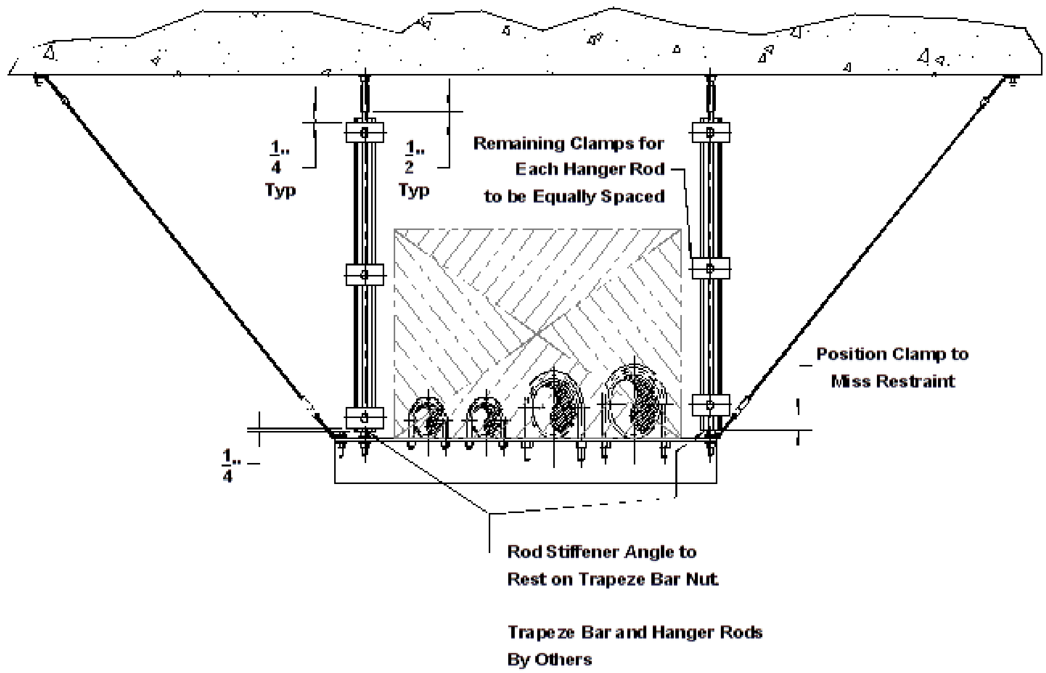
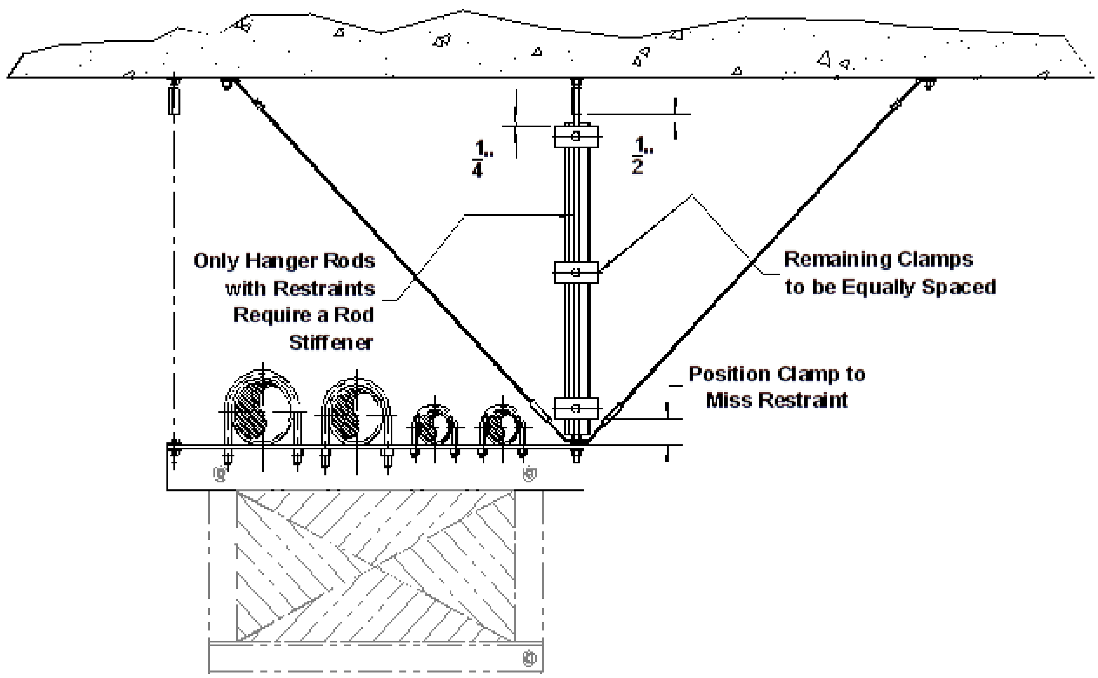
Trapeze Supported System with "Balanced" Restraints, Figure D4.4.12-4



Trapeze Supported System with "Offset" Restraints, Figure D4.4.12-5



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SECTION D5.0 – TABLE OF CONTENTS

D5.0 – Floor and Wall Mounted Equipment

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FLOOR MOUNTED EQUIPMENT PRIMER

Introduction

This section will deal with the basics of the Kinetics Seismic Certification analysis for floor mounted equipment and the basic location and placement of the required isolators or restraints around the perimeter of the equipment. Also, there will be a general discussion concerning the required number and size of fasteners at each isolator or restraint location.

We will begin the discussion with seismic isolators and restraints that have three axis restraint elements. Table D5.1.1-1 is a listing of the common isolator and restraint models having tri-axial restraints offered by Kinetics Noise Control.

Table D5.1.1-1: Typical Kinetics Tri-axial Seismic Isolator and Restraint Models.

Isolator Models	Restraint Models
FHS	HS-5
FLS	HS-7
FLSS	KSMS
FMS	FMS
KRMS	--------
Titan	--------

Kinetics Seismic Certification Analysis Program

Figure D5.1.1-1 shows a typical arrangement for these types of devices around a typical piece of equipment. The piece of equipment in Figure D5.1.1-1 may be a generator on an inertia base located on a concrete housekeeping pad. The Kinetics Seismic Certification analysis program calculates the code values for horizontal and vertical seismic forces acting on the equipment. These seismic forces are applied at the center of gravity (***C.G***.) of the equipment. The horizontal seismic force may come from any direction. So, the program will cycle through a full ***360°*** to determine the worst case loading condition for the isolators or restraints. Then the program will compute the forces acting at each isolator or restraint location, and then compare these values to the allowable limits for the selected isolator or restraint model and size. These allowable limits are based on the strength of the isolator or restraint components as well as the strength of the attachment of the isolator to the structural steel framing of the building. One half of the lower of these two values then defines the allowable limit for the isolator or restraint. If the isolator or restraint is to be attached to concrete, the concrete anchors are evaluated separately. The Kinetics Seismic Certification program will print out the

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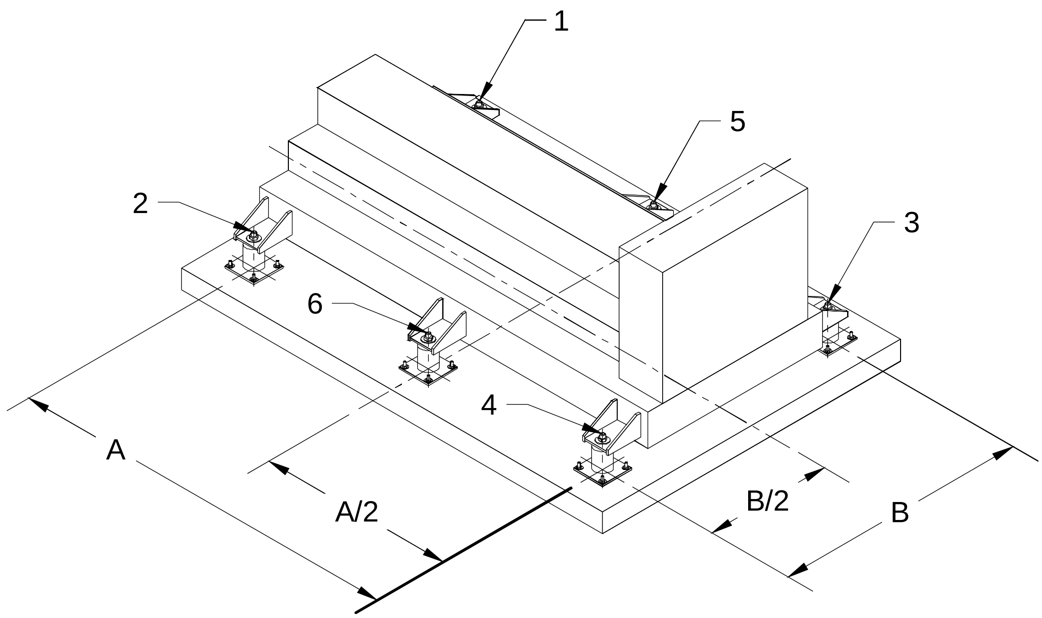
safety factor for each isolator or restraint, the safety factor for the bolts required to attach the isolator to the building's structural steel, and the safety factor for the concrete anchors that fit the holes in the isolator or restraint mounting plate. Also included in the information will be the number of bolts or anchors required for each isolator or restraint location.

Occasionally the anchorage to concrete is insufficient when using the anchor size, number, and spacing provided by the standard base plate on the isolator or restraint. In these cases the Kinetics Seismic Certification program will recommend a standard oversized base plate to be used with the isolators/restraints. For a discussion on the Kinetics Noise Control oversized base plates see Documents D5.2.1 and D5.2.2.

Figure D5.1.1-1: Typical Equipment and Isolator or Restraint Layout.



Isolator or Restraint Locations

The isolator or restraints are located of the geometric center lines of the equipment as indicated in Figure D5.1.1-1. On the Kinetics Seismic Certification sheet there is a schematic of the plan view of the equipment showing the general isolator or restraint locations. An example of this schematic is shown in Figure D5.1.1-2. The **ATTACHMENT POINT** numbers in Figure D5.1.1-2 correspond to the isolator or restraint numbers in Figure D5.1.1-1. Isolators or restraints ***5*** and ***6*** in Figure D5.1.1-1 are represented by the unnumbered **ATTACHMENT POINTS** in Figure D5.1.1-2. Note that the odd numbered isolators or restraints are always on one side of the equipment, and the even numbered Isolators or restraints are on the other. If there are more than three pairs of isolators or restraints, they should be spaced as evenly as possible along the length of the equipment between pair ***1 & 2***, and pair ***3 & 4*** starting with pair ***5 & 6*** closest to pair ***1 & 2***. This is further illustrated in Figures D5.1.1-3 through D5.1.1-5.

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These figures represent the plan view of a typical air handling unit that is restrained with Kinetics Noise Control Model **KSMS Seismic Equipment Brackets**. In these figures the terms ***L*** and ***W*** are the overall length and width of the equipment respectively. Dimensions ***A*** and ***B*** are the dimensions that establish the isolator/restraint locations. The variable ***N*** represents the number of isolators/restraints.

Figure D5.1.1-2: Seismic Certification Isolator or Restraint Location Schematic.

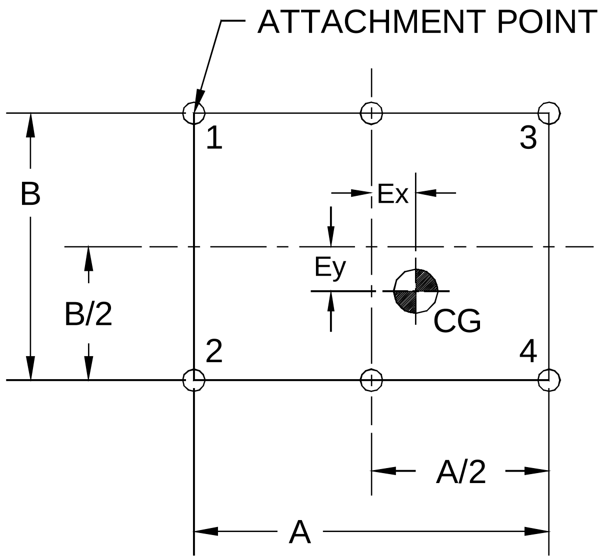

Figure D5.1.1-3: Typical of Four Isolator or Restraint Locations.

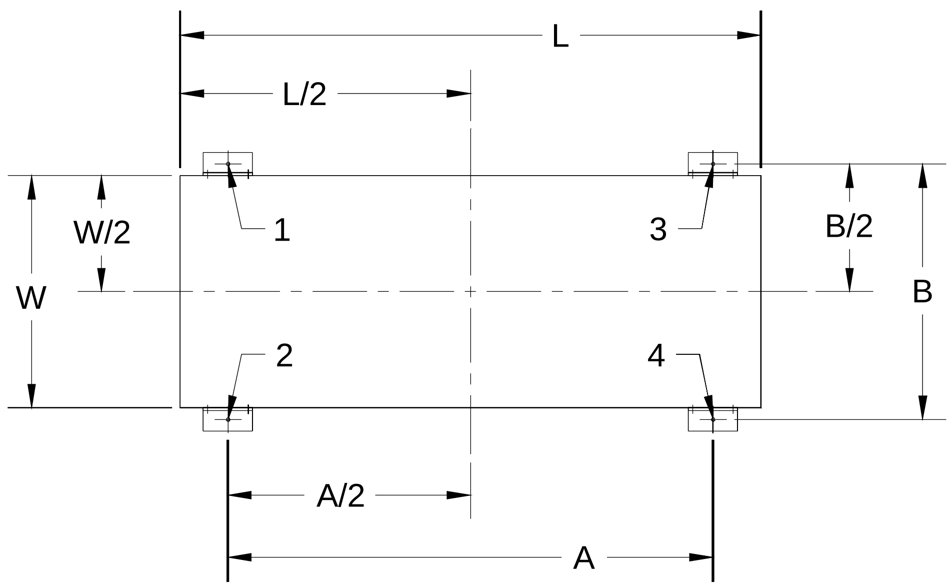

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Figure D5.1.1-4: Typical of Six Isolator or Restraint Locations.

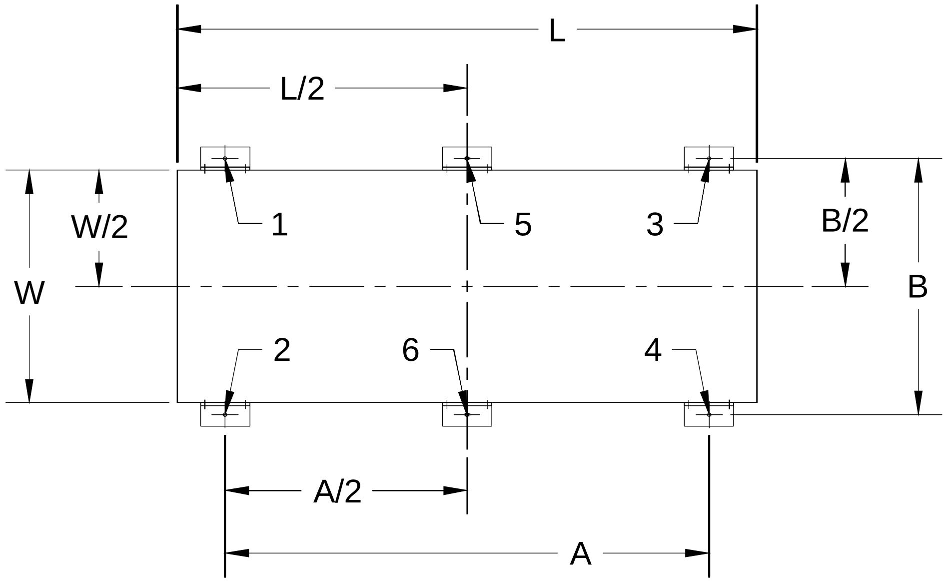
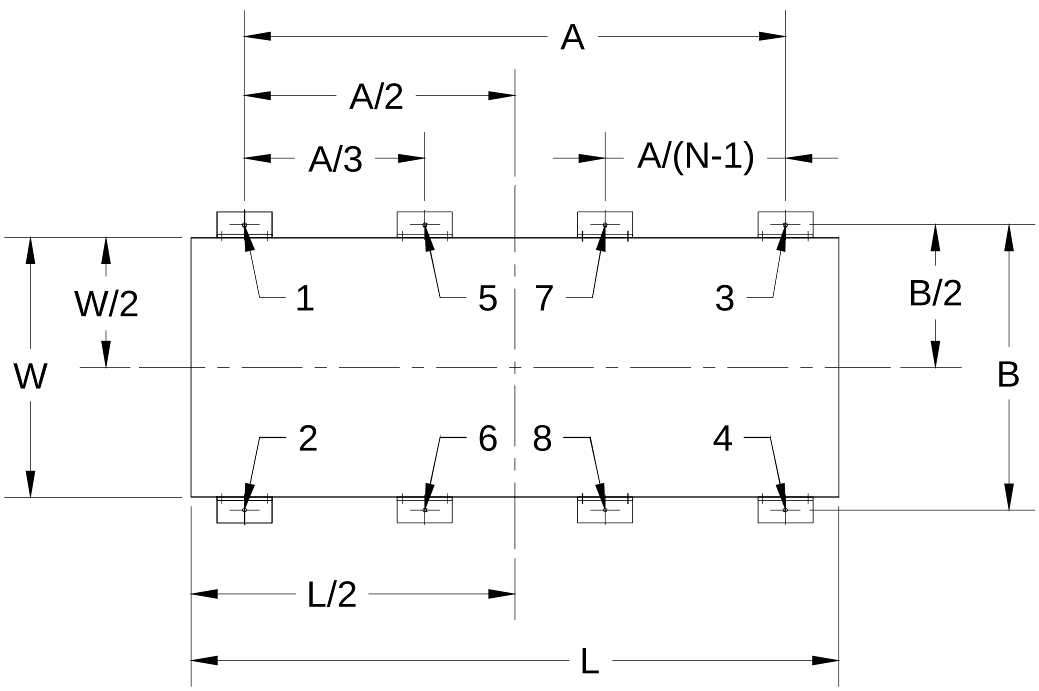


Figure D5.1.1-5: Typical of Eight or More Isolator or Restraint Locations.



Bolt/Anchor Number & Size and Weld Size & Length

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In general, the number of bolts or anchors used to attach the isolator/restraint to the building structure and their size are specified on the Kinetics Seismic Certification sheet. The bolts may be ***ASTM A-307***, ***SAE Grade 2***, or better. In some instances, they may be ***ASTM A-325, SAE Grade 5*** or better. *However care must be taken if **ASTM A-490** or **SAE Grade 8** bolts are used. These fasteners are made from highly heat treated steels and may behave in a brittle manner in service.* The concrete anchors certified by Kinetics Noise Control for use with isolators and restraints sold by Kinetics Noise Control are Model ***KCAB Seismically Rated Wedge – Type Anchors for Masonry,*** Model ***KUAB Seismically Rated Undercut Type Anchors,*** Model ***KCCAB Seismically Rated Cracked Concrete Type Anchors,*** Model ***KAAB Seismically Rated Adhesive Anchor Bolts,*** Model ***KSAB Seismically Rated Screw Type Anchors*** and Model ***KAST Seismically Rated Cast in Place Anchors.***.

In lieu of proper documentation, the appropriate bolt or anchor size may be determined by the size of the holes in the mounting plate or the oversized base plate. Table D5.1.1-2 will be useful in obtaining the proper bolt or anchor size.

Table D5.1.1-2: Bolt or Anchor Size vs. Hole Size

Hole Size (in)	Bolt or Anchor Size (in)
5/16	1/4
7/16	3/8
9/16	1/2
11/16	5/8
13/16	3/4
15/16	7/8
1-1/16	1
1-3/16	1-1/8
1-5/16	1-1/4

Unless otherwise specified by Kinetics Noise Control, all of the mounting holes in the isolator or restraint mounting plate or the oversized base plate are to be used with the appropriate sized fastener to attach the isolator or restraint to the building structure.

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If the isolator or restraint is to be attached to building structure by welding, the weld size and the linear length as well approximate locations will be specified on the Kinetics Seismic Certification sheet. The welds specified will have the same strength as the proper number and type of bolts for the most highly loaded isolator or restraint.

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FORCES TRANSFERRED BETWEEN THE EQUIPMENT & RESTRAINT

Introduction:

Due to the nature of certain seismically restrained isolators, and certain types of seismic restraints, the forces that are transferred between the equipment and the restraint, and the restraint and the ground are not what would be normally expected from the normal static force analysis. In this document we will discuss the basic types of restraints and isolators, and point out the effects that each will have on the magnitude of the forces transferred.

The newer building codes such as the ***IBC*** Code family and ***TI-809-04*** have mandated design seismic forces that are much larger in magnitude than were previously specified in the older model building codes. This means that the restraints that will be specified, oversized base plates that will be required, and the building structure required to support the equipment with its isolators, and/or restraints will all increase in size and capacity.

Basic Restraint Types:

The most basic types of restraints are those with built in clearance, and those without built in clearance. The following list shows the basic restraint types with the Kinetics Noise Control Models that apply to each.

1.) **Restraints with Built In Clearance: Tri-Axial Restraints – HS-5, HS-7, and FMS; Bi-Axial Restraints – HS-2; Single-Axis Restraint – HS-1.**

2.) **Restraints without Built In Clearance: KSMS**

The restraints with built in clearance are used primarily for three reasons. First this type of restraint is used when free standing steel coil springs are specified for isolation of the equipment. This allows the equipment to move, vibrate, slightly when operating without contacting the restraints. Second they may be used for equipment that is sitting on the floor and has no provisions to allow it to be attached solidly to the building structure, such as mounting feet or a structurally sound base. Third, certain models of this type of restraint, such as the ***HS-1***, may be added after the equipment has been installed and is operational, if there is enough space on the floor or housekeeping pad.

When restraints with built in clearance are used, the engineer, contractor, equipment supplier, and building owner need to be aware that impact forces greatly in excess of the basic code values for the horizontal and vertical seismic forces may be transferred between the equipment and the restraint. These built in clearances allow the equipment to be accelerated relative to the restraint. When the restraint is finally contacted, the equipment has generated an appreciable amount of kinetic energy that must be dissipated in the restraint. If the contact forces are stiff, the impact forces will be large. If the contact surfaces are relatively soft, the impact forces will be smaller in magnitude.

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In an effort to address this impact between the equipment and the restraint, the newer codes require that an ***Impact Factor*** of ***2:1*** be applied to the basic computed seismic force. Depending on the design of the restraint and the magnitude of a seismic event, this factor may or may not, be representative of the actual acceleration values encountered in service, however, it is a good point from which to begin.

The equipment manufacturers must to be cognizant of these impact forces as they will affect the reliability of their equipment. They must be considered when designing equipment that will be certified under the provisions of the ***IBC*** for continued operation after an earthquake for facilities that are categorized as essential or hazardous.

For restraints with built in vertical clearance, the forces that resist the overturning of the equipment are concentrated at the corner restraints. This sometimes leads to the necessity to select restraints and/or oversized base plates that seem to be larger than common practice would normally recommend.

The restraints without built in clearance used to mount rigid equipment will not have the impact force issues that the restraints with clearance have. Also, the forces that resist overturning are more-or-less evenly distributed between the restraints. These restraints are equivalent to solid mounting the equipment using the mounting feet provided by the equipment manufacturer. These restraints may also be used in conjunction with the pre-existing mounting feet on the equipment to provide additional restraint as required by the code provisions.

Basic Seismic Isolator Types:

The isolators that utilize steel coil springs fall into two basic types as shown below with Kinetics Noise Control models that typify each type.

1.) **Contained Spring Seismic Isolators: FHS with an Oversized Base Plate; FLS; FLSS; and FMS. In these isolators, when the equipment moves upward, and the vertical restraint is contacted, the spring force *is not* added to the loads in the bolts, anchors, or welds that attach the isolator to the building structure. The spring forces are, thus, tied up in the isolator housing.**

2.) **Uncontained Spring Isolators: FHS without an Oversized Base Plate, or any tri-axial restraint arrangement where the isolator is a separate component from the restraint and is supported directly by the building structure. In this type of isolator, when the equipment moves upward and contacts the vertical restraint, the spring force *is* added to the loads in the bolts, anchors, or welds.**

For all of the seismic isolator types listed above, the seismic restraint is a tri-axial type with built in clearance. As such, the previous discussion concerning restraints with built in clearance will apply to these products as well. Also, the forces that resist the overturning of the equipment will tend to be concentrated at the corner isolator locations in a similar fashion.

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The Kinetics Noise Control Model ***KRMS Seismic Neoprene Isolator*** falls in to the category of a restraint/isolator assembly without built in clearance. The vertical restraints forces are carried entirely though the housing to the bolts, anchors, or welds attaching the isolator to the building structure. So, it does not fall into either the category of restrained spring, or unrestrained spring. It exhibits the characteristics of both, and must be treated accordingly.

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ATTACHMENT OF EQUIPMENT TO RESTRAINTS

Introduction:

Restraints can be attached to equipment in a number of ways. The most obvious is by directly bolting the equipment mounting face or stud on the restraint devise to the equipment via a factory provided hole in the equipment. Unfortunately many pieces of equipment (particularly those not initially designed for seismic service) do not include mounting provisions. In some cases, several independent components make up the piece of equipment and often, if provided, holes are not well located or of appropriate size for direct connection to the restraint device.

Wherever the restraints are attached to the equipment, the equipment manufacturer must offer assurances that the application of seismically generated forces at these locations will not exceed the structural capabilities of the equipment. When reviewing the forces, the manufacturer must take into account shear, tensile and bending forces at the connection points.

D5.1.3.1 Equipment Directly Bolted to Restraints:

Where equipment can be directly bolted to the restraints and where the pattern is reasonably appropriate, this is the most appropriate method to use. The installer should refer to the certification that was performed on that particular piece of equipment and ensure that the number of attachment points and geometry used are consistent with the mounting pattern on the equipment. If the computation addressed several similar pieces of equipment, the spacing used would have been the smallest of all of those included in the analysis (as this would be the worst case). As such, if the actual bolt pattern found on the equipment is larger than that used in the analysis, mounting using the larger pattern is quite acceptable and would not negate the analysis.

It is further assumed, when performing an analysis or certification, that the hardware used matches the holes or studs in the restraint device. It is not permitted to downsize this hardware relative to that originally intended for the restraint. If the hole in the equipment is larger than the restraint hardware, it must be “fitted” to the bolt used in the restraint. This can be done by welding a washer plate to the equipment, adding a sleeve or using a grommet such as the Kinetics “TG” grommet. The hole size cannot exceed the nominal hardware diameter by more than 1/8”.

If the hole in the equipment is smaller than the size required by the restraint, it must either be enlarged (with the equipment manufacturer’s knowledge and permission) or the equipment must be fitted with an appropriately sized adapter to allow the use of the larger hardware.

D5.1.3.2 Equipment Welded to Restraints:

In many instances, there is no provision for bolt down attachment of the equipment, the arrangement is not conducive to seismic restraint or the bolt attachment provisions are simply inadequate. In these cases, welding is the most common method of attachment. Optional

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welding information is provided on Kinetics Noise Control's standard Certification document. Where this information is not provided, but the acceptable bolt size is known and bending forces are not significant, the following table can be used to size the weld based on the bolt size.

Table D5.1.3-1; Weld Length in Inches that are Equivalent to 1 Bolt

	Weld Equivalents to A307 Hardware					Weld Equivalents to A325 Hardware				
Bolt Dia	1/8 Weld	3/16 Weld	1/4 Weld	3/8 Weld	1/2 Weld	1/8 Weld	3/16 Weld	1/4 Weld	3/8 Weld	1/2 Weld
0.25	1.11	0.74	0.56	0.37	0.28	2.44	1.63	1.22	0.81	0.61
0.375	2.50	1.67	1.25	0.83	0.62	5.50	3.67	2.75	1.83	1.37
0.5	4.44	2.96	2.22	1.48	1.11	9.78	6.52	4.89	3.26	2.44
0.625	6.94	4.63	3.47	2.31	1.74	15.27	10.18	7.64	5.09	3.82
0.75	10.00	6.67	5.00	3.33	2.50	22.00	14.66	11.00	7.33	5.50
0.875	13.61	9.07	6.80	4.54	3.40	29.94	19.96	14.97	9.98	7.48
1	17.77	11.85	8.89	5.92	4.44	39.10	26.07	19.55	13.03	9.78

When using the above table (D5.1.3.1), each weld used should be approximately centered at the restraint location indicated in the analysis. In addition the leg **size** must not be larger in size than the thickness of either of the materials that are being welded together. Welds should be made to structural members within the equipment and should not be performed without the knowledge and approval of the equipment manufacturer.

D5.1.3.3 Intermediate Structure:

Intermediate structures are used for a number of reasons. First, they are used where the equipment is not structurally adequate for the direct attachment of the restraints. Second are cases where the equipment is "floated" on springs and there are multiple individual components that must be held in proper alignment with one another. Occasions when mass must be added to the system for stability can require an intermediate structure and lastly, when the type of restraint or isolator desired is not directly compatible with the type of mounting arrangement available on the equipment.

If an intermediate structure is fitted, this structure must be designed to withstand the full local restraint loads at their points of attachment and must interface with the equipment in such a fashion that the forces transmitted to the equipment are within the structural capabilities of the equipment. One of the biggest benefits of the use of intermediate frames is to distribute the high point loads (and often bending loads) that can be applied by the restraint components over several connections to the equipment. In the case of bending loads, intermediate structures can sometimes prevent them from being transmitted into the equipment at all.

D5.1.3.4 Cautions and Equipment Durability Design Factors:

When connecting restraints to equipment, they must be connected in such a way as to be "permanently" connected. They cannot be connected to removable panels, doors or covers.

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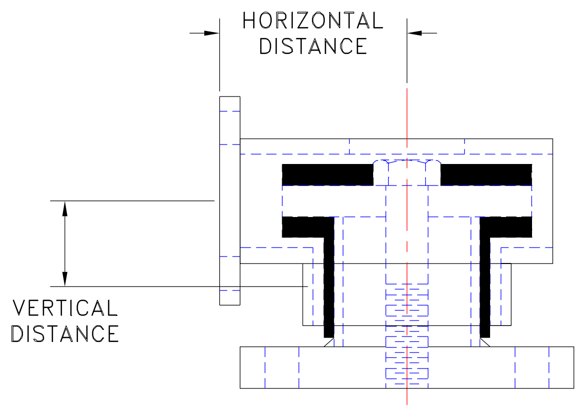
They also must not be located in such a way that they obstruct removable panels, doors or covers.

Care must be taken to ensure that the equipment has the capability to resist the seismic loads (particularly bending). Shear and Tensile forces can be obtained directly from Certification documents. These forces act at the center of the snubbing elements in the restraint device. Bending can be determined by factoring in the distance in the horizontal and vertical axis between the center of the snubbing element and the center of the mounting face or stud at the equipment surface.

The maximum moment that the equipment must be capable of withstanding is the sum of the horizontal and vertical moments. The Horizontal moment is the peak horizontal force from the analysis multiplied by the vertical distance from the snubber centerline to the center of the mounting surface face. This must be added to the peak vertical force multiplied by the horizontal distance between the snubber centerline and the center of the mounting surface face.

Figure D.5.1.2-1; Horizontal and Vertical Offsets



For floor mounted equipment, the peak vertical force is compressive however, depending on the restraint type, the springs in isolated systems may generate an uplift force on the restraint attachment hardware that is greater than would be predicted by a simple overturning analysis. Were appropriate, this must be taken into account. This occurs when the restraint is separate from the support system or if the spring force is not trapped within the isolator housing (For example an FHS without an oversized baseplate). The Kinetics Certification takes these factors into account when evaluating restraints, however if someone is looking to validate the numbers by hand, The peak vertical force to which the anchors would be exposed would equal listed the dead load (expressed as a positive number) plus the listed uplift force indicated in the standard certification document.

Below is listed some typical output data in which the worst case location is Loc 4. For it, the peak horizontal force would be 775 lb. If the restraint device in this instance included a fully contained spring coil (like an FLS) the peak vertical uplift force to which the anchors would be

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exposed would be the listed 728 lb. In the case of an FHS, the peak vertical load to which the anchors would be exposed would be *(The static load expressed as a positive number + the uplift load.* In this case, it works out to be 1704 lb.

Table D5.1.3-2; Vertical Load Components

Output Data				
Certification Loads (Seismic) (lb)	Loc 1	Loc 2	Loc 3	Loc 4
Static Load	**-552**	**-685**	**-787**	**-976**
Max Uplift Load at Loc:	**728**	**728**	**728**	**728**
Max Horiz Load at Loc:	**439**	**544**	**625**	**775**
Effective Corner Wt	**-553**	**-686**	**-787**	**-976**
Calculated Restraint Safety Factors (Must be greater than or equal to 1)				
	Loc 1	Loc 2	Loc 3	Loc 4
Restraint SF if Welded to Steel	**2.04**	**1.86**	**1.73**	**1.53**
Restraint SF if Bolted to Steel	**2.04**	**1.86**	**1.73**	**1.53**
Restraint SF if Anchored to Concrete	**.36**	**.34**	**.32**	**.29**
Anchor/Attachment Bolt Size/Qty	**0.375 / 2**	**0.375 / 2**	**0.375 / 2**	**0.375 / 2**
Min Anchor Embedment Req'd	**3"**	**3"**	**3"**	**3"**

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ATTACHMENT OF RESTRAINTS TO STRUCTURE

Introduction:

Unlike the connection between restraints and equipment (which is almost always a metal to metal connection), the connection to structure can be made to a wide variety of materials. The most frequent connection is to concrete, but connections to structural steel, wood and gage materials are also common. As the structural connection has the potential to be the weakest link in the anchorage chain, proper treatment is critical.

In addition to being critical to the anchorage of the equipment, the structural connection also has the potential to impact the durability of the structure. Because of this, all connections to structure should be reviewed with the engineer of record prior to installation to ensure that the attachment method chosen cannot result in a structural weak spot that can cause an unintended failure in the building or other dangerous situation.

Of particular concern are the following:

1) Connections to structural steel involving drilling holes or otherwise weakening the structure.
2) Connections to post-tensioned concrete slabs involving drilling into the slab.
3) Bolt or screwed connections to the narrow edge of wooden beams.
4) Any connections to gage material.

Connections to Concrete

Because of the brittle nature of concrete, it is particularly susceptible to failures that result from the pounding loads generated by earthquakes. As a result, the anchors selected must be sized conservatively. While cast in place anchors are preferable from a loading standpoint, the ability to properly locate them at the time of the pour is very low and they are rarely used in equipment mounting applications. If this hurdle is overcome, they can be sized using conventional anchor sizing procedures as identified in the current version of ACI 318 or through the use of the Kinetics Seismic Certification Program.

Most commonly, post-installed anchors are used. While these can be installed at the time the equipment is placed, they do not have the same positive grip as to the cast in place anchors. As a result, reduced capacities based on ICBO/ICC tests must be used and frequently factors are added to increase the design forces used in the analysis to further ensure that the anchors will remain functional.

In past versions of the IBC, wedge type anchors had been preferred. These anchors are relatively easy to install, continue to expand as they are exposed to tensile loads and offer added confidence that they will continue to function, even in cracked concrete. On the newer versions of the IBC however, many different types of anchors have been tested and approved and depending on the application, one type may have better performance characteristics than another.

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Unless directed otherwise or for cases where very large anchors are required and in places where they qualify, Kinetics Noise Control will design around seismically approved wedge type anchors.

In the early IBC codes (2000/2003), the codes dictate that undercut anchors be used for hard mounted equipment of greater than 10 hp. The later versions of the code allows the use of approved, properly selected adhesive anchors in their place. This requirement does not exist for isolated equipment. If used, undercut anchors require that a hole be drilled and then be modified to include an oversized pocket at their base. These pockets can be created with a special tool or in some cases, can be cut with the anchor itself. These pockets offer a more positive lock for the bolt than can be obtained with a wedge type anchor.

When using post-installed concrete anchors, all anchors are to be embedded, spaced and located far enough away from the edge of a slab to meet their rating requirements. Generally speaking, they must also retain 1" or more cover of concrete between the bottom of the hole and the opposite face of the concrete. For slabs on grade, this value should increase to at least 1-1/2". Because of this requirement, the size of the thickness of the concrete has a direct impact on the maximum permitted anchor size. Generally these limitations restrict the use of anchors larger than 3/8" when the popular floor slab thickness of 4" is used. If a larger anchor is required, some special treatment of the floor slab is needed.

All anchors are rated for installation into a single, uninterrupted layer of concrete. Because of this, unless poured at the same time and as one piece with the floor slab, the added thickness of a housekeeping pad cannot be added to the floor slab thickness when determining the maximum allowed anchor embedment. Instead, the housekeeping pad by itself, must be adequately thick to accommodate the anchors and must be tied with an array of smaller anchors to the structural floor. There is more information on designing housekeeping pads in the appendix of this manual.

Because post-installed anchors are dependent on friction for their capacity, it is critical that they are torqued to the appropriate level. Also, because anchors of similar sizes as manufactured by different manufacturers do not possess equal capacities, it is not permissible to substitute away from those that were assumed in the evaluation and certification process. All Kinetics Certifications are based on the use of Kinetics Noise Control provided anchors, torqued in conformance with the anchor torque data provided in the submittal information and also available in the product section of this manual.

An optional attachment method is to drill through a floor slab above grade and install the restraint device using bolts and nuts. If this is done, any factors that may have been used in the analysis to derate the anchors, can be ignored and the attachment can be treated as a through bolted connection.

A second option is to cast an oversized embedment plate into the floor in the approximately location of the required restraint device. This plate can be interfaced with the steel reinforcement in the slab to ensure that it will not pull out. When the equipment is installed at

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some later time, the restraints can be welded to the embed plate and the entire restraint arrangement can be treated as though it was attached to concrete.

Connections to Structural Steel

There are two different types of steel structures to which equipment may attach. The first is a purpose built structure that was designed specifically to support the equipment being restrained and the second is a structure whose primary design intent is based on the capacity of the building envelope to withstand building design loads.

In the first case, attachment holes are common and have typically been accounted for in the design of the structure. The use of bolts to attach the equipment is common practice, but should be coordinated with the structure's designer.

In the second case however, the attachment of equipment is frequently an afterthought. While the structure would globally have been designed to have adequate capacity for both its intended building function and equipment support, the addition of holes or of the locally generated stress concentration caused by the holes can weaken it to the point that serious building structural issues can emerge. Under no circumstances should the structure be modified in such a way that it would be weakened without prior review of the structural engineer of record. Connections to the building structure are normally accomplished by welding components to the structure. These components can include holes or other bolting provisions. If the attachment process involves the removal of fire proofing material on the steel, it must be replaced prior to completion.

When sizing holes to match the bolts in a restraint, they are not permitted to exceed the nominal hardware size by more than 1/8". Thus the largest hole permitted for a 5/8" bolt is 3/4". Slotting this hole for alignment is not permitted and if required, the hole must be repaired to limit the clearance to 1/8" prior to the installation of hardware. All bolts are to be tightened in conformance with normal practice.

Connections to Wood

There are a wide variety of wood sections to which people attach equipment. These range from heavy timber members and engineered lumber to roof sheeting. When seismically restraining equipment, connections should be made to structural grade or "engineered" lumber only.

Where possible, the preferred connection is with a through-bolt that penetrates the wood member and bears against a load spreading washer plate (or fishplate) on the back side of the wood to prevent crushing.

Where it is necessary to screw into the wood, lag screws inserted into properly drilled holes can be used providing the following rules are followed:

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1) The edge distance from the center of the screw hole to the edge of the wooden member in which it is inserted must be at least 1-1/2 bolt diameters.

2) The end distance (from the bolt to the end of the wooden member in the direction of the grain's axis) must be at least 7 bolt diameters.

3) Spacing between bolts must be at least 4 bolt diameters.

4) Embedment must be adequate for the design loads expected.

Of these items, the first 3 are relatively straightforward. The last item is more ambiguous and needs further explanation. The bolt capacity is a function of many factors and should be sized specifically for the application under review. The density and type of the wood, the angle of the screw relative to the grain and the redundancy of the connections all have significant impact on the rating of the connection. In order to achieve the full rated capacity of the restraint device (if connected with lag screws), the limiting capacity of the screw must be a metal failure in the screw itself. In general, this means that for a reasonably dense grade of structural lumber and a screw mounted at 90 degrees to the grain axis, an embedment depth of 9 diameters is needed to achieve full capacity. Further information on the design of lag screw connections is available in the NDS/ASD *National Design Specification for Wood Construction Manual* published by American Forest and Paper Association / American Wood Council or Section A7.3 in the Appendix portion of this manual.

As with connections to steel, it is mandatory that the structural engineer of record is aware of and approves connections to wood structures because of possible adverse effects that the connections might have on the ability of the structure to carry primary building loads.

Connections to Gage Materials

The most common applications that involve connections to gage materials involve curbs and roof mounted equipment. In these cases, if light equipment is involved (like mushroom fans), connections directly to sheet metal can frequently be adequate. In order to be successful however, the connections need to be made up of a series of small fasteners spaced evenly around the component being anchored. In general, applications involving screws larger than #10 cannot be directly connected to gage materials.

Where these connections can be made, it is also mandatory that the gage materials themselves are also attached to larger structural elements with a series of smaller connections. Again these must be designed such that the can transfer any seismic loads forced into them by the equipment back into the structure without damage.

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OVERSIZED BASEPLATES - HOW THEY WORK & WHY USE THEM

Introduction

The normal design philosophy for Kinetics Noise Control, when designing a new seismic isolator or restraint, is to size the components to allow the smallest package when the isolator or bracket is to be attached to the structural steel of the building. This means that the mounting fasteners and the footprint of the isolator or bracket optimized for the attachment to steel. As a result, the maximum capacity of the isolator or bracket can not be utilized when it is to be attached to concrete using either wedge type anchors or even the undercut type concrete anchors.

An isolator or bracket that is designed to optimize the capacity of the concrete anchors would have a footprint and fastener requirement that would be way too large for efficient attachment to structural steel. Also, we at Kinetics Noise Control feel that it would be prohibitively expensive to design one complete line of isolators or brackets for attachment to steel, and another complete line of isolators or brackets for attachment to concrete. Therefore, we design to optimize the isolator or bracket for attachment to structural steel, and employ the appropriate oversized base plate for an application that specifies attachment to concrete.

The oversized base plate is typically a square piece of steel plate with four anchor holes in it. The isolator or bracket is welded more-or-less to the center of the plate with the recommended amount of weld for attaching the isolator or bracket to structural steel. This oversized base plate allows us to use an anchor size larger than would be allowed by the mounting holes in the isolator or bracket. Also, the oversized base plate will allow us to space the anchors far enough apart to take full advantage of the allowable loads published for the concrete anchors. A typical wedge type concrete anchor, when loaded, tends to produce a cone shaped stress field where the point of the cone is at the embedded end of the anchor, and the large end of the cone is at the surface of the concrete. When the anchors are too close together, the cone shaped stress fields will interact and reduce the allowable capacities of the anchors.

Basic Analysis for Oversized Base Plates

Shown in Figure D5.2.1-1 is a typical oversized base plate with an isolator or bracket attached to it at the center of the plate. In this figure, L is the length and width of the base plate and t is the thickness of the base plate. The variable d represents the anchor size, or diameter, to be used with the base plate. The height H is the distance from mounting surface of the isolator or bracket to the center of the restraint. The seismic force is represented by F_h for the horizontal component of the seismic force, and F_v for the vertical component of the seismic force. The force component F_h is assumed to act at the center of the restraint, and the force component F_v acts act the center of the base plate. There will be three analyses, one for $F_v = 0$, one for $F_h = 0$, and on where $F_h = F_v$.

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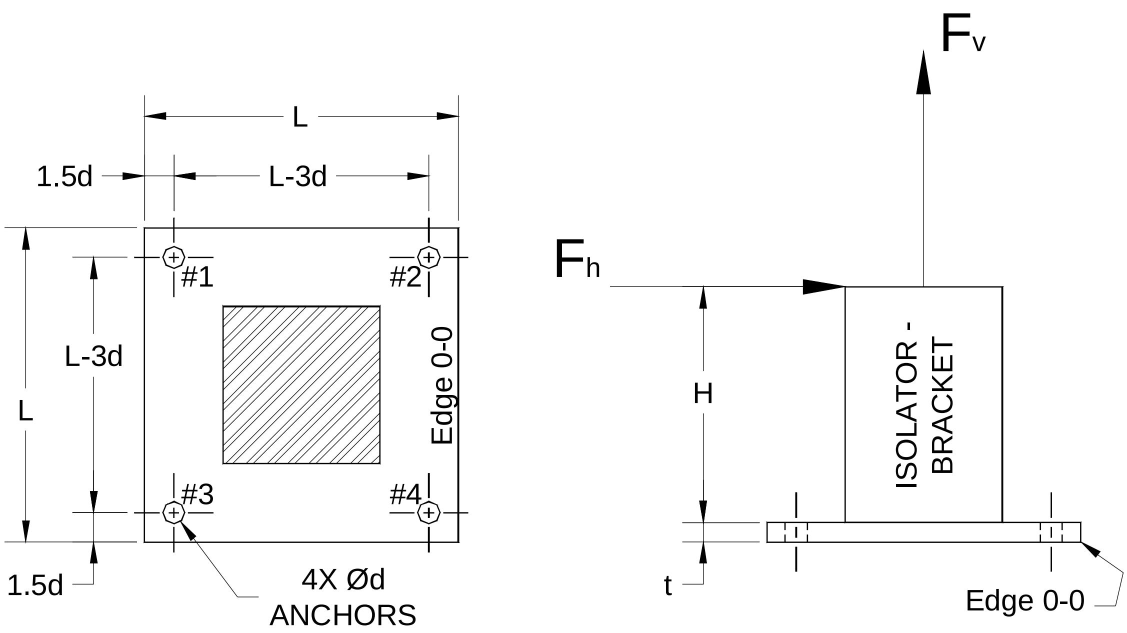
Figure D5.2.1-1; Typical Oversized Base Plate



Case 1: $F_v = 0$

In this case, the base plate will tend to tip around Edge 0-0. The analysis is based on the following assumptions.

1.) The base plate acts as a rigid member.
2.) The loads are such that there will be no concrete failure.
3.) The deflections and rotations of the base plate will be small.
4.) The tension in anchors ***#1*** and ***#3*** will be equal, $T_1 = T_3$.
5.) The tension in anchors ***#2*** and ***#4*** will be equal, $T_2 = T_4$.
Sum moments about Edge 0-0 to determine the tension in the anchors. Counter clockwise moments will be positive (+).

$$\Sigma M_{0\text{-}0} = 0 = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d)-F_h*(H+t) \qquad \text{(Eq. D5.2.1-1)}$$

And;

$$F_h*(H+t) = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d) \qquad \text{(Eq. D5.2.1-2)}$$

It is clear that anchors ***#1*** and ***#3*** will be more highly loaded than anchors ***#2*** and ***#4***. So, we will ultimately need to determine the tension in anchors ***#1*** and ***#3***. Through the assumptions it is possible to relate the tension in anchors ***#2*** and ***#4*** to the tension in anchors ***#1*** and ***#3*** in a linear fashion as follows.

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$T_2 = T_1*\{(1.5*d) / [L-(1.5*d)]\}$ **(Eq. D5.2.1-3)**

Substitute Equation D5.2.1-3 into Equation D5.2.1-2, simplify and solve for T_1.

$F_h*(H+t) = 2*T_1*[L-(1.5*d)]+2*T_1*\{(1.5*d)^2 / [L-(1.5*d)]\}$ **(Eq. D5.2.1-4)**

$F_h*(H+t)*[L-(1.5*d)] = 2*T_1*[L-(1.5*d)]^2+2*T_1*(1.5*d)^2$ **(Eq. D5.2.1-5)**

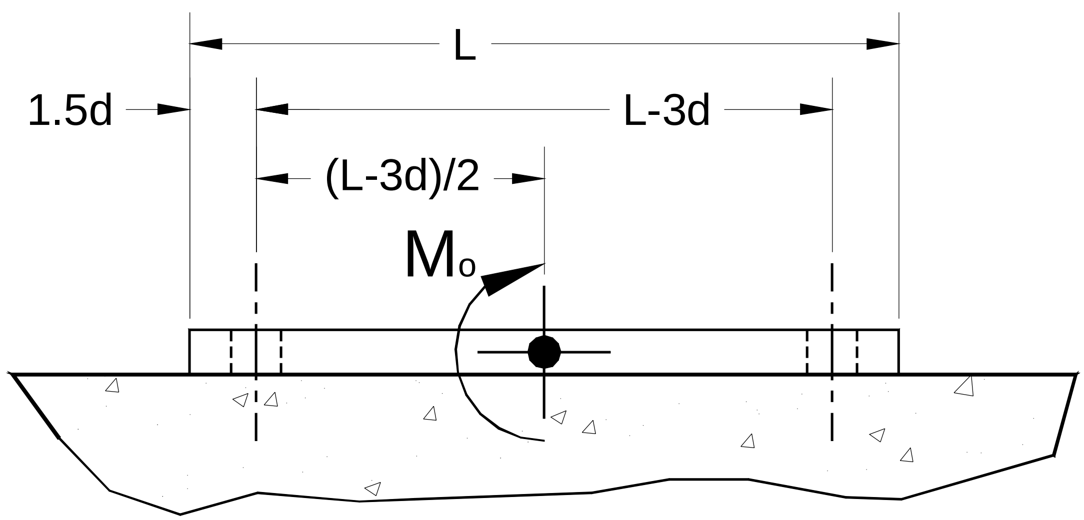
$T_1 = F_h*(H+t)*[L-(1.5*d)] / \{2*[(L-(1.5*d))^2+(1.5*d)^2]\}$ **(Eq. D5.2.1-6)**

The anchors will also be loaded in shear. Let's assume that all of the anchors are loaded equally in shear. The shear load on each anchor, P_1, will be as follows.

$P_1 = F_h / 4$ **(Eq. D5.2.1-7)**

The base plate thicknesses were selected in order to make the anchors the limiting components for values of ***H*** up to and including ***20*** inches. The stress in the base plate is estimated by assuming that the base plate is a beam with both ends fixed, and a couple M_o applied to the center of the beam, as shown in Figure D5.2.1-2.

Figure D5.2.1-2; Assumed Base Plate Loading Arrangement for Case 1



Because the isolator or bracket will be rather large, the center of the base plate will not be subjected to a great deal of bending. The maximum bending will occur at the anchor holes. The maximum applied moment in the at the anchor holes is;

$M = M_o / 4$ **(Eq. D5.2.1-8)**

The applied moment may be approximated as;

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$M_o \approx F_h*H$ **(Eq. D5.2.1-9)**

Then;

$M = F_h*H / 4$ **(Eq. D5.2.1-10)**

In general, the bending stress, s_b, in the base plate is given by;

$s_b = M*c / I$ **(Eq. D5.2.1-11)**

In this equation, ***c*** is the distance from the neutral axis to the outer fibers of the beam, and ***I*** is the area moment of inertia of the beam cross-section. For all of the cases presented in this document, ***I*** and ***c*** have the following values.

$I = L*t^3 / 12$ **(Eq. D5.2.1-12)**

And;

$c = t / 2$ **(Eq. D5.2.1-13)**

The final form of the bending stress equation will be as follows.

$s_b = 3*F_h*H / (2*L*t^2)$ **(Eq. D5.2.1-14)**

The allowable bending stress, s_A, is;

$s_A = 0.6*S_y$ **(Eq. D5.2.1-15)**

S_y is the yield strength of the base plate.

The factors of safety for the anchors and the base plate are now computed. For each case they must be greater than or equal to ***1.00***. For the anchors, the factor of safety is;

$F.S. = \{1 / [(T_1 / T_A)^{5/3}+(P_1 / P_A)^{5/3}]\} \geq 1.00$ **(Eq. D5.2.1-16)**

In the above equation, T_A and P_A are the allowable tension and shear loads for the anchors being used. The factor of safety for the base plate is given by;

$F.S. = s_A / s_b \geq 1.00$ **(Eq. D5.2.1-17)**

Case 2: $F_h = 0$

Since the base plate has been assumed to be rigid and the deflections have been assumed to be small, there will be little or no prying action on the anchors due to the vertical component of the seismic force F_v. Also, since $F_h = 0$, there will be no shear forces acting on the anchors. The

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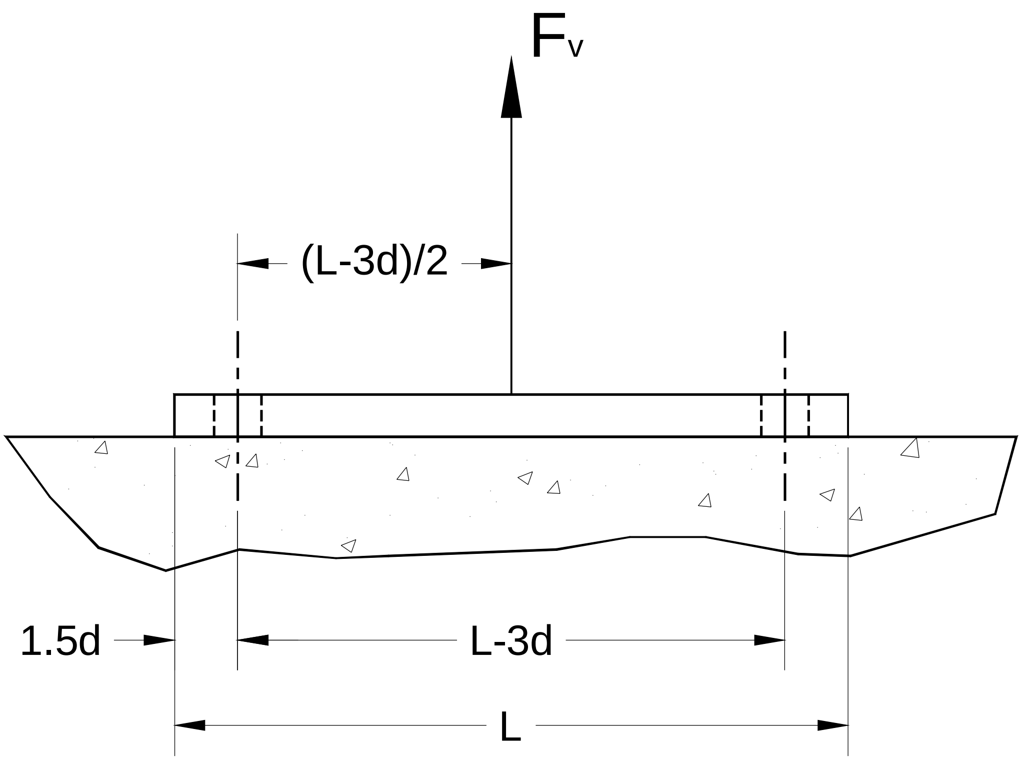
vertical component of the seismic force will be equally distributed between the four anchors, and;

$T_1 = F_v / 4$ and $P_1 = 0$ **(Eq. D5.2.1-18)**

The maximum bending will occur at the anchor holes. The base plate loading for Case 2 is shown in Figure D5.2.1-3.

Figure D5.2.1-3; Assumed Base Plate Loading Arrangement for Case 2



The maximum applied moment in the at the anchor holes is;

$M = F_v*(L-3*d) / 8$ **(Eq. D5.2.1-19)**

Substitute Equations D5.2.1-12, D5.2.1-13, and D5.2.1-19 into Equation D5.2.1-11 to obtain the maximum bending stress in the base plate.

$s_b = 3*F_v*(L-3*d) / (4*L*t^2)$ **(Eq. D5.2.1-20)**

Case 3: $F_h = F_v = F_c$

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This is the combined loading case that helps determine the final shape of the capacity envelope for the base plate. Again, we will sum moments about Edge 0-0 to determine the maximum tension in the bolts. All of the assumptions that applied to Case 1 will apply for Case 3.

$$\Sigma M_{0-0} = 0 = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d)-F_c*(H+t)- F_c*L/2 \qquad \text{(Eq. D5.2.1-21)}$$

And;

$$F_c*(2*H+2*t+L)/2 = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d) \qquad \text{(Eq. D5.2.1-22)}$$

Substitute Equation D5.32.1-3 into Equation D5.2.1-22, solve for T_1.

$$F_c*(2*H+2*t+L)/2 = 2*T_1*[L-(1.5*d)]+2*T_1*\{(1.5*d)^2 / [L-(1.5*d)]\} \qquad \text{(Eq. D5.2.1-23)}$$

$$F_c*(2*H+2*t+L)*[L-(1.5*d)]/2 = 2*T_1*[L-(1.5*d)]^2+2*T_1*(1.5*d)^2 \qquad \text{(Eq. D5.2.1-24)}$$

$$T_1 = F_c*(2*H+2*t+L)*[L-(1.5*d)] / \{4*[(L-(1.5*d))^2+(1.5*d)^2]\} \qquad \text{(Eq. D5.2.1-25)}$$

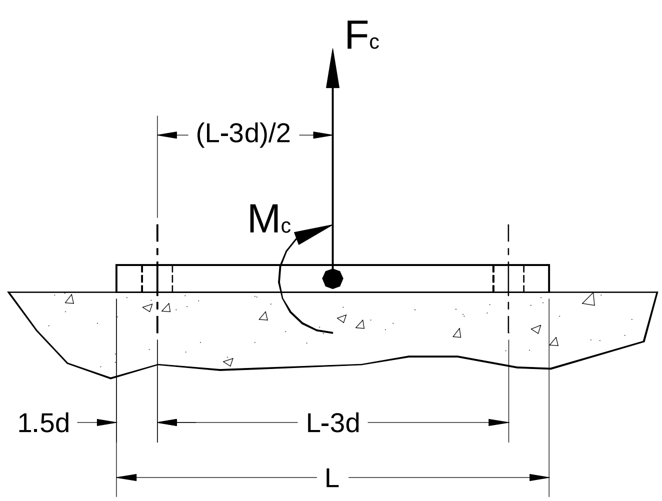
The anchors will be also be loaded in shear, and this shear load may be estimated using Equation D5.2.1-7.

The maximum bending will occur at the anchor holes in this case as well. The base plate loading for Case 3 is shown in Figure D5.2.1-4. The maximum bending moment at the bolt holes will be,

$$M = M_c/4+F_c*(L-3*d)/8 \qquad \text{(Eq. D5.2.1-26)}$$

$$M_c = F_c*H \qquad \text{(Eq. D5.2.1-27)}$$

Figure D5.2.1-4; Assumed Base Plate Loading Arrangement for Case 3



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$M = F_c*H/4+F_c*(L-3*d)/8$ **(Eq. D5.2.1-28)**

$M = (F_c/8)*[2*H+L-3*d]$ **(Eq. D5.2.1-29)**

Substitute Equations D5.2.1-29, D5.2.1-12, and D5.2.1-13 into Equation D5.2.1-11 to obtain the bending stress in the base plate.

$s_b = 3*F_c*(2*H+L-3*d) / (4*L*t^2)$ **(Eq. D5.2.1-30)**

The results of this analysis are presented and their applications are discussed in Document D5.2.2.

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OVERSIZED BASEPLATES - HOW THEY WORK & WHY USE THEM

Introduction

The normal design philosophy for Kinetics Noise Control, when designing a new seismic isolator or restraint, is to size the components to allow the smallest package when the isolator or bracket is to be attached to the structural steel of the building. This means that the mounting fasteners and the footprint of the isolator or bracket optimized for the attachment to steel. As a result, the maximum capacity of the isolator or bracket can not be utilized when it is to be attached to concrete using either wedge type anchors or even the undercut type concrete anchors.

An isolator or bracket that is designed to optimize the capacity of the concrete anchors would have a footprint and fastener requirement that would be way too large for efficient attachment to structural steel. Also, we at Kinetics Noise Control feel that it would be prohibitively expensive to design one complete line of isolators or brackets for attachment to steel, and another complete line of isolators or brackets for attachment to concrete. Therefore, we design to optimize the isolator or bracket for attachment to structural steel, and employ the appropriate oversized base plate for an application that specifies attachment to concrete.

The oversized base plate is typically a square piece of steel plate with four anchor holes in it. The isolator or bracket is welded more-or-less to the center of the plate with the recommended amount of weld for attaching the isolator or bracket to structural steel. This oversized base plate allows us to use an anchor size larger than would be allowed by the mounting holes in the isolator or bracket. Also, the oversized base plate will allow us to space the anchors far enough apart to take full advantage of the allowable loads published for the concrete anchors. A typical wedge type concrete anchor, when loaded, tends to produce a cone shaped stress field where the point of the cone is at the embedded end of the anchor, and the large end of the cone is at the surface of the concrete. When the anchors are too close together, the cone shaped stress fields will interact and reduce the allowable capacities of the anchors.

Basic Analysis for Oversized Base Plates

Shown in Figure D5.2.1-1 is a typical oversized base plate with an isolator or bracket attached to it at the center of the plate. In this figure, ***L*** is the length and width of the base plate and ***t*** is the thickness of the base plate. The variable ***d*** represents the anchor size, or diameter, to be used with the base plate. The height ***H*** is the distance from mounting surface of the isolator or bracket to the center of the restraint. The seismic force is represented by F_h for the horizontal component of the seismic force, and F_v for the vertical component of the seismic force. The force component F_h is assumed to act at the center of the restraint, and the force component F_v acts act the center of the base plate. There will be three analyses, one for $F_v = 0$, one for $F_h = 0$, and on where $F_h = F_v$.

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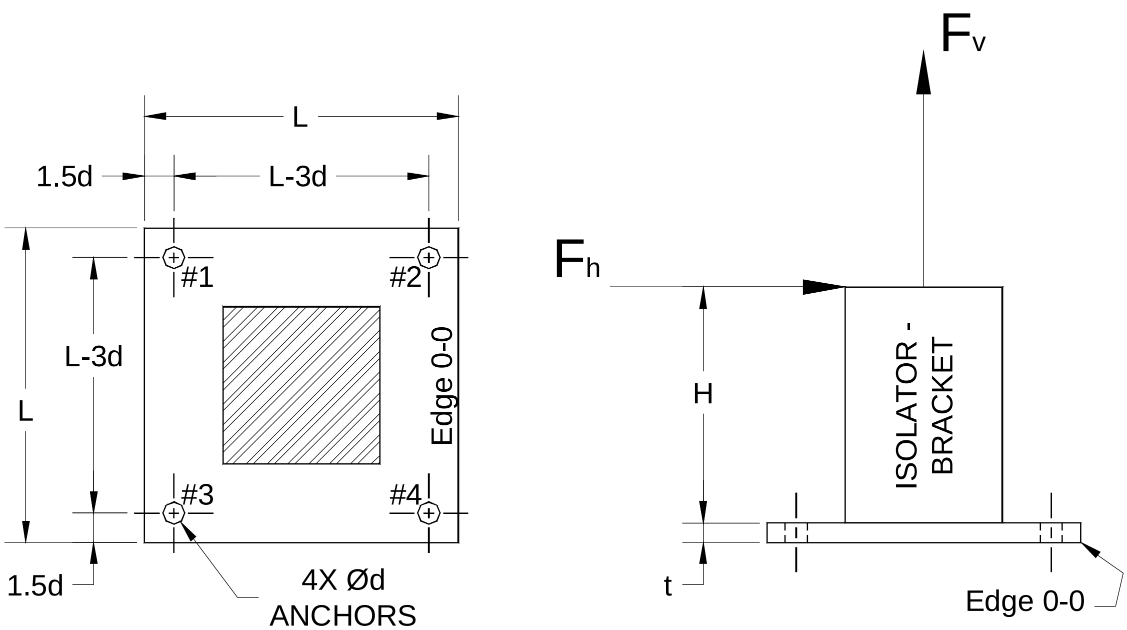
Figure D5.2.1-1; Typical Oversized Base Plate



Case 1: $F_v = 0$

In this case, the base plate will tend to tip around Edge 0-0. The analysis is based on the following assumptions.

1.) The base plate acts as a rigid member.
2.) The loads are such that there will be no concrete failure.
3.) The deflections and rotations of the base plate will be small.
4.) The tension in anchors ***#1*** and ***#3*** will be equal, $T_1 = T_3$.
5.) The tension in anchors ***#2*** and ***#4*** will be equal, $T_2 = T_4$.
Sum moments about Edge 0-0 to determine the tension in the anchors. Counter clockwise moments will be positive (+).

$$\Sigma M_{0\text{-}0} = 0 = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d)-F_h*(H+t)$$ **(Eq. D5.2.1-1)**

And;

$$F_h*(H+t) = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d)$$ **(Eq. D5.2.1-2)**

It is clear that anchors ***#1*** and ***#3*** will be more highly loaded than anchors ***#2*** and ***#4***. So, we will ultimately need to determine the tension in anchors ***#1*** and ***#3***. Through the assumptions it is possible to relate the tension in anchors ***#2*** and ***#4*** to the tension in anchors ***#1*** and ***#3*** in a linear fashion as follows.

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$T_2 = T_1*\{(1.5*d) / [L-(1.5*d)]\}$ **(Eq. D5.2.1-3)**

Substitute Equation D5.2.1-3 into Equation D5.2.1-2, simplify and solve for T_1.

$F_h*(H+t) = 2*T_1*[L-(1.5*d)]+2*T_1*\{(1.5*d)^2 / [L-(1.5*d)]\}$ **(Eq. D5.2.1-4)**

$F_h*(H+t)*[L-(1.5*d)] = 2*T_1*[L-(1.5*d)]^2+2*T_1*(1.5*d)^2$ **(Eq. D5.2.1-5)**

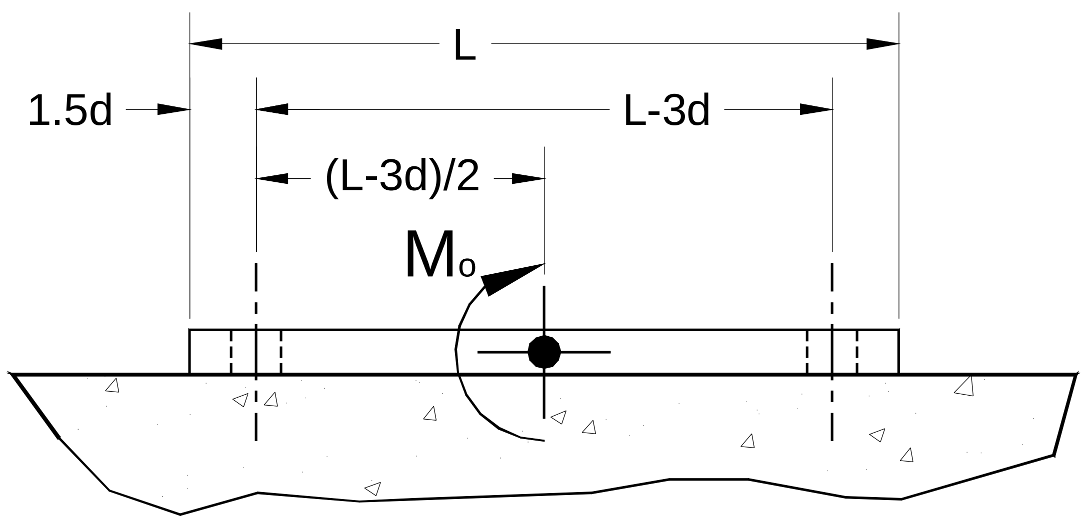
$T_1 = F_h*(H+t)*[L-(1.5*d)] / \{2*[(L-(1.5*d))^2+(1.5*d)^2]\}$ **(Eq. D5.2.1-6)**

The anchors will also be loaded in shear. Let's assume that all of the anchors are loaded equally in shear. The shear load on each anchor, P_1, will be as follows.

$P_1 = F_h / 4$ **(Eq. D5.2.1-7)**

The base plate thicknesses were selected in order to make the anchors the limiting components for values of ***H*** up to and including ***20*** inches. The stress in the base plate is estimated by assuming that the base plate is a beam with both ends fixed, and a couple M_o applied to the center of the beam, as shown in Figure D5.2.1-2.

Figure D5.2.1-2; Assumed Base Plate Loading Arrangement for Case 1



Because the isolator or bracket will be rather large, the center of the base plate will not be subjected to a great deal of bending. The maximum bending will occur at the anchor holes. The maximum applied moment in the at the anchor holes is;

$M = M_o / 4$ **(Eq. D5.2.1-8)**

The applied moment may be approximated as;

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$$M_o \approx F_h*H$$ (Eq. D5.2.1-9)

Then;

$$M = F_h*H / 4$$ (Eq. D5.2.1-10)

In general, the bending stress, s_b, in the base plate is given by;

$$s_b = M*c / I$$ (Eq. D5.2.1-11)

In this equation, ***c*** is the distance from the neutral axis to the outer fibers of the beam, and ***I*** is the area moment of inertia of the beam cross-section. For all of the cases presented in this document, ***I*** and ***c*** have the following values.

$$I = L*t^3 / 12$$ (Eq. D5.2.1-12)

And;

$$c = t / 2$$ (Eq. D5.2.1-13)

The final form of the bending stress equation will be as follows.

$$s_b = 3*F_h*H / (2*L*t^2)$$ (Eq. D5.2.1-14)

The allowable bending stress, s_A, is;

$$s_A = 0.6*S_y$$ (Eq. D5.2.1-15)

S_y is the yield strength of the base plate.

The factors of safety for the anchors and the base plate are now computed. For each case they must be greater than or equal to ***1.00***. For the anchors, the factor of safety is;

$$F.S. = \{1 / [(T_1 / T_A)^{5/3}+(P_1 / P_A)^{5/3}]\} \geq 1.00$$ (Eq. D5.2.1-16)

In the above equation, T_A and P_A are the allowable tension and shear loads for the anchors being used. The factor of safety for the base plate is given by;

$$F.S. = s_A / s_b \geq 1.00$$ (Eq. D5.2.1-17)

Case 2: $F_h = 0$

Since the base plate has been assumed to be rigid and the deflections have been assumed to be small, there will be little or no prying action on the anchors due to the vertical component of the seismic force F_v. Also, since $F_h = 0$, there will be no shear forces acting on the anchors. The

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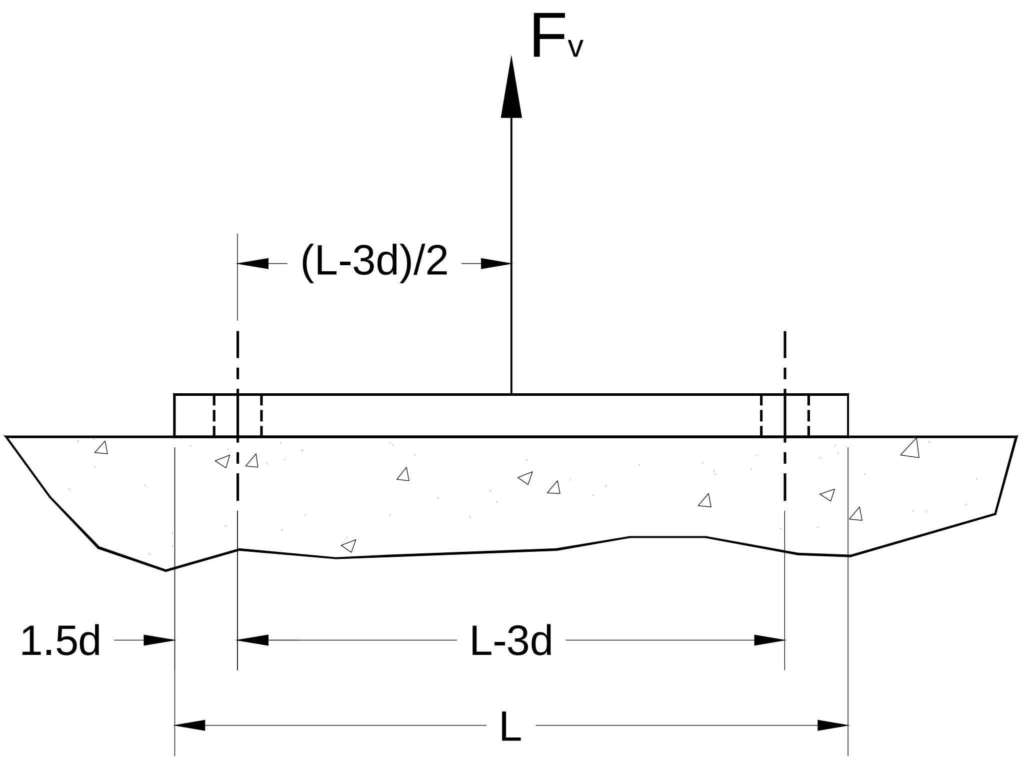
vertical component of the seismic force will be equally distributed between the four anchors, and;

$T_1 = F_v / 4$ and $P_1 = 0$ **(Eq. D5.2.1-18)**

The maximum bending will occur at the anchor holes. The base plate loading for Case 2 is shown in Figure D5.2.1-3.

Figure D5.2.1-3; Assumed Base Plate Loading Arrangement for Case 2



The maximum applied moment in the at the anchor holes is;

$M = F_v*(L-3*d) / 8$ **(Eq. D5.2.1-19)**

Substitute Equations D5.2.1-12, D5.2.1-13, and D5.2.1-19 into Equation D5.2.1-11 to obtain the maximum bending stress in the base plate.

$s_b = 3*F_v*(L-3*d) / (4*L*t^2)$ **(Eq. D5.2.1-20)**

Case 3: $F_h = F_v = F_c$

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This is the combined loading case that helps determine the final shape of the capacity envelope for the base plate. Again, we will sum moments about Edge 0-0 to determine the maximum tension in the bolts. All of the assumptions that applied to Case 1 will apply for Case 3.

$$\Sigma M_{0-0} = 0 = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d)-F_c*(H+t)-F_c*L/2 \quad \text{(Eq. D5.2.1-21)}$$

And;

$$F_c*(2*H+2*t+L)/2 = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d) \quad \text{(Eq. D5.2.1-22)}$$

Substitute Equation D5.32.1-3 into Equation D5.2.1-22, solve for T_1.

$$F_c*(2*H+2*t+L)/2 = 2*T_1*[L-(1.5*d)]+2*T_1*\{(1.5*d)^2 / [L-(1.5*d)]\} \quad \text{(Eq. D5.2.1-23)}$$

$$F_c*(2*H+2*t+L)*[L-(1.5*d)]/2 = 2*T_1*[L-(1.5*d)]^2+2*T_1*(1.5*d)^2 \quad \text{(Eq. D5.2.1-24)}$$

$$T_1 = F_c*(2*H+2*t+L)*[L-(1.5*d)] / \{4*[(L-(1.5*d))^2+(1.5*d)^2]\} \quad \text{(Eq. D5.2.1-25)}$$

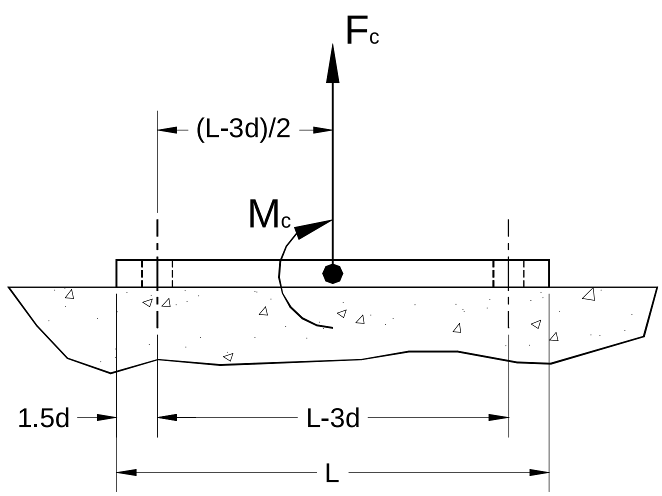
The anchors will be also be loaded in shear, and this shear load may be estimated using Equation D5.2.1-7.

The maximum bending will occur at the anchor holes in this case as well. The base plate loading for Case 3 is shown in Figure D5.2.1-4. The maximum bending moment at the bolt holes will be,

$$M = M_c/4+F_c*(L-3*d)/8 \quad \text{(Eq. D5.2.1-26)}$$

$$M_c = F_c*H \quad \text{(Eq. D5.2.1-27)}$$

Figure D5.2.1-4; Assumed Base Plate Loading Arrangement for Case 3



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$M = F_c*H/4+F_c*(L-3*d)/8$ **(Eq. D5.2.1-28)**

$M = (F_c/8)*[2*H+L-3*d]$ **(Eq. D5.2.1-29)**

Substitute Equations D5.2.1-29, D5.2.1-12, and D5.2.1-13 into Equation D5.2.1-11 to obtain the bending stress in the base plate.

$s_b = 3*F_c*(2*H+L-3*d) / (4*L*t^2)$ **(Eq. D5.2.1-30)**

The results of this analysis are presented and their applications are discussed in Document D5.2.2.

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SEISMIC/WIND FORCES AND CURB MOUNTED EQUIPMENT

Introduction

Since the introduction of the 97 UBC, all of the building codes have mandated design seismic forces that are much larger in magnitude than were previously specified. One of the features of these new codes is that they have written the design horizontal seismic force equation to account for the amplification of the accelerations due to increasing flexibility as you go up in a building. Therefore, equipment that is mounted on the roof of a building will have design seismic forces that are three times larger than a similar piece of equipment that is mounted on grade. Wind forces also increase with height. These additional forces must be addressed in the design, selection, and installation of supports and restraints for roof top curb mounted equipment.

Basic Curb Types

The roof curbs may be broken down into ***isolated*** and ***non-isolated*** types. The ***isolated*** roof curbs may be further broken down into ***sheet metal*** and ***structural*** types. The discussion will start with the ***isolated*** curb types.

Sheet Metal Seismic Isolation Curbs:

Kinetics Noise Control provides three products that combine isolation with a compatible sheet metal roof curb. First is the Kinetics Noise Control model ***KSR Isolation Rail***. These rail systems have been designed to address the bulk of the needs of smaller pieces of equipment up to 20 ft long and up to 5000 lb in weight (Note: under severe seismic or wind load conditions, these limits may be reduced further). The ***KSR-1*** and ***KSR-2*** are seismically restrained steel coil spring isolation systems that are built to be installed on compatible third party sheet metal roof curbs. Figure D6.1-1 shows a typical cross-section through the springs of a ***KSR*** installation. Figure D6.1-2 is a typical cross-section through the seismic/wind restraints of the ***KSR***. ***KSR-1*** systems are designed to operate with a system ***Static Deflection*** of ***1"*** when loaded, which gives a system ***Natural Frequency*** of ***3.13 Hz***. The ***KSR-2*** systems are intended to operate with a loaded system ***Static Deflection*** of ***2"***, which produces a system ***Natural Frequency*** of ***2.21 Hz***. The ***Static Deflection*** of the ***KSR*** systems is adjustable by adding or removing the spring coils, which are easily accessible and must be compressed for insertion or withdrawal.

The seismic/wind restraints consist of stainless steel leaves for the horizontal restraints, and reinforced neoprene straps for the vertical restraints. Each ***KSR*** installation requires a minimum of one horizontal restraint per curb side. The vertical restraints are required if there is a chance that the applied loads could generate an uplift condition at any of the equipment corners. The leaves and straps, when required are attached to the extruded aluminum top rail and the curb side wall through the nailer and sheet metal member as shown in Figure D6.1-2. The locations for the restraints are specified by the by Kinetics Noise Control. The required number of restraints, horizontal and vertical, is determined by analysis using the Kinetics Noise Control Seismic/Wind Certification Program.

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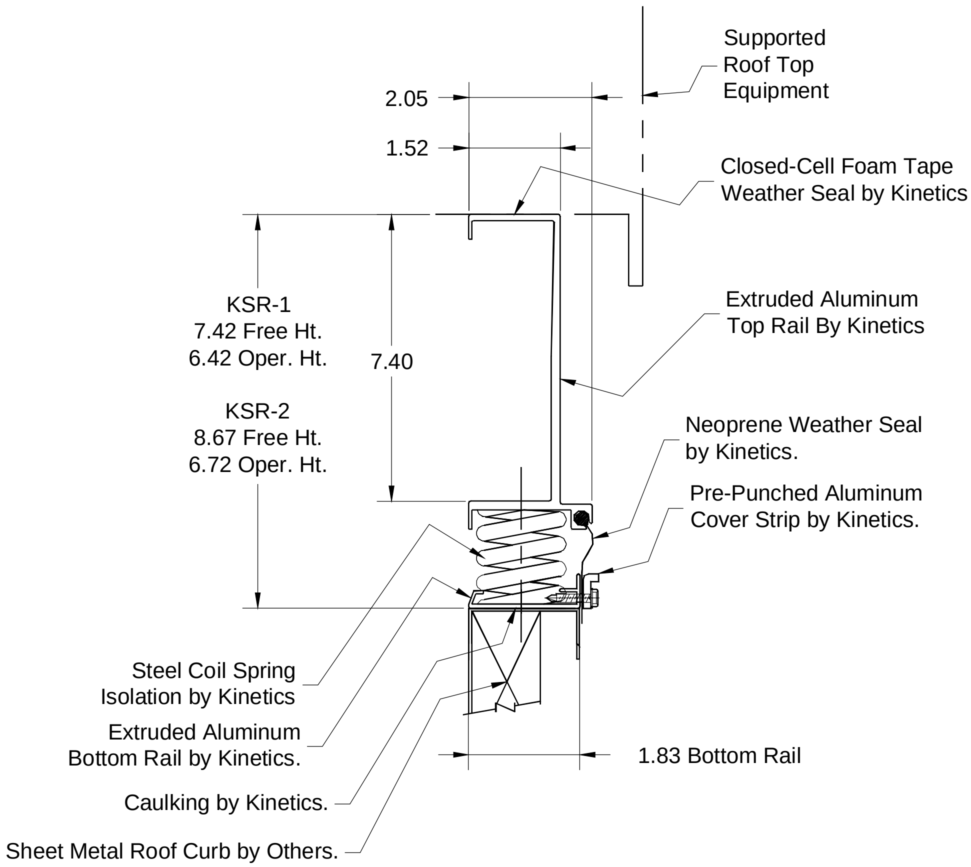
Figure D6.1-1; Typical Cross-Section through KSR Showing Isolation Springs



Compatible sheet metal roof curbs will allow the attachment of the restraint elements to their inner perimeter with hardware that penetrates the sheet steel body of the curb itself. KSR isolation rails are not generally compatible with sheet metal roof curbs whose nailer is mounted on top of the sheet metal curb body unless some form of steel element is fitted that positively attaches to the curb wall and fully surrounds the hardware that attaches the lower end of the restraint and generates a continuous steel load path between the restraint and the roof structure.

The second product offered by Kinetics Noise Control is the ***KSCR*** with 1" and 2" deflection versions identified as the ***KSCR-1*** and ***KSCR-2*** isolation rail factory mounted on a factory provided sheet metal curb assembly A typical cross-section through the ***KSCR*** is shown in Figure D6.1-3.

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Figure D6.1-2; Typical Cross-Section through KSR Showing Restraints

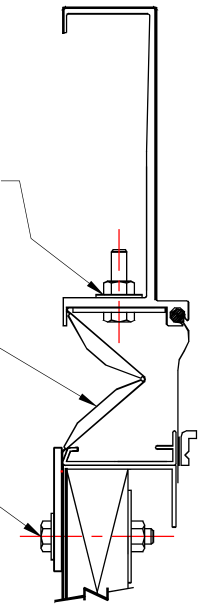
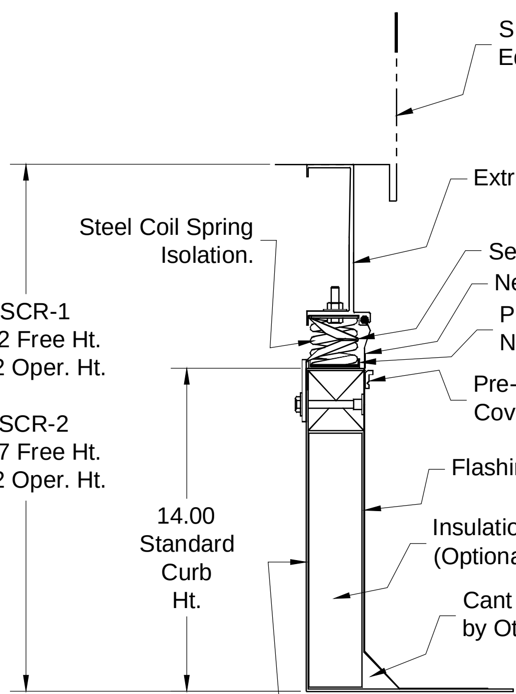


Figure D6.1-3; Typical Cross-Section through a KSCR



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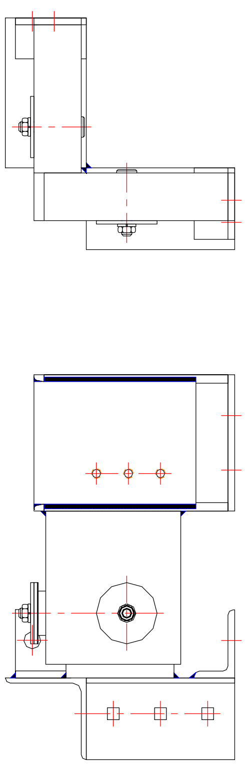
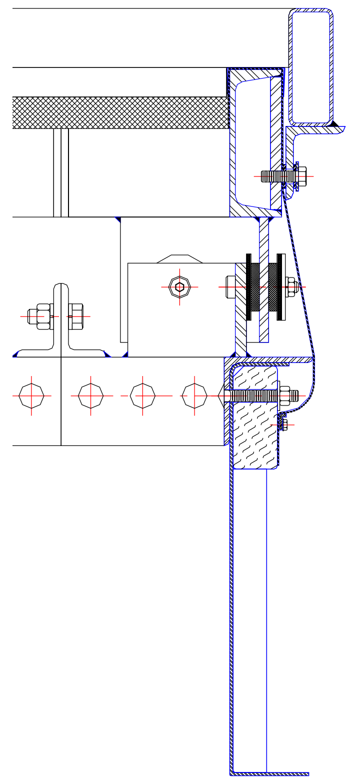
As with the ***KSR-1 & -2***, The ***KSCR-1*** is a ***1" Static Deflection*** isolation system, and the ***KSCR-2*** is a ***2" Static Deflection*** isolation system. The horizontal and vertical restraints used for the ***KSCR*** are the same ones used on the ***KSR***. At least one horizontal restraint per curb side wall is required, and more are added as indicated by analysis through the Kinetics Noise Control Seismic/Wind Certification Program. The vertical restraints are added where indicated by the analysis. Typically the curb itself is ***16 Gage*** Galvanized steel reinforced with structural grade ***2x4's*** at ***30"*** On Center. Curb heights greater may require the use of heavier gage sheet steel in order to carry the seismic and wind loads without danger of buckling failure.

The third isolation rail product offered by Kinetics Noise Control is the ***HD-KSR***. This product is a structural steel element that is intended for installation on compatible third party sheet metal curbs. It's more rugged construction than the ***KSR*** products make it more suitable for higher seismic or wind loads on smaller units and still allows good performance for units up into the 12,000 lb, 40 ft long class. The ***HD-KSR*** is also available in ***1"*** and ***2" static deflection*** versions. Figure D6.1-4 shows a plan view, elevation and a section through the critical corner element of the ***HD-KSR***.

Figure D6.1-4; HD-KSR Plan View, Elevation and Section of corner restraint elements





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A significant difference between the ***HD-KSR*** and the lighter duty ***KSR*** and ***KSCR*** is that the primary restraint elements are located at the corners of the curb. This is done because a) the sheet metal corner is much more able to resist lateral forces than are the central portions of the curb side walls and b) because it is in the corners where the peak seismic and wind overturning loads are generated.

Structural Seismic Isolation Curbs

Kinetics Noise Control provides the model ***ESR-1***, ***ESR-2***, and ***ESR-4*** structural seismic isolation curb systems. They are, respectively, ***1"***, ***2"***, and ***4" Static Deflection*** isolation systems. The intended system ***Natural Frequencies*** are ***3.13 Hz***, ***2.12 Hz***, and ***1.56 Hz*** respectively.

Figure D6.1-5; Typical ESR Pedestal Installation

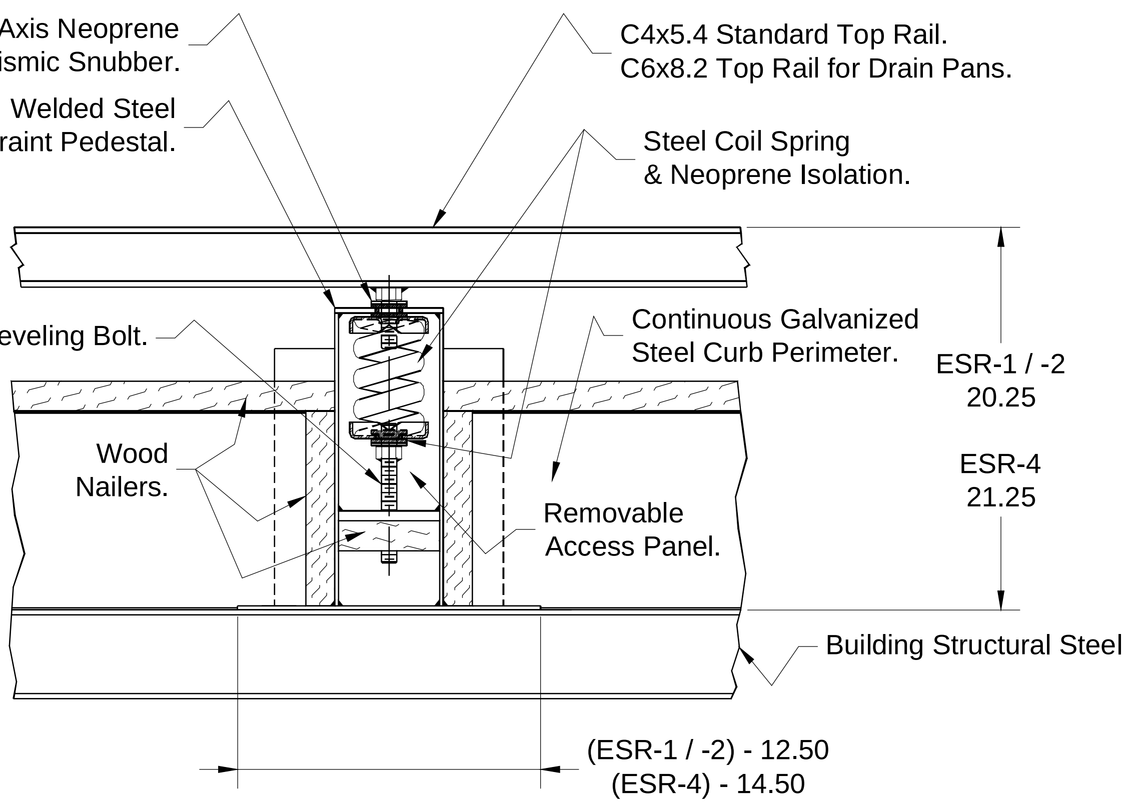

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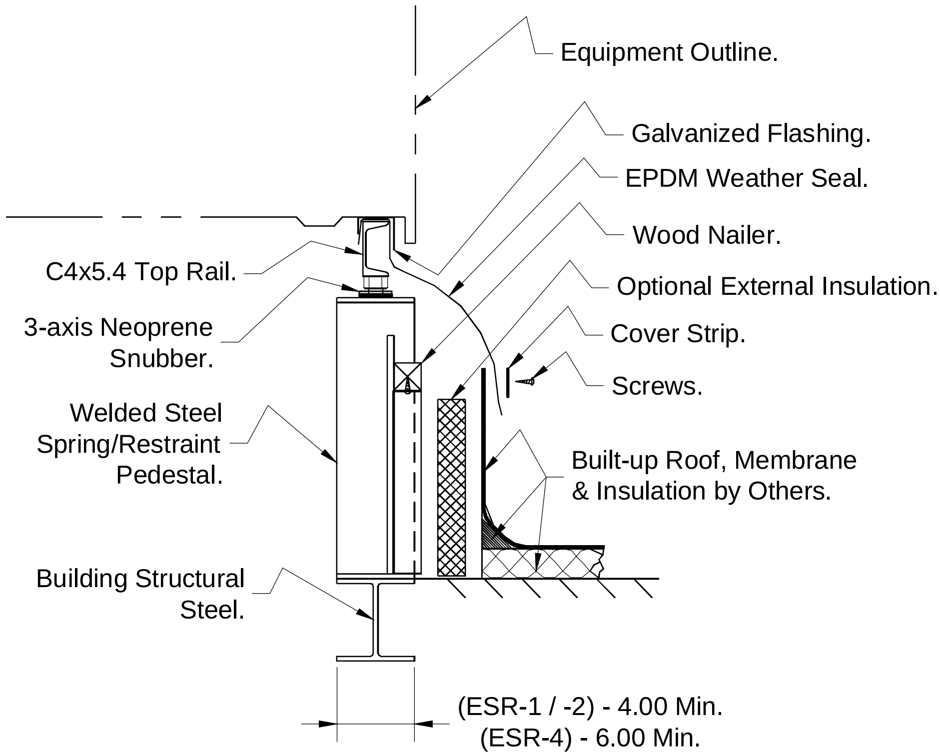
Figure D6.1-6; Typical Cross-Section through an ESR Pedestal Installation



The seismic forces are transferred from the equipment to the top rail through fasteners or welds at each pedestal location. The size and number of the fasteners, and the size and length of weld required at each pedestal is specified by the Kinetics Noise Control Seismic/Wind Certification Program. The loads are transferred to the welded steel spring restraint pedestal through the 3-axis neoprene snubber assembly. The loads then are transferred from the pedestal to the building structure. The ***ESR*** is intended to be attached directly to the building structural steel either by bolting or welding. Mounting holes are provided for three ***(3) 5/8"*** Bolts/Anchors in the base plate of each pedestal. An equivalent amount of weld is specified by Kinetics Noise Control for each pedestal. Attachment of the ***ESR*** to the building structural steel will maximize the seismic capacity of the system. If the ***ESR*** is to be attached to concrete or some type of wooden structure, special analysis and additional components will be required to make an adequate attachment, and in most instances, the full capacity of the ***ESR*** will not be realized.

When larger units are encountered, in particular when in conjunction with higher seismic or wind load conditions, it will be necessary to upgrade from the ***ESR*** to the ***MegaCurb***. The Mega Curb is a full structural curb that can be tailored to units weighing as much as 50,000 lb. Its structure is of I-Beams and other structural shapes and its base forms a rigid box onto which the isolation/restraint system can be integrated. It is available with ***1"***, ***2"***, and ***4" Static Deflection*** isolation systems. These are highly custom units because of the nature of the

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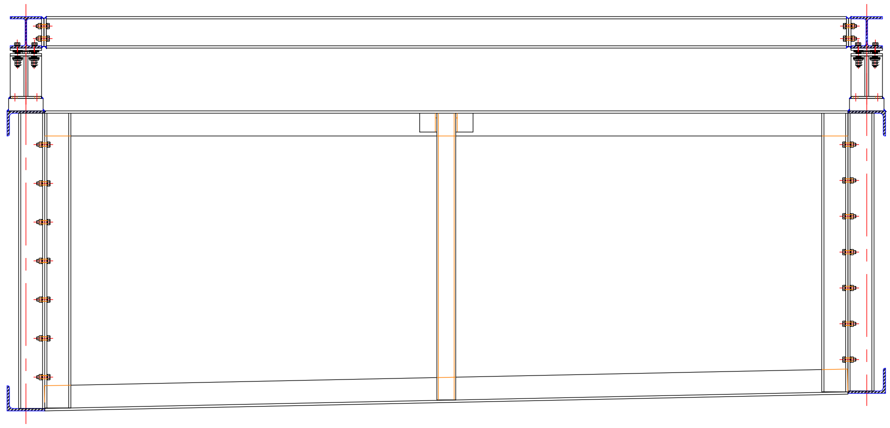
forces that they must resist and are custom designed from the base up for each installation. A “typical” section is illustrated below to offer an idea of how these look, but all of the members are subject to change to optimize them based on the actual load requirements.

Figure D6.1-7; MegaCurb Section



Application of Isolated Roof Curbs

With each successive version of the IBC and other building codes, the design loads have increased. As a result, restraint systems that were quite adequate for a particular piece of equipment 5–10 years ago, are no longer substantial enough to meet the restraint requirement for the same piece of equipment today. As a result, the ratings on some of the older model isolation rails have dropped. The ***KSR & KSCR*** for instance, were generally useful for equipment weights of up to 10,000 lb and lengths of up to 40 ft. They are now good for half of that (5,000 lb and 20 ft). The ***HD-KSR*** was designed to fill in the void that resulted from the decreased rating potential of the ***KSR***. It is suitable for units in the 5,000 lb to 12,000 lb, 40 ft long class for most seismic and wind conditions.

As the sizes increase beyond 12,000 lb and 40 ft of length, attachment to a sheet metal roof curb becomes impractical. For these applications, ***ESR***’s and ***MegaCurb***’s are required. When attaching to steel and if crossbracing can be fitted, the ***ESR***’s are generally good for equipment up to 20,000 lb and 50 ft long. If anchored to concrete or if there are limitations on the ability to crossbrace, the ***ESR*** capacity will drop off.

For extremely large or heavy units, in particular those subjected to extreme wind or seismic forces, a ***MegaCurb*** will likely be required. These are custom tailored to the application and have been used on units as heavy as 100,000 lb and as long as 80 ft.

Non-Isolated Sheet Metal Seismic Roof Curbs:

Except for extremely high capacity non-isolated MegaCurbs, Kinetics Noise Control does not produce a ***non-isolated*** roof curb. For smaller curbs however, Kinetics Noise Control can

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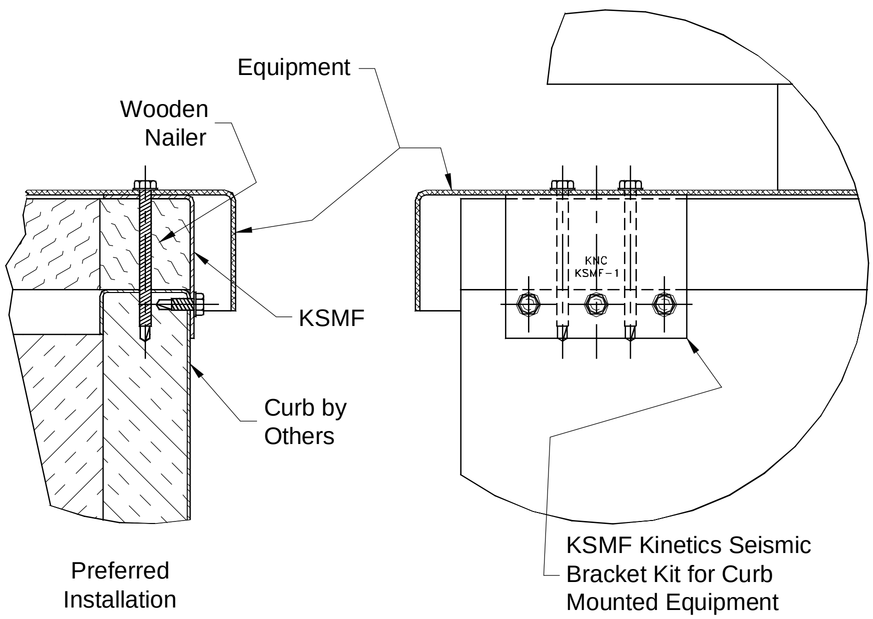
provide custom kits to attach the supported piece of equipment to a roof curb that is built by others, or to the building structure. The attachment of equipment to third party curbs is an issue that has not been well addressed by either the equipment manufacturers or the curb manufacturers and there are no standardized components that will work efficiently for all cases. Except in the case of small mushroom fans, for which a kit is available, KNC must be provided with dimensionally accurate sections of the unit and of the curb so that appropriate components can be manufactured.

For smaller mushroom fans or similar pieces of equipment, Kinetics Noise Control offers the model ***KSMF***, Figure D6.1-8. A minimum of four (***4***) clips are required for each curb.

Additional kits may be required based on an analysis by Kinetics Noise Control. The required number and location of each kit are specified by Kinetics Noise Control.

Figure D6.1-8; Typical KSMF Seismic Attachment Kit Installation



When reviewing the attachment of equipment restraints to sheet metal curbs, the analysis performed by Kinetics Noise Control also looks at the curb side walls if enough information is provided in the submittal sent to Kinetics. If the curb side walls do not appear to be able to carry the design seismic or wind loads, Kinetics Noise Control will make recommendations that reinforcements are to be used for the curb side walls and/or that heavier gage steel is to be used in the curb side walls in order to meet the design load requirements. If reinforcements are indicated by the analysis, Kinetics Noise Control can provide the model ***KSVR***, Figure D6.1-9, curb side wall reinforcement kit. The ***KSVR*** kit is intended to carry the vertical loads generated by the equipment and leave the curb side walls to carry the horizontal seismic loads. The

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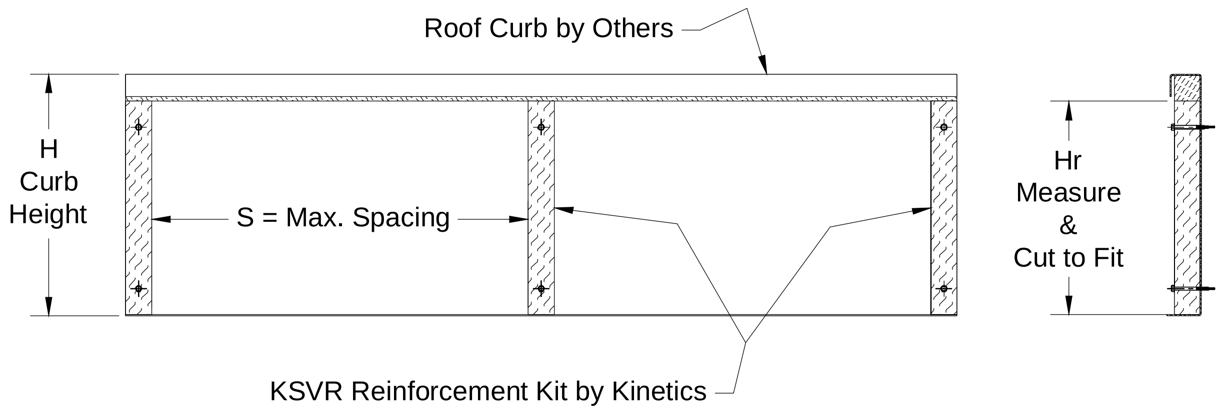
analysis performed by Kinetics Noise Control will recommend the number and spacing for the reinforcements.

Figure D6.1-9; Typical KSVR Reinforcement Kit Installation



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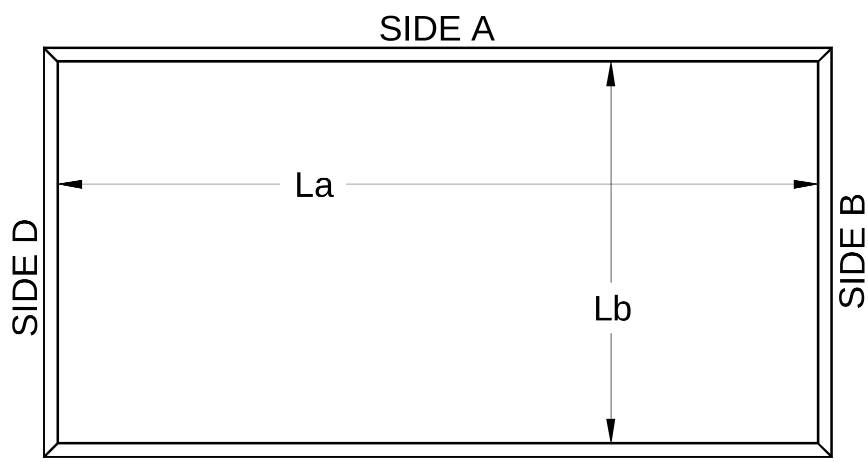
BASIC PRIMER FOR SHEET METAL CURBS

Rooftop HVAC units normally require some type of penetration through the roof to allow air to be transferred to and from the unit. These pieces of equipment are supported on a curb that is built around the penetration in the roof. This allows the roof to be attached to the curb and permanently sealed from the elements.

One of the most popular constructions for curbs is the sheet metal curb. Sheet metal curbs are light, economical, and easily installed. They may be field fabricated or purchased in pre-fabricated sections from a curb manufacturer. The plan view of the curb may be rectangular, square, or "L" shaped. In this document, and the ones to follow, we will be concerned with curbs that have a rectangular plan view. Shown in Figure 6.2.1-1 is a plan view of a rectangular sheet metal curb.

Figure 6.2.1-1; Plan View of Rectangular Sheet Metal Curb



The two long sides will be identified as SIDE A and SIDE C as shown in Figure 6.2.1-1. The short sides will be labeled as SIDE B and SIDE D, as in figure 6.2.1-1. The term L_a will be the inside length of the long sides of the curb. The term L_b will represent the inside length of the curb's short sides. Another term we will need to define now for later use is the inside perimeter of the curb, L_p. The value of the inside perimeter will be as follows:

$$L_p = 2(L_a + L_b) \qquad \textbf{(Eq. 6.2.1-1)}$$

Figure 6.2.1-2 shows two section views through a typical sheet metal curb. Each of the views represents a slightly different construction. Some manufacturers use a 2 X 2 nailer, others a 2 X 4 nailer and some a 1 X () Nailer. The primary purpose of the wooden nailer is to permit the roof flashing to be easily attached to the curb. A secondary purpose is to aid in the attachment of the equipment. Because the upper edge of the curb is relative pliable to forces acting against it

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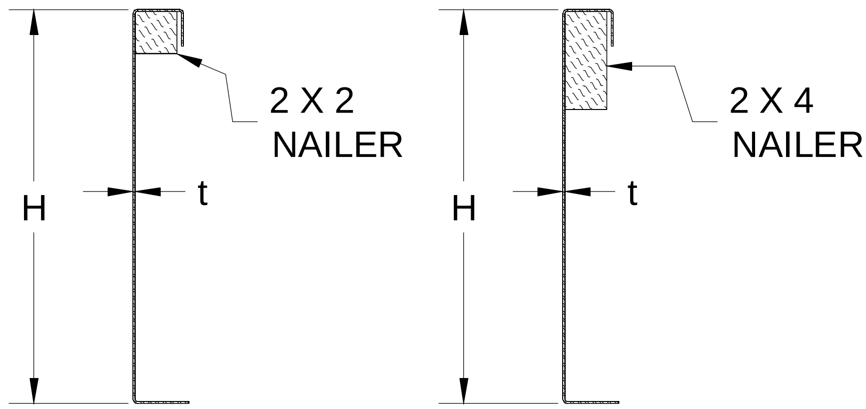
from the side, the wooden nailer also adds to the lateral strength to the curb. Unfortunately the wood used is often sub-standard and apart from cursory loads, cannot be counted on to carry more than the roof flashing. To aid in the attachment of equipment when working with applications involving wind or seismic resistance, roof curbs should as a minimum, have a good grade of 2 x () lumber specified for the nailer..

Figure 6.2.1-2; Typical Sheet Metal Curb Sections



In Figure 6.2.1-2, H is the height of the curb. Normally, the standard height of the curb is 14 inches. This provides enough standoff to accommodate most roofing systems and still allow for the flashing. The height of the curb can however, vary depending on the requirements of the equipment, the sound attenuation equipment, and the slope of the roof, if any. The term t is the thickness of the sheet metal used to construct the curb. There are three basic material thickness values that are commonly used for the construction of curbs: 18 gage (0.0478 inches), 16 gage (0.0598 inches), and 14 gage (0.0747 inches).

The curb height, H, and the sheet metal thickness, t, will determine the loads that can be carried by the curb, as we shall see in Documents 6.2.3 and 6.2.4. It should be mentioned here, as well as Document 6.2.3, that all of the loads must be carried in the plane side walls of the curb. The sides of the curb do not behave as a beam. The curb walls are really very thin plates that are loaded in compression on their long edges due to the equipment weight, and in uniform shear along each edge. The principal failure mode of the curb wall will be buckling. Documents 6.2.3, 6.2.4, 6.2.5, and 6.2.6 go into greater detail concerning the applications and limitations of sheet metal curbs in areas prone to earthquakes or high winds.

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ATTACHMENT OF EQUIPMENT TO SHEEP METAL CURBS

Introduction

There are a wide variety of pieces of equipment, equipment manufacturers and curb types to the point that devising a "standard" set of brackets and hardware to inter-connect the two is not practical. In the past, many pieces of equipment were not physically fastened to the curb and relied on gravity and the boxing in "picture frame" relationship between the equipment and curb to hold the equipment in place. In geographical areas that can experience high, or even moderate, wind and/or seismic loads, gravity and the "boxing" affect have proven to be inadequate and a more positive method is required. This document will present several different styles of attachment brackets and attachment configurations.

The transfer of loads is also made more complicated by the fact that curb side walls can carry loads only in the plane of the side wall. They cannot carry significant loads that act perpendicular to the side wall. They do however, carry the weight load of the equipment as a distributed compressive load in the side wall and when combined with significant horizontal seismic or wind loads, the combination can become a problem. Depending on the equipment profile or weight and the seismic or wind conditions, uplift forces can occur and must be addressed. For a complete discussion of the transfer of forces through a sheet metal curb refer to document D6.2.3.

Small Hard Mounted Equipment Attachments/Restraints

There are many different types of equipment that are mounted on sheet metal roof curbs. We will start with the smaller types. Typical of these are the powered ventilator "mushroom" fans, louvers, and un-powered ventilators. A typical "mushroom" fan attached to a curb is shown in Figure 6.2.2-1. The ventilators and louvers usually have weights that are low enough and perimeters small enough that they are sufficiently rigid to carry the required uplift forces without damage. Therefore, they are an exception to the rules in the previous paragraph. Also, the curbs for ventilators and louvers often have the wooden nailer attached directly to the top of the sheet metal. Thus, the attachment of the equipment to the curbs has usually involved fastening directly to the wood of the nailer.

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Figure D6.2.2-1; Typical "Mushroom" Fan on Curb

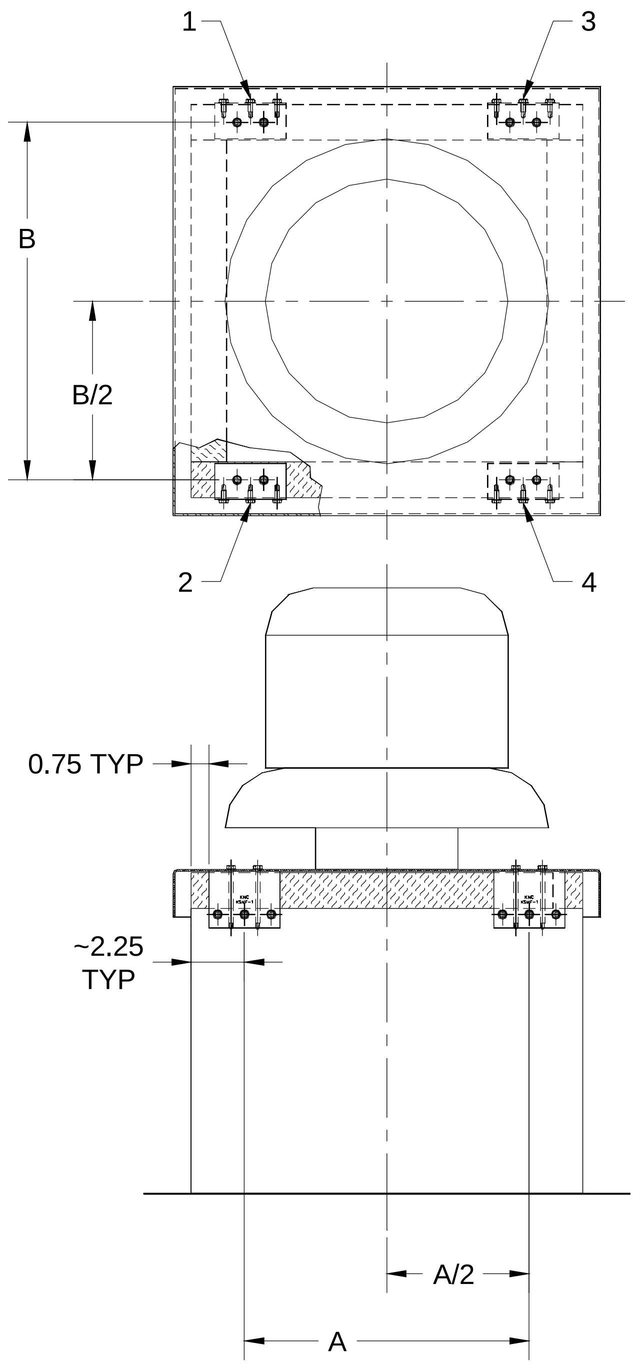

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Figure D6.2.2-2; Typical Restraint Installation for "Mushroom" Fans

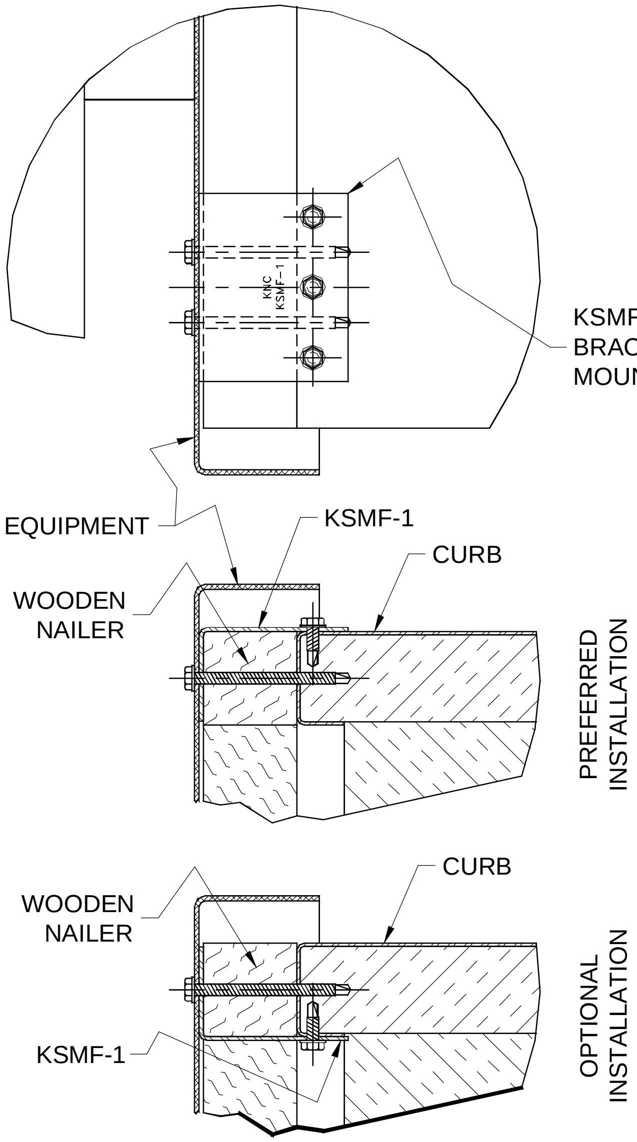

Figure D6.2.2-2 shows a typical installation of a seismic equipment bracket kit provided by Kinetics Noise Control. For curb-mounted ventilators and louvers the model name for the kit is the KSMF-1 (Kinetics Seismic Mushroom Fan), see Chapter P1 for product details and ratings. This bracket design allows the attachments to be made to the sheet metal part of the curb. The threads on the sheet metal screws must completely engage the sheet metal of the curb in order to develop full strength. Sheet metal screws of the appropriate diameter and length to accommodate most curb designs are provided in the kit by Kinetics Noise Control.

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Shown also in Figure D6.2.2-1 is the locating scheme for this type of seismic bracket kit. The dimensions “A” and “B” are the locations of the restraints as specified on the Kinetics Seismic and/or Wind Certification sheet.

A minimum of four kits are required for each piece of equipment. The restraints are placed to keep the horizontal wind, and/or seismic force loads in the plane of the curb walls. More may be required per the certification sheet. They should be evenly spaced along the sides.

Large Hard Mounted Equipment Attachments/Restraints

Larger pieces of rooftop equipment such as air handling units, makeup air units, etc. are considerably more problematic. Because of their size, the rocking forces that they generate can exceed the capacity of many lighter duty curb walls to resist them. The combinations of weight, compressive and uplift forces in combination with the wind or seismically generated horizontal forces can require an increased gage thickness or some form of positive reinforcement. When attaching larger equipment to these types of curbs, it is essential to obtain a statement from the curb supplier that it will indeed be adequate for the job.

Having said that, the focus of this section is connecting the equipment to the curb and for our purposes, we will assume that the curb is substantial enough.

The first key requirement in generating the attachment is that there must be a well-defined load path that leads completely from the equipment to the structure on which the curb is placed. Each component in the load path must be capable of resisting the total combined loads that it might be subjected to. For this reason, it becomes critical to eliminate the inconsistent and relatively unpredictable wooden nailer member from the load path. Connections can be made through the nailer (so that it might function as a spacer), however restraint against significant seismic or wind loads should not be dependent on its structural integrity.

The second key major issue that is encountered when restraining equipment to curbs is that any interconnecting bracket or connection device must be fully capable of resisting the full range of loads that it might encounter. Devising brackety that can bridge between equipment and a curb and resist horizontal loads is relatively simple. Sheet metal “L” shaped brackets along the lines of the KSCM-1 (shown in the figure below) will do a good job in resisting these forces.

Care should be taken when installing this type of restraint that a) there are no uplifting loads present that could cause the unit to lift and b) that the restraints are located in areas where the curb wall is resistant to forces that act at 90 degrees to the its axis. If the curb wall is not substantial enough or backed up by a cross brace or end panel, loads applied in a sideways direction will simply cause it to buckle inward or outward.

Figure D6.2.2-3; KSCM-1 Horizontal Load Resistant Sheet Metal Restraint

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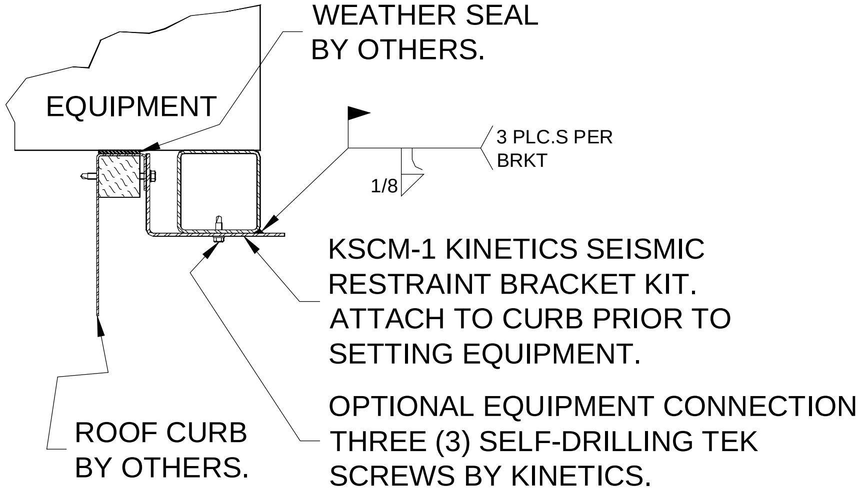
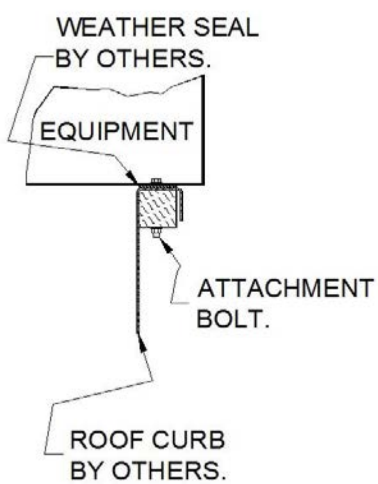


An additional factor that must be addressed is that sheet metal curbs are generally not receptive to large point loads. As such, the attachment to the curb must be done in a manner that will not result in damaging localized stresses at the attachment points. The use of multiple small fasteners, bearing plates or other load spreading members is important.

When dealing with forces that include vertical (uplifting) loads on a curb, the safest most reliable method of attachment is with a simple vertical bolt through the floor of the equipment being restrained, the nailer and the metal lip that forms the top of the curb. (See figure D6.2.2-4)

Figure D6.2.2-4; Preferred Method of Attachment between Equipment and Sheet Metal Curb



Unfortunately, this is not always possible and the alternates tend to be much more difficult. There are several reasons for this. First is because the actual construction and geometry of

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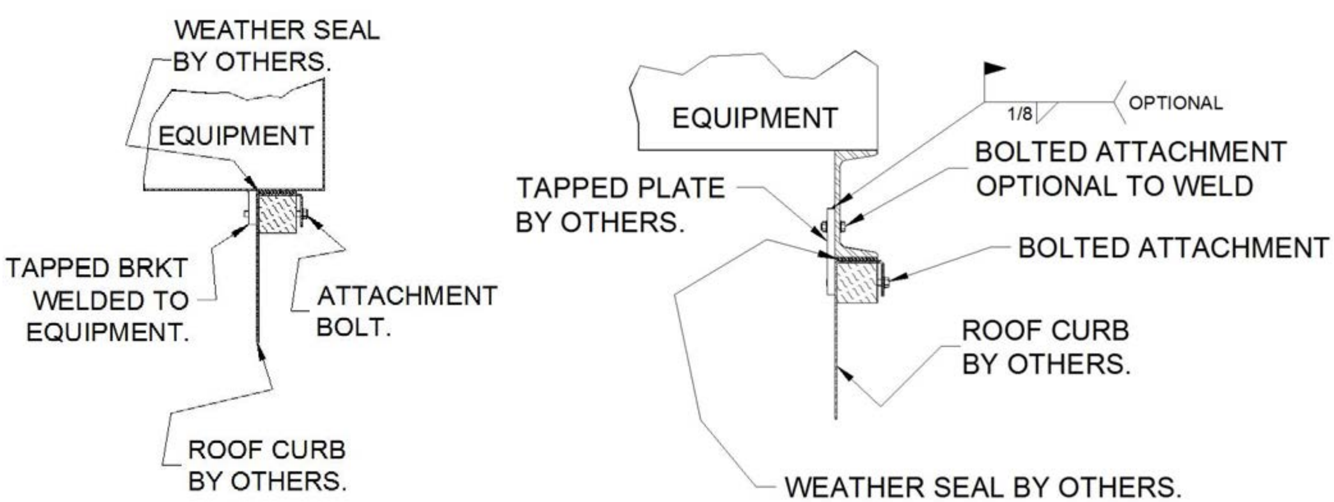
both the curbs and the equipment varies widely eliminating the option of coming up with a "standardized" approach. Second, sheet metal curb walls are inconsistent, but generally weak in bending and one cannot count on being able to subject them to vertical load offset from the vertical sheet metal panel forming the wall. Third, since the equipment/curb combination is used to seal a portion of the roof against weather, there is typically no access to the inner surface of the curb which makes the installation of through bolted hardware once the unit is set, very difficult. Lastly, the roof membrane typically attaches to the nailer located at the top of the curb and is normally installed prior to setting the unit. This requires that either the membrane must be penetrated or that the attachment location must be through the nailer (at the very top of the curb).

Note that the device shown in figure D6.2.2-3 would perform very poorly against uplifting loads as if they are encountered; the light gauge bracket would simple bend. Stiffening the bracket is of no real help either as if it were to be made substantial enough not to bend, the curb wall would simply bend or the weld would become the weak link instead. The arrangement shown in figure D6.2.2-4 avoids this problem.

The options for designing some type of external bracket require that (to prevent bending or buckling the light gauge curb wall, the load needs to be applied as almost a "pure" shear load. This can be accomplished in one of 2 ways. The first way is for the Curb wall to be aligned with a structural bracket or element on the underside of the unit that can accept a bolt. The second is that the connection bolt can be set out from the curb wall if it penetrates a rigid bracket or member that locks the bolt into a horizontal orientation. (Note that in the latter case, the bolt would be subjected to bending that would need to be considered during the selection process).

Figure D6.2.2-5; Equipment attachment via a structural tab welded or bolted to the underside of the unit



Moving beyond the simple through bolt, the options that are available which can resist uplifting forces while still being field "installable" become much more limited and present significant

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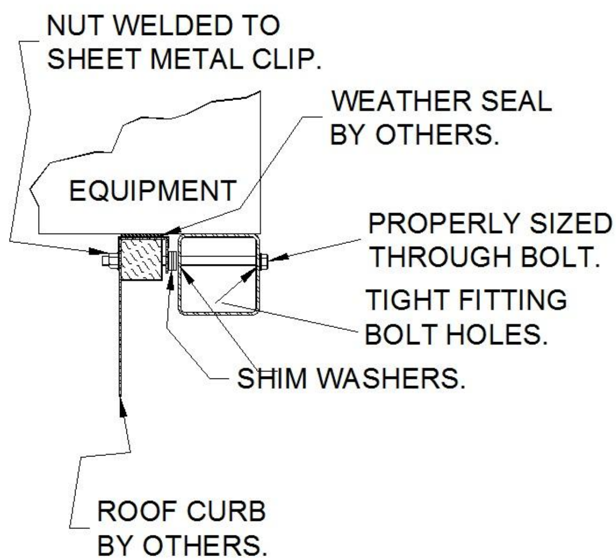
drawbacks. Shown here are options that can work if there is no perimeter frame that forms a pocket at the base of the equipment (or if the frame has access points in it through which bolts can be installed). These require that some form of welded or bolted on tab be fitted to the underside of the unit that is thick enough to be tapped and that the holes be aligned with holes in the curb wall. The addition of these tabs must be done in the field as they would normally protrude out the bottom and would be problematic for shipping and handling once installed.

Figure D6.2.2-6 shows the option whereby the restraint bolt passes through a perimeter frame member, is held in a rigid horizontal orientation and then passes through the top portion of the curb wall.

Figure D6.2.2-6; Equipment attachment via a cantilevered bolt



This is arrangement offers the simplest method of matching the holes during installation in that the unit can be temporarily set in place, match drilled holes made, then the unit lifted and sheet metal supported bolt tabs be aligned to the holes. A major downside however is that the attachment bolts will be exposed to bending for the width of the nailer. This greatly decreases the capacity of the bolt, likely dropping its capacity by a factor of 5:1 meaning that many more

Vertical Reinforcement of Curb Side Walls

There will be certain applications where a given curb will be marginally inadequate. Kinetics Noise Control cannot analyze and certify the entire curb for a specified application unless the curb is provided by Kinetics Noise Control. However, Kinetics Noise Control can perform a basic analysis of the strength of the curb wall based on the curb height, sheet metal thickness, the length of the curb walls, the equipment weight, and its C.G. location. From that analysis Kinetics Noise Control can make a recommendation as to whether reinforcement of the curb

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side walls would lead to an adequate curb installation from a seismic or wind resistant point of view.

Kinetics Noise Control provides a kit that may be used to reinforce the curb side walls. The kit consists of 2 X 2 treated lumber and self-drilling sheet metal screws, from which several reinforcements may be made depending on the curb height. The philosophy behind the KSVR Seismic Curb Wall Vertical Reinforcement Kit is to provide enough vertical reinforcements to carry the entire weight load of the equipment. This will leave the sheet metal curb side walls to carry the horizontal loads thus maximizing the curb's seismic and wind load capacity. Figure 6.2.2-7 shows the KSVR kit installed on one curb wall.

The analysis performed by Kinetics Noise Control will recommend a maximum spacing for the installation of the vertical reinforcements. The minimum number of vertical reinforcements that will ever be recommended per side is three (3). There will be a vertical reinforcement on each end of the curb side wall and one in the middle. The treated 2 X 2 provided by Kinetics Noise Control is cut to fit tightly between the foot of the curb, and the wooden nailer at the top of the curb. Then, the vertical reinforcement is fastened to the curb side wall using the sheet metal screws provided in the KSVR kit. The number of screws, their spacing, and installation is specified in the product submittals found in Chapter P1.

Figure 6.2.2-7; Typical KSVR Kit Installation on a Curb Side Wall

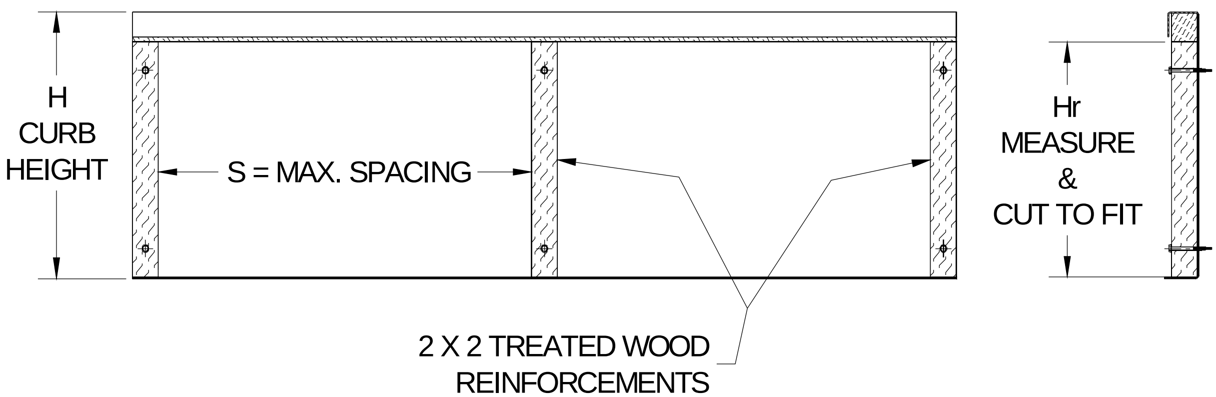

Figure D6.2.2-8 shows the range of curb heights for which the KSVR kit is suitable. Table D6.2.2-1 will show how many vertical reinforcements can be made from one KSVR kit.

Figure D6.2.2-8; Application Range for KSVR Kits

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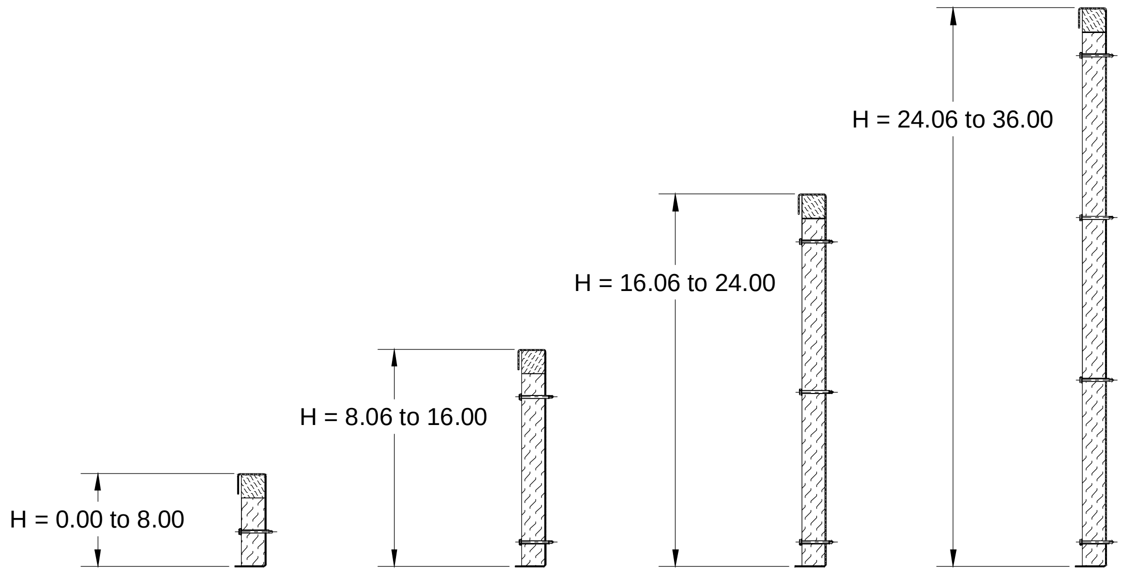

Table D6.2.2-1; Vertical Reinforcements per KSVR Kit

APPLICABLE CURB HEIGHT RANGE INCLUSIVE (H) (in.)	NUMBER OF VERTICAL REINFORCEMENTS PER KIT	NUMBER OF SELF-DRILLING SHEET METAL SCREWS PER REINFORCEMENT
0.00 to 8.00	4	1
8.06 to 16.00	3	2
16.06 to 24.00	2	3
24.06 to 36.00	1	4

The kits described in this section provide components that will allow various pieces of rooftop equipment to be attached to sheet metal curbs in areas that may be subjected to high seismic and/or wind loadings. The analysis and ratings provided with the kits will permit the curb manufacturer, and/or Design Professional of Record for a project, to certify the curb for the specified seismic and/or wind loadings.

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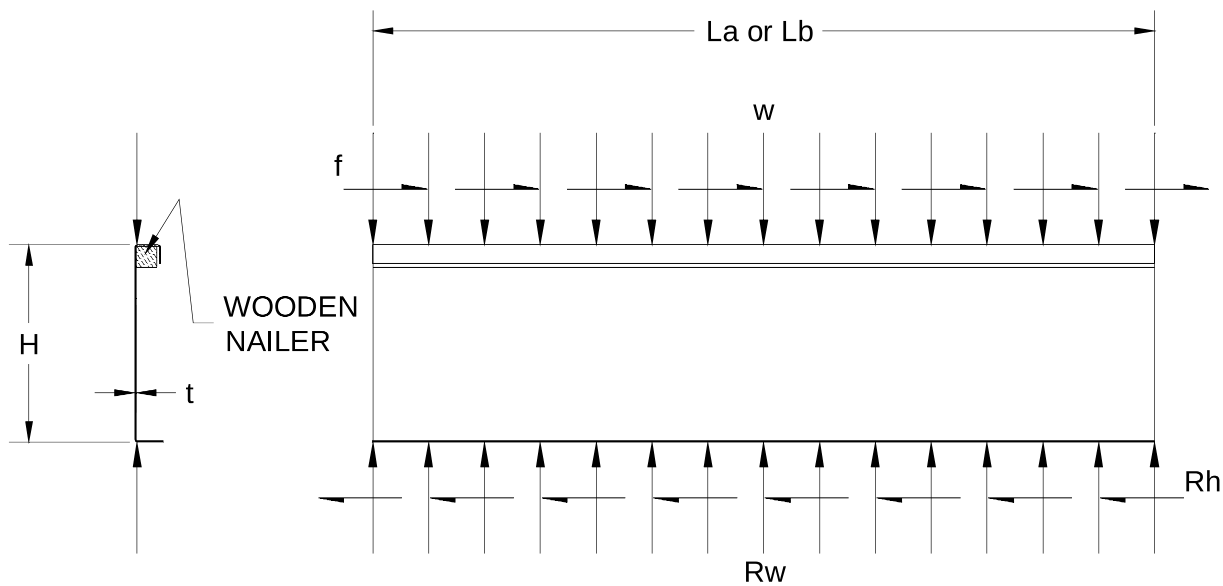
Transferring Forces through a Sheet Metal Curb

In general, sheet metal curbs have a very limited structural capacity. The sides of a sheet metal curb have no load-carrying capability unless they form a closed section in the plan view. The sides must be fully attached to one another for the full height of the curb in order to generate full strength in the individual sides. Figure D6.2.3-1, shown below, presents one side of a typical sheet metal curb and the loads that the curb may be expected to carry.

Figure D6.2.3-1; Loading on a Sheet Metal Curb



H is the height of the curb, and *t* is the thickness of the sheet metal used in the construction of the curb. The lengths represented by L_a and L_b are the inside lengths of the long sides and the short sides of the curb, respectively. For the sake of simplicity, assume that the weight of the equipment is evenly distributed around the perimeter of the curb. This is close enough to the truth for our purposes assuming that the CG of the equipment is more or less, located at the geometric center of the plan view of the curb. This distributed weight load is denoted by *w*. The value of *w* may be determined by considering a typical plan view for a rectangular curb as in Figure D6.2.3-2. The distributed weight load will be given by the following equation.

$$w = W/\left(2\left(L_a + L_b\right)\right) = W/L_p \qquad \textbf{(Eq. 6.2.3-1)}$$

where *W* is the weight of the equipment, and L_p is the length of the inside perimeter of the curb.

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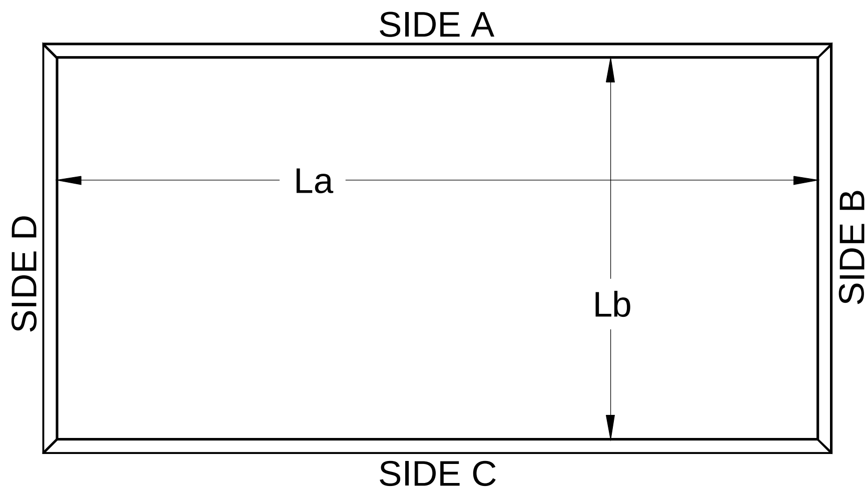
Figure D6.2.3-2; Plan View of a Rectangular Sheet Metal Curb



The horizontal seismic force acting on the curb is shown as a uniformly distributed shear load (*f*) acting along the top of the curb. The terms R_w and R_h are the reactions for the distributed weight load, and distributed seismic force respectively.

It is very important to realize that the walls of the curb can only carry loads in the plane of the wall. The curb wall can not effectively resist forces that act perpendicular to the wall of the curb. This is especially true if the sides of the curb are long. The walls of the curb are very thin plates that are loaded in compression on the top and bottom edges by the distributed weight load of the equipment. The horizontal seismic load will be a distributed shear load along the top and bottom edges.

Failure of the curb wall will generally be by buckling. Buckling is a very dangerous and catastrophic failure mode. It is dangerous because it occurs at a stress that is well below the yield point of the materials. It is catastrophic because the collapse is usually complete.

For a given curb height and material thickness there is a critical equipment weight in the absence of a seismic load that will buckle the curb. Table D6.2.3-1 identifies the variation in the critical equipment weight on the curb wall with the height of the curb (*H*) and the thickness of the curb material (*t*). Again the critical equipment weight (*w'*) is in terms of the distributed weight of the equipment. Note that the load carrying ability of the curb will decrease by approximately 70% as the thickness of the curb material decreases from 14 gage to 18 gage. In addition, there is an 80% decrease in the load-carrying capability of the curb as its height is increased from 14 inches to 36 inches. Thus great care must be exercised when placing large pieces of equipment on curbs fabricated from the lighter gages of steel or when placing large pieces of equipment on extended-height curbs.

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Table D6.2.3-1; Critical Equipment Weight (w') (lbs./in.)

CURB HEIGHT (H) (in.)	w' FOR MATERIAL THICKNESS 14 GAGE t = 0.0747 in.	w' FOR MATERIAL THICKNESS 16 GAGE t = 0.0598 in.	w' FOR MATERIAL THICKNESS 18 GAGE t = 0.0478 in.
14.0	57.66	29.58	15.11
15.0	50.23	25.77	13.16
18.0	34.88	17.90	9.14
21.0	25.63	13.15	6.71
24.0	19.62	10.07	5.14
27.0	15.50	7.95	4.06
30.0	12.56	6.44	3.29
33.0	10.38	5.32	2.72
36.0	8.72	4.47	2.28

As one might expect, there is a critical horizontal seismic distributed load (*f'*) that, when applied to the top edge of the curb, will cause the curb to fail in buckling. The critical seismic load will be a function of the height of the curb, the material thickness, and the weight of the equipment being supported by the curb. For ease of use, the equipment weight can be represented as an evenly distributed load (*w*). The variation of this critical seismic load with the variables mentioned above is shown in Tables D6.2.3-2, D6.2.3-3, and D6.2.3-4.

Table D6.2.3-2; Critical Seismic Load for a 14 Gage Curb (*t* = 0.0747 in.)

W lbs./in.	0.00	5.00	10.00	20.00	30.00	40.00	50.00	55.00
H (in.)	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	F 'lbs./in.
14.0	326.2	320.8	315.1	302.6	288.3	271.0	247.1	227.9
15.0	284.2	278.7	272.9	260.1	244.9	224.8	181.8	N/A
18.0	197.3	191.8	185.8	171.5	150.2	N/A	N/A	N/A
21.0	145.0	139.4	133.0	115.7	N/A	N/A	N/A	N/A
24.0	111.0	105.3	98.4	N/A	N/A	N/A	N/A	N/A
27.0	87.7	81.9	74.3	N/A	N/A	N/A	N/A	N/A
30.0	71.0	65.0	56.2	N/A	N/A	N/A	N/A	N/A
33.0	58.7	52.5	40.5	N/A	N/A	N/A	N/A	N/A
36.0	49.3	42.9	N/A	N/A	N/A	N/A	N/A	N/A

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Table D6.2.3-3; Critical Seismic Load for a 16 Gage Curb (*t* = 0.0598 in.)

W lbs./in.	0.00	2.50	5.00	10.00	15.00	20.00	25.00	30.00
H (in.)	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.
14.0	167.4	164.6	161.8	155.6	148.5	140.0	128.7	N/A
15.0	145.8	143.1	140.2	133.8	126.3	116.6	99.4	N/A
18.0	101.2	98.5	95.5	88.4	78.2	N/A	N/A	N/A
21.0	74.4	71.6	68.4	60.0	N/A	N/A	N/A	N/A
24.0	56.9	54.1	50.7	36.8	N/A	N/A	N/A	N/A
27.0	45.0	42.1	38.3	N/A	N/A	N/A	N/A	N/A
30.0	36.4	33.5	29.2	N/A	N/A	N/A	N/A	N/A
33.0	30.1	27.0	21.4	N/A	N/A	N/A	N/A	N/A
36.0	25.3	22.1	N/A	N/A	N/A	N/A	N/A	N/A

Table D6.2.3-4; Critical Seismic Load for an 18 Gage Curb (*t* = 0.0478 in.)

W lbs./in.	0.00	2.50	5.00	7.50	10.00	12.50	15.00	20.00
H (in.)	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.
14.0	85.5	82.7	79.6	76.1	71.9	66.4	55.3	N/A
15.0	74.5	71.7	68.5	64.8	60.0	52.3	N/A	N/A
18.0	51.7	48.8	45.3	40.4	N/A	N/A	N/A	N/A
21.0	38.0	35.0	30.9	33.8	N/A	N/A	N/A	N/A
24.0	29.1	26.0	19.8	N/A	N/A	N/A	N/A	N/A
27.0	23.0	19.7	N/A	N/A	N/A	N/A	N/A	N/A
30.0	18.6	15.0	N/A	N/A	N/A	N/A	N/A	N/A
33.0	15.4	11.2	N/A	N/A	N/A	N/A	N/A	N/A
36.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note that no safety factor has been applied to any of the values in Tables D6.2.3-1, D6.2.3-2, D6.2.3-3, or D6.2.3-4. These values should not be used for design or certifying sheet metal curbs for seismic applications unless a factor of safety of not less than 2:1 is applied to them. Values listed as "N/A" indicate combinations of equipment load, curb height, and material thickness that are absolutely not viable for seismic applications. They *indicate that a thicker gage of material must be used for the construction of the curb. In the case of Table D6.2.3-2, the combinations that are marked "N/A" indicate that a structural seismic curb is required.*

An obvious conclusion drawn from Tables D6.2.3-2, D6.2.3-4 is that if the equipment load could be carried by components other than the wall of the curb, the seismic load-carrying capacity of the curb

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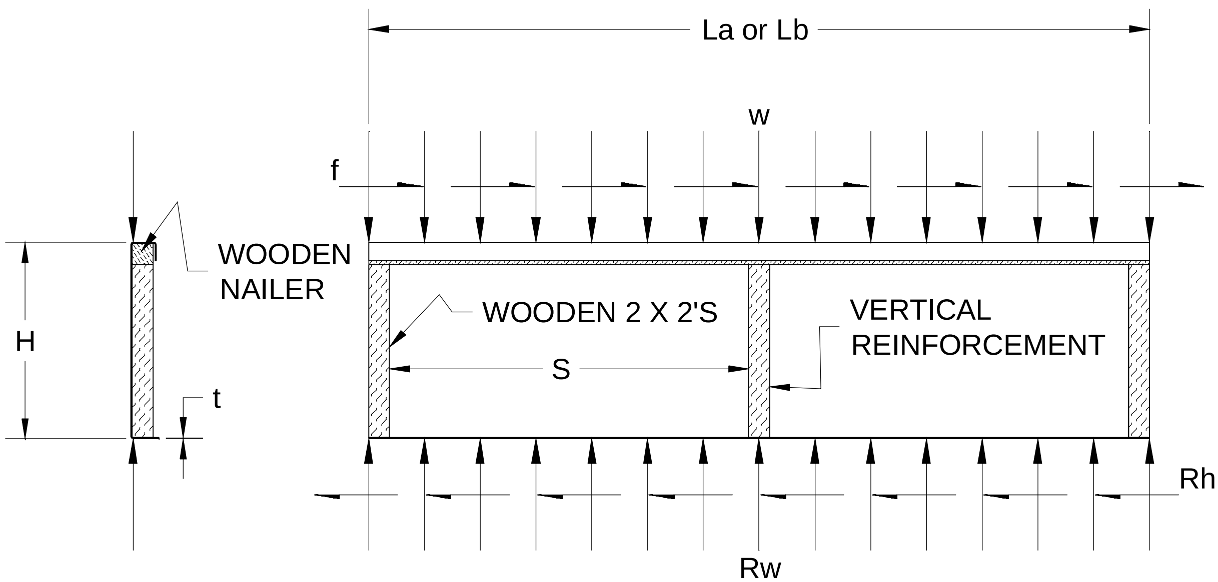
could be maximized. The most cost-effective method of providing vertical reinforcement to carry the equipment weight load is to use treated wood 2 X 4's or 2 X 2's. This is usually the same material that is used for the nailer at the top of the curb. A typical view of the side of a curb that has been vertically reinforced with 2 X 2's is shown in Figure D6.2.3-3. This figure shows the minimum number of vertical reinforcements. A vertical reinforcement is required on each end of the side of the curb with at least one additional member located in the middle. Table D6.2.3-5 gives the maximum allowable vertical reinforcement spacing (*S*) as a function of the curb height, and the equipment weight load. These reinforcement members must be cut to fit tightly between the underside of the nailer or curb lip and the top of the structural support member at the base of the curb. If a gap exists they will not function properly. The controlling failure mode is buckling. For selection purposes in the table below, a factor of safety of 4:1 was applied to the vertical reinforcements to account for the variation in grade and structure of the treated wood 2 X 2's. Table D6.2.3-5 indicates that for many cases the minimum number of vertical reinforcements will be sufficient to carry the weight of the equipment.

Figure D6.2.3-3; Typical Vertically Reinforced Curb



In the course of a seismic event, the most significant vertical seismic loads occur at the corners of the curb. This type of load will put the curb wall in bending. In the presence of a horizontal seismic load, a vertical seismic load will cause the load-carrying ability of the curb to drop to an unacceptable level. Thus vertical seismic loads should be transferred from the equipment to the building structure in as direct a manner as possible. The mode of transfer must minimize the bending moments in the curb wall to maintain the ability of the curb to carry the equipment weight load and the horizontal seismic load.

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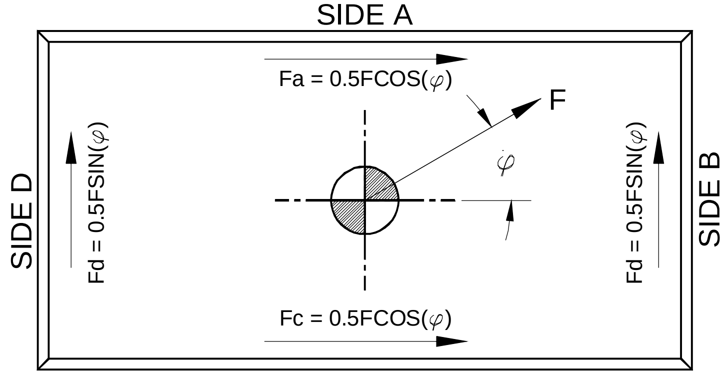
Table D6.2.3-5;. Maximum Spacing for Vertical Reinforcements – Treated Wood 2x2's – Factor of Safety = 4:1 with Respect to Buckling

W lbs./in.	0.00	5.00	10.00	20.00	30.00	40.00	50.00	55.00
H (in.)	S (in.)	S (in.)	S (in.)	S (in.)	S (in.)	S (in.)	S (in.)	S (in.)
14.0	2,762	1,381	690	345	230	173	138	126
15.0	2,406	1,203	601	401	200	150	120	109
18.0	1,671	835	418	209	139	104	84	76
21.0	1,227	614	307	153	102	77	61	56
24.0	940	470	235	117	78	59	47	43
27.0	743	371	186	93	62	46	37	34
30.0	601	301	150	75	50	38	30	27
33.0	497	249	124	62	41	31	25	23
36.0	418	209	104	52	35	26	21	19

The distribution of the horizontal seismic load is addressed through a rational analysis. Figure 6.2.3-4 shows the plan view of a curb with the equipment CG at the center of

Figure D6.2.3-4; Seismic Loading of Curb



the curb. In this figure *F* is the horizontal seismic force. The angle f represents the direction of motion for the seismic wave front. Since the curb wall can transfer forces only in the plane of the wall as previously discussed, the forces carried by the individual curb walls will be as shown in Figure D6.2.3-4. The resulting distributed seismic force acting on the long sides of the curb will be equal to

$$f_a = (0.5/L_a)F\cos\varphi. \quad \textbf{(Eq. 6.2.3-2)}$$

In a similar fashion, the distributed seismic force acting on the short sides of the curb will be

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$$f_b = (0.5/L_b)F\sin\varphi .$$ **(Eq. 6.2.3-3)**

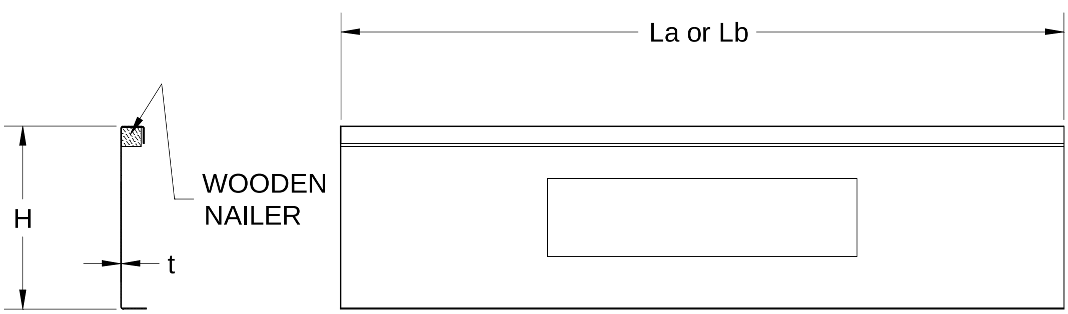
Note that the ability of a sheet metal curb to resist a horizontal seismic load depends on the length of the curb available to carry the loads. Thus, the worst-case scenario for a curb would occur when f was equal to 90 degrees. The seismic load is parallel to the short sides of the curb, which means that the short sides of the curb must be able to resist the entire horizontal seismic load. So, for calculation purposes, the distributed seismic load on the short sides of the curb would be as follows.

$$f_h = 0.5F/L_b$$ **(Eq. 6.2.3-4)**

Equations 6.2.3-1 and 6.2.3-4 with Tables D6.2.3-1 through D6.2.3-4, along with a healthy factor of safety, allow us to determine the suitability of a given curb in a specified seismic application. Since the curb walls are very thin compared to any other dimensions, any dents, creases, or other defects will drastically lower the critical buckling loads, a factor of safety in the range of 3:1 or 4:1 is considered appropriate to account for the possibility of such minor damage. Major damage must be corrected.

The last issue that must be addressed is the presence of large-scale penetrations in the curb walls. Screw and pop rivet holes are not considered to be large-scale holes. Large-scale penetrations are those that are made for ducts, pipes, or conduits. Figure D6.2.3-5 shows a rectangular penetration for a duct.

Figure D6.2.3-5; Typical Duct Penetration



If left un-reinforced, this penetration would eliminate any significant seismic load-carrying ability for that side of the curb. However, in some case an appropriate reinforcement scheme for a duct penetration, similar to that shown in Figure D6.2.3-6, can be added. In this scheme, the reinforcement "ring" made out of sheet metal is placed around the hole.

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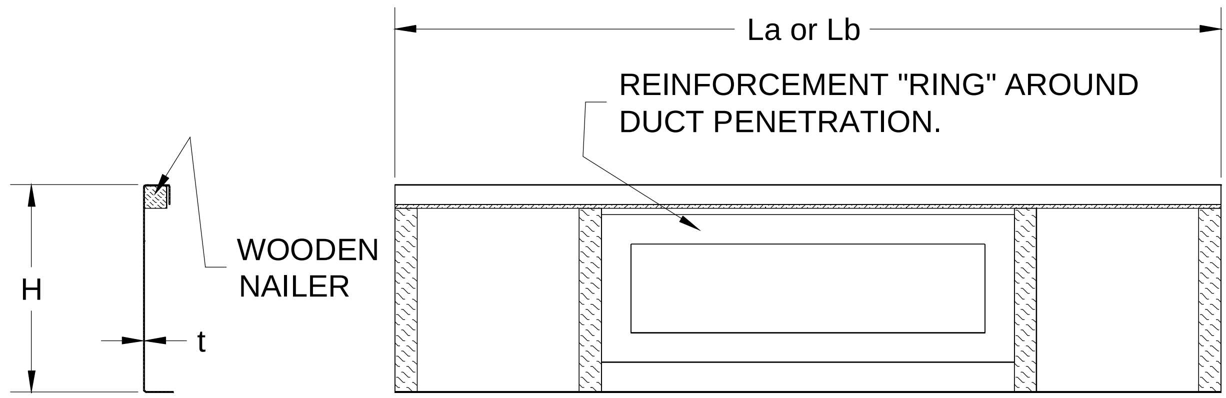
Figure D6.2.3-6; Reinforcement of Duct Penetrations



The ring must have a thickness equal to or greater than that of the curb wall and extend at least 2 inches beyond the penetration. The "ring" must be pop riveted, screwed, or spot welded in place. Enough fasteners should be used to ensure that the loads are transferred to the "ring." In addition to the ring, vertical restraints made up of treated wood 2 X 2's should be placed as shown in Figure D6.2.3-6. The total seismic load carrying ability of this side of the curb should be reduced as follows:

$$f_{ap} = 0.5F/(L_a - L_h) \qquad \textbf{(Eq. 6.2.3-5)}$$

and,

$$f_{bp} = 0.5F/(L_b - L_h) \qquad \textbf{(Eq. 6.2.3-6)}$$

In these two equations, f_{ap} and f_{bp} are the distributed horizontal seismic loads carried by the long and short sides, respectively, of a curb with a duct penetration in one of the walls. The term L_h represents the length of the duct penetration. Another type of penetration is a circular penetration for either a pipe or a cable conduit. This type of penetration is shown in Figure D6.2.3-7. These penetrations are much smaller than the one for a duct. "Ringing" these penetrations as shown in Figure D6.2.3-8 should provide sufficient reinforcement without the loss of seismic load-carrying capacity. The "rings" should have the same thickness as the walls of the curb and extend at least 2 inches beyond the penetration. The attachment may be by pop rivet, screw, or spot weld. A sufficient number of fasteners must be used to ensure that loads are effectively transferred to the reinforcing "rings."

The intent of this document is to provide input and guidance as to how loads are transferred through a sheet metal curb. The tables and equations presented in this document may be used with factors of safety of 3:1 to 4:1 in order to estimate the performance of a curb for a specific seismic application. However, prior to installation a thorough analysis should be made by the curb manufacturer.

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Figure D6.2.3-7; Typical Piping/Conduit Penetrations

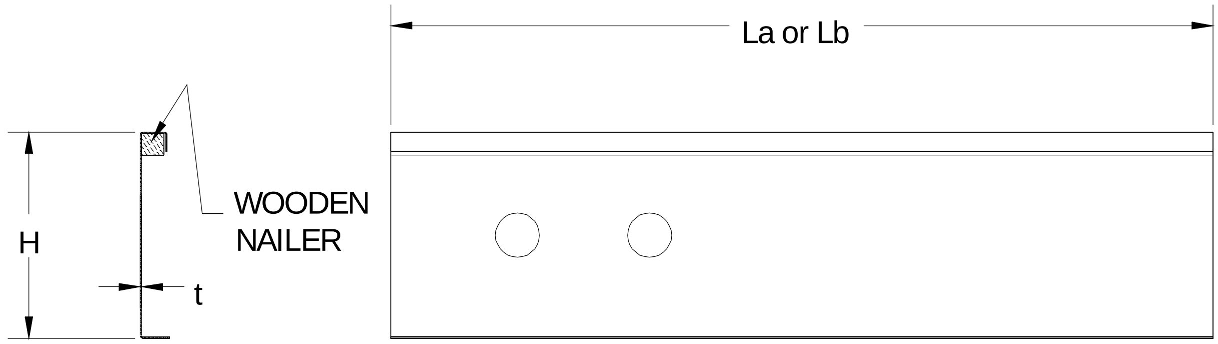
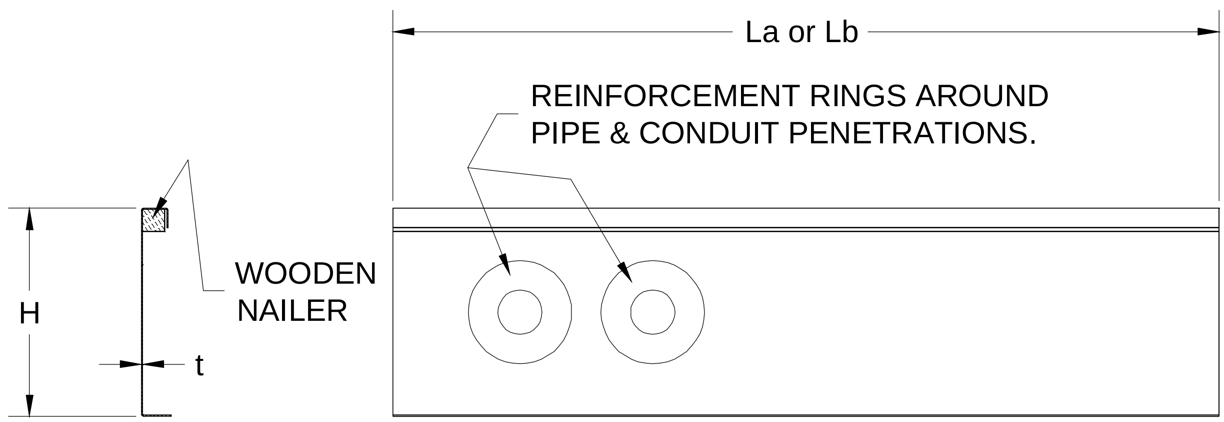


Figure D6.2.3-8; Reinforcement of Piping/Conduit Penetrations



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ATTACHMENT OF SHEET METAL CURBS TO THE BUILDING STRUCTURE

Attachment of a sheet metal curb to a roof structure involves intimate knowledge of the type of roof being used, the slope of the roof, the location of the curb on the roof, and the orientation of the curb with respect to the roof structure and slope. We, at Kinetics Noise Control, usually do not have access to all of the information necessary to completely specify the connection between the curb and the roof structure. Having said all of that, this document will provide some of the requisite guidelines for attaching a sheet metal curb to a roof structure.

D6.2.4-1; General Comments

We will begin by making some general comments on attaching sheet metal curbs to roofs made of different materials.

1.) The attachment fasteners at the foot of the sheet metal curb must be tight up against the vertical curb wall or must be fitted with a member capable of transmitting uplifting loads from the curb wall to the attachment fastener.
2.) If the requirements of item 1 above cannot be observed and the curb manufacturer cannot or will not certify that the curb flange will not yield under tensile loading conditions, a separate means of addressing uplift forces independent of the curb (ie: cables) must be fitted..
3.) ***If not connected to a primary structural member, the local attachment between the roof deck material to which it does attach and the building structural framing must have a capacity greater than or equal to the loads transferred from the sheet curb foot to the roof deck!***
4.) The minimum number of fasteners per curb side will be three regardless of the fastener type or size. There will be one fastener approximately at each end of the curb side, and one approximately at the middle.
5.) Where exposed to tensile (uplifting) loads, the specified number of fasteners (per side) should be evenly divided among the vertical restraints per side and shall be located within 15" (in plan view) of the points of restraint between the curb and the equipment. If this results in a spacing of greater than 36" between adjacent screws at any point around the perimeter of the curb, additional screws should be fitted to limit the maximum span between screws to 36".
6.) The actual positions of the fasteners may be indicated by dimension, these are approximate and can be altered slightly to account for vertical curb wall reinforcements, troughs in metal decking, etc.
7.) ***Support beneath the sheet metal curb side wall must be continuous around the entire perimeter to maintain the full horizontal seismic, and/or wind load rating. (Expressed another way, the curb wall should not be considered to be a beam that can span any further than 12".)***
8.) Sheet metal curbs may be allowed to span the valleys in metal roof decking. However, if vertical reinforcements are required for the curb side walls, the reinforcements ***must not*** be

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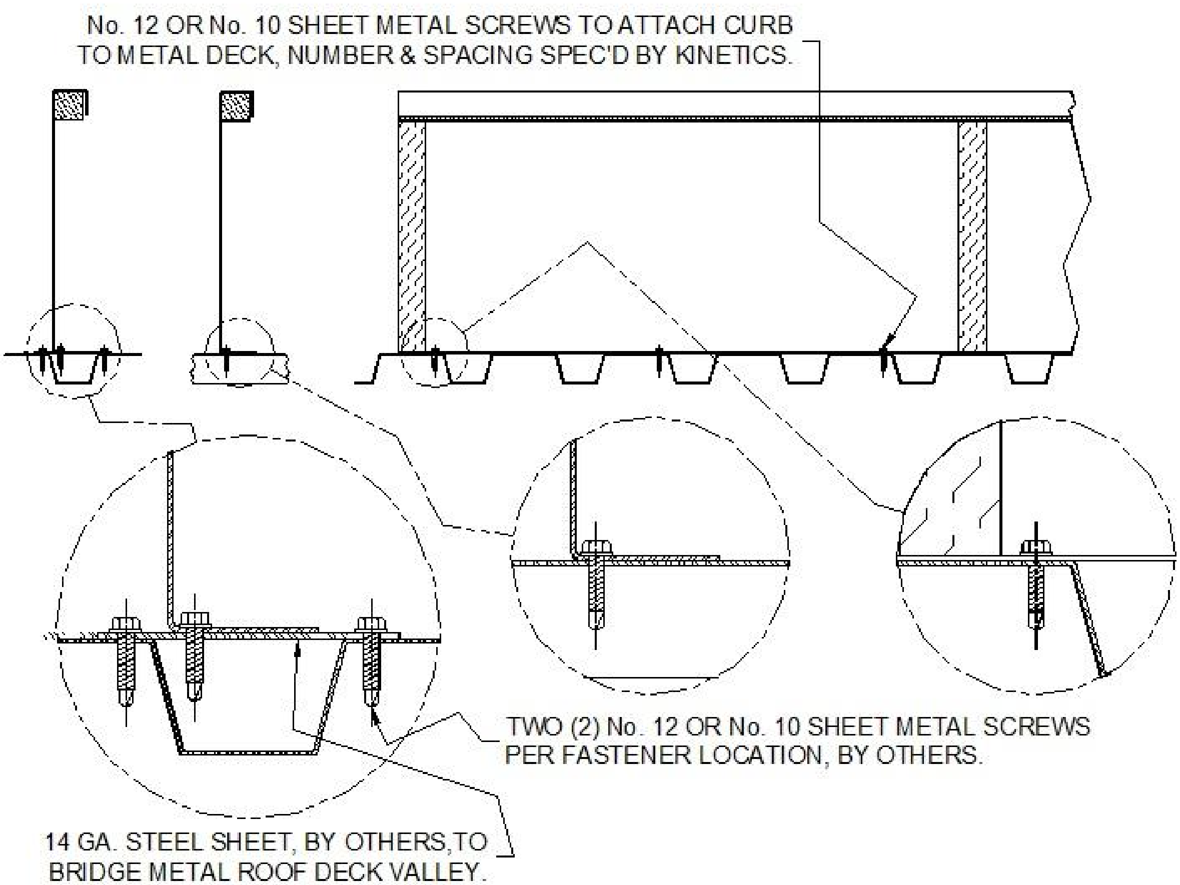
located above a valley in the metal roof decking, or the valley must be spanned with a support for the reinforcement as discussed in a later paragraph.

D6.2.4-2; Attachment to Metal Decking

The sheet metal curb foot may be fastened to metal decking using sheet metal screws of sufficient size and quantity to carry the required loads, see Figure D6.2.4-1. Kinetics Noise Control requires that the screws be no smaller than No. 10 and that they have a washer- type head. The washer-type head helps reduce the incidence of pull-through. The analysis provided by Kinetics Noise Control is based on a flat roof, and will give a recommended number of No. 10 or No. 12 sheet metal screws per side, and the maximum allowable spacing for each screw size. The sheet metal screws must be long enough so that their threads can be fully engaged at the maximum screw diameter to generate full screw strength. If required in order to meet the requirements in section D6.2.4-1 (above), 14 gage sheet steel may be used to bridge the valleys in the metal roof decking if it is attached to the decking in a manner equal to that of its attachment to the curb. See also Figure D6.2.4-1.

Figure D6.2.4-1; Attachment to Metal Decking Using Sheet Metal Screws



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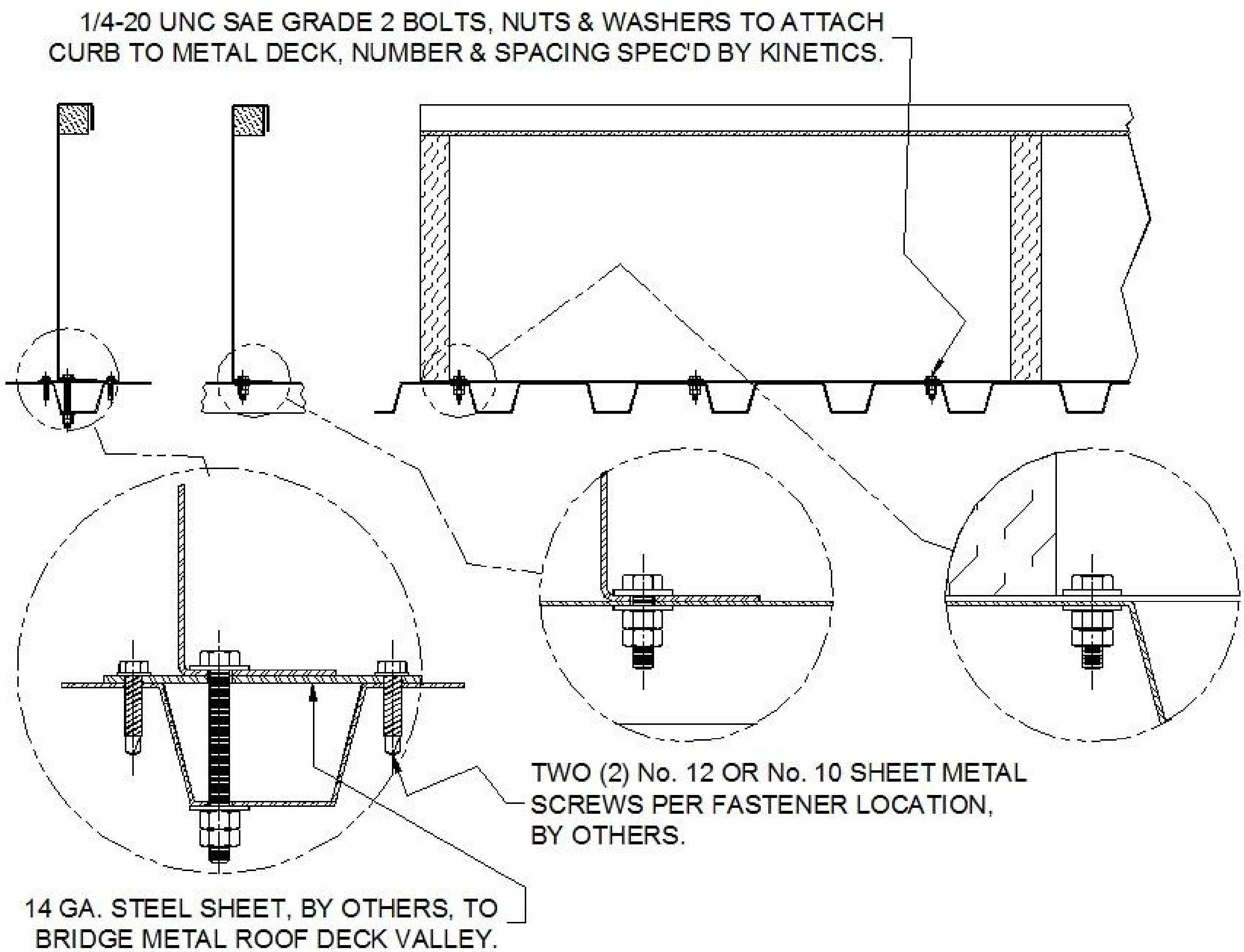
As shown in Figure D6.2.4-2, the curb may also be fastened to the metal deck with through bolts and nuts. Standard steel washers should be used under the nuts and bolt heads to prevent pull-through. It is good practice to insert the bolts as shown in Figure D6.2.4-2, and to use double nuts. This will help to maintain the integrity of the joint over time. The analysis by Kinetics Noise Control specifies the number of ¼-20 UNC SAE Grade 2 bolts to use per each curb side, and the maximum allowable spacing for use on a flat roof.

Figure D6.2.4-2; Attachment to Metal Decking Using Bolts



Curb installations have been made by welding the curb foot to the metal decking. The strength of these welds is dependent on the type of welder being used, the procedure being followed, and the actual materials involved in the weld joint. There are too many unknowns for Kinetics Noise Control to specify the number and size of the welds required to attach a curb to a metal roof deck. However, if the shear strength of the welds used is equivalent to the shear strength of the fasteners indicated by Kinetics Noise Control, the weld attachment will be adequate. It is up to the Design Professional of

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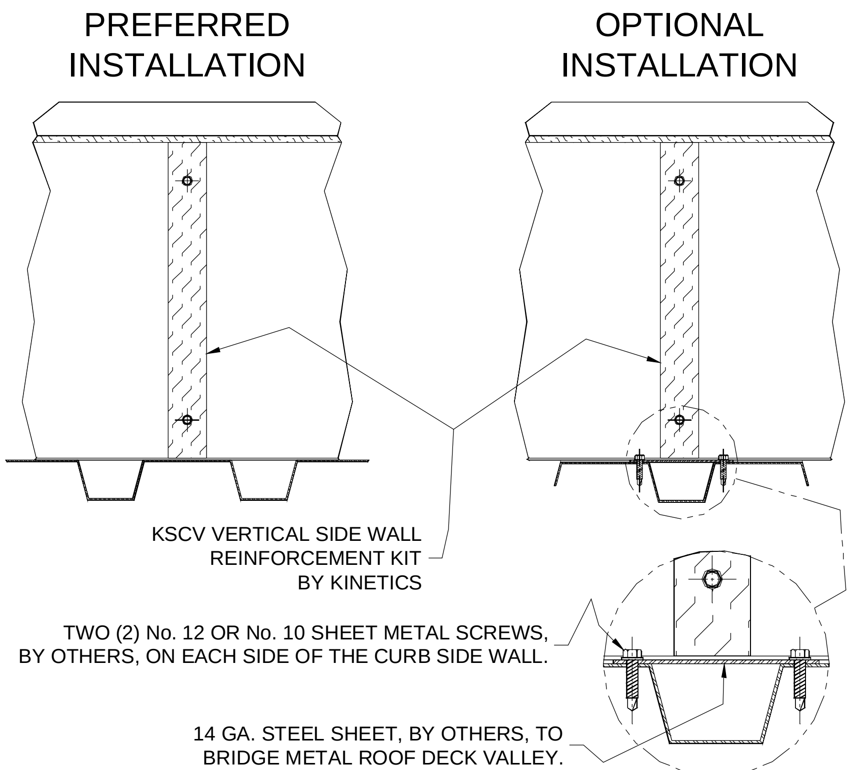
Record to specify the number and size of the welds required to attach the curb to the metal deck once the details of the welding process and materials are known.

When vertical reinforcements are used the reinforcement must not lie over top of an unsupported portion of the curb foot. This would occur if the foot of the curb was spanning a valley in the metal roof decking. A bridge that is tied into the adjacent portions of the decking must be created beneath the vertical reinforcement. Figure D6.2.4-3 shows one way this may be accomplished. It is important that at least two screws attach the bridge to the deck on both the inside and the outside of the curb side wall.

Figure D6.2.4-3; Vertical Reinforcement Placement for Metal Decking



D6.2.4-3; Attachment to Structural Steel

Kinetics Noise Control requires that sheet metal curbs be attached to structural steel with through bolts and nuts with washers beneath the bolt heads and nuts, as shown in Figure D6.2.4-4. Again it is good practice to insert the bolts as shown, and to use double nuts. Certain structural shapes will require the use of square beveled structural washers. For a flat roof the analysis provided by Kinetics Noise Control will indicate the proper number of ¼-20 UNC SAE Grade 2 bolts per curb side and the maximum allowable spacing. Note that the curb side wall is fully supported by the structural members.

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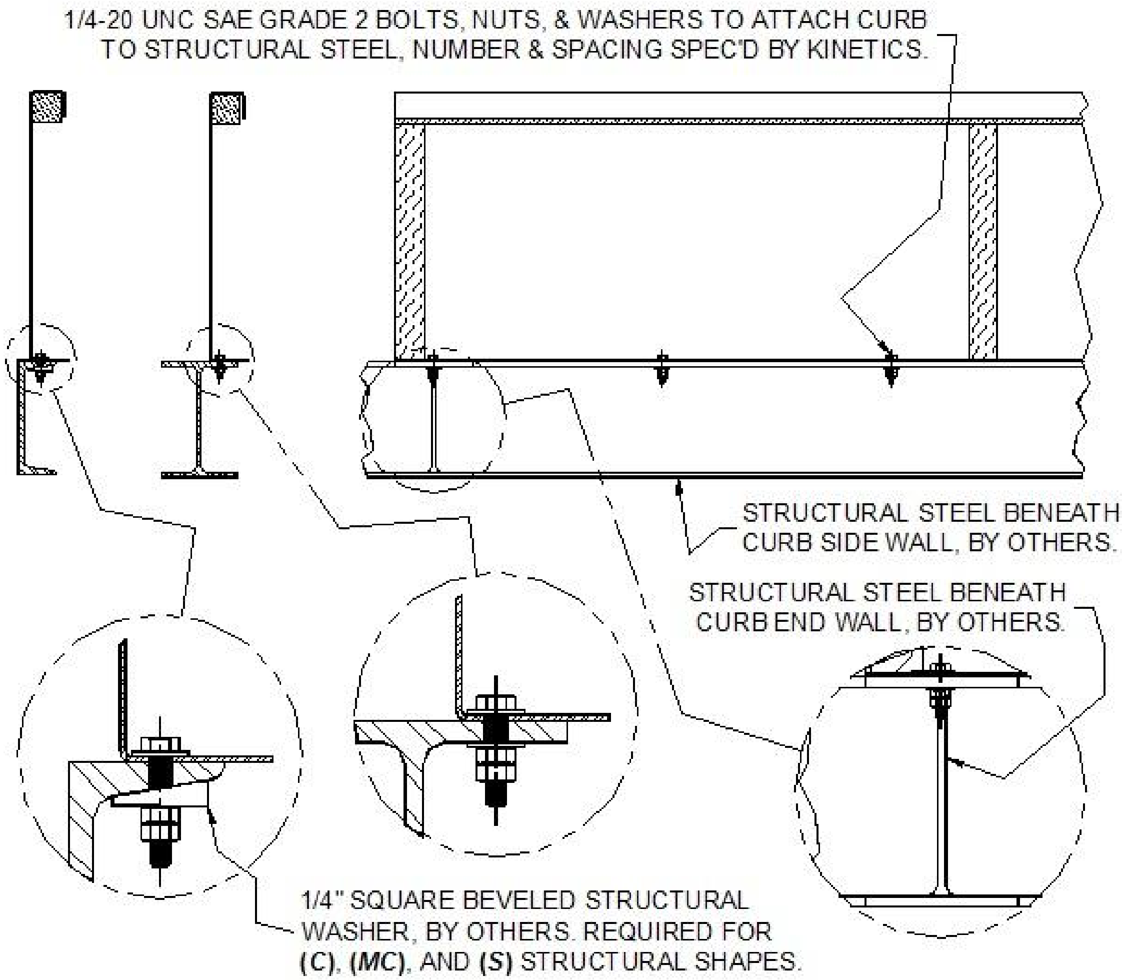
Figure D6.2.4-4; Attachment to Structural Steel



Curbs have been attached to structural steel by welding. As before, Kinetics Noise Control will not make any recommendations concerning the weld size and number. It will be up to the Design Professional of Record to specify the number of welds and their size. However, the welds must be of sufficient size and number to have a capacity greater than or equal to the number of ¼-20 UNC SAE Grade 2 bolts specified by Kinetics Noise Control for the application in question.

D6.2.4-4; Attachment to Concrete

In order to attach a curb to a concrete deck, the concrete must have a minimum compressive strength of 3,000 psi and be steel reinforced. Figure D6.2.4-5 shows a typical concrete roof installation. The analysis provided by Kinetics Noise Control will indicate the proper number of ¼" concrete wedge-type anchors per side and the maximum allowable spacing. The ¼" wedge-type anchors require an

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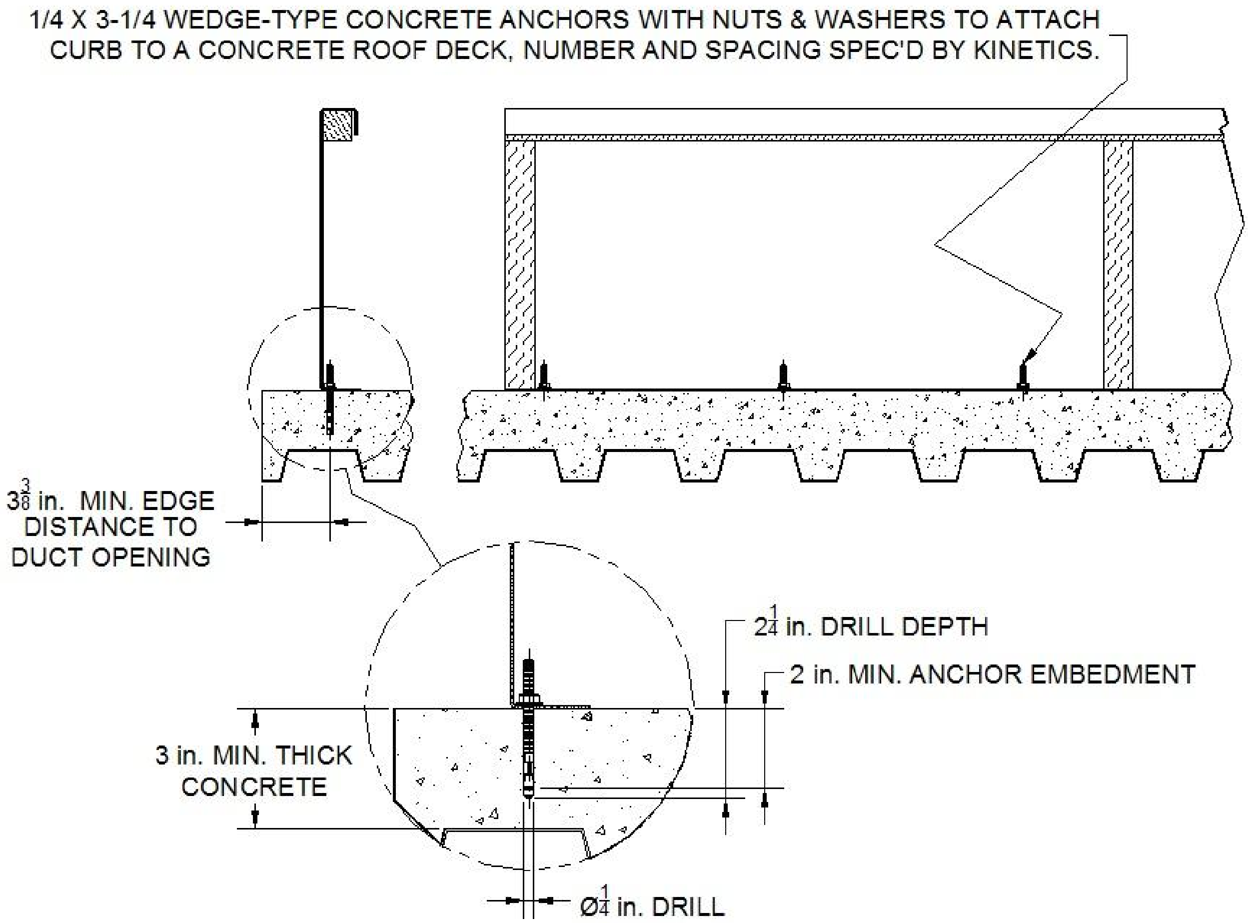
embedment depth of 2” and a minimum distance to any edge of the concrete of $3^3/_8$”. Double nuts are not necessary for this installation due to the wedging action of the anchor when properly tightened.

Figure D6.2.4-5; Attachment to Concrete Using Wedge-Type Anchors



In order to maintain the full capacity of the ¼” wedge-type anchors, the spacing between adjacent anchors must be no less than 4”. In addition, the deck must be thick enough to provide a minimum of 1” cover beneath the bottom of the hole for the ¼” wedge anchor.

D6.2.4-5; Attachment to Wood

In general, wood is a highly variable structural material in terms of its strength and uniformity. The strength of a piece of wood depends very strongly on its grain structure and direction, as well as its species, moisture content, and growing conditions. The in situ strength of the wood can change over time as its moisture content increases or decreases relative to the surrounding environment. Wood is also susceptible to strength reductions due to aging and insect infestations. Also, plywood decking

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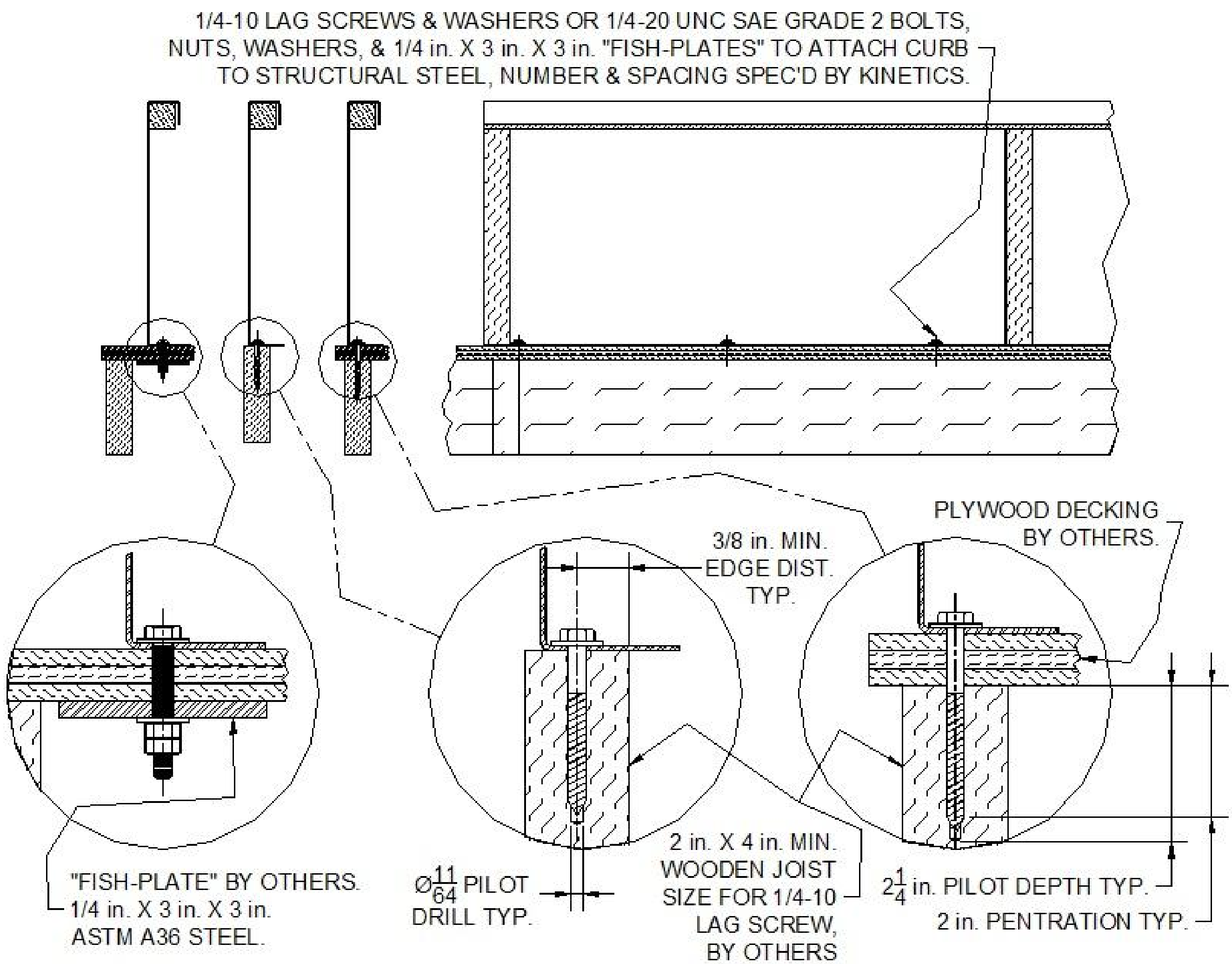
and "glulam" structural components may be delaminated over time through exposure to harsh environments, and thus lose their integrity.

Wherever possible, Kinetics Noise Control recommends that attachments be made to wood using through bolts, nuts, washers, and "fish-plates" against the wood side of the bolt joint. This arrangement is depicted in Figure D6.2.4-6. The bolts should be inserted as shown and retained with double nuts. The minimum recommended "fish-plate" size and material is ¼" X 3" X 3" ASTM A36 steel. The "fish-plate" distributes the compressive load from the nut, and prevents crushing of the wood fibers. The "fish-plate" is to be provided by others.

Figure D6.2.4-6; Attachment to Wood Using Through Bolts & Lag Screws



There may be some cases where the use of lag screws may be most appropriate. Two examples of this type of installation are also detailed in Figure D6.2.4-6. Note, in both of the cases shown, the

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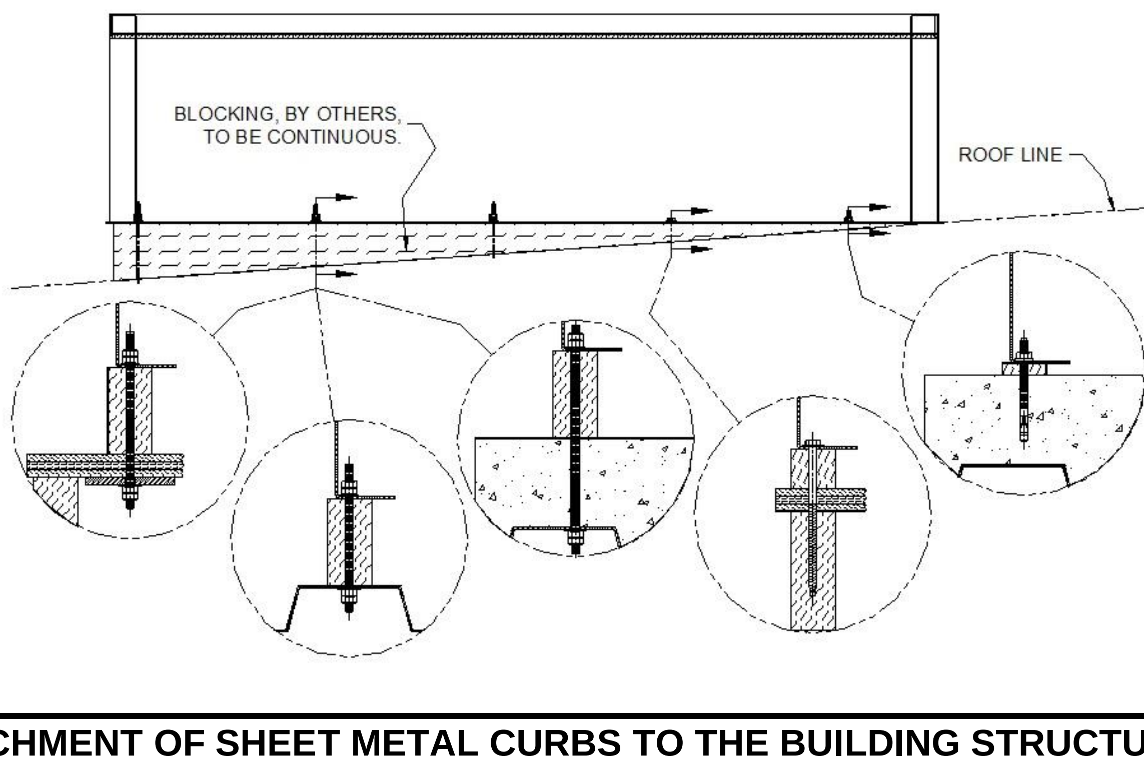
required embedment for the lag screw is into the structural timber. The embedment for the lag screw is measured to where the tapered point begins. Care must be taken to maintain the proper edge and end distances in the structural timbers for the lag screws in order to develop their full capacity. Pilot holes of the proper diameter must be drilled slightly beyond the required embedment for the lag screws to prevent splitting of the structural timbers. Do not allow the pilot holes to go clear through the structural timber. Note that the curb side wall is fully supported by the structural timbers.

D6.2.4-6; Attachment to Sloped Roofs

Sloped roofs present an interesting problem for the attachment of sheet metal curbs. The ideal sheet metal curb for a sloped roof would be one where the sheet metal was cut and bent to accommodate the slope. This would keep the equipment level, and still allow the curb to be attached to the roof directly using the fasteners as recommended by Kinetics Noise Control. However, frequently standard curbs of uniform height are ordered and applied to sloped roofs. Blocking is placed under the foot of the curb to level the curb. Depending on the slope of the roof, the height of the blocking could be considerable. This presents serious problems when attempting to create a competent connection between the curb and the roof.

The blocking for a seismically rated sheet metal roof curb must continuously support the curb side walls. This is required to prevent bending in the side walls which would drastically reduce the curb's ability to carry horizontal seismic and/or wind loads. A possible roof curb arrangement on a sloped roof is shown in Figure D6.2.4-7. The blocking is cut in such a way that it provides full and continuous support for the curb side walls.

Figure D6.2.4-7; Attachment to Sloped Roofs with Blocking



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The attachment hardware passes through the blocking. This ensures that the blocking will remain in position beneath the curb side wall. The holes through the blocking for the attachment hardware should be tight against the hardware. It would be best if the attachment hardware had to be "tapped" into place. A close fit with the attachment hardware will reduce the bending stress to near zero, and keep the hardware in shear.

When the height of the blocking exceeds (3) three inches, the attachment hardware that provides the most flexibility is ¼-20 UNC SAE Grade 2 All-Thread. Use double nuts and washers on each end of the All-Thread. Where the height of the blocking is not excessive, the attachment hardware discussed in the previous paragraphs may be used as long as it passes through the blocking with minimal clearance.

Figure D6.2.4-8 provides a detail to handle situations where the blocking on two adjacent sides meets at a corner. To help maintain the integrity of the attachments, it is necessary that the corners of the blocking be reinforced inside and out with field-fabricated sheet metal angles. The angles must be attached to the curb with sheet metal screws as shown. The threads of the screws must fully engage the sheet metal of both angles to develop the full capacity of the screws. The minimum number of screws recommended per leg is (3) three, (4) four screws per leg are shown. There will be corners where the blocking is short enough so that corner bracket is not needed. It is only necessary to install the corner brackets when the blocking exceeds (2) two inches in height.

D6.2.4-7; Conclusion

This section has taken a quick and very general look at the attachment of sheet metal curbs to roof structures. There will be many situations that are not specifically addressed by this document, which is not intended to be all encompassing. The drawings and descriptions are intended to provide general guidelines to help the Design Professional of Record, and the contractor with the installation of a curb.

The use of mounting hardware larger than 3/8" should be avoided. The use of a larger number of smaller fasteners will provide a better load distribution along the foot of the curb than a small number of larger fasteners. The key to using sheet metal curbs in seismic applications is to distribute the loads entering the curb from the equipment and exiting the curb to the equipment as evenly as possible.

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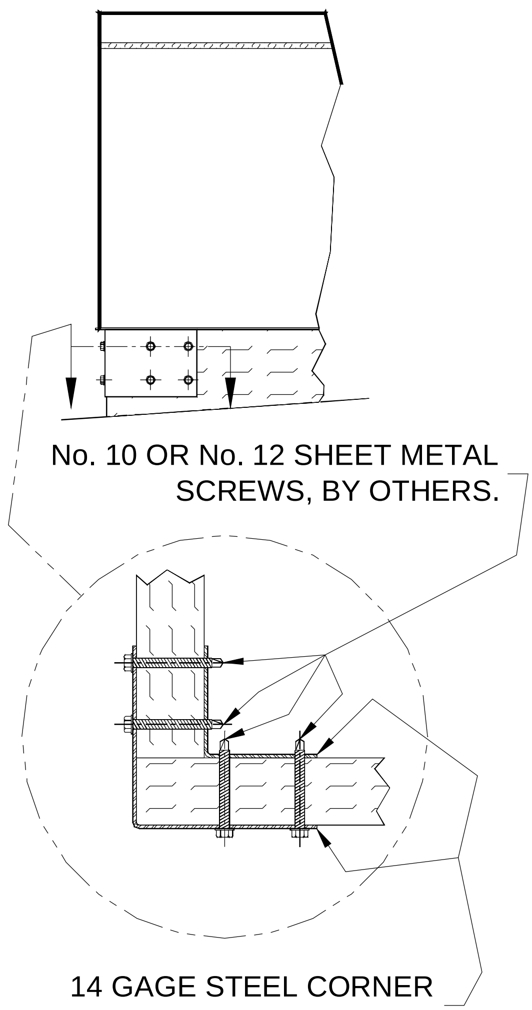
Figure D6.2.4-8; Curb Blocking Corner Detail



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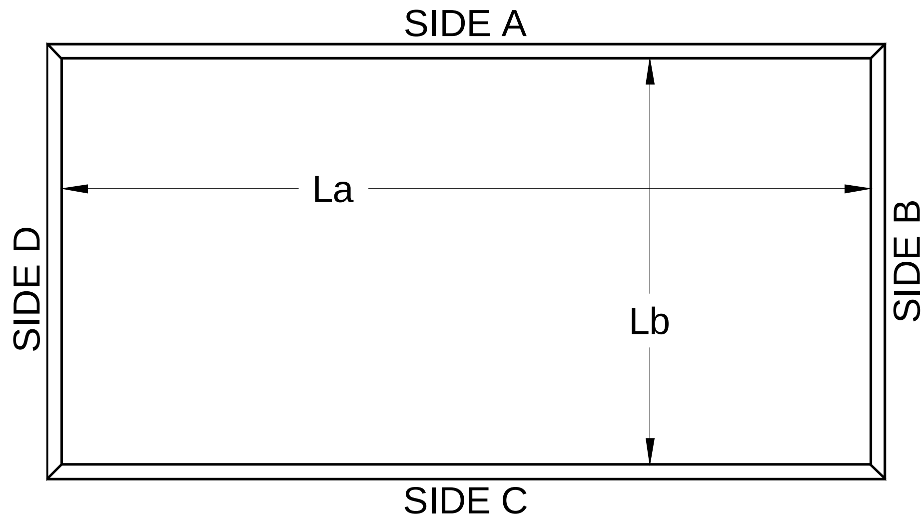
LIMITS OF SHEET METAL CURBS IN SEISMIC APPLICATIONS

D6.2.5-1; Introduction

In order to understand the limitations of sheet metal curbs in seismic applications, a review of how forces are transferred through the curb, which is covered in detail in Document D6.2.3, is in order. This discussion will evolve around curbs that have a rectangular plan view as shown in Figure D6.2.5-1. The sides of the curb will be designated as shown in Figure D6.2.5-1. The inside length of the curb is designated L_a. The inside width of the curb is given the designation L_b.

Figure D6.2.5-1. Plan View of a Rectangular Sheet Metal Curb.



An elevation view of any one of the curb side walls is shown in Figure D6.2.5-2. In this figure, ***H*** is the height of the curb side wall. The thickness of the curb wall material is designated as ***t***. The term ***w*** is the distributed weight of the equipment. It is shown as an even distribution; however, it may be an increasing quantity from one side to the other. The horizontal applied seismic and/or wind load is designated as ***f***. Again, ***f*** is shown as an evenly distributed load, although it may also be increasing from one side of the curb to the other. These loads must be carried in the plane of the curb wall. Loads that are perpendicular to the plane of the curb wall will lead to premature buckling of the curb wall.

D6.2.5-2; Curb Side Wall Weight Bearing Limit

The primary failure mode for the curb side walls is buckling. Buckling is a very dangerous failure mode. It is a geometry-related failure, it occurs in regions of compression loading, and always occurs at a stress that is much lower than the yield stress of the material. Structures that have at least one cross-sectional dimension that is small compared to the length or height dimension are candidates for a buckling type-failure. If one side wall buckles, the adjacent side walls may not be able to carry the

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additional load and may fail as well. Thus, buckling, when it occurs, is a catastrophic failure. We cannot predict the exact load at which buckling will occur. We can only predict a load above which buckling ***may*** occur in a perfect curb side wall. The actual buckling limit may be much lower due to dents and imperfections in the curb side walls.

Figure D6.2.5-2;. Typical Curb Side Wall Elevation View

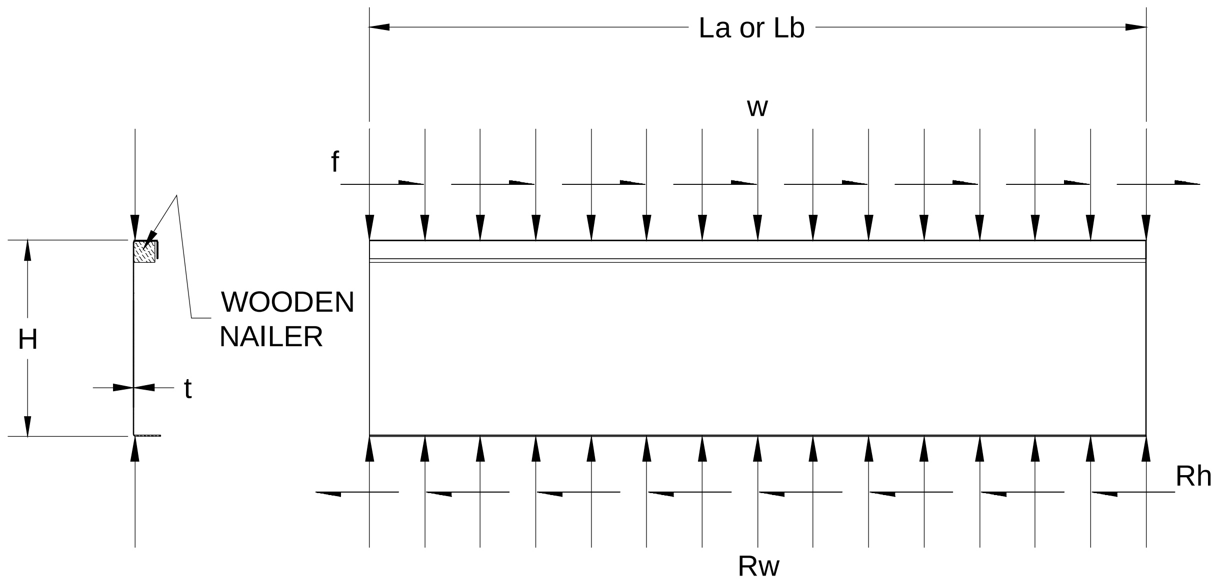

Table D6.2.5-1 presents the allowable distributed weight load, w_A', that may be applied to a curb side wall as a function of the curb height, ***H***, and the curb wall thickness, ***t***. This table is based on Table D6.2.3-1, and is expanded to include 12 gage sheet steel for the curb side walls. The allowable distributed weight load, w_A', includes a factor of safety of 2:1. As an initial check on the suitability of using a sheet metal curb with the specified piece of equipment, compute an average distributed weight load for the equipment assuming that the equipment C.G. is located in the geometric center of the equipment.

$$w = W/[2*(L_a+L_b)] \qquad \textbf{(Eq. 6.2.5-1)}$$

Equation 6.2.5-1 provides an estimate for the distributed weight loading for an application. An example of how this equation may be used in conjunction with Table D6.2.5-1 to determine the proper specifications for a curb to carry a given piece of equipment is presented. In Equation 6.2.5-1 ***W*** is the total weight of the equipment supported by the curb.

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Table D6.2.5-1; Allowable Vertical Curb Wall Loading (w_A') (lb/in)

CURB WALL	18 GAGE	16 GAGE	14 GAGE	12 GAGE	10 GAGE
t (in.)	0.0478	0.0598	0.0747	0.1046	0.1345
H (in.)					
6.0	41.1	80.5	157	431	916
9.0	18.3	35.8	69.8	192	407
12.0	10.3	20.1	39.2	108	229
14.0	7.55	14.8	28.8	79.2	168
15.0	6.58	12.9	25.1	69.0	147
18.0	4.57	8.95	17.4	47.9	102
21.0	3.36	6.57	12.8	35.2	74.8
24.0	2.57	5.03	9.81	26.9	57.3
30.0	1.65	3.22	6.28	17.2	36.7
36.0	1.14	2.24	4.36	12.0	25.5

Example No. 1:

W = 14,000 lbs.
L_a = 375 in.
L_b = 99 in.

w = 14,000/[2*(375+99)] = 14.8 lb/in

If, H = 14 in., and the application is for a non-essential facility in a low seismic area, the minimum curb wall must be 16 gage commercial quality sheet steel. If the application is for an essential facility, or a medium to high seismic area, then the minimum curb wall should be 14 gage commercial quality sheet steel.

If, H = 24 in., and the application falls into any facility and any seismic area, the minimum curb wall must be 12 gage commercial quality sheet steel.

The preceding example clearly shows that care must be used in selecting a sheet metal curb for any application. The example did not consider a piece of equipment where the C.G. was offset from the

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geometric center of the equipment by a significant amount, or a curb that has a large opening cut in the side wall to accommodate ductwork. The offset C.G. will lead to a non-uniform weight distribution and a concentration of load on one side or in one corner. If the C.G. is offset from the geometric center of the equipment by more than 5% of the length or width, then a detailed analysis must be done to ensure that local buckling is not an issue. Holes cut in the curb side walls drastically reduce the load- bearing capacity of the curb, and must be taken into account. The length of the curb side wall affected by the opening must be subtracted from the length of the curb side wall. Then, for the curb side wall with the duct opening, the result of Equation 6.2.5-1 may be modified for the side with the duct opening as follows for the long sides of the curb.

$$w_a = w*[L_a/(L_a-L_d)] \qquad \textbf{(Eq. 6.2.5-2)}$$

And, for the short sides of the curb, the modification is given below.

$$w_b = w*[L_b/(L_b-L_d)] \qquad \textbf{(Eq. 6.2.5-3)}$$

In Equations 6.2.5-2 and 6.2.5-3 w_a and w_b are the distributed weight loads on the long and short sides of the curb, respectively, when a duct opening is present in the curb side wall. The term L_d represents the length of the duct opening in the curb side wall. Example No. 2 demonstrates how the presence of a duct opening can affect the load-bearing capacity of a sheet metal curb.

Example No. 2:

W = 14,000 lbs.
L_a = 375 in.
L_b = 99 in.
L_d = 24 in. The duct opening is in the short sides.

w = 14,000/[2*(375+99)] = 14.8 lb/in

w_b = 14.8*[99/(99-24)] = 19.5 lb/in

If, H = 14 in., and the application is for a non-essential facility in a low seismic area, the minimum curb wall for the side with the duct opening must be 14 gage commercial quality sheet steel. If the application is for an essential facility, or a medium to high seismic area, then the minimum curb wall should be 12 gage commercial quality sheet steel.

When a duct opening is present, the curb wall with the opening will need to be made from heavier gage sheet steel than the curb walls without the duct opening.

D6.2.5-3; Curb Side Wall Horizontal Seismic and Wind Load Bearing Capacity

As with the weight bearing limit, the horizontal seismic and wind load bearing limit of the curb side walls will be dependent upon the buckling limit of the curb walls. The shearing loads enter the walls at

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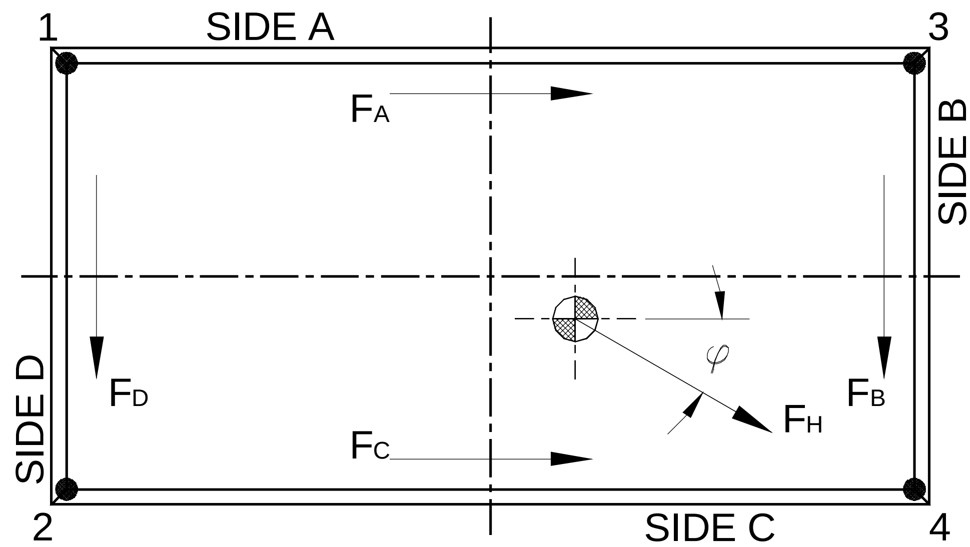
the top of the curb and exit at the bottom. They remain in the plane of the curb side wall. Thus, only horizontal loads that are parallel to the curb walls will be carried by those walls. This is demonstrated in the curb plane view shown in Figure D6.2.5-3.

Figure D6.2.5-3; General Horizontal Load Distribution to the Curb Walls



In Figure D6.2.5-3, the horizontal seismic and/or wind load, F_H, will be distributed into the four curb side walls. In the absence of evidence to the contrary, it is reasonable to assume the following:

$$F_A = F_C = F_H * Cos\varphi \qquad \text{(Eq. 6.2.5-4)}$$

and

$$F_B = F_D = F_H * Sin\varphi \qquad \text{(Eq. 6.2.5-5)}$$

The allowable horizontal seismic and wind loadings for various curb side wall material gages and curb heights are given in Tables D6.2.5-2 through D6.2.5-6. These are values based on the critical buckling shear load for the curb side walls. The allowable loads given in Tables D6.2.5-2 through D6.2.5-6 have a factor of safety of 2:1 with respect to the critical buckling load built into them. In these tables, w' is the maximum allowable vertical load with no shear load applied.

Since the horizontal load enters the curb as a distributed load, the horizontal load that may be resisted by a curb side wall will depend on its length. Thus, the shorter the curb wall, the less its capacity to resist a horizontal seismic and/or wind load. The worst possible seismic and/or wind load case for a sheet metal curb would be where the horizontal load was parallel to the two short sides of the curb as illustrated in Figure D6.2.5-4.

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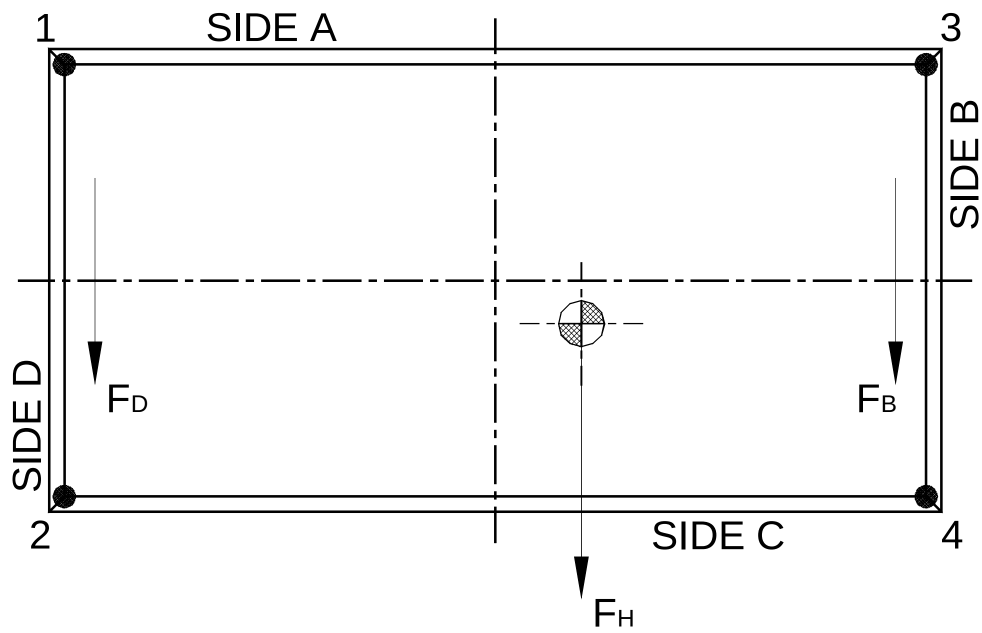
Figure 6.2.5-4; Worst-Case Horizontal Load Distribution to the Curb Walls



For this worst-case loading the force balance will give the following relationship.

$$F_H = F_B + F_D \qquad \textbf{(Eq. 6.2.5-6)}$$

For the purpose of determining the suitability of a particular curb for a given application, it will be convenient to assume that

$$F = F_B = F_D = F_H/2 \qquad \textbf{(Eq. 6.2.5-7)}$$

The distributed load applied to the short side walls of the curb, ***f***, will be as follows:

$$f = F_H/(2*L_b) \qquad \textbf{(Eq. 6.2.5-8)}$$

The actual value for F_H will be determined through the application of the building code in force for the project. Example No. 3 will illustrated the application of Tables D6.2.5-1 through D6.2.5-6.

Example No. 3:

W **= 2,000 lbs.**
L_a **= 115 in.**
L_b **= 45 in.**
H **= 24 in.**

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w = 2,000/[2*(150+50)] = 5.00 lb/in

For an un-reinforced curb wall, the minimum sheet metal for the curb walls will be 16 Gage, see Table D6.2.5-1.

A.) $F_H = 0.50*W$ (0.5g)
F_H = 0.50*2,000 = 1,000 lbs.

f = 1,000/(2*50) = 10.00 lb/in

From Table D6.2.5-3, for w = 5.0 lb/in, f_A' = 25.4 lb/in. This curb will perform well in this application.

B.) $F_H = 1.00*W$ (1g)
F_H = 1.0*2,000 = 2,000 lbs.

f = 2,000/(2*50) = 20.00 lb/in

From Table D6.2.5-3, for w = 5.0 lb/in, f_A' = 25.4 lb/in. This curb will perform well in this application.

C.) $F_H = 1.50*W$ (1.5g)
F_H = 1.50*2,000 = 3,000 lbs.

f = 3,000/(2*50) = 30.00 lb/in

From Table D6.2.5-3, for w = 5.0 lb/in, f_A' = 25.4 lb/in. In this case, the curb is inadequate. Table D6.2.5-3 also shows that even if the curb side walls were reinforced to carry the equipment weight load, the curb would be inadequate for the proposed seismic application. In order to have a 24 in. high curb in this seismic application, the minimum curb side wall would need to be 14 gage.

Duct openings will drastically reduce the ability of a curb wall to carry a horizontal seismic and/or wind load. In the presence of a duct opening, the load applied to a long side of the curb, f_a, will be given by

$$f_a = f*[L_a/(L_a-L_d)] \quad \text{(Eq. 6.2.5-2)}$$

In the presence of a duct opening, the load applied to the short side of the curb, f_b, will be

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$f_b = f*[L_b/(L_b-L_d)]$ **(Eq. 6.2.5-3)**

The effects of a duct opening on the seismic load carrying ability of the curb are illustrated in Example No. 4.

Example No. 4:

W = 2,000 lbs.
L_a = 150 in.
L_b = 50 in.
L_d = 25 in. (Duct opening in short curb side.)
H = 24 in.
t = 16 Gage = 0.0598 in. (Curb side wall material thickness.)

w = 2,000/[2*(150+50)] = 5.00 lb/in

w_b = 5.00*[50/(50-25)] = 10.00 lb/in

F_H = 0.50*W (0.5g)

F_H = 0.50*2,000 = 1,000 lbs.

f = 1,000/(2*50) = 10.00 lb/in

f_b = 10.00*[50/(50-25)] = 20.00 lb/in

The presence of a duct opening moves the curb specified in this example from being adequate for a 0.5g application to being inadequate. The curb wall with the duct opening would need to have a minimum material thickness of 14 gage.

The applicability of sheet metal curbs in seismic applications will be limited by many different factors. Each proposed application must be individually assessed to determine its suitability for a seismic or high wind installation. The tables and examples presented in this document will allow the reader to make a rough estimate on the suitability of a sheet metal curb for their application. However, the manufacturer of the curb, or Kinetics Noise Control as the manufacture of the seismic restraints should be consulted for a detailed assessment of the curb and its application. Kinetics Noise Control has developed a generalized analysis of sheet metal curbs based on the buckling strength of the curb side walls. This analysis is used to specify the number of horizontal and vertical restraints required to resist the code-determined loadings. The analysis will also determine whether vertical reinforcement will enhance the application of the curb.

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Table D6.2.5-2; Allowable Horizontal Seismic & Wind Curb Wall Loading (f_A') (lb/in)

CURB WALL: 18 GAGE; t = 0.0478 in

---------	w (lb/in	0.0	2.5	5.0	10.0	15.0	25.0	50.0	75.0	150
w' (lb/in)	H (in)									
82.3	6.0	233	231	230	227	224	218	200	170	N/A
36.6	9.0	104	102	101	97.8	94.5	86.4	N/A	N/A	N/A
20.6	12.0	58.3	56.9	55.4	52.0	47.7	N/A	N/A	N/A	N/A
15.1	14.0	42.7	41.3	39.8	35.9	27.6	N/A	N/A	N/A	N/A
13.2	15.0	37.3	35.9	34.4	30.1	N/A	N/A	N/A	N/A	N/A
9.14	18.0	25.9	24.4	22.7	N/A	N/A	N/A	N/A	N/A	N/A
6.71	21.0	19.0	17.5	15.4	N/A	N/A	N/A	N/A	N/A	N/A
5.14	24.0	14.5	13.0	9.87	N/A	N/A	N/A	N/A	N/A	N/A
4.06	27.0	11.5	9.83	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.29	30.0	9.31	7.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2.72	33.0	7.69	5.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2.28	36.0	6.45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Table 6.2.5-3; Allowable Horizontal Seismic & Wind Curb Wall Loading (f_A') (lb/in)

CURB WALL: 16 GAGE; t = 0.0598 in

---------	w (lb/in)	0.0	2.5	5.0	10.0	15.0	25.0	50.0	75.0	150
w' (lb/in)	H (in)									
161	6.0	455	454	453	450	447	442	426	409	327
71.6	9.0	203	201	200	197	194	188	168	N/A	N/A
40.3	12.0	114	113	111	108	105	97.4	N/A	N/A	N/A
29.6	14.0	83.7	82.4	80.9	77.8	74.3	64.4	N/A	N/A	N/A
25.8	15.0	73.0	71.6	70.2	67.0	63.2	49.9	N/A	N/A	N/A
17.9	18.0	50.6	49.3	47.8	44.2	39.1	N/A	N/A	N/A	N/A
13.1	21.0	37.1	35.7	34.1	29.8	N/A	N/A	N/A	N/A	N/A
10.1	24.0	28.6	27.1	25.4	18.6	N/A	N/A	N/A	N/A	N/A
7.95	27.0	22.5	21.0	19.2	N/A	N/A	N/A	N/A	N/A	N/A
6.44	30.0	18.2	16.7	14.6	N/A	N/A	N/A	N/A	N/A	N/A
5.32	33.0	15.0	13.5	10.7	N/A	N/A	N/A	N/A	N/A	N/A
4.47	36.0	12.6	11.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Table 6.2.5-4; Allowable Horizontal Seismic & Wind Curb Wall Loading (f_A') (lb/in)

CURB WALL: 14 GAGE; *t* = 0.0747 in

---------	w (lb/in)	0.0	2.5	5.0	10.0	15.0	25.0	50.0	75.0	150
w' (lb/in)	H (in)									
314	6.0	888	887	885	883	880	875	860	846	795
140	9.0	396	395	393	391	388	382	366	348	N/A
78.5	12.0	222	221	219	217	214	207	189	155	N/A
57.7	14.0	163	162	160	158	155	148	124	N/A	N/A
50.2	15.0	142	141	139	136	133	126	90.6	N/A	N/A
34.9	18.0	98.7	97.4	96.0	92.9	89.6	81.2	N/A	N/A	N/A
25.6	21.0	72.4	71.0	69.6	66.4	62.6	48.8	N/A	N/A	N/A
19.6	24.0	55.4	54.1	52.6	49.2	44.6	N/A	N/A	N/A	N/A
15.5	27.0	43.8	42.5	40.9	37.1	30.0	N/A	N/A	N/A	N/A
12.6	30.0	35.6	34.2	32.6	28.2	N/A	N/A	N/A	N/A	N/A
10.4	33.0	29.4	28.0	26.3	20.3	N/A	N/A	N/A	N/A	N/A
8.72	36.0	24.7	23.2	21.4	N/A	N/A	N/A	N/A	N/A	N/A

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Table 6.2.5-5; Allowable Horizontal Seismic & Wind Curb Wall Loading (f_A') (lb/in)

CURB WALL: 12 GAGE; *t* = 0.1046 in

---------	w (lb/in)	0.0	2.5	5.0	10.0	15.0	25.0	50.0	75.0	150
w' (lb/in)	H (in)									
862	6.0	2,438	2,437	2,435	2,433	2,430	2,425	2,411	2,397	2,355
383	9.0	1,083	1,082	1,081	1,078	1,075	1,070	1,056	1,041	993
215	12.0	608	607	605	603	600	594	580	564	504
158	14.0	447	446	444	441	439	433	418	400	314
138	15.0	390	389	388	385	382	376	361	342	N/A
95.8	18.0	271	270	268	266	263	257	239	216	N/A
70.4	21.0	199	198	196	194	191	184	164	N/A	N/A
53.9	24.0	152	151	150	147	144	137	110	N/A	N/A
42.6	27.0	120	119	118	115	112	104	N/A	N/A	N/A
34.5	30.0	97.6	96.2	94.8	91.8	88.4	80.0	N/A	N/A	N/A
28.5	33.0	80.6	79.3	77.8	74.7	71.1	60.6	N/A	N/A	N/A
23.9	36.0	67.6	66.2	64.8	61.5	57.6	N/A	N/A	N/A	N/A

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Table 6.2.5-6; Allowable Horizontal Seismic & Wind Curb Wall Loading (f_A') (lb/in)

CURB WALL: 10 GAGE; t = 0.1345 in

---------	w (lb/in)	0.0	2.5	5.0	10.0	15.0	25.0	50.0	75.0	150
w' (lb/in)	H (in)									
1,833	6.0	5,185	5,183	5,182	5,179	5,177	5,171	5,158	5,144	5,103
814	9.0	2,302	2,301	2,300	2,297	2,294	2,289	2,275	2,262	2,219
458	12.0	1,295	1,294	1,293	1,290	1,287	1,282	1,268	1,254	1,208
337	14.0	953	952	951	948	945	940	926	911	861
293	15.0	829	827	826	823	821	815	801	786	734
204	18.0	577	576	574	572	569	563	549	532	471
150	21.0	424	423	422	419	416	410	395	377	260
115	24.0	325	324	323	320	317	311	295	275	N/A
90.5	27.0	256	255	253	251	248	242	224	199	N/A
73.3	30.0	207	206	205	202	199	193	173	N/A	N/A
60.6	33.0	171	170	169	166	163	156	133	N/A	N/A
50.9	36.0	144	143	141	138	135	128	95.9	N/A	N/A

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RULES FOR SHEET METAL CURBS IN SEISMIC APPLICATIONS

1. The seismic load carrying capability of a sheet metal roof curb is greatly improved with the addition of sufficient vertical reinforcement to the curb walls to carry the weight load of the equipment. Reinforcement in the form of treated wooden 2 X 2's is adequate. A minimum of three per side is required: one at each end and one in the middle. More reinforcement may be required for tall, narrow equipment particularly in conjunction with high seismic loads.
2. Provisions must be made to transfer vertical uplift loads produced by seismic or wind forces directly to the roof structure without producing excess bending in the curb wall.
3. For light-gage curbs, horizontal loads may be transmitted only in the plane of the curb walls. Opposite curb walls will carry similar loads.
4. For design purposes, the short sides of the curb must be able to carry the entire horizontal seismic or wind load.
5. If the Center of Gravity (CG) of the equipment is more than 10% off of the geometric center of the plan view of the curb special attention must be given to more heavily loaded portions of the curb. CG variation greater than that mentioned above causes high stresses and possible local buckling of the curb in the corner carrying the highest weight.
6. Large penetrations (larger than a screw or bolt hole) of the curb walls for ductwork, piping, and power cable conduits are not to be permitted unless the penetration has been adequately reinforced. Adequate reinforcement shall consist of enough treated wood 2 X 2's to carry the weight load of the equipment across the penetration, see Document D6.2.3. Also, the curb wall is to be reinforced with sheet metal of a thickness equal to that of the curb wall. The width of this reinforcement is to be not less than 2 inches, see Document D6.2.3. This is necessary to transfer the horizontal seismic force around the penetration. The allowable seismic load of the side with the penetration and its opposite side should also be reduced by 50%.

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SEISMIC FORCES ACTING ON PIPING SYSTEMS

When subjected to an earthquake, piping systems must resist lateral and axial buckling forces, and the restraint components for these systems must resist pullout and localized structural failures.

Most piping systems are suspended from the deck above on either fixed or isolated hanger rod systems. They may be supported singly or there may be several pipes attached to a common trapeze. On some occasions the pipes may run vertically or may be mounted to the floor.

D7.1.1 Suspended Systems

Most codes do not require that piping supported on non-moment generating (swiveling) hanger rods 12 in or less in length be restrained. The 12 in length was determined based on the natural frequency of systems supported on the short hanger rods. In practice, it has been found that the vibrations generated by earthquakes do not excite these types of systems and, although the pipes move back and forth somewhat as a result of an earthquake, they do not tend to oscillate severely and tear themselves apart.

There are also exclusions in most codes for small pipes, no matter what the hanger rod length. Again, the basis for this exclusion is based on the post-earthquake review of many installations. It has been found that smaller pipes are light and flexible enough that they cannot generate enough energy to do significant damage to themselves.

For cases where restraints are required, however, the forces involved can be significant. This is due to the difference between the spacing of piping system supports and piping system restraints. Supports for piping systems are typically sized to carry approximately a 10 ft length of piping (in the case of trapezes, multiple pipes each approximately 10 ft long). Seismic restraints, on the other hand, are normally spaced considerably further apart with the spacing varying by restraint type, restraint capacity, pipe sizes, and the seismic design load. It is very important to be aware of the impact of the difference in spacing as the wider this spacing, the larger the seismic load when compared to the support load. Guidance in determining restraint spacing requirements is available in Chapter D4 of this manual.

To illustrate this difference, consider a simple example of a single pipe weighing 50 lb/ft being restrained against a 0.2g seismic force with restraints located on 80 ft centers and supports located on 10 ft centers. The load that is applied to the hanger rods by the weight of the pipe is 50 lb/ft x 10 ft or 500 lb each (assuming single rod supports). The horizontal load that occurs at the restraint locations is the total restrained weight (50 lb/ft x 80 ft = 4000 lb) multiplied by the seismic force (0.2g) or 800 lb. Thus the seismic load is larger than the vertical dead load.

Restraints for suspended systems are normally in the form of cables or struts that run from the pipe up to the deck at an angle. Because of the angle, horizontal seismic loads also generate

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vertical forces that must be resisted. Therefore, restraint devices must be attached at support locations so that there is a vertical force-resisting member available.

As the angle becomes steeper (the restraint member becomes more vertical), the vertical forces increase. At 45 degrees the vertical force equals the horizontal force and at 60 degrees the vertical force is 1.73 times the horizontal force.

The net result is that for cable systems or for struts loaded in tension, the uplift force at the bottom end of the restraint can be considerably higher than the downward weight load of the pipe. Returning to our example, assume that we have a restraint member installed at a 60 degree angle from horizontal and that the lateral force will load it in tension. In this case, the 800 lb seismic force generates an uplift force of 1.73 x 800 lb or 1384 lb. This is 884 lb more than the support load and, depending upon the support rod length and stiffness, can cause the support rod to buckle. Rod stiffeners are used to protect against this condition and sizing information is available in Chapter D4 of this manual.

Unlike cables, if struts are used for restraint they can also be loaded in compression. In the example above, if the strut were loaded in compression, the 1384 lb load would be added to the support load (trying to pry the hanger rod out of the deck). The total support capacity required would be 1384 lb + 500 lb or 1884 lb. As a consequence, when using struts, the hanger rod must be designed to support 1884 lb instead of the 500 lb maximum generated with cables. Hanger rod sizing information is also available in Chapter D4 of this manual.

D7.1.2 Riser Systems

Where piping systems are running vertically in structures, except for the loads directly applied by vertical seismic load components identified in the code, there will be little variation in vertical forces from the static condition. Lateral loads are normally addressed by pipe guides and the spacing between pipe guides is not to exceed the maximum tabulated lateral restraint spacing indicated in the design tables in Chapter D4.

D7.1.3 Floor-Mounted Systems

The primary difference between floor- and ceiling-mounted piping systems is that the support loads in the pipe support structure are in compression instead of tension (as in the hanger rods). Although a support column and diagonal cables can be used, a fixed stand made of angle or strut is generally preferred. Rules relating to restraint spacing and the sizing information for diagonal struts are the same as for hanging applications.

However, the support legs need to be designed to support the combined weight and vertical seismic load (for a two-legged stand and the example above, 500 lb / 2 + 1384 lb or 1634 lb) in compression (Note: 500 lb / 2 is the load per leg for two legs). The anchorage for the legs needs to be able to withstand the difference between the dead weight and the vertical seismic load (in the example above 1384 lb - 500 lb / 2 or 1134 lb).

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BASIC PRIMER FOR SUSPENDED PIPING

Failures in piping systems resulting from earthquakes have historically resulted in large quantities of water or other materials being dumped into occupied spaces of the building structure. The resulting dollar damage to the building and its contents is often considerably more than the costs of damage to the building structure itself. In addition, failure of the building's mechanical systems can render the structure unfit for occupation until the damage is corrected, and result in major problems for the tenants and/or owners.

Because of the impact that failures of these systems have had in the past, design requirements for piping systems have become much more stringent.

Within a building structure, there are multitudes of different kinds of piping systems, each with its own function and requirements. These include potable water, sanitary, HVAC, fire piping, fuel, gas, medical gases, and process systems to name a few. Requirements for the systems vary based on the criticality or hazardous nature of the transported fluid. Code mandated requirements for the restraint of piping systems are addressed in Chapter D2 of this manual (Seismic Building Code Review).

Prior to applying this section of the manual, it is assumed that the reader has reviewed Chapter D2 and has determined that there is indeed a requirement for the restraint of piping. This chapter of the manual is a "how to" guide and will deal only with the proper installation and orientation of restraints and not whether or not they are required by code or by specification.

This chapter also does not address the sizing of restraint hardware. Chapter D4 includes sections on sizing componentry based on the design seismic force and the weight of the system being restrained.

Process piping is not directly associated with building operating systems and often has its own set of requirements. If there are no applicable special requirements, these systems should be restrained in a similar fashion to the building mechanical systems. This manual will not address any special requirements for process piping systems.

Building mechanical systems (potable water, HVAC, sanitary) can normally be grouped together and have similar design requirements. In many cases, requirements for fuel, gas, and medical gasses are more stringent. Refer to the code review chapter (D2) of the manual for applicable design requirements.

Fire piping restraint is normally addressed in the applicable fire code. There is always some requirement for restraint, as triggering a nozzle generates thrust in the piping and must be countered. This thrust may be unidirectional, unlike the loads generated by an earthquake, and can sometimes be countered by unsymmetrical restraint arrangements.

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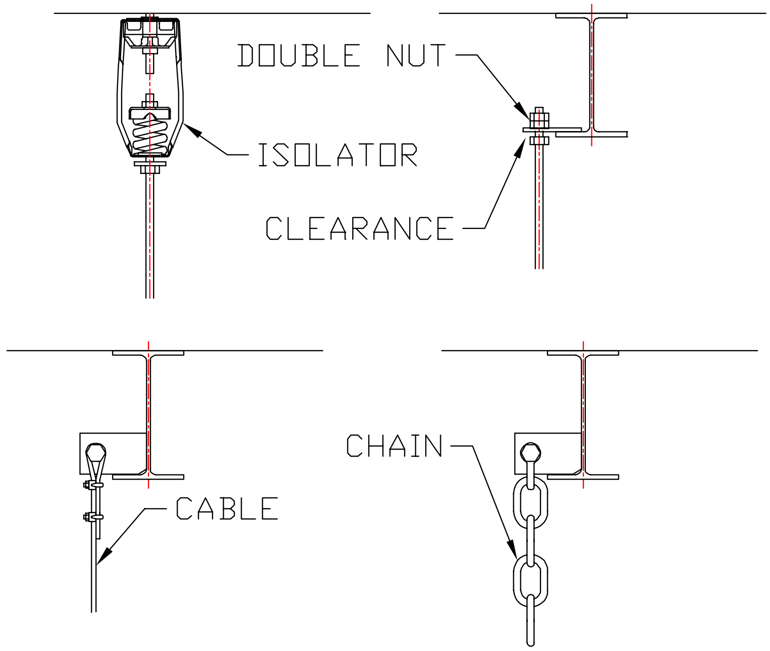
These types of non-seismic restraints are not addressed in this chapter. To determine the design requirements for seismic applications, refer again back to the code review Chapter D2.

In many cases, piping can be excluded from restraint if it is small enough in size or mounted in close proximity to the ceiling structure. When applying this exemption, current codes require the installation of a "non-moment generating connection" at the top anchorage point. This term is often confusing and deserves further clarification. A "non-moment generating connection" is one that will allow the supported pipe to swing freely in any direction if acted on by an outside force. Some examples of "non-moment generating connections" are illustrated below.

Figure D7.2-1; Non-moment generating connections



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PROS AND CONS OF STRUTS VERSUS CABLES

Both cables and struts have their place in the restraint of piping. In order to minimize costs and speed up installation, the differences between the two should be understood.

In general, piping restrained by struts will require only 1 brace per restraint location while piping restrained with cables requires that 2 cables be fitted forming an “X” or a “V”. As a trade-off, the number of restraint points needed on a given run of piping will typically be considerably higher for a strut-restrained system than for the cable-restrained system and, generally, strut-restrained systems will be more costly to install.

An added factor to consider when selecting a restraint system is that once a decision is reached on the type to use for a particular run, code requirements state that the same type of system must be used for the entire run (all cable or all strut). Later sections in this chapter will define runs, but for our purposes at present, it can be considered to be a more or less straight section of piping.

The obvious advantage to struts is that, when space is at a premium, cables angling up to the ceiling on each side of a run may take more space than is available. Struts can be fitted to one side only, allowing a more narrow packaging arrangement.

The advantages of cables, where they can be used, are numerous. First, they can usually be spaced less frequently along a pipe than can struts. Second, they cannot increase the tensile forces in the hanger rod that results from the weight load, so rod and rod anchorage capacities are not impacted. Third, they are easily set to the proper length. And fourth, they are well suited to isolated piping applications.

To better explain the differences between the systems, it is necessary to look at how seismic forces are resisted with cables and struts. Shown below are sketches of both cable-restrained and strut-restrained piping.

Figure D7.3-1; Cable Restrained

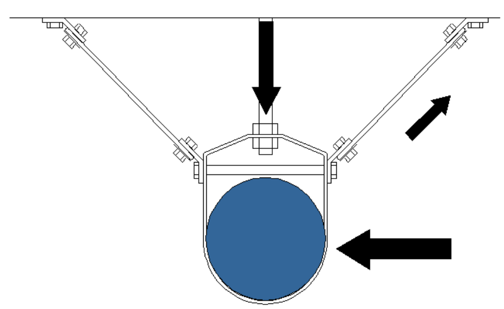

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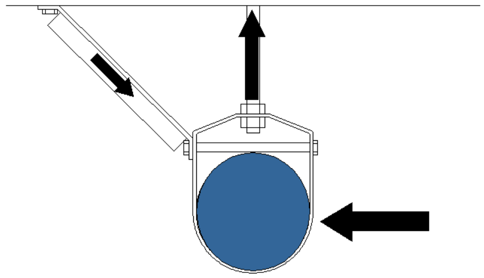
Figure D7.3-2; Strut Restrained



The key factor to note is that cables can only be loaded in tension. This means that seismic forces can only generate compressive loads in the pipe hanger rod. Seismic forces can, however, load the strut in compression resulting in a tensile load on the hanger rod.

This tensile load is in addition to any deadweight load that may already be supported by the hanger and is often significantly higher than the original load. This has the potential to rip the hanger rod out of the support structure and must be considered when sizing components.

Because of this added tensile component and the resulting impact on the necessary hanger rod size, most strut manufacturers limit the maximum allowable strut angle (to the horizontal) to 45 degrees. This is lower than typical allowable angles for cables that often reach 60 degrees from the horizontal. Although the data provided in Section D4.4 of this manual allow the use of higher angles for strut systems, users will find that the penalties in hanger rod size and anchorage will likely make these higher angles unusable in practice. To put this into context, examples will be provided at both 45 degrees and 60 degrees from the vertical to indicate the impact on capacity that results from the angle.

For a 45 degree restraint angle, if we assume a trapeze installation with the weight (W) equally split between 2 supports, the initial tension in each support is 0.5*W. Using a 0.25g lateral design force (low seismic area), the total tensile load in a hanger increases to 0.75*W for bracing on every support and 1.0W for bracing on every other support, if a strut is used.

For reference, if struts are used in a 60 degree angle configuration (from the horizontal), the tensile force in the hanger rod for all cases increases by a factor of 1.73 *(tan 60)* over that listed in the previous paragraph. This means that the tensile force becomes .94*W for bracing on every support and 1.36*W for bracing on every other support.

On the other hand, where 0.25g is applicable, buckling concerns in the pipe are such that the spacing between lateral restraints can be as high as 40 ft and for axial restraints, 80 ft. If we were to try to use struts placed at a 40 ft spacing in conjunction with supports spaced at 10 ft, the tensile force developed by a seismic event in the rod increases to 1.5*W for 45 degree configurations and to 2.23*W for 60 degree configurations.

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As mentioned earlier, there is no increase in the rod forces for cable restrained systems.

Using real numbers based on a 40 ft restraint spacing and a 60 degree angle configuration, if the peak tensile load in the hanger rod is 500 lb for a cable restrained system, it becomes 2230 lb for an otherwise identical strut restrained system.

A summary of the above data, based on a 500 lb weight per hanger rod (1000 lb per trapeze bar) and including concrete anchorage sizes and minimum embedment is shown below.

Table D7.3-1; Hanger Rod Tensile Loads

Summary of Hanger Rod Tensile Loads based on 500 lb per Rod Weight				
	Tens Force (lb)	Min Rod (in)	Min Anc (in)	Embed (in)
Every Hanger Braced (10')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	750	0.38	0.38	3.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	933	0.50	0.50	4.00
Every other Hanger Braced (20')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	1000	0.50	0.50	4.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	1365	0.50	0.63	5.00
Every fourth Hanger Braced (40')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	1500	0.63	0.63	5.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	2230	0.63	0.75	6.00
Max Spacing between Braces (80')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	2500	0.75	0.75	6.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	3960	0.88	1.00	8.00

Note: The above anchorage rating is based on typical anchor allowables only. Often the underside of a concrete floor slab is in tension and if this is the case, the anchorage capacity may need to be further de-rated (forcing the need for an even larger hanger rod than is indicated here).

The net result is that the ability to use struts is highly dependent on the hanger rods that are in place. If these were sized simply on deadweight, the added seismic load, even in relatively low seismic areas, can quickly overload them. The only recourse is to either replace the hanger rods with larger ones or decrease the restraint spacing to the point at which virtually every support rod is braced.

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It should also be noted that the hanger rods in tension become seismic elements. This occurs with struts, but does not with cables. As a result, the system must comply with all of the anchor requirements specified by ICC. This includes the use of seismically rated anchors and embedment depths that are in conformance with ICC requirement for those types of anchors. With larger anchor sizes, floor slab thickness may cause this to become a significant problem.

With both cables and struts, the hanger rods can be loaded in compression. As the seismic force increases, it eventually overcomes the force of gravity and produces a buckling load in the hanger rod. It is mandatory in all cases that the rod be able to resist this force.

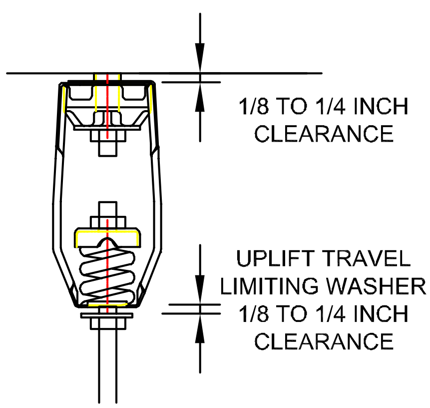
There is a wide range of variables involved in determining the need for rod stiffeners to resist this buckling load. Factors that impact this include 1) the magnitude of the compressive force, 2) the weight load carried by the hanger rod, 3) the length of the hanger rod, 4) the diameter of the hanger rod, and 5) the angle between the restraint strut or cable and the horizontal axis.

Charts are included in Section D4.4 of this manual that allow the user to determine if there is a need for a stiffener and to allow the proper selection if required.

Because uplift occurs, some attention must be given to isolated systems. First, when using isolators, the location of the isolation element needs to be at the top end of the hanger rod (close to, but not tight against the ceiling). If placed at the middle of the hanger rod, the rod/isolator combination will have virtually no resistance to bending and will quickly buckle under an uplift load.

Second, a limit stop must be fit to the hanger rod, just beneath the hanger such that when the rod is pushed upward a rigid connection is made between the hanger housing and the hanger rod that prevents upward motion. This is accomplished by adding a washer and nut to the hanger rod just below the isolator (see the sketch below).

Figure D7.3-3; Installation for an Isolation Hanger in a Seismic Application



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PIPE RESTRAINTS-DEFINITIONS AND LOCATING REQUIREMENTS

There are a number of design guides that have been developed over the years but the one with the longest history and most widely accepted is SMACNA. They have developed a handbook that offers conservative guidance that an end user can reference in selecting and installing restraints for distribution systems. While the information provided in that handbook is good, it suffers from a couple of inherent drawbacks. The first is that because it is linked to generically available hardware, the ratings that are assumed for the various hardware components are the lowest of any of the many possibilities available in the marketplace. The net result is that the suggested hardware is larger in general than that which could be used if higher quality componentry it specified. The second is that their presentation of the results is extremely cumbersome and difficult to use.

While the criteria presented in this document is based on the guidance offered by SMACNA, it has been possible to increase the component ratings as the actual capacity, type and manufacture of these components is clearly known. In addition, based on a critical review of the data presentation in the SMACNA handbook, it has been possible to greatly simplify the method of selection making the end result much simpler to use.

With respect to the conceptual restraint arrangement illustrations, the SMACNA concepts are appropriate and are referenced here.

In general, pipes are restrained in lengths called “runs.” Therefore before getting into a detailed review of the restraint systems it is imperative that a definition of “run” as well as other key terms be addressed.

D7.4.1-1; Definitions

Axial In the direction of the axis of the pipe.

Lateral Side to side when looking along the axis of the pipe.

Pipe Clamp A heavy duty split ring clamp tightened against the pipe to the point that it can be used to control the axial motion of the pipe.

Restraint Any device that limits the motion of a pipe in either the lateral or axial direction.

Run A more or less straight length of pipe where offsets are limited to not more than S/16 where S is the maximum permitted lateral restraint spacing (a function of pipe size and seismic forces) and the total length is greater than S/2. (Note: S dimensions for various conditions are listed in Chapter D4.)

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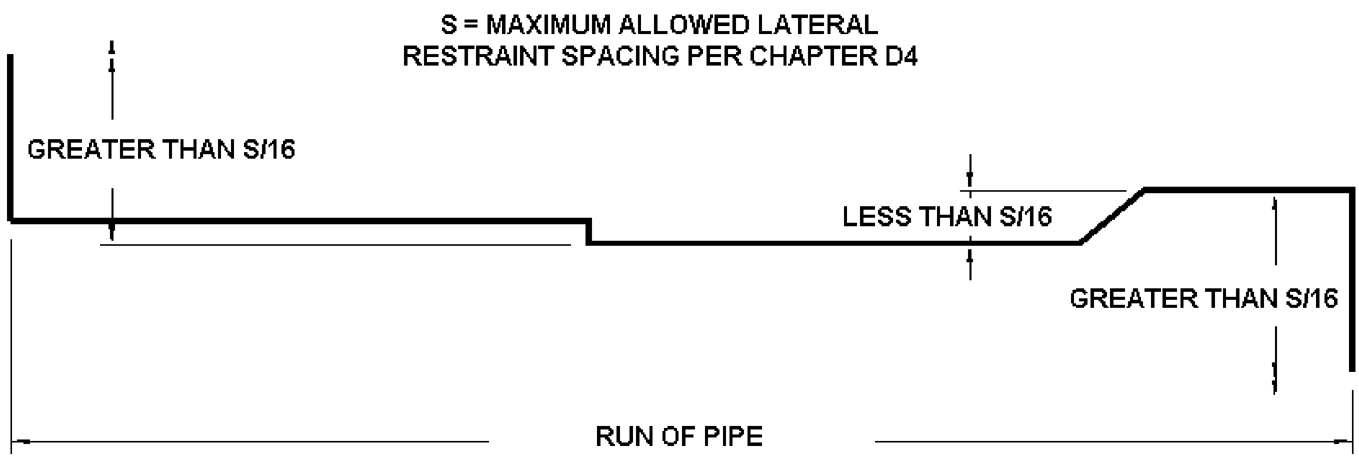
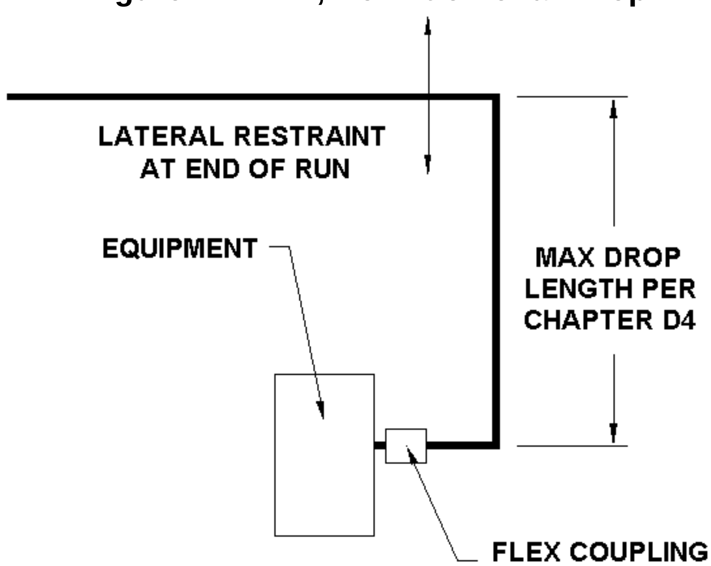
Figure D7.4.1-1; Definition of a "Run" of Pipe



Short Run A run as defined above where the total length is less than S/2 and where it is connected on both ends to other runs or short runs.

Drop A length of pipe that normally extends down from an overhead run of pipe and connects to a piece of equipment, usually through some type of flex connector. The drop can also extend horizontally. In order to qualify as a drop, the length of this pipe must be less than S/2. If over S/2, the length of pipe would be classified as a run.

Figure D7.4.1-2; Definition of a "Drop"



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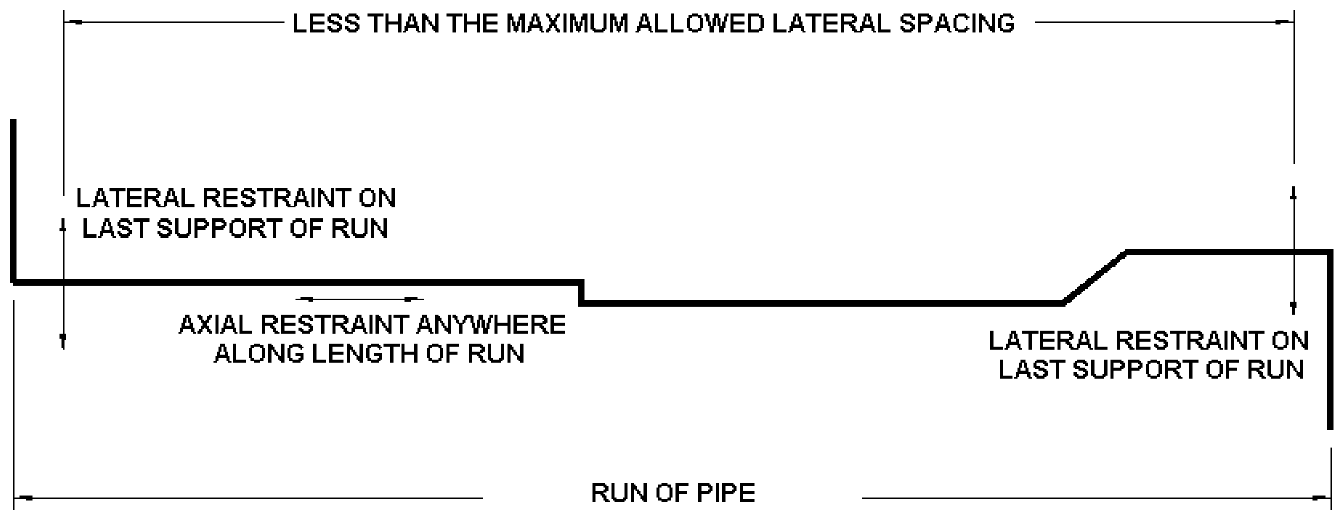
D7.4.1-2; Restraint Requirements

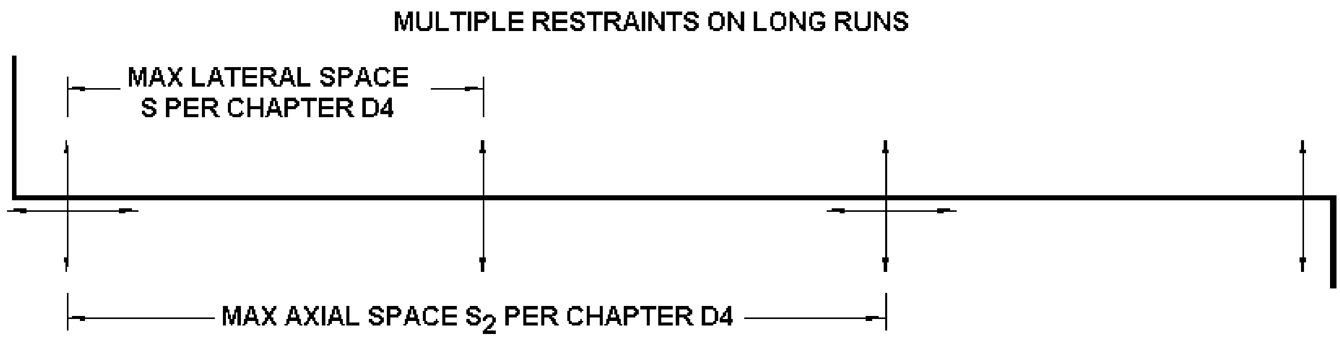
1) Full runs (Greater in length than S/2) must be restrained in both the axial and lateral direction. If the run is not a short run or a drop, it must, as a minimum, be laterally restrained at the last support location on each end.

Figure D7.4.1-2; Basic Restraint Requirements for a Typical "Run" of Pipe



2) If a run is longer than "S", intermediate restraints are required to limit the spacing to that permitted by the building code (see table in Chapter D4).

Figure D7.4.1-3; Basic Restraint Requirements for a Long "Run" of Pipe



3) Axial restraints attached to the run of piping along its length must be connected using a pipe clamp (as previously defined).

4) Short runs or drops need only have one lateral and one axial restraint.

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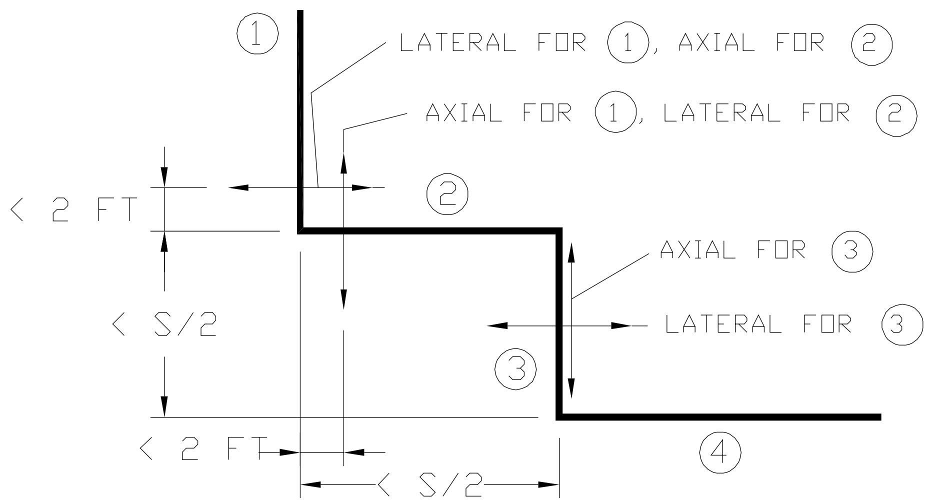
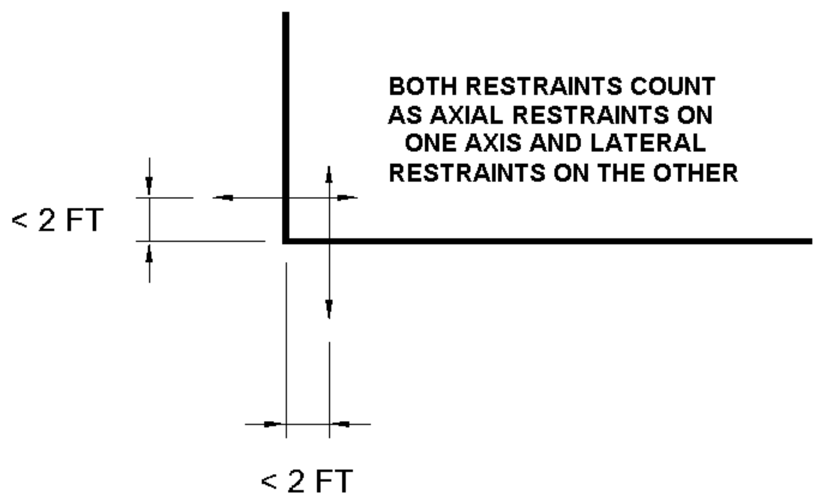
Figure D7.4.1-4; Basic Restraint Requirements for Multiple Short "Runs" of Pipe



5) If a lateral restraint is located within 2 feet of a corner (based on a measurement to the pipe centerline), it can be used as an axial restraint on the intersecting run.

Figure D7.4.1-5; "Double Duty" for Corner Restraints



6) Larger pipes cannot be restrained with restraints located on smaller branch lines.

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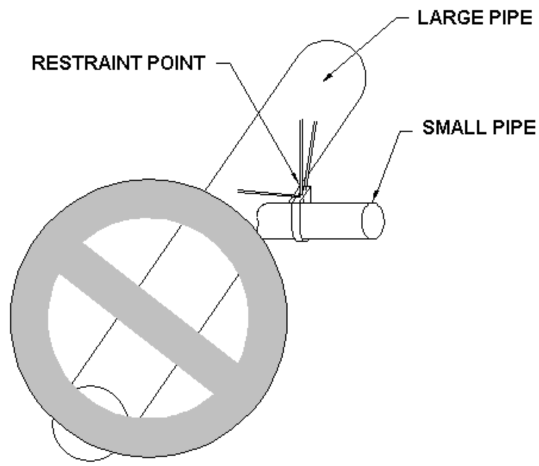
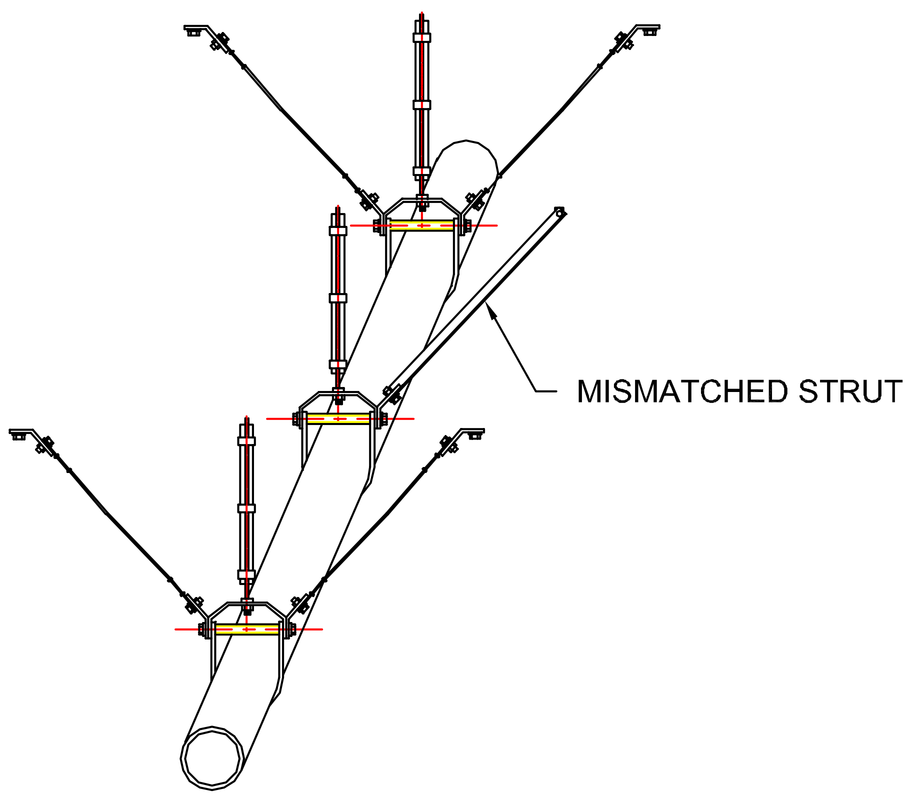
Figure D7.4.1-6; Do not Restrain Larger Pipes with Restraints on Smaller Ones



7) Within a run, the type of restraint used must be consistent. For example, mixing a strut with cable restraints is not permitted.

Figure D7.4.1-7; Mismatched Struts and Cable Restraints



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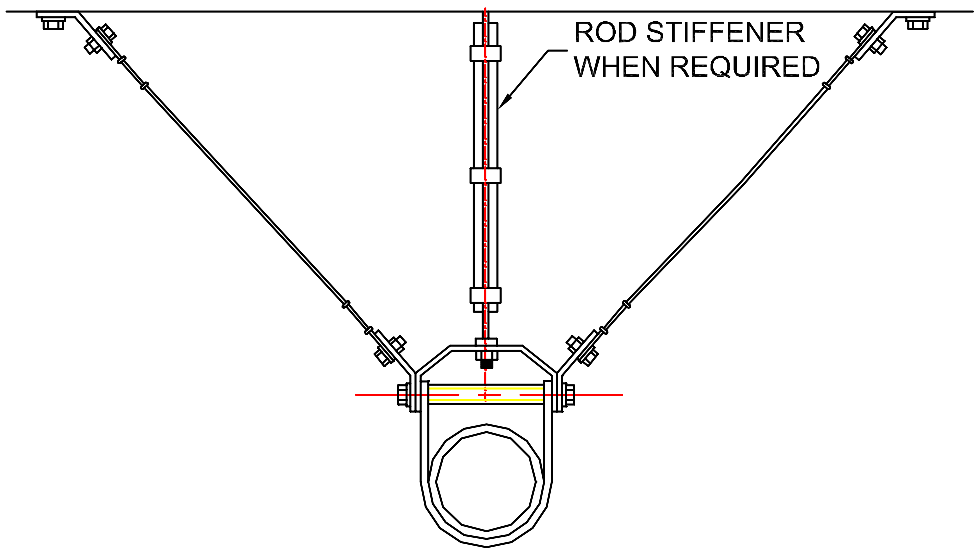
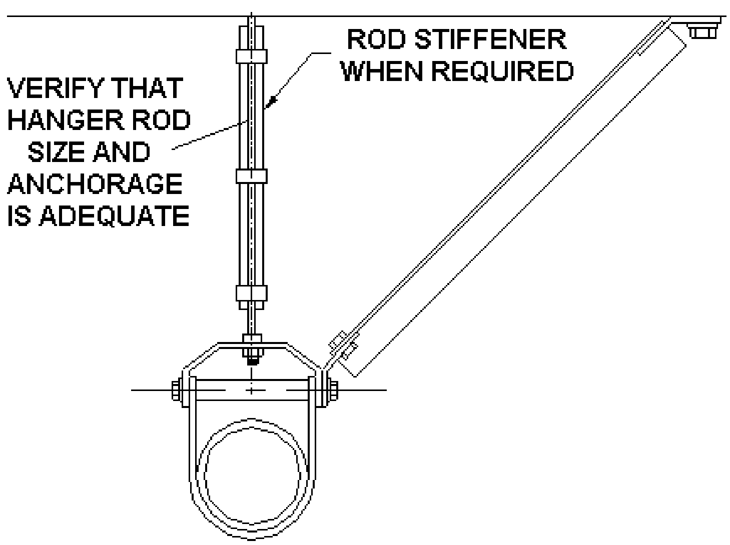
8) With longer hanger rods, rod stiffeners are likely to be required. Refer to the appropriate Document in Chapter D4 to determine: (1) if needed, (2) what size stiffener material is appropriate, and (3) how frequently it needs to be clamped to the hanger rod.

Figure D7.4.1-8; Rod Stiffener



9) In addition to possibly requiring rod stiffeners, when struts are used to restrain piping, the size of the hanger rod and its anchorage also become critical. Again refer to the appropriate Document in Chapter D4 to determine the minimum allowable size for the hanger rod and anchor.

Figure D7.4.1-9; Hanger Rod Sizing (For Strut Applications)



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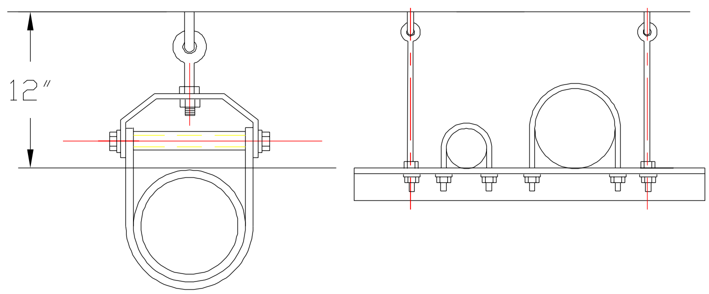
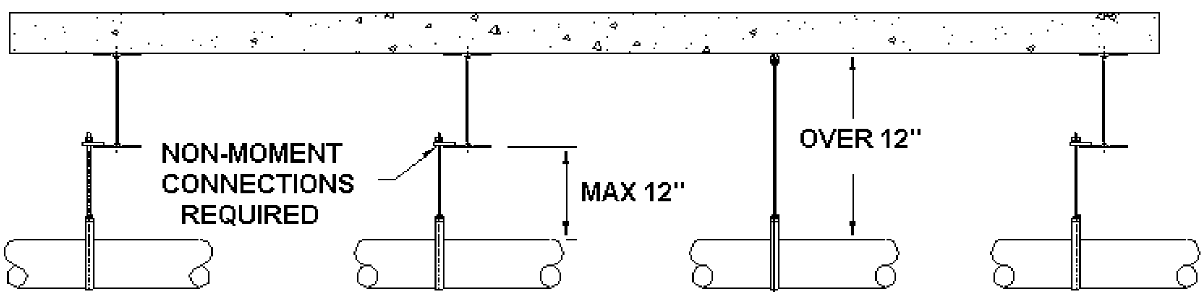
10) In some cases, it may be possible to locate the piping system close enough to the support structure (12”) to eliminate the need for restraint. (Refer to the building code review chapter (D2) to determine if this exemption is applicable.) If it is applicable, the 12” dimension is measured as shown below. (Note also the required non-moment generating connection at the top of the hanger rod.)

Figure D7.4.1-10; 12” Hanger Rod Exemption



11) When using the above rule it is critical that all support locations in a run conform. If even one location exceeds 12”, the run cannot be exempted from restraint.

Figure D7.4.1-11; Run Fails the Consistency Requirement for 12” Exemption



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CEILING-SUPPORTED PIPE RESTRAINT ARRANGEMENTS

Although the basic principle of diagonal bracing is almost always used to design restraint systems, the actual arrangement of these systems can vary significantly. Despite what looks like substantially different designs, the design forces in the members remain the same, and the same rules apply when sizing components. Illustrated here are many different restraint arrangements, all of which can be used in conjunction with the design "rules" provided in this manual.

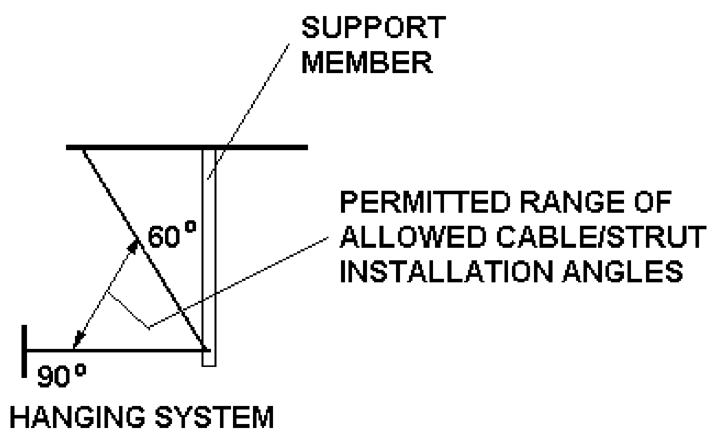
Details of the end connections and anchorage hardware are shown in subsequent sections of the manual. It is assumed in this manual that the restraint component is attached to a structural element capable of resisting the design seismic load.

Due to variations in the installation conditions such as structural clearance, locations of structural attachment points and interference with other pieces of equipment or systems, there will likely be significant benefits to using varying arrangements in different locations on the same job.

The only significant caution here is that it is not permissible to mix struts and cables on the same run.

This manual addresses diagonal bracing slopes of between horizontal and 60 degrees from the horizontal. Angles in excess of 60 degrees to the horizontal are not permitted.

Figure D7.4.2-1; Permissible Restraint Angles



When installing restraints, Transverse restraints should be installed perpendicular (±10 degrees) to the pipe from above. Longitudinal restraints should be in line with the pipe, (±10 degrees) again as viewed from above. All restraint cables should be aligned with each other. See the sketch below.

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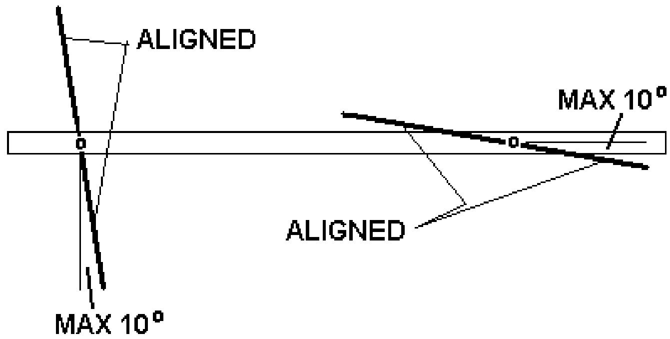
Figure D7.4.2-2; Restraint Alignment



Transverse Restraint **Longitudinal Restraint**

In general, when restraining piping the component actually being restrained is the support device for the pipe. This may be a pipe clevis, a heavy-duty pipe clamp, or a trapeze bar. Because the goal is to restrain the actual pipe, it is necessary that the restrained element be connected to the pipe in such a way as to transfer the appropriate forces between the two. For example, if an axial restraint is installed on a trapeze bar which in turn supports a pipe that is carried by a roller, it is obvious that the Longitudinal forces generated by the pipe cannot be restrained by the connection to the trapeze bar, and some other arrangement is needed.

When firmly connecting restraints to piping there are a few general rules that should be followed:
1)A basic pipe clevis is not capable of restraining a pipe in the axial direction.
2)If the pipe is wrapped with insulation and an axial restraint is needed, a riser clamp should be tightly clamped to the pipe prior to wrapping it with insulation and the restraint device should penetrate the insulation material.
3)If the pipe is wrapped with insulation and Transverse restraint is needed, a hardened insulation material should be fitted at the restraint location.
4)Piping which expands and contracts significantly should include expansion joints or loops between each axial restraint component.
5)Trapeze-mounted piping should be tightly clamped to the trapeze bar.

In addition, when sizing restraint components for multiple pipes, the total weight of all of the restrained piping must be considered.

Hanging Systems Restrained with Cables

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Hanging systems may include supports for single pipes or multiple pipes. Single pipes can be supported using clevis hangers but multiple pipes are normally supported on trapeze bars.

Transverse Restraint Examples

For a cable-restrained pipe supported by a hanger clevis, there are two common options for non-isolated installations and two similar options for isolated installations. These options are shown below. Note that the isolator is mounted with minimal clearance to the structure and that a travel limiting washer is fitted to the hanger rod just below the isolator in the isolated arrangements. While commonly used, the option of attaching restrains to the hanger rod introduces additional stressed into the hanger rod because of the Force acting at the center of the pipe will rock the clevis back and forth on the hanger rod itself. While this is typically not a problem for smaller piping or for piping installed in areas where the seismic accelerations are low in magnitude, it is not the preferred arrangement when working with large piping or areas of the world where seismic forces are significant. In these cases the option of attaching the restraints directly to the cable clevis is preferred. Not shown below is a third option whereby a separate heavy duty riser clamp is fitted to the pipe adjacent to a clevis hanger and it is used as the attachment point for the restraint cable.

Figure D7.4.2-3; Transverse Cable Restraints clamped to Hanger Rod and attached to Clevis Tie Bolt (Non-isolated)

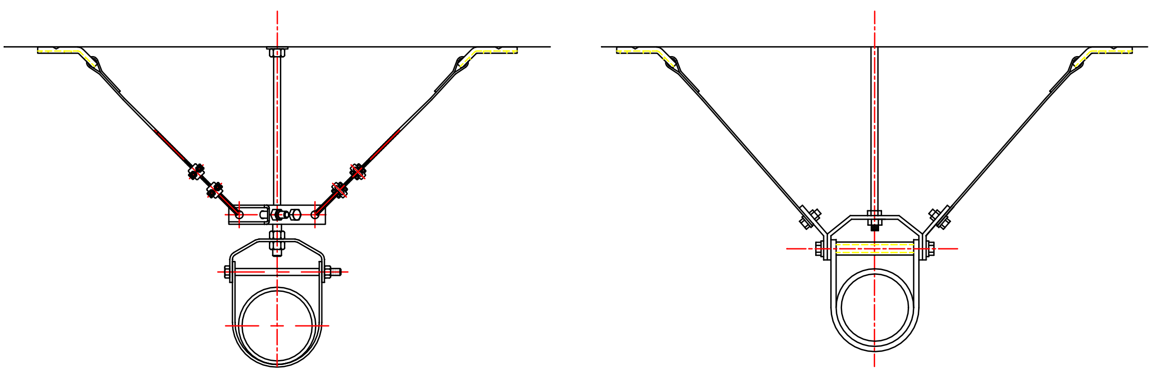

Figure D7.4.2-4; Transverse Cable Restraints clamped to Hanger Rod and attached to Clevis Tie Bolt (Isolated)

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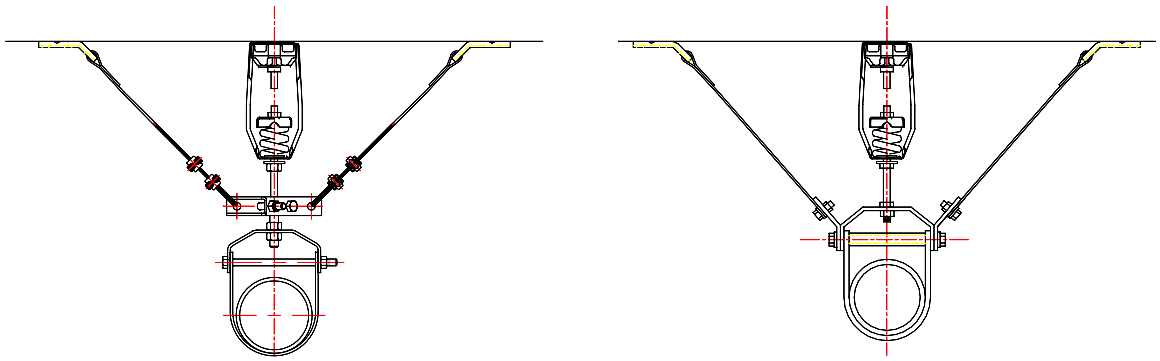
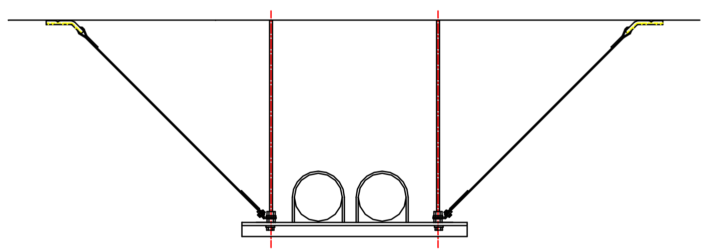


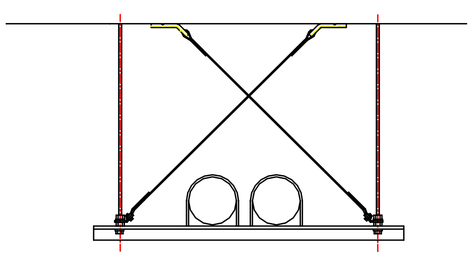
When working with trapezed piping, there are many options that exist for the arrangement of transverse restraints. Shown below are three options each for both non-isolated and isolated cable-restrained systems.

Figure D7.4.2-5; Transverse Cable Restraints Mounted to a Trapeze (Non-isolated)

TRAPEZE _/ (TOP)



TRAPEZE X (TOP)



TRAPEZE \/ (TOP)

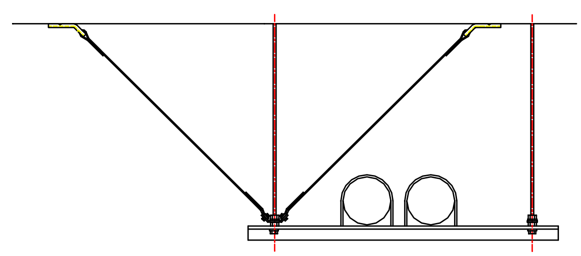


Figure D7.4.2-6; Transverse Cable Restraints Mounted to a Trapeze (Isolated)

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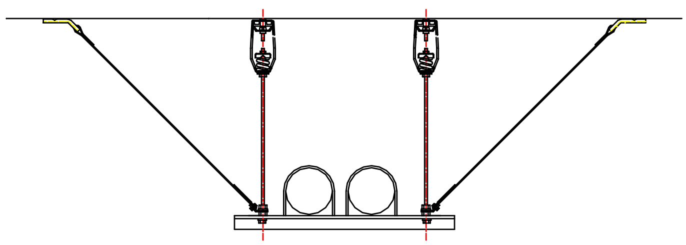
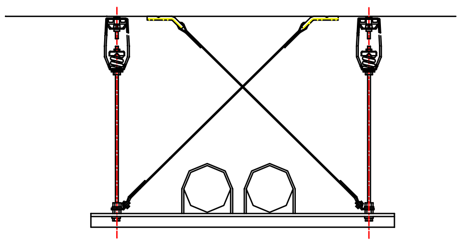
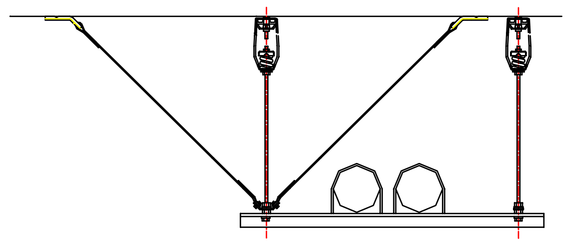
TRAPEZE _/ (TOP)



TRAPEZE X (TOP)



TRAPEZE \/ (TOP)



Longitudinal Restraint Examples

Longitudinal restraints cannot be connected to a standard pipe clevis. This is because the only longitudinal resistance present between the clevis and the piping is the friction that results from the weight of the pipe and this is simply not enough to transfer the forces in the pipe to the restraint. When longitudinally restraining piping, a U-Bolt to a trapeze or riser clamp tightly attached to the pipe are the most common interfacing devices used. On occasion, weld-on tabs or connections to a flange are also possibilities in some cases. Details on these connections will be addressed in later sections.

If the details of the connection are ignored at this point, general longitudinal restraint arrangements recognized in this manual are illustrated below.

Note: Longitudinal restraints should be installed in such a manner that they act along the centerline of the pipe in the case of an individual pipe or on the center of mass of a trapeze bar if there are multiple pipes attached to that trapeze bar. This is because offsetting the restraint from the center of mass will generate additional bending forces in the restrained pipe which can add to complications and failures.

Figure D7.4.2-7; Longitudinal Cable Restraints (Non-isolated)

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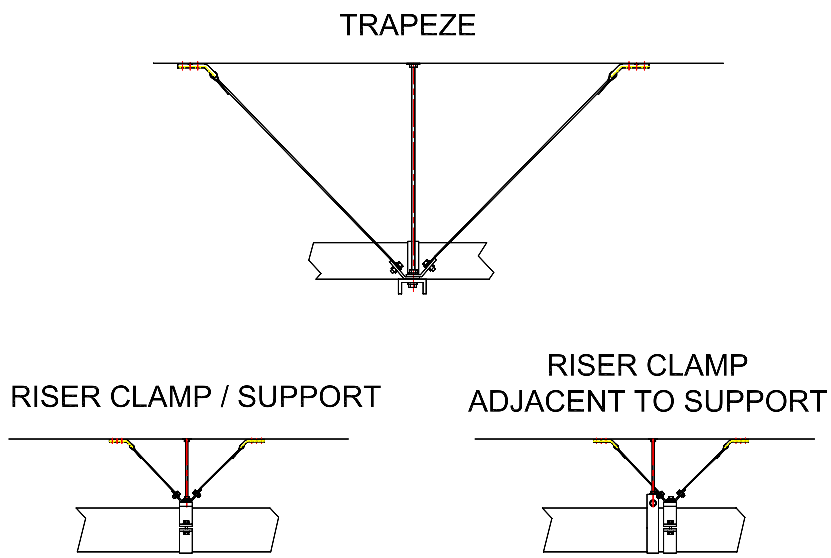
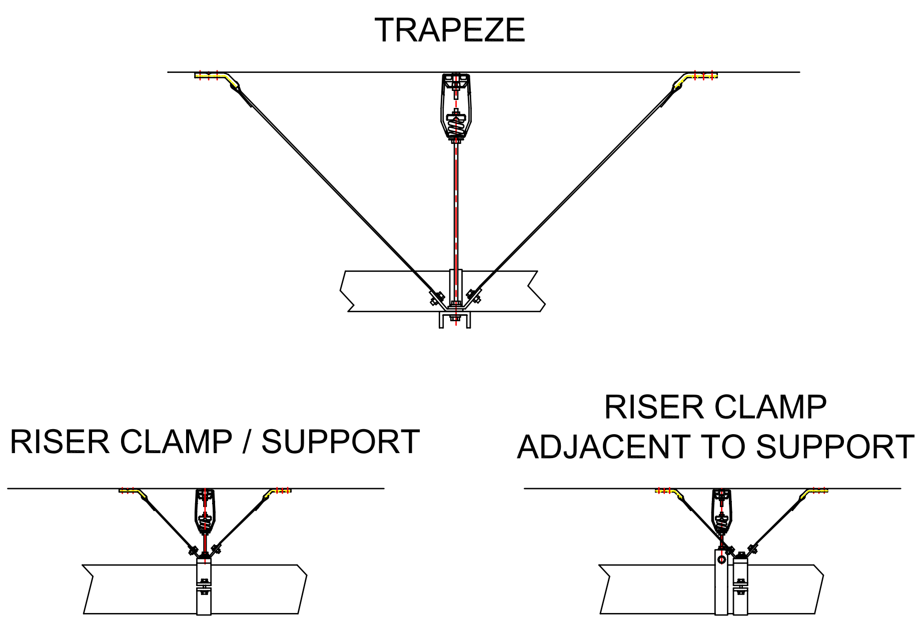


Figure D7.4.2-8; Longitudinal Cable Restraints (Isolated)



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Hanging Systems Restrained with Struts

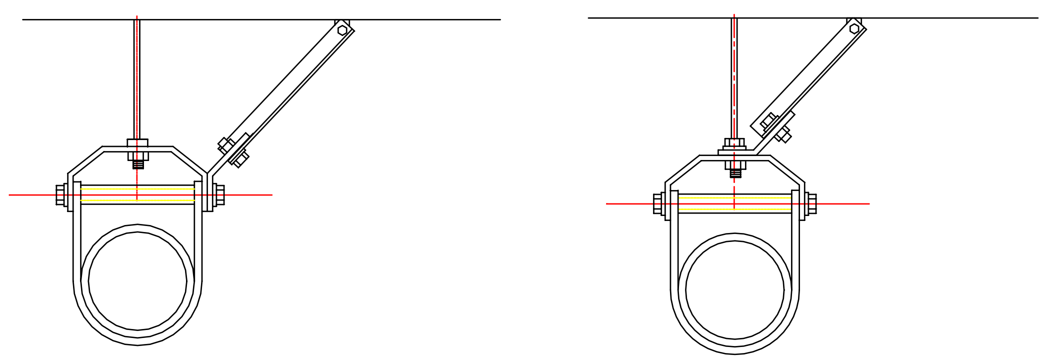
It is recommended that struts not be used to restrain isolated piping systems. Struts will generate hard connections between the piping and structure and will greatly reduce the efficiency of the isolation system. Having said that, in some special situations it may be possible to design restraint struts with integral isolation elements, but this is tedious and should be avoided unless drastic measures are required.

As with cable restraints, hanging systems may include supports for single pipes or multiple pipes. Single pipes can be supported using clevis hangers, but multiple pipes are normally supported on trapeze bars.

Transverse Restraint Examples

For a strut-restrained pipe supported by a hanger clevis there are two common options. One is to connect the restraint to the clevis bolt and the other is to connect the restraint to the hanger rod. These are shown below. A third option of fitting a heavy duty riser clamp adjacent to the clevis bracket and attaching the strut to it is viable as well.

Figure D7.4.2-9; Typical Transverse Restraint Strut Arrangements for Clevis-Supported Pipe



Shown below are 3 options for trapeze-supported piping. All are equivalent.

Figure D7.4.2-10; 3 Arrangements for Transversely Restrained Trapezes with Struts

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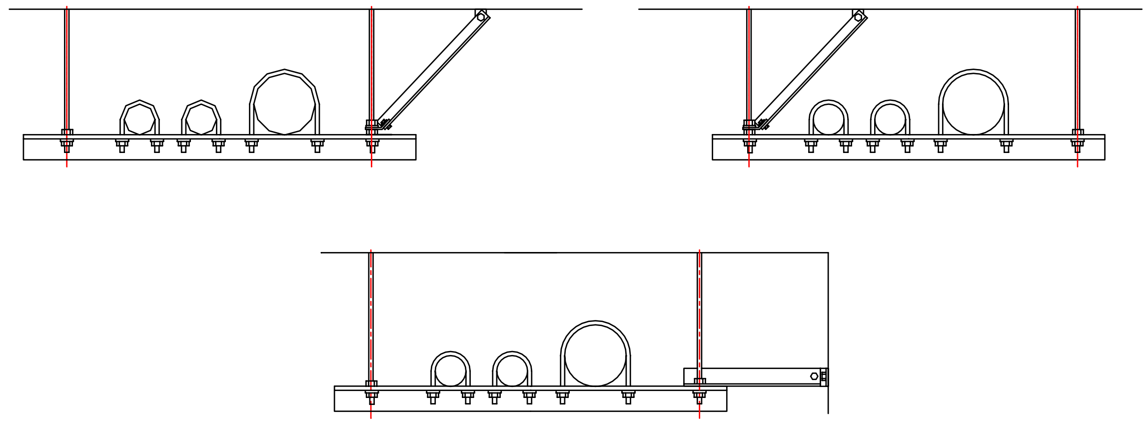


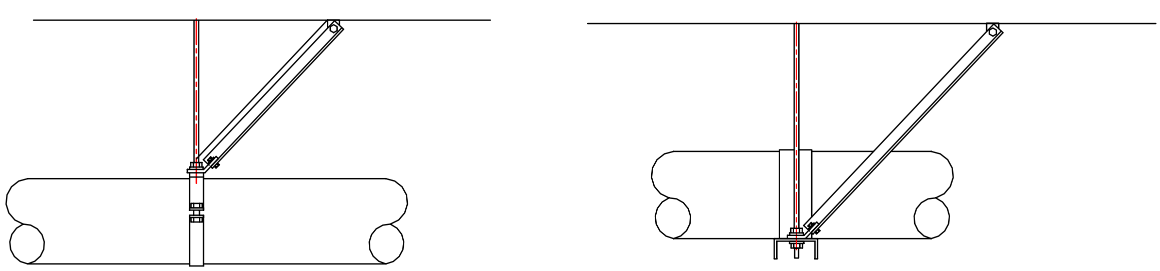
Longitudinal Restraint Examples

As with cables, longitudinal restraints using struts cannot be connected to a standard pipe clevis. When longitudinally restraining piping, a trapeze U-bolted or a riser clamp tightly attached to the pipe is the most common connecting device between the component actually restrained by the strut and the pipe itself. A weld-on tab or connection to a flange can also be used. Details on these connections will be addressed in later sections.

As with the cable section earlier, if we Ignore the details of the connection at this point, common longitudinal restraint arrangements recognized in this manual are illustrated below.

As with the cable restraints, Longitudinal restraints should be installed in such a manner that they act along the centerline of the pipe in the case of an individual pipe or on the center of mass of a trapeze bar if there are multiple pipes attached to that trapeze bar. This reduces the forces that generate bending in the restrained piping that result from an offset between the restraint and the center of mass. Depending on the situation, these forces can be large and can generate failures in the piping itself.

Figure D7.4.2-11; Piping Longitudinally Restrained with Struts



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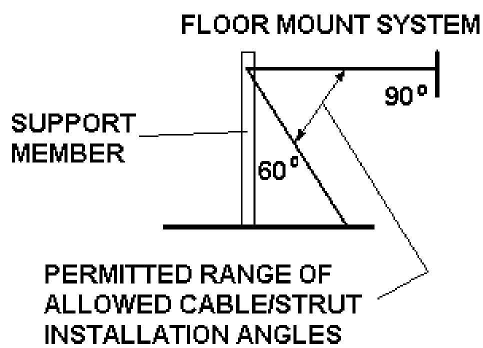
FLOOR OR ROOF SUPPORTED PIPE RESTRAINT ARRANGEMENTS

Although the basic principle of diagonal bracing is almost always used to design restraint systems, the actual arrangements of these systems can vary significantly. Despite what looks like substantially different designs, the design forces in the members remain the same, and the same rules apply when sizing components. Illustrated here are many different floor- and roof-mounted restraint arrangements, all of which can be used in conjunction with the design "rules" provided in this manual.

Details of the end connections and anchorage hardware are shown in subsequent sections of this manual. It is assumed in this manual that the restraint component is attached to a structural element capable of resisting the design seismic load.

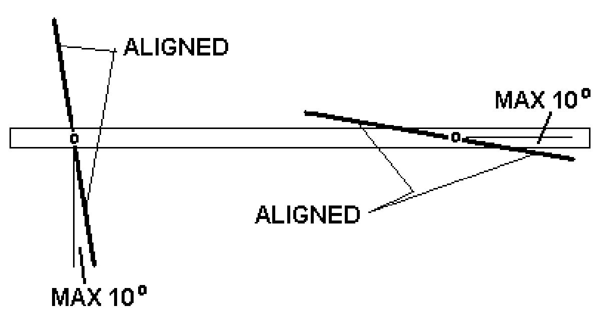
This manual addresses diagonal bracing oriented between horizontal and 60 degrees from the horizontal. Angles in excess of 60 degrees to the horizontal are not permitted.

Figure D7.4.3-1; Permissible Restraint Angles



When installing restraints, Transverse restraints should be installed perpendicular (±10 degrees) to the pipe from above. Longitudinal restraints should be in line with the pipe, (±10 degrees) again as viewed from above. All restraint cables should be aligned with each other. See the sketch below.

Figure D7.4.3-2; Restraint Alignment



Transverse Restraint **Longitudinal Restraint**

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In general, when restraining piping the component actually being restrained is the support device for the pipe. This may be a pipe clevis, a heavy-duty pipe clamp, or a trapeze bar. Because the goal is to restrain the actual pipe, it is necessary that the restrained element be connected to the pipe in such a way as to transfer the appropriate forces between the two. For example, if an axial restraint is installed on a trapeze bar which in turn supports a pipe that is carried by a roller, it is obvious that the Longitudinal forces generated by the pipe cannot be restrained by the connection to the trapeze bar, and some other arrangement is needed.

When firmly connecting restraints to piping there are a few general rules that should be followed:

1) A basic pipe clevis is not capable of restraining a pipe in the axial direction.
2) If the pipe is wrapped with insulation and an axial restraint is needed, a riser clamp should be tightly clamped to the pipe prior to wrapping it with insulation and the restraint device should penetrate the insulation material.
3) If the pipe is wrapped with insulation and Transverse restraint is needed, a hardened insulation material should be fitted at the restraint location.
4) Piping which expands and contracts significantly should include expansion joints or loops between each axial restraint component.
5) Trapeze-mounted piping should be tightly clamped to the trapeze bar.

In addition, when sizing restraint components for multiple pipes the total weight of all of the restrained piping must be considered.

D7.4.3.1 Floor or Roof mounted Systems Restrained with Cables

Floor- or roof-mounted systems may include supports for single pipes or multiple pipes. Typically, simple box frames are fabricated to support piping, whether it is a single pipe or multiple pipes.

Transverse Restraint Examples

For a cable-restrained pipe support bracket there are four options normally encountered for non-isolated systems and four similar arrangements for isolated systems. These options are shown below. The vertical legs of the support bracket must be sized to carry both the weight load of the supported pipes as well as the vertical component of the seismic forces. Refer to Chapter D4 for more detailed information as to how to size these members.

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Figure D7.4.3-3; Transverse Cable Restraints for Floor/Roof (Non-isolated)

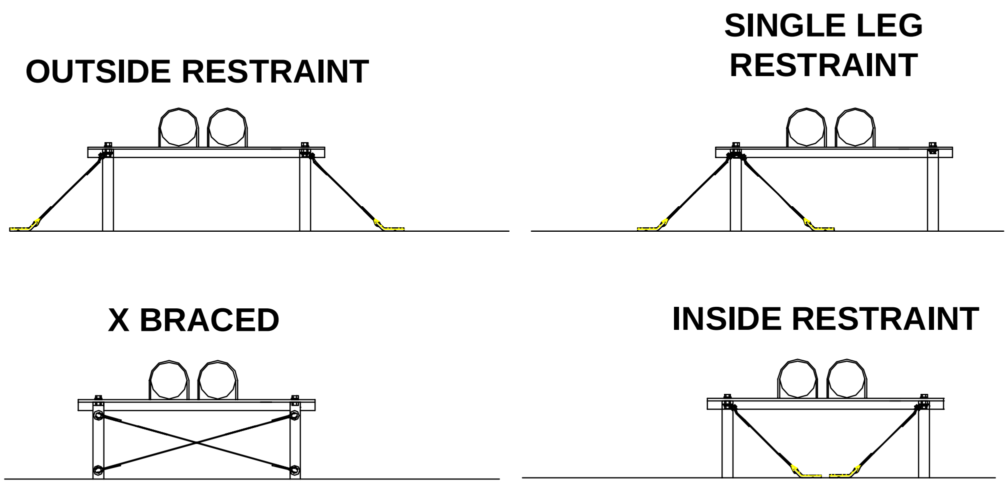
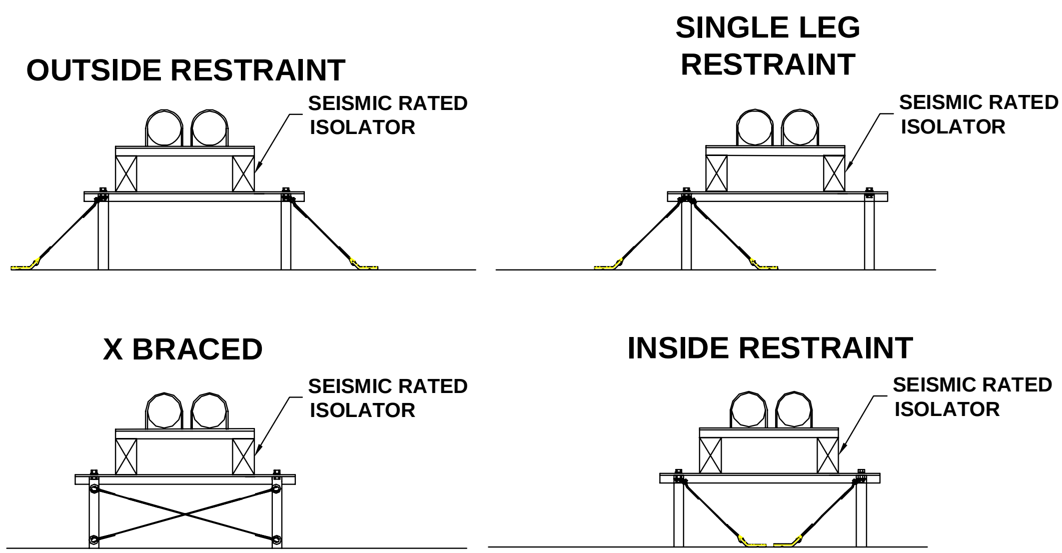


Figure D7.4.3-4; Transverse Cable Restraints for Floor/Roof (Isolated)



Longitudinal Restraint Examples

When longitudinally restraining piping, a U-Bolt to a trapeze or riser clamp tightly attached to the pipe are the most common interfacing devices used. On occasion, weld-on tabs or connections to a flange are also possibilities in some cases. Details on these connections will be addressed in later sections.

If the details of the connection are ignored at this point, general longitudinal restraint arrangements recognized in this manual are illustrated below.

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Note: Longitudinal restraints should be installed in such a manner that they act along the centerline of the pipe in the case of an individual pipe or on the center of mass of a trapeze bar if there are multiple pipes attached to that trapeze bar. This is because offsetting the restraint from the center of mass will generate additional bending forces in the restrained pipe which can add to complications and failures.

Figure D7.4.3-5; Longitudinal Cable Restraints (Non-isolated)

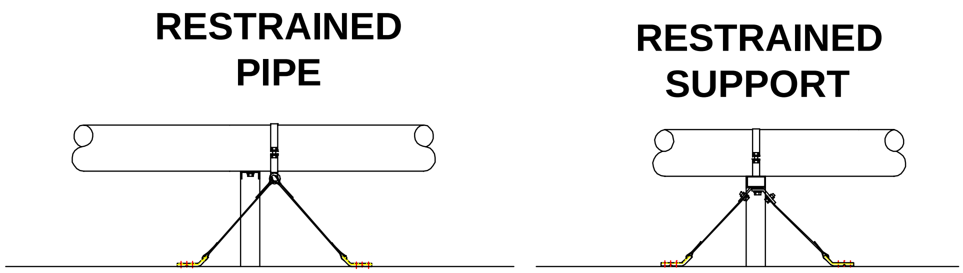
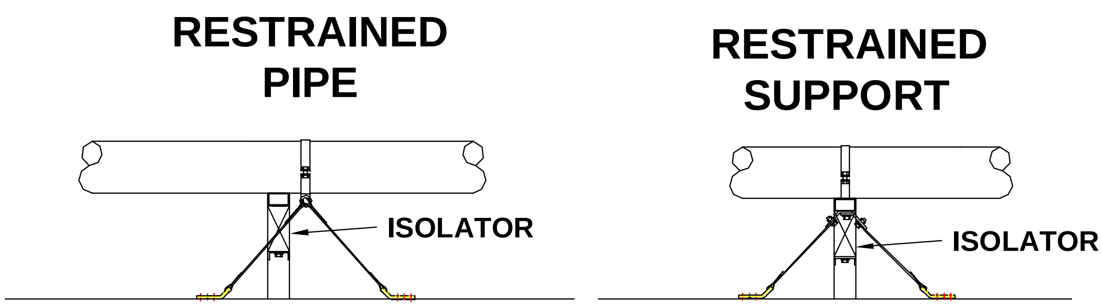


Figure D7.4.3-6; Longitudinal Cable Restraints (Isolated)



D7.4.3.2 Floor or Roof Mounted Systems Restrained with Struts

As with cable restraints, floor- or roof-mounted pipe support systems will normally involve a box frame that supports the piping (single or multiple) with some kind of a trapeze bar.

Transverse Restraint Examples

For a strut-restrained pipe supported by a box frame there are three common transverse restraint options. Two involve diagonal bracing to the deck and one is to connect the restraint to a vertical wall or structure. Examples are shown below.

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Figure D7.4.3-7; Typical Transverse Restraint Strut Arrangements for Pipe (Non isolated)

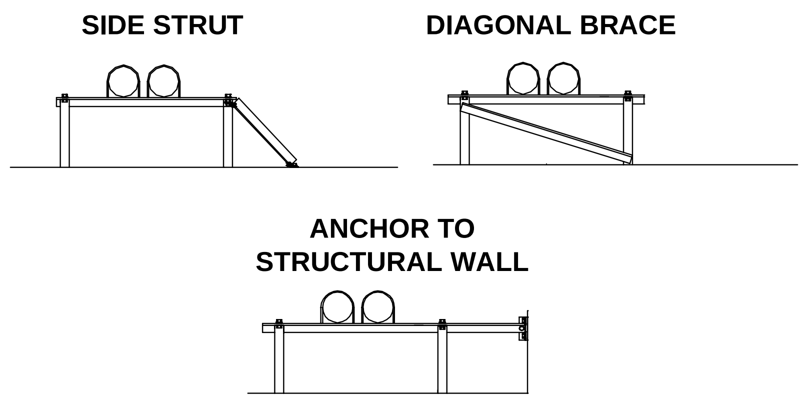
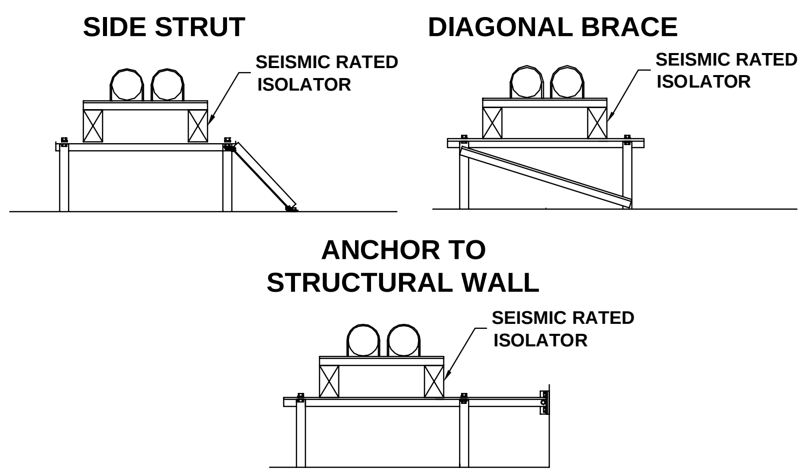


Figure D7.4.3-8; Typical Transverse Restraint Strut Arrangements for Pipe (Isolated)



Longitudinal Restraint Examples

When longitudinally restraining piping, a trapeze U-bolted or a riser clamp tightly attached to the pipe is the most common connecting device between the component actually restrained by the strut and the pipe itself. A weld-on tab or connection to a flange can also be used. Details on these connections will be addressed in later sections.

Ignoring the details of the connection at this point, common longitudinal restraint arrangements recognized in this manual are illustrated below.

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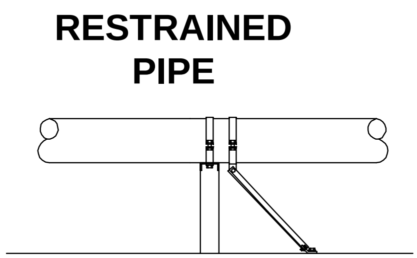
As with the cable restraints, longitudinal restraints should be installed in such a manner that they act along the centerline of the pipe in the case of an individual pipe or on the center of mass of a trapeze bar if there are multiple pipes attached to that trapeze bar. This reduces the forces that generate bending in the restrained piping that result from an offset between the restraint and the center of mass. Depending on the situation, these forces can be large and can generate failures in the piping itself.

Figure D7.4.3-9; Piping Longitudinally Restrained with Struts (Non-isolated)



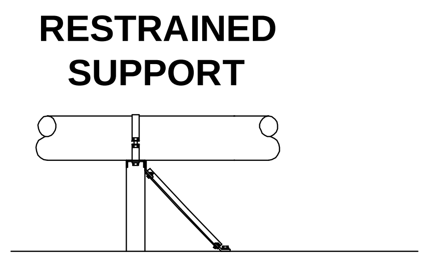
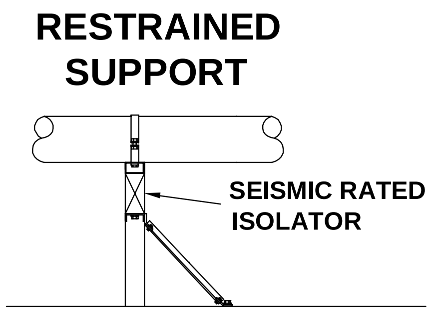


Figure D7.4.3-10; Piping Longitudinally Restrained with Struts (Isolated)



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VERTICAL PIPE RUN RESTRAINT ARRANGEMENTS

Vertical runs of piping need to be restrained in the same manner as horizontal runs. The anchorage provided for the riser system will normally, but not always, have enough capacity to resist the maximum longitudinal (vertical) seismic load. If anchors were selected based on simple deadweight loads and included little or no overload capacity, the possibility exists that they might have to be upsized to meet the seismic requirements. Because the seismic requirements would be low as compared to the support loads, upsizing the anchor by one step is normally more than adequate to meet these requirements. The required capacity of transverse (horizontal) restraints (guides) would, however, be closely linked to the seismic forces.

Cables or struts are not normally used restrain riser systems. Instead the risers resistance to seismic accelerations is controlled by special guide and anchor components. In non-seismic applications, these parts are put in place to limit the buckling factors that are generated in the piping by gravity factors. These are very similar to the forces generated in horizontally oriented piping by earthquakes.

Spacing for restraints on risers must meet the same maximum span condition that applies to horizontal runs, but in most instances the spacing used to place these items for resistance to typical buckling loads will meet this requirement.

Having indicated that the spacing will likely not be a concern based on conventional riser design practices the capacity of the guides can be impacted. These must be adequate to withstand the higher seismic forces. Applicable seismic forces for risers are the same as for horizontal runs and more detail on how to determine these can be found in chapter D4.

Typical Axial Restraint Arrangements

Below are illustrations for longitudinal (vertical only) pipe restraints. A simple riser clamp can often act as a Longitudinal restraint. It need not be attached to the structure to perform the axial restraint function as the vertical weight loads will always be larger than the seismically generated uplift loads. The same basic arrangement will work for either non-isolated or pad-isolated systems and for attachment to concrete or steel. It should be noted however that these components will not offer any transverse (horizontal) restraint.

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Figure D7.4.4-1; Concrete Supported Longitudinal Restraint for Vertical Pipe Run

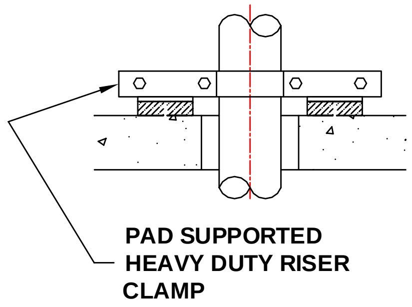
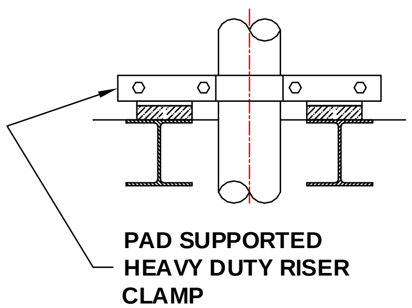


Figure D7.4.4-2; Steel Supported Longitudinal Restraint for Vertical Pipe Run

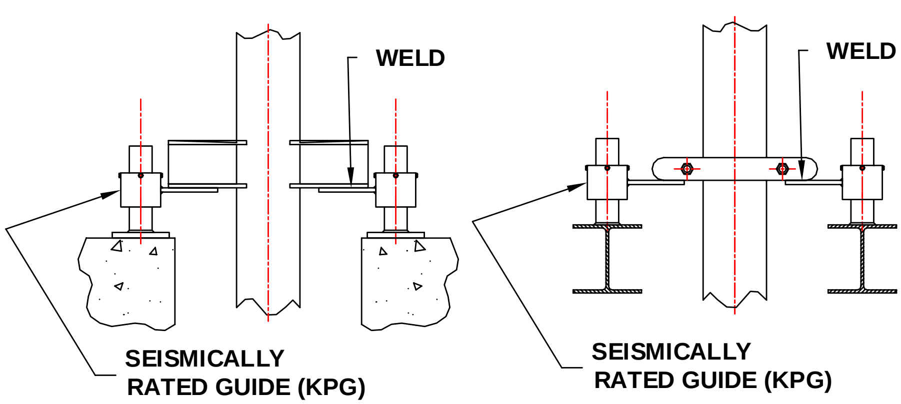


Typical Transverse Restraint Arrangements

Pipe guides act as Transverse restraints only and have a rated force capacity that is based on loads in the horizontal axis. These components do not offer any Longitudinal restraint capabilities.

There are two typical guide types. The first includes a component hard mounted to the structure, a mating portion hard mounted to the pipe, and a slip fit connection between the two. This is shown below.

Figure D7.4.4-3; Supported Transverse Restraint (Guide) for Vertical Pipe Run



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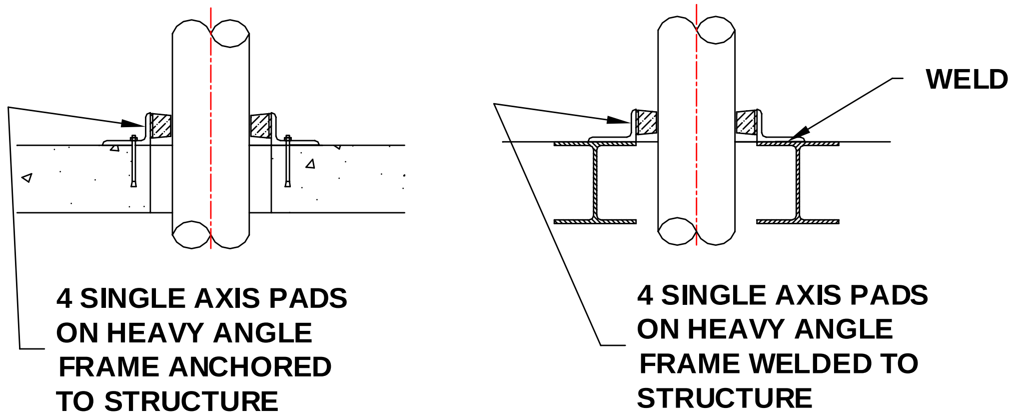
The second type is comprised of a frame with cushioned pads located on the perimeter that bear directly against the pipe itself. This eliminates the need for a direct connection to the pipe. However, if the pipe is insulated, it does require that the insulation be adequately hardened or that a hard shield be provided to prevent damage to the insulation under seismic loads. Typical concrete slab and steel structural examples are shown below.

Figure D7.4.4-4; Perimeter Type Transverse Restraint (Guide) for Vertical Pipe Run



Combined Lateral and Axial Restraints

In addition to the above details showing independent axial and lateral restraint devices, there are several devices used in vertical runs of pipe that offer both of these together. Anchors for riser systems are the first of these and several types are illustrated below:

Figure D7.4.4-5; Simple Hard-mounted Riser Clamp

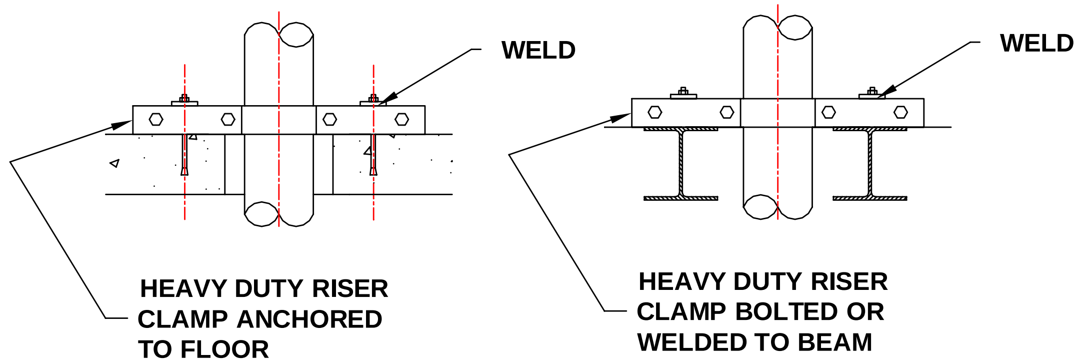


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Figure D7.4.4-6; Simple Hard-mounted Riser Clamp

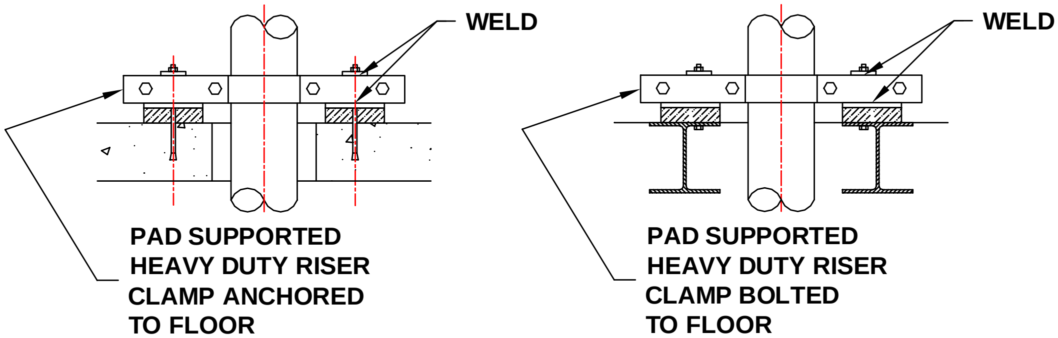
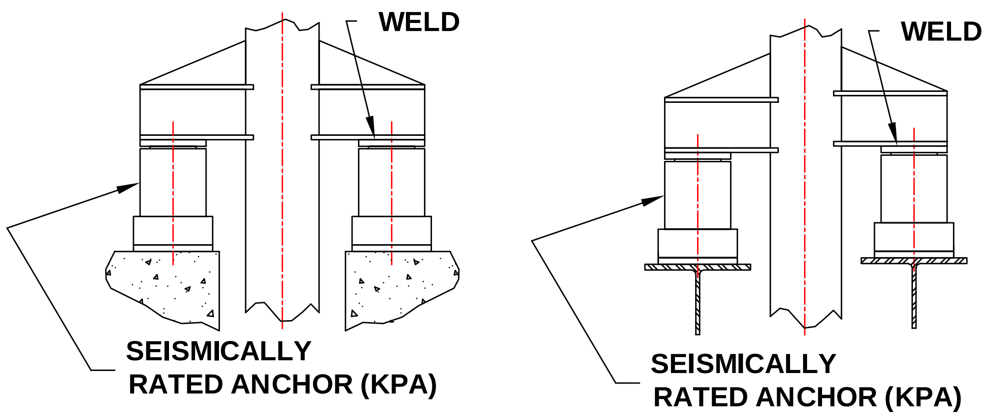
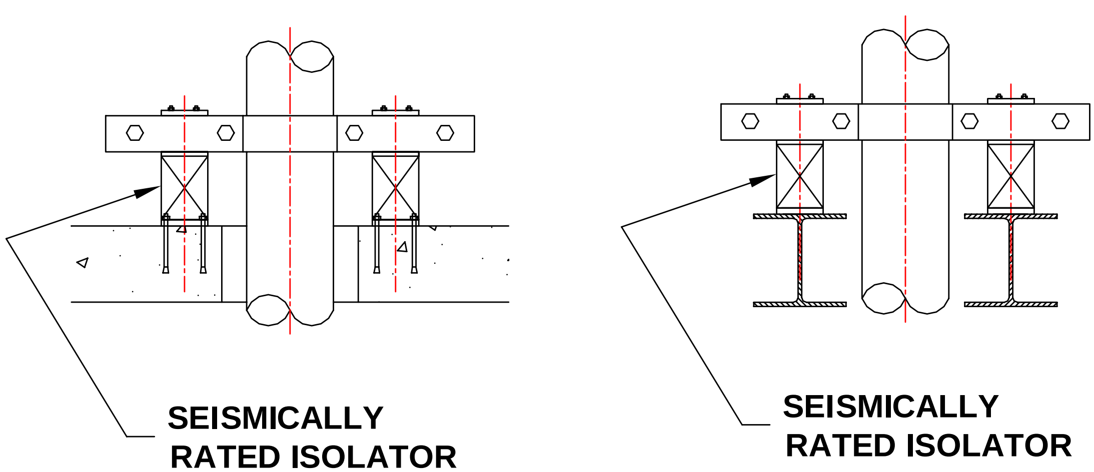


Figure D7.4.4-7; Riser Mounted on Cushioned Rated Anchor



The final combination axial and lateral restraint is a seismically rated, floor-supported isolator.

Figure D7.4.4-8; Riser Piping Mounted on Floor-Mounted Seismically-Rated Isolator



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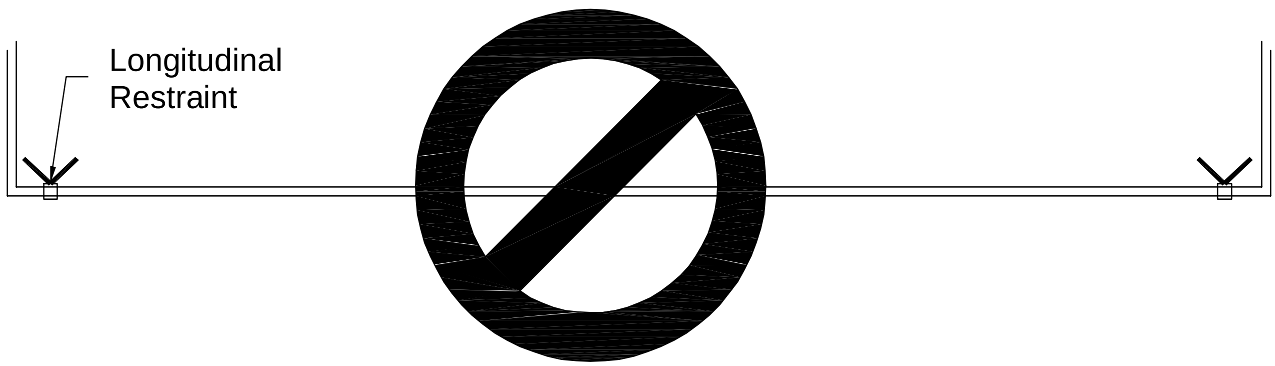
LONGITUDINAL RESTRAINT OF STEAM OR HOT WATER PIPING

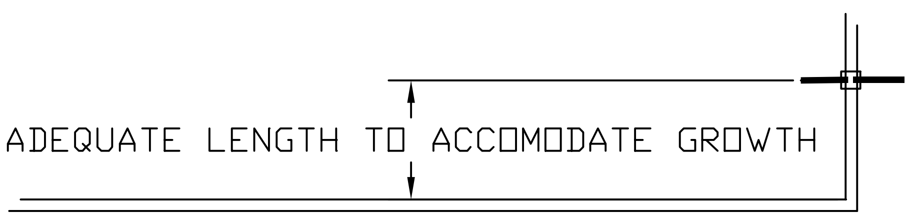
The Axial Restraint of Steam Piping raises important design configuration issues. As the pipe length grows with the temperature, the use of more than one restraint on any individual run will resist this growth and will either cause the pipe to buckle or will result in the failure of the restraint. This is unacceptable.

Figure D7.4.5-1; Limit Longitudinal Restraints to 1 per Run



For short runs, a single Longitudinal restraint should be used and caution should be exercised to ensure that if restraints are fitted at the junction points of different runs, they do not fall at both ends of the same run. Caution should also be exercised to be sure that there is adequate length between corners and the first Transverse restraint on a run to allow for the growth that can occur on the adjacent run.

Figure D7.4.5-2; Ensure Adequate Corner Spacing when Fitting Transverse restraints to Allow Growth in Adjacent Run



For long runs that require more than 1 Longitudinal Restraint, a device must be fitted into the run to absorb expansions and contractions between the restraint locations. This can take the form of an expansion loop or an expansion compensator as illustrated below.

If an expansion loop is fitted, the middle leg of the loop requires Longitudinal restraint as well. Because this restricts its movement, some caution must be used to ensure that the legs on each side of the loop are adequate to absorb the expansion for their respective runs. If the

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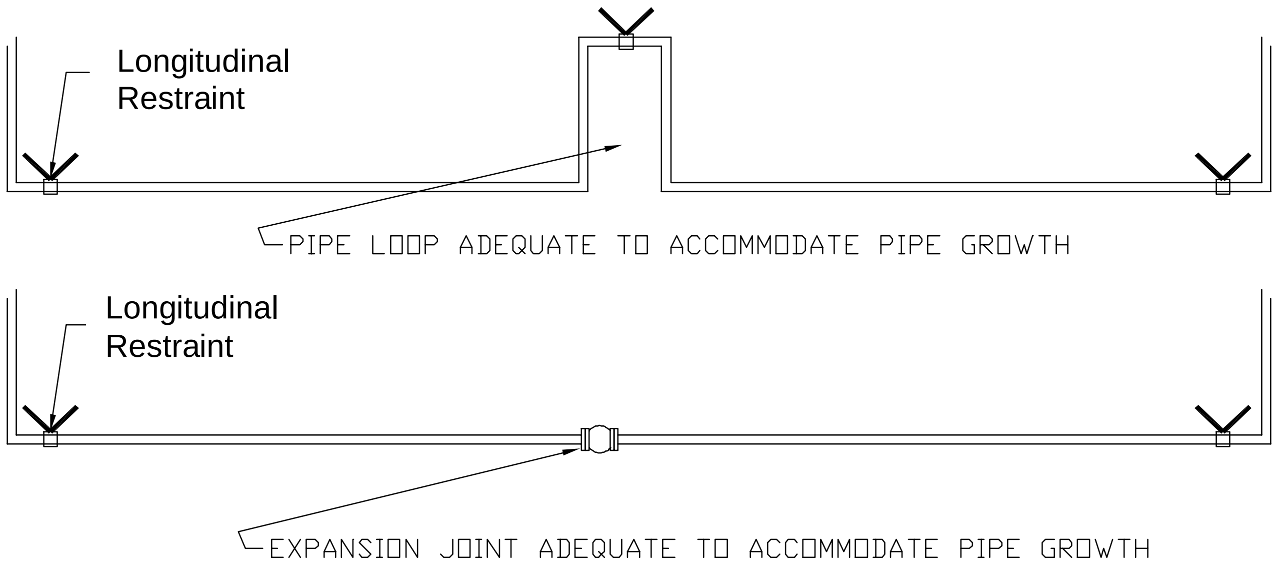
distance between the loop and the restraints on adjacent runs is approximately the same the system will be balanced and both legs will bend about the same. If the dimensions to the axial restraints vary significantly, the distortion of the two different legs will vary from one another in direct proportion and this should be addressed in design. Kinetics is not responsible for the design of these loops.

Figure D7.4.5-2; Longitudinal Restraints on Expansion Loops



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TRANSFERRING FORCES (PIPING RESTRAINTS)

In order for a restraint system to do its job, all elements of the connections need to be sized and installed properly. Because of the large variety and quantity of interfacing conditions in any given installation, piping, duct, and electrical distribution systems are particularly prone to problems in this area.

The next several sections of this manual will deal with specific components used to clamp cable ends together, or anchor cables or struts to steel members, wood members, and concrete or masonry. There are several types of connections used for each of these conditions, and each type of connection requires some degree of care and understanding to achieve full capacity.

There are a few general rules that apply when adding restraints to systems. These are listed below along with a few comments meant to provide a basic understanding or rationale.

1) Friction generally cannot be counted on when dealing with dynamic, seismic load conditions. Connections, with the following exceptions, should be positive in nature and not require friction to ensure their continued long-term operation.

Exceptions:

A) Cable end connections (swaged ends, U-bolts, QuakeLocs can be used with appropriate installation procedures).

B) Toothed strut nuts used in conjunction with a purpose-designed strut material (Unistrut, for example). *(Rationale: Permitted friction connections have been well researched and deal with a narrow range of applications. In addition, once properly tightened, the components are such that the likelihood of their coming loose as a result of seismic load conditions is very low.)*

2) Anchors used for the support of overhead equipment cannot also be used for the anchorage of seismic restraints. *(Rationale: The loads used to size hanger rods and anchors are based on the weight loads generated by the piping system. Seismic forces can increase the tensile loads significantly, and the combination of loads can cause the anchorage to fail.)*

3) Anchors to concrete must comply with minimum edge distance, spacing and slab thickness requirements. To achieve full capacity ratings they must further not be installed into a surface containing significant tensile forces. *(Rationale: All anchorage must be in compliance with ICC allowables for seismic applications. Unless otherwise noted, it is assumed that connections are not made to the underside of structural concrete beams.)*

4) Screws attached to wood must comply with minimum edge distance, spacing and embedment requirements, and must further <u>not</u> be embedded into the end grain of the

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wooden member. *(Rationale: All wood anchorage must be in compliance with NDS allowables for seismic applications. Full capacity can only be achieved with adequate embedment, end, and edge distances into the side grain of structural wood members.)*

5) Connections that have the potential to expose open bar joist chords to significant lateral loads perpendicular to their primary axis are not permitted. *(Rationale: Open joists are notoriously weak at 90 degrees to their long axis. They are not designed to take loads in this direction, particularly on the lower cord. Even light lateral loads can generate buckling and quickly cause catastrophic failure.)*

6) Connections that have the potential to generate significant lateral loads on the weak axis of I-beams or channels used as joists or columns are not permitted unless approved by the structural engineer of record. *(Rationale: Floor or roof support beams are significantly weaker in their minor axis than in their major axis. While they can, under some conditions, withstand some lateral loads, the engineer of record should be consulted to ensure that capacity exists on particular members to withstand the anticipated loads. If these loads are exceeded, catastrophic failures can quickly result.)*

7) Holes should not be added to key structural members without prior authorization from the engineer of record. *(Rationale: The addition of holes, particularly in flanges, can greatly reduce the structural capacity.*

8) The pipe-to-pipe connection can become a critical factor in evaluating the performance of the system. Unless otherwise informed, Kinetics Noise Control assumes connections to be of "medium" deformability as defined by the design code. This is generally appropriate for steel or welded fittings, brazed connections. The use of groove-type coupling, cast iron couplings, glass lined pipe, Plastic or other non-standard materials will impact this and must be addressed during the design stage. *(Rationale: While generic data is available for some of these materials, it is not for groove-type or other specialty couplings and the specifying agency, prior selecting this type of hardware, must obtain the approval of the coupling manufacturer for its use in a seismic application.)*

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NON-MOMENT GENERATING CONNECTIONS

The IBC codes allow the omission of seismic restraints for piping, conduit and ductwork runs under many conditions without regard to size but that are located within 12” of the structure. Refer also to section D2 of this manual for specific exemptions by code version. This figure is 6” for fire sprinkler piping. In order to qualify for this, the following parameters must be met:

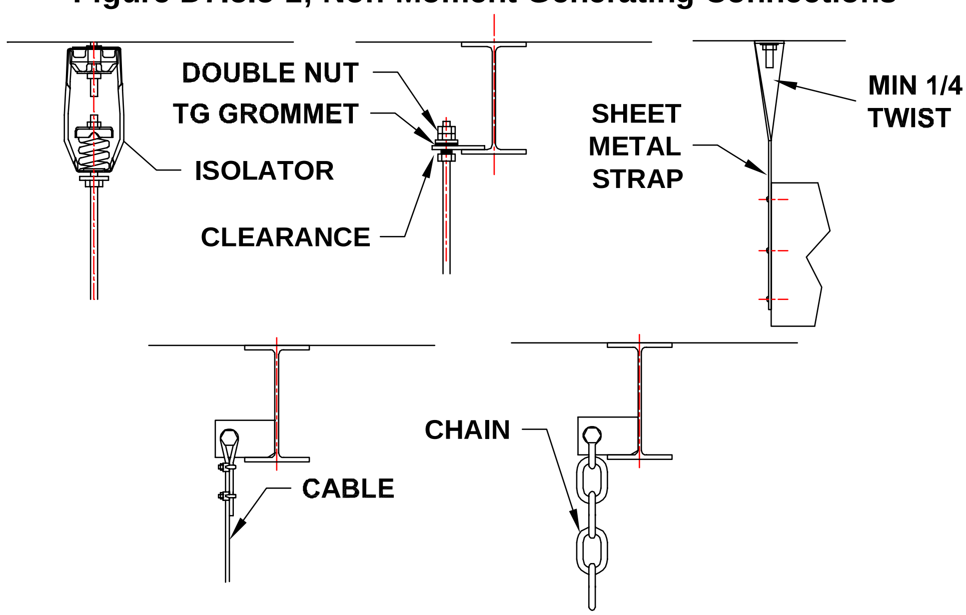
1)The length of **all** supports on the run measuring from the top anchorage point to the connection point to the trapeze bar or the top of a singly supported pipe or conduit run must not exceed 12” (6” for fire piping).
2)Unrestrained free travel of the supported system must be such that over the course of its movement, contact is not made with any other system, component or structural element that can result in damage to either the supported system or the object it hit.
3)The top connection to the structure must include a Non-Moment generating connection to prevent damage to the hanger rod or support strap.

A Non-Moment generating connection is any device that would allow a free flexing action of the hanger rod or support strap for an unlimited number of cycles without its being weakened. This motion must be permitted in any direction.

Shown below are typical examples of acceptable Non-Moment generating connections. Any other device that allows the same freedom of motion is equally acceptable.

A hanger rod rigidly embedded into the underside of a concrete structural slab is not.

Figure D7.5.5-1; Non-Moment Generating Connections



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CONNECTION OPTIONS FOR AWKWARD SITUATIONS

Almost every project will include some areas where installing restraints in a conventional fashion will be difficult. This segment of the manual offers options to consider when confronted with various situations.

D7.6.1 Long, Narrow Hallways

Probably the most common issue in the field is how to deal with transverse restraints in long, narrow hallways. Normally there is considerable congestion in these areas and not enough room to angle restraints up to the ceiling structure. Often the walls are not structural and do not offer a surface to which to anchor.

When evaluating halls, the first issue is to determine if either of the walls of the hall is structural. If either wall is structural, it offers a surface to which the restraints can often be attached. For structural walls, any relative displacement issues between the wall and the structure supporting the pipe must be identified. The maximum permitted relative displacement is ¼ inch, which for most structures correspond to a difference in elevation of approximately 2 feet (see also the Structural Attachment Section of this chapter).

Assuming the wall meets both of the above requirements, a transverse restraint can be run either directly over to the wall or up at a slight angle to the wall. Normally this would be done with a strut as shown below.

Figure D7.6-1; Trapeze-Mounted Piping Restrained to Structural Wall or Column with a Horizontal Strut

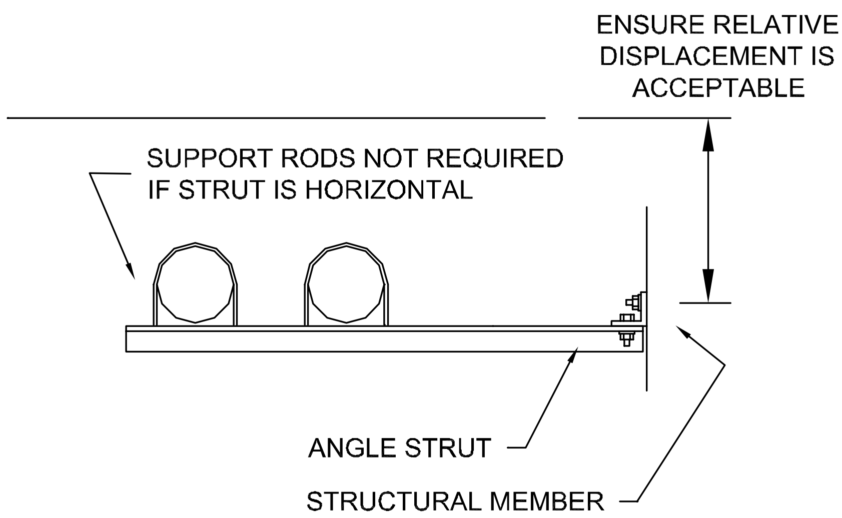

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Figure D7.6-2; Trapeze-Supported Piping Restrained to Structural Wall or Column with an Sloping Strut

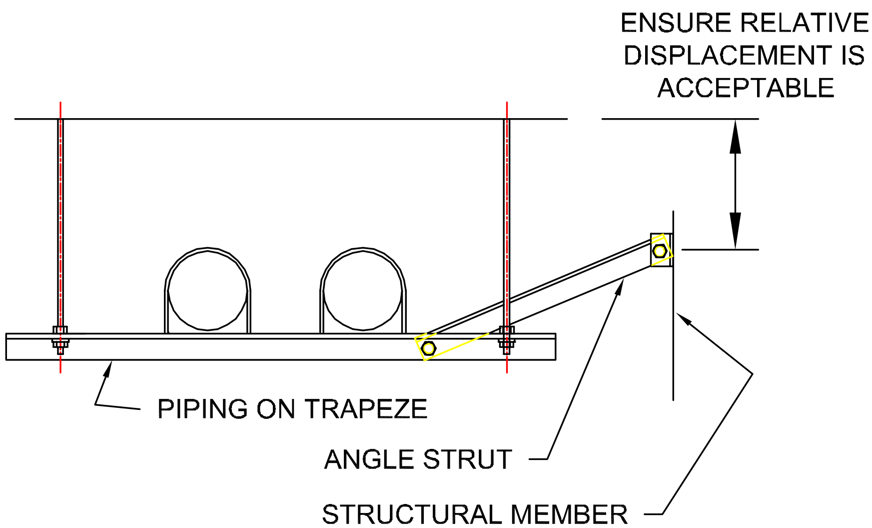
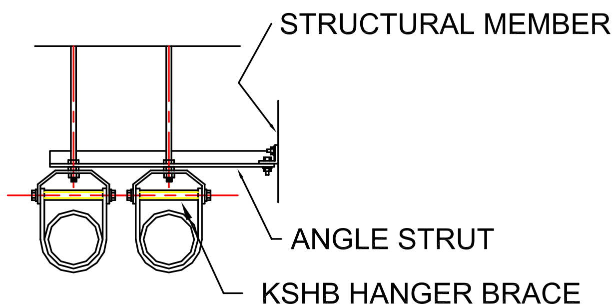


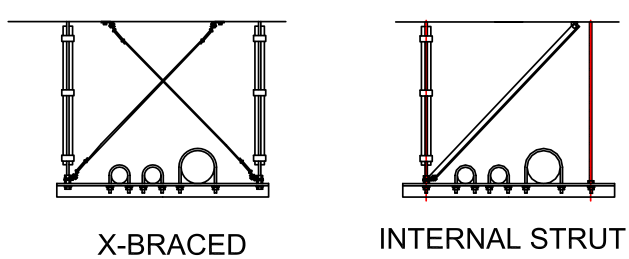
Figure D7.6-3; Clevis-Supported Piping Restrained to Structural Wall or Column



For the case where there are no nearby structural connection points or where the nearby structural elements are not suitable, there are several options that can be considered.

The first option is to restrain to the ceiling using "X" bracing or a diagonal strut.

Figure D7.6-4; "X" or Diagonally Braced Restraint Arrangement



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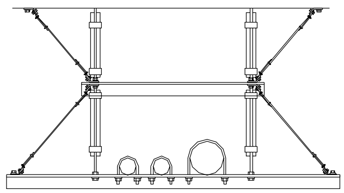
A "K" or double "K" brace can also be used. The "K" can either be located inside the support rods or outside the support rods, but in the case of a double "K", both sides must be identical (either inside or outside).

Figure D7.6-5; Single and Double "K" Brace Restraint Arrangement



In cases where only non-structural walls limit access for restraint, it is frequently possible to penetrate the non-structural wall and shift the lateral restraint device to the opposite side of the wall or partition as shown here.

Figure D7.6-6; Wall Penetration Restraint (Cable)

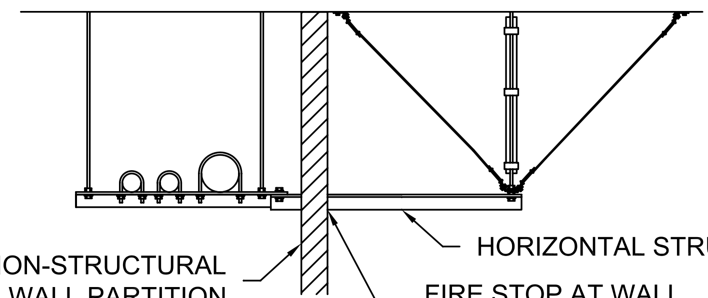
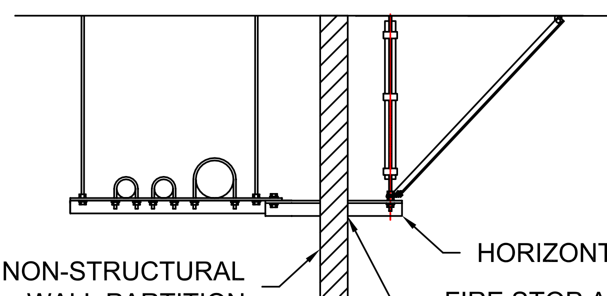


Figure D7.6-7; Wall Penetration Restraint (Strut)



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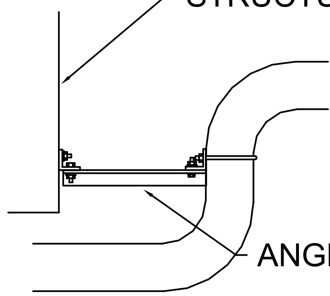
D7.6.2 Axial Restraint Strut at a Dogleg

This arrangement is often a convenient way to connect an axial restraint and can occur both in the horizontal and vertical plane. Often it will be found that when installing piping, a jog has been added to a run to avoid running into a column or other structural member. Where this occurs, it offers an easy way to connect an axial restraint.

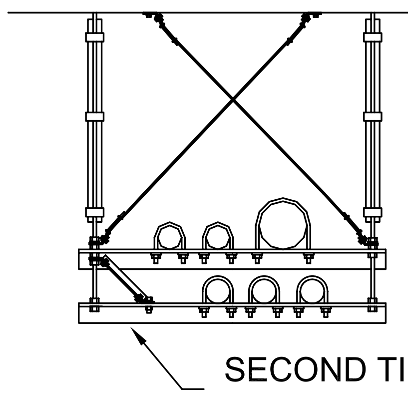
Figure D7.6-8; Axial Restraint Strut at a Dogleg



D7.6.3 Piggyback or Double-Tier Restraint

In congested areas, there is often a double layer of piping supported off a single trapeze arrangement. It is possible under some conditions to brace one trapeze bar to the other, and then restrain the second trapeze bar to the structure. If doing this, there are a couple of cautions. First, the restraint capacity for the second trapeze bar must be adequate to restrain the total load from both bars and, second, the piping must be similar in nature and ductility.

Figure D7.6-8; Piggyback or Double-Tier Restraint Arrangement



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D7.6.4 Restraints for Piping Mounted Well Below the Support Structure

This situation is not easily handled. Past history has shown, and the code is quite clear, that it is not a good idea to support the pipe from one structural element and restrain it using another structural element that will undergo significantly different motions. Restraints fit in this fashion will likely fail or cause the supports for the system that is being supported to fail. Neither of these outcomes is desirable..

About the only solution to this is to add a support structure for the piping that is located either just above or just below the piping. The piping can then be both attached and restrained to this structure.

The structure can be supported off the floor, off the ceiling, or from structural walls or columns. The support structure must be rigid enough to absorb all of the seismic loads, and particularly the moments, with minimal deformation, transferring pure shear or tensile forces into the supports.

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SECTION D8.0 - TABLE OF CONTENTS

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SEISMIC FORCES ACTING ON DUCTWORK

When subjected to an earthquake, ductwork must resist lateral and axial buckling forces, and the restraint components for these systems must resist pullout and localized structural failures.

Most duct systems are suspended from the deck above on either fixed or isolated hanger rod systems. While ducts are normally supported singly, there may occasionally be multiple ducts attached to a common trapeze. On some occasions ducts may run vertically or may be mounted to the floor.

D8.1.1 Suspended Systems

Most codes do not require that ductwork supported on non-moment generating (swiveling) hanger rods 12 in or less in length be restrained. The 12 in length was determined based on the natural frequency of systems supported on the short hanger rods. In practice, it has been found that the vibrations generated by earthquakes do not excite these types of systems and, although the ducts move back and forth somewhat as a result of an earthquake, they do not tend to oscillate severely and tear themselves apart.

There are also exclusions in most codes for small ducts (under 6 square ft in area) no matter what the hanger rod length. Again, the basis for this exclusion is based on the post-earthquake review of many installations. It has been found that smaller ducts are light and flexible enough that they cannot generate enough energy to do significant damage to themselves.

For cases where restraints are required, however, the forces involved can be significant. This is due to the difference between the required spacing of ductwork supports and restraints. Supports for ductwork will normally carry the weight of approximately 10 ft of duct (in the case of trapezes, this could be multiple ducts, but the length is still held to approx 10 ft). Seismic restraints, on the other hand, are normally spaced considerably further apart, with the spacing varying by restraint type, restraint capacity, duct size, and the seismic design load. It is very important to be aware of the impact of the difference in spacing, as the wider this spacing, the larger the seismic load when compared to the support load. Guidance in determining restraint spacing requirements is available in Chapter D4 of this manual.

To illustrate this difference, consider a simple example of a 54 x 60 inch duct weighing about 50 lb/ft being restrained against a 0.2g seismic force. Assume the axial restraints are located on 80 ft centers (the max permitted) and supports are located on 10 ft centers. The load that is applied to the hanger rods by the weight of the duct is 50 lb/ft x 10 ft or 250 lb each (assuming two support rods). The horizontal load that occurs at the restraint locations is the total restrained weight (50 lb/ft x 80 ft = 4000 lb) multiplied by the seismic force (0.2g) or 800 lb. Thus the seismic load is considerably larger than the vertical dead load.

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Restraints for suspended systems are normally in the form of cables or struts that run from the duct up to the deck at an angle. Because of the angle, horizontal seismic loads also generate vertical forces that must be resisted. Therefore, restraint devices must be attached at support locations so that there is a vertical force-resisting member available.

As the angle becomes steeper (the restraint member becomes more vertical), the vertical forces increase. At 45 degrees the vertical force equals the horizontal force and at 60 degrees the vertical force is 1.73 times the horizontal force.

The net result is that for cable systems or for struts loaded in tension, the uplift force at the bottom end of the restraint can be considerably higher than the downward weight load of the duct. Returning to our example, assume that we have a restraint member installed at a 60 degree angle from horizontal and that the lateral force will load it in tension. In this case, the 800 lb seismic force generates an uplift force of 1.73 x 800 lb or 1384 lb. This is 884 lb more than the support load and, depending upon the support rod length and stiffness, can cause the support rod to buckle. Rod stiffeners are used to protect against this condition and sizing information is available in Chapter D4 of this manual.

Unlike cables, if struts are used for restraint they can also be loaded in compression. In the example above, if the strut were loaded in compression, the 1384 lb load would be added to the support load (trying to pry the hanger rod out of the deck). The total support capacity required would be 1384 lb + 500 lb or 1884 lb. As a consequence, when using struts, the hanger rod must be designed to support 1884 lb instead of the 500 lb maximum generated with cables. Hanger rod sizing information is also available in Chapter D4 of this manual.

D8.1.2 Riser Systems

Where ductwork systems are running vertically in structures, except for the loads directly applied by vertical seismic load components identified in the code, there will be little variation in vertical forces from the static condition. Lateral loads are normally addressed by duct guides and the spacing between duct guides is not to exceed the maximum tabulated lateral restraint spacing indicated in the design tables in Chapter D4.

D8.1.3 Floor-Mounted Systems

The primary difference between floor- and ceiling-mounted ductwork systems is that the support loads in the duct support structure are in compression instead of tension (as in the hanger rods). Although a support column and diagonal cables can be used, a fixed stand made of angle or strut is generally preferred. Rules relating to restraint spacing and the sizing information for diagonal struts are the same as for hanging applications.

However, the support legs need to be designed to support the combined weight and vertical seismic load (for a two-legged stand and the example above, 500 lb / 2 + 1384 lb or 1634 lb) in compression (Note: 500 lb / 2 is the load per leg for two legs). The anchorage for the legs

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needs to be able to withstand the difference between the dead weight and the vertical seismic load (in the example above 1384 lb - 500 lb / 2 or 1134 lb).

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BASIC PRIMER FOR SUSPENDED DUCTWORK

Probably the two biggest immediate concerns with failed ductwork following earthquakes has to do with the maintenance of adequate smoke ventilation capability and personal injury for those that might be in the area when a duct fails. These are applicable to virtually all types of structures. For hospitals and other emergency response facilities, the loss of heating or air-conditioning can effectively shut down the facility. The shutdown can occur not only because of thermal issues, but also because the flow of air in a hospital is controlled to minimize the spread of infection.

Frequently the costs and damage to relationships between building owners and tenants incurred as a result of the inability to occupy a structure can be considerably more than the costs of damage to the building structure itself.

Because of the impact that failures in air distribution systems have had in the past, design requirements for these kinds of systems have become much more stringent.

Within a building structure there can be several different kinds of air distribution and venting systems, each with its own function and requirements. These include fire smoke control ventilation, laboratory ventilation, medical filtration and isolation systems, and kitchen or bathroom vents. Requirements for the systems vary based on the criticality or hazardous nature of what is being transported. Code-mandated requirements for the restraint of ductwork is addressed in Section D2 of this manual (Seismic Building Code Review).

Prior to applying this section of the manual, it is assumed that the reader has reviewed Chapter D2 and has determined that there is indeed a requirement for the restraint of piping. This chapter of the manual is a "how to" guide and will deal only with the proper installation and orientation of restraints and not whether or not they are required by code or by specification.

This chapter also does not address the sizing of restraint hardware. Chapter D4 includes sections on sizing componentry based on the design seismic force and the weight of the system being restrained.

Process piping is not directly associated with building operating systems and often has its own set of requirements. If there are no applicable special requirements, these systems should be restrained in a similar fashion to the building mechanical systems. This manual will not address any special requirements for process piping systems.

Building mechanical systems (potable water, HVAC, sanitary) can normally be grouped together and have similar design requirements. In many cases, requirements for fuel, gas, and medical gasses are more stringent. Refer to the code review chapter (D2) of the manual for applicable design requirements.

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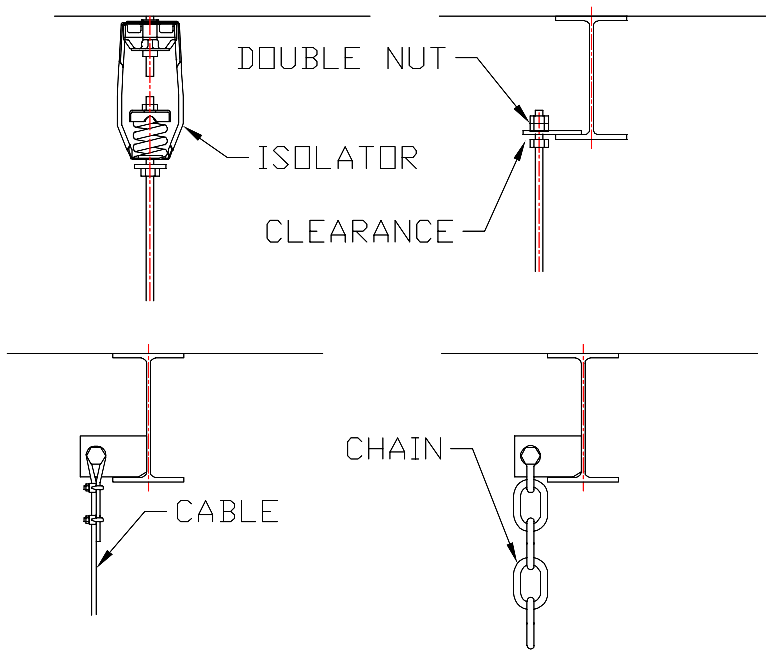
In many cases, ducts can be excluded from restraint if they are small enough in size or mounted in close proximity to the ceiling structure. When applying this exemption, current codes require the installation of a "non-moment generating connection" at the top anchorage point. This term is often confusing and deserves further clarification. A "non-moment generating connection" is one that will allow the supported duct to swing freely in any direction if acted on by an outside force. Some examples of "non-moment generating connections" are illustrated below.

Figure D8.2-1; Non-moment generating connections



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PROS AND CONS OF STRUTS vs CABLES

Both cables and struts have their place in the restraint of ductwork. In order to minimize costs and speed up installation, the differences between the two should be understood.

In general, ducts restrained by struts will require only 1 brace per restraint location while ducts restrained with cables require that 2 cables be fit forming an “X” or a “V”. As a trade-off, the number of restraint points needed on a given run of duct will typically be considerably higher for a strut-restrained system than for the cable-restrained system and, generally, strut-restrained systems will be more costly to install.

An added factor to consider when selecting a restraint system is that once a decision is reached on the type to use for a particular run, code requirements state that the same type of system must be used for the entire run (all cable or all strut). Later sections in this chapter will define runs, but for our purposes at present it can be considered to be a more or less straight section of duct.

The obvious advantage to struts is that, when space is at a premium, cables angling up to the ceiling on each side of a run may take more space than is available. Struts can be fit to one side only, allowing a more narrow packaging arrangement.

The advantages of cables, where they can be used, are numerous. First, they can usually be spaced less frequently along a duct than can struts. Second, they cannot increase the tensile forces in the hanger rod that result from the weight load, so rod and rod anchorage capacities are not impacted. Third, they are easily set to the proper length. And fourth, they are well suited to isolated duct applications.

To better explain the differences between the systems, it is necessary to look at how seismic forces are resisted with cables and struts. Shown below are sketches of both cable-restrained and strut-restrained duct.

Figure D8.3-1; Cable Restrained Duct

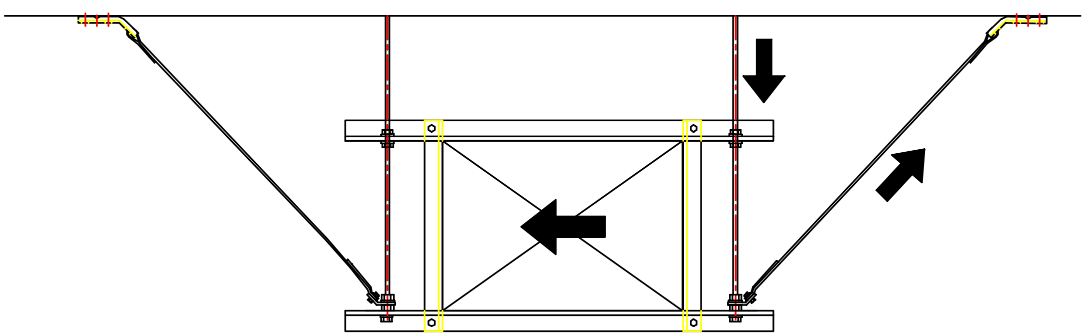

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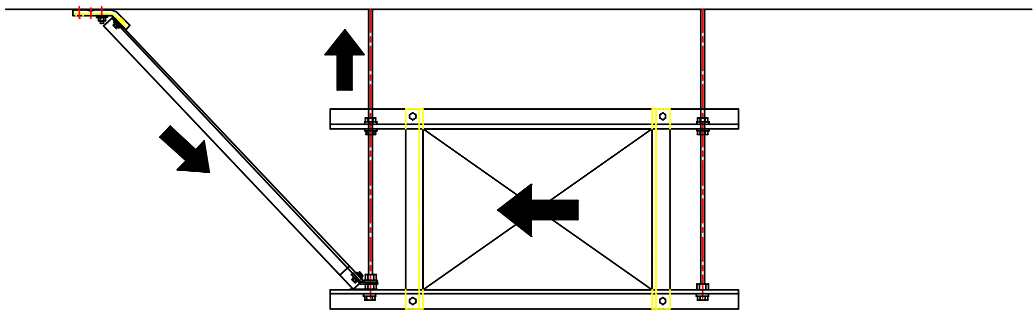
Figure D8.3-2; Strut Restrained Duct



The key factor to note is that cables can only be loaded in tension. This means that seismic forces can only generate compressive loads in the hanger rod. Seismic forces can, however, load the strut in compression resulting in a tensile load on the hanger rod.

This tensile load is in addition to any deadweight load that may already be supported by the hanger and is often significantly higher than the original load. This has the potential to rip the hanger rod out of the support structure and must be considered when sizing components.

Because of this added tensile component and the resulting impact on the necessary hanger rod size, most strut manufacturers limit the maximum allowable strut angle (to the horizontal) to 45 degrees. This is lower than typical allowable angles for cables that often reach 60 degrees from the horizontal. Although the data provided in Section D4.4 of this manual allow the use of higher angles for strut systems, users will find that the penalties in hanger rod size and anchorage will likely make these higher angles unusable in practice. To put this into context, examples will be provided at both 45 degrees and 60 degrees from the vertical to indicate the impact on capacity that results from the angle.

For a 45 degree restraint angle, if we assume a trapeze installation with the weight (W) equally split between 2 supports, the initial tension in each support is 0.5W. Using a 0.25g lateral design force (low seismic area), the total tensile load in a hanger increases to 0.75W for bracing on every support and 1.0W for bracing on every other support, if a strut is used.

For reference, if struts are used in a 60 degree angle configuration (from the horizontal), the tensile force in the hanger rod for all cases increases by a factor of 1.73 *(tan 60)* over that listed in the previous paragraph. This means that the tensile force becomes .94W for bracing on every support and 1.36W for bracing on every other support.

On the other hand, where 0.25g is applicable, buckling concerns in the duct are such that the spacing between lateral restraints can be as high as 40 ft and for axial restraints, 80 ft. If we were to try to use struts placed at a 40 ft spacing in conjunction with supports spaced at 10 ft, the tensile force developed by a seismic event in the rod increases to 1.5W for 45 degree configurations and to 2.23W for 60 degree configurations.

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As mentioned earlier, there is no increase in the rod forces for cable-restrained systems.

Using real numbers based on a 40 ft restraint spacing and a 60 degree angle configuration, if the peak tensile load in the hanger rod is 500 lb for a cable restrained system, it becomes 2230 lb for an otherwise identical strut-restrained system.

A summary of the above data, based on a 500 lb weight per hanger rod (1000 lb per trapeze bar) and including concrete anchorage sizes and minimum embedment is shown below.

Table D8.3-1; Hanger Rod Tensile Loads

Summary of Hanger Rod Tensile Loads based on 500 lb per Rod Weight				
	Tens Force (lb)	Min Rod (in)	Min Anc (in)	Embed (in)
Every Hanger Braced (10')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	750	0.38	0.38	3.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	933	0.50	0.50	4.00
Every other Hanger Braced (20')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	1000	0.50	0.50	4.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	1365	0.50	0.63	5.00
Every fourth Hanger Braced (40')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	1500	0.63	0.63	5.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	2230	0.63	0.75	6.00
Max Spacing between Braces (80')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	2500	0.75	0.75	6.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	3960	0.88	1.00	8.00

Note: The above anchorage rating is based on typical anchor allowables only. Often the underside of a concrete floor slab is in tension and if this is the case, the anchorage capacity may need to be further de-rated (forcing the need for an even larger hanger rod than is indicated here).

The net result is that the ability to use struts is highly dependent on the hanger rods that are in place. If the hangers were sized simply on deadweight, the added seismic load, even in relatively low seismic areas, can quickly overload them. The only recourse is to either replace the hanger rods with larger ones or decrease the restraint spacing to the point at which virtually every support rod is braced.

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It should also be noted that the hanger rods in tension become seismic elements. This occurs with struts, but does not with cables. As a result, the system must comply with all of the anchor requirements specified by ICC. This includes the use of seismically rated anchors and embedment depths that are in conformance with ICC requirement for those types of anchors. With larger anchor sizes, floor slab thickness may cause this to become a significant problem.

With both cables and struts, the hanger rods can be loaded in compression. As the seismic force increases, it eventually overcomes the force of gravity and produces a buckling load in the hanger rod. It is mandatory in all cases that the rod be able to resist this force.

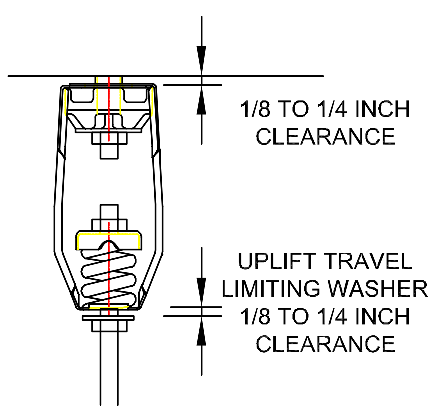
There is a wide range of variables involved in determining the need for rod stiffeners to resist this buckling load. Factors that impact this need are 1) the magnitude of the compressive force, 2) the weight load carried by the hanger rod, 3) the length of the hanger rod, 4) the diameter of the hanger rod, and 5) the angle between the restraint strut or cable and the horizontal axis.

Charts are included in Section D4.4 of this manual that allow the user to determine if there is a need for a stiffener and to allow the proper selection if required.

Because uplift occurs, some attention must be given to isolated systems. First, when using isolators, the location of the isolation element needs to be at the top end of the hanger rod (close to but not tight against the ceiling). If placed at the middle of the hanger rod, the rod/isolator combination will have virtually no resistance to bending and will quickly buckle under an uplift load.

Second, a limit stop must be fit to the hanger rod, just beneath the hanger such that when the rod is pushed upward a rigid connection is made between the hanger housing and the hanger rod that prevents upward motion. This is accomplished by adding a washer and nut to the hanger rod just below the isolator (see the sketch below).

Figure D8.3-3; Installation for an Isolation Hanger in a Seismic Application



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DUCT RESTRAINTS-DEFINITIONS AND LOCATING REQUIREMENTS

There are a number of design guides that have been developed over the years but the one with the longest history and most widely accepted is SMACNA. They have developed a handbook that offers conservative guidance that an end user can reference in selecting and installing restraints for distribution systems. While the information provided in that handbook is good, it suffers from a couple of inherent drawbacks. The first is that because it is linked to generically available hardware, the ratings that are assumed for the various hardware components are the lowest of any of the many possibilities available in the marketplace. The net result is that the suggested hardware is larger in general than that which could be used if higher quality componentry it specified. The second is that their presentation of the results is extremely cumbersome and difficult to use.

While the criteria presented in this document is based on the guidance offered by SMACNA, it has been possible to increase the component ratings as the actual capacity, type and manufacture of these components is clearly known. In addition, based on a critical review of the data presentation in the SMACNA handbook, it has been possible to greatly simplify the method of selection making the end result much simpler to use.

With respect to the conceptual restraint arrangement illustrations, the SMACNA concepts are appropriate and are referenced here.

In general, Ducts are restrained in lengths called "runs." Therefore before getting into a detailed review of the restraint systems it is imperative that a definition of "run" as well as other key terms be addressed.

D8.4.1-1; Definitions

Axial In the direction of the axis of the duct.

Lateral Side to side when looking along the axis of the duct.

Restraint Any device that limits the motion of a duct in either the lateral or axial direction.

Run A more or less straight length of duct where offsets are limited to not more than S/16 where S is the maximum permitted lateral restraint spacing (a function of ductwork size and seismic forces) and the total length is greater than S/2. (Note: S dimensions for various conditions are listed in Chapter D4.)

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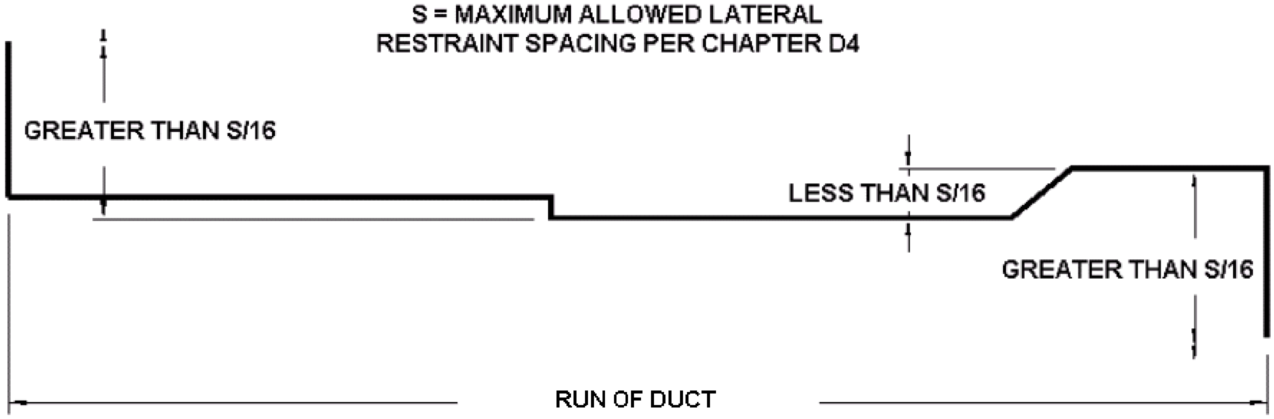
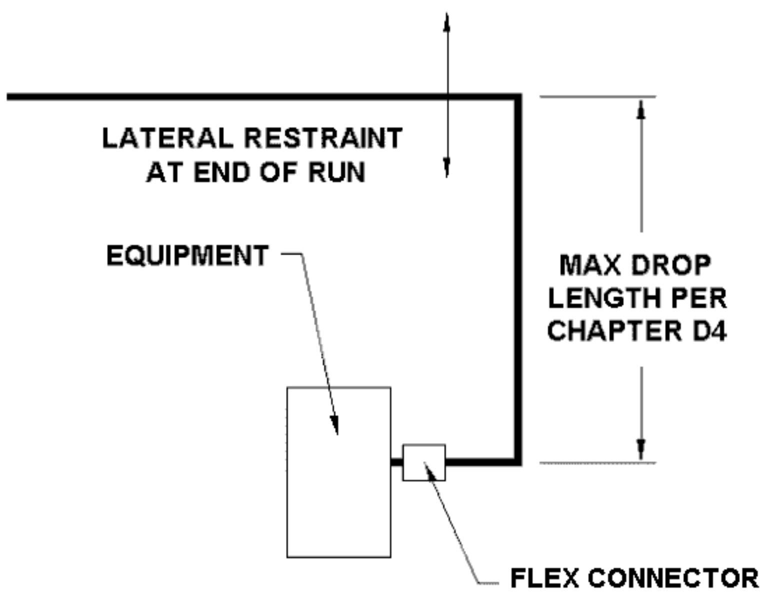
Figure D8.4.1-1; Definition of a "Run" of Duct



Short Run A run as defined above where the total length is less than S/2 and where it is connected on both ends to other runs or short runs.

Drop A length of duct that normally extends down from an overhead run and connects to a piece of equipment, usually through some type of flex connector. The drop can also extend horizontally. In order to qualify as a drop, the length of this pipe must be less than S/2. If over S/2, the length of pipe would be classified as a run.

Figure D8.4.1-2; Definition of a "Drop"



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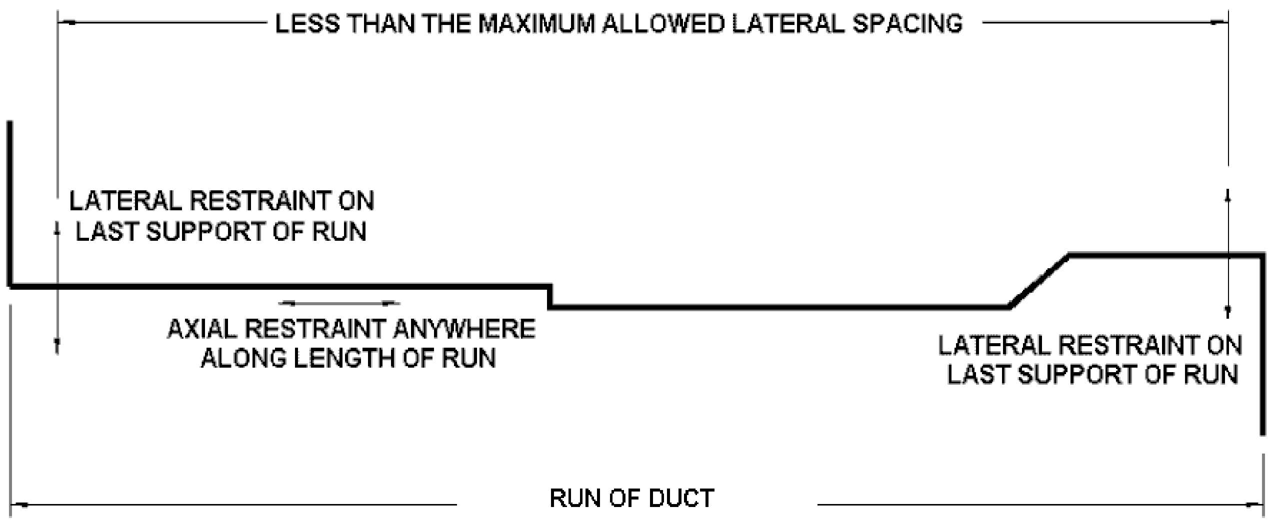
D8.4.1-2; Restraint Requirements

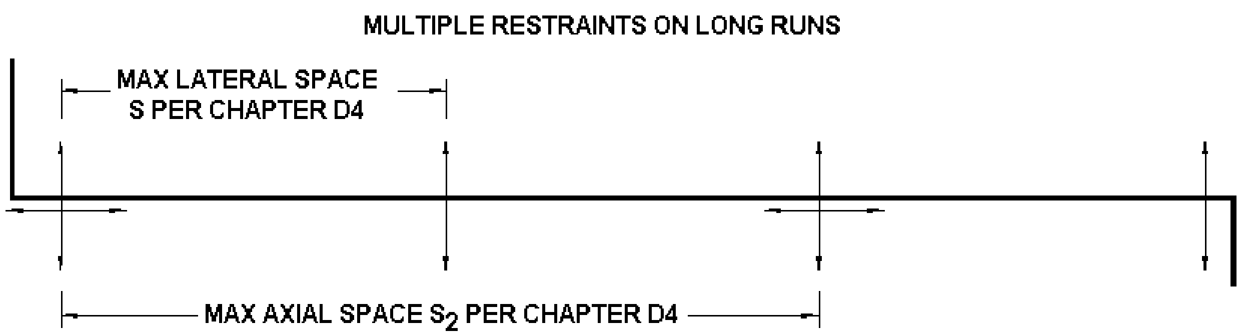
1) Full runs (greater in length than S/2) must be restrained in both the axial and lateral direction. If the run is not a short run or a drop, it must, as a minimum, be laterally restrained at the last support location on each end.

Figure D8.4.1-2; Basic Restraint Requirements for a Typical "Run" of Duct



2) If a run is longer than "S," intermediate restraints are required to limit the spacing to that permitted by the building code (see table in Chapter D4).

Figure D8.4.1-3; Basic Restraint Requirements for a Long "Run" of Duct



3) Axial restraints attached to the run of duct along its length must be connected using a positive connection between the duct and the restraint.

4) Short runs or drops need only have one lateral and one axial restraint.

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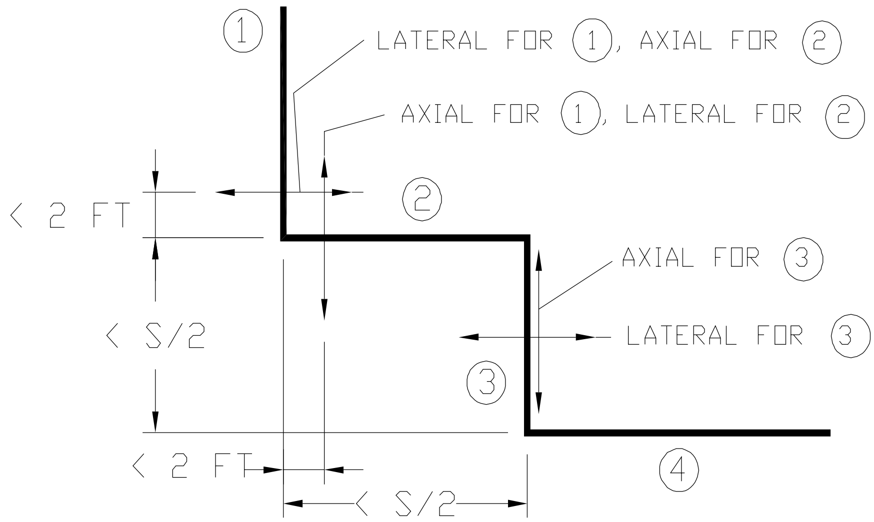
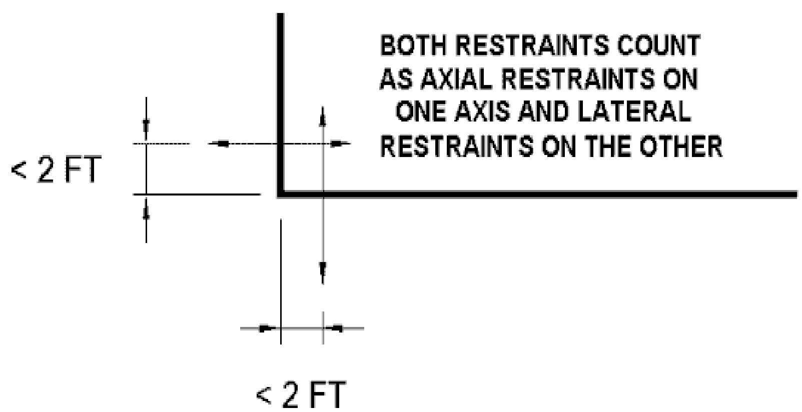
Figure D8.4.1-4; Basic Restraint Requirements for Multiple Short "Runs" of Duct



5) If a lateral restraint is located within 2 feet of a corner (based on a measurement to the duct centerline) or is immediately adjacent to the duct for larger ducts, it can be used as an axial restraint on the intersecting run.

Figure D8.4.1-5; "Double Duty" for Corner Restraints



6) Larger ducts cannot be restrained with restraints located on smaller branches.

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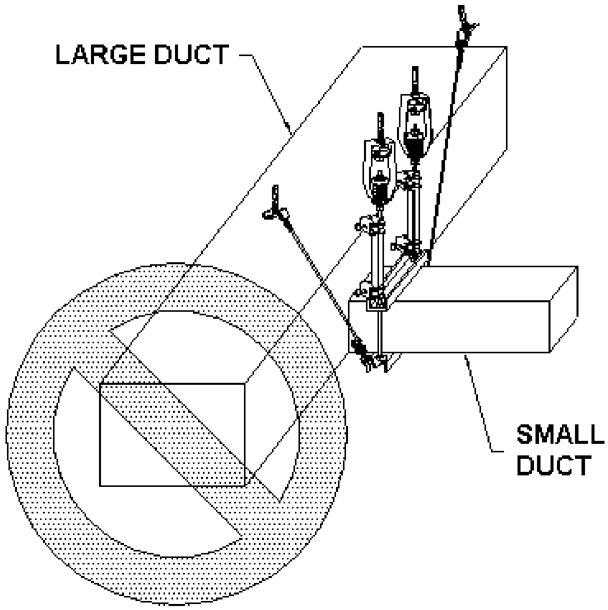
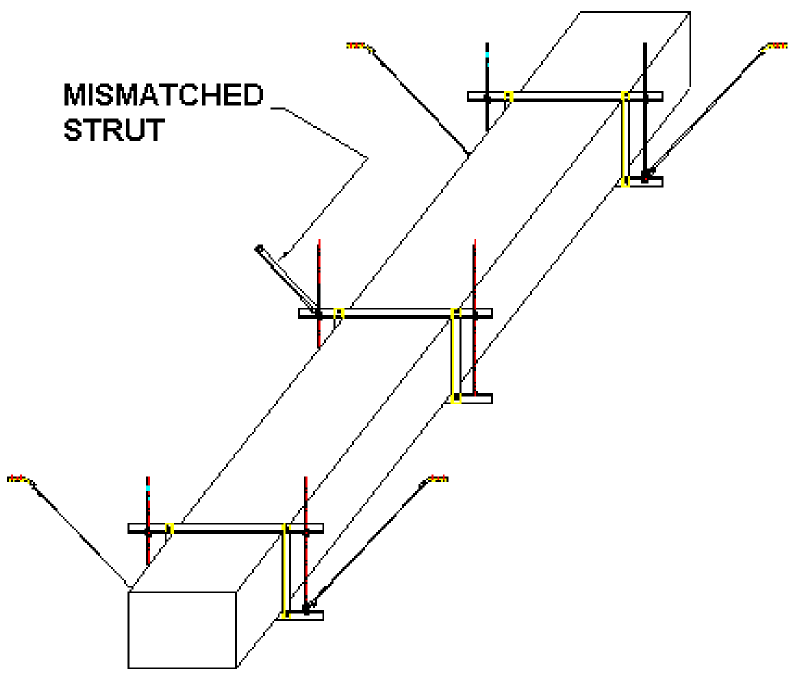
Figure D8.4.1-6; Do not Restrain Larger Ducts with Restraints on Smaller Ones



7) Within a run, the type of restraint used must be consistent. For example, mixing a strut with cable restraints is not permitted.

Figure D8.4.1-7; Mismatched Struts and Cable Restraints



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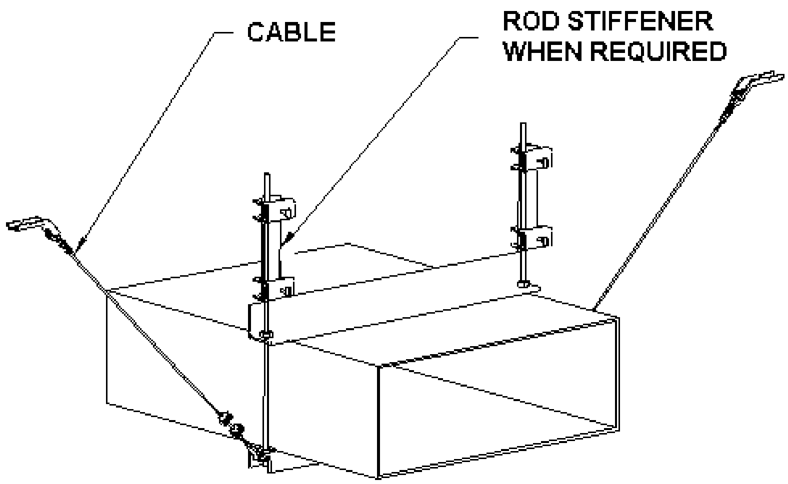
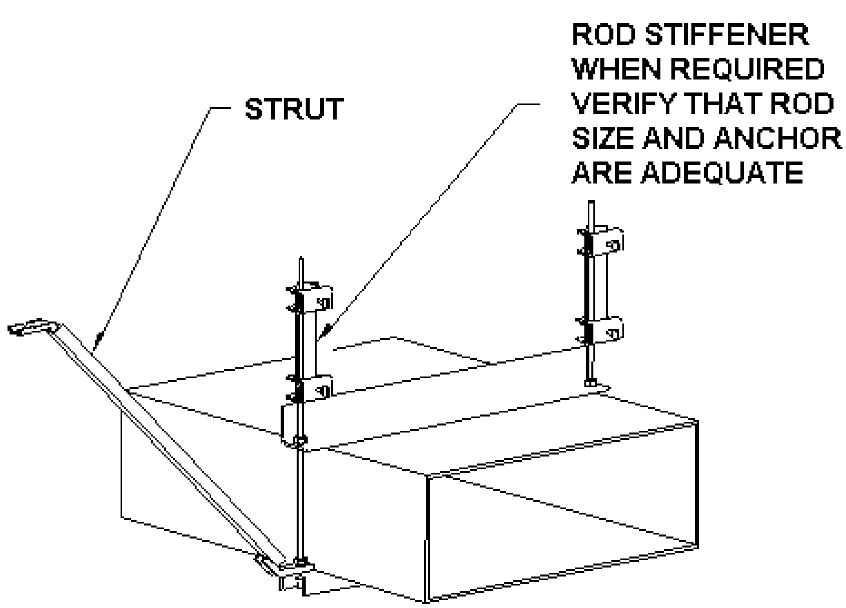
8) With longer hanger rods, rod stiffeners are likely to be required. Refer to the appropriate table in Chapter D4 to determine: (1) if needed, (2) what size stiffener material is appropriate, and (3) how frequently it needs to be clamped to the hanger rod.

Figure D8.4.1-8; Rod Stiffener



9) In addition to possibly requiring rod stiffeners, when struts are used to restrain ductwork, the size of the hanger rod and its anchorage also become critical. Again refer to the appropriate table in Chapter D4 to determine the minimum allowable size for the hanger rod and anchor.

Figure D8.4.1-9; Hanger Rod Sizing (For Strut Applications)



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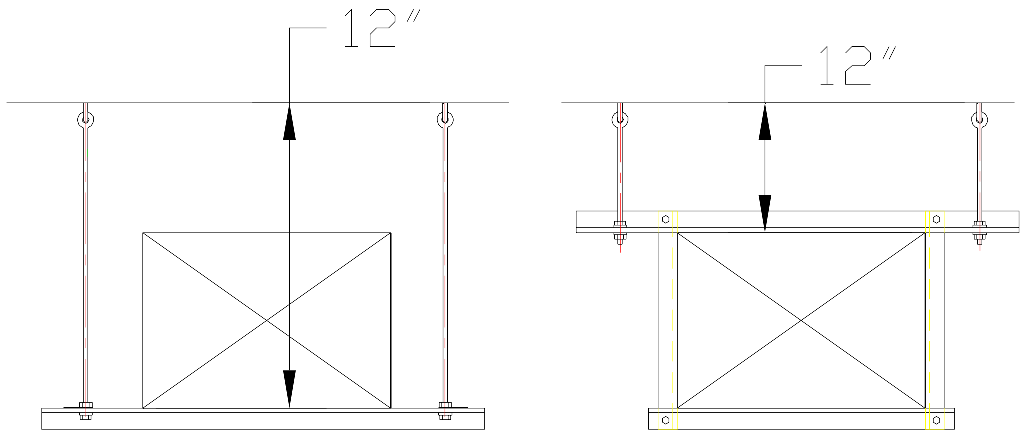
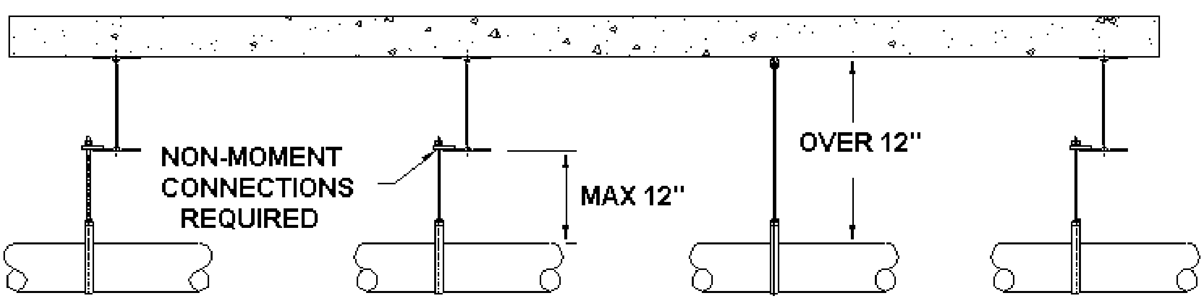
10)In some cases, it may be possible to locate the ducts close enough to the support structure (12") to eliminate the need for restraint. (Refer to the building code review chapter (D2) to determine if this exemption is applicable.) If it is applicable, the 12" dimension is measured as shown below.

Figure D8.4.1-10; 12" Hanger Rod Exemption



11)When using the above rule it is critical that all support locations in a run conform. If even one location exceeds 12", the run cannot be exempted from restraint.

Figure D8.4.1-11; Run Fails the Consistency Requirement for 12" Exemption



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CEILING SUPPORTED RESTRAINT ARRANGEMENTS

Although the basic principle of diagonal bracing is almost always used to design restraint systems, the actual arrangement of these systems can vary significantly. Despite what looks like substantially different designs, the design forces in the members remain the same, and the same rules apply when sizing components. Illustrated here are many different restraint arrangements, all of which can be used in conjunction with the design "rules" provided in this manual.

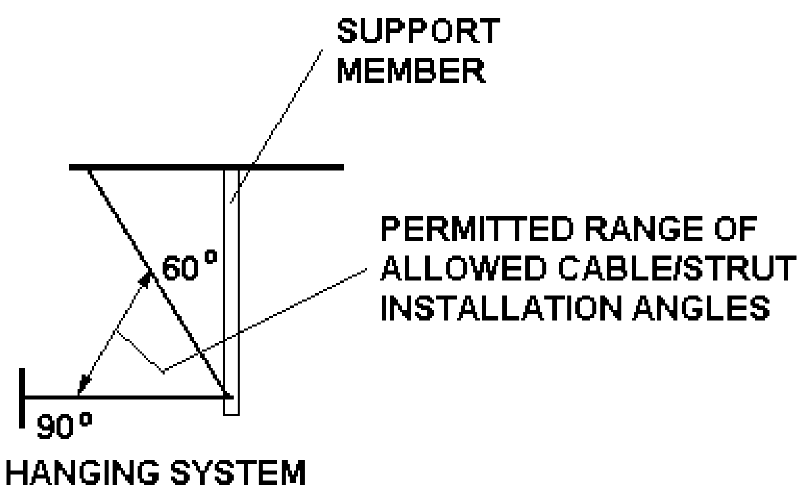
Details of the end connections and anchorage hardware are shown in subsequent sections of the manual. It is assumed in this manual that the restraint component is attached to a structural element capable of resisting the design seismic load.

Due to variations in the installation conditions such as structural clearance, locations of structural attachment points, and interference with other pieces of equipment or systems, there will likely be significant benefits to using different arrangements in different locations on the same job.

The only significant caution here is that it is not permissible to mix struts and cables on the same run.

This manual addresses diagonal bracing slopes of between horizontal and 60 degrees from the horizontal. Angles in excess of 60 degrees to the horizontal are not permitted.

Figure D8.4.2-1; Permissible Restraint Angles



When installing restraints, lateral restraints should be installed perpendicular (±10 degrees) to the duct in plan. Axial restraints should be in line with the duct,

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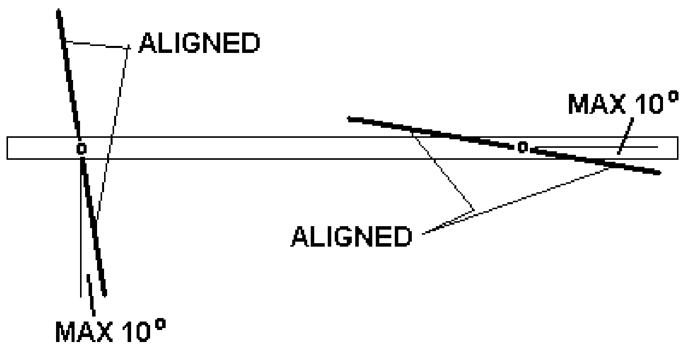
±10 degrees, again in the plan view. All restraint cables should be aligned with each other. See the sketch below.

Figure D8.4.2-2; Restraint Alignment



Lateral Restraint **Axial Restraint**

In general, when restraining ductwork, the component actually being restrained is the support device for the duct. This is normally either a ring clamp made of gauge material, or a trapeze bar. Because the goal is to restrain the actual duct, it is necessary that the restrained element be connected to the duct in such a way as to transfer the appropriate forces between the two.

Based on the Maximum Horizontal Force requirement, the appropriate size and quantity of fasteners to connect ducts to support/restraint members is as follows:

Force (Lbs)	250	500	1000	2000	5000	10000
#10 Screw	3	5	10	20		
Force (Lbs)			3	6	20	40

When firmly connecting restraints to ductwork there are a few general rules that should be followed:

1) Attachment screws should be spread evenly either around or along the top and bottom of the duct.
2) To minimize wind noise, short screws with minimal projection into the air stream should be selected.
3) Trapeze-mounted ductwork must be fully encompassed by a frame or screwed to the trapeze at each lateral restraint point.
4) Axially restrained duct connections must be positive and require screws as indicated above.

In addition, when sizing restraint components for multiple ducts, the total weight of all of the restrained ductwork must be considered.

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D8.4.2.1 Hanging Systems Restrained with Cables

Hanging systems may include supports for single or multiple ducts. Single ducts can be supported using brackets made of gauge material but multiple ducts are normally supported on or suspended from trapeze bars.

Lateral Restraint Examples

For a cable-restrained duct supported by a circular bracket made of gauge material, there is really only one mounting arrangement. It can be used with both isolated and non-isolated systems as shown below. Note that the isolators are mounted with minimal clearance to the structure and that a travel limiting washer is fitted to the hanger rod just below the isolator in the isolated arrangement.

Figure D8.4.2-3; Lateral Cable Restraints used with a Gauge Material Ring Clamp (Non-isolated)

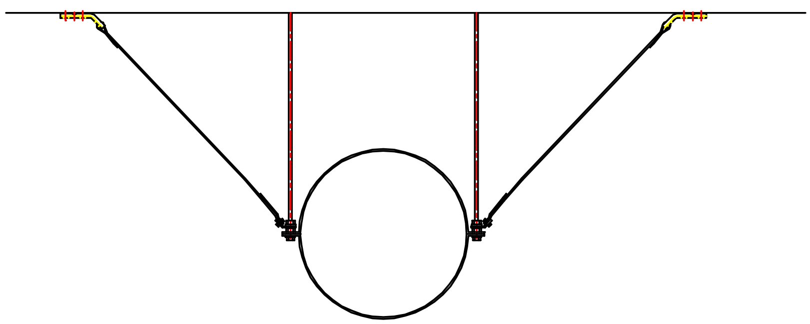
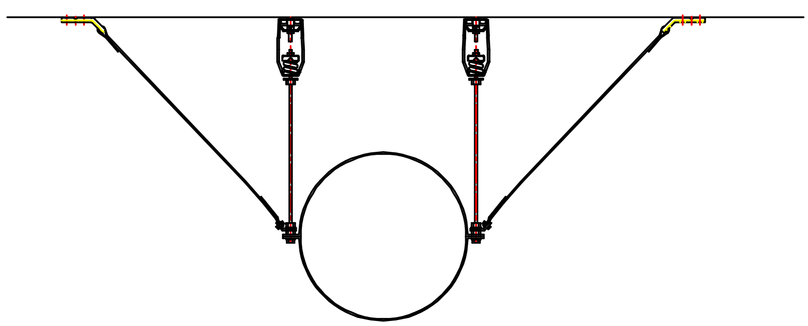


Figure D8.4.2-4; Lateral Cable Restraints used with a Gauge Material Ring Clamp (Isolated)



There are many options that exist for the arrangements of lateral restraints used in conjunction with trapeze-mounted systems. Shown below are several options for both non-isolated and isolated cable-restrained systems.

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Figure D8.4.2-5; Lateral Cable Restraints Mounted to a Trapeze (Non-isolated)

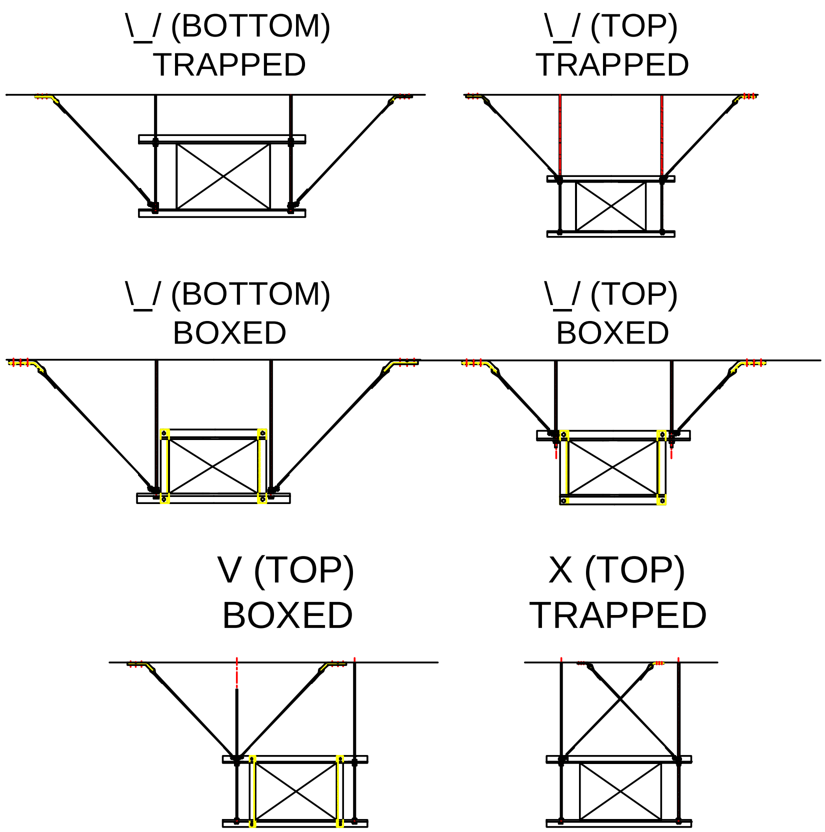
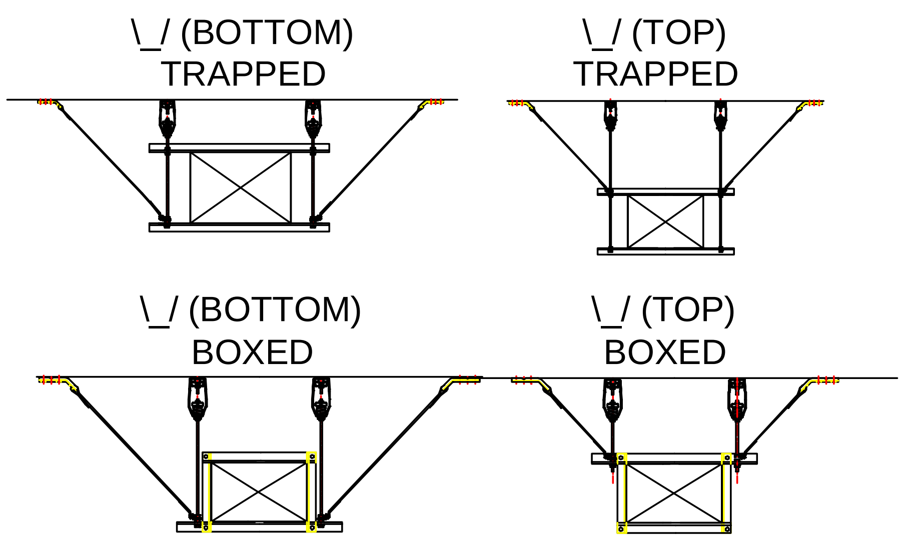


Figure D8.4.2-6; Lateral Cable Restraints Mounted to a Trapeze (Isolated)



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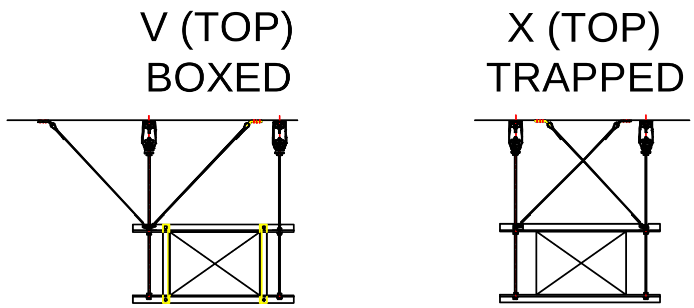

Axial Restraint Examples

When axially restraining ductwork, a perimeter metal strap or angle tightly screwed to the duct is the most common device used to retain the duct to the support bar. Occasionally connections to flanges are used. (Caution: Connections to flanges should only be used with the flange manufacturer's concurrence that the flange can withstand the seismic forces.) Details on these connections will be addressed in later sections.

Axial restraints offset from the centerline of restrained ductwork will generate additional bending forces in the duct. Because of the nature of ducts, unless restraints are fit on both sides, there will be an offset. As long as the restraint is immediately adjacent to the duct, it is permissible to use a single restraint point for axial restraint. For cases where multiple ducts are being supported on a common structure, the axial restraint should be between ducts in line with the approximate side-to-side center of gravity location.

Figure D8.4.2-7; Axial Cable Restraints (Non-isolated)

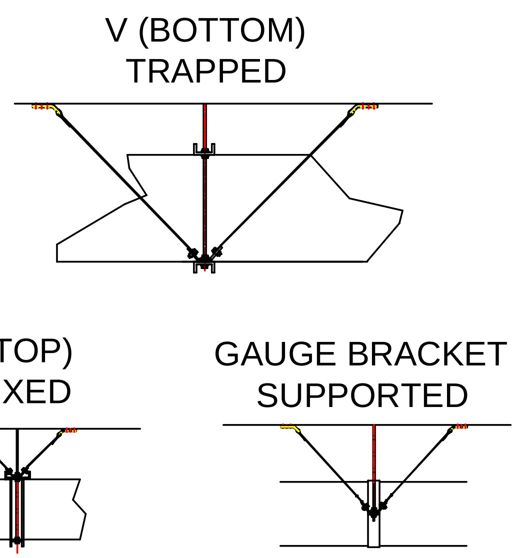

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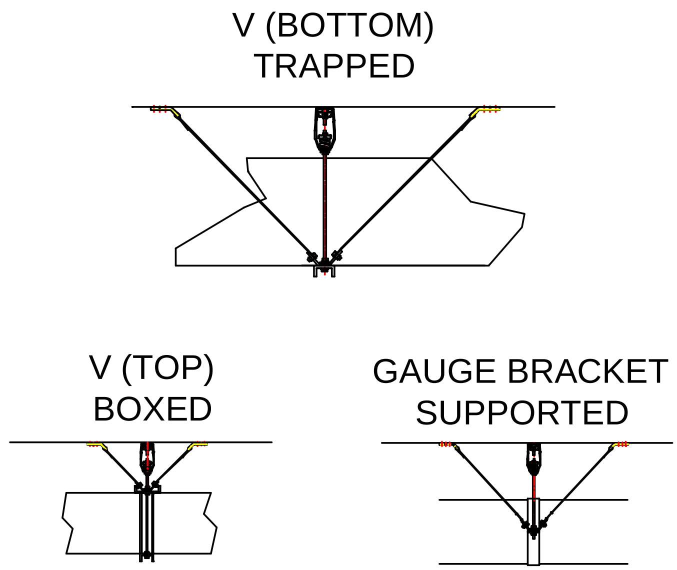
Figure D8.4.2-8; Axial Cable Restraints (Isolated)



D8.4.2.2 Hanging Systems Restrained with Struts

Struts typically should not be used to restrain isolated ductwork as they will generate hard connections between the duct and structure and will greatly reduce the efficiency of the isolation system. Having said that, in some special situations it may be possible to design restraint struts with integral isolation elements, but this is tedious and should be avoided unless drastic measures are required.

Lateral Restraint Examples

For a strut-restrained duct supported by a bracket made from gauge material there is only one common arrangement. It is to connect the restraint to the base of the hanger rod at the attachment point to the bracket. It is shown below.

Figure D8.4.2-9; Typical Lateral Restraint Strut Arrangements for Gauge Bracket Supported Duct

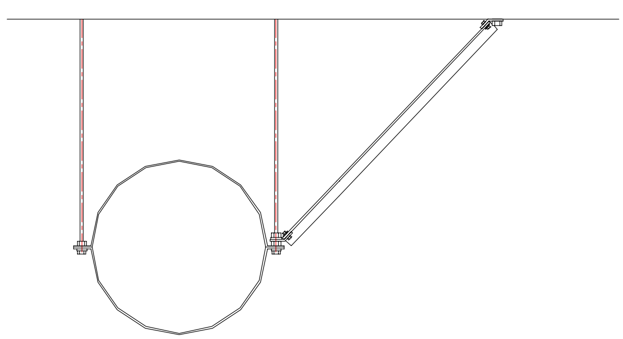


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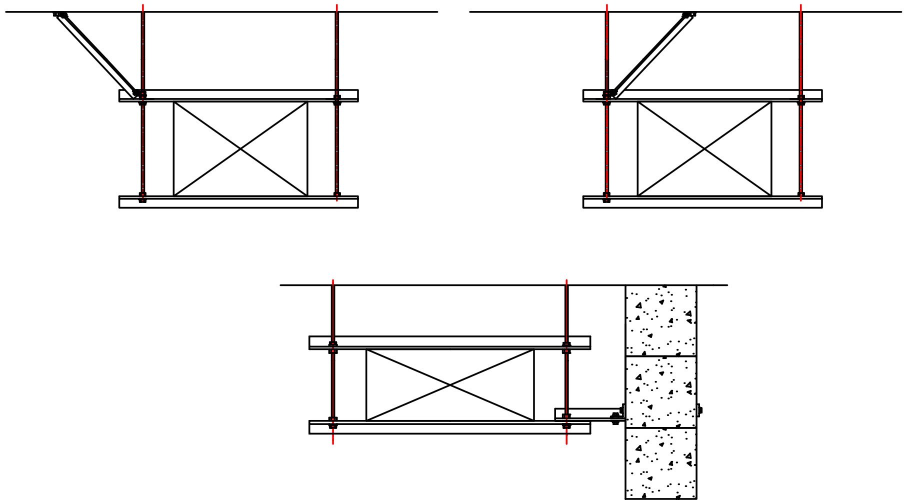
Figure D8.4.2-10; Shown below are 3 options for trapeze-supported ductwork. All are equivalent.



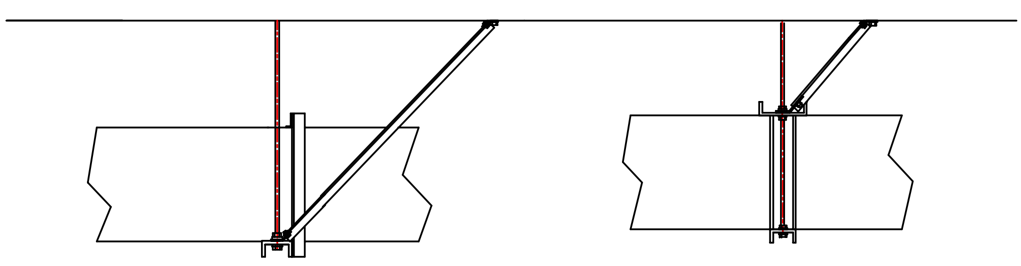
Axial Restraint Examples

When axially restraining ductwork with struts, a perimeter metal strap or angle tightly screwed to the duct is the most common device used to retain the duct to the support bar. Occasionally connections to flanges are used. (Caution: Connections to flanges should only be used with the flange manufacturer's concurrence that the flange can withstand the seismic forces.) Details on these connections will be addressed in later sections.

As with cables, struts offset from the centerline of restrained ductwork will generate additional bending forces in the duct. Because of the nature of ducts, unless restraints are fitted on both sides, there will be an offset. As long as the restraint is immediately adjacent to the duct, it is permissible to use a single restraint point for axial restraint. For cases where multiple ducts are being supported on a common structure, the axial restraint should be between ducts in line with the approximate side-to-side center of gravity location.

Ignoring the details of the connection at this point, common axial restraint arrangements recognized in this manual are illustrated below.

Figure D8.4.2-10; Ductwork Axially Restrained with Struts



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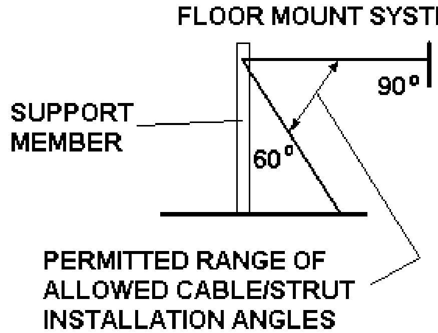
FLOOR- OR ROOF-SUPPORTED DUCT RESTRAINT ARRANGEMENTS

Although the basic principle of diagonal bracing is almost always used to design restraint systems, the actual arrangements of these systems can vary significantly. Despite what look like substantially different designs, the design forces in the members remain the same, and the same rules apply when sizing components. Illustrated here are many different floor- and roof-mounted restraint arrangements, all of which can be used in conjunction with the design “rules” provided in this manual.

Details of the end connections and anchorage hardware are shown in subsequent sections of this manual. It is assumed in this manual that the restraint component is attached to a structural element capable of resisting the design seismic load.

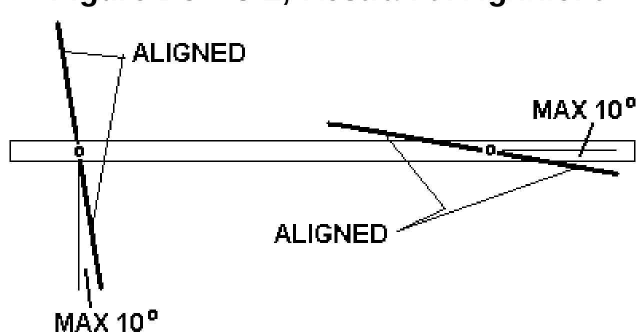
This manual addresses diagonal bracing oriented between horizontal and 60 degrees from the horizontal. Angles in excess of 60 degrees to the horizontal are not permitted.

Figure D8.4.3-1; Permissible Restraint Angles



When installing restraints, lateral restraints should be installed perpendicular (±10 degrees) to the duct in the plan view. Axial restraints should be in line with the duct (±10 degrees) again in the plan view. All restraint cables should be aligned with each other. See the sketch below.

Figure D8.4.3-2; Restraint Alignment



Lateral Restraint **Axial Restraint**

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In general, when restraining ductwork the component actually being restrained is the support device for the duct. For floor-mounted equipment this would normally be either a fabricated frame or a trapeze bar. Because the goal is to restrain the actual duct, it is necessary that the restrained element be connected to the duct in such a way as to transfer the appropriate forces between the two.

Based on the Maximum Horizontal Force requirement and Force Class from Section D4, the appropriate size and quantity of fasteners to connect ducts to support/restraint members is as follows:

Based on the Maximum Horizontal Force requirement, the appropriate size and quantity of fasteners to connect ducts to support/restraint members is as follows:

Force (Lbs)	250	500	1000	2000	5000	10000
#10 Screw	3	5	10	20		
Force (Lbs)			3	6	20	40

When firmly connecting restraints to ductwork there are a few general rules that should be followed:

1) Attachment screws should be spread evenly either around or along the top and bottom of the duct.
2) To minimize wind noise, short screws with minimal projection into the air stream should be selected.
3) Trapeze-mounted ductwork must be fully encompassed by a frame or screwed to the trapeze at each lateral restraint point.
4) Axially restrained duct connections must be positive and require screws as indicated above.

In addition, when sizing restraint components for multiple ducts the total weight of all of the restrained ductwork must be considered.

D8.4.3.1 Floor- or Roof-mounted Systems Restrained with Cables

Floor- or roof-mounted systems may include supports for single or multiple ducts. Typically, simple box frames are fabricated to support the ductwork, whether independent or in groups.

Transverse Restraint Examples

For a cable-restrained duct support bracket there are four options normally encountered for non-isolated systems and four similar arrangements for isolated systems. These options are shown below. The vertical legs of the support bracket must be sized to carry both the weight

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load of the supported ductwork as well as the vertical component of the seismic forces. Refer to Chapter D4 for more detailed information as to how to size these members.

Figure D8.4.3-3; Transverse Cable Restraints used in conjunction with Floor-Mounted Duct Support Stands (Non-isolated)

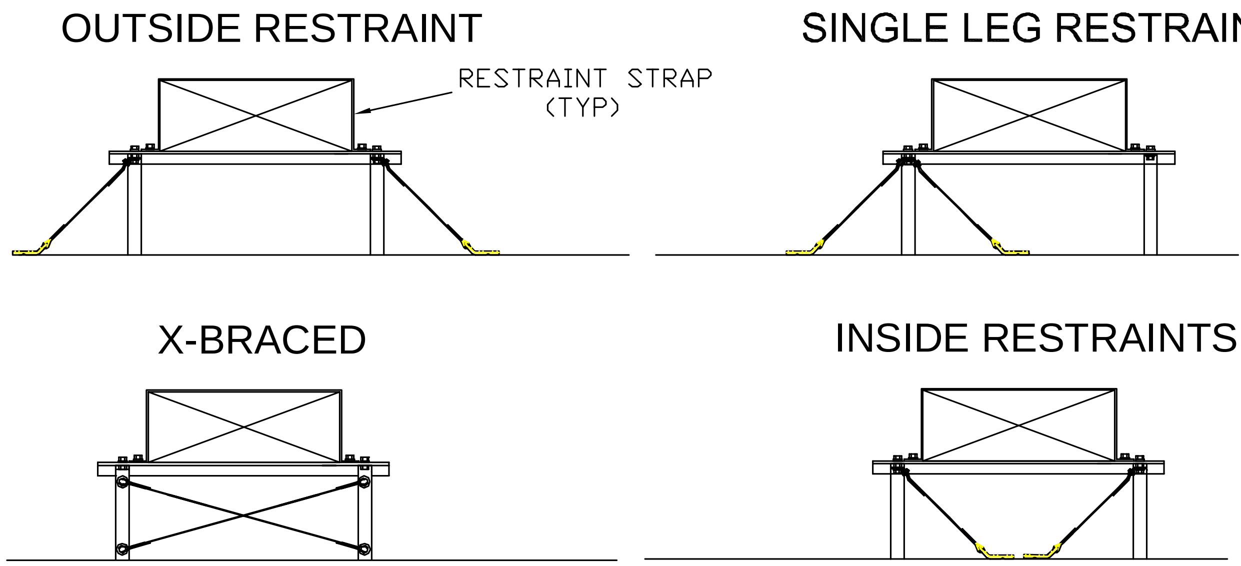
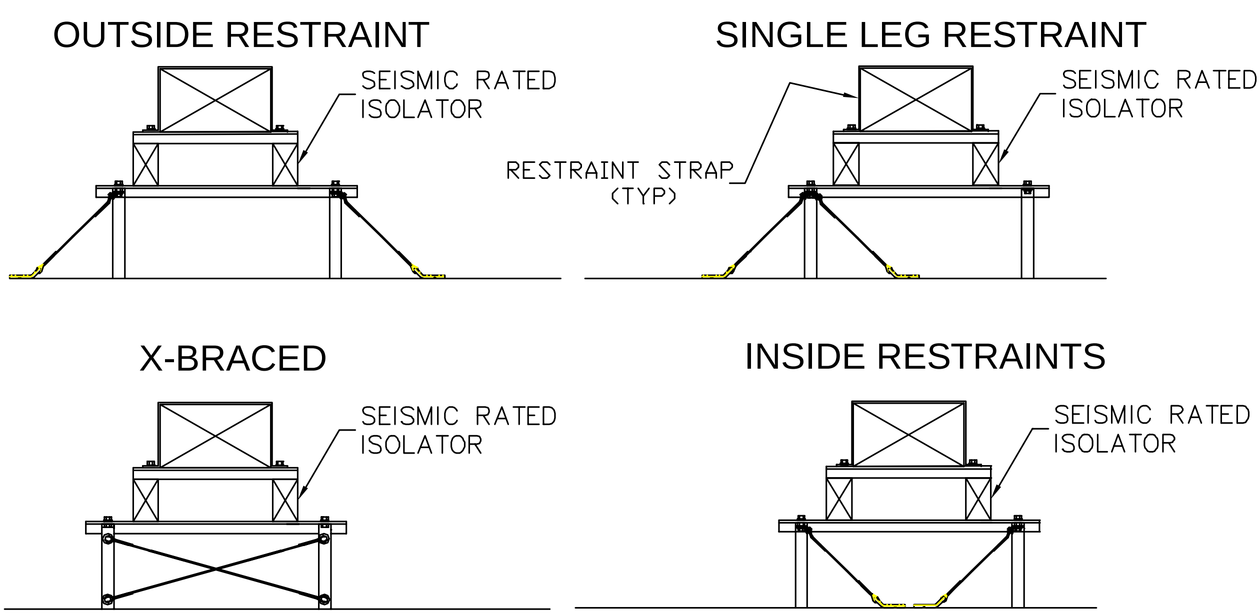


Figure D8.4.3-4; Transverse Cable Restraints used in conjunction with Floor-Mounted Duct Support Stands (Isolated)



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Longitudinal Restraint Examples

When longitudinally restraining ductwork, a perimeter metal strap or angle tightly screwed to the duct is the most common device used to retain the duct to the support bar. Occasionally connections to flanges are used. (Caution: Connections to flanges should only be used with the flange manufacturer's concurrence that the flange can withstand the seismic forces.) Details on these connections will be addressed in later sections.

If the details of the connection are ignored at this point, general Longitudinal restraint arrangements recognized in this manual are illustrated below.

Longitudinal restraints offset from the centerline of restrained ductwork will generate additional bending forces in the duct. Because of the nature of ducts, unless restraints are fitted on both sides, there will be an offset. As long as the restraint is immediately adjacent to the duct, it is permissible to use a single restraint point for Longitudinal restraint. For cases where multiple ducts are being supported on a common structure, the Longitudinal restraint should be between ducts in line with the approximate side-to-side center of gravity location.

Figure D8.4.3-5; Axial Cable Restraints (Non-isolated)

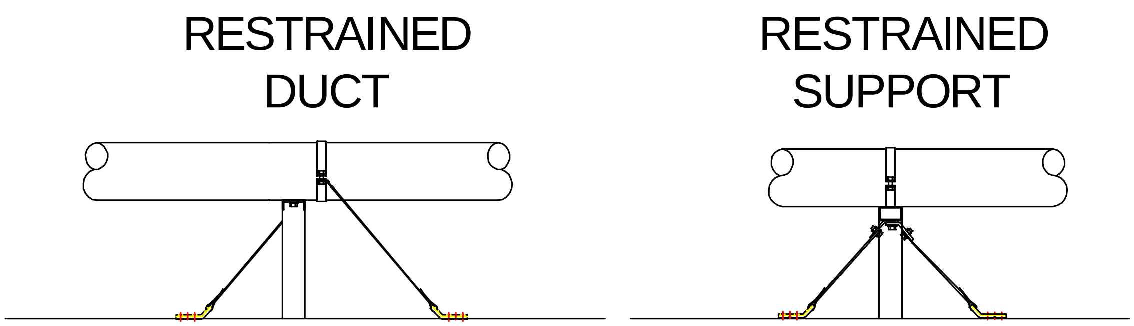
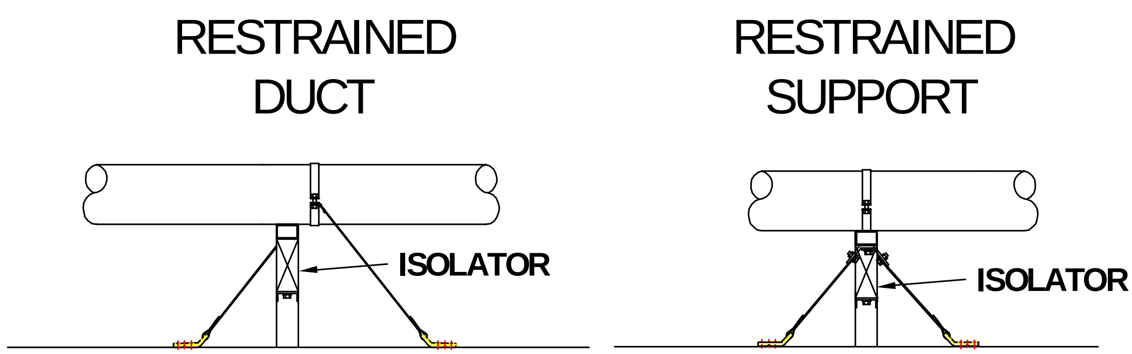


Figure D8.4.3-6; Axial Cable Restraints (Isolated)



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D8.4.3.2 Floor or Roof Mounted Systems Restrained with Struts

As with cable restraints, floor- or roof-mounted duct support systems will normally involve a box frame that supports the duct (single or multiple) with some kind of a trapeze bar. Direct connections between an isolated duct and structure using a strut are not recommended.

Transverse Restraint Examples

With struts there are three typical configurations. As with the cable systems, these arrangements can be used with or without isolation as shown below.

Figure D8.4.3-7; Typical Transverse Restraint Strut Arrangements for Ductwork (Non-Isolated)

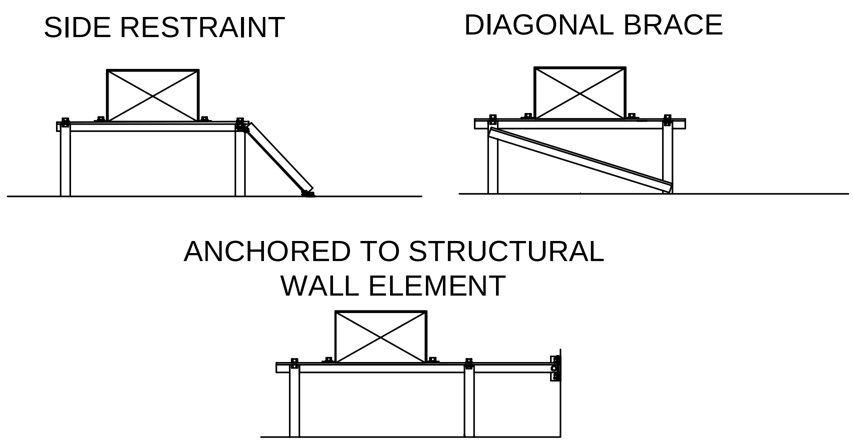
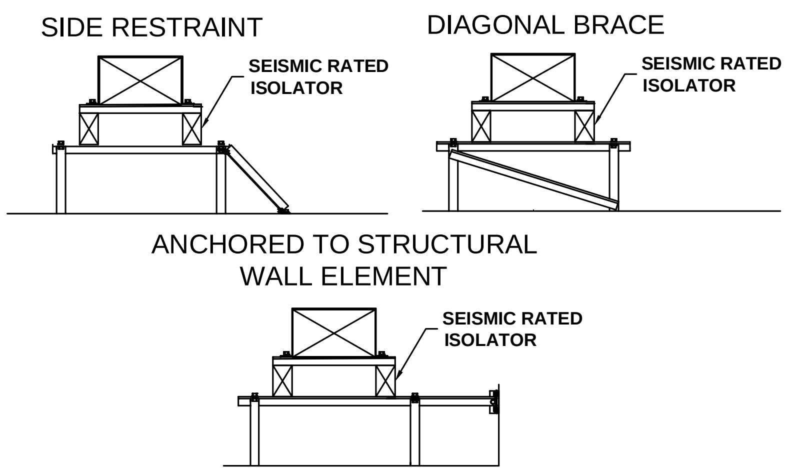


Figure D8.4.3-8; Typical Transverse Restraint Strut Arrangements for Ductwork (Isolated)



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Longitudinal Restraint Examples

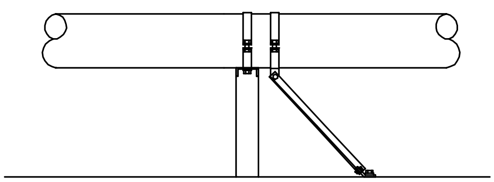
When longitudinally restraining ductwork, a perimeter metal strap or angle tightly screwed to the duct is the most common device used to retain the duct to the support bar. Occasionally welded tabs or connections to flanges are used. (Caution: Connections to flanges should only be used with the flange manufacturer's concurrence that the flange can withstand the seismic forces.) Details on these connections will be addressed in later sections.

Ignoring the details of the connection at this point, common longitudinal restraint arrangements recognized in this manual are illustrated below.

As with the cable restraints, longitudinal restraints offset from the centerline of restrained ductwork will generate additional bending forces in the duct. Because of the nature of ducts, unless restraints are fitted on both sides, there will be an offset. As long as the restraint is immediately adjacent to the duct, it is permissible to use a single restraint point for longitudinal restraint. For cases where multiple ducts are being supported on a common structure, the longitudinal restraint should be between ducts in line with the approximate side-to-side center of gravity location.

Figure D8.4.3-9; Ductwork Longitudinally Restrained with Struts (Non-Isolated)

RESTRAINED
DUCT



RESTRAINED
SUPPORT

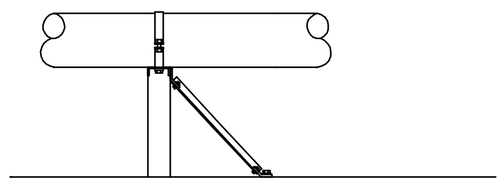
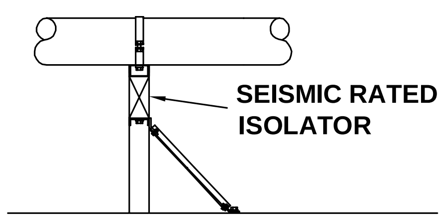


Figure D8.4.3-10; Ductwork Longitudinally Restrained with Struts (Isolated)

RESTRAINED
SUPPORT



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TRANSFERRING FORCES (DUCT RESTRAINTS)

In order for a restraint system to do its job, all elements of the connections need to be sized and installed properly. Because of the large variety and quantity of interfacing conditions in any given installation, piping, duct, and electrical distribution systems are particularly prone to problems in this area.

The next several sections of this manual will deal with specific components used to clamp cable ends together or anchor cables or struts to steel members, wood members, and concrete or masonry. There are several types of connections used for each of these conditions, and each type of connection requires some degree of care and understanding to achieve full capacity.

There are a few general rules that apply when adding restraints to systems. These are listed below along with a few comments meant to provide a basic understanding or rationale.

1) Friction generally cannot be counted on when dealing with dynamic, seismic load conditions. Connections, with the following exceptions, should be positive in nature and not require gravity to ensure their continued long-term operation.

Exceptions:

A) Cable end connections (Swaged ends, U-bolts, and QuakeLocs can be used with appropriate installation procedures).

B) Toothed strut nuts used in conjunction with a purpose-designed strut material (Unistrut, for example). *(Rationale: Permitted friction connections have been well researched and deal with a narrow range of applications. In addition, once properly tightened, the components are such that the likelihood of their coming loose as a result of seismic load conditions is very low.)*

2) Anchors used for the support of overhead equipment cannot also be used for the anchorage of seismic restraints. *(Rationale: The loads used to size hanger rods and anchors are based on the weight loads generated by the Ductwork. Seismic forces can increase the tensile loads significantly, and the combination of loads can cause the anchorage to fail.)*

3) Anchors to concrete must comply with minimum edge distance, spacing, and slab thickness requirements. To achieve full capacity ratings they must further not be installed into a surface containing significant tensile forces. *(Rationale: All anchorage must be in compliance with ICC allowables for seismic applications. Unless otherwise noted, it is assumed that connections are not made to the underside of structural concrete beams.)*

4) Screws attached to wood must comply with minimum edge distance, spacing, and embedment requirements, and must further not be embedded into the end grain of the

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wooden member. *(Rationale: All wood anchorage must be in compliance with NDS allowables for seismic applications. Full capacity can only be achieved with adequate embedment, end, and edge distances into the side grain of structural wood members.)*

5) Connections that have the potential to expose open bar joist chords to significant lateral loads are not permitted. *(Rationale: Open joists are notoriously weak in their lateral axis. They are not designed to take loads, particularly on the lower cord, and even light lateral loads can generate buckling and quickly cause catastrophic failure.)*

6) Connections that have the potential to generate significant lateral loads on the weak axis of I-beams or channels used as joists or columns are not permitted unless approved by the structural engineer of record. *(Rationale: Floor or roof support beams are significantly weaker in their minor axis than in their major axis. While they can, under some conditions, withstand some lateral loads, the engineer of record should be consulted to ensure that capacity exists on particular members to withstand the anticipated loads. If these loads are exceeded, catastrophic failures can quickly result.)*

7) Holes should not be added to key structural members without prior authorization from the engineer of record. *(Rationale: The addition of holes, particularly in flanges, can greatly reduce the structural capacity.*

8) The duct-to-duct connection can become a critical factor in evaluating the performance of the system. Unless otherwise informed, Kinetics Noise Control assumes connections to be of "medium" deformability as defined by the design code. This is generally appropriate for most types of inter-duct connections including proprietary flange systems (but this is subject to verification by others). Often it is desired to use flanges for support or restraint connections in the field. This should not be attempted without the knowledge and permission of the flange manufacturer. *(Rationale: The magnitude of the forces transferred through these connections during a seismic event can far exceed those required for normal use and the potential exists for restraint connections to these flanges to fail causing significant damage to the system.)*

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NON-MOMENT GENERATING CONNECTIONS

The IBC codes allow the omission of seismic restraints for piping, conduit and ductwork runs under many conditions without regard to size but that are located within 12" of the structure. Refer also to section D2 of this manual for specific exemptions by code version. In order to qualify for this, the following parameters must be met:

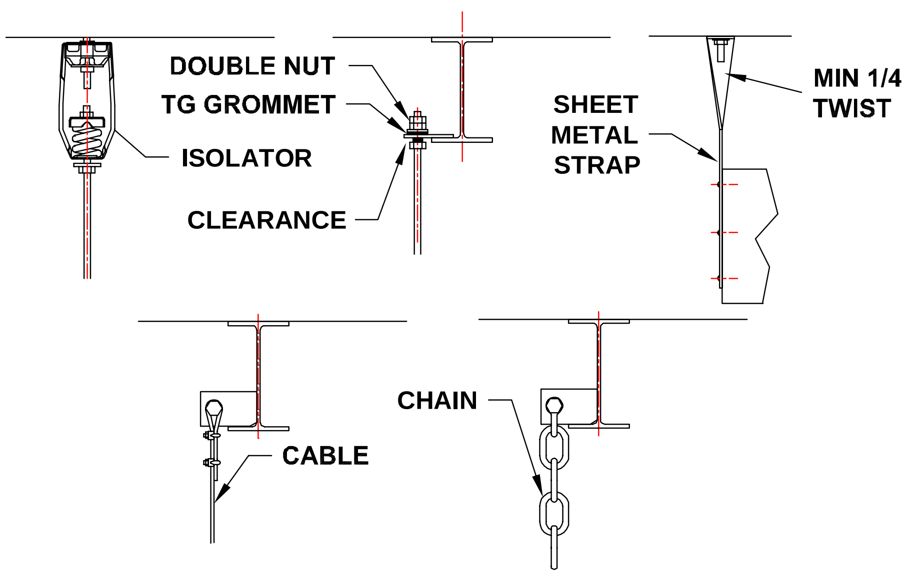
1) The length of **all** supports on the run measuring from the top anchorage point to the connection point to the trapeze bar or the top of a singly supported pipe or conduit run must not exceed 12".
2) Unrestrained free travel of the supported system must be such that over the course of its movement, contact is not made with any other system, component or structural element that can result in damage to either the supported system or the object it hit.
3) The top connection to the structure must include a Non-Moment generating connection to prevent damage to the hanger rod or support strap.

A Non-Moment generating connection is any device that would allow a free flexing action of the hanger rod or support strap for an unlimited number of cycles without its being weakened. This motion must be permitted in any direction.

Shown below are typical examples of acceptable Non-Moment generating connections. Any other device that allows the same freedom of motion is equally acceptable.

A hanger rod rigidly embedded into the underside of a concrete structural slab is not.

Figure D8.5.5-1; Non-moment generating connections



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CONNECTION OPTIONS FOR AWKWARD SITUATIONS

Almost every project will include some areas where installing restraints in a conventional fashion will be difficult. This segment of the manual offers options to consider when confronted with various situations.

D8.6.1 Long, Narrow Hallways

Probably the most common issue in the field is how to deal with transverse restraints in long, narrow hallways. Normally there is considerable congestion in these areas and not enough room to angle restraints up to the ceiling structure. Often the walls are not structural and do not offer a surface to which to anchor.

When evaluating halls, the first issue is to determine if either of the walls of the hall is structural. If either wall is structural, it offers a surface to which the restraints can often be attached. For structural walls, any relative displacement issues between the wall and the structure supporting the pipe must be identified. The maximum permitted relative displacement is ¼ inch, which for most structures corresponds to a difference in elevation of approximately 2 feet (see also the structural attachment section of this chapter).

Assuming the wall meets both of the above requirements, a transverse restraint can be run either directly over to the wall or up at a slight angle to the wall. Normally this would be done with a strut as shown below.

Figure D8.6-1; Trapeze-Mounted Duct Restrained to Structural Wall or Column with a Horizontal Strut

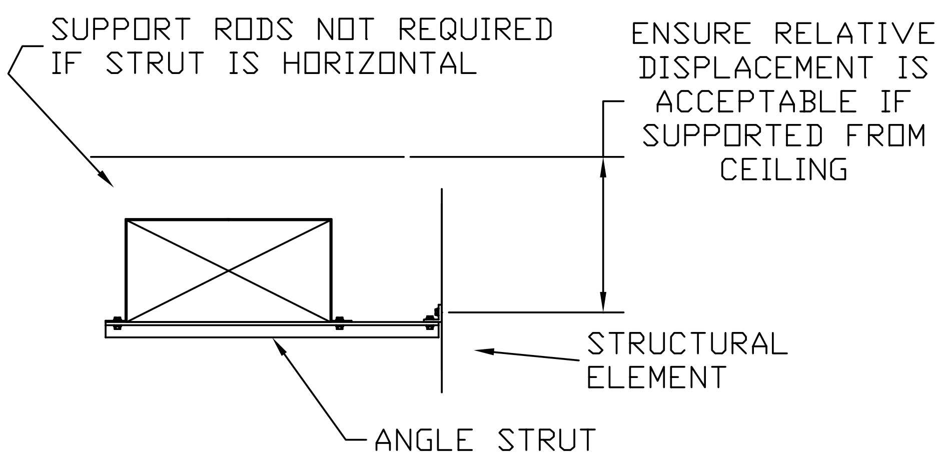

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Figure D8.6-2; Trapeze-Supported Duct Restrained to Structural Wall or Column with an Sloping Strut

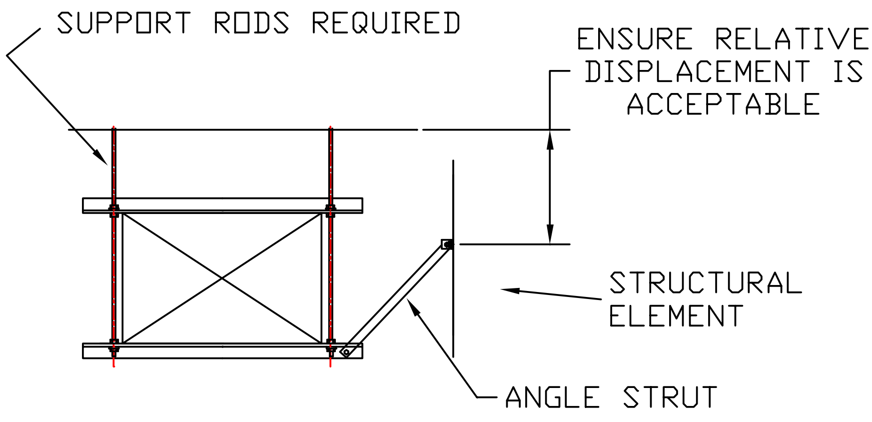
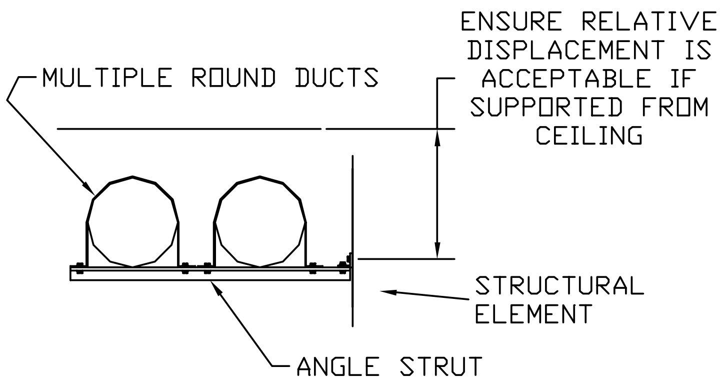


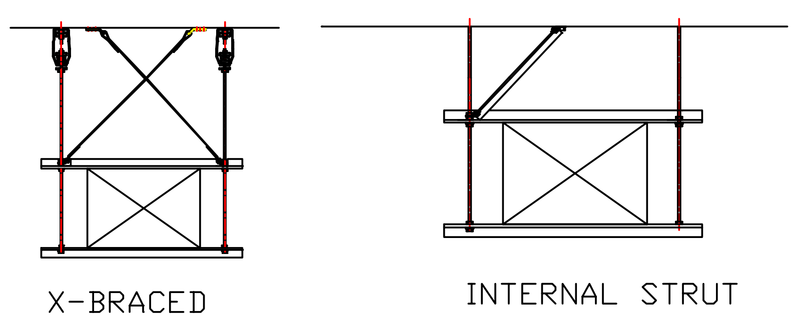
Figure D8.6-3; Clevis-Supported Ductwork Restrained to Structural Wall or Column



For the case where there are no nearby structural connection points or where the nearby structural elements are not suitable, there are several options that can be considered.

The first option is to restrain to the ceiling using "X" bracing or a diagonal strut.

Figure D8.6-4; "X" or Diagonally Braced Restraint Arrangement



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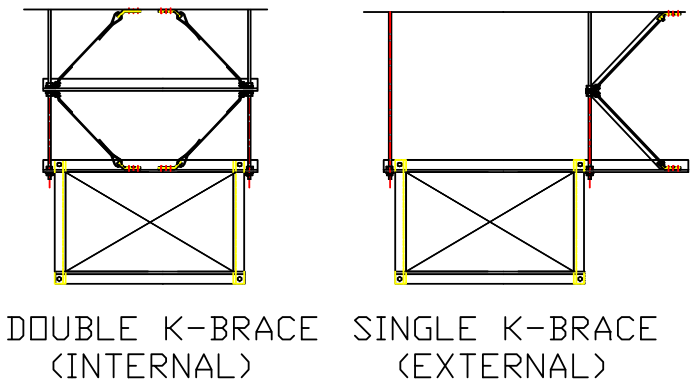
A "K" or double "K" brace can also be used. The "K" can either be located inside the support rods or outside the support rods, but in the case of a double "K", both sides must be identical (either inside or outside).

Figure D8.6-5; Single and Double "K" Brace Restraint Arrangement



In cases where only non-structural walls limit access for restraint, it is frequently possible to penetrate the non-structural wall and shift the lateral restraint device to the opposite side of the wall or partition as shown here.

Figure D8.6-6; Wall Penetration Restraint (Cable)

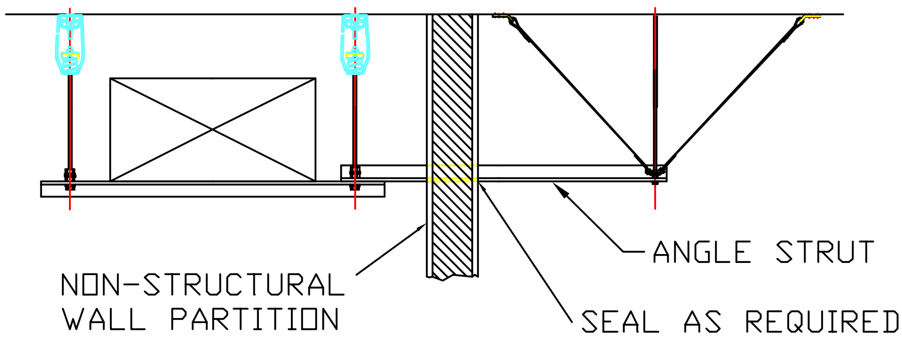
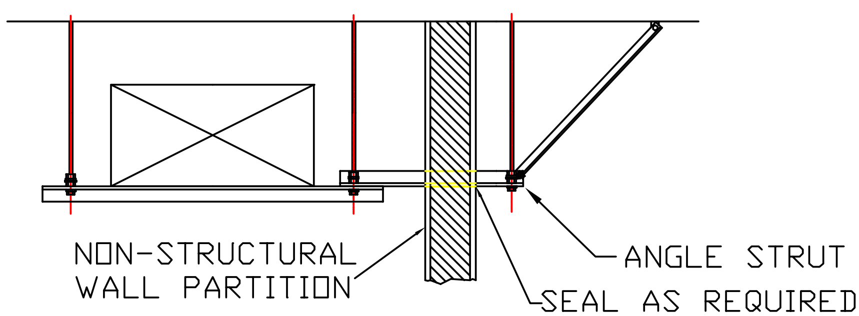


Figure D8.6-7; Wall Penetration Restraint (Strut)



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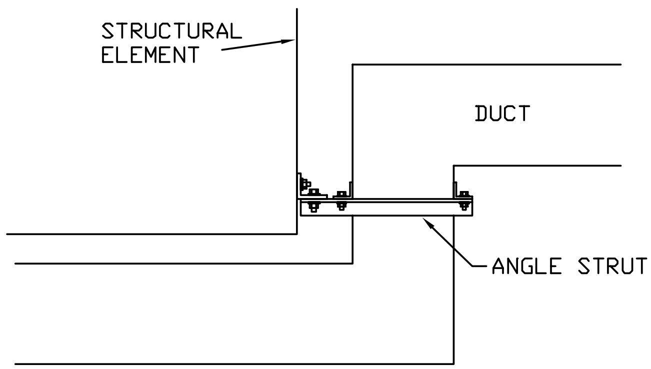
D8.6.2 Axial Restraint Strut at a Dogleg

This arrangement is often a convenient way to connect an axial restraint and can occur both in the horizontal and vertical plane. Often it will be found that when installing ductwork, a jog has been added to a run to avoid running into a column or other structural member. Where this occurs, it offers an easy way to connect an axial restraint.

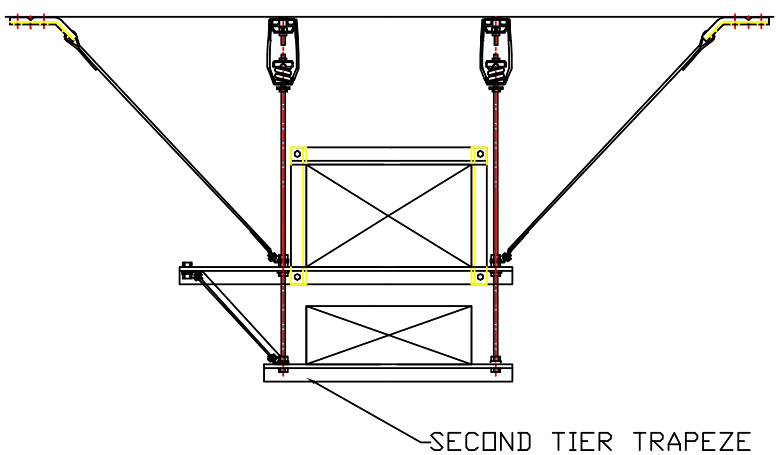
Figure D8.6-8; Axial Restraint Strut at a Dogleg



D8.6.3 Piggyback or Double-Tier Restraint

In congested areas, occasionally there is a double layer of ductwork supported off a single trapeze arrangement. It is possible under some conditions to brace one trapeze bar to the other, and then restrain the second trapeze bar to the structure. If doing this, there are a couple of cautions. First, the restraint capacity for the second trapeze bar must be adequate to restrain the total load from both bars and, second, the ductwork must be similar in nature and ductility.

Figure D8.6-9; Piggyback or Double-Tier Restraint Arrangement



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D8.6.4 Restraints for Ductwork Mounted Well Below the Support Structure

This situation is not easily handled. Past history has shown, and the code is quite clear, that it is not a good idea to support the duct from one structural element and restrain it using another structural element that will undergo significantly different motions. Restraints fit in this fashion will likely fail or cause the supports for the system that is being supported to fail. Neither of these outcomes is desirable..

About the only solution to this is to add a support structure for the ductwork that is located either just above or just below the level of the duct. The ductwork can then be both attached and restrained to this structure.

The structure can be supported off the floor, off the ceiling, or from structural walls or columns. The support structure must be rigid enough to absorb all of the seismic loads, and particularly the moments, with minimal deformation, transferring pure shear or tensile forces into the supports.

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SECTION D9.0 – TABLE OF CONTENTS

D9.0 – Electrical Distribution Systems

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SEISMIC FORCES ACTING ON ELECTRICAL DISTRIBUTION SYSTEMS

When subjected to an earthquake, electrical distribution systems must resist lateral and axial buckling forces, and the restraint components for these systems must resist pullout and localized structural failures.

Most electrical distribution systems are suspended from the deck above on fixed hanger rod systems. They may be supported singly or there may be several pieces of conduit or buss ducts attached to a common trapeze. On some occasions the conduit may run vertically or may be mounted to the floor.

D9.1.1 Suspended Systems

Most codes do not require that electrical distribution supported on non-moment generating (swiveling) hanger rods 12 in or less in length be restrained. The 12 in length was determined based on the natural frequency of systems supported on the short hanger rods. In practice, it has been found that the vibrations generated by earthquakes do not excite these types of systems and, although the systems move back and forth somewhat as a result of an earthquake, they do not tend to oscillate severely and tear themselves apart.

There are also exclusions in most codes for small pieces of conduit, no matter what the hanger rod length. Again, the basis for this exclusion is based on the post-earthquake review of many installations. It has been found that smaller conduit runs are light and flexible enough that they cannot generate enough energy to do significant damage to themselves.

For cases where restraints are required, however, the forces involved can be significant. This is due to the difference between the spacing of the system supports and their restraints. Supports for these systems are typically sized to carry approximately a 10 ft length of conduit or duct (in the case of trapezes, multiple pieces of conduit each approx 10 ft long). Seismic restraints, on the other hand, are normally spaced considerably further apart with the spacing varying by restraint type, restraint capacity, conduit size, and the seismic design load. It is very important to be aware of the impact of the difference in spacing as the wider this spacing, the larger the seismic load when compared to the support load. Guidance in determining restraint spacing requirements is available in Chapter D4 of this manual. (Note when using these tables that conduit should be assumed to be similar in weight and performance to the equivalent pipe size.)

To illustrate this difference, consider a simple example of a single piece of conduit weighing 50 lb/ft being restrained against a 0.2g seismic force with restraints located on 80 ft centers and supports located on 10 ft centers. The load that is applied to the hanger rods by the weight of the conduit is 50 lb/ft x 10 ft or 500 lb each (assuming single rod supports). The horizontal load that occurs at the restraint locations is the total restrained weight (50 lb/ft x 80 ft = 4000 lb) multiplied by the seismic force (0.2g) or 800 lb. Thus the seismic load is larger than the vertical dead load.

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Restraints for suspended systems are normally in the form of cables or struts that run from the conduit up to the deck at an angle. Because of the angle, horizontal seismic loads also generate vertical forces that must be resisted. Therefore, restraint devices must be attached at support locations so that there is a vertical force-resisting member available.

As the angle becomes steeper (the restraint member becomes more vertical), the vertical forces increase. At 45 degrees the vertical force equals the horizontal force and at 60 degrees the vertical force is 1.73 times the horizontal force.

The net result is that for cable systems or for struts loaded in tension, the uplift force at the bottom end of the restraint can be considerably higher than the downward weight load of the conduit. Returning to our example, assume that we have a restraint member installed at a 60 degree angle from horizontal and that the lateral force will load it in tension. In this case, the 800 lb seismic force generates an uplift force of 1.73 x 800 lb or 1384 lb. This is 884 lb more than the support load and, depending upon the support rod length and stiffness, can cause the support rod to buckle. Rod stiffeners are used to protect against this condition and sizing information is available in Chapter D4 of this manual.

Unlike cables, if struts are used for restraint they can also be loaded in compression. In the example above, if the strut were loaded in compression, the 1384 lb load would be added to the support load (trying to pry the hanger rod out of the deck). The total support capacity required would be 1384 lb + 500 lb or 1884 lb. As a consequence, when using struts, the hanger rod must be designed to support 1884 lb instead of the 500 lb maximum generated with cables. Hanger rod sizing information is also available in Chapter D4 of this manual.

D9.1.2 Riser Systems

Where conduit is running vertically in structures, except for the loads directly applied by vertical seismic load components identified in the code, there will be little variation in vertical forces from the static condition. Lateral loads are normally addressed by local anchorage and the spacing between these anchors is not to exceed the maximum tabulated lateral restraint spacing indicated in the design tables in Chapter D4.

D9.1.3 Floor-Mounted Systems

The primary difference between floor- and ceiling-mounted electrical distribution systems is that the support loads in the distribution system support structure are in compression instead of tension (as in the hanger rods). Although a support column and diagonal cables can be used, a fixed stand made of angle or strut is generally preferred. Rules relating to restraint spacing and the sizing information for diagonal struts are the same as for hanging applications.

However, the support legs need to be designed to support the combined weight and vertical seismic load (for a two-legged stand and the example above, 500 lb / 2 + 1384 lb or 1634 lb) in

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compression (Note: 500 lb / 2 is the load per leg for two legs). The anchorage for the legs needs to be able to withstand the difference between the dead weight and the vertical seismic load (in the example above 1384 lb - 500 lb / 2 or 1134 lb).

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BASIC PRIMER FOR SUSPENDED ELECTRICAL DISTRIBUTION SYSTEMS

Failures in electrical distribution systems resulting from earthquakes have historically resulted in loss of building services, are possible fire sources and carry with them the risk of occupant electrocution. While to date, the recorded instances of dollar damage to the building and its contents has been less than that of the building mechanical and electrical systems, the risk exists for serious damage and possible loss of life. In addition, failure of the building's mechanical and electrical systems can render the structure unoccupiable until the damage is corrected, and result in major problems for the tenants and/or owners.

As with the piping and duct systems, requirements for the restraint of electrical distribution systems have also become much more stringent.

Within a building structure, there are multitudes of different kinds of electrical systems, each with its own function and requirements. These include building power, communication, system monitoring, HVAC control to name a few. Requirements for the systems vary based on the criticality of the system and those systems with which it interacts. Code mandated requirements for the restraint of electrical distribution systems are addressed in Chapter D2 of this manual (Seismic Building Code Review).

Prior to applying this section of the manual, it is assumed that the reader has reviewed Chapter D2 and has determined that there is indeed a requirement for the restraint of the system. This chapter of the manual is a "how to" guide and will deal only with the proper installation and orientation of restraints and not whether or not they are required by code or by specification.

This chapter also does not address the sizing of restraint hardware. Chapter D4 includes sections on sizing componentry based on the design seismic force and the weight of the system being restrained.

Process electronics that are not directly associated with building operating systems may have their own set of requirements that should be addressed separately. High voltage electrical systems, whether building or process related should be restrained per code requirements. If there are no applicable special requirements, all systems should be restrained in a similar fashion to the building mechanical systems. This manual will not address any special requirements.

Building electrical systems must be restrained per code. Refer to the code review chapter (D2) of the manual for applicable design requirements.

In many cases, conduit can be excluded from restraint if it is small enough in size or mounted in close proximity to the ceiling structure. When applying this exemption, current codes require

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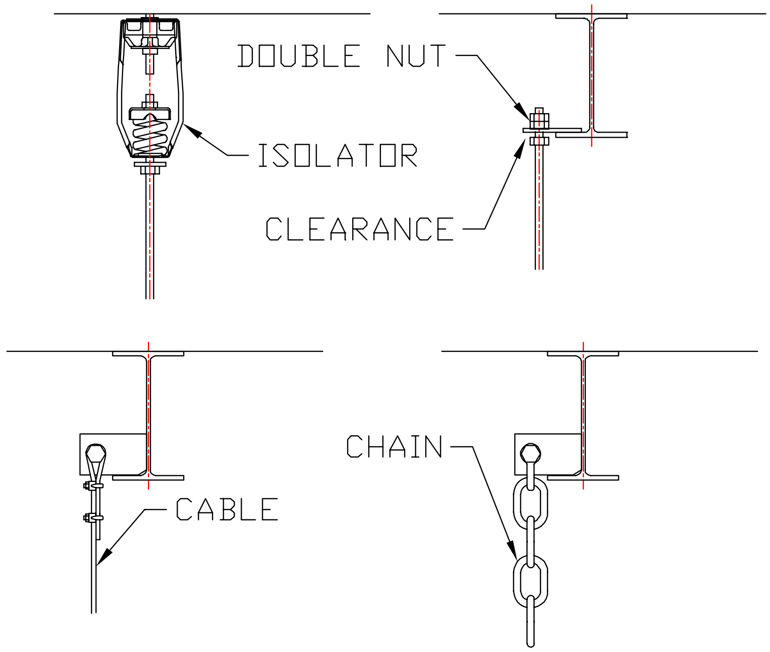
the installation of a "non-moment generating connection" at the top anchorage point. This term is often confusing and deserves further clarification. A "non- moment generating connection" is one that will allow the supported pipe to swing freely in any direction if acted on by an outside force. Some examples of "non-moment generating connections" are illustrated below.



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PROS AND CONS OF STRUTS VERSUS CABLES

Both cables and struts have their place in the restraint of conduit and other electrical distributions systems. In order to minimize costs and speed up installation, the differences between the two should be understood.

In general, distribution systems restrained by struts will require only 1 brace per restraint location while systems restrained with cables requires that 2 cables be fitted forming an "X" or a "V". As a trade-off, the number of restraint points needed on a given run of conduit or distribution ducts will typically be considerably higher for a strut-restrained system than for the cable-restrained system and, generally, strut-restrained systems will be more costly to install.

An added factor to consider when selecting a restraint system is that once a decision is reached on the type to use for a particular run, code requirements state that the same type of system must be used for the entire run (all cable or all strut). Later sections in this chapter will define runs, but for our purposes at present, it can be considered to be a more or less straight section of piping.

The obvious advantage to struts is that, when space is at a premium, cables angling up to the ceiling on each side of a run may take more space than is available. Struts can be fitted to one side only, allowing a more narrow packaging arrangement.

The advantages of cables, where they can be used, are numerous. First, they can usually be spaced less frequently along a distribution run than can struts. Second, they cannot increase the tensile forces in the hanger rod that results from the weight load, so rod and rod anchorage capacities are not impacted. And third, they are easily set to the proper length.

To better explain the differences between the systems, it is necessary to look at how seismic forces are resisted with cables and struts. Shown below are sketches of both a cable-restrained and strut-restrained piece of conduit.

Figure D9.3-1; Cable Restrained Conduit

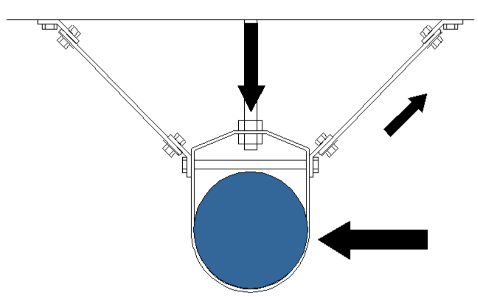

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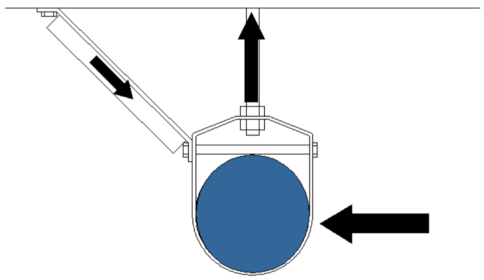
Figure D9.3-2; Strut Restrained Conduit



The key factor to note is that cables can only be loaded in tension. This means that seismic forces can only generate compressive loads in the hanger rod. Seismic forces can, however, load the strut in compression resulting in a tensile load on the hanger rod.

This tensile load is in addition to any deadweight load that may already be supported by the hanger and is often significantly higher than the original load. This has the potential to rip the hanger rod out of the support structure and must be considered when sizing components.

Because of this added tensile component and the resulting impact on the necessary hanger rod size, most strut manufacturers limit the maximum allowable strut angle (to the horizontal) to 45 degrees. This is lower than typical allowable angles for cables that often reach 60 degrees from the horizontal. Although the data provided in Section D4.4 of this manual allow the use of higher angles for strut systems, users will find that the penalties in hanger rod size and anchorage will likely make these higher angles unusable in practice. To put this into context, examples will be provided at both 45 degrees and 60 degrees from the vertical to indicate the impact on capacity that results from the angle.

For a 45 degree restraint angle, if we assume a trapeze installation with the weight (W) equally split between 2 supports, the initial tension in each support is 0.5W. Using a 0.25g lateral design force (low seismic area), the total tensile load in a hanger increases to 0.75W for bracing on every support and 1.0W for bracing on every other support, if a strut is used.

For reference, if struts are used in a 60 degree angle configuration (from the horizontal), the tensile force in the hanger rod for all cases increases by a factor of 1.73 *(tan 60)* over that listed in the previous paragraph. This means that the tensile force becomes .94W for bracing on every support and 1.36W for bracing on every other support.

On the other hand, where 0.25g is applicable, buckling concerns in conduit are such that the spacing between lateral restraints can be as high as 40 ft and for axial restraints, 80 ft. If we were to try to use struts placed at a 40 ft spacing in conjunction with supports spaced at 10 ft, the tensile force developed by a seismic event in the rod increases to 1.5W for 45 degree configurations and to 2.23W for 60 degree configurations.

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As mentioned earlier, there is no increase in the rod forces for cable restrained systems.

Using real numbers based on a 40 ft restraint spacing and a 60 degree angle configuration, if the peak tensile load in the hanger rod is 500 lb for a cable restrained system, it becomes 2230 lb for an otherwise identical strut restrained system.

A summary of the above data, based on a 500 lb weight per hanger rod (1000 lb per trapeze bar) and including concrete anchorage sizes and minimum embedment is shown below.

Table D9.3-1; Hanger Rod Tensile Loads

Summary of Hanger Rod Tensile Loads based on 500 lb per Rod Weight				
	Tens Force (lb)	Min Rod (in)	Min Anc (in)	Embed (in)
Every Hanger Braced (10')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	750	0.38	0.38	3.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	933	0.50	0.50	4.00
Every other Hanger Braced (20')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	1000	0.50	0.50	4.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	1365	0.50	0.63	5.00
Every fourth Hanger Braced (40')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	1500	0.63	0.63	5.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	2230	0.63	0.75	6.00
Max Spacing between Braces (80')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	2500	0.75	0.75	6.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	3960	0.88	1.00	8.00

Note: The above anchorage rating is based on ICC allowables only. Often the underside of a concrete floor slab is in tension and if this is the case, the anchorage capacity may need to be further de-rated (forcing the need for an even larger hanger rod than is indicated here).

The net result is that the ability to use struts is highly dependent on the hanger rods that are in place. If these were sized simply on deadweight, the added seismic load, even in relatively low seismic areas, can quickly overload them. The only recourse is to either replace the hanger rods with larger ones or decrease the restraint spacing to the point at which virtually every support rod is braced.

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It should also be noted that the hanger rods in tension become seismic elements. This occurs with struts, but does not with cables. As a result, the system must comply with all of the anchor requirements specified by ICC. This includes the use of seismically rated anchors and embedment depths that are in conformance with ICC requirement for those types of anchors. With larger anchor sizes, floor slab thickness may cause this to become a significant problem.

With both cables and struts, the hanger rods can be loaded in compression. As the seismic force increases, it eventually overcomes the force of gravity and produces a buckling load in the hanger rod. It is mandatory in all cases that the rod be able to resist this force.

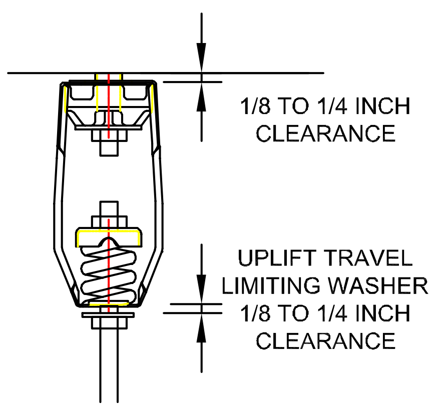
There is a wide range of variables involved in determining the need for rod stiffeners to resist this buckling load. Factors that impact this need are 1) the magnitude of the compressive force, 2) the weight load carried by the hanger rod, 3) the length of the hanger rod, 4) the diameter of the hanger rod, and 5) the angle between the restraint strut or cable and the horizontal axis.

Charts are included in Section D4.4 of this manual that allow the user to determine if there is a need for a stiffener and to allow the proper selection if required.

In rare instances, electrical distribution systems are isolated. In these cases and because uplift occurs, some attention must be given to the isolator itself. First, when using isolators, the location of the isolation element needs to be at the top end of the hanger rod (close to, but not tight against the ceiling). If placed at the middle of the hanger rod, the rod/isolator combination will have virtually no resistance to bending and will quickly buckle under an uplift load.

Second, a limit stop must be fit to the hanger rod, just beneath the hanger such that when the rod is pushed upward a rigid connection is made between the hanger housing and the hanger rod that prevents upward motion. This is accomplished by adding a washer and nut to the hanger rod just below the isolator (see the sketch below).

Figure D9.3-3; Installation for an Isolation Hanger in a Seismic Application



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REQUIREMENTS FOR DISTRIBUTION SYSTEM RESTRAINTS DEFINITIONS AND LOCATING REQUIREMENTS

There are a number of design guides that have been developed over the years but the one with the longest history and most widely accepted is SMACNA. They have developed a handbook that offers conservative guidance that an end user can reference in selecting and installing restraints for distribution systems. While the information provided in that handbook is good, it suffers from a couple of inherent drawbacks. The first is that because it is linked to generically available hardware, the ratings that are assumed for the various hardware components are the lowest of any of the many possibilities available in the marketplace. The net result is that the suggested hardware is larger in general than that which could be used if higher quality componentry it specified. The second is that their presentation of the results is extremely cumbersome and difficult to use.

While the criteria presented in this document is based on the guidance offered by SMACNA, it has been possible to increase the component ratings as the actual capacity, type and manufacture of these components is clearly known. In addition, based on a critical review of the data presentation in the SMACNA handbook, it has been possible to greatly simplify the method of selection making the end result much simpler to use.

With respect to the conceptual restraint arrangement illustrations, the SMACNA concepts are appropriate and are referenced here.

In general, conduit and other components used for electrical distribution are restrained in lengths called “runs.” Therefore before getting into a detailed review of the restraint systems it is imperative that a definition of “run” as well as other key terms be addressed.

D9.4.1-1 Definitions

Axial In the direction of the axis of the run.

Lateral Side to side when looking along the axis of the run.

Pipe or Conduit Clamp A heavy duty split ring clamp tightened against the conduit to the point that it can be used to control the axial motion of the conduit, tray or duct.

Restraint Any device that limits the motion of a conduit or duct in either the lateral or axial direction.

Run A more or less straight length of conduit or duct where offsets are limited to not more than S/16 where S is the maximum permitted lateral restraint spacing (a function of conduit or duct size and seismic forces) and the total length is greater than S/2. (Note: S dimensions for various conditions are listed in Chapter D4.)

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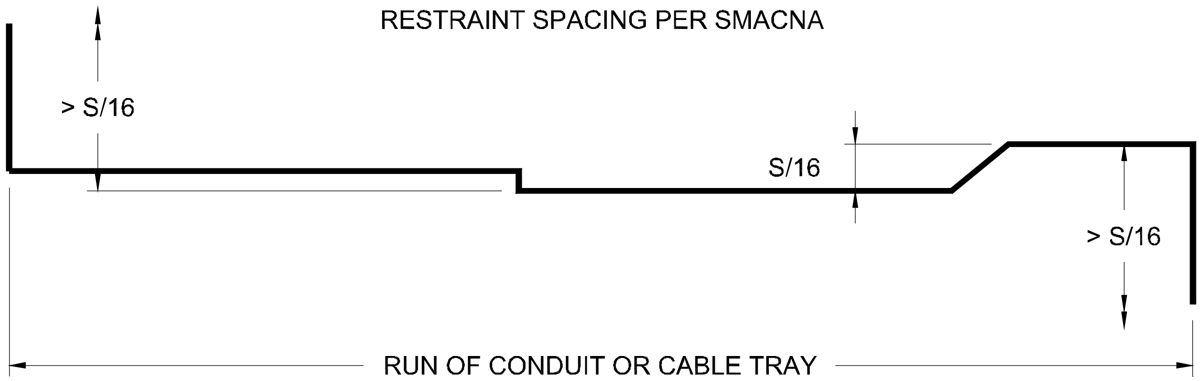
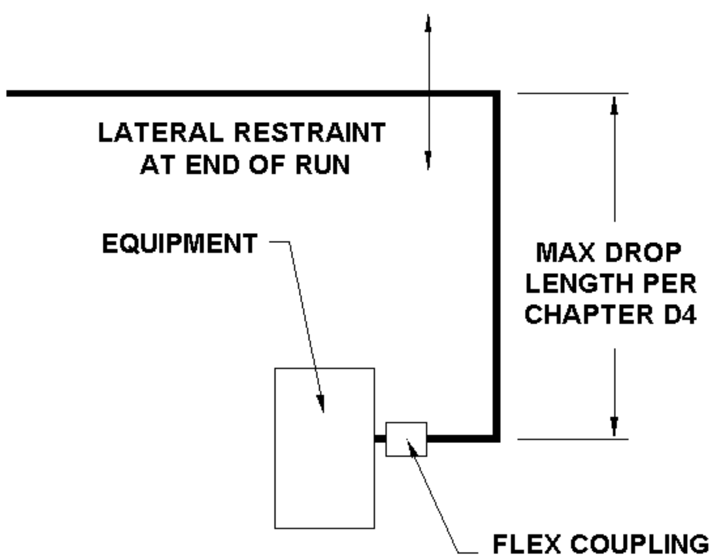
Figure D9.4.1-1; Definition of a "Run" of Duct



Short Run A run as defined above where the total length is less than S/2 and where it is connected on both ends to other runs or short runs.

Drop A length of conduit that normally extends down from an overhead distribution system and connects to a piece of equipment, usually through some type of flex connector. The drop can also extend horizontally. In order to qualify as a drop, the length of this conduit must be less than S/2. If over S/2, the length of conduit would be classified as a run.

Figure D9.4.1-2; Definition of a "Drop"



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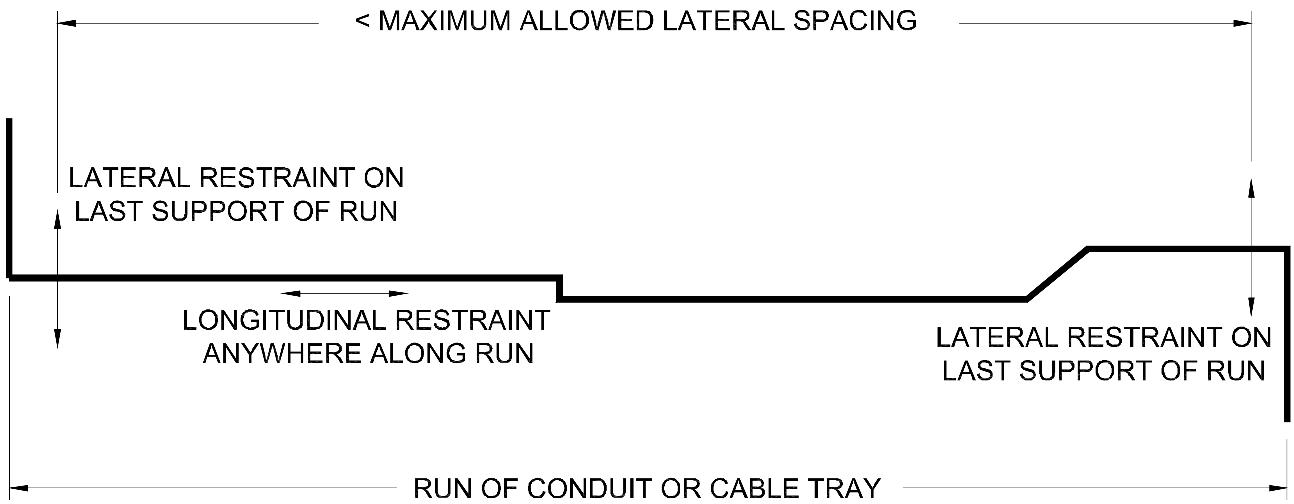
D9.4.1-2 Restraint Requirements

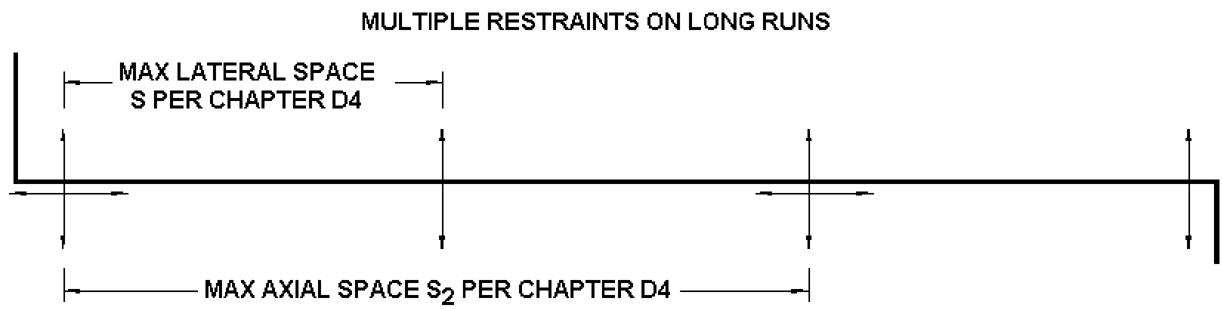
1) Full runs greater in length than S/2) must be restrained in both the axial and lateral direction. If the run is not a short run or a drop, it must, as a minimum, be laterally restrained at the last support location on each end.

Figure D9.4.1-2; Basic Restraint Requirements for a Typical "Run" of Conduit



2) If a run is longer than "S", intermediate restraints are required to limit the spacing to that permitted by the building code (see table in Chapter D4).

Figure D9.4.1-3; Basic Restraint Requirements for a Long "Run" of Conduit



3) Axial restraints attached to the run of conduit along its length must be connected using a conduit clamp (as previously defined).

4) Short runs or drops need only have one lateral and one axial restraint.

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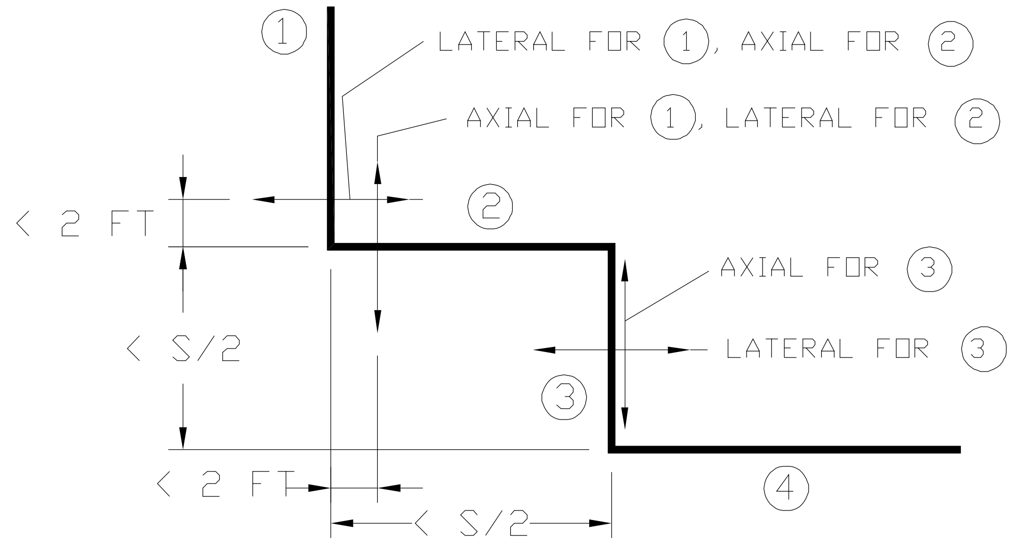
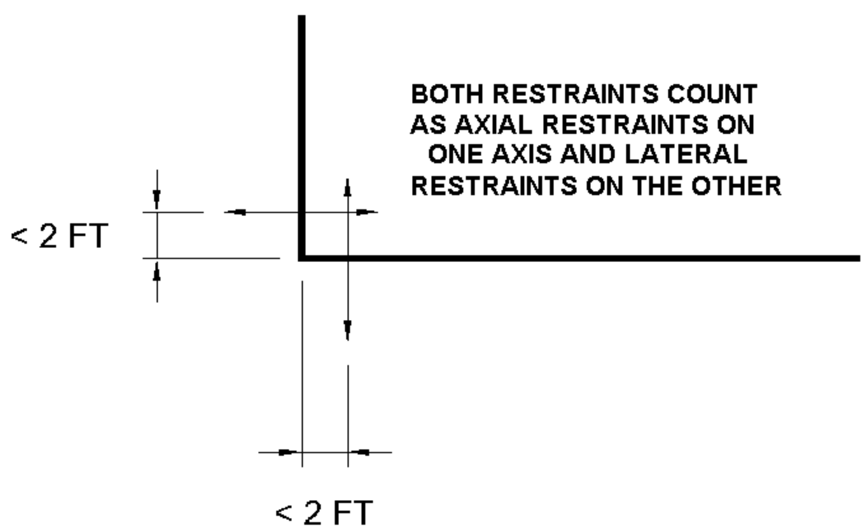
Figure D9.4.1-4; Basic Restraint Requirements for Multiple Short "Runs" of Conduit



5) If a lateral restraint is located within 2 feet of a corner (based on a measurement to the conduit or duct centerline), it can be used as an axial restraint on the intersecting run.

Figure D9.4.1-5; "Double Duty" for Corner Restraints



6) Larger trays or conduit cannot be restrained with restraints located on smaller branch runs.

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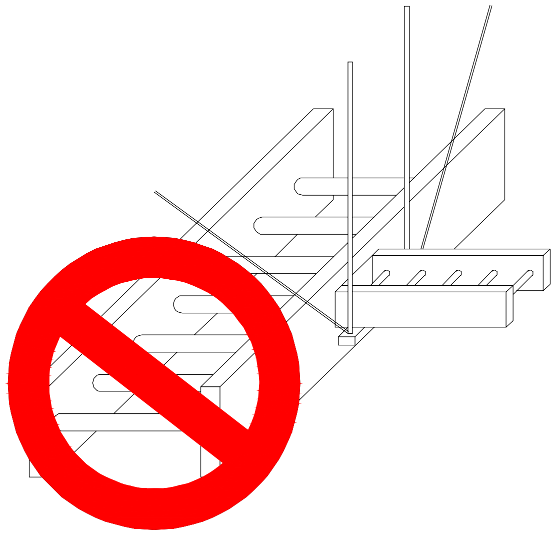
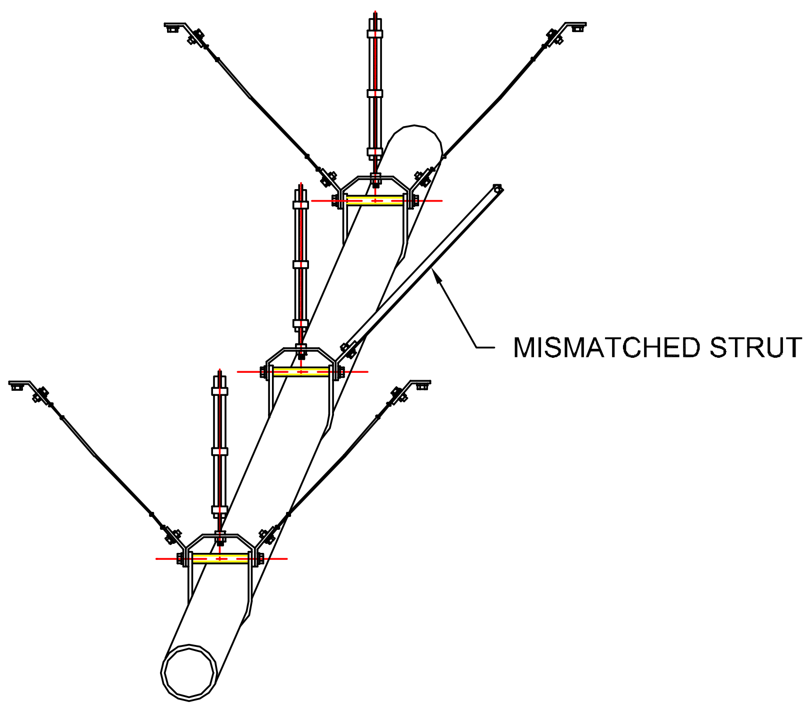
Figure D9.4.1-6; Do not Restrain Larger Electrical Runs with Restraints on Smaller Ones



7) Within a run, the type of restraint used must be consistent. For example, mixing a strut with cable restraints is not permitted.

Figure D9.4.1-7; Mismatched Struts and Cable Restraints



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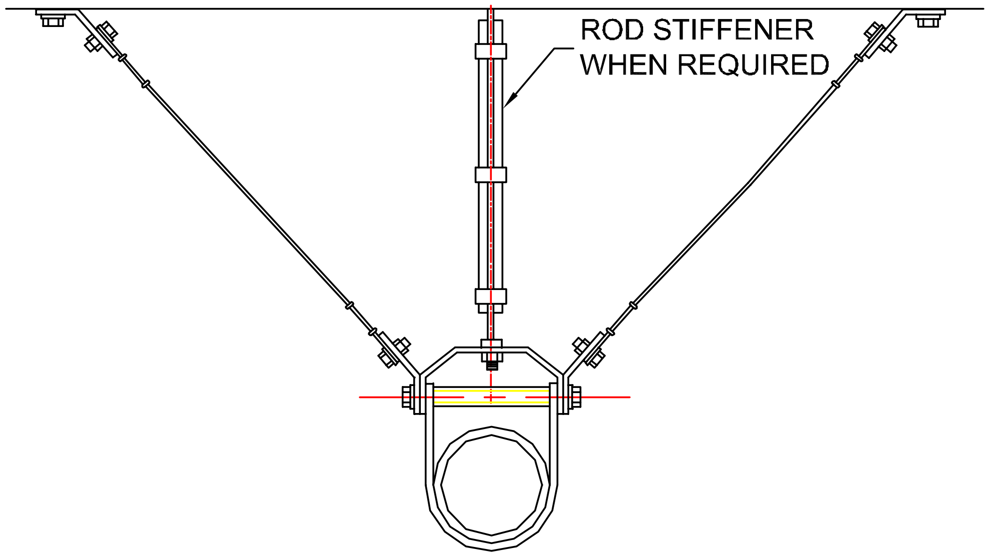
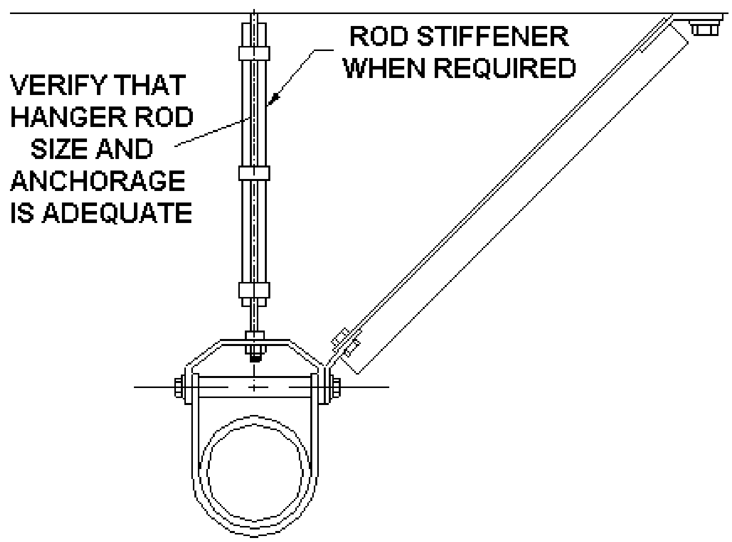
8) With longer hanger rods, rod stiffeners are likely to be required. Refer to the appropriate table in Chapter D4 to determine: (1) if needed, (2) what size stiffener material is appropriate, and (3) how frequently it needs to be clamped to the hanger rod.

Figure D9.4.1-8; Rod Stiffener



9) In addition to possibly requiring rod stiffeners, when struts are used to restrain conduit, the size of the hanger rod and its anchorage also become critical. Again refer to the appropriate table in Chapter D4 to determine the minimum allowable size for the hanger rod and anchor.

Figure D9.4.1-9; Hanger Rod Sizing (For Strut Applications)



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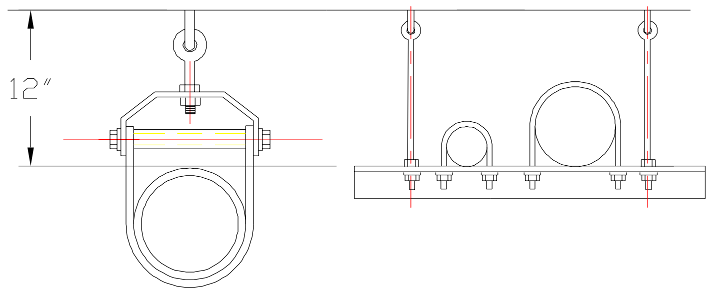
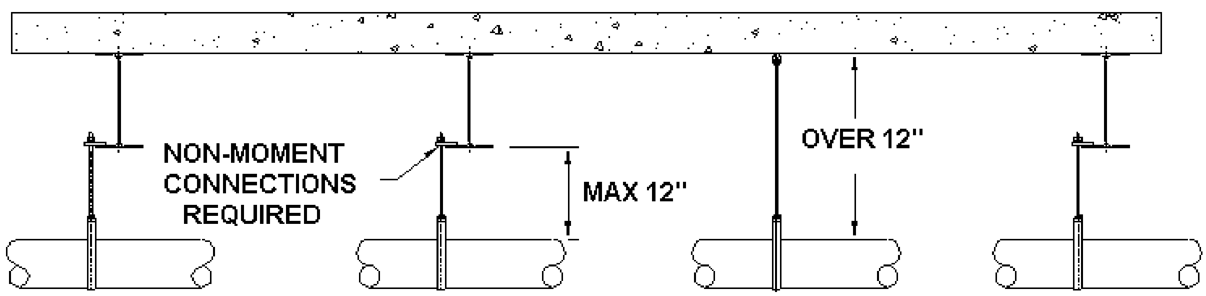
10) In some cases, it may be possible to locate the electrical distribution system close enough to the support structure (12") to eliminate the need for restraint. (Refer to the building code review chapter (D2) to determine if this exemption is applicable.) If it is applicable, the 12" dimension is measured as shown below.

Figure D9.4.1-10; 12" Hanger Rod Exemption



11) When using the above rule it is critical that all support locations in a run conform. If even one location exceeds 12", the run cannot be exempted from restraint.

Figure D9.4.1-11; Run Fails the Consistency Requirement for 12" Exemption



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CEILING-SUPPORTED ELECTRICAL DISTRIBUTION SYSTEM RESTRAINT ARRANGEMENTS

Although the basic principle of diagonal bracing is almost always used to design restraint systems, the actual arrangement of these systems can vary significantly. Despite what looks like substantially different designs, the design forces in the members remain the same, and the same rules apply when sizing components. Illustrated here are many different restraint arrangements, all of which can be used in conjunction with the design "rules" provided in this manual.

It is assumed in this section that all conduit is rigid. For non-rigid conduit and if the conduit is large enough to require restraint, adequate hardware to accomplish this task is required at each support location.

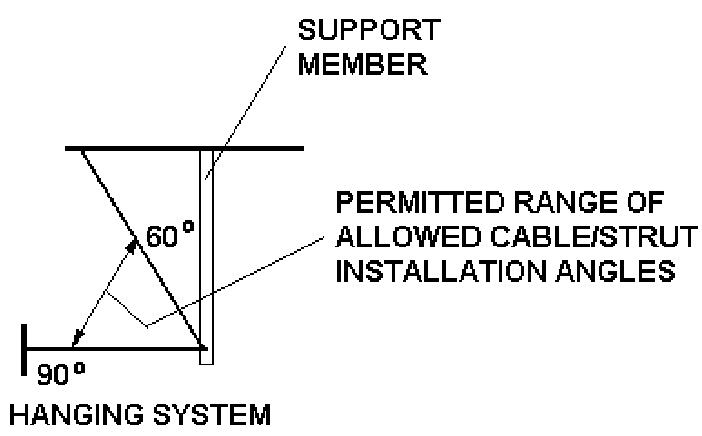
Details of the end connections and anchorage hardware are shown in subsequent sections of the manual. It is assumed in this manual that the restraint component is attached to a structural element capable of resisting the design seismic load.

Due to variations in the installation conditions such as structural clearance, locations of structural attachment points, and interference with other pieces of equipment or systems, there will likely be significant benefits to using different arrangements in different locations on the same job.

<u>The only significant caution here is that it is not permissible to mix struts and cables on the same run.</u>

This manual addresses diagonal bracing slopes of between horizontal and 60 degrees from the horizontal. Angles in excess of 60 degrees to the horizontal are not permitted.

Figure D9.4.2-1; Permissible Restraint Angles



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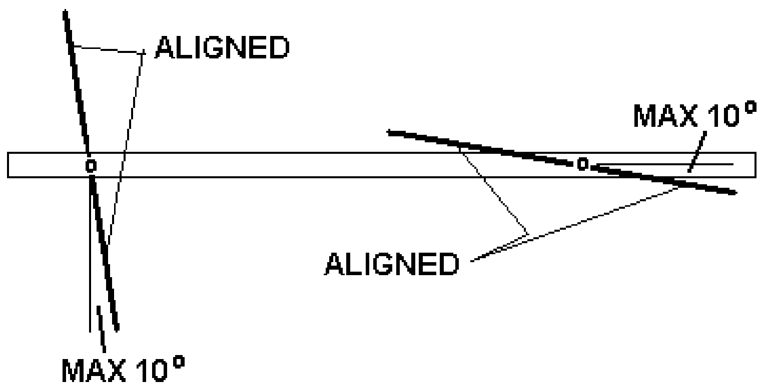
When installing restraints, lateral restraints should be installed perpendicular (±10 degrees) to the run in plan. Axial restraints should be in line with the run, ±10 degrees, again in the plan view. All restraint cables should be aligned with each other. See the sketch below.

Figure D9.4.2-2; Restraint Alignment



Lateral Restraint **Axial Restraint**

In general, when restraining electrical distribution systems and conduit the component actually being restrained is the system support device. This may be a clevis, a clamp, or a trapeze bar. Because the goal is to restrain the actual cable tray, duct or piece of conduit, it is necessary that the restrained element be connected in such a way as to transfer the appropriate forces between the two. For example, if an axial restraint is installed on a trapeze bar which in turn supports a piece of conduit that is not clamped in place, it is obvious that the axial forces generated by the conduit cannot be restrained by the connection to the trapeze bar. Some other arrangement is needed.

Based on the Maximum Horizontal Force requirement, the appropriate size and quantity of fasteners to connect ducts to support/restraint members is as follows:

Force (Lbs)	250	500	1000	2000	5000	10000
#10 Screw	3	5	10	20		
Force (Lbs)			3	6	20	40

When firmly connecting restraints to cable trays, ducts or conduit there are a few general rules that should be followed:

1) A conventional pipe or conduit clevis hanger cannot restrain a piece of conduit in the axial direction.
2) Trapeze-mounted ducts, trays and conduit should be tightly connected to the trapeze bar.

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3) If a tray or duct is used and it is mounted with the long dimension in the horizontal plane, the maximum spacing for restraints should be based on the allowable spacing for a pipe of a diameter equal to the tray's long axis dimension.
4) If a tray or duct is used and it is mounted with the short dimension in the horizontal plane, the maximum spacing for restraints should be based on the allowable spacing for a pipe of a diameter equal to the tray's short axis dimension.

In addition, when sizing restraint components for multiple pieces of conduit, the total weight of all the restrained conduit must be considered.

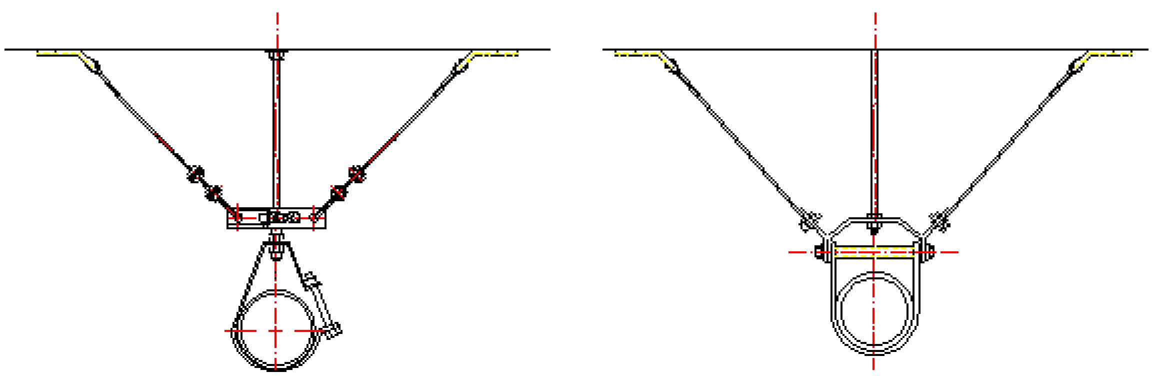
D9.4.2.1 Hanging Systems Restrained with Cables

Hanging systems may include supports for single or multiple conduit runs, buss ducts or cable trays. Single conduit runs can be supported using clevis hangers but wherever multiple items are used, they are normally supported on trapeze bars.

Lateral Restraint Examples

For a cable-restrained conduit supported by a hanger clevis, there are two options for non-isolated installations. Since the isolation of conduit is rare, it will not be addressed here, but would be similar to the isolated arrangements for piping and ductwork shown in the previous two chapters. These non-isolated options are shown below.

Figure D9.4.2-3; Lateral Cable Restraints used with a Gauge Material Ring Clamp



There are many options that exist for the arrangements of lateral restraints used in conjunction with trapeze-mounted systems. Shown below are several options for cable-restrained systems.

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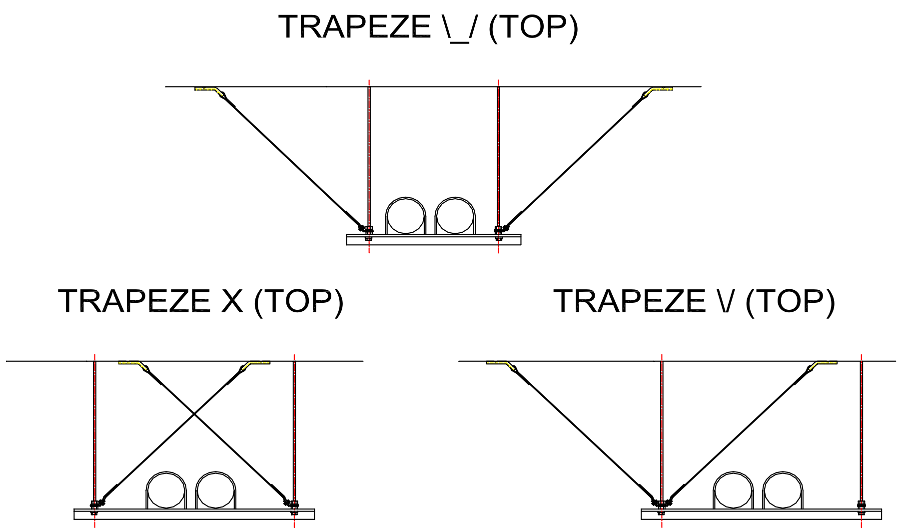
Figure D9.4.2-5; Lateral Cable Restraints Mounted to a Trapeze

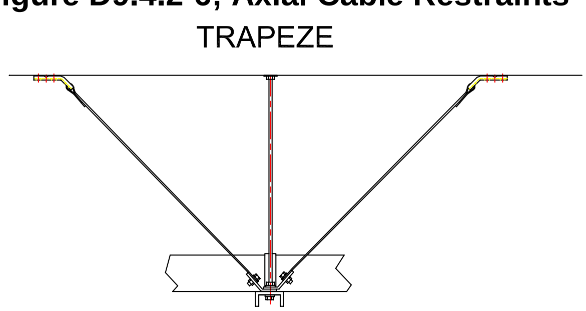


Axial Restraint Examples

Axial restraints cannot be connected to a standard clevis and be expected to work. This is because there is inadequate friction between the bracket and the conduit to transfer the forces in the conduit to the restraint. When axially restraining conduit, a trapeze or conduit clamp tightly attached to the conduit is the most common connecting device used. Details on these connections will be addressed in later sections.

Axial restraints offset from the centerline of restrained electrical run will generate additional bending forces in the tray or bus. Because of the nature of these components, unless restraints are fit on both sides, there will be an offset. Because these components are relatively fragile, the use of a single axial restraint offset from the center of the run is not recommended. For cases where multiple electrical runs are being supported on a common structure, the axial restraint should be between components in line with the approximate side-to-side center of gravity location.

Figure D9.4.2-6; Axial Cable Restraints



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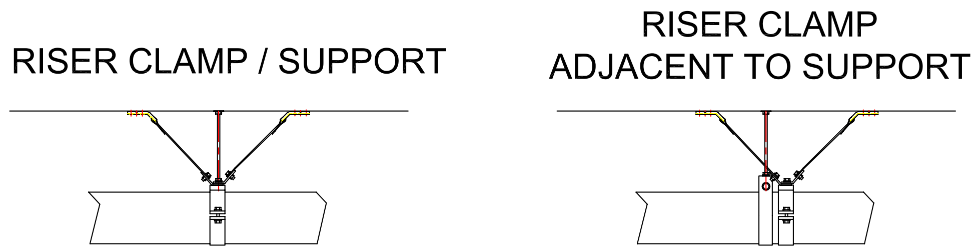

D9.4.2.2 Hanging Systems Restrained with Struts

As with cable restraints, hanging systems may include supports for single pieces of conduit, multiple conduit runs or a mixture of cable trays, ducts and conduit. Single conduit arrangements can be supported using a clevis or conduit hanger, but multiple components are normally supported on trapeze bars.

Lateral Restraint Examples

For a strut-restrained conduit supported by a hanger clevis there are two typical options. One is to connect the restraint to the clevis bolt and the other is to connect the restraint to the hanger rod. These are shown below.

Figure D9.4.2-7; Typical Lateral Restraint Strut Arrangements for Clevis-Supported Conduit

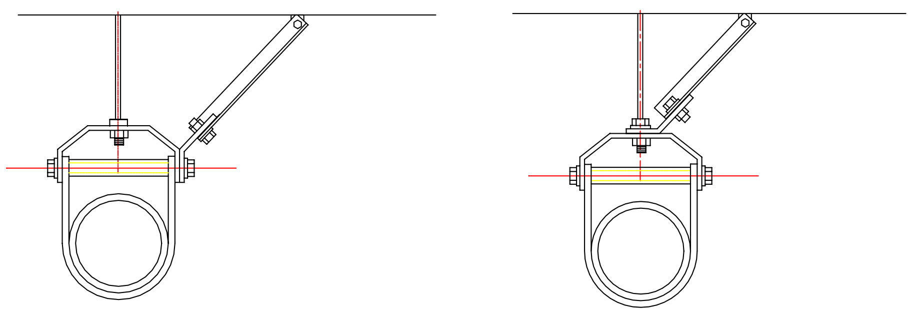

Figure D9.4.2-8; Shown below are 3 options for trapeze-supported conduit. All are equivalent.

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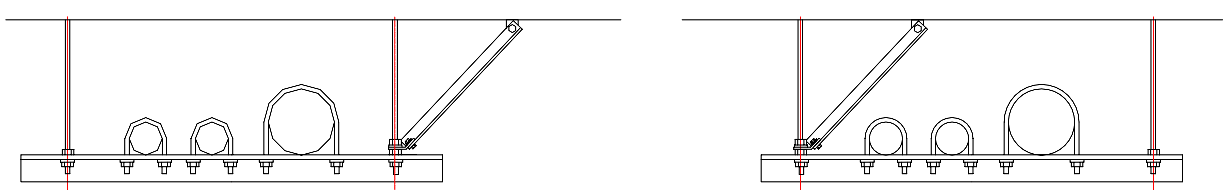

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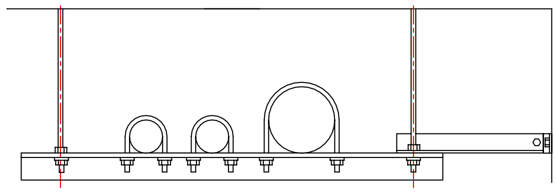


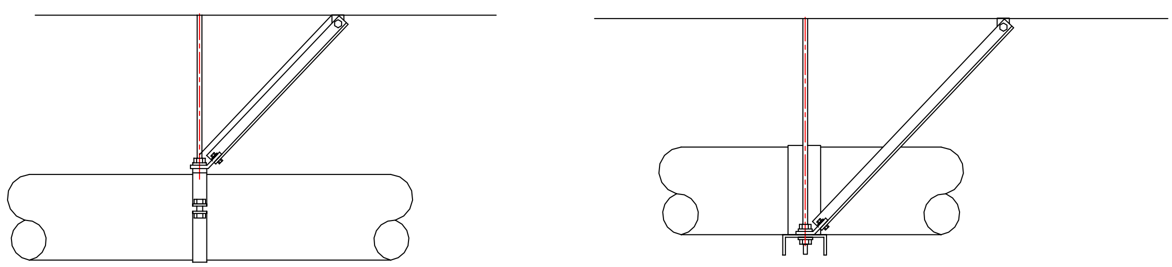
Axial Restraint Examples

As with cables, axial restraints using struts cannot be connected to a standard clevis and be expected to work. When axially restraining conduit, a trapeze or conduit clamp tightly attached to the conduit is the most common connecting device. It may however be possible to attach the restraint to a connector fitting in some cases.

Ignoring the details of the connection at this point, common axial restraint arrangements recognized in this manual are illustrated below.

As with the cable restraints, it must be recognized that axial restraints offset from the restrained run will generate additional bending forces in the duct, tray or conduit itself. This is true whether mounted to one end of a trapeze or along side a single piece of conduit rather than directly on its center. When the restraint is offset, the maximum permissible offset from the center of the conduit is not to exceed 1 times the conduit diameter. For duct or tray installations, the maximum offset (from the centerline) cannot exceed the width dimension of the tray or duct. For trapezed systems supporting multiple components, a single axial restraint should be located at the approximate center of the trapeze bar or pairs of axial restraints should be installed on each end of the trapeze bar.

Figure D9.4.2-10; Electrical Distribution systems axially restrained with Struts



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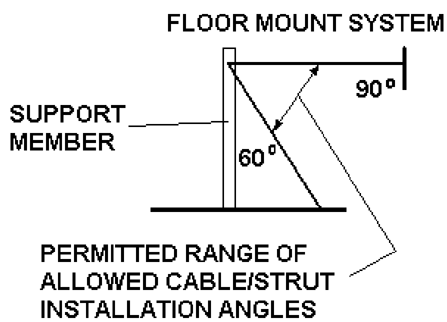
FLOOR OR ROOF SUPPORTED ELECTRICAL SYSTEM RESTRAINTS

Although the basic principle of diagonal bracing is almost always used to design restraint systems, the actual arrangements of these systems can vary significantly. Despite what looks like substantially different designs, the design forces in the members remain the same, and the same rules apply when sizing components. Illustrated here are many different floor- and roof-mounted restraint arrangements, all of which can be used in conjunction with the design "rules" provided in this manual.

Details of the end connections and anchorage hardware are shown in subsequent sections of this manual. It is assumed in this manual that the restraint component is attached to a structural element capable of resisting the design seismic load.

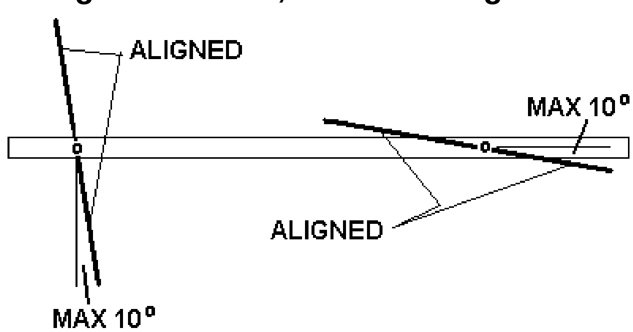
This manual addresses diagonal bracing oriented between horizontal and 60 degrees from the horizontal. Angles in excess of 60 degrees to the horizontal are not permitted.

Figure D9.4.3-1; Permissible Restraint Angles



When installing restraints, lateral restraints should be installed perpendicular (±10 degrees) to the conduit or tray in the plan view. Axial restraints should be in line with the conduit or tray (±10 degrees) again in the plan view. All restraint cables should be aligned with each other. See the sketch below.

Figure D9.4.3-2; Restraint Alignment



Lateral Restraint **Axial Restraint**

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In general, when restraining conduit or trays, the component actually being restrained is the support device for the system. For floor-mounted equipment this would normally be either a fabricated frame or a trapeze bar. Because the goal is to restrain the actual conduit or tray, it is necessary that the restrained element be connected to the conduit or tray in such a way as to transfer the appropriate forces between the two. For example, if an axial restraint is installed on a trapeze bar which in turn supports a conduit or tray that is not clamped tightly to it, it is obvious that the axial forces generated by the conduit or tray cannot be restrained by the connection to the trapeze bar and some other arrangement is needed.

With respect to firmly connecting restraints to conduit or tray, there are a few general rules that should be followed:

1) For Axial restraints, conduit clamps must be heavy duty and must be tightly clamped against the conduit itself.
2) If the pipe is wrapped or covered with a material that can reduce the clamps ability to grip it, the material must be removed or hardened to the point that positive clamping action can be assured.
3) Trapeze-mounted conduit or trays should be tightly clamped or bolted to the trapeze bar.

In addition, when sizing restraint components that affect multiple components, the total weight of all of the restrained componentry must be considered.

D9.4.3.1 Floor or Roof mounted Systems Restrained with Cables

Floor- or roof-mounted systems may include supports for single runs of conduit, multiple runs, cable trays or bus ducts. Typically, simple box frames are fabricated to support these, no matter what they are.

Transverse Restraint Examples

For a cable-restrained support brackets there are four options normally encountered for non-isolated systems. As Electrical distribution systems are rarely isolated, for the purposes of this document, isolated systems will not be addressed. These options are shown below. The vertical legs of the support bracket must be sized to carry both the weight load of the supported pipes as well as the vertical component of the seismic forces. Refer to Chapter D4 for more detailed information as to how to size these members.

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Figure D9.4.3-3; Transverse Cable Restraints for Floor/Roof (Non-isolated)

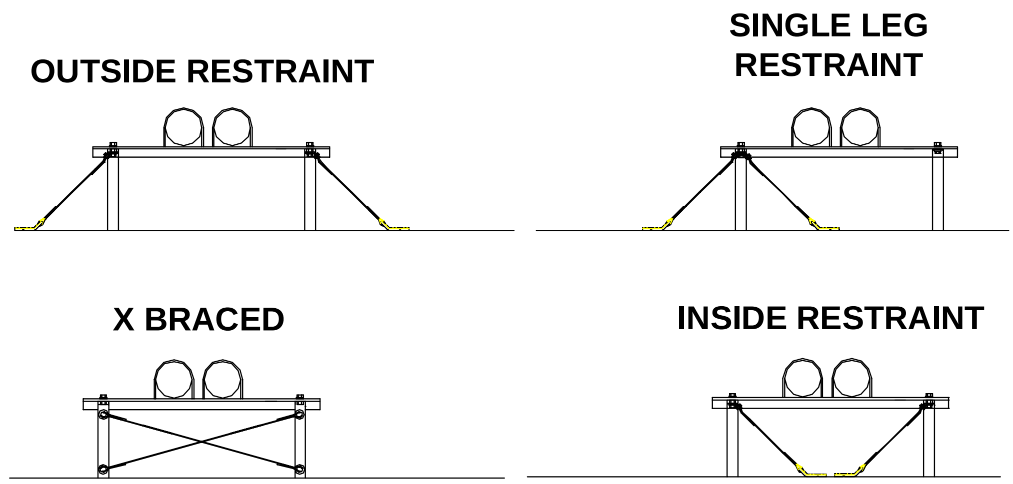
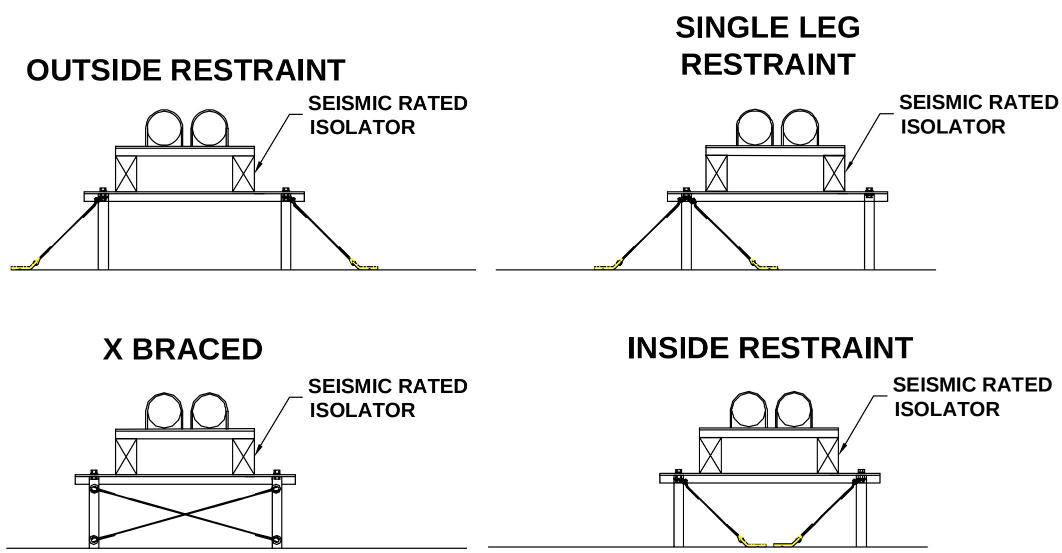


Figure D9.4.3-4; Transverse Cable Restraints for Floor/Roof (Isolated)



Longitudinal Restraint Examples

When longitudinally restraining conduit, a trapeze or clamp tightly fitted to the conduit is the most common connecting device between the restraint strut and a single piece of conduit. When connecting to a cable tray or bus duct, bolts or tray clamps are typically used. Details on these connections will be addressed in later sections.

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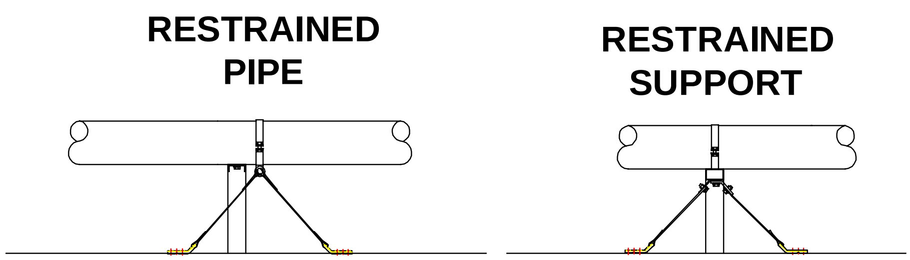
If the details of the connection are ignored at this point, general Longitudinal restraint arrangements recognized in this manual are illustrated below.

Note: Longitudinal restraints offset from the restrained run will generate additional bending forces in the restrained system. This is true whether mounted to one end of a trapeze or along side a single piece of conduit rather than directly under its center. When the restraint is offset, the maximum permissible offset from the center of the conduit, tray or duct is equal to its diameter or width. For trapezed systems supporting multiple runs, a single Longitudinal restraint should be located at the approximate center of the trapeze bar or pairs of Longitudinal restraints should be installed on each end of the trapeze bar or support frame.

Figure D9.4.3-5; Longitudinal Cable Restraints



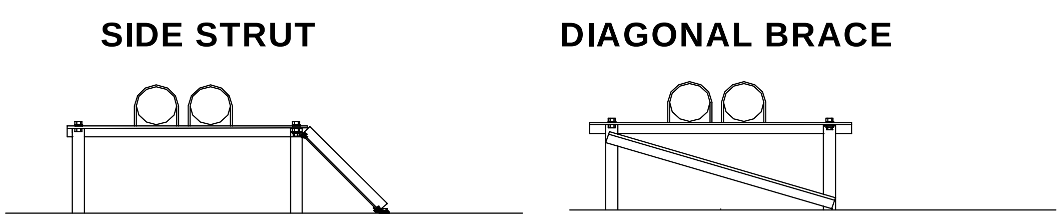
D9.4.3.2 Floor or Roof Mounted Systems Restrained with Struts

As with cable restraints, floor- or roof-mounted electrical distribution support systems will normally involve a box frame that supports the system (single or multiple runs) with some kind of a trapeze bar.

Transverse Restraint Examples

With struts there are three typical configurations as shown below.

Figure D9.4.3-6; Typical Transverse Restraint Strut Arrangements for Conduit



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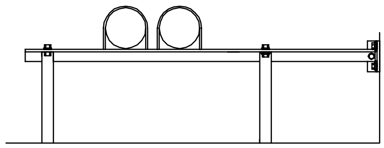


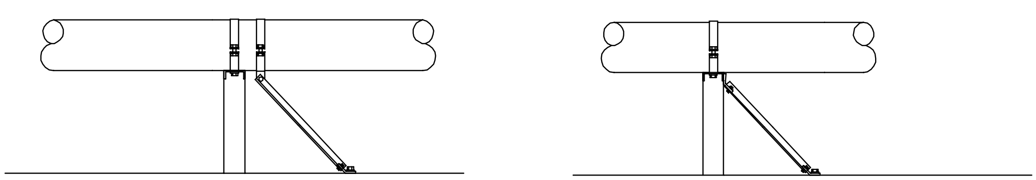
Longitudinal Restraint Examples

When longitudinally restraining conduit, a trapeze or clamp tightly fitted to the conduit is the most common connecting device between the restraint strut and a single piece of conduit. When connecting to a cable tray or bus duct, bolts or tray clamps are typically used. Details on these connections will be addressed in later sections.

Ignoring the details of the connection at this point, common longitudinal restraint arrangements recognized in this manual are illustrated below.

As with the cable restraints, it must be recognized that longitudinal restraints offset from the restrained conduit, trays or ducts will generate additional bending forces in the component. This is true whether mounted to one end of a trapeze or alongside a single piece of conduit rather than directly under its center. When the restraint is offset, the maximum permissible offset from the center of the conduit, tray or duct is equal to its diameter or width. For trapezed systems supporting multiple components, a single longitudinal restraint should be located at the approximate center of the trapeze bar or pairs of longitudinal restraints should be installed on each end of the trapeze bar or support frame.

Figure D9.4.3-8; Conduit Longitudinally Restrained with Struts



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TRANSFERRING FORCES (ELECTRICAL SYSTEM RESTRAINTS)

In order for a restraint system to do its job, all elements of the connections need to be sized and installed properly. Because of the large variety and quantity of interfacing conditions in any given installation, piping, duct, and electrical distribution systems are particularly prone to problems in this area.

The next several sections of this manual will deal with specific components used to clamp cable ends together, or anchor cables or struts to steel members, wood members, and concrete or masonry. There are several types of connections used for each of these conditions, and each type of connection requires some degree of care and understanding to achieve full capacity.

There are a few general rules that apply when adding restraints to systems. These are listed below along with a few comments meant to provide a basic understanding or rationale.

1) Friction generally cannot be counted on when dealing with dynamic, seismic load conditions. Connections, with the following exceptions, should be positive in nature and not require gravity to ensure their continued long-term operation.

Exceptions:

A) Cable end connections (Swaged ends, U-bolts, and QuakeLocs can be used with appropriate installation procedures).

B) Properly installed heavy-duty riser clamps seated against steel pipes, heavy conduit or other compression resistant materials.

C) Toothed strut nuts used in conjunction with a purpose-designed strut material (Unistrut, for example). *(Rationale: Permitted friction connections have been well researched and deal with a narrow range of applications. In addition, once properly tightened, the components are such that the likelihood of their coming loose as a result of seismic load conditions is very low.)*

2) Anchors used for the support of overhead equipment or systems cannot also be used for the anchorage of seismic restraints. *(Rationale: The loads used to size hanger rods and anchors are based on the weight loads generated by the system. Seismic forces can increase the tensile loads significantly, and the combination of loads can cause the anchorage to fail.)*

3) Anchors to concrete must comply with minimum edge distance, spacing and slab thickness requirements. To achieve full capacity ratings they must further not be installed into a surface containing significant tensile forces. *(Rationale: All anchorage must be in compliance with ICC allowables for seismic applications. Unless otherwise noted, it is assumed that connections are not made to the underside of structural concrete beams .)*

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4) Screws attached to wood must comply with minimum edge distance, spacing and embedment requirements, and must further not be embedded into the end grain of the wooden member. *(Rationale: All wood anchorage must be in compliance with NDS allowables for seismic applications. Full capacity can only be achieved with adequate embedment, end, and edge distances into the side grain of structural wood members.)*

5) Connections that have the potential to expose open bar joist chords to significant lateral loads are not permitted. *(Rationale: Open joists are notoriously weak in their lateral axis. They are not designed to take loads, particularly on the lower cord, and even light lateral loads can generate buckling and quickly cause catastrophic failure.)*

6) Connections that have the potential to generate significant lateral loads on the weak axis of I-beams or channels used as joists or columns are not permitted unless approved by the structural engineer of record. *(Rationale: Floor or roof support beams are significantly weaker in their minor axis than in their major axis. While they can, under some conditions, withstand some lateral loads, the engineer of record should be consulted to ensure that capacity exists on particular members to withstand the anticipated loads. If these loads are exceeded, catastrophic failures can quickly result.)*

7) Holes should not be added to key structural members without prior authorization from the engineer of record. *(Rationale: The addition of holes, particularly in flanges, can greatly reduce the structural capacity.*

8) Connections between sections of conduit, trays or bus ducts can become critical factors in evaluating the performance of the system. Unless otherwise informed, Kinetics Noise Control assumes connections to be of “medium” deformability as defined by the design code. This is generally appropriate for steel connecting materials and fittings, brazed connections, and plastic pipe.

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NON-MOMENT GENERATING CONNECTIONS

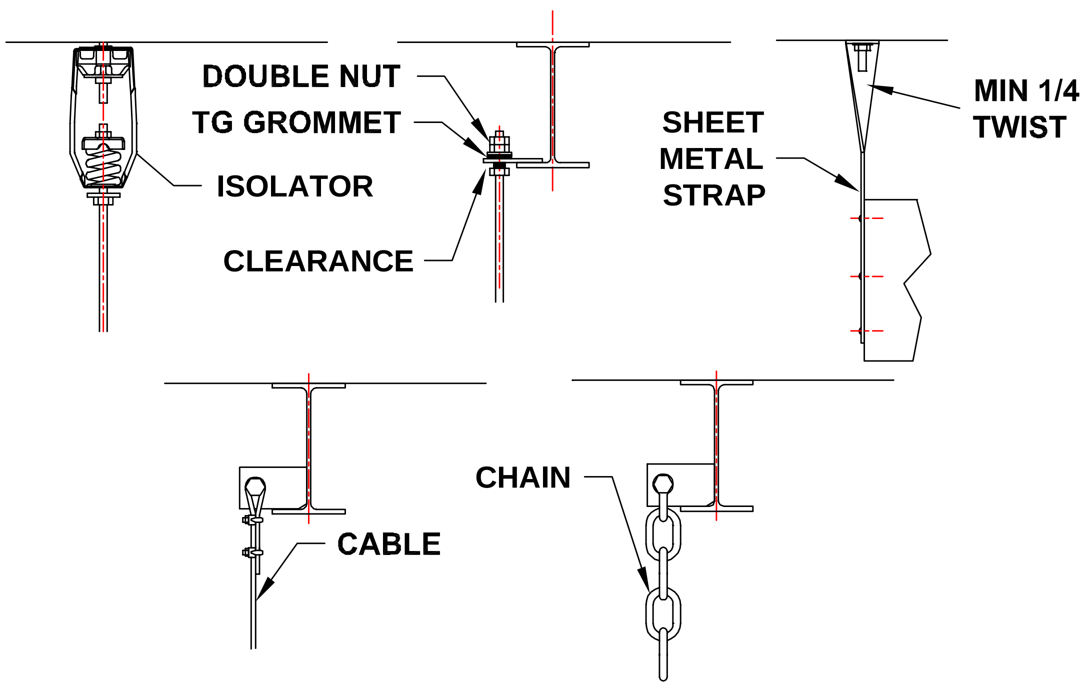
The IBC and 97 UBC codes allow the omission of seismic restraints for most piping, conduit and ductwork runs without regard to size but that are located within 12" of the structure. Refer also to section D2 of this manual for specific exemptions by code version. In order to qualify for this, the following parameters must be met:

1) The length of **all** supports on the run measuring from the top anchorage point to the connection point to the trapeze bar or the top of a singly supported pipe or conduit run must not exceed 12".
2) Unrestrained free travel of the supported system must be such that over the course of its movement, contact is not made with any other system, component or structural element that can result in damage to either the supported system or the object it hit.
3) The top connection to the structure must include a Non-Moment generating connection to prevent damage to the hanger rod or support strap.

A Non-Moment generating connection is any device that would allow a free flexing action of the hanger rod or support strap for an unlimited number of cycles without its being weakened. This motion must be permitted in any direction.

Shown below are typical examples of acceptable Non-Moment generating connections. Any other device that allows the same freedom of motion is equally acceptable.

A hanger rod rigidly embedded into the underside of a concrete structural slab is not.



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CONNECTION OPTIONS FOR AWKWARD SITUATIONS

Almost every project will include some areas where installing restraints in a conventional fashion will be difficult. This segment of the manual offers options to consider when confronted with various situations.

D9.6.1 Long, Narrow Hallways

Probably the most common issue in the field is how to deal with transverse restraints in long, narrow hallways. Normally there is considerable congestion in these areas and not enough room to angle restraints up to the ceiling structure. Often the walls are not structural and do not offer a surface to which to anchor.

When evaluating halls, the first issue is to determine if either of the walls of the hall is structural. If either wall is structural, it offers a surface to which the restraints can often be attached. For structural walls, any relative displacement issues between the wall and the structure supporting the electrical distribution system in question must be identified. The maximum permitted relative displacement is ¼ inch, which for most structures correspond to a difference in elevation of approximately 2 feet (see also the Structural Attachment Section of this chapter).

Assuming the wall meets both of the above requirements, a transverse restraint can be run either directly over to the wall or up at a slight angle to the wall. Normally this would be done with a strut as shown below.

Figure D9.6-1; Trapeze-Mounted Conduit Restrained to Structural Wall or Column with a Horizontal Strut (Trays would be similar)

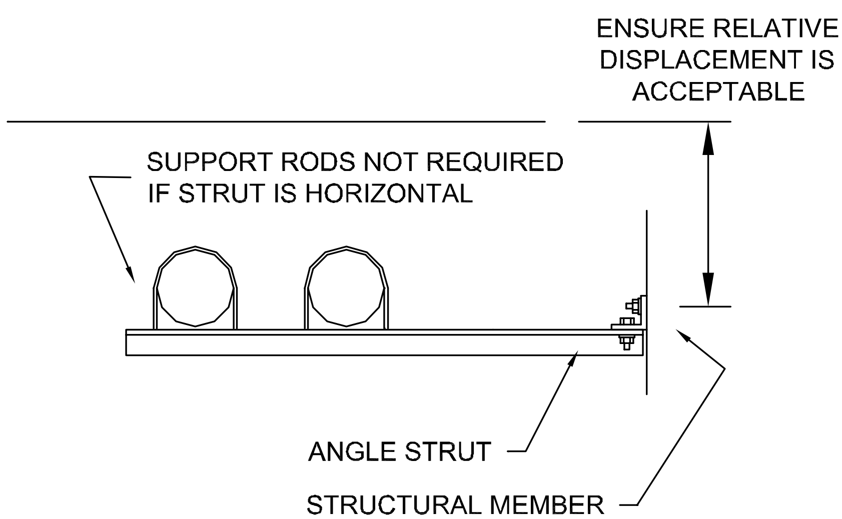

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Figure D9.6-2; Trapeze-Supported Bus Duct Restrained to Structural Wall or Column with an Sloping Strut

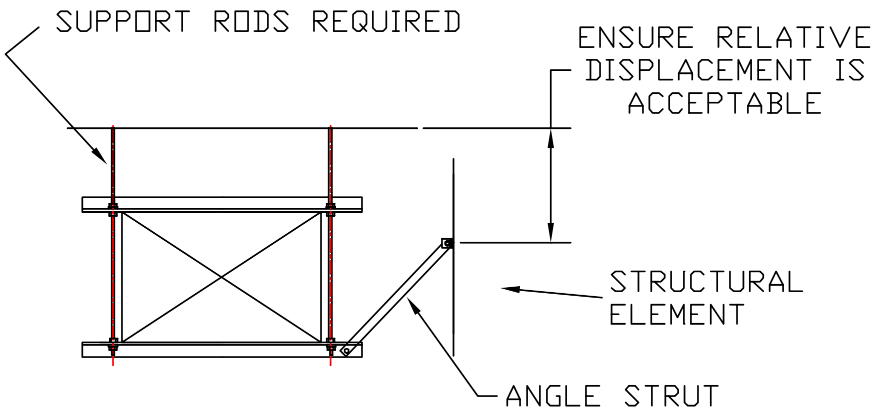
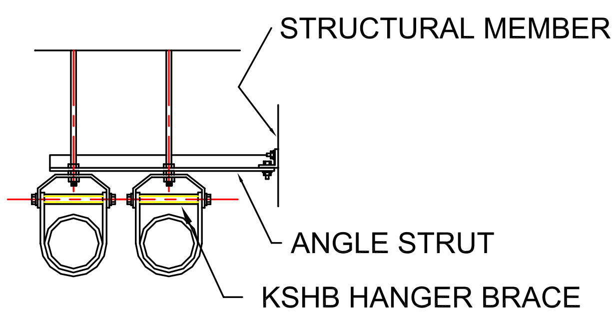


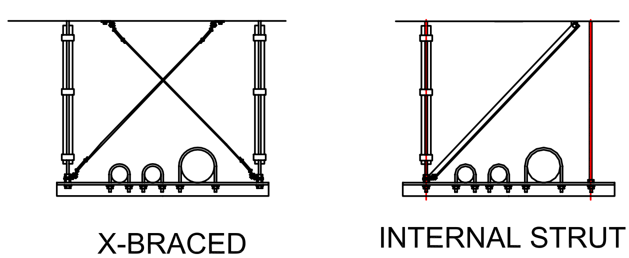
Figure D9.6-3; Clevis-Supported Conduit Restrained to Structural Wall or Column



For the case where there are no nearby structural connection points or where the nearby structural elements are not suitable, there are several options that can be considered.

The first option is to restrain to the ceiling using “X” bracing or a diagonal strut.

Figure D9.6-4; “X” or Diagonally Braced Restraint Arrangement



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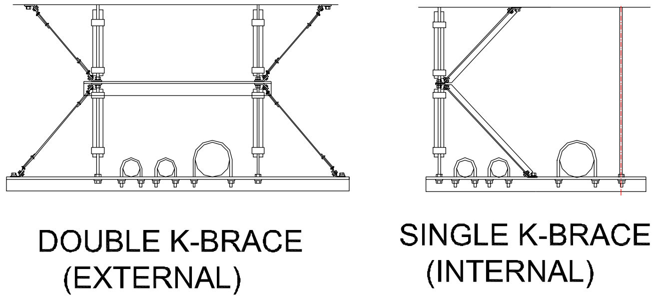
A "K" or double "K" brace can also be used. The "K" can either be located inside the support rods or outside the support rods, but in the case of a double "K", both sides must be identical (either inside or outside).

Figure D9.6-5; Single and Double "K" Brace Restraint Arrangement



In cases where only non-structural walls limit access for restraint, it is frequently possible to penetrate the non-structural wall and shift the lateral restraint device to the opposite side of the wall or partition as shown here.

Figure D9.6-6; Wall Penetration Restraint (Cable)

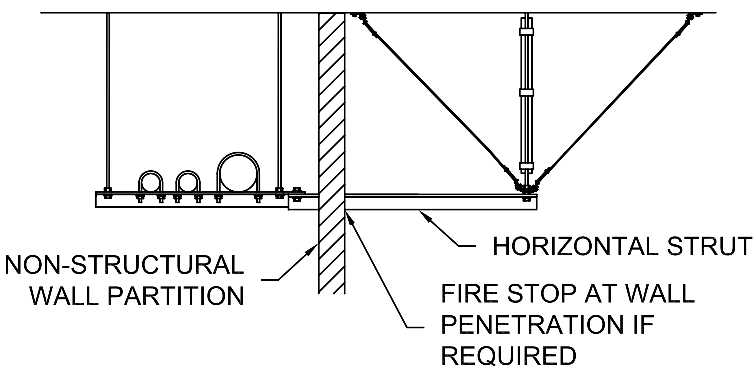
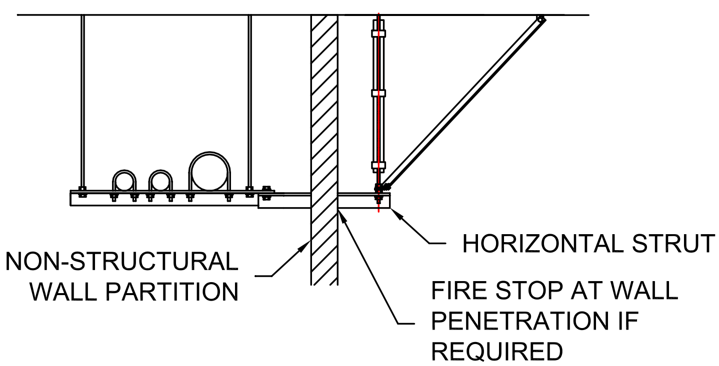


Figure D9.6-7; Wall Penetration Restraint (Strut)



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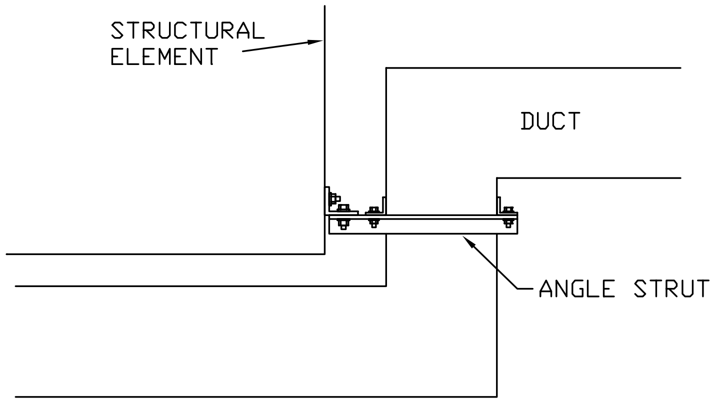
D9.6.2 Axial Restraint Strut at a Dogleg

This arrangement is often a convenient way to connect an axial restraint and can occur both in the horizontal and vertical plane. Often it will be found that when installing bus ducts, a jog has been added to a run to avoid running into a column or other structural member. Where this occurs, it offers an easy way to connect an axial restraint.

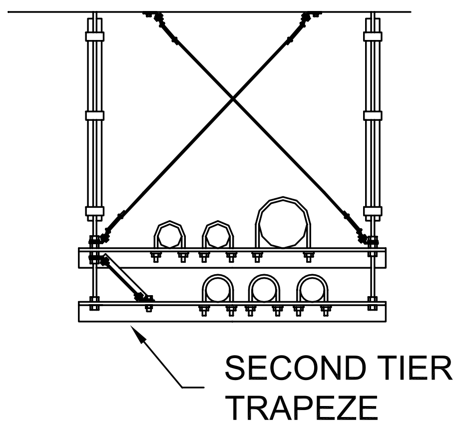
Figure D9.6-8; Axial Restraint Strut at a Dogleg



D9.6.3 Piggyback or Double-Tier Restraint

In congested areas, there is often a double layer of conduit supported off a single trapeze arrangement. It is possible under some conditions to brace one trapeze bar to the other, and then restrain the second trapeze bar to the structure. If doing this, there are a couple of cautions. First, the restraint capacity for the second trapeze bar must be adequate to restrain the total load from both bars and, second, the supported components must be similar in nature and ductility.

Figure D8.6-9; Piggyback or Double-Tier Restraint Arrangement



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D9.6.4 Restraints for conduits, ducts or trays mounted well below the support structure

This situation is not easily handled. Past history has shown, and the code is quite clear, that it is not a good idea to support a system from one structural element and restrain it using another structural element that will undergo significantly different motions. Restraints fit in this fashion will likely fail or cause the supports for the system that is being supported to fail. Neither of these outcomes is desirable.

About the only solution to this is to add a support structure for the system that is located either just above or just below its installed elevation. The system can then be both attached and restrained to this structure.

The structure can be supported off the floor, off the ceiling, or from structural walls or columns. The support structure must be rigid enough to absorb all of the seismic loads, and particularly the moments, with minimal deformation, transferring pure shear or tensile forces into the supports.

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SECTION D10.0 – TABLE OF CONTENTS

D10.0 – SUSPENDED EQUIPMENT

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SEISMIC FORCES ACTING ON SUSPENDED EQUIPMENT

When subjected to an earthquake, Suspended equipment must resist all lateral forces, without regard to their direction. The restraint components for these systems must resist pullout and localized structural failures. Unlike piping and ductwork, there are rarely concerns about the buckling of the equipment. Generally the equipment is assumed to be rugged enough to maintain it shape throughout the seismic event.

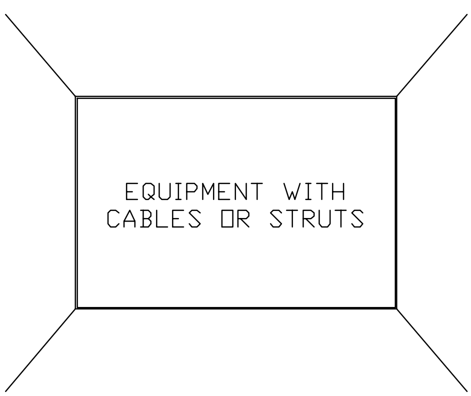
In most cases, equipment is suspended from the deck above on either fixed or isolated hanger rod systems. On more rare occasions the equipment may be bolted directly to the underside of the structure without the inclusion of hanger rods. For the later, the anchorage must be assumed to resist the seismic as well as gravity forces. When mounted on hanger rods, struts or cables are used to absorb the seismic forces.

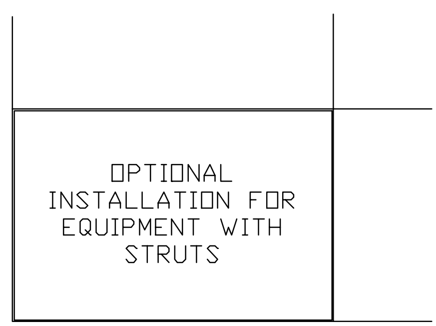
When working with suspended equipment, unlike piping and ductwork, the codes in general do not identify global exemptions. Refer to the code section for specific exemptions, but in general equipment less than 20 pounds in weight does not require the installation of “purpose built” seismic restraint componentry. Conventional attachment is assumed to be adequate.

When installing restraints on hanging equipment, it must be kept from moving in any horizontal direction. The use of cable restraints or struts can induce uplifting forces at their attachment point and if these overcome gravity forces, devices to resist this uplift are also required.

Whether restraining equipment with cables or struts, a minimum of 4 restraints are needed for each piece of equipment. Cables are typically connected to the equipment corners (approx) and run in a direction diagonal to the unit. When looking up at the equipment, each cable should be oriented at approximately 90 degrees to the cables on either side of it creating a “paddle wheel” look with 4 paddles.

When struts are used, they can be oriented like the cables or they can be oriented as shown below.





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The requirement for 4 struts is to prevent the rotation of the equipment that will occur if 2 struts are used that do not line up exactly with the equipment's center of gravity.
Ideally, the restraint members should be at as shallow an angle as possible (mostly horizontal). As the angle becomes steeper (the restraint member becomes more vertical), the vertical forces in the hanger rods increase. At 45 degrees the vertical force equals the horizontal force and at 60 degrees the vertical force is 1.73 times the horizontal force.

The net result is that for cable systems or for struts loaded in tension, the uplift force caused by the cable or strut can be greater than the downward weight load from the equipment. Depending on the support rod length and stiffness, this can cause the support rod to buckle. Rod stiffeners are used to protect against this condition and sizing information is available in Chapter D4 of this manual.

Unlike cables, if struts are used for restraint they can also be loaded in compression. The hanger rod and its anchorage for these applications must be designed to accommodate these combined loads. Hanger rod sizing information is also available in Section D4.4 of this manual.

Use of Graphs (Section D4.4) to select restraints for Equipment

The graphs in Section D4.4 can be used for restraint selection for equipment. To do this, simply reference the weight on the left hand horizontal axis and proceed from that point using the same procedure as is used for the selection of restraints for distributed systems.

A more detailed explanation of the use of these tables is in section D4.4 of the manual.

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BASIC PRIMER FOR SUSPENDED EQUIPMENT

Failures in piping systems equipment that interfaces with them resulting from earthquakes have historically resulted in large quantities of water or other materials being dumped into occupied spaces of the building structure. The resulting dollar damage to the building and its contents is often considerably more than the costs of damage to the building structure itself. In addition, failure of the building's mechanical systems can render the structure unoccupiable until the damage is corrected, and result in major problems for the tenants and/or owners.

Because of the impact that failures of these systems have had in the past, design requirements for piping systems and interfacing equipment have become much more stringent.

Within a building structure, there are multitudes of different kinds of systems, each with its own function and requirements, many of which interface with suspended equipment or are in the immediate proximity of this equipment. Significant effort must be expended to ensure that motion of the equipment induced by an earthquake will not damage surrounding systems or the equipment itself.

This chapter of the manual is a "how to" guide and will deal only with the proper installation and orientation of restraints and not whether or not they are required by code, which can be researched further in Chapter D2, or by specification.

This chapter also does not address the sizing of restraint hardware. Section D10.1 and Section D4.4 include sections on sizing componentry based on the design seismic force and the weight of the system being restrained and should be consulted for this task.

Process equipment is not directly associated with building operating systems and often has its own set of requirements. If there are no applicable special requirements, this equipment should be restrained in a similar fashion to the building mechanical systems.

This manual will not address any special requirements for non-building processes.

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PROS AND CONS OF STRUTS VERSUS CABLES

Both cables and struts have their place in the restraint of equipment. In order to minimize costs and speed up installation, the differences between the two should be understood.

When restraining equipment whether struts or cables are used, there is typically no difference in the number of restraints needed. This is unlike piping or ductwork where normally a single strut can replace 2 cable assemblies. The difference between equipment and piping/ductwork is that the equipment is small enough that in addition to swinging laterally from a seismic input, it can easily rotate. 2 struts acting at 90 degrees to one another cannot resist this rotation. Under some cases it can be resisted using 3 struts properly aligned, but unless carefully reviewed a minimum of 4 struts is recommended.

The obvious advantage to struts is that, when space is at a premium, cables angling up to the ceiling on each side of a piece of equipment may take more space than is available. Struts can be fitted to one side only, allowing a more narrow packaging arrangement.

There are three significant advantages of cables, where they can be used. First, they cannot increase the tensile forces in the hanger rod that results from the weight load, so rod and rod anchorage capacities are not impacted. Second, they are easily set to the proper length. And third, they are well suited to isolated equipment applications.

To better explain the differences between the systems, it is necessary to look at how seismic forces are resisted with cables and struts. Shown below are sketches of both cable-restrained and strut-restrained equipment.

Figure D10.3-1; Cable Restrained

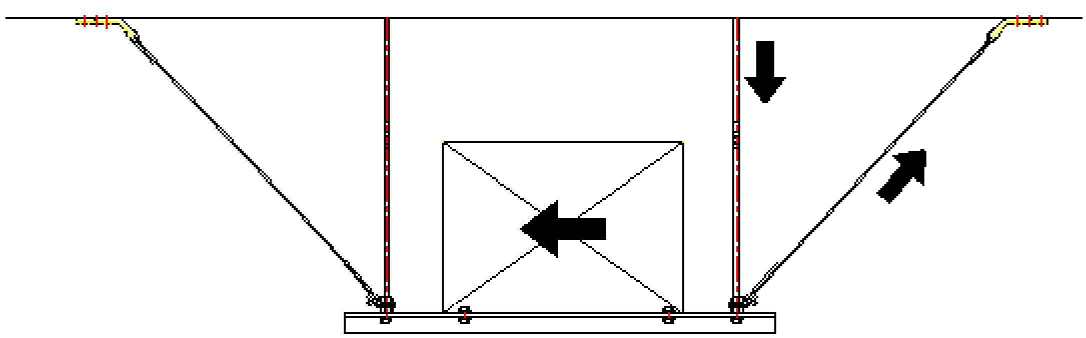

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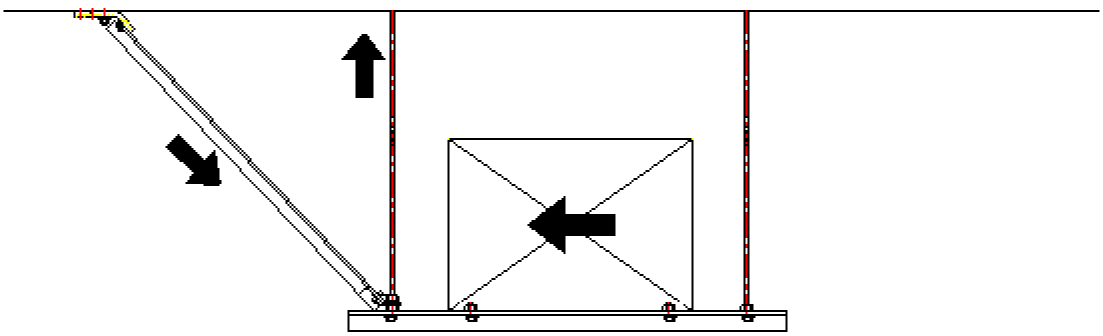
Figure D9.3-2; Strut Restrained



The key factor to note is that cables can only be loaded in tension. This means that seismic forces can only generate compressive loads in the hanger rod. Seismic forces can, however, load the strut in compression resulting in a tensile load on the hanger rod.

This tensile load is in addition to any deadweight load that may already be supported by the hanger and is often significantly higher than the original load. This has the potential to rip the hanger rod out of the support structure and must be considered when sizing components.

Because of this added tensile component and the resulting impact on the necessary hanger rod size, most strut manufacturers limit the maximum allowable strut angle (to the horizontal) to 45 degrees. This is lower than typical allowable angles for cables that often reach 60 degrees from the horizontal. Although the data provided in Section D4.4 of this manual allow the use of higher angles for strut systems, users will find that the penalties in hanger rod size and anchorage will likely make these higher angles unusable in practice.

It should also be noted that the hanger rods in tension become seismic elements. This occurs with struts, but does not with cables. As a result, the hanger rods now must comply with all of the anchor requirements specified by ICC. This includes the use of pre-qualified anchors and embedment depths as specified in the pre-qualification documentation. With larger anchor sizes, floor slab thickness may cause this to become a significant problem.

With both cables and struts, the hanger rods can be loaded in compression. As the seismic force increases, it eventually overcomes the force of gravity and produces a buckling load in the hanger rod. It is mandatory in all cases that the rod be able to resist this force.

There is a wide range of variables involved in determining the need for rod stiffeners to resist this buckling load. Factors that impact this need are 1) the magnitude of the compressive force, 2) the weight load carried by the hanger rod, 3) the length of the hanger rod, 4) the diameter of the hanger rod, and 5) the angle between the restraint strut or cable and the horizontal axis.

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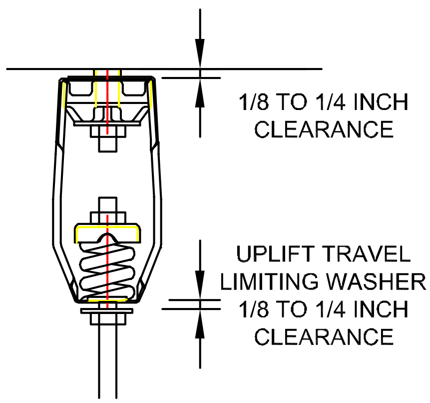
Charts are included in Section D4.4 of this manual that allow the user to determine if there is a need for a stiffener and to allow the uplift load to be determined. From this the weight load at the restraint point (typically approx. 20% of the equipment weight) can be deducted and the appropriate rod stiffener selected from the rod stiffener charts in that Section.

Because uplift can occur, some attention must be given to isolated systems. First, when using isolators, the location of the isolation element needs to be at the top end of the hanger rod (close to, but not tight against the ceiling). If placed at the middle of the hanger rod, the rod/isolator combination will have virtually no resistance to bending and will quickly buckle under an uplift load.

Second, a limit stop must be fit to the hanger rod, just beneath the hanger such that when the rod is pushed upward a rigid connection is made between the hanger housing and the hanger rod that prevents upward motion. This is accomplished by adding a washer and nut to the hanger rod just below the isolator (see the sketch below).



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REQUIREMENTS FOR SUSPENDED EQUIPMENT RESTRAINTS DEFINITIONS AND LOCATING REQUIREMENTS

While SMACNA has developed a set of restraint placement criteria based on analytical review, practical experience, and historical analysis for piping and ductwork, their material does not address the restraint of equipment. The criterion presented in this manual is generally based on SMACNA concepts and criteria, except that it is modified to make it appropriate for use on equipment applications. The only exception to this is that the data has been extrapolated to higher seismic force levels and hardware capacity limited forces and is not limited by buckling issues as is the case with piping and ductwork.

With respect to the conceptual restraint arrangement illustrations, many of the SMACNA concepts are appropriate and are referenced here.

In general, equipment is restrained on a unit by unit basis and the concept of “runs” as defined in the piping and ductwork sections of the manual are not appropriate. In places where there are long lengths of pipe or duct integral to the equipment (like radiant heaters), that portion of the equipment should be restrained in the same manner as piping or ductwork. More information on this can be found in the piping/ductwork Chapters of the manual on this.

Also, in some cases, small pieces of equipment may be “hard” mounted into the ductwork. Under some conditions (see the code section of the manual), these can be treated as part of the duct and properly restraining the duct will result in acceptable restraint of the equipment. This is not true if the equipment is connected to the duct using a flexible material.

Definitions

Lateral A horizontal force acting on the equipment in any direction.

Restraint A device that limits the motion of the equipment in any horizontal direction.

Rod Stiffener A component added to a hanger rod to prevent it from buckling

Restraint Requirements

1) Equipment must be restrained against a lateral force that can act in any direction. Multiple restraint components may be required to accomplish this task.

2) For long modularized equipment (20 ft or longer), additional restraints should be installed so the span between the restraints does not exceed 20 ft.

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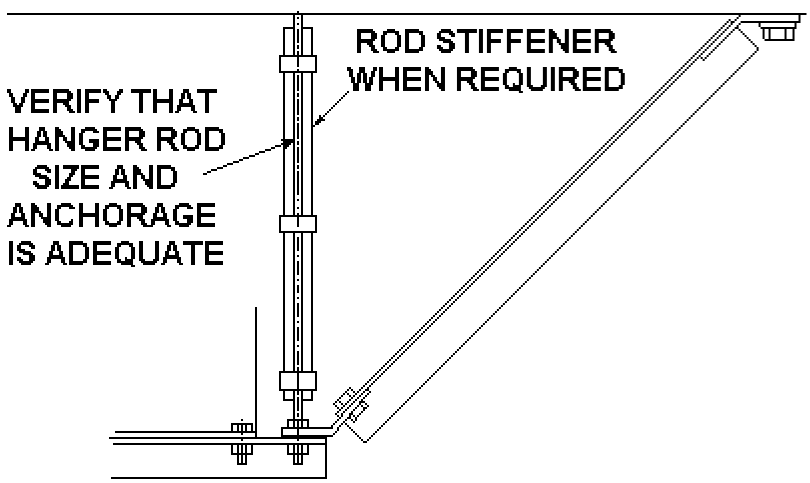
3) Restraints must be connected to substantial attachment points on the equipment or to equipment support members that are in turn connected substantially to the equipment. Hardware in size equal to that identified for the restraint attachment (Chapter D4) should be used to attach the equipment.

4) All restraints for a given piece of equipment must be the same. (You cannot mix struts and cables.)

5) With longer hanger rods, rod stiffeners are likely to be required. Refer to the appropriate table in Chapter D4 to determine: (1) if needed, (2) what size stiffener material is appropriate, and (3) how frequently it needs to be clamped to the hanger rod.

6) In addition to possibly requiring rod stiffeners, when struts are used to restrain equipment, the size of the hanger rod and its anchorage also become critical. Again refer to the appropriate table in Chapter D4 to determine the minimum allowable size for the hanger rod and anchor.

Figure 10.4.1-1 Rod Stiffener



7) There is no hanger rod length or component size based exclusion rules for equipment as there is for piping or ductwork with the following exception. If the equipment is hard connected to a duct, small enough to be considered part of the duct (see appropriate code section) and the duct is exempted by one of these rules, the equipment can also be considered to be exempted.

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SUSPENDED EQUIPMENT RESTRAINT ARRANGEMENTS

Although the basic principle of diagonal bracing is almost always used to design restraint systems, the actual arrangement of these systems can vary significantly. Despite what looks like substantially different designs, the design forces in the members remain the same, and the same rules apply when sizing components. Illustrated here are many different restraint arrangements, all of which can be used in conjunction with the design "rules" provided in this manual.

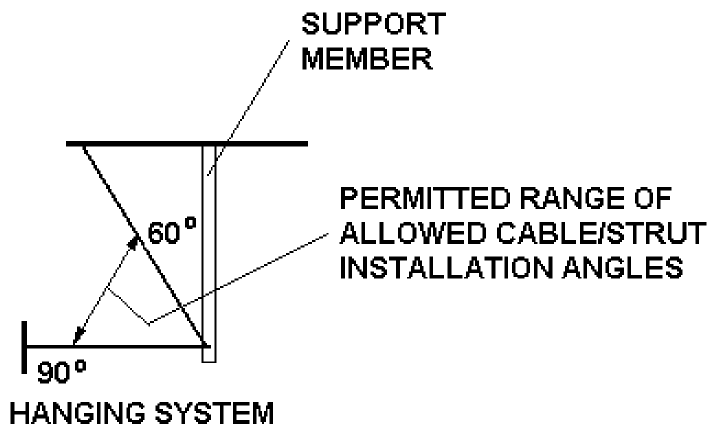
Details of the end connections and anchorage hardware are shown in subsequent sections of the manual. It is assumed in this manual that the restraint component is attached to a structural element capable of resisting the design seismic load.

Due to variations in the installation conditions such as structural clearance, locations of structural attachment points, and interference with other pieces of equipment or systems, there will likely be significant benefits to using different arrangements in different locations on the same job.

<u>The only significant caution here is that it is not permissible to mix struts and cables on the same piece of equipment.</u>

This manual addresses diagonal bracing slopes of between horizontal and 60 degrees from the horizontal. Angles in excess of 60 degrees to the horizontal are not permitted.

Figure D10.4.2-1; Permissible Restraint Angles



When installing restraints, each individual restraint should be installed perpendicular (±10 degrees) to the adjacent restraint as viewed from underneath. In addition, the restraints should be approximately aligned with the center of gravity of the piece of equipment being restrained. Although it is typical to install restraints at each corner extending radially outward from the piece of equipment, this arrangement is not mandatory. See the sketches below.

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Figure D10.4.2-2; 4 Restraint Options, Restraint angles can vary 10 degrees from those shown

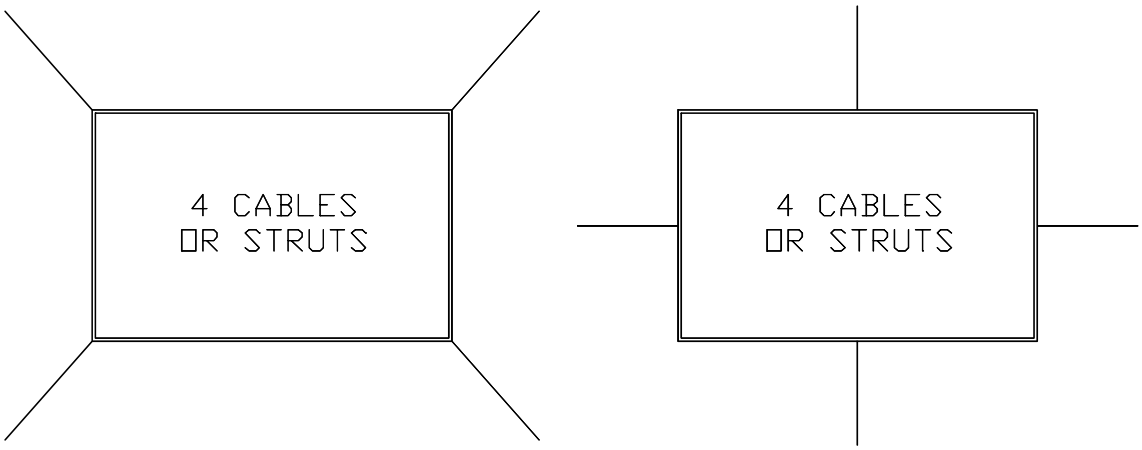


Figure D10.4.2-3; 8 Restraint Options, Restraint angles can vary 10 degrees from those

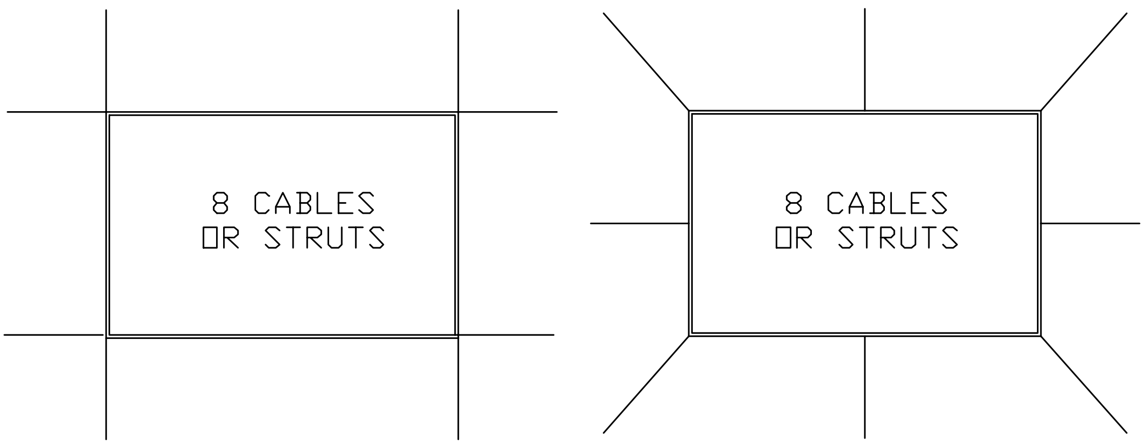
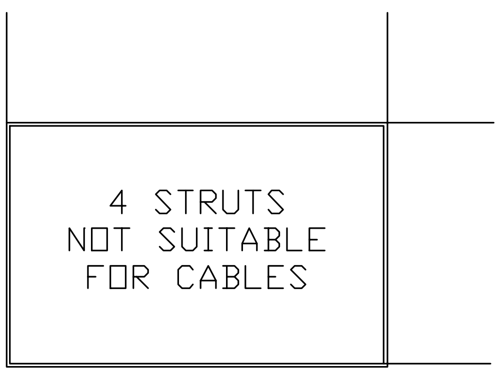


Figure D10.4.2-3; 4 Strut Arrangement, Restraint angles can vary 10 degrees from those



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In general, when restraining equipment, the component actually being restrained is the member that supports the equipment rather than the equipment itself. This is normally a trapeze bar. Because the goal is to restrain the actual equipment, it is necessary that the restrained element be connected to the equipment in such a way as to transfer the appropriate forces between the two.

Based on the Maximum Horizontal Force requirement, the appropriate size and quantity of fasteners to connect ducts to support/restraint members is as follows:

Force (Lbs)	250	500	1000	2000	5000	10000
#10 Screw	3	5	10	20		
Force (Lbs)			3	6	20	40

D10.4.2.1 Hanging Equipment Restrained with Cables

(Note on these and all sections below, the cables must be oriented in the plan view as identified earlier in this document.)

Restraint Examples

For some pieces of equipment that are intended to be suspended, mounting points are normally provided. An example is an axial flow fan. For these kinds of equipment the restraints and the supporting hangers are normally connected to these mounting points directly as shown below. This arrangement works with both isolated and non-isolated systems. Note that the isolators are mounted with minimal clearance to the structure and that a travel limiting washer is fitted to the hanger rod just below the isolator in the isolated arrangement.

Figure D10.4.2-4; Fan with Cable Restraints (Non-Isolated)

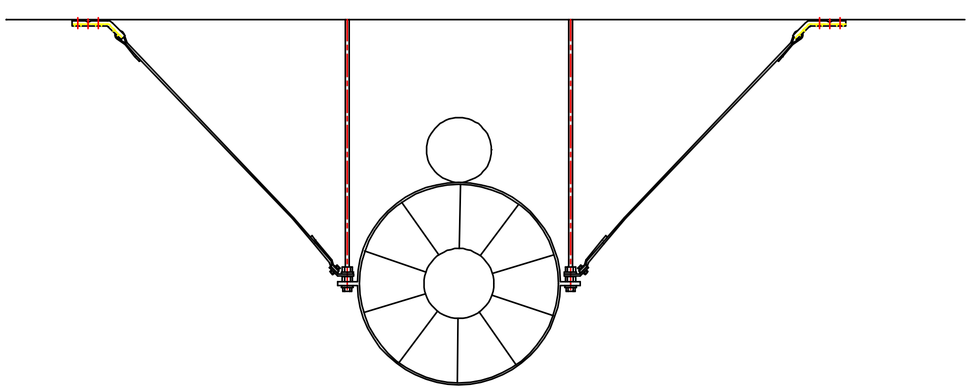

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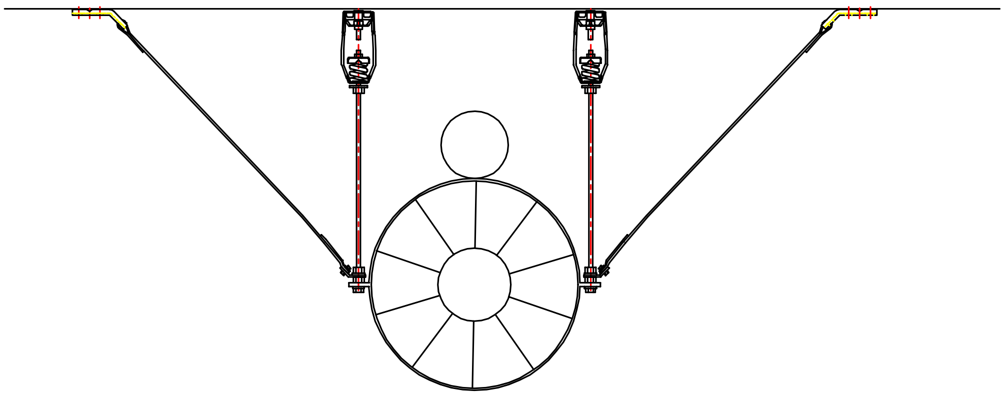
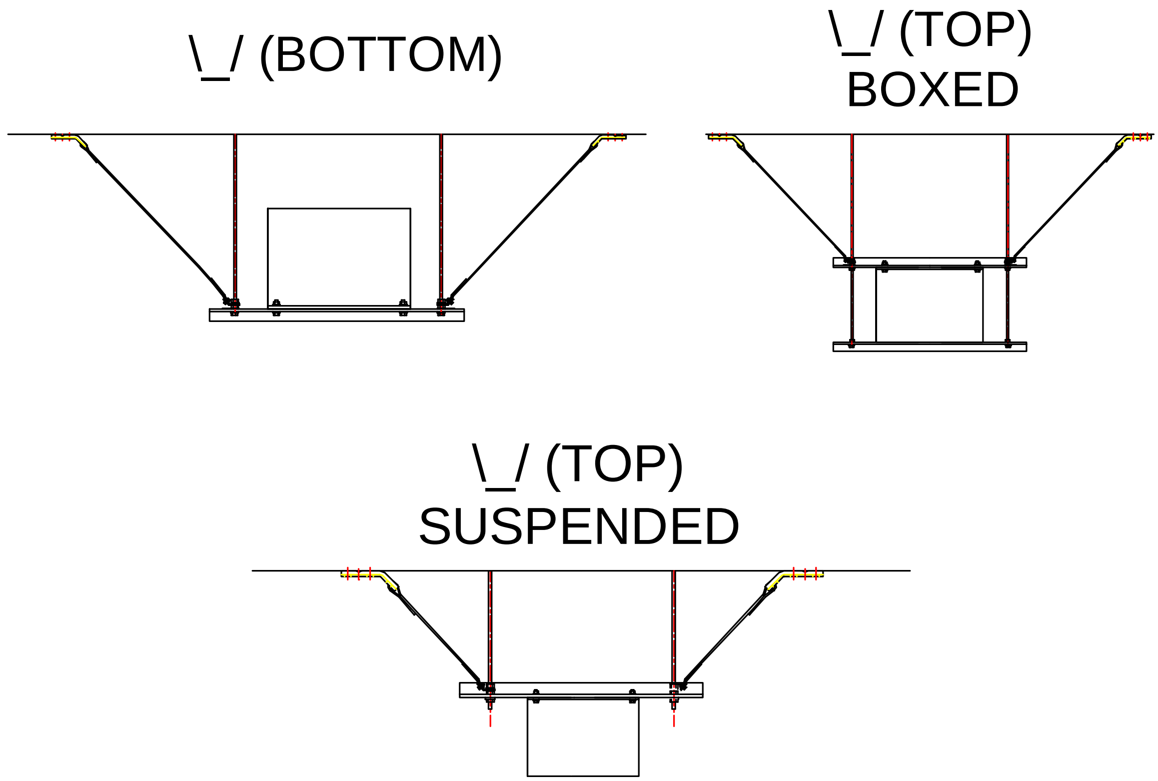
Figure D10.4.2-5; Fan with Cable Restraints (Isolated)



Most equipment however is mounted using a trapeze bar arrangement. There are many options that exist for the arrangements of restraints used in conjunction with trapeze-mounted systems. Shown below are several options for both non-isolated and isolated cable-restrained systems.

Figure D10.4.2-6; Typical Cable Restraint Arrangements Mounted to a Trapeze (Non-isolated)



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In addition to the conventional _/ mounting arrangement, where there is sufficient room above the equipment, and X type of arrangement shown below can often be an attractive alternative.

Figure D10.4.2-7; X Type Cable Restraint Arrangement Mounted to a Trapeze (Non-Isolated)

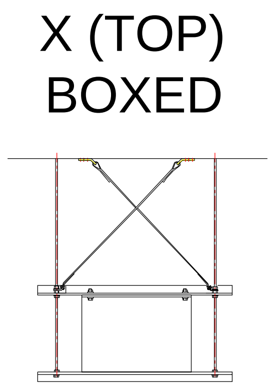

Figure D10.4.2-8; Typical Cable Restraint Arrangements Mounted to a Trapeze (Isolated)

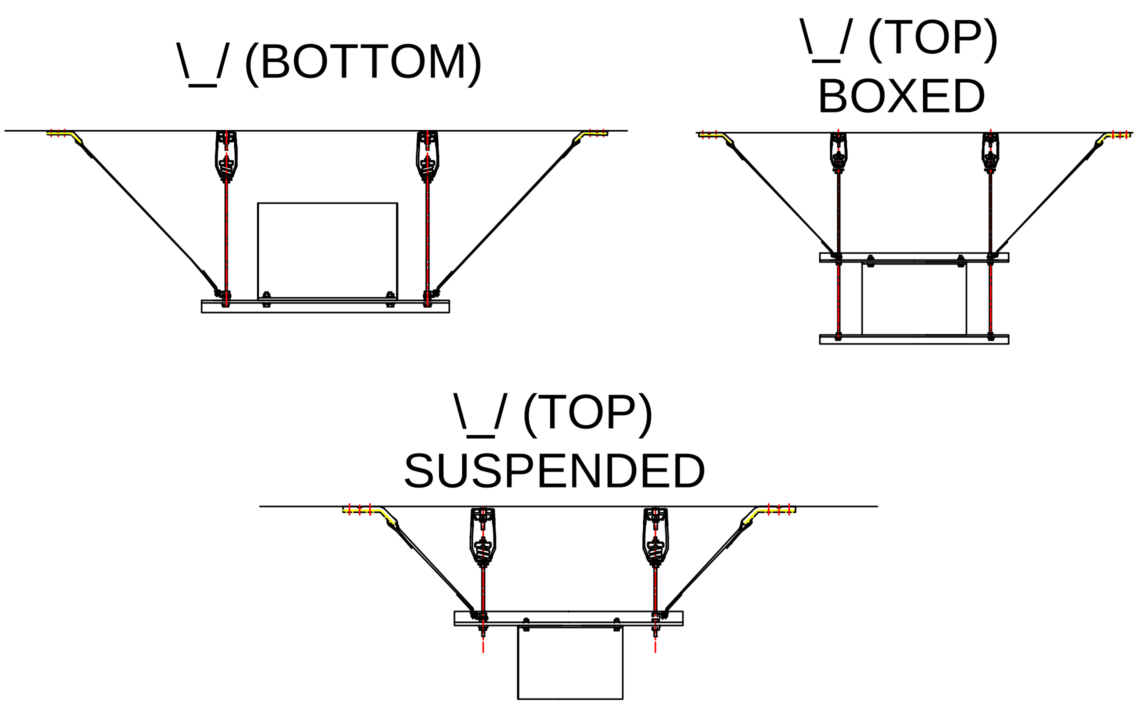

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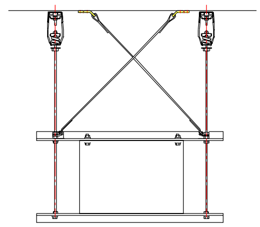
Figure D10.4.2-9; X Type Cable Restraint Arrangement Mounted to a Trapeze (Isolated)

X (TOP)
TRAPPED



D10.4.2.2 Hanging Equipment Restrained with Struts

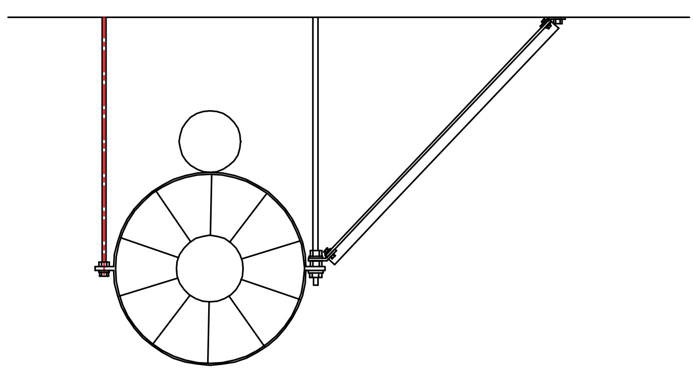
(Note on these and all sections below, the cables must be oriented in the plan view as identified earlier in the paper.)

It is recommended that struts not be used to restrain isolated equipment. Struts will generate hard connections between the equipment and structure and will greatly reduce the efficiency of the isolation system. Having said that, in some special situations it may be possible to design restraint struts with integral isolation elements, but this is tedious and should be avoided unless drastic measures are required.

Restraint Examples

For a strut-restrained piece of equipment with integral attachment points located away from the top surface, there is only one common arrangement. It is to connect the restraint and the support to the attachment point as shown below.

Figure D10.4.2-10; Strut Restraint Arrangement for Axial Fan (Non-Isolated only)



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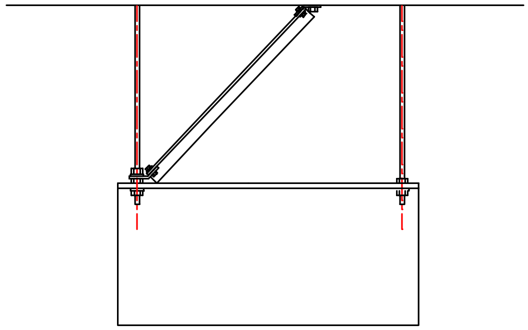
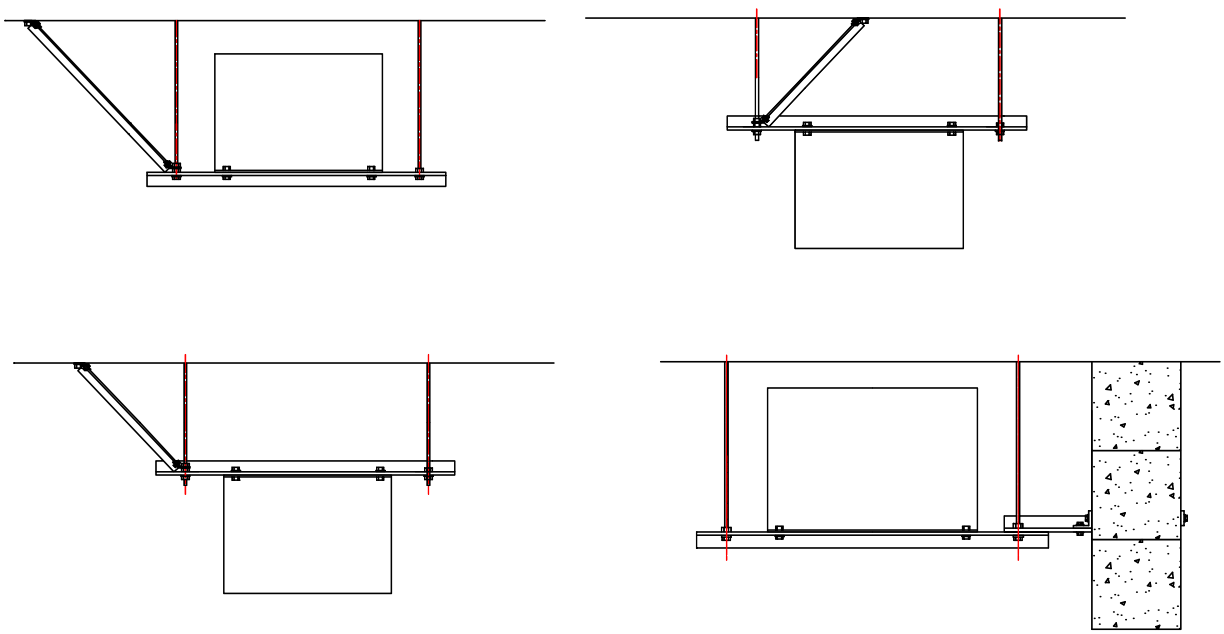
If the connection points for the equipment are on the top surface, the strut can be angled in the opposite direction as shown below.

Figure D10.4.2-11; Strut Angled over Top of Equipment (Non-Isolated only)



Shown below are 4 options for trapeze-mounted equipment. All are equivalent.

Figure D10.4.2-12; Typical Strut Restrained Equipment (Non-Isolated only)



D10.4.2.3 Special Cases

Equipment Supported at 2 points

When equipment is supported on only 2 points, caution must be used to ensure that the restraints are connected in such a way as to prevent lateral motion of the equipment without

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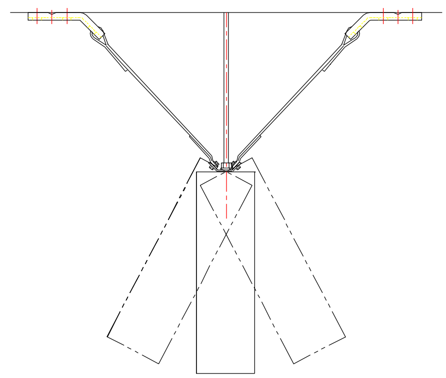
allowing it to sway and put undo stress on the hanger rods. Classic examples of this type of equipment are Unit Heaters.

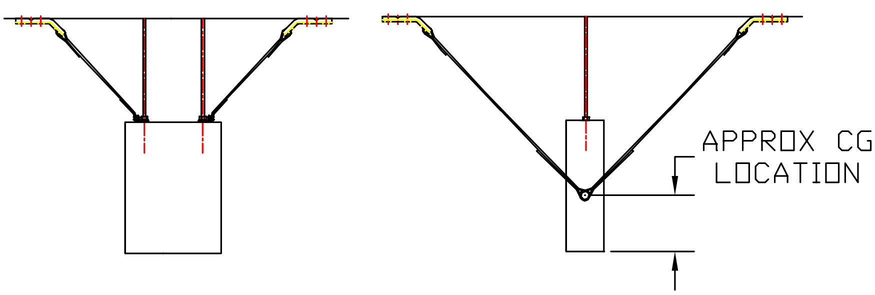
The condition of concern is illustrated below.

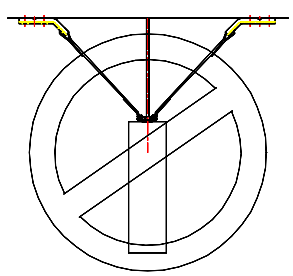
Figure D10.4.2-13; Possible Sway in Equipment Mounted on 2 Support Hanger Rods



In order to keep this swaying motion from occurring, it is necessary to ensure that on the axis where swaying can occur, the restraints connect to the equipment at its vertical center of gravity (approx). This is not necessary on the opposite axis. See Below.

Figure D10.4.2-13; Proper Restraint of Equipment Suspended by 2 Hanger Rods





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TRANSFERRING FORCES (SUSPENDED EQUIPMENT)

In order for a restraint system to do its job, all elements of the connections need to be sized and installed properly. Because of the large variety and quantity of interfacing conditions in any given installation, suspended systems in general are prone to problems in this area.

The next several sections of this manual will deal with specific components used to clamp cable ends together or anchor cables or struts to steel members, wood members, and concrete or masonry. There are several types of connections used for each of these conditions, and each type of connection requires some degree of care and understanding to achieve full capacity.

There are a few general rules that apply when adding restraints to systems. These are listed below along with a few comments meant to provide a basic understanding or rationale.

1) Friction generally cannot be counted on when dealing with dynamic, seismic load conditions. Connections, with the following exceptions, should be positive in nature and not require friction to ensure their continued long-term operation.

Exceptions:

A) Cable end connections (swaged ends, U-bolts, QuakeLocs can be used with appropriate installation procedures).

B) Toothed strut nuts used in conjunction with a purpose-designed strut material (Unistrut, for example). *(Rationale: Permitted friction connections have been well researched and deal with a narrow range of applications. In addition, once properly tightened, the components are such that the likelihood of their coming loose as a result of seismic load conditions is very low.)*

2) Anchors used for the support of overhead equipment cannot also be used for the anchorage of seismic restraints. *(Rationale: The loads used to size hanger rods and anchors are based on the weight loads generated by the piping system. Seismic forces can increase the tensile loads significantly, and the combination of loads can cause the anchorage to fail.)*

3) Anchors to concrete must comply with minimum edge distance, spacing, and slab thickness requirements. To achieve full capacity ratings they must further not be installed into a surface containing significant tensile forces. *(Rationale: All anchorage must be in compliance with ICC allowables for seismic applications. Unless otherwise noted, it is assumed that connections are not made to the underside of structural concrete beams.)*

4) Screws attached to wood must comply with minimum edge distance, spacing, and embedment requirements, and must further not be embedded into the end grain of the

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wooden member. *(Rationale: All wood anchorage must be in compliance with NDS allowables for seismic applications. Full capacity can only be achieved with adequate embedment, end, and edge distances into the side grain of structural wood members.)*

5) Connections that have the potential to expose open bar joist chords to significant lateral loads are not permitted. *(Rationale: Open joists are notoriously weak in their lateral axis. They are not designed to take loads, particularly on the lower cord, and even light lateral loads can generate buckling and quickly cause catastrophic failure.)*

6) Connections that have the potential to generate significant lateral loads on the weak axis of I-beams or channels used as joists or columns are not permitted unless approved by the structural engineer of record. *(Rationale: Floor or roof support beams are significantly weaker in their minor axis than in their major axis. While they can, under some conditions, withstand some lateral loads, the engineer of record should be consulted to ensure that capacity exists on particular members to withstand the anticipated loads. If these loads are exceeded, catastrophic failures can quickly result.)*

7) Holes should not be added to key structural members without prior authorization from the engineer of record. *(Rationale: The addition of holes, particularly in flanges, can greatly reduce the structural capacity.*

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CONNECTION OPTIONS FOR AWKWARD SITUATIONS

Almost every project will include some areas where installing restraints in a conventional fashion will be difficult. This segment of the manual offers options to consider when confronted with various situations.

Note: The options shown below illustrate equipment viewed on a single axis, Equivalent restraint is however needed on both principle axies.

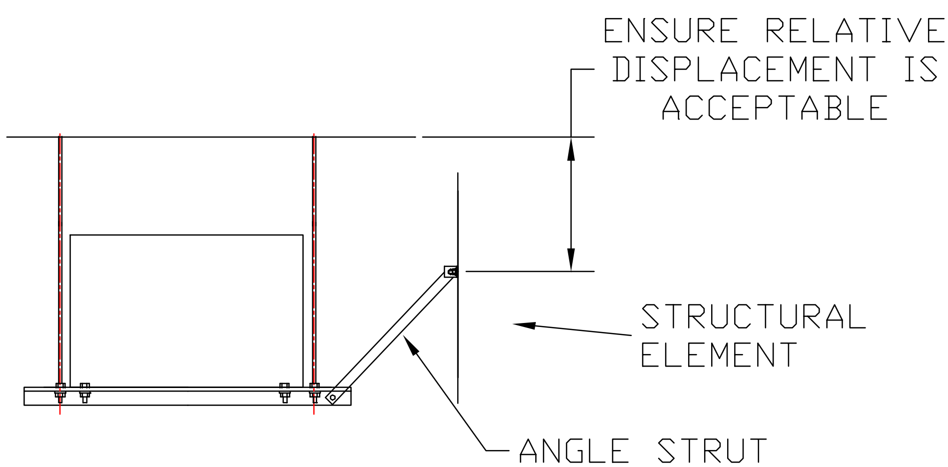
D10.6.1 Equipment Tight to Walls

Probably the most common issue in the field is how to deal with restraints where there is little room to slope cables or struts up to the ceiling structure. Frequently the walls are not structural and do not offer a surface to which to anchor.

When evaluating these kinds of spaces, the first issue is to determine if either of the walls bordering the space are structural. If they are, they can offer a surface to which the restraints can often be attached. For structural walls, any relative displacement issues between the wall and the structure supporting the pipe must be identified. The maximum permitted relative displacement is ¼ inch, which for most structures correspond to a difference in elevation of approximately 2 feet (see also the structural attachment section of this chapter).

Assuming the wall meets both of the above requirements, a lateral restraint can be run either directly over to the wall or up at a slight angle to the wall. Normally this would be done with a strut as shown below.

Figure D10.6.1; Trapeze-Mounted Equipment Restrained to Structural Wall or Column with a Strut



For the case where there are no nearby structural connection points or where the nearby structural elements are not suitable, there are several options that can be considered.

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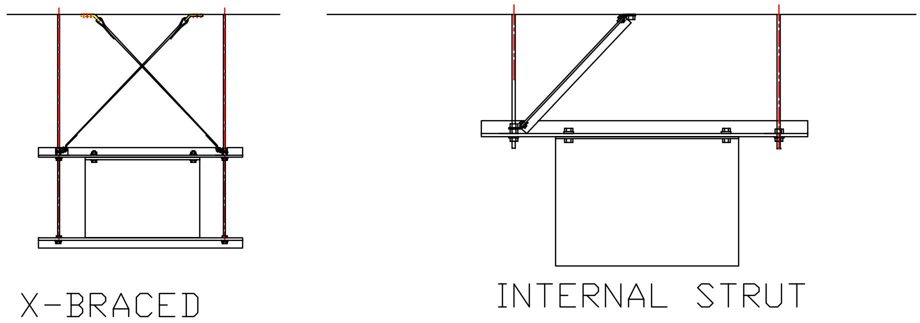
The first option is to restrain to the ceiling using "X" bracing or a diagonal strut.

Figure D10.6.2; "X" or Diagonally Braced Restraint Arrangements



A "K" or double "K" brace can also be used. The "K" can either be located inside the support rods or outside the support rods, but in the case of a double "K", both sides must be identical (either inside or outside).

Figure D10.6.2; Single and Double "K" Brace Restraint Arrangement

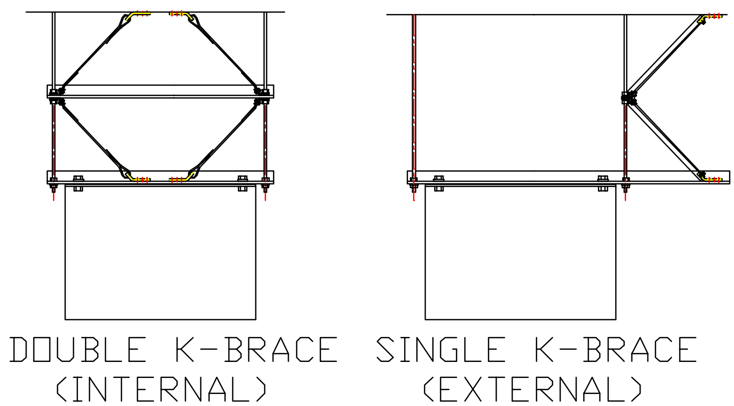


Figure D10.6.3; Wall Penetration Restraint (Cable)

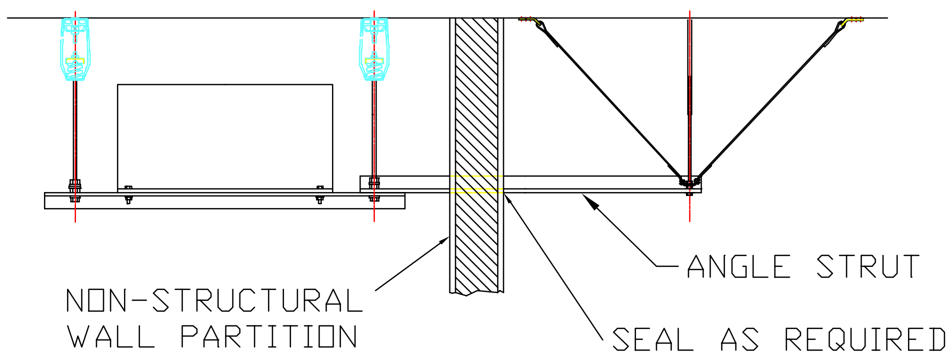


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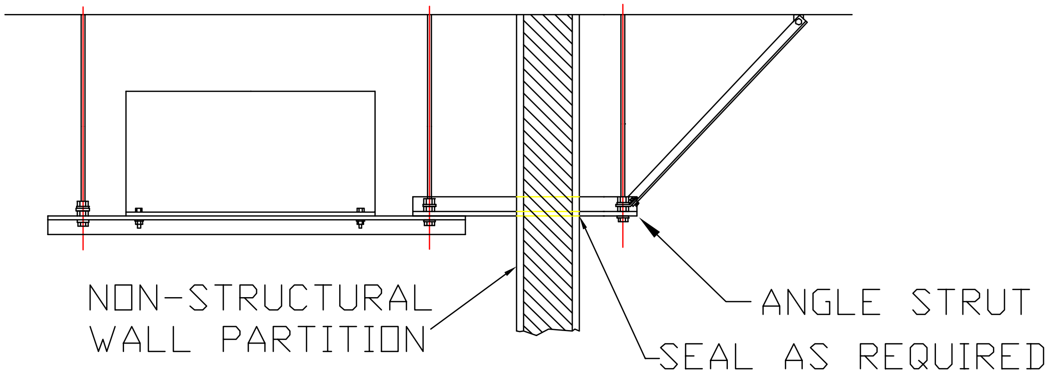
Figure D10.6.4; Wall Penetration Restraint (Strut)



D10.6.2 Piggyback or Double-Tier Restraint

In congested areas, It may be possible to restrain a piece of equipment as well as an associated distribution system with one set of restraints. Care should be used in doing this to ensure that the the components restrained together have similar properties. For example:

1) Ductwork can be restained with small AHU units or VAV boxes.
2) Pumps can be restrained with piping, valves or other piping components
3) Piping should not be restrained with AHU's
4) Ductwork should not be restrained with pumps.
5) Isolated systems must be restrained with other isolated systems
6) If piping or ductwork does not require restraint because of size or proximity to the ceiling, it cannot be connected to a piece of equipment that does.

When selecting restraints, the restraints must be adequate in capacity to resist the total load generated by both the equipment and distribution system. The graphs in Section D4.4 can be used for restraint selection for multiple components. To do this, simply reference the total weight on the left hand horizontal axis and proceed from that point using the same procedure as is used for the selection of restraints for distributed systems.

A more detailed explanation of the use of these tables is in section D4.4 of the manual.

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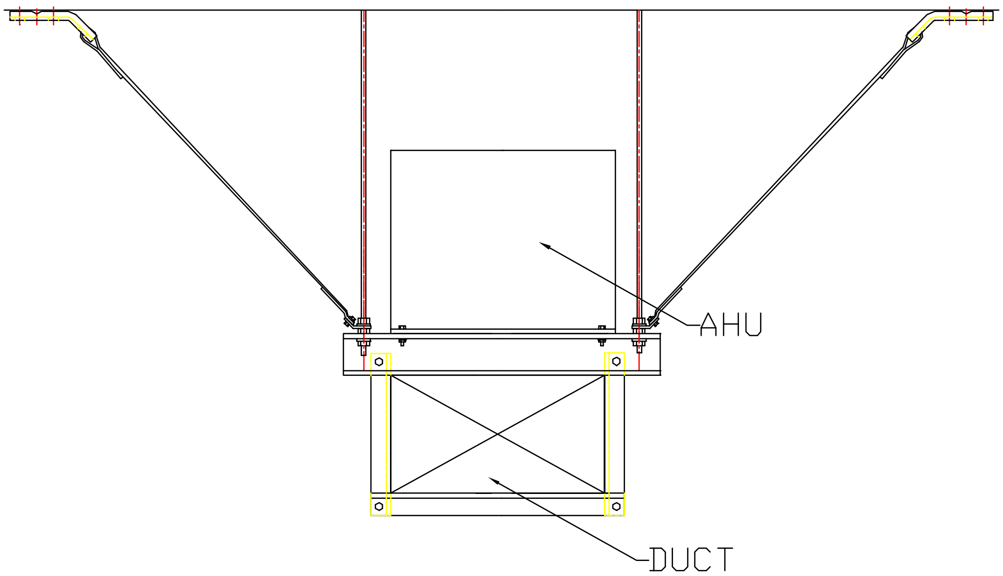
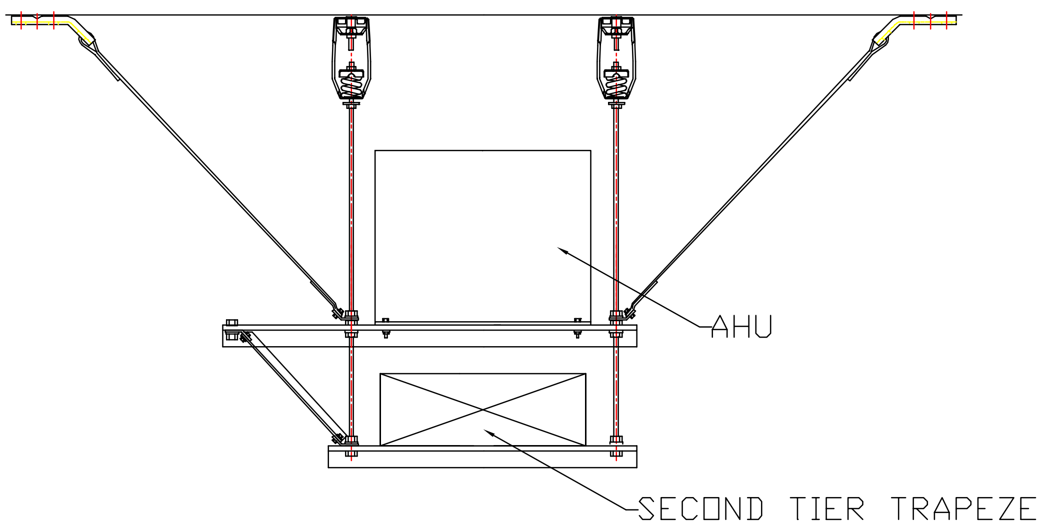
Figure D10.6.5; Piggyback Restraint Arrangement



It is possible under some conditions to brace one trapeze bar to the other, and then restrain the second trapeze bar to the structure. This is shown below:

Figure D10.6.6; Double-Tier Restraint Arrangement



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D10.6.3 Restraints for Equipment Mounted Well Below the Support Structure

This situation is not easily handled. Past history has shown, and the code is quite clear, that it is not a good idea to support the equipment from one structural element and restrain it using another structural element that will undergo significantly different motions. Restraints fit in this fashion will likely fail or cause the equipment supports to fail. Neither of these outcomes is desirable.

About the only solution to this is to add a support structure for the equipment that is located either just above or just below the level of that equipment. The equipment can then be both attached and restrained to this structure.

The structure can be supported off the floor, off the ceiling, or from structural walls or columns. The support structure must be rigid enough to absorb all of the seismic loads, and particularly the moments, with minimal deformation, transferring pure shear or tensile forces into the supporting structure.

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SECTION D11.0 – TABLE OF CONTENTS

D11.0 – ARCHITECTURAL ELEMENTS

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FLOATING FLOOR SEISMIC RESTRAINT DESIGN

Floating floors, by nature of their design, can move horizontally when subjected to earthquakes. Large lateral movements could generate instability in the isolation pads or springs and must be prevented. The amount and type of restraint required is a function of the design earthquake and the properties of both the isolation system and the floor design.

Restraint Types

There are two basic types of floating floor seismic restraints – perimeter and interior. A perimeter isolation system consists of shock-absorbing pads spaced around the perimeter of the floor and attached to structural supports. These pads prevent direct contact between the floating floor and the supporting structural elements and their flexibility reduces the impact load on the floor and provides some damping for the horizontal motion. Ideally, the structural support will be integral with the building structural system, consisting of a structural wall or curb around the floor perimeter. Alternatively, the support system can be installed after the structure is complete by anchoring structural angles to the structural system. Both types of restraints are shown in Figures D11.1-1 and D11.1-2.

Interior restraints are embedded within the floating floor. Each restraint restricts seismic motion in all horizontal directions, reducing the number of restraints required. Large floors often require internal restraints to prevent buckling of the floor during an earthquake. Another common application is for a floor without perimeter supports where the use of angles is not desired. Figures D11.1-1 and D11.1-2 show typical installations of internal seismic restraints.

Restraint Selection

The choice of internal versus external seismic restraint most often depends upon the size of the floor to be restrained (preventing buckling in the floor system) and the presence or absence of a perimeter structural support. Kinetics Noise Control or the Structural Engineer or Architect of Record for the project should determine the buckling characteristics of the floor.

If a perimeter system is selected, the ability of any supporting structure (curb or wall) to carry the applied seismic load must be determined by the Structural Engineer of Record. If no adequate support is available, a support can be designed and supplied by Kinetics. The perimeter isolation system usually consists of twelve-inch wide neoprene pads spaced five to six feet on center, with the actual spacing determined by calculation. Kinetics PIB is placed between the pads to eliminate any flanking path for noise.

Internal restraints are used when they are required to prevent buckling of the floor or when no adequate perimeter support is available. The restraints are placed before the floor is formed in either the final position (RIM-type floor) or on the structural slab (lift-slab system). The outer portion of the restraint is attached to the floating floor while the inner portion is attached to the

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structural slab. Neoprene pads integral to the support provide the impact cushioning and damping required for proper restraint.

Figure D11.1-1; Floating Floor Perimeter Isolation w/Structural Support

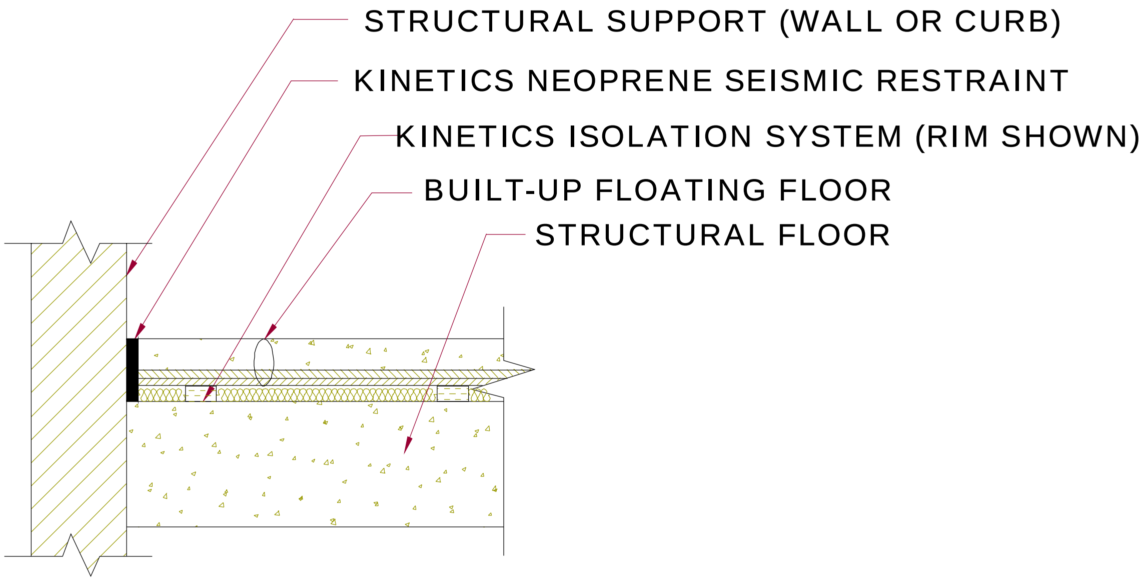

Figure D11.1-2; Floating Floor Perimeter Isolation w/Kinetics Structural Support

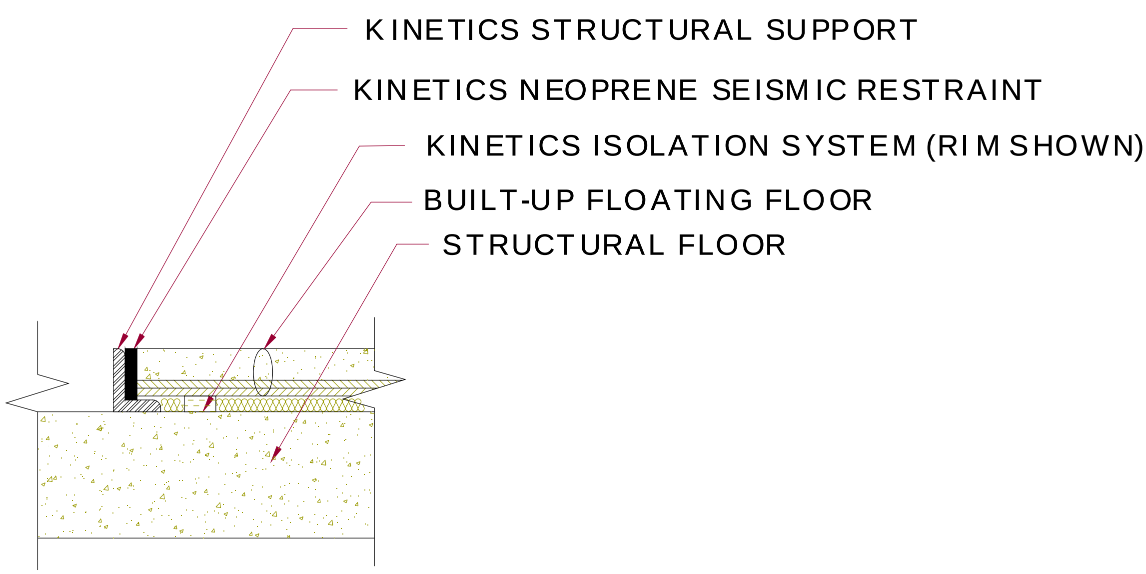

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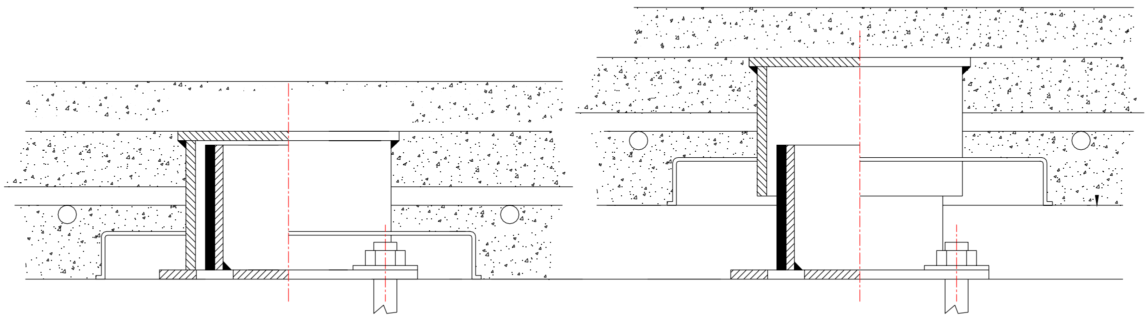
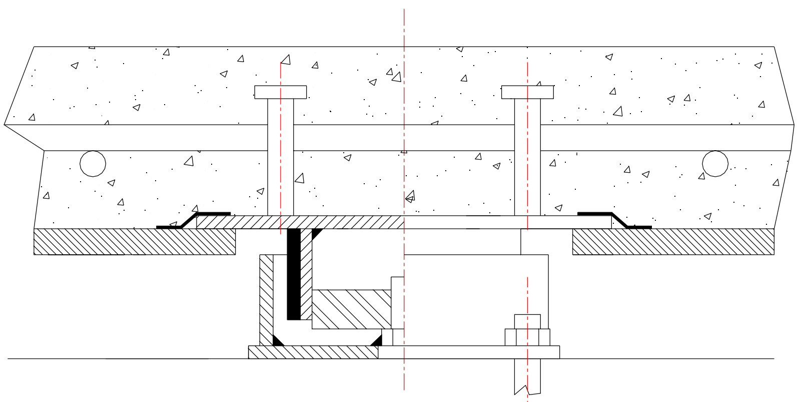
Figure D11.1-3; Internal Restraint for Lift-Slab System



a) Initial Position

b) Raised Position

Figure D11.1-4; Internal Restraint for Roll-Out System



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ISOLATED CEILING SEISMIC RESTRAINT

Isolated ceilings typically weigh between 2 and 7.5 pounds per square ft and are made of 1, 2 or 3 layers of drywall. Over larger areas, the total weight of a ceiling system can become significant and the resulting seismic forces can be significant as well. In addition, it is not uncommon for ceilings to have a stepped or otherwise non-flat profile that can limit the ability to transfer these forces out to the perimeter. Even where this is not the case, significant crushing can occur along the perimeter on even moderately sized ceilings if no centralized restraint system is provided. Because of this, for ceilings either whose length or width exceeds 15 ft, internal seismic restraint elements are recommended.

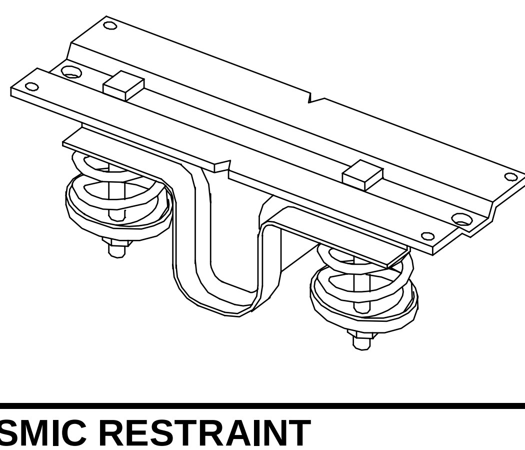
Even on smaller ceilings in some cases, equipment or light fixtures can add to the seismic loading that must be resisted and requires that appropriately sized restraints be fitted.

Restraint Types

Typically cable restraint systems are used to transfer seismic forces from the isolated ceiling to the structure in much the same way as with piping or duct systems. Because the ceilings are isolated, there is a need for cables rather than struts. An added issue when fitting restraint cables is that the cables must typically be installed and adjusted prior to the installation of the ceiling. As the drywall is added, the springs that support it will continue to deflect a noticeable additional amount. Care must be taken to ensure that this added deflection does not take all of the clearance out of the restraint cables and in so doing, generate a mechanical “short” for vibrations.

In some cases, seismically rated, housed ceiling isolators can be used. These are tolerant of the added deflection which occurs with the addition of the drywall. These however may not be suitable for all applications. More commonly conventional cable restraints are used with special attention given to ensure that no mechanical shorts will occur.

Figure D11.2-1; Seismically Rated KSCH Ceiling Support Isolator



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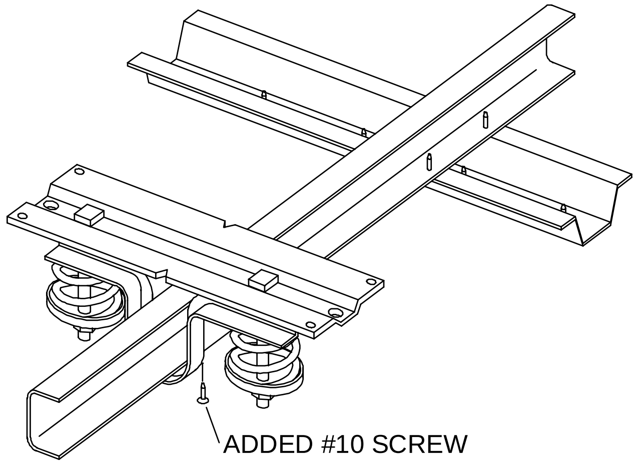
This isolator bolts directly to wood or concrete and offers positive seismic restraint for a broad range of applications. Included is a saddle that fully contains the CR channel commonly used to support isolated drywall ceiling systems. This saddle prevents side to side motion of the channel in its basic configuration. For use in seismic applications, it must be fitted with an additional #10 screw to prevent the channel from sliding through the saddle. See below.

Figure D11.2-2; KSCH Ceiling Support Isolator Installation



These Isolators are capable of supporting loads up to 140 lb per isolator while at the same time offer a horizontal restraint capacity of 100 lb each.

Figure D11.2-3; KSCH Typical Arrangement

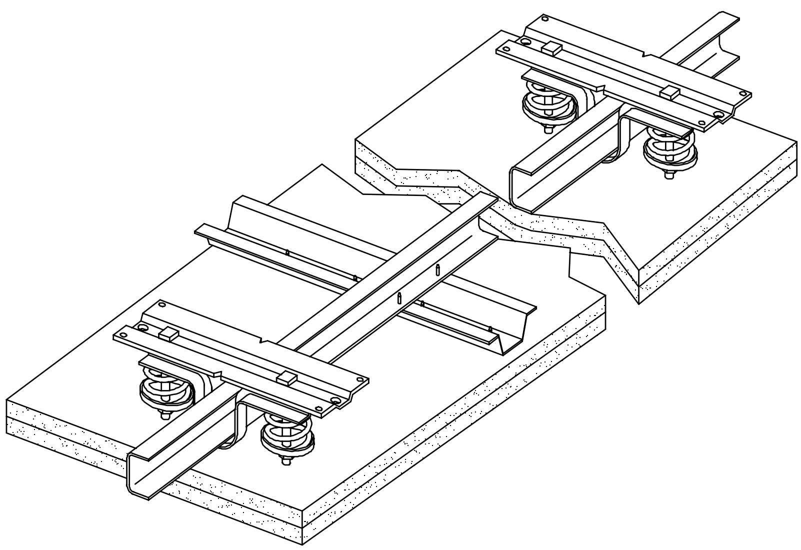


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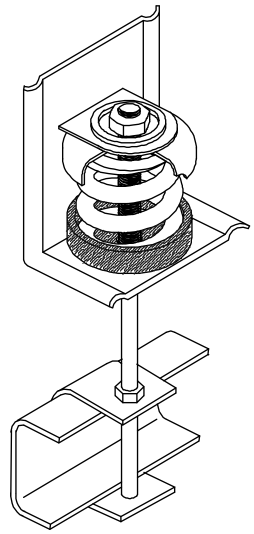
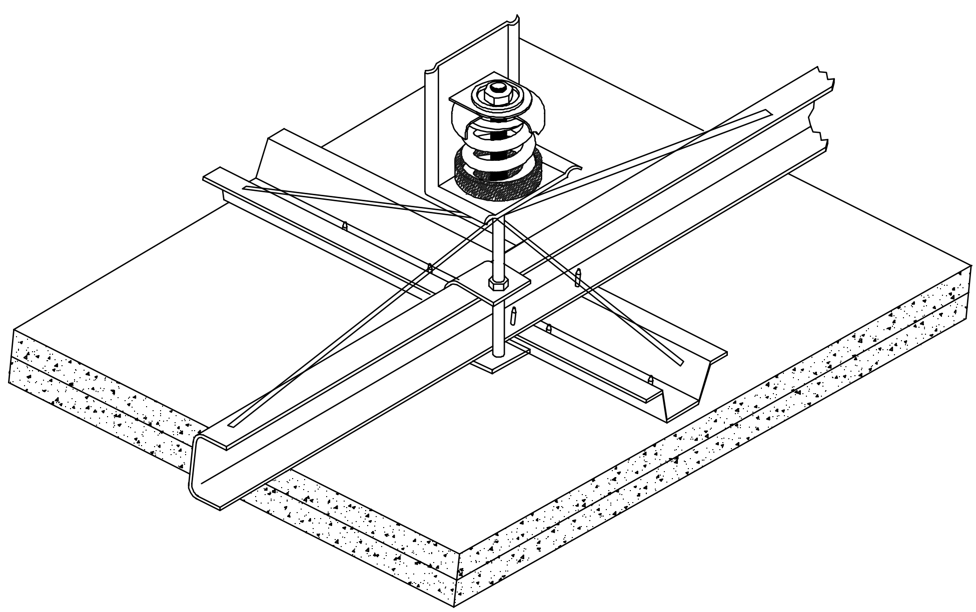
Figure D11.2-3; Seismically Rated ICW Ceiling Support Hanger



Where the isolated ceiling is suspended tight below the structure such that the CR channel is not more than 1/2" below the bottom of the bracket, the ICW Seismic Isolator can often be used.

If however, the ceiling grid is not tight up against the underside of the Isolator, it is necessary to incorporate additional cable restraint assemblies to protect the hanger rod as shown below.

Figure D11.2-4; Seismically Rated ICW Ceiling Support Hanger with Cables Added



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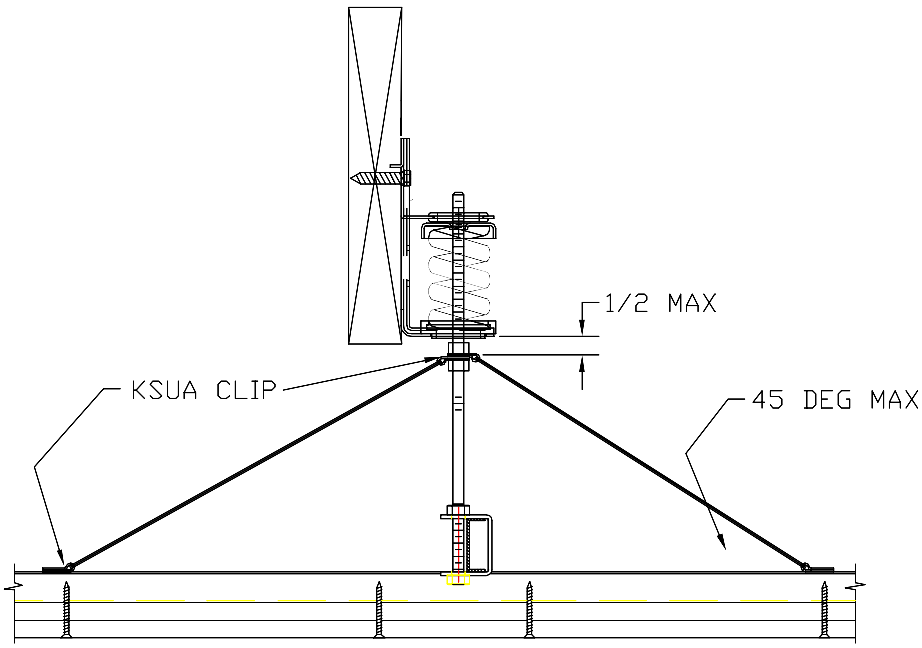
The cable restraint assemblies must connect to the hanger rod within ½" of the underside of the ICW restraint bracket as shown, but the actual exposed length of the hanger rod can be as much as 12". Connections to the ceiling grid must be with a ¼" bolt (min).

Figure D11.2-5; Seismically Rated ICW Ceiling Support Hanger Section



This restraint device is rated for 60 lb in any direction.

Restraining Ceiling Systems with Cables

Ceiling systems can be restrained using cable restraints in fashion similar to that shown above, but with the restraints connected directly to structure. When this is done, the graphs in section D4.4 of this manual can be used to aid in the selection process.

When installed, it should be assumed that the ceiling will drop ½" - 1" for most systems and provisions must be made in the cable tightness to accommodate this. It is generally recommended that the cable be put in on a shallow slope not to exceed 15 degrees from the horizontal. In addition the grid should be deflected downward manually when installing the cables to approximately the expected deflection amount. In that condition, the cable should be slightly loose (1/16" to 3/16" lateral motion allowed).

In addition, the isolation hangers should be mounted close to, but not in contact with the underside of the ceiling structure. Maximum clearance under load should not exceed 1/8".

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ISOLATED WALL SEISMIC RESTRAINT

Proper installation of isolated walls requires that the wall not only be resiliently supported, but that they are also resiliently stabilized. Because the walls are not part of the building structure, they do not have a membrane to support the upper edges. This makes them inherently unstable. They are also subject to lateral loads from contact with other objects or due to the attachment of wall mounted components to them. The requirement for stabilization is compounded in seismic areas where the walls can be exposed to significant lateral acceleration forces.

Because masonry walls require high compressive loads to prevent internal buckling and because they possess a high level of mass, the requirement for restraint becomes more critical. The stabilizing compressive load present in a load bearing wall is not present in a free standing wall rendering them easily susceptible to seismic damage.

To determine the amount of support required by the wall several factors must be taken into account. These are: 1) the amount of natural support dictated by the room geometry (corners and intersections), 2) the stability provided by the type of construction, 3) the unit mass of the isolated wall and 4) the anticipated lateral loading to which the wall may be subjected.

Beginning with the rooms "natural support", it is safe to assume that any corner or intersection point that occurs in the isolated wall system where at least 2 of the intersecting walls extend a distance equal to 50% of the walls height can be considered to form a natural restraint. For example, a 10 ft x 10 ft room with 8 ft tall isolated walls can be considered to have 4 naturally supported corners. However, if we consider a wall with a 6 in long jog in its center, the jog (since it's length is less than 50% of the wall height) cannot be considered to be a natural support.

The various methods used to construct isolated walls have different levels of resistance against buckling. For example, a masonry wall that is not subjected to weight bearing loads is quite weak in buckling, where a masonry wall that is bearing weight can be quite resistant to it. In non-weight bearing applications, frame construction is generally more resistant to vertical buckling loads than masonry. On the other hand, frame construction is also generally weaker than masonry walls when evaluating the transfer of loads along the length of the wall. This is because, apart from the top and bottom, the framing members do not normally run in the horizontal axis.

The surface mass of a wall works in conjunction with seismic accelerations to generate buckling and toppling forces. Lower surface mass framed walls are much less subject to damage from seismic loads than are heavy masonry ones.

Floating walls subjected to horizontal loads can buckle or topple in the vertical plane or can buckle along their length. Illustrations of the vertical failure modes are shown below. The first

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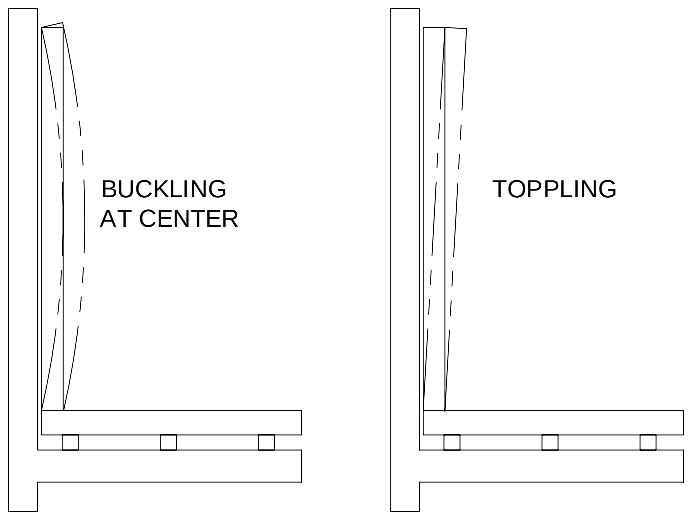
case (buckling) is the result of the wall being restrained top and bottom but with too great a vertical center distance between restraints. The second (toppling) is the result of inadequate restraint at the top.

Figure 11.3-1; Wall Failure Modes



The buckling mode along the walls length is similar to the buckling case above except that it occurs in the horizontal plane. It most commonly occurs along the top edge of a wall where there is no positive continuous restraint fitted and where the horizontal distance between localized restraints is excessive.

All walls must be designed to resist the anticipated seismic forces (as a minimum) and if there are known or anticipated forces that may result from other factors which exceed the seismic loads, they must be identified and used for sizing the appropriate restraint devices. This document will identify the restraints necessary based on seismic requirements only.

In the case of seismic events, the driving force is created by horizontal accelerations acting on the mass of the wall. Resisting this loading are the restraints and the buckling strength of the wall itself. The wall's buckling strength and mass can be determined for commonly used building cross sections and using this, the wall's natural ability to withstand horizontal accelerations can be determined. This resistance/force relationship can then be used to determine the maximum allowable span length between restraints.

Once the spacing is determined, the actual load that the restraint must be capable of handling can be quickly determined by dividing the supported wall mass among the supporting restraints and applying the appropriate acceleration factor to it.

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As wall restraints/isolators include no running clearance, these devices must be capable of developing this force while still maintaining a low enough natural frequency to ensure the isolation characteristics of the wall.

As the natural frequency of a system is a function of its supported mass and spring rate (measured as deflection if the spring is oriented vertically). A restraint should be selected based on its having the desired spring rate in the unloaded condition. It is also desirable to have a relatively short working range to minimize wall motion during a seismic event. Restraints with a graduated spring rate such as occur in neoprene pads with simple shapes tend to be ideal for this.

It is always worthy of note to indicate that when isolators are oriented horizontally and are not affected by gravity, the installed deflection is not part of the design requirement. This is because natural frequency is a function of mass and spring rate and not of deflection.

Based on the trade-off between the inherent or natural strength of isolated walls of various constructions and their mass, the following table has been generated. It provides a recommended maximum spacing for restraints on both the vertical and horizontal axis based on seismic accelerations and is broken down by wall type. It also lists the approximate maximum load that the restraint is likely to see.

Seismic Acceleration in G's

Acceleration Factor	2		1		0.75		0.4		0.2		0.1		Maximum Restraint Force
Type Wall	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Force
Masonry	CD (in)	CD (in)	CD (in)	CD (in)	CD (in)	CD (in)	CD (in)	CD (in)	CD (in)	CD (in)	CD (in)	CD (in)	lbs
6" Block/Hollow	22	22	31	31	36	36	49	49	70	70	99	99	509
6" Block/Sand Filled	26	26	36	36	42	42	57	57	81	81	114	114	509
8" Block/Hollow	23	23	33	33	38	38	52	52	73	73	104	104	749
8" Block/Sand Filled	27	27	38	38	44	44	60	60	85	85	120	120	749
12" Block/Hollow	24	24	34	34	40	40	54	54	77	77	109	109	1232
12" Block/Sand Filled	28	28	40	40	46	46	63	63	89	89	120	120	1232
Frame/Drywall													
16" Centers / 1/2" Drywall	22	78	32	111	37	120	50	120	71	120	71	120	61
16" Centers / 1" Drywall	17	60	24	85	28	98	38	120	54	120	77	120	61
16" Centers / 1-1/2" Drywall	14	51	20	72	24	83	32	113	46	120	65	120	61
16" Centers / 5/8" Drywall	21	72	29	102	34	118	46	120	65	120	93	120	61
16" Centers / 1-1/4" Drywall	16	55	22	77	26	89	35	120	50	120	70	120	61
16" Centers / 1-7/8" Drywall	13	46	19	65	21	75	29	102	41	120	59	120	61
24" Centers / 1/2" Drywall	24	67	33	95	39	110	53	120	75	120	75	120	50
24" Centers / 1" Drywall	18	51	25	72	29	83	40	113	56	120	79	120	50
24" Centers / 1-1/2" Drywall	15	42	21	60	24	69	33	94	47	120	66	120	50
24" Centers / 5/8" Drywall	22	62	31	87	35	101	48	120	68	120	97	120	50
24" Centers / 1-1/4" Drywall	16	46	23	65	26	75	36	102	51	120	72	120	50
24" Centers / 1-7/8" Drywall	13	38	19	54	22	62	30	85	42	120	60	120	50

To ensure that the wall is not damaged when subjected to the max loading condition, total design deflection in the restraint device should be limited to 1/4" (max).

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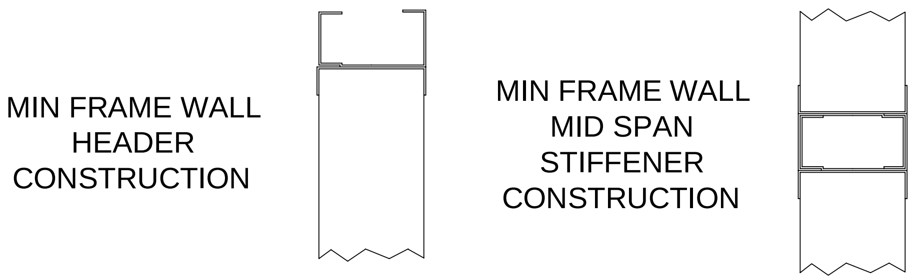
The following assumptions were used in compiling these tables:

The masonry construction assumes a tensile strength of 275 PSI in the mortar.

The frame construction assumes the use of 20 ga metal 2 x 4 studs. It also requires that if the frame wall exceeds 120" in height, 2-20 ga metal 2 x 4 studs are interlocked and sandwiched between 2-20 ga 2 x 4 metal framing channels. These must run horizontally along the walls length and are oriented to align the ends of the upper and lower vertically oriented studs. For all frame walls a single 20 ga metal 2 x 4 stud is welded or screwed to a 20 ga 2 x 4 metal framing channel to form the top plate of the wall.

Figure 11.3-2; Framed Wall Typical Sections



Isolated Masonry walls are normally set into a pocket formed by extending the recess in the structural slab allowed for installation of a floating floor beyond the perimeter of the floating floor itself. When used, this gap is sized to allow an isolated wall to penetrate the floating floor and sit on its own set of support pads. As an option, masonry walls can also be set onto the perimeter of the floating floor and doweled to it in a fashion that can resist seismic shear loads at the wall's base.

Framed walls are frequently supported either on the perimeter of the floating floor as mentioned above or are mounted on their own set of isolation pads that are spaced at regular intervals down the length of the base rail. In either case, the anchors used to connect the wall to the floor must be sized to resist the seismic shear loads that can occur at the base of the wall. Normal spacing as specified by Kinetics Noise Control is adequate for this task in all seismic conditions

As the isolated wall is intended to reduce the flow of noise from one space to another, the tops of these walls will normally about the underside of a floor or ceiling element. These connections should be sealed to resist the flow of sound and frequently this is accomplished via the use of rubber faced angles that hard attach to the structure and cradle the top of the wall. If these are used for restraint purposes, they must be sized based on the expected load. Kinetics Noise Control offers the IPRB, neoprene faced angle brackets that are frequently used for this task.

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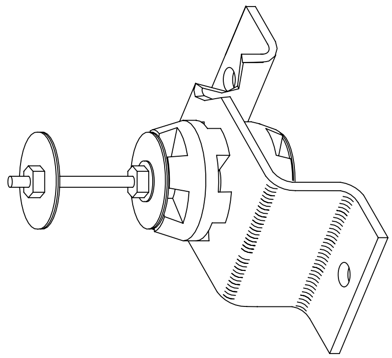
Seismic Sway Braces for Masonry

For the interior expanse of isolated walls or where the IPRB does not possess adequate capacity on its own to restrain the top, there are several products that can be used. The Kinetics PSB sway brace is commonly used for the restraint of isolated walls made of masonry. These are rated with capacities up to 2000 lb.

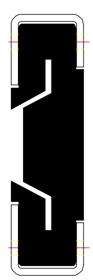
Figure 11.3-3; PSB Sway Brace



An additional option for lighter duty applications is the KWSB. This is lighter duty and is made to connect to the framing members that make up the structure of the isolated wall. Capacities on KWSB go up to 50 lb.

Probably the best solution for gauge material is the Isomax wall clip. This is designed to both support a wall and when spaced in a 24" x 48" array, can provide adequate restraint for walls made up of as much as 3 layers of 5/8" drywall in applications as high as .5 G. The Seismic rating can increase with reduced spacing if need be.

Figure 11.3-4; IsoMax Wall Isolation Clip



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CHAPTER D12

RECOMMENDED SEISMIC SPECIFICATIONS

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KINETICS LONG FORM SEISMIC SPECIFICATION

1.0 General

1.01 Related Work Specified Elsewhere

(Vibration Isolation portion of specs, fill in as required)

1.02 Definitions

1) A_v: Effective peak velocity related acceleration coefficient BOCA, SBC Code.
2) S_1: Mapped Long Period Seismic acceleration coefficient IBC, TI-809-04 Code.
3) S_s: Mapped Short Period Seismic acceleration coefficient IBC, TI-809-04 Code.
4) v: Zonal Velocity coefficient NBC-Canada
5) SMACNA: (Sheet Metal and Air Conditioning Contractors National Association) has developed Guidelines for the installation of restraints for piping and duct systems.
6) VISCMA: (Vibration Isolation and Seismic Control Manufactures Association) has developed Testing and Rating Standards for Seismic Restraint Components that comply with Code and ASHRAE based requirements.
7) Z: Seismic Zone defines Seismic Coefficient C_a used by UBC Code.

1.03 Performance Requirements

1) Design Ground Acceleration Coefficient (A_v, S_s, v or Z depending on Code =X.XX)
2) *(If IBC or TI-809-04)* Design Long Period Ground Acceleration Coefficient (S_1 =X.XX)
3) Design Soil Type = (S_a, S_b, S_c, S_d) as appropriate. (If NBC Canada, the Foundation Factor)
4) Importance or Performance Factor appropriate to structure = X.XX
5) If UBC Zone 4, Proximity to Fault and, if less than 10km, Fault Type
6) Equipment Schedule (IBC, TI-808-04, 97UBC) The Mechanical Engineer of record will provide a comprehensive Equipment Schedule indication individual equipment importance factors, Ip, (including equipment whose importance factor, Ip, may be increased by proximity to essential life safety or hazardous components), equipment elevation both in the structure and(if floor mounted, relative to the floor), roof elevation and structural interface material, i.e., anchored to concrete, bolted or welded to steel.
7) Schedule or drawings indicating critical (Ip=1.5) Duct/Piping systems, including systems whose importance factor may be increased by proximity to critical components.

1.04 Submittals

1) Product Data: Include Seismic Rating Curve for each seismically rated isolator or

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restraint component

2) Samples: The contractor shall submit samples of specified seismic snubber devices upon request of the engineer for approval

3) Shop Drawings: Include the following:

   A) Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases. Certification documents to be signed and sealed by a qualified Professional Engineer with at least 5 years experience in the design of seismic restraints.

   B) Vibration Isolation Bases: Dimensional drawings including anchorage and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, base weights, equipment static loads.

   C) Seismic-Restraint Details: Detail submittal drawings of seismic restraints and snubbers. Show anchorage details and indicate quantity, diameter, and depth of penetration of anchors.

   D) Submittals for Interlocking Snubbers: Include ratings for horizontal, vertical and combined loads.

   E) Equipment Manufacturer Seismic Qualification Certification: The Equipment Manufacturer must submit certification that each piece of provided equipment will withstand seismic forces identified in "Performance Requirements" Article above. Include the following:

      1) Basis for Certification: Indicate whether the “withstand” certification is based on actual test of assembled components or on calculations.

      2) Indicate the equipment is certified to be durable enough to:

         A) structurally resist the design forces and/or

         B) will also remain functional after the seismic event.

   F) Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

   G) Detailed description of the assumed equipment anchorage devices on which the certification is based.

1.05 Work Furnished But Not Installed

1) The materials and systems specified in this section shall be purchased by the mechanical contractor from a single seismic snubber restraint materials manufacturer to assure sole source responsibility for the performance of the seismic restraints used.

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2) The materials and systems specified in this section can, at the contractor's option, be installed by the subcontractor who installs the mechanical equipment, piping, or ductwork.

1.06 Coordination

1) Coordinate size, shape, reinforcement and locate cast in place anchor-bolt inserts for concrete Inertia bases. 3000 psi min Concrete and/or formwork as needed is provided by others.

2) Coordinate design of roof curbs and equipment supports to be compatible with equipment parameters.

1.07 Description of System

1) It shall be understood that the requirements of this seismic restraint section are in addition to other requirements as specified elsewhere for the support and attachment of equipment and mechanical services, and for the vibration isolation of same equipment. Nothing on the project drawings or specifications shall be interpreted as justification to waive the requirements of this seismic restraint section.

2) The work under this section shall include furnishing all labor, materials, tools, appliances, and equipment, and performing all operations necessary for the complete execution of the installation of seismic snubber restraint assemblies as shown, detailed, and/or scheduled on the drawing and/or specified in this section of the specifications

3) All seismic snubber restraint assemblies shall meet the following minimum requirements:

A) The snubber shall include a high quality elastomeric element that will ensure that no un-cushioned shock can occur.

B) It shall be possible to visually inspect the resilient material for damage and replace it if necessary.

C) Resilient material used in snubber assemblies to be a minimum of 0.25" (6 mm) thick.

D) Resilient material used in snubber grommets to be a minimum of 0.12" (3 mm) thick.

E) All Interlocking Snubbers to include a maximum air gap of .25 in (6mm).

F) Assembly must be designed to offer seismic restraint in all directions, unless otherwise noted below.

G) Seismic restraint capacities to be verified by an independent test laboratory or certified by an experienced registered Professional Engineer to ensure that the design intent of this specification is realized.

4) Vibration Isolation Bases: Dimensional drawings including anchorage and attachments to structure and to supported equipment. Include auxiliary motor slides

1.08 System Design

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1) Seismic snubber manufacturer shall be responsible for the structural design of attachment hardware as required to attach snubbers to both the equipment and supporting structure on vibration isolated equipment, or to directly attach equipment to the building structure for non-isolated equipment.

2) The contractor shall furnish a complete set of approved shop drawings of all mechanical and electrical equipment which is to be restrained to the seismic restraint manufacturer, from which the selection and design of seismic restraint devices and/or attachment hardware will be completed. The shop drawings furnished shall include, at a minimum, basic equipment layout, length and width dimensions, installed operating weights of the equipment to be restrained and the distribution of weight at the restraint points.

3) All piping and ductwork is to be restrained to meet code requirements. Spacing between restraints is not to exceed the allowable spacing listed in the latest revision of the SMACNA manual (Sheet Metal and Air Conditioning Contractors National Association, Inc.) "Seismic Restraint Manual Guidelines for Mechanical Systems", Second Edition, 1998. At a minimum, the seismic restraint manufacturer will provide documentation on maximum restraint spacing for various cable sizes and anchors, as well as 'worst case' reaction loads at restraint locations. In addition, seismic restraint manufacturer will provide support documentation containing adequate information to allow the installation contractor to make reasonable field modifications to suit special case conditions.

4) The contractor shall ensure that all housekeeping pads used are adequately reinforced and are properly attached to the building structural flooring, so to withstand anticipated seismic forces. In addition, the size of the housekeeping pad is to be coordinated with the seismic restraint manufacturer so to ensure that adequate edge distances exist in order to obtain desired design anchor capabilities.

1.09 Alternate Systems

1) Provisions of the General Conditions and Supplemental Conditions of the specifications shall govern the use of alternate systems to those specified.

2) Manufacturers not listed as approved in "Part 2 Materials" of this section must secure approval to bid a minimum of ten (10) days prior to the project bid date.

3) Uncertified internal equipment seismic restraint systems are disallowed for use on this project.

1.10 Installation

1) Installation of all seismic restraint materials specified herein shall be accomplished following the manufacturer's written instructions. Installation instructions shall be submitted to the engineer for approval prior to the beginning of the work.

2.0 Materials

2.01 Source of Materials

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1) All seismic snubbers and combination snubber / vibration isolation materials specified herein shall be provided by a single manufacturer to assure sole source responsibility for the proper performance of the materials used. Manufacturer is to be a member of VISCMA (Vibration Isolation and Seismic Control Manufacturers Association).

2) Mechanical anchor types and sizes are to be per the design data as provided by the seismic restraint manufacturer.

3) Materials and systems specified herein and detailed or scheduled on the drawings are based upon materials manufactured by Kinetics Noise Control, Inc. Materials and systems provided by other manufacturers are acceptable, provided that they meet all requirements as listed in this specification.

4) Where not protected by a shield, resilient materials shall be easy to visually inspect for damage.

2.02 Factory Finishes

1) Manufacturer's standard prime-coat finish ready for field painting.

2) Finish: Manufacturer's standard paint applied to factory-assembled and -tested equipment before shipping.

    A) Powder coating on springs and housings.

    B) All hardware shall be electrogalvanized. Hot-dip galvanize or powder coat metal housings for exterior use.

    C) Enamel or powder coat metal components on isolators for interior use.

    D) Color-code or otherwise mark vibration isolation and seismic-control devices to indicate capacity range.

2.03 Seismic Snubber Types

Isolator / Snubber Types contained herein are per ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.) Handbook, 2003 HVAC Applications, Chapter 54 "Seismic and Wind Restraint Design", Pages 12 and 13.

1) Type A): Coil Spring Isolator Incorporated Within A Ductile Iron Or Cast Aluminum Housing

    A) Cast iron or aluminum housings are brittle when subjected to shock loading and are therefore not approved for seismic restraint applications.

2) Type B): Coil Spring Isolator Incorporated Within A Steel Housing

    A) Spring isolators shall be seismic control restrained spring isolators, incorporating a single or multiple coil spring element, having all of the characteristics of free standing coil spring isolators as specified in the vibration isolation portion of this specification. Springs shall be restrained using a housing engineered to limit both lateral and vertical

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movement of the supported equipment during an earthquake without degrading the vibration isolation capabilities of the spring during normal equipment operating conditions.

B) Vibration isolators shall incorporate a steel housing and neoprene snubbing grommet system designed to limit motion to no more than ¼" (6 mm) in any direction and to prevent any direct metal-to-metal contact between the supported member and the fixed restraint housing. The restraining system shall be designed to withstand the seismic design forces in any lateral or vertical direction without yield or failure. Where the capacity of the anchorage hardware in concrete is inadequate for the required seismic loadings, a steel adapter base plate to allow the addition of more or larger anchors will be fitted to fulfill these requirements. In addition to the primary isolation coil spring, the load path will include a minimum ¼" (6 mm) thick neoprene pad.

C) Spring elements shall be color coded or otherwise easily identified. Springs shall have a lateral stiffness greater than 1.2 times the rated vertical stiffness and shall be designed to provide a minimum of 50% overload capacity. Non-welded spring elements shall be epoxy powder coated and shall have a minimum of a 1000 hour rating when tested in accordance with ASTM B-117.

D) To facilitate servicing, the isolator will be designed in such a way that the coil spring element can be removed without the requirement to lift or otherwise disturb the supported equipment.

E) Spring isolators shall be Model FHS as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (2).

3) Type C): Coil Spring Isolator Incorporated Within A Steel Housing

A) Spring isolators shall be seismic control restrained spring isolators, incorporating one or more coil spring elements, having all of the characteristics of free standing coil spring isolators per the vibration isolation section of this specification, for equipment which is subject to load variations and/or large external forces. Isolators shall consist of one or more laterally stable steel coil springs assembled into fabricated welded steel housings designed to limit movement of the supported equipment in all directions.

B) Housing assembly shall be made of fabricated steel members and shall consist of a top load plate complete with adjusting and leveling bolts, adjustable vertical restraints, isolation washers, and a bottom load plate with internal non-skid isolation pads and holes for anchoring the housing to the supporting structure. Housing shall be hot dipped galvanized for outdoor corrosion resistance. Housing shall be designed to provide a constant free and operating height within 1/8" (3 mm).

C) The isolator housing shall be designed to withstand the project design

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seismic forces in all directions.

D) Coil spring elements shall be selected to provide static deflections as shown on the vibration isolation schedule or as indicated or required in the project documents. Spring elements shall be color coded or otherwise easily identified. Springs shall have a lateral stiffness greater than 1.2 times the rated vertical stiffness and shall be designed to provide a minimum of 50% overload capacity. Non-welded spring elements shall be epoxy powder coated and shall have a minimum of a 1000 hour rating when tested in accordance with ASTM B-117.

E) Spring isolators shall be Model FLSS as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (3)

4) Type D): Coil Spring Isolator Incorporated With Integral Seismic Restraint

A) Spring isolators shall be single or multiple coil spring elements which have all of the characteristics of free standing coil spring isolators as specified in the vibration isolation portion of this specification, incorporating lateral and vertically restrained seismic housing assemblies. Spring elements shall be readily replaceable without the need to lift or remove the supported equipment.

B) Restraint housing shall be sized to meet or exceed the force requirements of the application and shall have the capability of accepting coil springs of various sizes, capacities, and deflections as required to meet the required isolation criteria. All spring forces shall be contained within the coil / housing assembly, and the restraint anchoring hardware shall not be exposed to spring generated forces under conditions of no seismic force. Spring element leveling adjustment shall be accessible from above and suitable for use with a conventional pneumatic or electric impact wrench.

C) Restraint element shall incorporate a steel housing with elastomeric elements at all dynamic contact points. Elastomeric elements shall be replaceable. Restraint shall allow ¼" (6 mm) free motion in any direction from the neutral position. Restraint shall have an overturning factor (ratio of effective lateral snubber height to short axis anchor spacing) of 0.33 or less to ensure optimum anchorage capacity.

D) Spring isolators shall be Model FMS as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (4).

5) Type E): All Direction Neoprene Isolator

A) Vibration Isolators shall be neoprene, molded from oil resistant compounds, designed to operate within the strain limits of the isolator so to provide the maximum isolation and longest life expectancy possible

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using neoprene compounds. Isolators shall include encapsulated cast-in-place top steel load transfer plate for bolting to equipment and a steel base plate with anchor holes for bolting to the supporting structure. Ductile iron or cast aluminum components are not acceptable alternatives and shall not be used due to brittleness when subjected to shock loading.

B) Isolator shall be capable of withstanding the design seismic loads in all directions with no metal-to-metal contact.

C) Isolator shall have minimum operating static deflections as shown on the project Vibration Isolation Schedule or as otherwise indicated in the project documents and shall not exceed published load capacities.

D) Neoprene isolators shall be Model RQ as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (5)

6) Type F): Light Capacity All Direction 3-Axis External Seismic Snubber Assembly

A) Equipment shall be restrained against excessive movement during a seismic event by the use of 3-axis resilient snubbers, designed to withstand the project required seismic forces. A minimum of two (2) snubbers are to be used at each equipment installation, oriented to effectively restrain the isolated equipment in all three directions, and additional snubbers shall be used as required by seismic design conditions.

B) Snubbers shall be of interlocking steel construction and shall be attached to the equipment structure and equipment in a manner consistent with anticipated design loads. Snubbers shall limit lateral and vertical equipment movement at each snubber location to a maximum of ¼" (6 mm) in any direction.

C) Snubbers shall include a minimum ¼" (6 mm) thick resilient neoprene pads to cushion any impact and to avoid any potential for metal-to-metal contact. Maximum neoprene bearing pressure shall not exceed 1500 pounds / sq. inch (10.4 N / sq. mm). Snubber shall be capable of withstanding an externally applied seismic force of up to 3,000 pounds (1360 kg.) in any direction. Snubber shall be installed only after the isolated equipment is mounted, piped, and operating so as to ensure that no contact occurs during normal equipment operation.

D) Three-axis seismic snubbers shall be Model HS-5 as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and 2.01, 2.02 and 2.03 (6)

7) Type G): Lateral 2-Axis External Seismic Snubber Assembly

A) Equipment shall be restrained against excessive lateral movement

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during a seismic event by the use of 2-axis horizontal resilient snubbers, designed to withstand the project required seismic forces. A minimum of two (2) snubbers are to be used at each equipment installation, oriented to effectively restrain the isolated equipment in all horizontal directions, and additional snubbers shall be used as required by seismic design conditions.

B) Snubbers shall be of interlocking steel construction and shall be attached to the equipment structure and equipment in a manner consistent with anticipated design loads. Snubbers shall limit lateral equipment movement at each snubber location to a maximum of ¼" (6 mm).

C) Snubbers shall include a minimum of ¼" (6 mm) thick resilient neoprene pads to cushion any impact and to avoid any potential for metal-to-metal contact. Snubber shall be installed only after the isolated equipment is mounted, piped, and operating so as to ensure that no contact occurs during normal equipment operation.

D) Two-axis lateral seismic snubbers shall be Model HS-2 as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (7)

8) Type H): Heavy Capacity All Direction 3-Axis External Seismic Snubber Assembly

A) Equipment shall be restrained against excessive vertical and horizontal movement during a seismic event by the use of 3-axis resilient snubbers, designed to withstand the project required seismic forces. A minimum of two (2) snubbers are to be used at each equipment installation, oriented to effectively restrain the isolated equipment in all three directions, and additional snubbers shall be used as required by seismic design conditions.

B) Snubbers shall be of welded interlocking steel construction and shall be attached to the equipment structure and equipment in a manner consistent with anticipated design loads. Snubbers shall limit lateral and vertical equipment movement at each snubber location to a maximum of ¼" (6 mm) in any direction.

C) Snubbers shall include resilient neoprene pads with a minimum thickness of ¼" (6 mm) to cushion any impact and to avoid any potential for metal-to-metal contact. Snubber shall be capable of withstanding an externally applied seismic force of up to 10,000 pounds (4,540 kg.) in any direction. Snubber shall be installed only after the isolated equipment is mounted, piped, and operating so as to ensure that no contact occurs during normal equipment operation.

D) Three-axis seismic snubbers shall be Model HS-7 as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and

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sections 2.01, 2.02 and 2.03 (8)

9) Type I): Horizontal 1-Axis External Seismic Snubber Assembly

A) Equipment shall be restrained against excessive horizontal one-axis movement during a seismic event by the use of single-axis resilient snubbers, designed to withstand the project required seismic forces. A minimum of four (4) snubbers are to be used at each equipment installation, oriented to effectively restrain the isolated equipment in all lateral directions.

B) Snubbers shall be of steel construction and shall be attached to the equipment structure and equipment in a manner consistent with anticipated design loads. Snubbers shall limit lateral equipment movement at each snubber location in the direction of impact to a maximum of ¼" (6 mm).

C) Snubbers shall include resilient neoprene pads with a minimum thickness of ¼" (6 mm) to cushion any impact and to avoid any potential for metal-to-metal contact. Snubber shall be installed only after the isolated equipment is mounted, piped, and operating so as to eliminate any contact during normal equipment operation.

D) Single-axis seismic snubbers shall be Model HS-1 as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (9)

10) Type J): Cable Restraints For Suspended Piping and Ductwork

A) Seismic wire rope cable restraints shall consist of steel wire strand cables, sized to resist project seismic loads, arranged to offer seismic restraint capabilities for piping, ductwork, and suspended equipment in all lateral directions.

B) Building and equipment attachment brackets at each end of the cable shall be designed to permit free cable movement in all directions up to a 45 degree misalignment. Protective thimbles shall be used at sharp connection points as required to eliminate potential for dynamic cable wear and strand breakage.

C) Restraints shall be sized to the capacity of the cable or to the capacity of the anchorage, whichever is the lesser.

D) Seismic wire rope connections shall be made using overlap wire rope "U" clips or seismically rated tool-less wedge insert lock connectors.

E) Vertical suspension rods shall be braced as required to avoid potential for buckling due to vertical 'up' forces. Braces shall be structural steel angle uniquely selected to be of sufficient strength to prevent support rod bending. Brace shall be attached to the vertical suspension rod by a series of adjustable clips. Clips shall be capable of securely locking brace to suspension rod without the need for hand tools.

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F) Where clevis hanger brackets are used for seismic restraint attachment, they will be fitted with clevis internal braces to prevent buckling of the hanger brackets.

G) Seismic cable shall be as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.03 through 1.07 inclusive, and sections 2.01, 2.02 and 2.03 (10)

H) Seismic cable building and equipment attachment brackets shall be Model KSCA, KSCU or KSCC as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (10).

I) Seismic cable concrete anchor bolts shall be (Model KCAB Wedge) / (Model KUAB Undercut) as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (10).

J) Seismic wire rope connectors shall be (Model KWRC - 'U' clamp) / (Model KWGC - Tool-less wedge lock) as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (10).

K) Seismic vertical suspension stiffener rod clips shall be Model KHRC as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (10).

L) Clevis Internal Braces shall be Model KHHB as manufactured by Kinetics Noise Control, or by other manufacturers who can meet the requirements as listed in sections 1.04 through 1.09 inclusive, and sections 2.01, 2.02 and 2.03 (10).

3.0 Execution

3.01 Installation

1) Installation of all seismic restraint materials specified in this section shall be accomplished as per the manufacturer's written instructions.

2) Upon completion of installation of all seismic restraint materials and before start up of restrained equipment, all debris shall be cleaned from beneath all protected equipment, leaving equipment free to contact snubbers.

3) No rigid connections between the equipment and the building structure shall be made which degrades the seismic restraint system herein specified. All electrical conduit to restrained equipment shall be looped to allow free motion of equipment without damage to the electrical wiring.

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4) Adjust isolators after piping systems have been filled and equipment is at operating weight.

5) Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

6) Adjust snubbers according to manufacturer's written recommendations.

7) Adjust seismic restraints to permit free movement of equipment within normal mode of operation.

8) Torque anchor bolts according to equipment manufacturer's written recommendations to resist seismic forces

3.02 Execution

1) Shackle piping to the trapeze when restraining trapeze mounted piping, conduit and ductwork. Install cables so they do not bend across sharp edges of adjacent equipment or building structure.

2) Install steel angles to stiffen hanger rods and prevent buckling where appropriate. Clamp with adjustable steel clamps to hanger rods. Requirements apply equally to hanging equipment. Do not weld angles to rods

3) If there is greater than a 1/8" diameter mismatch between anchorage hardware and hole diameter, reduce clearance in hole with epoxy grout or flanged neoprene bushings.

4) Housekeeping Pads must be adequately reinforced and adequately thick for proper embedment of equipment anchors. Refer also to written restraint manufacturers instructions.

   A) Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of the base.

   B) Install adequate reinforcement in the concrete base to ensure its integrity in a seismic event.

   C) Install wedge type anchors into concrete base. If base thickness is inadequate for full anchor embedment, install epoxy-coated anchor bolts that extend through concrete base and adequately anchor into structural concrete floor.

   D) Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

   E) Install anchor bolts to elevations required for proper attachment to supported equipment.

   F) Install anchor bolts according to anchor bolt manufacturer's written instructions.

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3.03 Inspection

1) The contractor shall notify the local representative of the seismic restraint materials manufacturer prior to installing any seismic restraint devices. The contractor shall seek the representative's guidance in any installation procedures with which he is unfamiliar.

2) Upon completion of the installation of all seismic restraint devices herein specified, the local representative of the seismic snubbers manufacturer shall, at the contractors request, inspect the completed system and report in writing any installation errors, improperly selected snubber devices, or other fault in the system which could affect the performance of the system.

3) The installing contractor shall submit a report upon request to the building architect and/or engineer, including the manufacturer's representative's final report, indicating that all seismic restraint material has been properly installed, or steps to be taken by the contractor to properly complete the seismic restraint work as per the specifications.

4.0 Seismic Restraint for Piping and Ductwork

4.01 Piping

1) Seismically restrain all piping listed below. Use Type J Cable Restraints for all piping supported by vibration isolation hanger assemblies, including:

   A) Natural gas piping, medical gas piping, vacuum piping, petroleum based liquid piping, and compressed air piping equal to or greater than 1" (25 mm) in inside diameter.

   B) Brace remainder of piping to code requirements (IBC or TI-809-04)) or in conformance with SMACNA (Sheet Metal and Air Conditioning Contractors National Association, Inc.) "Seismic Restraint Manual Guidelines for Mechanical Systems", Second Edition (Remaining Codes)

4.02 Ductwork

1) Seismically restrain all ductwork listed below. Use Type J Cable Restraints for all ductwork supported by vibration isolation hanger assemblies, including:

   A) All rectangular and oval ducts with cross sectional area equal to or greater than 6 sq. ft. (0.55 sq. meters).

   B) All round ducts with diameters equal to or greater than 32" (812 mm).

   C) Brace remaining ductwork to code requirements (IBC or TI-809-04)) or in conformance with SMACNA (Sheet Metal and Air Conditioning Contractors National Association, Inc.) "Seismic Restraint Manual Guidelines for Mechanical Systems", Second Edition (Remaining Codes)

4.03 Conduit

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1) Seismically restrain all electrical conduit listed below. Use Type J Cable Restraints for all conduit supported by vibration isolation hanger assemblies, including:

A) All round ducts with diameters equal to or greater than 32” (812 mm).

B) Brace all conduit to code requirements (IBC or TI-809-04) or in conformance with SMACNA (Sheet Metal and Air Conditioning Contractors National Association, Inc.) “Seismic Restraint Manual Guidelines for Mechanical Systems”, Second Edition (Remaining Codes).

4.04 Fire Protection Piping

1) Fire protection, sprinkler piping, and related equipment is considered as “Life Safety Equipment” and is to be seismically restrained per guidelines as published by NFPA (National Fire Protection Association).

End of Section

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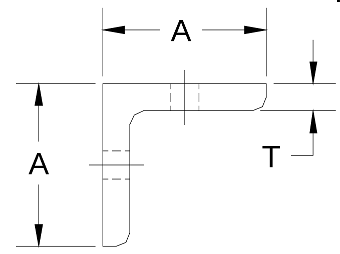
VISCMA MEMBER

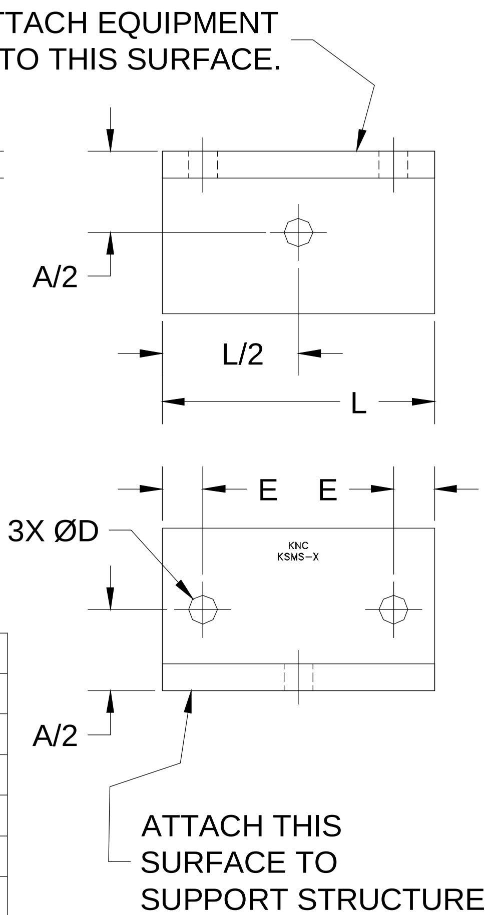
KSMS SEISMIC EQUIPMENT BRACKET

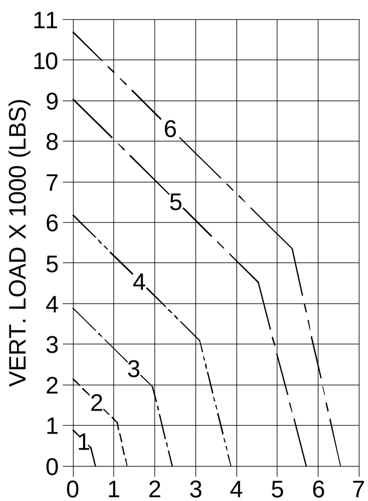
PAGE 1 OF 3 - DRAWING: S-88.071-2A

RELEASE DATE: 5/13/04

MODEL	A (in.)	L (in.)	T (in.)	E (in.)	ØD (in.)
KSMS-1	2.00	4.25	0.25	0.38	0.31
KSMS-2	2.50	5.75	0.38	0.56	0.44
KSMS-3	3.00	7.00	0.50	0.75	0.56
KSMS-4	4.00	9.50	0.63	0.94	0.69
KSMS-5	5.00	12.00	0.75	1.13	0.81
KSMS-6	6.00	10.00	1.00	1.50	1.06







HORIZ. LOAD X 1000 (LBS)
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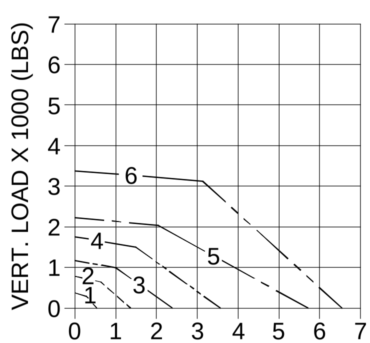

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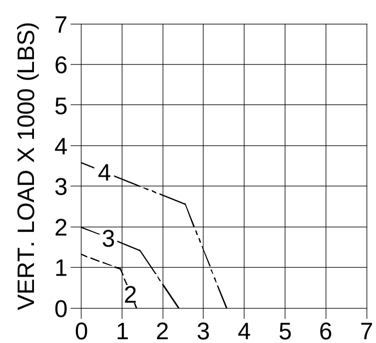
ATTACHED TO CONCRETE
WEDGE TYPE ANCHORS



HORIZ. LOAD X 1000 (LBS)
ATTACHED TO CONCRETE
UNDERCUT ANCHORS

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P1.2.1

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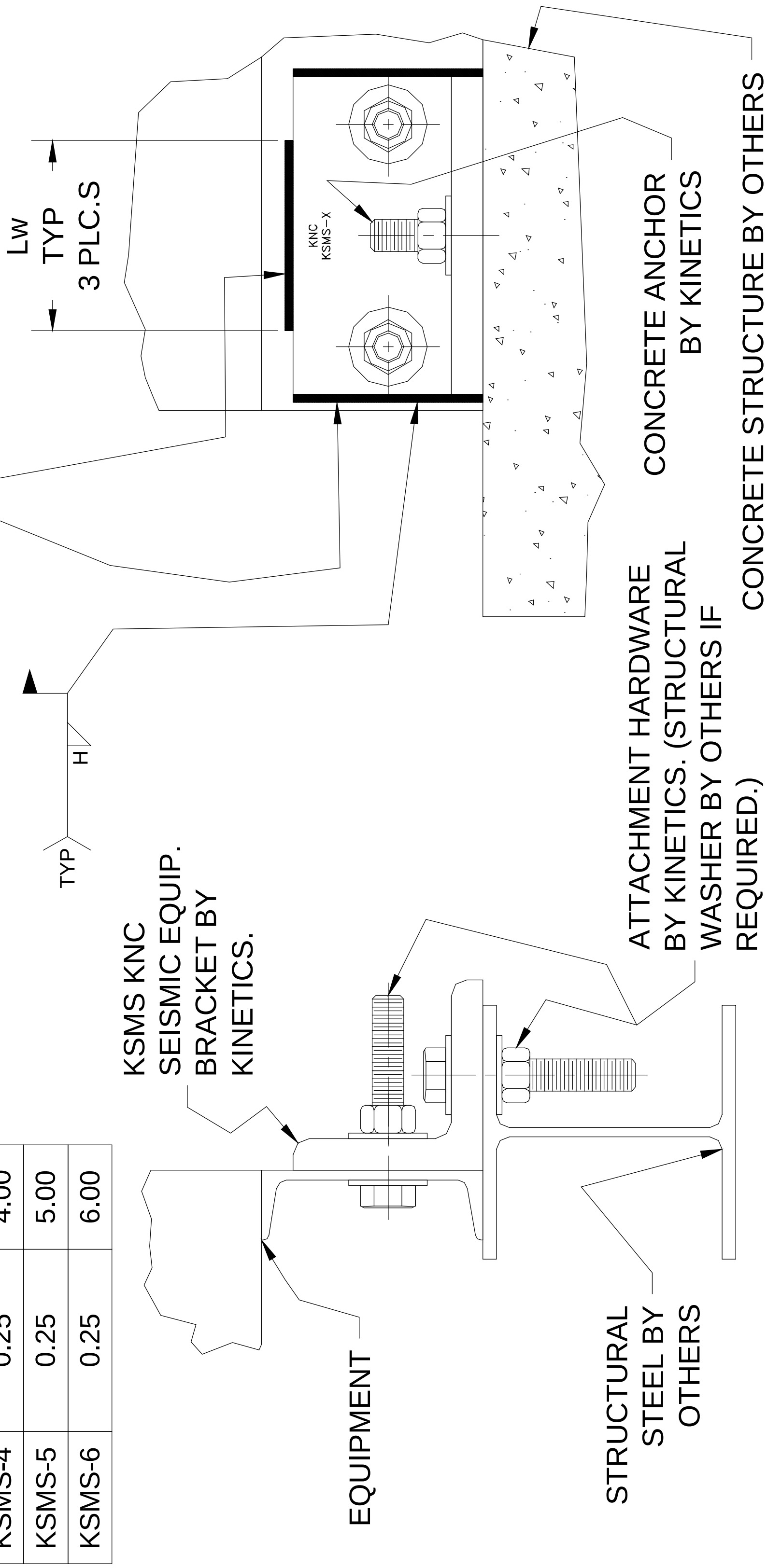
VIEWS ON THIS DRAWING ARE INTENDED TO SHOW THE VARIOUS ATTACHMENT OPTIONS TO THE EQUIPMENT & STRUCTURE. THEY MAY BE USED IN OTHER COMBINATIONS THAN THOSE SHOWN.

MODEL	H (in.)	Lw (in.)
KSMS-1	0.13 OR 0.25	1.00
KSMS-2	0.13 OR 0.25	2.00
KSMS-3	0.25	2.75
KSMS-4	0.25	4.00
KSMS-5	0.25	5.00
KSMS-6	0.25	6.00



KSMS SEISMIC EQUIPMENT BRACKET

PAGE 2 OF 3 – DRAWING: S-88.071-2B

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KSMS BRACKET INSTALLATION INSTRUCTIONS:

1.) LOCATE AND SET EQUIPMENT PER THE MECHANICAL DRAWINGS, OR PER THE INSTRUCTIONS OF THE DESIGN PROFESSIONAL OF RECORD.
2.) THE KSMS BRACKETS ARE THEN POSITIONED AGAINST THE LONG SIDES OF THE EQUIPMENT PER THE THE INSTRUCTIONS GIVEN IN DRAWINGS S-88.071-1A AND S-88.071-1B, AND THE "KINETICS SEISMIC CERTIFICATION". THE EQUIPMENT MOUNTING SURFACE OF THE KSMS BRACKET MUST BE ENTIRELY ON THE EQUIPMENT AS SHOWN IN DRAWING S-88.071-2B.
3.) THE DIMENSIONS (A) AND (B) GIVEN IN THE "KINETICS SEISMIC CERTIFICATION" ARE APPROXIMATE. HOLES IN THE BUILDING STRUCTURE SHOULD BE DRILLED ONLY AFTER THE KSMS BRACKETS HAVE BEEN POSITIONED AS DESCRIBED IN STEP 2.
4.) IF "BACKING" STEEL MUST BE ADDED TO THE EQUIPMENT TO MOUNT AND SUPPORT THE KSMS BRACKET IT MUST HAVE A THICKNESS AT LEAST AS GREAT AS THE KSMS BRACKET BEING USED TO MOUNT ATTACH THE EQUIPMENT TO THE BUILDING STRUCTURE.
5.) IF USING THE BOLTS OR ANCHORS TO ATTACH THE KSMS BRACKET TO THE BUILDING STRUCTURE, LOCATE, MARK, AND DRILL THE APPROPRIATE HOLES IN THE STRUCTURE BEFORE PERMANENTLY ATTACHING THE BRACKET TO THE EQUIPMENT.
6.) IF USING BOLTS TO PERMANENTLY ATTACH THE KSMS BRACKET TO THE EQUIPMENT, LOCATE, MARK AND DRILL THE APPROPRIATE HOLES IN THE EQUIPMENT. THE KSMS BRACKET MOUNTING SURFACE MUST BE ENTIRELY ON THE EQUIPMENT AS SHOWN IN DRAWING S-88.071-2B.
7.) REPOSITION THE KSMS BRACKETS, AND MAKE THE PERMANENT ATTACHMENTS TO THE EQUIPMENT. THIS ATTACHMENT MAY BE EITHER BY USING THE BOLTS, NUTS, AND WASHERS PROVIDED WITH THE KSMS KITS, OR THE OPTIONAL WELDS AS SHOWN IN DRAWING S-88.071-2B.
8.) INSTALL THE CONCRETE ANCHORS OR BOLTS IN THE RESPECTIVE HOLES THAT HAVE BEEN DRILLED IN STRUCTURE.
9.) THE KSMS BRACKET MAY BE WELDED TO THE STRUCTURE USING THE WELD SIZE & LENGTH GIVEN IN DRAWING S-88.071-2B FOR THE OPTIONAL WELD ATTACHMENT TO THE EQUIPMENT.

KSMS SEISMIC EQUIPMENT BRACKET

PAGE 3 OF 3 – DRAWING: S-88.071-2C

RELEASE DATE: 5/13/04

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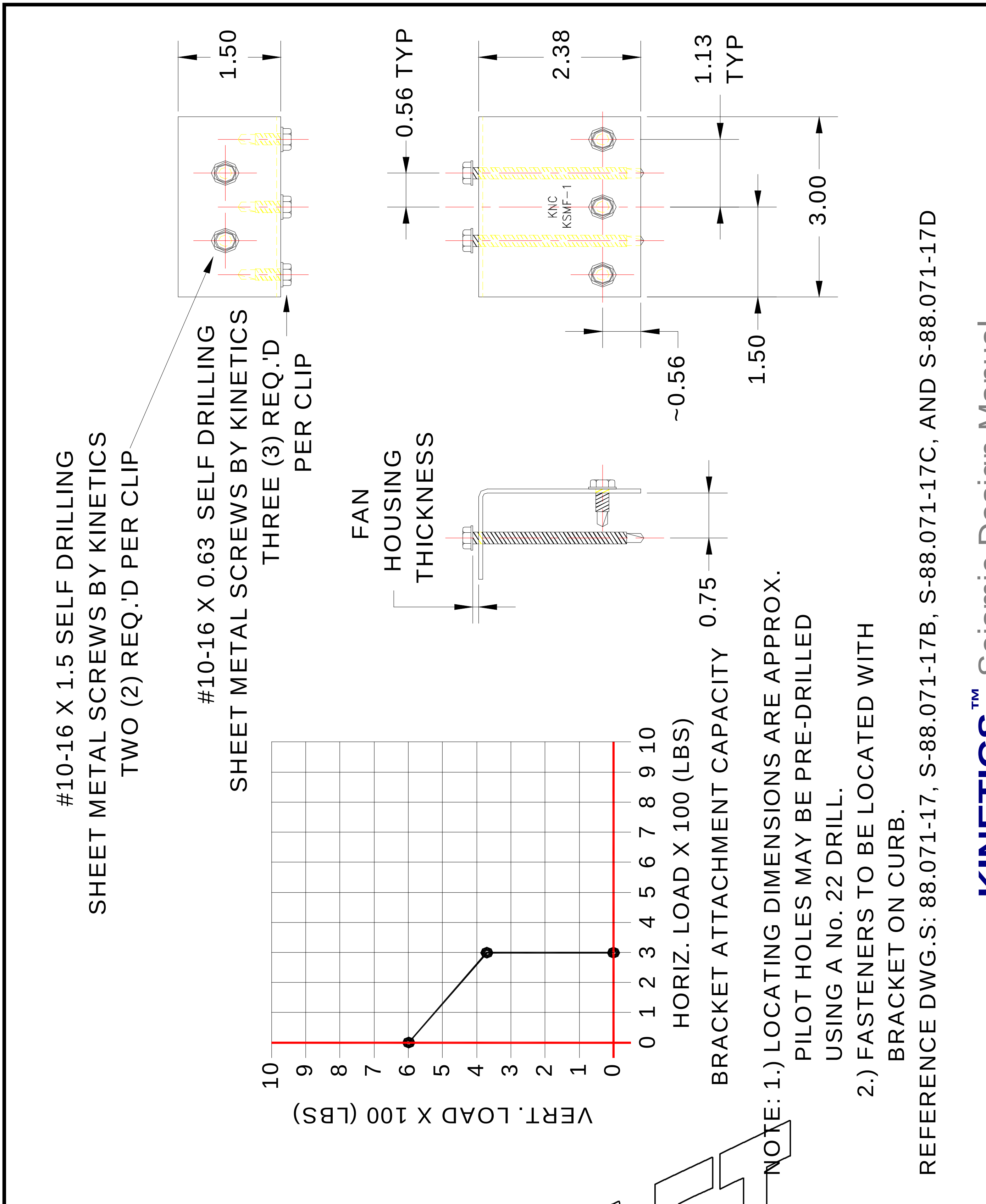

KSMF-1 KNC SEISMIC "MUSHROOM" FAN BRACKET

DRAWING # S-88.071-17A

RELEASE DATE: 10/31/03

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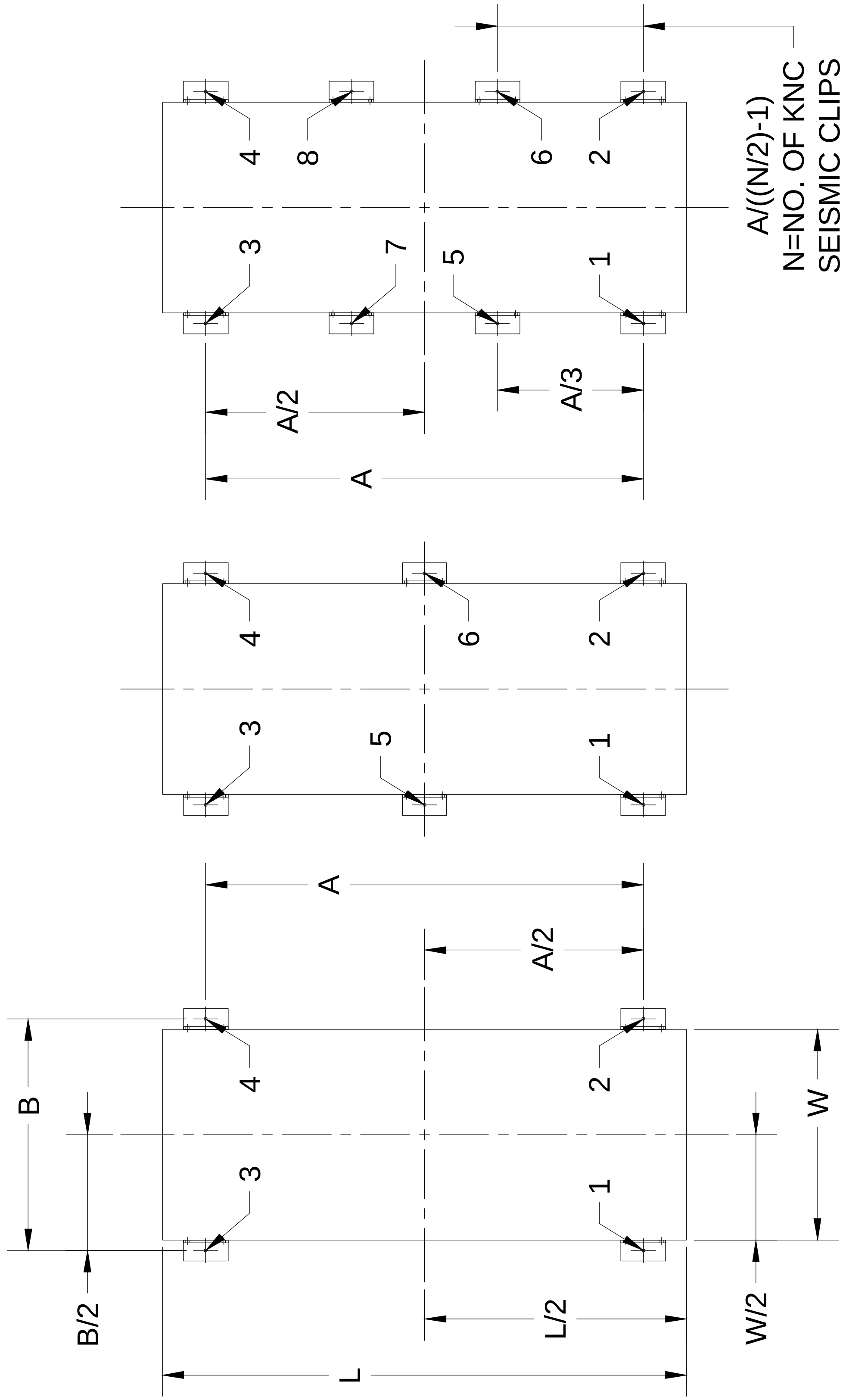

KSMS & KSMG LOCATING GUIDE

PAGE 1 OF 2 – DRAWING: S-88.071-1A

RELEASE DATE: 5/13/04

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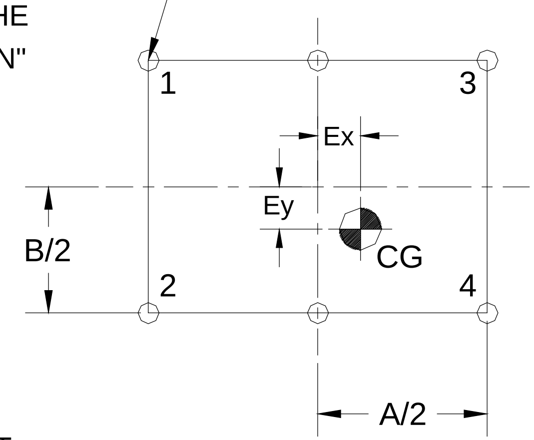
KSMS & KSMG BRACKET LOCATING INSTRUCTIONS:



1.) SHOWN AT THE RIGHT IS A COPY OF THE FIGURE THAT APPEARS IN THE TOP LEFT HAND QUADRANT OF THE "KINETICS SEISMIC CERTIFICATION" FOR THE PIECE OF EQUIPMENT TO BE MOUNTED. THE POINTS 1, 2, 3, AND 4 INDICATE THE CORNER ATTACHMENT BRACKETS. THEY ARE LOCATED OFF OF THE GEOMETRIC CENTER LINES FOR THE EQUIPMENT.

2.) TYPICALLY (A) IS THE LOCATING DIMENSION ALONG THE LENGTH OF THE EQUIPMENT, AND (B) IS THE LOCATING DIMENSION ACROSS THE WIDTH OF THE EQUIPMENT.

3.) THE C.G. LOCATION FOR THE EQUIPMENT IS LOCATED OFF OF THE GEOMETRIC CENTER OF THE EQUIPMENT BY (Ex) ALONG THE LENGTH OF THE EQUIPMENT, AND (Ey) ACROSS THE WIDTH OF THE EQUIPMENT.

4.) DRAWING S-88.071-1A SHOWS THREE PLAN VIEWS OF A TYPICAL AIR HANDLING UNIT CABINET. THEY COULD ALSO REPRESENT TYPICAL PUMP BASES, FAN BASES, OR FAN HOUSINGS. IN THESE FIGURES, (L) IS THE LENGTH OF THE PIECE OF EQUIPMENT. THE DIMENSION (A) IS THE DISTANCE BETWEEN ATTACHMENT POINTS 1 & 3 AND 2 & 4. EACH OF THESE POINTS IS A DISTANCE (A/2) OFF OF THE CENTER OF THE EQUIPMENT. THE DIMENSION (B) IS THE DISTANCE BEWEEN ATTACHMENT POINTS 1 & 2 AND 3 & 4. EACH OF THESE POINTS IS A DISTANCE (B/2) OFF OF THE CENTER OF THE EQUIPMENT.

5.) IF THE "KINETICS SEISMIC CERTIFICATION" INDICATES THAT MORE THAN FOUR ATTACHMENT POINTS ARE REQUIRED FOR A PIECE OF EQUIPMENT, THERE WILL ALWAYS BE AN EVEN NUMBER OF ATTACHMENT POINTS. HALF OF THE ATTACHMENT POINTS WILL BE ON ONE LONG SIDE OF THE EQUIPMENT, AND HALF WILL BE ON THE OTHER LONG SIDE OF THE EQUIPMENT.

6.) THE ADDITIONAL ATTACHMENT POINTS WILL BE EQUALLY SPACED BETWEEN ATTACHMENT POINTS 1 & 3 AND 2 & 4.

KSMS & KSMG LOCATING GUIDE

PAGE 2 OF 2 – DRAWING: S-88.071-1B

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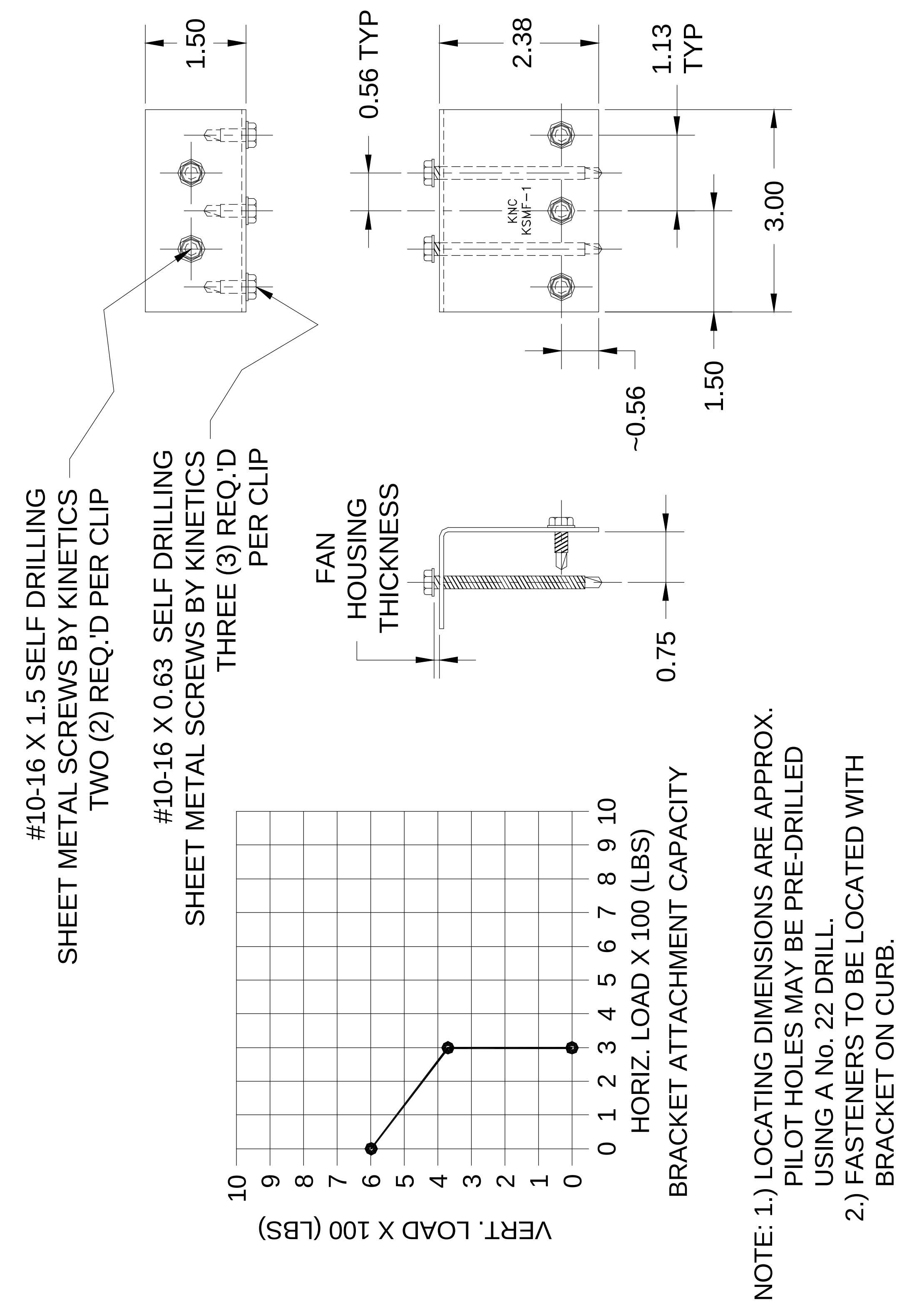

KSMF MOUNTING KIT (MUSHROOM FANS, LOUVERS, AND ETC.)

PAGE 1 OF 4 – DRAWING: S-88.071-17A

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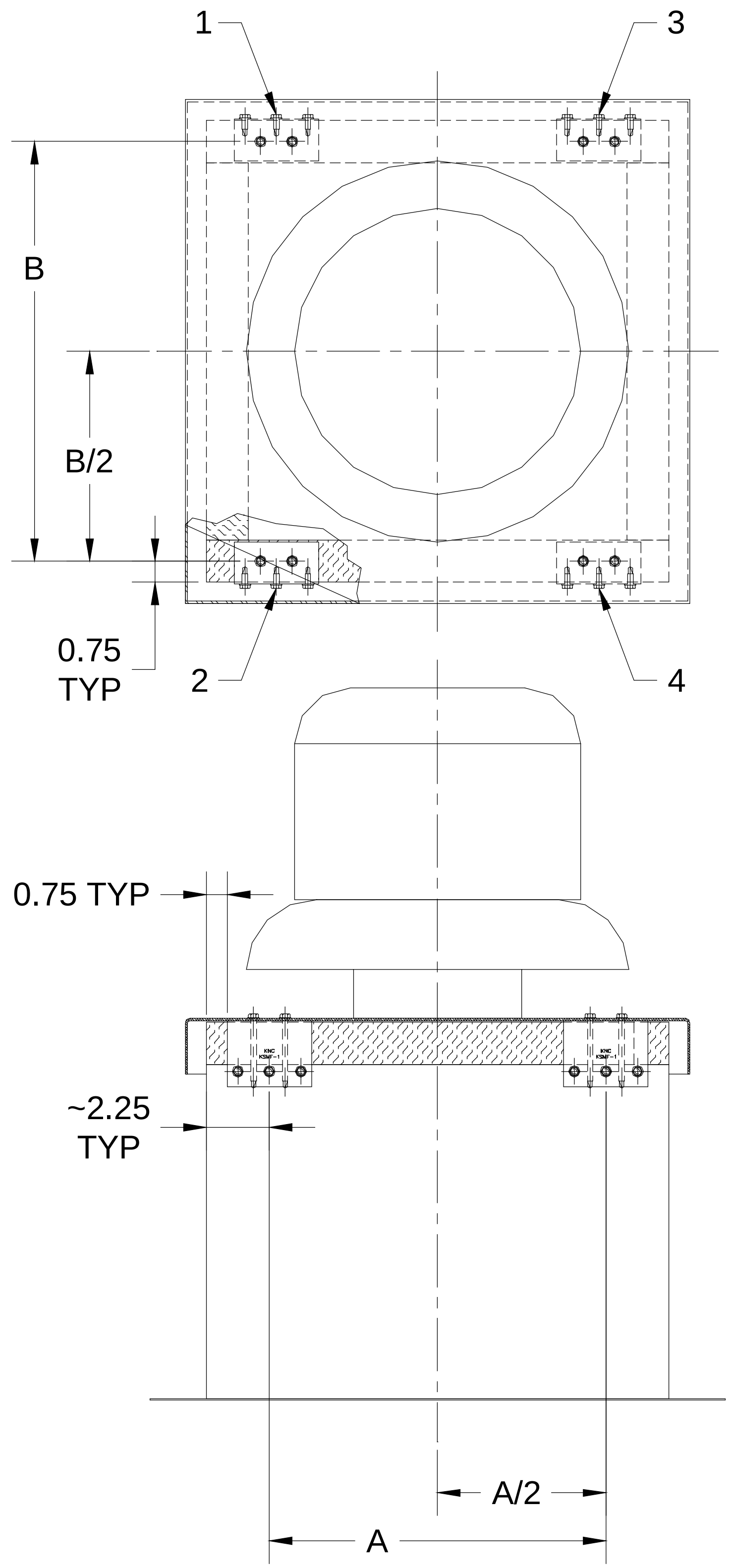

KSMF MOUNTING KIT (MUSHROOM FANS, LOUVERS, AND ETC.)

PAGE 2 OF 4 – DRAWING: S-88.071-17B

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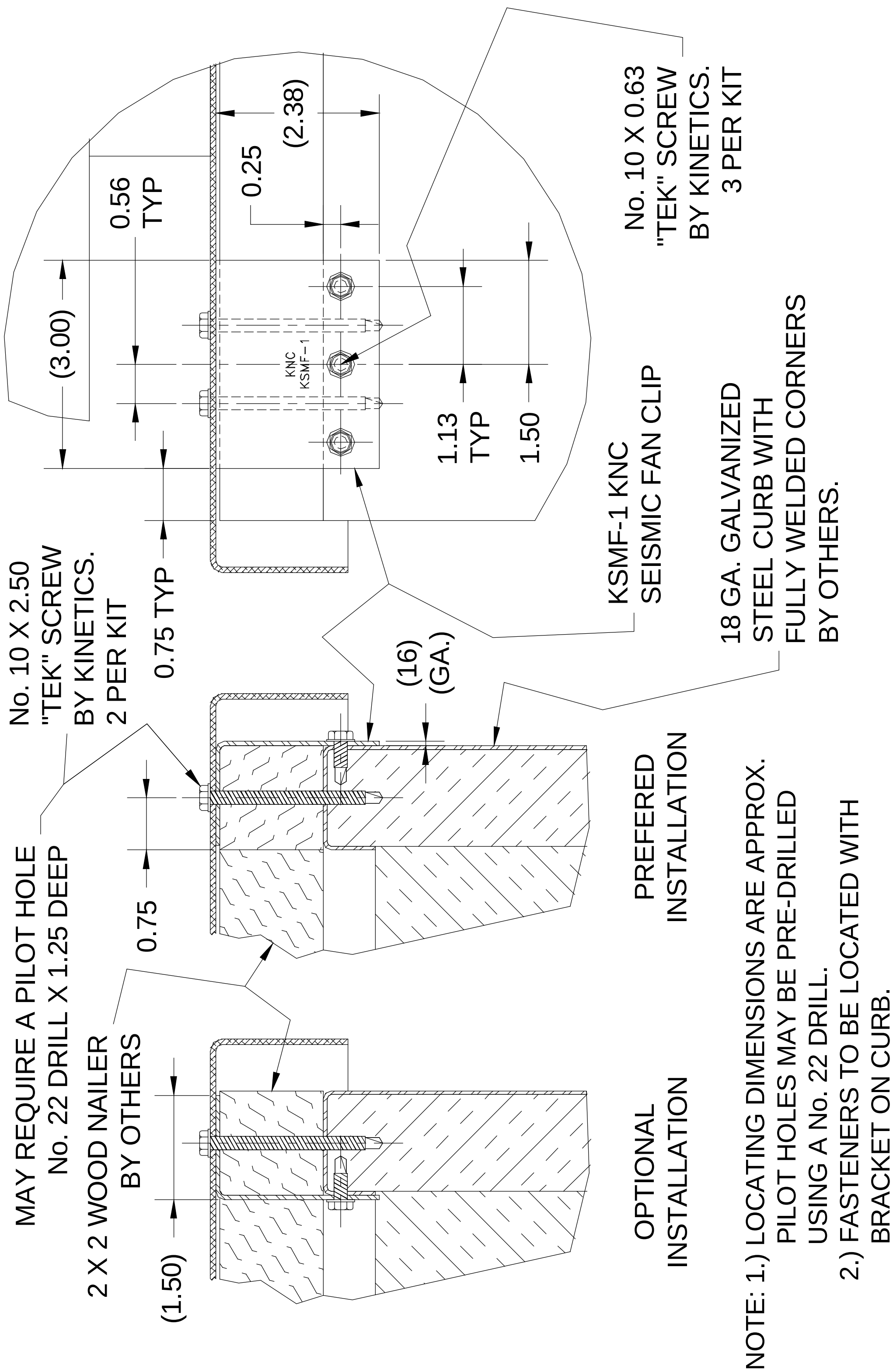

KSMF MOUNTING KIT (MUSHROOM FANS, LOUVERS, AND ETC.)

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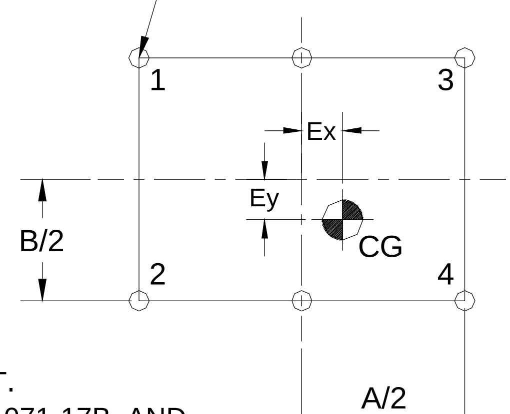
KSMF-1 "MUSHROOM" FAN BRACKET INSTRUCTIONS:

1.) SHOWN AT THE RIGHT IS A COPY OF THE FIGURE THAT APPEARS IN THE TOP LEFT HAND QUADRANT OF THE "KINETICS SEISMIC CERTIFICATION" FOR THE PIECE OF EQUIPMENT TO BE MOUNTED. THE POINTS 1, 2, 3, AND 4 INDICATE THE CORNER ATTACHMENT BRACKETS. THEY ARE LOCATED OFF OF THE GEOMETRIC CENTER LINES FOR THE EQUIPMENT.

2.) TYPICALLY (A) IS THE LOCATING DIMENSION ALONG THE LENGTH OF THE EQUIPMENT, AND (B) IS THE LOCATING DIMENSION ACROSS THE WIDTH OF THE EQUIPMENT. THESE DIMENSIONS, AS APPLIED, TO "MUSHROOM" FANS ARE DEFINED IN S-88.071-17B.

3.) THE C.G. LOCATION FOR THE EQUIPMENT IS LOCATED OFF OF THE GEOMETRIC CENTER OF THE EQUIPMENT BY (Ex) ALONG THE LENGTH OF THE EQUIPMENT, AND (Ey) ACROSS THE WIDTH OF THE EQUIPMENT.



4.) LOCATE THE KSMF-1 BRACKETS ON THE FAN CURB AS SHOWN IN S-88.071-17B, AND INSTALL (3) No. 10 X 0.63 SELF-DRILLING TEK SCREWS PER BRACKET AS SHOWN IN S-88.071-17C. THESE TEK SCREWS ARE TO HOLD THE BRACKET IN PLACE WHILE THE FAN IS BEING SET.

5.) INSTALL WEATHER STRIPPING (BY OTHERS) OVER THE TOP OF THE CURB & KSMF-1 BRACKETS.

6.) CAREFULLY MEASURE THE MOUNTING FLANGE OF THE FAN AND THE TOP OF THE CURB WITH THE KSMF-1 BRACKETS PROPERLY LOCATED. MARK THE BRACKET LOCATIONS AND APPROXIMATE LOCATIONS FOR (2) No. 10 X 2.50 TEK SCREWS ON THE TOP OF THE FAN FLANGE.

7.) SET THE FAN ON THE CURB AND ADJUST ITS POSITION SO THAT THE LOCATIONS MARKED IN STEP 5.) LINE UP WITH THE KSMF-1 BRACKETS ON THE CURB.

8.) INSTALL (2) No. 10 X 2.50 SELF -DRILLING TEK SCREWS PER KSMF-1 BRACKET AS SHOWN IN S-88.071-17B AND S-88.071-C. THE SCREWS MUST PASS THROUGH THE BRACKET, CURB NAILER, AND CURB SHEET METAL TO BE EFFECTIVE.

9.) APPLIED CAULKING (BY OTHERS) TO THE TOPS OF THE No. 10 X 2.50 TEK SCREWS & FAN FLANGE TO SEAL THE CURB.

KSMF MOUNTING KIT (MUSHROOM FANS, LOUVERS, AND ETC.)

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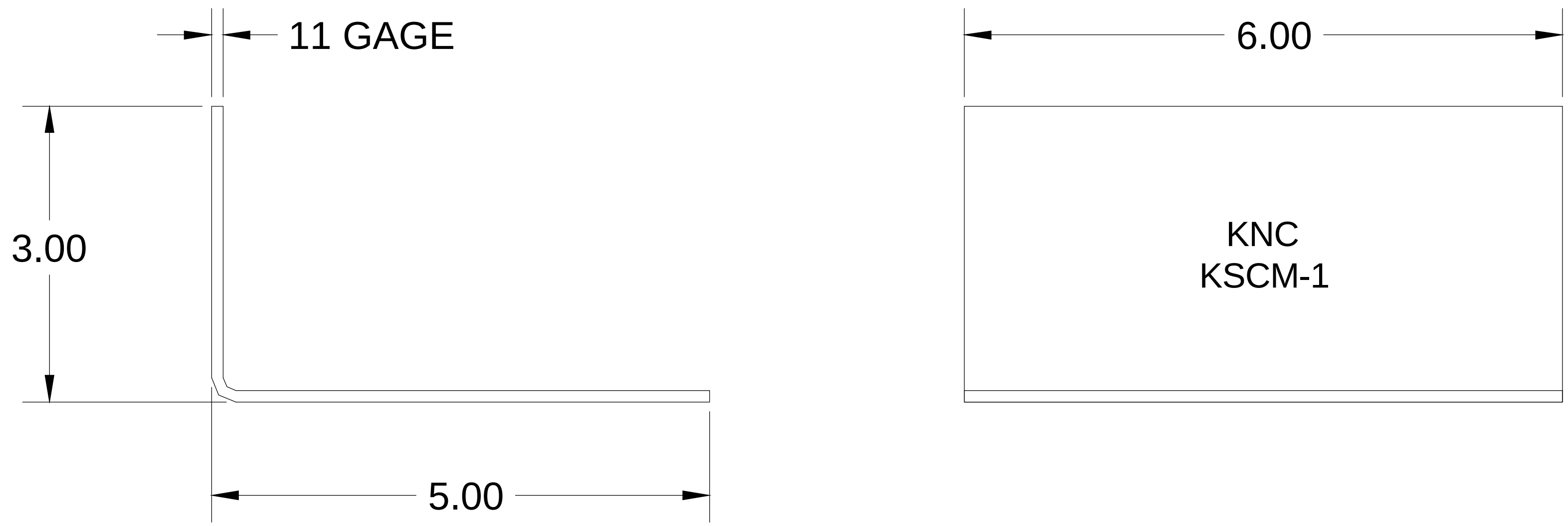

NOTES:

1.) EACH KSCM-1, KINETICS SEISMIC CURB ATTACHMENT BRACKET, KIT IS APPROX. EQUIVALENT TO ONE (1) 1/4-20 SAE GRADE 2 BOLT IN SHEAR.
HORIZONTAL RESTRAINT CAPACITY = 625 LBS.

2.) AT LEAST ONE (1) KSCM-1 KIT IS REQUIRED FOR EACH SIDE OF THE CURB, SEE DRAWING S-88.071-18B.

3.) ATTACHMENT TO THE CURB IS BY THREE (3) No. 12-14 X 2.50 SELF DRILLING TEK SCREWS PER BRACKET.

4.) ATTACHMENT TO EQUIPMENT MAY BE BY WELD OR THREE (3) No. 12-14 X 0.75 SELF DRILLING TEK SCREWS SEE DRAWING S-88.071-18D DETAILS.

KSCM-1 MOUNTING KIT (EQUIPMENT TO CURB ATTACHMENT)

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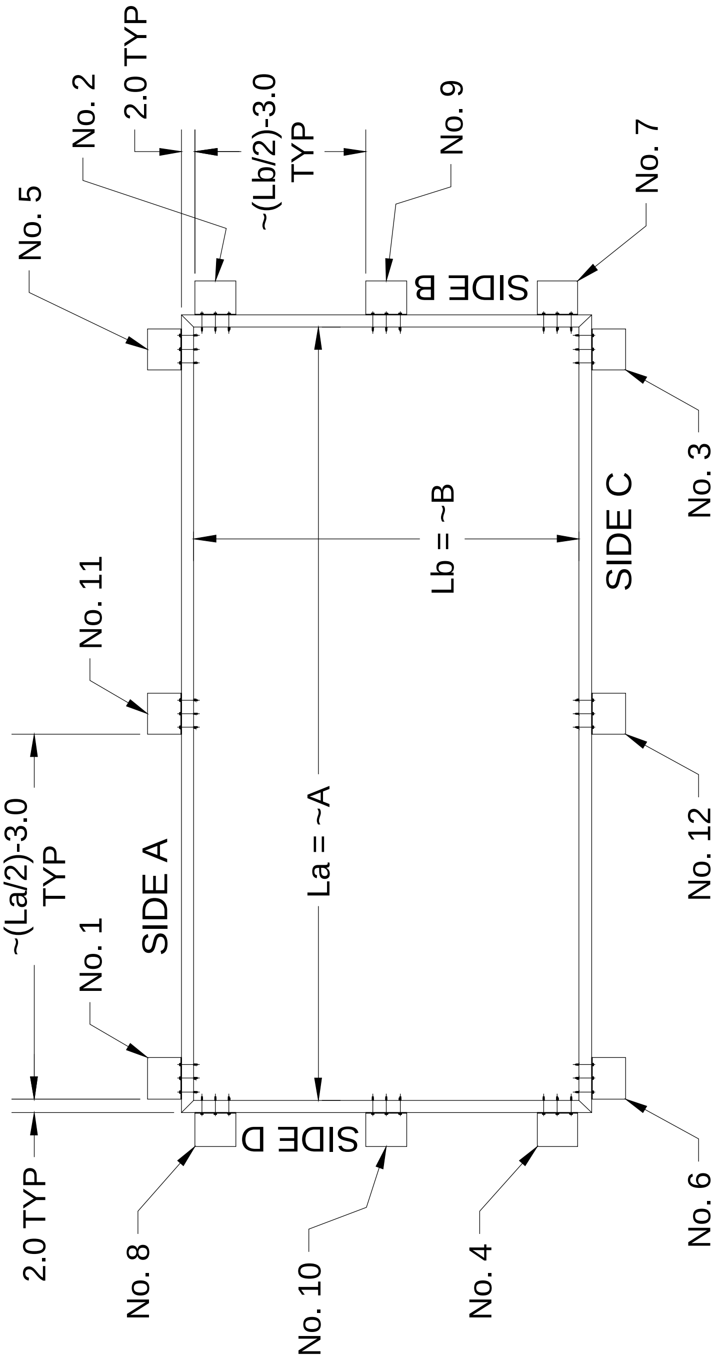

NOTES:

1.) KSCM-1 SEISMIC RESTRAINT BRACKETS (No. 1) THRU (No. 4) ARE REQUIRED FOR EACH CURB INSTALLATION.

2.) ADDITIONAL KSCM-1 RESTRAINT BRACKETS MAY BE REQUIRED AS INDICATED BY A KINETICS SEISMIC CERTIFICATION.

3.) ADDITIONAL KSCM-1 RESTRAINT BRACKETS ARE TO BE ADDED IN PAIRS (No. 5) & (No. 6); (No. 7) & (No. 8); (No. 9) & (No. 10); AND (No. 11) & (No. 12) AS SHOWN IN THE FIGURE ABOVE.

KSCM-1 MOUNTING KIT (EQUIPMENT TO CURB ATTACHMENT)

PAGE 2 OF 5 – DRAWING: S-88.071-18B

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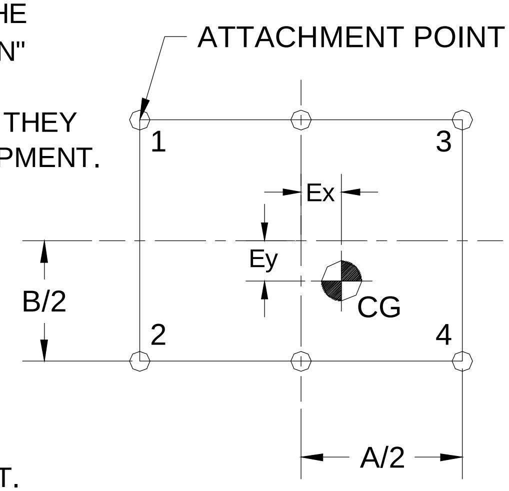
KSCM-1 SEISMIC RESTRAINT KIT INSTALLATION INSTRUCTIONS:

1.) SHOWN AT THE RIGHT IS A COPY OF THE FIGURE THAT APPEARS IN THE TOP LEFT HAND QUADRANT OF THE "KINETICS SEISMIC CERTIFICATION" FOR THE PIECE OF EQUIPMENT TO BE MOUNTED. THE POINTS 1, 2, 3, AND 4 INDICATE THE APPROX. POSITIONS OF THE FIRST KSCM-1 KITS. THEY ARE LOCATED OFF OF THE GEOMETRIC CENTER LINES FOR THE EQUIPMENT.



2.) TYPICALLY (A) IS THE LOCATING DIMENSION ALONG THE LENGTH OF THE EQUIPMENT, AND (B) IS THE LOCATING DIMENSION ACROSS THE WIDTH OF THE EQUIPMENT. THESE DIMENSIONS, AS APPLIED, TO THE KSCM-1 KITS ARE DEFINED IN S-88.071-18B. A WILL BE APPROX. EQUAL TO La, AND B WILL BE APPROX. EQUAL TO Lb AS SHOWN IN S-88.071-18B.

3.) THE C.G. LOCATION FOR THE EQUIPMENT IS LOCATED OFF OF THE GEOMETRIC CENTER OF THE EQUIPMENT BY (Ex) ALONG THE LENGTH OF THE EQUIPMENT, AND (Ey) ACROSS THE WIDTH OF THE EQUIPMENT.

4.) MEASURE AND MARK THE LOCATIONS OF THE KSCM-1 RESTRAINT KITS ON THE CURB USING S-88.071-18B AS A GUIDE. THERE MUST BE AT LEAST ONE KSCM-1 KIT FOR EACH SIDE OF THE CURB. WHEN LOCATED ACCORDING TO S-88.071-18B, THE KSCM-1 SEISMIC BRACKET KITS WILL ALLOW THE OPTIMUM LOAD DISTRIBUTION IN ALL SIDES OF THE CURB.

5.) DEPENDING ON THE CONSTRUCTION OF THE EQUIPMENT THE KSCM-1 KITS MAY BE INSTALLED BEFORE OR AFTER THE EQUIPMENT IS SET IN PLACE, SEE S-88.071-18D FOR EXAMPLES. IN SOME CASES, ONE OF THE KSCM-1 BRACKETS MUST BE INSTALLED BEFORE THE EQUIPMENT IS SET IN PLACE. THE CONSTRUCTION OF THE EQUIPMENT MUST BE KNOWN AND STUDIED BEFORE SETTING THE TO ENSURE PROPER INSTALLATION OF THE KSCM-1 BRACKETS.

6.) ATTACHMENT OF THE KSCM-1 BRACKET TO THE CURB IS ACCOMPLISHED WITH THE THREE (3) No. 12-14 X 2.50 SELF-DRILLING TEK SCREWS. ***TO BE EFFECTIVE, THE THREADED PORTION OF THESE SCREWS MUST PASS THROUGH THE WOODEN NAILER, AND THE SHEET METAL OF THE CURB SIDE WALL!***

CONTINUED ON S-88.071-18C SHT 2.

KSCM-1 MOUNTING KIT (EQUIPMENT TO CURB ATTACHMENT)

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KSCM-1 SEISMIC RESTRAINT KIT INSTALLATION INSTRUCTIONS CONT'D:

7.) THE EQUIPMENT ATTACHMENT IS MADE WITH ***THREE (3) No. 12-14 X 0.75 SELF DRILLING TEK SCREWS.*** OPTIONAL ATTACHMENT IS MADE BY ***THREE (3) 1/8 X 1.0 WELDS.*** SEE S-88.071-18D FOR DETAILED EXAMPLES.

8.) SEAL ALL EQUIPMENT PENETRATIONS WITH A GOOD RTV CAULKING COMPOUND, BY OTHERS.

9.) ***WARNING:*** WHEN ATTACHING TO EQUIPMENT USING SELF DRILLING TEK SCREWS, BE SURE THAT ELECTRICAL & CONTROL WIRES & CONDUITS, AND FLUIDS HOSES ARE NOT IN THE PATHS OF THE TEK SCREWS!

10.) ***CAUTION:*** DO NOT BLOCK EQUIPMENT ACCESS & MAINTENANCE DOORS WITH KSCM-1 BRACKETS!

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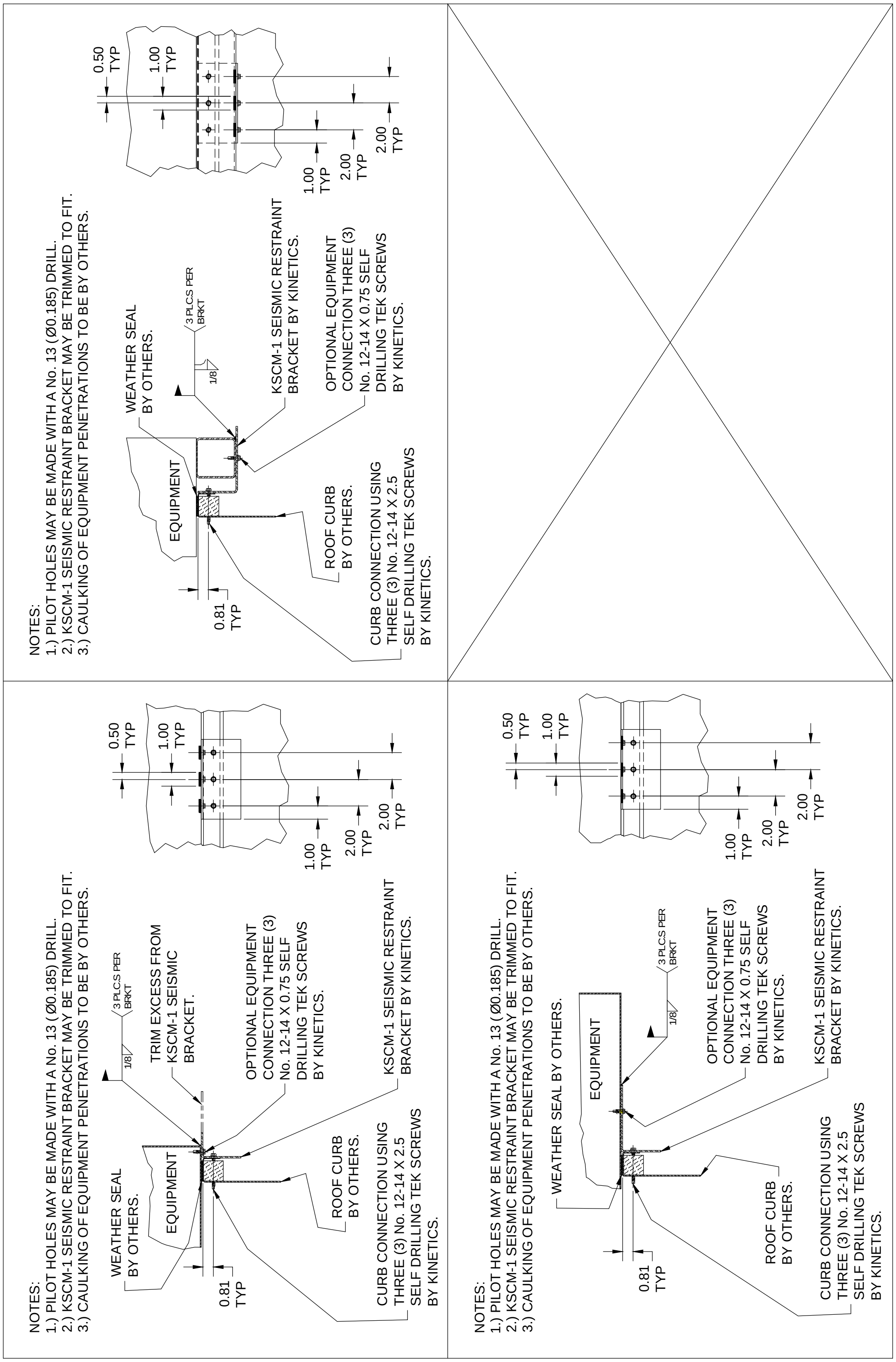

KSCM-1 MOUNTING KIT (EQUIPMENT TO CURB ATTACHMENT)

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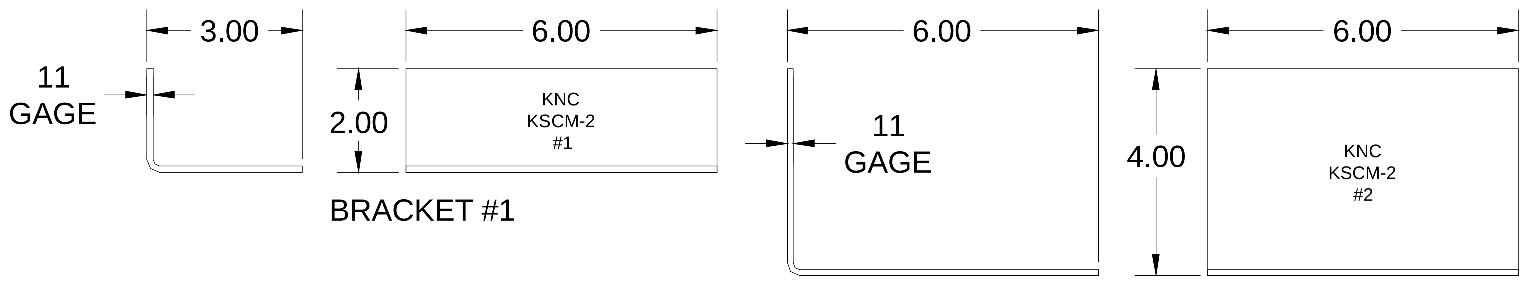

BRACKET #1

BRACKET #2

NOTES:

1.) EACH KSCM-2, KINETICS SEISMIC CURB ATTACHMENT BRACKET, KIT IS APPROX. EQUIVALENT TO ONE (1) 1/4-20 SAE GRADE 2 BOLT IN SHEAR.
HORIZONTAL RESTRAINT CAPACITY = 625 LBS.

2.) EACH KSCM-2 KIT CONTAINS TWO (2) "L" SHAPED BRACKETS OF DIFFERENT SIZE AS SHOWN ABOVE.

3.) AT LEAST ONE (1) KSCM-2 KIT IS REQUIRED FOR EACH SIDE OF THE CURB, SEE DRAWING S-88.071-19B.

4.) ATTACHMENT TO THE CURB IS BY THREE (3) No. 12-14 X 2.50 SELF DRILLING TEK SCREWS PER BRACKET.

5.) ATTACHMENT OF ONE BRACKET TO THE OTHER MAY BE BY WELD OR THREE (3) No. 12-14 X 0.75 SELF DRILLING TEK SCREWS.

6.) ATTACHMENT TO EQUIPMENT MAY BE BY WELD OR THREE (3) No. 12-14 X 0.75 SELF DRILLING TEK SCREWS SEE DRAWINGS S-88.071-19D & S-88.071-19E FOR DETAILS.

KSCM-2 MOUNTING KIT (EQUIPMENT TO CURB ATTACHMENT)

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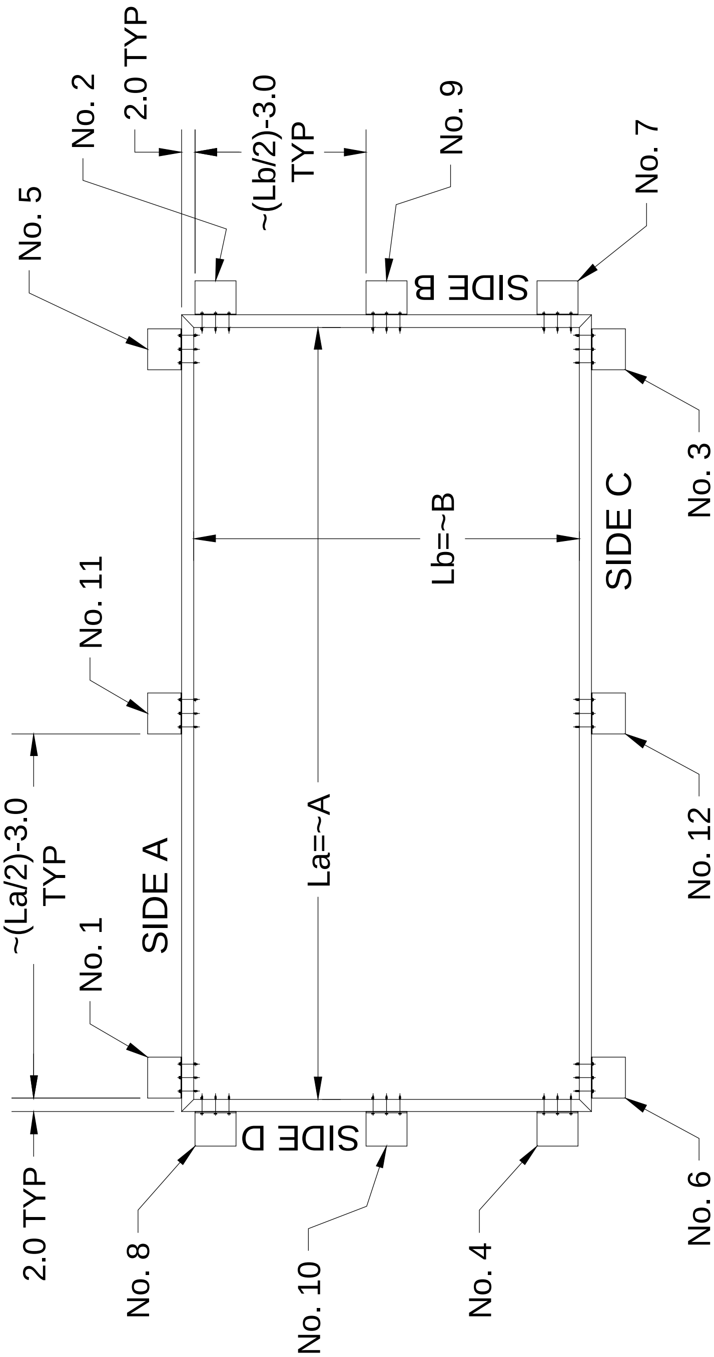

NOTES:

1.) KSCM-2 SEISMIC RESTRAINT BRKT. KITS (No. 1) THRU (No. 4) ARE REQUIRED FOR EACH CURB INSTALLATION.

2.) ADDITIONAL KSCM-2 RESTRAINT BRKT. KITS MAY BE REQUIRED AS INDICATED BY A KINETICS SEISMIC CERTIFICATION.

3.) ADDITIONAL KSCM-2 RESTRAINT BRKT. KITS ARE TO BE ADDED IN PAIRS (No. 5) & (No. 6); (No. 7) & (No. 8); (No. 9) & (No. 10); AND (No. 11) & (No. 12) AS SHOWN IN THE FIGURE ABOVE.

KSCM-2 MOUNTING KIT (EQUIPMENT TO CURB ATTACHMENT)

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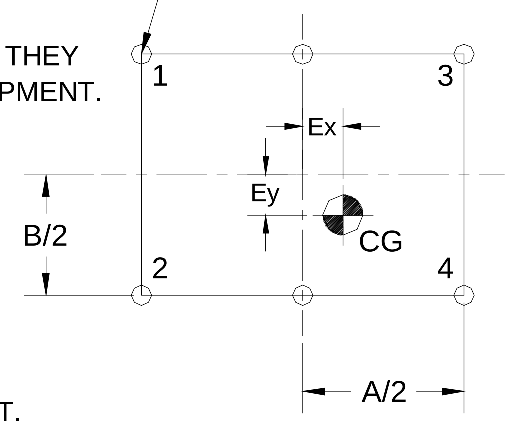
KSCM-2 SEISMIC RESTRAINT KIT INSTALLATION INSTRUCTIONS:

1.) SHOWN AT THE RIGHT IS A COPY OF THE FIGURE THAT APPEARS IN THE TOP LEFT HAND QUADRANT OF THE "KINETICS SEISMIC CERTIFICATION" FOR THE PIECE OF EQUIPMENT TO BE MOUNTED. THE POINTS 1, 2, 3, AND 4 INDICATE THE APPROX. POSITIONS OF THE FIRST KSCM-2 KITS. THEY ARE LOCATED OFF OF THE GEOMETRIC CENTER LINES FOR THE EQUIPMENT.

2.) TYPICALLY (A) IS THE LOCATING DIMENSION ALONG THE LENGTH OF THE EQUIPMENT, AND (B) IS THE LOCATING DIMENSION ACROSS THE WIDTH OF THE EQUIPMENT. THESE DIMENSIONS, AS APPLIED, TO THE KSCM-2 KITS ARE DEFINED IN S-88.071-19B. A WILL BE APPROX. EQUAL TO La, AND B WILL BE APPROX. EQUAL TO Lb AS SHOWN IN S-88.071-19B.



3.) THE C.G. LOCATION FOR THE EQUIPMENT IS LOCATED OFF OF THE GEOMETRIC CENTER OF THE EQUIPMENT BY (Ex) ALONG THE LENGTH OF THE EQUIPMENT, AND (Ey) ACROSS THE WIDTH OF THE EQUIPMENT.

4.) MEASURE AND MARK THE LOCATIONS OF THE KSCM-2 RESTRAINT KITS ON THE CURB USING S-88.071-19B AS A GUIDE. THERE MUST BE AT LEAST ONE KSCM-2 KIT FOR EACH SIDE OF THE CURB. WHEN LOCATED ACCORDING TO S-88.071-19B, THE KSCM-2 SEISMIC BRACKET KITS WILL ALLOW THE OPTIMUM LOAD DISTRIBUTION IN ALL SIDES OF THE CURB.

5.) DEPENDING ON THE CONSTRUCTION OF THE EQUIPMENT THE KSCM-2 KITS MAY BE INSTALLED BEFORE OR AFTER THE EQUIPMENT IS SET IN PLACE, SEE S-88.071-19D & S-88.071-19E FOR EXAMPLES. IN SOME CASES, ONE OF THE KSCM-2 BRACKETS MUST BE INSTALLED BEFORE THE EQUIPMENT IS SET IN PLACE. THE CONSTRUCTION OF THE EQUIPMENT MUST BE KNOWN AND STUDIED BEFORE SETTING THE TO ENSURE PROPER INSTALLATION OF THE KSCM-2 BRACKETS.

6.) ATTACHMENT OF THE KSCM-2 BRACKET TO THE CURB IS ACCOMPLISHED WITH THE THREE (3) No. 12-14 X 2.50 SELF-DRILLING TEK SCREWS. ***TO BE EFFECTIVE, THE THREADED PORTION OF THESE SCREWS MUST PASS THROUGH THE WOODEN NAILER, AND THE SHEET METAL OF THE CURB SIDE WALL!***

CONTINUED ON S-88.071-19C SHT 2.

KSCM-2 MOUNTING KIT (EQUIPMENT TO CURB ATTACHMENT)

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KSCM-2 SEISMIC RESTRAINT KIT INSTALLATION INSTRUCTIONS CONT'D:

7.) WHEN ATTACHING THE TWO KSCM-2 BRACKETS TOGETHER, USE ***THREE (3) No. 12-14 X 0.75 SELF-DRILLING TEK SCREWS.*** OPTIONAL ATTACHEMENT MAY BE MADE WITH ***THREE (3) 1/8 X 1.0 WELDS.*** SEE S-88.071-19D & S-88.071-19E FOR DETAILED EXAMPLES.

8.) THE EQUIPMENT ATTACHMENT IS MADE WITH ***THREE (3) No. 12-14 X 0.75 SELF DRILLING TEK SCREWS.*** OPTIONAL ATTACHMENT IS MADE BY ***THREE (3) 1/8 X 1.0 WELDS.*** SEE S-88.071-19D & S-88.071-19E FOR DETAILED EXAMPLES.

9.) SEAL ALL EQUIPMENT PENETRATIONS WITH A GOOD RTV CAULKING COMPOUND, BY OTHERS.

10.) ***WARNING:*** WHEN ATTACHING TO EQUIPMENT USING SELF DRILLING TEK SCREWS, BE SURE THAT ELECTRICAL & CONTROL WIRES & CONDUITS, AND FLUIDS HOSES ARE NOT IN THE PATHS OF THE TEK SCREWS!

11.) ***CAUTION:*** DO NOT BLOCK EQUIPMENT ACCESS & MAINTENANCE DOORS WITH KSCM-2 BRACKETS!

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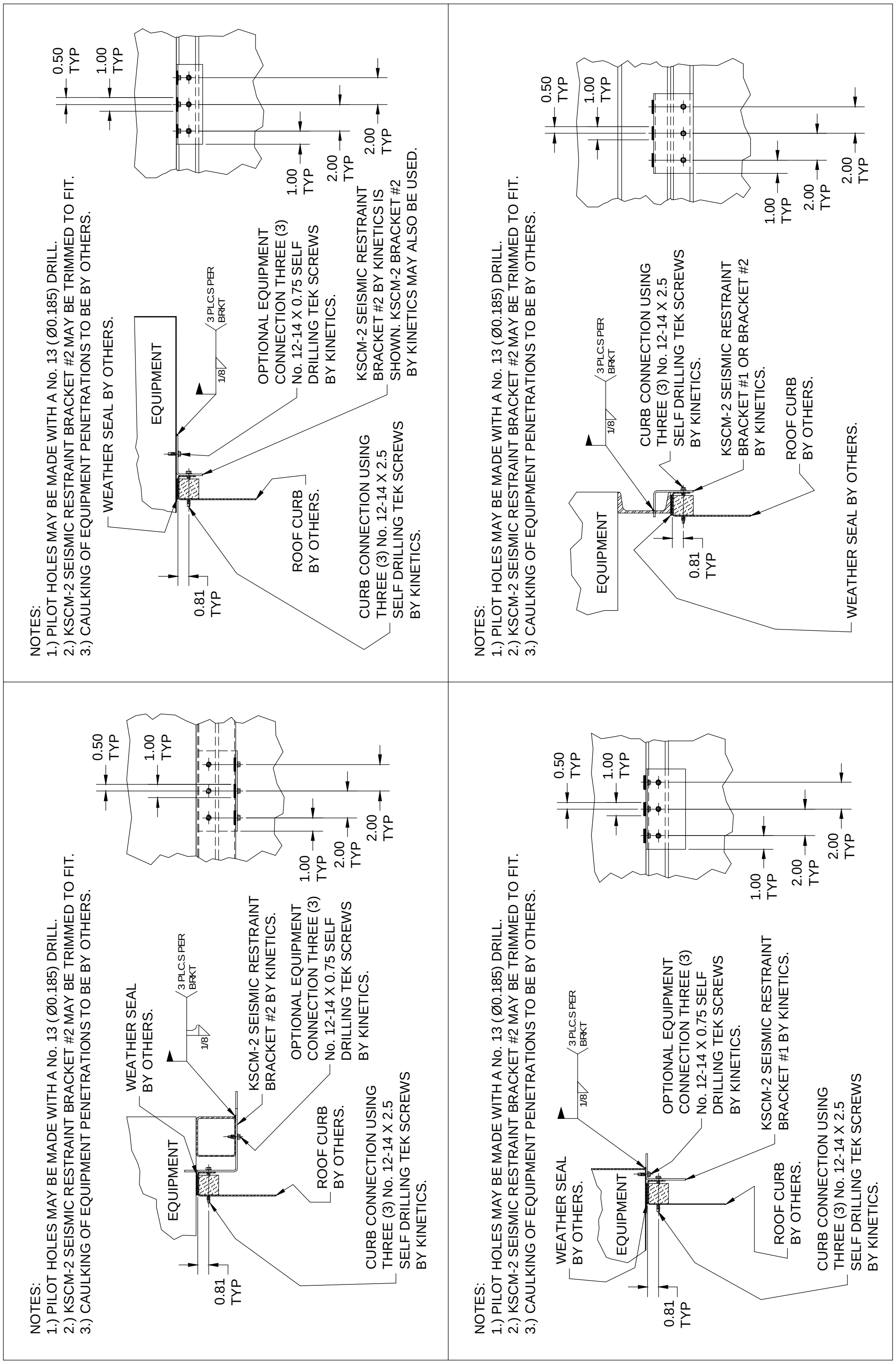

KSCM-2 MOUNTING KIT (EQUIPMENT TO CURB ATTACHMENT)

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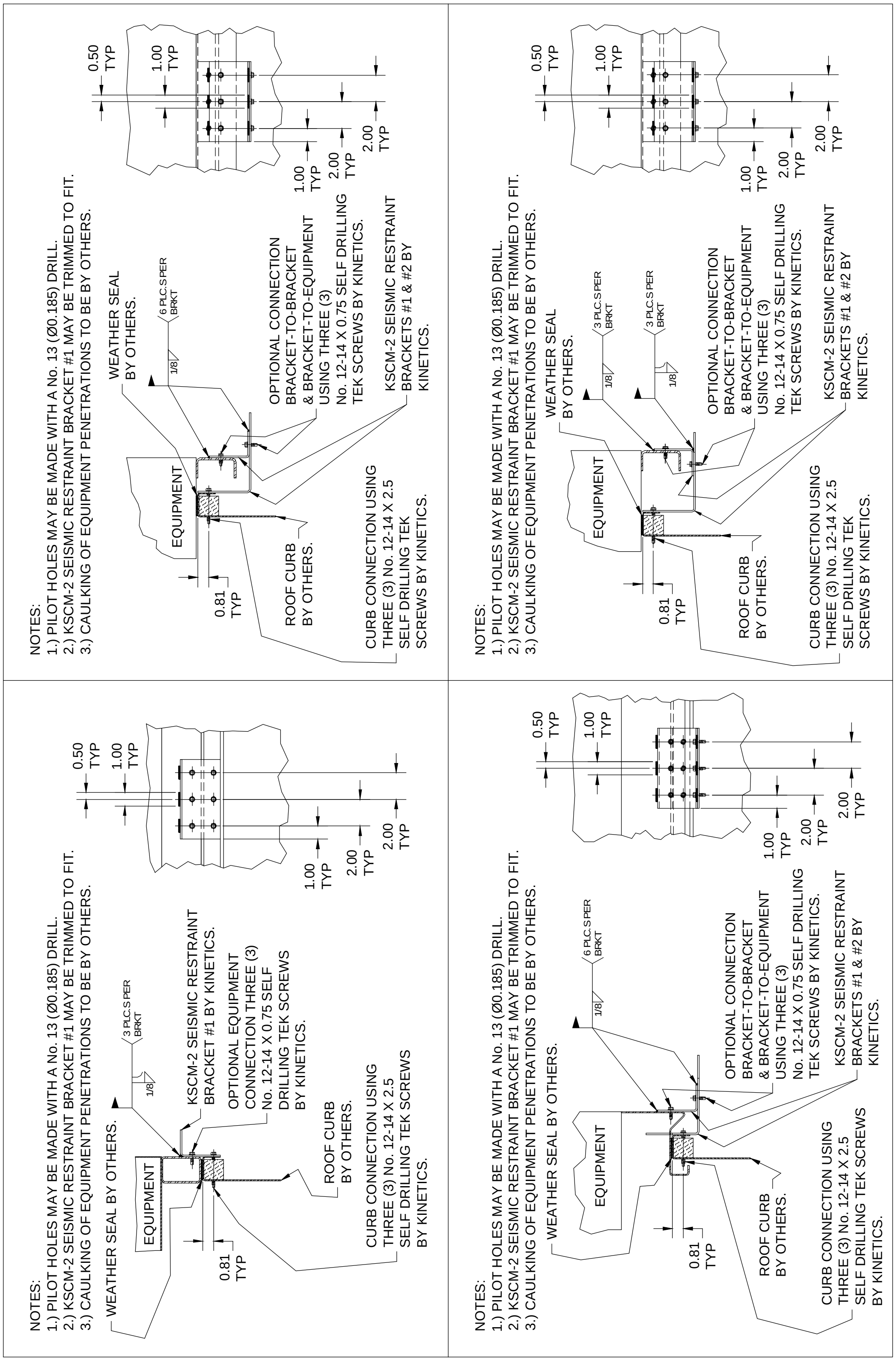

KSCM-2 MOUNTING KIT (EQUIPMENT TO CURB ATTACHMENT)

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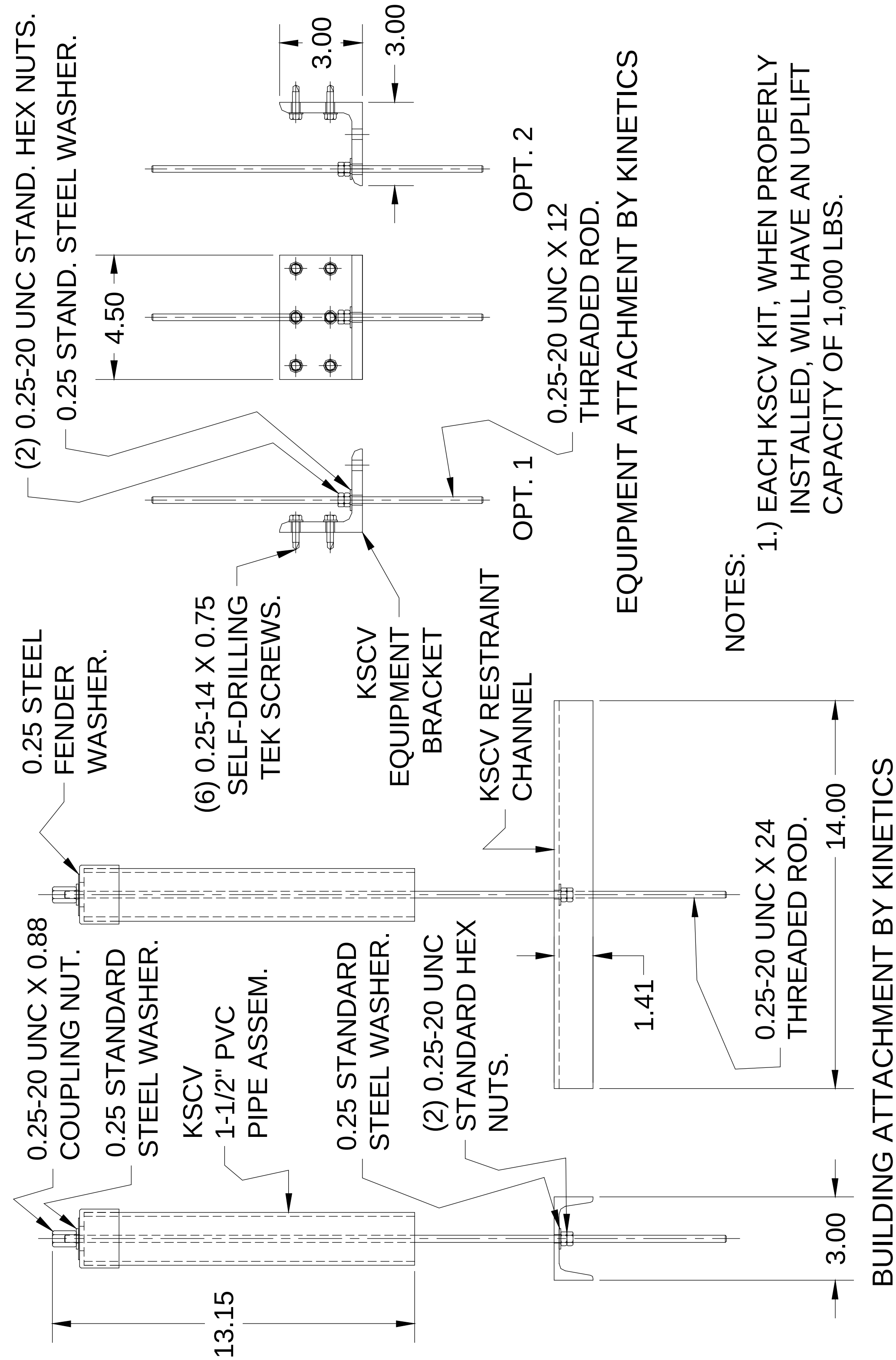

KSCV SEISMIC & WIND VERTICAL RESTRAINT

PAGE 1 OF 7 – DRAWING: S-88.071-20A

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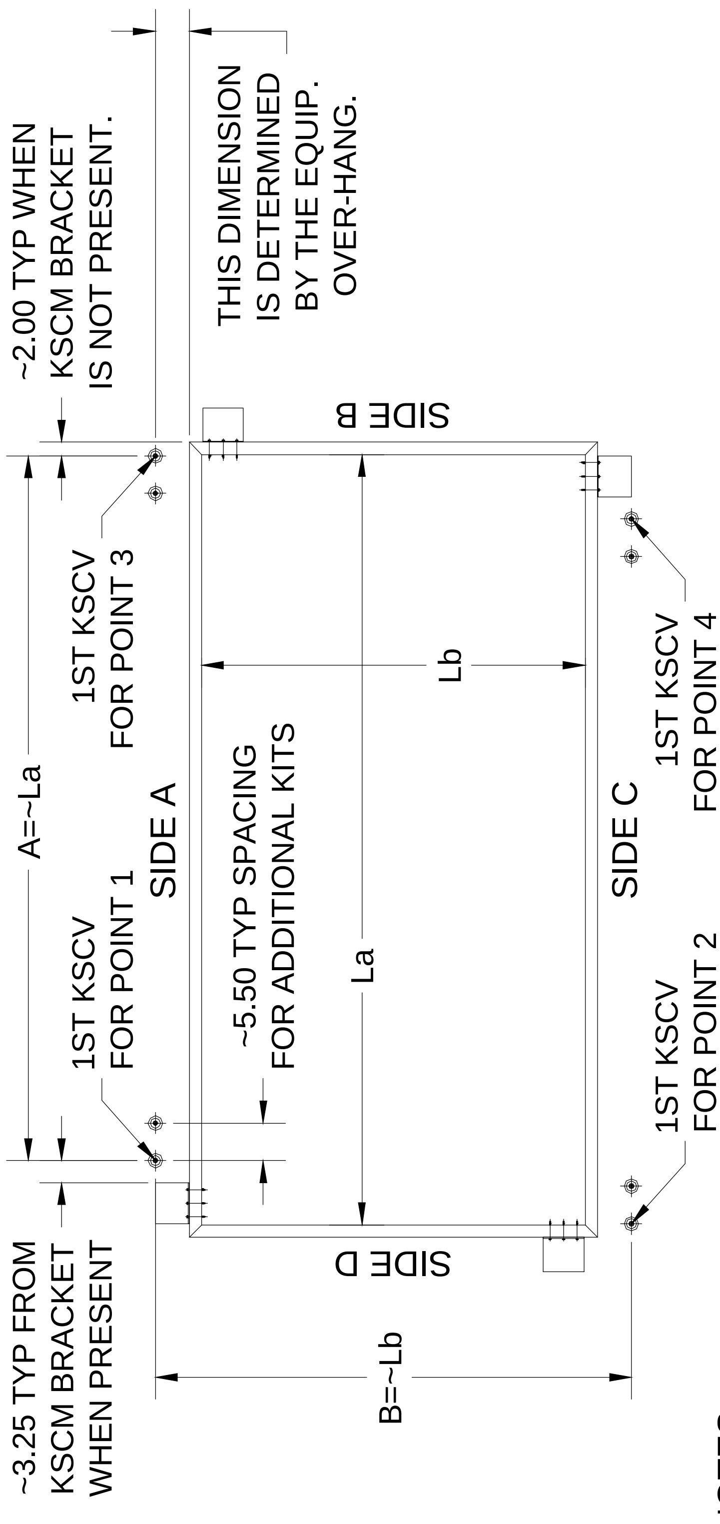

NOTES:

1.) A MINIMUM OF FOUR (4) KSCV VERTICAL SEISMIC & WIND RESTRAINT KITS ARE PER CURB WHEN INDICATED BY A KINETICS SEISMIC OR WIND CERTIFICATION.

2.) ADDITIONAL KSCV VERTICAL RESTRAINT KITS MAY BE REQUIRED AS INDICATED BY A KINETICS SEISMIC OR WIND CERTIFICATION.

3.) ADDITIONAL KSCV KITS MUST BE ADDED IN SETS OF FOUR (4). EACH ADDITIONAL KIT MAY BE INSTALLED IMMEDIATELY ADJACENT TO THE PREVIOUS KIT AT EACH CORNER POINT. MAINTAIN 1.00 INCH CLEARANCE BETWEEN KSCV EQUIPMENT BRACKETS.

KSCV SEISMIC & WIND VERTICAL RESTRAINT

PAGE 2 OF 7 – DRAWING: S-88.071-20B

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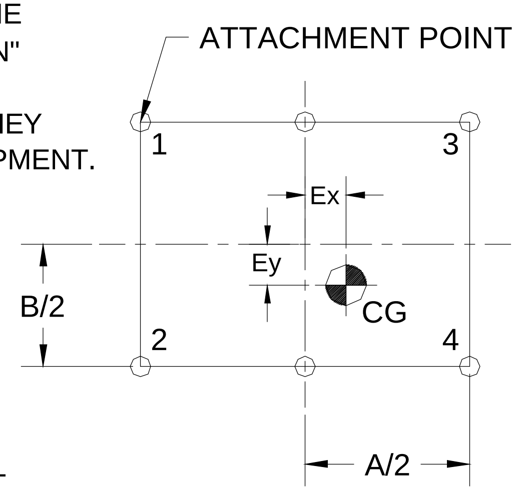
KSCV SEISMIC & WIND VERTICAL RESTRAINT INSTRUCTIONS:

1.) SHOWN AT THE RIGHT IS A COPY OF THE FIGURE THAT APPEARS IN THE TOP LEFT HAND QUADRANT OF THE "KINETICS SEISMIC CERTIFICATION" FOR THE PIECE OF EQUIPMENT TO BE MOUNTED. THE POINTS 1, 2, 3, AND 4 INDICATE THE APPROX. POSITIONS OF THE FIRST KSCV KITS. THEY ARE LOCATED OFF OF THE GEOMETRIC CENTER LINES FOR THE EQUIPMENT.



2.) TYPICALLY (A) IS THE LOCATING DIMENSION ALONG THE LENGTH OF THE EQUIPMENT, AND (B) IS THE LOCATING DIMENSION ACROSS THE WIDTH OF THE EQUIPMENT. THESE DIMENSIONS, AS APPLIED, TO THE KSCV RESTRAINTS ARE DEFINED IN S-88.071-20B. A WILL BE APPROX. EQUAL TO La, AND B WILL BE APPROX. EQUAL TO Lb. ACTUAL VARIATIONS OF 10% TO 15% MAY BE EASILY TOLERATED.

3.) THE C.G. LOCATION FOR THE EQUIPMENT IS LOCATED OFF OF THE GEOMETRIC CENTER OF THE EQUIPMENT BY (Ex) ALONG THE LENGTH OF THE EQUIPMENT, AND (Ey) ACROSS THE WIDTH OF THE EQUIPMENT.

4.) LOCATE THE POSITIONS OF THE REQUIRED KSCV BUILDING ATTACHMENT COMPONENTS RELATIVE TO THE CURB AND EXPECTED EQUIPMENT OVER-HANGS ***BEFORE*** THE INSULATION AND ROOF SYSTEM ARE INSTALLED. POSITIONS OF KSCV'S MAY BE MODIFIED TO AVOID STRUCTURAL SUPPORT STEEL.

5.) DRILL CLEARANCE HOLES THROUGH THE ROOF STRUCTURE FOR THE 0.25-20 UNC THREADEDED RODS. CLEARANCE HOLES MAY BE Ø0.31 TO Ø0.50 INCHES. THE LARGER CLEARANCE HOLES WILL ALLOW MORE LATITUDE FOR ADJUSTMENT AT FINAL ASSEMBLY.

6.) ESTIMATE THE THICKNESS OF THE INSULATION, ROOFING SYSTEM, AND BOOT OR FLASHING. IF NECESARRY, TRIM THE KSCV PIPE ASSEMBLY SO THAT THE PIPE CAP CLEARS THE BOOT OR FLASHING LEAVING ENOUGH ROOM TO SEAL THE JOINT.

7.) THREAD THE COUPLING NUT ***NINE (9) TURNS*** ONTO ONE END OF THE 0.25-20 UNC X 24 THREADED ROD. USE A THREAD LOCKING ADHESIVE, BY OTHERS, TO LOCK THE COUPLING NUT TO THE THREADED ROD.

CONTINUED ON S-88.071-20C SHT 2.

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KSCV SEISMIC & WIND VERTICAL RESTRAINT INSTRUCTIONS CONT'D:

8.) PLACE ON THE 0.25-20 UNC X 24 THREAED ROD A STANDARD 0.25 WASHER, AND THE 0.25 FENDER WASHER. THE FENDER WASHER MUST BEAR AGAINST THE KSCV PIPE ASSEMBLY, PER S-88.071 -20A.

9.) FEED THE 0.25-20 UNC X 24 THREAED ROD THROUGH THE KSCV PIPE ASSEMBLY SO THAT THE FENDER WASHER BEARS AGAINST THE PIPE CAP IN THE KSCV PIPE ASSEMBLY, SEE S-88.071-20A.

10.) SEAL THE JOINT BETWEEN THE KSCV PIPE ASSEMBLY AND THE THREADED ROD WITH A GOOD RTV TYPE CAULKING COMPOUND, BY OTHERS. CAULKING MATERIAL SHOULD BE USED BETWEEN THE COUPLING NUT AND STANDARD WASHER, BETWEEN THE STANDARD WASHER AND FENDER WASHER, AND BTETWEEN THE FENDER WASHER AND PIPE CAP ON THE KSCV PIPE ASSEMBLY.

11.) FEED THE THREADED ROD THROUGH THE CLEARANCE HOLE IN THE ROOF STRRUCTURE UNTIL THE KSCV PIPE ASSEMBLY SITS FLUSH ON THE ROOF STRUCTURE. CORRUGATED ROOF STRUCTURES MAY NEED TO BE BRIDGED AS SHOWN IN S-88.071-20D.

12.) FEED THE KSCV RESTRAINT CHANNEL ONTO THE TREADED ROD, AND SECURE USING A 0.25 WASHER AND TWO 0.25-20 UNC NUTS AS SHOWN IN S-88.071-20D. THE KSCV ROOF BRACKET MAY BRIDGE ANY CORRUGATIONS IN THE ROOF STRUCTURE, OR IT MAY SIT IN A TROUGH, OR ON A CREST OF ANY CORRUGATIONS IN THE ROOF STRUCTURE.

13.) SEAL THE JOINT BETWEEN THE KSCV PIPE ASSEMBLY AND THE ROOF STRUCTURE WITH A GOOD RTV CAULKING MATERIAL, BY OTHERS. ALSO SEAL ANY PENETRATIONS IN THE ROOF STRUCTURE THAT WERE MADE BY FASTENERS USED TO ATTACH SHEET METAL BRIDGING MATERIAL WITH THE SAME RTV CAULKING MATERIAL, BY OTHERS.

14.) AFTER THE EQUIPMENT HAS BEEN PLACED, THREAD THE 0.25-20 UNC X 12 THREAD ROD INTO THE TOP OF THE COUPLING NUT UNTIL IT BOTTOMS OUT. THE THREADED ROD MAY NOW BE USED TO HELP LOCATE THE KSCV EQUIPMENT BRACKET TO THE EQUIPMENT.

15.) LOCATE AND ATTACH THE KSCV EQUIPMENT BRACKET TO THE SIDE OF THE EQUIPMENT IN A MANNER SIMILAR TO THE EXAMPLES SHOWN IN S-88.071-20E. ***DO NOT BLOCK EQUIPMENT ACCESS AND MAINTENANCE DOORS WITH THE KSCV EQUIPMENT BRACKET.***

CONTINUED ON S-88.071-20C SHT3.

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KSCV SEISMIC & WIND VERTICAL RESTRAINT INSTRUCTIONS CONT'D:

16.) WITH THE 0.25-20 UNC X 12 THREADED ROD IN THE APPROPRIATE HOLE IN THE KSCV EQUIPMENT BRACKET INSTALL THE STANDARD 0.25 WASHER AND TWO (2) 0.25-20 UNC NUTS AS SHOWN IN S-88.071-20E. SLIGHT MISALIGNMENTS MAY BE ACCOMODATED BY BENDING THE TWO THREADED RODS UNTIL CONTACT IS MADE WITH THE HOLE IN THE TOP OF THE KSCV PIPE ASSEMBLY.

17.) SEAL ANY PENETRATIONS IN THE EQUIPMENT MADE DURING THE ATTACHMENT OF THE KSCV EQUIPMENT BRACKET WITH CAULKING COMPOUND, BY OTHERS.

18.) RE-SEAL THE JOINT BETWEEN THE THREADED ROD AND THE TOP OF THE KSCV PIPE ASSEMBLY WITH RTV CAULKING COMPOUND.

19.) IF NECESSARY, RE-SEAL THE JOINT BETWEEN THE KSCV PIPE ASSEMBLY AND THE BOOT OR FLASHING.

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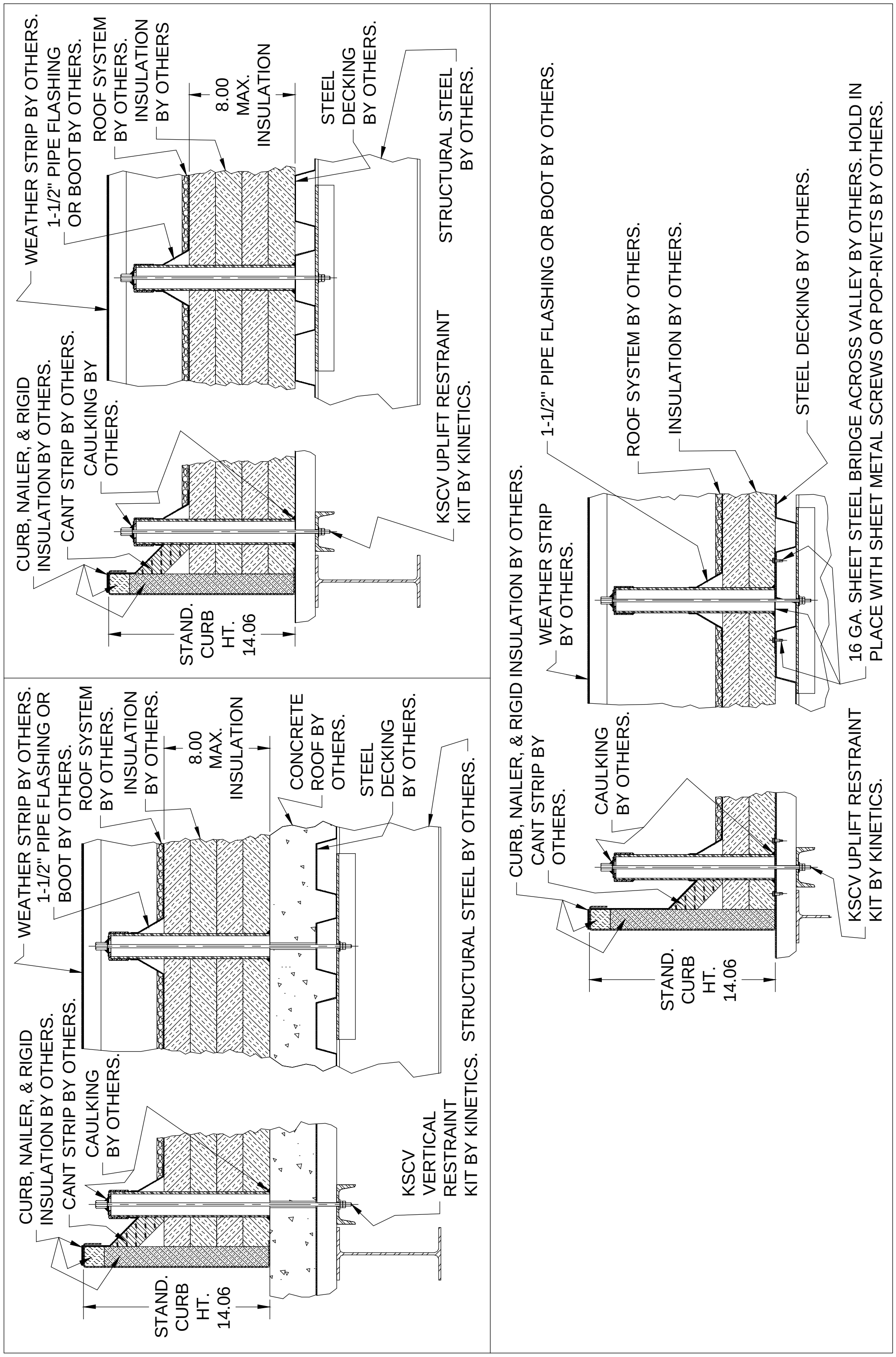

KSCV SEISMIC & WIND VERTICAL RESTRAINT

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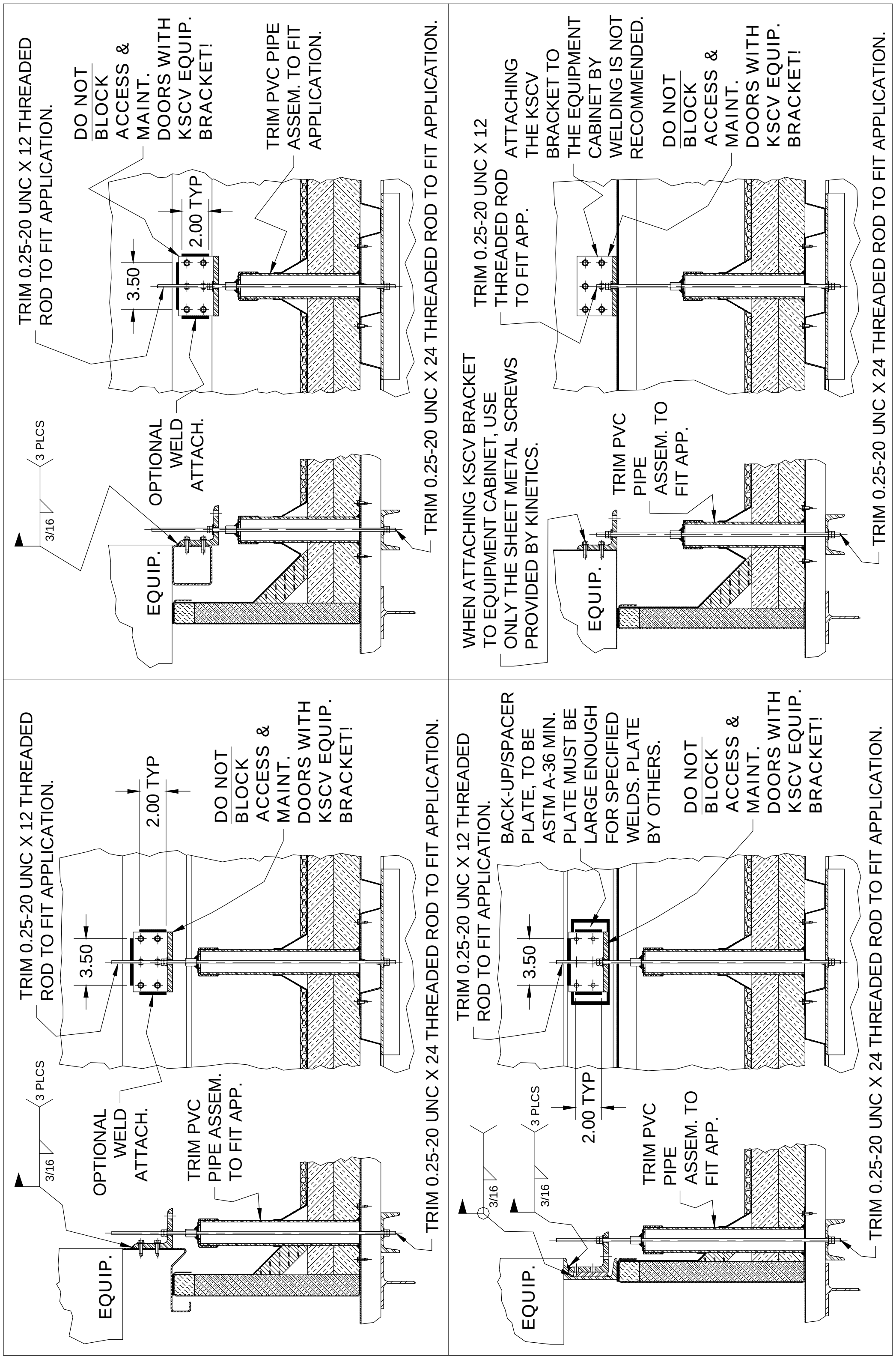

KINETICS™ Seismic Design Manual

KSCV SEISMIC & WIND VERTICAL RESTRAINT

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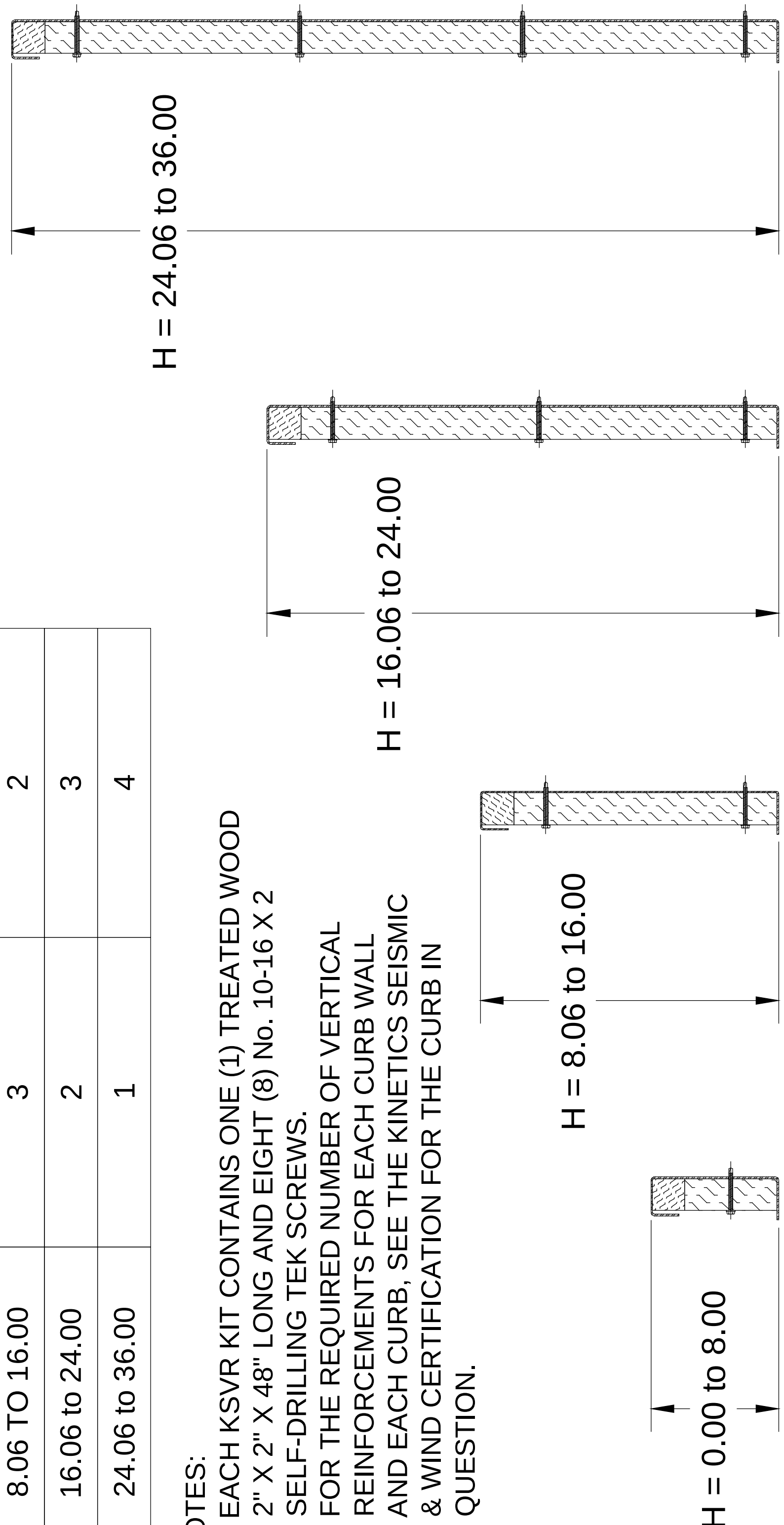
APPLICABLE CURB HEIGHT RANGE INCLUSIVE (H) (in.)	NUMBER OF VERTICAL REINFORCEMENTS PER KIT	NUMBER OF No. 10-16 X 2 SELF-DRILLING TEK SCREWS PER REINFORCEMENT
0.00 to 8.00	4	1
8.06 TO 16.00	3	2
16.06 to 24.00	2	3
24.06 to 36.00	1	4

NOTES:

1.) EACH KSVR KIT CONTAINS ONE (1) TREATED WOOD 2" X 2" X 48" LONG AND EIGHT (8) No. 10-16 X 2 SELF-DRILLING TEK SCREWS.

2.) FOR THE REQUIRED NUMBER OF VERTICAL REINFORCEMENTS FOR EACH CURB WALL AND EACH CURB, SEE THE KINETICS SEISMIC & WIND CERTIFICATION FOR THE CURB IN QUESTION.



KSVR SEISMIC CURB WALL REINFORCEMENT

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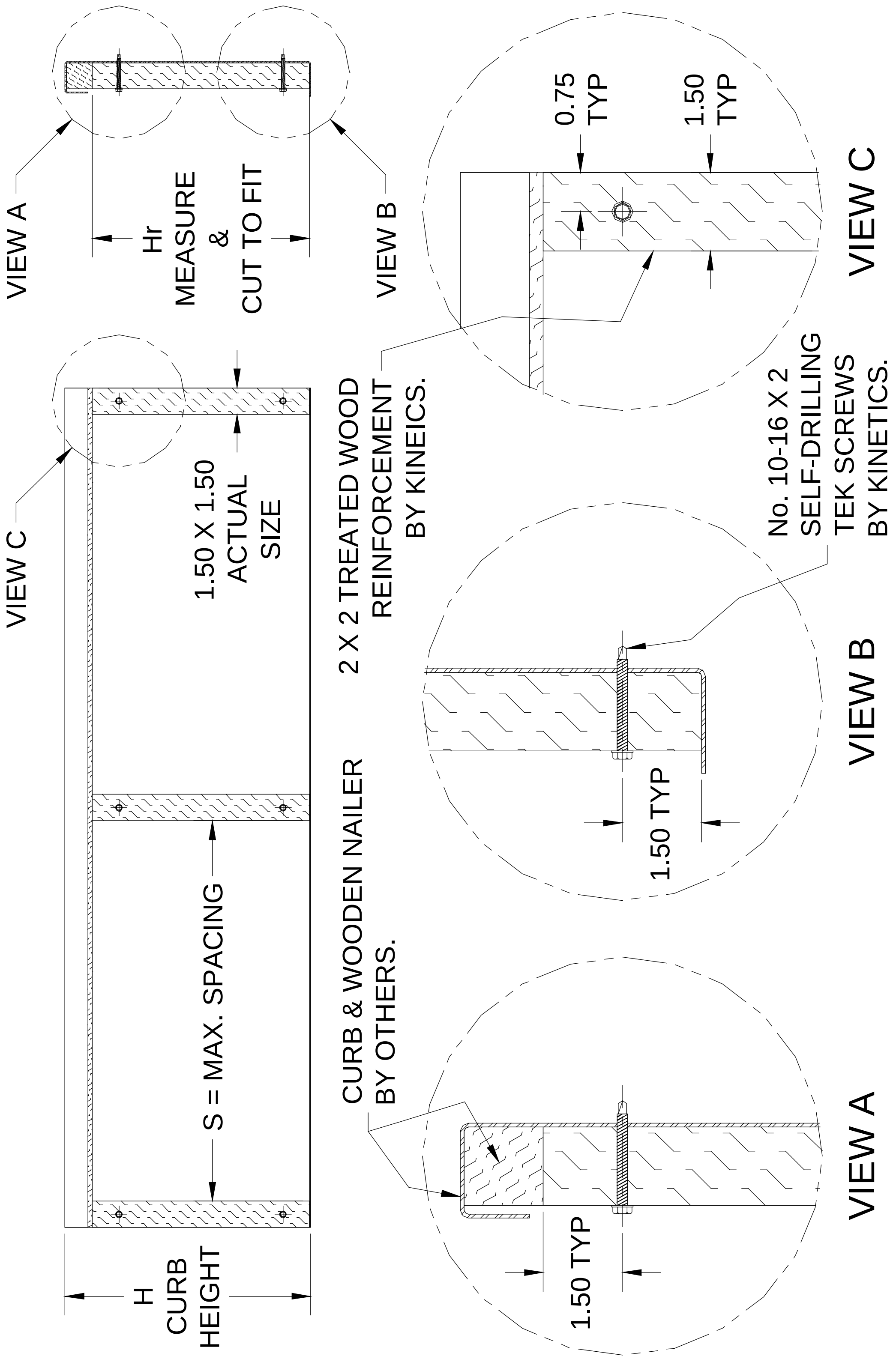

KSVR SEISMIC CURB WALL REINFORCEMENT

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KSVR CURB WALL VERTICAL REINFORCEMENT KIT INSTRUCTIONS:

1.) MARK THE LOCATIONS FOR THE VERTICAL REINFORCEMENTS ON THE CURB WALLS ACCORDING TO THE KINETICS SEISMIC & WIND CERTIFICATION AND S-88.071-21B. THE MINIMUM NUMBER OF VERTICAL REINFORCEMENTS PER SIDE IS THREE (3). ONE (1) LOCATED ON EACH END OF THE CURB WALL AND ONE (1) AT APPROXIMATELY THE CENTER OF THE CURB WALL. IF MORE THAN THREE (3) VERTICAL REINFORCEMENTS ARE REQUIRED PER SIDE, ONE (1) REINFORCEMENT GOES AT EACH END OF THE CURB WALL AND THE REST ARE MORE-OR-LESS EQUALLY DISTRIBUTED ALONG THE CURB WALL AT A SPACING EQUAL TO (S) FROM THE KINETICS SEISMIC & WIND CERTIFICATION. THE SPACING BETWEEN ADJACENT VERTICAL REINFORCEMENTS MAY BE VARIED SLIGHTLY TO MISS THE CURB ATTACHMENTS TO THE ROOF.

2.) MEASURE AND CUT THE VERTICAL REINFORCEMENT FOR EACH LOCATION. THE FIT OF THE VERTICAL REINFORCEMENT BETWEEN THE NAILER AND THE FOOT OF THE CURB MUST BE SNUG. THE PURPOSE OF THE VERTICAL REINFORCEMENT IS TO CARRY MOST OR ALL OF THE VERTICAL LOADS ACTING DOWNWARD ON THE CURB WALLS.

3.) ATTACH THE VERTICAL REINFORCEMENT TO THE CURB WALL USING THE No.10-16 X 2 SELF-DRILLING TEK SCREWS PROVIDED IN THE KSCR KIT. THE NUMBER OF SCREWS REQUIRED FOR EACH REINFORCEMENT IS DEFINED BY S-88.071-21A. WHEN ONLY ONE (1) SCREW IS REQUIRED PER VERTICAL REINFORCEMENT, IT SHOULD BE PLACED IN THE CENTER OF THE REINFORCEMENT AS SHOWN ON S-88.071-21A. WHEN TWO (2) OR MORE SCREWS ARE REQUIRED FOR EACH VERTICAL REINFORCEMENT, AS SHOWN ON S-88.071-21A, THE TOP MOST AND BOTTOM MOST SHOULD BE 1.50 INCHES FROM THE ENDS OF THE VERTICAL REINFORCEMENT. WHEN MORE THAN TWO (2) SCREWS ARE REQUIRED PER VERTICAL REINFORCEMENT, THEY SHOULD BE EVENLY DISTRIBUTED BETWEEN THE TOP MOST, AND BOTTOM MOST SCREWS. THE HEADS OFTHESE SCREWS MAY BE DRIVEN INTO THE VERTICAL REINFORCEMENT SLIGHTLY TO MAKE AN EASIER SURFACE TO FLASH OVER. ***DO NOT DRIVE THE SCREW HEAD IN FAR ENOUGH TO SPLIT THE VERTICAL REINFORCEMENT!***

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CHAPTER P2

FMS ISOLATOR / RESTRAINTS
TABLE OF CONTENTS

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Kinetics Model FMS

This isolator was developed to handle a variety of seismic zones. The seismic element is placed on the bottom, close to the mounting surface, to minimize the tensile loading generated in the attachment hardware. The isolation element is mounted above the restraint and its size and shape can be varied independently of the restraint's size and shape

Specification

All Direction High Capacity Modular Seismic Isolator

1. Spring Isolators shall be comprised of two interfacing but independent elements, a coil spring element and a seismically rated housing. The spring coil element shall be comprised of one or more coil assemblies having all of the characteristics of free standing coil spring isolators as specified in the vibration isolation portion of the specification. The seismically rated housing shall be sized to match the force requirements applicable to the project and have the capability of accepting coils of various sizes, shapes, capacities and deflections as needed to meet the desired isolation criteria.

2. All spring forces will be contained within the coil/housing assembly and under no external load condition shall spring forces be carried through the restraint anchorage system.

3. The restraint element shall incorporate a steel housing and elastomeric elements at all dynamic contact points. The restraint will allow ¼" motion in any lateral or vertical direction from the neutral position. All elastomeric elements shall be replaceable.

4. To ensure the optimum anchorage capacity, the restraint will have an **overturning factor** (The ratio of the effective lateral snubber height to the short axis anchor spacing) of .33 or less.

5. The leveling nut or screw shall be made accessible for adjustment with the use of a pneumatic or electric impact wrench.

6. The spring element shall be replaceable without having to lift or otherwise remove any supported equipment.

7. Where required, a soft lateral cushioning element shall be fitted that can absorb the minor lateral forces generated by hydraulic or wind loads without contact being made at the main snubbing element.

The isolator shall be Model FMS as manufactured by Kinetics Noise Control or by other manufacturers who can meet the requirements above.

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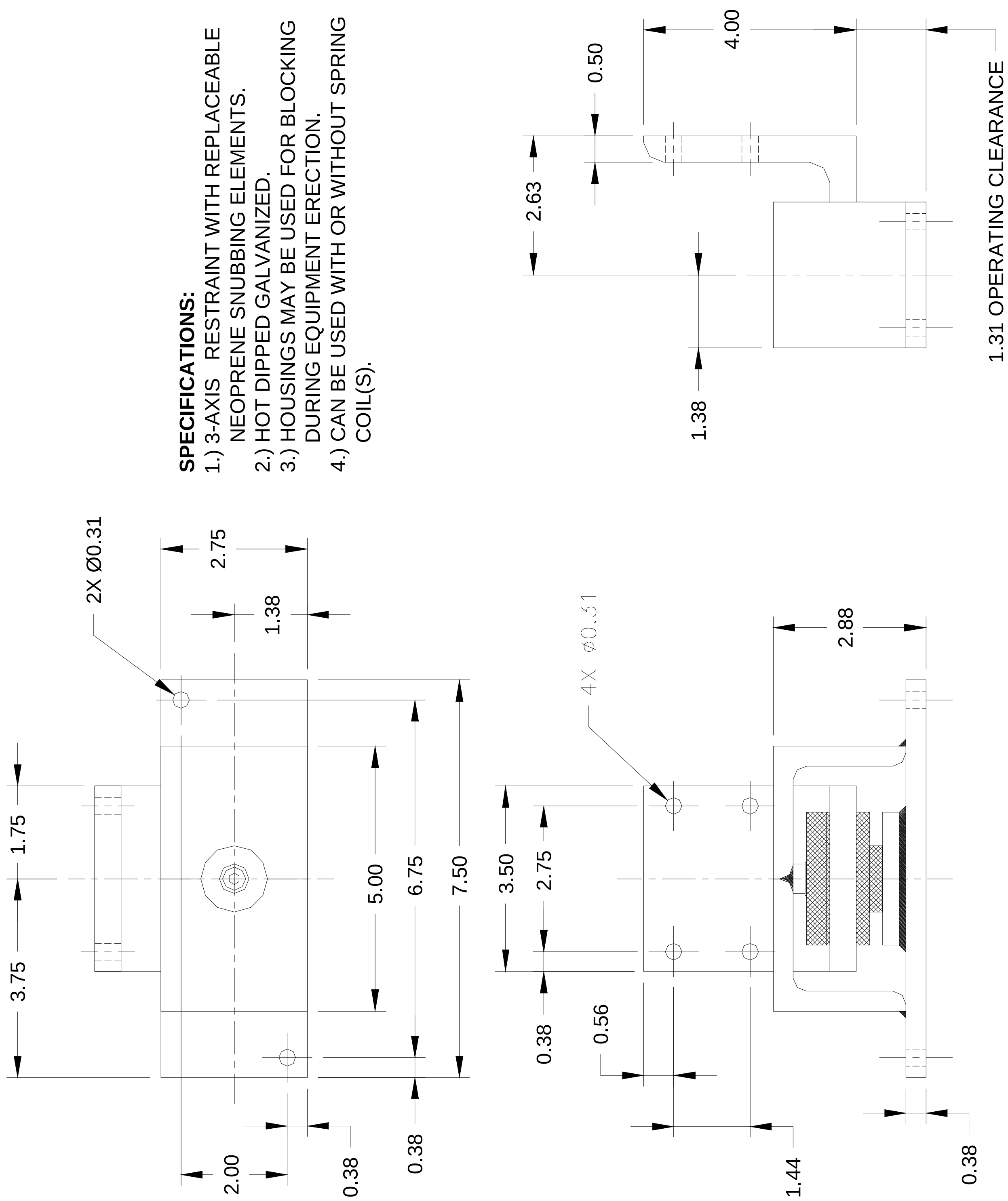
SPECIFICATIONS:

1.) 3-AXIS RESTRAINT WITH REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
2.) HOT DIPPED GALVANIZED.
3.) HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION.
4.) CAN BE USED WITH OR WITHOUT SPRING COIL(S).



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INTRUCTIONS FOR CONSTRUCTION OF A CAPACITY ENVELOPE:

1.) TO GENERATE THE SEISMIC RESTRAINT CAPACITY ENVELOPE, THE HIGHEST ISOLATOR LOAD FOR THE PIECE OF EQUIPMENT UNDER REVIEW IS USED AS A STARTING POINT.
2.) DETERMINE WHETHER THE ATTACHMENT IS TO BE TO STEEL, SELECT FIGURE 2, OR CONCRETE, SELECT FIGURE 3.
3.) THE VERTICAL RESTRAINT CAPACITY @ THE LOAD DETERMINED IN STEP 1 IS READ FROM CURVE #1 (FIG. 2) OR CURVE #4 (FIG. 3) AND PLOTTED ON THE VERTICAL AXIS OF FIGURE 1.
4.) THE HORIZONTAL RESTRAINT CAPACITY @ THE LOAD DETERMINED IN STEP 1 IS READ FROM CURVE #3 (FIG. 2) OR CURVE #6 (FIG. 3) AND PLOTTED ON THE HORIZONTAL AXIS OF FIGURE 1.
5.) THE COMBINED RESTRAINT CAPACITY IS THE POINT WHERE VERTICAL & HORIZONTAL CAPACITIES ARE EQUAL. THE COMBINED RESTRAINT CAPACITY @ THE LOAD DETERMINED IN STEP 1 IS READ FROM CURVE #2 (FIG. 2) OR CURVE #5 (FIG. 3). DRAW A HORIZONTAL LINE FROM THIS VALUE ON THE VERTICAL AXIS, AND A VERTICAL LINE FROM THIS VALUE ON THE HORIZONTAL AXIS. THE INTERSECTION POINT IS THE COMBINED CAPACITY POINT FOR THE GIVEN APPLICATION.
6.) CONNECT THE VERTICAL RESTRAINT CAPACITY, COMBINED RESTRAINT CAPACITY, AND THE HORIZONTAL RESTRAINT CAPACITY POINTS THAT YOU PLOTTED FOR YOUR APPLICATION. THIS WILL PRODUCE THE RESTRAINT CAPACITY ENVELOPE FOR YOUR APPLICATION.
7.) FOR THE RESTRAINT TO BE SUITABLE FOR THE APPLICATION, ALL WORST CASE SEISMIC LOAD COMBINATIONS MUST FALL WITHIN THE RESTRAINT ENVELOPE.

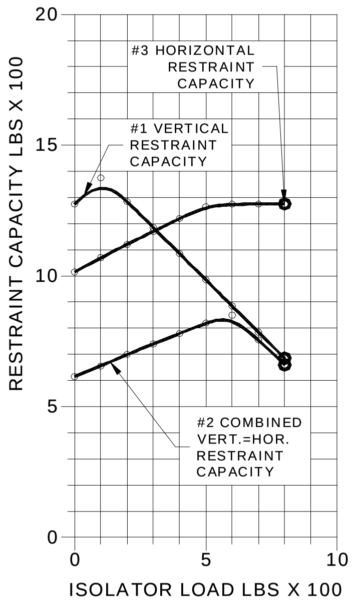

FIGURE 2
STEEL ATTACHMENT

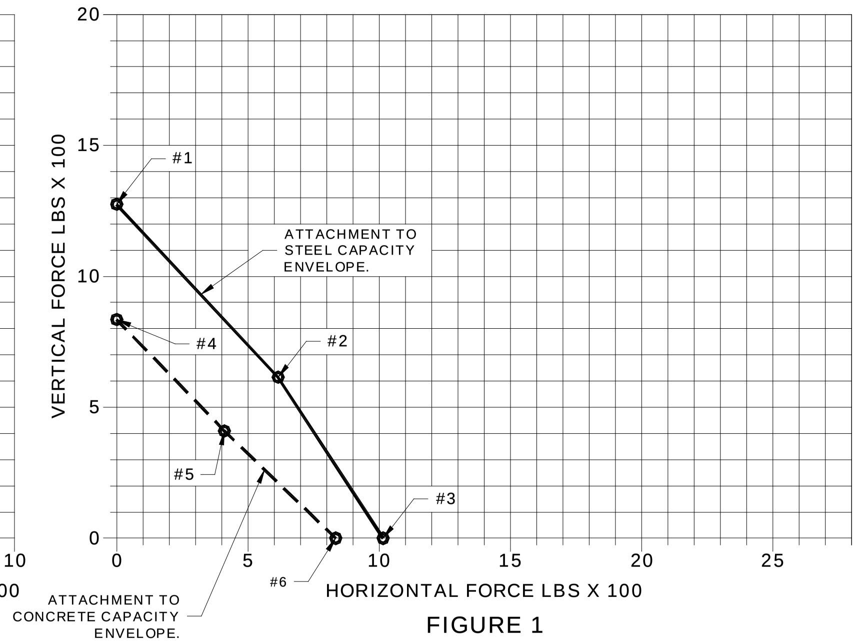

FIGURE 1
RESTRAINT CAPACITY ENVELOPE

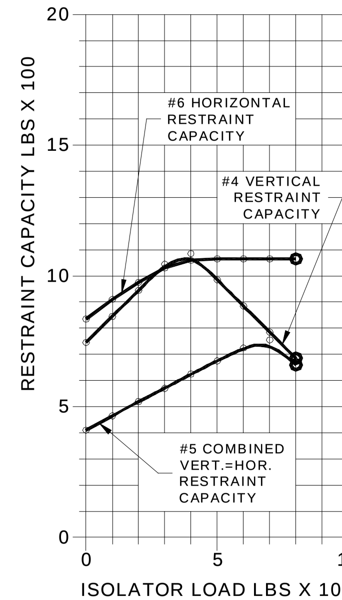

FIGURE 3
CONCRETE ATTACHMENT

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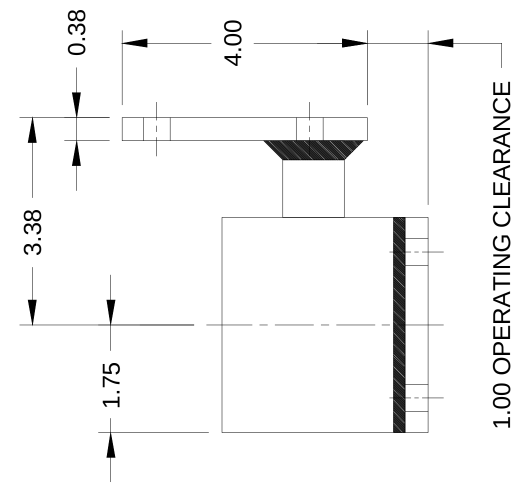
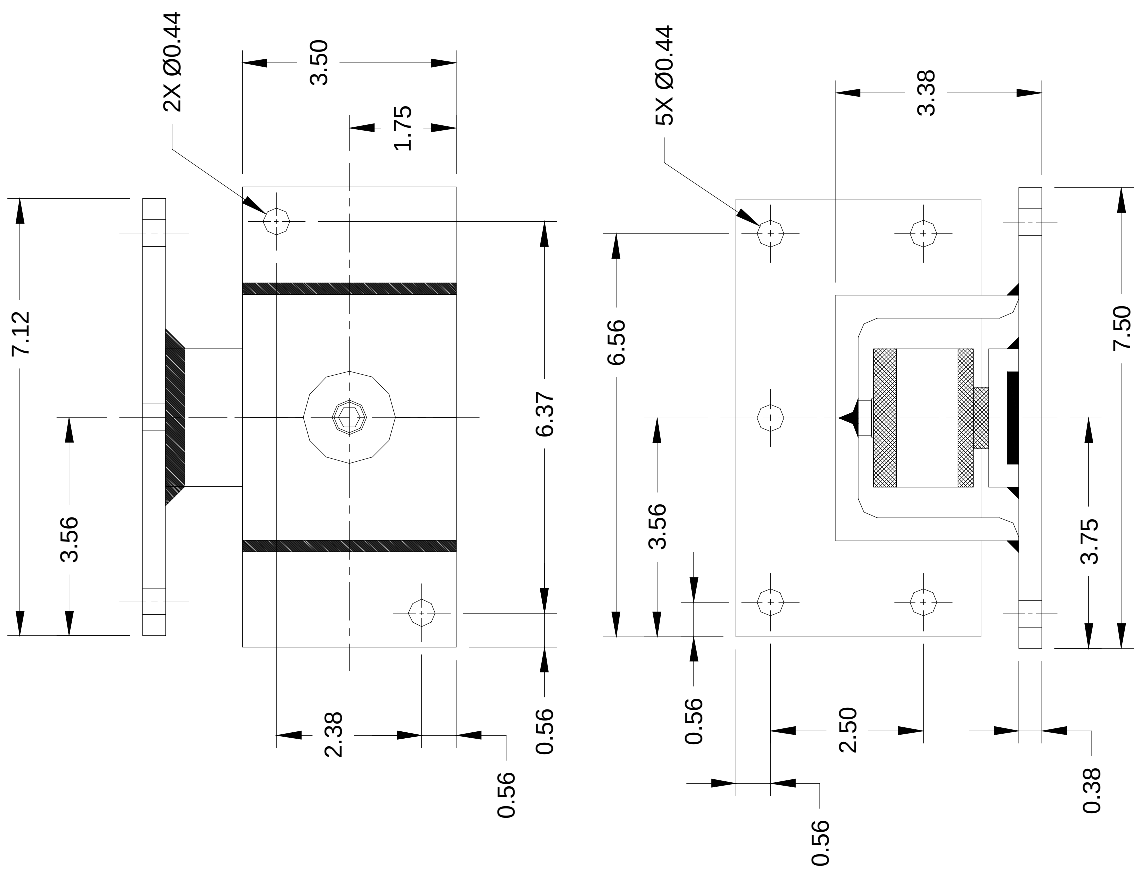
SPECIFICATIONS:

1.) 3-AXIS RESTRAINT WITH REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
2.) HOT DIPPED GALVANIZED.
3.) HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION.
4.) CAN BE USED WITH OR WITHOUT SPRING COIL(S).





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INTRUCTIONS FOR CONSTRUCTION OF A CAPACITY ENVELOPE:

1.) TO GENERATE THE SEISMIC RESTRAINT CAPACITY ENVELOPE, THE HIGHEST ISOLATOR LOAD FOR THE PIECE OF EQUIPMENT UNDER REVIEW IS USED AS A STARTING POINT.
2.) DETERMINE WHETHER THE ATTACHMENT IS TO BE TO STEEL, SELECT FIGURE 2, OR CONCRETE, SELECT FIGURE 3.
3.) THE VERTICAL RESTRAINT CAPACITY @ THE LOAD DETERMINED IN STEP 1 IS READ FROM CURVE #1 (FIG. 2) OR CURVE #4 (FIG. 3) AND PLOTTED ON THE VERTICAL AXIS OF FIGURE 1.
4.) THE HORIZONTAL RESTRAINT CAPACITY @ THE LOAD DETERMINED IN STEP 1 IS READ FROM CURVE #3 (FIG. 2) OR CURVE #6 (FIG. 3) AND PLOTTED ON THE HORIZONTAL AXIS OF FIGURE 1.
5.) THE COMBINED RESTRAINT CAPACITY IS THE POINT WHERE VERTICAL & HORIZONTAL CAPACITIES ARE EQUAL. THE COMBINED RESTRAINT CAPACITY @ THE LOAD DETERMINED IN STEP 1 IS READ FROM CURVE #2 (FIG. 2) OR CURVE #5 (FIG. 3). DRAW A HORIZONTAL LINE FROM THIS VALUE ON THE VERTICAL AXIS, AND A VERTICAL LINE FROM THIS VALUE ON THE HORIZONTAL AXIS. THE INTERSECTION POINT IS THE COMBINED CAPACITY POINT FOR THE GIVEN APPLICATION.
6.) CONNECT THE VERTICAL RESTRAINT CAPACITY, COMBINED RESTRAINT CAPACITY, AND THE HORIZONTAL RESTRAINT CAPACITY POINTS THAT YOU PLOTTED FOR YOUR APPLICATION. THIS WILL PRODUCE THE RESTRAINT CAPACITY ENVELOPE FOR YOUR APPLICATION.
7.) FOR THE RESTRAINT TO BE SUITABLE FOR THE APPLICATION, ALL WORST CASE SEISMIC LOAD COMBINATIONS MUST FALL WITHIN THE RESTRAINT ENVELOPE.

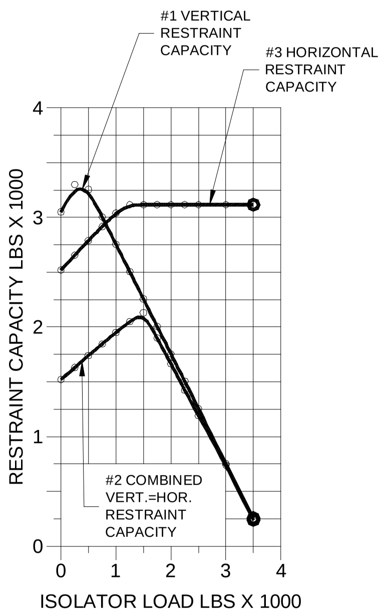

FIGURE 2
STEEL ATTACHMENT

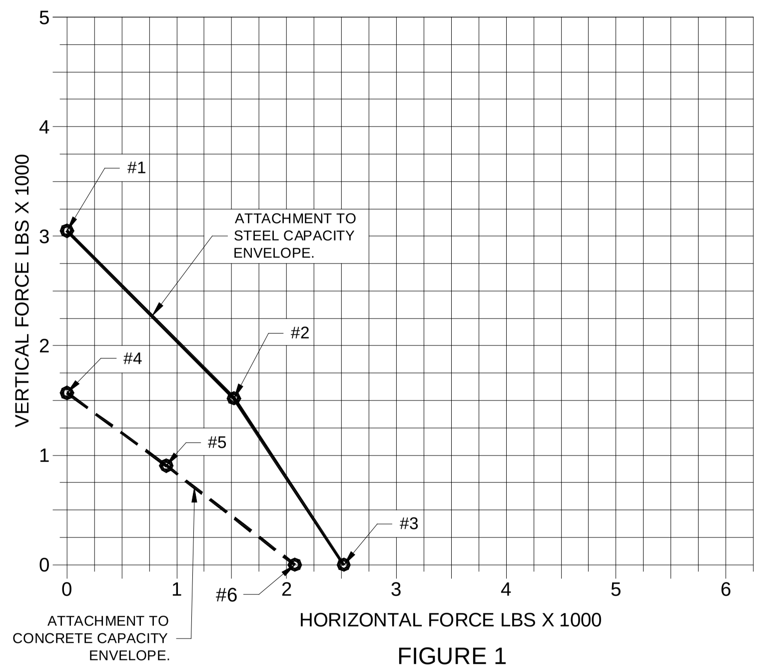

FIGURE 1
RESTRAINT CAPACITY ENVELOPE

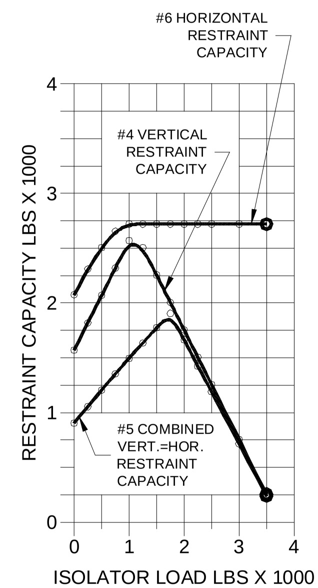

FIGURE 3
CONCRETE ATTACHMENT

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DOCUMENT:
P2.2.2

VISCMA MEMBER

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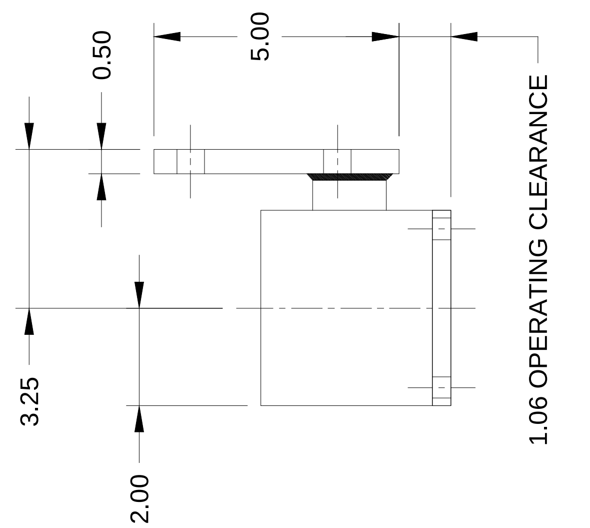

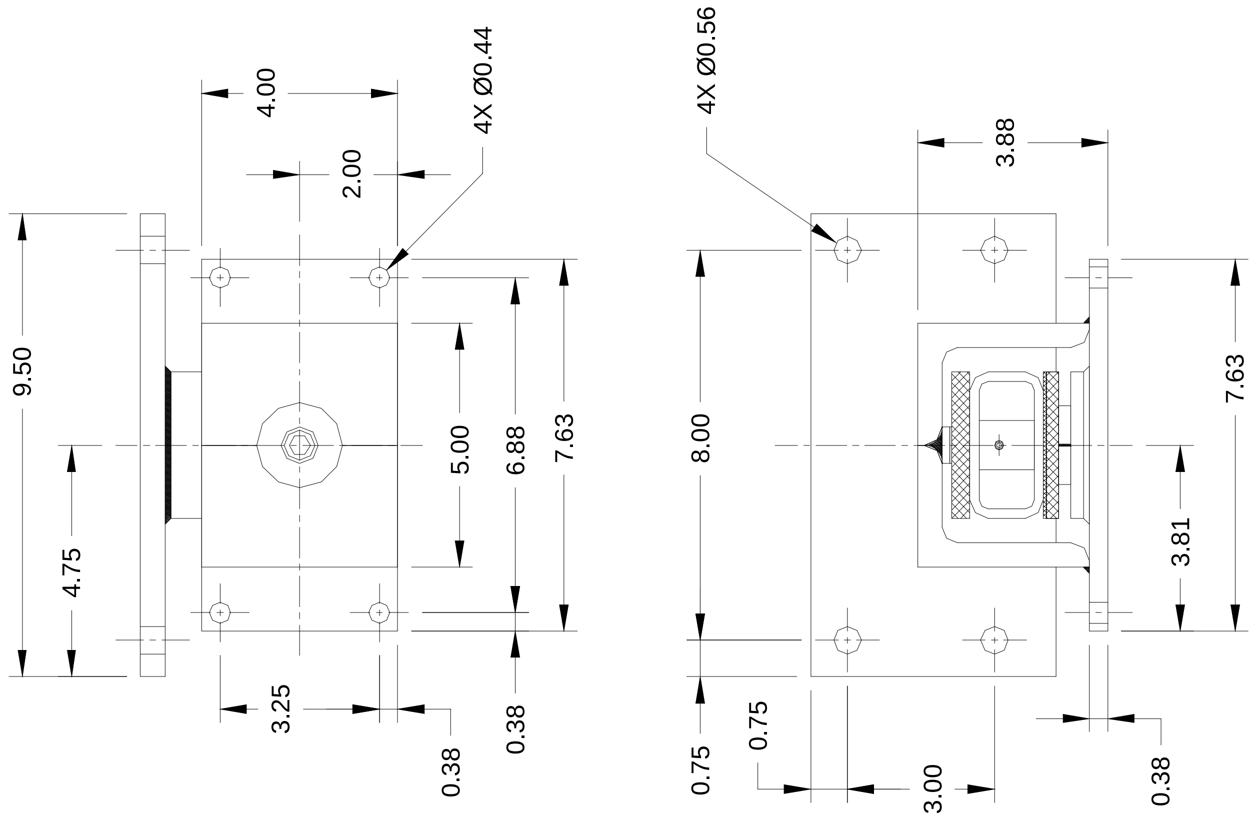

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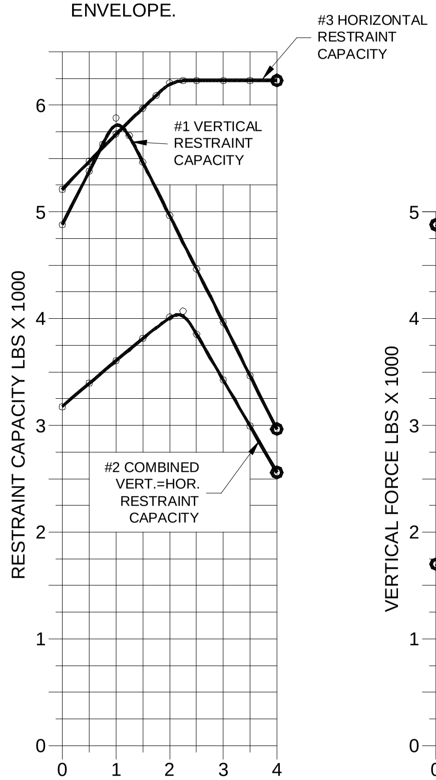

FIGURE 2
STEEL ATTACHMENT

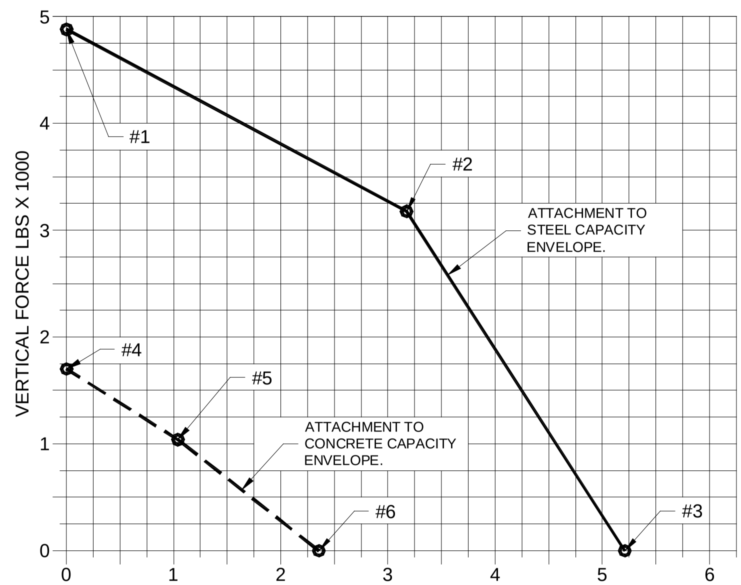

FIGURE 1
RESTRAINT CAPACITY ENVELOPE

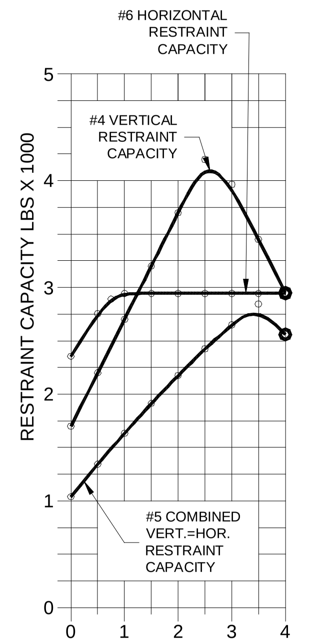

FIGURE 3
CONCRETE ATTACHMENT

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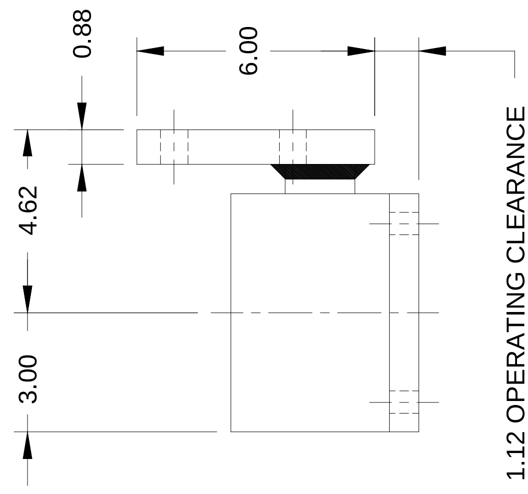

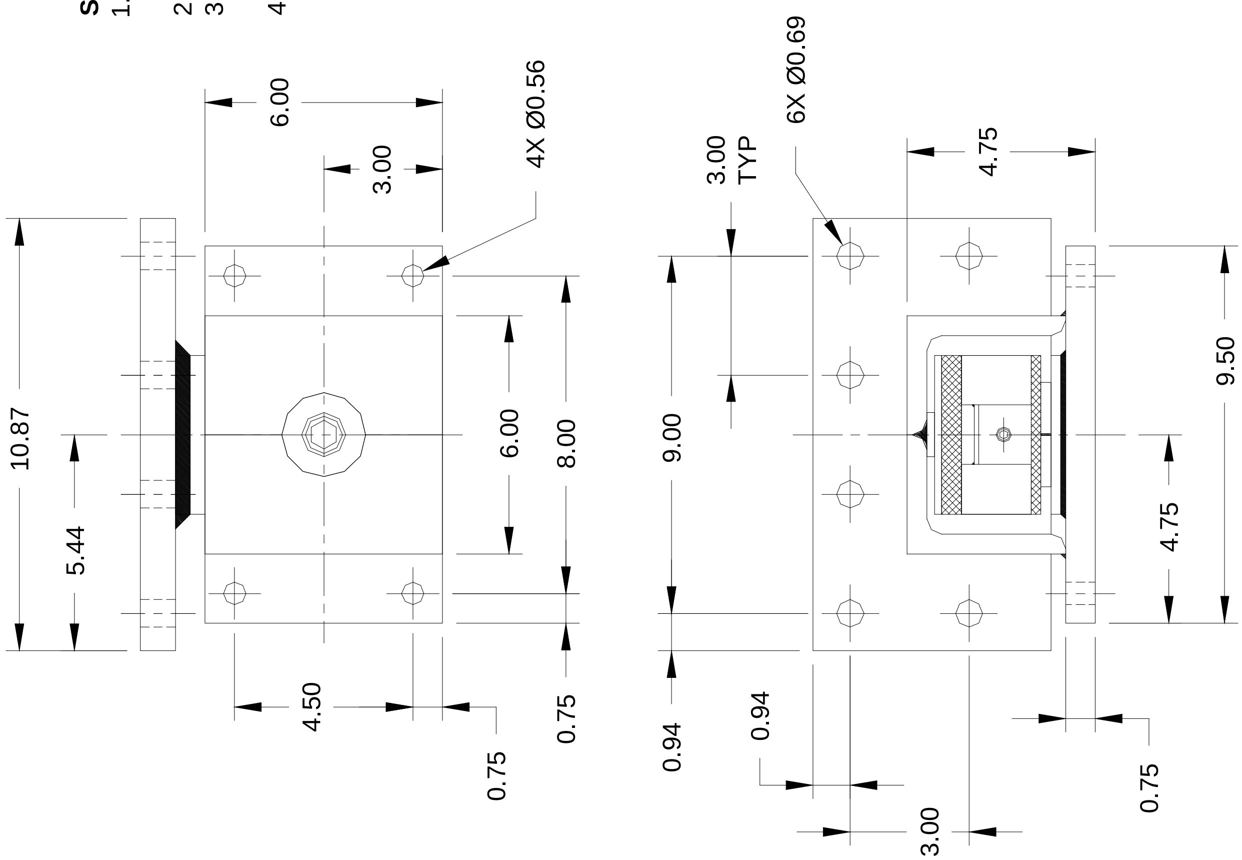

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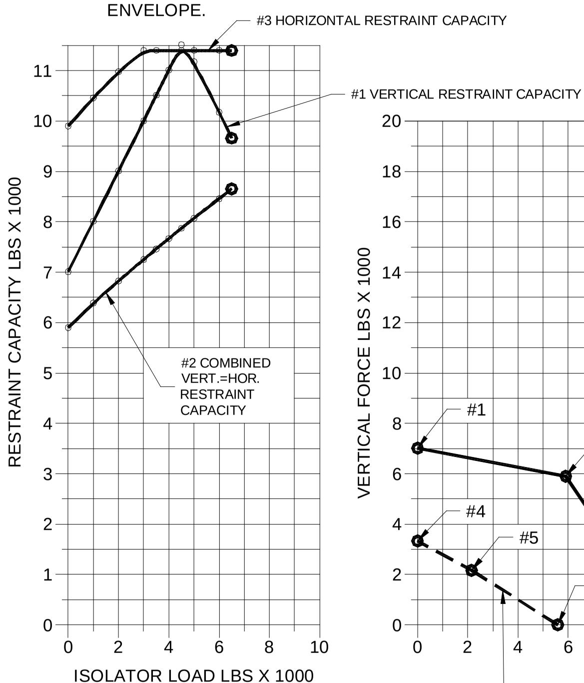

FIGURE 2
STEEL ATTACHMENT

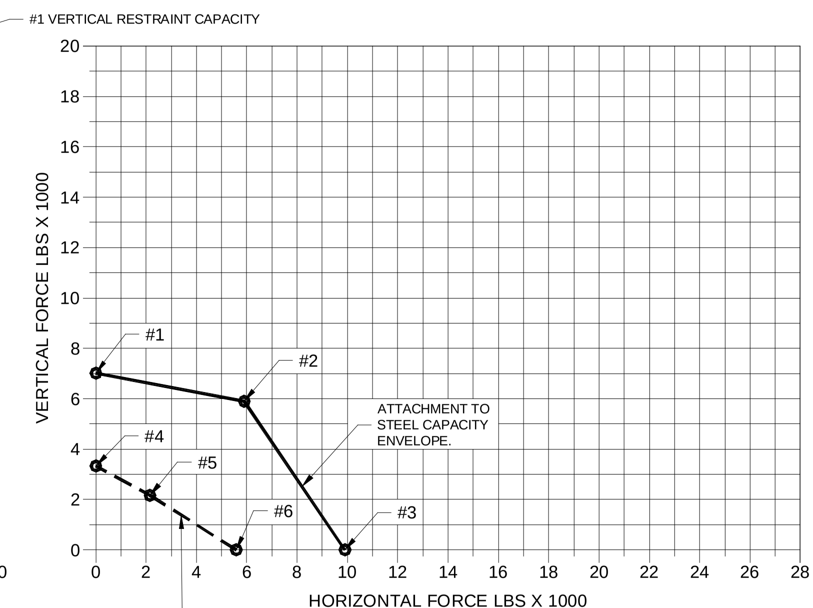

FIGURE 1
RESTRAINT CAPACITY ENVELOPE

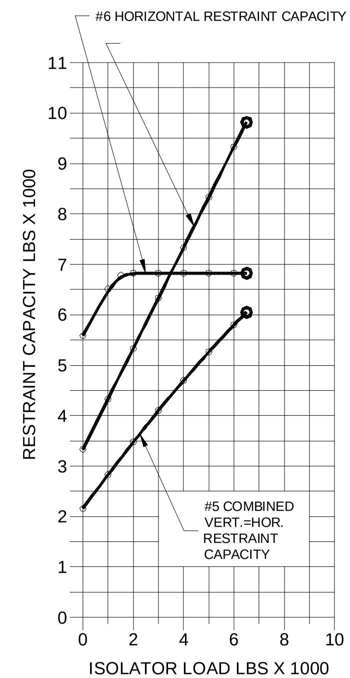

FIGURE 3
CONCRETE ATTACHMENT

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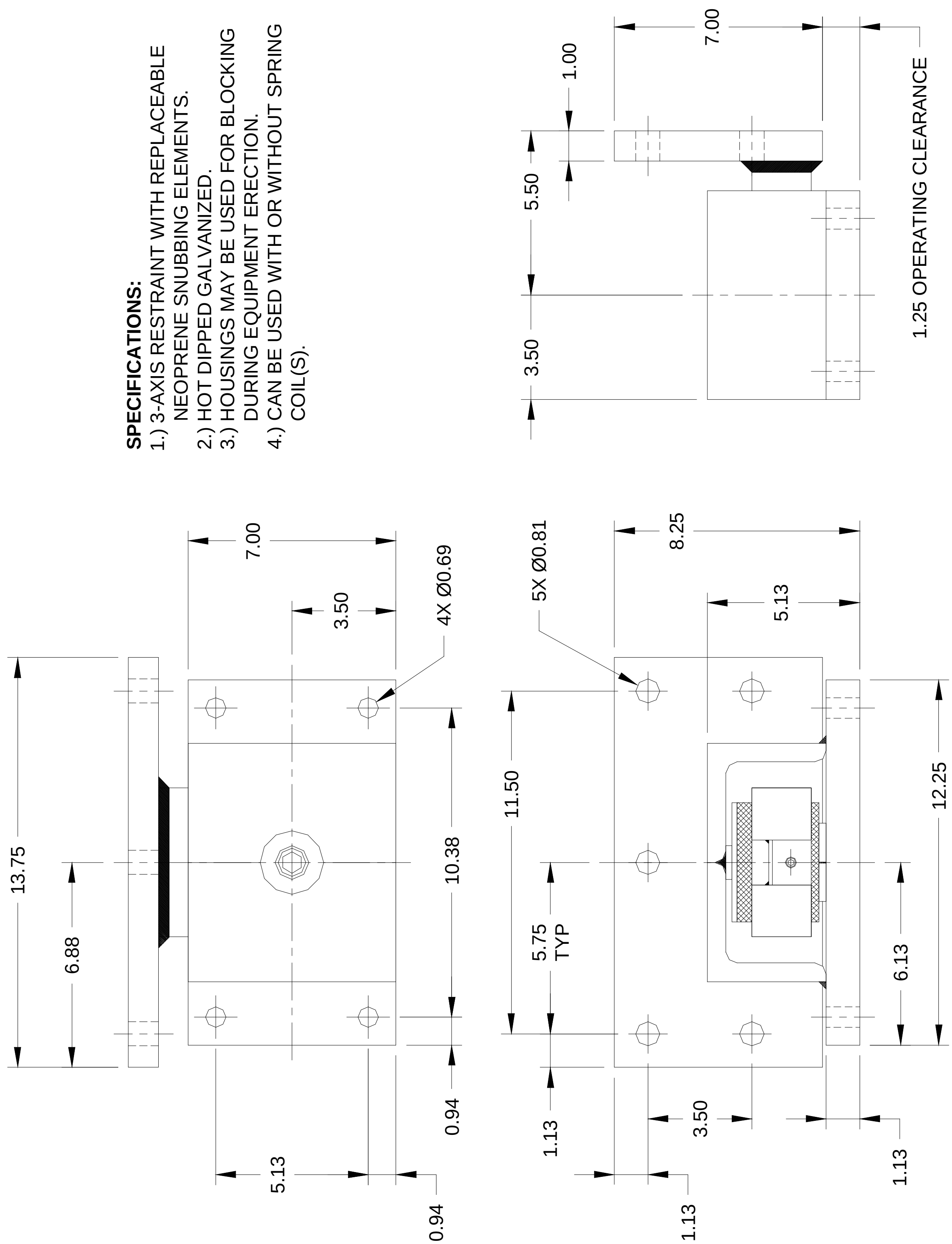

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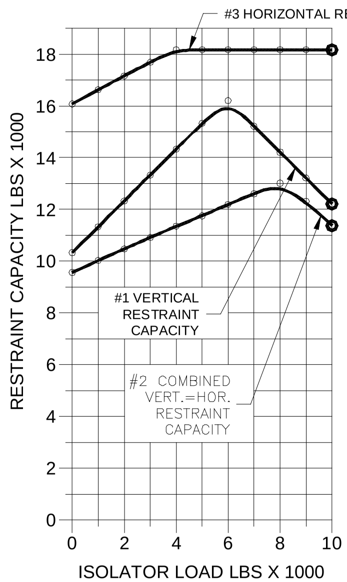
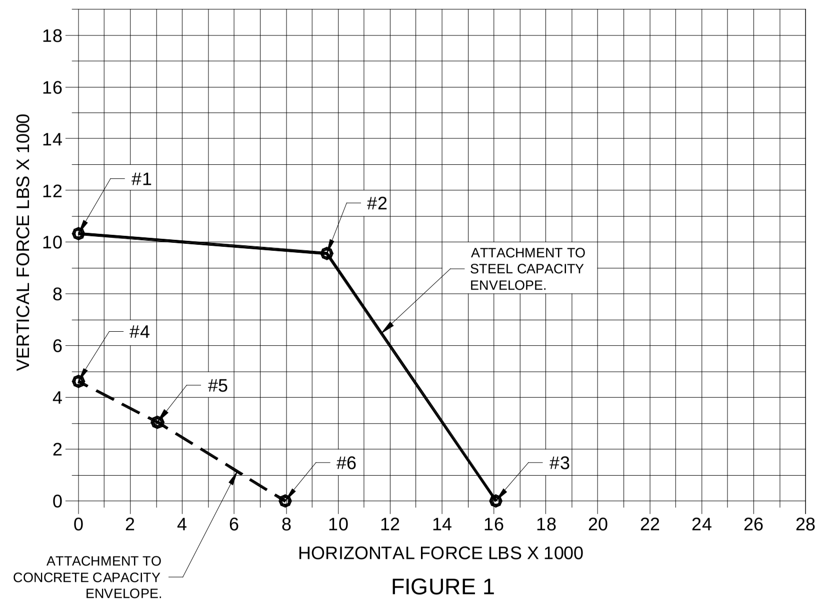


FIGURE 2
STEEL ATTACHMENT



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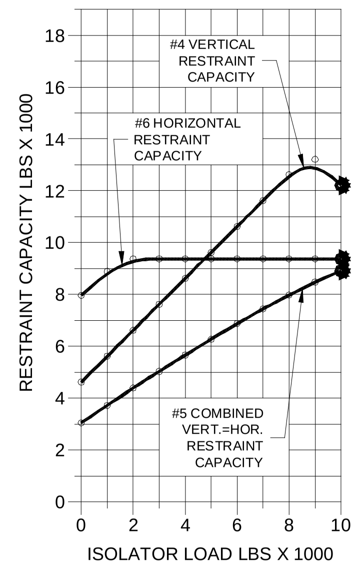

FIGURE 3
CONCRETE ATTACHMENT

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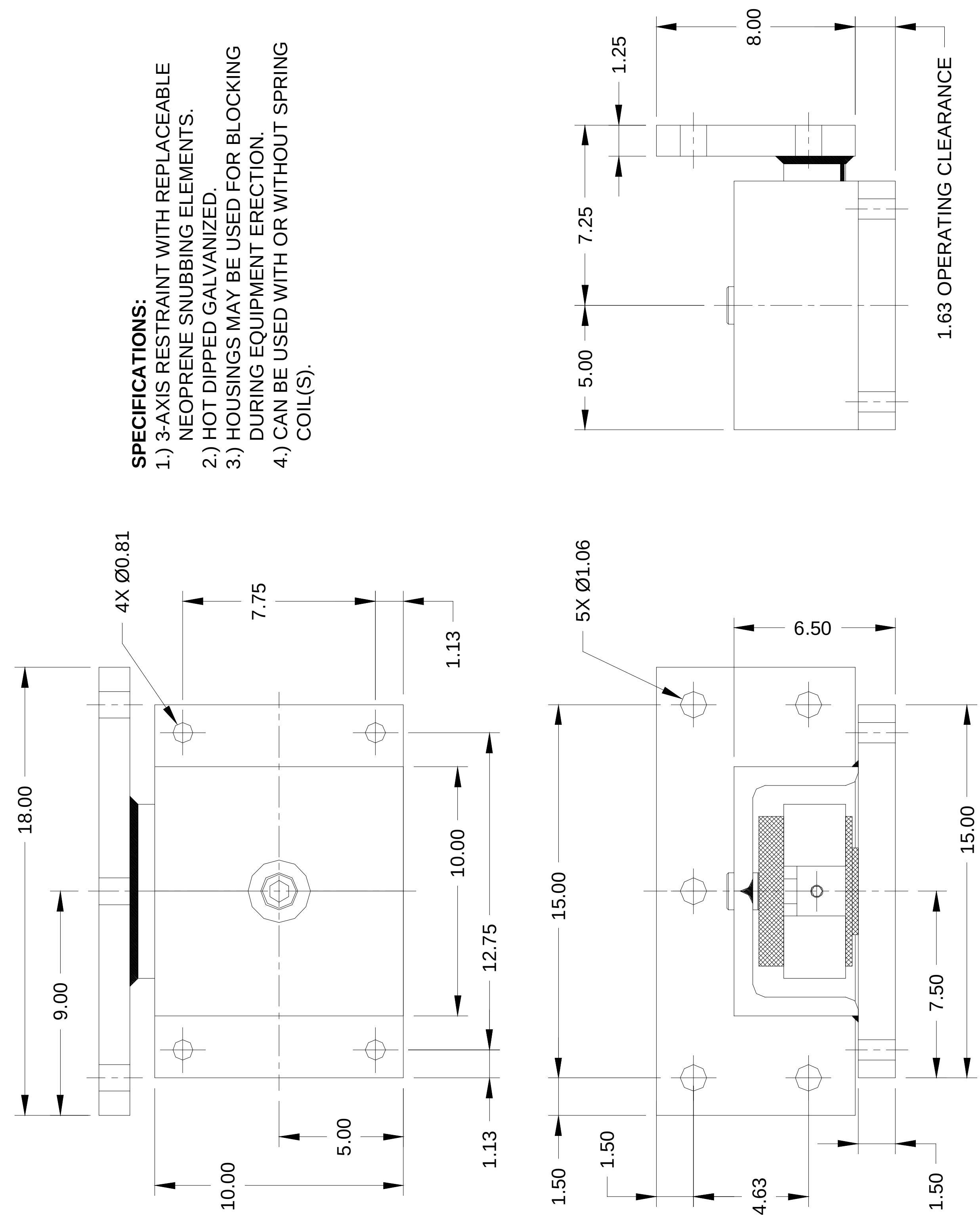

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VISCMA MEMBER

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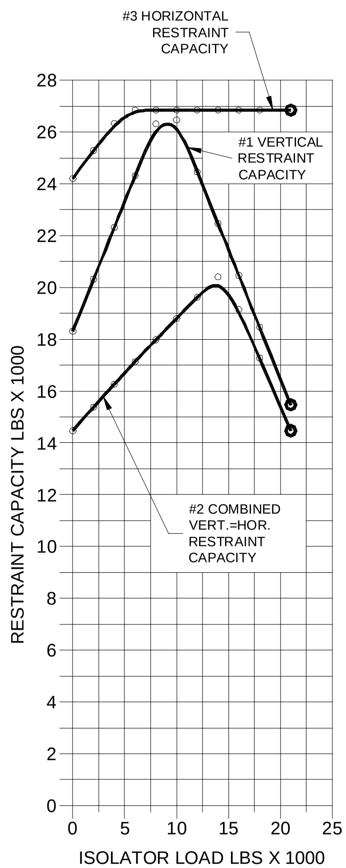
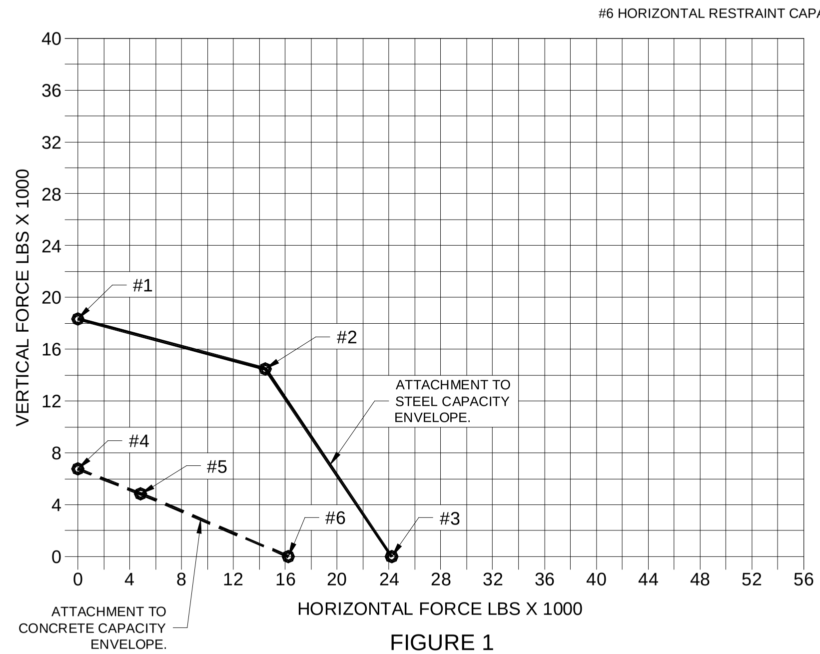


FIGURE 2
STEEL ATTACHMENT



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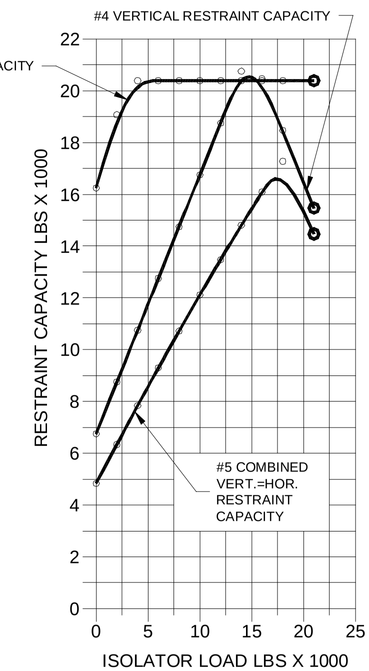

FIGURE 3
CONCRETE ATTACHMENT

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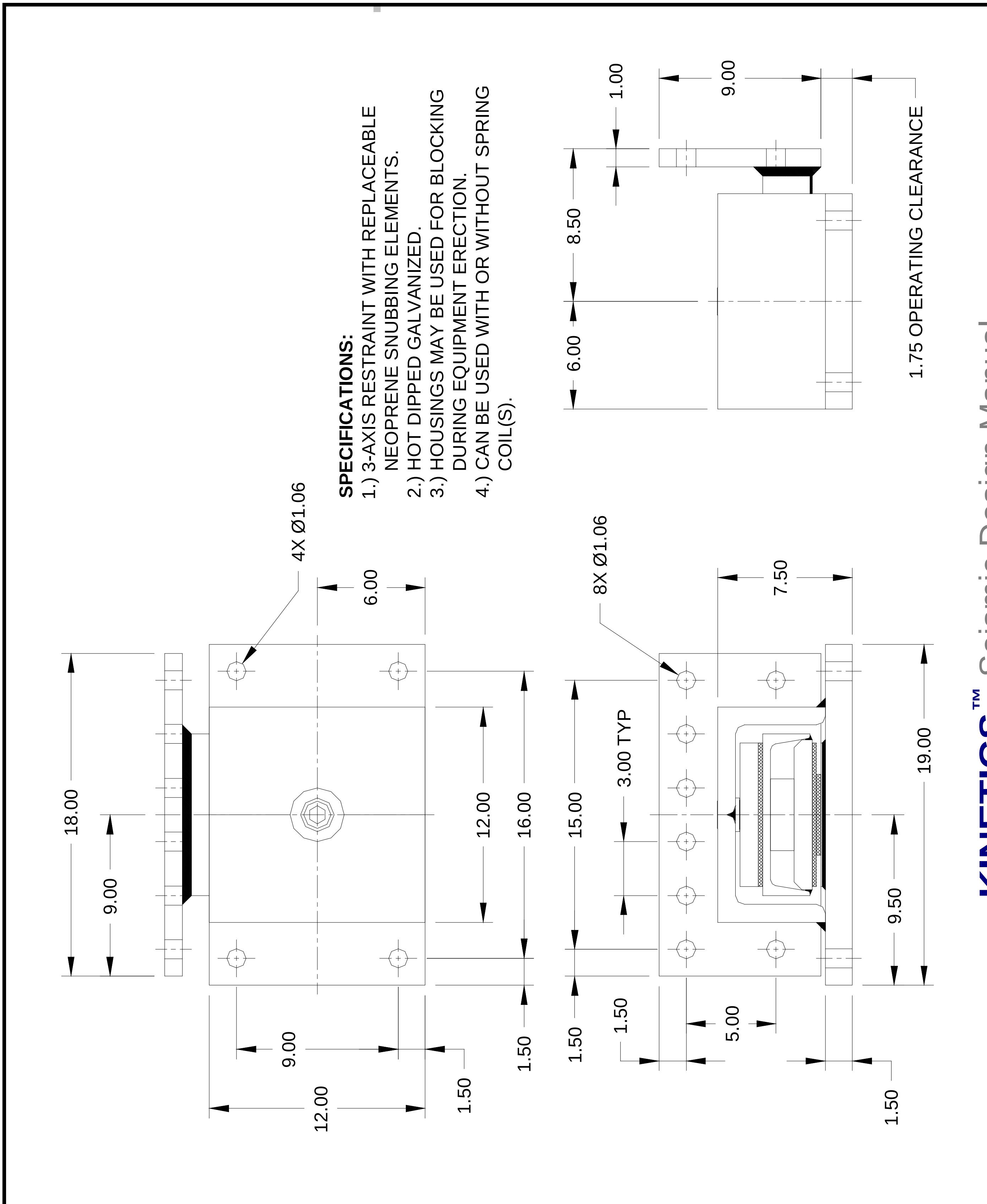

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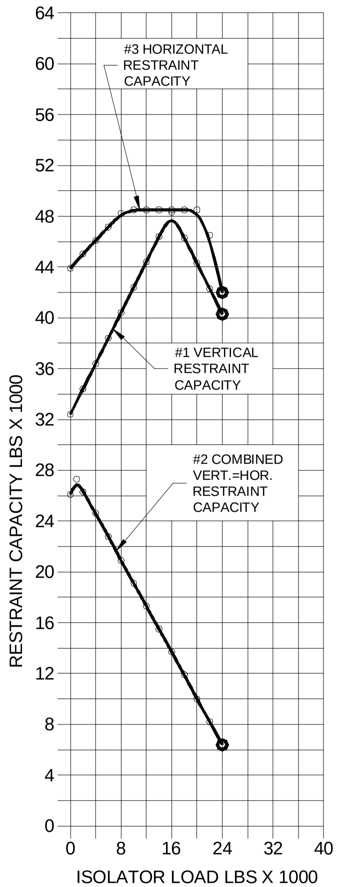

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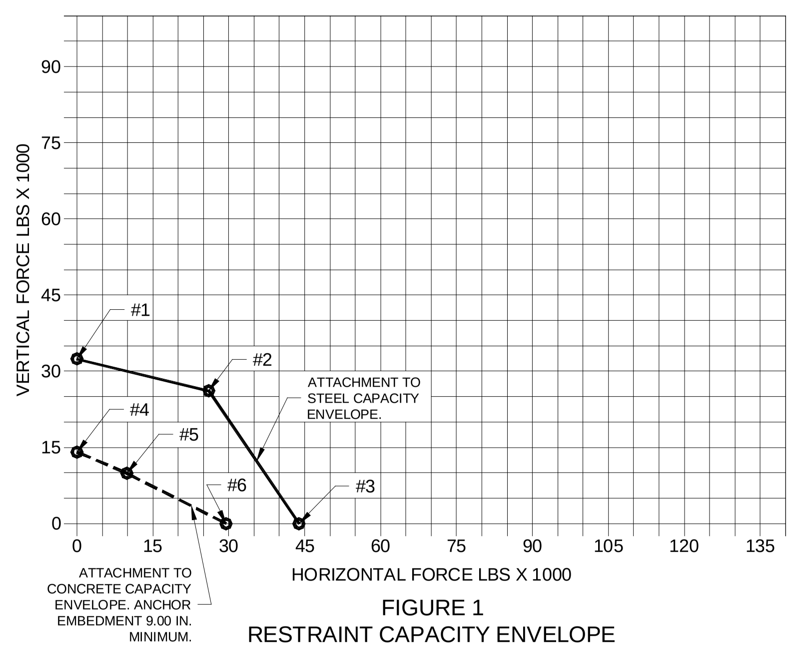

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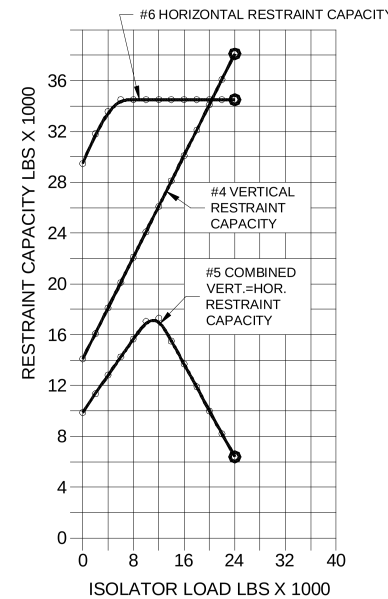

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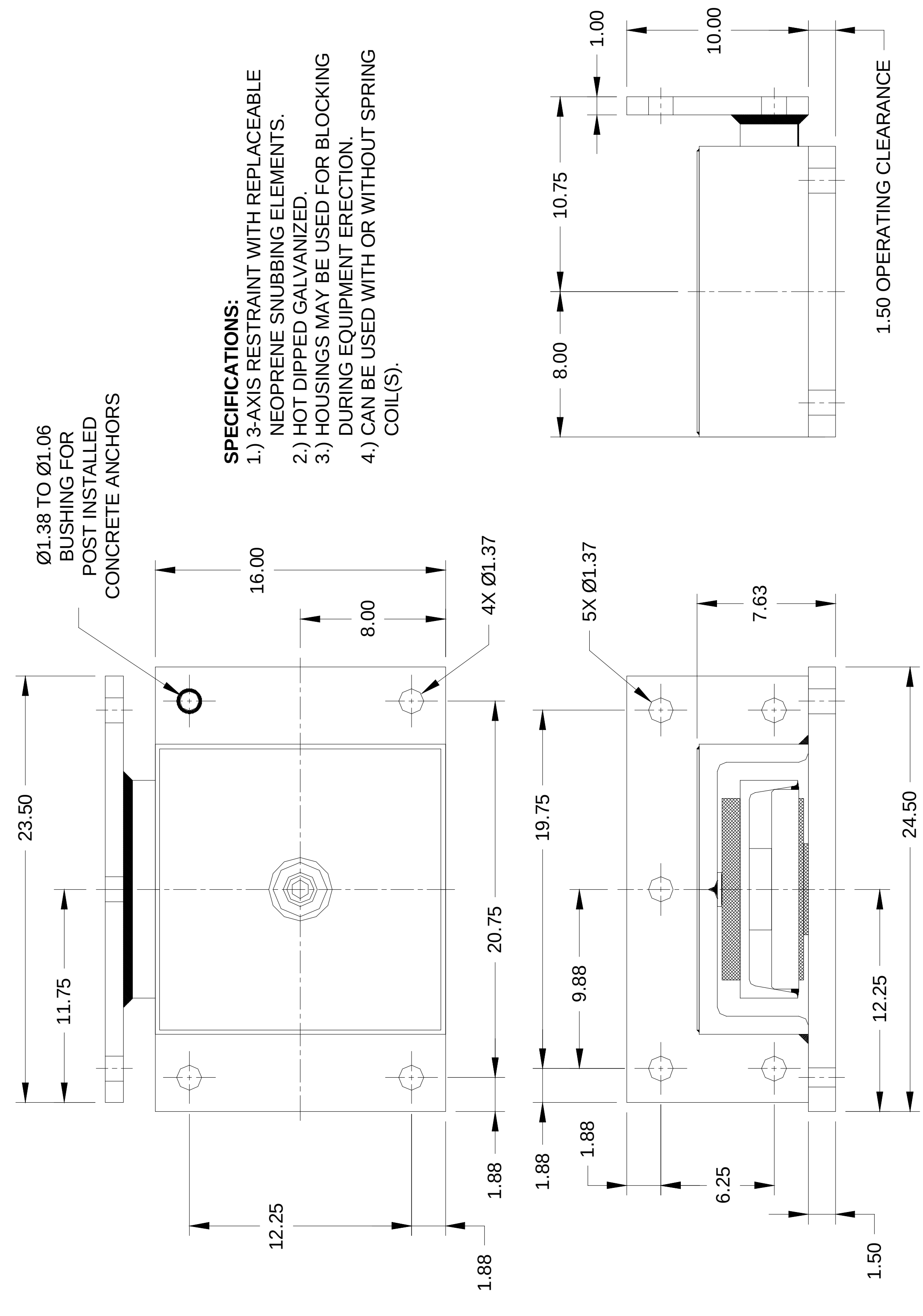

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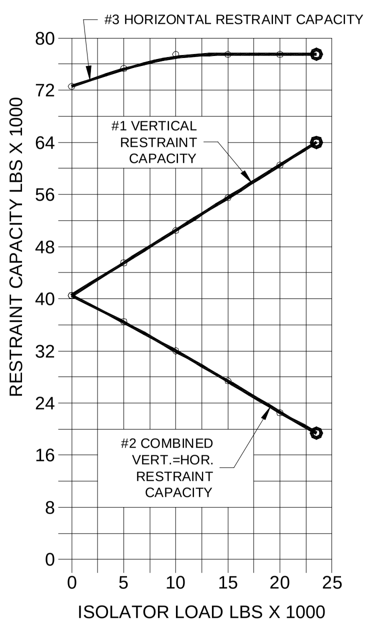

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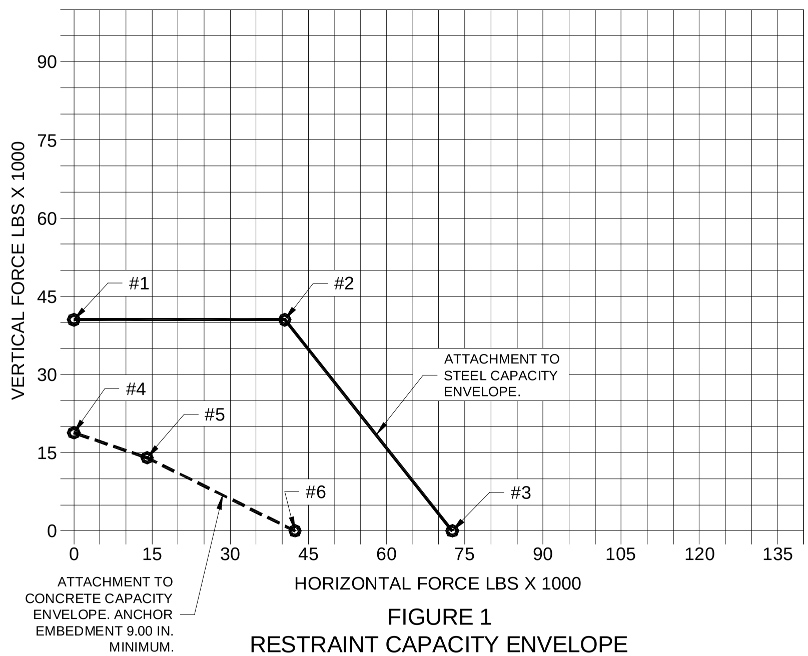

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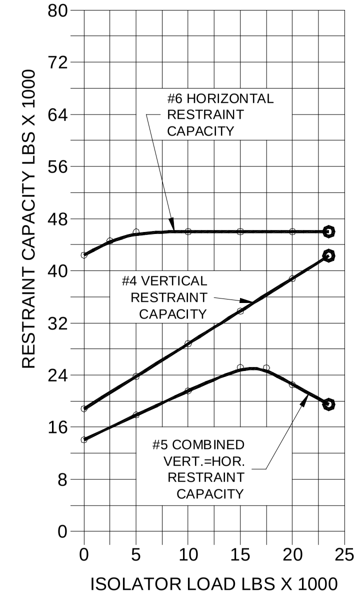

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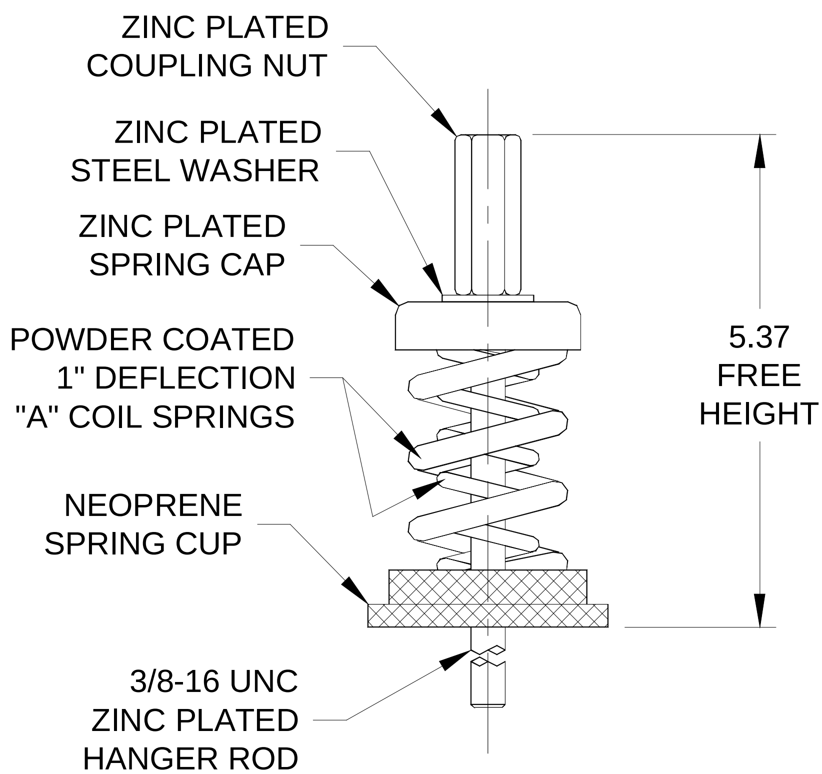
DOCUMENT:
P2.2.8

VISCMA MEMBER

1 Deflection – Single "A" Coil Set – 35 lbs to 800 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/INNER	LOAD @ 1 IN. DEFLECTION (LBS)
1-35	AA/A/B	35	1.52	23.0	Blue/-----	23
1-70	AA/A/B	70	1.36	51.5	Green/-----	51
1-120	AA/A/B	120	1.18	101.7	Gray/-----	102
1-220	AA/A/B	220	1.07	205.6	Brown/-----	206
1-370	AA/A/B	370	0.96	385.4	Orange/-----	385
1-500	AA/A/B	500	1.00	500.0	Beige/-----	500
1-600	AA/A/B	600	1.00	600.0	Chrome/-----	600
1-700	AA/A/B	700	1.00	700.0	Beige/White	700
1-805	AA/A/B	800	1.00	800.0	Chrome/White	800



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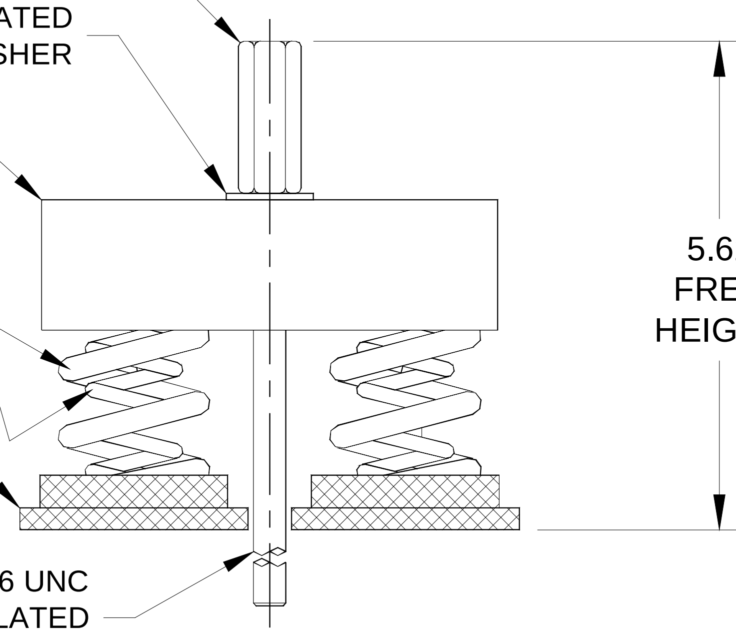
1 Deflection – Double "A" Coil Sets – 740 lbs to 1,600 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/INNER	LOAD @ 1 IN. DEFLECTION (LBS)
1-740	AA/A/B	740	0.96	770.8	Orange/-----	771
1-840	AA/A/B	840	1.07	811.2	Brown/White	811
1-1000	AA/A/B	1,000	1.00	1,000.0	Beige/-----	1,000
1-1200	AA/A/B	1,200	1.00	1,200.0	Chrome/-----	1,200
1-1400	AA/A/B	1,400	1.00	1,400.0	Beige/White	1,400
1-1600	----/A/B	1,600	1.00	1,600.0	Chrome/White	1,600



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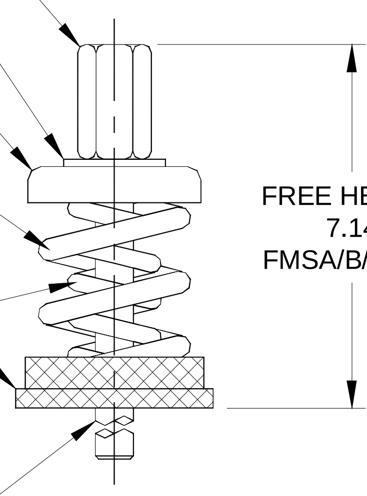
1 Deflection – Single "C" Coil Set – 250 lbs to 3,500 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/INNER	LOAD @ 1 IN. DEFLECTION (LBS)
1-250	A/B/C/D/E	250	1.79	139.7	Blue/-----	140
1-450	A/B/C/D/E	450	1.54	292.2	Green/-----	292
1-625	A/B/C/D/E	625	1.44	434.0	Black/-----	434
1-800	A/B/C/D/E	800	1.31	610.7	Gray/-----	611
1-1000	A/B/C/D/E	1,000	1.15	869.6	Red/-----	870
1-1250	A/B/C/D/E	1,250	1.09	1,146.8	Brown/-----	1,147
1-1700	A/B/C/D/E	1,700	0.95	1,789.5	Orange/-----	1,790
1-2100	A/B/C/D/E	2,080	0.95	2,189.5	Orange/Gray	2,190
1-2465	A/B/C/D/E	2,465	1.00	2,465.0	Blue/-----	2,465
1-2865	A/B/C/D/E	2,865	1.00	2,865.0	Blue/Gray	2,865
1-3500	A/B/C/D/E	3,500	1.00	3,500.0	Blue/Brown	3,500



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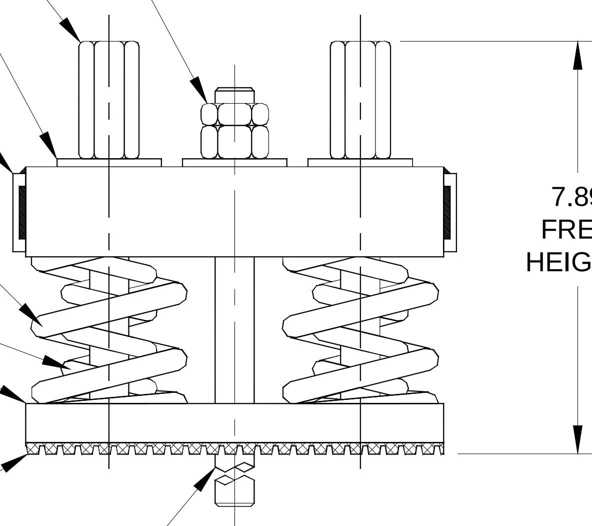
1 Deflection – Double "C" Coil Sets – 3,400 lbs to 7,000 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/INNER	LOAD @ 1 IN. DEFLECTION (LBS)
1-3400	C/D/E/F/G	3,400	0.95	3,579.0	Orange/-----	3,579
1-4200	C/D/E/F/G	4,160	0.95	4,379.0	Orange/Gray	4,379
1-4930	C/D/E/F/G	4,930	1.00	4,930.0	Blue/-----	4,930
1-5730	C/D/E/F/G	5,730	1.00	5,370.0	Blue/Gray	5,730
1-7000	--/D/E/F/G	7,000	1.00	7,000.0	Blue/Brown	7,000



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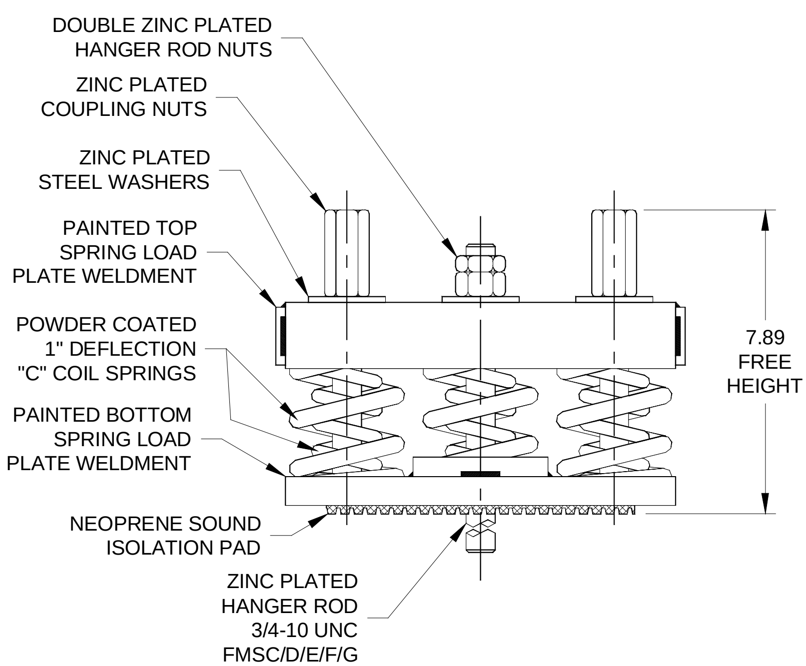
1 Deflection – Triple "C" Coil Sets – 3,750 lbs to 10,500 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/INNER	LOAD @ 1 IN. DEFLECTION (LBS)
1-3750	C/D/E/F/G	3,750	1.09	3,440.4	Brown/-----	3,440
1-5100	C/D/E/F/G	5,100	0.95	5,368.5	Orange/-----	5,369
†1-5900	C/D/E/F/G	5,860	0.95	6,168.5	Orange/Gray	6,169
‡1-6300	C/D/E/F/G	6,240	0.95	6,568.5	Orange/Gray	6,569
1-7395	--/D/E/F/G	7,395	1.00	7,395.0	Blue/-----	7,395
†1-8195	--/D/E/F/G	8,195	1.00	8,195.0	Blue/Gray	8,195
‡1-8595	--/D/E/F/G	8,595	1.00	8,595.0	Blue/Gray	8,595
†1-9500	--/D/E/F/G	9,465	1.00	9,465.0	Blue/Brown	9,465
‡1-10500	--/--/E/F/G	10,500	1.00	10,500.0	Blue/Brown	10,500

†Center coil set does not contain an inner coil.
‡Center coil set contains an inner coil and requires a special load washer.



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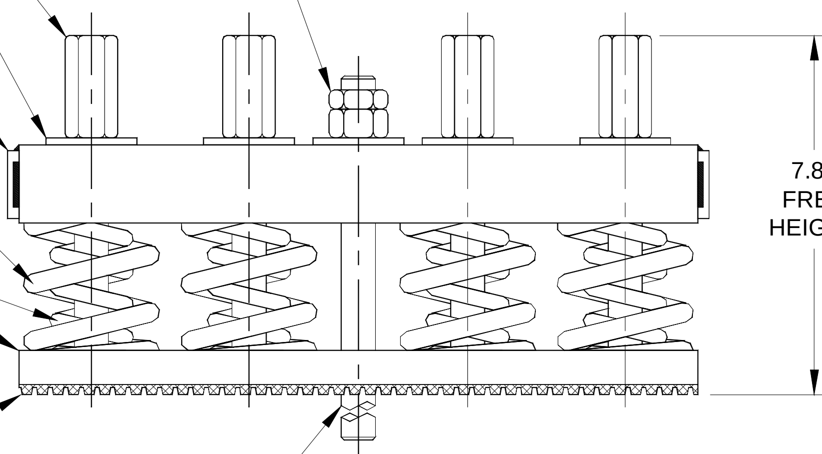
1 Deflection – Quad "C" Coil Sets – 9,860 lbs to 14,000 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/INNER	LOAD @ 1 IN. DEFLECTION (LBS)
1-9860	E/F/G	9,860	1.00	9,860.0	Blue/-----	9,860
1-11460	E/F/G	11,460	1.00	11,460.0	Blue/Gray	11,460
1-14000	E/F/G	14,000	1.00	14,000.0	Blue/Brown	14,000



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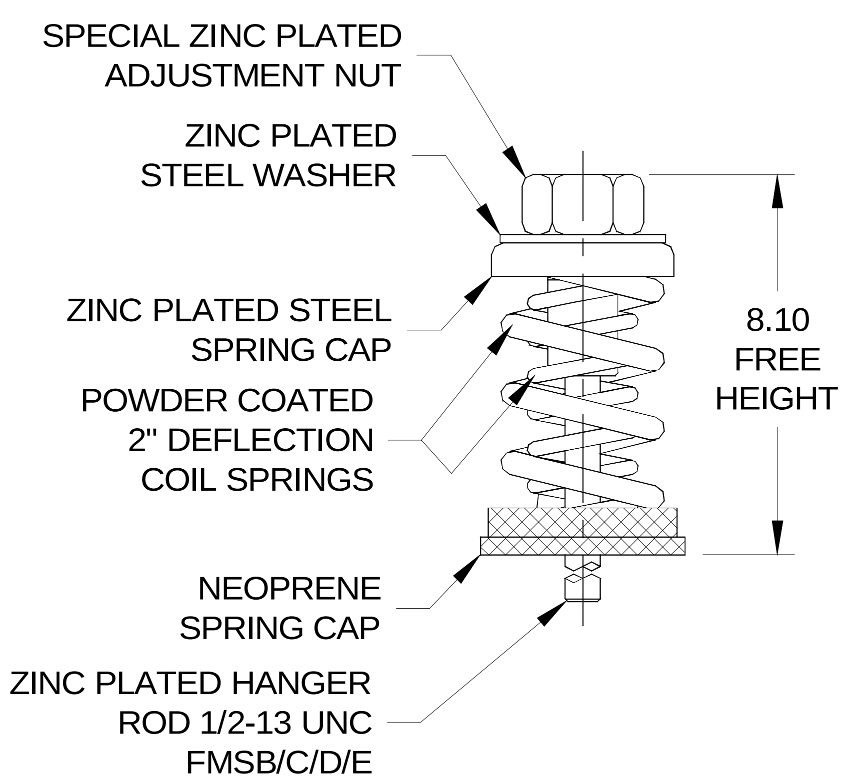
2 Deflection – Single Coil Set – 100 lbs to 2,000 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/INNER
2-100	B/C/D/E	100	2.00	50.0	Gray/-----
2-250	B/C/D/E	250	2.00	125.0	Blue/-----
2-500	B/C/D/E	500	2.00	250.0	Green/-----
2-750	B/C/D/E	750	2.00	375.0	Black/-----
2-995	B/C/D/E	995	2.00	497.5	Orange/-----
2-1395	B/C/D/E	1,395	2.00	697.5	Orange/Green
2-1600	B/C/D/E	1,600	2.00	800.0	Red/-----
2-1975	B/C/D/E	2,000	2.00	1,000.0	Red/Green



2 DEFL. – 100 to 2,000 SINGLE COIL ISOLATION SUBMITTAL DATA

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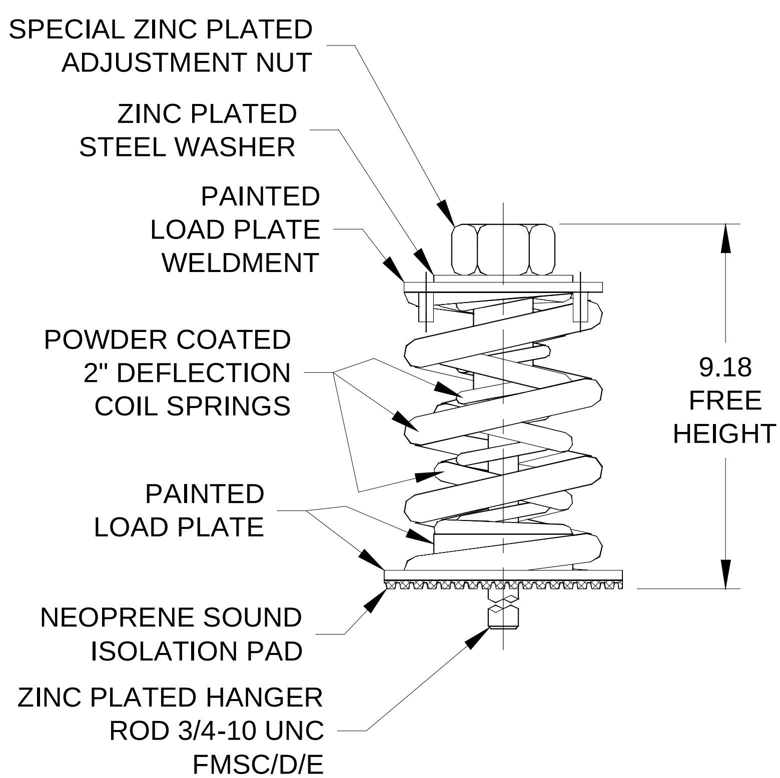
2 Deflection – Single Coil Set – 2,000 lbs to 4,500 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/MIDDLE/INNER
2-2000	C/D/E	2,000	2.00	1,000.0	Orange/-----/-----
2-2250	C/D/E	2,250	2.00	1,125.0	Orange/Blue/-----
2-2500	C/D/E	2,500	2.00	1,250.0	Blue/-----/-----
2-2750	C/D/E	2,750	2.00	1,375.0	Orange/Black/-----
2-3000	C/D/E	3,000	2.00	1,500.0	Blue/Green/-----
2-3600	C/D/E	3,600	2.00	1,800.0	Orange/Red/-----
2-4500	C/D/E	4,500	2.00	2,250.0	Blue/Red/Green



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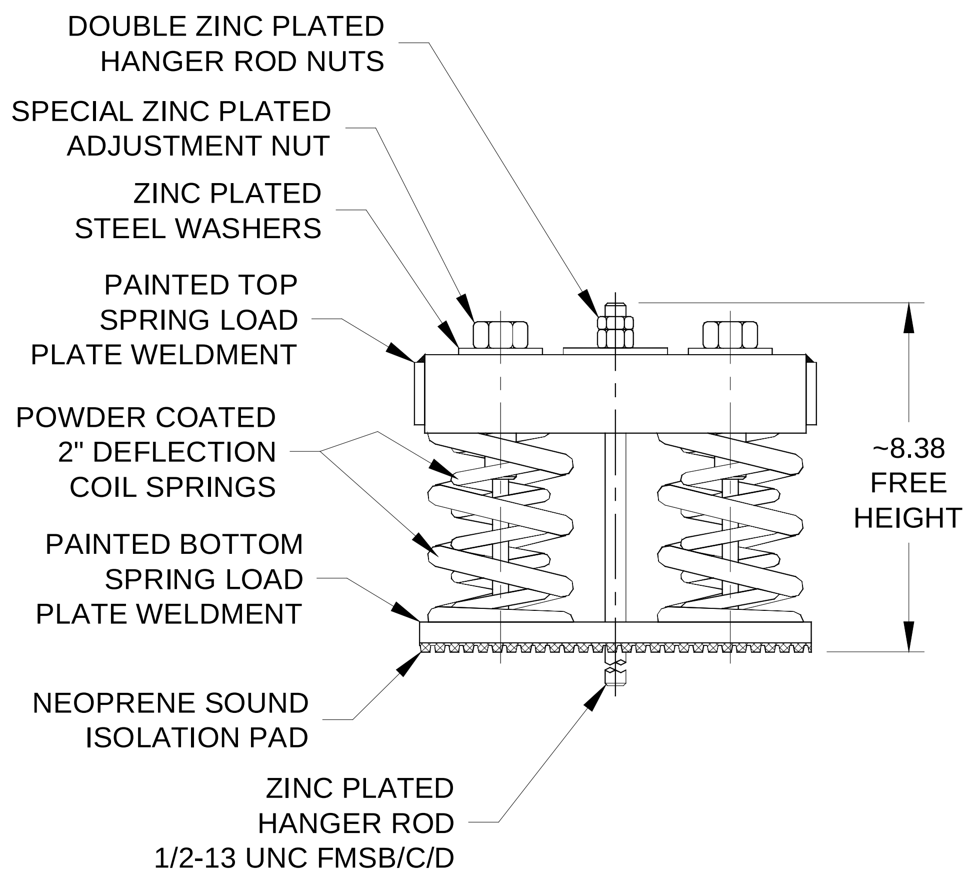
2 Deflection – Double Coil Set – 1,990 lbs to 4,000 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/INNER
2-1990	B/C/D/E	1,990	2.00	995.0	Orange/-----
2-2300	B/C/D/E	2,300	2.00	1,150.0	Black/Green
2-2790	B/C/D/E	2,790	2.00	1,395.0	Orange/Green
2-3200	B/C/D/E	3,200	2.00	1,600.0	Red/-----
2-4000	B/C/D/E	4,000	2.00	2,000.0	Red/Green



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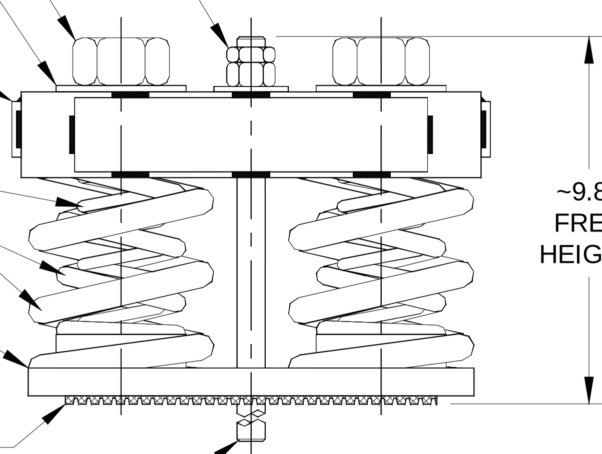
2 Deflection – Double Coil Set – 5,000 lbs to 9,000 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/MIDDLE/INNER
2-5000	C/D/E/F/G	5,000	2.00	2,500.0	Blue/-----/-----
2-5500	C/D/E/F/G	5,550	2.00	2,750.0	Orange/Black/-----
2-6000	C/D/E/F/G	6,000	2.00	3,000.0	Blue/Green/-----
2-7200	--/D/E/F/G	7,200	2.00	3,600.0	Orange/Red/-----
2-9000	--/D/E/F/G	9,000	2.00	4,500.0	Blue/Red/Green



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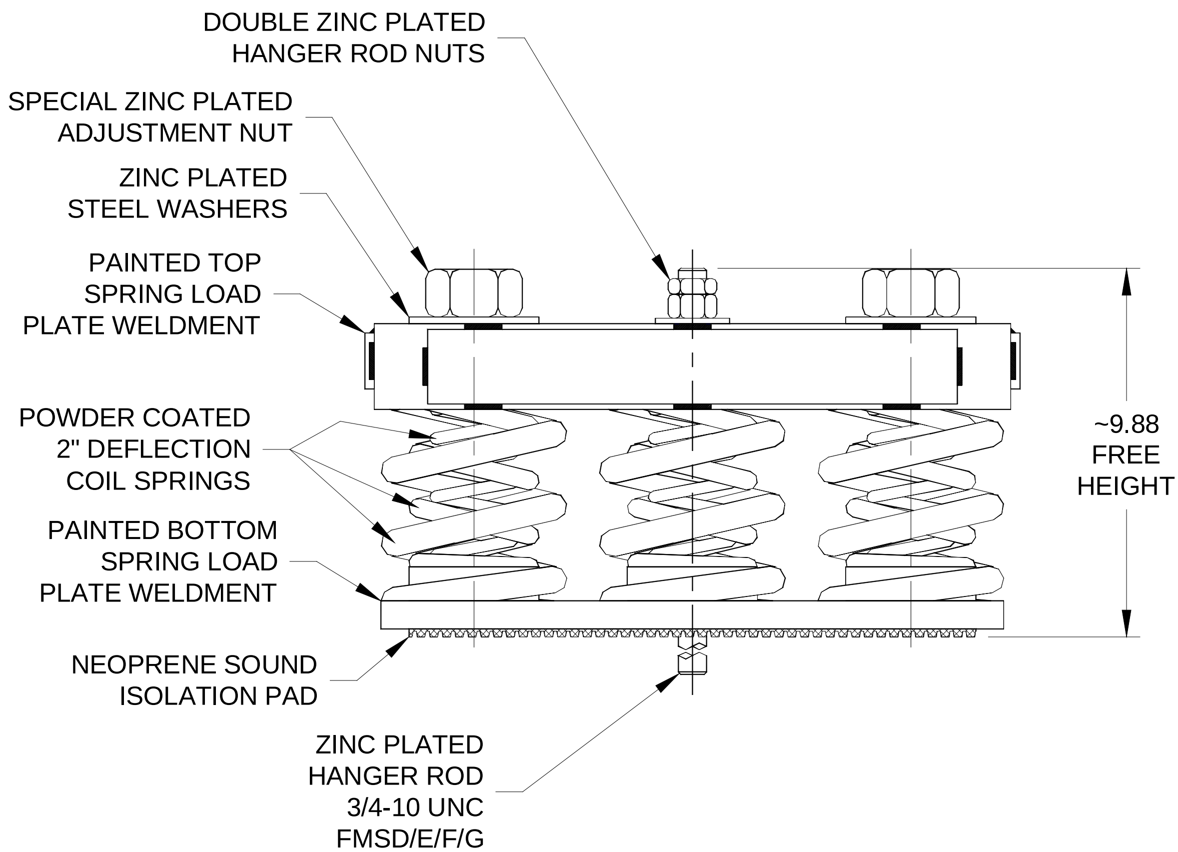
2 Deflection – Triple Coil Set – 9,100 lbs to 13,500 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/MIDDLE/INNER
2-9100	D/E/F/G	9,000	2.00	4,500.0	Blue/Green/-----
2-9750	D/E/F/G	9,750	2.00	4,875.0	Blue/Black/-----
2-10800	--/E/F/G	10,800	2.00	5,400.0	Orange/Red/-----
2-12000	--/E/F/G	12,000	2.00	6,000.0	Orange/Red/Green
2-13500	--/E/F/G	13,500	2.00	6,750.0	Blue/Red/Green



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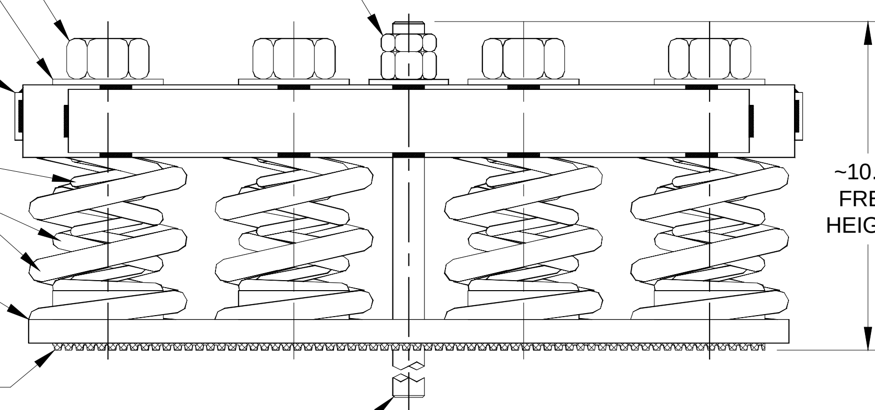
2 Deflection – QUAD Coil Set – 14,000 lbs to 18,000 lbs

ISOLATOR MODEL	USED WITH FMS MODELS	RATED LOAD (LBS)	DEFLECTION @ RATED LOAD (IN)	SPRING RATE (LBS/IN)	SPRING COLOR OUTER/MIDDLE/INNER
2-14000	E/F/G	13,980	2.00	6,990.0	Blue/Orange/-----
2-16000	E/F/G	16,000	2.00	8,000.0	Orange/Red/Green
2-18000	E/F/G	18,000	2.00	4,500.0	Blue/Red/Green



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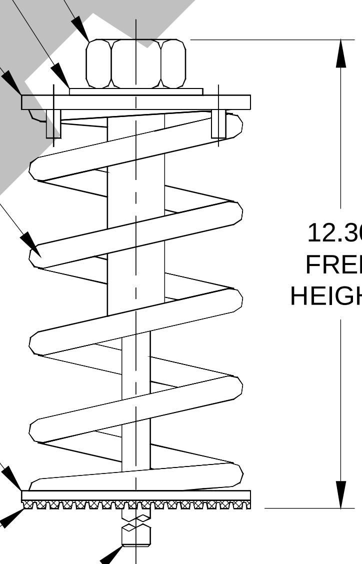
4″ Deflection – Single Coil Set – 100 lbs to 1,600 lbs

Isolator Model	Used With FMS Models	Rated Load (lbs)	Deflection @ Rated Load (in)	Spring Rate (lbs/in)	Spring Color
4-100	C/D/E	100	4.00	25.0	Gray
4-250	C/D/E	250	4.00	62.5	Blue
4-500	C/D/E	500	4.00	125.0	Green
4-750	C/D/E	750	4.00	187.5	Black
4-1000	C/D/E	1,000	4.00	250.0	Red
4-1250	C/D/E	1,250	4.00	312.5	Brown
4-1600	C/D/E	1,600	4.00	400.0	Orange



4″ DEFL. – 100 to 1,600 SINGLE COIL ISOLATION SUBMITTAL DATA

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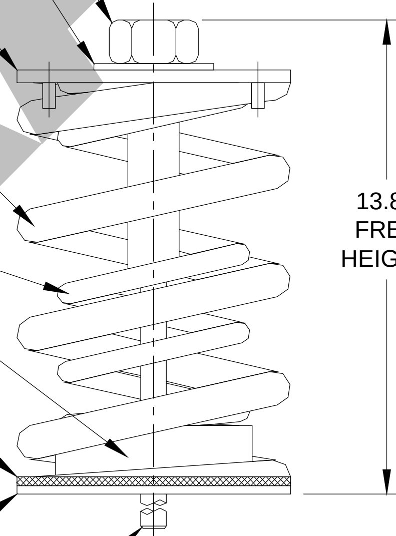
4″ Deflection – Single Coil Set – 2,250 lbs to 5,800 lbs

Isolator Model	Used With FMS Models	Rated Load (lbs)	Deflection @ Rated Load (in)	Spring Rate (lbs/in)	Spring Color Outer/Inner
4-2250	E/F/G	2,250	4.00	562.5	Beige/-----
4-2750	E/F/G	2,750	4.00	687.5	Beige/Green
4-3250	E/F/G	3,250	4.00	812.5	Beige/Red
4-3900	E/F/G	3,850	4.00	962.5	Beige/Orange
4-4200	E/F/G	4,200	4.00	1,050.0	Chrome/-----
4-4700	E/F/G	4,700	4.00	1,175.0	Chrome/Green
4-5200	E/F/G	5,200	4.00	1,300.0	Chrome/Red
4-5800	E/F/G	5,800	4.00	1,450.0	Chrome/Orange



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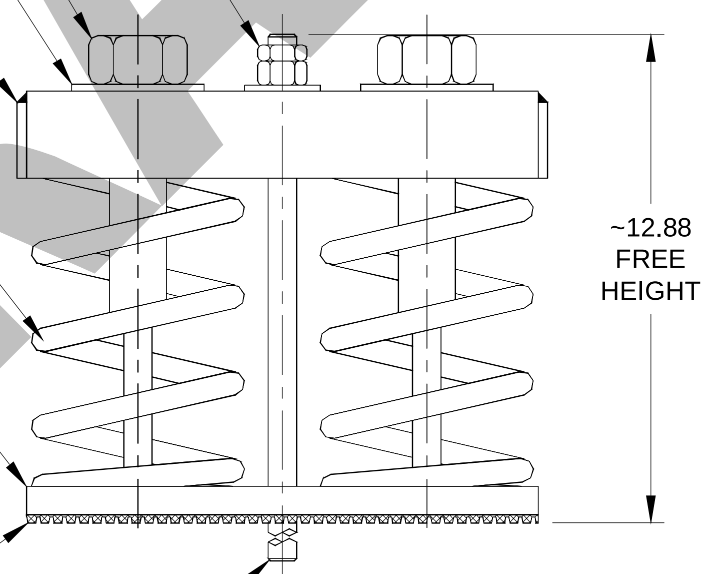
4″ Deflection – Double Coil Set – 1,500 lbs to 3,200 lbs

Isolator Model	Used With FMS Models	Rated Load (lbs)	Deflection @ Rated Load (in)	Spring Rate (lbs/in)	Spring Color
4-1500	C/D/E	1,500	4.00	375.0	Black
4-2000	C/D/E	2,000	4.00	500.0	Red
4-2500	C/D/E	2,500	4.00	625.0	Brown
4-3200	C/D/E	3,200	4.00	800.0	Orange



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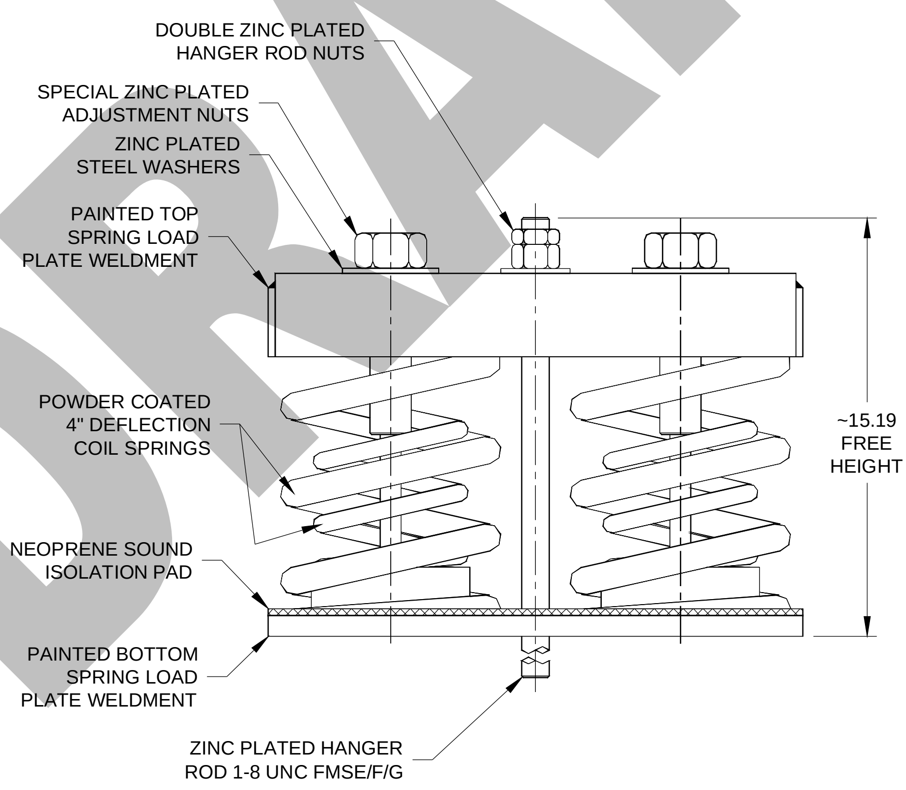
4″ Deflection – Double Coil Set – 5,500 lbs to 11,600 lbs

Isolator Model	Used With FMS Models	Rated Load (lbs)	Deflection @ Rated Load (in)	Spring Rate (lbs/in)	Spring Color Outer/Inner
4-5500	E/F/G	5,500	4.00	1,375.0	Beige/Green
4-6500	E/F/G	6,500	4.00	1,625.0	Beige/Red
4-7700	E/F/G	7,700	4.00	1,925.0	Beige/Orange
4-8400	E/F/G	8,400	4.00	2,100.0	Chrome/-----
4-9400	E/F/G	9,400	4.00	2,350.0	Chrome/Green
4-10400	E/F/G	10,400	4.00	2,600.0	Chrome/Red
4-11600	E/F/G	11,600	4.00	2,900.0	Chrome/Orange



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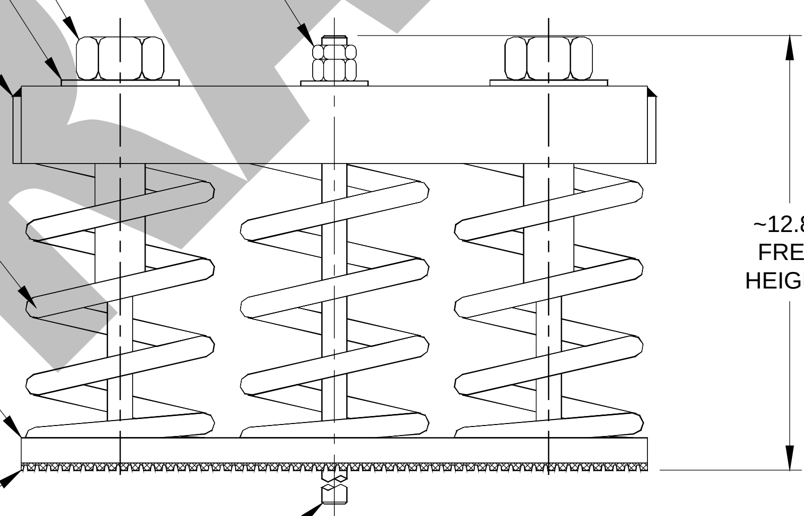
4″ Deflection – Triple Coil Set – 3,000 lbs to 4,800 lbs

Isolator Model	Used With FMS Models	Rated Load (lbs)	Deflection @ Rated Load (in)	Spring Rate (lbs/in)	Spring Color
4-3000	C/D/E/F/G	3,000	4.00	750.0	Red
4-3750	C/D/E/F/G	3,750	4.00	937.5	Brown
4-4800	C/D/E/F/G	4,800	4.00	1,200.0	Orange



4″ DEFL. – 3,000 to 4,800 TRIPLE COIL ISOLATION SUBMITTAL DATA

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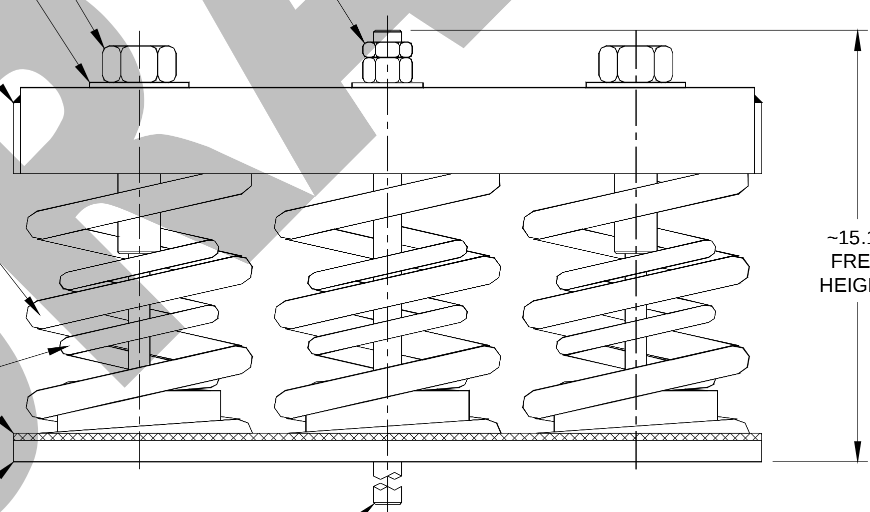
4″ Deflection – Triple Coil Set – 11,700 lbs to 17,400 lbs

Isolator Model	Used With FMS Models	Rated Load (lbs)	Deflection @ Rated Load (in)	Spring Rate (lbs/in)	Spring Color Outer/Inner
4-11700	E/F/G	11,550	4.00	2,887.5	Beige/Orange
4-14100	E/F/G	14,100	4.00	3,525.0	Chrome/Green
4-17400	E/F/G	17,400	4.00	5,350.0	Chrome/Orange



4″ DEFL. – 11,700 to 17,400 TRIPLE COIL ISOLATION SUBMITTAL DATA

RELEASE DATE: 5/13/04

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DOCUMENT:
P2.3.4

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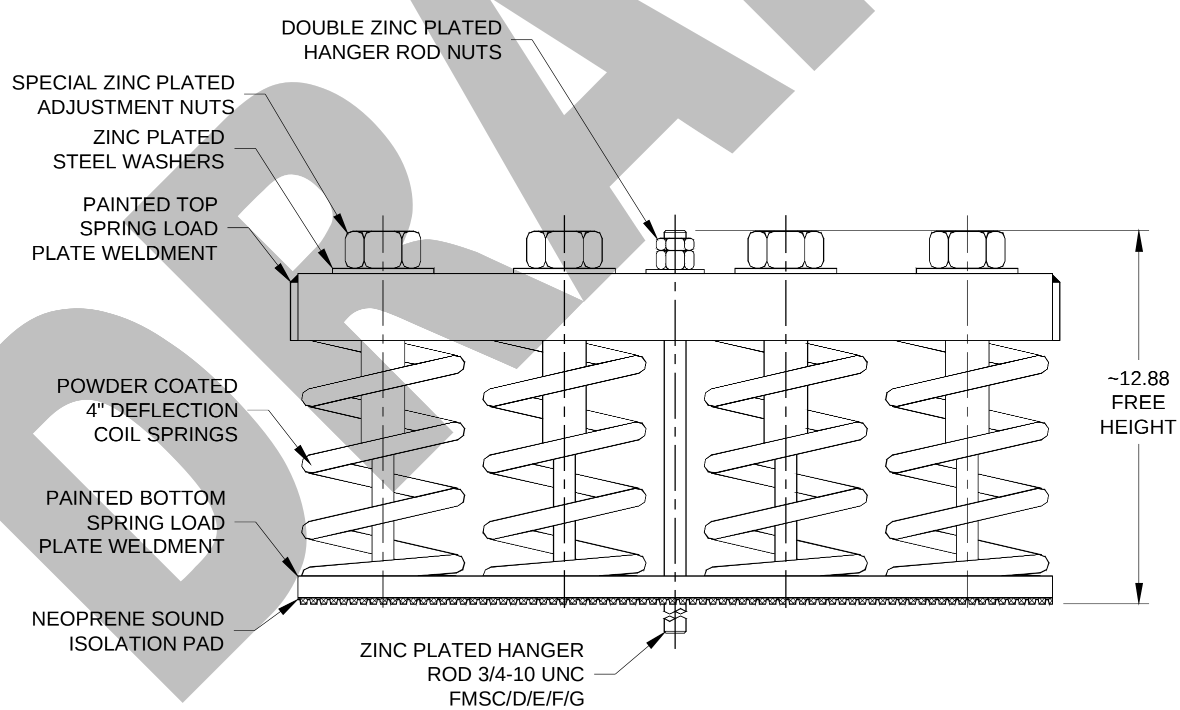
4″ Deflection – Quad Coil Set – 5,000 lbs to 6,400 lbs

Isolator Model	Used With FMS Models	Rated Load (lbs)	Deflection @ Rated Load (in)	Spring Rate (lbs/in)	Spring Color
4-5000	C/D/E/F/G	5,000	4.00	1,250.0	Brown
4-6400	--/D/E/F/G	6,400	4.00	1,600.0	Orange



4″ DEFL. – 5,000 to 6,400 QUAD COIL ISOLATION SUBMITTAL DATA

RELEASE DATE: 5/13/04

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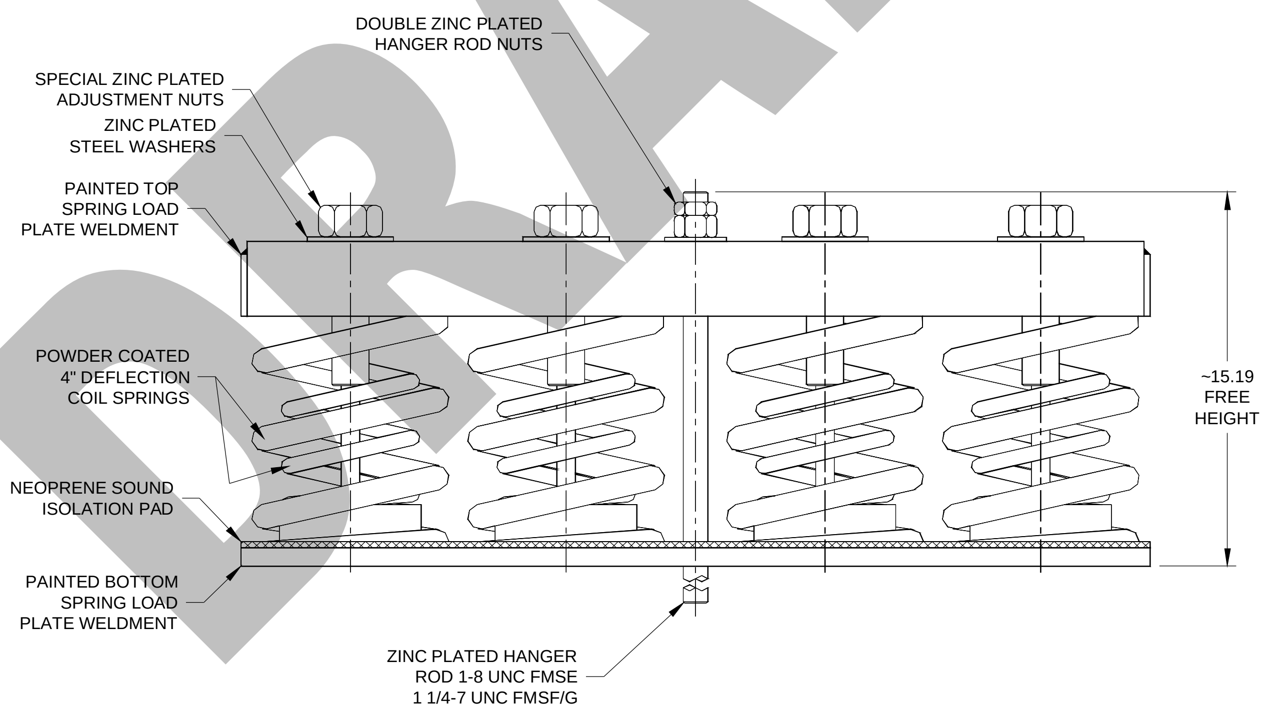
4″ Deflection – Quad Coil Set – 17,800 lbs to 23,200 lbs

Isolator Model	Used With FMS Models	Rated Load (lbs)	Deflection @ Rated Load (in)	Spring Rate (lbs/in)	Spring Color Outer/Inner
4-17800	E/F/G	17,800	4.00	4,450.0	Chrome/Blue
4-20800	E/F/G	20,800	4.00	5,200.0	Chrome/Red
4-23200	--/F/G	23,200	4.00	5,800.0	Chrome/Orange



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FMS Isolator/Restraint Selection Information

The purpose of this section is to provide enough data to allow the reader to make a preliminary FMS Isolator/Restraint selection for your application. The final selection should be made with the help of Kinetics Noise Control Engineering. Since the FMS is a seismic device, a detailed analysis must be performed to ensure that the proper restraint and/or isolator model has been chosen for your application based on your building code, specification, geographical location, and geotechnical data.

Table P2.4-1 lists the various FMS models, and some of the basic application data.

Table P2.4-1; General Comparison of FMS Isolator/Restraint Models

FMS RESTRAINT MODEL	SUBMITTAL DRAWING NUMBER	MAXIMUM [1]COMBINED RESTRAINT CAPACITY ([2]STEEL) (LB)	MAXIMUM [1]COMBINED RESTRAINT CAPACITY ([3]CONCRETE) (LB)	MAXIMUM ISOLATION RATING (LB)	APPROXIMATE RESTRAINT WEIGHT (LB)
FMSAA	S-10-40.100	615	410	805	9.0
FMSA	S-10-40.800	1,520	905	2,500	11.6
FMSB	S-10-40.200	3,175	1,040	3,000	18.4
FMSC	S-10-40.300	5,900	2,160	6,500	49.3
FMSD	S-10-40.400	9,565	3,045	10,000	86.7
FMSE	S-10-40.500	14,470	4,840	21,000	189.7
FMSF	S-10-40.600	26,100	9,875	24,000	268.0
FMSG	S-10-40.700	40,500	23,500	24,000	437.0

[1] Maximum restraint values for a load having equal horizontal and vertical components without isolation.

[2] Bolted or welded to structural steel.

[3] Anchored to 3,000 psi minimum compressive strength steel reinforced concrete using post installed wedge type anchors.

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Figure P2.4-1 shows the restraint capacity envelopes for the entire FMS family if the restraint is attached to structural steel. These curves are for non-isolated restraints. The FMS family is unique in that isolation will change the restraint capacities of the unit, and quite often for the better. However, these curves will allow the reader to select one or two FMS models that may fit their application. Figure P2.4-2 presents the restraint capacity envelopes for the entire FMS family if the restraint is to be attached to 3,000 psi minimum compressive strength steel reinforced concrete. Again, these curves are for non-isolated restraints. The restraint capacities are affected, normally in a positive manner, by the addition of isolation to the system.

Tables P2.4-2 through P2.4-9 give the restraint capacities for the FMS family with various isolation loads applied to the restraints. These values will allow the reader to make a reasonable estimate as to whether a given isolator/restraint combination will work for the application under consideration. When a tentative selection has been made a plot of the appropriate capacity envelope should be constructed for the isolator/restraint combination being used, see the appropriate submittal sheets for the selected FMS, and the actual load points plotted on the capacity envelope chart. If the actual load points fall inside the capacity envelope, the selected FMS is adequate. If they do not fall inside the capacity envelope, select the next largest FMS.

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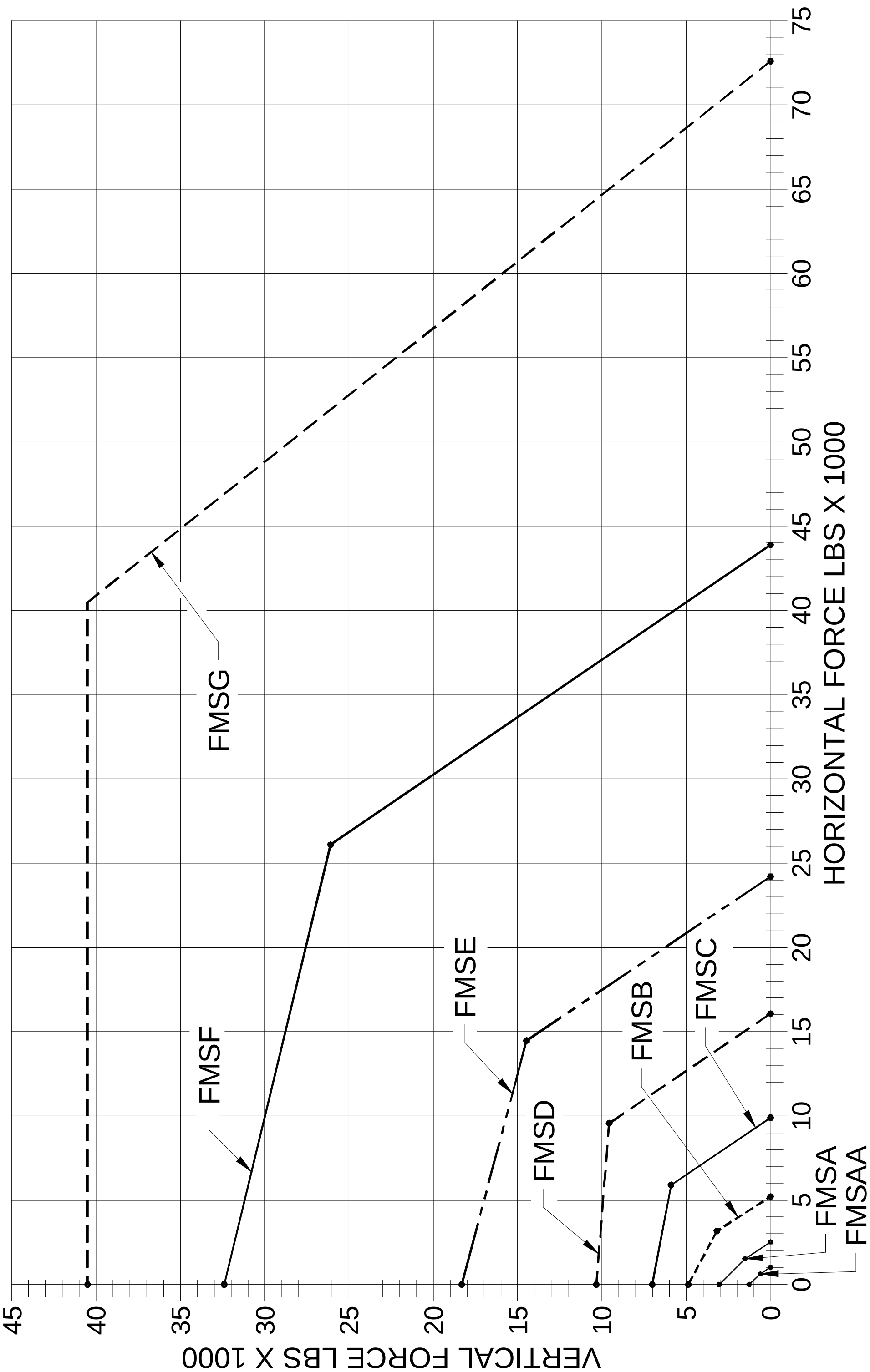

Figure P2.4-2; FMS Restraint Capacity Envelopes for Steel Attachment.

FMS ISOLATOR/RESTRAINT SELECTION INFORMATION

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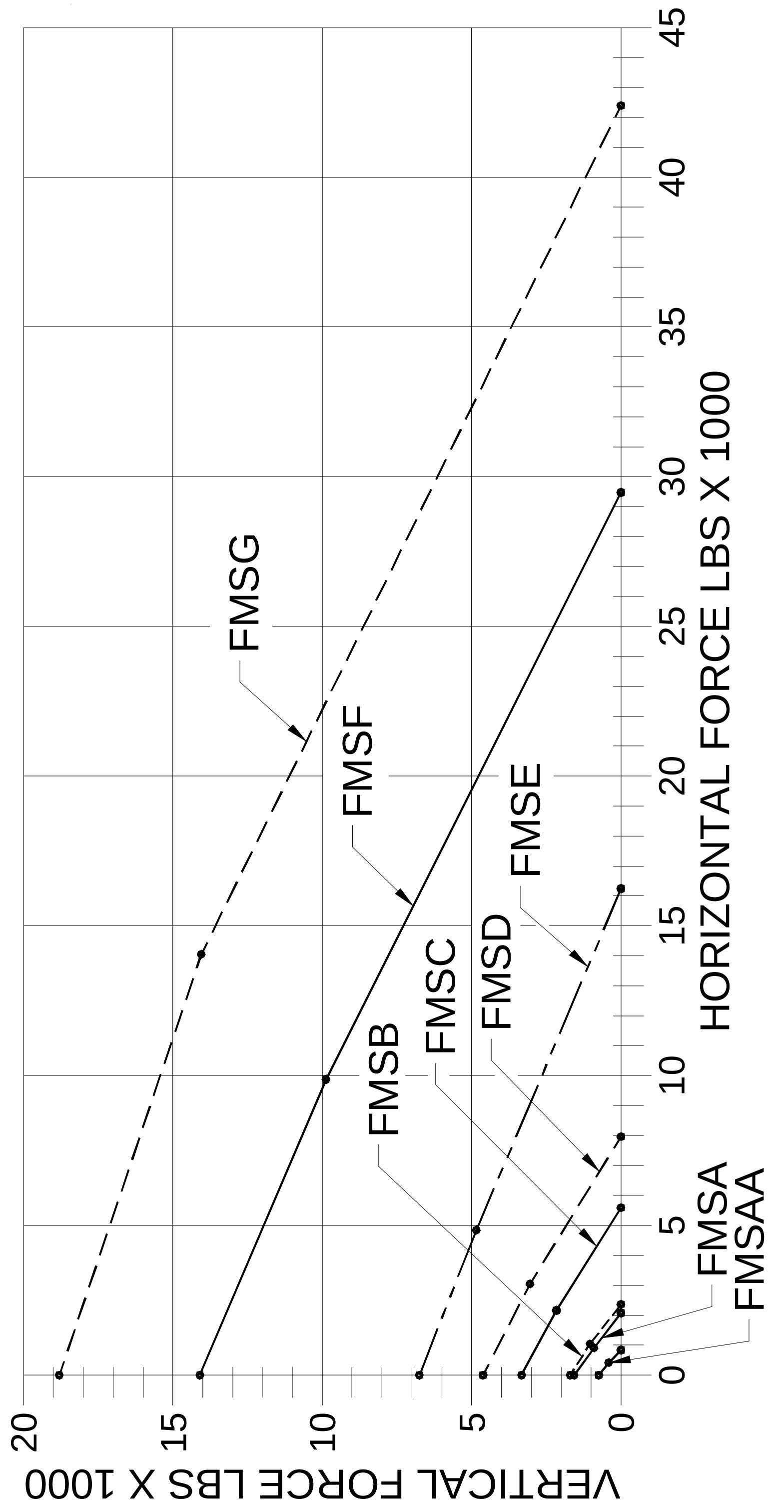

Figure P2.4-1; FMS Restraint Capacity Envelopes for Concrete Attachment.

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Table P2.4-2; FMSAA Restraint Capacities at Various Isolator Loads.

ISOLATOR LOAD (LB)	HORIZ. CAPACITY ([2]STEEL) (LB)	VERT. CAPACITY ([2]STEEL) (LB)	[1]COMB. CAPACITY ([2]STEEL) (LB)	HORIZ. CAPACITY ([3]CONCRETE) (LB)	VERT. CAPACITY ([3]CONCRETE) (LB)	[1]COMB. CAPACITY ([3]CONCRETE) (LB)
0	1,015	1,275	615	835	745	410
100	1,070	1,375	655	910	845	465
200	1,120	1,285	700	975	945	520
300	1,170	1,185	740	1,030	1,045	570
400	1,220	1,085	780	1,060	1,085	625
500	1,265	985	820	1,065	985	675
600	1,275	885	850	1,065	885	725
700	1,275	885	755	1,065	785	755
805	1,275	685	660	1,065	685	660

[1] Maximum restraint values for a load having equal horizontal and vertical components without isolation.

[2] Bolted or welded to structural steel.

[3] Anchored to 3,000 psi minimum compressive strength steel reinforced concrete using post installed wedge type anchors.

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Table P2.4-3; FMSA Restraint Capacities at Various Isolator Loads.

ISOLATOR LOAD (LB)	HORIZ. CAPACITY ([2]STEEL) (LB)	VERT. CAPACITY ([2]STEEL) (LB)	[1]COMB. CAPACITY ([2]STEEL) (LB)	HORIZ. CAPACITY ([3]CONCRETE) (LB)	VERT. CAPACITY ([3]CONCRETE) (LB)	[1]COMB. CAPACITY ([3]CONCRETE) (LB)
0	2,520	3,050	1,520	2,075	1,570	905
250	2,655	3,300	1,630	2,310	1,820	1,055
500	2,790	3,255	1,740	2,505	2,070	1,205
750	2,915	3,005	1,845	2,655	2,320	1,355
1,000	3,040	2,755	1,950	2,720	2,570	1,495
1,250	3,115	2,505	2,050	2,720	2,505	1,635
1,500	3,115	2,255	2,130	2,720	2,255	1,775
1,750	3,115	2,005	1,900	2,720	2,005	1,905
2,000	3,115	1,755	1,665	2,720	1,755	1,665
2,250	3,115	1,505	1,425	2,720	1,505	1,425
2,500	3,115	1,255	1,190	2,720	1,255	1,190
3,000	3,115	755	740	2,720	755	715
3,500	3,035	255	240	2,720	255	240

[1] Maximum restraint values for a load having equal horizontal and vertical components without isolation.

[2] Bolted or welded to structural steel.

[3] Anchored to 3,000 psi minimum compressive strength steel reinforced concrete using post installed wedge type anchors.

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Table P2.4-4; FMSB Restraint Capacities at Various Isolator Loads.

ISOLATOR LOAD (LB)	HORIZ. CAPACITY ([2]STEEL) (LB)	VERT. CAPACITY ([2]STEEL) (LB)	[1]COMB. CAPACITY ([2]STEEL) (LB)	HORIZ. CAPACITY ([3]CONCRETE) (LB)	VERT. CAPACITY ([3]CONCRETE) (LB)	[1]COMB. CAPACITY ([3]CONCRETE) (LB)
0	5,210	4,880	3,175	2,355	1,700	1,040
250	5,345	5,130	3,285	2,575	1,950	1,195
500	5,475	5,380	3,395	2,755	2,200	1,345
750	5,605	5,630	3,500	2,890	2,450	1,490
1,000	5,730	5,880	3,605	2,945	2,700	1,635
1,250	5,850	5,715	3,710	2,945	2,950	1,775
1,500	5,970	5,465	3,815	2,945	3,200	1,915
1,750	6,090	5,215	3,915	2,945	3,450	2,045
2,000	6,210	4,965	4,015	2,945	3,700	2,175
2,250	6,230	4,715	4,070	2,945	3,950	2,300
2,500	6,230	4,465	3,855	2,945	4,200	2,425
3,000	6,230	3,965	3,425	2,945	3,965	2,650
3,500	6,230	3,465	2,995	2,945	3,450	2,845
4,000	6,230	2,965	2,560	2,945	2,950	2,560

[1] Maximum restraint values for a load having equal horizontal and vertical components without isolation.

[2] Bolted or welded to structural steel.

[3] Anchored to 3,000 psi minimum compressive strength steel reinforced concrete using post installed wedge type anchors.

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Table P2.4-5; FMSC Restraint Capacities at Various Isolator Loads.

ISOLATOR LOAD (LB)	HORIZ. CAPACITY ([2]STEEL) (LB)	VERT. CAPACITY ([2]STEEL) (LB)	[1]COMB. CAPACITY ([2]STEEL) (LB)	HORIZ. CAPACITY ([3]CONCRETE) (LB)	VERT. CAPACITY ([3]CONCRETE) (LB)	[1]COMB. CAPACITY ([3]CONCRETE) (LB)
0	9,900	7,010	5,900	5,585	3,330	2,160
1,000	10,460	8,010	6,390	6,515	4,330	2,830
2,000	10,980	9,010	6,825	6,825	5,330	3,480
3,000	11,400	10,000	7,250	6,825	6,330	4,100
4,000	11,400	11,010	7,665	6,825	7,330	4,700
5,000	11,400	11,175	8,070	6,825	8,330	5,265
6,000	11,400	10,175	8,460	6,825	9,330	5,800
6,500	11,400	9,660	8,655	6,825	9,815	6,050

[1] Maximum restraint values for a load having equal horizontal and vertical components without isolation.

[2] Bolted or welded to structural steel.

[3] Anchored to 3,000 psi minimum compressive strength steel reinforced concrete using post installed wedge type anchors.

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Table P2.4-6; FMSD Restraint Capacities at Various Isolator Loads.

ISOLATOR LOAD (LB)	HORIZ. CAPACITY ([2]STEEL) (LB)	VERT. CAPACITY ([2]STEEL) (LB)	[1]COMB. CAPACITY ([2]STEEL) (LB)	HORIZ. CAPACITY ([3]CONCRETE) (LB)	VERT. CAPACITY ([3]CONCRETE) (LB)	[1]COMB. CAPACITY ([3]CONCRETE) (LB)
0	16,075	10,330	9,565	7,960	4,620	3,045
1,000	16,625	11,330	10,025	8,885	5,620	3,715
2,000	17,160	12,330	10,475	9,370	6,620	4,395
3,000	17,685	13,330	10,915	9,370	7,620	5,030
4,000	18,170	14,330	11,350	9,370	8,620	5,660
5,000	18,170	15,330	11,750	9,370	9,620	6,275
6,000	18,170	16,210	12,195	9,370	10,620	6,875
7,000	18,170	15,210	12,605	9,370	11,620	7,445
8,000	18,170	14,210	13,010	9,370	12,620	7,980
9,000	18,170	13,210	12,310	9,370	13,210	8,480
10,000	18,170	12,210	11,375	9,370	12,210	8,910

[1] Maximum restraint values for a load having equal horizontal and vertical components without isolation.

[2] Bolted or welded to structural steel.

[3] Anchored to 3,000 psi minimum compressive strength steel reinforced concrete using post installed wedge type anchors.

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Table P2.4-7; FMSE Restraint Capacities at Various Isolator Loads.

ISOLATOR LOAD (LB)	HORIZ. CAPACITY ([2]STEEL) (LB)	VERT. CAPACITY ([2]STEEL) (LB)	[1]COMB. CAPACITY ([2]STEEL) (LB)	HORIZ. CAPACITY ([3]CONCRETE) (LB)	VERT. CAPACITY ([3]CONCRETE) (LB)	[1]COMB. CAPACITY ([3]CONCRETE) (LB)
0	24,205	18,315	14,470	16,245	6,750	4,840
2,000	25,285	20,315	15,380	19,075	8,750	6,335
4,000	26,325	22,315	16,270	20,390	10,750	7,840
6,000	26,850	24,315	17,135	20,390	12,750	9,295
8,000	26,850	26,315	17,980	20,390	14,750	10,720
10,000	26,850	26,465	18,805	20,390	16,750	12,115
12,000	26,850	24,465	19,615	20,390	18,750	13,480
14,000	26,850	22,465	20,405	20,390	20,750	14,805
16,000	26,850	20,465	19,145	20,390	20,470	16,090
18,000	26,850	18,465	17,275	20,390	18,465	17,275
21,000	26,850	15,465	14,470	20,390	15,465	14,470

[1] Maximum restraint values for a load having equal horizontal and vertical components without isolation.

[2] Bolted or welded to structural steel.

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Table P2.4-8; FMSF Restraint Capacities at Various Isolator Loads.

ISOLATOR LOAD (LB)	HORIZ. CAPACITY (²STEEL) (LB)	VERT. CAPACITY (²STEEL) (LB)	¹COMB. CAPACITY (²STEEL) (LB)	HORIZ. CAPACITY (³CONCRETE) (LB)	VERT. CAPACITY (³CONCRETE) (LB)	¹COMB. CAPACITY (³CONCRETE) (LB)
0	43,900	32,400	26,100	29,475	14,100	9,875
2,000	45,025	34,400	26,300	31,825	16,100	11,350
4,000	46,100	36,400	24,600	33,575	18,100	12,810
6,000	47,150	38,400	22,800	34,500	20,100	14,245
8,000	48,200	40,400	20,900	34,500	22,100	15,660
10,000	48,200	42,400	19,100	34,500	24,100	17,060
12,000	48,200	44,400	17,300	34,500	26,100	17,300
14,000	48,200	46,400	15,500	34,500	28,100	15,500
16,000	48,200	48,300	13,700	34,500	30,100	13,700
18,000	48,200	46,300	11,900	34,500	32,100	11,900
20,000	48,200	44,300	10,000	34,500	34,100	10,000
22,000	48,200	42,300	8,200	34,500	36,100	8,200
24,000	48,200	40,300	6,400	34,500	38,100	6,400

[1] Maximum restraint values for a load having equal horizontal and vertical components without isolation.

[2] Bolted or welded to structural steel.

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Table P2.4-9; FMSG Restraint Capacities at Various Isolator Loads.

ISOLATOR LOAD (LB)	HORIZ. CAPACITY ([2]STEEL) (LB)	VERT. CAPACITY ([2]STEEL) (LB)	[1]COMB. CAPACITY ([2]STEEL) (LB)	HORIZ. CAPACITY ([3]CONCRETE) (LB)	VERT. CAPACITY ([3]CONCRETE) (LB)	[1]COMB. CAPACITY ([3]CONCRETE) (LB)
0	72,600	40,500	40,500	42,400	18,800	14,050
5,000	75,350	45,500	36,500	45,950	23,800	17,880
10,000	77,500	50,500	32,000	46,000	28,800	21,570
15,000	77,500	55,500	27,400	46,000	33,800	25,150
20,000	77,500	60,500	22,500	46,000	38,800	22,500
24,000	77,500	64,000	19,400	46,000	42,300	19,500

[1] Maximum restraint values for a load having equal horizontal and vertical components without isolation.

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CHAPTER P3

FLSS/FLS/FHS ISOLATORS AND RESTRAINTS

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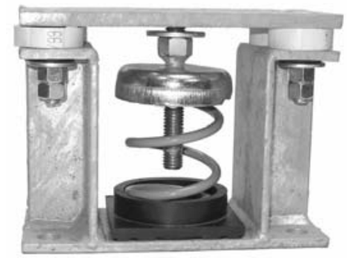
Kinetics Model FLSS



Seismic control restrained spring vibration isolators consist of free-standing, large diameter, laterally stable steel springs assembled into welded steel housing assemblies that are designed to limit vertical movement of the isolated equipment if equipment loads are reduced or if the equipment is subjected to large external forces such as seismic events. The housings also provide a constant free and operating height to facilitate installation. Spring elements are complete with internal noise isolation pads and have an adjusting and leveling bolt as a part of the top load plate assembly. Large holes are provided in all isolators for bolting to the structure and to the supported equipment. To assure stability, the springs have a lateral spring stiffness greater than 1.2 times the rated vertical stiffness and are designed to provide a minimum of 50% overload capacity. FLSS springs are available with deflections to 4 inches (100 mm) and with load capacities to 11,800 lbs. (5364 kg) as standard products. Custom isolators with higher deflection and greater load capabilities are also available. Kinetics Model FLSS spring isolators are recommended for the isolation of vibration produced by equipment carrying a large fluid load which may be drained, such as boilers and chillers, and for the isolation of cooling towers, air-cooled condensers, etc., where motion due to wind loads must be minimized.

Specification

Vibration isolators shall be seismically rated restrained spring isolators for equipment that is subject to load variations and large external forces. Isolators shall consist of large diameter, laterally stable steel springs assembled into welded steel housing assemblies designed to limit movement of the supported equipment in all directions.

Housing assembly shall be of fabricated steel members and shall consist of a top load plate complete with adjusting and leveling bolts, adjustable vertical restraints, isolation washers, and a bottom plate with internal non-skid noise isolation pads and holes for anchoring of the housing to the supporting structure. Housing shall be electro-zinc plated or hot-dip galvanized for corrosion resistance. Housing shall be designed to provide a constant free and operating height within 1/8 inch (3 mm).

The isolator housing shall provide a minimum of 1g restraint in all directions if attached with through bolts. Spring elements shall be selected to provide static deflections as shown on the vibration isolation schedule or as indicated or required in the project documents. Springs shall be color coded or otherwise identified.

Spring elements shall have a lateral stiffness greater than 1.0 times the rated vertical stiffness and shall be designed to provide a minimum of 50% overload capacity. Spring elements shall be epoxy powder coated, and shall have a 1000-hour rating when tested in accordance with ASTM B-117.

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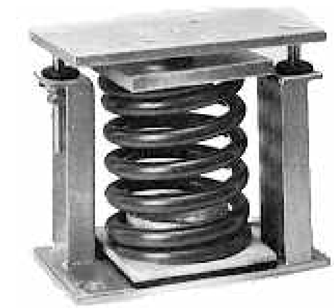
Kinetics Model FLS

Vibration isolators consist of free-standing large diameter laterally stable steel springs assembled into welded steel housing assemblies that are designed to limit vertical movement of the isolated equipment if equipment loads are reduced or if the equipment is subjected to large external forces. The housings also provide a constant free and operating height to facilitate installation. Spring elements are complete with internal noise isolation pads and have an adjusting and leveling bolt as a part of the top load plate assembly. Springs are epoxy powder coated, with a 1000-hour salt spray rating per ASTM B-117. Holes are provided in all isolators for bolting to the structure and to the supported equipment. The isolator can be welded to the structure as well. To assure stability, the springs have a lateral spring stiffness greater than 1.0 times the rated vertical stiffness, and are designed to provide a minimum of 50% overload capacity. FLS springs are available with deflections to 2.03 inches (52 mm) and with load capacities to 15,600 lbs. (7076 kg) as standard products. Custom isolators with higher deflection and greater load capabilities are also available. Kinetics Model FLS spring isolators are recommended for the isolation of vibration produced by equipment carrying a large fluid load which may be drained, such as boilers, cooling towers and chillers, and for the isolation of cooling towers, air-cooled condensers, etc., where motion due to wind loads must be minimized.



Specification

Vibration isolators for equipment which is subject to load variations and large external or torque forces shall consist of large diameter laterally stabile steel springs assembled into welded steel housing assemblies designed to limit vertical movement of the supported equipment.

Housing assembly shall be of fabricated steel members and shall consist of a top load plate complete with adjusting and leveling bolts, vertical restraints, isolation washers, and a bottom plate with internal non-skid noise isolation pads and holes provided for anchoring to the supporting structure. Housing shall be hot dip galvanized for corrosion resistance. Housing should be designed to provide a constant free and operating height within 1/8 inch (0.06 mm).

Spring elements shall have a lateral stiffness greater than 1.0 times the rated vertical stiffness and shall be designed to provide a minimum of 50% overload capacity. Spring elements shall be epoxy powder coated, and shall have a 1000-hour rating when tested in accordance with ASTM B-117.

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Kinetics Model FHS

Seismic control restrained spring isolators meet specifications for Kinetics Model FDS isolators and include a steel housing assembly to limit both lateral and vertical movement of the supported equipment during an earthquake without degrading the vibration isolation of the spring during normal equipment operating conditions. Standard FHS isolators incorporate a steel housing which encloses a neoprene snubber. Depending on the load and seismic zone, an optional steel load spreader plate to distribute the load among concrete anchors may be applied. A neoprene pad fitted in series with the spring is provided. Equipment attachment is by way of a bolt screwed downward through the equipment foot. Removal of the isolator for servicing can be easily accomplished as the isolator is not fitted with a protruding stud. In conformance with all current building code standards, the restraining system is designed to withstand a minimum 1.0g acceleration force. Motion is limited to approximately 0.2" in any direction.

Specification

Spring isolators shall be seismic control restrained spring isolators, incorporating a single or multiple coil spring element, having all of the characteristics of free-standing coil spring isolators as specified in the vibration isolation portion of this specification. Springs shall be restrained using a housing engineered to limit both lateral and vertical movement of the supported equipment during an earthquake without degrading the vibration isolation capabilities of the spring during normal equipment operating conditions.

Vibration isolators shall incorporate a steel housing and neoprene snubbing grommet system designed to limit motion to no more than 1/4" (6 mm) in any direction and to prevent any direct metal-to-metal contact between the supported member and the fixed restraint housing. The restraining system shall be designed to withstand the seismic design forces in any lateral or vertical direction without yield or failure. Where the capacity of the anchorage hardware in concrete is inadequate for the required seismic loadings, an adapter base plate to allow the addition of more or larger anchors will be fitted to fulfill these requirements. In addition to the primary isolation coil spring, the load path will include a minimum 1/4" (6 mm) thick neoprene pad.

Spring elements shall be color coded or otherwise easily identified. Springs shall have a lateral stiffness greater than 1.2 times the rated vertical stiffness and shall be designed to provide a minimum of 50% overload capacity. Non-welded spring elements shall be epoxy powder coated and shall have a minimum of a 1000-hour rating when tested in accordance with ASTM B-117.

To facilitate servicing, the isolator will be designed in such a way that the coil spring element can be removed without the requirement to lift or otherwise disturb the supported equipment.

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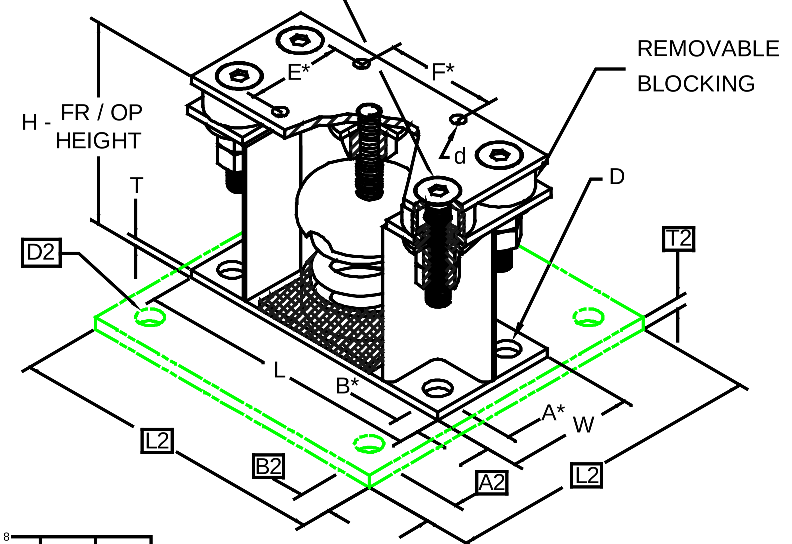
FLSS 1" DEFLECTION SEISMIC ISOLATOR

IP UNITS (INCHES AND POUNDS)

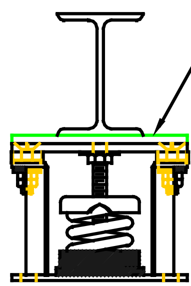
TYPE	L	W	T	A	B	D	E	F	d	H
1-250/3500	9.00	4.00	0.31	0.75	0.75	0.69	2.75	2.75	0.56	6.25

STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLSS	1-250	BLUE		4.20	3.00	250	1.79
FLSS	1-450	GREEN		4.20	3.00	450	1.54
FLSS	1-625	BLACK		4.20	3.00	625	1.44
FLSS	1-800	GRAY		4.20	3.00	800	1.31
FLSS	1-1000	RED		4.20	3.00	1000	1.15
FLSS	1-1250	BROWN		4.20	3.00	1250	1.09
FLSS	1-1700	ORANGE		4.20	3.00	1700	0.95
FLSS	1-2200	ORANGE	GRAY	4.20	3.00	2200	1.00
FLSS	1-2465	BLUE		4.20	3.00	2465	1.00
FLSS	1-2865	BLUE	GRAY	4.20	3.00	2865	1.00
FLSS	1-3500	BLUE	BROWN	4.20	3.00	3500	1.00

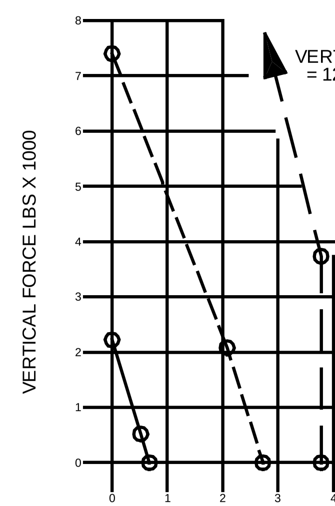
1-250/3500 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
1-250/3500 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



WELDED TO STEEL — —
THROUGH BOLTED — - —
ANCHORED TO CONCRETE ——

Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLSS Submittal Drawings

DRAWING #S-01-22.11S – FLSS 1-250/3500

RELEASE DATE: : 2/01/05

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DOCUMENT:
P3.2.1-1

VISCMA MEMBER

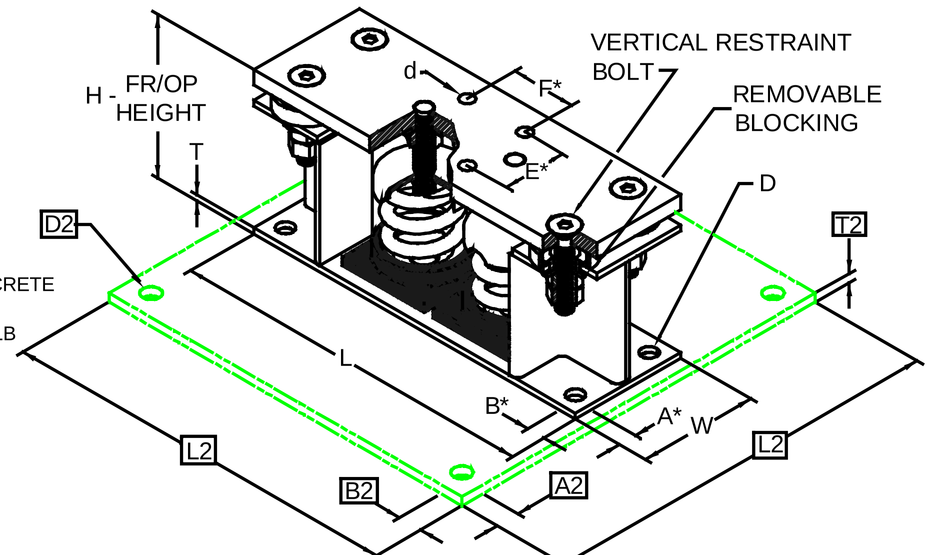
FLSS 1" DEFLECTION SEISMIC ISOLATOR
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
1-2500/7000	15.25	5.00	0.38	0.75	0.75	0.69	2.75	2.75	0.56	6.88

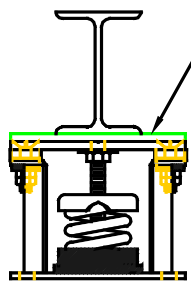
A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE

STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLSS	1-2500	BROWN		4.20	3.00	2500	1.09
FLSS	1-3400	ORANGE		4.20	3.00	3400	0.95
FLSS	1-4400	ORANGE	GRAY	4.20	3.00	4400	1.00
FLSS	1-4930	BLUE		4.20	3.00	4930	1.00
FLSS	1-5730	BLUE	GRAY	4.20	3.00	5730	1.00
FLSS	1-7000	BLUE	BROWN	4.20	3.00	7000	1.00

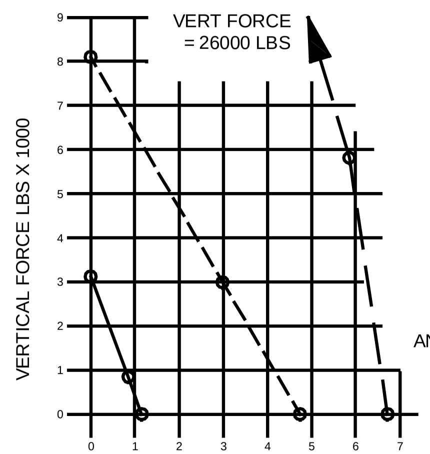
1-2500/7000 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
1-2500/7000 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLSS Submittal Drawings

DRAWING #S-01-22.12S – FLSS 1-2500/7000

RELEASE DATE: : 2/01/05

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DOCUMENT:
P3.2.1-2

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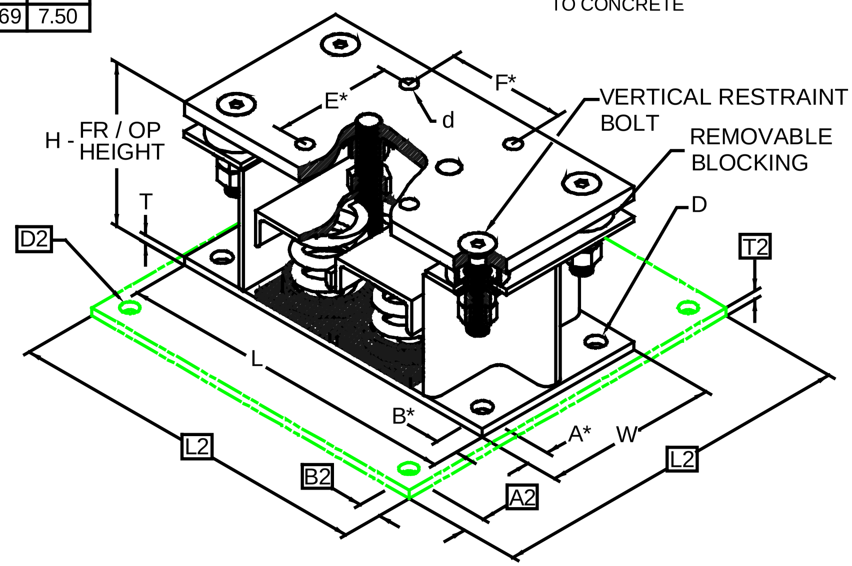
FLSS 1" DEFLECTION SEISMIC ISOLATOR
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
1-5000/14000	15.75	8.00	0.50	1.00	1.00	0.81	5.50	5.50	0.69	7.50

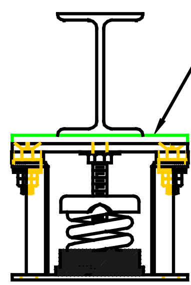
STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLSS	1-5000	BROWN		4.20	3.00	5000	1.09
FLSS	1-6800	ORANGE		4.20	3.00	6800	0.95
FLSS	1-8800	ORANGE	GRAY	4.20	3.00	8800	1.00
FLSS	1-9860	BLUE		4.20	3.00	9860	1.00
FLSS	1-11460	BLUE	GRAY	4.20	3.00	11460	1.00
FLSS	1-14000	BLUE	BROWN	4.20	3.00	14000	1.00

1-5000/14000 REQUIRES 0.75 DIA. x 4.75 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
1-5000/14000 ANCHOR BOLT TORQUE - 150 FT-LB, PULL TEST - 3625 LB

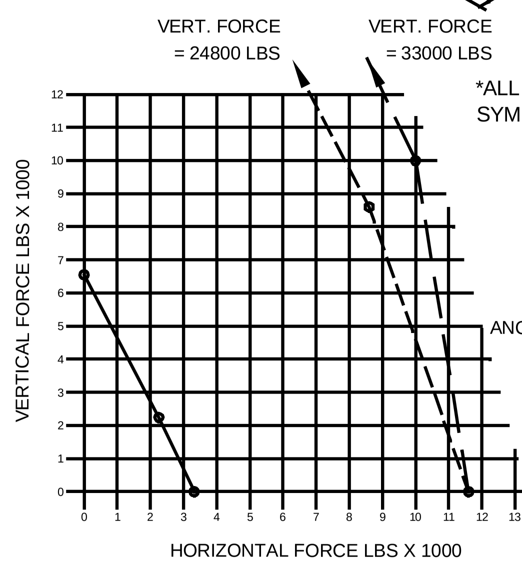
A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE
- NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLSS Submittal Drawings

DRAWING #S-01-22.13S – FLSS 1-5000/14000

RELEASE DATE: : 2/01/05

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P3.2.1-3

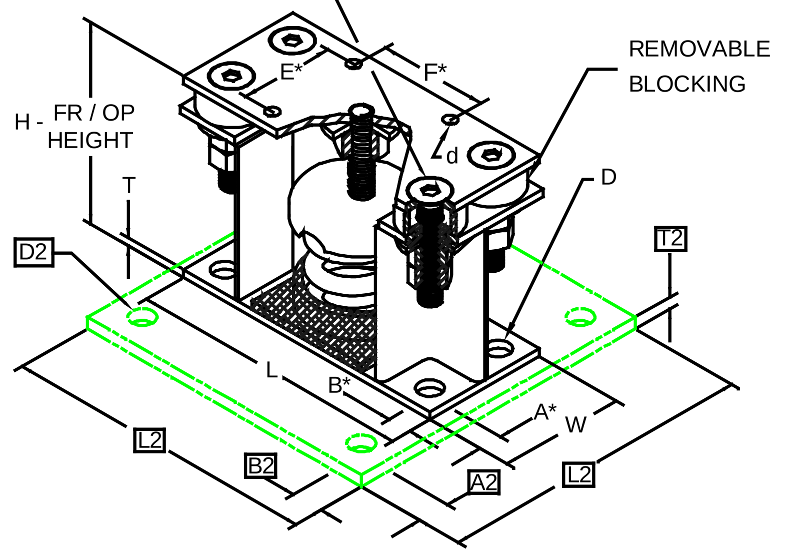
VISCMA MEMBER

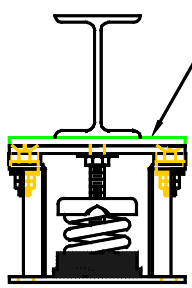
FLSS 2" DEFLECTION SEISMIC ISOLATOR
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
2-100/1975	10.00	5.00	0.31	0.75	0.75	0.69	2.75	2.75	0.56	8.00

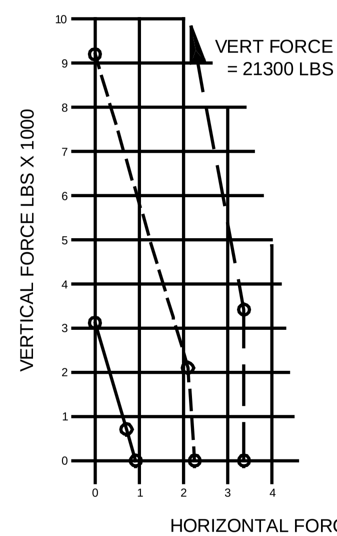
STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLSS	2-100	GRAY		6.09	3.50	100	2.00
FLSS	2-250	BLUE		6.09	3.50	250	2.00
FLSS	2-500	GREEN		6.09	3.50	500	2.00
FLSS	2-750	BLACK		6.09	3.50	750	2.00
FLSS	2-995	ORANGE		6.09	3.50	995	2.00
FLSS	2-1400	ORANGE	GREEN	6.09	3.50	1400	2.01
FLSS	2-1600	RED		6.09	3.50	1600	2.00
FLSS	2-1975	RED	GREEN	6.09	3.50	1975	1.98

2-100/1975 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
2-100/1975 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB





IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE

WELDED TO STEEL
THROUGH BOLTED
ANCHORED TO CONCRETE

Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50 %.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLSS Submittal Drawings

DRAWING #S-01-22.21S – FLSS 2-100/1975

RELEASE DATE: : 2/01/05

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DOCUMENT:
P3.2.1-4

VISCMA MEMBER

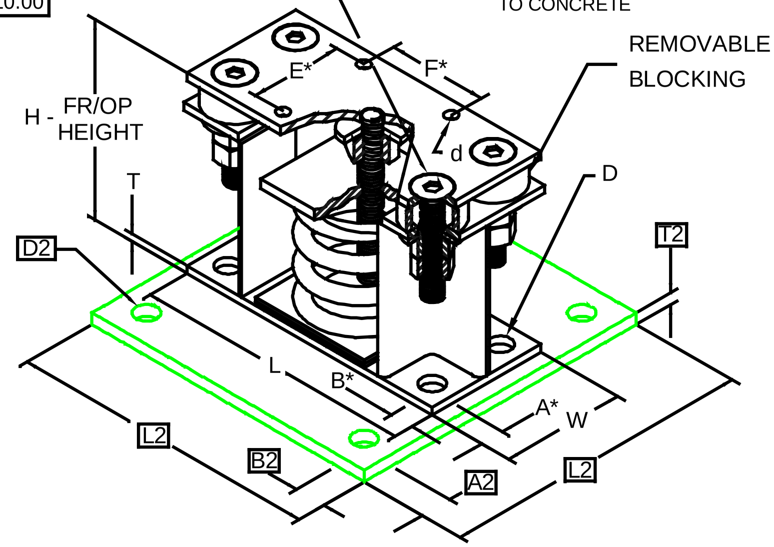
FLSS 2" DEFLECTION SEISMIC ISOLATOR

IP UNITS (INCHES AND POUNDS)

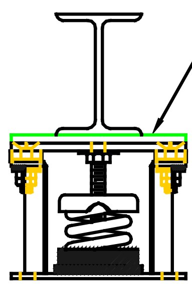
TYPE	L	W	T	A	B	D	E	F	d	H
2-2000/4500	11.00	5.00	0.31	0.75	0.75	0.69	2.75	2.75	0.56	10.00

STANDARD RATINGS		SPRING COIL						
		COLOR			FREE		RATED	
TYPE	SIZE	OUTER	INNER1	INNER2	HT.	O.D.	LOAD	DEFL.
FLSS	2-2000	ORANGE			7.00	5.00	2000	2.00
FLSS	2-2500	BLUE			7.00	5.00	2500	2.00
FLSS	2-2750	BLUE	BLUE		7.00	5.00	2750	2.00
FLSS	2-3025	BLUE	GREEN		7.00	5.00	3025	2.02
FLSS	2-3250	BLUE	BLACK		7.00	5.00	3250	2.00
FLSS	2-3500	BLUE	ORANGE		7.00	5.00	3500	2.00
FLSS	2-3900	BLUE	ORANGE	GREEN	7.00	5.00	3900	2.00
FLSS	2-4100	BLUE	RED		7.00	5.00	4100	2.00
FLSS	2-4500	BLUE	RED	GREEN	7.00	5.00	4500	2.00

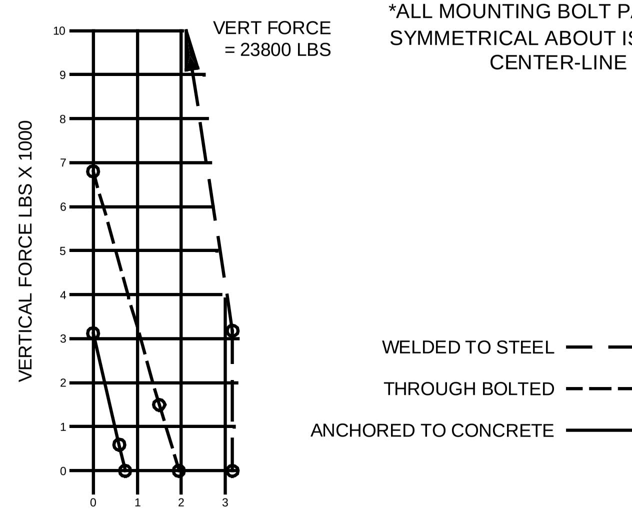
2-2000/4500 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
2-2000/4500 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADDT'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- ISOLATORS MUST BE BOLTED OR WELDED TOP AND BOTTOM IN AN APPROVED MANNER
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLSS Submittal Drawings

DRAWING #S-01-22.22S – FLSS 2-2000/4500

RELEASE DATE: : 2/01/05

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World Wide Web: www.kineticsnoise.com
Email: sales@kineticsnoise.com

DOCUMENT:
P3.2.1-5

VISCMA MEMBER

FLSS 2" DEFLECTION SEISMIC ISOLATOR

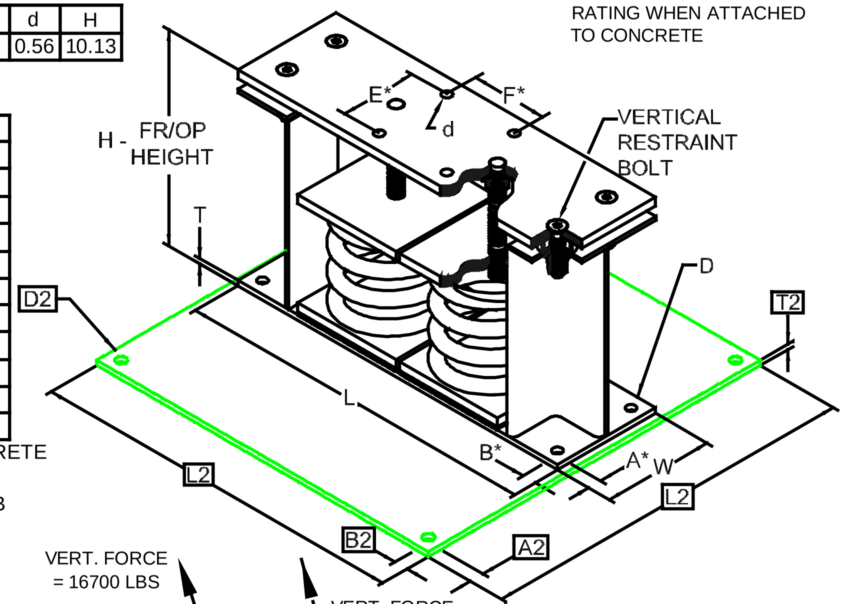
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
2-4000/9000	17.50	6.00	0.50	0.75	0.75	0.69	2.75	2.75	0.56	10.13

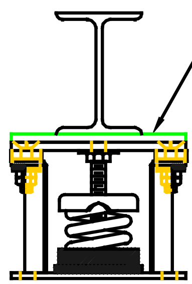
STANDARD RATINGS		SPRING COIL						
		COLOR			FREE		RATED	
TYPE	SIZE	OUTER	INNER1	INNER2	HT.	O.D.	LOAD	DEFL.
FLSS	2-4000	ORANGE			7.00	5.00	4000	2.00
FLSS	2-5000	BLUE			7.00	5.00	5000	2.00
FLSS	2-5500	BLUE	BLUE		7.00	5.00	5500	2.00
FLSS	2-6050	BLUE	GREEN		7.00	5.00	6050	2.02
FLSS	2-6500	BLUE	BLACK		7.00	5.00	6500	2.00
FLSS	2-7000	BLUE	ORANGE		7.00	5.00	7000	2.00
FLSS	2-7800	BLUE	ORANGE	GREEN	7.00	5.00	7800	2.00
FLSS	2-8200	BLUE	RED		7.00	5.00	8200	2.00
FLSS	2-9000	BLUE	RED	GREEN	7.00	5.00	9000	2.00

2-4000/9000 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
2-4000/9000 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB

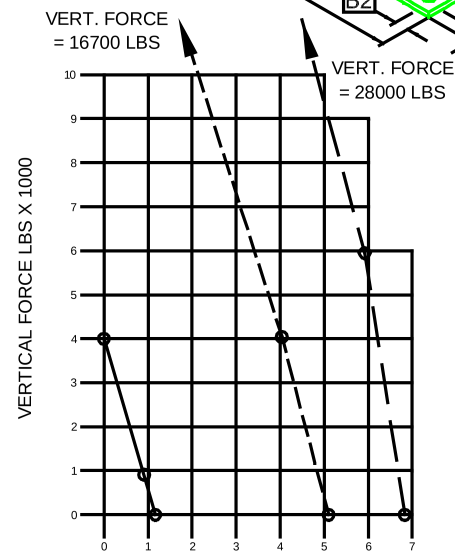
A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLSS Submittal Drawings

DRAWING #S-01-22.23S – FLSS 2-4000/9000

RELEASE DATE: : 2/01/05

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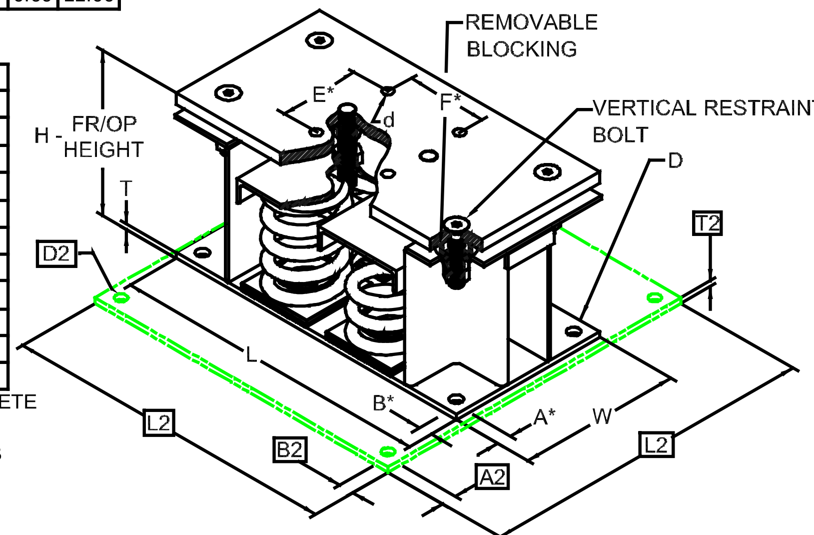
VISCMA MEMBER

A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE

FLSS 2" DEFLECTION SEISMIC ISOLATOR

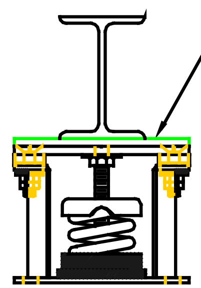
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
2-8000/18000	21.50	11.00	0.50	1.00	1.00	0.81	5.50	5.50	0.69	11.00

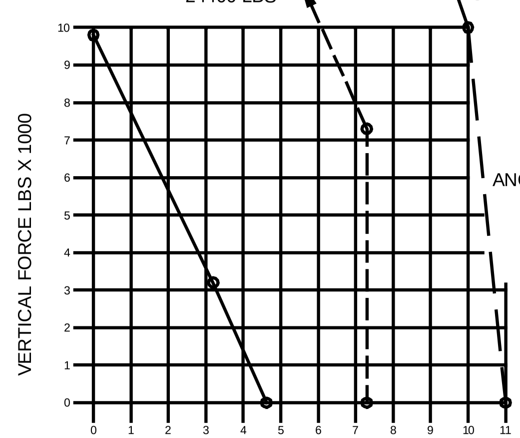


STANDARD RATINGS		SPRING COIL						
		COLOR			FREE		RATED	
TYPE	SIZE	OUTER	INNER1	INNER2	HT.	O.D.	LOAD	DEFL.
FLSS	2-8000	ORANGE			7.00	5.00	8000	2.00
FLSS	2-10000	BLUE			7.00	5.00	10000	2.00
FLSS	2-11000	BLUE	BLUE		7.00	5.00	11000	2.00
FLSS	2-12100	BLUE	GREEN		7.00	5.00	12100	2.02
FLSS	2-13000	BLUE	BLACK		7.00	5.00	13000	2.00
FLSS	2-14000	BLUE	ORANGE		7.00	5.00	14000	2.00
FLSS	2-15600	BLUE	ORANGE	GREEN	7.00	5.00	15600	2.00
FLSS	2-16400	BLUE	RED		7.00	5.00	16400	2.00
FLSS	2-18000	BLUE	RED	GREEN	7.00	5.00	18000	2.00

2-8000/18000 REQUIRES 0.75 DIA. x 4.75 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
2-8000/18000 ANCHOR BOLT TORQUE - 150 FT-LB, PULL TEST - 3625 LB



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE

Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50 %.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLSS Submittal Drawings

DRAWING #S-01-22.24S – FLSS 2-8000/18000

RELEASE DATE: : 2/01/05

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DOCUMENT:
P3.2.1-7

VISCMA MEMBER

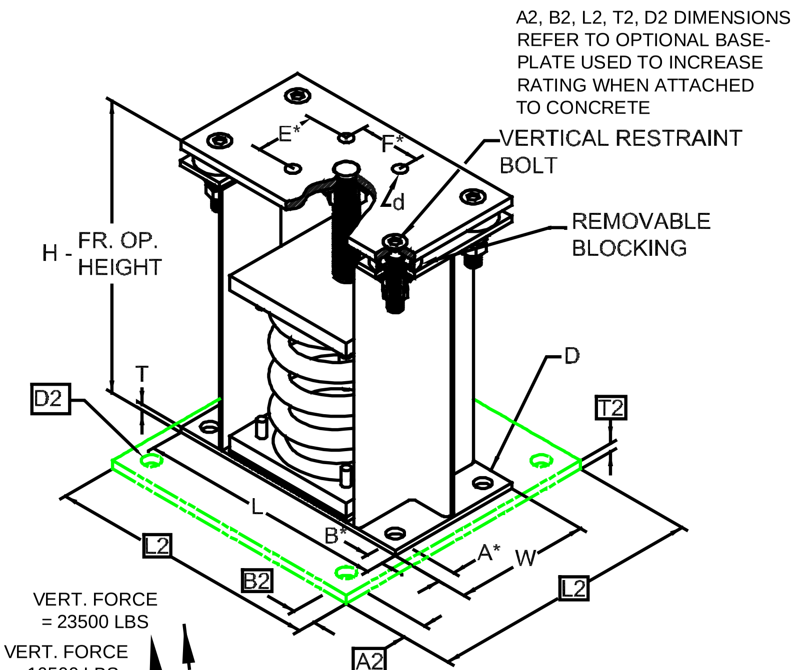
FLSS 4" DEFLECTION SEISMIC ISOLATOR

IP UNITS (INCHES AND POUNDS)

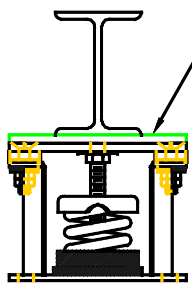
TYPE	L	W	T	A	B	D	E	F	d	H
4-100/1600	11.00	6.00	0.38	0.75	0.75	0.69	2.75	2.75	0.56	13.00

STANDARD RATINGS		SPRING COIL				
			FREE		RATED	
TYPE	SIZE	COLOR	HT.	O.D.	LOAD	DEFL.
FLSS	4-100	GRAY	10.00	5.63	100	4.00
FLSS	4-250	BLUE	10.00	5.63	250	4.00
FLSS	4-500	GREEN	10.00	5.63	500	4.00
FLSS	4-750	BLACK	10.00	5.63	750	4.00
FLSS	4-1000	RED	10.00	5.63	1000	4.00
FLSS	4-1250	BROWN	10.00	5.63	1250	4.00
FLSS	4-1600	ORANGE	10.00	5.63	1600	4.00

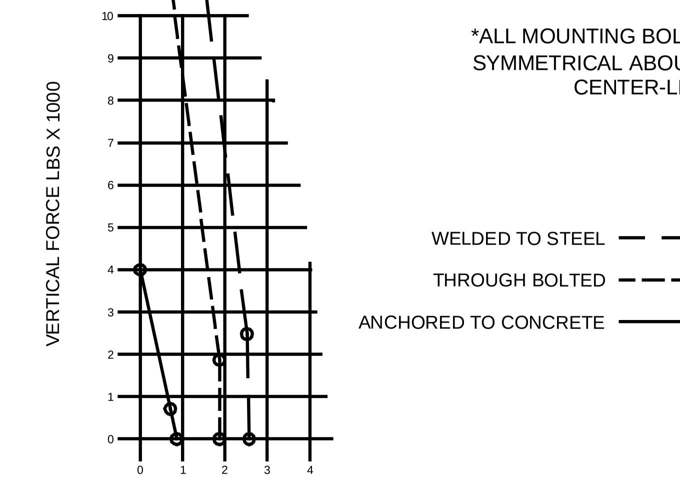
4-100/1600 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
4-100/1600 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50 %.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLSS Submittal Drawings

DRAWING #S-01-22.41S – FLSS 4-100/1600

RELEASE DATE: : 2/01/05

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DOCUMENT:
P3.2.1-8

VISCMA MEMBER

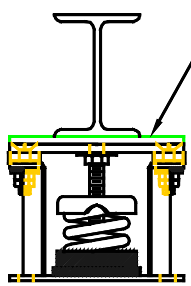
FLSS 4" DEFLECTION SEISMIC ISOLATOR

IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
4-2250/5800	16.25	8.00	0.50	1.00	1.00	0.69	5.50	5.50	0.69	15.00

STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLSS	4-2250	BEIGE		11.50	8.00	2250	4.00
FLSS	4-2500	BEIGE	BLUE	11.50	8.00	2500	4.00
FLSS	4-2750	BEIGE	GREEN	11.50	8.00	2750	4.00
FLSS	4-3000	BEIGE	BLACK	11.50	8.00	3000	4.00
FLSS	4-3250	BEIGE	RED	11.50	8.00	3250	4.00
FLSS	4-3500	BEIGE	BROWN	11.50	8.00	3500	4.00
FLSS	4-3850	BEIGE	ORANGE	11.50	8.00	3850	4.00
FLSS	4-4200	CHROME		11.50	8.00	4200	4.00
FLSS	4-4450	CHROME	BLUE	11.50	8.00	4450	4.00
FLSS	4-4700	CHROME	GREEN	11.50	8.00	4700	4.00
FLSS	4-4950	CHROME	BLACK	11.50	8.00	4950	4.00
FLSS	4-5200	CHROME	RED	11.50	8.00	5200	4.00
FLSS	4-5450	CHROME	BROWN	11.50	8.00	5450	4.00
FLSS	4-5800	CHROME	ORANGE	11.50	8.00	5800	4.00

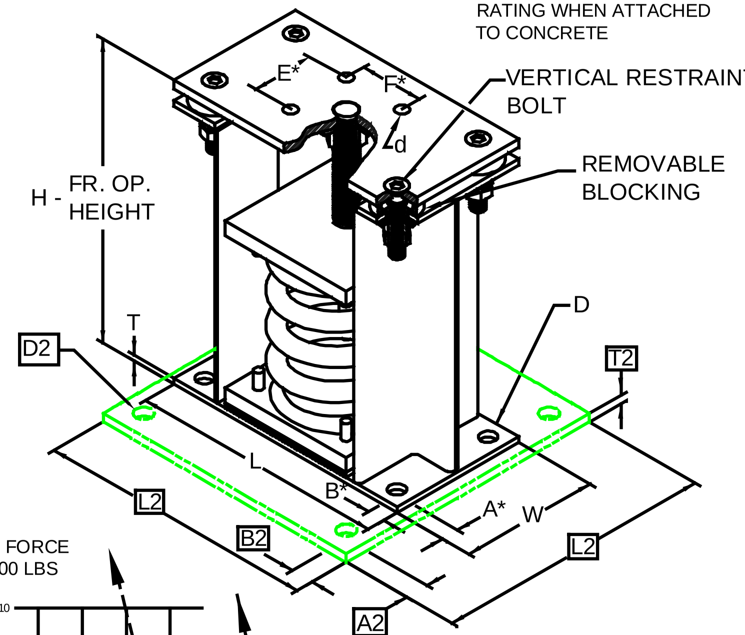
4-2250/5800 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
4-2250/5800 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB

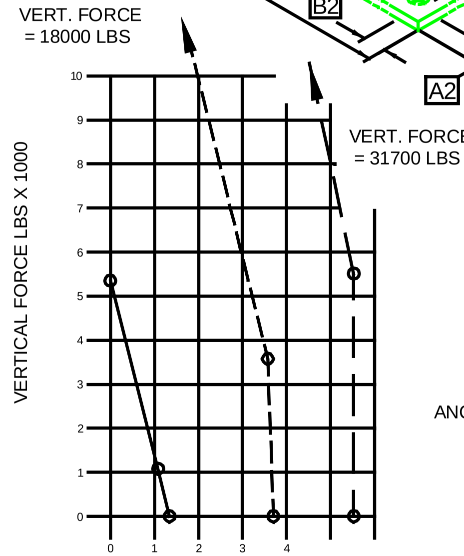


SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE





*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE

WELDED TO STEEL
THROUGH BOLTED
ANCHORED TO CONCRETE

Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

FLSS Submittal Drawings

DRAWING #S-01-22.42S – FLSS 4-2250/5800

RELEASE DATE: : 2/01/05

KINETICS Noise Control
DUBLIN, OHIO, USA • MISSISSAUGA, ONTARIO, CANADA

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DOCUMENT:
P3.2.1-9

VISCMA MEMBER

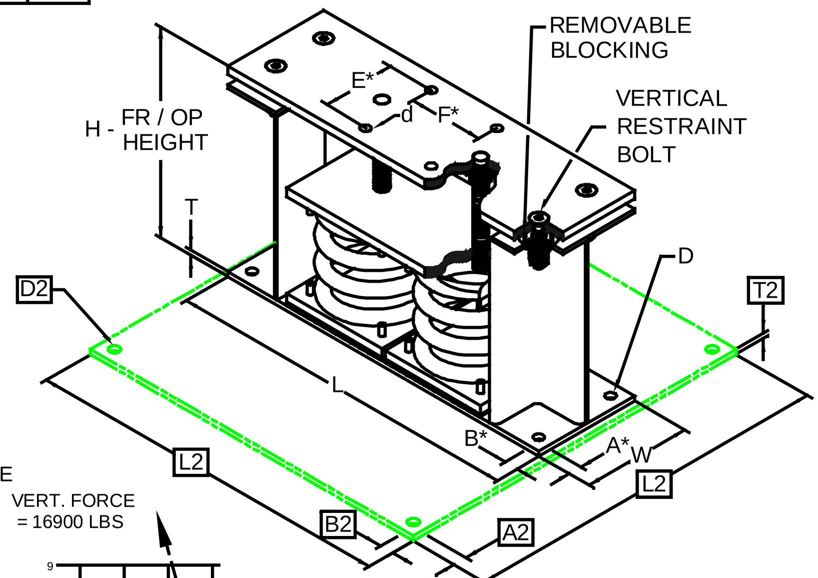
FLSS 4" DEFLECTION SEISMIC ISOLATOR
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
4-5500/11600	26.00	8.00	0.50	1.00	1.00	0.69	5.50	5.50	0.69	15.25

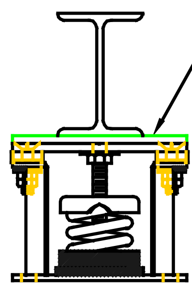
STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLSS	4-5500	BEIGE	GREEN	11.50	8.00	5500	4.00
FLSS	4-6000	BEIGE	BLACK	11.50	8.00	6000	4.00
FLSS	4-6500	BEIGE	RED	11.50	8.00	6500	4.00
FLSS	4-7000	BEIGE	BROWN	11.50	8.00	7000	4.00
FLSS	4-7700	BEIGE	ORANGE	11.50	8.00	7700	4.00
FLSS	4-8400	CHROME		11.50	8.00	8400	4.00
FLSS	4-8900	CHROME	BLUE	11.50	8.00	8900	4.00
FLSS	4-9400	CHROME	GREEN	11.50	8.00	9400	4.00
FLSS	4-9900	CHROME	BLACK	11.50	8.00	9900	4.00
FLSS	4-10400	CHROME	RED	11.50	8.00	10400	4.00
FLSS	4-10900	CHROME	BROWN	11.50	8.00	10900	4.00
FLSS	4-11600	CHROME	ORANGE	11.50	8.00	11600	4.00

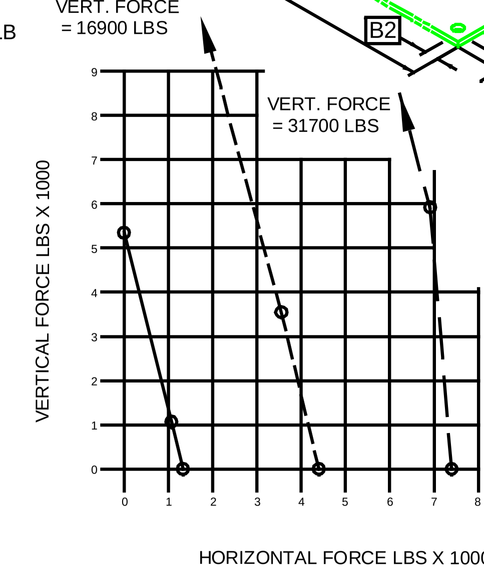
4-5500/11600 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
4-5500/11600 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB

A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE





Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50 %.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLSS Submittal Drawings

DRAWING #S-01-22.43S – FLSS 4-5500/11600

RELEASE DATE: : 2/01/05

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DOCUMENT:
P3.2.1-10

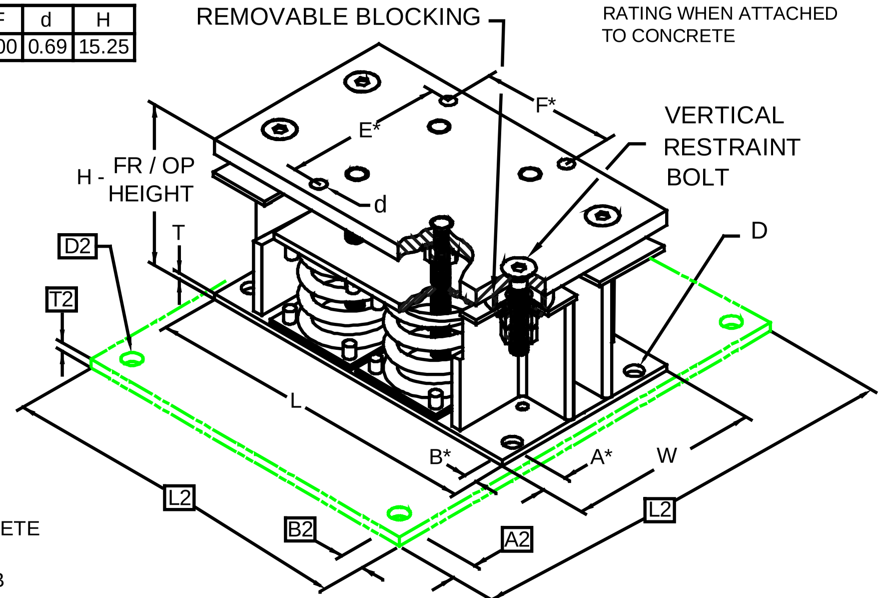
VISCMA MEMBER

FLSS 4" DEFLECTION SEISMIC ISOLATOR

IP UNITS (INCHES AND POUNDS)

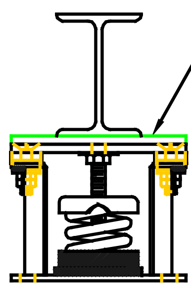
TYPE	L	W	T	A	B	D	E	F	d	H
4-11000/23200	27.00	17.00	0.75	1.00	1.00	0.81	9.00	9.00	0.69	15.25

A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE



STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLSS	4-11000	BEIGE	GREEN	11.50	8.00	11000	4.00
FLSS	4-12000	BEIGE	BLACK	11.50	8.00	12000	4.00
FLSS	4-13000	BEIGE	RED	11.50	8.00	13000	4.00
FLSS	4-14000	BEIGE	BROWN	11.50	8.00	14000	4.00
FLSS	4-15400	BEIGE	ORANGE	11.50	8.00	15400	4.00
FLSS	4-16800	CHROME		11.50	8.00	16800	4.00
FLSS	4-17800	CHROME	BLUE	11.50	8.00	17800	4.00
FLSS	4-18800	CHROME	GREEN	11.50	8.00	18800	4.00
FLSS	4-19800	CHROME	BLACK	11.50	8.00	19800	4.00
FLSS	4-20800	CHROME	RED	11.50	8.00	20800	4.00
FLSS	4-21800	CHROME	BROWN	11.50	8.00	21800	4.00
FLSS	4-23200	CHROME	ORANGE	11.50	8.00	23200	4.00

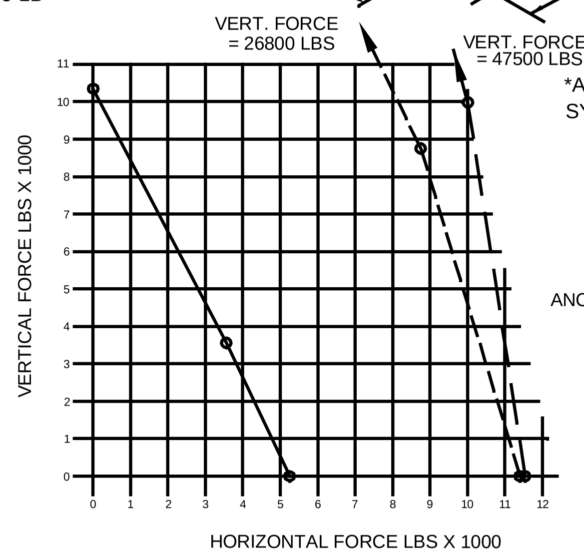
4-11000/23200 REQUIRES 0.75 DIA. x 4.75 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
4-11000/23200 ANCHOR BOLT TORQUE - 150 FT-LB, PULL TEST - 3625 LB



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADDT'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- ISOLATORS MUST BE BOLTED OR WELDED TOP AND BOTTOM IN AN APPROVED MANNER
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE

WELDED TO STEEL — —
THROUGH BOLTED — — —
ANCHORED TO CONCRETE ——

Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

FLSS Submittal Drawings

DRAWING #S-01-22.44S – FLSS 4-11000/23200

RELEASE DATE: 2/01/05

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DOCUMENT:
P3.2.1-11

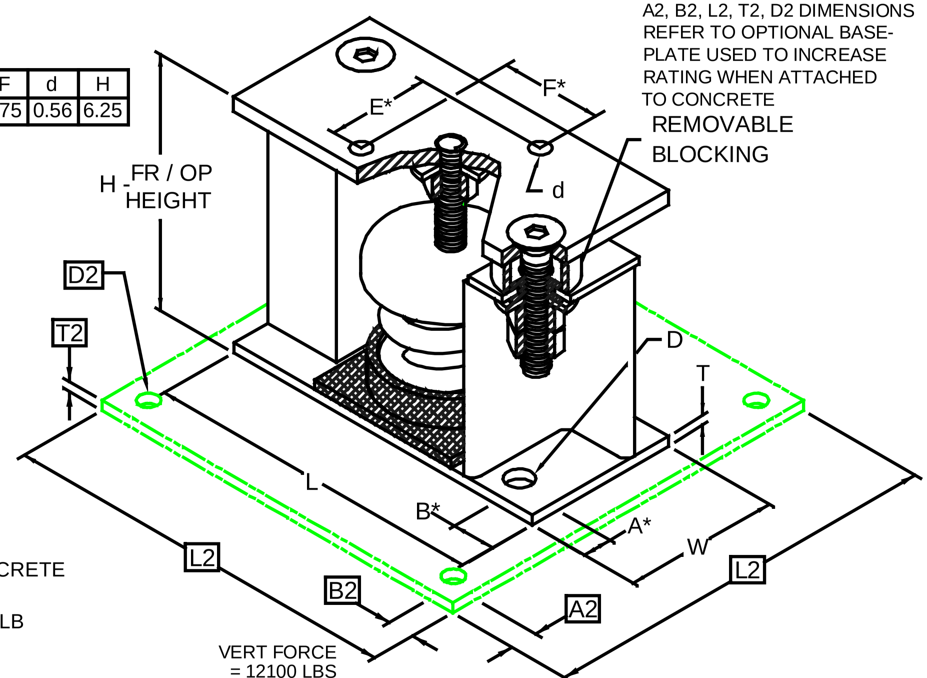
VISCMA MEMBER

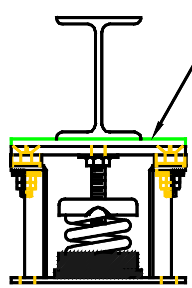
FLS 1" DEFLECTION ISOLATOR
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
1-250/3500	8.75	4.00	0.25	0.75	1.13	0.69	2.75	2.75	0.56	6.25

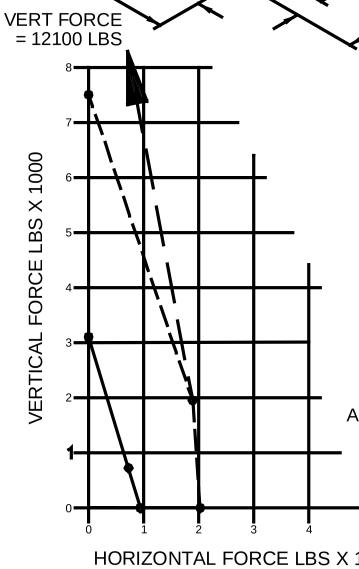
STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLS	1-250	BLUE		4.20	3.00	250	1.79
FLS	1-450	GREEN		4.20	3.00	450	1.54
FLS	1-625	BLACK		4.20	3.00	625	1.44
FLS	1-800	GRAY		4.20	3.00	800	1.31
FLS	1-1000	RED		4.20	3.00	1000	1.15
FLS	1-1250	BROWN		4.20	3.00	1250	1.09
FLS	1-1700	ORANGE		4.20	3.00	1700	0.95
FLS	1-2200	ORANGE	GRAY	4.20	3.00	2200	1.00
FLS	1-2465	BLUE		4.20	3.00	2465	1.00
FLS	1-2865	BLUE	GRAY	4.20	3.00	2865	1.00
FLS	1-3500	BLUE	BROWN	4.20	3.00	3500	1.00

1-250/3500 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
1-250/3500 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB





IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE

Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:
- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings
DRAWING #S-01-22.11 – FLS 1-250/3500

RELEASE DATE: 02/01/05

KINETICS Noise Control
DUBLIN, OHIO, USA • MISSISSAUGA, ONTARIO, CANADA

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DOCUMENT:
P3.2.2-1

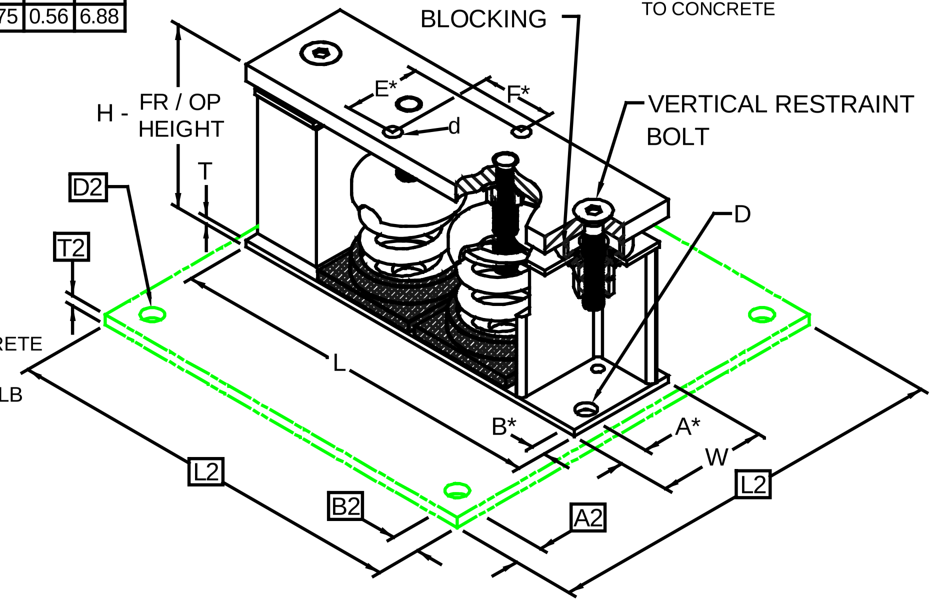
VISCMA MEMBER

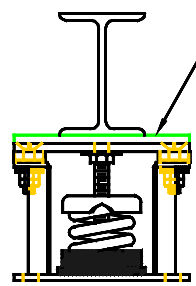
FLS 1" DEFLECTION ISOLATOR
IP UNITS (INCHES AND POUNDS)

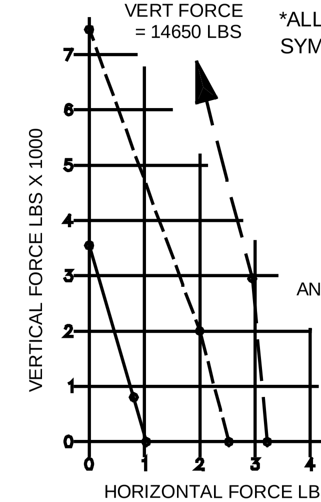
TYPE	L	W	T	A	B	D	E	F	d	H
1-2500/7000	14.00	4.00	0.38	1.00	0.50	0.69	2.75	2.75	0.56	6.88

STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLS	1-2500	BROWN		4.20	3.00	2500	1.09
FLS	1-3400	ORANGE		4.20	3.00	3400	0.95
FLS	1-4400	ORANGE	GRAY	4.20	3.00	4400	0.50
FLS	1-4930	BLUE		4.20	3.00	4930	0.50
FLS	1-5730	BLUE	GRAY	4.20	3.00	5730	0.50
FLS	1-7000	BLUE	BROWN	4.20	3.00	7000	0.50

1-2500/7000 REQUIRES 0.62 DIA x 4.00 MIN EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
1-2500/7000 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB







Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings

DRAWING #S-01-22.12 – FLS 1-2500/7000

RELEASE DATE: 02/01/05

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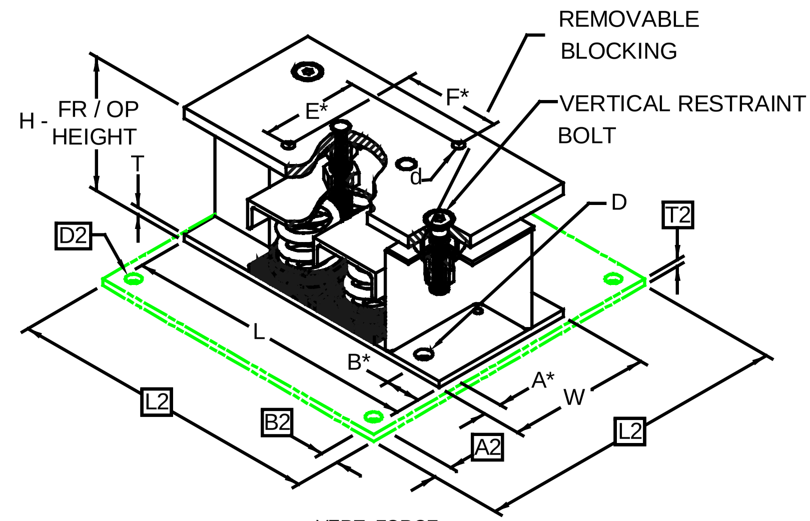
P3.2.2-2

VISCMA MEMBER

FLS 1" DEFLECTION ISOLATOR
IP UNITS (INCHES AND POUNDS)

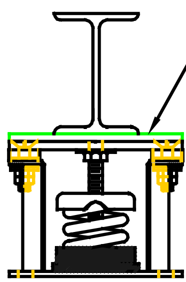
TYPE	L	W	T	A	B	D	E	F	d	H
1-5000/14000	16.50	8.00	0.38	1.00	2.00	0.81	5.50	5.50	0.69	7.50

A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE

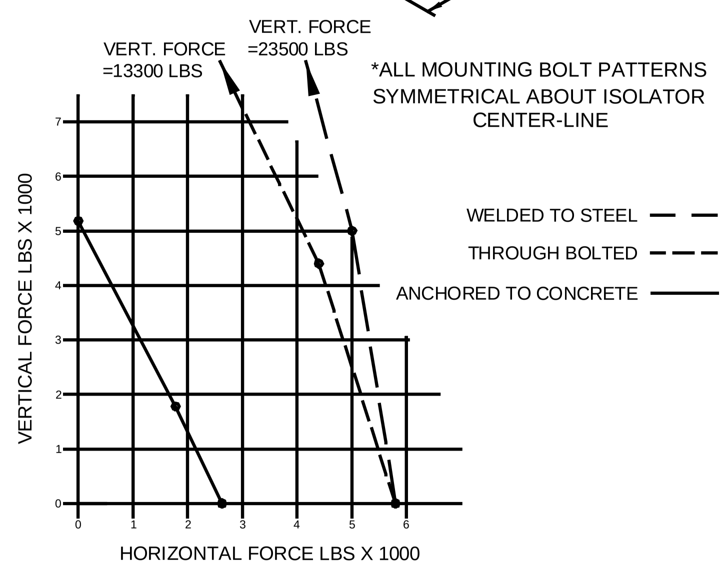


STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLS	1-5000	BROWN		4.20	3.00	5000	1.09
FLS	1-6800	ORANGE		4.20	3.00	6800	0.95
FLS	1-8800	ORANGE	GRAY	4.20	3.00	8800	1.00
FLS	1-9860	BLUE		4.20	3.00	9860	1.00
FLS	1-11460	BLUE	GRAY	4.20	3.00	11460	1.00
FLS	1-14000	BLUE	BROWN	4.20	3.00	14000	1.00

1-5000/14000 REQUIRES 0.75 DIA. x 4.75 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
1-5000/14000 ANCHOR BOLT TORQUE - 150 FT-LB, PULL TEST - 3625 LB



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE

Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings

DRAWING #S-01-22.13 – FLS 1-5000/14000

RELEASE DATE: 02/01/05

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DOCUMENT:
P3.2.2-3

VISCMA MEMBER

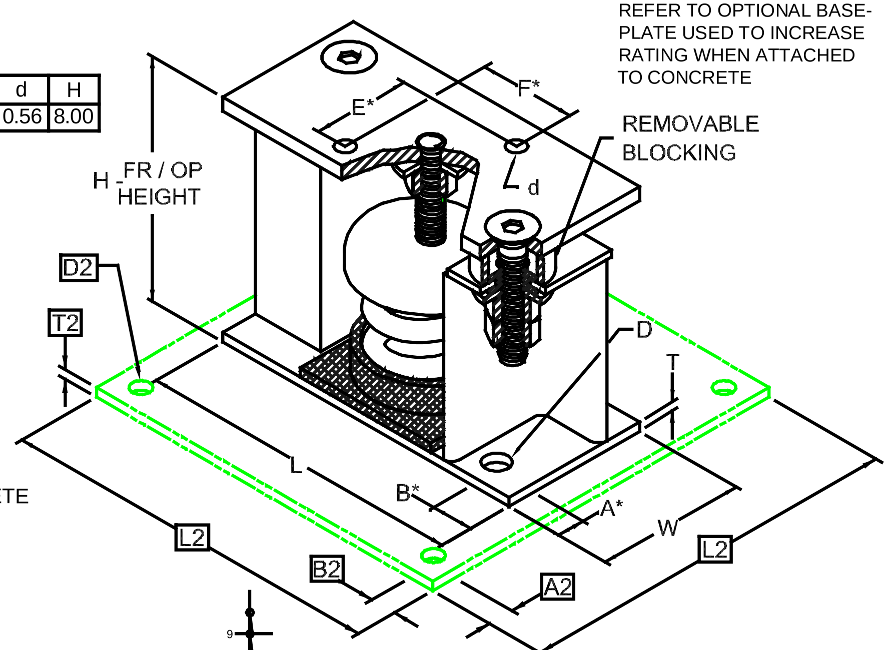
FLS 2" DEFLECTION ISOLATOR
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
2-100/1975	9.00	5.00	0.25	0.75	0.75	0.69	2.75	2.75	0.56	8.00

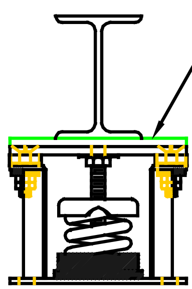
STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLS	2-100	GRAY		6.09	3.50	100	2.00
FLS	2-250	BLUE		6.09	3.50	250	2.00
FLS	2-500	GREEN		6.09	3.50	500	2.00
FLS	2-750	BLACK		6.09	3.50	750	2.00
FLS	2-995	ORANGE		6.09	3.50	995	2.00
FLS	2-1400	ORANGE	GREEN	6.09	3.50	1400	2.01
FLS	2-1600	RED		6.09	3.50	1600	2.00
FLS	2-1975	RED	GREEN	6.09	3.50	1975	1.98

2-100/1975 REQUIRES 0.62 DIA x 4.00 MIN EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
2-100/1975 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB

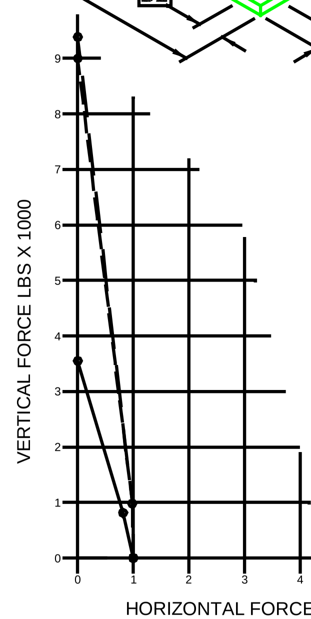
A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings

DRAWING #S-01-22.21 – FLS 2-100/1975

RELEASE DATE: 02/01/05

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VISCMA MEMBER

FLS 2" DEFLECTION ISOLATOR

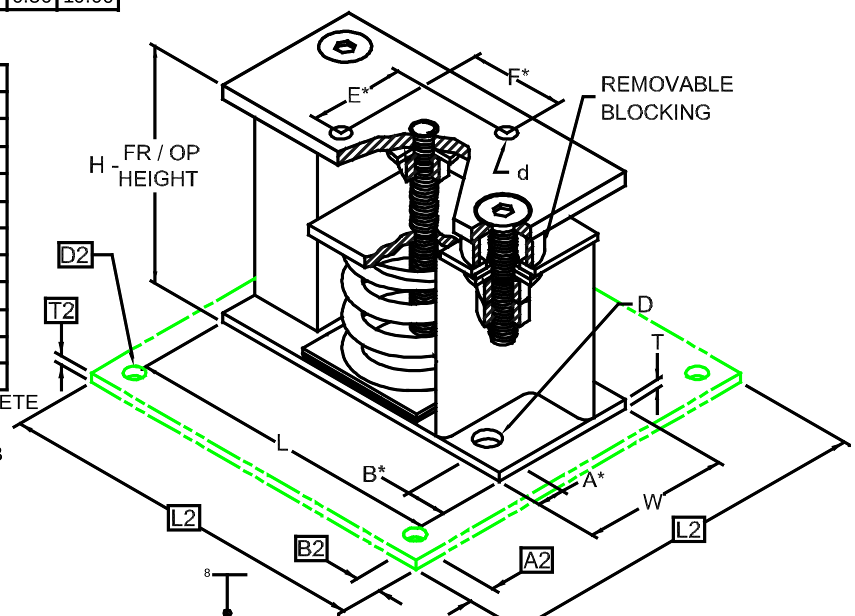
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
2-2000/4500	10.75	5.00	0.25	0.75	1.38	0.69	2.75	2.75	0.56	10.00

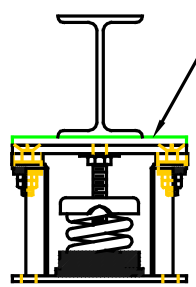
STANDARD RATINGS		SPRING COIL						
		COLOR			FREE		RATED	
TYPE	SIZE	OUTER	INNER1	INNER2	HT.	O.D.	LOAD	DEFL.
FLS	2-2000	ORANGE			7.00	5.00	2000	2.00
FLS	2-2500	BLUE			7.00	5.00	2500	2.00
FLS	2-2750	BLUE	BLUE		7.00	5.00	2750	2.00
FLS	2-3025	BLUE	GREEN		7.00	5.00	3025	2.02
FLS	2-3250	BLUE	BLACK		7.00	5.00	3250	2.00
FLS	2-3500	BLUE	ORANGE		7.00	5.00	3500	2.00
FLS	2-3900	BLUE	ORANGE	GREEN	7.00	5.00	3900	2.00
FLS	2-4100	BLUE	RED		7.00	5.00	4100	2.00
FLS	2-4500	BLUE	RED	GREEN	7.00	5.00	4500	2.00

2-2000/4500 REQUIRES 0.62 DIA x 4.00 MIN EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
2-2000/4500 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB

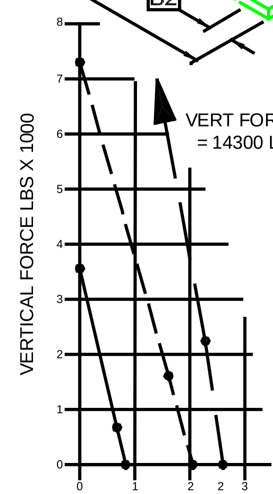
A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings

DRAWING #S-01-22.22 – FLS 2-2000/4500

RELEASE DATE: 02/01/05

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DOCUMENT:
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VISCMA MEMBER

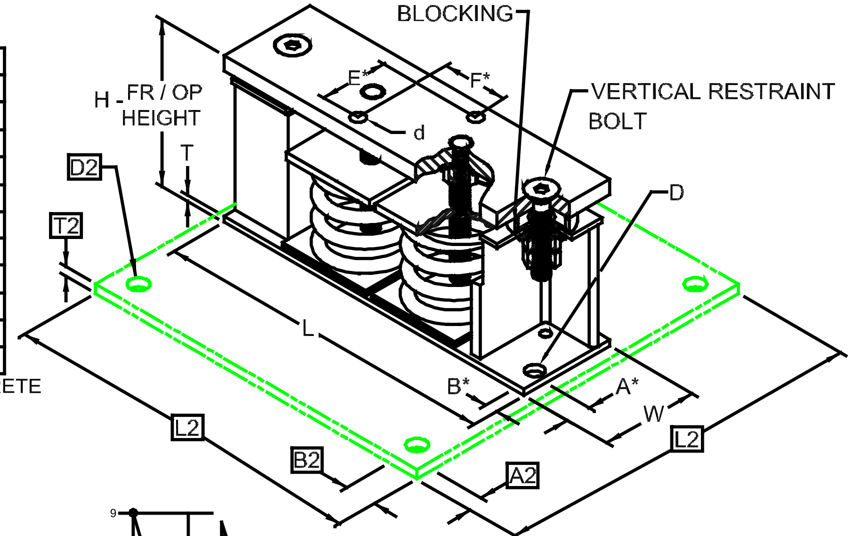
FLS 2" DEFLECTION ISOLATOR
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
2-4000/9000	17.50	6.00	0.38	1.25	1.00	0.69	2.75	2.75	0.56	10.00

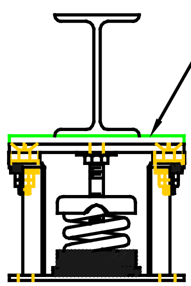
STANDARD RATINGS		SPRING COIL						
		COLOR			FREE		RATED	
TYPE	SIZE	OUTER	INNER1	INNER2	HT.	O.D.	LOAD	DEFL.
FLS	2-4000	ORANGE			7.00	5.00	4000	2.00
FLS	2-5000	BLUE			7.00	5.00	5000	2.00
FLS	2-5500	BLUE	BLUE		7.00	5.00	5500	2.00
FLS	2-6050	BLUE	GREEN		7.00	5.00	6050	2.02
FLS	2-6500	BLUE	BLACK		7.00	5.00	6500	2.00
FLS	2-7000	BLUE	ORANGE		7.00	5.00	7000	2.00
FLS	2-7800	BLUE	ORANGE	GREEN	7.00	5.00	7800	2.00
FLS	2-8200	BLUE	RED		7.00	5.00	8200	2.00
FLS	2-9000	BLUE	RED	GREEN	7.00	5.00	9000	2.00

2-4000/9000 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
2-4000/9000 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB

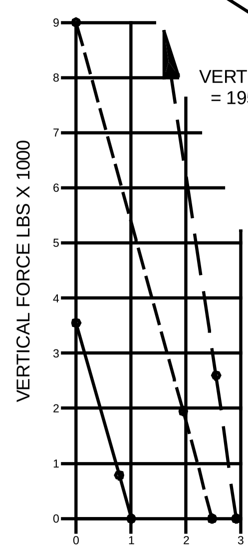
A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50 %.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings

DRAWING #S-01-22.23 – FLS 2-4000/9000

RELEASE DATE: 02/01/05

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DOCUMENT: P3.2.2-6

VISCMA MEMBER

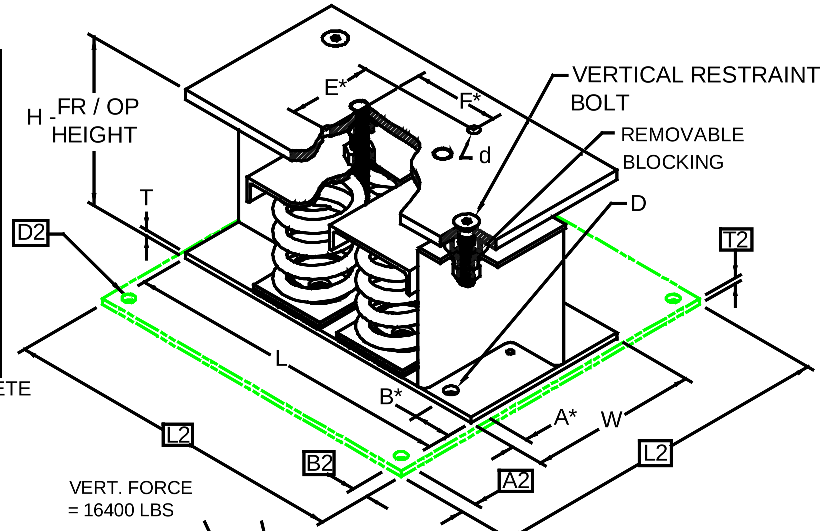
FLS 2" DEFLECTION ISOLATOR
IP UNITS (INCHES AND POUNDS)

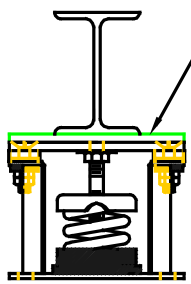
TYPE	L	W	T	A	B	D	E	F	d	H
2-8000/18000	21.50	11.00	0.38	1.50	1.50	1.06	5.50	5.50	0.69	11.00

A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE

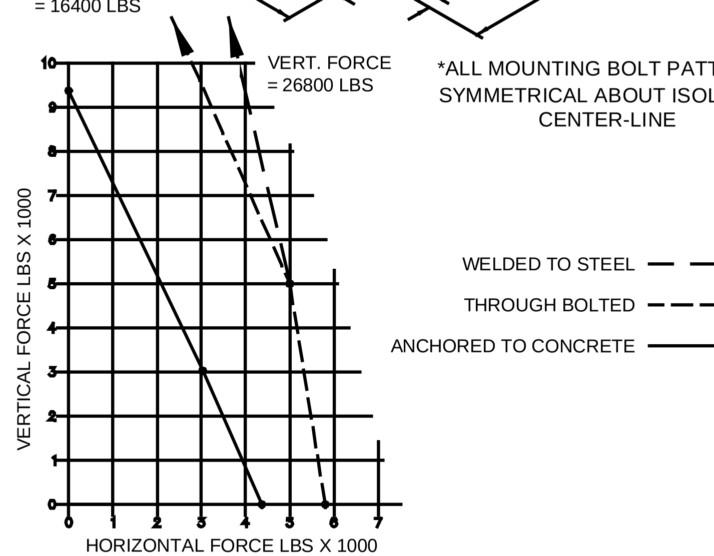
STANDARD RATINGS		SPRING COIL						
		COLOR			FREE		RATED	
TYPE	SIZE	OUTER	INNER1	INNER2	HT.	O.D.	LOAD	DEFL.
FLS	2-8000	ORANGE			7.00	5.00	8000	2.00
FLS	2-10000	BLUE			7.00	5.00	10000	2.00
FLS	2-11000	BLUE	BLUE		7.00	5.00	11000	2.00
FLS	2-12100	BLUE	GREEN		7.00	5.00	12100	2.02
FLS	2-13000	BLUE	BLACK		7.00	5.00	13000	2.00
FLS	2-14000	BLUE	ORANGE		7.00	5.00	14000	2.00
FLS	2-15600	BLUE	ORANGE	GREEN	7.00	5.00	15600	2.00
FLS	2-16400	BLUE	RED		7.00	5.00	16400	2.00
FLS	2-18000	BLUE	RED	GREEN	7.00	5.00	18000	2.00

2-8000/18000 REQUIRES 0.75 DIA. x 4.75 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
2-8000/18000 ANCHOR BOLT TORQUE - 150 FT-LB, PULL TEST - 3625 LB





IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE

Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings

DRAWING #S-01-22.24 – FLS 2-8000/18000

RELEASE DATE: 02/01/05

KINETICS Noise Control
DUBLIN, OHIO, USA • MISSISSAUGA, ONTARIO, CANADA

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Email: sales@kineticsnoise.com

DOCUMENT:
P3.2.2-7

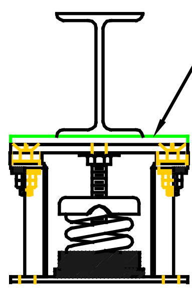
VISCMA MEMBER

FLS 4" DEFLECTION ISOLATOR
IP UNITS (INCHES AND POUNDS)

TYPE	L	W	T	A	B	D	E	F	d	H
4-100/1600	10.75	6.00	0.25	0.75	0.75	0.69	2.75	2.75	0.56	13.00

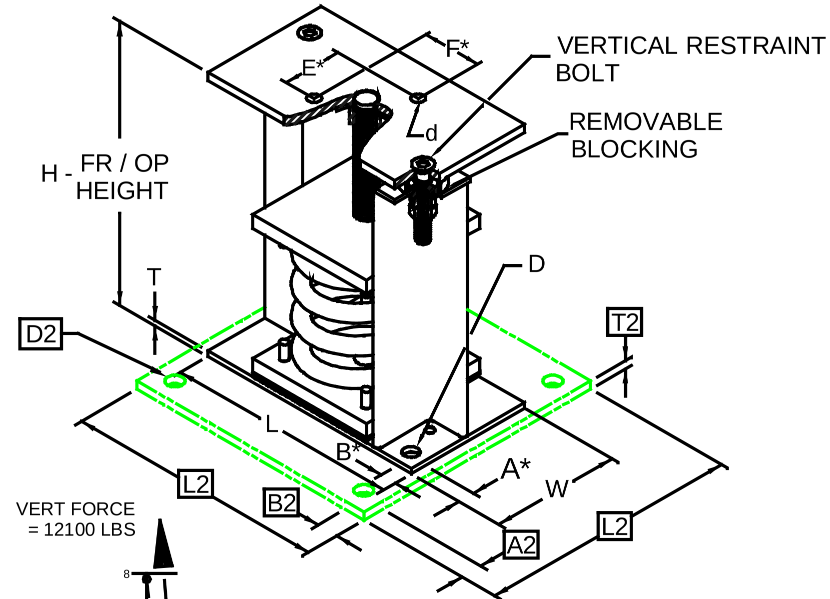
STANDARD RATINGS		SPRING COIL				
			FREE		RATED	
TYPE	SIZE	COLOR	HT.	O.D.	LOAD	DEFL.
FLS	4-100	GRAY	10.00	5.63	100	4.00
FLS	4-250	BLUE	10.00	5.63	250	4.00
FLS	4-500	GREEN	10.00	5.63	500	4.00
FLS	4-750	BLACK	10.00	5.63	750	4.00
FLS	4-1000	RED	10.00	5.63	1000	4.00
FLS	4-1250	BROWN	10.00	5.63	1250	4.00
FLS	4-1600	ORANGE	10.00	5.63	1600	4.00

4-100/1600 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
4-100/1600 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB

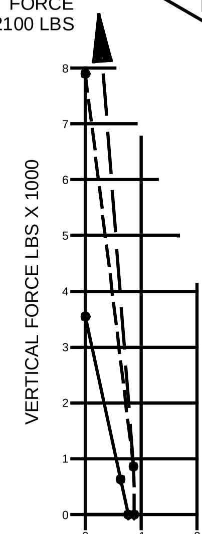


IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED

A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings

DRAWING #S-01-22.41 – FLS 4-100/1600

RELEASE DATE: 02/01/05

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DOCUMENT:
P3.2.2-8

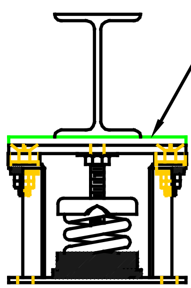
VISCMA MEMBER

FLS 4" DEFLECTION ISOLATOR
IP UNITS (INCHES AND POUNDS)

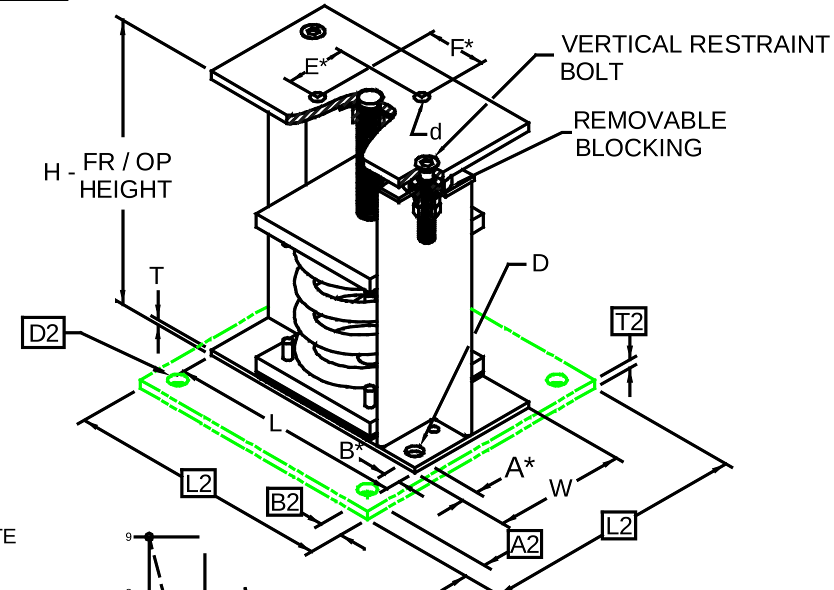
TYPE	L	W	T	A	B	D	E	F	d	H
4-2250/5800	15.50	8.00	0.25	0.75	1.75	0.69	5.50	5.50	0.69	14.88

STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLS	4-2250	BEIGE		11.50	8.00	2250	4.00
FLS	4-2500	BEIGE	BLUE	11.50	8.00	2500	4.00
FLS	4-2750	BEIGE	GREEN	11.50	8.00	2750	4.00
FLS	4-3000	BEIGE	BLACK	11.50	8.00	3000	4.00
FLS	4-3250	BEIGE	RED	11.50	8.00	3250	4.00
FLS	4-3500	BEIGE	BROWN	11.50	8.00	3500	4.00
FLS	4-3850	BEIGE	ORANGE	11.50	8.00	3850	4.00
FLS	4-4200	CHROME		11.50	8.00	4200	4.00
FLS	4-4450	CHROME	BLUE	11.50	8.00	4450	4.00
FLS	4-4700	CHROME	GREEN	11.50	8.00	4700	4.00
FLS	4-4950	CHROME	BLACK	11.50	8.00	4950	4.00
FLS	4-5200	CHROME	RED	11.50	8.00	5200	4.00
FLS	4-5450	CHROME	BROWN	11.50	8.00	5450	4.00
FLS	4-5800	CHROME	ORANGE	11.50	8.00	5800	4.00

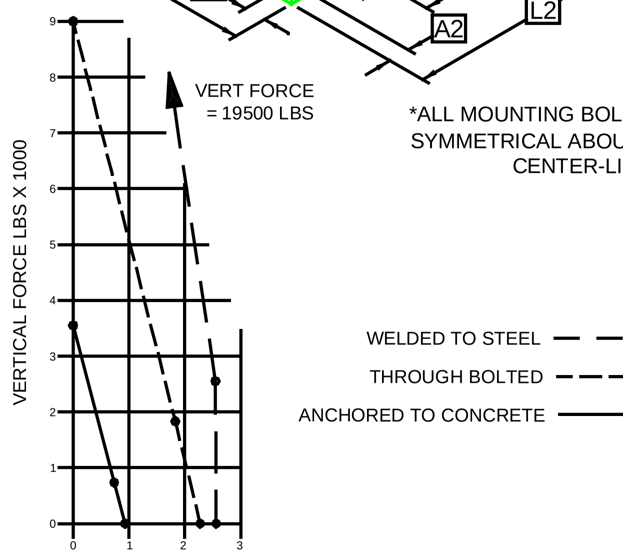
4-2250/5800 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
4-2250/5800 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB



A2, B2, L2, T2, D2 DIMENSIONS REFER TO OPTIONAL BASE-PLATE USED TO INCREASE RATING WHEN ATTACHED TO CONCRETE



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings

DRAWING #S-01-22.42 – FLS 4-2250/5800

RELEASE DATE: 02/01/05

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DOCUMENT:
P3.2.2-9

VISCMA MEMBER

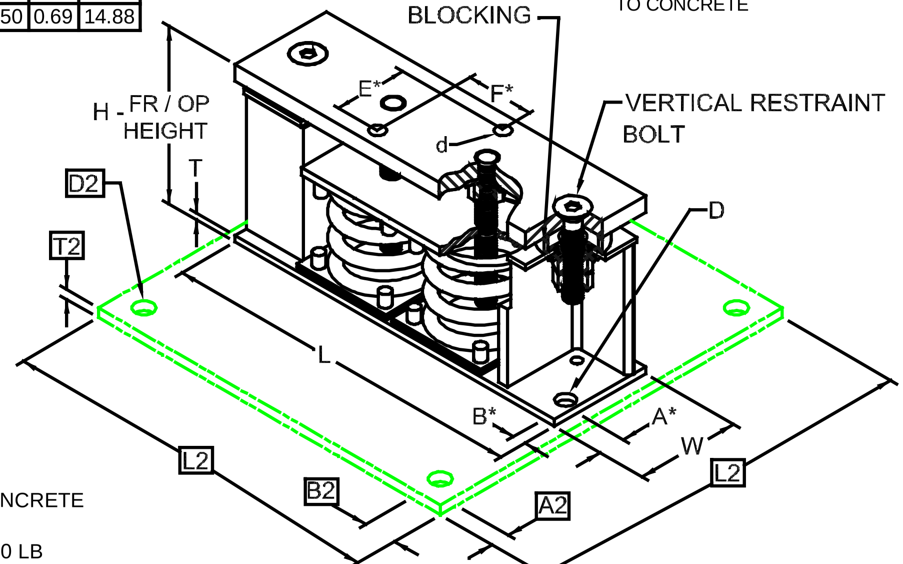
FLS 4" DEFLECTION ISOLATOR

IP UNITS (INCHES AND POUNDS)

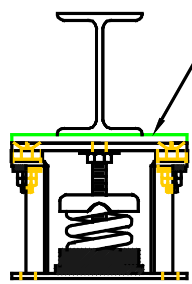
TYPE	L	W	T	A	B	D	E	F	d	H
4-5500/11600	25.50	8.00	0.38	1.13	1.75	0.81	5.50	5.50	0.69	14.88

STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLS	4-5500	BEIGE	GREEN	11.50	8.00	5500	4.00
FLS	4-6000	BEIGE	BLACK	11.50	8.00	6000	4.00
FLS	4-6500	BEIGE	RED	11.50	8.00	6500	4.00
FLS	4-7000	BEIGE	BROWN	11.50	8.00	7000	4.00
FLS	4-7700	BEIGE	ORANGE	11.50	8.00	7700	4.00
FLS	4-8400	CHROME		11.50	8.00	8400	4.00
FLS	4-8900	CHROME	BLUE	11.50	8.00	8900	4.00
FLS	4-9400	CHROME	GREEN	11.50	8.00	9400	4.00
FLS	4-9900	CHROME	BLACK	11.50	8.00	9900	4.00
FLS	4-10400	CHROME	RED	11.50	8.00	10400	4.00
FLS	4-10900	CHROME	BROWN	11.50	8.00	10900	4.00
FLS	4-11600	CHROME	ORANGE	11.50	8.00	11600	4.00

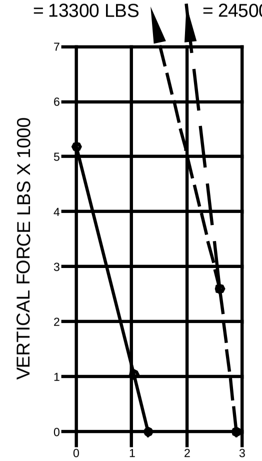
4-5500/11600 REQUIRES 0.62 DIA. x 4.00 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
4-5500/11600 ANCHOR BOLT TORQUE - 75 FT-LB, PULL TEST - 2670 LB



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE



IF EQUIP SUPPORT STEEL IS 90° TO THE LONG ISOLATOR AXIS, AN ADD'L PLATE EQUAL IN THICKNESS TO THE TOP PLATE IS REQUIRED



Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings

DRAWING #S-01-22.43 – FLS 4-5500/11600

RELEASE DATE: 02/01/05

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DOCUMENT: P3.2.2-10

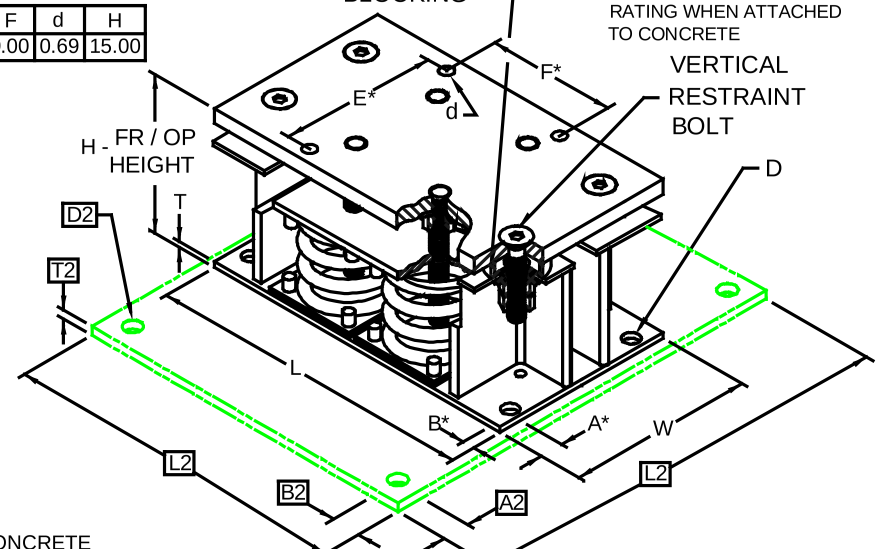
VISCMA MEMBER

FLS 4" DEFLECTION ISOLATOR
IP UNITS (INCHES AND POUNDS)

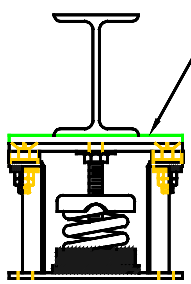
TYPE	L	W	T	A	B	D	E	F	d	H
4-11000/23200	27.00	17.00	0.75	1.00	1.00	0.81	9.00	9.00	0.69	15.00

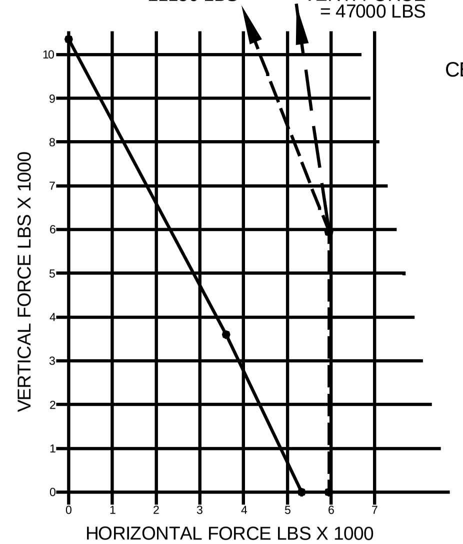
STANDARD RATINGS		SPRING COIL					
		COLOR		FREE		RATED	
TYPE	SIZE	OUTER	INNER	HT.	O.D.	LOAD	DEFL.
FLS	4-11000	BEIGE	GREEN	11.50	8.00	11000	4.00
FLS	4-12000	BEIGE	BLACK	11.50	8.00	12000	4.00
FLS	4-13000	BEIGE	RED	11.50	8.00	13000	4.00
FLS	4-14000	BEIGE	BROWN	11.50	8.00	14000	4.00
FLS	4-15400	BEIGE	ORANGE	11.50	8.00	15400	4.00
FLS	4-16800	CHROME		11.50	8.00	16800	4.00
FLS	4-17800	CHROME	BLUE	11.50	8.00	17800	4.00
FLS	4-18800	CHROME	GREEN	11.50	8.00	18800	4.00
FLS	4-19800	CHROME	BLACK	11.50	8.00	19800	4.00
FLS	4-20800	CHROME	RED	11.50	8.00	20800	4.00
FLS	4-21800	CHROME	BROWN	11.50	8.00	21800	4.00
FLS	4-23200	CHROME	ORANGE	11.50	8.00	23200	4.00

4-11000/23200 REQUIRES 0.75 DIA. x 4.75 MIN. EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
4-11000/23200 ANCHOR BOLT TORQUE - 150 FT-LB, PULL TEST - 3625 LB



*ALL MOUNTING BOLT PATTERNS SYMMETRICAL ABOUT ISOLATOR CENTER-LINE





Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- MINIMUM COIL OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- HOUSINGS MAY BE USED FOR BLOCKING DURING EQUIPMENT ERECTION

FLS Submittal Drawings
DRAWING #S-01-22.44 – FLS 4-11000/23200

RELEASE DATE: 02/01/05

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DOCUMENT:
P3.2.2-11

VISCMA MEMBER

FHS 1" DEFLECTION SEISMIC ISOLATOR

TYPE	L	W	H	D	Z	T	A	E
1-35/805	7.32	3.00	5.86	0.44	0.50	0.38	0.69	1.50
1-250/2200	9.56	5.00	7.36	0.81	0.62	0.38	0.88	2.50
1-2465/3500	9.56	5.00	7.36	0.81	0.62	0.38	0.88	2.50

I-P UNITS (INCHES AND POUNDS)

STANDARD RATINGS

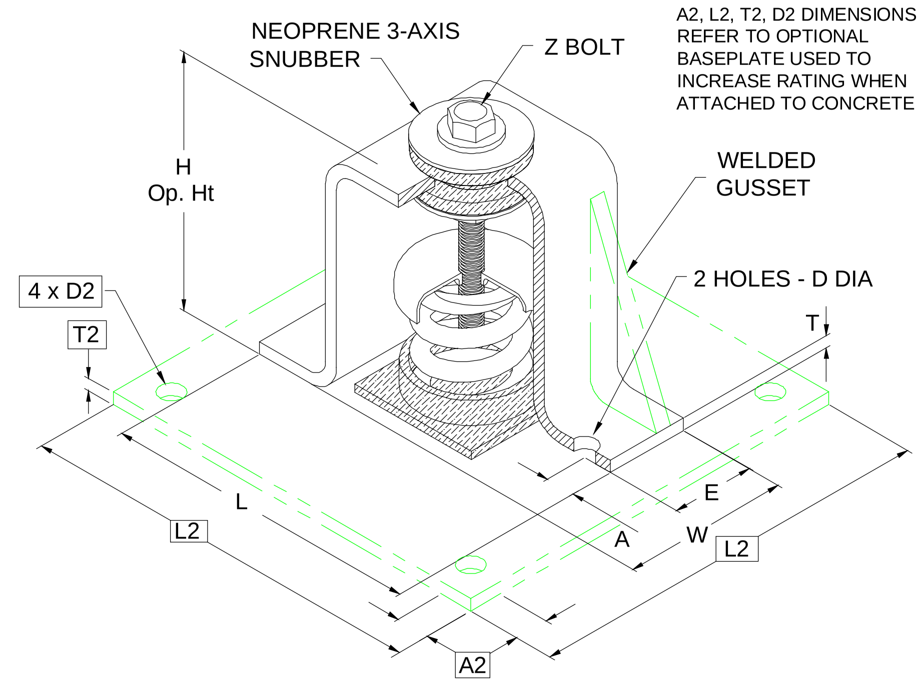
TYPE	SIZE	COIL	NOMINAL FREE HT	O.D.	CAPACITY
1-35/805	1-35	BLUE	3.00	1.75	35
	1-70	GREEN	3.00	1.75	70
	1-120	GRAY	3.00	1.75	120
	1-220	BROWN	3.00	1.75	220
	1-370	ORANGE	3.00	1.75	370
	1-500	BEIGE	3.00	1.75	500
	1-600	CHROME	3.00	1.75	600
	1-700	BGE/WHT	3.00	1.75	700
	1-805	CHR/WHT	3.00	1.75	800
1-250/2200	1-250	BLUE	4.00	3.00	250
	1-450	GREEN	4.00	3.00	450
	1-625	BLACK	4.00	3.00	625
	1-800	GRAY	4.00	3.00	800
	1-1000	RED	4.00	3.00	1000
	1-1250	BROWN	4.00	3.00	1250
	1-1700	ORANGE	4.00	3.00	1700
	1-2200	ORG/GRY	4.00	3.00	2200
1-2465/3500 *	1-2465	BLUE	4.00	3.00	2465
	1-2865	BLU/GRY	4.00	3.00	2865
	1-3500	BLU/BRN	4.00	3.00	3500

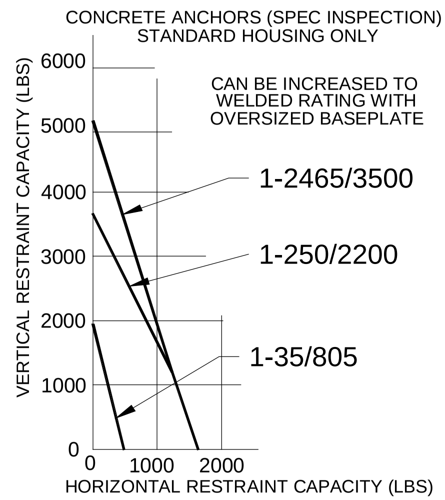
* INCLUDES WELDED GUSSET AS SHOWN

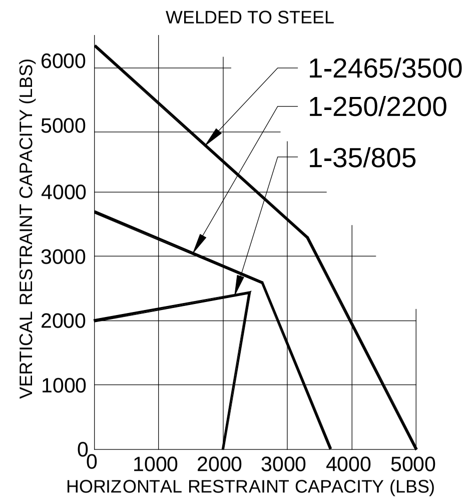
1-35/805 REQUIRES 0.38 DIA x 2.50 MIN EMBED ANCHORS IN CONCRETE
1-250/3500 REQUIRES 0.75 DIA x 4.75 MIN EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
1-35/805 ANCHOR BOLT TORQUE - 25 FT LB, PULL TEST - 1210 LB
1-250/3500 ANCHOR BOLT TORQUE - 150 FT LB, PULL TEST - 3625 LB

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- 0.25 NOMINAL CLEARANCE IN SNUBBING ELEMENTS.
- MINIMUM OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- OSHPD APPROVAL NUMBER R-0433







Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

FHS Submittal Drawings

DRAWING # S-01.35-1A – FHS 1-35/805 1-250/2200 1-2465/3500

RELEASE DATE: 11/3/03

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DOCUMENT:
P3.2.3-1

VISCMA MEMBER

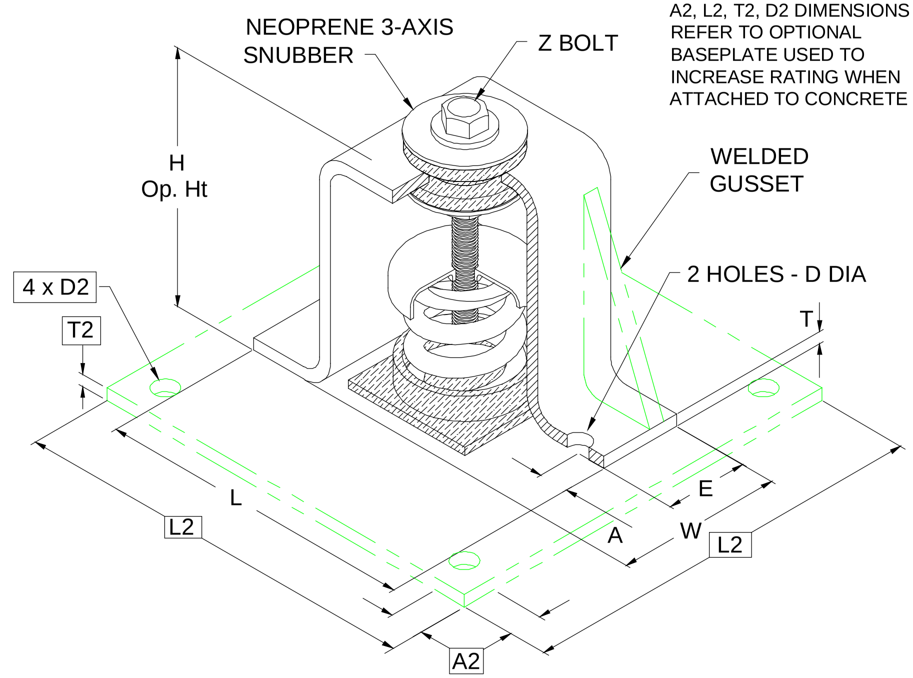
FHS 2" DEFLECTION SEISMIC ISOLATOR

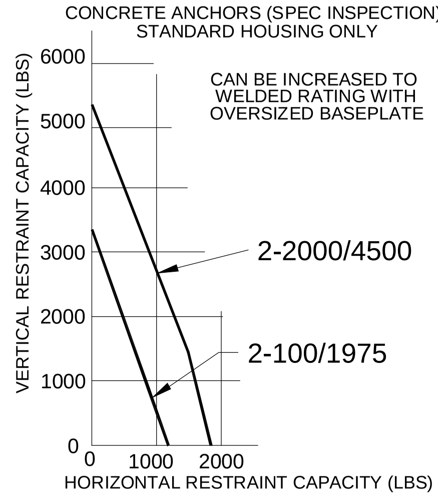
TYPE	L	W	H	D	Z	T	A	E
2-100/1600	10.38	5.00	8.72	0.69	0.50	0.50	0.75	2.50
2-1975	10.38	5.00	8.72	0.69	0.50	0.50	0.75	2.50
2-2000/4500	11.50	6.00	11.13	1.06	0.75	0.50	0.88	3.00

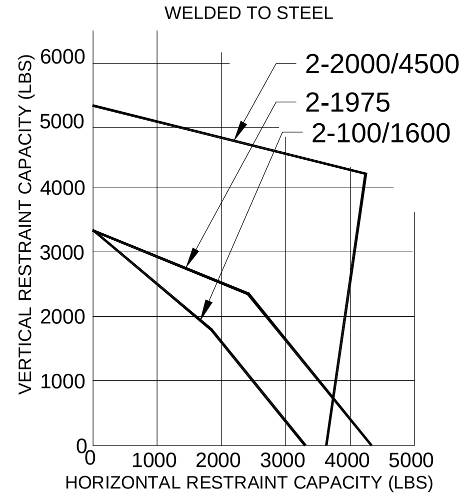
I-P UNITS (INCHES AND POUNDS)

STANDARD RATINGS		COIL	NOMINAL FREE HT	O.D.	CAPACITY
TYPE	SIZE				
2-100/1600	2-100	GRAY	5.75	3.50	100
	2-250	BLUE	5.75	3.50	250
	2-500	GREEN	5.75	3.50	500
	2-750	BLACK	5.75	3.50	750
	2-995	ORANGE	5.75	3.50	995
	2-1400	ORG/GRN	5.75	3.50	1400
	2-1600	RED	5.75	3.50	1600
2-1975 *	2-1975	RED/GRN	5.75	3.50	1975
2-2000/4500*	2-2000	ORANGE	7.00	5.00	2000
	2-2500	BLUE	7.00	5.00	2500
	2-2750	BLU/BLU	7.00	5.00	2750
	2-3025	BLU/GRN	7.00	5.00	3025
	2-3500	BLU/ORG	7.00	5.00	3500
	2-3900	BLU/ORG/GRN	7.00	5.00	3900
	2-4100	BLU/RED	7.00	5.00	4100
	2-4500	BLU/RED/GRN	7.00	5.00	4500

* INCLUDES WELDED GUSSET AS SHOWN







Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

2-100/1975 REQUIRES 0.62 DIA x 4.0 MIN EMBED ANCHORS IN CONCRETE
2-2000/4500 REQUIRES 1.0 DIA x 6.0 MIN EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
2-100/1975 ANCHOR BOLT TORQUE - 75 FT LB, PULL TEST - 2670 LB
2-2000/4500 ANCHOR BOLT TORQUE - 200 FT LB, PULL TEST - 5310 LB

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- 0.25 NOMINAL CLEARANCE IN SNUBBING ELEMENTS.
- MINIMUM OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- OSHPD APPROVAL NUMBER R-0433

FHS Submittal Drawings

DRAWING # S-01.35-2A – FHS 2-100/1600 2-1975 2-2000/4500

RELEASE DATE: 11/3/03

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FHS 4" DEFLECTION SEISMIC ISOLATOR

TYPE	L	W	H	D	Z	T	A	E
4-100/1600	12.25	7.00	13.85	0.69	0.62	0.50	0.81	3.50
4-2250/5800	14.76	10.00	16.00	1.06	0.88	0.50	0.94	5.00

I-P UNITS (INCHES AND POUNDS)

STANDARD RATINGS

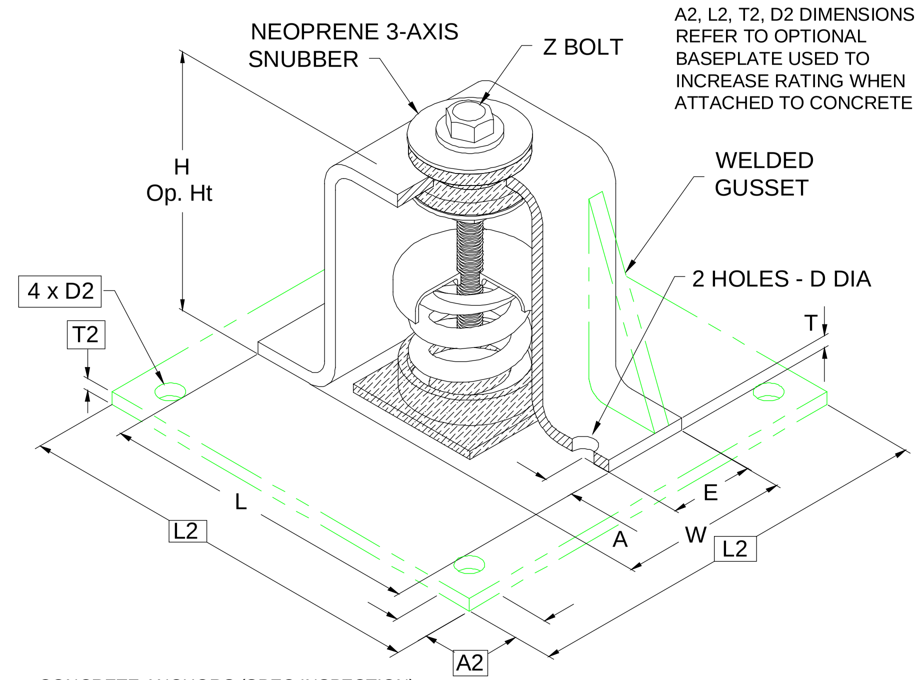
TYPE	SIZE	COIL	NOMINAL FREE HT	O.D.	CAPACITY
4-100/1600	4-100	GRAY	10.00	5.63	100
	4-250	BLUE	10.00	5.63	250
	4-500	GREEN	10.00	5.63	500
	4-750	BLACK	10.00	5.63	750
	4-1000	RED	10.00	5.63	1000
	4-1250	BROWN	10.00	5.63	1250
	4-1600	ORANGE	10.00	5.63	1600
2-2250/5800 *	4-2250	BEIGE	11.50	8.00	2250
	4-2500	BGE/BLU	11.50	8.00	2500
	4-2750	BGE/GRN	11.50	8.00	2750
	4-3000	BGE/BLK	11.50	8.00	3000
	4-3250	BGE/RED	11.50	8.00	3250
	4-3500	BGE/BRN	11.50	8.00	3500
	4-3850	BGE/ORG	11.50	8.00	3850
	4-4200	CHROME	11.50	8.00	4200
	4-4450	CHR/BLU	11.50	8.00	4450
	4-4700	CHR/GRN	11.50	8.00	4700
	4-4950	CHR/BLK	11.50	8.00	4950
	4-5200	CHR/RED	11.50	8.00	5200
	4-5450	CHR/BRN	11.50	8.00	5450
	4-5800	CHR/ORG	11.50	8.00	5800

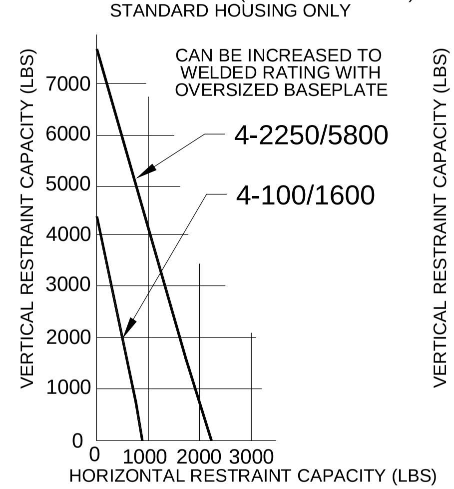
* INCLUDES WELDED GUSSET AS SHOWN

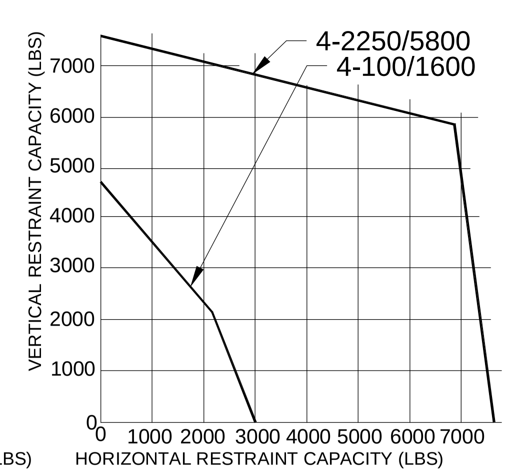
4-100/1600 REQUIRES 0.62 DIA x 4.0 MIN EMBED ANCHORS IN CONCRETE
4-2250/5800 REQUIRES 1.0 DIA x 9.0 MIN EMBED ANCHORS IN CONCRETE
(ALLOWABLE LOADS BASED ON 3000 PSI MIN CONCRETE)
4-100/1600 ANCHOR BOLT TORQUE - 75 FT LB, PULL TEST - 2670 LB
4-2250/5800 ANCHOR BOLT TORQUE - 200 FT LB, PULL TEST - 5310 LB

SPECIFICATIONS:

- VERTICALLY AND LATERALLY RESTRAINED SPRING ISOLATOR WITH CONSTANT FREE AND OPERATING HEIGHT AND REPLACEABLE NEOPRENE SNUBBING ELEMENTS.
- 0.25 NOMINAL CLEARANCE IN SNUBBING ELEMENTS.
- MINIMUM OVERLOAD OF 50%.
- MINIMUM Kx/Ky RATIO OF 1.0.
- ALL ELEMENTS SAFE AT SOLID LOADING.
- POWDER COATED COILS AND HOT DIPPED GALVANIZED BRACKET
- OSHPD APPROVAL NUMBER R-0433







Computed horiz and vert seismic load combinations must fall within the restraint capacity envelope. Contact KNC for bolted to steel data.

FHS Submittal Drawings

DRAWING # S-01.35-3A – FHS 4-100/1600 4-2250/5800

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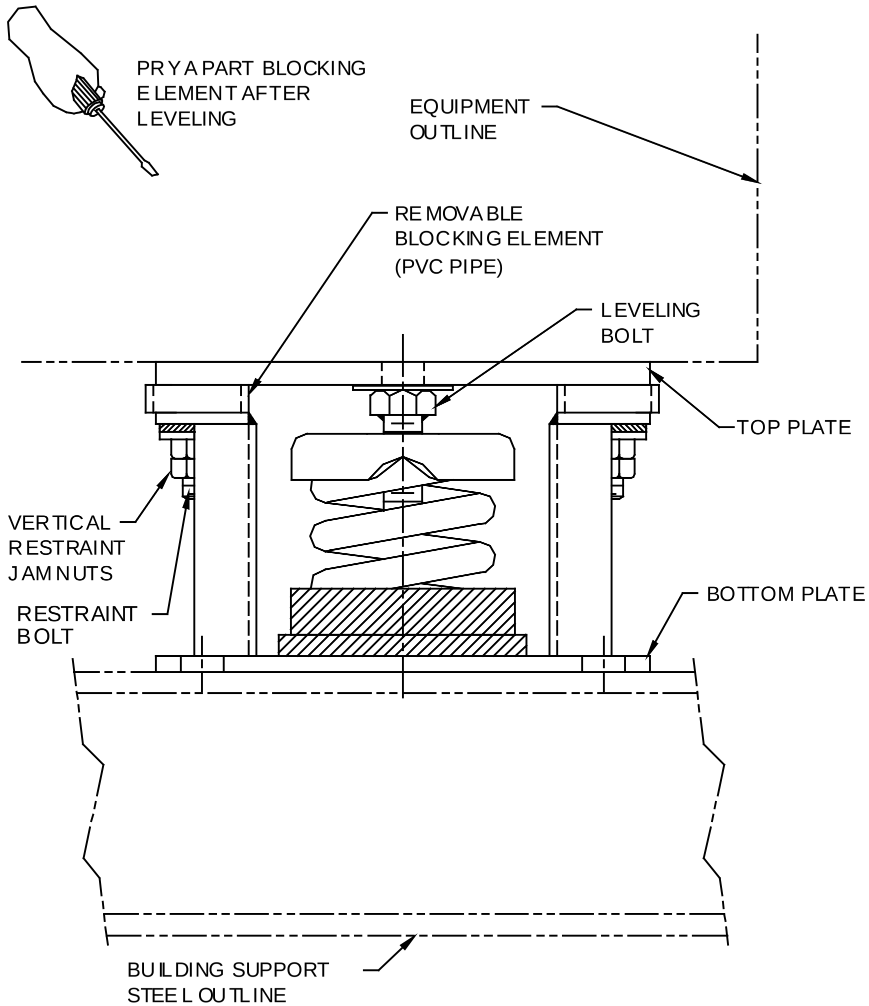

INSTALLATION INSTRUCTIONS

KINETICS MODEL (FLS & FLSS) SPRING ISOLATOR

NOTE:
KINETICS NOISE CONTROL SUGGESTS THAT MODEL FLS & FLSS ISOLATORS BE ON THE JOBSITE PRIOR TO ARRIVAL OF THE EQUIPMENT.

1. COORDINATE THE LOCATION OF EACH ISOLATOR WITH THE APPROPRIATE SUBMITTAL DRAWING AND WITH THE COLOR CODE CHART PROVIDED FOR THE SPRINGS.
2. PLACE THE ISOLATORS IN THEIR PROPER LOCATION AND ATTACH BOTTOM PLATE TO THE BUILDING SUPPORT STEEL.
3. SET THE EQUIPMENT FOOT, BRACKET OR SUPPORT STEEL ON TOP OF THE ISOLATORS AND ATTACH TO THE FLS TOP PLATE PER PROJECT SPECIFICATIONS.
4. LOOSEN THE VERTICAL RESTRAINT JAM NUTS TO THE END OF THE RESTRAINT BOLTS.
5. IN TURN, ROTATE THE LEVELING BOLTS COUNTER-CLOCKWISE SEVERAL COMPLETE TURNS ON EACH ISOLATOR UNTIL THE BLOCKING ELEMENT CAN BE REMOVED BY PRYING APART WITH A SCREWDRIVER. IT WILL BE NECESSARY TO MAKE SEVERAL CIRCUITS OF THE ISOLATORS IN ORDER TO UNIFORMLY RAISE THE EQUIPMENT. DO NOT ATTEMPT TO PLACE ALL THE WEIGHT ON ANY ONE ISOLATOR, THIS MAY RESULT IN DAMAGE TO THE ISOLATOR.
6. DO NOT ATTEMPT TO MOVE ISOLATORS LATERALLY WITH THE WEIGHT OF THE EQUIPMENT ON THEM. IF IT IS NECESSARY TO MOVE THE EQUIPMENT, REMOVE THE EQUIPMENT FROM THE ISOLATORS FIRST. FAILURE TO FOLLOW THIS PROCEDURE COULD RESULT IN DAMAGE TO THE ISOLATORS.
7. WHEN THE EQUIPMENT IS LEVEL PER THE EQUIPMENT MANUFACTURER'S TOLERANCE, TIGHTEN THE VERTICAL RESTRAINING NUTS FINGER TIGHT, THE BACK OFF ONE FULL TURN. LOCK THE BOLTS WITH JAM NUTS PROVIDED.
8. DISCARD ALL BLOCKING ELEMENTS.

FLSS / FLS Installation Instructions

Drawing # SS-900915

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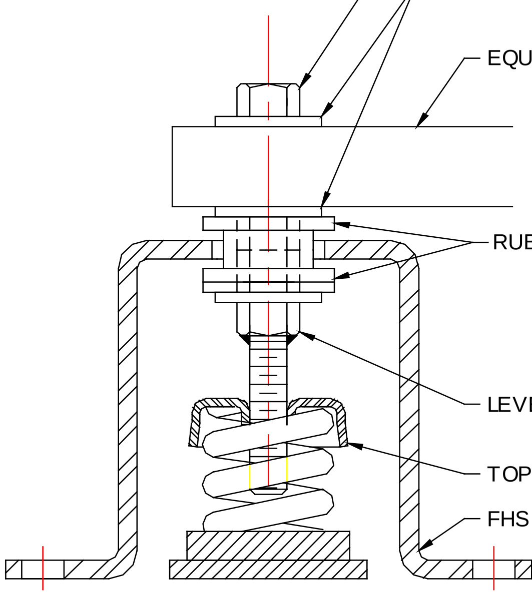

INSTALLATION DRAWING

INSTALLATION INSTRUCTIONS FOR TYPE FHS KINETICS SPRING ISOLATION MOUNT

1. COORDINATE THE LOCATION OF EACH ISOLATOR WITH THE APPROPRIATE SUBMITTAL DRAWING.
2. REMOVE THE ATTACHMENT BOLT AND ONE WASHER FROM THE TOP OF THE LEVELING NUT. INSERT IT INTO THE EQUIPMENT BRACKET (IT IS NOT NECESSARY TO INSTALL THE SPRING AT THIS POINT)
3. ALIGN THE EQUIPMENT AND CENTER THE ISOLATOR

   ISOLATOR HOUSING ANCHOR BOLT LOCATIONS.
4. RAISE THE EQUIPMENT OR EQUIPMENT BASE AND INSTALL THE ISOLATOR ANCHORS IN THE FLOOR.
5. LOCATE THE SPRINGS AND LOWER THE EQUIPMENT. NOTE

   WITH APPROXIMATELY THE DESIRED FLOOR CLEARANCE. (TAKE CARE NOT TO PUSH THE EQUIPMENT SIDEWAYS.)
6. INSTALL ANCHOR NUTS TO FIRMLY ATTACH THE FHS HOUSING TO THE FLOOR OR HOUSEKEEPING PAD.
7. LOOSELY BOLT EQUIPMENT TO THE ISOLATOR USING THE ATTACHMENT BOLT.
8. ADJUST THE ISOLATOR BY TURNING THE LEVELING NUT CCW UNTIL THE FHS HOUSING TOP PLATE IS CENTERED BETWEEN THE RUBBER SNUBBING PADS ON THE LEVELING SCREW. IN A SIMILAR MANNER, CONTINUE WITH THE ADJUSTMENT OF THE REMAINING ISOLATORS.
9. TIGHTEN THE ADJUSTMENT BOLT, THUS BOLTING THE SPRING TO THE SUPPORTED EQUIPMENT AND LOCKING THE LEVELING BOLT AGAINST TURNING
10. DO NOT ATTEMPT TO MOVE THE ISOLATORS LATERALLY WITH THE WEIGHT OF THE EQUIPMENT ON THEM. IF IT IS NECESSARY TO MOVE THE EQUIPMENT, REMOVE THE WEIGHT FROM THE ISOLATORS BY RAISING THE EQUIPMENT BEFORE MOVING.

FHS Installation Instructions

Drawing # SS-960892

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CHAPTER P4

KRMS / RQ ELASTOMERIC ISOLATORS AND RESTRAINTS

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Description

Kinetics Model RQ Vibration Isolators are one-piece molded neoprene mounts with encapsulated metal inserts. The metal inserts provide all-directional resistance for horizontally and vertically applied loads. Each isolator incorporates two bolt-down holes on the bottom load surface and a steel top load plate for attachment to the supported equipment. The neoprene is highly oil resistant and has been designed to operate within the strain limits of the isolator to provide the maximum isolation and longest life expectancy possible using neoprene compounds. Model RQ is designed for up to 0.15" (4 mm) deflection, available in two sizes and four capacities from 500 lbs. to 1300 lbs. (227 kg to 591 kg). Kinetics Model RQ is recommended for the isolation of vibration produced by small pumps, vent sets, low pressure packaged air-handling units, etc., and is usually selected when first cost must be minimized.

Specifications

Vibration isolators shall be neoprene, molded from oil-resistant compounds, with a cast-in-top steel load transfer plate for bolting to supported equipment and a bolt-down plate with holes provided for anchoring to the supporting structure. Isolator shall provide lateral load resistance for loads applied parallel to mounting surface. Neoprene vibration isolators shall have minimum operating static deflections as shown on the Vibration Isolation Schedule or as indicated on the project documents but not exceeding published load capabilities.

Neoprene vibration isolators shall be Model RQ, by Kinetics Noise Control, Inc.

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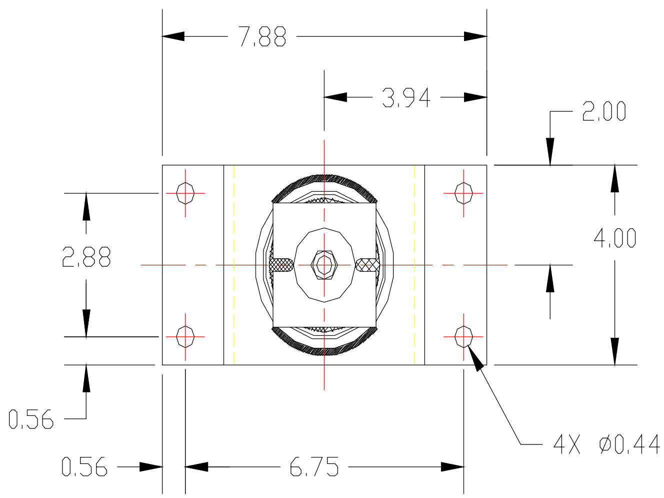
KRMS-A-125/700

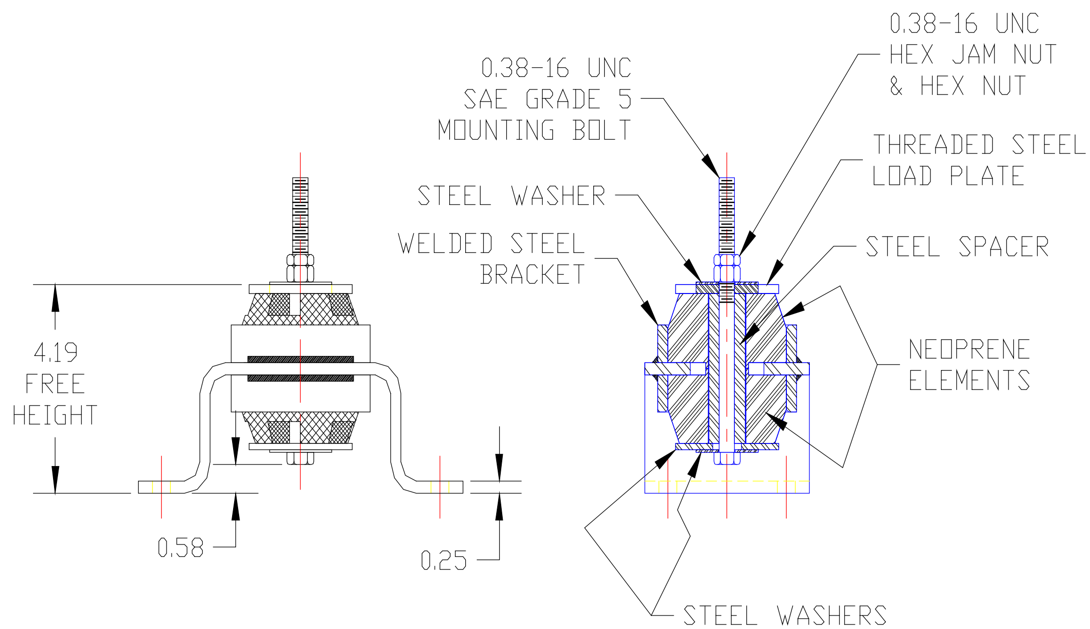
DRAWING # SS-20030150

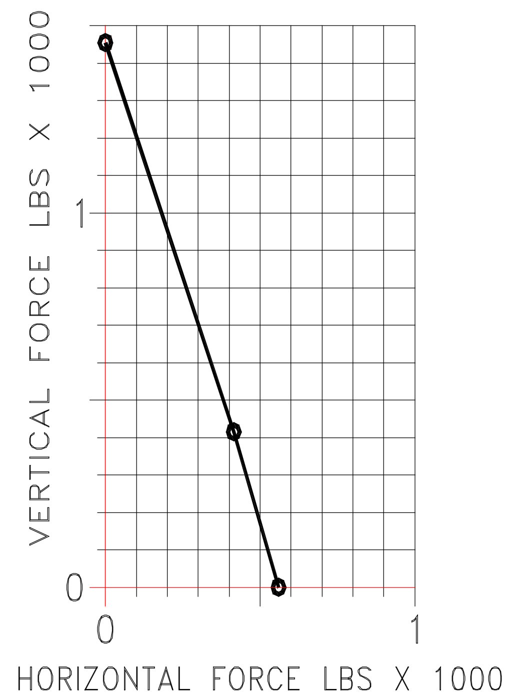
RELEASE DATE: 12/19/03



MODEL	RATED LOAD (LBS)	RATED DEFLECTION (CONFINED) (IN)	DUROMETER (SHORE A)	COLOR CODE DOT
KRMS-A-125	125	0.25	30	BLACK
KRMS-A-175	175	0.25	40	RED
KRMS-A-300	300	0.25	55	GREEN
KRMS-A-450	450	0.25	65	WHITE
KRMS-A-700	700	0.25	75	PURPLE

REFERENCE DRAWING: M-20030150





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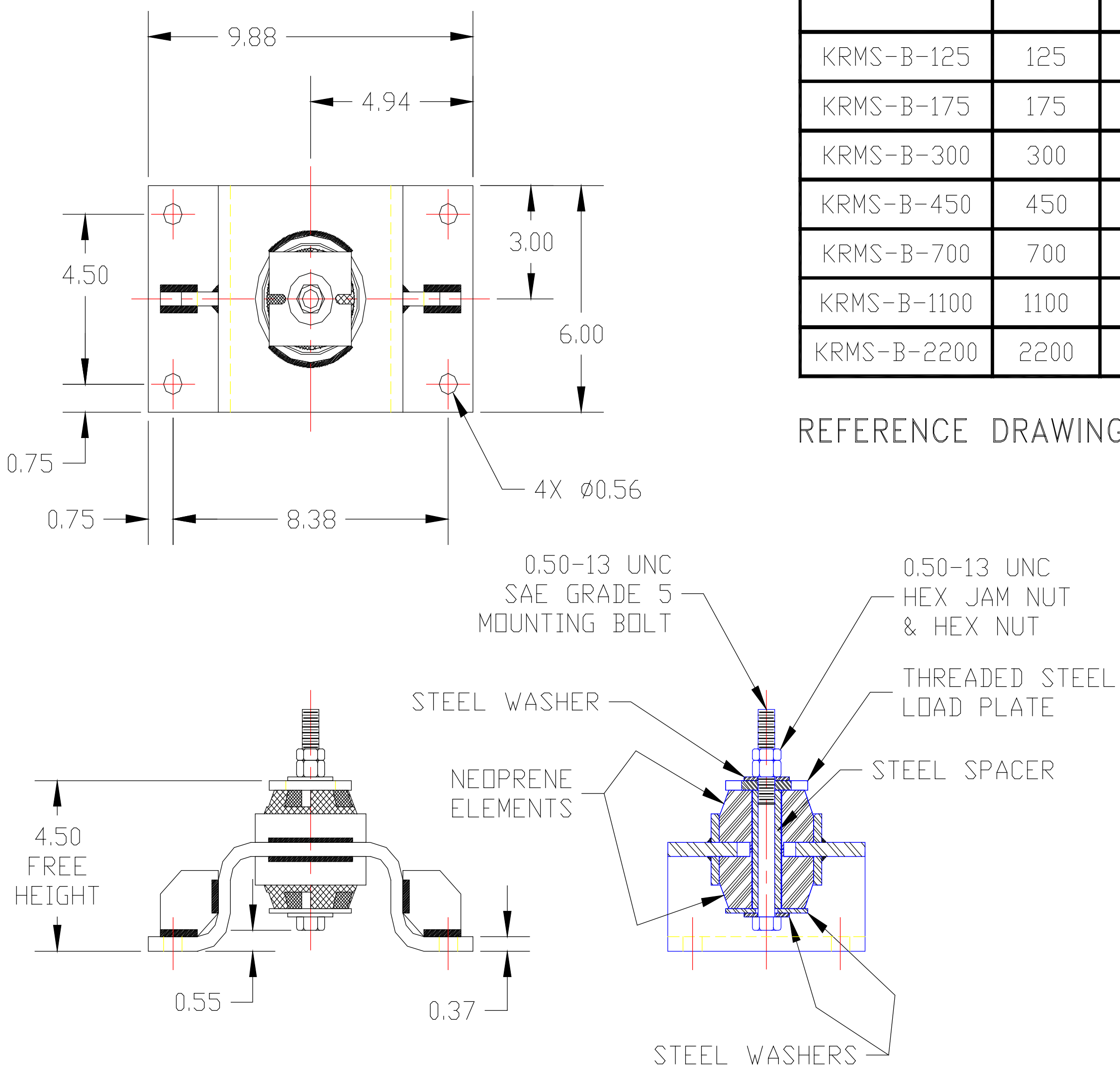
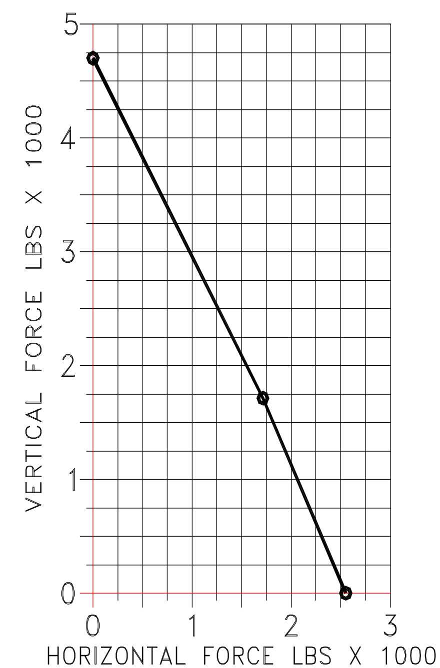
MODEL	RATED LOAD (LBS)	RATED DEFLECTION (CONFINED) (IN)	DUROMETER (SHORE A)	COLOR CODE DOT
KRMS-B-125	125	0.25	30	BLACK
KRMS-B-175	175	0.25	40	RED
KRMS-B-300	300	0.25	55	GREEN
KRMS-B-450	450	0.25	65	WHITE
KRMS-B-700	700	0.25	75	PURPLE
KRMS-B-1100	1100	0.33	80	YELLOW
KRMS-B-2200	2200	0.33	90	PINK

REFERENCE DRAWING: M-20030160





KINETICS™ Seismic Design Manual

KRMS-B-125/2200

DRAWING # SS-20030160

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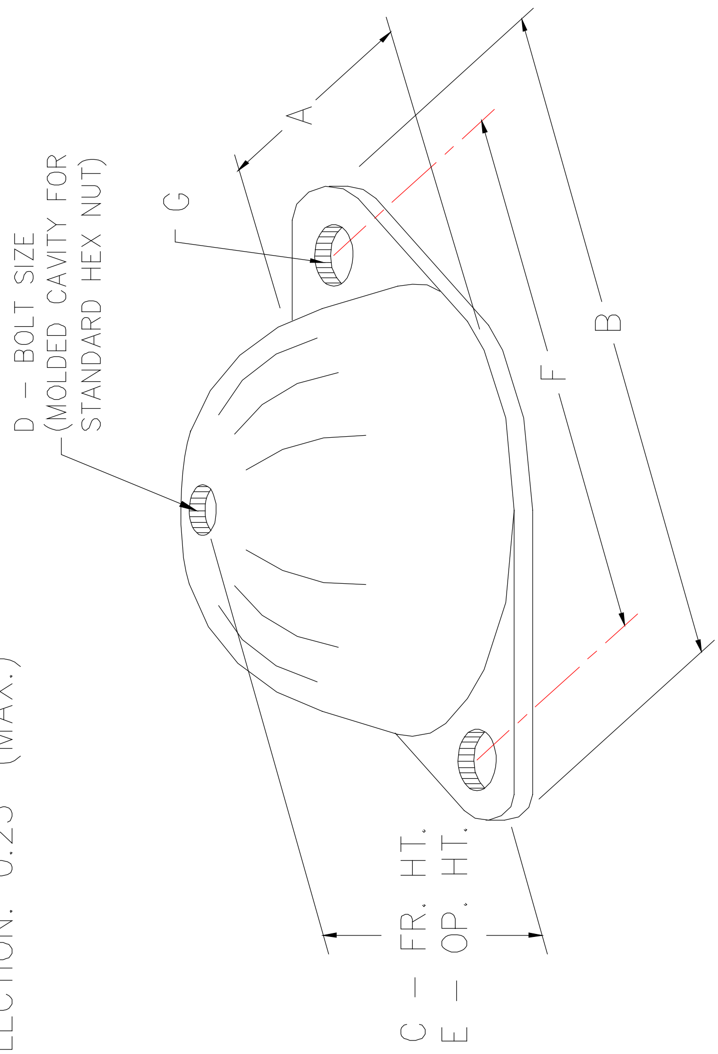
ISOLATOR TYPE	DURO.	RATED COMPRESSION CAPACITY	RATED DEFLECTION	A	B	C	D	E	F	G
RQ−500	40	500 LBS.	0.15	3.25	5.38	1.65	0.50	1.50	4.12	0.53
RQ−750	50	750 LBS.	0.15	3.25	5.38	1.65	0.50	1.50	4.12	0.53
RQ−1000	50	1000 LBS.	0.15	3.88	6.25	1.65	0.62	1.50	5.00	0.53
RQ−1300	60	1300 LBS.	0.15	3.88	6.25	1.65	0.62	1.50	5.00	0.53
RQ−1950	70	1950 LBS.	0.15	3.88	6.25	1.65	0.62	1.50	5.00	0.53

HORIZONTAL SHEAR CAPACITY: 1800 LBS.
HORIZONTAL DEFLECTION: 0.25" (MAX.)



MODEL RQ

DRAWING # S-02.05-1C

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DOCUMENT:

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CHAPTER P5

HS SERIES RESTRAINTS

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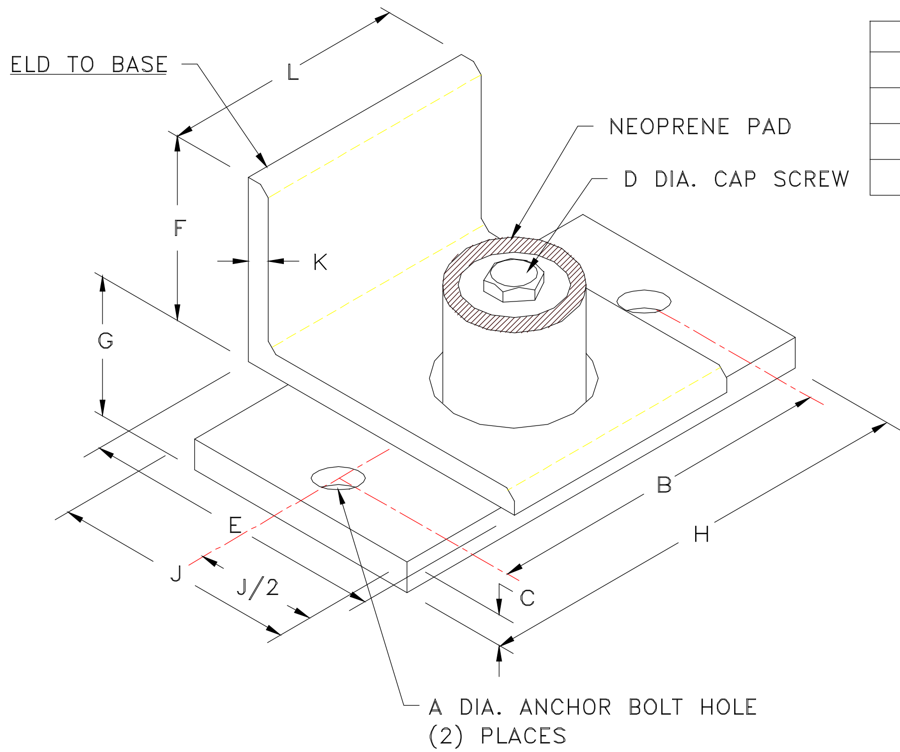
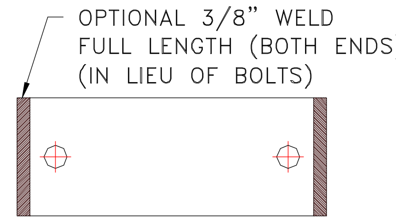
DIMENSIONS

MODEL NO.	A	B	C	D	E	F	G	H	J	K	L
HS−2−2000	.44	6.00	.50	.50	5.00	3.00	1.25	7.50	4.00	.38	4.50
HS−2−4000	.56	6.00	.63	.75	5.00	3.00	1.25	7.50	4.00	.38	4.50
HS−2−6000	.69	7.50	.75	.75	6.00	4.00	2.00	9.50	5.00	.50	6.00
HS−2−8000	.94	10.50	1.00	1.00	6.00	4.00	2.00	13.50	5.00	.50	8.00



LOAD LIMIT VALUES	2000	4000	6000	8000
STANDARD ANCHORS	945#	1308#	1677#	3354#
ANCHORS 100% INSP.	1267#	1854#	2646#	5235#
BOLTED TO STEEL	1624#	2887#	4300#	6966#
WELDED TO STEEL	1779#	3387#	4922#	6966#

ANCHOR LOADS BASED ON ITW TRUBOLT WEDGE ANCHORS IN 3500 PSI STONE AGGREGATE CONCRETE



WELDED ANCHOR PLATE

NOTE:
1. ALL DIMENSIONS IN INCHES.

HS-2 SEISMIC SNUBBER

DRAWING # S-04.13-1A

RELEASE DATE: 12/19/03

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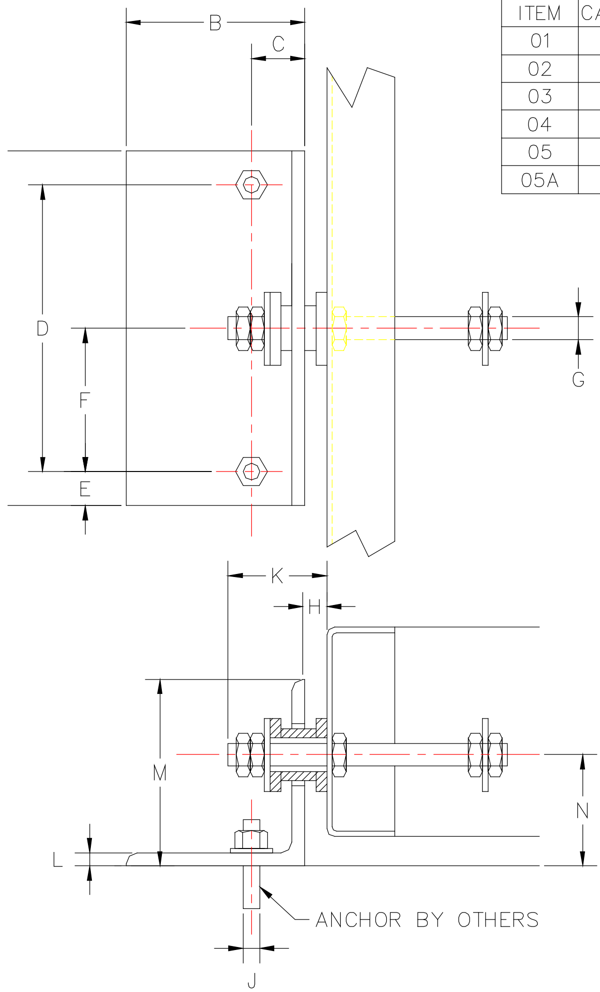
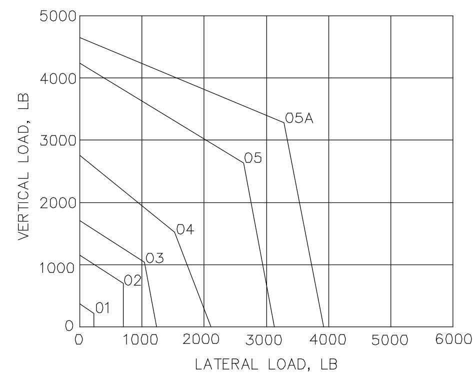
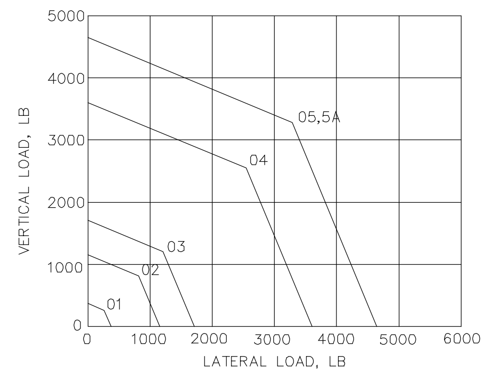
ITEM	LISTED CAPACITY	NO. OF ANC'S	A	B	C	D	E	F	G	H	J	K	L	M	N	EMBED.
01	250	2	6.00	6.00	1.50	4.00	1.00	2.00	0.50	0.50	0.38	3.00	0.38	6.00	3.00	2.5
02	650	2	7.00	6.00	1.50	5.00	1.00	2.50	0.75	0.50	0.50	3.00	0.38	6.00	3.00	3.5
03	1125	2	9.00	6.00	1.75	7.00	1.00	3.50	0.88	0.50	0.63	3.50	0.50	6.00	3.00	4.0
04	2075	2	11.50	6.00	2.00	9.50	1.00	4.75	1.25	0.50	0.88	4.00	0.50	6.00	3.00	4.75
05	3275	2	15.00	8.00	2.00	12.00	1.50	6.00	1.25	0.50	1.00	4.25	0.50	6.00	3.00	6.0
05A	3275	2	15.00	8.00	2.00	12.00	1.50	6.00	1.25	0.50	1.00	4.25	0.50	6.00	3.00	9.0



HS-5 LOAD CAPACITY IN POUNDS



ANCHORED TO CONCRETE



BOLTED OR WELDED TO STEEL

OPERATING CLEARANCE FOR THE HS-5 SNUBBER IS APPROX. 0.25 IN ALL DIRECTIONS.

KINETICS HS-5 SNUBBER LISTED CAPACITIES ARE BASED ON EQUAL SIMULTANEOUSLY APPLIED VERTICAL AND HORIZONTAL LOADS. HORIZONTAL LOADS CAN BE APPLIED ON EITHER AXIS.

CAPACITIES FOR INDIVIDUALLY APPLIED LOADS ARE HIGHER, CONSULT KINETICS FOR DETAILS.

CAPACITIES ASSUME THE USE OF THE INDICATED ANCHORS EMBEDDED THEIR APPROVED EMBEDMENT DEPTH IN 3000 PSI CONCRETE. (NO SPECIAL INSPECTION IS REQUIRED.)

HS-5 SEISMIC SNUBBER

DRAWING # S-04.80-1A

RELEASE DATE: 12/19/03

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ESR / KSR / KSCR **ROOF TOP EQUIPMENT RATED CURBS**

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Kinetics Model ESR

- 1g seismic restraint & 125 mph wind restraint for most equipment
- Access ports for each isolator to inspect, level or change springs after equipment placement
- Up to 4" deflection, powder-coated steel springs with 50% overload capacity
- High-frequency noise isolation pads
- Environmentally inert elastomeric seal for an air- and water-tight closure between the curb and isolation rail
- Supply and return duct support hardware
- Structural steel curb with wood nailer.

Specification

All rooftop air-handling units shall be supported by vibration isolation curbs as manufactured by Kinetics Noise Control. The vibration isolation curbs shall be complete assemblies designed to resiliently support the equipment at the specified elevation and shall constitute a fully enclosed air- and weather-tight system. The isolation curb shall consist of an upper support rail with supply and return duct supports on which the equipment and duct openings rest, and a lower support curb which is attached to the roof structure, separated by free-standing, housed, laterally stable steel springs.

The upper support rail shall provide continuous structural support for the rooftop equipment and shall be designed to provide isolation against casing-radiated vibration in the rooftop equipment housing and structure borne vibration from rotating and mechanical equipment in the rooftop package.

The upper support rail shall consist of a structural channel with sufficient elevation above the spring to preclude interference with the rooftop equipment and permit access to inspect the isolation system after placement of the rooftop equipment. Support of the RTU by weather seal attachment bolt heads is not permitted.

The lower support curb shall be a formed channel fabricated of heavy gauge galvanized steel with a continuous 1-1/2 in x 1-1/2 in (38 mm x 38 mm) nominal wood nailer attached to the isolation support pedestals. The isolation support pedestal, which includes the seismic and wind load restraints, shall be bolted or welded to the building support steel to suitably transfer seismic and wind load forces to the building structure. The lower support curb shall have a minimum elevation of 14 in (356 mm) from the top of the wood nailer to the base of the curb.

Spring components shall be (1 in/25 mm)(2 in/51 mm)(4 in/102 mm) deflection, free-standing, laterally stable steel springs. Springs shall have a lateral stiffness greater than

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1.2 times the rated vertical stiffness and shall be designed for a typical 50% overload to solid. All springs shall have an epoxy-based, powder-coated finish and be color coded to indicate load capacity. Spring coils shall rest on minimum 0.25 in (6 mm) neoprene noise pads.

Seismic and wind load restraints shall be designed to limit movement in all directions. Restraint components shall include neoprene snubbers at all contact points for energy absorption. There shall be no metal-to-metal contact. The isolation curb shall be designed to withstand horizontal wind loads of 125 mph (200 km/h) and seismic forces of 1g. The vibration isolation curb shall be air and weather tight using an elastomeric seal, which is attached to the upper support frame with a galvanized steel clip. The seal shall extend down past the wood nailer of the lower support assembly and flash over the roof material at the wood nailer on the lower support curb. The seal shall be Class A, as tested in accordance with approved Underwriter's Laboratories, Inc., provisions. Metal or combination metal and elastomer seals are not permitted. The seal may not be penetrated for isolator adjustment.

The isolation curb system shall be complete with cross-bracing, as required, as a part of the upper and lower assemblies. Supply and return flex connector support hardware shall be supplied for installation by the contractor in the field. The supports will be clearly marked and dimensioned on the submittal and installation drawings. The support hardware shall be cut-to-length, galvanized steel channels supported and connected with stamped and punched galvanized steel duct support hangers. The support hangers shall allow the support elevation to be equal to or lower than the equipment rail elevation. Supply air and return duct shall be flexibly attached by the contractor to prevent transmission of vibration to the building structure.

Airborne noise control packages, if required, shall be supported by the roof structure within the curb and shall have no rigid contact with the isolation curb. The isolation curb assemblies shall be shipped to the job site with the upper support rail, lower support curb, springs, and restraints completely assembled. The contractor shall be required to assemble the four corners, attach the curb to the roof structure, install cross-bracing and flex connector supports as necessary, and install and attach rooftop equipment.

Vibration isolators shall be selected by the manufacturer for each specific application to comply with deflection requirements as shown on the Vibration Isolation Schedule or as indicated on the project documents.

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Kinetics Model KSCR

- Internal seismic restraint
- 100 mph wind restraint
- 1 in or 2 in deflection springs
- Supply and return flexible connector support hardware
- EPDM air- and weather-tight seal for non-ducted applications
- High profile, non-interference aluminum equipment rail
- Accessible, interchangeable springs

Specification

All rooftop air-handling units shall be supported by vibration isolation curbs as manufactured by Kinetics Noise Control. The vibration isolation curbs shall be complete assemblies designed to resiliently support the equipment at the specified elevation and shall constitute a fully enclosed air- and weather-tight system.

The isolation curb shall consist of an upper support rail with supply and return flexible connector supports on which the equipment and duct openings rest and a lower support curb which is attached to the roof structure, separated by free-standing, unhoused, laterally stable steel springs and lateral seismic and/or wind load restraints. The upper support rail shall provide continuous structural support for the rooftop equipment and shall be designed to provide isolation against casing-radiated vibration in the rooftop equipment housing and structure borne vibration from rotating and mechanical equipment in the rooftop package.

The upper support rail shall consist of an extruded aluminum structural shape with a minimum height of 4.75 in (121 mm) above the spring to preclude interference with the rooftop equipment and permit access to inspect, level, or change the springs after placement of the rooftop equipment.

The lower support curb shall be a formed channel fabricated of heavy gauge galvanized steel with a continuous 1-1/2 in x 1-1/2 in (38 mm x 38 mm) nominal wood nailer. The base plate of the curb shall be 1 in (25 mm) wide and shall be welded, bolted or screwed to the building support steel.

The lower support curb shall have a minimum elevation of 14 in (356 mm). Spring components shall be (1 in/25 mm) (2 in/51 mm) deflection, free-standing, unhoused, laterally stable steel springs. Springs shall have a lateral stiffness greater than 1.0 times the rated vertical stiffness and shall be designed for a typical 50% overload to solid. All springs shall have an epoxy-based, powder-coated finish and be color coded to indicate load capacity. Springs shall rest on a neoprene noise pad. The spring and

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noise pad shall be captured in a retainer cap secured to the lower support curb. The lateral stabilizers shall be stainless steel spring assemblies factory-located and installed to provide seismic and/or wind load restraint. The standard system shall have a 100 mph (161 km/h) wind load restraint capacity and a minimum horizontal restraint capacity of 1,000 lbs. (455 kg) in both axes.

The weather seal shall run continuously around the perimeter of the curb and be joined in the field with one seam using a double-faced elastomeric adhesive. The weather seal shall be fastened to the wood nailer of the lower support curb using screws and an aluminum fascia strip.

Supply and return flexible connector support hardware shall be supplied for installation by the contractor in the field. The supports will be clearly marked and dimensioned on the submittal and installation drawings. The support hardware shall be cut-to-length, galvanized steel channels supported and connected with stamped and punched galvanized steel duct support hangers. The support hangers shall allow the duct support elevation to be equal to or lower than the equipment rail elevation. Supply and return air duct shall be flexibly attached by the contractor to prevent transmission of vibration to the building structure.

The isolation curb assemblies shall be shipped to the job site with the upper support rail, lower support curb, springs, and stabilizers completely assembled. The contractor shall assemble the four corners and attach the curb to the roof structure.

The isolation curb assembly shall include a troubleshooting kit to permit the contractor to level or adjust the loading of the isolation system immediately after placement of the rooftop equipment should the actual weight and/or distribution differ from design values. Vibration isolators shall be selected by the manufacturer for each specific application to comply with deflection requirements as shown on the Vibration Isolation Schedule or as indicated on the project documents.

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Kinetics Model KSR

Kinetics KSR perimeter isolation system is designed and engineered to mount on top of an existing fixed curb system and isolate packaged rooftop equipment from the roof structure. Designed for easy installation, minimum interference with equipment overhang, and with accessible springs, the Kinetics KSR goes well beyond internal isolation by reducing casing-radiated vibration caused by turbulent air flow as well as compressor and fan vibration. KSR rails have a positive elastomeric air and weather seal permitting the inside of the unit to be used as a return air plenum. The KSR mates with the inside of the manufacturer's curb eliminating any internal interference. The KSR also features an impressive family of options including:

- Aluminum weather seal flashing
- Seismic restraint
- Airborne noise control package
- Duct block offs

Specification

Spring components shall be (1 in/25 mm), (2 in/51 mm) deflection, free-standing, unhoused, laterally stable steel springs. Springs shall have a lateral stiffness greater than 1.0 times the rated vertical stiffness and shall be designed for 50% overload to solid.

Springs shall be color coded to indicate load capacity.

Rails shall provide continuous support for the rooftop equipment and shall be designed to provide isolation against casing-radiated vibration in the rooftop equipment housing and structure borne vibration from rotating and mechanical equipment in the rooftop package. Rail assembly shall consist of extruded aluminum top and bottom members connected by spring isolators and a continuous air- and water-tight seal. The seal shall be a beaded elastomeric material retained in a keyway along the top extrusion. The weather strip shall be sealed along the bottom with an aluminum fascia strip.

Rail assemblies shall incorporate means for attachment to the building and the supported equipment and shall incorporate additional stiffening members if necessary to assure stability. Vibration isolators shall be selected by the manufacturer for each specific application to comply with deflection requirements as shown on the Vibration Isolation Schedule or as indicated on the project documents.

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VISCMA MEMBER

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 1 INCH (25 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.

RESTRAINT AND ATTACHMENT DATA

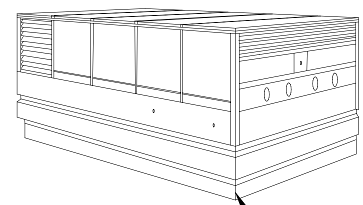
RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL AND VERTICAL SIMULTANEOUS LOADING

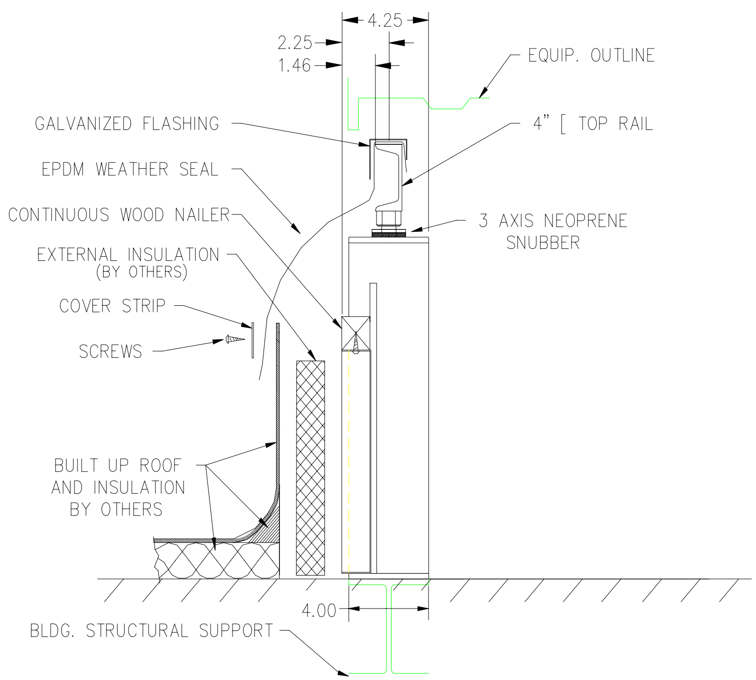
EACH PEDESTAL MUST BE WELDED TO SUPPORTING STEEL WITH A MIN .25" WELD 12" LONG AT EACH END OF THE PEDESTAL BASE

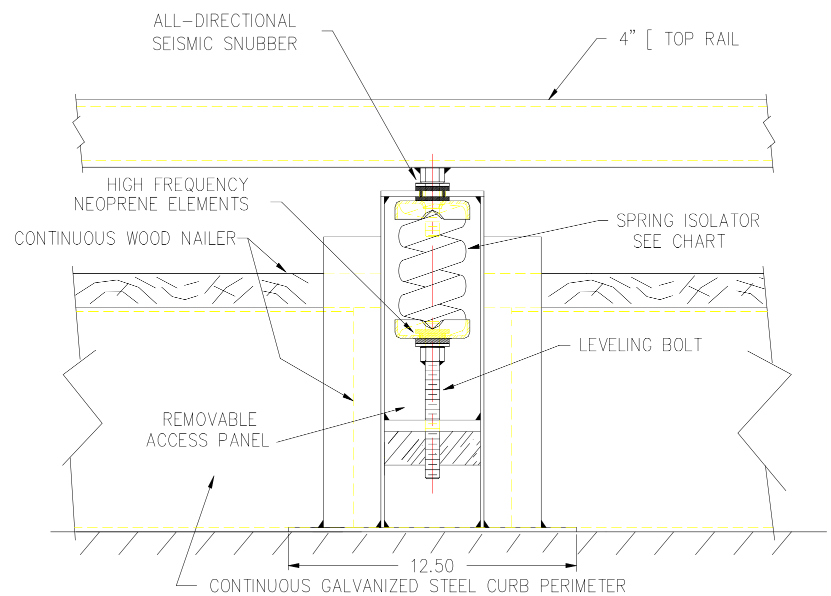
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
250/113	1.00/25	4.0/101	3.0/76	BLUE
450/204	1.00/25	4.0/101	3.0/76	GREEN
625/284	1.00/25	4.0/101	3.0/76	BLACK
800/364	1.00/25	4.0/101	3.0/76	GRAY
1000/455	1.00/25	4.0/101	3.0/76	RED
1250/568	1.00/25	4.0/101	3.0/76	BROWN
1700/773	1.00/25	4.0/101	3.0/76	ORANGE
2200/998	1.00/25	4.0/101	3.0/76	ORG/GRAY
2465/1118	1.00/25	4.0/101	3.0/76	BLUE
2865/1300	1.00/25	4.0/101	3.0/76	BLU/GRAY
3500/1588	1.00/25	4.0/101	3.0/76	BLU/BRN

CAPACITY PER PEDESTAL BY SPRING TYPE

ROOFTOP EQUIPMENT







MODEL ESR-1 ISOLATION RAIL

DRAWING # S-89.100-1A

RELEASE DATE: 4/10/00

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DOCUMENT:
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VISCMA MEMBER

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 1 INCH (25 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

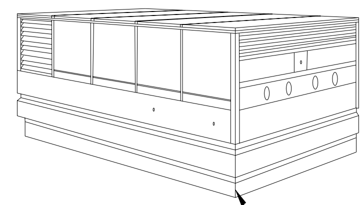
SPRING ISOLATORS ARE PAINTED.

RESTRAINT AND ATTACHMENT DATA

RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL AND VERTICAL SIMULTANEOUS LOADING

FOR STANDARD HEIGHT CURBS THE BOLTING ATTACHMENT SHOWN IS SUITABLE FOR 3000 LB LOADS AS WELL, WITH EXTENDED HEIGHT CURBS CONTACT FACTORY FOR RESTRAINT RATINGS.

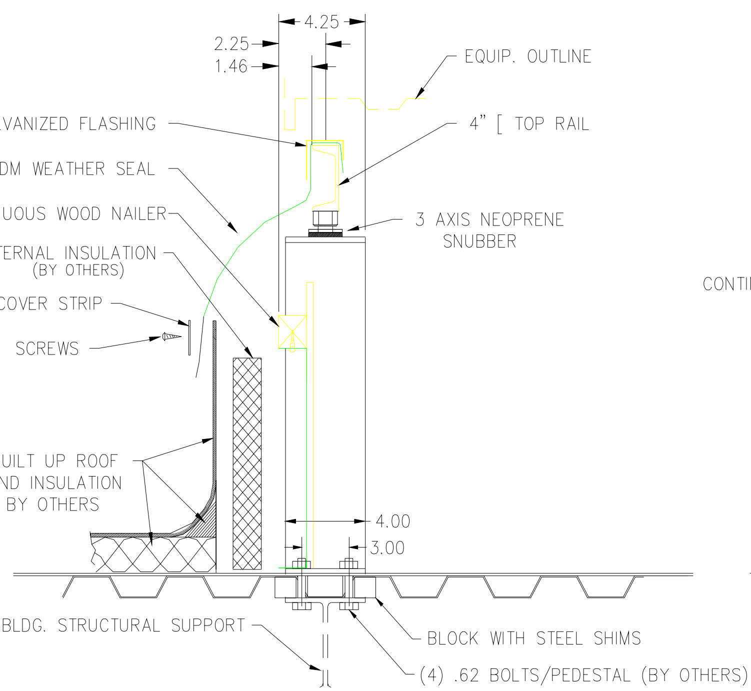
ROOFTOP EQUIPMENT

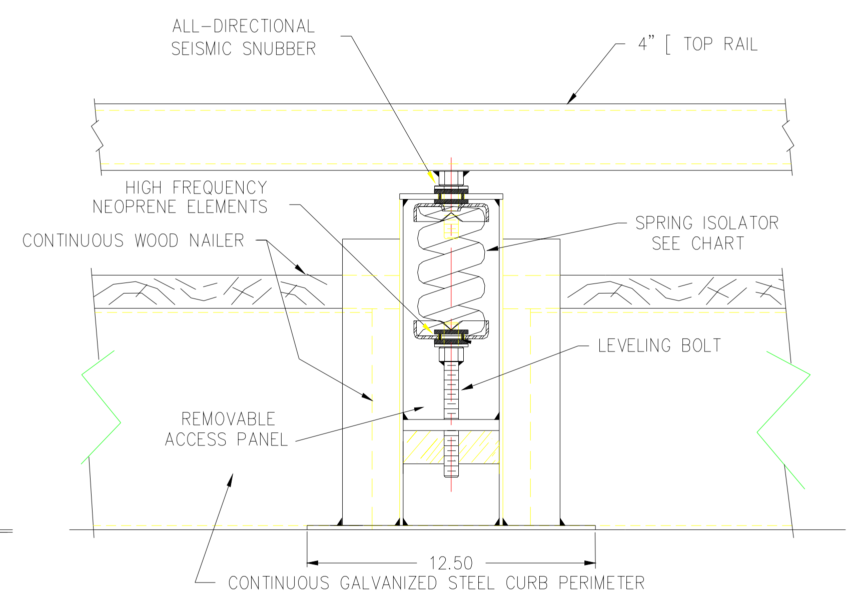


ROOF CURB/ ISOLATION RAIL

RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
250/113	1.00/25	4.0/101	3.0/76	BLUE
450/204	1.00/25	4.0/101	3.0/76	GREEN
625/284	1.00/25	4.0/101	3.0/76	BLACK
800/364	1.00/25	4.0/101	3.0/76	GRAY
1000/455	1.00/25	4.0/101	3.0/76	RED
1250/568	1.00/25	4.0/101	3.0/76	BROWN
1700/773	1.00/25	4.0/101	3.0/76	ORANGE
2100/955	1.00/25	4.0/101	3.0/76	BRN/BRN
2300/1045	1.00/25	4.0/101	3.0/76	BRN/ORG
3200/1454	1.00/25	4.0/101	3.0/76	BRN/BLU

CAPACITY PER PEDESTAL BY SPRING TYPE





MODEL ESR-1 ISOLATION RAIL (BOLT DOWN)

DRAWING # S-89.101

RELEASE DATE: 12/17/96

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DOCUMENT:
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VISCMA MEMBER

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 1 INCH (25 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.

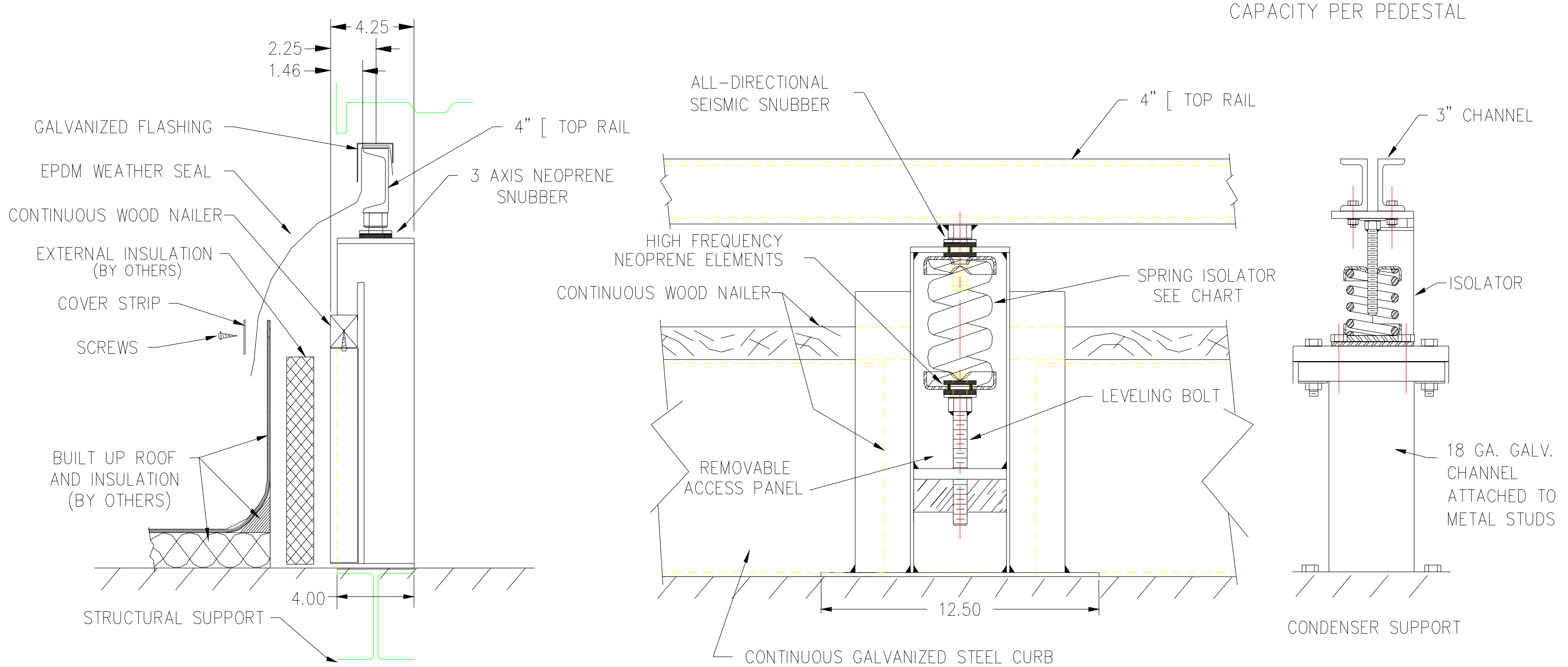
RESTRAINT AND ATTACHMENT DATA

RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL AND VERTICAL SIMULTANEOUS LOADING

EACH PEDESTAL MUST BE WELDED TO SUPPORTING STEEL WITH A MIN .25" WELD 4" LONG AT EACH END OF THE PEDESTAL BASE

RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
250/113	1.00/25	4.0/101	3.0/76	BLUE
450/204	1.00/25	4.0/101	3.0/76	GREEN
625/284	1.00/25	4.0/101	3.0/76	BLACK
800/364	1.00/25	4.0/101	3.0/76	GRAY
1000/455	1.00/25	4.0/101	3.0/76	RED
1250/568	1.00/25	4.0/101	3.0/76	BROWN
1700/773	1.00/25	4.0/101	3.0/76	ORANGE
2200/998	1.00/25	4.0/101	3.0/76	ORG/GRAY
2465/1118	1.00/25	4.0/101	3.0/76	BLUE
2865/1300	1.00/25	4.0/101	3.0/76	BLU/GRAY
3500/1588	1.00/25	4.0/101	3.0/76	BLU/BRN

CAPACITY PER PEDESTAL



ESR-1 ISOLATION CURB W/ CONDENSER SUPPORT

DRAWING # S-89.102-1A

RELEASE DATE: 4/10/00

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VISCMA MEMBER

ESR-2 ISOLATION RAIL

DRAWING # S-89.200-1A

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 2 INCH (50 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.

NOTE:
MODEL ESR WILL PROVIDE CONTINUOUS SUPPORT OF UNIT WEIGHT WITH 4" TOP RAIL.

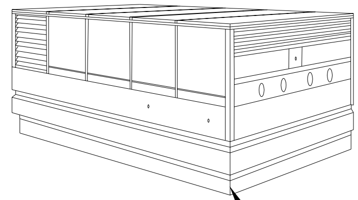
RESTRAINT AND ATTACHMENT DATA

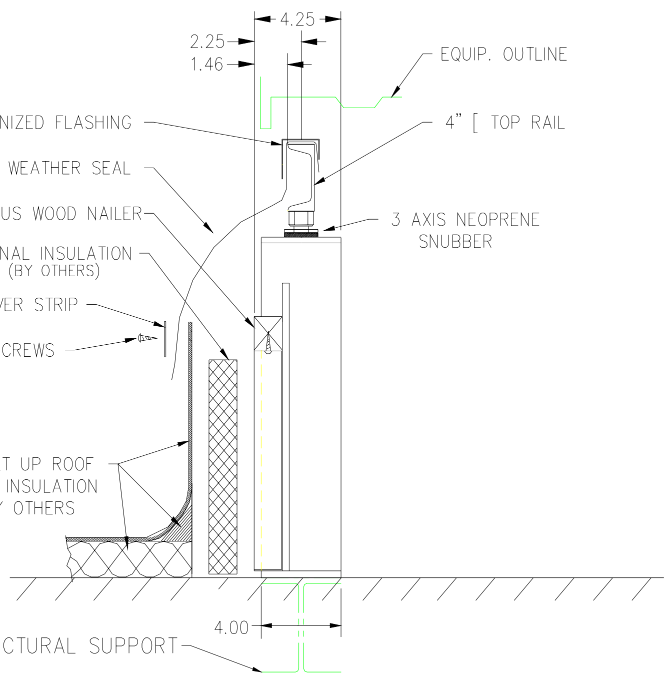
RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL WIND OR SEISMIC LOADING. TO ACHEIVE FULL RATING, ESR MUST BE STANDARD HEIGHT AND EACH PEDESTAL MUST BE WELDED TO SUPPORTING STRUCTURAL STEEL WITH A MIN. 0.25" WELD 12" LONG AT EACH END. 3000 LB CAPACITY CAN ALSO BE ACHIEVED IF BOLTED TO STRUCTURAL STEEL USING 5/8" HARDWARE.

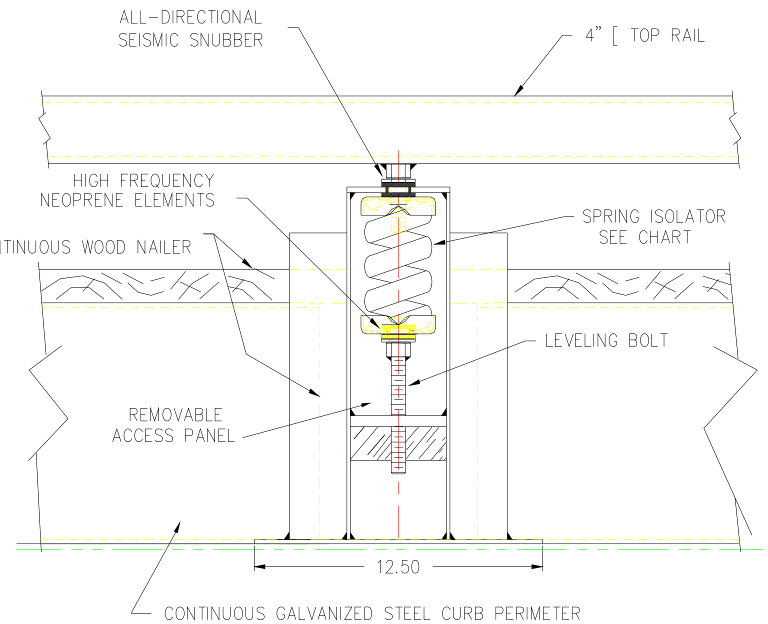
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
100/45	2.00/50	5.75/146	3.5/89	GRAY
250/113	2.00/50	5.75/146	3.5/89	BLUE
500/226	2.00/50	5.75/146	3.5/89	GREEN
750/339	2.00/50	5.75/146	3.5/89	BLACK
995/450	2.00/50	5.88/149	3.5/89	ORANGE
1400/636	2.00/50	5.88/149	3.5/89	ORG/GRN
1600/725	2.00/50	5.88/149	3.5/89	RED
1975/900	2.00/50	5.88/149	3.5/89	RED/GRN

CAPACITY PER PEDESTAL BY SPRING TYPE

ROOFTOP EQUIPMENT







RELEASE DATE: 1/16/01

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VISCMA MEMBER

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 2 INCH (50 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.

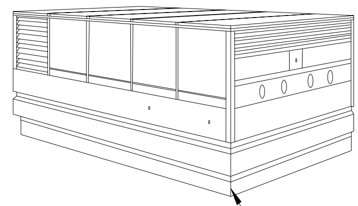
NOTE:
MODEL ESR TO PROVIDE CONTINUOUS SUPPORT OF UNIT WEIGHT WITH 4" TOP RAIL.

RESTRAINT AND ATTACHMENT DATA

RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL AND VERTICAL SIMULTANEOUS LOADING

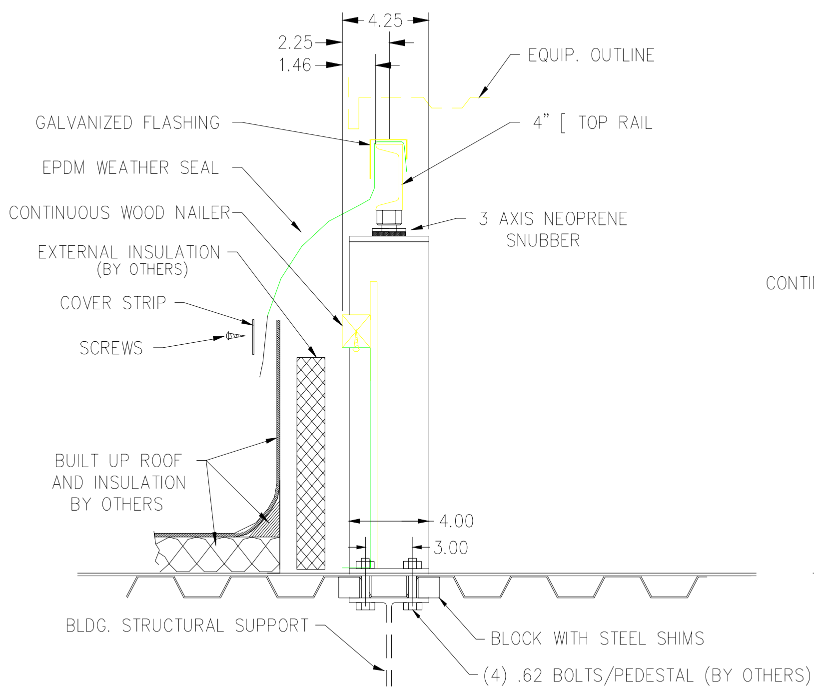
FOR STANDARD HEIGHT CURBS THE BOLTING ATTACHMENT SHOWN IS SUITABLE FOR 3000 LB LOADS AS WELL, WITH EXTENDED HEIGHT CURBS CONTACT FACTORY FOR RESTRAINT RATINGS.

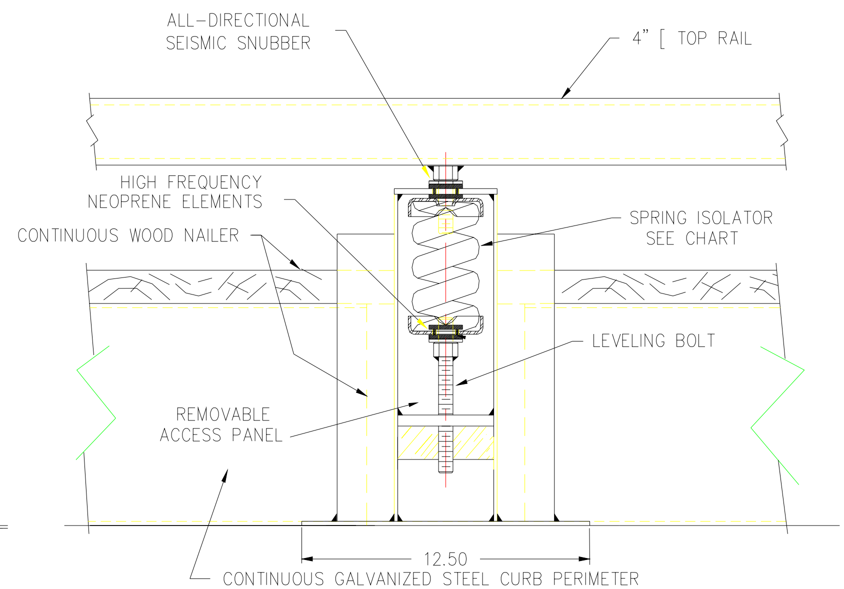
ROOFTOP EQUIPMENT



RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
250/113	2.00/50	5.75/146	3.5/89	BLUE
500/226	2.00/50	5.75/146	3.5/89	GREEN
750/339	2.00/50	5.75/146	3.5/89	BLACK
995/450	2.00/50	5.88/149	3.5/89	ORANGE
1400/636	2.00/50	5.88/149	3.5/89	ORNG/GRN

CAPACITY PER PEDESTAL BY SPRING TYPE





KINETICS™ Seismic Design Manual

MODEL ESR-2 ISOLATION RAIL (BOLT DOWN)

DRAWING # S-89.201

RELEASE DATE: 12/17/96

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DOCUMENT:
P6.2.1

VISCMA MEMBER

ESR-2 ISOLATION CURB W/ CONDENSER SUPPORT

DRAWING # S-89.202-1A

RELEASE DATE: 1/16/01

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 2 INCH (50 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.

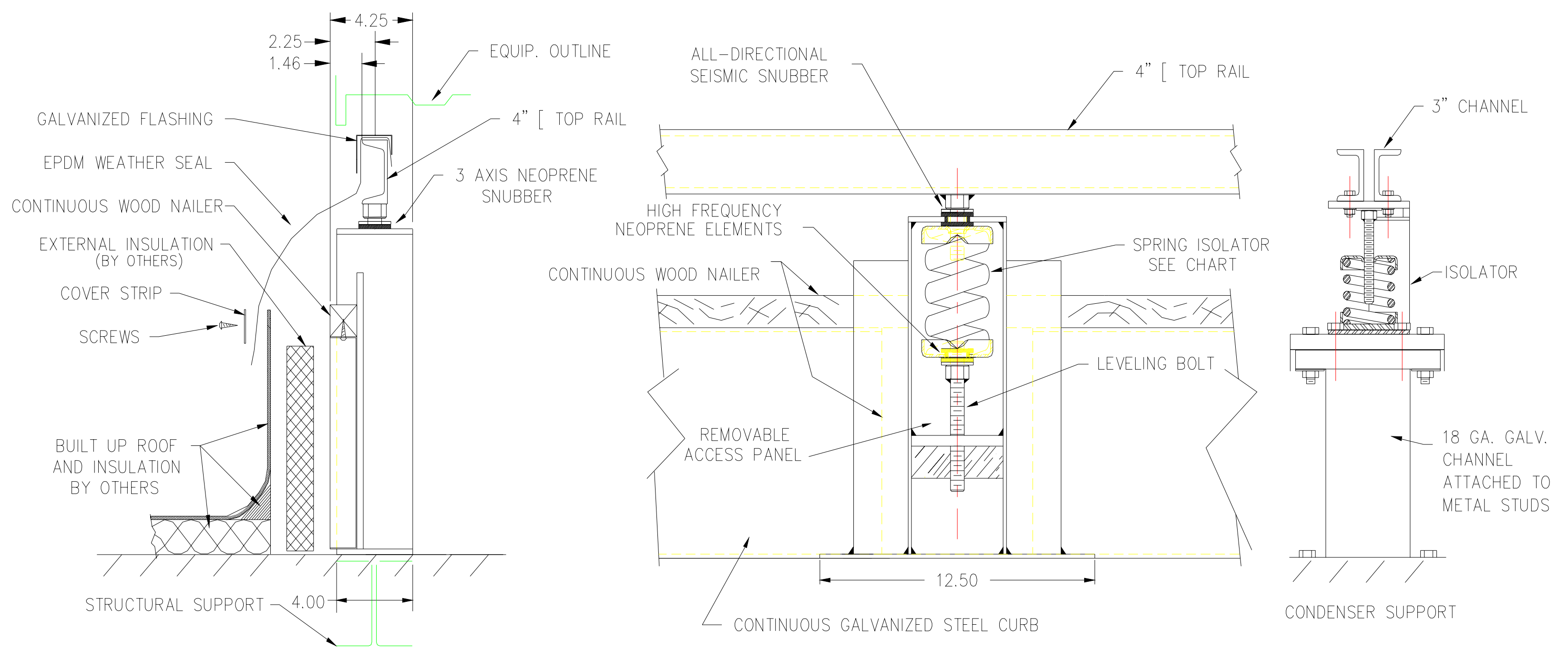
NOTE:
MODEL ESR TO PROVIDE CONTINUOUS SUPPORT OF UNIT WEIGHT WITH 4" TOP RAIL.

RESTRAINT AND ATTACHMENT DATA

RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL WIND OR SEISMIC LOADING. TO ACHEIVE FULL RATING, ESR MUST BE STANDARD HEIGHT AND EACH PEDESTAL MUST BE WELDED TO SUPPORTING STRUCTURAL STEEL WITH A MIN. 0.25" WELD 12" LONG AT EACH END. 3000 LB CAPACITY CAN ALSO BE ACHIEVED IF BOLTED TO STRUCTURAL STEEL USING 5/8" HARDWARE.

RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
100/45	2.00/50	5.75/146	3.5/89	GRAY
250/113	2.00/50	5.75/146	3.5/89	BLUE
500/226	2.00/50	5.75/146	3.5/89	GREEN
750/339	2.00/50	5.75/146	3.5/89	BLACK
995/450	2.00/50	5.88/149	3.5/89	ORANGE
1400/636	2.00/50	5.88/149	3.5/89	ORG/GRN
1600/725	2.00/50	5.88/149	3.5/89	RED
1975/900	2.00/50	5.88/149	3.5/89	RED/GRN

CAPACITY PER PEDESTAL



KINETICS™ Seismic Design Manual

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DOCUMENT:
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VISCMA MEMBER

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 3 INCH (76 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.

RESTRAINT AND ATTACHMENT DATA

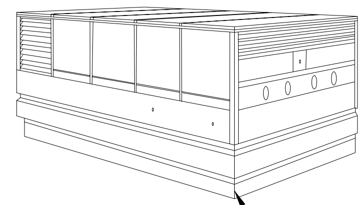
RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL AND VERTICAL SIMULTANEOUS LOADING

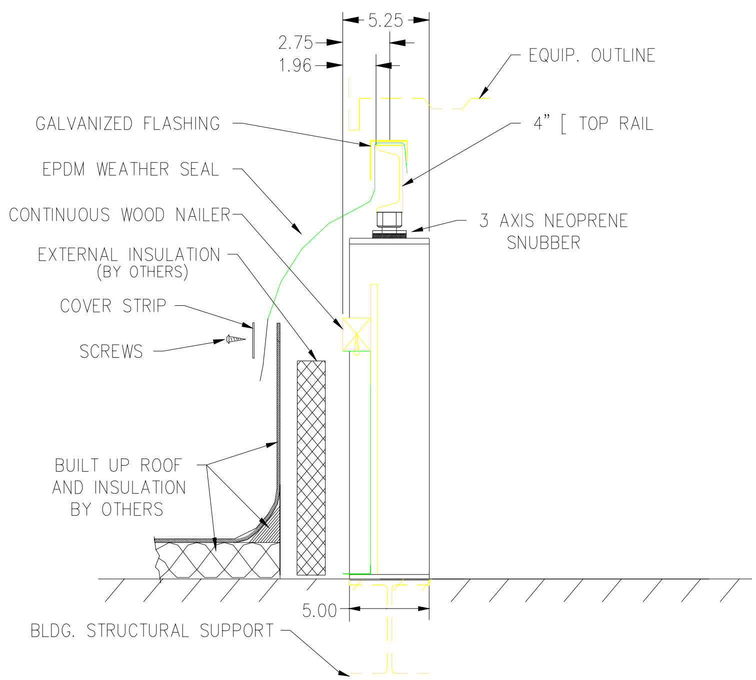
EACH PEDESTAL MUST BE WELDED TO SUPPORTING STEEL WITH A MIN .25" WELD 12" LONG AT EACH END OF THE PEDESTAL BASE

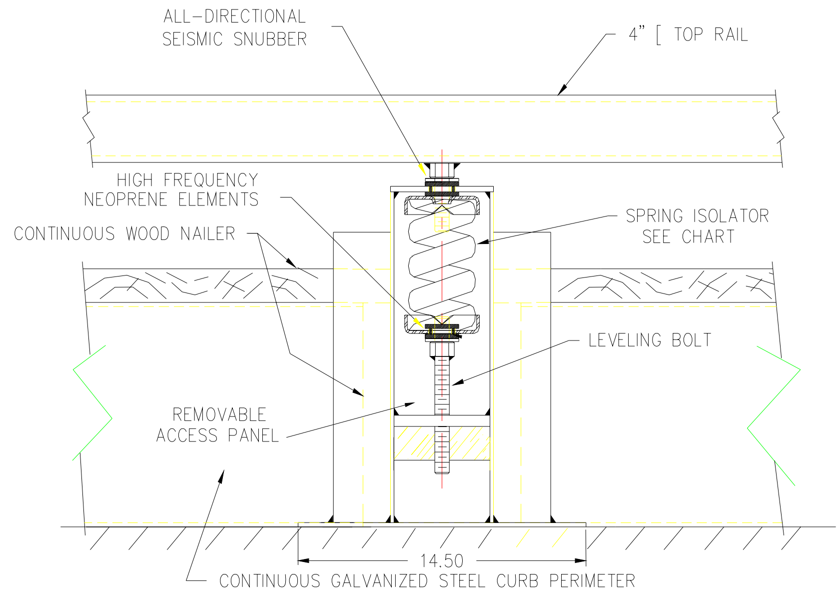
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
115/52	4.0/100	8.5/216	5.0/127	GRAY
285/130	4.0/100	8.5/216	5.0/127	BLUE
570/259	4.0/100	8.5/216	5.0/127	GREEN
850/386	4.0/100	8.5/216	5.0/127	BLACK
1140/518	4.0/100	8.5/216	5.0/127	RED
1400/635	4.0/100	8.5/216	5.0/127	RED/BLU
1750/790	4.0/100	8.5/216	5.0/127	RED/GRN
1900/880	4.0/100	8.5/216	5.0/127	RED/BLK

CAPACITY PER PEDESTAL BY SPRING TYPE

ROOFTOP EQUIPMENT







KINETICS™ Seismic Design Manual

MODEL ESR-3 ISOLATION RAIL

DRAWING # S-89.300

RELEASE DATE: 8/20/97

KINETICS Noise Control
DUBLIN, OHIO, USA • MISSISSAUGA, ONTARIO, CANADA

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World Wide Web: www.kineticsnoise.com
Email: sales@kineticsnoise.com

DOCUMENT:
P6.2.1

VISCMA MEMBER

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 3 INCH (75 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

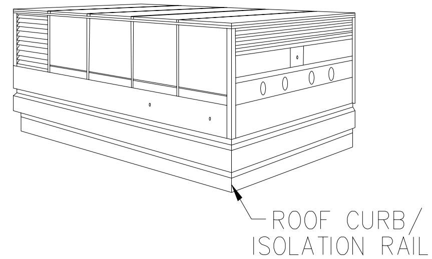
SPRING ISOLATORS ARE PAINTED.

RESTRAINT AND ATTACHMENT DATA

RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL AND VERTICAL SIMULTANEOUS LOADING

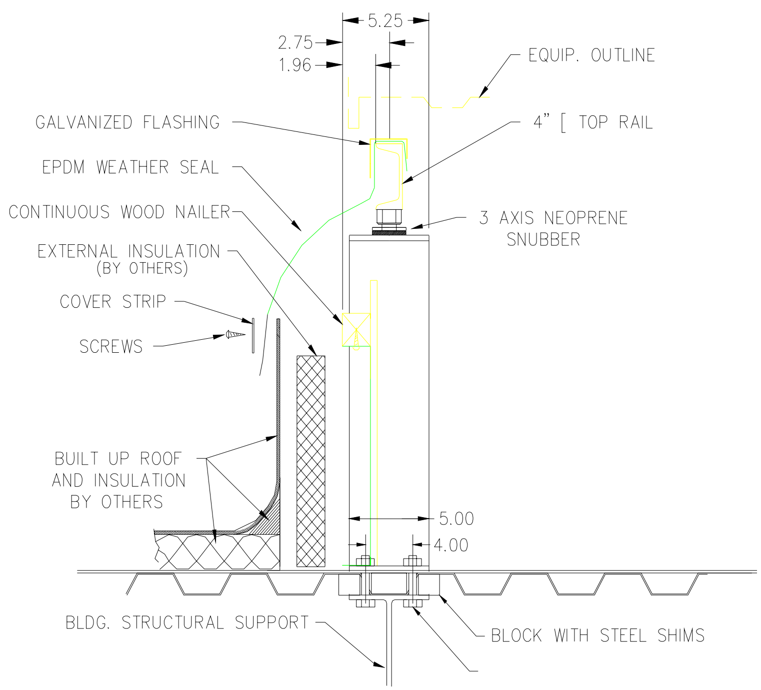
FOR STANDARD HEIGHT CURBS THE BOLTING ATTACHMENT SHOWN IS SUITABLE FOR 3000 LB LOADS AS WELL, WITH EXTENDED HEIGHT CURBS CONTACT FACTORY FOR RESTRAINT RATINGS.

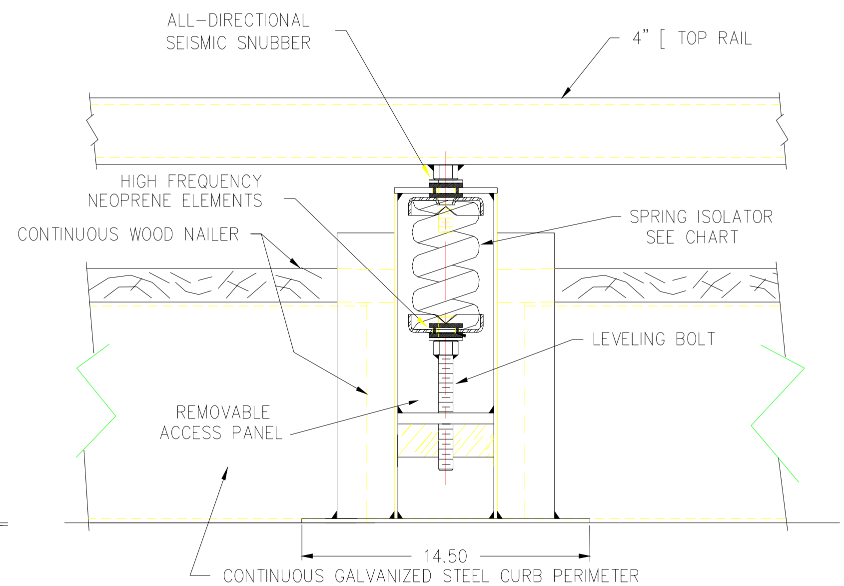
ROOFTOP EQUIPMENT



RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
85/37	3.00/75	8.5/216	5.0/127	GRAY
215/98	3.00/75	8.5/216	5.0/127	BLUE
425/193	3.00/75	8.5/216	5.0/127	GREEN
640/291	3.00/75	8.5/216	5.0/127	BLACK
850/386	3.00/75	8.5/216	5.0/127	RED
1062/483	3.00/75	8.5/216	5.0/127	RED/BLU
1300/591	3.00/75	8.5/216	5.0/127	RED/GRN
1450/660	3.00/75	8.5/216	5.0/127	RED/BLK
1800/818	3.00/75	8.5/216	5.0/127	RED/GRY

CAPACITY PER PEDESTAL BY SPRING TYPE





MODEL ESR-3 ISOLATION RAIL (BOLT DOWN)

DRAWING # S-89.301

RELEASE DATE: 12/17/96

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World Wide Web: www.kineticsnoise.com
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DOCUMENT:
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VISCMA MEMBER

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 4 INCH (100 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.

RESTRAINT AND ATTACHMENT DATA

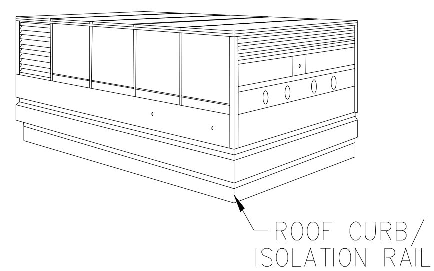
RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL AND VERTICAL SIMULTANEOUS LOADING

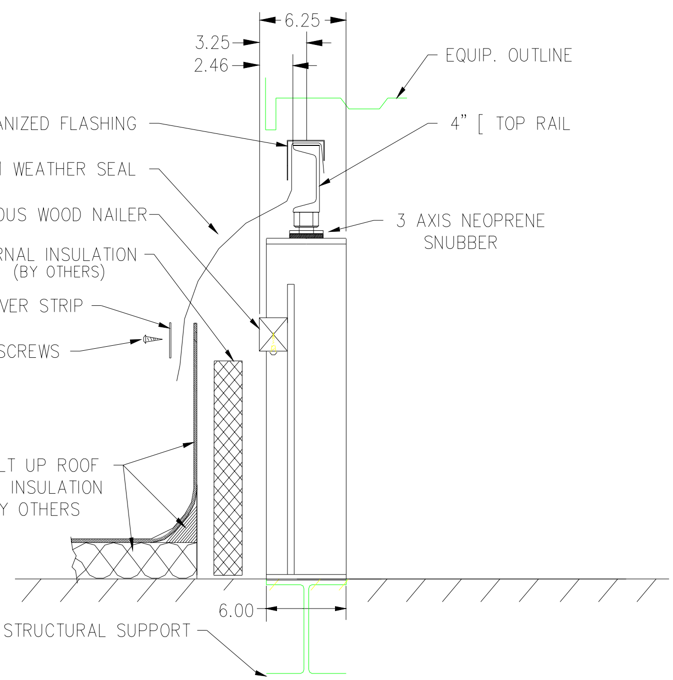
EACH PEDESTAL MUST BE WELDED TO SUPPORTING STEEL WITH A MIN .25" WELD 12" LONG AT EACH END OF THE PEDESTAL BASE

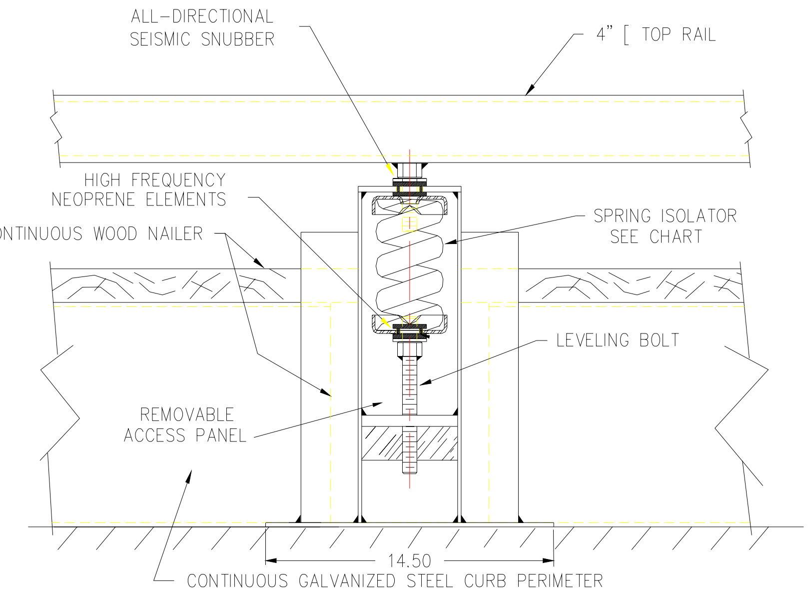
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
100/45	4.0/100	10.0/254	5.63/149	GRAY
250/114	4.0/100	10.0/254	5.63/149	BLUE
500/227	4.0/100	10.0/254	5.63/149	GREEN
750/341	4.0/100	10.0/254	5.63/149	BLACK
1000/455	4.0/100	10.0/254	5.63/149	RED
1250/568	4.0/100	10.0/254	5.63/149	BROWN
1600/727	4.0/100	10.0/254	5.63/149	ORANGE
1850/841	4.0/100	10.0/254	5.63/149	ORG/BLU
2100/955	4.0/100	10.0/254	5.63/149	ORG/GRN

CAPACITY PER PEDESTAL BY SPRING TYPE

ROOFTOP EQUIPMENT







MODEL ESR-4 ISOLATION RAIL

DRAWING # S-89.400-1A

RELEASE DATE: 6/12/00

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DOCUMENT: P6.2.1

VISCMA MEMBER

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 4 INCH (100 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.

RESTRAINT AND ATTACHMENT DATA

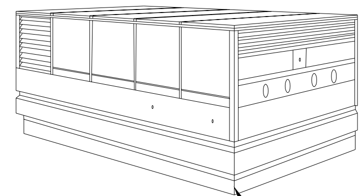
RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL AND VERTICAL SIMULTANEOUS LOADING

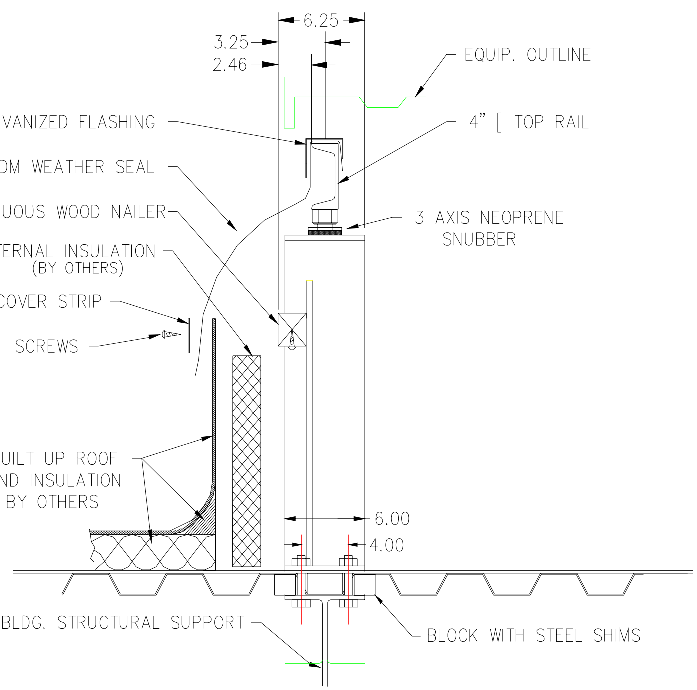
FOR STANDARD HEIGHT CURBS THE BOLTING ATTACHMENT SHOWN IS SUITABLE FOR 3000 LB LOADS AS WELL, WITH EXTENDED HEIGHT CURBS CONTACT FACTORY FOR RESTRAINT RATINGS.

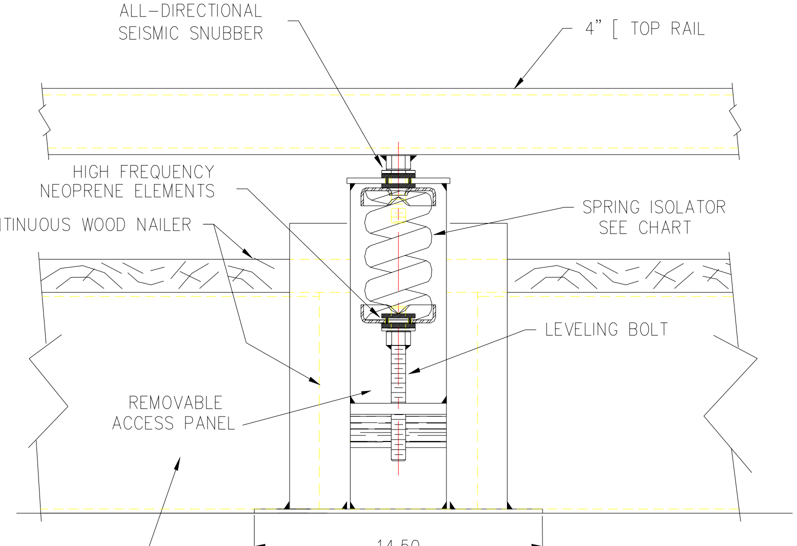
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
100/45	4.0/100	10.0/254	5.63/149	GRAY
250/114	4.0/100	10.0/254	5.63/149	BLUE
500/227	4.0/100	10.0/254	5.63/149	GREEN
750/341	4.0/100	10.0/254	5.63/149	BLACK
1000/455	4.0/100	10.0/254	5.63/149	RED
1250/568	4.0/100	10.0/254	5.63/149	BROWN
1600/727	4.0/100	10.0/254	5.63/149	ORANGE
1850/841	4.0/100	10.0/254	5.63/149	ORG/BLU
2100/955	4.0/100	10.0/254	5.63/149	ORG/GRN

CAPACITY PER PEDESTAL BY SPRING TYPE

ROOFTOP EQUIPMENT







MODEL ESR-4 ISOLATION RAIL (BOLT DOWN)

DRAWING # S-89.401-1A

RELEASE DATE: 6/12/00

KINETICS Noise Control
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Email: sales@kineticsnoise.com

DOCUMENT:
P6.2.1

VISCMA MEMBER

SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 4 INCH (100 mm) STATIC DEFLECTION

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.

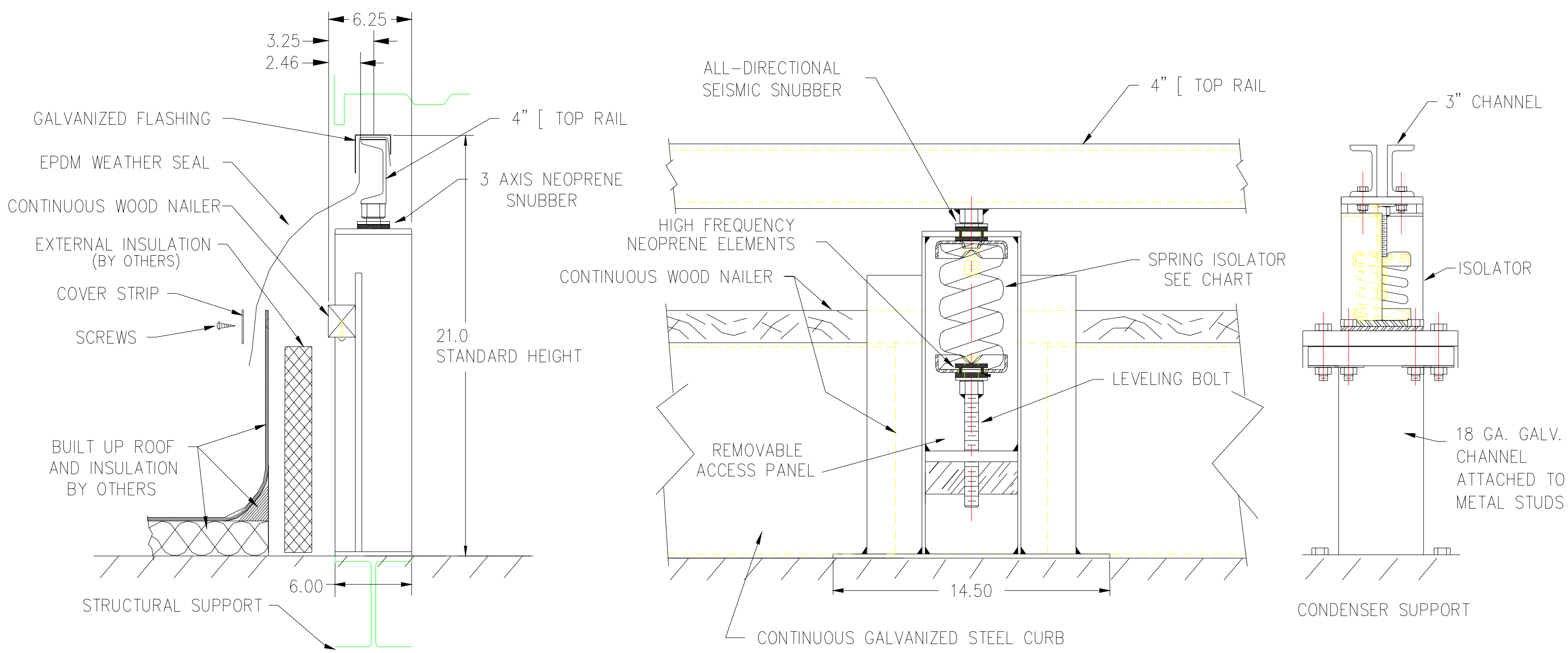
RESTRAINT AND ATTACHMENT DATA

RESTRAINT PEDESTALS DESIGNED FOR 3000 LB LATERAL AND VERTICAL SIMULTANEOUS LOADING

EACH PEDESTAL MUST BE WELDED TO SUPPORTING STEEL WITH A MIN .25" WELD 4" LONG AT EACH END OF THE PEDESTAL BASE

RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
100/45	4.0/100	10.0/254	5.63/149	GRAY
250/114	4.0/100	10.0/254	5.63/149	BLUE
500/227	4.0/100	10.0/254	5.63/149	GREEN
750/341	4.0/100	10.0/254	5.63/149	BLACK
1000/455	4.0/100	10.0/254	5.63/149	RED
1250/568	4.0/100	10.0/254	5.63/149	BROWN
1600/727	4.0/100	10.0/254	5.63/149	ORANGE
1850/841	4.0/100	10.0/254	5.63/149	ORG/BLU
2100/955	4.0/100	10.0/254	5.63/149	ORG/GRN

CAPACITY PER PEDESTAL



MODEL ESR-4 ISOLATION CURB W/ COND. SUPPORT

DRAWING # S-89.402-1A

RELEASE DATE: 6/12/00

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DOCUMENT: P6.2.1

VISCMA MEMBER

SPRING DATA

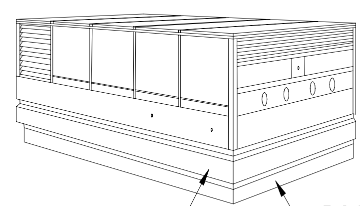
SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 1 INCH (25 mm) STATIC DEFLECTION.

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

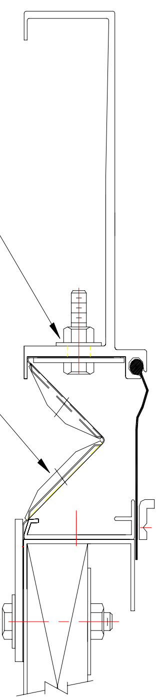
SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.



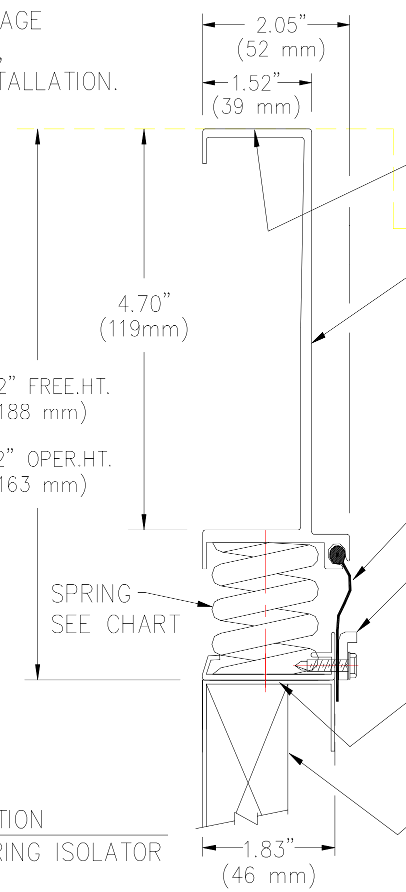
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
30/14	1.00/25	2.50/63	1.46/37	BLUE
65/30	1.00/25	2.50/63	1.46/37	GREEN
120/55	1.00/25	2.50/63	1.46/37	GRAY
205/93	1.00/25	2.50/63	1.46/37	BROWN

SPECIAL NOTE:
ALL UNITS SUPPLIED WITH A TROUBLE SHOOTING PACKAGE FOR LEVELING EQUIPMENT, IF REQUIRED, DURING INSTALLATION.



TYPICAL SECTION
SHOWING WIND/SEISMIC RESTRAINT

NOTE:
IF SEISMIC APPLICATION IS REQUIRED CONSULT SALES REPRESENTATIVE.



TYPICAL SECTION
SHOWING SPRING ISOLATOR

MODEL KSR-1 ISOLATION RAIL

PAGE 1 OF 4 - DRAWING # S-88.300

RELEASE DATE: 5/17/04

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DOCUMENT:
P6.2.2

VISCMA MEMBER

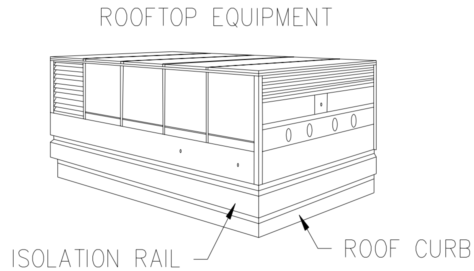
SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 2 INCH (50 mm) STATIC DEFLECTION.

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.0

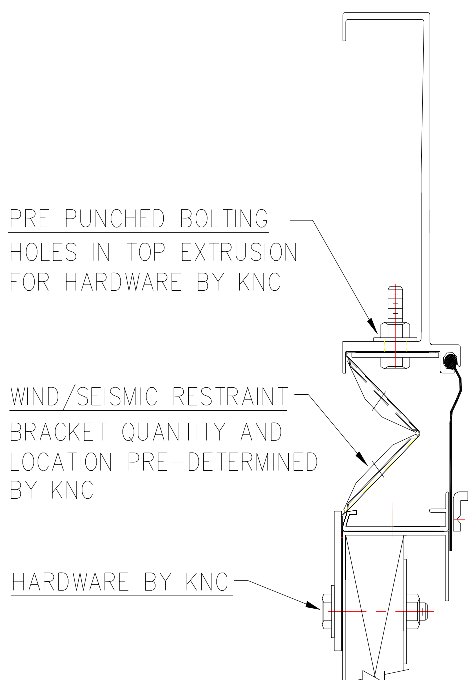
SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.



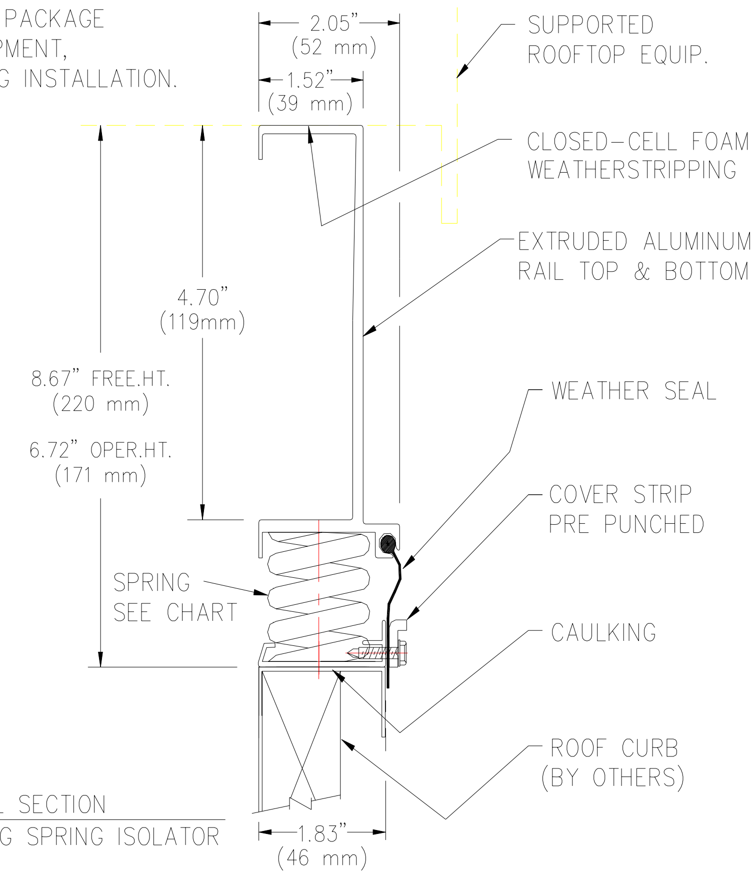
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
30/14	2.00/50	3.75/95	1.46/37	GRAY
65/30	2.00/50	3.75/95	1.46/37	BLUE
120/55	2.00/50	3.75/95	1.46/37	GREEN
205/93	2.00/50	3.75/95	1.46/37	BLACK

SPECIAL NOTE:
ALL UNITS SUPPLIED WITH A TROUBLE SHOOTING PACKAGE FOR LEVELING EQUIPMENT, IF REQUIRED, DURING INSTALLATION.



TYPICAL SECTION
SHOWING WIND/SEISMIC RESTRAINT

NOTE:
IF SEISMIC APPLICATION IS REQUIRED
CONSULT SALES REPRESENTATIVE.



TYPICAL SECTION
SHOWING SPRING ISOLATOR

KINETICS™ Seismic Design Manual

MODEL KSR-2 ISOLATION RAIL

PAGE 2 OF 4 - DRAWING # S-88.350

RELEASE DATE: 5/17/04

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Email: sales@kineticsnoise.com

DOCUMENT:
P6.2.2

VISCMA MEMBER

SPRING DATA

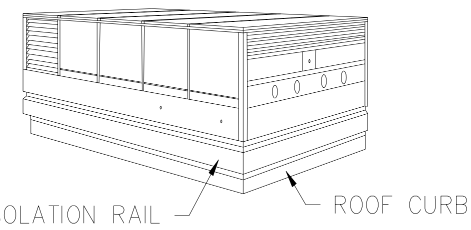
SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 1 INCH (25 mm) STATIC DEFLECTION.

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

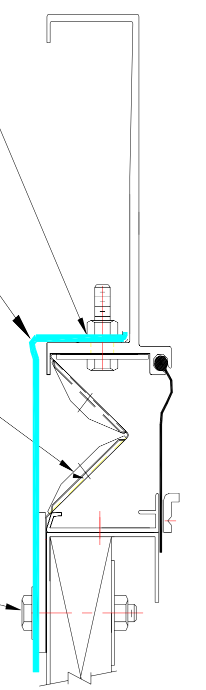
SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.



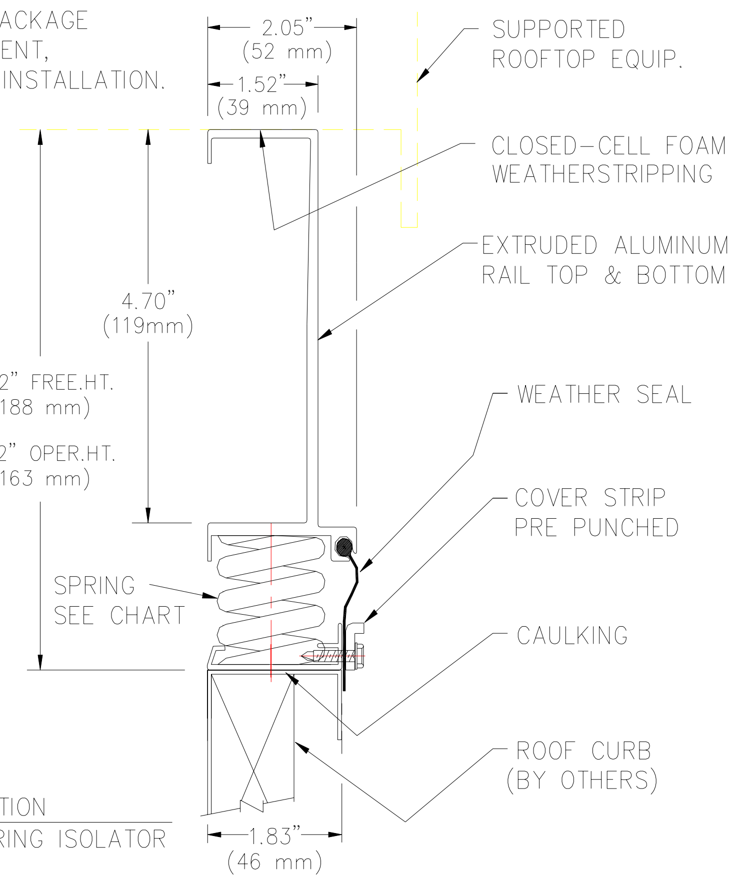
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
30/14	1.00/25	2.50/63	1.46/37	BLUE
65/30	1.00/25	2.50/63	1.46/37	GREEN
120/55	1.00/25	2.50/63	1.46/37	GRAY
205/93	1.00/25	2.50/63	1.46/37	BROWN

SPECIAL NOTE:
ALL UNITS SUPPLIED WITH A TROUBLE SHOOTING PACKAGE FOR LEVELING EQUIPMENT, IF REQUIRED, DURING INSTALLATION.



TYPICAL SECTION
SHOWING WIND/SEISMIC LATERAL & VERTICAL RESTRAINT

NOTE:
IF SEISMIC APPLICATION IS REQUIRED CONSULT SALES REPRESENTATIVE.



TYPICAL SECTION
SHOWING SPRING ISOLATOR

MODEL KSR-1 ISOLATION RAIL

PAGE 3 OF 4 - DRAWING # S-88.400

RELEASE DATE: 5/17/04

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DOCUMENT: P6.2.2

VISCMA MEMBER

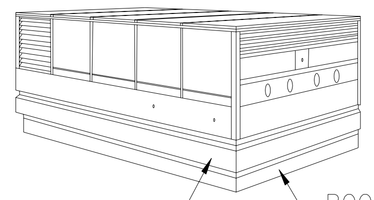
SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 2 INCH (50 mm) STATIC DEFLECTION.

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.0

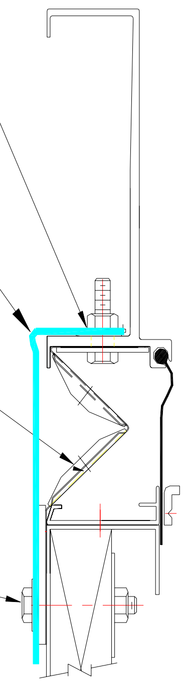
SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.



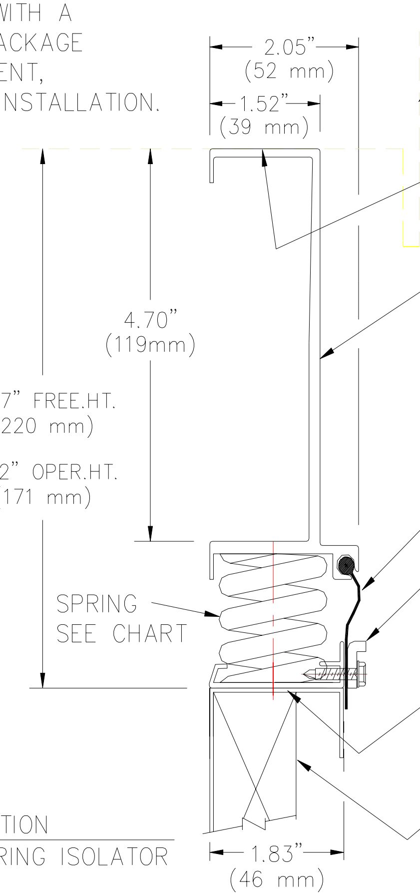
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
30/14	2.00/50	3.75/95	1.46/37	GRAY
65/30	2.00/50	3.75/95	1.46/37	BLUE
120/55	2.00/50	3.75/95	1.46/37	GREEN
205/93	2.00/50	3.75/95	1.46/37	BLACK

SPECIAL NOTE:
ALL UNITS SUPPLIED WITH A TROUBLE SHOOTING PACKAGE FOR LEVELING EQUIPMENT, IF REQUIRED, DURING INSTALLATION.



TYPICAL SECTION
SHOWING WIND/SEISMIC LATERAL & VERTICAL RESTRAINT

NOTE:
IF SEISMIC APPLICATION IS REQUIRED CONSULT SALES REPRESENTATIVE.



TYPICAL SECTION
SHOWING SPRING ISOLATOR

MODEL KSR-2 ISOLATION RAIL

PAGE 4 OF 4 - DRAWING # S-88.450

RELEASE DATE: 5/17/04

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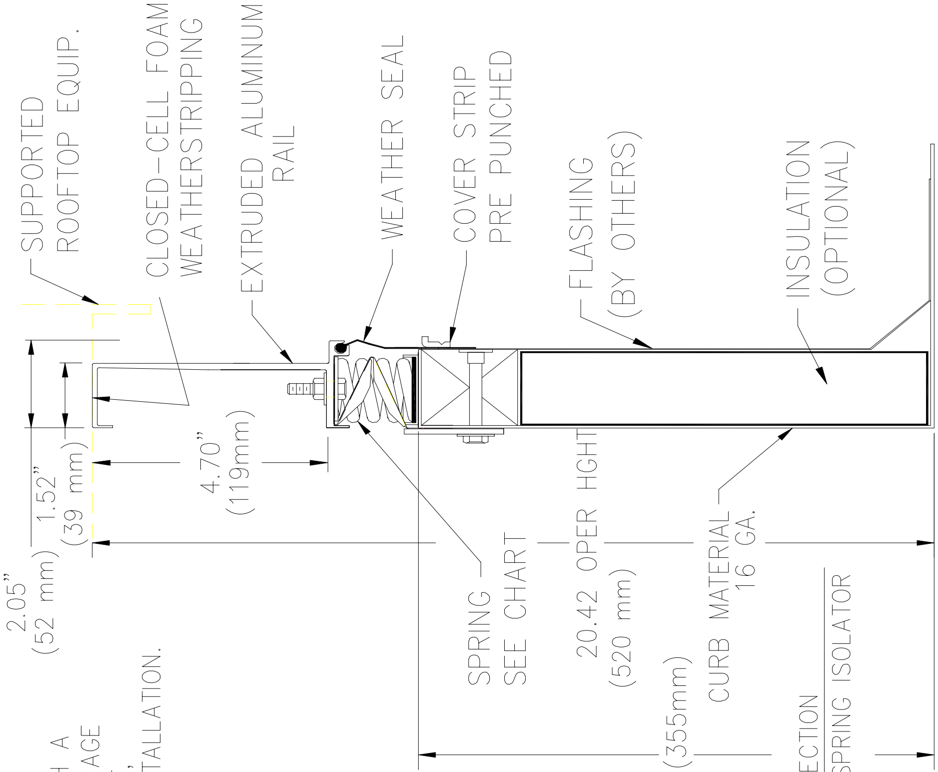
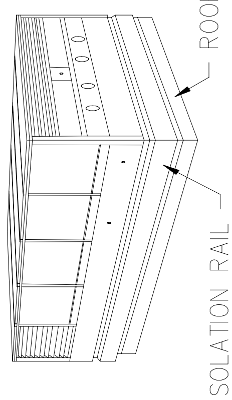
DOCUMENT:
P6.2.2

VISCMA MEMBER

RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
30/14	1.00/25	2.50/63	1.46/37	BLUE
65/30	1.00/25	2.50/63	1.46/37	GREEN
120/55	1.00/25	2.50/63	1.46/37	GRAY
205/93	1.00/25	2.50/63	1.46/37	BROWN



TYPICAL SECTION
SHOWING SPRING ISOLATOR



SPECIAL NOTE:
ALL UNITS SUPPLIED WITH A TROUBLE SHOOTING PACKAGE FOR LEVELING EQUIPMENT, IF REQUIRED, DURING INSTALLATION.

SPRING DATA

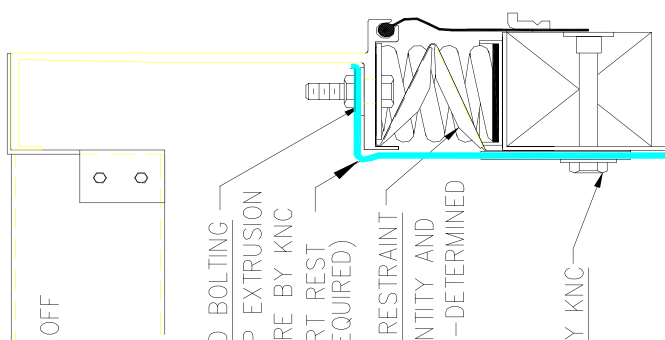
SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 1 INCH (25 mm) STATIC DEFLECTION.

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.2

SPRING ISOLATORS HAVE A TYPICAL OVERLOAD CAPACITY OF 50%

SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.



TYPICAL SECTION
SHOWING WIND/SEISMIC RESTRAINT

NOTE:
IF SEISMIC APPLICATION IS REQUIRED CONSULT SALES REPRESENTATIVE.

MODEL KSCR-1 ISOLATION RAIL

PAGE 1 OF 2 - DRAWING # S-88.500

RELEASE DATE: 5/17/04

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DOCUMENT:
P6.2.3

VISCMA MEMBER

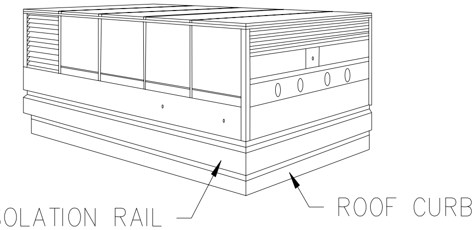
SPRING DATA

SPRING ISOLATORS ARE COMPUTER SELECTED AND LOCATED TO PROVIDE A NOMINAL 2 INCH (50 mm) STATIC DEFLECTION.

SPRING ISOLATORS HAVE A MINIMUM Kx/Ky OF 1.0

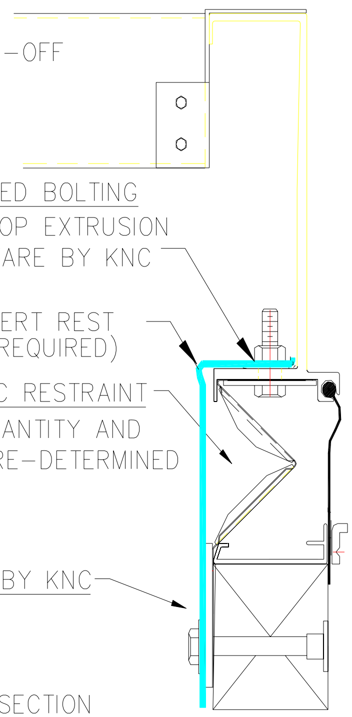
SPRING ISOLATORS ARE SAFE AT SOLID LOADING

SPRING ISOLATORS ARE PAINTED.



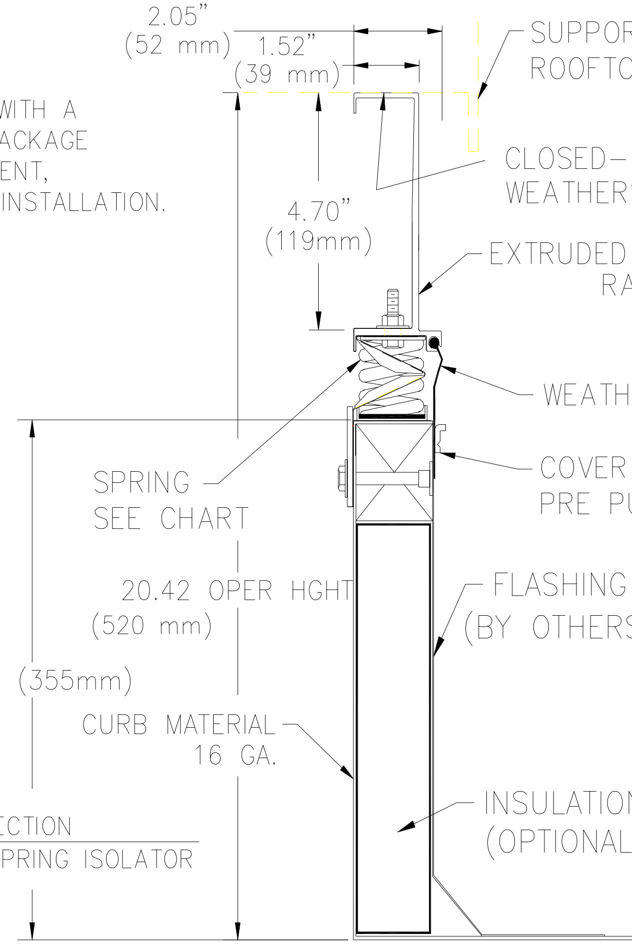
RATED LOAD LB/KG	RATED DEFL. IN/mm	SPRING FR. HT. IN/mm	SPRING O. D. IN/mm	COLOR CODE
30/14	2.00/50	3.75/95	1.46/37	GRAY
65/30	2.00/50	3.75/95	1.46/37	BLUE
120/55	2.00/50	3.75/95	1.46/37	GREEN
205/93	2.00/50	3.75/95	1.46/37	BLACK

SPECIAL NOTE:
ALL UNITS SUPPLIED WITH A TROUBLE SHOOTING PACKAGE FOR LEVELING EQUIPMENT, IF REQUIRED, DURING INSTALLATION.



TYPICAL SECTION
SHOWING WIND/SEISMIC RESTRAINT

NOTE:
IF SEISMIC APPLICATION IS REQUIRED CONSULT SALES REPRESENTATIVE.



TYPICAL SECTION
SHOWING SPRING ISOLATOR

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MODEL KSCR-2 ISOLATION RAIL

PAGE 2 OF 2 - DRAWING # S-88.600

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The installation instruction for the ESR, KSR, and KSCR can be found on our website, http://www.kineticsnoise.com

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CABLE / WIRE ROPE RESTRAINTS

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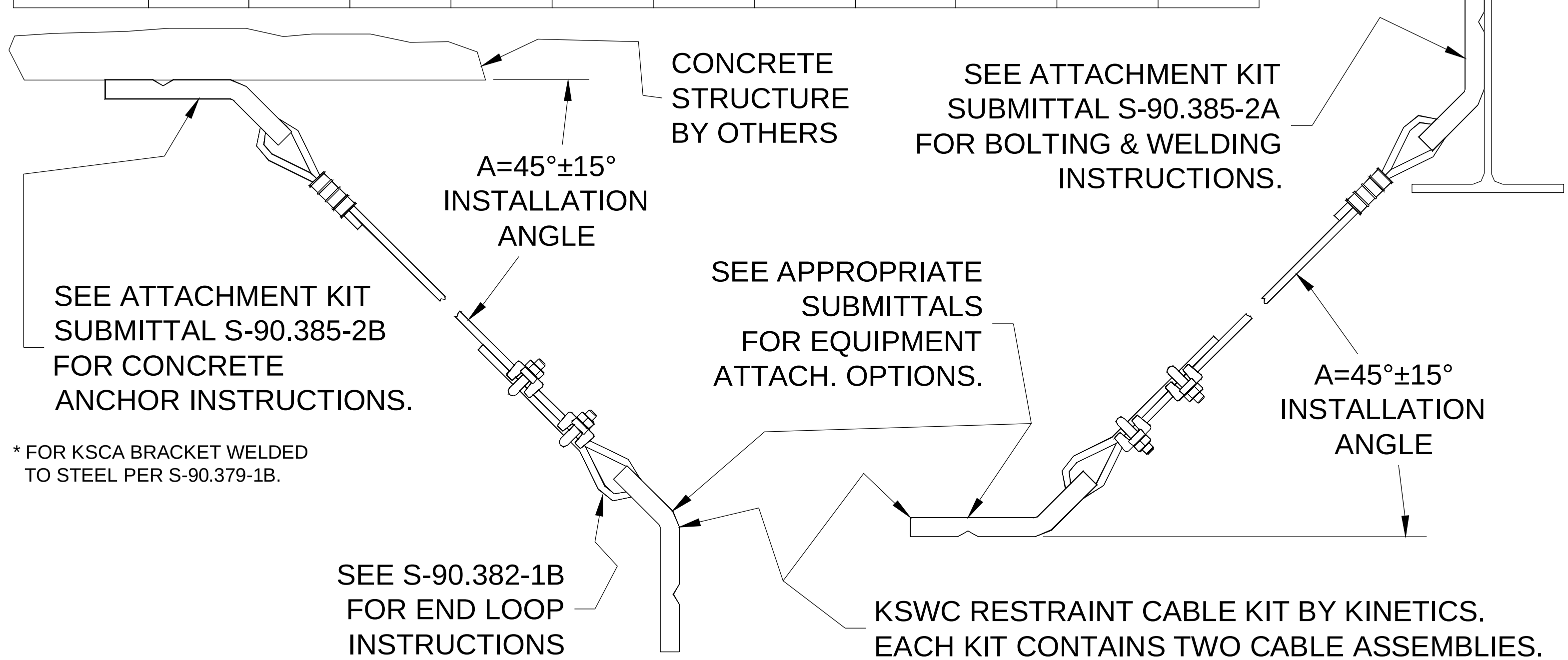
MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSWC-125	1/8	955	II	955	II	825	II	675	II	475	I
KSWC-187	3/16	1,635	III	1,175	III	1,415	III	1,155	III	815	II
KSWC-250	1/4	2,960	IV	1,175	III	2,560	IV	2,090	IV	1,480	III



* FOR KSCA BRACKET WELDED TO STEEL PER S-90.379-1B.

KSWC U-BOLT CLIP CABLE RESTRAINT KIT (KSCA – KSCA)

PAGE 1 OF 1 - DRAWING # S-90.382-1A

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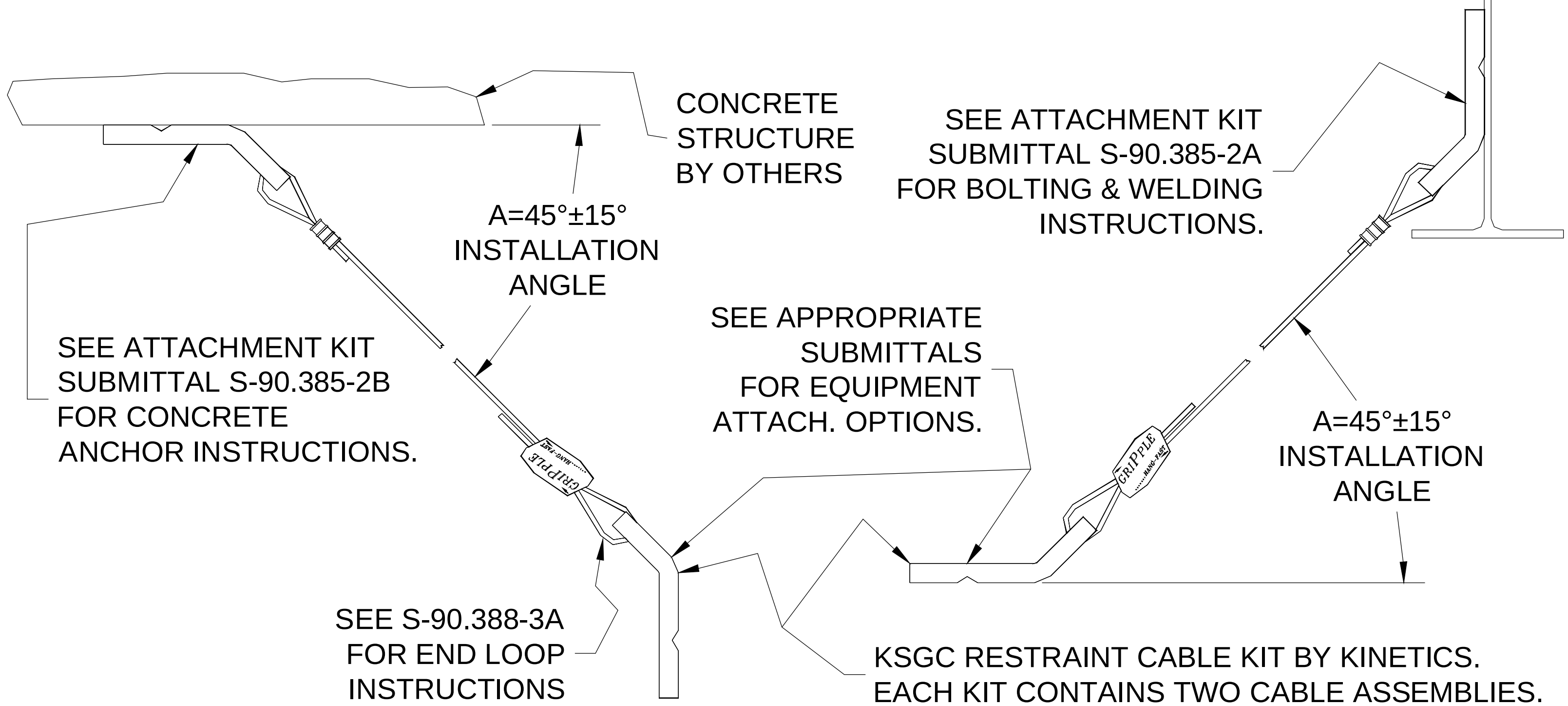
MODEL	CABLE SIZE	MAX. CABLE TENSION		MAX. HORIZONTAL CABLE FORCE @ A=0°		MAX. HORIZONTAL CABLE FORCE @ A=30°		MAX. HORIZONTAL CABLE FORCE @ A=45°		MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSGC-125	1/8	500	--------	500	I	430	I	350	I	250	-0-
KSGC-187	3/16	1,235	--------	1,235	III	1,065	III	870	III	615	II



KSGC GRIPPLE CABLE RESTRAINT KIT (KSCA – KSCA)

PAGE 1 OF 1 - DRAWING # S-90.391-1A

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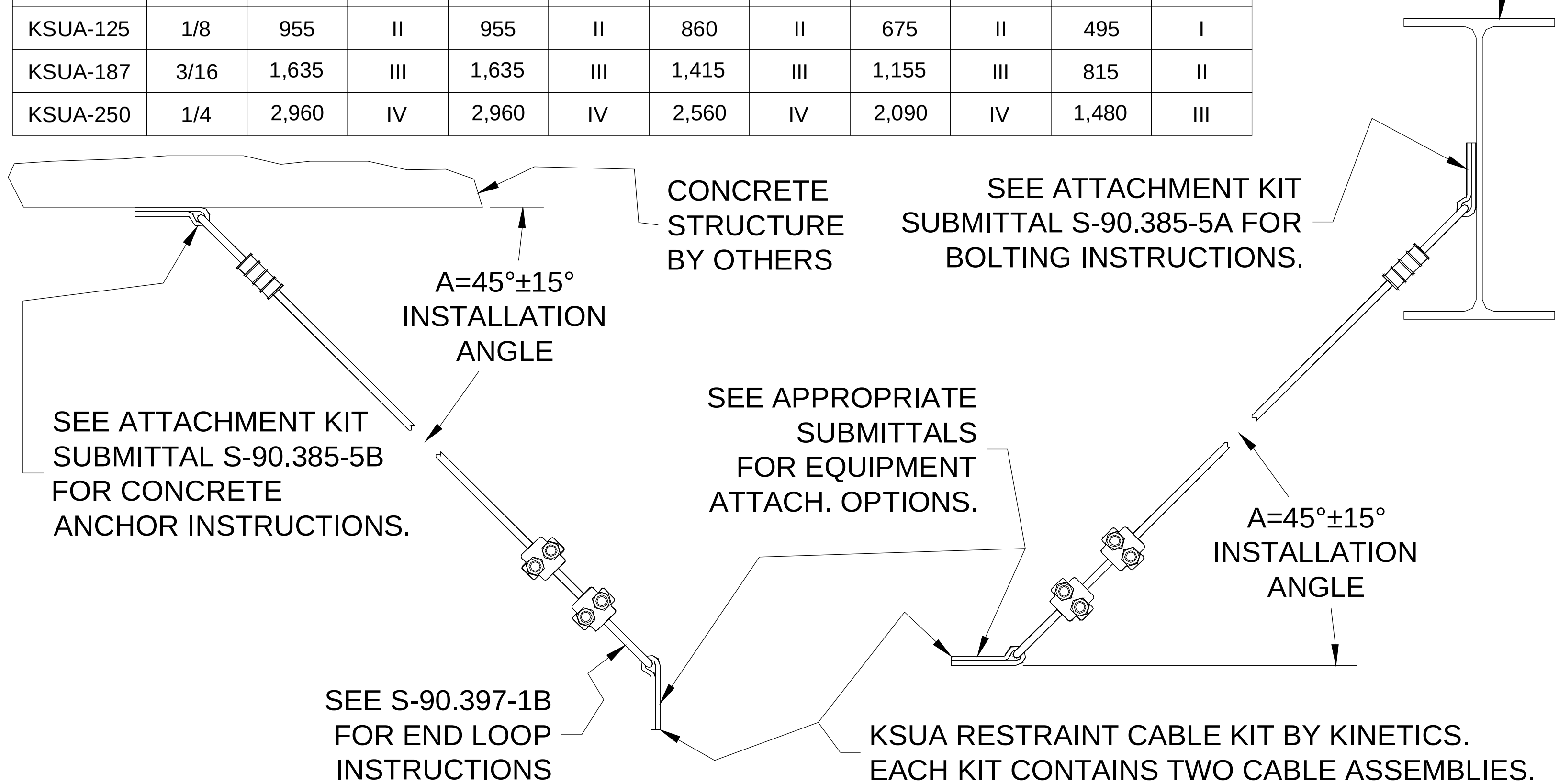
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUA-125	1/8	955	II	955	II	860	II	675	II	495	I
KSUA-187	3/16	1,635	III	1,635	III	1,415	III	1,155	III	815	II
KSUA-250	1/4	2,960	IV	2,960	IV	2,560	IV	2,090	IV	1,480	III



KSUA U-BOLT CLIP CABLE RESTRAINT KIT (KSUA – KSUA)

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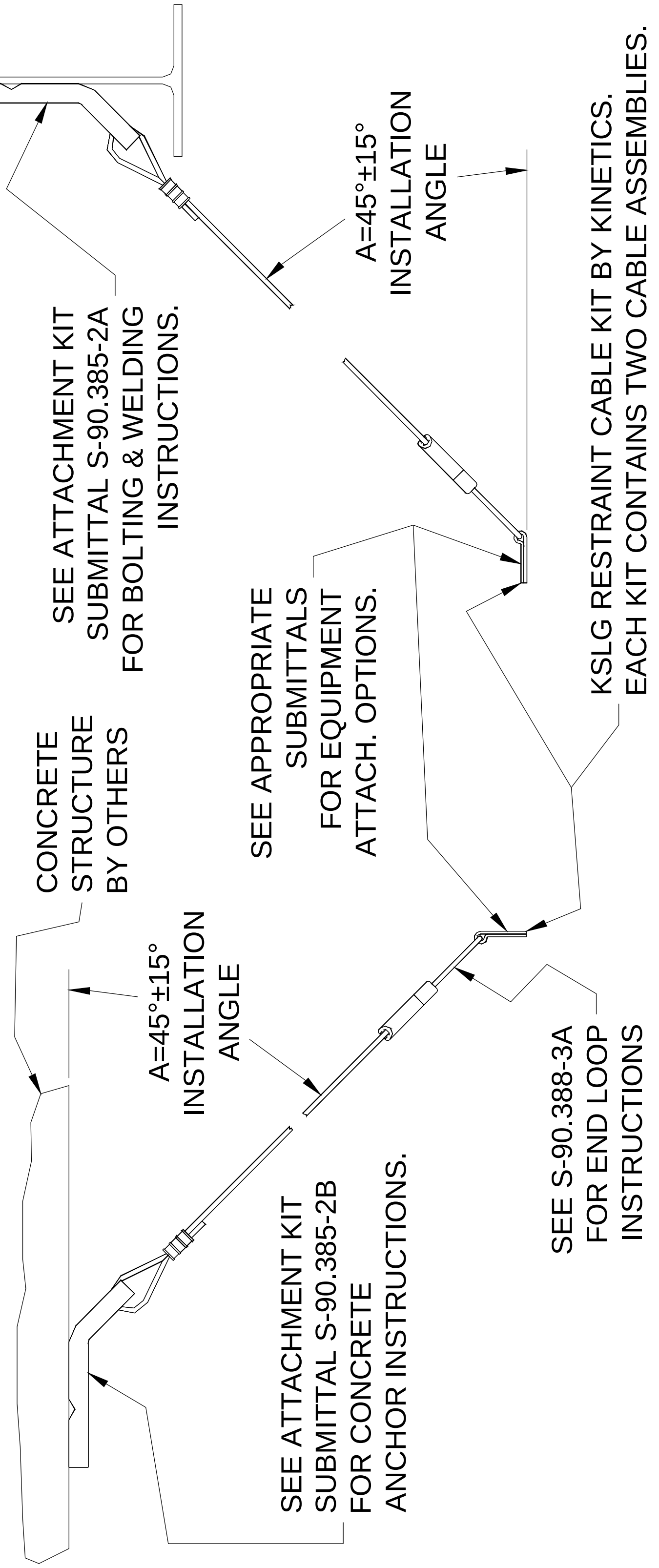
VISCMA MEMBER

MODEL	CABLE SIZE	MAX. CABLE TENSION		MAX. HORIZONTAL CABLE FORCE @ A=0°		MAX. HORIZONTAL CABLE FORCE @ A=30°		MAX. HORIZONTAL CABLE FORCE @ A=45°		MAX. HORIZONTAL CABLE FORCE @ A=60°	
-------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSLG-125	1/8	500	--------	500	I	430	I	350	I	250	-0-
KSLG-187	3/16	1,235	--------	1,235	III	1,065	III	870	III	615	II



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KSLG GRIPPLE CABLE RESTRAINT KIT (KSCA – KSUA)

PAGE 1 OF 1 - DRAWING # S-90.412-1A

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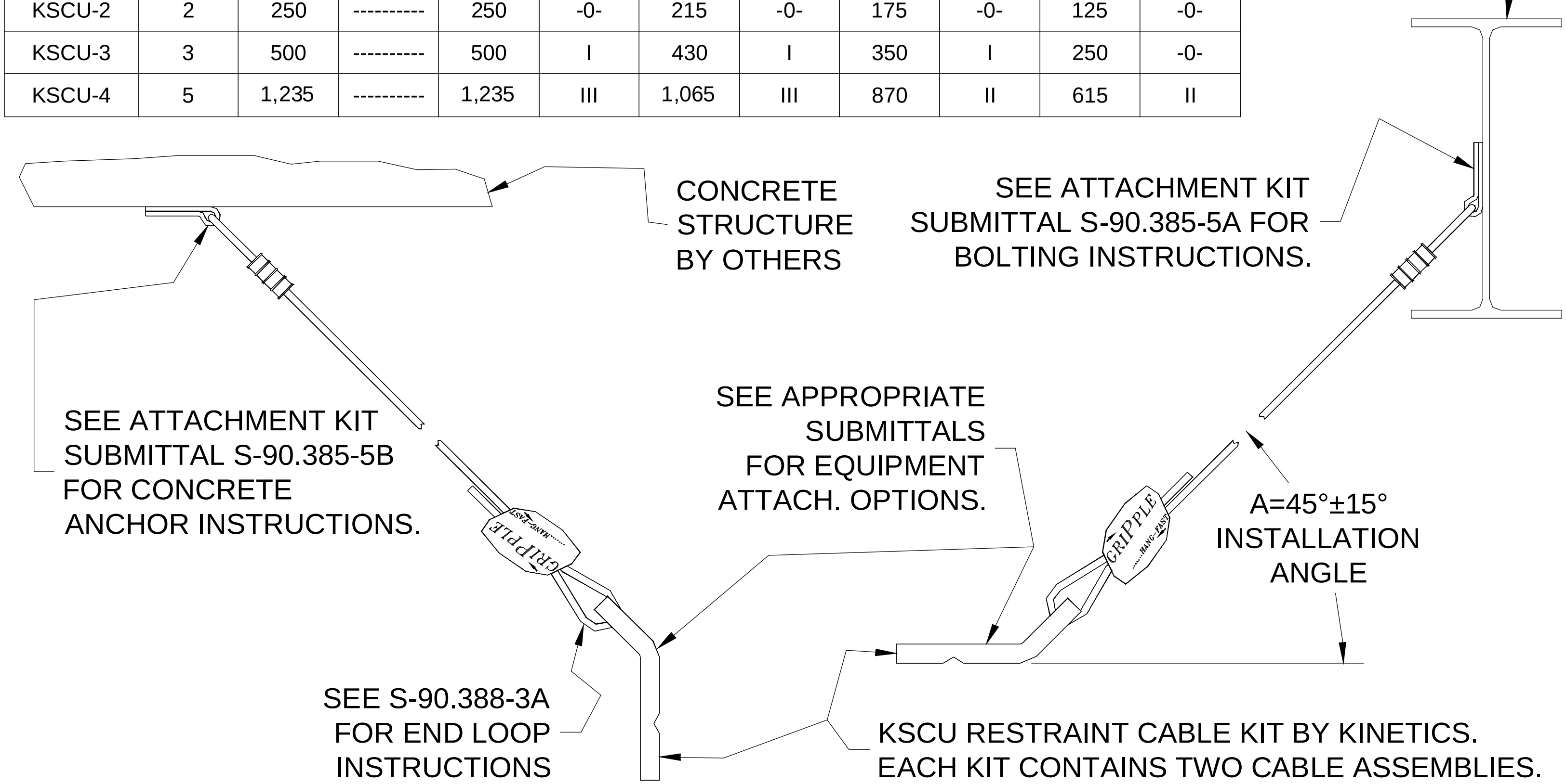
VISCMA MEMBER

MODEL	CABLE SIZE	MAX. CABLE TENSION		MAX. HORIZONTAL CABLE FORCE @ A=0°		MAX. HORIZONTAL CABLE FORCE @ A=30°		MAX. HORIZONTAL CABLE FORCE @ A=45°		MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	mm	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCU-2	2	250	----------	250	-0-	215	-0-	175	-0-	125	-0-
KSCU-3	3	500	----------	500	I	430	I	350	I	250	-0-
KSCU-4	5	1,235	----------	1,235	III	1,065	III	870	II	615	II



KSCU GRIPPLE CABLE RESTRAINT KIT (KSUA – KSCA)

PAGE 1 OF 1 - DRAWING # S-90.404-1A

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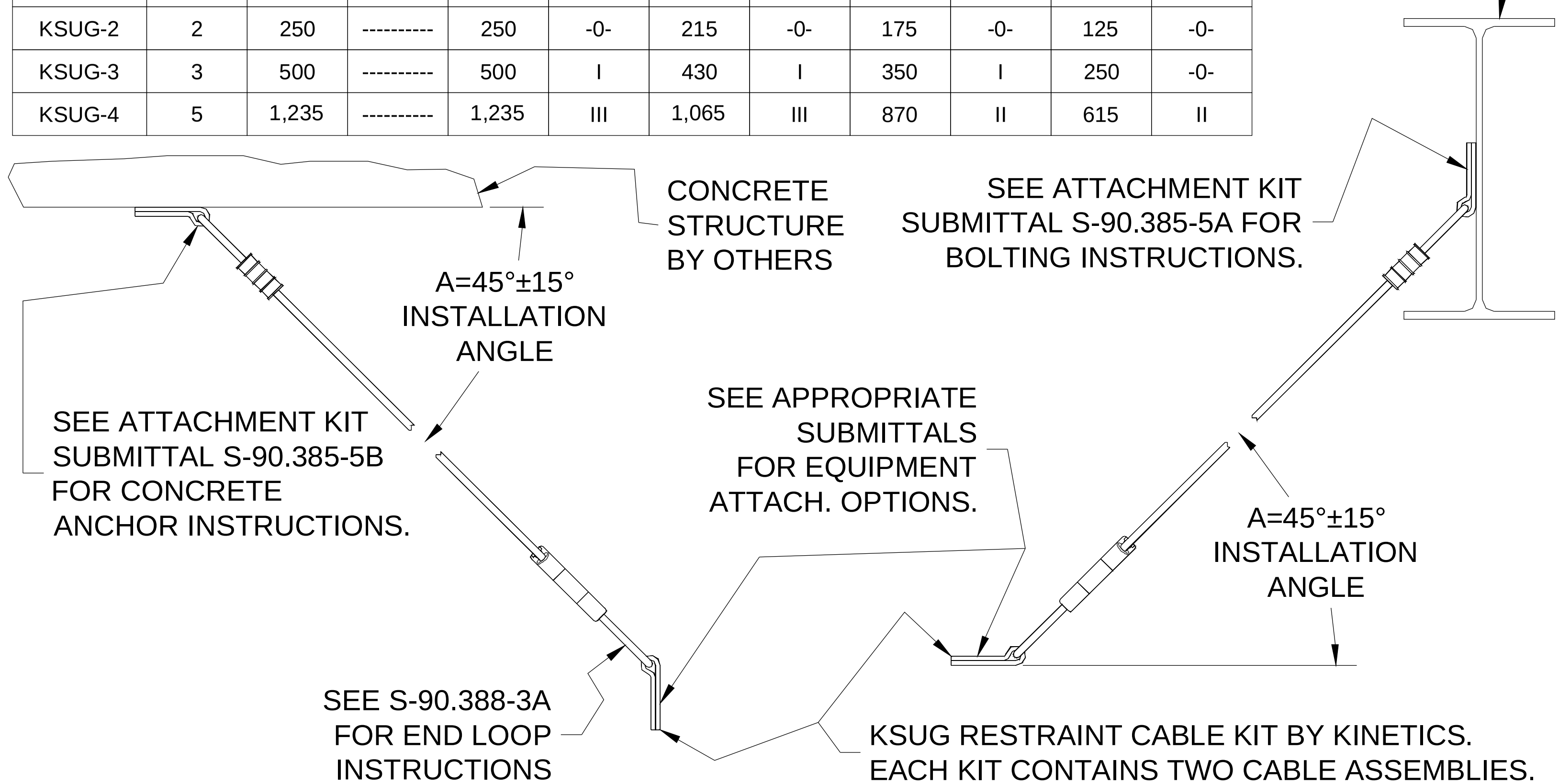
VISCMA MEMBER

MODEL	CABLE SIZE	MAX. CABLE TENSION		MAX. HORIZONTAL CABLE FORCE @ A=0°		MAX. HORIZONTAL CABLE FORCE @ A=30°		MAX. HORIZONTAL CABLE FORCE @ A=45°		MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	mm	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUG-2	2	250	----------	250	-0-	215	-0-	175	-0-	125	-0-
KSUG-3	3	500	----------	500	I	430	I	350	I	250	-0-
KSUG-4	5	1,235	----------	1,235	III	1,065	III	870	II	615	II



KSUG GRIPPLE CABLE RESTRAINT KIT (KSUA – KSUA)

PAGE 1 OF 1 - DRAWING # S-90.409-1A

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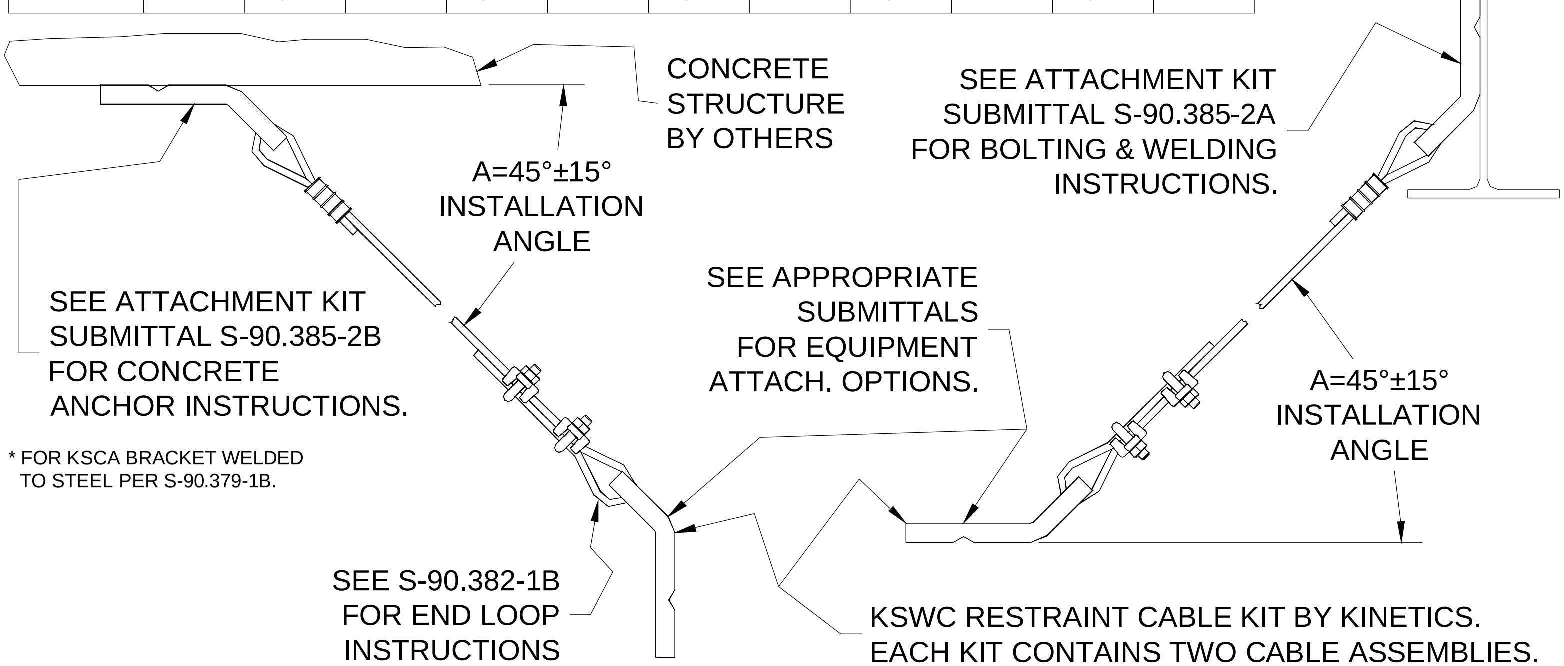
MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSWC-125	1/8	955	II	955	II	825	II	675	II	475	I
KSWC-187	3/16	1,635	III	1,175	III	1,415	III	1,155	III	815	II
KSWC-250	1/4	2,960	IV	1,175	III	2,560	IV	2,090	IV	1,480	III



* FOR KSCA BRACKET WELDED TO STEEL PER S-90.379-1B.

KSWC U-BOLT CLIP CABLE RESTRAINT KIT (KSCA – KSCA)

PAGE 1 OF 1 - DRAWING # S-90.382-1A

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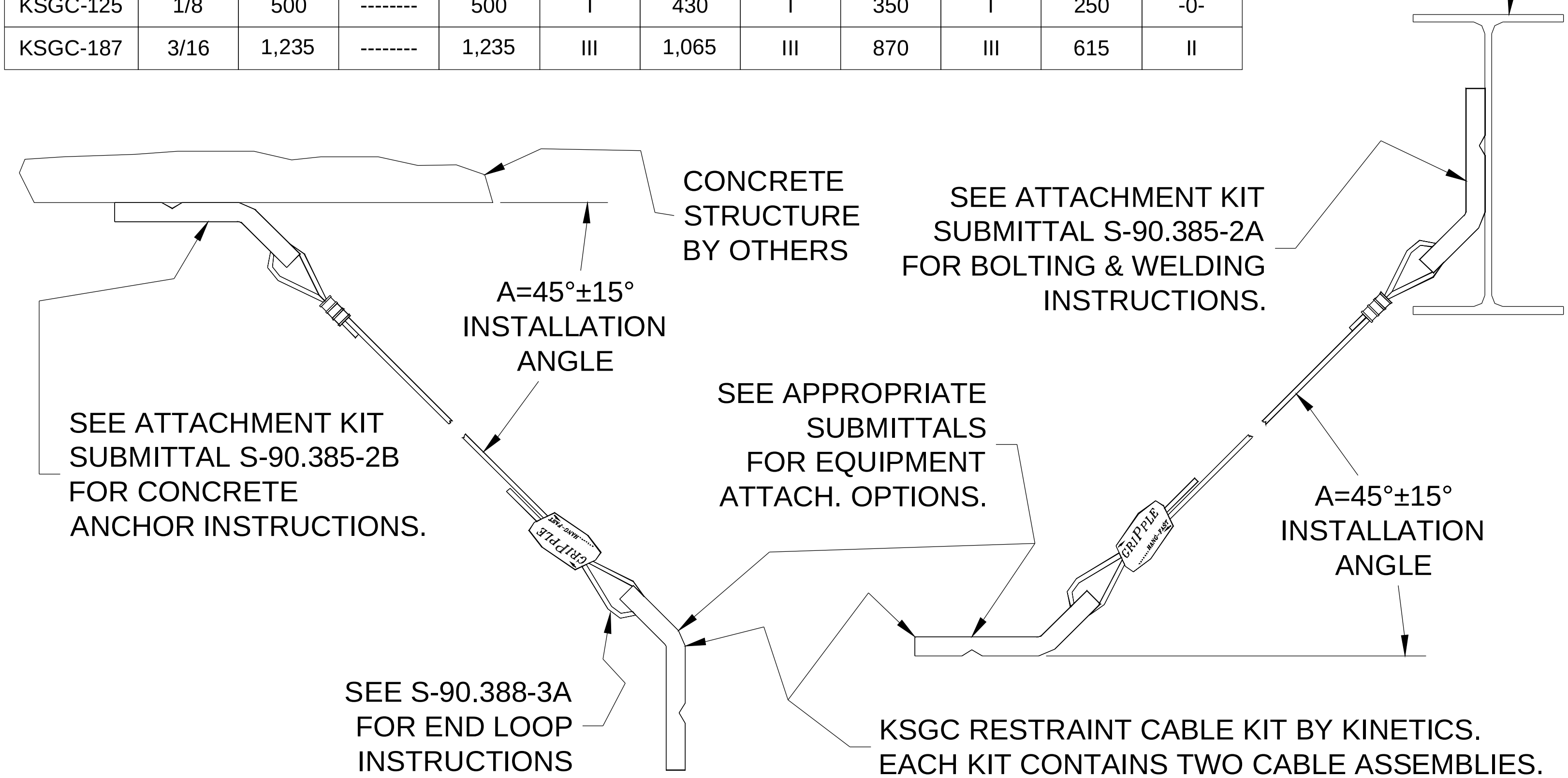
VISCMA MEMBER

MODEL	CABLE SIZE	MAX. CABLE TENSION		MAX. HORIZONTAL CABLE FORCE @ A=0°		MAX. HORIZONTAL CABLE FORCE @ A=30°		MAX. HORIZONTAL CABLE FORCE @ A=45°		MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSGC-125	1/8	500	--------	500	I	430	I	350	I	250	-0-
KSGC-187	3/16	1,235	--------	1,235	III	1,065	III	870	III	615	II



KSGC GRIPPLE CABLE RESTRAINT KIT (KSCA – KSCA)

PAGE 1 OF 1 - DRAWING # S-90.391-1A

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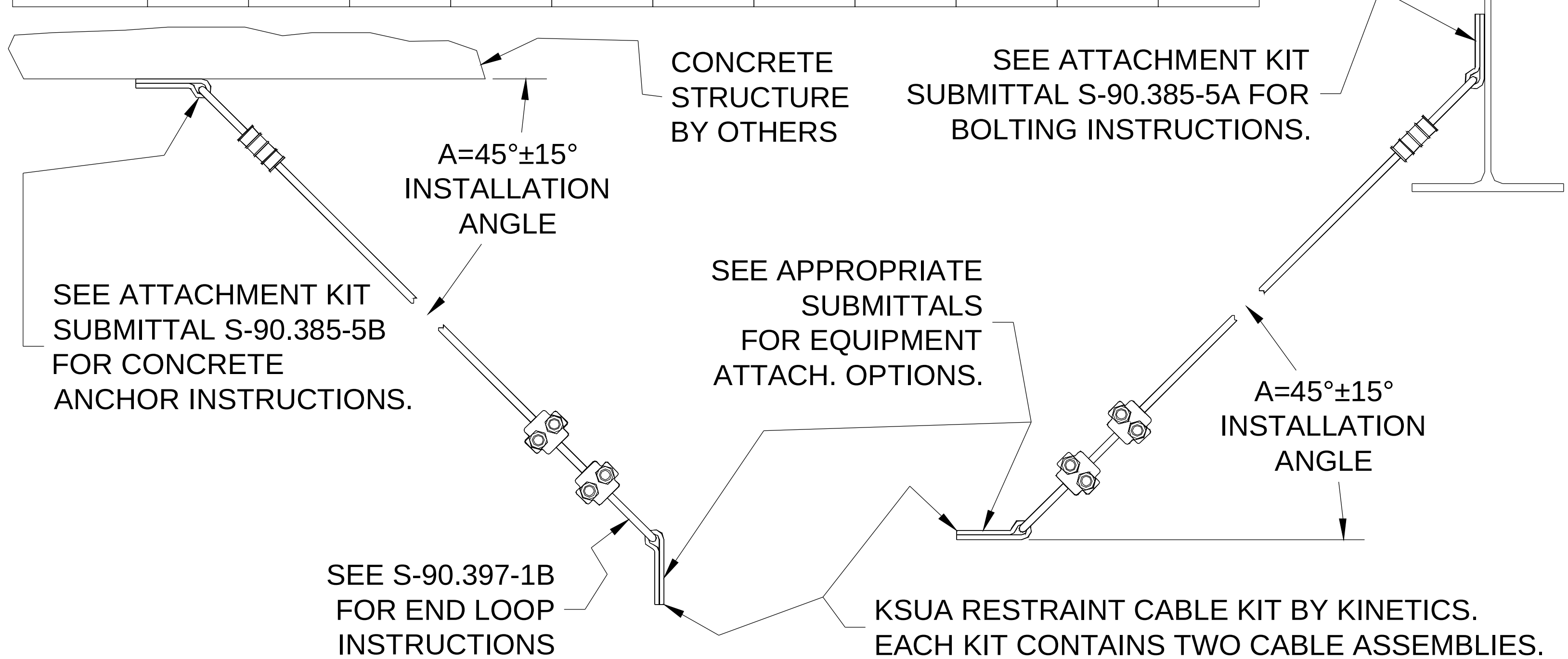
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUA-125	1/8	955	II	955	II	860	II	675	II	495	I
KSUA-187	3/16	1,635	III	1,635	III	1,415	III	1,155	III	815	II
KSUA-250	1/4	2,960	IV	2,960	IV	2,560	IV	2,090	IV	1,480	III



KSUA U-BOLT CLIP CABLE RESTRAINT KIT (KSUA – KSUA)

PAGE 1 OF 1 - DRAWING # S-90.397-1A

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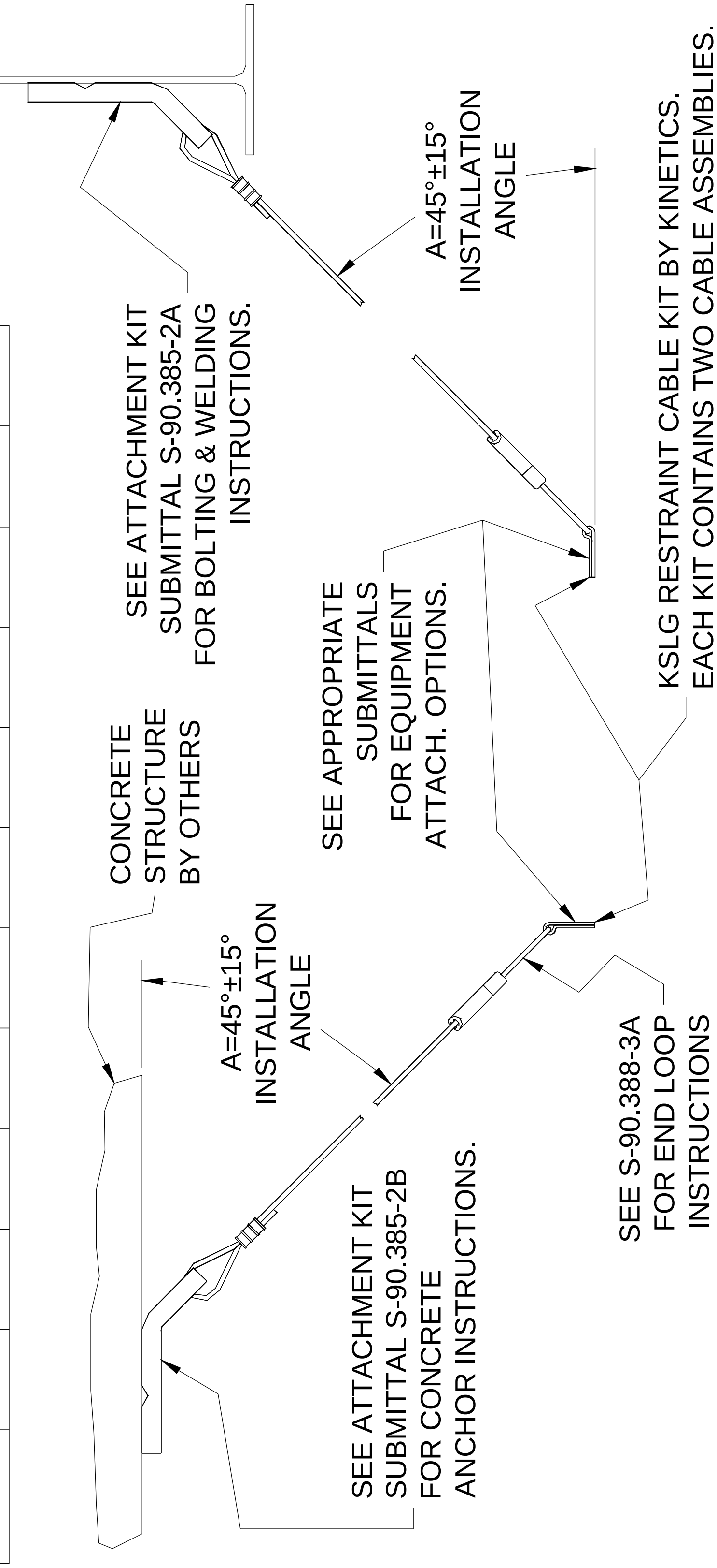
VISCMA MEMBER

MODEL	CABLE SIZE	MAX. CABLE TENSION		MAX. HORIZONTAL CABLE FORCE @ A=0°		MAX. HORIZONTAL CABLE FORCE @ A=30°		MAX. HORIZONTAL CABLE FORCE @ A=45°		MAX. HORIZONTAL CABLE FORCE @ A=60°	
------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSLG-125	1/8	500	--------	500	I	430	I	350	I	250	-0-
KSLG-187	3/16	1,235	--------	1,235	III	1,065	III	870	III	615	II



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KSLG GRIPPLE CABLE RESTRAINT KIT (KSCA – KSUA)

PAGE 1 OF 1 - DRAWING # S-90.412-1A

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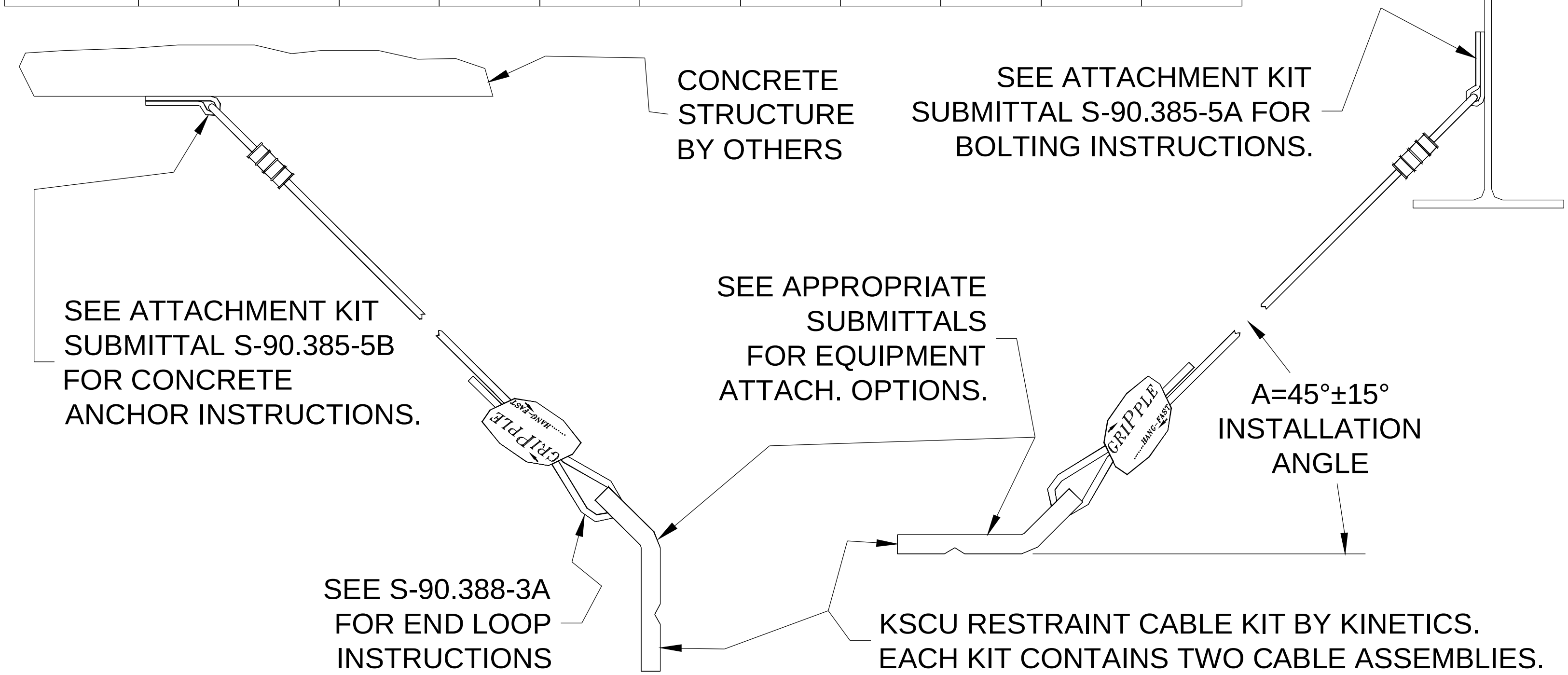
----------------	mm	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCU-2	2	250	----------	250	-0-	215	-0-	175	-0-	125	-0-
KSCU-3	3	500	----------	500	I	430	I	350	I	250	-0-
KSCU-4	5	1,235	----------	1,235	III	1,065	III	870	II	615	II



KSCU GRIPPLE CABLE RESTRAINT KIT (KSUA – KSCA)

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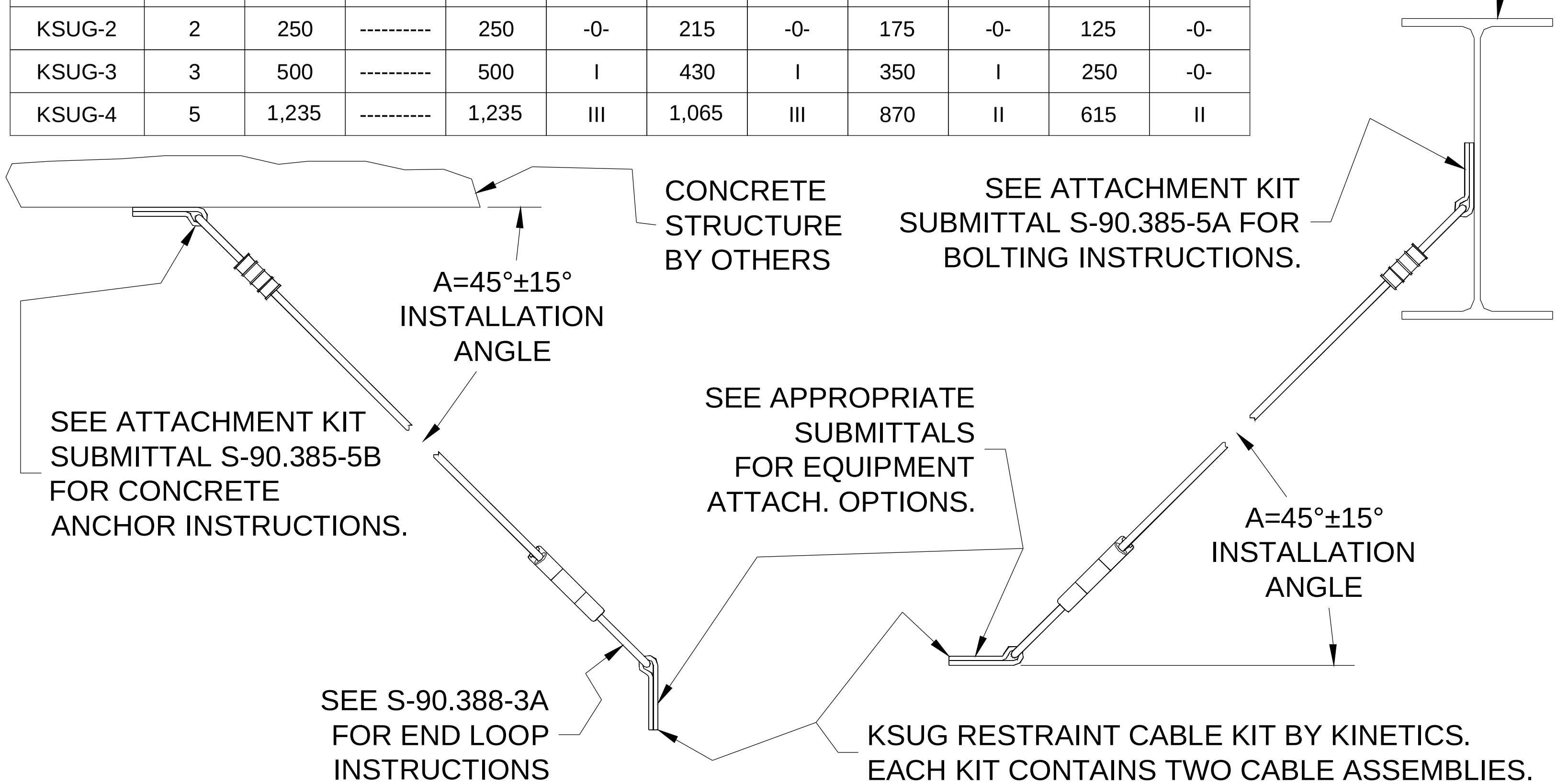
MODEL	CABLE SIZE	MAX. CABLE TENSION		MAX. HORIZONTAL CABLE FORCE @ A=0°		MAX. HORIZONTAL CABLE FORCE @ A=30°		MAX. HORIZONTAL CABLE FORCE @ A=45°		MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	mm	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUG-2	2	250	----------	250	-0-	215	-0-	175	-0-	125	-0-
KSUG-3	3	500	----------	500	I	430	I	350	I	250	-0-
KSUG-4	5	1,235	----------	1,235	III	1,065	III	870	II	615	II



KSUG GRIPPLE CABLE RESTRAINT KIT (KSUA – KSUA)

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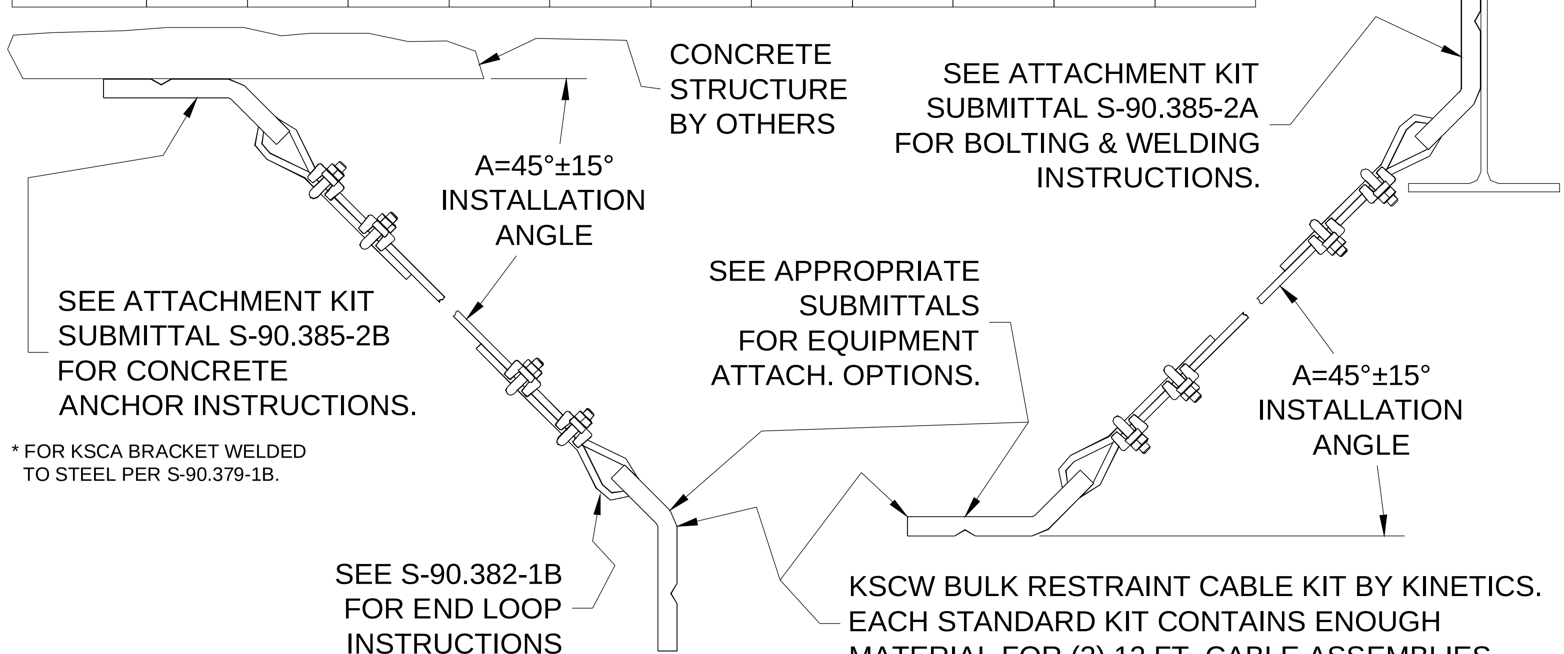
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSWC-125B	1/8	955	II	955	II	825	II	675	II	475	I
KSWC-187B	3/16	1,635	III	1,175	III	1,415	III	1,155	III	815	II
KSWC-250B	1/4	2,960	IV	1,175	III	2,560	IV	2,090	IV	1,480	III



* FOR KSCA BRACKET WELDED TO STEEL PER S-90.379-1B.

KSWC U-BOLT CLIP BULK CABLE RESTRAINT KIT (KSCA – KSCA)

PAGE 1 OF 1 - DRAWING # S-90.384-2A

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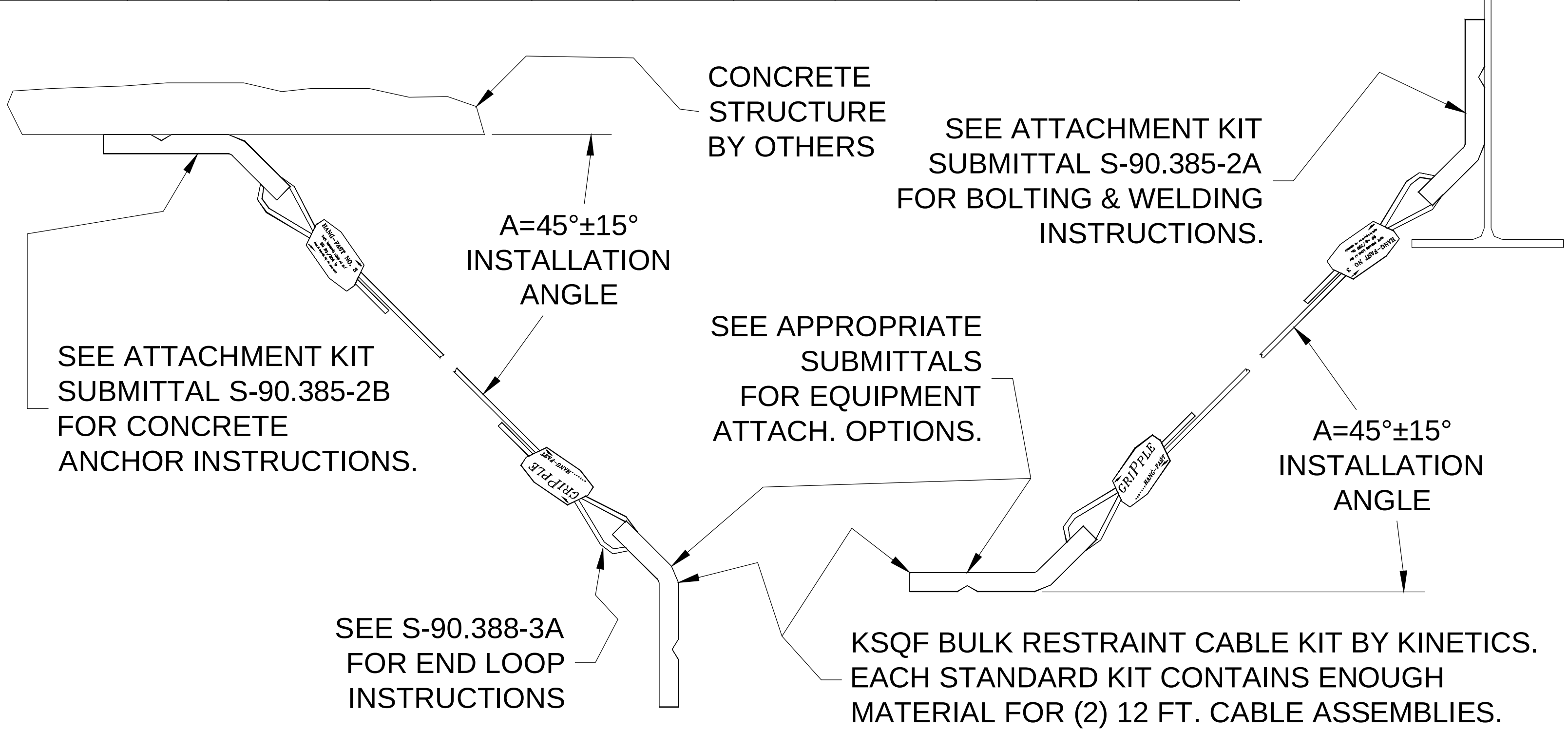
VISCMA MEMBER

MODEL	CABLE SIZE	MAX. CABLE TENSION		MAX. HORIZONTAL CABLE FORCE @ A=0°		MAX. HORIZONTAL CABLE FORCE @ A=30°		MAX. HORIZONTAL CABLE FORCE @ A=45°		MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSQF-125	1/8	500	--------	500	I	430	I	350	I	250	-0-
KSQF-187	3/16	1,235	--------	1,235	III	1,065	III	870	III	615	II



KSQF GRIPPLE BULK CABLE RESTRAINT KIT (KSCA – KSCA)

PAGE 1 OF 1 - DRAWING # S-90.384-4A

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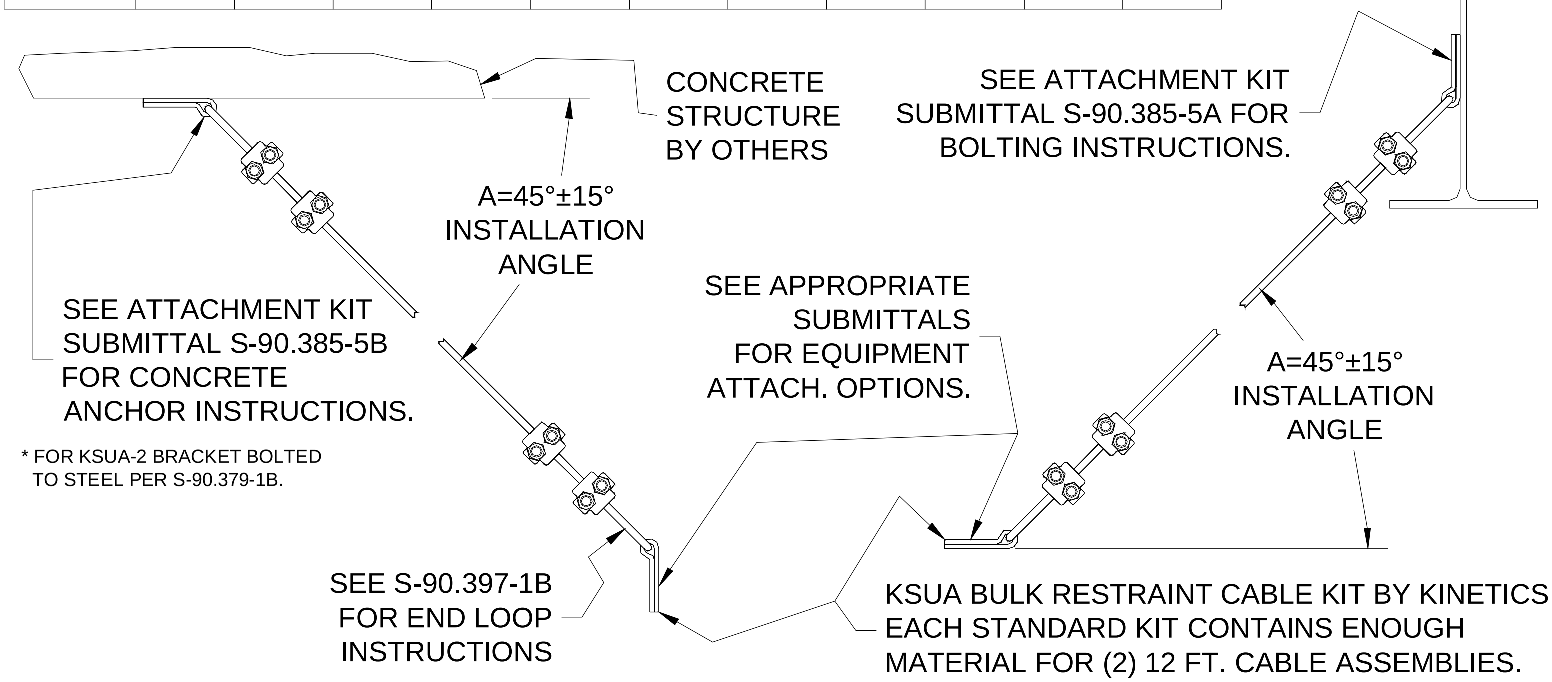
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUA-125B	1/8	955	II	955	II	825	II	675	II	475	I
KSUA-187B	3/16	1,635	III	1,635	III	1,415	III	1,155	III	815	II
KSUA-250B	1/4	2,960	IV	2,960	IV	2,560	IV	2,090	IV	1,480	III



* FOR KSUA-2 BRACKET BOLTED TO STEEL PER S-90.379-1B.

KSUA U-BOLT CLIP BULK CABLE RESTRAINT KIT (KSUA – KSUA)

RELEASE DATE: 5/21/04

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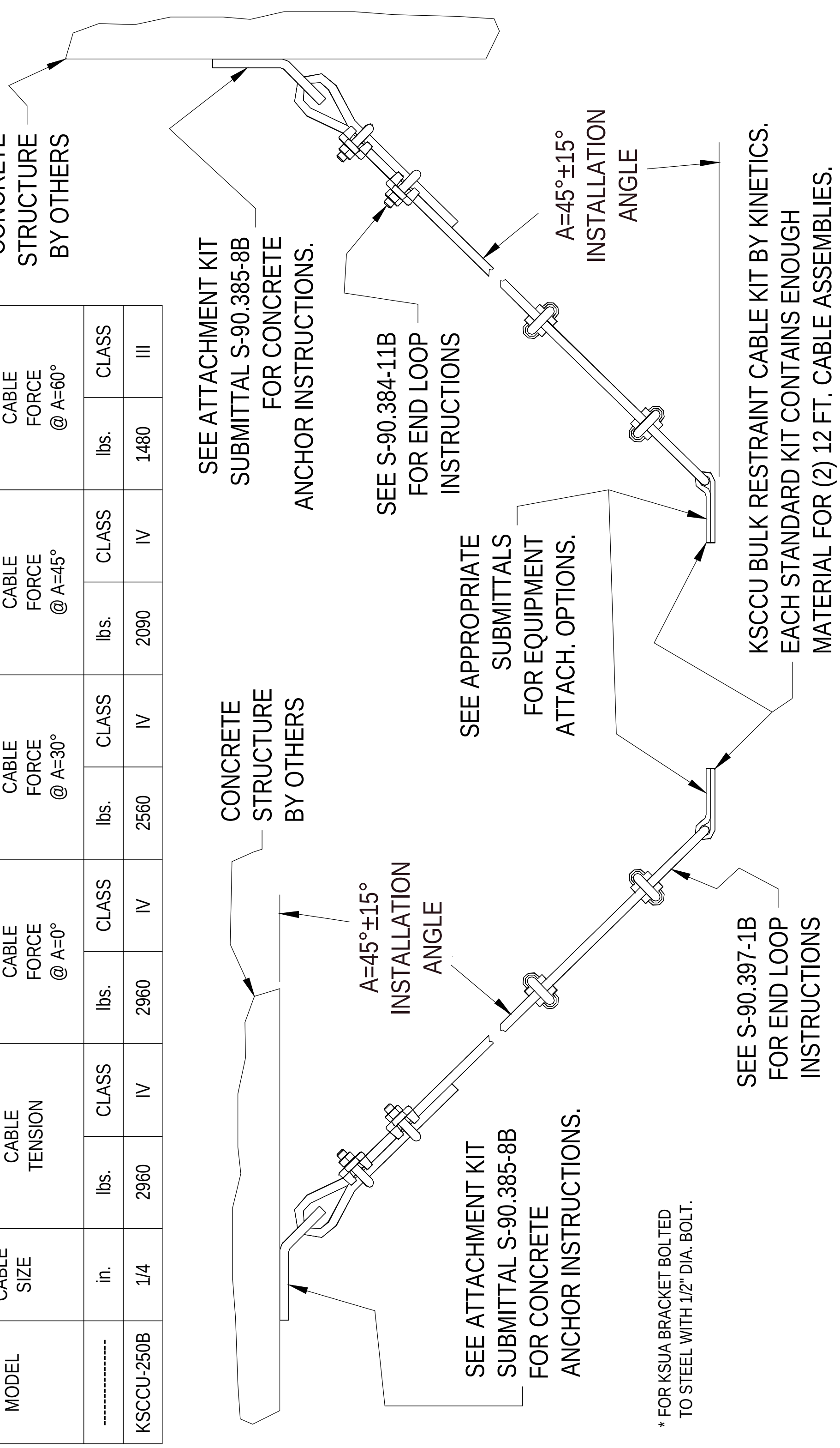
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
------------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCCU-250B	1/4	2960	IV	2960	IV	2560	IV	2090	IV	1480	III



* FOR KSUA BRACKET BOLTED TO STEEL WITH 1/2" DIA. BOLT.

KSCCU U-BOLT CLIP BULK CABLE RESTRAINT KIT (CCA – KSUA)

PAGE 1 OF 1 - DRAWING # S-90.384-10A

RELEASE DATE: 5/21/04

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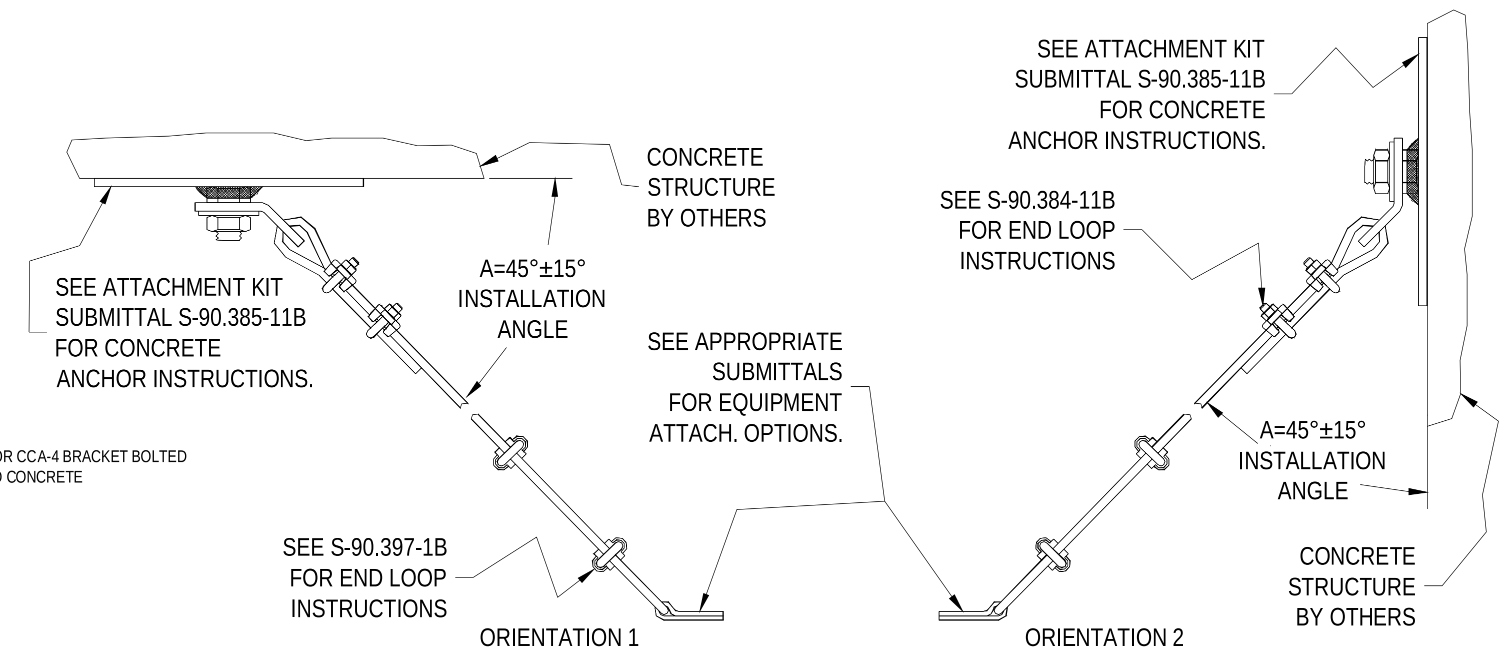
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°		
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	ORIENTATION
KSCCU4-250B	1/4	2960	IV	2960	IV	2560	IV	2090	IV	1480	III	1 or 2



* FOR CCA-4 BRACKET BOLTED TO CONCRETE

KSCCU4 U-BOLT CLIP BULK CABLE RESTRAINT KIT (CCA-4 – KSUA)

PAGE 1 OF 1 - DRAWING # S-90.384-13A

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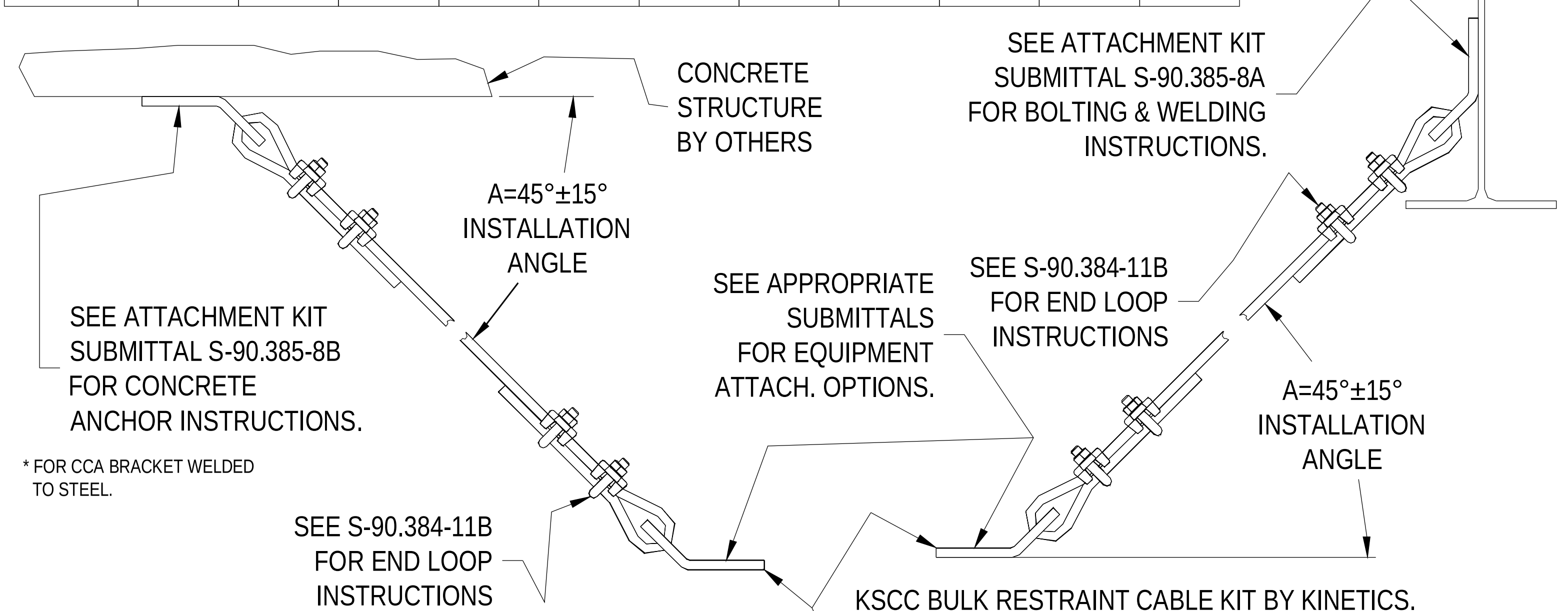
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCC-250B	1/4	2960	IV	2960	IV	2560	IV	2090	IV	1480	III
KSCC-375B	3/8	5915	V	3375	IV	5120	V	4180	IV	2955	IV
KSCC-500B	1/2	8500	V	3375	IV	6250	V	6010	V	4250	IV



* FOR CCA BRACKET WELDED TO STEEL.

KSCC U-BOLT CLIP BULK CABLE RESTRAINT KIT (CCA – CCA)

PAGE 1 OF 1 - DRAWING # S-90.384-11A

RELEASE DATE: 5/21/04

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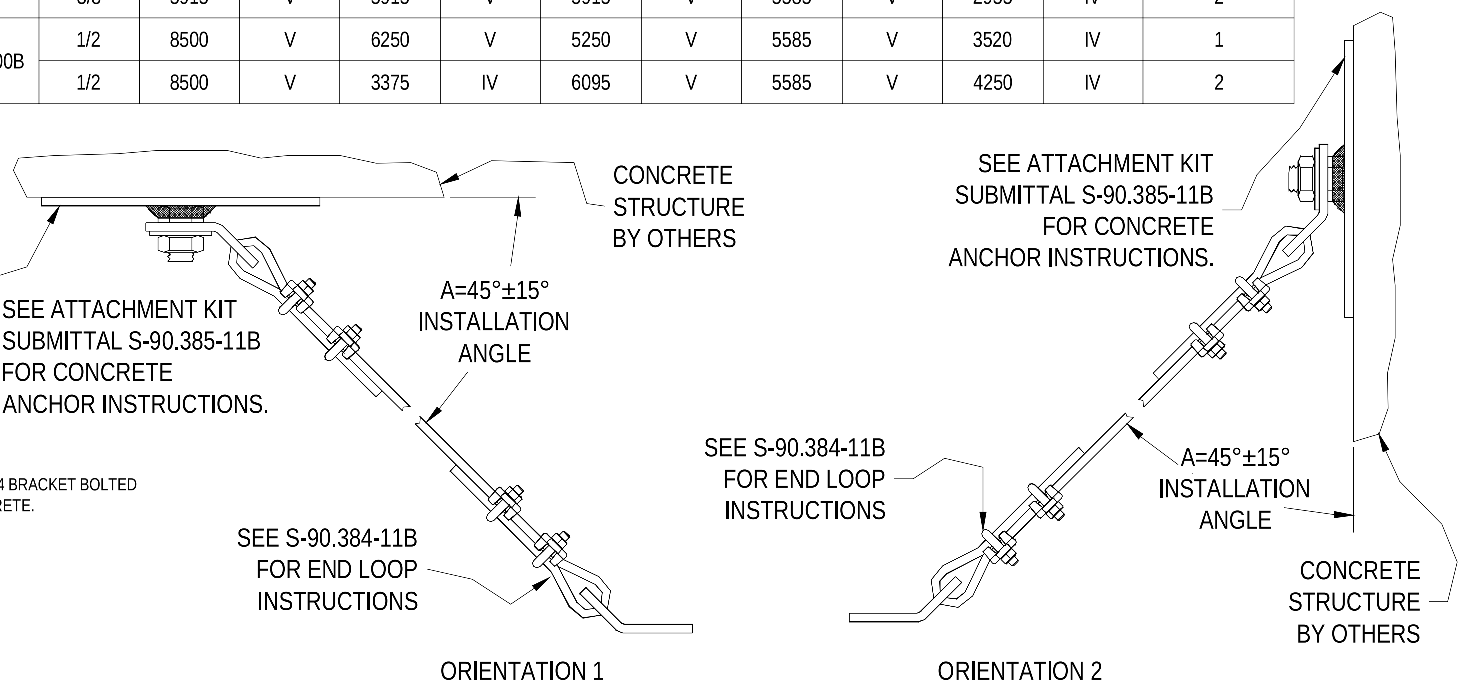
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°		
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	ORIENTATION
KSCC4-250B	1/4	2960	IV	2960	IV	2560	IV	2090	IV	1470	III	1 or 2
KSCC4-375B	3/8	5915	V	5915	V	5020	V	5585	V	2955	IV	1
	3/8	5915	V	5915	V	5915	V	5585	V	2955	IV	2
KSCC4-500B	1/2	8500	V	6250	V	5250	V	5585	V	3520	IV	1
	1/2	8500	V	3375	IV	6095	V	5585	V	4250	IV	2



* FOR CCA-4 BRACKET BOLTED TO CONCRETE.

KSCC4 U-BOLT CLIP BULK CABLE RESTRAINT KIT (CCA-4 – CCA)

PAGE 1 OF 1 - DRAWING # S-90.384-12A

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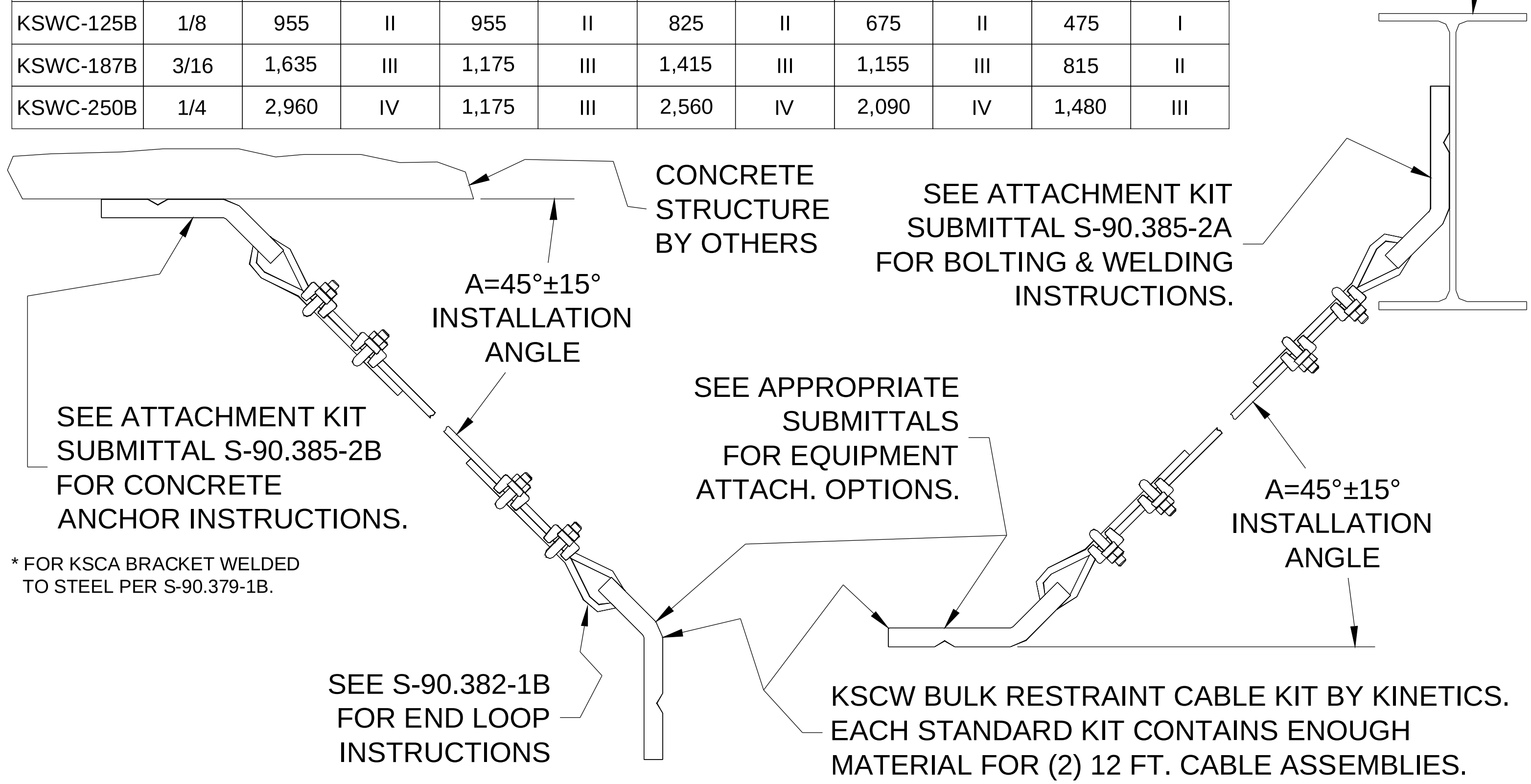
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSWC-125B	1/8	955	II	955	II	825	II	675	II	475	I
KSWC-187B	3/16	1,635	III	1,175	III	1,415	III	1,155	III	815	II
KSWC-250B	1/4	2,960	IV	1,175	III	2,560	IV	2,090	IV	1,480	III



* FOR KSCA BRACKET WELDED TO STEEL PER S-90.379-1B.

KSWC U-BOLT CLIP BULK CABLE RESTRAINT KIT (KSCA – KSCA)

PAGE 1 OF 1 - DRAWING # S-90.384-2A

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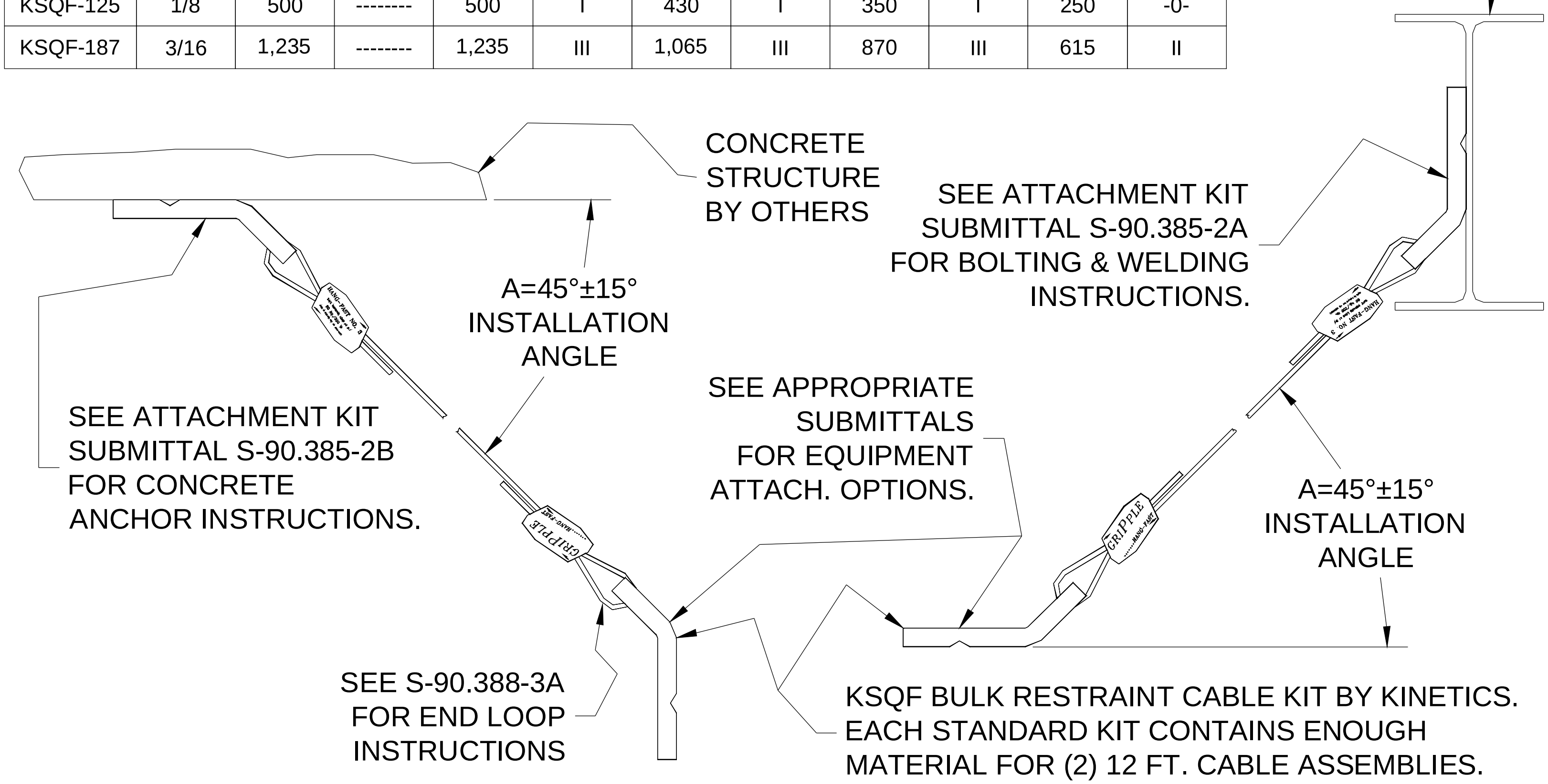
VISCMA MEMBER

MODEL	CABLE SIZE	MAX. CABLE TENSION		MAX. HORIZONTAL CABLE FORCE @ A=0°		MAX. HORIZONTAL CABLE FORCE @ A=30°		MAX. HORIZONTAL CABLE FORCE @ A=45°		MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSQF-125	1/8	500	--------	500	I	430	I	350	I	250	-0-
KSQF-187	3/16	1,235	--------	1,235	III	1,065	III	870	III	615	II



KSQF GRIPPLE BULK CABLE RESTRAINT KIT (KSCA – KSCA)

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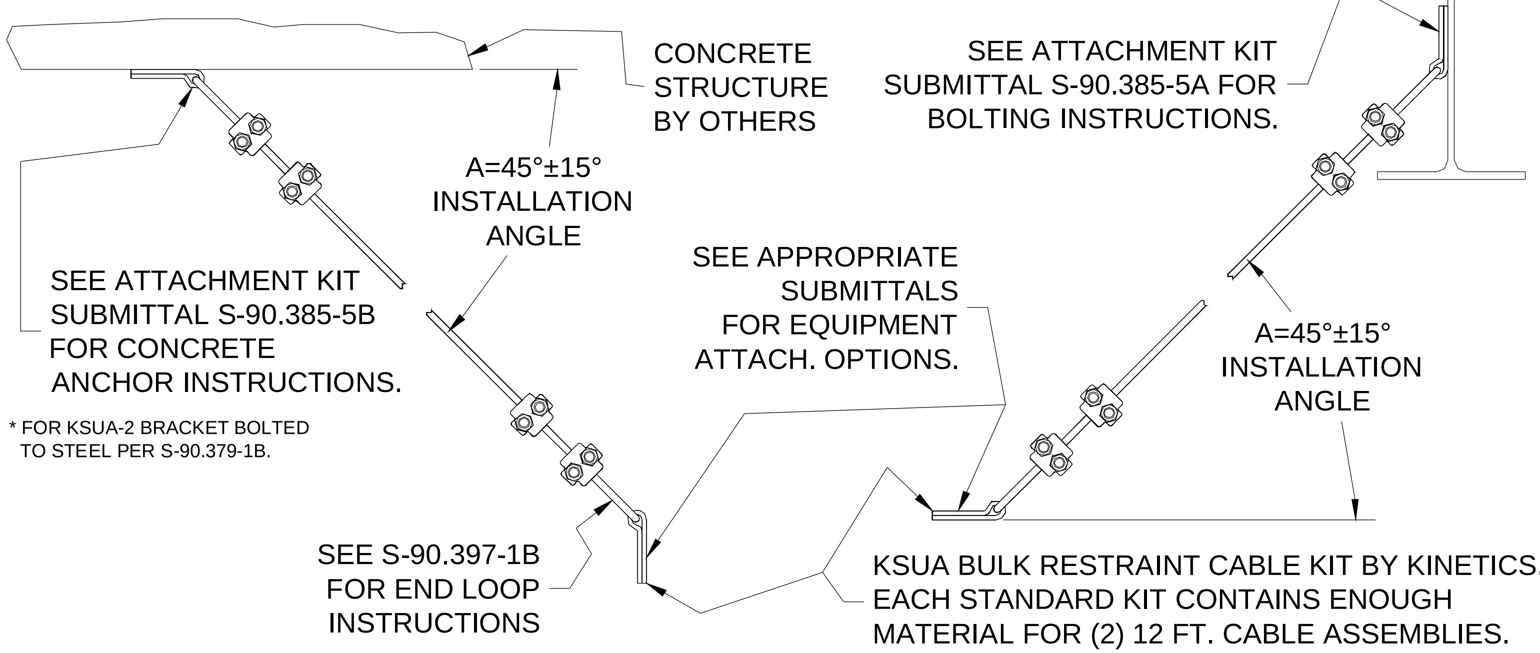
VISCMA MEMBER

KSUA U-BOLT CLIP BULK CABLE RESTRAINT KIT (KSUA – KSUA)

PAGE 1 OF 1 - DRAWING # S-90.384-8A

RELEASE DATE: 5/21/04

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUA-125B	1/8	955	II	955	II	825	II	675	II	475	I
KSUA-187B	3/16	1,635	III	1,635	III	1,415	III	1,155	III	815	II
KSUA-250B	1/4	2,960	IV	2,960	IV	2,560	IV	2,090	IV	1,480	III



* FOR KSUA-2 BRACKET BOLTED TO STEEL PER S-90.379-1B.

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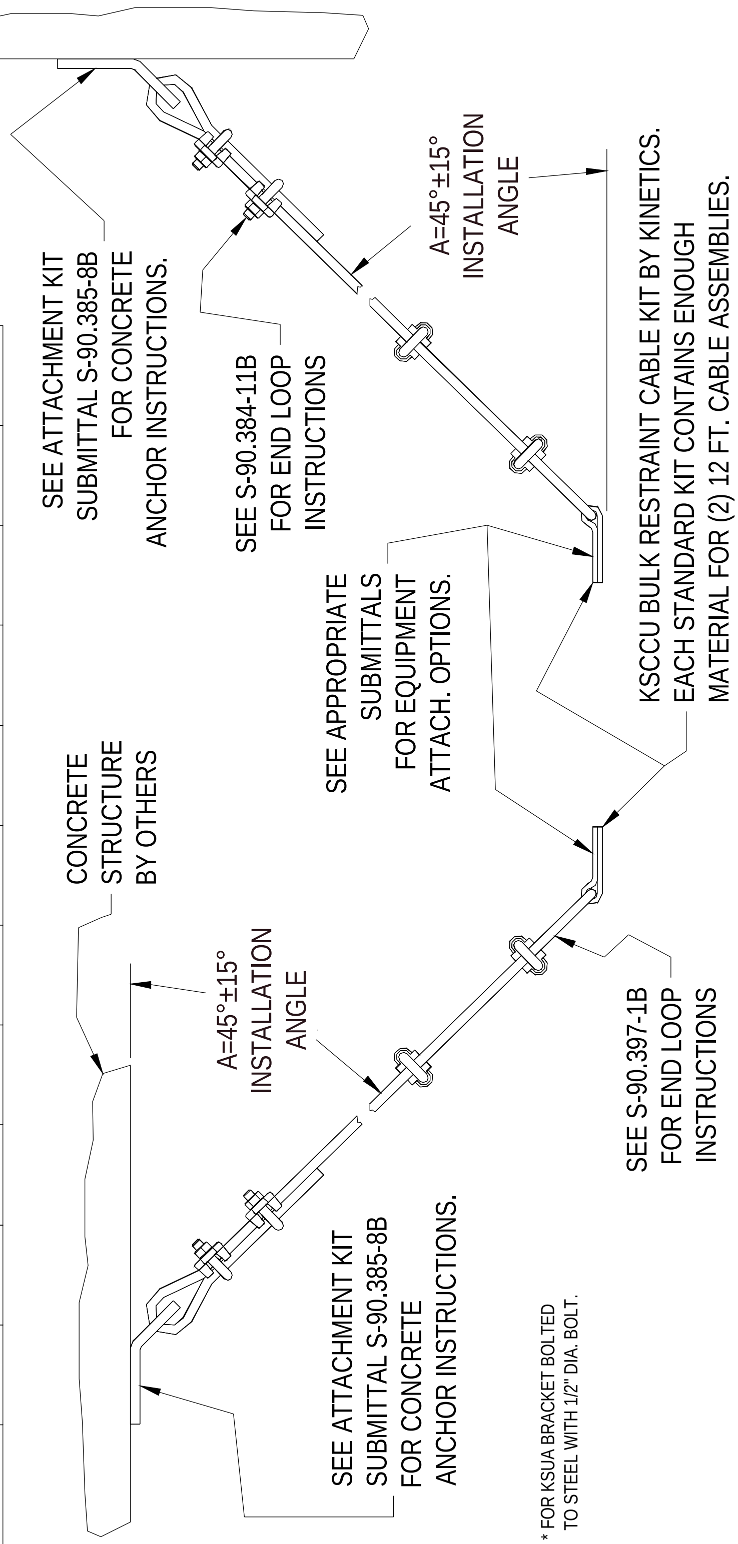
DOCUMENT: P7.3.3

VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
------------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCCU-250B	1/4	2960	IV	2960	IV	2560	IV	2090	IV	1480	III



* FOR KSUA BRACKET BOLTED TO STEEL WITH 1/2" DIA. BOLT.

KSCCU U-BOLT CLIP BULK CABLE RESTRAINT KIT (CCA – KSUA)

PAGE 1 OF 1 - DRAWING # S-90.384-10A

RELEASE DATE: 5/21/04

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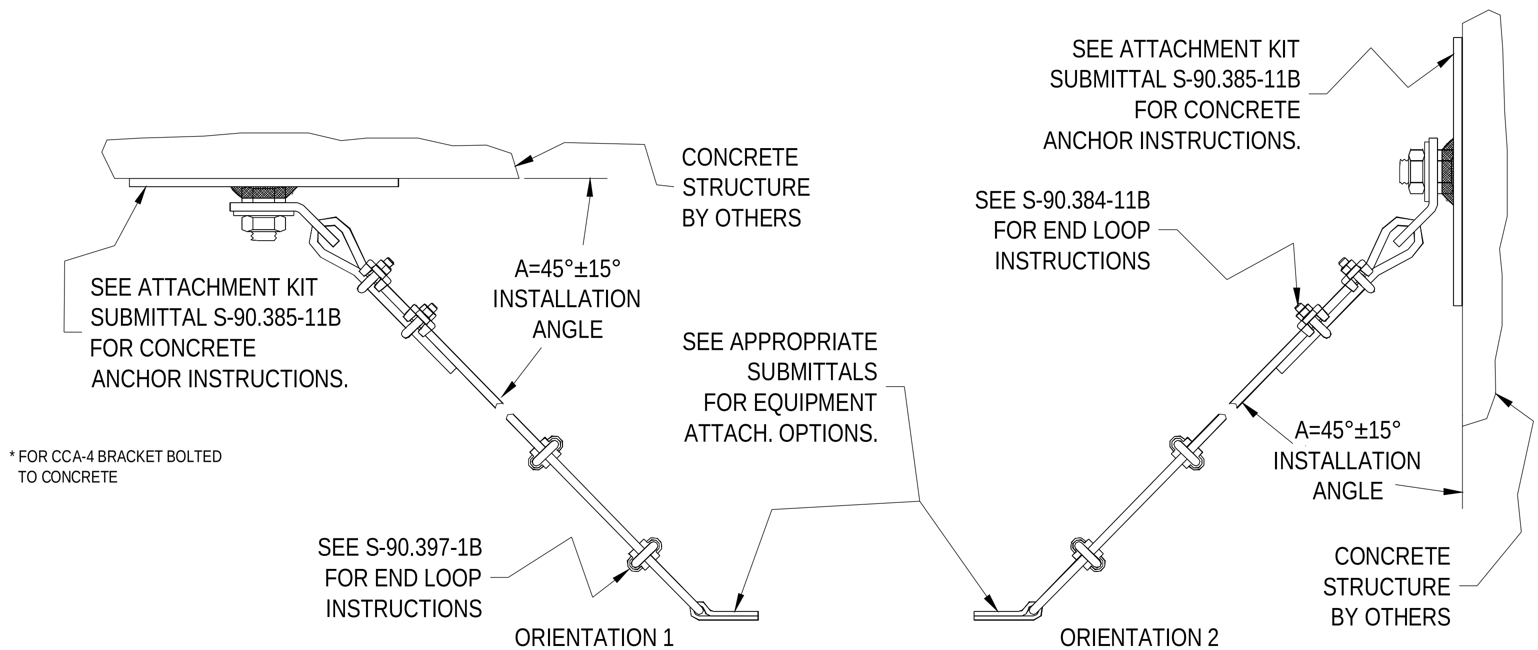
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°		
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	ORIENTATION
KSCCU4-250B	1/4	2960	IV	2960	IV	2560	IV	2090	IV	1480	III	1 or 2



* FOR CCA-4 BRACKET BOLTED TO CONCRETE

KSCCU4 U-BOLT CLIP BULK CABLE RESTRAINT KIT (CCA-4 – KSUA)

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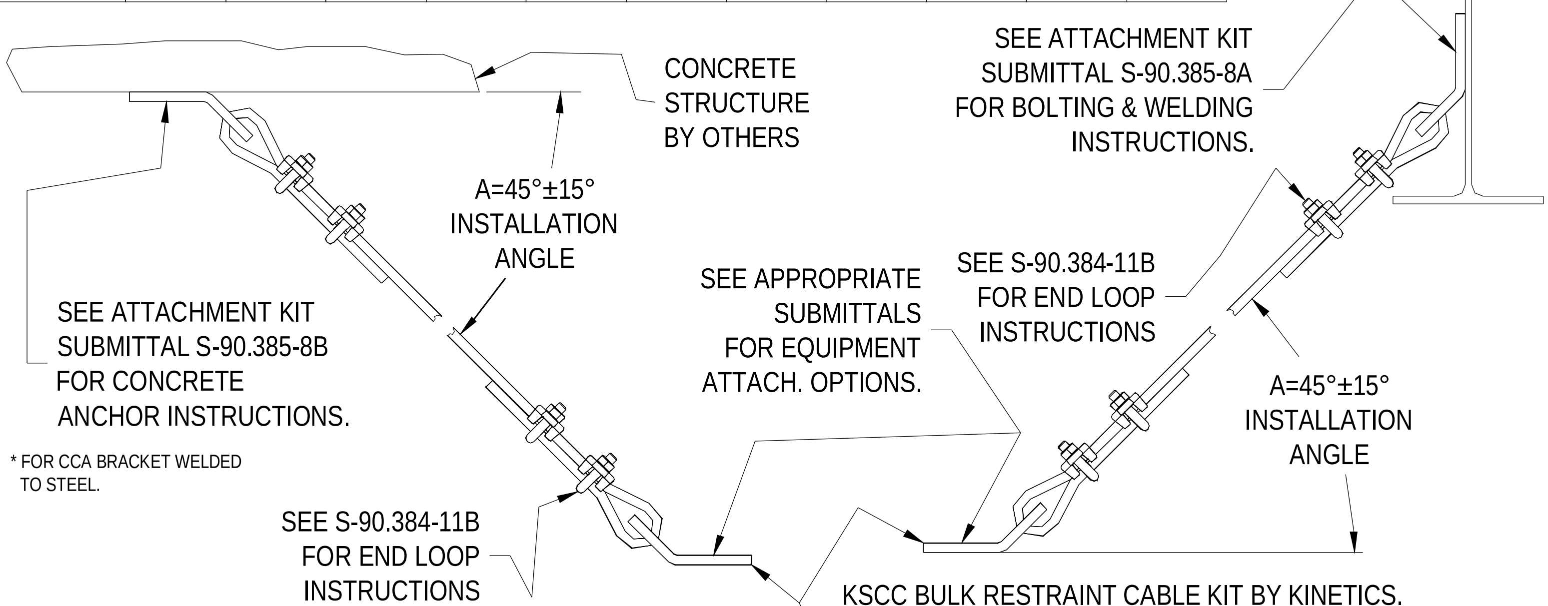
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°	
---------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCC-250B	1/4	2960	IV	2960	IV	2560	IV	2090	IV	1480	III
KSCC-375B	3/8	5915	V	3375	IV	5120	V	4180	IV	2955	IV
KSCC-500B	1/2	8500	V	3375	IV	6250	V	6010	V	4250	IV



* FOR CCA BRACKET WELDED TO STEEL.

KSCC U-BOLT CLIP BULK CABLE RESTRAINT KIT (CCA – CCA)

PAGE 1 OF 1 - DRAWING # S-90.384-11A

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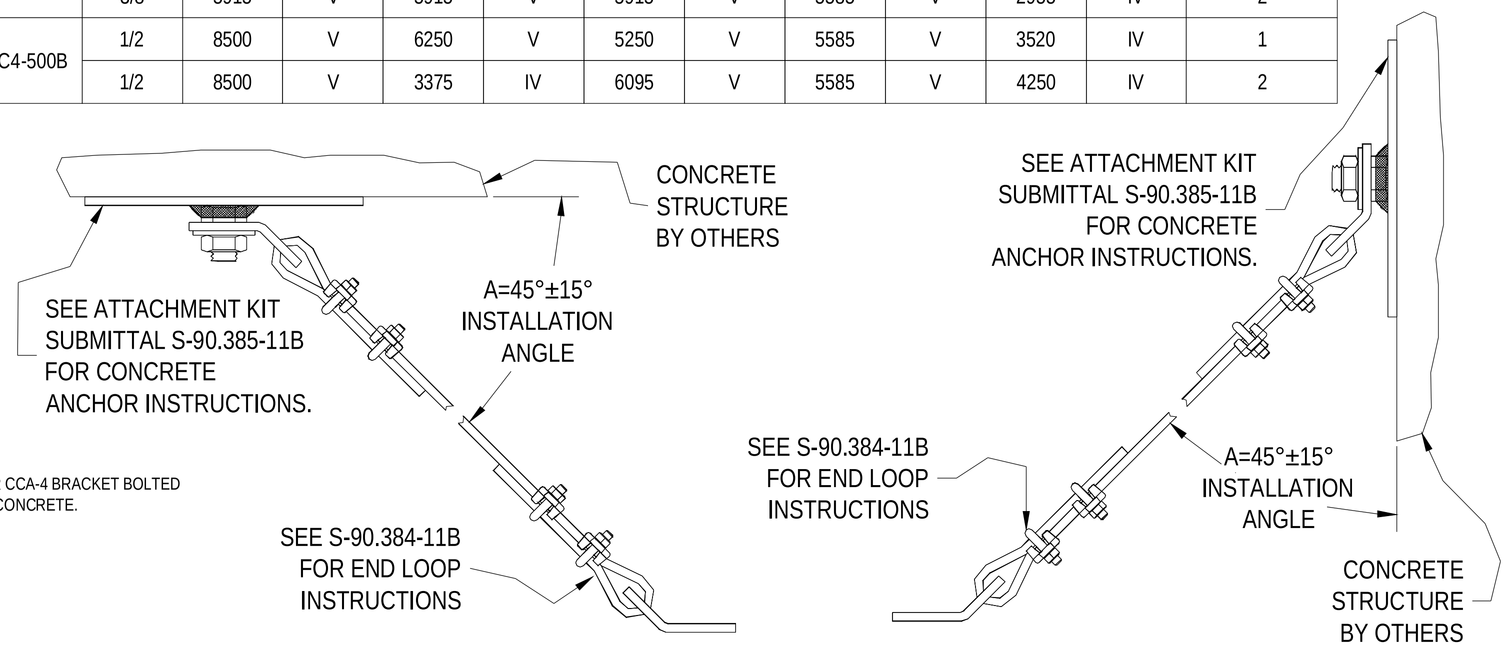
VISCMA MEMBER

MODEL	CABLE SIZE	* MAX. CABLE TENSION		* MAX. HORIZONTAL CABLE FORCE @ A=0°		* MAX. HORIZONTAL CABLE FORCE @ A=30°		* MAX. HORIZONTAL CABLE FORCE @ A=45°		* MAX. HORIZONTAL CABLE FORCE @ A=60°		
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	ORIENTATION
KSCC4-250B	1/4	2960	IV	2960	IV	2560	IV	2090	IV	1470	III	1 or 2
KSCC4-375B	3/8	5915	V	5915	V	5020	V	5585	V	2955	IV	1
	3/8	5915	V	5915	V	5915	V	5585	V	2955	IV	2
KSCC4-500B	1/2	8500	V	6250	V	5250	V	5585	V	3520	IV	1
	1/2	8500	V	3375	IV	6095	V	5585	V	4250	IV	2



ORIENTATION 1 ORIENTATION 2

* FOR CCA-4 BRACKET BOLTED TO CONCRETE.

KSCC4 U-BOLT CLIP BULK CABLE RESTRAINT KIT (CCA-4 – CCA)

PAGE 1 OF 1 - DRAWING # S-90.384-12A

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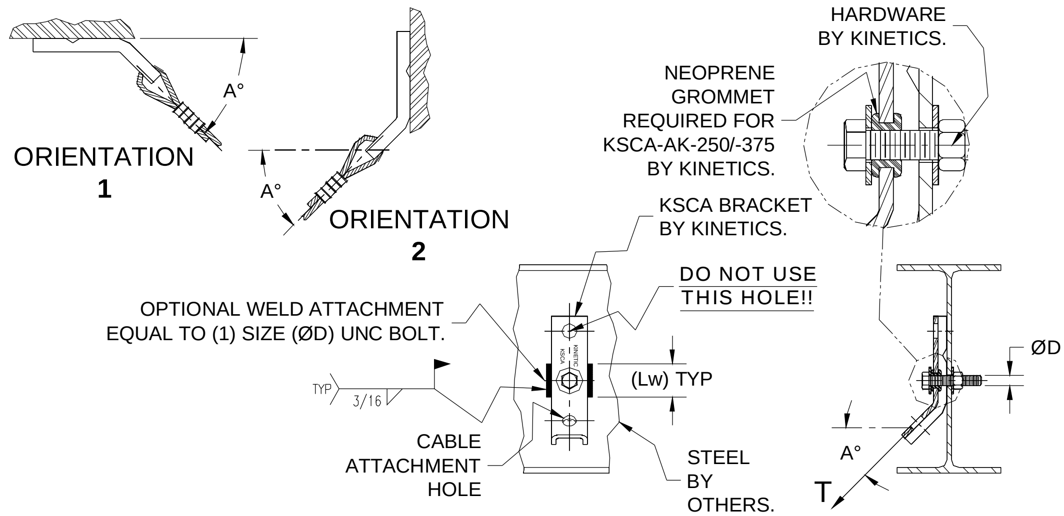
VISCMA MEMBER

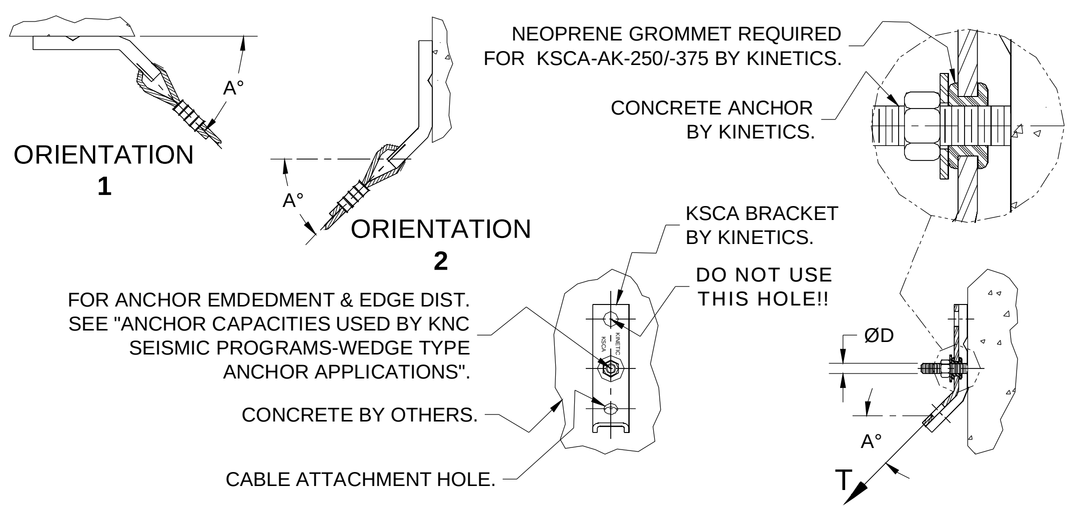
THROUGH BOLTED OR WELDED

MODEL	BOLT/ ANCHOR SIZE (ØD) (UNC)	WELD LENGTH (Lw)	MAX. HORIZ. FORCE ORIENTATION **1** @ A=0°		MAX. HORIZ. FORCE ORIENTATION **1** @ A=30°		MAX. HORIZ. FORCE ORIENTATION **1** @ A=45°		MAX. HORIZ. FORCE ORIENTATION **1** @ A=60°		MAX. HORIZ. FORCE ORIENTATION **2** @ A=0°		MAX. HORIZ. FORCE ORIENTATION **2** @ A=30°		MAX. HORIZ. FORCE ORIENTATION **2** @ A=45°		MAX. HORIZ. FORCE ORIENTATION **2** @ A=60°	
----------------	in.	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCA-AK-250	0.25	1.00	570	II	985	II	695	II	405	I	625	II	705	II	695	II	570	II
KSCA-AK-375	0.38	1.25	1,175	III	2,405	III	1,700	III	995	II	1,175	III	1,725	III	1,700	III	1,385	III
KSCA-AK-500	0.50	2.00	1,175	III	2,970	IV	2,970	IV	1,820	III	1,175	III	2,970	IV	2,970	IV	2,540	IV



ANCHORED TO CONCRETE

MODEL	BOLT/ ANCHOR SIZE (ØD) (UNC)	MAX. HORIZ. FORCE ORIENTATION **1** @ A=0°		MAX. HORIZ. FORCE ORIENTATION **1** @ A=30°		MAX. HORIZ. FORCE ORIENTATION **1** @ A=45°		MAX. HORIZ. FORCE ORIENTATION **1** @ A=60°		MAX. HORIZ. FORCE ORIENTATION **2** @ A=0°		MAX. HORIZ. FORCE ORIENTATION **2** @ A=30°		MAX. HORIZ. FORCE ORIENTATION **2** @ A=45°		MAX. HORIZ. FORCE ORIENTATION **2** @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCA-AK-250	0.25	200	-0-	415	I	255	I	140	-0-	215	-0-	240	-0-	255	I	240	-0-
KSCA-AK-375	0.38	435	I	990	II	560	II	300	I	450	I	520	II	560	II	570	II
KSCA-AK-500	0.50	665	II	1,620	III	865	II	455	I	670	II	785	II	865	II	935	II



KSCA-AK CABLE ANCHORAGE HARDWARE KIT FOR KSCA BRACKETS

PAGE 1 OF 1 - DRAWING # S-90.385-2A & S-90.385-2B

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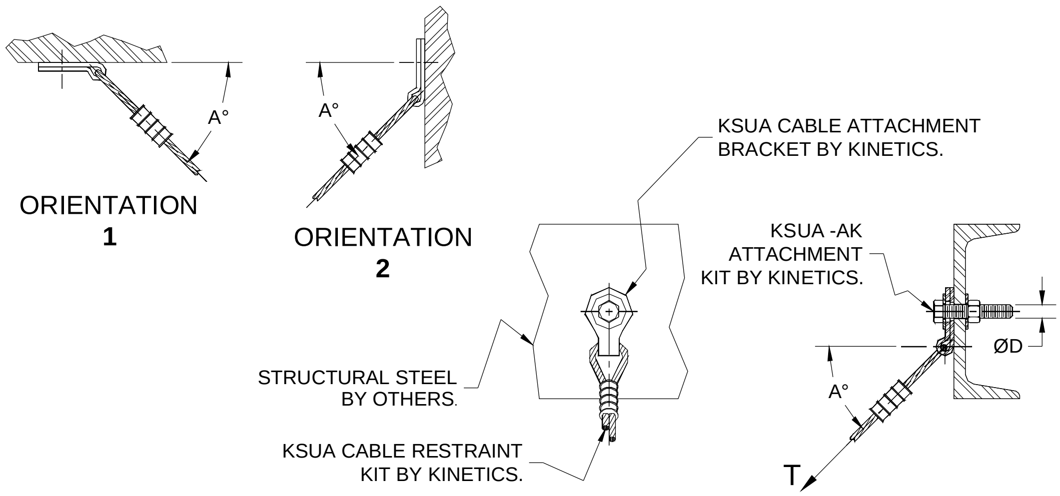
VISCMA MEMBER

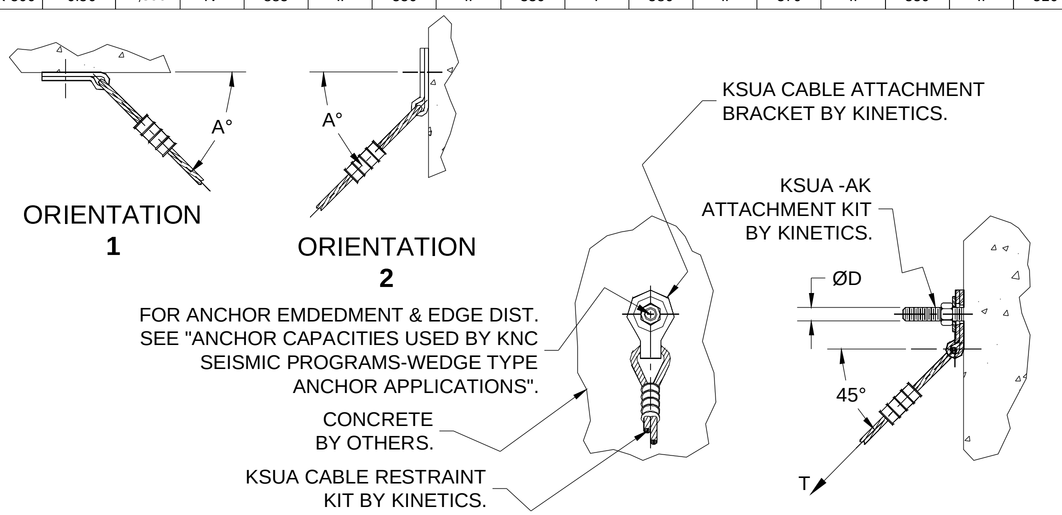
THROUGH BOLTED OR WELDED

MODEL	BOLT/ ANCHOR SIZE (ØD) (UNC)	MAX. HORIZ. FORCE ORIENTATION 1 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=60°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUA-AK-250	0.25	1,085	III	625	II	450	I	290	I	540	II	505	II	450	I	360	I
KSUA-AK-375	0.38	2,650	IV	1,530	III	1,095	III	710	II	1,325	III	1,230	III	1,095	III	880	II
KSUA-AK-500	0.50	4,850	IV	2,800	IV	2,010	IV	1,300	III	2,425	IV	2,250	IV	2,010	IV	1,615	III



ANCHORED TO CONCRETE

MODEL	BOLT/ ANCHOR SIZE (ØD) (UNC)	MAX. HORIZ. FORCE ORIENTATION 1 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=60°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUA-AK-250	0.25	530	II	260	I	170	-0-	100	-0-	185	-0-	175	-0-	170	-0-	150	-0-
KSUA-AK-375	0.38	1,360	III	575	II	360	I	220	-0-	390	I	380	I	360	I	330	I
KSUA-AK-500	0.50	2,390	IV	885	II	550	II	330	I	580	II	570	II	550	II	510	II



KSUA-AK CABLE ANCHORAGE HARDWARE KIT FOR KSUA BRACKETS

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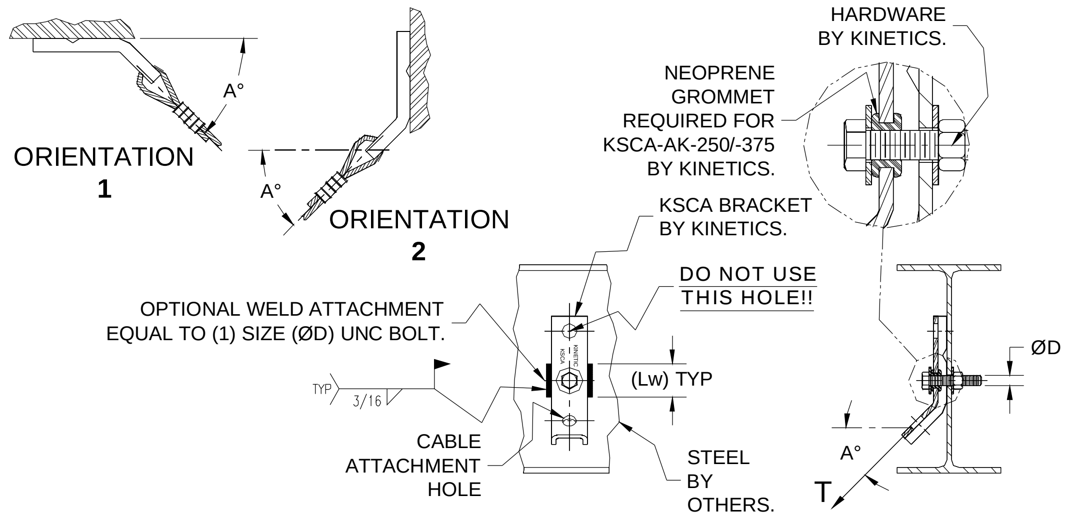
THROUGH BOLTED OR WELDED

MODEL	BOLT/ ANCHOR SIZE (ØD) (UNC)	WELD LENGTH (Lw)	MAX. HORIZ. FORCE ORIENTATION 1 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=60°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=60°	
----------------	in.	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCA-AK-250	0.25	1.00	570	II	985	II	695	II	405	I	625	II	705	II	695	II	570	II
KSCA-AK-375	0.38	1.25	1,175	III	2,405	III	1,700	III	995	II	1,175	III	1,725	III	1,700	III	1,385	III
KSCA-AK-500	0.50	2.00	1,175	III	2,970	IV	2,970	IV	1,820	III	1,175	III	2,970	IV	2,970	IV	2,540	IV



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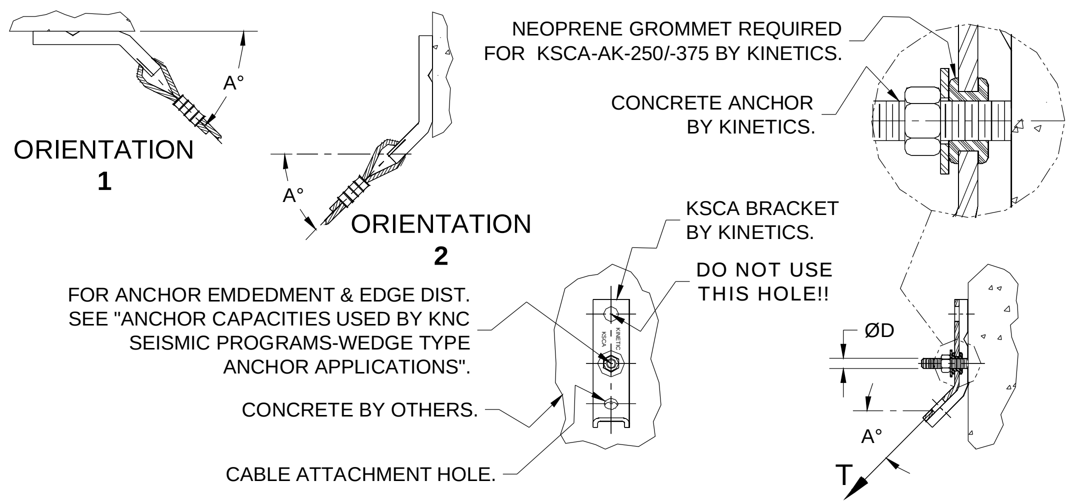
MODEL	BOLT/ ANCHOR SIZE (ØD) (UNC)	MAX. HORIZ. FORCE ORIENTATION 1 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=60°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSCA-AK-250	0.25	200	-0-	415	I	255	I	140	-0-	215	-0-	240	-0-	255	I	240	-0-
KSCA-AK-375	0.38	435	I	990	II	560	II	300	I	450	I	520	II	560	II	570	II
KSCA-AK-500	0.50	665	II	1,620	III	865	II	455	I	670	II	785	II	865	II	935	II



KSCA-AK CABLE ANCHORAGE HARDWARE KIT FOR KSCA BRACKETS

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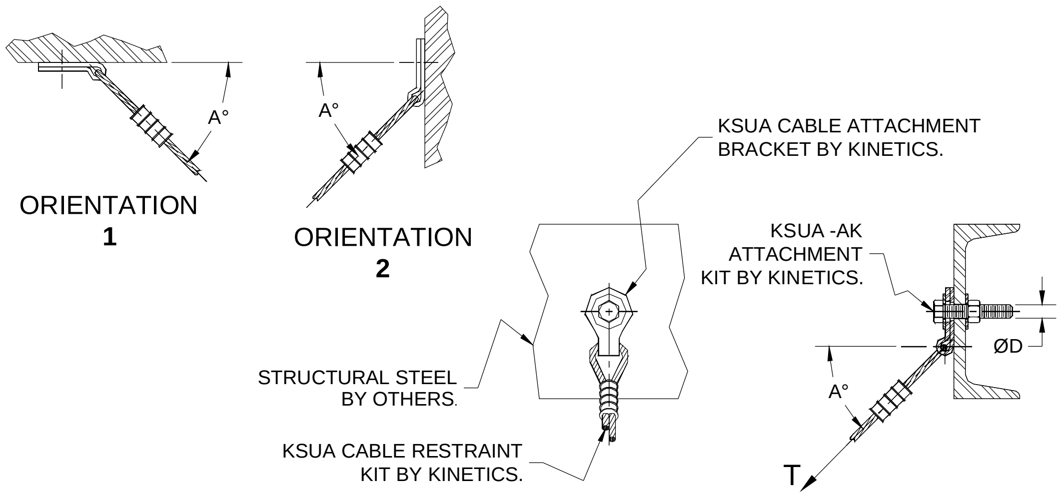
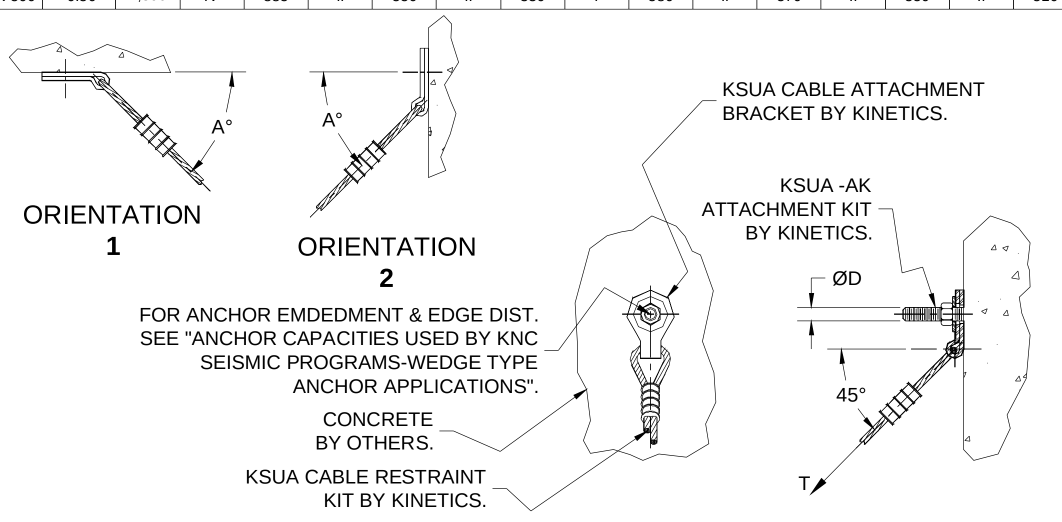
THROUGH BOLTED OR WELDED

MODEL	BOLT/ ANCHOR SIZE (ØD) (UNC)	MAX. HORIZ. FORCE ORIENTATION 1 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=60°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUA-AK-250	0.25	1,085	III	625	II	450	I	290	I	540	II	505	II	450	I	360	I
KSUA-AK-375	0.38	2,650	IV	1,530	III	1,095	III	710	II	1,325	III	1,230	III	1,095	III	880	II
KSUA-AK-500	0.50	4,850	IV	2,800	IV	2,010	IV	1,300	III	2,425	IV	2,250	IV	2,010	IV	1,615	III



ANCHORED TO CONCRETE

MODEL	BOLT/ ANCHOR SIZE (ØD) (UNC)	MAX. HORIZ. FORCE ORIENTATION 1 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 1 @ A=60°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=0°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=30°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=45°		MAX. HORIZ. FORCE ORIENTATION 2 @ A=60°	
----------------	in.	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS	lbs.	CLASS
KSUA-AK-250	0.25	530	II	260	I	170	-0-	100	-0-	185	-0-	175	-0-	170	-0-	150	-0-
KSUA-AK-375	0.38	1,360	III	575	II	360	I	220	-0-	390	I	380	I	360	I	330	I
KSUA-AK-500	0.50	2,390	IV	885	II	550	II	330	I	580	II	570	II	550	II	510	II



KSUA-AK CABLE ANCHORAGE HARDWARE KIT FOR KSUA BRACKETS

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CHAPTER P8

OTHER REQUIRED COMPONENTS FOR SUSPENDED SYSTEMS

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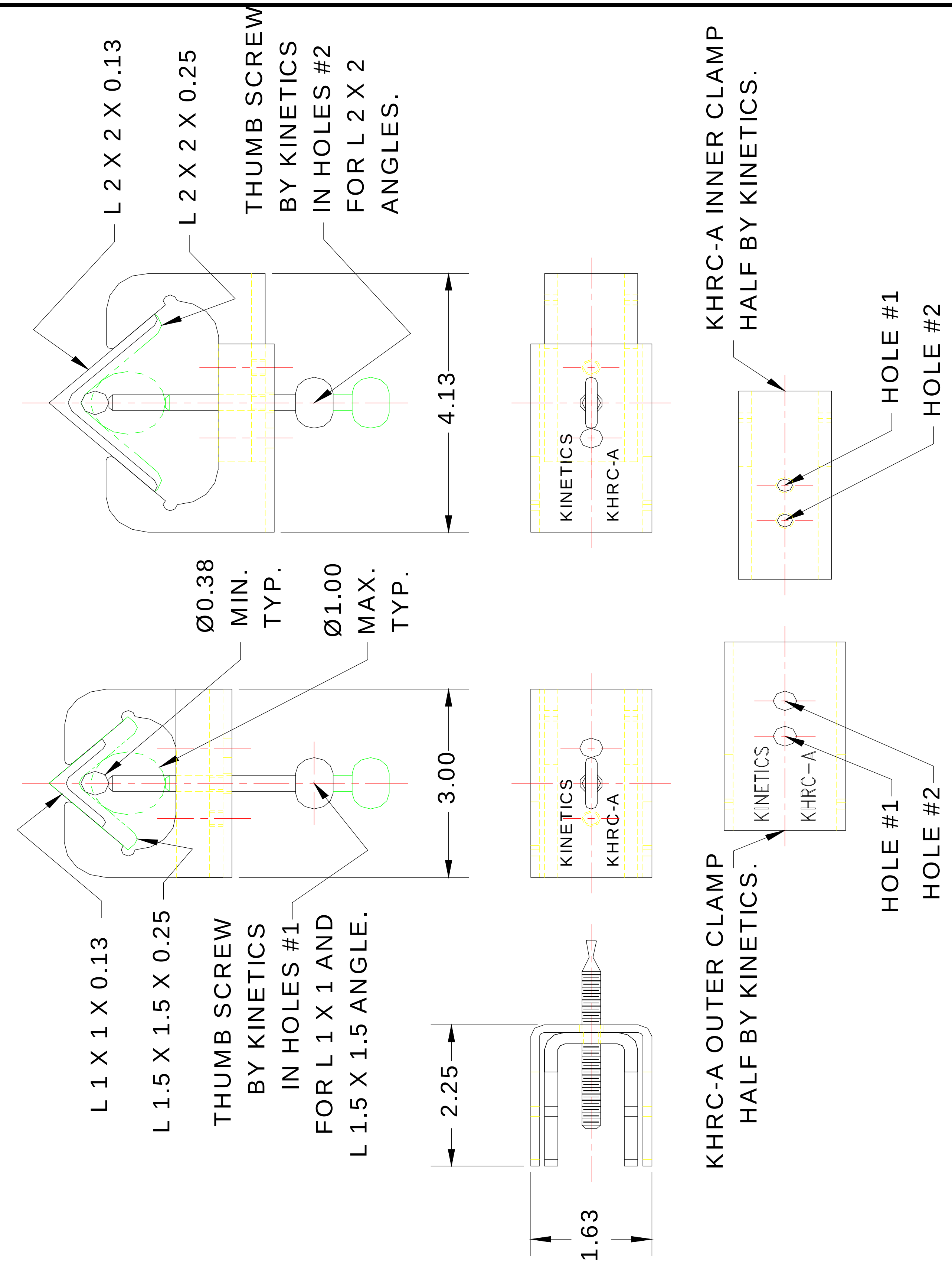

KHRC-A ADJUSTABLE STIFFENER KIT

DRAWING # S-90.500-1A

RELEASE DATE: 12/19/03

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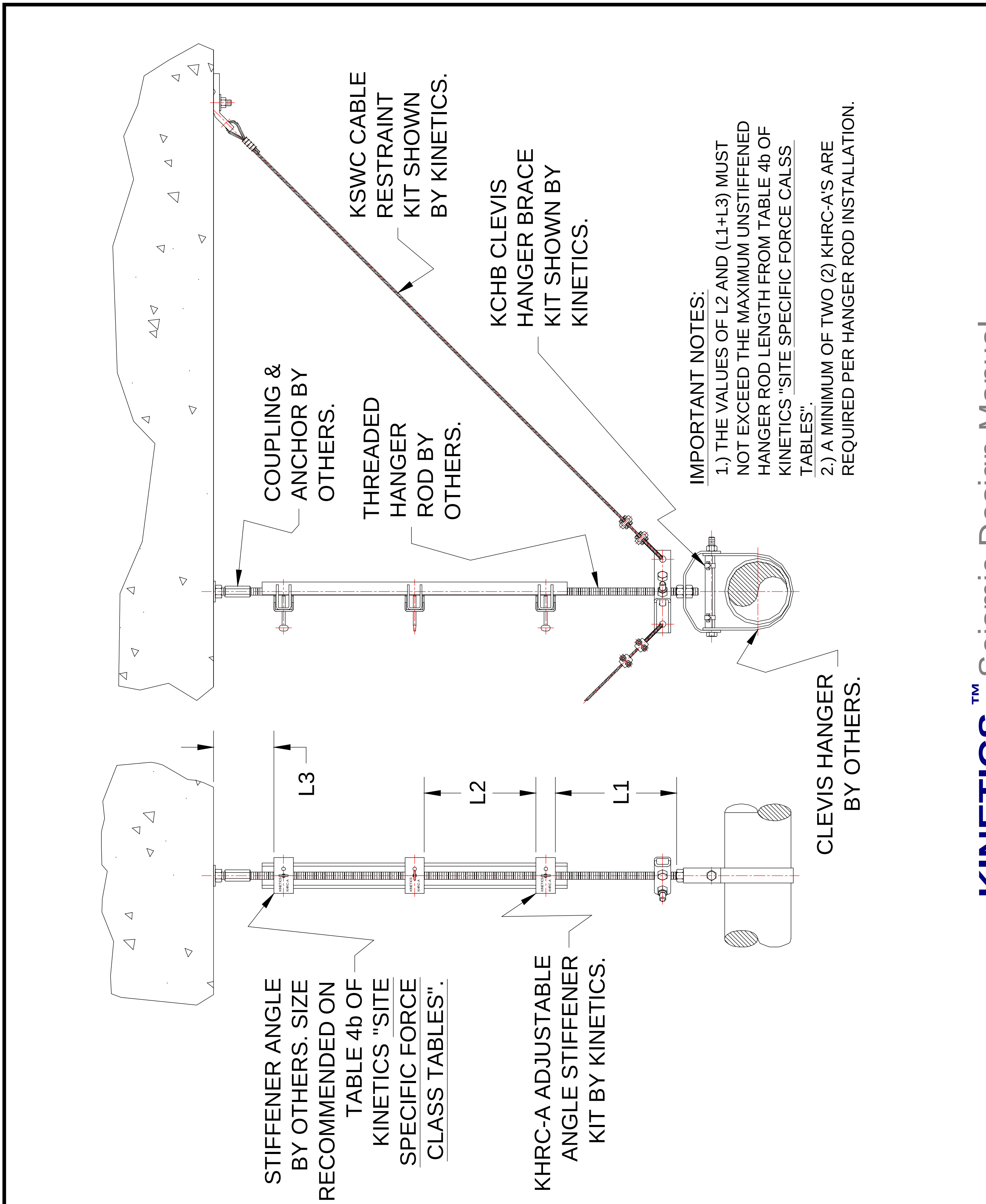

KHRC-A ADJUSTABLE STIFFENER KIT

DRAWING # S-90.500-1B

RELEASE DATE: 12/19/03

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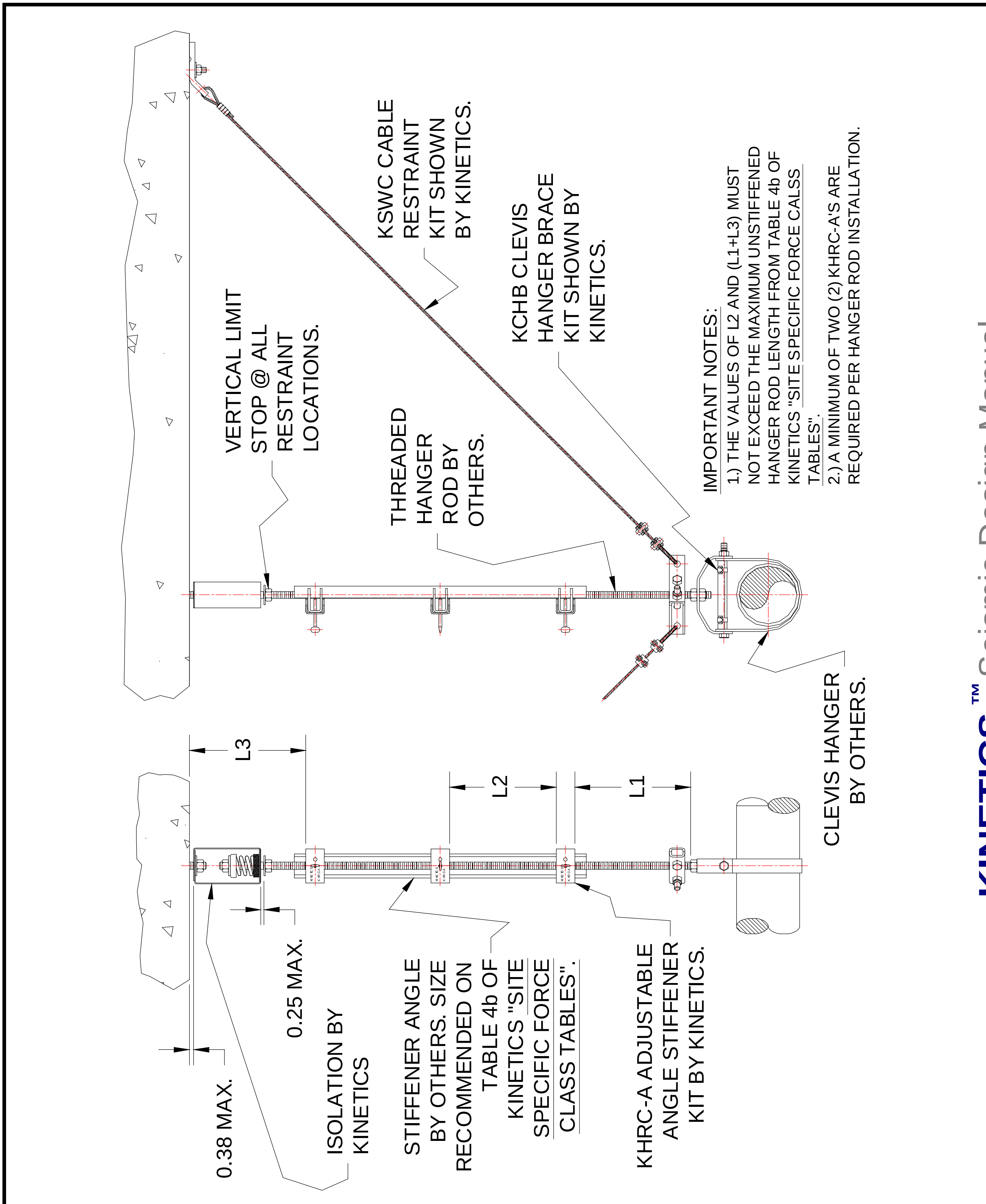

KHRC-A ADJUSTABLE STIFFENER KIT

DRAWING # S-90.500-1C

RELEASE DATE: 12/19/03

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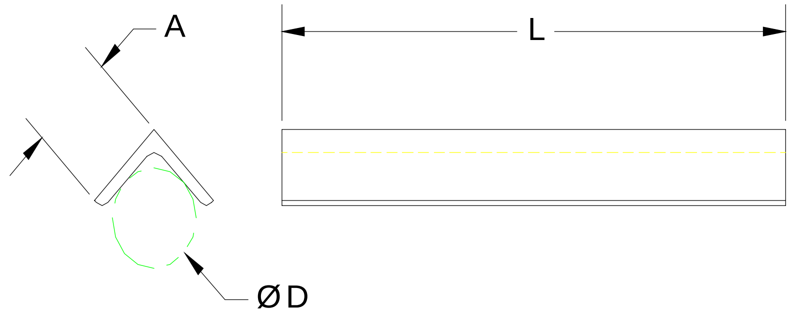
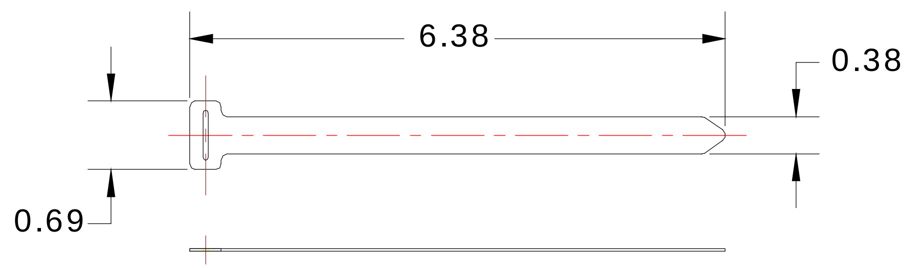


KCHB BRACE ANGLE

EACH KIT CONTAINS (1)
PER MODEL DESCRIPTION
IN TABLE AT THE RIGHT.

MODEL	PIPE SIZE	A (in.)	L (in.)	ØDmin. (in.)	ØDmax. (in.)
KCHB-01	1-1/2"	0.50	1.88	0.25	0.38
KCHB-02	2"	0.50	2.38	0.25	0.38
KCHB-03	2-1/2"	0.50	2.88	0.25	0.38
KCHB-04	3"	0.50	3.50	0.25	0.38
KCHB-05	3-1/2"	0.50	4.00	0.25	0.38
KCHB-06	4"	0.75	4.50	0.50	0.75
KCHB-07	5"	0.75	5.56	0.50	0.75
KCHB-08	6"	0.75	6.63	0.50	0.75
KCHB-09	8"	0.75	8.63	0.50	0.75
KCHB-10	10"	0.75	10.75	0.50	0.75
KCHB-11	12"	0.75	12.75	0.50	0.75
KCHB-12	14"	1.00	14.00	0.88	1.25
KCHB-13	16"	1.00	16.00	0.88	1.25
KCHB-14	18"	1.00	18.00	0.88	1.25
KCHB-15	20"	1.00	20.00	0.88	1.25
KCHB-16	24"	1.00	24.00	0.88	1.25
KCHB-17	30"	1.00	30.00	0.88	1.25



KCHB BRACE ANGLE STRAP

EACH KIT CONTAINS (2).

KCHB CLEVIS HANGER BRACE

DRAWING # S-90.600-1A

RELEASE DATE: 12/19/03

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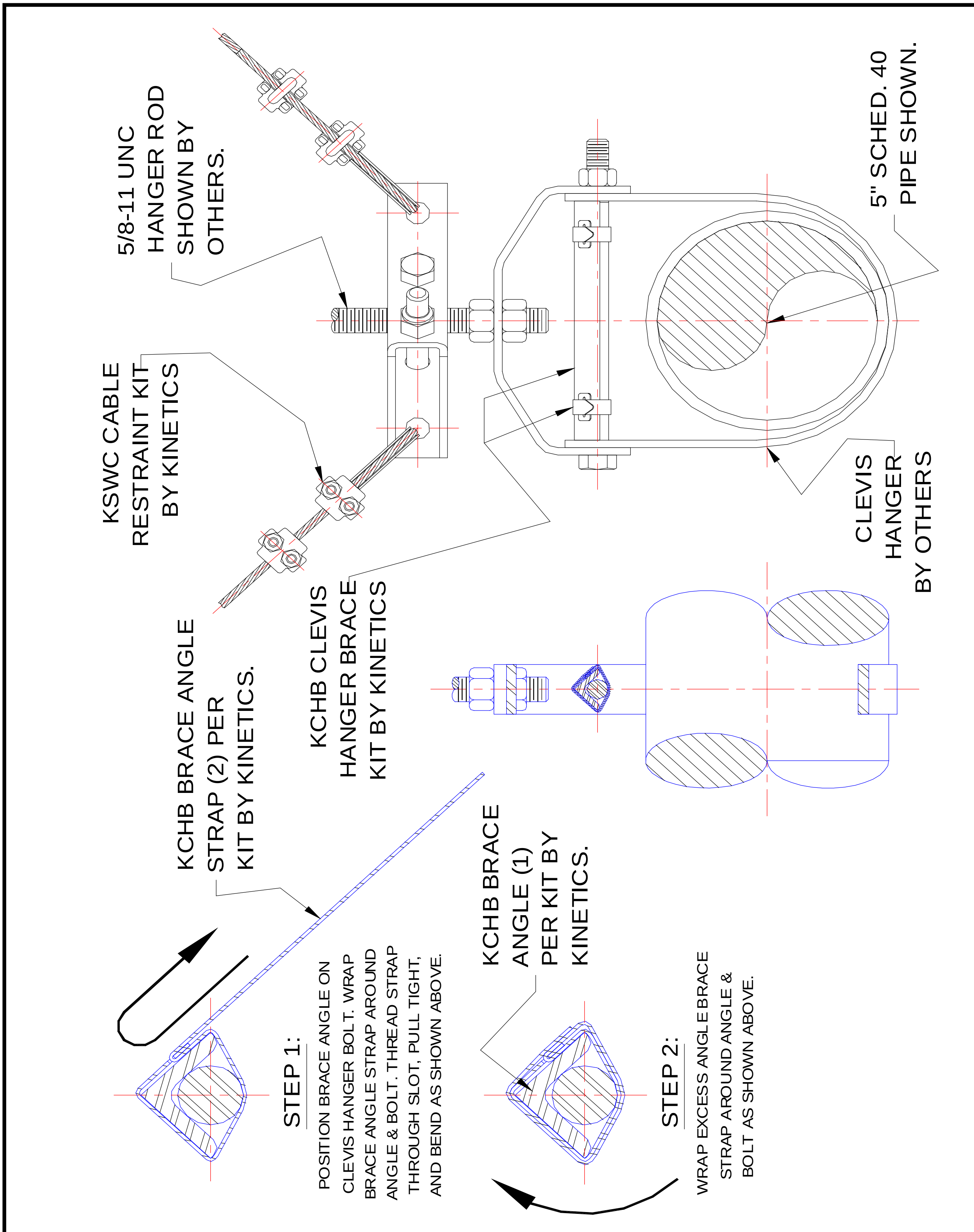

KCHB CLEVIS HANGER BRACE

DRAWING # S-90.600-1B

RELEASE DATE: 12/19/03

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Kinetics KSBC Seismically Rated Beam Clamp

There is frequently a desire to attach seismic restraints to roof or floor support I-beams. Equally often the ability to add holes to these beams for bolts or to weld tabs to them is not possible or practical. In these conditions, Beam Clamps can often be used as long as they are of the proper type, are properly sized and are properly installed.

Before proceeding in the selection of a beam clamp, first determine that the beams to which the restraint is to be attached are oriented properly. All connections must be positive and not rely on friction to carry the seismic load. This means that the direction of the cable and/or strut used to resist the forces must be at right angles to the beam. If the cable or strut is oriented in line with the beam axis, a beam clamp cannot be used and a weld-on tab or bolted connection is required.

If, based on the above, it is possible to use a beam clamp, an appropriate type and size must be selected. Most commercially available Beam Clamps are not appropriate for the attachment of restraints as they are designed to support vertical loads and not transfer horizontal ones. Unless rated for horizontal loads by the manufacturer, "conventional" beam clamps should not be used. As a minimum, appropriate beam clamps must meet the following set of requirements:

1) Beam clamps must engage both sides of a beam such that, even if the attachment bolt is not fully tightened, there is **no** possibility that the clamp can be pulled off of the beam.
2) Both the clamp bracket itself and the arm that engages the opposite side of the beam must be adequate to transfer the full horizontal load that is required for the application
3) The hardware used to attach the restraint or strut bracket to the beam clamp must also be adequate to transfer the full horizontal load that is required for the application.
4) All components used must be rated using factors consistent with code requirements and appropriate for seismic design.

The Kinetics Noise Control KSBC Beam Clamp is designed to address the horizontal loads expected from seismic events. The two (2) sizes available use 3/8" and 1/2" attachment hardware and are equivalent to full bolted connections for hardware of the same size. (Thus if documentation requires that a 3/8" bolt be used, a 3/8" beam clamp is equally acceptable.)

Note that, as with any seismic connection to structural elements, the ability of the structural element to resist the design seismic load is known only by the structural engineer of record. As these forces can be significant and because beams used to support structures are typically designed around the vertical or gravity loads, there may be structural issues that must be addressed when connecting to and applying large horizontal forces to these members. Always, before connecting restraints to beams or

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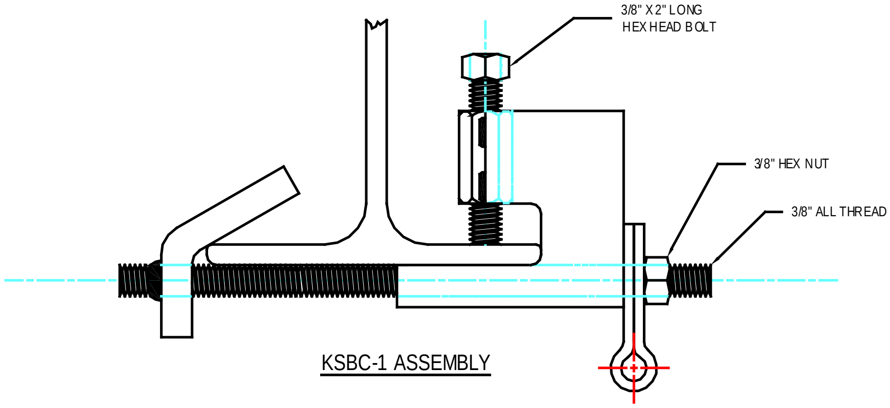
other structural elements, ensure that the capacity of the elements to resist these loads is adequate. Kinetics Noise Control is not in a position to accept any responsibility for problems that develop from restraints being attached to inadequate structural elements.



Typical KSBC shown with KSUA attachment clip
(Can also be used with KSCA clip)

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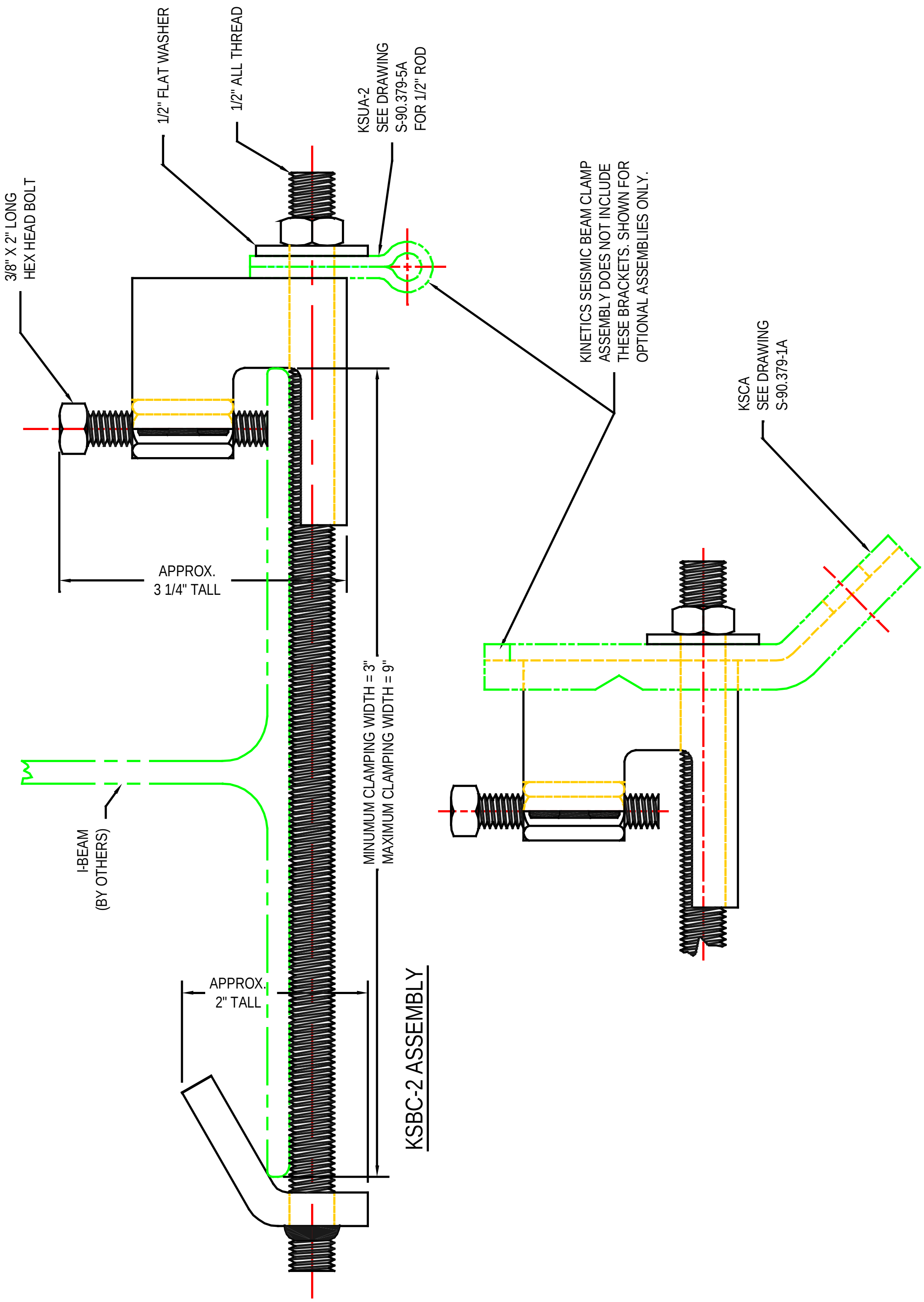

KSBC Beam Clamp

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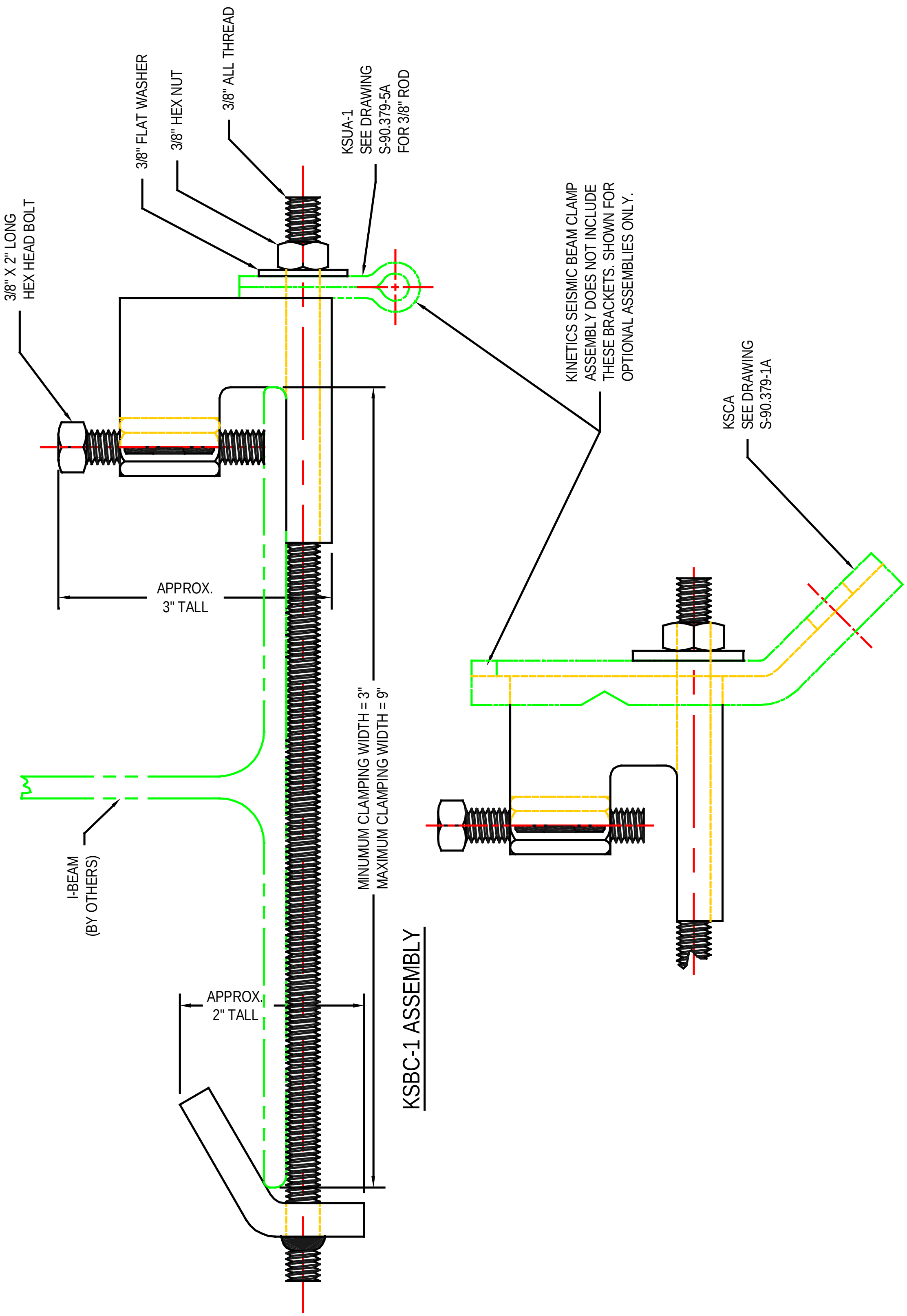

KSBC Beam Clamp

RELEASE DATE: 1/6/05

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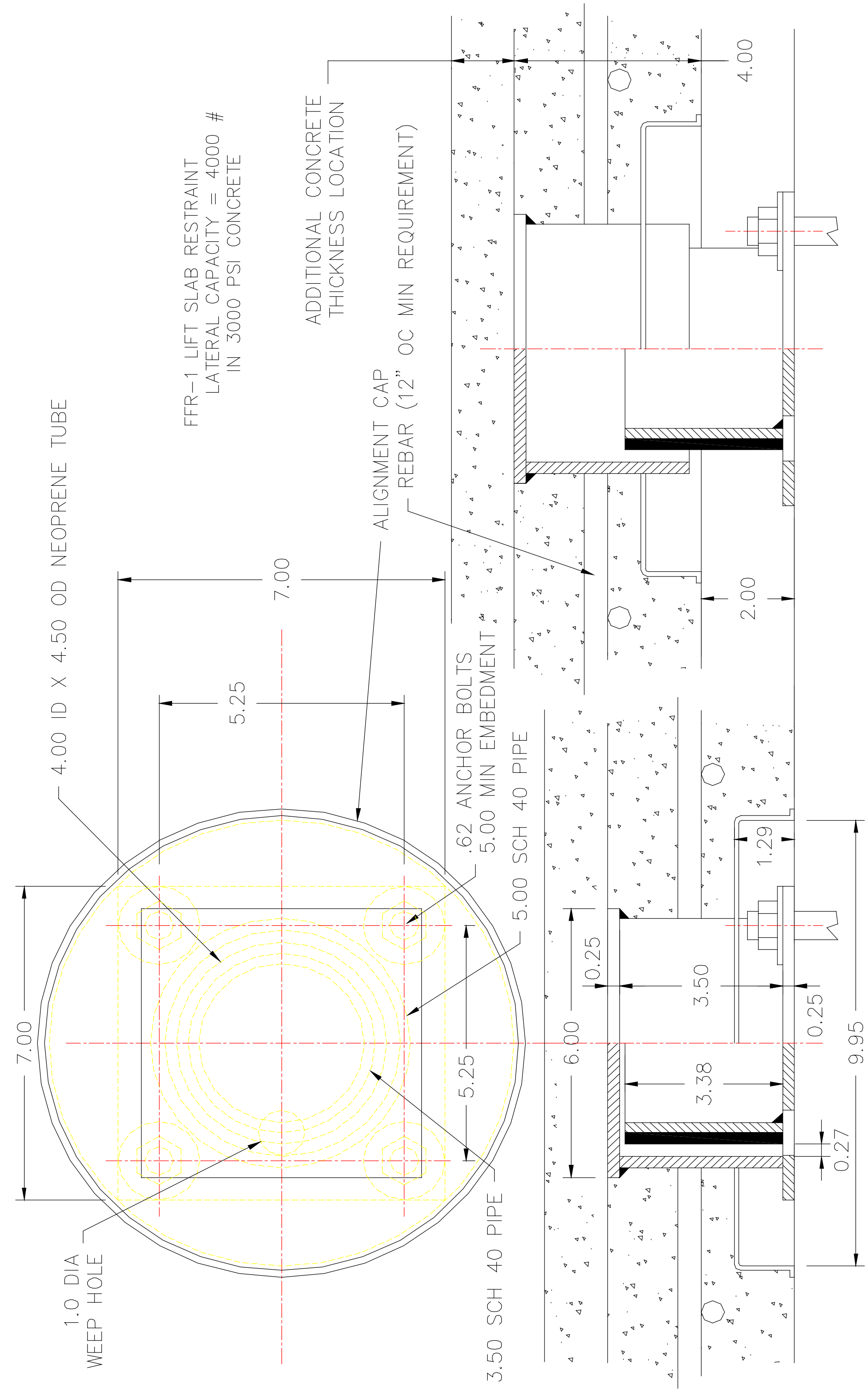

FFR-1 FLOOR RESTRAINT (LIFT SLAB)

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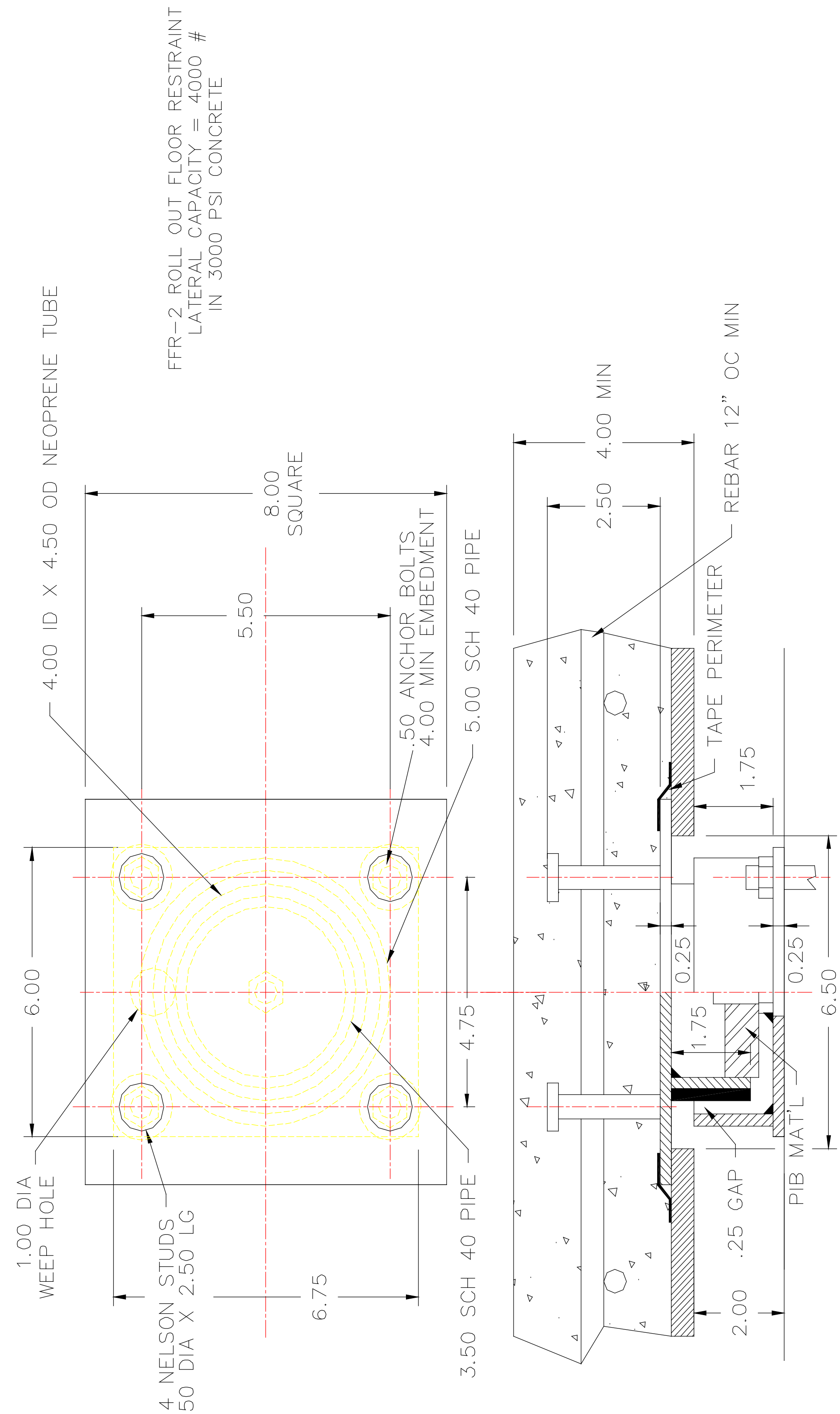

FFR-2 FLOOR RESTRAINT (ROLL OUT SYSTEM)

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ANCHOR BOLTS AND ATTACHMENT HARDWARE

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KCAB Wedge Type Seismic Anchor Data

The Seismic Certification programs written and used by Kinetics Noise Control use the model ***KCAB Wedge Type Anchor*** data listed in Table P10.2.1-1 below. The various terms and dimensions referenced in this document are defined in Figure P10.2.1-1. Any anchors that are substituted and/or supplied by others must be evaluated and approved by the Design Professional of Record. The data listed in Table P10.2.1-1 is drawn form ***ICBO*** report data. All relevant factors for proper installation of these anchors are defined in documentation provided by Kinetics Noise Control.

The data provided in Table P10.2.1-1 is based on concrete with a minimum compressive strength of ***3,000 psi*** and a minimum embedment depth equal to ***8*** anchor diameters.

Table P10.2.1-1: KCAB Wedge Type Seismic Anchor Basic Capacities (Reference: Figure P10.2.1-1)

Anchor Size[3] (in)	Minimum Embedment (in)	Basic ASD Tensile Allowable[1] (lbs)	Basic ASD Shear Allowable[1] (lbs)	Minimum Spacing[2] (in)	Minimum Edge Distance[2] (in)
1/4	2	280	400	4	3-3/8
3/8	3	588	1,018	6	4-7/8
1/2	4	874	1,769	7	6-3/4
5/8	5	1,317	2,640	8	8-1/4
3/4	6	1,668	4,225	10-1/4	9-3/4
7/8	7	2,264	6,210	12-5/16	9-1/8
1	8	2,535	8,328	14-5/8	13-1/2
1	9	2,730	8,328	12	13-1/2
1-1/4	10	5,105	9,918	15	12-15/16

1) For Non-California projects these values may be inflated by 33-1/3% for seismic and wind applications. For California Non-OSHPD projects these values must be reduced by 20%. For California OSHPD projects the allowable loads for lightweight, 2,000 psi, concrete must be reduced by 20% to simulate cracked concrete. In this case the values listed here do not apply.
2) Minimum spacing and edge distance are required to develop the maximum listed allowable loads.
3) If the Clearance Hole Diameter is greater than or equal to 1/8″ more than the Anchor Size, fill the clearance space with grout or epoxy, or use the appropriate Kinetics Noise Control model TG Grommet.

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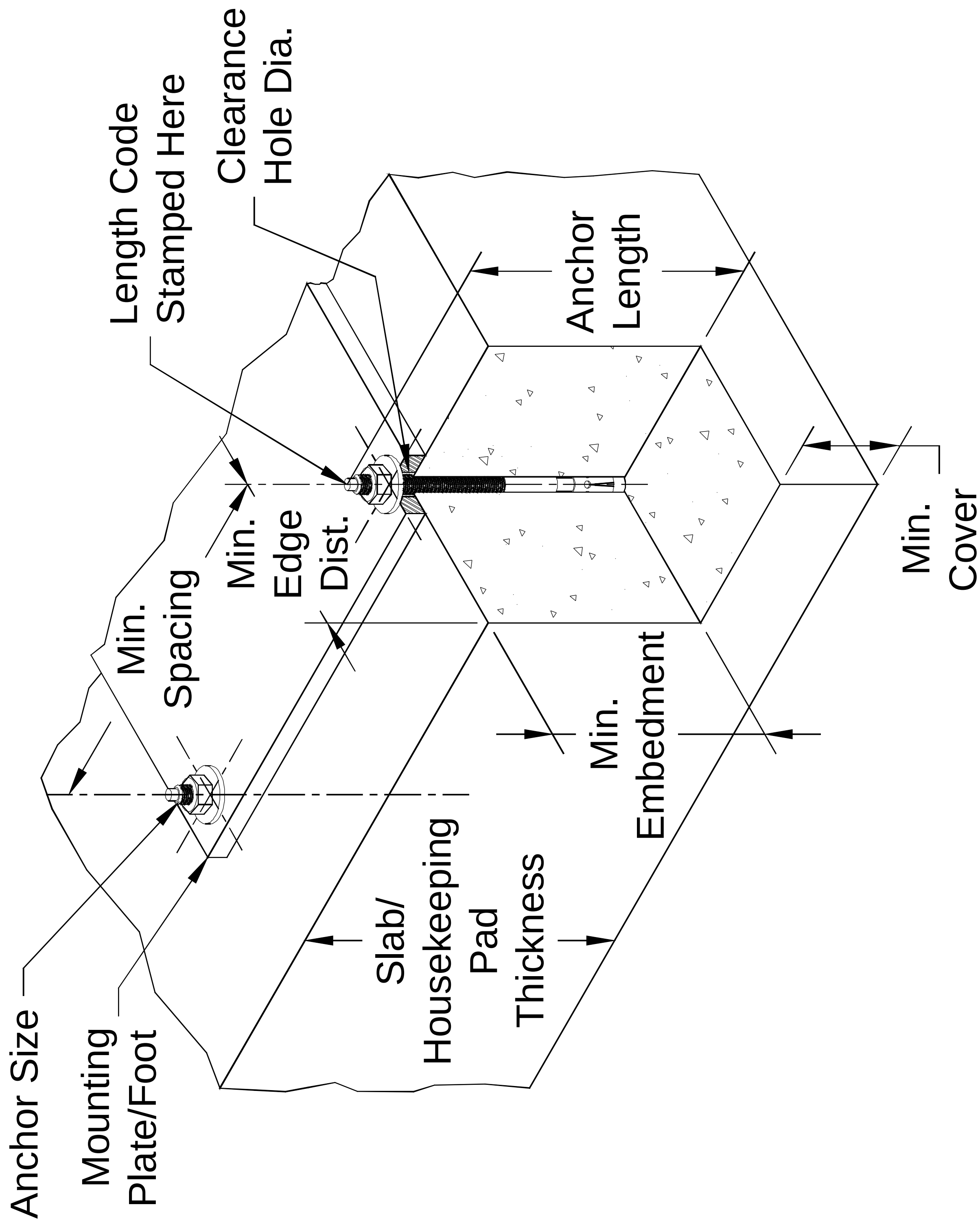

Figure P10.2.1-1: KCAB Wedge Type Seismic Anchor Installation Guide.

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Table P10.2.1-2: Anchor Length by Length Code Stamp (Anchor Size Independent)

Length Code Stamp	Anchor Length (in)	Length Code Stamp	Anchor Length (in)
A	1.5 to 2.0	K	6.5 to 7.0
B	2.0 to 2.5	L	7.0 to 7.5
C	2.5 to 3.0	M	7.5 to 8.0
D	3.0 to 3.5	N	8.0 to 8.5
E	3.5 to 4.0	O	8.5 to 9.0
F	4.0 to 4.5	P	9.0 to 9.5
G	4.5 to 5.0	Q	9.5 to 10.0
H	5.0 to 5.5	R	10.0 to 11.0
I	5.5 to 6.0	S	11.0 to 12.0
J	6.0 to 6.5	----------	---------------

Table P10.2.1-3: Anchor Size vs. Tightening Torque for Standard Weight Concrete

Anchor Size (in)	Anchor Tightening Torque (ft-lbs)
1/4	8.00
3/8	25.00
1/2	55.00
5/8	90.00
3/4	175.0
7/8	250.0
1	300.0

Table P10.2.1-4: Minimum Cover Requirements per ACI 318-02

Minimum Cover (in)	Concrete Exposure Condition Cast-in-Place & Nonprestressed
3	Cast-in-place and permanently exposed to the ground.
1-1/2	Exposed to the ground or weather.
3/4	Slabs, walls, or joists not exposed to the weather or ground.
1-1/2	Beams or Columns not exposed to the weather or ground.
3/4	Shells or folded plate members not exposed to the weather or ground.

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KUAB Type P Undercut Seismic Anchor Data

The Seismic Certification programs written and used by Kinetics Noise Control use the model ***KUAB Type P Undercut Anchor*** data listed in Tables P10.2.2-1, P10.2.2-2, and P10.2.2-3 below. ***Type P*** indicates that the anchor is a ***pre-setting*** or ***pre-positioning*** type of anchor. The various terms and dimensions referenced in this document are defined in Figures P10.2.2-1, P10.2.2-2, and P10.2.2-3. Any other anchors that are substituted and/or supplied by others must be evaluated and approved by the Design Professional of Record. The data listed in Tables P10.2.2-1 through P10.2.2-3 is drawn from ***ICC ES Report ESR-1546 (Issued August 1, 2004)***. All relevant factors for proper installation of these anchors are defined in documentation provided by Kinetics Noise Control.

The values in Table P10.2.2-1 are based on normal-weight concrete with a compressive strength of ***3,000 psi***, and are adjusted for seismic and wind loading applications in accordance with the provisions established in ***ACI 318-02 Appendix D***.

Table P10.2.2-1: KUAB Type P Undercut Seismic Anchor Capacities. (Reference: Figure P10.2.2-1)

Undercut Anchor Model	Anchor Size[1] mm (in)	Req. Embed.[2] mm (in)	Seismic Tensile Allow. ASD[3] N (lbs)	Seismic Shear Allow. ASD[3] N (lbs)	Req. Spacing[2] mm (in)	Req. Edge Dist.[2] mm (in)	Length Code Stamp
KUAB-01	M10 (3/8)	100 (3.94)	19,424 (4,365)	8,869 (1,993)	300 (11.81)	150 (5.91)	I
KUAB-02	M12 (1/2)	125 (4.92)	24,284 (5,457)	12,856 (2,889)	375 (14.76)	188 (7.38)	L
KUAB-03	M16 (5/8)	190 (7.48)	48,567 (10,914)	23941 (5,380)	570 (22.44)	285 (11.22)	R
KUAB-04	M20 (3/4)	250 (9.84)	72,851 (16,371)	36797 (8,269)	750 (29.53)	375 (14.76)	V

1 - If the Clearance Hole Diameter is greater than or equal to 1/8″ more than the Anchor Size, fill the clearance space with grout or epoxy, or use the appropriate Kinetics Noise Control model TG Grommet.

2 - Required embedment, spacing, and edge distance are required to develop the maximum listed allowable loads.

3 - These values *may not* be inflated by 33-1/3% for seismic and wind applications!

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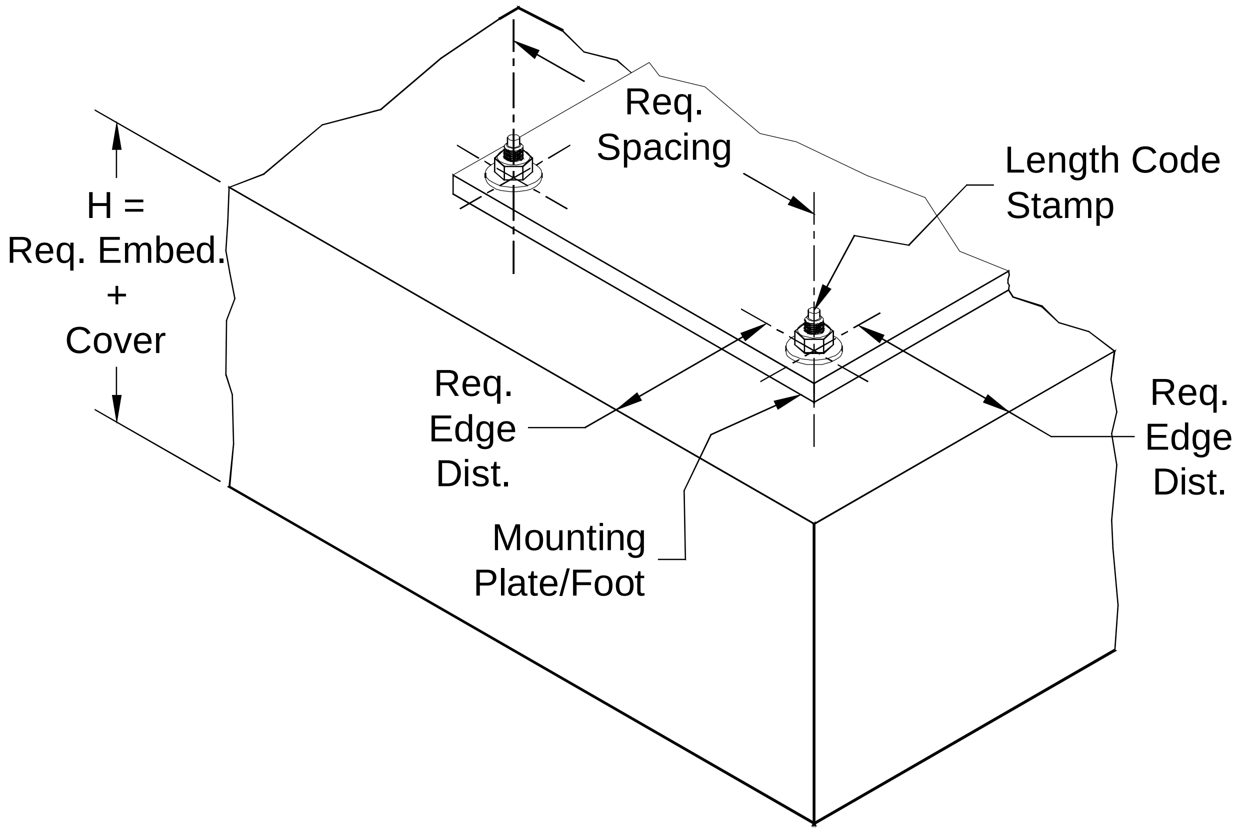

Figure P10.2.2-1: KUAB Type P Undercut Seismic Anchor Placement Guide.

Table P10.2.2-2: KUAB Type P Undercut Seismic Anchor Dimensional Data.
(Reference: Figure P10.2.2-2)

Undercut Anchor Model	Anchor Size mm (in)	ΦA mm (in)	B mm (in)	C mm (in)	ΦD mm (in)	ΦE mm (in)	F mm (in)	ΦG mm (in)	H mm (in	Length Code Stamp
KUAB-01	M10 (3/8)	20 (0.79)	107 (4.21)	20 (0.79)	12 (0.47)	10 (0.39)	17 (0.67)	27.5 (1.08)	170 (6.69)	I
KUAB-02	M12 (1/2)	22 (0.87)	135 (5.31)	30 (1.18)	14 (0.55)	12 (0.47)	19 (0.75)	33.5 (1.32)	190 (7.48)	L
KUAB-03	M16 (5/8)	30 (1.18)	203 (7.99)	40 (1.57)	18 (0.71)	16 (0.63)	24 (0.94)	45.5 (1.79)	270 (10.63)	R
KUAB-04	M20 (3/4)	37 (1.46)	266 (10.47)	50 (1.97)	22 (0.87)	20 (0.79)	30 (1.18)	50 (1.97)	350 (13.78)	V

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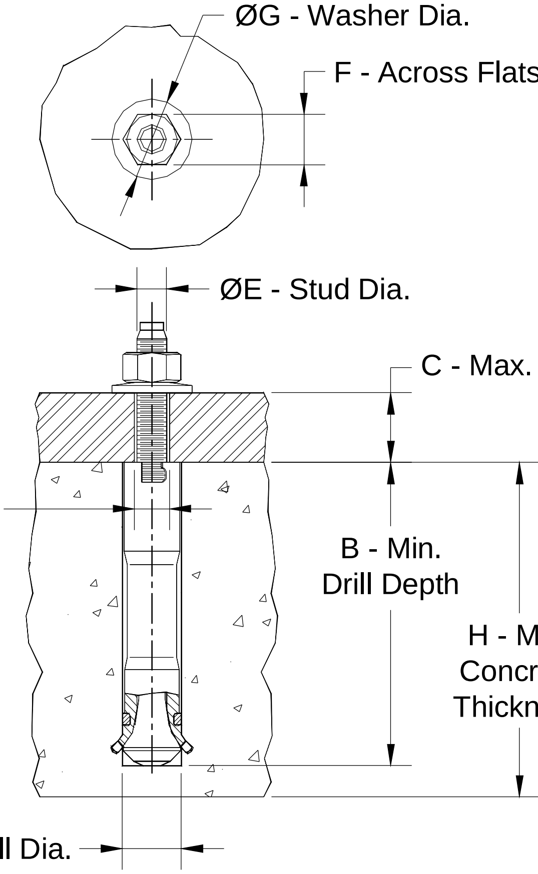

Figure P10.2.2-2: KUAB Type P Undercut Seismic Anchor Installation Guide.

Table P10.2.2-3: Anchor Size vs. Tightening Torque for Standard Weight Concrete.

Undercut Anchor Model	Anchor Size mm (in)	Anchor Tightening Torque N-m (ft-lbs)	Length Code Stamp
KUAB-01	M10 (3/8)	50 (37)	I
KUAB-02	M12 (1/2)	80 (59)	L
KUAB-03	M16 (5/8)	120 (88)	R
KUAB-04	M20 (3/4)	300 (221)	V

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TG Bolt Isolation Grommet Submittal Data

The Kinetics Noise Control model ***TG Bolt Isolation Grommet*** is used primarily to fill the excess clearance in the anchor/bolt holes in equipment/isolator mounting plates/feet. The codes and best practice require that the diameter of an anchor/bolt hole not exceed the diameter of the anchor/bolt by more than ***1/8 inch***. In many cases, the seismic analysis will indicate that an anchor/bolt of smaller size than that provided for in the mounting plate/foot may be used for a specific application. The Kinetics Noise Control model ***TG Bolt Isolation Grommet*** may be used in these cases to bring the anchor/bolt hole clearance into line with the code and best practice recommended clearance for the smaller anchor/bolt size. In order to perform satisfactorily in this type of application, the material used for the model ***TG Bolt Isolation Grommet*** is ***80 Durometer Neoprene***. A typical Kinetics Noise Control model ***TG Bolt Isolation Grommet*** is shown below in Figure P10.2.3-1. The dimensional data for the product family line is given in Tables P10.2.3-1 and P10.2.3-2. A typical ***TG Bolt Isolation Grommet Installatio***n is shown in Figure P10.2.3-2.

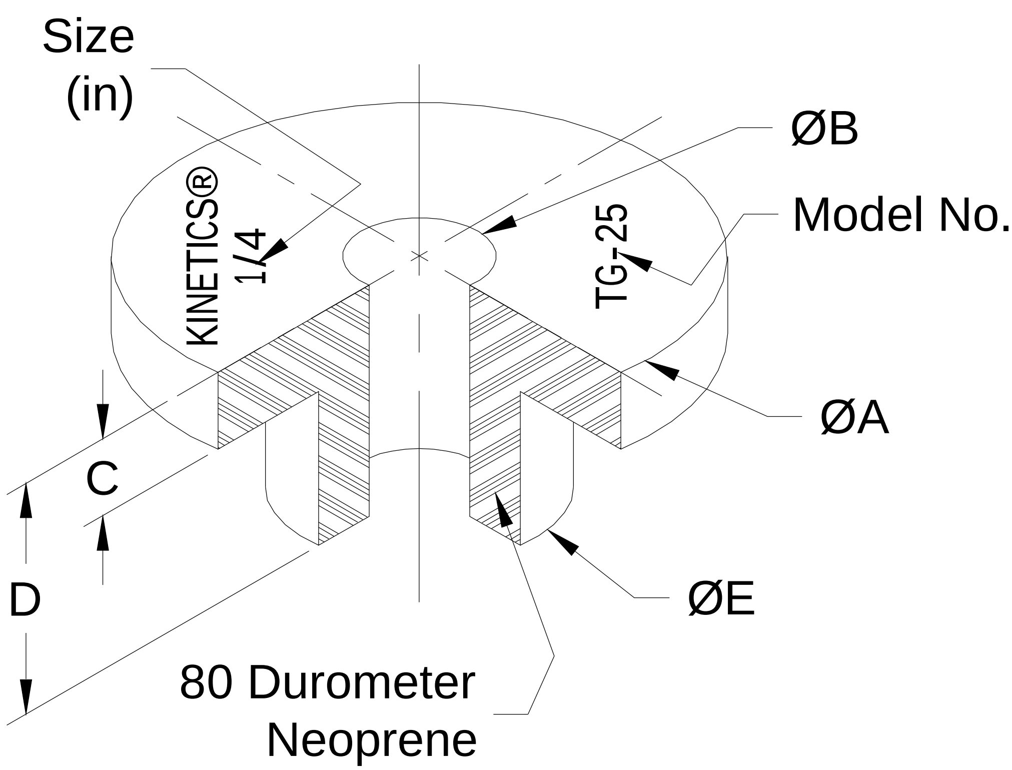

Figure P10.2.3-1: Typical Model TG Bolt Isolation Grommet.

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Table P10.2.3-1: TG Bolt Isolation Grommet English Dimensional Data.

Model	Anchor/ Bolt Size (in)	ΦA (in)	ΦB (in)	C (in)	D (in)	ΦE (in)
TG-25	1/4	1.00	0.25	0.13	0.38	0.50
TG-38	3/8	1.25	0.38	0.13	0.50	0.63
TG-50	1/2	1.63	0.50	0.13	0.50	0.75
TG-63	5/8	2.00	0.63	0.19	0.63	0.88
TG-75	3/4	2.25	0.75	0.19	0.63	1.00
TG-100	1	2.75	1.00	0.25	0.88	1.25
TG-125	1-1/4	3.25	1.25	0.25	0.88	1.50
TG-150	1-1/2	3.75	1.50	0.25	1.00	1.75

Table P10.2.3-2: TG Bolt Isolation Grommet Metric Dimensional Data.

Model	Anchor/ Bolt Size (in)	ΦA (mm)	ΦB (mm)	C (mm)	D (mm)	ΦE (mm)
TG-25	1/4	25.4	6.4	3.2	9.5	12.7
TG-38	3/8	31.8	9.5	3.2	12.7	15.9
TG-50	1/2	41.3	12.7	3.2	12.7	19.1
TG-63	5/8	50.8	15.9	4.8	15.9	22.2
TG-75	3/4	57.2	19.1	4.8	15.9	25.4
TG-100	1	69.9	25.4	6.4	22.2	31.8
TG-125	1-1/4	82.6	31.8	6.4	22.2	38.1
TG-150	1-1/2	95.3	38.1	6.4	25.4	44.4

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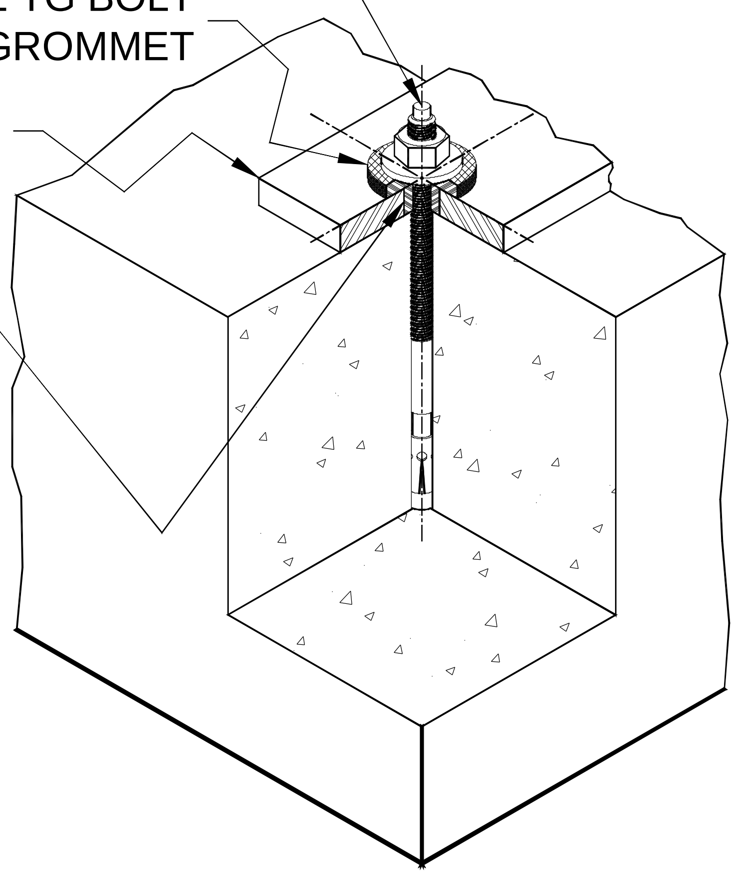

Figure P10.2.3-2: Typical TG Bolt Isolation Grommet Installation.

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KCCAB CRACKED CONCRETE WEDGE TYPE SEISMIC ANCHOR DATA

Table P10.2.4-1; Model KCCAB Anchor Capacities – Standard Embedment in 3,000 psi Normal Weight Concrete

Anchor Size (in)	Pilot Hole Depth (in)	Anchor Embedment (in)	Allowable Tensile Load (ASD) (lbs)	Allowable Combined Load (ASD) (lbs)	Allowable Shear Load (ASD) (lbs)	Critical Anchor Spacing (in)	Critical Anchor Edge Distance (in)	Minimum Concrete Thickness (in)
3/8	2 5/8	2	1,102	691	999	6	4 3/8	4
1/2	4	3 1/4	2,386	1,706	2,839	9 3/4	7 1/2	6
5/8	4 3/4	4	2,835	2,284	4,678	12	8 3/4	6
3/4	5 3/4	4 3/4	4,272	3,321	6,313	14 1/4	9	8

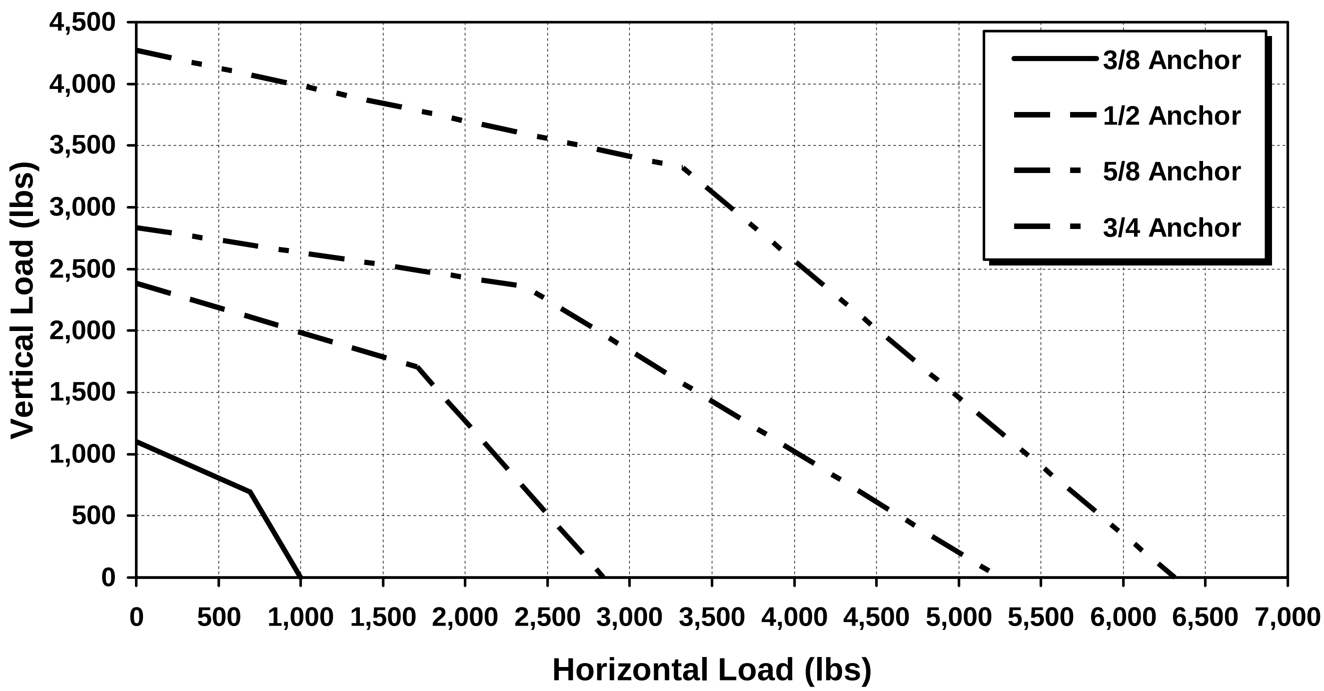

Figure P10.2.4-1; Seismic Capacity Envelopes for Model KCCAB Concrete Anchors with Standard Embedment

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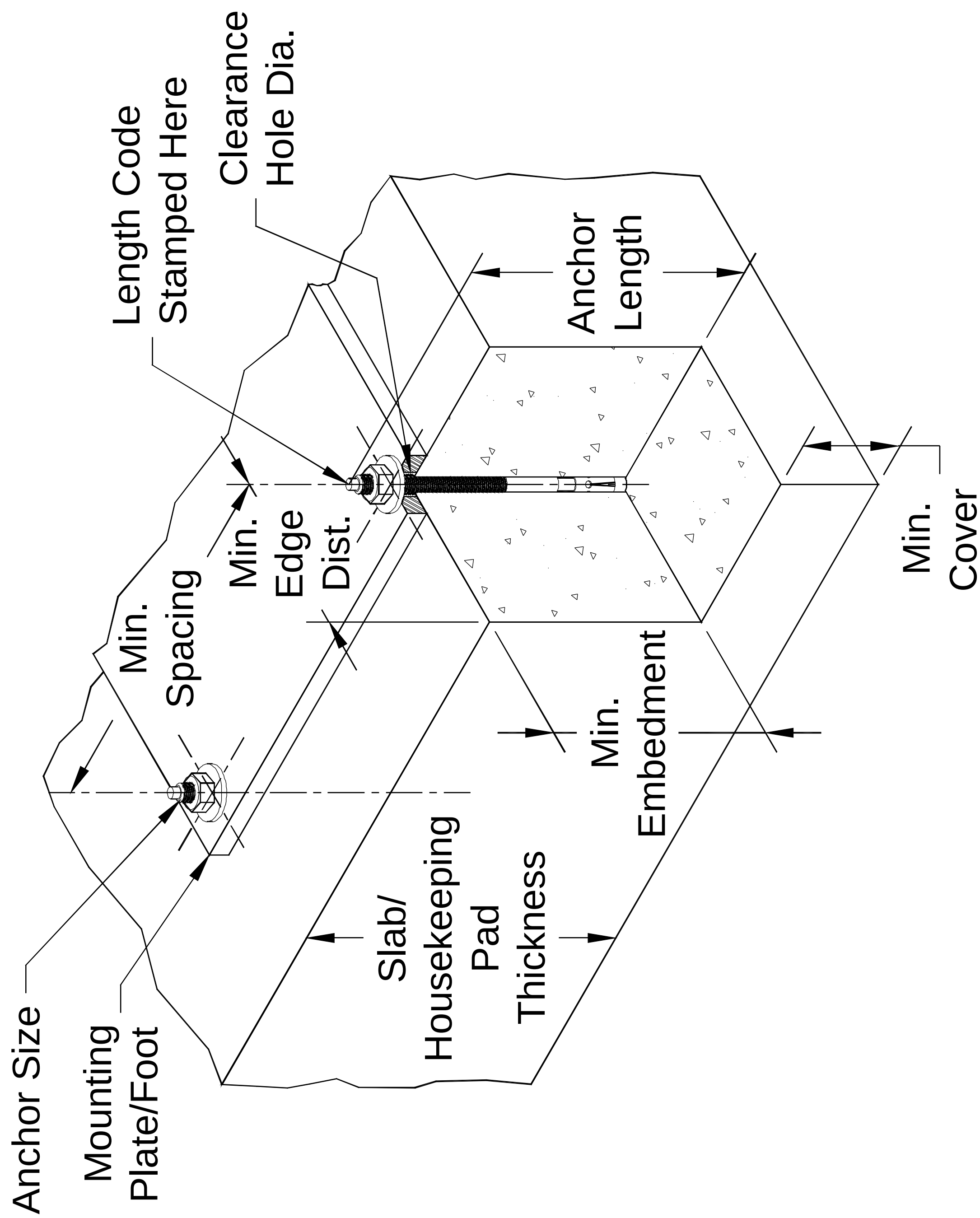

Figure P10.2.4-2; KCCAB Cracked Concrete Seismic Anchor Installation Guide

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Table P10.2.4-2: Anchor Length by Length Code Stamp (Anchor Size Independent)

Length Code Stamp	Anchor Length (in)		Length Code Stamp	Anchor Length (in)
A	1.5 up to 2.0		M	7.5 up to 8.0
B	2.0 up to 2.5		N	8.0 up to 8.5
C	2.5 up to 3.0		O	8.5 up to 9.0
D	3.0 up to 3.5		P	9.0 up to 9.5
E	3.5 up to 4.0		Q	9.5 up to 10.0
F	4.0 up to 4.5		R	10.0 up to 11.0
G	4.5 up to 5.0		S	11.0 up to 12.0
H	5.0 up to 5.5		T	12.0 up to 13.0
I	5.5 up to 6.0		U	13.0 up to 14.0
J	6.0 up to 6.5		V	14.0 up to 15.0
K	6.5 up to 7.0		W	15.0 up to 16.0
L	7.0 up to 7.5		----------	---------------

Table P10.2.4-3: Anchor Size vs. Tightening Torque for Standard Weight Concrete

Anchor Size (in)	Anchor Tightening Torque (ft-lbs)
3/8	25.00
1/2	40.00
5/8	60.00
3/4	110.0

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KCAB Wedge Type Anchor Selection Guide

For wedge type concrete anchors, the factor of safety is computed using the following equation.

$$F.S. \geq 1 = 1/[(T/T_A)^{(5/3)} + (P/P_A)^{(5/3)}] \quad \text{(Eq. P10.3.1-1)}$$

Where:

F.S. = the factor of safety.
T = the applied tensile force acting on the anchor (lbs).
T_A = the allowable tensile load for the specified anchor size (lbs).
P = the applied shear force acting on the anchor (lbs).
P_A = the allowable shear load for the specified anchor size (lbs).

It is possible to use Equation P10.3.1-1 to compute an allowable combined anchor load where the applied tensile force is equal to the applied shear force. With this information, a capacity envelope may be constructed for the various wedge type concrete anchors that are specified and used by Kinetics Noise Control. In Equation P10.3.1-2 the applied tensile load has been made equal to the applied shear load, and is designated as F_C.

$$1 = 1/[(F_C/T_A)^{(5/3)} + (F_C/P_A)^{(5/3)}] \quad \text{(Eq. P10.3.1-2)}$$

Solving Equation P10.3.1-2 for F_C and simplifying will yield the following result.

$$F_C = (T_A * P_A) * [1/(T_A^{(5/3)} + P_A^{(5/3)})]^{(3/5)} \quad \text{(Eq. P10.3.1-3)}$$

The data provided in Table P10.3.1-1 is based on concrete with a minimum compressive strength of ***3,000 psi*** and a minimum embedment depth equal to ***8*** anchor diameters. The capacity envelopes for the anchors presented in Table P10.3.1-1 are plotted in Figures P10.3.1-1 through P10.3.1-4.

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Table P10.3.1-1; KCAB Wedge Type Anchor Basic Capacities.

Anchor Size[2] (in)	Minimum Required Embed. Depth (in)	ASD Allow. Tensile Load[1] (*T=0*) (lbs)	ASD Allow. Shear Load[1] (*P=0*) (lbs)	ASD Allow. Comb. Load[1] (F_C=*T*=*P*) (lbs	LRFD Allow. Tensile Load[1] (*T=0*) (lbs)	LRFD Allow. Shear Load[1] (*P=0*) (lbs)	LRFD Allow. Com. Load[1] (F_C=*T*=*P*) (lbs)
1/4	2	280	400	215	392	560	301
3/8	3	588	1,018	480	823	1,425	672
1/2	4	874	1,769	744	1,224	2,477	1,041
5/8	5	1,317	2,640	1,118	1,844	3,696	1,565
3/4	6	1,668	4,225	1,486	2,335	5,915	2,080
7/8	7	2,264	6,210	2,044	3,170	8,694	2,861
1	8	2,535	8,328	2,346	3,549	11,659	3,285
1	9	2,730	8,328	2,503	3,822	11,659	3,504
1-1/4	10	5,105	9,918	4,301	7,147	13,885	6,021

1) For Non-California projects these values may be inflated by 33-1/3% for seismic and wind applications. For California Non-OSHPD projects these values must be reduced by 20%. For California OSHPD projects the allowable loads for lightweight, 2,000 psi, concrete must be reduced by 20% to simulate cracked concrete. In this case the values listed here do not apply.
2) If the Clearance Hole Diameter is greater than or equal to 1/8″ more than the Anchor Size, fill the clearance space with grout or epoxy, or use the appropriate Kinetics Noise Control model TG Grommet.

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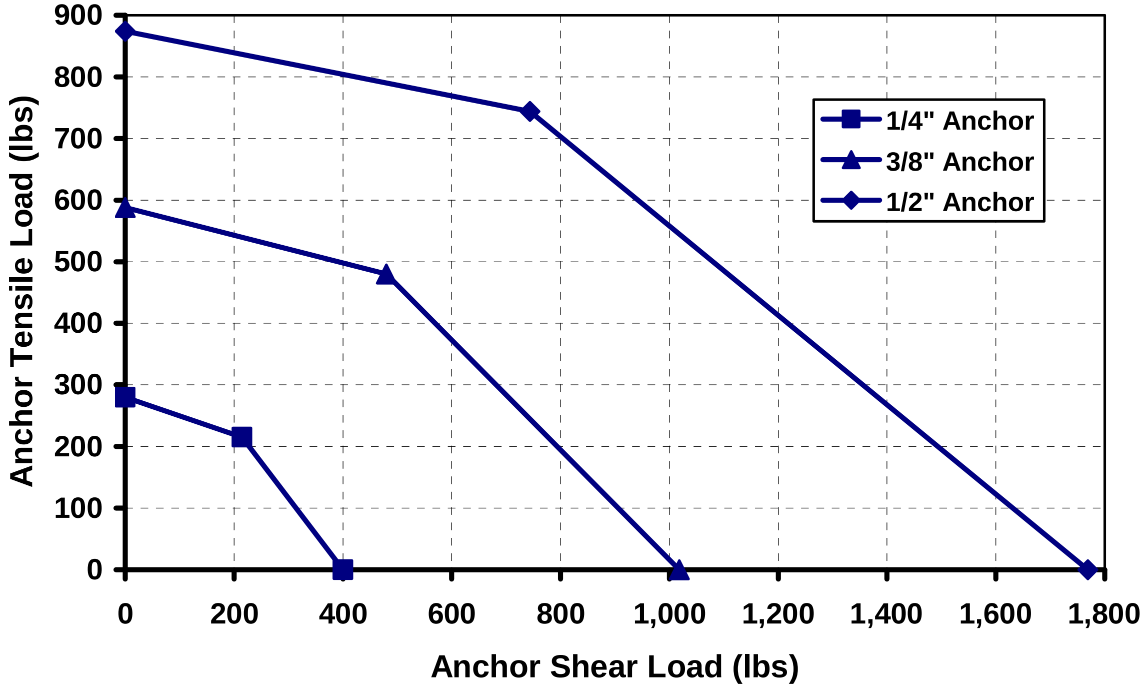

Figure P10.3.1-1; Basic ASD Values for 1/4″ through 1/2″ Anchors.

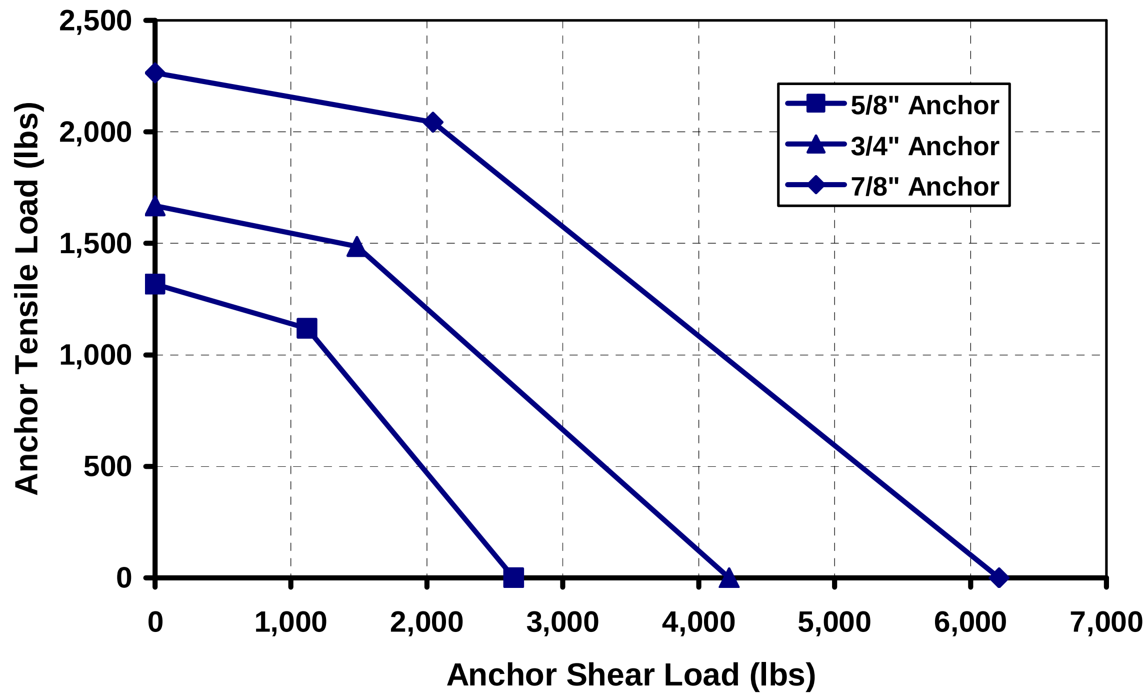

Figure 10.3.1-2; Basic ASD Values for 5/8″ Though 7/8″ Anchors

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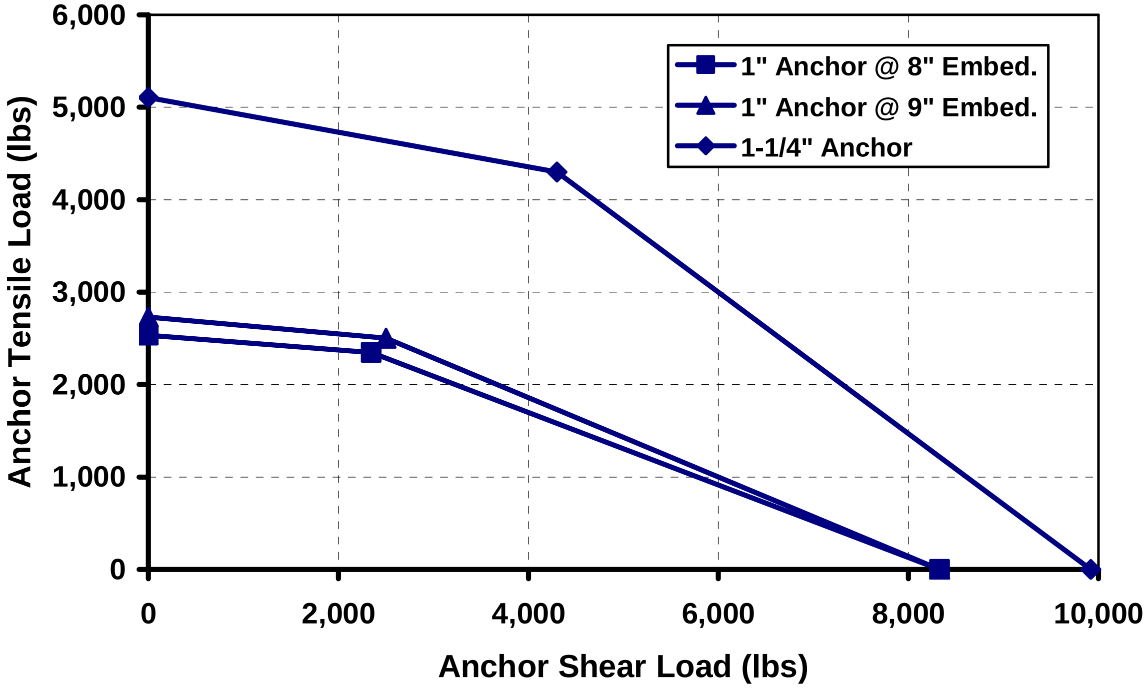

Figure P10.3.1-3; Basic ASD Values for 1″ through 1-1/4″ Anchors.

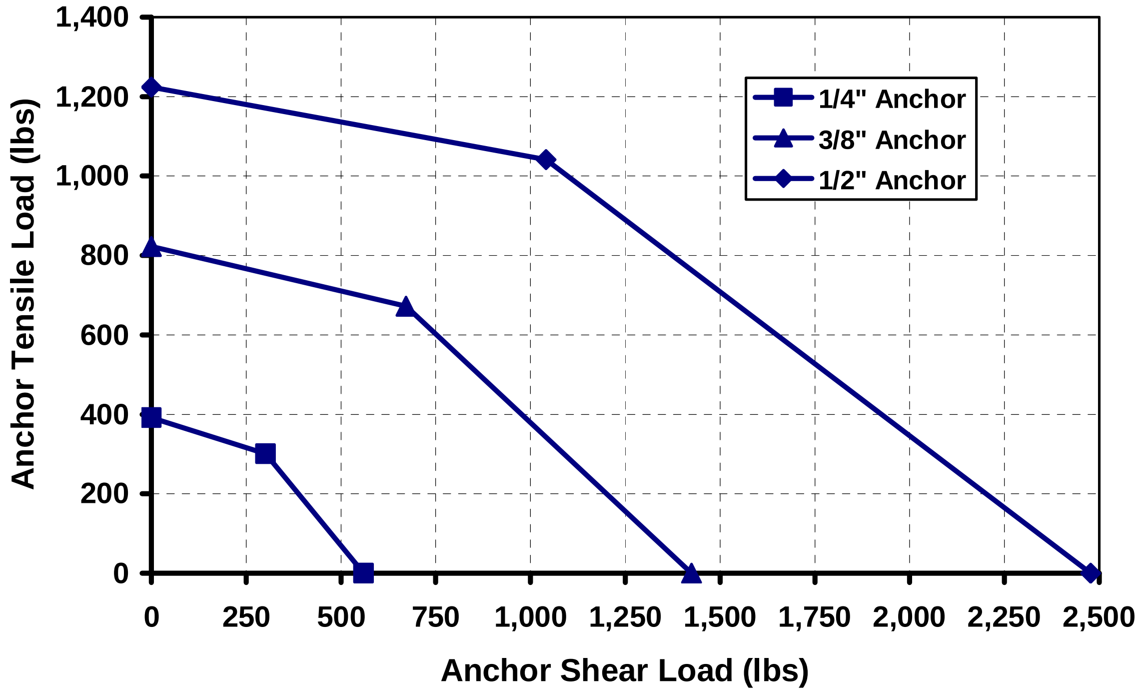

Figure 10.3.1-4; Basic LRFD Values for 1/4″ Though 5/8″ Anchors

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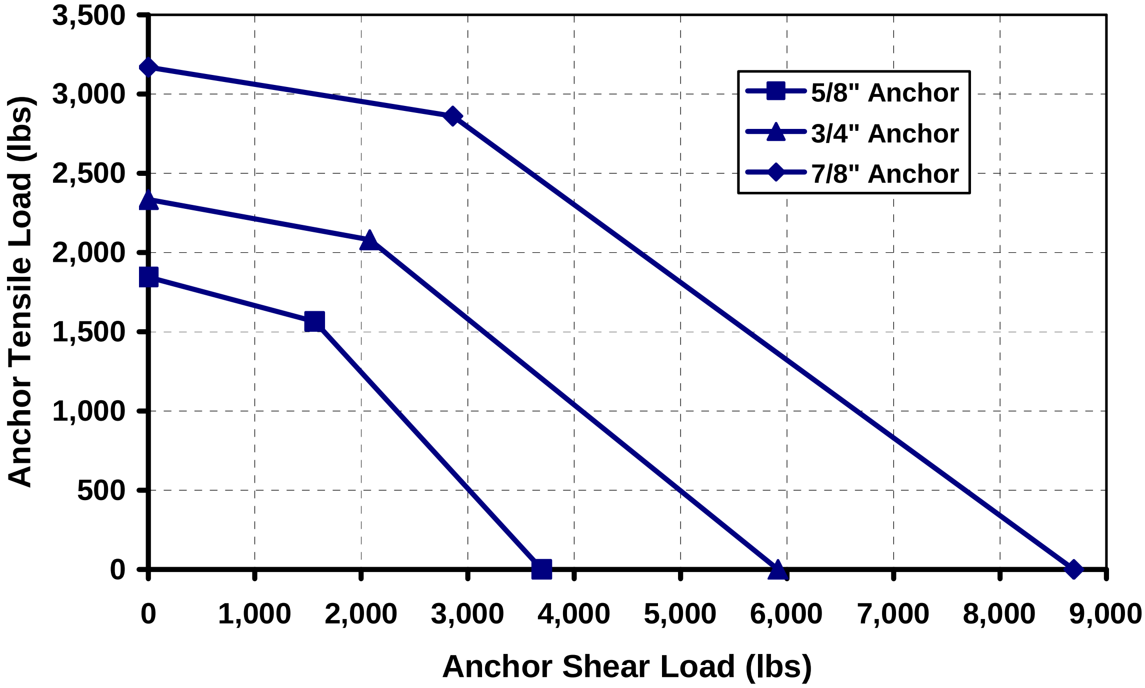

Figure P10.3.1-5; Basic LRFD Values for 5/8″ through 7/8″ Anchors.

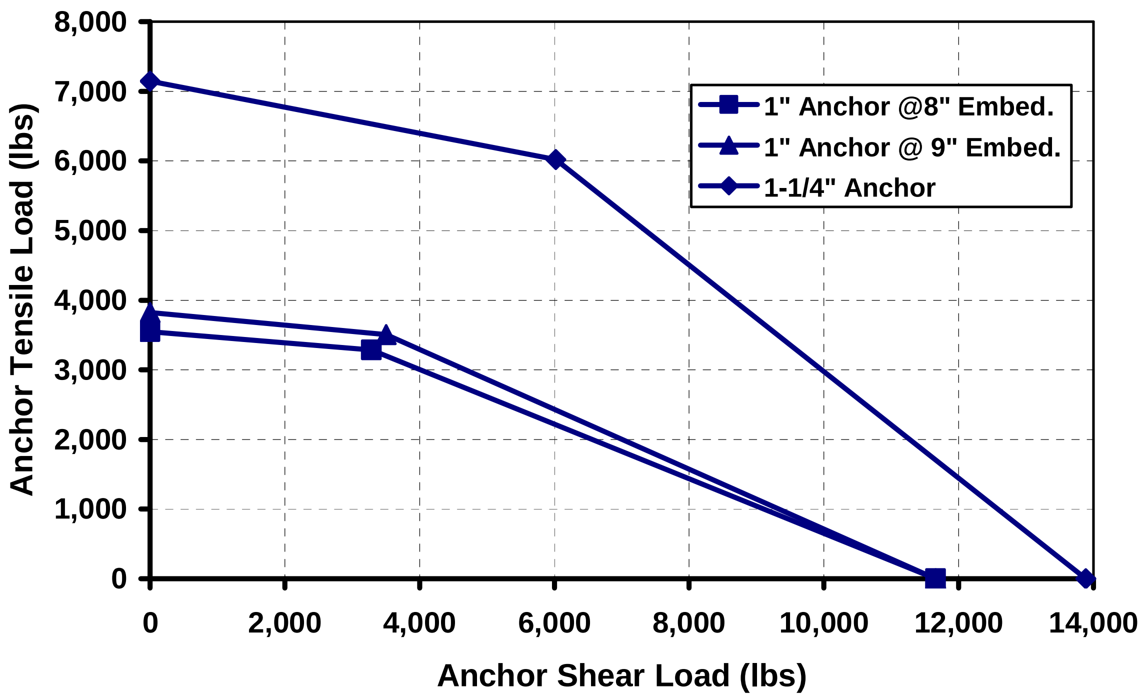

Figure 10.3.1-2; Basic LRFD Values for 1″ Though 1-1/4″ Anchors

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KUAB Type P Undercut Seismic Anchor Selection Guide

The **Kinetics Noise Control** model ***KUAB Type P*** Undercut Seismic Anchors are purchased from **HILTI, Inc.**, and are described in Document P.10.2.2. The Seismic Restraint Envelopes for this type of anchor will be constructed according to the information found in **ICC ES Report** number ***ESR-1546***, Section 4.2.1. In this document, the following definitions will apply.

T = the applied tensile load in the anchor.
T_A = the allowable tensile load in the anchor, **ASD** or **LRFD**.
P = the applied shear load in the anchor.
P_A = the allowable shear load in the anchor, **ASD** or **LRFD**.
F_C = the combined load case where $T = P$.

For applied shear loads $P \leq 0.2P_A$ the full allowable load in tension T_A may be taken. For applied tensile loads $T \leq 0.2T_A$ the full allowable load in shear P_A may be taken. For all other conditions;

$$(T/T_A) + (P/P_A) \leq 1.2 \qquad \textbf{(Eq. P10.3.2-1)}$$

Setting $T = P = F_C$, and solving for the combined load F_C will provide the closing data point for the Seismic Restraint Envelopes.

$$F_C = 1.2T_AP_A/(P_A+T_A) \qquad \textbf{(Eq. P10.3.2-2)}$$

The ASD, and LRFD Allowable Tensile, Shear, Combined Loads for the **Kinetics Noise Control** model ***KUAB Type P*** Undercut Seismic Anchors are given in Table P10.3.2-1. The Seismic Restraint Envelopes for those anchors are presented in Figures P10.3.2-1 and P10.3.2-2 for ASD values, and Figures P10.3.2-3 and P10.3.2-4 for LRFD values.

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Table P10.3.2-1; KUAB Type P Undercut Seismic Type Anchor Capacities (HILTI HDA-P Undercut Concrete Anchors)

Anchor Size[1] (mm) [Φ Stud] (in)	Min. Req.'d Embed. Depth (in)	ASD Allow. Tensile Load[2] (*T=0*) (lbs)	ASD Allow. Shear Load[2] (*P=0*) (lbs)	ASD Allow. Comb. Load[2] ($F_C=T=P$) (lbs)	LRFD Allow. Tensile Load[2] (*T=0*) (lbs)	LRFD Allow. Shear Load[2] (*P=0*) (lbs)	LRFD Allow. Comb. Load[2] ($F_C=T=P$) (lbs)
M10 [3/8]	4	4,365	1,993	1,642	6,111	2,790	2,299
M12 [1/2]	5	5,457	2,889	2,267	7,640	4,045	3,174
M16 [5/8]	7-1/2	10,914	5,380	4,324	15,280	7,532	6,054
M20 [3/4]	9-7/8	16,371	8,269	6,593	22,919	11,577	9,230

1) If the Clearance Hole Diameter is greater than or equal to 1/8″ more than the Anchor Size, fill the clearance space with grout or epoxy, or use the appropriate Kinetics Noise Control model TG Grommet.
2) These values ***may not*** be inflated by 33-1/3% for seismic and wind applications!

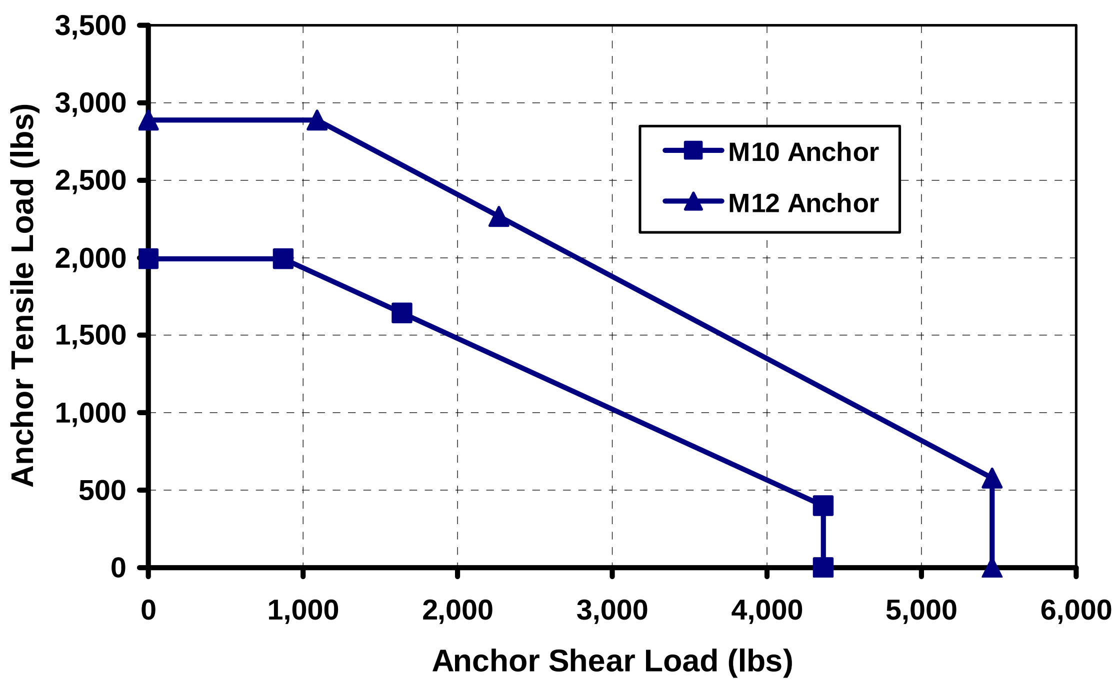

Figure P10.3.2-1; Basic ASD Values for M10 and M12 Anchors.

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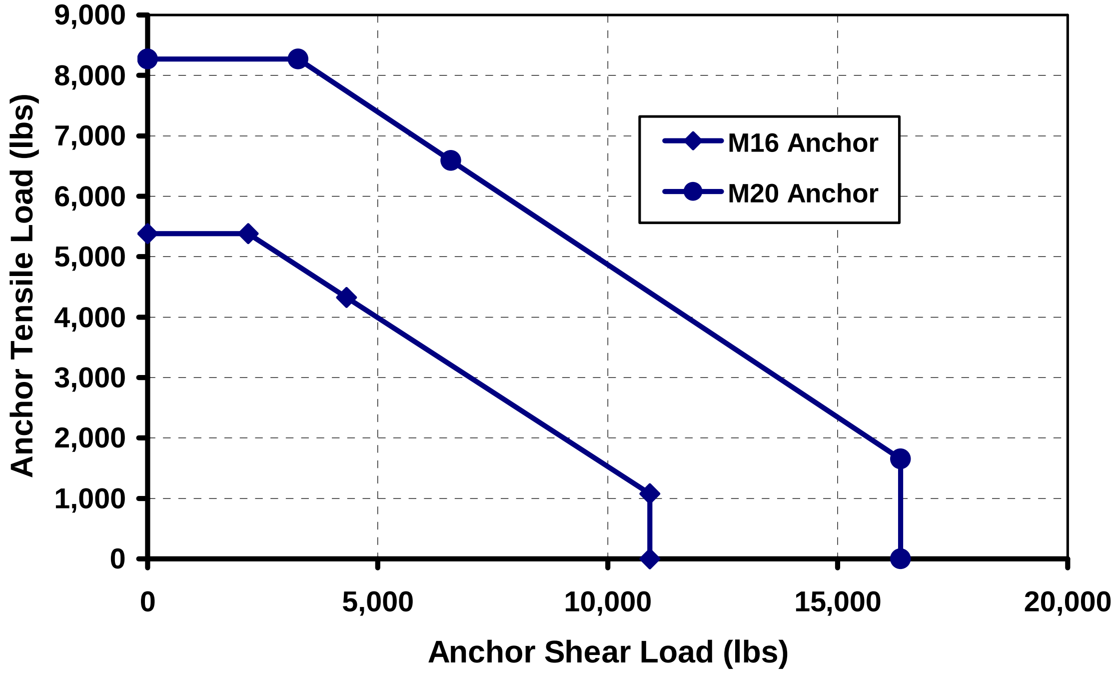

Figure P10.3.2-2; Basic ASD Values for M16 and M20 Anchors.

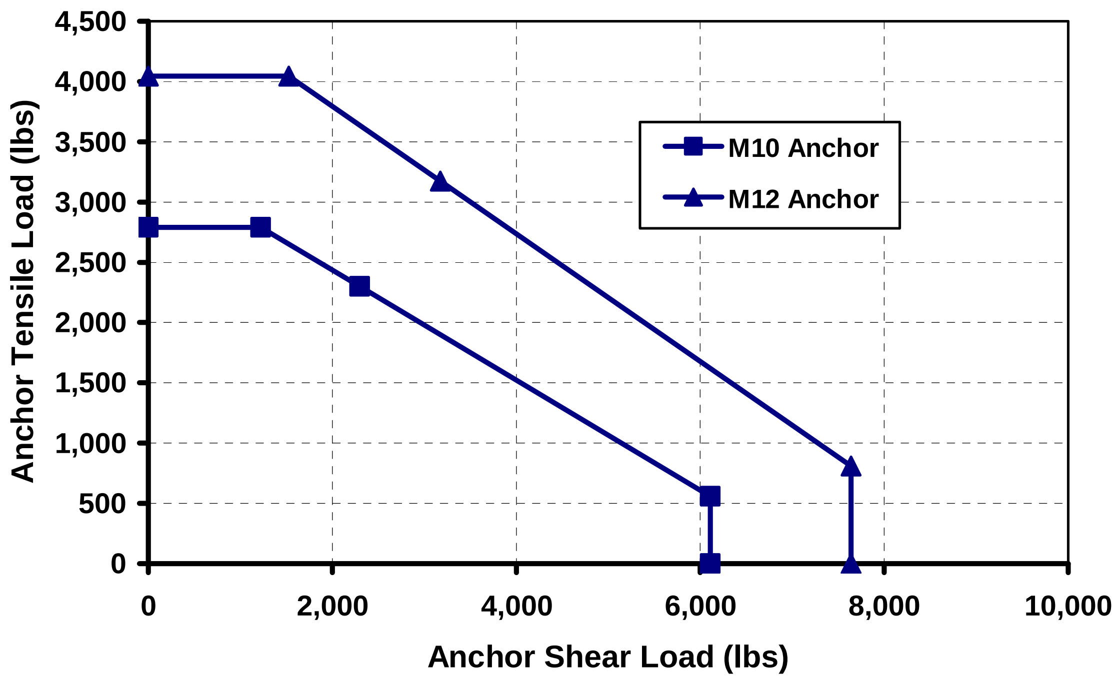

Figure P10.3.2-3; Basic LRFD Values for M10 and M12 Anchors.

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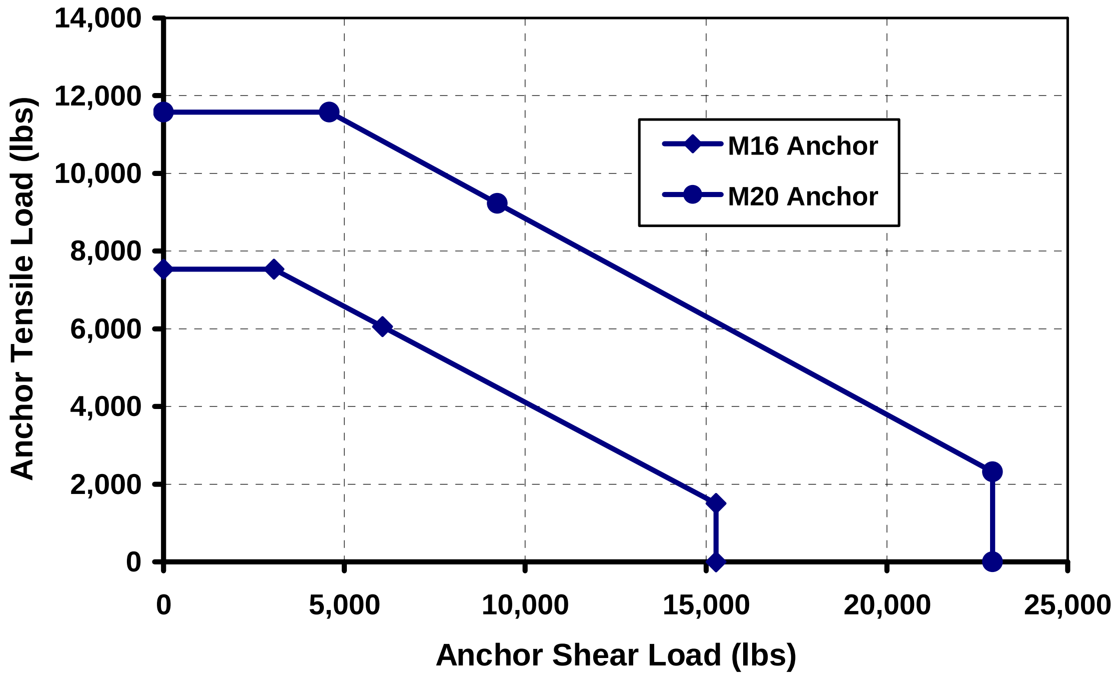

Figure P10.3.2-4; Basic LRFD Values for M16 and M20 Anchors.

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ANCHOR INSTALLATION INSTRUCTION KCAB-KCCAB

KCAB and KCCAB anchors shall be installed in holes drilled into the base material using carbide-tipped masonry drill bits complying with ANSI B212.15-1994. The nominal drill bit diameter shall be equal to that of the anchor. The drilled hole shall exceed the required anchor embedment depth by at least one anchor diameter to permit over-driving of anchors and to provide a dust collection area.

Anchors shall be installed to a minimum embedment depth and with at least the minimum edge distance as specified in the table below.

	KCAB Data		KCCAB Data	
Anchor Size	Minimum Embedment (in)	Minimum Edge Distance (in)	Minimum Embedment (in)	Minimum Edge Distance (in)
0.25	2.0	3.38		
0.38	3.0	4.88	2.00	6.50
0.50	4.0	6.75	3.25	7.50
0.62	5.0	8.25	4.00	8.75
0.75	6.0	9.75	4.75	9.00
1.00	8.0	13.50		
1.00 (Hi Capacity)	9.0	13.50		

The anchor shall be hammered into the predrilled hole until at least 6 threads (KCAB) or 4 threads (KCCAB) are below the fixture surface. The nut shall be tightened against the washer until the torque values specified in the table below are obtained.

	KCAB Data		KCCAB Data	
Anchor Size	Torque (in lb)	Torque (Nm)	Torque (in lb)	Torque (Nm)
0.25	4	6		
0.38	20	27	25	34
0.50	40	54	40	54
0.62	85	115	60	81
0.75	150	202	110	149
1.00	325	439		

See page to follow for detailed installation procedure.

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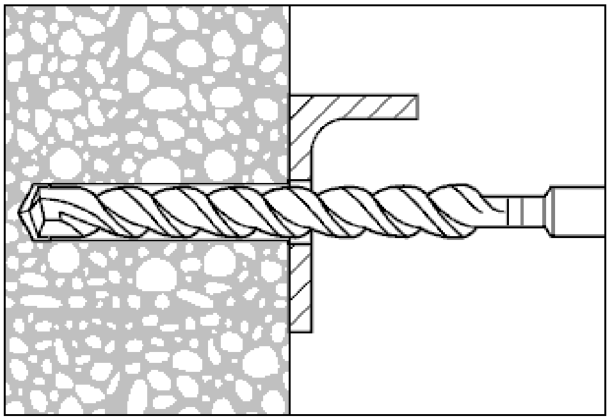

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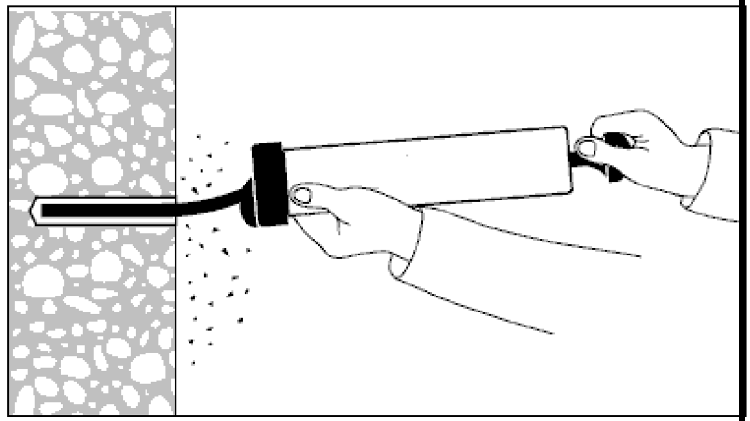

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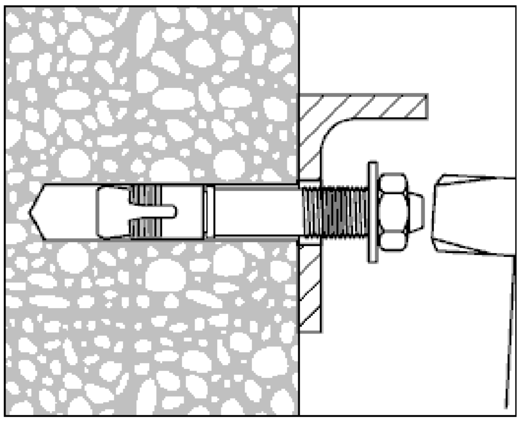

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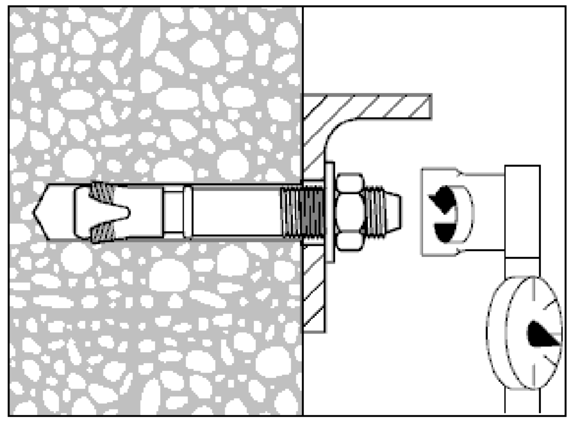

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1) Hammer drill a hole to the same nominal diameter as the KCAB or KCCAB using a bit complying with ANSI B212.15-1994. The hole depth should exceed the listed embedment depth by 1 anchor diameter. The component being restrained can be used as a guide to properly locate the hole.
2) Clean the hole using an air source to blow the debris out.
3) Drive the anchor bolt into the hole using a hammer.
    a) KCAB anchors should be driven in to their rated embedment depth (with at least 6 threads being driven below the surface against which the nut will bear).
    b) KCCAB anchors should be driven in to their rated embedment depth (with the marker on the side of the anchor flush with the concrete surface and with at least 4 threads being driven below the surface against which the nut will bear).
4) Tighten the nut to the recommended installation torque.

TITLE: KCAB & KCCAB ANCHOR INSTALLATION INSTRUCTIONS

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APPENDIX - TABLE OF CONTENTS

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INSPECTION PREPARATION CHECKLIST

In preparation for a field inspection, the following is a list of recommended inspection items and project documents that will be needed in the field to document the conformance of the project under review to the certifications provided by KNC.

Before even considering performing a review, the individual performing the inspection must have a thorough knowledge of what is required for seismic compliance. This includes at least 4 hours of training in this area from Kinetics office staff and a good broad knowledge of what is in the Kinetics Seismic Design and Pipe and Duct manuals and how to quickly locate answers to specific questions.

Tools:

1) Camera (4 mp or higher resolution digital camera that can produce decent pictures in relatively low light conditions.)
2) Tape Measure (Good for measuring equipment dimensions, edge distances, etc)
3) Ultrasonic measuring device (for working with longer spans like pipe and duct)
4) Flashlight
5) Laser pointer (not required, but handy if it is planned that you will be pointing things out to contractors in the field.)
6) Hard clip pad that can act as a surface to write against
7) Colored pens that will show up clearly when writing on black and white documents.
8) Additional paper for sketches and other notes

Project Documentation:

1) Clear definition of Project Scope as defined and agreed to at the proposal level (this can serve to limit scope creep when we are looking at things in the field).
2) A copy of the applicable submittal documentation packet (letter size docs) provided by KNC for the equipment/systems under review.
3) A copy of all applicable pipe/duct/electrical distribution drawings. Ideally these should be in an easily handled size (like 11 x 17), but only as long as the reduced size is legible and can easily be worked with.
4) A numbered listing of potential deficiencies likely to be present on equipment, piping/ductwork/electrical distribution systems being inspected that can act as a key when marking comments on the “inspection” copy of the drawings or other documents.

Additional Support Information:

1) Either a thorough and complete knowledge of the appropriate sections of the Kinetics Seismic and/or Pipe and Duct manuals (as appropriate) or copies of those sections that can be used for reference.

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INSPECTING DISTRIBUTION SYSTEMS

A1.2.1 Scope:

When inspecting Distribution Systems (Pipe, Duct, Conduit, etc) in the field, it is important to maintain an awareness of the scope of the Kinetics Noise Control's (KNC) Certification and recognize that KNC must limit comments and observations as much as possible to the confines of that scope. It is a regular occurrence in the field for the installation contractors to ask KNC representatives to offer comments and even make decisions for items that KNC as a design team may have nothing to do with. It is also common to be asked to discuss aspects of equipment beyond the bounds of the actual restraint connection. An example might have to do with the durability of a contractor designed support bracket or the ability of a masonry wall to resist the design forces. These components would be beyond KNC's control and must be referred to the Structural Engineer of Record. In order to offer any design input or guidance on items such as this implies that whoever is offering that input fully understands all of the loads being carried by the item, what it's total capacity might be and is willing to take responsibility for that knowledge.

KNC's involvement in a project is legally limited to those components provided by KNC. The scope is therefore limited to those issues related to the proper selection and installation of those pieces of hardware that restrain the distribution system to the structure. It includes the anchors or bolts that connect the restraint to the structure, the restraint components provided by KNC and the attachment of the restraint to the piping, ductwork or conduit. With the exception of generic A307 hardware with industry standard ratings, any non-KNC component provided by others would be outside of KNC's ability to offer any binding recommendation or certification.

The scope also does not include an evaluation of the building structure and its ability to resist the loads applied to it. Only the engineer of record for that structure can state categorically that the structure is capable of resisting the design loads.

Further, KNC must limit the scope of the inspection to only those objects that can be seen. KNC cannot offer any positive comments on attachments or components that are hidden from view.

It is recommended that the Installation Contractor inspect his own equipment using this checklist prior to having the equipment inspected by an external organization. This will allow corrections to be made prior to an official inspection and will make it much more likely that the inspection will be passed successfully.

Special Note: *As rod stiffener requirements cannot be fully evaluated until specific site conditions are known, they are not designed and specified by KNC except under special circumstances. Section D4.4 of this manual includes a "tool" that allows contractors to determine specific requirements for this purpose. Should the contractor wish for KNC to take responsibility for the sizing and installation of these components, it will be necessary to collect data in the field, process it and generate a report for each restraint location. In the field, 5 minutes should be allowed to*

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collect the data at each point and then later in the office, 5 minutes should be assumed to process the data at each point to generate a report.

A1.2.2 Setup

1) Prior to performing an inspection, obtain a full set of drawings for the distribution system being inspected and label each restraint location with a reference number. For convenience, it is best for this to be an 11 x 17 drawing, but if this it too small to be clear, a larger copy will work.
2) Print off several copies of the checklist that is provided as the last sheet of this document to use for records.
3) Print off a copy of section D4.4 of this manual which provides guidance as to when rod stiffeners are required

A1.2.3 Inspection Process

1) In the field, locate each restraint location documented on the installation drawing and on a copy of the checklist, identify it by drawing number and reference number.
2) Using the check boxes and additional comments box provided for each location on the checklist, identify the condition of the restraint as you found it. Should corrective action be taken to correct a deficiency, a notation should be included in the additional comments box that the situation was corrected.
3) Should a deficiency be identified that is not listed on the checklist, describe it in the additional comments box.
4) Should additional areas exist that warrant comment (such as re-routed piping), additional tags can be added to the inspection drawing in the field and linked to the inspection document.
5) Copies of both the inspection checklists and the marked inspection drawings should be provided to KNC for records.
6) For clarity, it may be desirable to take photographs of some of the restraint locations, link them by tag number to the drawing and provide them to KNC for records as well. This is highly recommended for unusual installation arrangements.

A1.2.4 Items to be inspected:

1) Basic Geometry (as compared to the certification documents)
   a) Check restraint type, size and approximate location as compared to the drawing callouts.
   b) Check that 4 way restraints are provided at the locations marked “TL” or “TT” on the submitted installation documents and that “L” restraints are aligned to prevent axial motion of the system and “T” restraints are aligned to prevent transverse motion of the system.
   c) Where the system design has changed and restrained systems have been rerouted or eliminated, identify these on the drawing including the re-routing path and include restraint locations compatible with the relocated system.
   d) Where the distribution system has been covered and is not accessible, indicate on the inspection documents that these locations cannot be verified.

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2) Exemptions
   a) If a Restraint has been eliminate due to and exemption condition (most likely the 12" rule), ensure that all other required factors apply (Free swinging connector, adequate swing clearance, adequate flex at equipment attachment points, no mismatched [over 12" long supports] on the run.)
3) Restraint Factors
   a) Verify that the Cable angles relative to the horizontal plane are consistent with the documentation provided (Note: in general this permits a maximum 60 deg angle from the horizontal plane for the cables, but in some cases may limit the angle to 45 deg. This limit would be indentified on the project specific tabulated restraint sizing charts (listing the bubble codes)).
   b) Verify that the Cable angles relative to one another as viewed in the plan view are within 10 degrees of being aligned.
   c) Visually inspect the hardware used for size compliance versus the drawing callout.
   d) Cables must be installed in a snug (non-isolated) or near snug (isolated) condition.
4) Structural Attachment Factors
   a) Ensure that the connections to the structure are aligned with the restraint cables.
   b) If a KSCA clip is used, that a single anchor are located in the hole closest to the cable end.
   c) Compare the connection viewed in the field to an arrangement drawing representative of the connection specified on the drawing. A pictorial representation is present on the restraint cover sheet generated by KNC.
   d) Ensure that restraint connections are made using KNC provided hardware. Connections made without KNC hardware have not been tested and ratings cannot be verified.
   e) Check that attachments made via beam clamps are positive and that beam clamps are equipped with straps of sufficient capacity to ensure that the beam clamps cannot be pulled off the beam by lateral forces.
5) Component Attachment Factors
   a) Ensure that the connections to the component will positively prevent relative motion between the component and the restraint. (ie: clevis support hangers cannot be used in conjunction with Longitudinal (L) restraints and ductwork must also be adequately screwed to support trapeze bars to resist Longitudinal (L) forces.)
   b) Transverse and/or Longitudinal restraints must connect to the distribution system within 4 inches of a support point.
6) Hanger Rod Issues
   a) Ensure that Hanger rod is made of a material that can resist uplift forces (Rod or structure shape, not cable or sheet metal strap)
   b) If the system is isolated, check that the isolator brackets are within ¼" of the support structure and that they are fitted with limit stops that prevent the hanger rods from pushing up more than ¼" into the housing.
   c) Refer to this manual, Section D4.4 to determine if Rod Stiffeners are required and for sizing purposes.

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Project:	
KNC Number:	
Inspection Date:	
Inspected By:	

		Global Installation Issues										Component Attachment or Sizing Issues			Cable Installation and Orientation Issues						Hanger Rod Issues			
Reference Drawing	Location Identifier	No Discrepancies found	Restraint required, but not present	Component not Visible and could not be inspected	Distribution System Re-Rounted, Eliminated - Restraint not Present	New Restraint Location on Re-Routed System	Strut restraint substituted for cable restraint	Restraint function replaced by support bracket (design by others)	Struts and Cables Mismatched on same run	Excessive Spacing Between Restraints	Restraint eliminated, Run within 12" of structure, has free swinging connections, adequate swing clearance and has flexible equipment connections	Improper connection to structure	Lack of positive connection between Pipe/Duct/Conduit and the Restraint	Restraint/Anchor undersized	Excessively steep cable angle	Cables not Oriented square to each other	Improper Restraint type (Should be 4 way)	4 way Restraints not oriented at 90 degrees to each other	Cables bearing against intermediate obstruction	Cables are installed in an overly slack condition	Hanger rod not adequately stiff	Excessive misalignment between the Restraint and the Support hanger	Isolator Brachets not within 1/4" of structure or limit stops not adjusted to 1/4" clearance	Additional Comments
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Each Restraint point on the distribution system being inspected should be identified with a numerical identifier on this checklist and its mate on a marked version of the submitted installation drawing. Any applicable boxes identified by the KNC representatives are to be checked. In the case that correction is required, the identified installation problem(s) should still be identified with a note in the comments provided indicating that the problem was corrected. Note that KNC nor its representatives take any responsibility for components that are not left viewable at the time of the scheduled inspection. Note also that this inspection addresses overall geometric factors only and does not address detailed installation procedures such as proper bolt torquing or other factors that need to be addressed by the installation contractor at the time of installation. With regard to this inspection, KNC guarantees only that we will use that degree of care and skill ordinarily excercised under similar conditions by reputable members of our profession to validate that the provided components were installed in accordance with the previously provided KNC certification documentation.

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KINETICS Noise Control

Project:
KNC Number:
Inspection Date:
Inspected By:

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		Hanger Rod Data		Support Spacing and Load Data			Distribution System Size/Weight data. Enter data in only one column		
Reference Drawing	Location Identifier	Approx Hanger Rod Length	Hanger Rod Diameter	Span between system supports	Span between system restraints (Note: "L" restraint spacing for "L" analysis, "T" restraint spacing for "T" analysis, longest of "T" and "L" for "TL" analysis)	Is System Trapezed (T) or hung on a single support (S)?	System Weight per foot	Pipe Size(s) and Quanitity, for multiple pipes on a trapeze indicate size (qty) for each supported pipe size [ie: 3-1/2(2),6(1),4(3)]	Duct Size and Quantity

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INSPECTING EQUIPMENT

A1.3.1 Scope:

When inspecting equipment in the field, it is important to maintain an awareness of the scope of the Kinetics Noise Control's (KNC) Certification and recognize that KNC must limit comments and observations as much as possible to the confines of that scope. It is a regular occurrence in the field for the installation contractors to ask KNC representatives to offer comments and even make decisions for items that we have nothing to do with. It is also common to be asked to discuss aspects of equipment beyond the bounds of the actual restraint connection. An example might have to do with the durability of an equipment stand or a masonry wall. These components would be beyond KNC's control and must be referred to the Structural Engineer of Record. In order to offer any design input or guidance on items such as this implies that whoever is offering that input fully understands all of the loads being carried by the item, what it's total capacity might be and is willing to take responsibility for that knowledge.

KNC's scope is limited to those issues related to the direct attachment of the equipment to the structure. It includes the anchorage to the structure, the restraint component and the attachment of the restraint to the equipment. In some cases, it may include other KNC provided items like Inertia Bases, Structural frames or beams. All of these items, when provided by KNC, would fall into KNC's scope. If provided by others, they would not and legally KNC could not offer guidance or input on them.

The scope also does not include an evaluation of the building structure and its ability to resist the loads applied to it. Only the engineer of record for that structure can state categorically that the structure is capable of resisting the design loads.

Further, KNC must limit the scope of the inspection to only those objects that can be seen. KNC cannot offer any positive comments on attachments or components that are hidden from view.

It is recommended that the Installation Contractor inspect his own equipment using this checklist prior to having the equipment inspected by an external organization. This will allow corrections to be made prior to an official inspection and will make it much more likely that the inspection will be passed successfully.

A1.3.2 Items to be inspected:

1) Basic Geometry (as compared to the certification documents)
   a) Approximate overall mounting dimensions (this is particularly true for equipment that might not be provided with "built in" mounting holes and instead, clips like the KSMS have been fitted or holes were drilled for mounting by the contractor). Verify that the spacing between the restraints and the quantity of restraints used combine to generate an arrangement that is at least as good as that specified in the certification document. (Increasing the restraint quantity or spacing is good, decreased restraint quantity or spacing is not.)

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b) Verify that the overall dimensions of the equipment appear to be in line with what has been analyzed. This does not need to be measured critically, a simple approximation is adequate.

2) Bolts, welds or anchors that attach to the structure.
   a) Verify that the anchors or bolts are at least as large as those identified in the certification document.
   b) To the extent possible, check that the holes for these attachment points are not to be more than 1/8" in diameter larger than the bolt body.
   c) If anchored to concrete, check that the edge distance and spacing meets the minimum requirements called out on the certification document.
   d) Check that the anchors are installed at 90 degrees to the parent slab (vertical for floor mounted equipment) and are not canted at an angle.
   e) If welded, verify that the welds are in conformance with those shown on the certification document.

3) Restraint component.
   a) If an oversized base plate is shown as being required by the certification document, verify that the appropriate sized base plate has been fitted.
   b) Check that the internal clearances in the snubbing element do not sum to more that 1/2" in any axis (ie: since 1/4" movement is allowed in any direction, this can show up as 1/4" on each side of the snubbing element or as 1/8" on one side and 3/8" on the other. This is particularly critical for isolators like the FLS, FLSS and HS-1 where the installer controls the spacing.)
   c) Ensure that all restraints called for are properly in place (particularly true for curb mounted equipment like KSR's)

4) Bolts/welds that attach to the equipment.
   a) Verify that the restraint is attached to the equipment using all of the provided attachment holes in the restraint or a weld equivalent to that identified on the certification document.
   b) Check that curb mounted equipment is positively connected to the curb or curb isolation system.

5) Suspended equipment
   a) Compare the installation to the certification document and ensure that if required, rod stiffeners have been fitted.
   b) If the component is supported by only 2 hanger rods, check that the restraints are attached to it at its approximate CG.
   c) Visually check that the cable angles are no steeper than 60 degrees from the horizontal plane.
   d) Visually check that cables do not have excessive slack (they are to be snug, but not tensioned).
   e) Visually check that cables are oriented approx 90 degrees apart when viewed looking straight up from the floor.

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f) Visually check that cables are straight and are not contacting or distorted by an intermediate obstruction.

g) If the system is isolated, check that the isolator brackets are within ¼" of the support structure and that they are fitted with limit stops that prevent the hanger rods from pushing up more than ¼" into the housing.

6) Documentation

a) Complete the Inspection Checklist for each piece of equipment indicating the observed installed equipment condition and note any discrepancies.

b) In performing this inspection, identify the condition of the piece of equipment as you found it. Should corrective action be taken to correct a deficiency, A notation should be included in the additional comments box of the checklist indicating that the situation was corrected.

c) Retain the installation Inspection Checklist for records

d) Where appropriate, photos should be taken, linked to tags and retained for records as well.

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Project:
KNC Number:
Inspection Date:
Inspected By:

		All Equipment													Curb Mtd Equip	Suspended Equipment							
Equipment Tag	If duplicate Tags, Location Identifier	No Discrepancies found	Equipment not Visible and could not be inspected	Mounting Geometry does not match Certification	Equipment varies significantly from that analyzed	The structural attachment hardware or welds too small	Excessive Clearance in holes at the attachment to the structure	In adequate edge distance or spacing for anchorage	Anchors not installed 90 degrees to the parent surface	Weld attachment to the structure is inadequate	Inappropriate or missing oversized baseplate	Improperly adjusted Snubber (excessive clearance in snubbing element)	Not all required restraints installed	The equipment attachment hardware or welds too small	Curb mounted equipment not positively attached to curb	Required rod stiffeners missing	Equipment suspended on 2 hanger rods must have restraints attached at approximate CG elevation	Cable angles too steep	Cables are installed in an overly slack condition	Cables not oriented at 90 degrees to one another	Isolator Brackets not within 1/4" of structure or limit stops not adjusted to 1/4" clearance	Cables bearing against intermediate obstruction	Additional Comments
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Each piece of equipment inspected should be identified on this checklist and any applicable boxes identified by KNC representatives are to be checked. Note that KNC nor its representatives take any responsibility for components that are not left viewable at the time of the scheduled inspection. Note also that this inspection addresses overall geometric factors only and does not address detailed installation procedures such as proper bolt torquing or other factors that need to be addressed by the installation contractor at the time of installation. With regard to this inspection, KNC guarantees only that we will use that degree of care and skill ordinarily excercised under similar conditions by reputable members of our profession to validate that the provided components were installed in accordance with the previously provided KNC certification documentation.

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HOUSEKEEPING PAD DESIGN

The following section identifies those procedures that should be followed to ensure that Housekeeping pads used in structures located in seismically prone areas, will remain intact and in place when exposed to a seismic event. However, no claims are made in this document as to the ability of the structural slab underneath the housekeeping pad to withstand the seismic loads being transmitted into it. The guide is offered solely as a recommendation to other engineers and contractors as a tool that can aid in selecting an appropriate housekeeping pad design. As with other elements of the structure, the Engineer of record has the final say as to the suitability of these parameters to the project at hand.

A2.1.1 General

Housekeeping pads have been used for years as a device to allow isolated equipment to be more easily kept clear of debris and to enhance both the time required for maintenance and the appearance of mechanical rooms. As the demand for appropriate seismic restraint has become more stringent, housekeeping pads have evolved to serve as a structural interface that distributes localized point loads generated by attached equipment to the more globally designed mechanical room floor structure.

It is not untypical for the anchorage embedment requirements for particular pieces of equipment to exceed the maximum permitted embedment depth in a mechanical room floor slab. In these cases, the housekeeping slab thickness can be selected to meet the equipment anchor needs and then through an array of anchors that connect the housekeeping pad to the structure, this load can be distributed to a larger quantity of smaller anchors that are compatible with the floor slab.

Critical to this interface is the housekeeping pad thickness, the grade of concrete used, the adequacy of the connection between the housekeeping pad and the floor slab and appropriate reinforcement in the housekeeping pad to keep it from splitting apart. It is equally critical to ensure that the equipment anchors can not rupture the housekeeping pad and pull free. This is accomplished by providing an adequate edge distance between the anchor and the perimeter of the housekeeping pad itself as well as proper spacing between the anchors.

A2.1.2 Housekeeping Pad Thickness and Perimeter Dimensions

Before specifying a housekeeping pad, it is critical to determine the size and locations of the anchors that are being used to attach the equipment. Kinetics Noise Control or some other reputable source should perform an analysis, with the appropriate mounting hardware being selected and mounting locations determined. Once anchors are selected, the embedment depth for the anchors can be identified. This is generally 8 times the anchor diameter, but in a few cases, could be more. Refer to the Anchor section (P10) in this manual or the calculation performed to verify this dimension. As it is necessary that anchors be embedded in a single contiguous pour, it will be necessary for the anchor to achieve its full embedment in either the structural floor slab or the housekeeping pad. The only exception to this is when the

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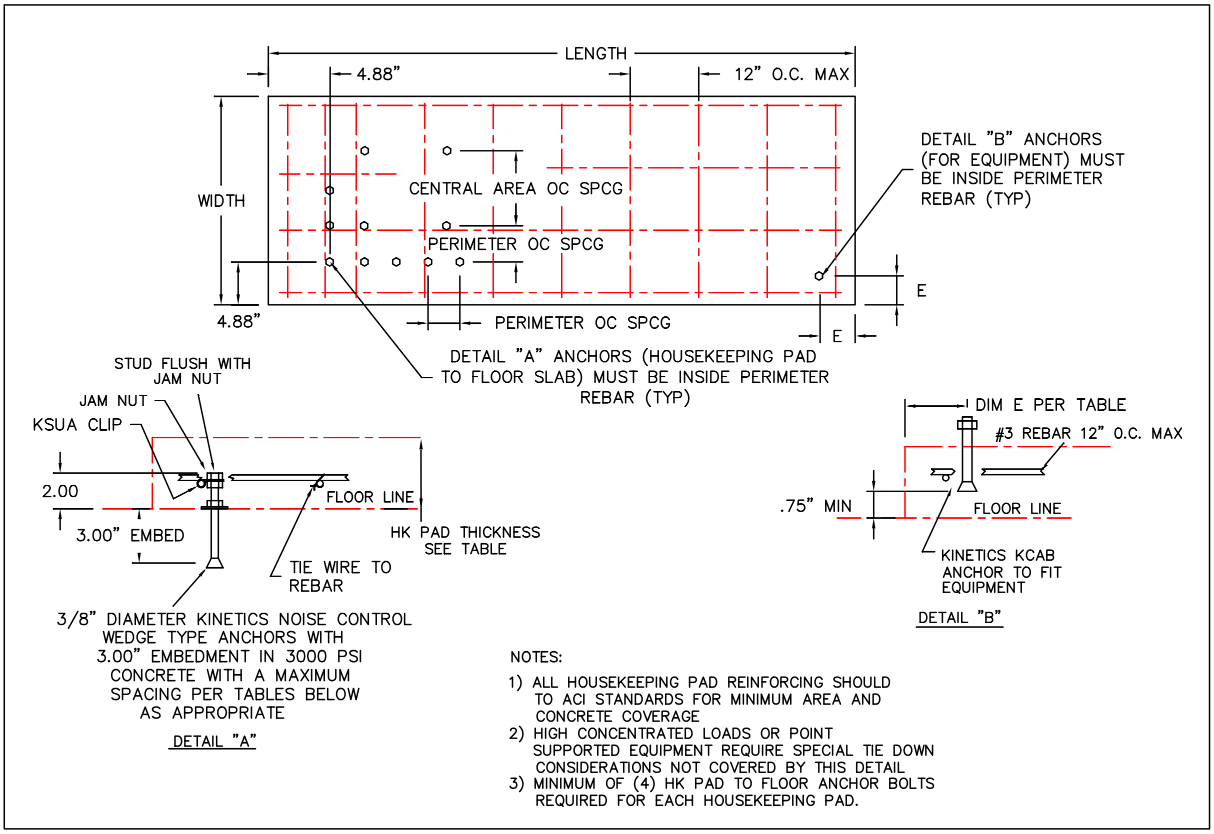
housekeeping pad has been poured along with the structural slab. In addition, for most applications using KCCAB anchors at least 1" of cover under the anchor is required. Thus, if 6" of embedment is required for the anchor, a minimum contiguous concrete thickness of 7" is needed to accommodate this. (Note, if the anchor is being directly embedded into a slab on grade, the minimum cover over the end of the anchor increases to 1-1/2".

Referring also to the Anchor section (P10) of this manual, the minimum allowed edge distance is also identified by anchor size. This is the minimum allowed distance from the anchor centerline to the nearest edge of a housekeeping pad. Using this information along with the previously identified anchor attachment pattern, a minimum housekeeping pad profile can be determined.

Figure A2.1-1; Housekeeping pad layout



Housekeeping Pad General Layout

A2.1.3 Tabulated Design Data Assumptions

In using the tabulated data listed in this section, the following assumptions have been made.

1) The concrete used is in the housekeeping pad is 3000 psi min, standard weight.

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2) Anchorage ratings have been de-rated to meet current US standards for all applications except those requiring certification from OSHPD.
3) The structural concrete used is 3000 psi min and standard weight.
4) The thickness and profile are in accordance with the sizing information listed above.
5) The housekeeping pad is attached to the structural slab using 3/8" diameter x 5" long KCAB anchor bolts that are embedded 3" into the structural slab, protrude 2" into the housekeeping pad and are physically connected to internal #3 rebar using KSUA clips. (It is only possible to use larger anchors if the structural slab is greater than 4" in thickness.)

A2.1.4 Use of Tables

1) Divide the total Operating Equipment weight by the overall length of the housekeeping pad to get a weight per foot value.
2) Verify that the vertical dimension from the top of the housekeeping pad to the equipment CG is less than the 2/3 of the width of the housekeeping pad. (If this is not the case, either the pad will have to be made wider or a custom analysis will have to be performed by Kinetics Noise Control or other qualified source.)
3) Determine the Seismic acceleration for the equipment type and location in the structure under review. All acceleration values are listed in the attached tables include all factors and are expressed in stress based (ASD) units regardless of the code used. If the design forces are LRFD based as in the IBC or TI-809-04, the values should be reduced by a factor of 0.7 prior to using these tables. (Note: this has already been done if using Kinetics Noise Control provided certification documents.) If factors are provided in the project specification that exceed the code values, the higher values should be used as a basis for design.
4) Select the table with the appropriate design acceleration factor.
5) Reading across the top of the table, find the equipment weight per foot and the housekeeping pad thickness previously determined
6) Read down the column until you find the housekeeping width that will allow the equipment mounting anchors to be installed and maintain adequate edge distances.
7) The value listed in upper portion of the table is the maximum center to center distance for anchors placed around the perimeter of the housekeeping pad.
8) The value listed in lower portion of the table is the maximum spacing between anchors in the central area of the housekeeping pad.
9) A minimum of 4 anchors is required per pad.
10) Refer to the drawing below for reinforcement and housekeeping pad details.
11) All pad reinforcement should conform to ACI standards for minimum area and concrete coverage.

A2.1.5 Special Applications

For Design conditions outside of those allowed by the above Tables, consult Kinetics Noise Control.

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A2.1.6 Sample Pad Design

Conditions:
10,000 lb chiller
Seismic Acceleration .47 g (in ASD units at equipment location)
Anchorage spacing (from equipment) 112" x 48"
Anchor size (from equipment analysis) .75"

Pad Thickness
Embedment required for .75" anchor is 6" (from anchor table in P10.2.1 of this manual). Minimum cover is .75" so minimum thickness is 6.75". Use 8" pad.

Pad Length
Minimum edge distance for .75" anchor is 9.75" (from anchor table in P10.2.1 of this manual). Minimum pad length is 9.75" (edge distance) + 112" (spacing) + 9.75" (edge distance) or 131.5" (call it 11 ft).

Pad Width
Using above minimum edge distance the minimum width is 9.75" (edge distance) + 48" (spacing) + 9.75" (edge distance) or 67.5"

Weight per foot of length is 10,000/11 or 909 lb/ft.

Refering to the .5g table and the 1000 lb/ft column with an 8" thick pad, the maximum perimeter anchor spacing for a 4-6 ft wide pad is 36". The maximum central area anchor spacing is 48".

Table A2.1-1; Design Tables

Seismic Acceleration (at Equipment) 0.25 g ASD Based Values With IBC, or TI-809-04 code reduce the LRFD "g" value by 0.7

Maximum Anchor Spacing (in)

Equip Wt/Ft (lb)		250	250	250	500	500	500	750	750	750	750	1000	1000	1000	1000	1500	1500	1500	1500
HouseKeeping Pad Thk (in)		4	6	8	4	6	8	4	6	8	10	4	6	8	10	4	6	8	10
	Pad Wdth (ft)																		
Perimeter Spacing (in)	1 - 2	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	2 - 4	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	4 - 6	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	6 - 8	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	8 - 10	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	10 - 12	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	12 - 15	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	15 - 20	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
Central Area (OC Spg) (in)	1 - 2	48	48	48	48	48	48	48	48	48	48	47	46	45	45	34	34	33	33
	2 - 4	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	4 - 6	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	6 - 8	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	8 - 10	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	10 - 12	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	12 - 15	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	15 - 20	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48

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Seismic Acceleration (at Equipment) 0.5 g ASD Based Values With IBC, or TI-809-04 code reduce the LRFD "g" value by 0.7

Maximum Anchor Spacing (in)

Equip Wt/Ft (lb)		250	250	250	500	500	500	750	750	750	750	1000	1000	1000	1000	1500	1500	1500	1500
HouseKeeping Pad Thk (in)		4	6	8	4	6	8	4	6	8	10	4	6	8	10	4	6	8	10
	Pad Wdth (ft)																		
Perimeter Spacing (in)	1 - 2	36	36	36	36	36	36	36	36	36	36	31	30	30	29	21	21	20	20
	2 - 4	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	4 - 6	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	6 - 8	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	8 - 10	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	10 - 12	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	12 - 15	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	15 - 20	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
Central Area (OC Spg) (in)	1 - 2	48	48	48	45	44	42	33	32	32	31	26	26	25	25	19	19	19	18
	2 - 4	48	48	48	48	48	48	48	48	48	48	45	44	42	41	33	32	32	31
	4 - 6	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	6 - 8	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	8 - 10	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	10 - 12	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	12 - 15	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	15 - 20	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48

Seismic Acceleration (at Equipment) 0.75 g ASD Based Values With IBC, or TI-809-04 code reduce the LRFD "g" value by 0.7

Maximum Anchor Spacing (in)

Equip Wt/Ft (lb)		250	250	250	500	500	500	750	750	750	750	1000	1000	1000	1000	1500	1500	1500	1500
HouseKeeping Pad Thk (in)		4	6	8	4	6	8	4	6	8	10	4	6	8	10	4	6	8	10
	Pad Wdth (ft)																		
Perimeter Spacing (in)	1 - 2	36	36	36	36	36	36	27	26	26	24	21	20	19	17	13	12	11	10
	2 - 4	36	36	36	36	36	36	36	36	36	36	36	36	36	35	27	26	26	25
	4 - 6	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	6 - 8	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	8 - 10	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	10 - 12	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	12 - 15	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	15 - 20	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
Central Area (OC Spg) (in)	1 - 2	48	48	47	32	31	30	24	23	23	22	19	19	18	18	14	13	13	13
	2 - 4	48	48	48	48	48	47	40	38	37	35	32	31	30	29	24	23	23	22
	4 - 6	48	48	48	48	48	48	48	48	48	48	48	48	47	45	40	38	37	35
	6 - 8	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	47	45
	8 - 10	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	10 - 12	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	12 - 15	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	15 - 20	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48

Seismic Acceleration (at Equipment) 1.00 g ASD Based Values With IBC, or TI-809-04 code reduce the LRFD "g" value by 0.7

Maximum Anchor Spacing (in)

Equip Wt/Ft (lb)		250	250	250	500	500	500	750	750	750	750	1000	1000	1000	1000	1500	1500	1500	1500
HouseKeeping Pad Thk (in)		4	6	8	4	6	8	4	6	8	10	4	6	8	10	4	6	8	10
	Pad Wdth (ft)																		
Perimeter Spacing (in)	1 - 2	36	35	28	29	24	20	17	15	13	11	11	10	9	8	6	6	5	5
	2 - 4	36	36	36	36	36	36	32	29	27	25	23	21	19	18	13	12	11	10
	4 - 6	36	36	36	36	36	36	36	36	35	34	28	27	27	26	19	19	18	17
	6 - 8	36	36	36	36	36	36	36	36	36	36	29	29	29	29	19	19	19	19
	8 - 10	36	36	36	36	36	36	36	36	36	36	29	30	30	30	20	20	20	20
	10 - 12	36	36	36	36	36	36	36	36	36	36	30	30	31	31	20	20	20	20
	12 - 15	36	36	36	36	36	36	36	36	36	36	30	31	31	32	20	20	20	21
	15 - 20	36	36	36	36	36	36	36	36	36	36	30	31	32	33	20	20	21	21
Central Area (OC Spg) (in)	1 - 2	42	39	37	25	25	24	19	18	18	17	15	15	14	14	11	11	10	10
	2 - 4	48	48	48	42	39	37	32	30	29	28	25	25	24	23	19	18	18	17
	4 - 6	48	48	48	48	48	48	48	47	44	41	42	39	37	35	32	30	29	28
	6 - 8	48	48	48	48	48	48	48	48	48	48	48	48	47	43	42	39	37	35
	8 - 10	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	47	44	41
	10 - 12	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	45
	12 - 15	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	15 - 20	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48

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Seismic Acceleration (at Equipment) 1.50 g ASD Based Values With IBC, or TI-809-04 code reduce the LRFD "g" value by 0.7

Maximum Anchor Spacing (in)

	Equip Wt/Ft (lb)	250	250	250	500	500	500	750	750	750	750	1000	1000	1000	1000	1500	1500	1500	1500
	HouseKeeping Pad Thk (in)	4	6	8	4	6	8	4	6	8	10	4	6	8	10	4	6	8	10
	Pad Wdth (ft)																		
Perimeter Spacing (in)	1 - 2	24	19	14	12	10	8	7	6	5	-	-	-	-	-	-	-	-	-
	2 - 4	34	29	25	20	18	16	12	11	10	9	8	7	7	6	-	-	-	-
	4 - 6	36	36	36	23	22	21	16	15	14	13	11	10	9	9	6	5	5	5
	6 - 8	36	36	36	24	24	23	16	16	16	16	12	11	11	10	6	6	6	6
	8 - 10	36	36	36	25	25	24	17	17	16	16	12	12	12	11	6	6	6	6
	10 - 12	36	36	36	25	25	25	17	17	17	17	12	12	12	12	6	6	6	6
	12 - 15	36	36	36	25	26	26	17	17	17	17	13	13	12	12	7	6	6	6
	15 - 20	36	36	36	26	26	26	17	17	17	17	13	13	13	12	7	7	7	6
Central Area (OC Spg) (in)	1 - 2	30	28	26	18	18	17	13	13	13	12	11	10	10	10	8	8	7	7
	2 - 4	47	42	38	30	28	26	23	21	21	20	18	18	17	16	13	13	13	12
	4 - 6	48	48	48	47	42	38	37	34	31	29	30	28	26	25	23	21	21	20
	6 - 8	48	48	48	48	48	45	47	42	38	35	39	36	33	31	30	28	26	25
	8 - 10	48	48	48	48	48	48	48	48	43	39	47	42	38	35	37	34	31	29
	10 - 12	48	48	48	48	48	48	48	48	47	42	48	47	42	38	42	38	35	32
	12 - 15	48	48	48	48	48	48	48	48	48	45	48	48	45	41	47	42	38	35
	15 - 20	48	48	48	48	48	48	48	48	48	47	48	48	48	44	48	47	42	38

Seismic Acceleration (at Equipment) 2.00 g ASD Based Values With IBC, or TI-809-04 code reduce the LRFD "g" value by 0.7

Maximum Anchor Spacing (in)

	Equip Wt/Ft (lb)	250	250	250	500	500	500	750	750	750	750	1000	1000	1000	1000	1500	1500	1500	1500
	HouseKeeping Pad Thk (in)	4	6	8	4	6	8	4	6	8	10	4	6	8	10	4	6	8	10
	Pad Wdth (ft)																		
Perimeter Spacing (in)	1 - 2	14	10	8	6	5	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 - 4	22	19	16	11	9	8	6	5	5	-	-	-	-	-	-	-	-	-
	4 - 6	27	25	23	15	13	12	8	8	7	7	5	5	-	-	-	-	-	-
	6 - 8	29	27	26	15	15	14	9	8	8	8	6	5	5	5	-	-	-	-
	8 - 10	30	29	28	16	15	15	9	9	8	8	6	6	5	5	-	-	-	-
	10 - 12	31	30	29	16	16	15	9	9	9	9	6	6	6	6	-	-	-	-
	12 - 15	31	31	30	16	16	16	10	9	9	9	6	6	6	6	-	-	-	-
	15 - 20	32	31	31	16	16	16	10	10	9	9	6	6	6	6	-	-	-	-
Central Area (OC Spg) (in)	1 - 2	24	22	21	14	14	13	10	10	10	10	8	8	8	8	6	6	6	6
	2 - 4	37	33	30	24	22	21	18	17	16	15	14	14	13	13	10	10	10	10
	4 - 6	48	45	39	37	33	30	29	26	25	23	24	22	21	20	18	17	16	15
	6 - 8	48	48	44	47	40	36	37	33	30	28	31	28	26	24	24	22	21	20
	8 - 10	48	48	47	48	45	39	44	38	34	31	37	33	30	28	29	26	25	23
	10 - 12	48	48	48	48	48	42	48	42	37	33	42	37	33	30	33	30	28	25
	12 - 15	48	48	48	48	48	44	48	45	39	35	47	40	36	32	37	33	30	28
	15 - 20	48	48	48	48	48	47	48	48	42	37	48	44	39	34	42	37	33	30

Seismic Acceleration (at Equipment) 2.50 g ASD Based Values With IBC, or TI-809-04 code reduce the LRFD "g" value by 0.7

Maximum Anchor Spacing (in)

	Equip Wt/Ft (lb)	250	250	250	500	500	500	750	750	750	750	1000	1000	1000	1000	1500	1500	1500	1500
	HouseKeeping Pad Thk (in)	4	6	8	4	6	8	4	6	8	10	4	6	8	10	4	6	8	10
	Pad Wdth (ft)																		
Perimeter Spacing (in)	1 - 2	9	7	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 - 4	16	13	10	7	6	5	-	-	-	-	-	-	-	-	-	-	-	-
	4 - 6	20	18	17	9	8	7	5	-	-	-	-	-	-	-	-	-	-	-
	6 - 8	21	20	19	10	9	9	5	5	-	-	-	-	-	-	-	-	-	-
	8 - 10	22	21	20	10	10	9	6	5	5	-	-	-	-	-	-	-	-	-
	10 - 12	22	21	21	11	10	10	6	5	5	5	-	-	-	-	-	-	-	-
	12 - 15	23	22	21	11	10	10	6	6	5	5	-	-	-	-	-	-	-	-
	15 - 20	23	22	22	11	11	10	6	6	6	5	-	-	-	-	-	-	-	-
Central Area (OC Spg) (in)	1 - 2	20	18	17	12	11	11	9	8	8	8	7	7	7	7	5	5	-	-
	2 - 4	31	28	25	20	18	17	15	14	13	13	12	11	11	11	9	8	8	8
	4 - 6	45	38	33	31	28	25	24	22	20	19	20	18	17	16	15	14	13	13
	6 - 8	48	43	37	39	34	30	31	28	25	23	26	24	22	20	20	18	17	16
	8 - 10	48	47	39	45	38	33	36	32	28	26	31	28	25	23	24	22	20	19
	10 - 12	48	48	41	48	41	35	41	35	31	28	35	31	28	25	28	25	23	21
	12 - 15	48	48	42	48	43	37	45	38	33	29	39	34	30	27	31	28	25	23
	15 - 20	48	48	43	48	46	39	48	41	35	31	43	37	32	29	35	31	28	25

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STANDARD STEEL PIPE DATA – ENGLISH UNITS

Table A3.1.1-1; Bare Pipe – Water.

Pipe Size (in)	Pipe O.D. (in)	Pipe I.D. (in)	Pipe Weight Empty (lb/ft)	Water Weight (lb/ft)	Pipe + Water (lb/ft)
3/4	1.050	0.824	1.13	0.23	1.36
1	1.315	1.049	1.68	0.37	2.05
1-1/4	1.660	1.380	2.27	0.65	2.92
1-1/2	1.900	1.610	2.71	0.88	3.59
2	2.375	2.067	3.65	1.45	5.10
2-1/2	2.875	2.469	5.79	2.07	7.86
3	3.500	3.068	7.57	3.20	10.77
3-1/2	4.000	3.548	9.10	4.28	13.38
4	4.500	4.026	10.78	5.52	16.30
5	5.563	5.047	14.60	8.67	23.27
6	6.625	6.065	18.95	12.52	31.47
8	8.625	7.981	28.52	21.68	50.20
10	10.750	10.020	40.44	34.17	74.61
11	11.750	11.000	45.51	41.18	86.69
12	12.750	12.000	49.51	49.01	98.52
14	14.000	13.250	54.51	59.75	114.26
16	16.000	15.250	62.51	79.15	141.66
18	18.000	17.250	70.51	101.27	171.78
20	20.000	19.250	78.52	126.12	204.64
22	22.000	21.250	86.52	153.68	240.20
24	24.000	23.250	94.52	183.97	278.49
30	30.000	29.250	118.52	291.18	409.70
36	36.000	35.250	142.53	422.89	565.42
42	42.000	41.250	166.53	579.11	745.64
48	48.000	47.250	190.54	759.83	950.37

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Table A3.1.1-2; Insulated Pipe – Water (85% Magnesia Insulation).

Pipe Size (in)	Pipe O.D. (in)	Pipe I.D. (in)	Pipe Weight Empty (lb/ft)	Water Weight (lb/ft)	Insulation Thickness (in)	Insulation Weight (lb/ft)	Pipe + Water + Insulation (lb/ft)
3/4	1.050	0.824	1.13	0.23	1.00	0.76	2.12
1	1.315	1.049	1.68	0.37	1.00	0.86	2.91
1-1/4	1.660	1.380	2.27	0.65	1.00	0.99	3.91
1-1/2	1.900	1.610	2.71	0.88	1.00	1.08	4.67
2	2.375	2.067	3.65	1.45	1.00	1.25	6.18
2-1/2	2.875	2.469	5.79	2.07	1.00	1.44	9.30
3	3.500	3.068	7.57	3.20	1.00	1.67	12.44
3-1/2	4.000	3.548	9.10	4.28	1.00	1.85	15.23
4	4.500	4.026	10.78	5.52	1.00	2.04	18.34
5	5.563	5.047	14.60	8.67	1.50	3.93	27.20
6	6.625	6.065	18.95	12.52	1.50	4.52	35.99
8	8.625	7.981	28.52	21.68	1.50	5.63	55.83
10	10.750	10.020	40.44	34.17	1.50	6.81	81.42
11	11.750	11.000	45.51	41.18	1.50	7.37	94.06
12	12.750	12.000	49.51	49.01	1.50	7.93	106.45
14	14.000	13.250	54.51	59.75	1.50	8.62	122.88
16	16.000	15.250	62.51	79.15	1.50	9.74	151.40
18	18.000	17.250	70.51	101.27	1.50	10.85	182.63
20	20.000	19.250	78.52	126.12	1.50	11.96	216.60
22	22.000	21.250	86.52	153.68	1.50	13.07	253.27
24	24.000	23.250	94.52	183.97	1.50	14.19	292.68
30	30.000	29.250	118.52	291.18	1.50	17.52	427.22
36	36.000	35.250	142.53	422.89	1.50	20.86	586.28
42	42.000	41.250	166.53	579.11	1.50	24.20	769.84
48	48.000	47.250	190.54	759.83	1.50	27.54	977.91

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Table A3.1.1-3; Insulated Pipe – Steam (85% Magnesia Insulation).

Pipe Size (in)	Pipe O.D. (in)	Pipe I.D. (in)	Pipe Weight Empty (lb/ft)	Steam Weight (lb/ft)	Insulation Thickness (in)	Insulation Weight (lb/ft)	Pipe + Steam + Insulation (lb/ft)
3/4	1.050	0.824	1.13	0.0001	1.50	1.42	2.55
1	1.315	1.049	1.68	0.0002	1.50	1.57	3.25
1-1/4	1.660	1.380	2.27	0.0004	1.50	1.76	4.03
1-1/2	1.900	1.610	2.71	0.0005	1.50	1.89	4.60
2	2.375	2.067	3.65	0.0009	1.50	2.16	5.54
2-1/2	2.875	2.469	5.79	0.0012	1.50	2.43	8.22
3	3.500	3.068	7.57	0.0019	1.50	2.78	10.35
3-1/2	4.000	3.548	9.10	0.0026	1.50	3.06	12.16
4	4.500	4.026	10.78	0.0033	1.50	3.34	14.12
5	5.563	5.047	14.60	0.0052	2.00	5.61	20.22
6	6.625	6.065	18.95	0.0075	2.00	6.40	25.36
8	8.625	7.981	28.52	0.0129	2.00	7.88	36.41
10	10.750	10.020	40.44	0.0204	2.00	9.46	49.92
11	11.750	11.000	45.51	0.0246	2.00	10.20	55.73
12	12.750	12.000	49.51	0.0292	2.00	10.94	60.48
14	14.000	13.250	54.51	0.0356	2.00	11.87	66.42
16	16.000	15.250	62.51	0.0472	2.00	13.35	75.91
18	18.000	17.250	70.51	0.0604	2.00	14.84	85.41
20	20.000	19.250	78.52	0.0752	2.00	16.32	94.92
22	22.000	21.250	86.52	0.0916	2.00	17.80	104.41
24	24.000	23.250	94.52	0.1097	2.00	19.29	113.92
30	30.000	29.250	118.52	0.1736	2.00	23.74	142.43
36	36.000	35.250	142.53	0.2521	2.00	28.19	170.97
42	42.000	41.250	166.53	0.3452	2.00	32.64	199.52
48	48.000	47.250	190.54	0.4530	2.00	37.09	228.08

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STANDARD STEEL PIPE DATA – SI UNITS

Table A3.1.2-1; Bare Pipe – Water.

Pipe Size (mm)	Pipe O.D. (mm)	Pipe I.D. (mm)	Pipe Weight Empty (N/m)	Water Weight (N/m)	Pipe + Water (N/m)
19	26.67	20.93	16.5	3.4	19.9
25	33.40	26.64	24.5	5.5	30.0
32	42.16	35.05	33.1	9.5	42.6
38	48.26	40.89	39.6	12.9	52.5
51	60.33	52.50	53.3	21.2	74.5
64	73.03	62.71	84.5	30.3	114.8
76	88.90	77.93	110.4	46.8	157.2
89	101.60	90.12	132.8	62.5	195.3
102	114.30	102.26	157.3	80.5	237.8
127	141.30	128.19	213.2	126.5	339.7
152	168.28	154.05	276.7	182.7	459.4
203	219.08	202.72	416.3	316.4	732.7
254	273.05	254.51	590.1	498.7	1,089
279	298.45	279.40	664.2	601.0	1,265
305	323.85	304.80	722.5	715.2	1,438
356	355.60	336.55	795.5	872.0	1,668
406	406.40	387.35	912.3	1,155	2,067
457	457.20	438.15	1,029	1,478	2,507
508	508.00	488.95	1,146	1,841	2,986
559	558.80	539.75	1,263	2,243	3,506
610	609.60	590.55	1,379	2,685	4,064
762	762.00	742.95	1,730	4,249	5,979
914	914.40	895.35	2,080	6,172	8,252
1,219	1219.20	1200.15	2,781	11,089	13,870

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Table A3.1.2-2; Insulated Pipe – Water (85% Magnesia Insulation).

Pipe Size (mm)	Pipe O.D. (mm)	Pipe I.D. (mm)	Pipe Weight Empty (N/m)	Water Weight (N/m)	Insulation Thickness (mm)	Insulation Weight (N/m)	Pipe + Water + Insulation (N/m)
19	26.67	20.93	16.5	3.4	25.4	11.1	31.0
25	33.40	26.64	24.5	5.5	25.4	12.5	42.5
32	42.16	35.05	33.1	9.5	25.4	14.4	57.0
38	48.26	40.89	39.6	12.9	25.4	15.7	68.2
51	60.33	52.50	53.3	21.2	25.4	18.3	90.2
64	73.03	62.71	84.5	30.3	25.4	21.0	135.8
76	88.90	77.93	110.4	46.8	25.4	24.4	181.6
89	101.60	90.12	132.8	62.5	25.4	27.1	222.4
102	114.30	102.26	157.3	80.5	25.4	29.8	267.6
127	141.30	128.19	213.2	126.5	38.1	57.3	397.0
152	168.28	154.05	276.7	182.7	38.1	66.0	525.4
203	219.08	202.72	416.3	316.4	38.1	82.2	814.9
254	273.05	254.51	590.1	498.7	38.1	99.5	1,188
279	298.45	279.40	664.2	601.0	38.1	107.6	1,373
305	323.85	304.80	722.5	715.2	38.1	115.7	1,553
356	355.60	336.55	795.5	872.0	38.1	125.8	1,793
406	406.40	387.35	912.3	1,155	38.1	142.1	2,209
457	457.20	438.15	1,029	1,478	38.1	158.3	2,665
508	508.00	488.95	1,146	1,841	38.1	174.6	3,162
559	558.80	539.75	1,263	2,243	38.1	190.8	3,697
610	609.60	590.55	1,379	2,685	38.1	207.0	4,271
762	762.00	742.95	1,730	4,249	38.1	255.7	6,235
914	914.40	895.35	2,080	6,172	38.1	304.5	8,557
1,219	1219.20	1200.15	2,781	11,089	38.1	401.9	14,272

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Table A3.1.2-3; Insulated Pipe – Steam (85% Magnesia Insulation).

Pipe Size (mm)	Pipe O.D. (mm)	Pipe I.D. (mm)	Pipe Weight Empty (N/m)	Steam Weight (N/m)	Insulation Thickness (mm)	Insulation Weight (N/m)	Pipe + Steam + Insulation (N/m)
19	26.67	20.93	16.5	0.002	38.1	20.7	37.2
25	33.40	26.64	24.5	0.003	38.1	22.9	47.4
32	42.16	35.05	33.1	0.006	38.1	25.7	58.8
38	48.26	40.89	39.6	0.008	38.1	27.6	67.2
51	60.33	52.50	53.3	0.01	38.1	31.5	80.9
64	73.03	62.71	84.5	0.02	38.1	35.5	120.0
76	88.90	77.93	110.4	0.03	38.1	40.6	151.0
89	101.60	90.12	132.8	0.04	38.1	44.7	177.5
102	114.30	102.26	157.3	0.05	38.1	48.7	206.1
127	141.30	128.19	213.2	0.08	50.8	81.9	295.2
152	168.28	154.05	276.7	0.11	50.8	93.4	370.2
203	219.08	202.72	416.3	0.19	50.8	115.0	531.5
254	273.05	254.51	590.1	0.30	50.8	138.0	728.4
279	298.45	279.40	664.2	0.36	50.8	148.8	813.4
305	323.85	304.80	722.5	0.43	50.8	159.7	882.6
356	355.60	336.55	795.5	0.52	50.8	173.2	969.2
406	406.40	387.35	912.3	0.69	50.8	194.9	1,108
457	457.20	438.15	1,029	0.88	50.8	216.5	1,246
508	508.00	488.95	1,146	1.1	50.8	238.2	1,385
559	558.80	539.75	1,263	1.3	50.8	259.8	1,524
610	609.60	590.55	1,379	1.6	50.8	281.5	1,662
762	762.00	742.95	1,730	2.5	50.8	346.4	2,079
914	914.40	895.35	2,080	3.7	50.8	411.4	2,495
1,219	1219.20	1200.15	2,781	6.6	50.8	541.3	3,329

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PVC & CPVC Pipe Data – English Units

Table A4.2.1-1; Schedule 40 (Standard) Pipe – Water.

Pipe Size (in)	Pipe O.D. (in)	Pipe I.D. (in)	Pipe Weight Empty (lb/ft)	Water Weight (lb/ft)	Pipe + Water (lb/ft)
3/4	1.050	0.810	0.21	0.22	0.43
1	1.315	1.033	0.31	0.36	0.67
1-1/4	1.660	1.364	0.42	0.63	1.05
1-1/2	1.900	1.592	0.51	0.86	1.37
2	2.375	2.049	0.68	1.43	2.11
2-1/2	2.875	2.445	1.08	2.03	3.11
3	3.500	3.042	1.41	3.15	4.56
4	4.500	3.998	2.01	5.44	7.45
6	6.625	6.031	3.54	12.38	15.92
8	8.625	7.943	5.32	21.47	26.79
10	10.750	9.976	7.56	33.87	41.43

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Table A4.2.1-2; Schedule 80 (Extra Heavy) Pipe – Water.

Pipe Size (in)	Pipe O.D. (in)	Pipe I.D. (in)	Pipe Weight Empty (lb/ft)	Water Weight (lb/ft)	Pipe + Water (lb/ft)
3/4	1.050	0.724	0.27	0.18	0.45
1	1.315	0.935	0.40	0.30	0.70
1-1/4	1.660	1.256	0.56	0.54	1.10
1-1/2	1.900	1.476	0.67	0.74	1.41
2	2.375	1.913	0.93	1.25	2.18
2-1/2	2.875	2.289	1.43	1.78	3.21
3	3.500	2.864	1.91	2.79	4.70
4	4.500	3.786	2.79	4.88	7.67
6	6.625	5.709	5.32	11.09	16.41
8	8.625	7.565	8.09	19.48	27.57
10	10.750	9.492	12.00	30.66	42.66
12	12.750	11.294	16.50	43.41	59.91

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Table A4.2.1-3; Light Wall Duct Pipe – Water.

Pipe Size (in)	Pipe O.D. (in)	Pipe I.D. (in)	Pipe Weight Empty (lb/ft)	Water Weight (lb/ft)	Pipe + Water (lb/ft)
6	6.625	6.251	2.27	13.30	15.57
8	8.625	8.251	2.97	23.17	26.14
10	10.750	10.376	3.72	36.64	40.36
12	12.750	12.376	4.43	52.13	56.56
14	14.000	13.626	4.87	63.19	68.06
16	16.000	15.626	5.57	83.10	88.67

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Table A4.2.2-1; Schedule 40 (Standard) Pipe – Water.

Pipe Size (mm)	Pipe O.D. (mm)	Pipe I.D. (mm)	Pipe Weight Empty (N/m)	Water Weight (N/m)	Pipe + Water (N/m)
19	26.67	20.57	3.1	3.3	6.4
25	33.40	26.24	4.6	5.3	9.9
32	42.16	34.65	6.1	9.2	15.3
38	48.26	40.44	7.4	12.6	20.0
51	60.33	52.04	9.9	20.8	30.7
64	73.03	62.10	15.7	29.7	45.4
76	88.90	77.27	20.6	46.0	66.6
102	114.30	101.55	29.3	79.4	108.7
152	168.28	153.19	51.7	180.7	232.4
203	219.08	201.75	77.7	313.4	391.1
254	273.05	253.39	110.3	494.3	604.6

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Table A4.2.2-2; Schedule 80 (Extra Heavy) Pipe – Water.

Pipe Size (mm)	Pipe O.D. (mm)	Pipe I.D. (mm)	Pipe Weight Empty (N/m)	Water Weight (N/m)	Pipe + Water (N/m)
19	26.67	18.39	4.0	2.6	6.6
25	33.40	23.75	5.9	4.3	10.2
32	42.16	31.90	8.1	7.8	15.9
38	48.26	37.49	9.8	10.8	20.6
51	60.33	48.59	13.6	18.2	31.8
64	73.03	58.14	20.8	26.0	46.8
76	88.90	72.75	27.8	40.7	68.5
102	114.30	96.16	40.7	71.2	111.9
152	168.28	145.01	77.7	161.9	239.6
203	219.08	192.15	118.1	284.2	402.3
254	273.05	241.10	175.1	447.5	622.6
305	323.85	286.87	240.7	633.6	874.3

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Table A4.2.2-3; Light Wall Duct Pipe – Water.

Pipe Size (mm)	Pipe O.D. (mm)	Pipe I.D. (mm)	Pipe Weight Empty (N/m)	Water Weight (N/m)	Pipe + Water (N/m)
152	168.28	158.78	33.1	194.1	227.2
203	219.08	209.85	42.2	339.0	381.2
254	273.05	263.55	54.3	534.7	589.0
305	323.85	314.35	64.6	760.8	825.4
356	355.60	346.10	71.1	922.2	993.3
406	406.40	396.90	81.3	1,213	1,294

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PVC Fire Sprinkler Pipe Data – English Units
BlazeMaster® Brand Name Pipe by HARVEL®

Table A4.3.1-1; BlazeMaster® CPVC Sprinkler Pipe – Water.

Pipe Size (in)	Pipe O.D. (in)	Pipe I.D. (in)	Pipe Weight Empty (lb/ft)	Water Weight (lb/ft)	Pipe + Water (lb/ft)
3/4	1.050	0.874	0.16	0.26	0.42
1	1.315	1.101	0.24	0.41	0.65
1-1/4	1.660	1.394	0.38	0.66	1.04
1-1/2	1.900	1.598	0.50	0.87	1.37
2	2.375	2.003	0.77	1.37	2.14
2-1/2	2.875	2.423	1.13	2.00	3.13
3	3.500	2.950	1.67	2.96	4.63

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PVC Fire Sprinkler Pipe Data – SI Units
BlazeMaster® Brand Name Pipe by HARVEL®

Table A4.3.2-1; BlazeMaster® CPVC Sprinkler Pipe – Water.

Pipe Size (mm)	Pipe O.D. (mm)	Pipe I.D. (mm)	Pipe Weight Empty (N/m)	Water Weight (N/m)	Pipe + Water (N/m)
19	26.67	22.20	2.3	3.8	6.1
25	33.40	27.97	3.6	6.0	9.6
32	42.16	35.41	5.6	9.7	15.3
38	48.26	40.59	7.3	12.7	20.0
51	60.33	50.88	11.2	19.9	31.1
64	73.03	61.54	16.5	29.2	45.7
76	88.90	74.93	24.4	43.2	67.6

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Table A4.4.1-1; *Type K* Copper Tubing – Water – ASTM B88.

Tube Size (in)	Tube O.D. (in)	Wall Thickness (in)	Tube Weight Empty (lb/ft)	Water Weight (lb/ft)	Tube + Water (lb/ft)
1/4	0.375	0.035	0.14	0.03	0.17
3/8	0.500	0.049	0.27	0.06	0.33
1/2	0.625	0.049	0.34	0.09	0.43
5/8	0.750	0.049	0.42	0.14	0.56
3/4	0.875	0.065	0.64	0.19	0.83
1	1.125	0.065	0.84	0.34	1.18
1-1/4	1.375	0.065	1.03	0.53	1.56
1-1/2	1.625	0.072	1.36	0.75	2.11
2	2.125	0.083	2.06	1.31	3.37
2-1/2	2.625	0.095	2.92	2.02	4.94
3	3.125	0.109	3.99	2.88	6.87
3-1/2	3.625	0.120	5.11	3.90	9.01
4	4.125	0.134	6.49	5.06	11.55
5	5.125	0.160	9.64	7.86	17.50
6	6.125	0.192	13.83	11.22	25.05

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Table A4.4.1-2; *Type L* Copper Tubing – Water – ASTM B88.

Tube Size (in)	Tube O.D. (in)	Wall Thickness (in)	Tube Weight Empty (lb/ft)	Water Weight (lb/ft)	Tube + Water (lb/ft)
1/4	0.375	0.030	0.13	0.03	0.16
3/8	0.500	0.035	0.20	0.06	0.26
1/2	0.625	0.040	0.28	0.10	0.38
5/8	0.750	0.042	0.36	0.15	0.51
3/4	0.875	0.045	0.45	0.21	0.66
1	1.125	0.050	0.65	0.36	1.01
1-1/4	1.375	0.055	0.88	0.54	1.42
1-1/2	1.625	0.060	1.14	0.77	1.91
2	2.125	0.070	1.75	1.34	3.09
2-1/2	2.625	0.080	2.47	2.07	4.54
3	3.125	0.090	3.32	2.95	6.27
3-1/2	3.625	0.100	4.28	3.99	8.27
4	4.125	0.114	5.55	5.17	10.72
5	5.125	0.125	7.59	8.09	15.68
6	6.125	0.140	10.17	11.63	21.80

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Table A4.4.1-3; *Type M* Copper Tubing – Water – ASTM B88.

Tube Size (in)	Tube O.D. (in)	Wall Thickness (in)	Tube Weight Empty (lb/ft)	Water Weight (lb/ft)	Tube + Water (lb/ft)
1/4	0.375	N/A	N/A	N/A	N/A
3/8	0.500	0.025	0.14	0.07	0.21
1/2	0.625	0.028	0.20	0.11	0.31
5/8	0.750	N/A	N/A	N/A	N/A
3/4	0.875	0.032	0.33	0.22	0.55
1	1.125	0.035	0.46	0.38	0.84
1-1/4	1.375	0.042	0.68	0.57	1.25
1-1/2	1.625	0.049	0.94	0.79	1.73
2	2.125	0.058	1.46	1.37	2.83
2-1/2	2.625	0.065	2.02	2.12	4.14
3	3.125	0.072	2.67	3.02	5.69
3-1/2	3.625	0.083	3.57	4.07	7.64
4	4.125	0.095	4.65	5.27	9.92
5	5.125	0.109	6.64	8.19	14.83
6	6.125	0.122	8.89	11.77	20.66

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Copper Water Tubing Data – SI Units

Table A4.4.2-1; *Type A* Copper Tubing – Water – ASTM B88.

Tube Size {O.D.} (mm)	Wall Thickness (mm)	Tube Weight Empty (N/m)	Water Weight (N/m)	Tube + Water (N/m)
10	0.9	2.2	0.5	2.7
12	1.2	3.6	0.7	4.3
15	1.2	4.5	1.2	5.7
18	1.2	5.5	1.9	7.4
22	1.6	9.0	2.7	11.7
28	1.6	11.6	4.7	16.3
35	1.6	14.7	7.8	22.5
42	1.8	19.9	11.4	31.3
54	2.1	29.9	19.1	49.0
67	2.4	42.6	29.8	72.4
79	2.8	58.6	41.5	100.1
105	3.4	94.9	74.2	169.1
130	4.0	138.4	114.6	253.0
156	4.8	199.3	165.0	364.3
206	6.8	372.0	285.0	657.0
257	8.5	580.0	443.4	657.0
308	10.3	842.0	635.9	1,477.9

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Table A4.4.2-2; *Type B* Copper Tubing – Water – ASTM B88.

Tube Size {O.D.} (mm)	Wall Thickness (mm)	Tube Weight Empty (N/m)	Water Weight (N/m)	Tube + Water (N/m)
10	0.8	2.0	0.5	2.5
12	0.9	2.7	0.8	3.5
15	1.0	3.8	1.3	5.1
18	1.0	4.7	2.0	6.7
22	1.1	6.3	3.0	9.3
28	1.2	8.8	5.0	13.8
35	1.4	12.9	8.0	20.9
42	1.5	16.7	11.7	28.4
54	1.7	24.4	19.7	44.1
67	2.0	35.7	30.6	66.3
79	2.3	48.4	42.6	91.0
105	2.8	78.6	76.1	154.7
130	3.1	108.0	118.0	226.0
156	3.5	146.6	170.9	317.5
206	5.0	276.0	295.8	571.8
257	6.3	433.7	459.9	893.6
308	7.1	586.6	664.5	1,251.1

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Table A4.4.2-3; *Type C* Copper Tubing – Water – ASTM B88.

Tube Size {O.D.} (mm)	Wall Thickness (mm)	Tube Weight Empty (N/m)	Water Weight (N/m)	Tube + Water (N/m)
10	0.6	1.5	0.6	2.1
12	0.6	1.9	0.9	2.8
15	0.7	2.7	1.4	4.1
18	0.7	3.3	2.1	5.4
22	0.8	4.7	3.2	7.9
28	0.9	6.7	5.3	12.0
35	1.1	10.2	8.3	18.5
42	1.2	13.4	12.1	25.5
54	1.5	21.6	20.0	41.6
67	1.6	28.7	31.3	60.0
79	1.8	38.2	43.8	82.0
105	2.4	67.6	77.3	144.9
130	2.7	94.4	119.5	213.9
156	3.1	130.2	172.8	303.0
206	4.3	238.2	300.0	538.2
257	5.4	373.1	466.7	839.8
308	6.4	530.0	670.9	1,200.9

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Electrical Conduit Data – English Units

Table A4.5.1-1; EMT Conduit – 40% Copper Fill.

Conduit Size (in)	Conduit O.D. (in)	Conduit I.D. (in)	Conduit Weight Empty (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper (lb/ft)
1/2	0.706	0.622	0.30	0.47	0.77
3/4	0.922	0.824	0.46	0.82	1.28
1	1.163	1.049	0.67	1.34	2.01
1-1/4	1.510	1.380	1.00	2.31	3.31
1-1/2	1.740	1.610	1.16	3.15	4.31
2	2.197	2.067	1.48	5.19	6.67

Table A4.5.1-2; IMC Conduit – 40% Copper Fill.

Conduit Size (in)	Conduit O.D. (in)	Conduit I.D. (in)	Conduit Weight Empty (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper (lb/ft)
1/2	0.815	0.675	0.56	0.55	1.11
3/4	1.029	0.879	0.76	0.94	1.70
1	1.290	1.120	1.09	1.52	2.61
1-1/4	1.638	1.468	1.41	2.62	4.03
1-1/2	1.883	1.703	1.72	3.52	5.24
2	2.360	2.170	2.30	5.72	8.02

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Table A4.5.1-3; Rigid Conduit – 40% Copper Fill.

Conduit Size (in)	Conduit O.D. (in)	Conduit I.D. (in)	Conduit Weight Empty (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper (lb/ft)
1/2	0.840	0.632	0.82	0.48	1.30
3/4	1.050	0.836	1.08	0.85	1.93
1	1.315	1.063	1.60	1.37	2.97
1-1/4	1.660	1.394	2.17	2.36	4.53
1-1/2	1.900	1.624	2.59	3.20	5.79
2	2.375	2.083	3.47	5.27	8.74

Table A4.5.1-4; PVC Schedule 40 Rigid Conduit – 40% Copper Fill.

Conduit Size (in)	Conduit O.D. (in)	Conduit I.D. (in)	Conduit Weight Empty (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper (lb/ft)
1/2	0.840	0.622	0.15	0.47	0.62
3/4	1.050	0.824	0.20	0.82	1.02
1	1.315	1.049	0.30	1.34	1.64
1-1/4	1.660	1.380	0.40	2.31	2.71
1-1/2	1.900	1.610	0.48	3.15	3.63
2	2.375	2.067	0.64	5.19	5.83

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Electrical Conduit Data – SI Units

Table A4.5.2-1; EMT Conduit – 40% Copper Fill.

Conduit size (mm)	Conduit O.D. (mm)	Conduit O.D. (mm)	Conduit Weight Empty (N/m)	Copper Weight (N/m)	Conduit + Copper (N/m)
13	17.93	15.80	4.3	6.9	11.2
19	23.42	20.93	6.7	12.0	18.7
25	29.54	26.64	9.8	19.5	29.3
32	38.35	35.05	14.6	33.7	48.3
38	44.20	40.89	17.0	45.9	62.9
51	55.80	52.50	21.6	75.7	97.3

Table A4.5.2-2; IMC Conduit – 40% Copper Fill.

Conduit Size (mm)	Conduit O.D. (mm)	Conduit I.D. (mm)	Conduit Weight Empty (N/m)	Copper Weight (N/m)	Conduit + Copper (N/m)
13	20.70	17.15	8.1	8.1	16.2
19	26.14	22.33	11.1	13.7	24.8
25	32.77	28.45	16.0	22.2	38.2
32	41.61	37.29	20.6	38.2	58.8
38	47.83	43.26	25.1	51.4	76.5
51	59.94	55.12	33.5	83.4	116.9

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Table A4.5.2-3; Rigid Conduit – 40% Copper Fill.

Conduit Size (mm)	Conduit O.D. (mm)	Conduit I.D. (mm)	Conduit Weight Empty (N/m)	Copper Weight (N/m)	Conduit + Copper (N/m)
13	21.34	16.05	11.9	7.1	19.0
19	26.67	21.23	15.7	12.4	28.1
25	33.40	27.00	23.3	20.0	43.3
32	42.16	35.41	31.6	34.4	66.0
38	48.26	41.25	37.9	46.7	84.6
51	60.33	52.91	50.7	76.9	127.6

Table A4.5.2-4; PVC Schedule 40 Rigid Conduit – 40% Copper Fill.

Conduit Size (mm)	Conduit O.D. (mm)	Conduit I.D. (mm)	Conduit Weight Empty (N/m)	Copper Weight (N/m)	Conduit + Copper (N/m)
13	21.34	15.80	2.2	6.9	9.1
19	26.67	20.93	2.9	12.0	14.9
25	33.40	26.64	4.3	19.5	23.8
32	42.16	35.05	5.9	33.7	39.6
38	48.26	40.89	7.0	45.9	52.9
51	60.33	52.50	9.4	75.7	85.1

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Rectangular Unlined Duct Data – English Units

Table A5.1.1-1; Rectangular Unlined Duct – 16 Gage Steel.

Duct Width (in)	Duct Height (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
28	28	5.4	23
30	30	6.3	24
42	42	12.3	34
54	54	20.3	44
60	60	25.0	49
84	84	49.0	68
96	96	64.0	78
40	20	5.6	24
54	28	10.5	33
60	30	12.5	37
84	42	24.5	51
96	48	32.0	58
108	54	40.5	66
120	60	50.0	73

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Table A5.1.2-1; Rectangular Unlined Duct – 16 Gage Steel.

Duct Width (mm)	Duct Height (mm)	Duct Area (m^2)	Duct Weight (N/m)
700	700	0.49	327
750	750	0.56	350
1000	1000	1.00	467
1400	1400	1.96	653
1500	1500	2.25	700
2100	2100	4.41	980
2400	2400	5.76	1,120
1000	500	0.50	350
1300	650	0.85	455
1500	750	1.13	525
2000	1000	2.00	700
2400	1200	2.88	840
2600	1300	3.38	910
3000	1500	4.50	1,050

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Rectangular Lined Duct Data (1.5 pcf Liner) – English Units

Table A5.1.3-1; Rectangular Lined Duct – 16 Gage Steel. 1.0 in. Thick; 1.5 pcf Liner

Duct Width (in)	Duct Height (in)	Liner Weight (lb/ft)	Duct Area w/o Liner (ft^2)	Duct Area with Liner (ft^2)	Duct Weight (lb/ft)
28	28	1.16	5.4	4.7	24
30	30	1.24	6.3	5.4	26
42	42	1.74	12.3	11.1	36
54	54	2.24	20.3	18.8	46
60	60	2.49	25.0	23.4	51
84	84	3.49	49.0	46.7	72
96	96	3.99	64.0	61.4	82
40	20	1.24	5.6	4.8	26
54	28	1.70	10.5	9.4	35
60	30	1.86	12.5	11.3	38
84	42	2.61	24.5	22.8	54
96	48	2.99	32.0	30.0	61
108	54	3.36	40.5	38.3	69
120	60	3.74	50.0	47.5	77

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Table A5.1.3-2; Rectangular Lined Duct – 16 Gage Steel. 1.5 in. Thick; 1.5 pcf Liner

Duct Width (in)	Duct Height (in)	Liner Weight (lb/ft)	Duct Area w/o Liner (ft^2)	Duct Area with Liner (ft^2)	Duct Weight (lb/ft)
28	28	1.73	5.4	4.3	24
30	30	1.85	6.3	5.1	26
42	42	2.60	12.3	10.6	37
54	54	3.35	20.3	18.1	47
60	60	3.73	25.0	22.6	52
84	84	5.23	49.0	45.6	73
96	96	5.98	64.0	60.1	84
40	20	1.85	5.6	4.4	26
54	28	2.54	10.5	8.9	36
60	30	2.79	12.5	10.7	39
84	42	3.91	24.5	21.9	55
96	48	4.48	32.0	29.1	63
108	54	5.04	40.5	37.2	71
120	60	5.60	50.0	46.3	79

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Table A5.1.3-3; Rectangular Lined Duct – 16 Gage Steel. 2.0 in. Thick; 1.5 pcf Liner

Duct Width (in)	Duct Height (in)	Liner Weight (lb/ft)	Duct Area w/o Liner (ft^2)	Duct Area with Liner (ft^2)	Duct Weight (lb/ft)
28	28	2.29	5.4	4.0	25
30	30	2.46	6.3	4.7	27
42	42	3.46	12.3	10.0	38
54	54	4.46	20.3	17.4	48
60	60	4.96	25.0	21.8	54
84	84	6.96	49.0	44.4	75
96	96	7.96	64.0	58.8	86
40	20	2.46	5.6	4.0	27
54	28	3.38	10.5	8.3	37
60	30	3.71	12.5	10.1	40
84	42	5.21	24.5	21.1	56
96	48	5.96	32.0	28.1	64
108	54	6.71	40.5	36.1	73
120	60	7.46	50.0	45.1	81

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Table A5.1.5-1; Rectangular Lagged Duct – 20 Gage Steel.
One Layer of 5/8 in. Gypsum Board.

Duct Width (in)	Duct Height (in)	Lagging Weight (lb/ft)	Duct Area (ft^2)	Duct Weight (lb/ft)
28	28	73.73	5.4	87
30	30	78.94	6.3	94
42	42	110.19	12.3	131
54	54	141.44	20.3	168
60	60	157.06	25.0	186
84	84	219.56	49.0	261
96	96	250.81	64.0	298
40	20	78.94	5.6	94
54	28	107.58	10.5	128
60	30	118.00	12.5	140
84	42	164.88	24.5	196
96	48	188.31	32.0	223
108	54	211.75	40.5	251
120	60	235.19	50.0	279

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Table A5.1.5-2; Rectangular Lagged Duct – 20 Gage Steel.
Two Layers of 5/8 in. Gypsum Board.

Duct Width (in)	Duct Height (in)	Lagging Weight (lb/ft)	Duct Area (ft^2)	Duct Weight (lb/ft)
28	28	149.09	5.4	163
30	30	159.51	6.3	174
42	42	222.01	12.3	242
54	54	284.51	20.3	311
60	60	315.76	25.0	345
84	84	440.76	49.0	482
96	96	503.26	64.0	550
40	20	159.51	5.6	174
54	28	216.80	10.5	237
60	30	237.63	12.5	260
84	42	331.38	24.5	362
96	48	378.26	32.0	413
108	54	425.13	40.5	465
120	60	472.01	50.0	516

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Table A5.1.5-3; Rectangular Lagged Duct – 20 Gage Steel.
Three Layers of 5/8 in. Gypsum Board.

Duct Width (in)	Duct Height (in)	Lagging Weight (lb/ft)	Duct Area (ft^2)	Duct Weight (lb/ft)
28	28	226.07	5.4	240
30	30	241.70	6.3	256
42	42	335.45	12.3	356
54	54	429.20	20.3	456
60	60	476.07	25.0	505
84	84	663.57	49.0	705
96	96	757.32	64.0	804
40	20	241.70	5.6	256
54	28	327.64	10.5	348
60	30	358.89	12.5	381
84	42	499.51	24.5	530
96	48	569.82	32.0	605
108	54	640.14	40.5	680
120	60	710.45	50.0	754

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Round Unlined Duct Data – English Units

Table A5.2.1-1; Round Unlined Duct – 16 Gage Steel.

Duct Diameter (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
30	4.9	19
36	7.1	23
42	9.6	27
48	12.6	31
54	15.9	34
60	19.6	38
66	23.8	42
72	28.3	46
78	33.2	50
84	38.5	54
90	44.2	57
96	50.3	61
102	56.7	65
108	63.6	69

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Round Unlined Duct Data – SI Units

Table A5.2.2-1; Round Unlined Duct – 16 Gage Steel.

Duct Diameter (mm)	Duct Area (m^2)	Duct Weight (N/m)
750	0.44	275
900	0.64	330
1000	0.79	367
1200	1.13	440
1400	1.54	513
1500	1.77	550
1700	2.27	623
1800	2.54	660
2000	3.14	733
2100	3.46	770
2300	4.15	843
2400	4.52	880
2600	5.31	953
2700	5.73	990

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Flat Oval Unlined Duct Data – English Units

Table A5.3.1-1; Flat Oval Unlined Duct – 16 Gage Steel.

Duct Height (in)	Duct Width (in)	Duct Flat Width (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
14	60	46	5.5	33
14	66	52	6.1	36
14	72	58	6.7	38
14	78	64	7.3	41
14	84	70	7.9	43
16	48	32	5.0	30
16	54	38	5.6	32
16	60	44	6.3	35
20	36	16	4.4	27
20	48	28	6.1	32
20	60	40	7.7	37
20	72	52	9.4	42
20	84	64	11.1	47
22	36	14	4.8	29
22	48	26	6.6	34
22	60	38	8.4	38
22	72	50	10.3	43
30	72	42	13.7	48
30	78	48	14.9	51
30	84	54	16.2	53

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Flat Oval Unlined Duct Data – SI Units

Table A5.3.2-1; Flat Oval Unlined Duct – 16 Gage Steel.

Duct Height (mm)	Duct Width (mm)	Duct Flat Width (mm)	Duct Area (m^2)	Duct Weight (N/m)
350	1500	1150	0.50	478
350	1700	1350	0.57	525
350	1800	1450	0.60	548
350	2000	1650	0.67	595
350	2100	1750	0.71	618
400	1200	800	0.45	427
400	1400	1000	0.53	473
400	1500	1100	0.57	497
500	900	400	0.40	393
500	1200	700	0.55	463
500	1500	1000	0.70	533
500	1800	1300	0.85	603
500	2100	1600	1.00	673
550	900	350	0.43	412
550	1200	650	0.60	482
550	1500	950	0.76	552
550	1800	1250	0.93	622
750	1800	1050	1.23	695
750	2000	1250	1.38	742
750	2100	1350	1.45	765

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Restraint Element Deflection Limits

Introduction:

When testing any type of mechanical or structural component, it is necessary to have an adequate definition of failure, and measurable quantity that will allow the point of failure to be accurately determined. The first definition of failure is breakage or fracture of the component. If the component does not break, the failure criterion is usually linked to the yield point of the material of the component. The typically listed yield point of a ferrous material is the ***0.2% Offset Yield Point***. This is the stress level that corresponds to a permanent strain of ***0.002 in/in***.

The purpose of this document is to provide a set of guidelines for predicting the deflection of a component at the ***0.2% Offset Yield Point*** for various generic component types.

Axially Loaded Components:

Figure A6.1.1-1 shows a typical axially loaded component. The component may be either loaded in tension, or compression. The discussion which follows will apply to both tension and compression. If the component is long and slender, and loaded in compression, care must be taken to ensure that the primary failure mode is not in ***buckling***.

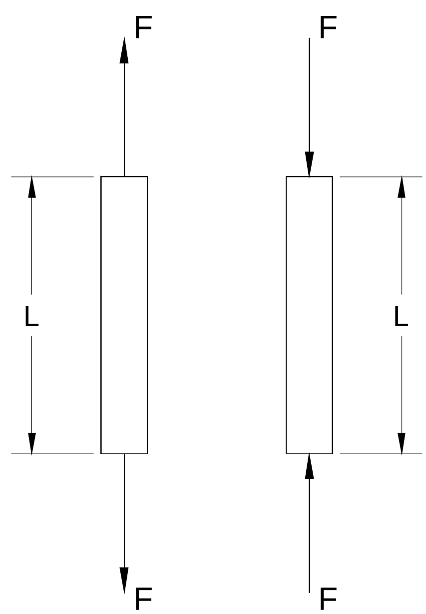

Figure A6.1.1-1: Axially Loaded Components.

For ferrous and other linear elastic materials, the following basic equations will apply.

$$\sigma_A = E * \varepsilon \qquad \text{(Eq. A6.1.1-1)}$$

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Where:

E = the elastic modulus of component material, also known as Young's Modulus.
ε = the strain in the component.
σ_A = the axial stress in the component.

The strain acting in the component, ε, is defined as the change in the length, ΔL, of the component under the action of the force F divided by the unloaded length, L, of the component, or:

$$\varepsilon = \Delta L / L \qquad \text{(Eq. A6.1.1-2)}$$

Rearrange Equation A6.1.1-1 to solve for ε.

$$\varepsilon = \sigma_A / E \qquad \text{(Eq. A6.1.1-3)}$$

Set Equation A6.1.1-2 equal to Equation A6.1.1-3, and solve for ΔL.

$$\Delta L = L * \sigma_A / E \qquad \text{(Eq. A6.1.1-4)}$$

Let σ_A be equal to the ***0.2% Offset Yield Point*** stress, σ_{YP}. Then, the deflection for the component at the ***0.2% Offset Yield Point*** is:

$$\Delta L = L * \sigma_{YP} / E \qquad \text{(Eq. A6.1.1-5)}$$

Table A6.1.1-1 presents the measurable value of ΔL for various values of L.

Table A6.1.1: ΔL vs. L for Axially Loaded Components.

At a 0.2% Offset Yield Point

Component Length L (in)	Length Change ΔL (in)	Component Length L (in)	Length Change ΔL (in)	Component Length L (in)	Length Change ΔL (in)
1.0	0.0020	16.0	0.0320	60.0	0.1200
2.0	0.0040	18.0	0.0360	72.0	0.1440
4.0	0.0080	24.0	0.0480	84.0	0.1680
6.0	0.0120	30.0	0.0600	96.0	0.1920
8.0	0.0160	36.0	0.0720	108.0	0.2160
10.0	0.0200	42.0	0.0840	120.0	0.2400
12.0	0.0240	48.0	0.0960	132.0	0.2640
14.0	0.0280	54.0	0.1080	148.0	0.2960

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Cantilever Component with an End Load:

Figure A6.1.1-2 shows an end loaded cantilever component.

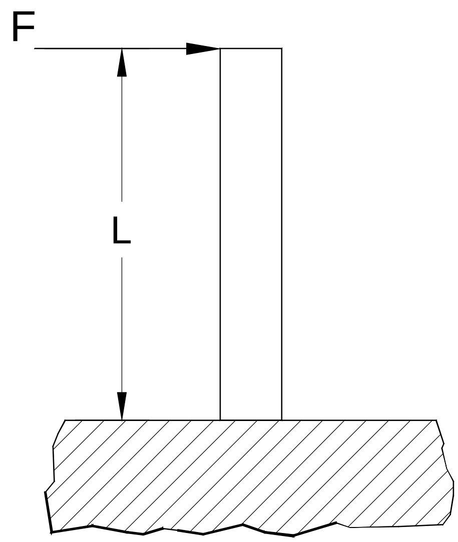

Figure A6.1.1-2: Cantilever Component with an End Load.

Because its impact is insignificant and for the sake of simplicity, the shear stress in the component will be ignored. The maximum deflection for a cantilever beam with an end load occurs at the load point and is found in many standard references as:

$$Y_M = F * L^3 / (3 * E * I) \qquad \text{(Eq. A6.1.1-6)}$$

Where:

- ***F*** = the load applied at the end of the cantilever component.
- ***I*** = the area moment of inertia of the component parallel to the load.
- ***L*** = the length of the component.
- Y_M = the maximum deflection at the end of the cantilever component.

In general the bending stress in any beam type component is given by:

$$\sigma_B = M * c / I \qquad \text{(Eq. A6.1.1-7)}$$

Where:

- c = the distance from the neutral axis to the outer fibers of the component.
- M = the bending moment in the component at the support.
- σ_B = the bending stress in the component at the support.

The bending moment at the support will be as follows.

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$$M = F * L \qquad \text{(Eq. A6.1.1-8)}$$

Let σ_{YP} be equal to σ_B and solve for F. This will be the force required to yield the component at the support.

$$F = \sigma_{YP} * I / (L * c) \qquad \text{(Eq. A6.1.1-9)}$$

Substitute Equation A6.1.1-9 into Equation A6.1.1-6 to yield the following result.

$$Y_M = (1/3) * (L^2 / c) *(\sigma_{YP} / E) \qquad \text{(Eq. A6.1.1-10)}$$

The result in Equation A6.1.1-10 will be more useful if it is expressed in a dimensionless form as shown below.

$$(Y_M / L) = (1/3) * (L / c) *(\sigma_{YP} / E) \qquad \text{(Eq. A6.1.1-11)}$$

Table A6.1.1-2 gives the results of Equation A6.1.1-11.

Table A6.1.1-2: (Y_M / L) vs. (L / c) For a Cantilever Component.

At a 0.2% Offset Yield Point

L/c	Y_M / L	L/c	Y_M / L	L/c	Y_M / L
1.0	0.00067	20.0	0.01333	80.0	0.05333
2.0	0.00133	30.0	0.02000	90.0	0.06000
4.0	0.00267	40.0	0.02667	100.0	0.06667
6.0	0.00400	50.0	0.03333	150.0	0.10000
8.0	0.00533	60.0	0.04000	200.0	0.13333
10.0	0.00667	70.0	0.04667	250.0	0.16667

Simply Supported Component with a Center Load:

Figure A6.1.1-3 shows a simply supported component with a center load. As it is insignificant and for simplicity's sake, the shear stress in the component will be ignored. The maximum deflection for a simply supported beam with a center load occurs at the load point and is found in many standard references as:

$$Y_M = F * L^3 / (48 * E * I) \qquad \text{(Eq. A6.1.1-12)}$$

The maximum bending moment occurs at the center of the beam, and is given by:

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$$M = F * L / 4 \quad \text{(Eq. A6.1.1-13)}$$

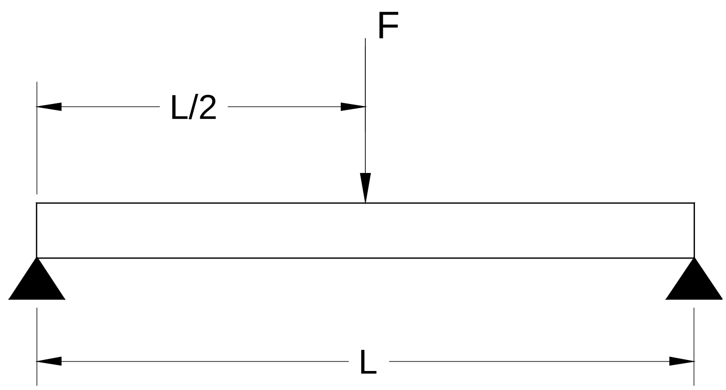

Figure A6.1.1-3: Simply Supported Component with a Center Load.

Following the same procedure as with the cantilever component, we may obtain the following results.

$$Y_M = (1/12) * (L^2 / c) *(\sigma_{YP} / E) \quad \text{(Eq. A6.1.1-14)}$$

The result in Equation A6.1.1-14 will be more useful if it is expressed in a dimensionless form as shown below.

$$(Y_M / L) = (1/12) * (L / c) *(\sigma_{YP} / E) \quad \text{(Eq. A6.1.1-15)}$$

Table A6.1.1-3 gives the results of Equation A6.1.1-15.

Table A6.1.1-3: (Y_M / L) vs. (L / c) For a Simply Supported Component.

At a 0.2% Offset Yield Point

L/c	Y_M / L	L/c	Y_M / L	L/c	Y_M / L
1.0	0.00017	20.0	0.00333	80.0	0.01333
2.0	0.00033	30.0	0.00500	90.0	0.01500
4.0	0.00067	40.0	0.00667	100.0	0.01667
6.0	0.00100	50.0	0.00833	150.0	0.02500
8.0	0.00133	60.0	0.01000	200.0	0.03333
10.0	0.00167	70.0	0.01167	250.0	0.04167

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Component with Fixed Supports and a Center Load:

Figure A6.1.1-4 shows a component with fixed ends and a center load. Due to its minimal impact and to simply the analysis, the shear stress in the component will be ignored.

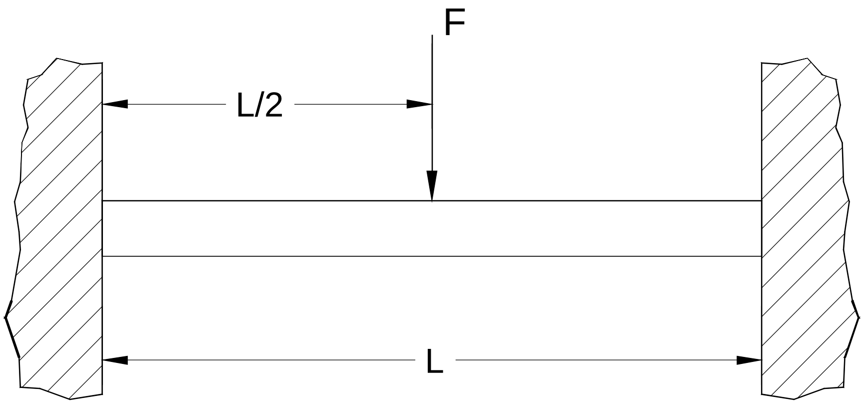

Figure A6.1.1-4: Component with Fixed Ends and a Center Load.

The maximum deflection for a beam with fixed ends and a center load, again, occurs at the load point and is found in many standard references as:

$$Y_M = F * L^3 / (192 * E * I) \quad \textbf{(Eq. A6.1.1-16)}$$

The maximum bending moment occurs at the center of the beam, and is given by:

$$M = F * L / 8 \quad \textbf{(Eq. A6.1.1-17)}$$

Following the same procedure as with the simply supported component, we may obtain the following results.

$$Y_M = (1/24) * (L^2 / c) *(\sigma_{YP} / E) \quad \textbf{(Eq. A6.1.1-18)}$$

The result in Equation A6.1.1-18 will be more useful if it is expressed in a dimensionless form as shown below.

$$(Y_M / L) = (1/24) * (L / c) *(\sigma_{YP} / E) \quad \textbf{(Eq. A6.1.1-19)}$$

Table A6.1.1-4 gives the results of Equation A6.1.1-19.

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Table A6.1.1-4: *(Y_M / L)* vs. *(L / c)* For a Component with Fixed Supports

At a 0.2% Offset Yield Point

L/c	Y_M / L	L/c	Y_M / L	L/c	Y_M / L
1.0	0.000083	20.0	0.00167	80.0	0.00667
2.0	0.000167	30.0	0.00250	90.0	0.00750
4.0	0.000333	40.0	0.00333	100.0	0.00833
6.0	0.000500	50.0	0.00417	150.0	0.01250
8.0	0.000667	60.0	0.00500	200.0	0.01667
10.0	0.000833	70.0	0.00583	250.0	0.02083

Summary of Results:

For the axially loaded components, Equation A6.1.1-5 may be written for a ***0.2% Offset Yield Point*** as follows.

$$\Delta L / L = 0.002 \quad \text{(Eq. A6.1.1-20)}$$

For the components that may be modeled as some type of beam element in bending, the results in Tables A6.1.1-2 through A6.1.1-4 may be best summarized, and be more useful in the graphical form as shown in Figure A6.1.1-5.

Equation A6.1.1-20 and Figure A6.1.1-5 will allow an investigator to predict the deflection of a component at failure as defined by the ***0.2% Offset Yield Stress***. If significant plastic deformation is to be permitted, then this deflection will allow the investigator to predict the deflection at which plastic deformation has truly begun.

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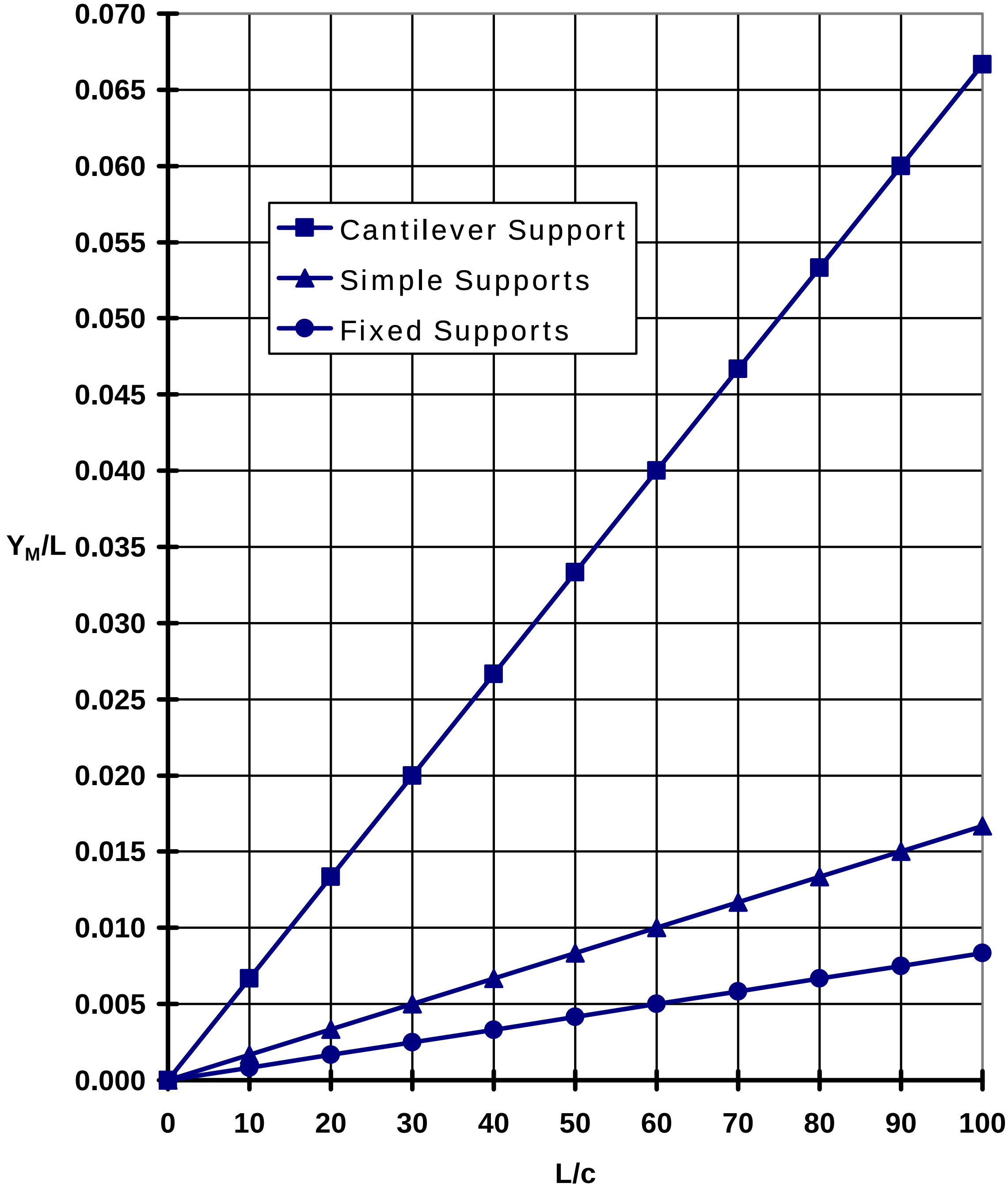
Figure A6.1.1-5: Y_M/L vs. L/c at a 0.2% Offset Yield Point For Beam Type Components



RESTRAINT ELEMENT DEFLECTION LIMITS

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Seismic Design Data for Lag Screws

Introduction:

Lag screws are used for connections and attachments to wooden structures. Care must be taken when using ***Lag Screws*** for critical installations because the effective strength of the connection will depend on the type, grade, and condition of the wood used in the structure to which the connection is being made. This document will assume that the wood is an ***Eastern Soft Woods (Spruce-Pine-Fir(s)), Western Cedars, or Western Woods*** with a ***Specific Gravity*** of ***0.36***. The tabulated values of allowable shear load, Z_S, will be based on single shear with the load being perpendicular to the grain of the wood, and on the use of a ***1/4"*** thick side plate. This will produce the most conservative allowable values.

Lag Screw Basic Data:

A typical ***Hex Head Lag Screw*** is shown in Figure A7.3-1. The basic information is tabulated in Table A7.3-1.

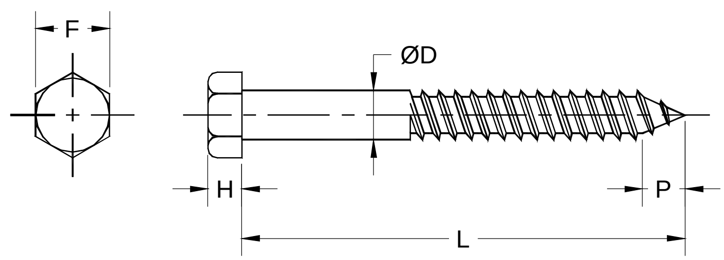

Figure A7.3-1; Typical Hex Head Lag Screw.

Table A7.3-1; Hex Head Lag Screw Dimensional Data.

Lag Screw Size ***ΦD*** (in)	Width Across Flats ***F*** (in)	Head Height ***H*** (in)	Point Length ***P*** (in)
1/4	3/8	0.172	0.217
5/16	1/2	0.219	0.271
3/8	9/16	0.250	0.325
1/2	3/4	0.344	0.433
5/8	15/16	0.422	0.541
3/4	1-1/8	0.500	0.650

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Lag Screw Installation Data:

The ***Basic Rules & Data*** for installing ***Lag Screws*** are illustrated in Figure A7.3-2 and Table A7.3-2. ***Do not install Lag Screws in the End Grain of a piece of wood for seismic applications!***

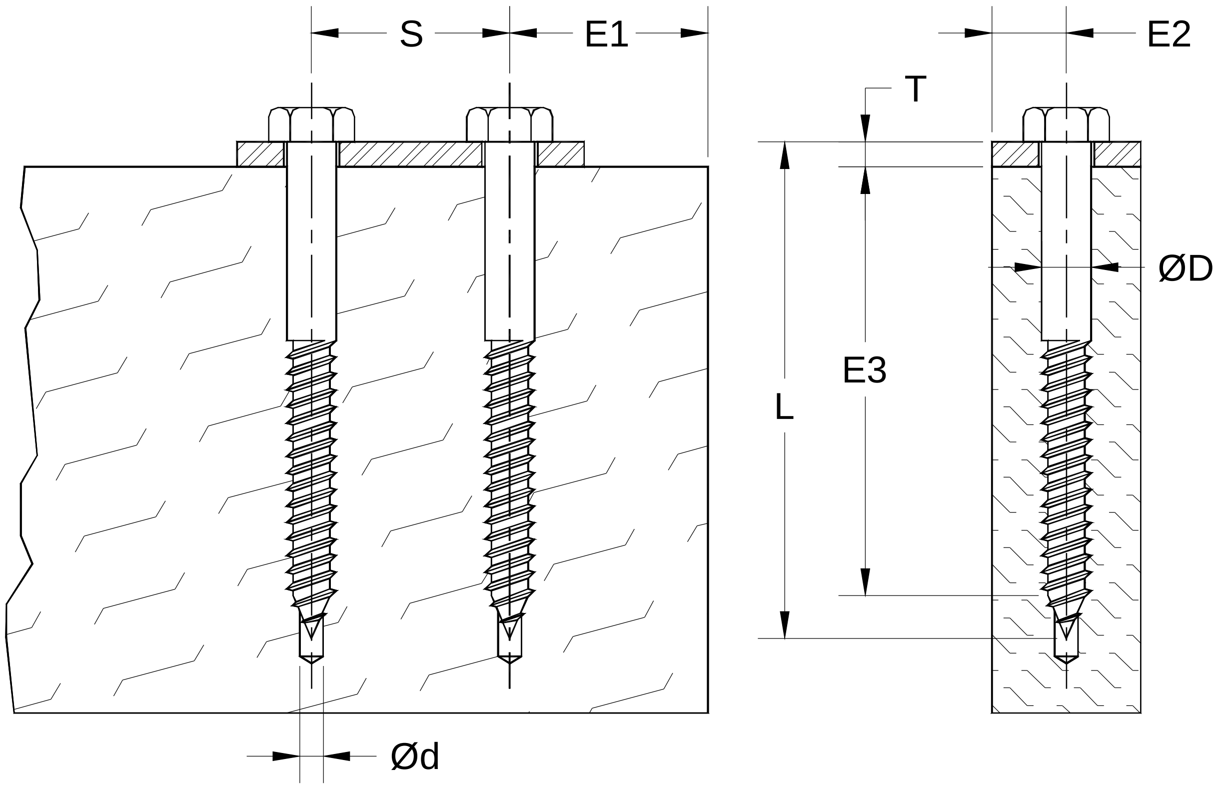

Figure A7.3-2; Typical Lag Screw Installation Guide.

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Table A7.3-2; Lag Screw Installation Data.

Lag Size *ΦD* (in)	Min. Spacing *S* (in)	Min. End Dist. *E1* (in)	Min. Edge Dist. *E2* (in)	Embed. Depth *E3* (in)	Mtg. Plate Thick. *T* (in)	Screw Length *L* (in)	Soft Wood Pilot Drill *Φd* (in)	Hard Wood Pilot Drill *Φd* (in)
1/4	1.00	1.00	0.375	2.00	0.125	2.50	1/8	5/32
					0.250	2.50		
					0.375	3.00		
					0.500	3.00		
5/16	1.25	1.25	0.469	2.50	0.125	3.00	9/32	13/64
					0.250	3.50		
					0.375	3.50		
					0.500	3.50		
3/8	1.50	1.50	0.563	3.00	0.125	3.50	3/16	1/4
					0.250	4.00		
					0.375	4.00		
					0.500	4.00		
1/2	2.00	2.00	0.75	4.00	0.125	5.00	15/64	21/64
					0.250	5.00		
					0.375	5.00		
					0.500	5.00		
5/8	2.50	2.50	0.938	5.00	0.125	6.00	19/64	13/32
					0.250	6.00		
					0.375	6.00		
					0.500	7.00		
3/4	3.00	3.00	1.125	6.00	0.125	7.00	23/64	31/64
					0.250	7.00		
					0.375	8.00		
					0.500	8.00		

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Lag Screw Allowable Load Data:

The ***Basic Allowable Load Data*** for ***Lag Screws*** with an embedment equal to eight (***8***) times the basic diameter, not including the point, are given in Figure A7.3-3 and Table A7.3-3. The basic allowable loads have been increased by a ***Duration Factor*** of **1.6** for seismic and wind loading. For an embedment of less than eight (***8***) times the basic diameter, the values in Table A7.3-3 may be multiplied by the ratio of the actual embedment divided by eight (***8***) times the basic diameter.

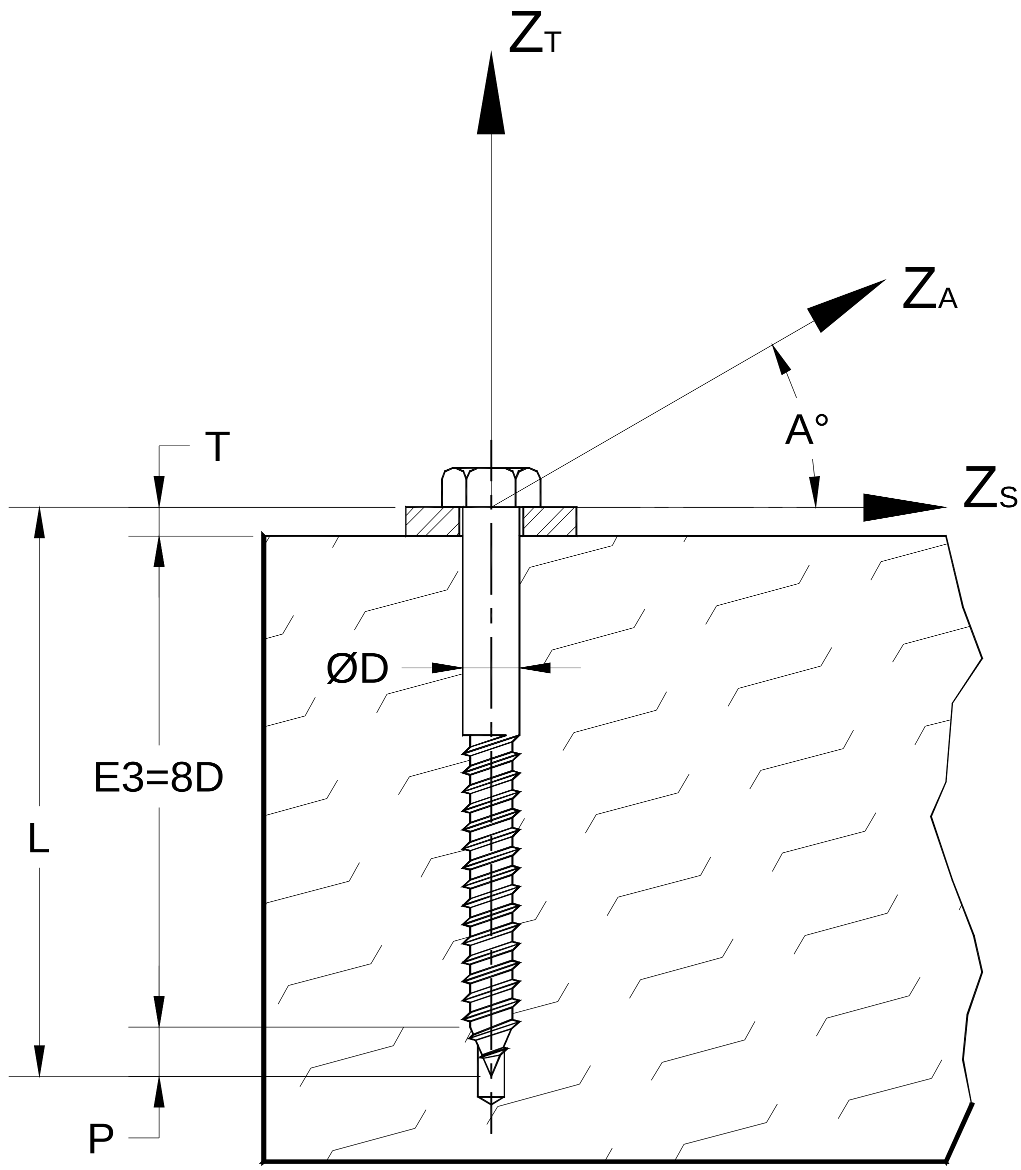

Figure A7.3-3; Typical Lag Screw in Combined Tension and Shear.

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Table A7.3-3; Lag Screw Allowable Load Data.

Lag Size *ΦD* (in)	Embedment Depth *8D* (in)	Allowable Tensile Load Z_T (lbs)	Allowable Shear Load Z_S (lbs)	Load Angle *A* (deg)	Allowable Combined Load Z_A (lbs)
1/4	2.00	438	272	0	272
				30	301
				45	336
				60	380
5/16	2.50	652	368	0	368
				30	413
				45	470
				60	547
3/8	3.00	893	432	0	432
				30	496
				45	582
				60	705
1/2	4.00	1,478	624	0	624
				30	729
				45	878
				60	1,101
5/8	5.00	2,184	880	0	880
				30	1,034
				45	1,255
				60	1,594
3/4	6.00	3,005	1,168	0	1,168
				30	1,379
				45	1,682
				60	2,157

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KHRC-A Rod Stiffener Data for 0° ≤ A ≤ 30°

Introduction:

This document will aid the designer in determining if hanger rod reinforcement, rod stiffeners, will be required for a given application. If they are required, recommendations for a minimum stiffener size will be made. Also, rod stiffener clamp locations and spacing will be made based on the use of **Kinetics Noise Control** model ***KHRC-A*** Adjustable Angle Stiffener Kit. This kit is a single clamp system that is shown in Figure A8.1.1-1. *One kit will be required for each clamp location. A minimum of two clamp kits will be required for each hanger rod stiffener*. The clamps and rod stiffener are assembled to the hanger rod as shown in Figure A8.1.1-2. The dimensions shown as L_1, L_2, and L_3 are the maximum allowable installation dimensions for locating and spacing the ***KHRC-A*** clamp kits.

Buckling Analysis:

Buckling failure is a catastrophic form of failure that occurs at stresses that are much lower that those required to yield the material. It is more of a function of the geometry of the components than it is a function of the material. In general it is very difficult to predict the onset of buckling. Thus, the approach used in this document will of necessity be very conservative. All of the basic assumptions described below will lead to a conservative result.

There are many theories that address buckling In general there are long, intermediate, and short columns. For long columns, Euler's formula is most often used with good results. For intermediate and short columns, there are many different approaches that would result in many iterative calculations for each case to be investigated. In order to provide reliable results with reasonable time expenditures, Euler's formula was used was used to determine the maximum un-reinforced hanger rod length. The hanger rods were modeled as having one end free, and one end fixed. If reinforcement was required for the hanger rod, it was selected based on the assumptions that the reinforcing angle was carrying the entire compressive load, and that the reinforcing angle was equal to the length of the hanger rod.

In a similar fashion, Euler's formula was used to determine the maximum allowable values for the clamp locating dimensions L_1 and L_3. However, in this case L_1 and L_3 assumed to be equal to each other, and their sum was set to be equal to the maximum un-reinforced length of the hanger rod computed using Euler's formula with one end of the rod fixed and the other end free. In determining the maximum value for the clamp spacing, L_2, Euler's formula was used assuming that both ends of the hanger rod were fixed at the clamps.

The horizontal seismic loads applied to the hanger rods are based on the **Kinetics Noise Control *Horizontal Force Class***, or ***Force Class***, designations of ***I*** through ***VI***. The

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installation angle (***A***), as measured from the horizontal, was taken to be ***30°***, and will be used to cover the range of installation angles from ***0°*** to ***30°*** inclusively. The Force Class system ranges are shown below.

Force Class I: 0 lbs through 250 lbs
Force Class II: 251 lbs through 500 lbs
Force Class III: 501 lbs through 1,000 lbs
Force Class IV: 1,001 lbs through 2,000 lbs
Force Class V: 2,001 lbs through 5,000lbs
Force Class VI: 5,001 lbs through 10,000lbs

The maximum load in each ***Force Class*** was used with a ***Factor of Safety*** of ***2:1*** in determining the maximum un-reinforced hanger rod length, the minimum angle size to be used for the rod stiffener, and the values used for L_1, L_2, and L_3.

<u>Use of the KHRC-A Rod Stiffener Data Tables:</u>

1.) **Data Tables:** There is a hanger rod stiffener selection data table for each ***Force Class***.
2.) **Hanger Rod Sizes:** The hanger rod sizes that may be used with the **Kinetics** Noise Control model ***KHRC-A***, and that are applicable for each ***Force Class*** are listed across the top of each data table.
3.) **Hanger Rod Length:** The hanger rod lengths that are applicable are listed in the left hand column of each table in ***6"*** and ***12"*** multiples. The maximum reinforced hanger rod length for each ***Force Class*** is the last entry in this column.
4.) **Rod Stiffener Requirement:** Determine the appropriate ***Force Class*** for the application. Select the column for the hanger rod size being used, and follow it down to the hanger rod length being considered. If the word "**Yes**" is found in this box, a hanger rod stiffener will be required. If, on the other hand, the word "**No**" is found in the box, then a hanger rod stiffener is not required. If the hanger rod length being used falls in between two of the tabulated rod lengths, use the larger value for the hanger rod length.
5.) **Minimum Stiffener Angle Size:** The minimum reinforcement angle size for each hanger rod length in each ***Force Class*** is listed in the right hand column of each table. Use the minimum Stiffener Angle size that corresponds to the hanger rod length used in step "**4.)**".
6.) **Maximum Installation Dimensions:** The maximum allowable installation dimensions, L_1, L_2, and L_3, are tabulated by hanger rod size beneath the rod stiffener selection data table for each ***Force Class***.
7.) **KHRC-A Clamp Kits:** A minimum of two (2) **Kinetics Noise Control** model ***KHRC-A*** clamps kits are required for each hanger rod stiffener installation. The ***KHRC-A*** clamp kits should be spaced approximately ***1"*** from each end of the rod stiffener angle. The distance from where the hanger rod is attached to the suspended component and the lower **KHRC-A** clamp kit must not exceed the value for L_1 listed for the ***Force Class*** and hanger rod size being used. If the spacing

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between the two **KHRC-A** clamp kits exceeds the value of L_2, maximum allowable spacing between clamps, listed for the Force Class and rod size for the application, another **KHRC-A** clamp kit must be added between the original pair. Finally, the distance from the upper **KHRC-A** clamp kit where the hanger rod attaches to the structure, or isolation hanger, must not exceed the value listed for L_3, based on the ***Force Class*** and rod size being considered. Also note that the thumb screw should be securely tightened. Pliers may be used after thumb screw is made finger tight.

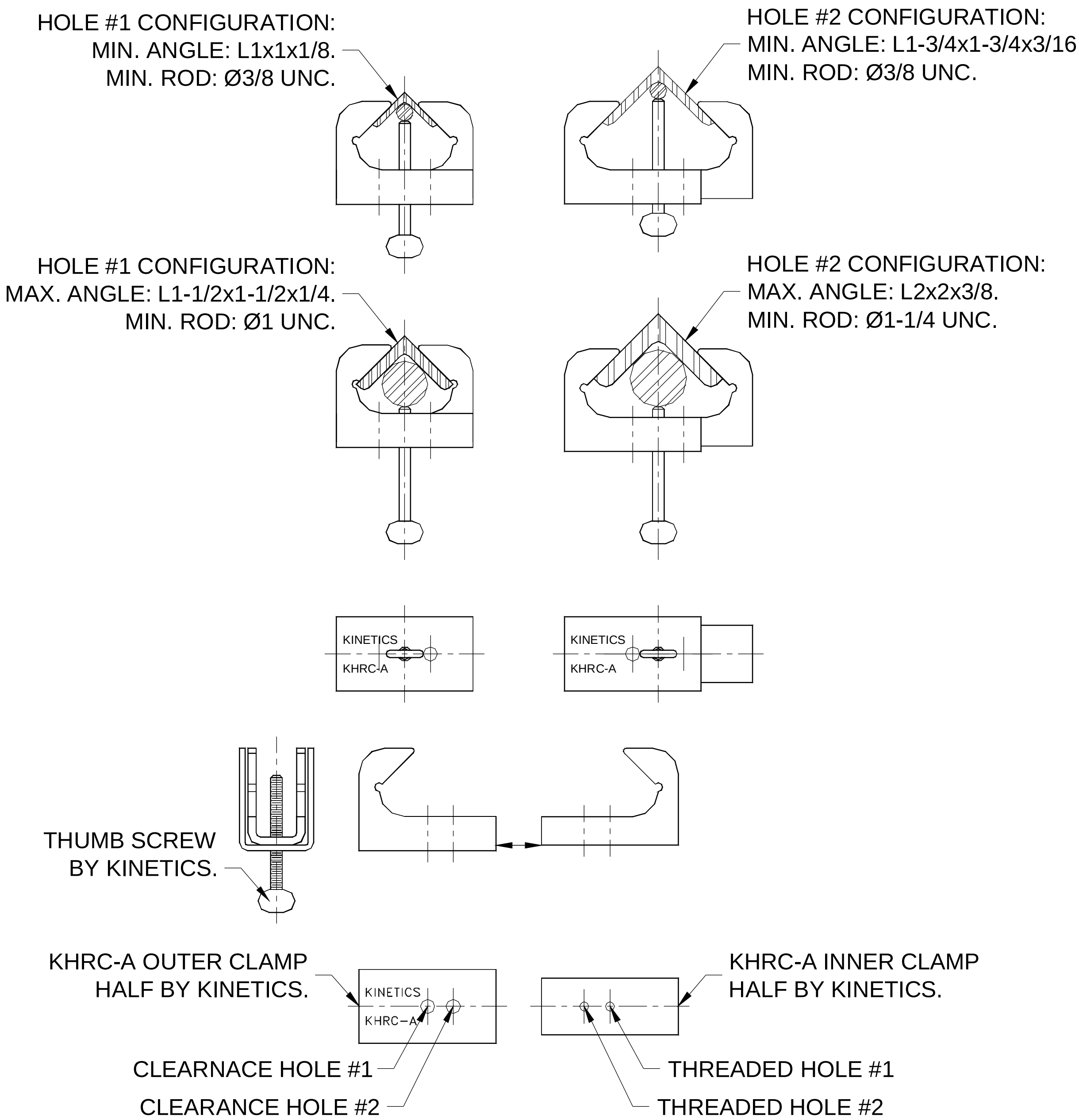

Figure A8.1.1-1; Kinetics Noise Control Model KHRC-A.

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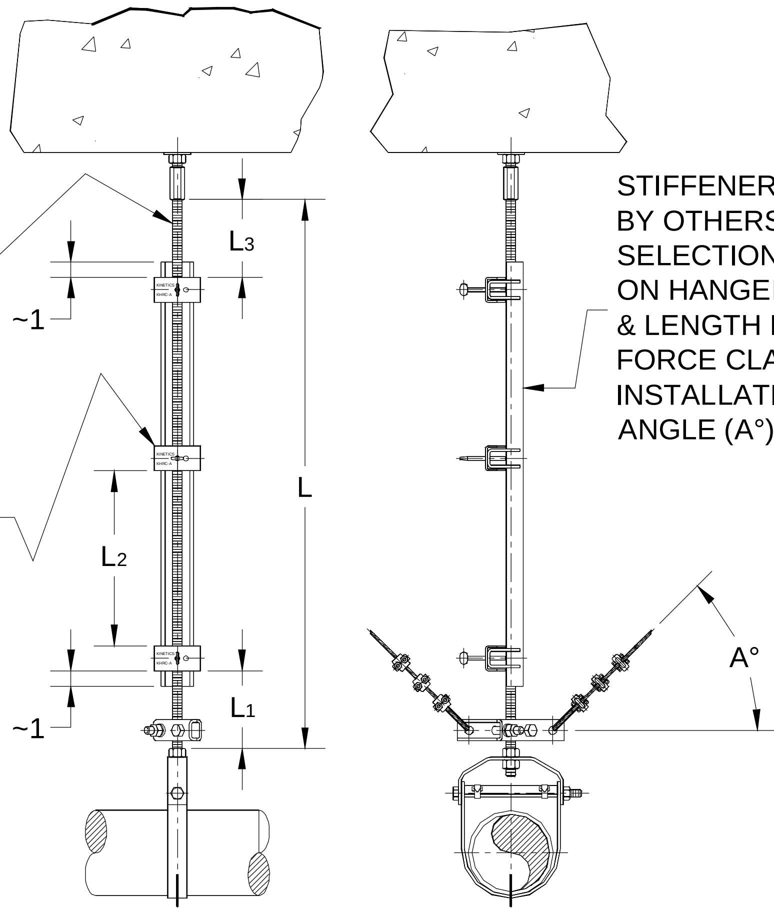

Figure A8.1.1-2; Typical Hanger Rod Stiffener Installation.

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Rod Length (″)	3/8″ Rod	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	No	No	No	No	No	No	No	------------------------
12	Yes	No	No	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	No	No	No	No	No	1 x 1 x 1/8
24	Yes	Yes	No	No	No	No	No	1 x 1 x 1/8
30	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
36	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
48	Yes	Yes	Yes	Yes	No	No	No	1 x 1 x 1/8
60	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
72	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
84	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 1/4
96	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
108	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
120	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
132	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 3/16
144	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
156	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
168	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
180	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
192	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
204	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
216	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
228	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
229 Max.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	3/8″ ROD	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	4	8	14	21	29	38	63
Max. L_2 =	17	34	56	84	118	155	155
Max. L_3 =	4	8	14	21	29	38	63

KHRC-A ROD STIFFENER DATA FOR 0° ≤ A ≤ 30° - FORCE CLASS I

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Rod Length (″)	3/8″ Rod	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	No	No	No	No	No	No	No	------------------------
12	Yes	No	No	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	No	No	No	No	No	1 x 1 x 1/8
24	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
30	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
36	Yes	Yes	Yes	Yes	No	No	No	1-1/8 x 1-1/8 x 1/8
48	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
60	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 1/4
72	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
84	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
96	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 3/16
108	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
120	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
132	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
144	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
156	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
162 Max.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	3/8″ ROD	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	3	5	9	14	20	27	44
Max. L_2 =	12	23	39	59	83	109	109
Max. L_3 =	3	5	9	14	20	27	44

KHRC-A ROD STIFFENER DATA FOR 0° ≤ A ≤ 30° - FORCE CLASS II

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Rod Length (″)	3/8″ Rod	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	No	No	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	No	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
24	Yes	Yes	Yes	Yes	No	No	No	1 x 1 x 1/8
30	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
36	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
48	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
60	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2x 1-1/2 x 1/4
72	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
84	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
96	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
108	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
114 Max.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	3/8″ ROD	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	2	4	6	10	14	19	31
Max. L_2 =	8	16	27	41	58	77	77
Max. L_3 =	2	4	6	10	14	19	31

KHRC-A ROD STIFFENER DATA FOR 0° ≤ A ≤ 30° - FORCE CLASS III

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Rod Length (″)	3/8″ Rod	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	No	No	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	Yes	Yes	No	No	No	1-1/8 x 1-1/8 x 1/8
24	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
30	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 1/4
36	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
48	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 3/16
60	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
72	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
81 Max.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	3/8″ ROD	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD	
Max. L_1 =	1	2	4	7	10	13	22	
Max. L_2 =	5	11	18	28	40	54	54	
Max. L_3 =	1	2	4	7	10	13	22	

KHRC-A ROD STIFFENER DATA FOR 0° ≤ A ≤ 30° - FORCE CLASS IV

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Rod Length (″)	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	No	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	Yes	No	No	No	1-1/8 x 1-1/8 x 1/8
18	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 3/16
24	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
30	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 3/16
36	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
48	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
51 Max.	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	1	2	4	6	8	13
Max. L_2 =	6	11	17	25	33	33
Max. L_3 =	1	2	4	6	8	13

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Rod Length (″)	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	Yes	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
18	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
24	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
30	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
36 Max.	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	1	1	3	4	5	9
Max. L_2 =	4	7	12	17	23	23
Max. L_3 =	1	1	3	4	5	9

KHRC-A ROD STIFFENER DATA FOR 0° ≤ A ≤ 30° - FORCE CLASS VI

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KHRC-A Rod Stiffener Data for 30° < A ≤ 45°

Introduction:

This document will aid the designer in determining if hanger rod reinforcement, rod stiffeners, will be required for a given application. If they are required, recommendations for a minimum stiffener size will be made. Also, rod stiffener clamp locations and spacing will be made based on the use of **Kinetics Noise Control** model ***KHRC-A*** Adjustable Angle Stiffener Kit. This kit is a single clamp system that is shown in Figure A8.2.1-1. *One kit will be required for each clamp location. A minimum of two clamp kits will be required for each hanger rod stiffener*. The clamps and rod stiffener are assembled to the hanger rod as shown in Figure A8.2.1-2. The dimensions shown as L_1, L_2, and L_3 are the maximum allowable installation dimensions for locating and spacing the ***KHRC-A*** clamp kits.

Buckling Analysis:

Buckling failure is a catastrophic form of failure that occurs at stresses that are much lower that those required to yield the material. It is more of a function of the geometry of the components than it is a function of the material. In general it is very difficult to predict the onset of buckling. Thus, the approach used in this document will of necessity be very conservative. All of the basic assumptions described below will lead to a conservative result.

There are many theories that address buckling In general there are long, intermediate, and short columns. For long columns, Euler's formula is most often used with good results. For intermediate and short columns, there are many different approaches that would result in many iterative calculations for each case to be investigated. In order to provide reliable results with reasonable time expenditures, Euler's formula was used was used to determine the maximum un-reinforced hanger rod length. The hanger rods were modeled as having one end free, and one end fixed. If reinforcement was required for the hanger rod, it was selected based on the assumptions that the reinforcing angle was carrying the entire compressive load, and that the reinforcing angle was equal to the length of the hanger rod.

In a similar fashion, Euler's formula was used to determine the maximum allowable values for the clamp locating dimensions L_1 and L_3. However, in this case L_1 and L_3 assumed to be equal to each other, and their sum was set to be equal to the maximum un-reinforced length of the hanger rod computed using Euler's formula with one end of the rod fixed and the other end free. In determining the maximum value for the clamp spacing, L_2, Euler's formula was used assuming that both ends of the hanger rod were fixed at the clamps.

The horizontal seismic loads applied to the hanger rods are based on the **Kinetics Noise Control *Horizontal Force Class***, or ***Force Class***, designations of ***I*** through ***VI***. The

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installation angle (***A***), as measured from the horizontal, was taken to be ***45°***, and will be used to cover the range of installation angles from ***31°*** to ***45°*** inclusively. The Force Class system ranges are shown below.

Force Class I: 0 lbs through 250 lbs
Force Class II: 251 lbs through 500 lbs
Force Class III: 501 lbs through 1,000 lbs
Force Class IV: 1,001 lbs through 2,000 lbs
Force Class V: 2,001 lbs through 5,000lbs
Force Class VI: 5,001 lbs through 10,000lbs

The maximum load in each ***Force Class*** was used with a ***Factor of Safety*** of ***2:1*** in determining the maximum un-reinforced hanger rod length, the minimum angle size to be used for the rod stiffener, and the values used for L_1, L_2, and L_3.

Use of the KHRC-A Rod Stiffener Data Tables:

1.) **Data Tables:** There is a hanger rod stiffener selection data table for each ***Force Class***.
2.) **Hanger Rod Sizes:** The hanger rod sizes that may be used with the **Kinetics** Noise Control model ***KHRC-A***, and that are applicable for each ***Force Class*** are listed across the top of each data table.
3.) **Hanger Rod Length:** The hanger rod lengths that are applicable are listed in the left hand column of each table in ***6"*** and ***12"*** multiples. The maximum reinforced hanger rod length for each ***Force Class*** is the last entry in this column.
4.) **Rod Stiffener Requirement:** Determine the appropriate ***Force Class*** for the application. Select the column for the hanger rod size being used, and follow it down to the hanger rod length being considered. If the word "**Yes**" is found in this box, a hanger rod stiffener will be required. If, on the other hand, the word "**No**" is found in the box, then a hanger rod stiffener is not required. If the hanger rod length being used falls in between two of the tabulated rod lengths, use the larger value for the hanger rod length.
5.) **Minimum Stiffener Angle Size:** The minimum reinforcement angle size for each hanger rod length in each ***Force Class*** is listed in the right hand column of each table. Use the minimum Stiffener Angle size that corresponds to the hanger rod length used in step "**4.)**".
6.) **Maximum Installation Dimensions:** The maximum allowable installation dimensions, L_1, L_2, and L_3, are tabulated by hanger rod size beneath the rod stiffener selection data table for each ***Force Class***.
7.) **KHRC-A Clamp Kits:** A minimum of two (2) **Kinetics Noise Control** model ***KHRC-A*** clamps kits are required for each hanger rod stiffener installation. The ***KHRC-A*** clamp kits should be spaced approximately ***1"*** from each end of the rod stiffener angle. The distance from where the hanger rod is attached to the suspended component and the lower **KHRC-A** clamp kit must not exceed the value for L_1 listed for the ***Force Class*** and hanger rod size being used. If the spacing

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between the two **KHRC-A** clamp kits exceeds the value of ***L_2***, maximum allowable spacing between clamps, listed for the Force Class and rod size for the application, another **KHRC-A** clamp kit must be added between the original pair. Finally, the distance from the upper **KHRC-A** clamp kit where the hanger rod attaches to the structure, or isolation hanger, must not exceed the value listed for ***L_3***, based on the ***Force Class*** and rod size being considered. Also note that the thumb screw should be securely tightened. Pliers may be used after thumb screw is made finger tight.

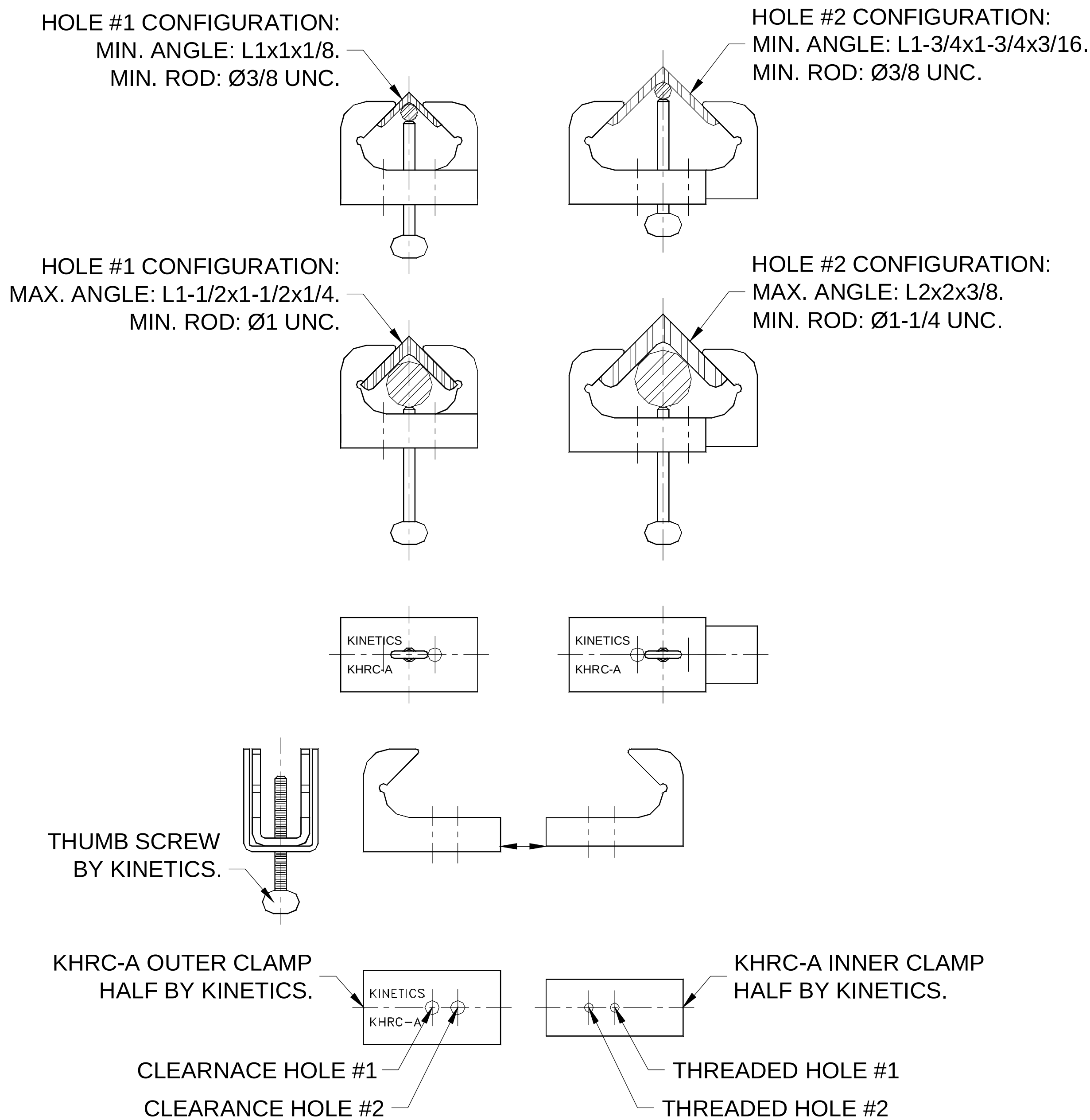

Figure A8.2.1-1; Kinetics Noise Control Model KHRC-A.

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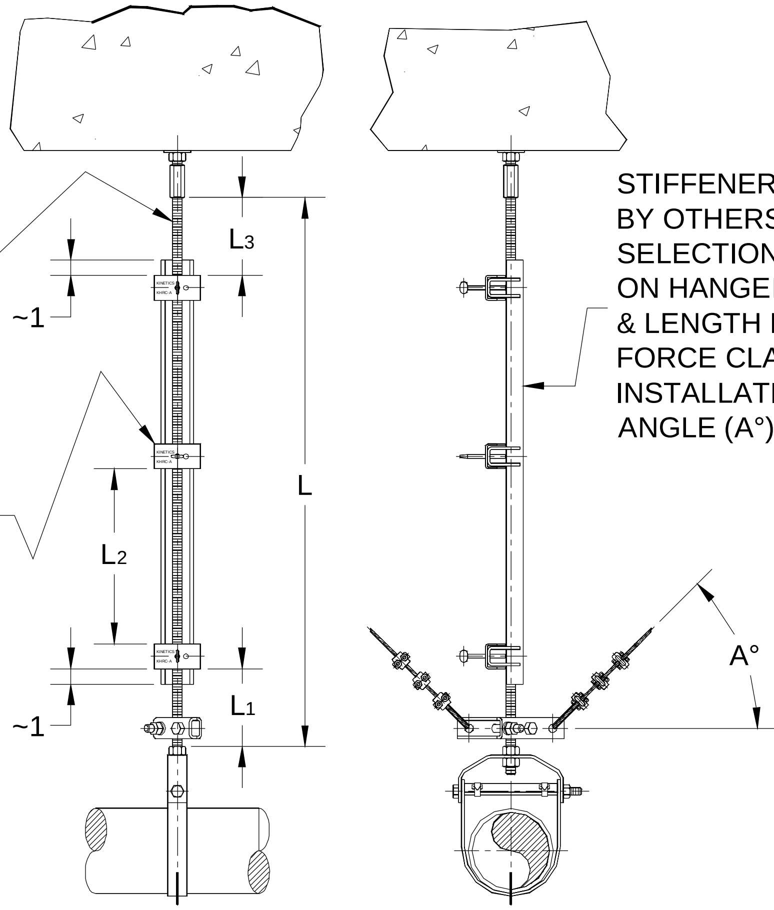

Figure A8.2.1-2; Typical Hanger Rod Stiffener Installation.

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Rod Length (″)	3/8″ Rod	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	No	No	No	No	No	No	No	------------------------
12	Yes	No	No	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	No	No	No	No	No	1 x 1 x 1/8
24	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
30	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
36	Yes	Yes	Yes	Yes	No	No	No	1 x 1 x 1/8
48	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
60	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 3/16
72	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
84	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
96	Yes	Yes	Yes	Yes	Yes	Yes	No	1-3/4 x 1-3/4 x 3/16
108	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
120	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
132	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
144	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
156	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
168	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
174 Max.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	3/8″ ROD	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	3	6	10	15	22	29	47
Max. L_2 =	13	25	42	63	89	117	117
Max. L_3 =	3	6	10	15	22	29	47

KHRC-A ROD STIFFENER DATA FOR 30° < A ≤ 45° - FORCE CLASS I

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Rod Length (″)	3/8″ Rod	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	No	No	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	No	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
24	Yes	Yes	Yes	Yes	No	No	No	1 x 1 x 1/8
30	Yes	Yes	Yes	Yes	No	No	No	1-1/8 x 1-1/8 x 1/8
36	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
48	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 1/4
60	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
72	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 3/16
84	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
96	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
108	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
120	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
123 Max.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	3/8″ ROD	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	2	4	7	11	15	20	33
Max. L_2 =	8	17	29	44	62	82	82
Max. L_3 =	2	4	7	11	15	20	20

KHRC-A ROD STIFFENER DATA FOR 30° < A ≤ 45° - FORCE CLASS II

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Rod Length (″)	3/8″ Rod	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	No	No	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	Yes	Yes	No	No	No	1 x 1 x 1/8
24	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
30	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 3/16
36	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
48	Yes	Yes	Yes	Yes	Yes	Yes	No	1-3/4 x 1-3/4 x 3/16
60	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
72	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
84	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
87 Max.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	3/8″ ROD	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	1	3	5	7	10	17	23
Max. L_2 =	5	12	20	31	43	58	58
Max. L_3 =	1	3	5	7	10	14	23

KHRC-A ROD STIFFENER DATA FOR 30° < A ≤ 45° - FORCE CLASS III

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Rod Length (″)	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	No	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	Yes	No	No	No	1 x 1 x 1/8
18	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
24	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 1/4
30	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
36	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 3/16
48	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
60	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
61 Max.	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	2	3	5	7	10	16
Max. L_2 =	8	13	21	30	40	40
Max. L_3 =	2	3	5	7	10	16

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Rod Length (″)	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	Yes	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
18	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
24	Yes	Yes	Yes	Yes	Yes	No	1-3/4 x 1-3/4 x 1/4
30	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
36	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
39 Max.	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD	
Max. L_1 =	1	2	3	4	6	10	
Max. L_2 =	4	8	13	18	25	41	
Max. L_3 =	1	2	3	4	6	10	

KHRC-A ROD STIFFENER DATA FOR 30° < A ≤ 45° - FORCE CLASS V

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Rod Length (″)	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	Yes	Yes	No	No	No	1-1/8 x 1-1/8 x 1/8
12	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
18	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
24	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
27 Max.	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	1	2	4	6	8	7
Max. L_2 =	2	5	8	12	17	28
Max. L_3 =	1	2	4	6	8	7

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KHRC-A Rod Stiffener Data for 45° < A ≤ 60°

Introduction:

This document will aid the designer in determining if hanger rod reinforcement, rod stiffeners, will be required for a given application. If they are required, recommendations for a minimum stiffener size will be made. Also, rod stiffener clamp locations and spacing will be made based on the use of **Kinetics Noise Control** model ***KHRC-A*** Adjustable Angle Stiffener Kit. This kit is a single clamp system that is shown in Figure A8.3.1-1. *One kit will be required for each clamp location. A minimum of two clamp kits will be required for each hanger rod stiffener*. The clamps and rod stiffener are assembled to the hanger rod as shown in Figure A8.3.1-2. The dimensions shown as L_1, L_2, and L_3 are the maximum allowable installation dimensions for locating and spacing the ***KHRC-A*** clamp kits.

Buckling Analysis:

Buckling failure is a catastrophic form of failure that occurs at stresses that are much lower that those required to yield the material. It is more of a function of the geometry of the components than it is a function of the material. In general it is very difficult to predict the onset of buckling. Thus, the approach used in this document will of necessity be very conservative. All of the basic assumptions described below will lead to a conservative result.

There are many theories that address buckling In general there are long, intermediate, and short columns. For long columns, Euler's formula is most often used with good results. For intermediate and short columns, there are many different approaches that would result in many iterative calculations for each case to be investigated. In order to provide reliable results with reasonable time expenditures, Euler's formula was used was used to determine the maximum un-reinforced hanger rod length. The hanger rods were modeled as having one end free, and one end fixed. If reinforcement was required for the hanger rod, it was selected based on the assumptions that the reinforcing angle was carrying the entire compressive load, and that the reinforcing angle was equal to the length of the hanger rod.

In a similar fashion, Euler's formula was used to determine the maximum allowable values for the clamp locating dimensions L_1 and L_3. However, in this case L_1 and L_3 assumed to be equal to each other, and their sum was set to be equal to the maximum un-reinforced length of the hanger rod computed using Euler's formula with one end of the rod fixed and the other end free. In determining the maximum value for the clamp spacing, L_2, Euler's formula was used assuming that both ends of the hanger rod were fixed at the clamps.

The horizontal seismic loads applied to the hanger rods are based on the **Kinetics Noise Control *Horizontal Force Class***, or ***Force Class***, designations of ***I*** through ***VI***. The

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installation angle (***A***), as measured from the horizontal, was taken to be ***60°***, and will be used to cover the range of installation angles from ***46°*** to ***60°*** inclusively. The Force Class system ranges are shown below.

Force Class I: 0 lbs through 250 lbs
Force Class II: 251 lbs through 500 lbs
Force Class III: 501 lbs through 1,000 lbs
Force Class IV: 1,001 lbs through 2,000 lbs
Force Class V: 2,001 lbs through 5,000lbs
Force Class VI: 5,001 lbs through 10,000lbs

The maximum load in each ***Force Class*** was used with a ***Factor of Safety*** of ***2:1*** in determining the maximum un-reinforced hanger rod length, the minimum angle size to be used for the rod stiffener, and the values used for L_1, L_2, and L_3.

<u>Use of the KHRC-A Rod Stiffener Data Tables:</u>

1.) **Data Tables:** There is a hanger rod stiffener selection data table for each ***Force Class***.
2.) **Hanger Rod Sizes:** The hanger rod sizes that may be used with the **Kinetics** Noise Control model ***KHRC-A***, and that are applicable for each ***Force Class*** are listed across the top of each data table.
3.) **Hanger Rod Length:** The hanger rod lengths that are applicable are listed in the left hand column of each table in ***6"*** and ***12"*** multiples. The maximum reinforced hanger rod length for each ***Force Class*** is the last entry in this column.
4.) **Rod Stiffener Requirement:** Determine the appropriate ***Force Class*** for the application. Select the column for the hanger rod size being used, and follow it down to the hanger rod length being considered. If the word "**Yes**" is found in this box, a hanger rod stiffener will be required. If, on the other hand, the word "**No**" is found in the box, then a hanger rod stiffener is not required. If the hanger rod length being used falls in between two of the tabulated rod lengths, use the larger value for the hanger rod length.
5.) **Minimum Stiffener Angle Size:** The minimum reinforcement angle size for each hanger rod length in each ***Force Class*** is listed in the right hand column of each table. Use the minimum Stiffener Angle size that corresponds to the hanger rod length used in step "**4.)**".
6.) **Maximum Installation Dimensions:** The maximum allowable installation dimensions, L_1, L_2, and L_3, are tabulated by hanger rod size beneath the rod stiffener selection data table for each ***Force Class***.
7.) **KHRC-A Clamp Kits:** A minimum of two (2) **Kinetics Noise Control** model ***KHRC-A*** clamps kits are required for each hanger rod stiffener installation. The ***KHRC-A*** clamp kits should be spaced approximately ***1"*** from each end of the rod stiffener angle. The distance from where the hanger rod is attached to the suspended component and the lower **KHRC-A** clamp kit must not exceed the value for L_1 listed for the ***Force Class*** and hanger rod size being used. If the spacing

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between the two **KHRC-A** clamp kits exceeds the value of L_2, maximum allowable spacing between clamps, listed for the Force Class and rod size for the application, another **KHRC-A** clamp kit must be added between the original pair. Finally, the distance from the upper **KHRC-A** clamp kit where the hanger rod attaches to the structure, or isolation hanger, must not exceed the value listed for L_3, based on the ***Force Class*** and rod size being considered. Also note that the thumb screw should be securely tightened. Pliers may be used after thumb screw is made finger tight.

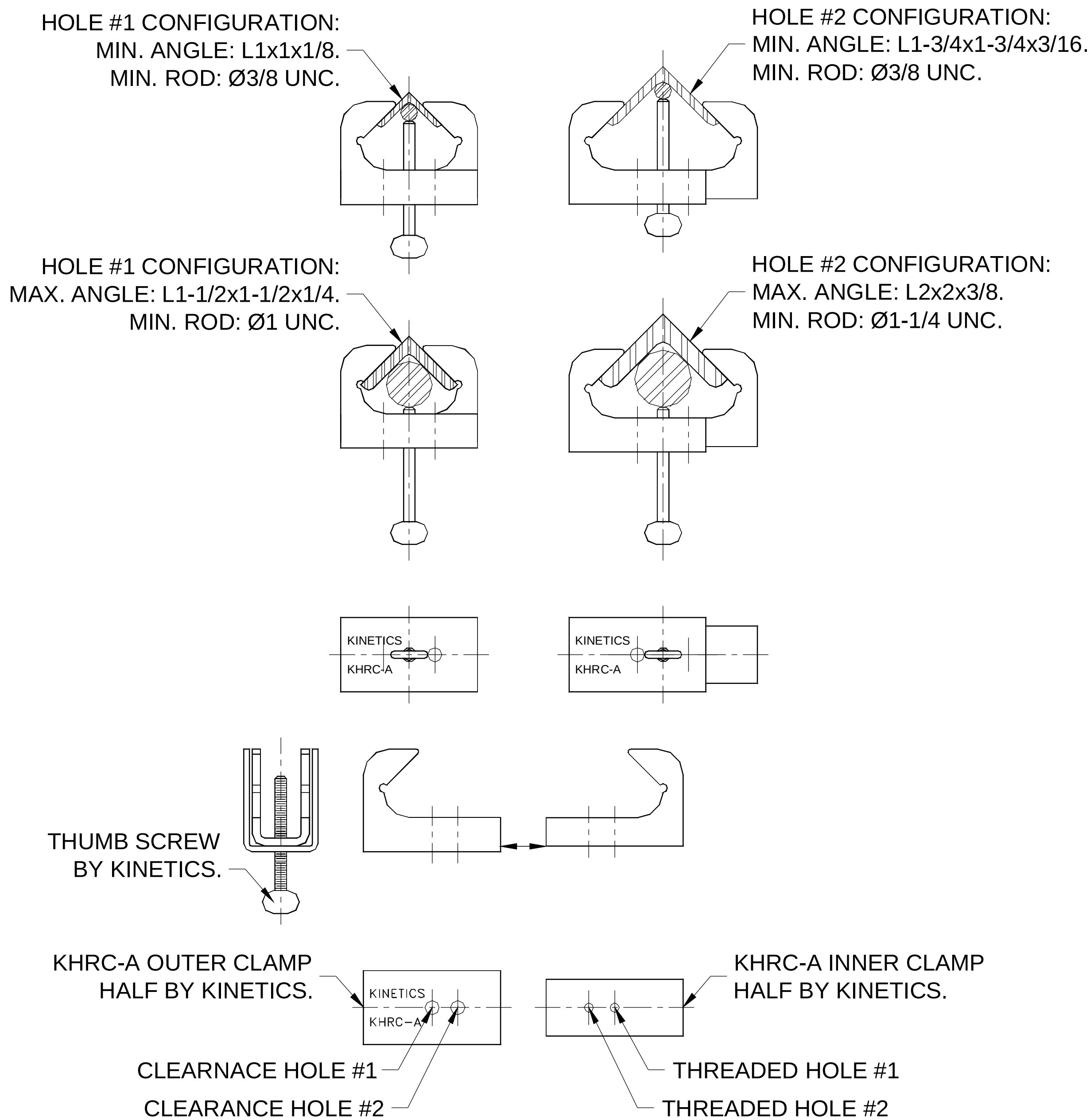

Figure A8.3.1-1; Kinetics Noise Control Model KHRC-A.

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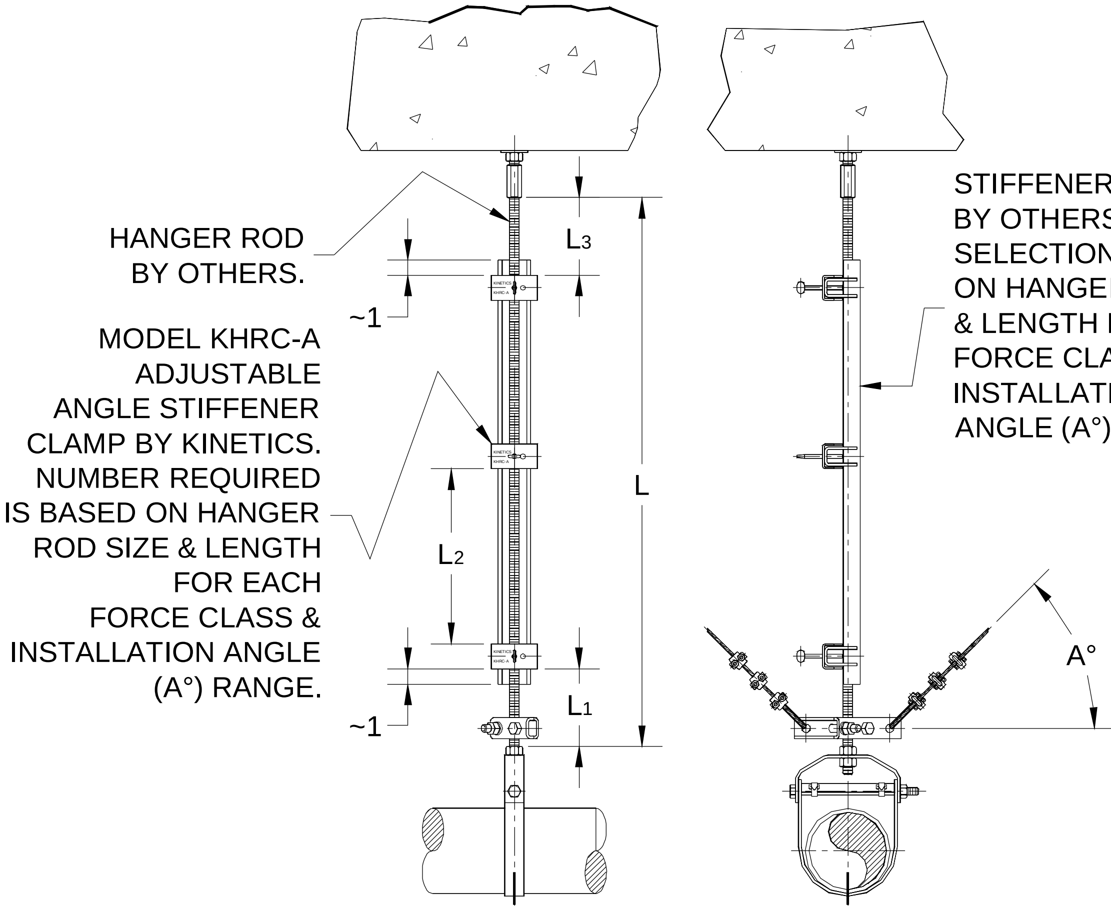

Figure A8.3.1-2; Typical Hanger Rod Stiffener Installation.

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Rod Length (″)	3/8″ Rod	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	No	No	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	No	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
24	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
30	Yes	Yes	Yes	Yes	No	No	No	1-1/8 x 1-1/8 x 1/8
36	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
42	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
48	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 1/4
54	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
60	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
66	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
72	Yes	Yes	Yes	Yes	Yes	Yes	No	1-3/4 x 1-3/4 x 3/16
78	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 3/16
84	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
90	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
96	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
102	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
108	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
114	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
120	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
126	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
132 Max.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	3/8″ ROD	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	2	4	7	12	16	22	36
Max. L_2 =	9	19	31	48	67	89	89
Max. L_3 =	2	4	7	12	16	22	36

KHRC-A ROD STIFFENER DATA FOR 45° < A ≤ 60° - FORCE CLASS I

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Rod Length (″)	3/8″ Rod	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	No	No	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	Yes	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	Yes	Yes	No	No	No	1 x 1 x 1/8
24	Yes	Yes	Yes	Yes	No	No	No	1-1/4 x 1-1/4 x 3/16
30	Yes	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
36	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 1/4
42	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
48	Yes	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
54	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 3/16
60	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
66	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
72	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
78	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
84	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
90	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
93 Max.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	3/8″ ROD	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	1	3	5	8	11	15	25
Max. L_2 =	6	13	21	33	47	62	62
Max. L_3 =	1	3	5	8	11	15	25

KHRC-A ROD STIFFENER DATA FOR 45° < A ≤ 60° - FORCE CLASS II

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Rod Length (″)	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	No	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	No	No	No	No	1 x 1 x 1/8
18	Yes	Yes	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
24	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 1/4
30	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
36	Yes	Yes	Yes	Yes	Yes	No	1-3/4 x 1-3/4 x 3/16
42	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
48	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/16
54	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
60	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
66 Max.	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (″)	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD
Max. L_1 =	2	3	5	8	10	17
Max. L_2 =	8	15	23	32	43	43
Max. L_3 =	2	3	5	8	10	17

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Rod Length (″)	1/2″ Rod	5/8″ Rod	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	Yes	No	No	No	No	1 x 1 x 1/8
12	Yes	Yes	Yes	No	No	No	1-1/4 x 1-1/4 x 3/16
18	Yes	Yes	Yes	Yes	Yes	No	1-1/4 x 1-1/4 x 1/4
24	Yes	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 1/4
30	Yes	Yes	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 1/4
36	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
42	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 5/16
46 Max.	Yes	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8
Mounting Dim. (″)	1/2″ ROD	5/8″ ROD	3/4″ ROD	7/8″ ROD	1″ ROD	1-1/4″ ROD	
Max. L_1 =	1	2	3	5	7	12	
Max. L_2 =	5	10	15	22	30	50	
Max. L_3 =	1	2	3	5	7	12	

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Rod Length (")	5/8" Rod	3/4" Rod	7/8" Rod	1" Rod	1-1/4" Rod	Minimum Rod Stiffener Angle
6	Yes	Yes	No	No	No	1 x 1 x 1/8
12	Yes	Yes	Yes	Yes	No	1-1/2 x 1-1/2 x 3/16
18	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/8
24	Yes	Yes	Yes	Yes	Yes	2 x 2 x 1/4
29 Max.	Yes	Yes	Yes	Yes	Yes	2 x 2 x 3/8

Mounting Dim. (")	5/8" ROD	3/4" ROD	7/8" ROD	1" ROD	1-1/4" ROD
Max. L_1 =	1	2	3	4	7
Max. L_2 =	5	9	13	18	18
Max. L_3 =	1	2	3	4	7

KHRC-A ROD STIFFENER DATA FOR 45° < A ≤ 60° - FORCE CLASS V

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Rod Length (″)	3/4″ Rod	7/8″ Rod	1″ Rod	1-1/4″ Rod	Minimum Rod Stiffener Angle
6	Yes	Yes	No	No	1-1/4 x 1-1/4 x 3/16
12	Yes	Yes	Yes	Yes	1-3/4 x 1-3/4 x 3/16
18	Yes	Yes	Yes	Yes	2 x 2 x 5/16
20 Max.	Yes	Yes	Yes	Yes	2 x 2 x 3/8
Mounting Dim. (″)	**3/4″ ROD**	**7/8″ ROD**	**1″ ROD**	**1-1/4″ ROD**	
Max. L_1 =	1	2	3	5	
Max. L_2 =	6	9	12	21	
Max. L_3 =	1	2	3	5	

KHRC-A ROD STIFFENER DATA FOR 45° < A ≤ 60° - FORCE CLASS VI

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EMT – Electrical Conduit Data

Table A9.1.1-1; EMT Conduit – 40% Copper Fill.

Conduit Size (in)	Conduit O.D. (in)	Conduit I.D. (in)	Conduit Weight Empty (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper (lb/ft)
1/2	0.706	0.622	0.30	0.47	0.77
3/4	0.922	0.824	0.46	0.82	1.28
1	1.163	1.049	0.67	1.34	2.01
1-1/4	1.510	1.380	1.00	2.31	3.31
1-1/2	1.740	1.610	1.16	3.15	4.31
2	2.197	2.067	1.48	5.19	6.67
2-1/2	2.875	2.731	2.15	9.05	11.20
3	3.500	3.356	2.63	13.67	16.30
3-1/2	4.000	3.834	3.47	17.84	21.31
4	4.500	4.334	3.91	22.80	26.71

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Table A9.1.1-2; EMT Conduit Maximum Support Spacing - Bending.

Conduit Size (in)	O.D. (in)	I.D. (in)	I (in^4)	Conduit + Copper (lb/ft)	Maximum Support Spacing (ft)[1]
1/2	0.706	0.622	0.0048	0.77	8.91
3/4	0.922	0.824	0.0128	1.28	9.88
1	1.163	1.049	0.0672	2.01	16.08
1-1/4	1.510	1.380	0.0772	3.31	11.12
1-1/2	1.740	1.610	0.1201	4.31	11.32
2	2.197	2.067	0.2476	6.67	11.63
2-1/2	2.875	2.731	0.6231	11.20	13.91
3	3.500	3.356	1.1395	16.30	14.13
3-1/2	4.000	3.834	1.9597	21.31	14.38
4	4.500	4.334	2.8098	26.71	14.50

1) Determined by assuming that the conduit was a beam with fixed ends and an evenly distributed load equal to the weight of the conduit and a 40% fill of copper. The conduit material was assumed to be equal to low carbon commercial quality steel sheet with a yield stress of 40,000 psi – 50,000 psi.

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Table A9.1.1-3; EMT Conduit Maximum Support Spacing – Buckling[1].

Conduit Size (in)	I (in^4)	Force Class I[2, 8]	Force Class II[3, 8]	Force Class III[4, 8]	Force Class IV[5, 8]	Force Class V[6, 8]	Force Class VI[7, 8]
1/2	0.0048	4.44	3.14	2.22	1.57	0.99	0.70
3/4	0.0128	7.26	5.13	3.63	2.57	1.62	1.15
1	0.0672	16.62	11.75	8.31	5.88	3.72	2.63
1-1/4	0.0772	17.82	12.60	8.91	6.30	3.98	2.82
1-1/2	0.1201	22.22	15.71	11.11	7.86	4.97	3.51
2	0.2476	31.91	22.56	15.95	11.28	7.14	5.05
2-1/2	0.6231	50.62	35.79	25.31	17.90	11.32	8.00
3	1.1395	68.45	48.40	34.23	24.20	15.31	10.82
3-1/2	1.9597	89.77	63.48	44.89	31.74	20.07	14.19
4	2.8098	107.49	76.01	53.75	38.00	24.04	17.00

1) The Maximum Support Spacing based on Buckling relies on Euler's Theory of Column Buckling. There is a Factor of Safety of 2:1 with respect to the applied Horizontal Seismic Load. Both ends of the conduit are assumed to be fixed, and the conservative end condition factor of 1.00 was used.
2) Horizontal Force Class I: 0 lbs. ≤ Horizontal Seismic Force ≤ 250 lbs.
3) Horizontal Force Class II: 251 lbs. ≤ Horizontal Seismic Force ≤ 500 lbs.
4) Horizontal Force Class III: 501 lbs. ≤ Horizontal Seismic Force ≤ 1,000 lbs.
5) Horizontal Force Class IV: 1,001 lbs. ≤ Horizontal Seismic Force ≤ 2,000 lbs.
6) Horizontal Force Class V: 2,001 lbs. ≤ Horizontal Seismic Force ≤ 5,000 lbs.
7) Horizontal Force Class VI: 5,001 lbs. ≤ Horizontal Seismic Force ≤ 10,000 lbs.
8) For Actual Horizontal Forces that fall between the minimum and maximum values for a given Horizontal Force Class, the Maximum Support Spacing for Buckling may be determined by multiplying the appropriate value from Table A9.1.1-3 by the following factor.

$$K_S = [\text{ Upper Horizontal Force Class Limit / Actual Horizontal Seismic Force }]^{1/2}$$

Example: 1/2″ EMT with and Actual Horizontal Seismic Force of 50 lbs (Force Class I Range).

$$K_S = [\text{ 250 lbs. / 50lbs. }]^{1/2} = \underline{2.24}$$

The Actual Maximum Support Spacing = 2.24 x 4.44 ft. = <u>9.95 ft.</u>

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IMC – Electrical Conduit Data

Table A9.2.1-1; IMC Conduit – 40% Copper Fill.

Conduit Size (in)	Conduit O.D. (in)	Conduit I.D. (in)	Conduit Weight Empty (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper (lb/ft)
1/2	0.815	0.675	0.56	0.55	1.11
3/4	1.029	0.879	0.76	0.94	1.70
1	1.290	1.120	1.09	1.52	2.61
1-1/4	1.638	1.468	1.41	2.62	4.03
1-1/2	1.883	1.703	1.72	3.52	5.24
2	2.360	2.170	2.30	5.72	8.02
2-1/2	2.857	2.557	4.33	7.94	12.27
3	3.476	3.196	4.98	12.40	17.38
3-1/2	3.971	3.691	5.72	16.54	22.26
4	4.466	4.186	6.46	21.27	27.73

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Table A9.2.1-2; IMC Conduit Maximum Support Spacing - Bending.

Conduit Size (in)	O.D. (in)	I.D. (in)	I (in^4)	Conduit + Copper (lb/ft)	Maximum Support Spacing (ft)[1]
1/2	0.815	0.675	0.0115	1.11	11.27
3/4	1.029	0.879	0.0257	1.70	12.12
1	1.290	1.120	0.1066	2.61	17.79
1-1/4	1.638	1.468	0.1254	4.03	13.78
1-1/2	1.883	1.703	0.2042	5.24	14.39
2	2.360	2.170	0.4343	8.02	15.15
2-1/2	2.857	2.557	1.1721	12.27	18.29
3	3.476	3.196	2.0447	17.38	18.40
3-1/2	3.971	3.691	3.0953	22.26	17.75
4	4.466	4.186	4.4556	27.73	17.99

1) Determined by assuming that the conduit was a beam with fixed ends and an evenly distributed load equal to the weight of the conduit and a 40% fill of copper. The conduit material was assumed to be equal to cold rolled carbon steel sheet with a yield stress of 45,000 psi – 50,000psi.

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Table A9.2.1-3; IMC Conduit Maximum Support Spacing – Buckling[1].

Conduit Size (in)	I (in^4)	Force Class I[2, 8]	Force Class II[3, 8]	Force Class III[4, 8]	Force Class IV[5, 8]	Force Class V[6, 8]	Force Class VI[7, 8]
1/2	0.0115	6.88	4.86	3.44	2.43	1.54	1.09
3/4	0.0257	10.28	7.27	5.14	3.63	2.30	1.63
1	0.1066	20.94	14.80	10.47	7.40	4.68	3.31
1-1/4	0.1254	22.71	16.06	11.35	8.03	5.08	3.59
1-1/2	0.2042	28.98	20.49	14.49	10.25	6.48	4.58
2	0.4343	42.26	29.88	21.13	14.94	9.45	6.68
2-1/2	1.1721	69.43	49.09	34.71	24.55	15.52	10.98
3	2.0447	91.70	64.84	45.85	32.42	20.50	14.50
3-1/2	3.0953	112.82	79.78	56.41	39.89	25.23	17.84
4	4.4556	135.36	95.72	67.68	47.86	30.27	21.40

1) The Maximum Support Spacing based on Buckling relies on Euler's Theory of Column Buckling. There is a Factor of Safety of 2:1 with respect to the applied Horizontal Seismic Load. Both ends of the conduit are assumed to be fixed, and the conservative end condition factor of 1.00 was used.
2) Horizontal Force Class I: 0 lbs. ≤ Horizontal Seismic Force ≤ 250 lbs.
3) Horizontal Force Class II: 251 lbs. ≤ Horizontal Seismic Force ≤ 500 lbs.
4) Horizontal Force Class III: 501 lbs. ≤ Horizontal Seismic Force ≤ 1,000 lbs.
5) Horizontal Force Class IV: 1,001 lbs. ≤ Horizontal Seismic Force ≤ 2,000 lbs.
6) Horizontal Force Class V: 2,001 lbs. ≤ Horizontal Seismic Force ≤ 5,000 lbs.
7) Horizontal Force Class VI: 5,001 lbs. ≤ Horizontal Seismic Force ≤ 10,000 lbs.
8) For Actual Horizontal Forces that fall between the minimum and maximum values for a given Horizontal Force Class, the Maximum Support Spacing for Buckling may be determined by multiplying the appropriate value from Table A9.2.1-3 by the following factor.

K_S = [Upper Horizontal Force Class Limit / Actual Horizontal Seismic Force]$^{1/2}$

Example: 1/2″ EMT with and Actual Horizontal Seismic Force of 50 lbs (Force Class I Range).

K_S = [250 lbs. / 50lbs.]$^{1/2}$ = 2.24

The Actual Maximum Support Spacing = 2.24 x 4.44 ft. = 9.95 ft.

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Rigid – Electrical Conduit Data

Table A9.3.1-1; Rigid Conduit – 40% Copper Fill.

Conduit Size (in)	Conduit O.D. (in)	Conduit I.D. (in)	Conduit Weight Empty (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper (lb/ft)
1/2	0.840	0.632	0.82	0.48	1.30
3/4	1.050	0.836	1.08	0.85	1.93
1	1.315	1.063	1.60	1.37	2.97
1-1/4	1.660	1.394	2.17	2.36	4.53
1-1/2	1.900	1.624	2.59	3.20	5.79
2	2.375	2.083	3.47	5.27	8.74
2-1/2	2.875	2.489	5.52	7.52	13.04
3	3.500	3.090	7.21	11.59	18.80
3-1/2	4.000	3.570	8.68	15.47	24.15
4	4.500	4.050	10.26	19.91	30.17
5	5.563	5.073	13.90	31.24	45.14
6	6.625	6.093	18.05	45.07	63.12

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Table A9.3.1-2; Rigid Conduit Maximum Support Spacing - Bending.

Conduit Size (in)	O.D. (in)	I.D. (in)	I (in^4)	Conduit + Copper (lb/ft)	Maximum Support Spacing (ft)[1]
1/2	0.840	0.632	0.0166	1.30	12.33
3/4	1.050	0.836	0.0357	1.93	13.27
1	1.315	1.063	0.1228	2.97	17.73
1-1/4	1.660	1.394	0.1874	4.53	15.79
1-1/2	1.900	1.624	0.2983	5.79	16.47
2	2.375	2.083	0.6377	8.74	17.53
2-1/2	2.875	2.489	1.4697	13.04	19.80
3	3.500	3.090	2.8911	18.80	19.89
3-1/2	4.000	3.570	4.5930	24.15	20.69
4	4.500	4.050	6.9223	30.17	21.42
5	5.563	5.073	14.501	45.14	22.80
6	6.625	6.093	26.907	63.12	24.06

1) Determined by assuming that the conduit was a beam with fixed ends and an evenly distributed load equal to the weight of the conduit and a 40% fill of copper. The conduit material was assumed to be equal to cold rolled carbon steel sheet with a yield stress of 45,000 psi – 50,000psi.

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Table A9.3.1-3; Rigid Conduit Maximum Support Spacing – Buckling[1].

Conduit Size (in)	I (in^4)	Force Class I[2, 8]	Force Class II[3, 8]	Force Class III[4, 8]	Force Class IV[5, 8]	Force Class V[6, 8]	Force Class VI[7, 8]
1/2	0.0166	8.26	5.84	4.13	2.92	1.85	1.31
3/4	0.0357	12.12	8.57	6.06	4.28	2.71	1.92
1	0.1228	22.47	15.89	11.24	7.95	5.02	3.55
1-1/4	0.1874	27.76	19.63	13.88	9.81	6.21	4.39
1-1/2	0.2983	35.02	24.77	17.51	12.38	7.83	5.54
2	0.6377	51.21	36.21	25.60	18.11	11.45	8.10
2-1/2	1.4697	77.74	54.97	38.87	27.49	17.38	12.29
3	2.8911	109.04	77.10	54.52	38.55	24.38	17.24
3-1/2	4.5930	137.43	97.18	68.72	48.59	30.73	21.73
4	6.9223	168.72	119.30	84.36	59.65	37.73	26.68
5	14.501	244.20	172.67	122.10	86.34	54.60	38.61
6	26.907	332.64	235.21	166.32	117.61	74.38	52.60

1) The Maximum Support Spacing based on Buckling relies on Euler's Theory of Column Buckling. There is a Factor of Safety of 2:1 with respect to the applied Horizontal Seismic Load. Both ends of the conduit are assumed to be fixed, and the conservative end condition factor of 1.00 was used.
2) Horizontal Force Class I: 0 lbs. ≤ Horizontal Seismic Force ≤ 250 lbs.
3) Horizontal Force Class II: 251 lbs. ≤ Horizontal Seismic Force ≤ 500 lbs.
4) Horizontal Force Class III: 501 lbs. ≤ Horizontal Seismic Force ≤ 1,000 lbs.
5) Horizontal Force Class IV: 1,001 lbs. ≤ Horizontal Seismic Force ≤ 2,000 lbs.
6) Horizontal Force Class V: 2,001 lbs. ≤ Horizontal Seismic Force ≤ 5,000 lbs.
7) Horizontal Force Class VI: 5,001 lbs. ≤ Horizontal Seismic Force ≤ 10,000 lbs.
8) For Actual Horizontal Forces that fall between the minimum and maximum values for a given Horizontal Force Class, the Maximum Support Spacing for Buckling may be determined by multiplying the appropriate value from Table A9.3.1-3 by the following factor.

K_S = [Upper Horizontal Force Class Limit / Actual Horizontal Seismic Force]$^{1/2}$

Example: 1/2″ EMT with and Actual Horizontal Seismic Force of 50 lbs (Force Class I Range).

K_S = [250 lbs. / 50lbs.]$^{1/2}$ = 2.24

The Actual Maximum Support Spacing = 2.24 x 4.44 ft. = 9.95 ft.

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