TABLE OF CONTENTS

Part I: Selection of Seismic Restraints for Pipe and Duct

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Title	**Section**

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Appendices

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REVISION RECORD

Gray highlighted sections indicate latest revisions.

Section	Title	Date Revised
T.O.C.	Table of Contents	12/09/10
RR	Revision Record	12/09/10
INTRO	Introduction	05/11/09

Part I: Selection of Seismic Restraints for Pipe and Duct

Section	Title	Date Revised
S1.0	Seismic Restraint Basics for Pipe and Duct	12/17/09
S2.0	Required Basic Product Information	05/28/09
S3.0	Pipe and Duct Component Importance Factor	04/21/08
S4.0	Code Based Exemptions	09/04/09
S5.0	Code Based Seismic Design Forces	02/16/10
S6.0	Anchorage of Seismic Restraints for Pipe and Duct	05/07/09
S7.0	Selection & Location of Seismic Restraints for Pipe and Duct	11/01/10
S8.0	Hanger Rod Reaction Forces & Stiffener Requirements	05/21/09
S9.0	Extreme Temperature Piping Applications	10/28/08
S10.0	Seismic Restraint for Drain, Waste, and Vent Lines	11/02/10
S11.0	Seismic Restraint Spacing for Pipe and Duct	05/07/09
S12.0	The 12″ Rule Explained	05/07/09
S13.0	Fire Protection Piping Systems	05/07/09
S14.0	Consequential Damage	05/27/09
S15.0	Electrical Distribution Systems	05/07/09

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Part II: Installation of Seismic Restraints for Pipe and Duct

Section	Title	Date Revised
I1.0	Quick Start – Read Me First	12/06/10
I2.0	Proper Prior Planning Prevents Poor Performance	05/28/09
I3.0	Cable Restraint Schematics for Piping	12/07/10
I4.0	Cable Restraint Schematics for Duct	12/08/10
I5.0	Structural Attachments for Pipe and Duct Restraints	09/04/09
I6.0	Pipe, Duct, Clevis, and Trapeze Bar Attachments	04/08/09
I7.0	Struts & Stuff	12/09/10
I8.0	Hanger Rod Stiffeners – Why, When, & How	09/08/09
I9.0	Electrical Distribution Systems – Contractor Summary	05/05/09

Appendices

Section	Title	Date Revised
A1.1	KSCU & KSCC Seismic Restraint Cable Capacities	04/09/10
A1.2	KSCU & KSCC Non-Isolated Restrained Weight Capacity	04/12/10
A2.1	Standard Steel Pipe Data	01/04/08
A2.2	Fire Protection Pipe Data	04/25/08
A2.3	Cast Iron Soil Pipe Data	04/11/08
A2.4	PVC & CPVC Pipe Data	08/05/08
A2.5	Copper Water Pipe Data	02/23/10
A2.6	Domestic Hot & Chilled Water piping Corner Data	08/15/08
A3.1	Rectangular Duct Data	07/07/08
A3.2	Round Duct Data	07/09/08
A3.3	Flat Oval Duct Data	11/29/07
A3.4	Sheet Metal Screws Required for Duct Restraint	11/07/07
A3.5	Fillet Weld Size & Length for Duct Restraint	07/11/08

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INTRODUCTION

The purpose of this manual is to provide design professionals, contractors, and building officials with the information and guidance required to select and install seismic restraints for pipe and duct distribution systems. General procedures and methods for selecting and installing seismic restraints will be covered in this manual. The actual as built details for the installation of the seismic restraints must be the responsibility of the design professional of record or the installing contractor, because these are the people who have an intimate knowledge of the building as it is being designed and constructed.

This manual is divided into three parts.

1. Selection of seismic restraints. These sections are designated S1.0, S2.0… and so on.
2. Installation of the seismic restraints. These sections are marked as I1.0, I2.0… etc.
3. Appendices of pipe, duct, seismic restraint, and attachment hardware data. The appendices will be listed as A1.0, A2.0… and so forth.

Those who have the responsibility for selecting the seismic restraints for a project will need to be familiar with all three parts of this manual. Those responsible for installing the seismic restraints will need to be familiar with the part of the manual dealing with the installation of the seismic restraints, and with the appendices. The building officials responsible for inspecting the seismic restraints will need a working knowledge of all three parts of this manual.

The selection and installation of seismic restraints for pipe and duct is closely controlled by the building codes in force for the jurisdiction in which the building is located. This manual will be 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 manual, it will be as 2000/2003 IBC. The latest version of the IBC that is currently being adopted by the various states is 2009 IBC which is identical to 2006 IBC for seismic requirements. This is the version that will form the core basis for this manual. When appropriate the differences between the 2006/2009 IBC and the 2000/2003 IBC will be pointed out. The intent is to have a working manual that is based on the

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current 2006/2009 IBC, but is also relevant to the 2000/2003 IBC. The code based requirements for the restraint of pipe and duct are found in the following references.

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.
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. 2008 ASHRAE Handbook – HVAC Systems and Equipment; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; 1791 Tullie Circle NE, Atlanta, Georgia,30329-2305; Chapter 45 – Pipes, Tubes, and Fittings, Pp 45.1-45.14.
9. NFPA 13 - Standard for the Installation of Sprinkler Systems 2007 Edition; National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, 2006; Chapter 9 and Annex A.
10. 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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11. Tauby, James R.; Lloyd, Richard; Noce, Todd; and Tünnissen, Joep; A Practical Guide to Seismic Restraint; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, Georgia 30329, 1999.

The selection and installation of the proper seismic restraints for a piping or duct system 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 will be a constant theme throughout this manual. 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 pipe and duct 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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SEISMIC RESTRAINT BASICS FOR PIPE AND DUCT

S1.1 – Introduction:

As with any task in the design and construction of buildings, there are certain terms, definitions, and standards of practice that must be understood and employed in order to maintain a consistent set of results in the "as built" environment. The seismic restraint of pipe and duct is a task that requires several disciplines and trades to interface well in order to produce a building that meets the intent of the code. This section will present the basic terms, definitions, and commonly followed standards of practice for the placement of seismic restraints for pipe and duct. SMACNA (Sheet Metal and Air Conditioning Contractors' National Association, Inc.) has been recognized as one of the leading authorities in the field of specifying and installing seismic restraints for pipe and duct. This section will be based on information contained in SMACNA's "Seismic Restraint Manual – Guidelines for Mechanical Systems".

S1.2 – Basic Terms and Definitions:

Seismic restraints for pipe and duct are separated into two categories.

1. Transverse seismic restraints (**T**): These act to prevent the pipe or duct from swinging side-to-side. They are normally placed perpendicular to the pipe or duct. The word lateral is often used for transverse when describing these restraints.
2. Longitudinal seismic restraints (**L**): These act to prevent the pipe or duct from swinging back-and-forth along the length of the pipe or duct. They are usually placed parallel to the pipe or duct. The word axial is also used when describing this type of restraints

Seismic restraints for pipe and duct may be further broken down into three basic types based on the way they operate.

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1. Strut Restraints (rigid braces) – these restraints carry both tension and compression loads along the axis of the strut. Only one strut is required to restrain a pipe or duct in one direction, either transverse or longitudinal. These types of restraints provide a rigid load path between the building and the pipe or duct so that the pipe or duct will move with the building, and there will be no relative displacement between the pipe or duct and the building at the restraint locations.
2. Cable Restraints (tension only braces) – these restraints carry only tension loads along the axis of the cable. They are used in pairs 180° apart to restrain the pipe or duct in one direction, either transverse or longitudinal. Here too, these types of restraints provide a rigid load path between the building and the pipe or duct so that the pipe or duct will move with the building, and there will be no relative displacement between the pipe or duct and the building at the restraint locations.
3. Post Restraints (omni-directional braces) – these restraints carry horizontal loads acting from any direction. One post will be required for each restraint location, and can be used to restrain the pipe or duct in both the transverse and longitudinal directions. The loads are carried as shear and an overturning moment at the building attachment point. This type of restraint forms a load path between the pipe or duct and the building that has some degree of flexibility, and will allow for some relative displacement between the pipe or duct and the building. Therefore, enough free space must be available around the pipe or duct to allow it to swing without impacting any other pipe or duct, equipment, or the building structure.

The following definitions will be helpful in the next section which discusses the basic rule for seismic restraints for pipe and duct.

A = the seismic restraint installation angle ($0^{\circ} \leq A \leq 60^{\circ}$). This is the angle between the cable or strut and structure is measured relative to a horizontal surface.

L_O = an offset or jog that occurs along the length of an otherwise straight run of pipe or duct when it must miss a portion of the building structure or another component.

S_H = the actual pipe or duct hanger spacing on a run.

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S_L = the actual longitudinal seismic restraint spacing on a run.

S_T = the actual transverse seismic restraint spacing on a run.

S1.3 – Basic Rules for Applying Seismic Restraints to Pipe and Duct:

RULE #1: Pipe and duct are spoken of in terms of "a run of pipe" or "a run of duct". As used here, a "run" is considered to be any straight section of pipe or duct between bends, as illustrated in Figure S1-1.

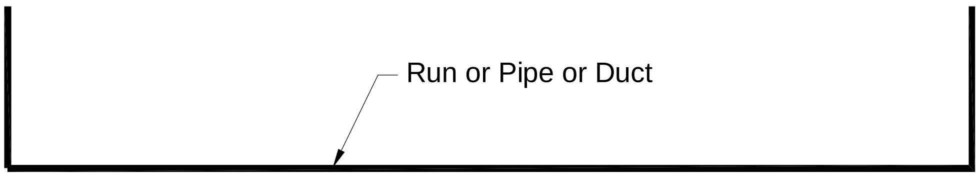

Figure S1-1; RULE #1 – A Run of Pipe or Duct

RULE #2: The pipe or duct is offset to miss part of the structure or another pipe or duct. This situation is illustrated in Figure S1-2. If the length of the offset is less than or equal to one sixteenth of the maximum allowable transverse seismic restraint spacing, the two sections of pipe or duct separated by the offset may be considered to be a single run of pipe or duct. If, on the other hand, the length of the offset is greater than one sixteenth of the maximum allowable transverse seismic restraint spacing, then the two sections of pipe or duct must be considered to be two separate runs of pipe or duct. (For example, if $S_T = 40\,ft$ then $L_O = 40/16 = 2.5\,ft = 30\,in$.)

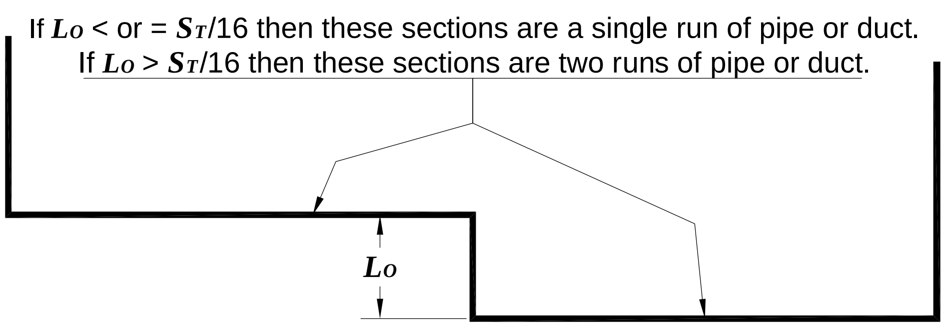

Figure S1-2; RULE #2 – Situation of an Offset in a Pipe or Duct

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RULE #3: The transverse and longitudinal seismic restraints are to be placed at or near the hanger locations for the pipe or duct, see Figure S1-3. Therefore, the transverse seismic restraint spacing should always be a whole multiple of the hanger spacing. The current accepted practice is to allow the restraint locations to be no more than ±4 in. away from a hanger location, see Figures S-14 and S-15 as examples Seismic restraints are placed at or near hanger locations because there will be an upward reaction in the hanger from the action of the seismic restraints that could overcome the weight of the pipe or duct that is being supported by the hanger. The intent is to allow the hanger to directly carry the upward reaction force to the building structure rather than introduce additional bending stresses in the pipe or duct between hangers. Table S1-1 lists commonly used seismic restraint spacings. When Kinetics Noise Control provides calculation results and makes recommendations for selecting seismic restraints for pipe and duct the information is based on the seismic restraint spacings shown in Table S1-1. Hanger spacings are often specified in whole multiples of 5 ft. For hanger spacings that are not some whole multiple of 5 ft, choose a seismic restraint spacing that is a multiple of the hanger rod spacing, but does not exceed the spacing identified in the information provided by Kinetics Noise Control.

Table S1-1; Typical Seismic Restraint Spacings

Transverse Seismic Restraint Spacing S_T (ft.)	Longitudinal Seismic Restraint Spacing S_L (ft.)	Comments on Maximum Allowable Restraint Spacings
10	10	Maximum Allowable Spacings for Low Deformability (Brittle) Piping.
10	20	Other Optional Spacings Used to Extend the Useful Range of Application for Specific Restraints.
15	30	
20	40	Maximum Allowable Restraint Spacings for Hazardous Gas Piping.
30	60	Maximum Allowable Restraint Spacings for Ductwork.
40	80	Maximum Allowable Restraint Spacings for HVAC & Plumbing Piping.

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RULE #4: The hanger rods used at seismic restraint locations must be a rigid member, such as all-thread rod, that is capable of carrying compressive loads. Spring isolated hangers are permitted as long as they comply with Rule #18. Cable type or other flexible hangers are not permitted.

RULE #5: The longitudinal seismic restraint spacing, S_L, can be greater than the maximum allowable transverse seismic restraint spacing, S_T, if the seismic restraints are adequately sized, but should not exceed twice the maximum allowable transverse seismic restraint spacing, $S_L \leq 2S_T$. See Section 8.0 for special treatment required by extreme temperature piping.

RULE #6: If over half the maximum allowable transverse (S_T) seismic restraint spacing in length, each straight run of pipe or duct must have a transverse seismic restraint at each end, see Figure S1-3. If under half the maximum allowable transverse seismic restraint spacing, only one end must have a transverse seismic restraint, see also Rule #10. For the instances where several short runs occur, see the Application Example #2 and Figure S1-9 below.

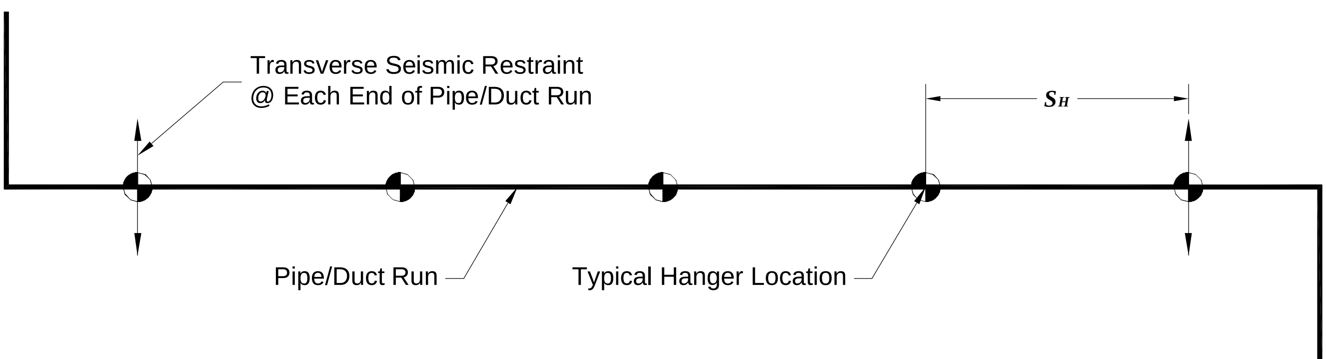

Figure S1-3; RULE #6– Transverse Seismic Restraints

RULE #7: Check the spacing between the transverse seismic restraints that have been placed at the ends of the run of pipe or duct, see Figure S1-3. If the spacing between the

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transverse seismic restraints exceeds the maximum allowable transverse seismic restraint spacing per the seismic analysis, add transverse seismic restraints until the spacing is less than the maximum allowable seismic restraint spacing as shown in Figure S1-4.

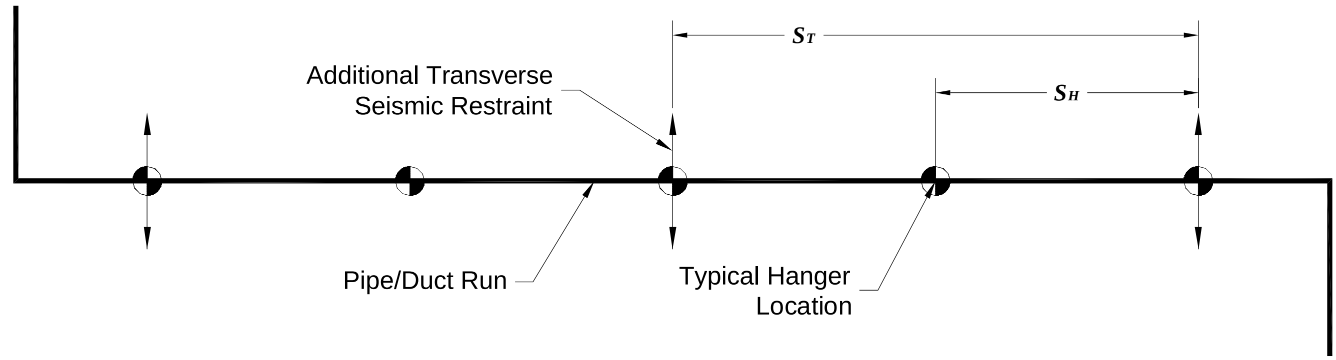

Figure S1-4; RULE #7 – Additional Transverse Seismic Restraints

RULE #8: Each run of pipe or duct must have at least one longitudinal seismic restraint, see Figure S1-5. It can be located anywhere along the run of pipe and need not be centered. If the run exceeds the maximum allowable longitudinal seismic restraint spacing in length, add longitudinal seismic restraints so that the distance between the longitudinal seismic restraints does not exceed the maximum allowable longitudinal seismic restraint spacing.

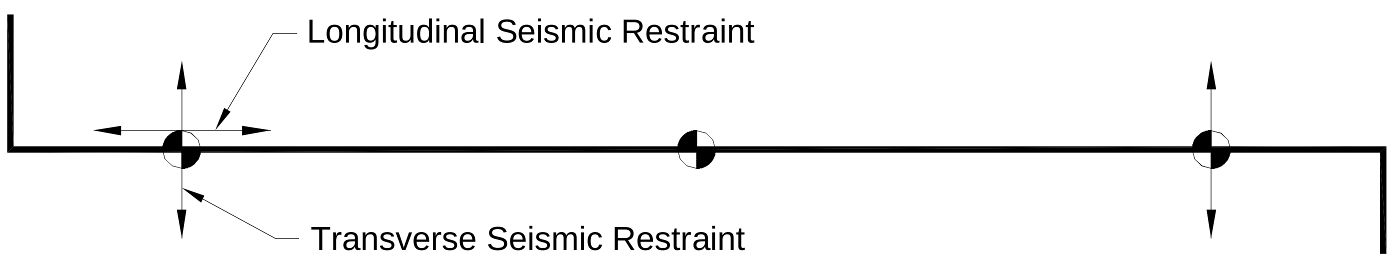

Figure S1-5; RULE #8 – Longitudinal Seismic Restraints

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Application Example #1:

In general, after the maximum allowable transverse seismic restraint spacing has been determined, the number of transverse and longitudinal seismic restraints that will be required on a run of pipe or duct will depend on the length of the run. Table S1-2 will provide the minimum number of transverse and longitudinal seismic restraints based on $S_L = 2S_T$. An exception to this rule occurs where the forces generated by the combination of the system weight per foot and the seismic acceleration exceed the capacity of the largest desired restraint device. In this case the spacing must be reduced to ensure the restraint has adequate capacity to resist the applied seismic loads.

Table S1-2; Application Example #1 – Minimum Number of Seismic Restraints Required Based on Run Length

Length of Run	Number of Seismic Restraints Required T=Transverse L=Longitudinal	
	T	**L**
0 up to $S_T/2$	1	1
$S_T/2$ up to S_T	2	1
S_T up to $2S_T$	3	1
$2S_T$ up to $3S_T$	4	2
$3S_T$ up to $4S_T$	5	2
$4S_T$ up to $5S_T$	6	3
$5S_T$ up to $6S_T$	7	3
$6S_T$ up to $7S_T$	8	4
$7S_T$ up to $8S_T$	9	4

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RULE #9: Figure S1-6 shows a pipe or duct system with transverse seismic restraints located within 24 in. of a bend, on both legs of the bend. In this case the transverse seismic restraint on one leg can serve as the longitudinal restraint on the other leg.

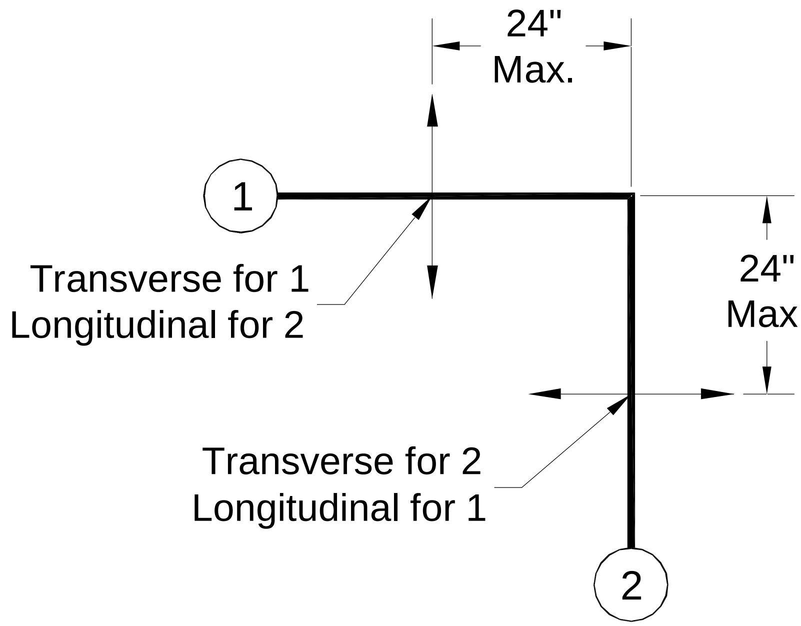

Figure S1-6; Rule #9 – Transverse Seismic Restraints Used as Longitudinal Seismic Restraints at Bends in Pipe and Duct

RULE #10: Figure S1-7 shows a section of pipe or duct whose length is less than half of the maximum allowable transverse seismic restraint spacing ($S_T/2$). AS long as this section of pipe or duct does not exceed this length ($S_T/2$), it may be considered to be a partial run, and will require one transverse and one longitudinal restraint. These restraints may be located anywhere along the length of the partial run of pipe or duct.

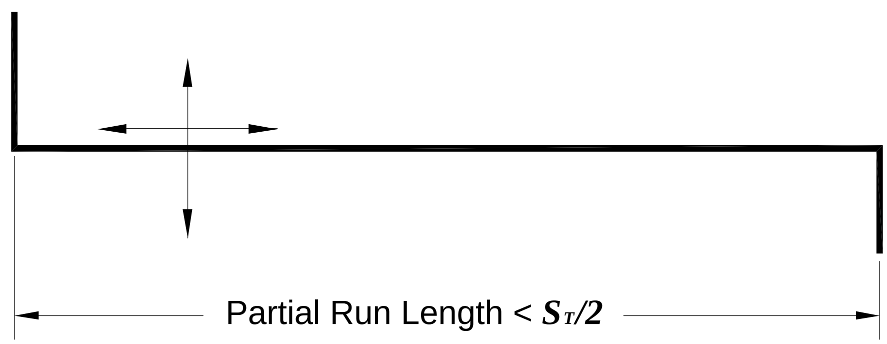

Figure S1-7; Rule #10 – Restraint Requirements for a Partial Run of Pipe or Duct

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RULE #11: Figure S1-8 below shows a case where a short section of pipe or duct T's off of a run of pipe or duct. We may call this short section of pipe or duct a "stub-out". If the length of the stub-out is less than or equal one sixteenth of the maximum allowable transverse seismic restraint spacing, $L_{SO} \le S_T/16$, the stub-out may be restrained as part of the run of pipe or duct, as long as its weight is distributed over the run of pipe or duct to which it is attached.

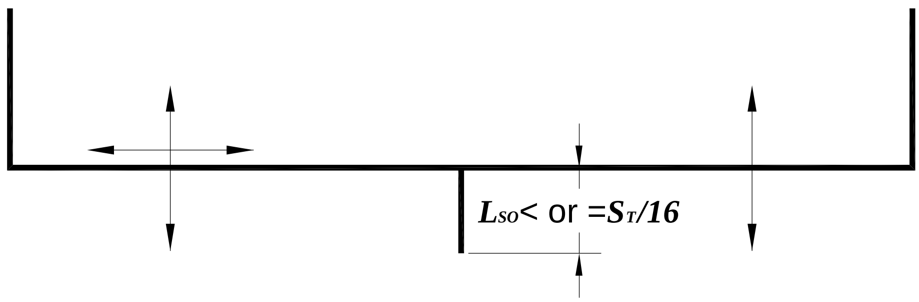

Figure S1-8; Rule # 11 – Restraint of a Pipe or Duct Stub-Out

Application Example #2:

For an application example, consider Figure S1-9 which shows a piping system with several full and partial runs of pipe or duct. The following information will apply to Figure S1-9 and Table S1-3, and the application example.

1. Lengths of Runs 1, 4, and 8 are $S_T/2 \le L \le S_T$.
2. The lengths of Runs 2, 3, 5, 6, and 7 are $L < S_T/2$.
3. The length of Run 9 is $L \le S_T/16$.
4. Seismic restraint locations B, C, and E are within 24 in. of the corner.

Table S1-3 below will show the seismic restraint requirements for each length of pipe or duct, and then list which seismic restraint locations will fulfill those requirements.

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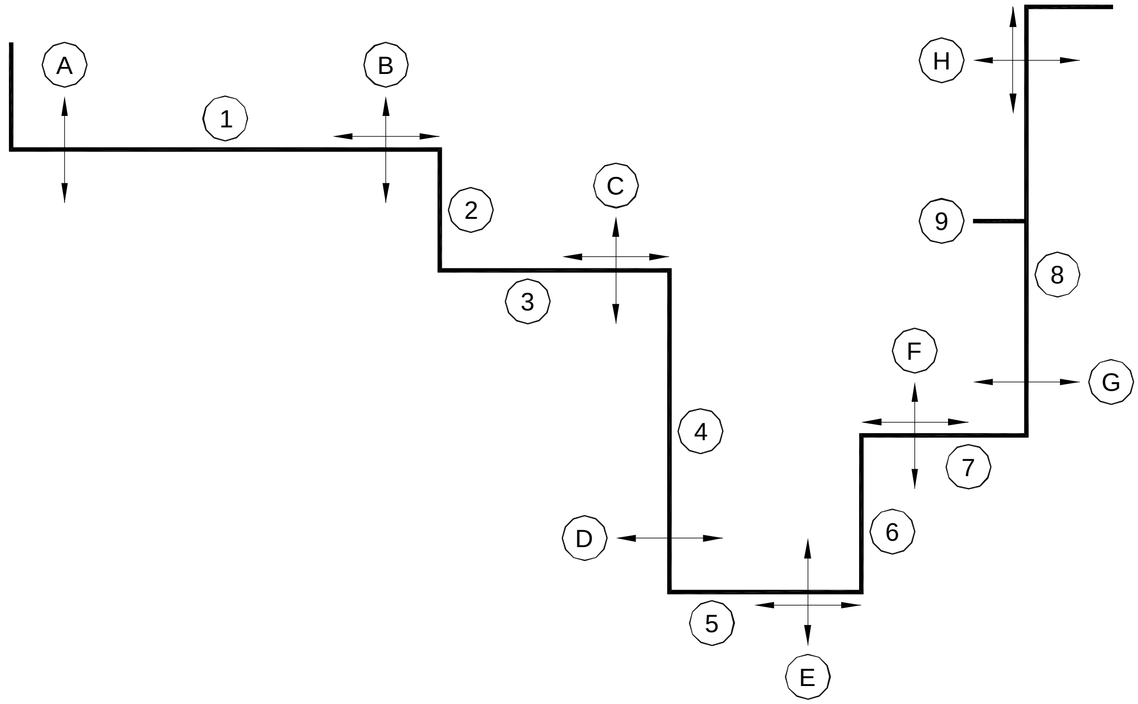

Figure S1-9; Application Example #2 – Restraints for Adjacent Short Sections of Pipe or Duct

Table S1-3; Application Example #2 – Results

Run of Pipe or Duct	Seismic Restraint Requirements T=Transverse L=Longitudinal		Seismic Restraint Requirements Fulfilled by Restraint Locations	Rules Followed For Applying Restraints
	T	**L**		
1	2	1	A & B	#6 & #8
2	1	1	B	#9 & #10
3	1	1	C	#10
4	2	1	C & D	#6 & #8
5	1	1	E	#10
6	1	1	E	#9 & #10
7	1	1	F	#10
8	2	1	G & H	#9 & #10
9	1	1	G & H	#11

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RULE #12: Where smaller pipes branch off from larger pipes, the seismic restraints on the smaller pipe ***can not*** be used as seismic restraints for the larger pipe. This is illustrated in Figure S1-10 below. There are two basic reasons for this rule.

1. The restraints selected for the smaller pipe may not have enough capacity to restrain the weight of both the small pipe and the large pipe.
2. The section properties of the small pipe may be insufficient to carry the seismic loads form the larger pipe to the seismic restraints on the smaller pipe without causing a failure in the smaller pipe itself.

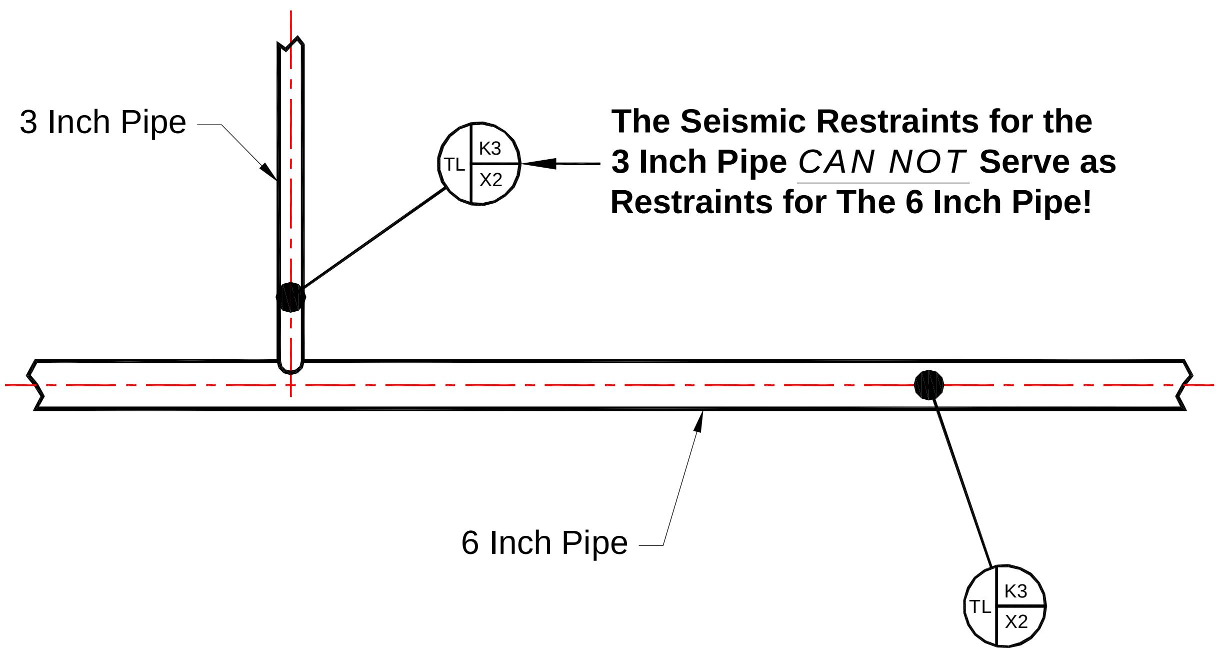

Figure S1-10; Rule #12 – Restraints on Smaller Branch Pipes Can Not Act as Restraints on the Larger Pipe.

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RULE #13: For vertical drops to equipment the relative motion between the piping and the equipment must be accommodated. This is especially true if the equipment is isolated. For cases where the equipment is isolated, a flexible coupling will be required to accomplish this, as shown in Figure S1-11.

RULE #14: Referring again to Figure S1-11, if the pipe or duct drop is less or equal to half of the transverse seismic restraint spacing, $H \leq S_T/2$, no further seismic restraints are required for the drop, provided that there is a transverse seismic restraint within 24″ of the top elbow of the drop. If, on the other hand the pipe or duct drop is greater than half the transverse seismic restraint spacing, the bottom of the drop will need to be restrained to the floor with a "4-way" restraint to prevent horizontal movement relative to the floor in all directions. (Note: If a pipe is restrained to two different levels in a structure, it must be designed to absorb a relative horizontal motion of 2% of the elevation difference between the levels without damage. See also Rule# 12)

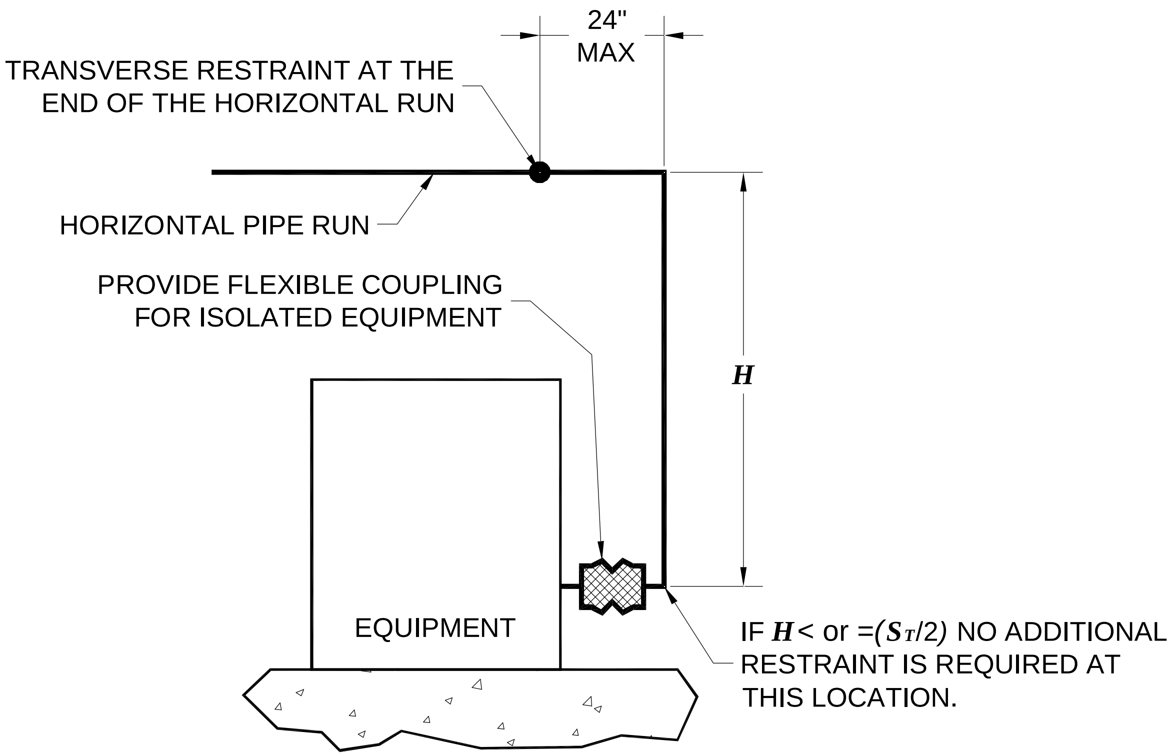

Figure S1-11; RULE #13 & RULE #14 – Vertical Drops for Pipe or Duct

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<u>RULE #15</u>: For cable or strut restraints, the installation angle ***A*** may be between 0° and 60°, as measured from the horizontal. This is shown in Figures S1-12 and S1-13 for transverse and longitudinal seismic restraints respectively.

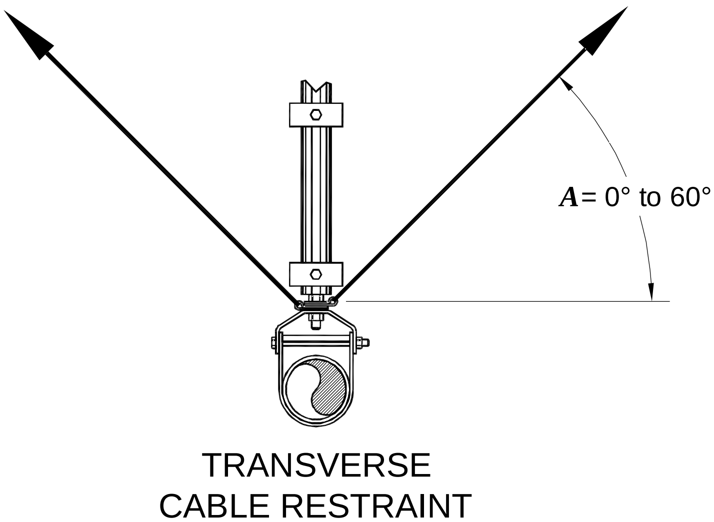

Figure S1-12; RULE #15 – Seismic Restraint Installation Angle for Transverse Restraints

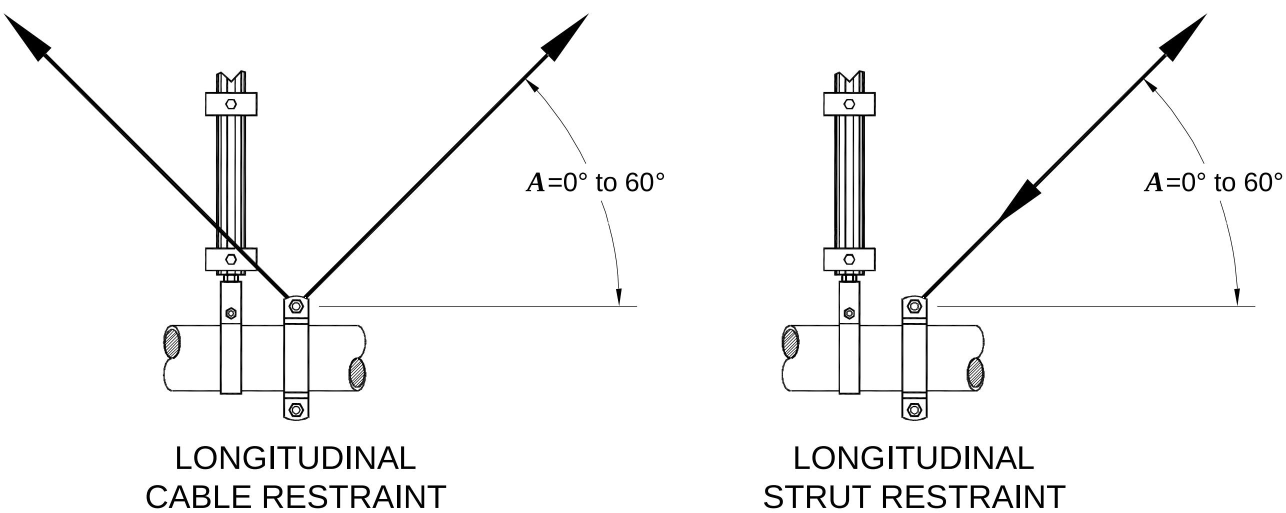

Figure S1-13; RULE #15 – Seismic Restraint Installation Angle for Longitudinal Restraints

<u>RULE #16</u>: Longitudinal seismic restraints for single clevis hung pipe must be attached directly to the pipe in a manner similar to that shown in Figures S1-14 and S1-15. The seismic

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restraints maybe attached to the pipe using a pipe clamp as shown in Figures S1-14 and S1-15, or by using properly sized tabs welded directly to the pipe.

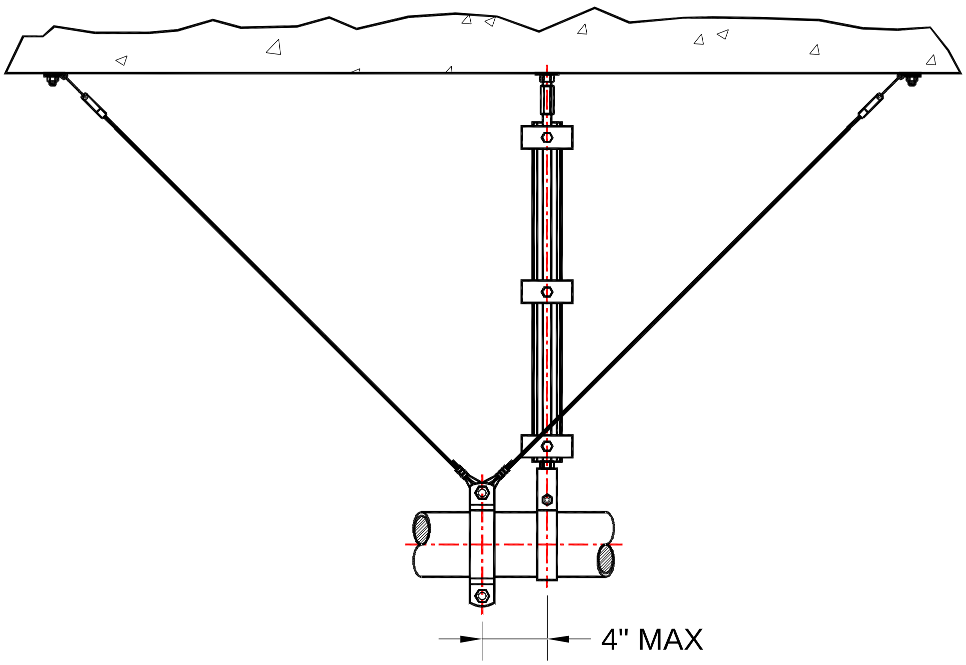

Figure S1-14; Rule #16 – Clevis Hung Pipe with Typical Longitudinal Seismic Cable Restraints

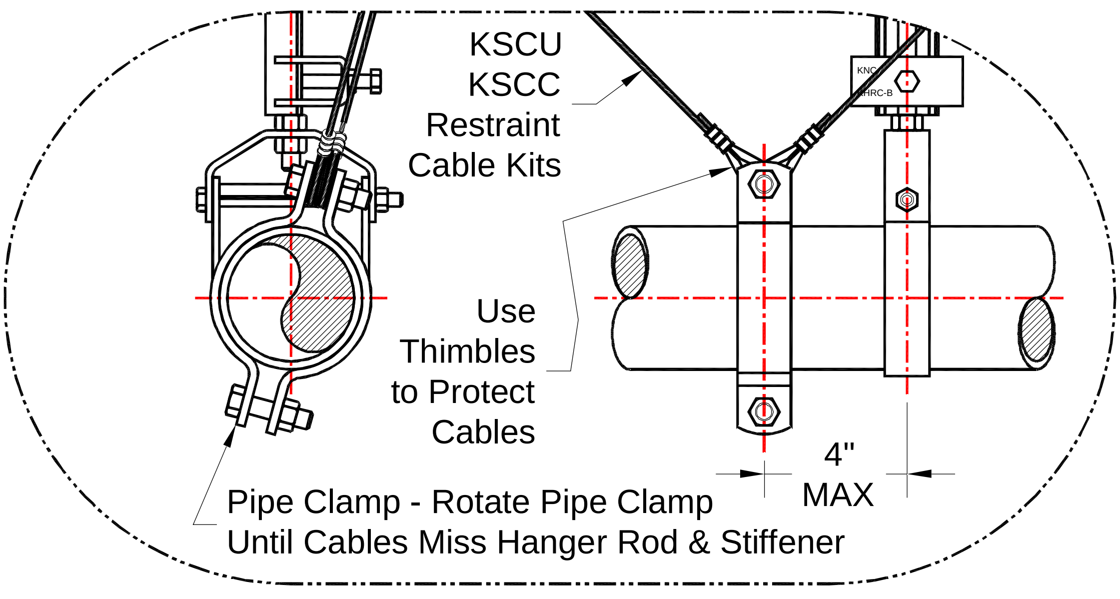

Figure S1-15; Rule #16 – Detail of Typical Longitudinal Cable Restraints for Clevis Hung Pipe

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RULE #17: For hanger rods which are very long or very small in diameter, rod stiffeners may need to be added to prevent buckling of the hanger rods, see Figure S1-16. Only the hanger rods at or near seismic restraint locations will require stiffeners.

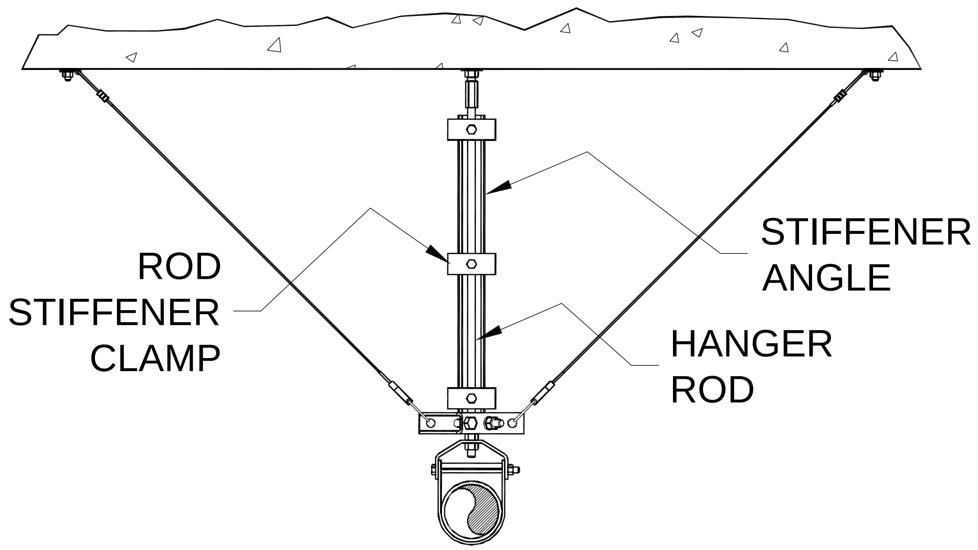

Figure S1-16; Rule #17 – Use of Rod Stiffeners at Seismic Restraint Locations

RULE #18: For isolated pipe or duct, the hanger rods at seismic restraint locations must be fitted with uplift limit stops as shown in Figure S1-13 to allow the compressive reaction loads to be transferred to the building structure.

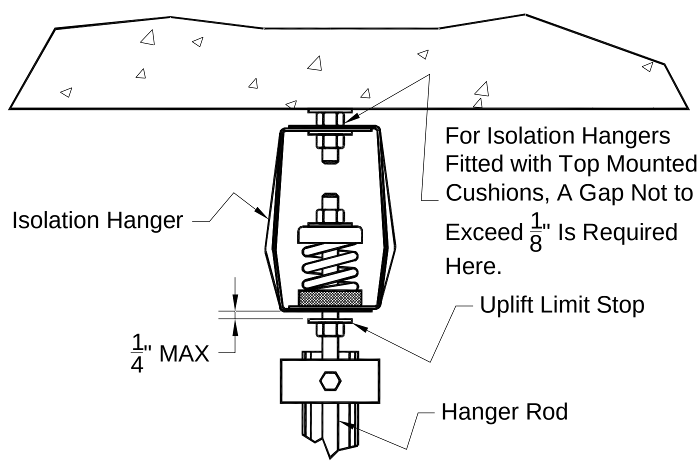

Figure S1-17; RULE #18 – Uplift Limit Stops for Isolation Hangers at Seismic Restraint Locations

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RULE #19: Domestic hot and chilled water piping instructions where there are typically no anchors or guides. However, they often have significant growth or shrinkage in the longitudinal direction that must be accounted for. To avoid problems with overloading the restraints, pipe, or building structure, the longitudinal restraints must be placed as follows.

1. Only one longitudinal restraint can be fitted to a run of pipe. Under normal conditions it should be located in the center of the piping run to allow the pipe to experience unrestrained axial growth or shrinkage at the ends of the run, as shown in Figure S1-18 below. See Section S7.7 of this manual for a description of the symbols used in Figure S1-18. In any case, care must be taken that the restrained length of pipe on each side of the restraint is less than the amount that would cause buckling of the pipe under the expected design horizontal seismic force for the project, see Appendices A6.1, A6.2, and A6.4.
2. If the piping run is long enough that multiple longitudinal restraints are required, an expansion/contraction joint or expansion/contraction loop must be placed between the longitudinal restraints, breaking the long run into several shorter ones, to accommodate the growth or shrinkage of the pipe.

RULE #20: For domestic hot and chilled water piping the distance from a corner to the first transverse seismic restraint, corner distance L_C, must be chosen to prevent the pipe from being overstressed or the transverse seismic restraint form being overloaded as the pipe grows or shrinks. For initial seismic restraint selection and placement, the dimensions for the corner distance in Table S1-4 may be used.

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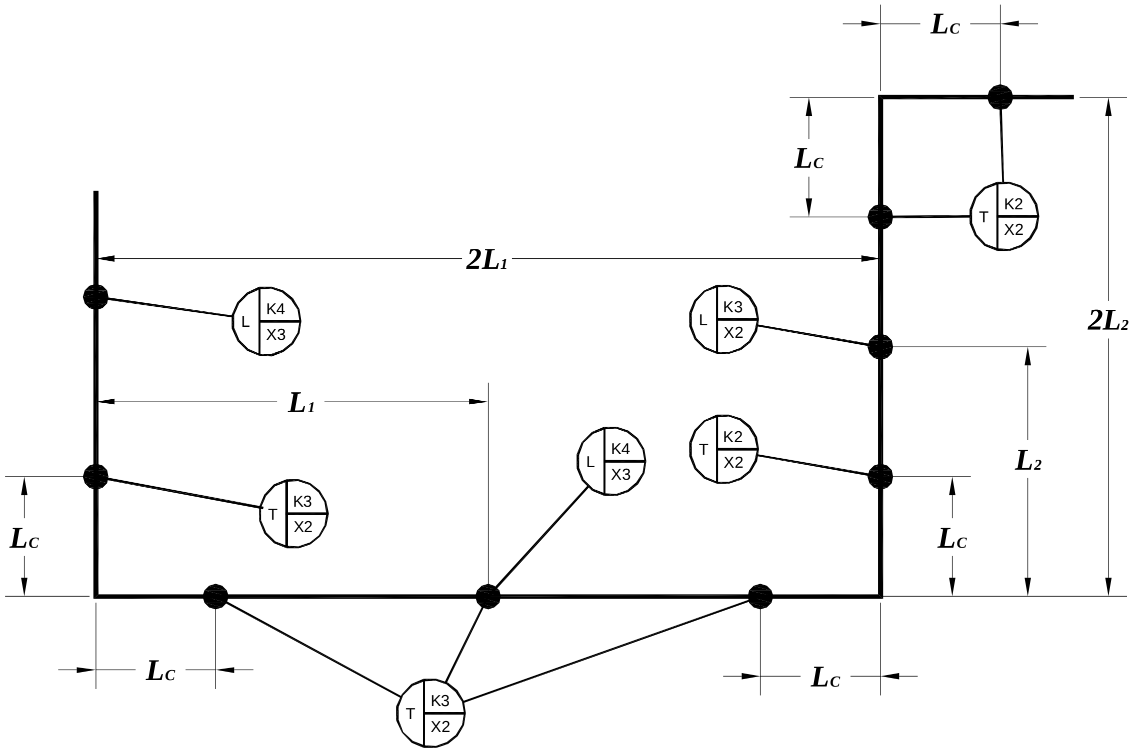

Figure S1-18; Rules #19 & #20 – Typical Seismic Restraint Layout for Domestic Hot & Chilled Water

Table S1-4; Rule #20 – Basic Corner Distance for Domestic Hot & Cold Water Piping to First Transverse Seismic Restraint for Distances from the Corner to the Longitudinal Restraint Up to and Including 40 ft and Temperature Differences Up to and Including 80° F.

Applicable Pipe/Tubing Size Range (in)	Distance From Corner To Transverse Seismic Restraint L_C (ft)
3/4 to 2-1/2	5
3 to 10	10
11 to 22	15

For conditions beyond the ranges specified above, use the formulae provided in Section S9.5 or the tables in Appendix A2.6 of this manual.

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RULE #21: Unless provisions are made in the design of the run of pipe or duct, the seismic restraints for the pipe or duct ***must*** attach to a part of the building structure that will have the same relative motion as the part of the building that is supporting the pipe or duct. This statement may be simplified by saying that the pipe or duct support system and the seismic restraint system must be connected to the building structure at the same elevation. This means that:

1. Suspended pipe and duct ***must be*** restrained to the same overhead structure that is supporting the pipe or duct.
2. Pipe and duct supported by "floor stands" ***must be*** restrained to the same floor structure that is supporting the stands.

The reason for this rule is that, during an earthquake, a floor will move independently of the ceiling structure above it. So, pipe and duct that are supported by floor stands ***may not*** be restrained to the ceiling above them.

RULE #22: Piping systems, duct systems, and equipment which could normally be designated I_P**=1.0**, but which have been suspended above fire protection piping or other essential or hazardous must be re-designated to have an I_P**=1.5**, and be restrained accordingly. When planning for seismic restraints for MEP systems and components check with the fire protection design professional of record or other responsible individuals to see if there are any systems that must be re-designated I_P**=1.5**.

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SEISMIC RESTRAINT FOR DRAIN, WASTE, AND VENT LINES

S10.1 – Introduction:

Waste, drain, and vent lines typically do not hold pressure; nor do they run completely full all the time. Typically the materials used for the manufacture of the pipes used for waste and drain lines are cast iron, steel, or PVC plastic. These materials are usually considered to be low deformability, brittle, materials. Also, the fittings used to connect the sections of pipe are traditionally slip type fittings. Therefore, extra care must be used when restraining waste, drain, and vent lines.

S10.2 – Restraint Locations for Drain, Waste, and Vent Lines:

Because these lines carry little if any pressure and do not normally run full, there is no real need to rigidly connect the pipe joints together. Pipes that are intended to carry pressure and run full a usually joined using threaded fittings, welding, soldering, brazing, or "grooved" type couplings Cast iron drain, waste, and vent lines usually have "slip type" couplings. Hub type pipes have a hub on one end with an I. D. that is just slightly larger than the O. D. of the pipe. The hub less end of one pipe goes into the hub end of the other pipe with some type of seal. Pipes without a hub are joined together with a flexible coupling that slips over the O. D. of the pipes and is clamped with band clamps. This is called a No-Hub pipe coupling, and will be discussed more fully in Section S10.5. PVC drain, waste, and vent lines are usually joined with socket type fittings whose joints are solvent welded. In general, hub type and No-Hub type fittings can not be counted on to carry tensile longitudinal loads. The plastic pipe and fittings are considered to be made from low deformability materials. This is because the solvent weld joints are certainly more brittle than the surrounding material and because the plastic itself has a lower modulus of elasticity and flexure strength that do its metal counterparts.

The problem with joining pipe with slip type fittings is that during an earthquake a run of drain, waste, or vent pipe could be placed in differential motion where two adjacent sections of would

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move in opposite directions. In this case the possibility of having the drain or waste line separate and empty in to living space is very real. Since, the materials used for the pipes in waste and drain lines are typically low deformability materials, that are brittle and can not tolerate large deflections, and the connections are suspect drain, waste, and vent lines require more restraints than other types of piping associated with normal construction. Figure S10-1 shows what might be a typical portion of a run of waste or drain line.

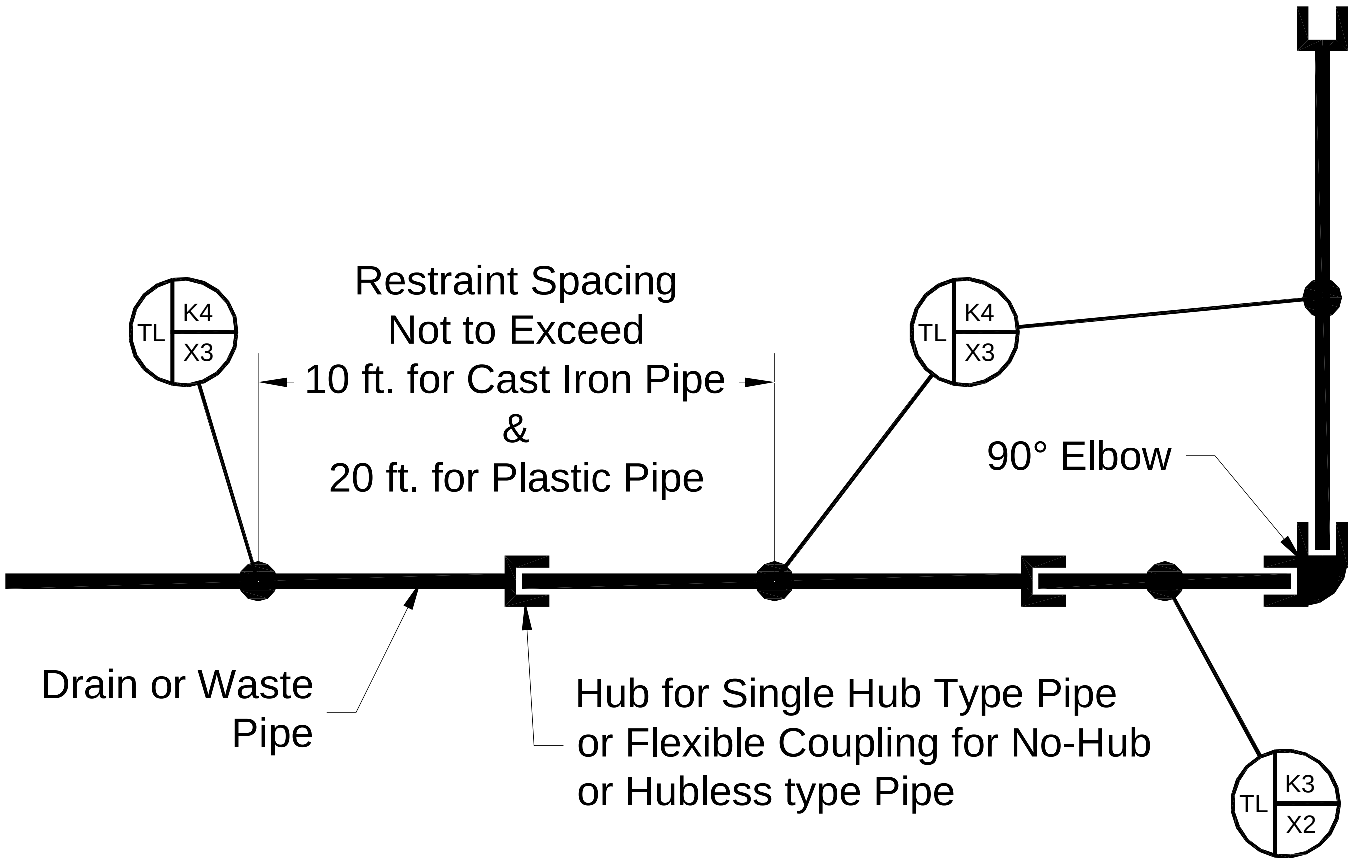

Figure S10-1; Typical Seismic Restraint Scheme for Drain and Waste Lines

Referring to Figure S10.1, drain, waste, and vent lines must be seismically restrained in the following manner.

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1. Each joint of drain, waste, and vent line must have at least one transverse and one longitudinal seismic restraint.
2. Even if adequately braced in accordance with this section the spacing between transverse restraints must not exceed 10 feet for cast iron pipe and 20 feet for PVC plastic pipe due to the brittle nature and low mechanical properties of the pipe material itself.
3. Seismic restraints must be located at or very near the support hangers for the drain, waste, or vent line, and this hanger must be capable of transferring compressive loads. See Section S1.0 RULE #3.
4. Longitudinal seismic restraints are not to be attached to a clevis hanger. They should be attached to the pipe as described in Section 1.0 RULE #16.
5. Section S1.0 RULE #9 ***does not*** apply to drain, waste, and vent piping.

S10.3 – Sizing Seismic Restraints for Drain, Waste, and Vent Lines:

Since these types of lines are typically empty, it is fair to select the seismic restraints based on something less than the filled pipe weight. It is recommended, however, that the seismic restraints for drain and waste lines be selected based on the pipes being at least half full of water. The seismic restraints for vent lines, however, may be based on the empty pipe weight. The weights of the pipe typically used for drain, waste, and vent lines are provided in Appendices A2.3 and A2.4.

S10.4 – Underground Buried Drain, Waste, and Vent Lines:

Drain, waste, and vent lines that are buried underground do not require additional seismic restraint. The soil compacted around the pipes will keep them moving together with the ground motion, and prevent separation. Any ground motion that causes excess differential transverse motion will fail the pipes whether they are restrained or not.

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S10.5 – No-Hub Pipe Couplings for Seismic Applications:

No-Hub piping utilizes straight joints of steel, plastic, or hub less cast iron pipes that are joined together by a slip "sleeve" type No-Hub coupling. An example of this type of pipe joint is illustrated in Figure S10-2. A No-Hub coupling consists of a "hose" that slips over the ends of the mating pipes. This "hose" is often covered by some type of corrugated stainless steel shield. The "hose" and shield are clamped to the pipes with band type clamps that are tightened to a specified torque level. The No-Hub coupling is still a slip type joint that is held together by friction forces between the pipe and the gasket.

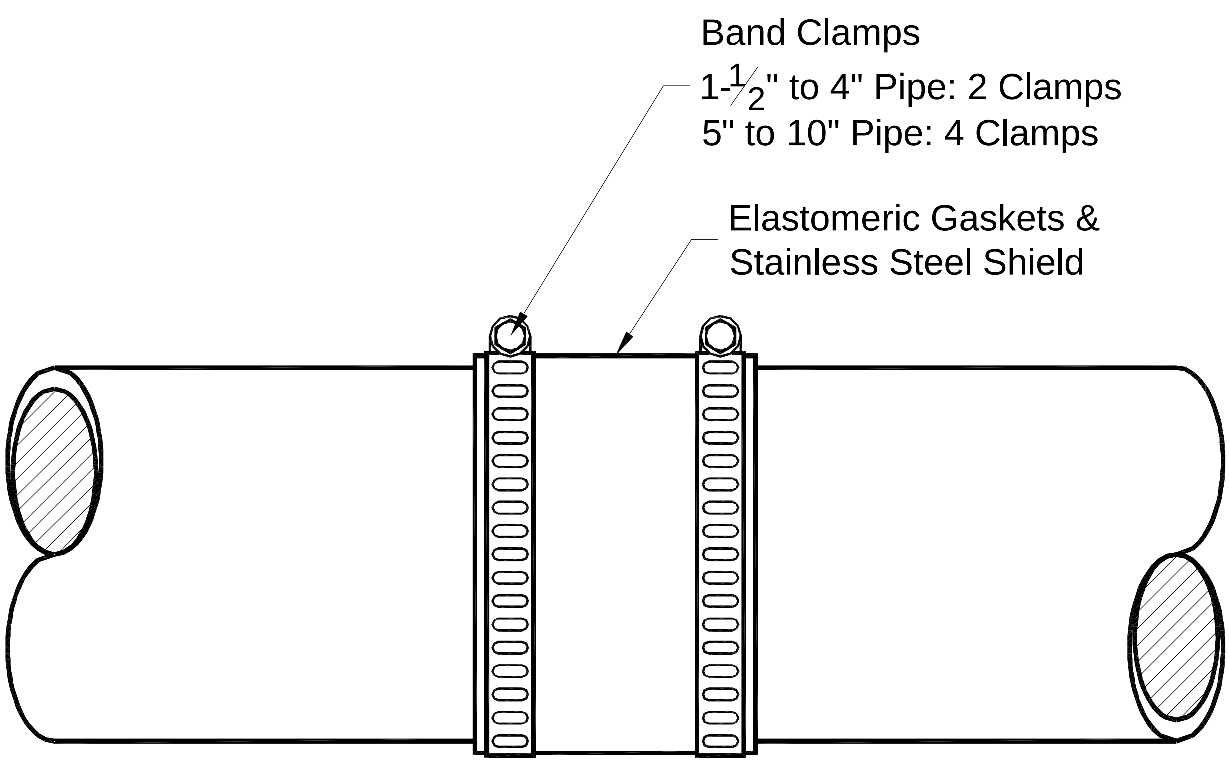

Figure S10-2; Typical Standard No-Hub Pipe Coupling

For seismic applications where the failure of the waste, drain, or vent lines could render an essential facility uninhabitable or inoperable, the level of safety that is provided by the standard No-Hub coupling, even with restrained piping is not considered to be sufficient. This is primarily

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due to a lack of redundancy with the band clamps providing the frictional resistance that maintains the joint integrity. ASHRAE's A Practical Guide to Seismic Restraint[1] recommends doubling the number of band clamps that secure the shield and gasket to the ends of the pipes. This may be accomplished by specifying heavy duty No-Hub couplings similar to that shown in Figure S10-3.

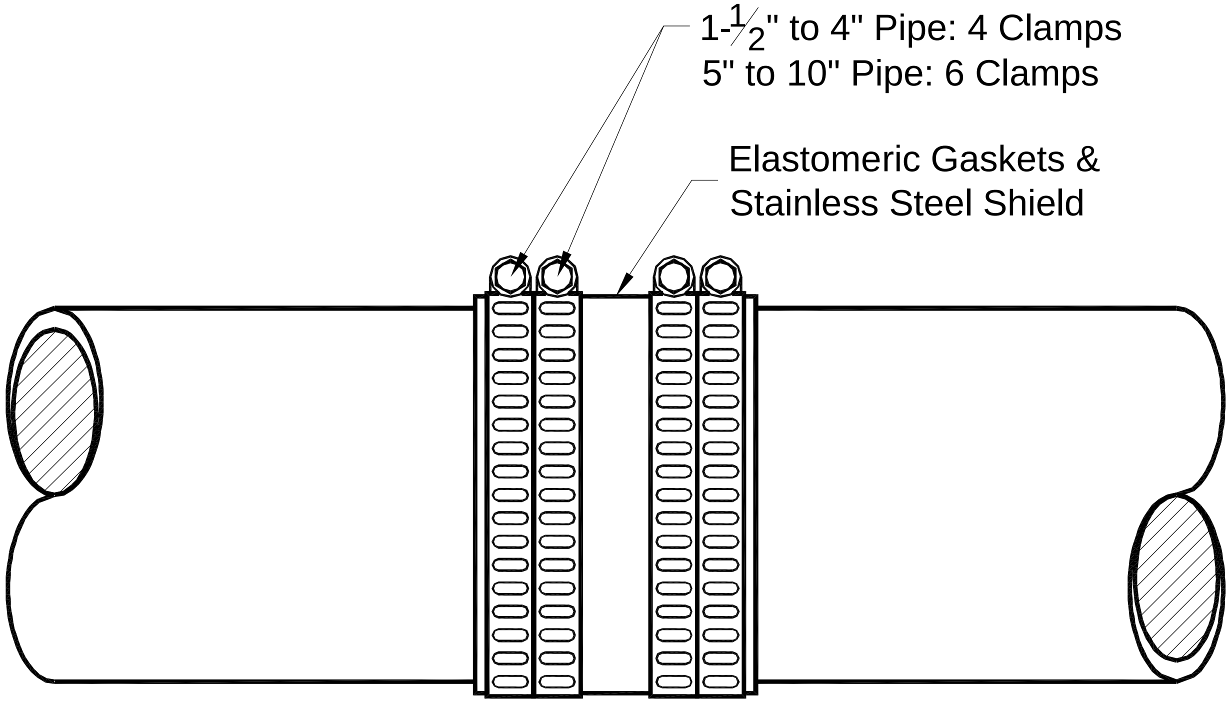

Figure S10-3; Typical Heavy Duty No-Hub Pipe Coupling

S10.6 – Reducing the Number of Restraints for Drain, Waste, and Vent Lines:

In order to reduce labor and material costs, there is always an interest in reducing the number of seismic restraints used for a run of pipe. With drain, waste, and vent lines, this is difficult, and can be accomplished only with proper planning.

[1] Tauby, James R.; Lloyd, Richard; Noce, Todd; and Tünnissen, Joep; A Practical Guide to Seismic Restraint; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, Georgia 30329, 1999.

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The first technique will apply to both hub type pipe and No-Hub pipe. It may be used when the run consists of more than two joints of pipe, and involves longitudinally "trapping" one joint of pipe between two others, see Figure S10-4 below. The longitudinal restraints on the two end joints of pipe trap and longitudinally restrain the center joint of pipe. This eliminates the need for a longitudinal restraint on the center joint of pipe. The center joint of pipe must still have a transverse restraint due to the fragile nature of the pipe couplings.

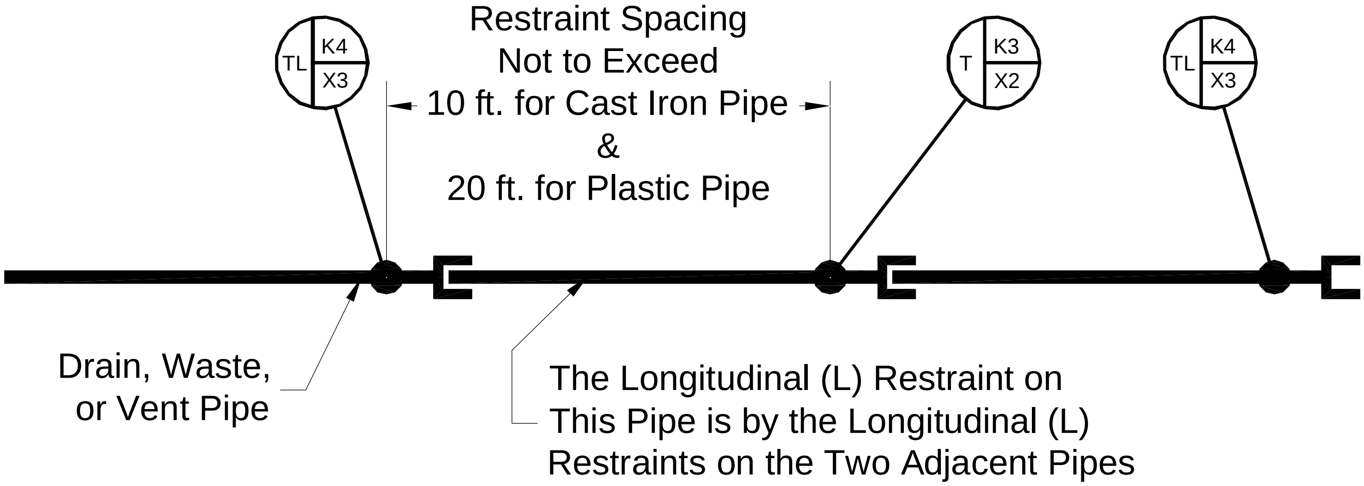

Figure S10-4; Reducing Longitudinal Restraints by "Trapping" a Joint of Pipe between Two Longitudinally Restrained Joints of Pipe

The second technique will also apply only to No-Hub and hub type pipe. For No-Hub pipe this technique involves the use of either a 16 gage steel half sleeve around the No-Hub coupling that is clamped to the pipe on each side of the coupling or two pipe clamps and two spacer bars. For hub type pipe the technique will involve the use of two pipe clamps and two spacer bars. Both of these methods have been proposed by SMACNA.[2] These arrangements are intended to carry the tensile longitudinal seismic loads across the coupling. A possible detail of the arrangement using the 16 gage steel half sleeve and clamps with No-Hub pipe is shown in Figure S10-5. The pipe clamps and spacer bars with No-Hub pipe is shown in Figure S10-6. Finally the pipe clamps and

[2] SMACNA; Seismic Restraint Manual – Guidelines for Mechanical Systems, 3rd Edition – March 2008; Sheet Metal and Air Conditioning Contractors' National Association, Inc. 4201 Lafayette Center Drive Chantilly, VA 20151-1209; Pp 10.10 and 10.11.

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spacer bars with hub type pipe is shown in Figure S10-7. The half sleeve and pipe clamps with spacer bars can be used to reduce the number of restraints required as shown in Figure S10-8. Because the two joints of pipe are "hard" connected via the half sleeve or pipe clamps with spacer bars, the longitudinal restraint on the joint of pipe on the left may be eliminated. The following rules should be applied for restraint spacing when a half sleeve or two pipe clamps with spacer bars are used to bridge across a No-Hub or hub type coupling to eliminate one longitudinal restraint.

1. For cast iron pipe in 10' long joints: Transverse Restraint Spacing = 10' Maximum & Longitudinal Restraint Spacing = 20' Maximum.
2. For PVC & CPVC pipe in 20' long joints: Transverse Restraint Spacing = 20' Maximum & Longitudinal Restraint Spacing = 40' Maximum.

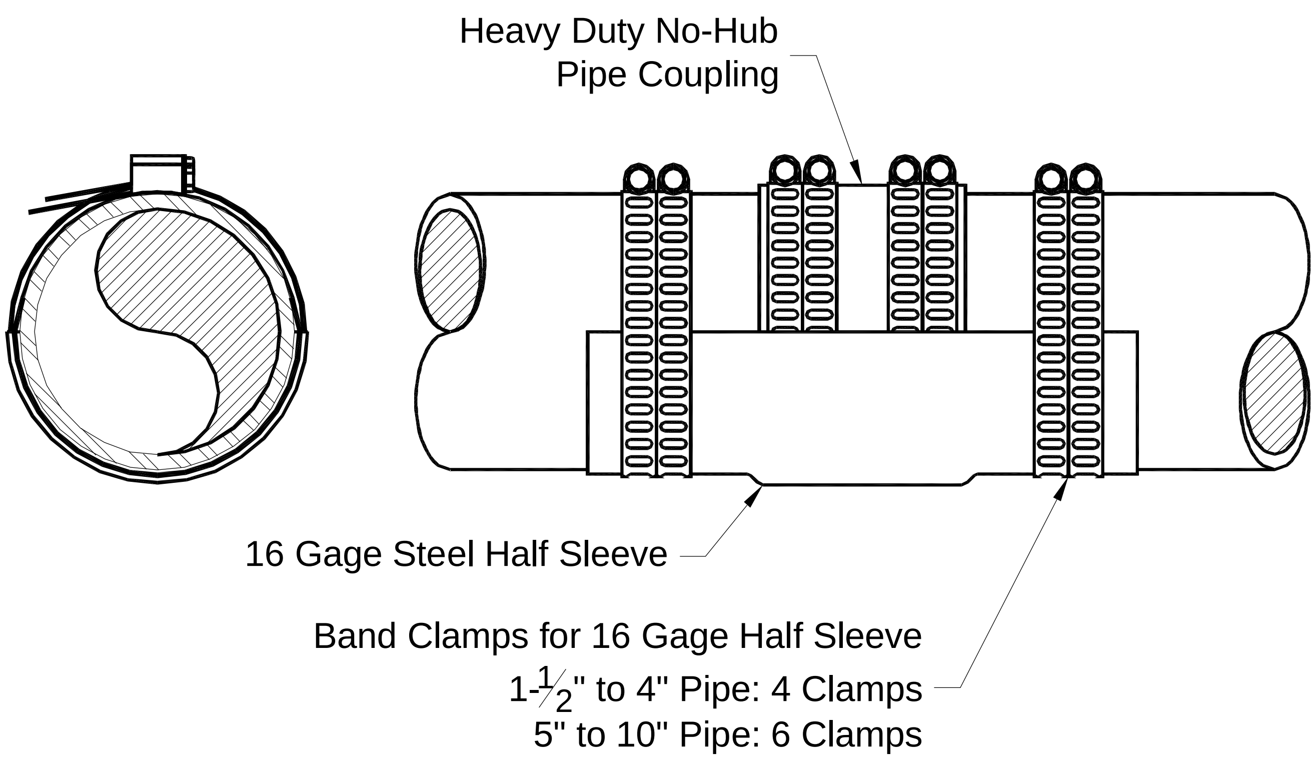

Figure S10-5; 16 Gage Steel Half Sleeve to Carry Seismic Tensile Loads Across a No-Hub Coupling

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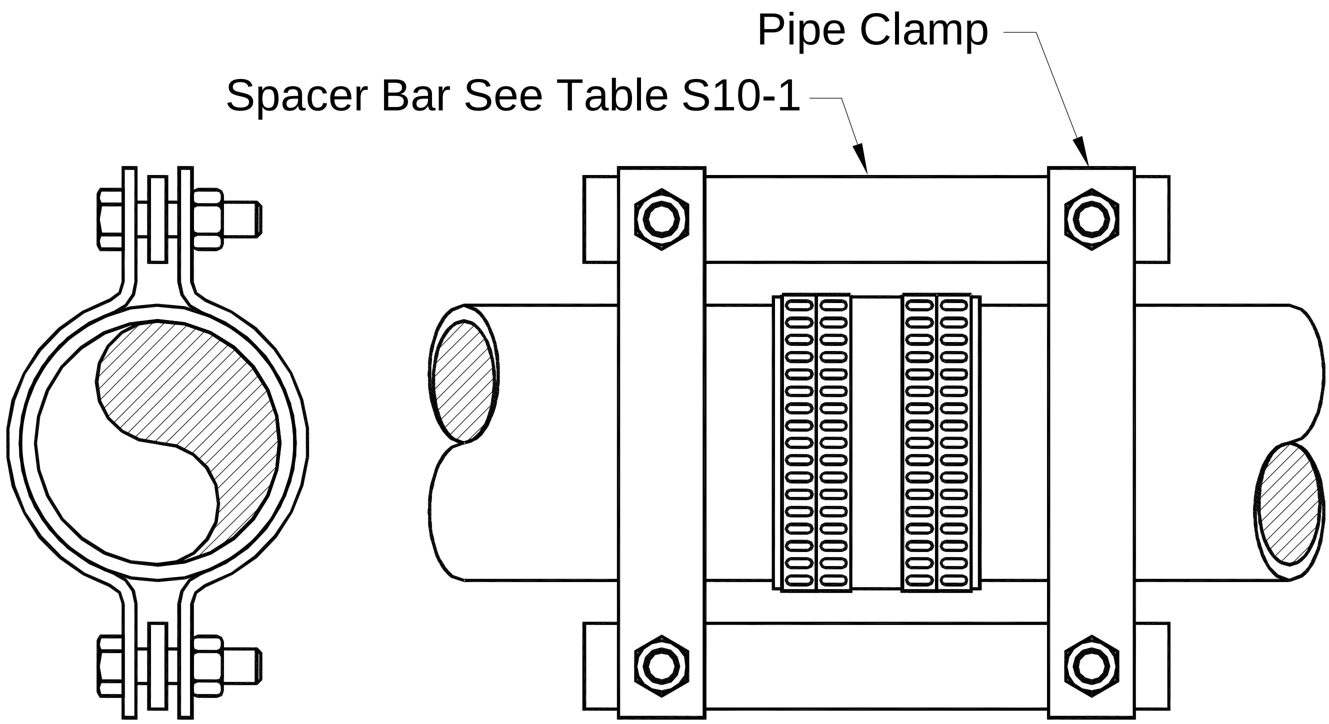

Figure S10-6; Two Pipe Clamps with Two Spacer Bars to Carry Seismic Tensile Loads Across a No-Hub Coupling

Table S10-1; Space Bar Section Sizes for Figures S10-6 and S10-7 – Length of Bars per Application[2]

Pipe Size (in)	Spacer Bar Size (in)
Up to 2	1/4 x 1-1/4
2-1/2 to 3	1/4 x 1-1/4
4 & 5	1/4 x 1-1/4
6	3/8 x 1-1/2
8	3/8 x 1-1/2

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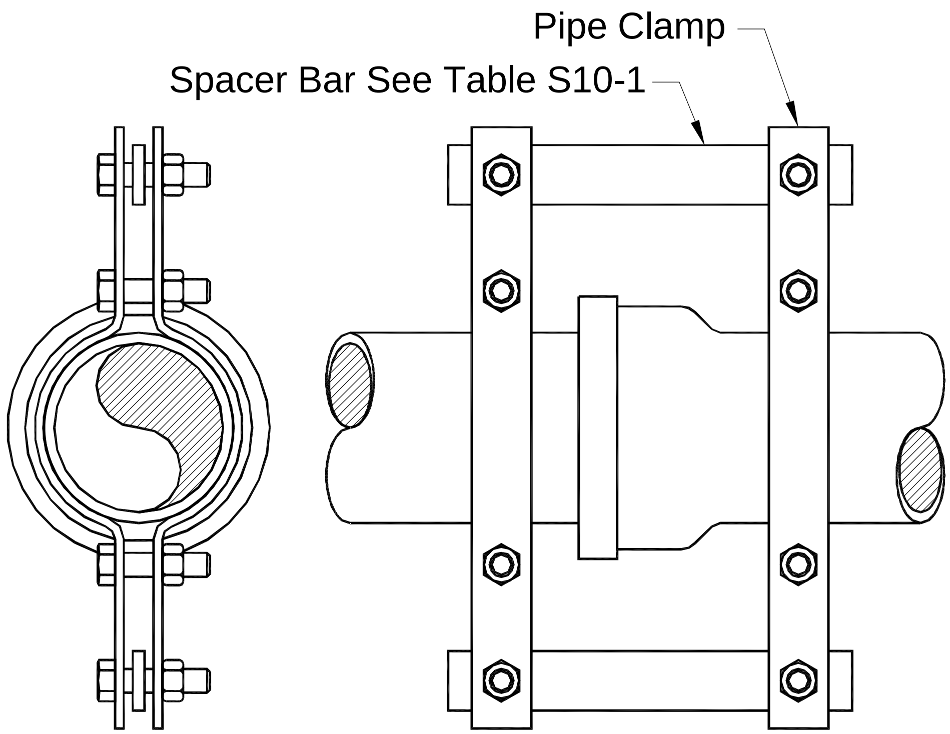

Figure S10-7; Two Pipe Clamps with Two Spacer Bars to Carry Seismic Tensile Loads Across a Hub Type Coupling

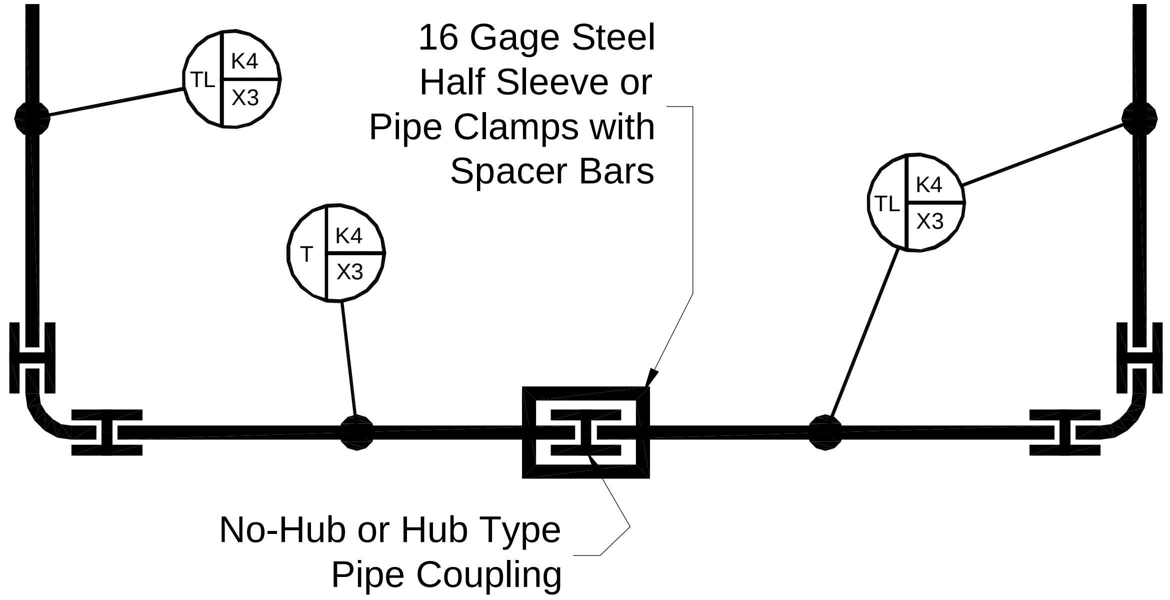

Figure S10-8; Application #1 of the 16 Gage Steel Half Sleeve

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When other lines Tee into a run of pipe, the half sleeve should be used to bridge across all of the fittings between hanger locations to eliminate the need to individually restrain the fittings as shown in Figure S10-9.

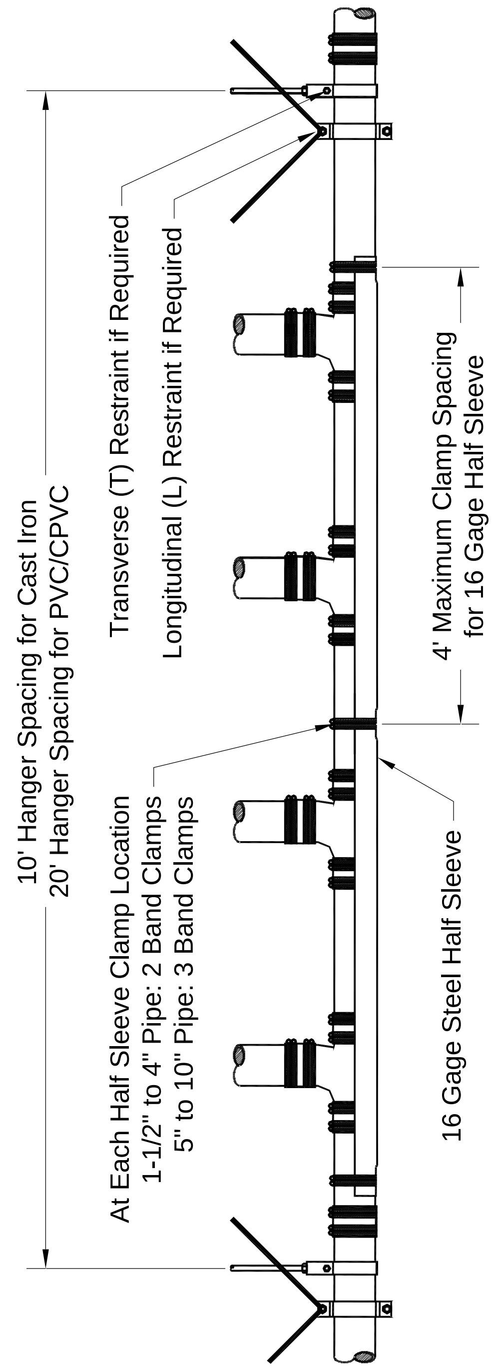

Figure S10-9; 16 Gage Steel Half Sleeve Used to Carry Tensile Loads Across Many Fittings

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SEISMIC RESTRAINT SPACING FOR PIPE AND DUCT

S11.1 – Introduction:

The SMACNA Seismic Restraint Manual – Guidelines for Mechanical Systems 3rd Edition has been an industry standard for many years. And, even though it is not specifically identified as a reference document for 2006/2009 IBC, ASCE/SEI 7-05, it is still widely accepted in most jurisdictions. The seismic restraint spacing traditionally used for piping and ductwork were developed by SMACNA, and represent the experience accumulated across the industry.

In reality the actual seismic restraint spacing used in any particular application will depend on several variables, of which the following four are probably the most important.

1. The buckling strength of the pipe or duct between the longitudinal seismic restraints.
2. The weight of the pipe or duct being restrained.
3. The capacity of the seismic restraints being used for the project.
4. The hanger rod spacing along the run of pipe or duct.

This section will determine the maximum allowable seismic restraint spacing for pipe and duct between the longitudinal seismic restraints. It will begin by examine the seismic restraint spacing requirements for pipe and duct developed by SMACNA.

S11.2 – Seismic Hazard Level SHL:

The seismic restraint spacing recommended by SMACNA for piping and ductwork is based on the Seismic Hazard Level, SHL. The SHL is related to the design horizontal seismic force defined in the various building codes. The determination of this force for 2006/2009 IBC is discussed in Section 5.0 of this manual. Historically, the code based design horizontal seismic force has had the following form.

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$$F_P = C_S W_P$$ **Equation S11-1**

Where:

F_P = the design horizontal seismic force acting on a pipe or duct acting at its center of gravity.

C_S = the seismic coefficient which represents a combination of various factors defining the expected ground level acceleration, ductility of the piping or ductwork and its attachment to the building, the importance of the piping or ductwork, and the elevation of the attachment of the piping and ductwork to the building's structure.

W_P = the operating weight of the pipe or duct that is being restrained.

SMACNA relates the SHL to the base seismic coefficient, which is defined as;

$$C_S = \left(\frac{F_P}{W_P}\right)$$ **Equation S11-2**

Comparing Equation S11-2 with the general horizontal seismic design force defining equation from ASCE 7-05 (Equation S5-1 of Section 5.0) leads to the following;

$$C_S = \frac{0.4 a_P I_P S_{DS}}{R_P}\left(1 + 2\frac{z}{h}\right)$$ **Equation S11-3**

Where:

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 is expected to be. Typically this will vary from 1.0 to 2.5, and is specified by component type in ASCE/SEI 7-05 and listed in Table S5-3.

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I_P = the component importance factor which be either 1.0 or 1.5.

R_P = the response modification factor which usually will vary from 1.0 to 12.0. 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 values are specified by component type in ASCE 7-05 and listed in Table S5-3.

z = the structural attachment mounting height of the pipe or duct hanger 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.

SMACNA defines the Seismic Hazard Level, SHL, for a project as shown in Table S11-1.

Table S11-1; Seismic Hazard Level Definition

Base Seismic Coefficient C_S	Seismic Hazard Level SHL
$0.75 < C_S \leq 1.00$	A
$0.50 < C_S \leq 0.75$	B
$0.25 < C_S \leq 0.50$	C
$0 \leq C_S \leq 0.25$	D

Note that the piping and ductwork on different floors in the same building can, and probably will, require design under a different seismic hazard level, SHL. Also, it is important to note that the newer building codes such the IBC make it possible to have a base seismic coefficient that exceeds 1.0. In which case, that project, or portion of the project, will not be covered under SMACNA, and will require special design consideration by a qualified design professional.

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S11.3 – SMACNA Seismic Restraint Spacing Recommendations:

S11.3.1 – Rectangular and Round Duct:

Transverse Seismic Restraint Spacing: S_T = 30 ft. Maximum

Longitudinal Seismic Restraint Spacing: S_L = 60 ft. Maximum

S11.3.2 – Single Clevis Supported Pipe and Conduit:

Pipe & Conduit Size ≤ 5″:

Transverse Seismic Restraint Spacing: S_T = 40 ft. Maximum

Longitudinal Seismic Restraint Spacing: S_L = 80 ft. Maximum

6″ ≤ Pipe & Conduit Size ≤ 8″:

Transverse Seismic Restraint Spacing: S_T = 40 ft. Maximum

Longitudinal Seismic Restraint Spacing: S_L = 40 ft. Maximum

10″ ≤ Pipe & Conduit Size ≤ 16″:

Transverse Seismic Restraint Spacing: S_T = 20 ft. Maximum

Longitudinal Seismic Restraint Spacing: S_L = 20 ft. Maximum

S11.3.3 – Trapeze and Floor Rack Supported Pipe:

The seismic restraint spacing recommendations per SMACNA are based on the total weight of the restrained components and assume the following arrangements.

Pipe Size ≤ 5″ – Four Equal Size Pipes per Trapeze Bar (109 lb/ft)

Pipe Size = 6″ – Three Equal Size Pipes per Trapeze Bar (108 lb/ft)

Pipe Size = 8″ – Two Equal Size Pipes per Trapeze Bar (112 lb/ft)

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Any combination of pipe sizes can be used as long as the total combined weight of the pipes on a trapeze bar is less than or equal to the maximum dead load up to 110 lb/ft.

Pipe Size < 4″:

Transverse Seismic Restraint Spacing: S_T = 40 ft. Maximum

Longitudinal Seismic Restraint Spacing: S_L = 40 ft. Maximum

4″ ≤ Pipe Size ≤ 8″:

Transverse Seismic Restraint Spacing: S_T = 20 ft. Maximum

Longitudinal Seismic Restraint Spacing: S_L = 20 ft. Maximum

The SMACNA seismic restraint spacing recommendations do not appear to take into account the gross buckling of the pipe or duct, and have been simplified to apply to all Seismic Hazard Levels.

11.4 – Maximum Seismic Restraint Spacing Based on the Gross Buckling:

Buckling failure of long slender structures such as pipe can be catastrophic and occur at stresses much lower than the yield point of the material. Also, for thin walled structures, localized buckling may determine the compressive failure load limit which may be lower than the load limit predicted by classical buckling theory. Also, for gross buckling some pipes and ducts, because of their relatively large cross-section may fall in to the "short column" realm, and again would not be covered by classical buckling theory. Failure modes such as local buckling and short column buckling are outside of the scope of this treatise, and should be investigated on a case by case basis. The intent of this section is to determine the validity of the SMACNA seismic restraint spacing recommendations for various pipe cross-sections and materials, and standard duct cross-sections base on the gross buckling of a long "Euler" column.

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At question here is not necessarily the maximum spacing between longitudinal seismic restraints, but how much pipe or duct can be handled by one set of longitudinal seismic restraints without the danger of buckling. This scenario is typified by the run of pipe or duct that has one set of longitudinal seismic restraints at one end of the run. The pipe and duct does not form a "column" with the axial load concentrated at the ends. Rather the axial load is evenly distributed along the length of the column, which is shown in Figure S11-1.

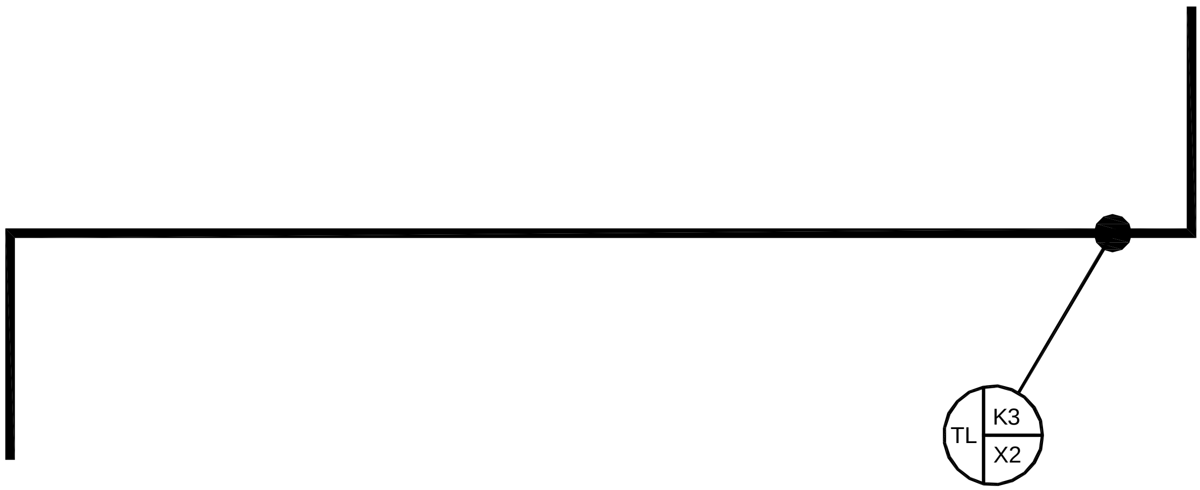

Figure S11-1; Typical Model for Determining the Maximum Length of Pipe or Duct That Can Be Supported by a Single Set of Longitudinal Seismic Restraints.

With the transverse and longitudinal seismic restraints located on the right end of the run, the run will behave as though that end were pinned. The left end of the run can be considered to be free. The analytical model of this situation is shown in Figure S11-2. The weight of the pipe will induce a bending stress in the pipe which would significantly shorten the length of the pipe or duct that can be supported by the longitudinal seismic restraints. However, that form of the analysis would be outside the bounds of an elastic stability analysis and would be too complicated for the purposes of this section. Instead, a healthy factor of safety will be imposed on the applied load to account for the effects of the weight of the pipe, and any other unknowns concerning the end conditions of the run of pipe.

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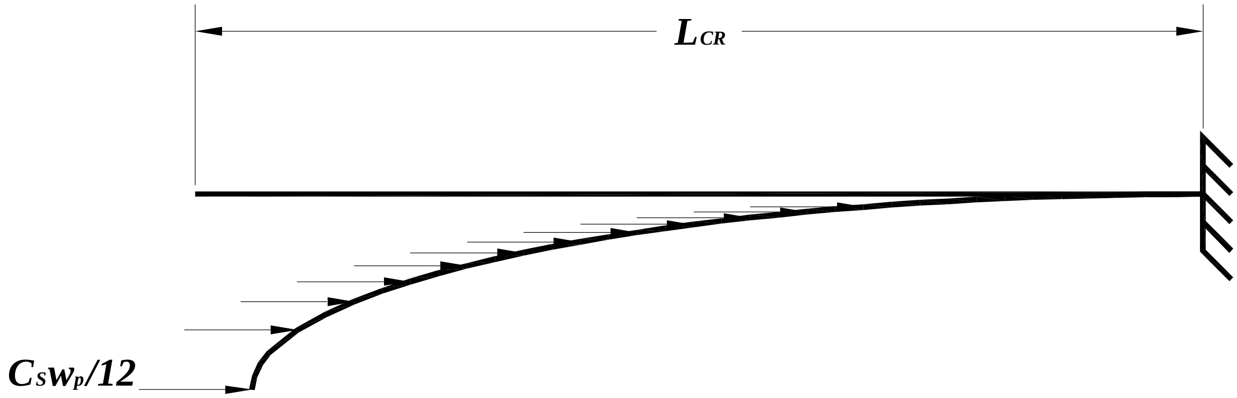

Figure S11-2; Seismic Gross Buckling Model for Pipe and Duct

Euler's buckling equation for this situation may be found in the following reference.

Hsu, Teng S.; Stress and Strain Data Handbook – Graphs, Tables, and Worked Examples for Design Engineers, Gulf Publishing Company, Huston, Texas, 1986; Pp 342-343.

The critical buckling load for the model in Figure S11-2 according to Hsu is;

$$p_{cr} L = \frac{C\pi^2 EI}{L^2}$$ **Equation S11-4**

Where:

p_{cr} = the critical distributed compressive load acting along the length column (lb/in).

L = the length of the column (in).

C = a constant determined by the loading and the end conditions.

E = the modulus of elasticity for the column material (psi).

I = the minimum area moment of inertia of the column cross-section (in^4).

In the case of the column shown in Figure S11-2, these variables will become;

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$$p_{cr} = \frac{C_S w_P}{12}$$ **Equation S11-5**

$$L = L_{cr}$$ **Equation S11-6**

Where:

w_P = the weight of the distributed pipe or duct (lb/ft).

L_{cr} = the critical length of the pipe or duct that can be supported by one set of longitudinal restraints without the fear of gross buckling (in).

Let:

N = the factor of safety with respect to the applied load.

From Table 11-1 of Teng, the value of C for the situation shown in Figure S11-2 will be $C = 0.794$. Equation S11-4 may now be rewritten as;

$$\frac{C_S w_P L_{cr}}{12} = \frac{C\pi^2 EI}{NL_{cr}^2}$$ **Equation S11-7**

Then;

$$L_{cr}^3 = \frac{12C\pi^2 EI}{NC_S w_P}$$ **Equation S11-8**

And;

$$L_{cr} = \sqrt[3]{\frac{12C\pi^2 EI}{NC_S w_P}}$$ **Equation S11-9**

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In practical terms, Equation S11-9 represents the distance from the transverse and longitudinal restraints on the right hand end of the run of pipe or duct in Figure S11-1 to the next transverse seismic restraint at the left hand end of the pipe or duct that would stabilize the pipe or duct and prevent the deflection that would precipitate gross buckling. Since this analysis is intended to cover a wide range of pipe and duct sizes and materials, and due to all of the unknowns, a suitable factor of safety with respect to the applied load is $N = 2.0$. Substituting this factor of safety and the value for C into Equation S11-9, the maximum allowable transverse seismic restraint spacing will be determine by Equation S11-10 or 40 ft. which ever is less.

$$S_T = \left(\frac{1}{12}\right)\sqrt[3]{\frac{4.764\pi^2 EI}{C_S w_P}}$$

Equation S11-10

The maximum allowable longitudinal seismic restraint spacing will be twice the value determined by Equation S11-10 or 80 ft. which ever is less. The addition of a transverse restraint at the spacing indicated by Equation S11-10 would stabilize the column formed by the pipe, essentially making it a guided column. Having the longitudinal seismic restraint spacing to be twice that of the transverse seismic restraint spacing will ensure that the stability of the pipe column is not compromised. Note; these findings do not affect the application of Rules #5, #6, #7, #8, #9, #10, or #11 of Section S1.0 of this manual.

11.5 – Discussion and Summary:

The results from Equation S11-10 for various pipe and duct sizes and materials are tabulated in Appendices A6.1 through A6.6 by Seismic Coefficient and Seismic Hazard Level. These results will be discussed appendix by appendix beginning with Appendix A6.1

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Appendix A6.1:

This appendix is based on single clevis hung standard steel pipe. For pipes with a nominal size that is less than or equal to 5 in. in size SMACNA recommends S_T =40 ft and S_L =80 ft. Note in Tables A6.1-1 through A6.1-4 that for nominal pipe sizes less than or equal to 2 in. that there may be instances where the SMACNA recommended spacings are too large. Kinetics Noise Control recommends that for these smaller pipe sizes, the maximum allowable transverse restraint spacing from the tables be used to prevent buckling of the pipes during a seismic event.

For nominal pipe sizes that are greater than or equal to 6 in. and less than or equal to 8 in., SMACNA recommends that $S_T = S_L$ =40 ft. This is consistent with the recommendations found in Tables A6.1-1 through A6.1-4, and indicates that the longitudinal seismic restraint spacing in SMACNA for these pipe sizes is limited by the capacity of the seismic restraints and attachment hardware specified by SMACNA.

For nominal pipe sizes that are greater than or equal to 10 in. and less than or equal to 16 in., SMACNA recommends that $S_T = S_L$ =20 ft. This recommendation also appears to be based on the capacity of the restraints and attachment hardware specified by SMACNA.

Appendix A6.2:

This appendix is based on single clevis hung fire protection piping. The comments made concerning the standard steel pipe in the discussion for Appendix A6.1 will also apply here. The transverse seismic restraint spacing recommendations made in NFPA 13 for fire protection piping should be followed unless the spacings indicated in Tables A6.2-1 through A6.2-6 are less and therefore, more stringent. Pay careful attention to fire protection piping systems utilizing copper pipes o the CPVC sprinkler piping such as BlazeMaster®. Due to the difference in material properties, these types of pipes have much lower critical buckling loads than steel pipes of an

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equivalent size, and therefore, must have seismic restraints placed closer together to prevent buckling under longitudinal seismic loads.

Appendix A6.3:

This appendix is for single clevis hung cast iron soil and drain pipe. The actual spacing of the restraints for this type of pipe will depend on the actual lengths of the sections of pipe, see Section S10.0 of this manual for the restraint of waste (soil), drain, and vent lines. The transverse seismic restraint spacing for the cast iron soil pipes must not exceed that shown in Appendix A6.3 Tables A6.3-1 through A6.3-9.

Appendix A6.4:

This appendix is based on single clevis hung PVC and CPVC pipe. The mechanical properties of PVC and CPVC that control bending and buckling are two orders of magnitude less than those for steel. The decrease in weight does not offset the loss in strength, and for many cases, the maximum allowable transverse seismic restraint spacing for a given pipe size is much less than that recommended by SMACNA for steel pipe. So, SMACNA recommendations for seismic restraint spacing on PVC and CPVC piping systems should not be followed blindly. Caution must be used when sizing, selecting, and locating seismic restraints for PVC and CPVC piping systems. Tables A6.4-1 through A6.4-20 covers several different conditions and applications for PVC and CPVC pipe.

Appendix A6.5:

This appendix applies to single clevis hung copper water piping. The mechanical properties of copper that control the bending and buckling of the pipe are approximately half of those for steel pipe. So, the normal SMACNA recommendations for seismic restraint spacing may not apply to all of the trade sizes for copper water piping. Tables A6.5-1 through A6.5-3 may be used for determining the maximum allowable transverse seismic restraint spacing for an application.

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General Notes for Piping Applications:

1. Where SMACNA recommendations represent the most conservative approach, it is always appropriate to follow the SMACNA recommendations.
2. Minimum seismic restraint spacings specified for special applications in other sections of the manual will apply unless they exceed the maximum allowable transverse seismic restraint spacings tabulated in Appendices A6.1 through A6.5.
3. For trapeze supported piping, the maximum allowable seismic restraint spacing will be determined by the smallest pipe size being supported on the trapeze bar.

Appendix A6.6:

This appendix applies to duct constructed from 22 gage steel sheet metal that has been reinforced to bring its supported weight up to that specified in the SMACNA Seismic Restraint Manual – Guidelines for Mechanical Systems. The maximum allowable transverse seismic restraint spacing in Table A6.6-1 for rectangular duct and in Table A6.6-2 for round duct exceeds the recommended value by SMACNA of S_T =30 ft. The SMACNA recommendation is more conservative and is probably based on local buckling and bending failures in the duct sheet metal. Therefore, it is prudent to use S_T =30 ft. and S_L =60 ft.

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THE 12″ RULE EXPLAINED

S12.1 – Introduction:

The 12″ Rule may be one of the most misunderstood and misapplied rules in the seismic restraint of pipe and duct. It is something that the contractors try to take advantage of at the last possible moment for the following reasons.

1. The contractor was unaware that seismic restraints for the pipe or duct were required before the bid was accepted, and now there is no money available to buy and install seismic restraints for the pipe or duct.
2. Other contractors "have gotten there first", and have left little or no space to install seismic restraints.
3. The contractor is trying to save money and believes this will reduce costs.

There may be many other last minute reasons for trying to apply the 12″ Rule, but these are probably the ones most cited.

The truth concerning the application of the 12″ Rule is that it is very difficult to implement in a consistent fashion. The application of the 12″ Rule for a particular run of pipe or duct requires the knowledge, consent, and participation of all of the design disciplines and installing contractors with components in the immediate vicinity.

S2.2 – Measuring the Distance for the 12″ Rule:

Regardless of any other arrangement, the 12″ dimension is ***always*** measured from the hanger attachment point on the building structure. For single clevis supported pipe the 12″ dimension is measured to the top of the pipe as shown in Figure S12-1. For trapeze supported pipe the 12″ dimension is measured to the top of the trapeze bar in the same fashion demonstrated in Figure S12-2.

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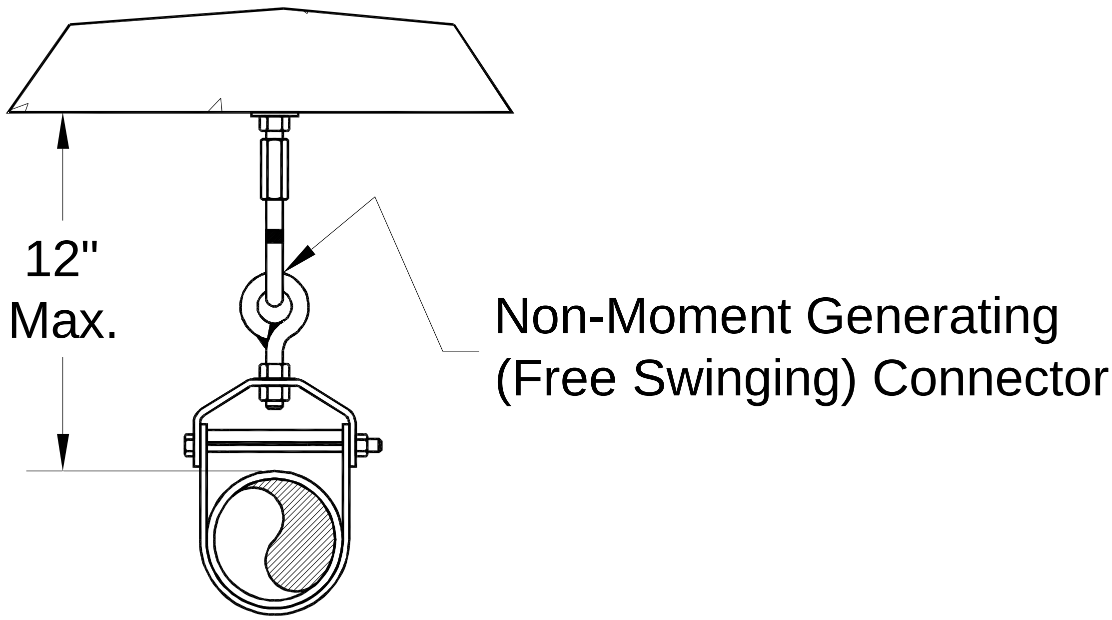

Figure S12-1; Measurement of 12″ Dimension for Single Clevis Supported Pipe

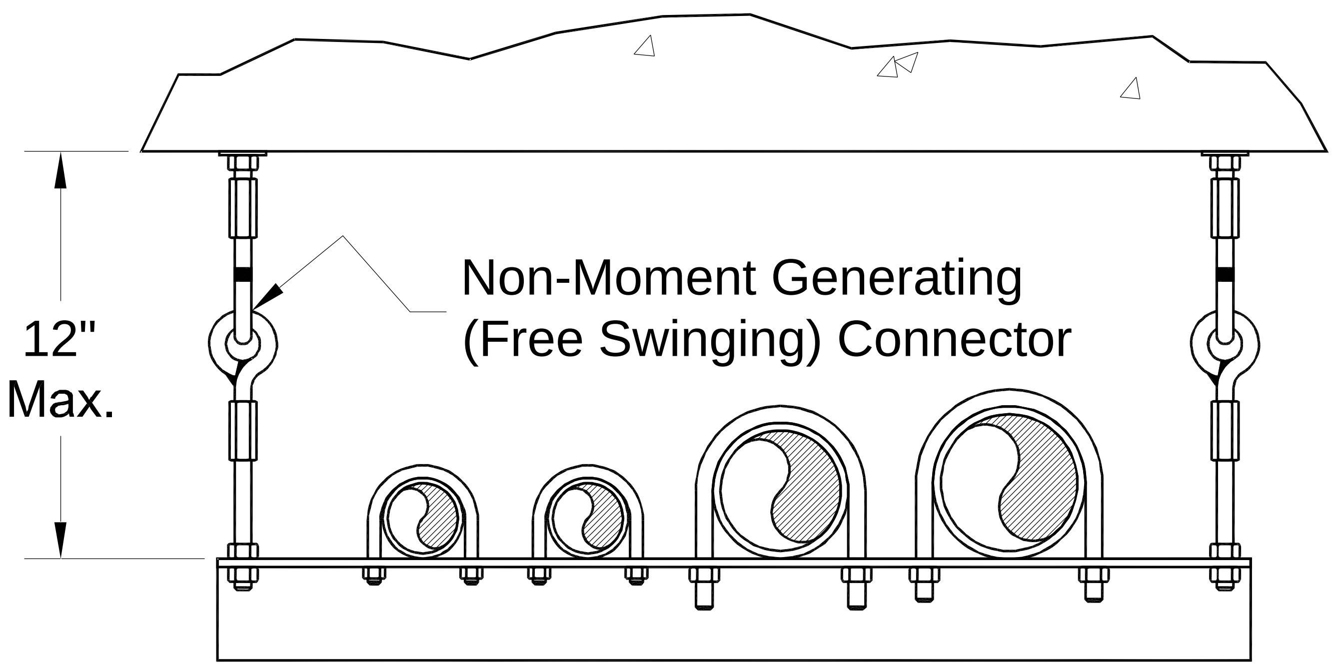

Figure S12-2; Measurement of 12″ Dimension for Trapeze Supported Pipe

For single hanger supported duct, the 12″ dimension is measured to the top of the duct as shown in Figure S12-3. And, finally, for double hanger supported duct the 12″ dimension is measured to

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the attachment point of the hangers to the duct or reinforcing steel. The case of lightweight duct is shown in Figure S12-4 where the 12″ dimension is measured to the top of the duct which for all intents and purposes is the attachment point for the hangers.

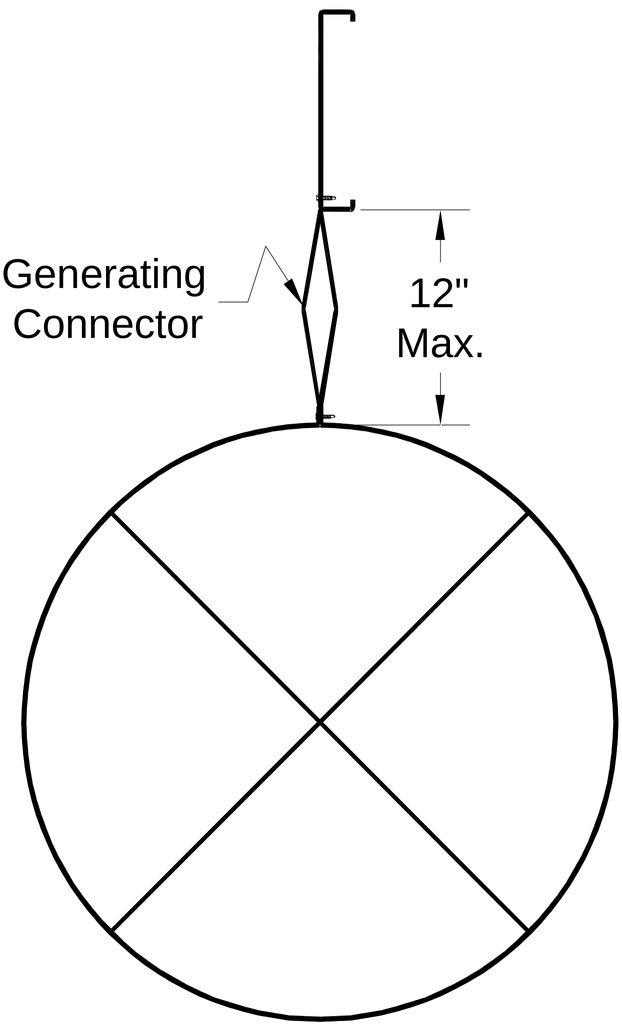

Figure S12-3; Measurement of 12″ Dimension for Single Hanger Supported Duct

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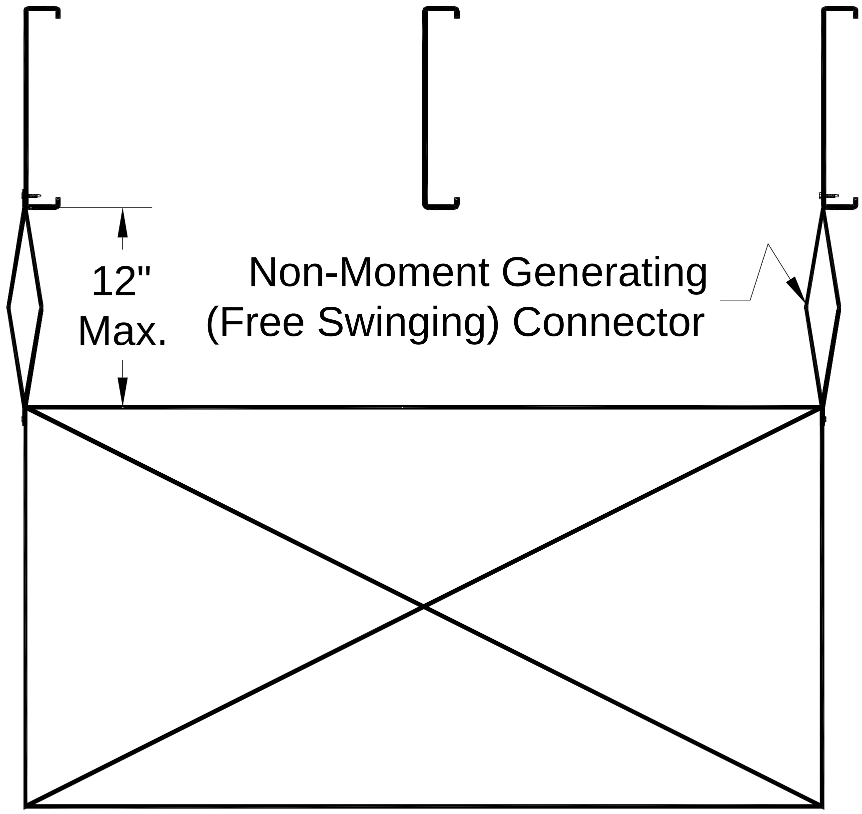

Figure S12-4; Measurement of 12″ Dimension for Double Hanger Supported Duct

S12.3 – Non-Moment Generating (Free Swinging) Connector:

The intent of making use of a non-moment generating connector is to prevent fatigue failure of the hangers during an earthquake or it's after shocks. In 2006/2009 IBC, ASCE/SEI 7-05, this requirement for piping is worded; "the hangers are to be detailed to avoid bending of the hangers or their attachments." For duct the wording in 2006/2009 IBC, ASCE 7-05, is; "the hangers have been detailed to avoid significant bending of the hangers and their attachments."

The intent in both cases is to prevent fatigue of the hanger or its attachments. Kinetics Noise Control has taken the position that if the 12″ Rule is to be applied, it is the responsibility of the design professional of record for the system and the installing contractor to design and/or select and install the non-moment generating connectors for each hanger location. It would be prudent

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for the design professional of record for the system to design and or select the non-moment generating connectors using the same criteria as that used for the "Chandelier Exception" which is found in Section 13.6.1 of ASCE/SEI 7-05. It is also the responsibility of the design professional of record for the system and the installing contractor to ensure that all of the other conditions specified in the code for the application of the 12″ Rule have been met, see Sections S4.3.1 and S4.5.1 of this manual. Primarily included in these requirements are the conditions that the piping system must be free to swing without contacting other components or the structure, and that connections to equipment must be designed to tolerate the maximum expected motions.

12.4 – Types of Non-Moment Generating (Free Swinging) Connectors:

There are various types of connector/hangers which will meet the requirements of the 12″ Rule. Some of these are listed below.

1. Chains.
2. Wire rope hangers.
3. Two forged or welded eyes.
4. Twisted strap hangers.
5. Isolation hangers.

Some of these connector/hangers can be quite long. So, their use at all hanger locations must be verified to avoid having a measurement that exceeds the compliance dimension for the 12″ Rule.

12.5 – The Whole Run and Nothing but the Run:

The title of this section refers to the range of applicability of the 12″ Rule. ***Every hanger*** in a run of pipe or duct ***must*** have a measurement that is ***less than or equal*** to the compliance dimension for the 12″ Rule! This requirement is demonstrated below in Figure S12-5.

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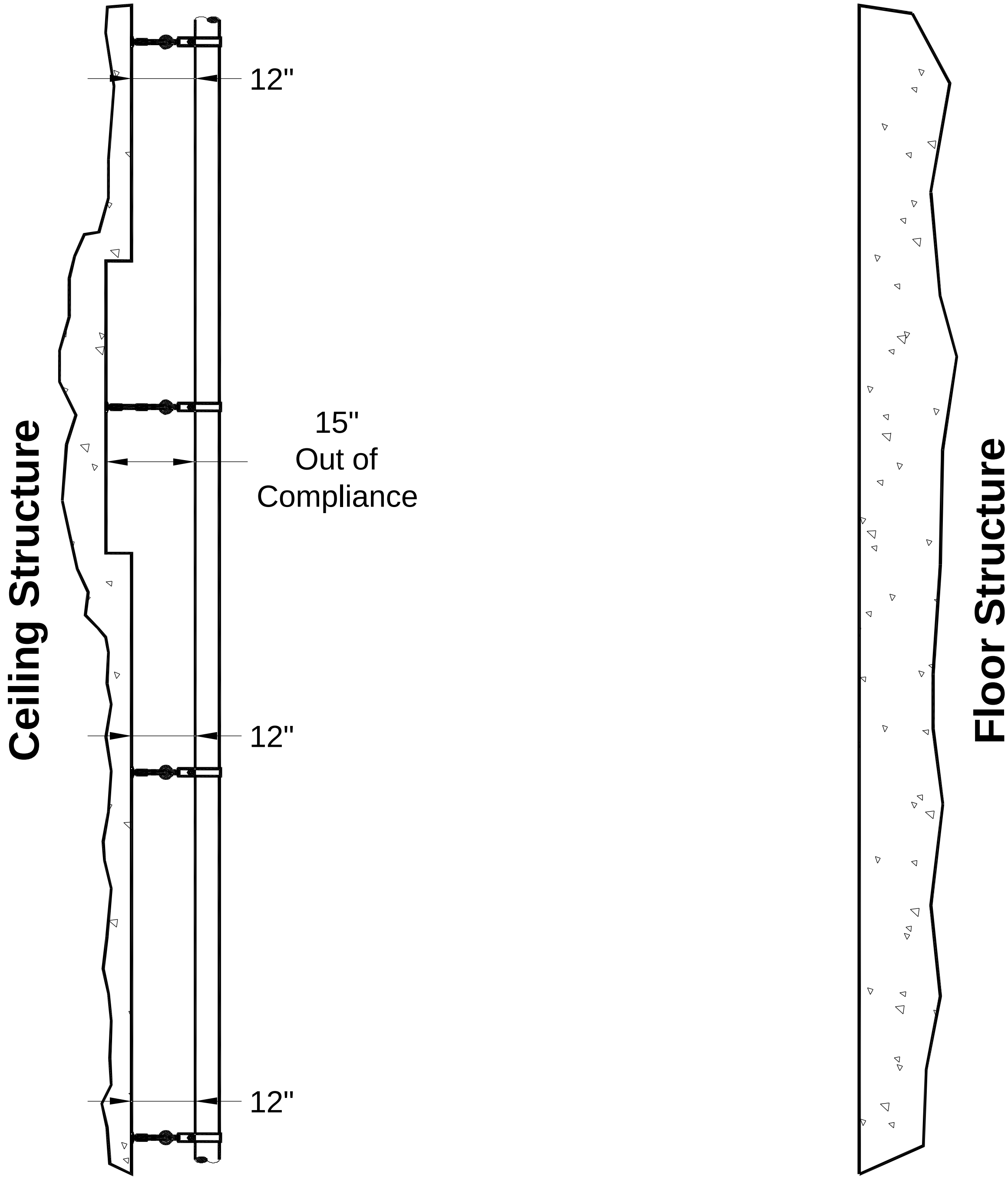

Figure S12-5; Every Hanger Location on a Run of Pipe or Duct Must be 12″ or Less

If even one hanger location exceeds the 12″ dimension, the entire run of pipe or duct must be restrained. The run of pipe shown in Figure S12-5 fails the test for the 12″ Rule.

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S12.6 – Summary:

The 12″ Rule is not a "***get out of jail free***" card. It is an exemption that may be designed into a piping or duct system during the initial stages of a project. It is not a last minute sort of thing that can be successfully implemented by the installing contractor. It is the responsibility of both the design professional of record and the installing contractor for a particular system to implement the requirements for the 12″ Rule. It is also the responsibility of the design professional of record for the system to interface with the other design professionals and contractors to ensure that the requirements for the 12″ Rule may be implemented at each projected hanger location. This will require very careful co-ordination between professions and trades.

Each run of pipe and duct from which the 12″ Rule is intended to be applied must be carefully designed to ensure that there will be building structure at the proper elevation to take advantage of the 12″ Rule.

It is wise to have a "fall back" plan in case one or more of the hanger locations fails to pass the test for the 12″ Rule. Putting a little extra money and installation time in the initial quotation will help alleviate non-compliance issues for pipe and duct runs planned for the 12″ Rule.

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FIRE PROTECTION PIPING SYSTEMS

S13.1 – Introduction:

Historically the ICC (2000, 2003, 2006, and 2009 IBC) and the NFPA (NFPA 5000) have been competing code writing bodies, and there have been some conflicts between the two. However, ASCE/SEI 7-98, -02, and -05 have been recognized as a reference standard in NFPA-13 which is the standard most often accepted as the code for fire protection systems by local jurisdictions. Therefore, this section will be based on the provisions found in ASCE/SEI 7-05 and NFPA 13 2007 Edition.

S13.2 –ASCE/SEI 7-05 Sections 13.6.8.2 & 13.6.8.3 Fire Protection Piping:

S13.2.1 – Section 13.6.8.2 Seismic Design Category C:

For buildings assigned to Seismic Design Category C, the fire protection sprinkler systems will meet the requirements of Chapter 13 of ASCE/SEI 7-05 if they are designed and constructed in accordance with NFPA 13.

S13.2.2 – Section 13.6.8.3 Seismic Design Categories D through F:

For buildings assigned to Seismic Design Categories D through F, the following requirements for the seismic restraint of fire sprinkler systems must be met.

1. The hangers and seismic restraints of the fire protection piping will meet the requirements of Chapter 13 of ASCE/SEI 7-05 if:
    a. The hangers and seismic restraints are designed and constructed in accordance with NFPA 13.
    b. The hangers and seismic restraints must meet the force and displacement requirements of Sections 13.3.1 and 13.3.2 of ASCE/SEI 7-05.

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2. The piping in the fire protection system must meet the force and displacement requirements of ASCE/SEI 7-05 Sections 13.3.1 and 13.3.2.

13.3 – Design Horizontal Seismic Force:

It is appropriate to discuss the design horizontal seismic force at this point because it will help explain the wording in ASCE/SEI 7-05. From Section S5.0 of this manual, the design seismic force from ASCE/SEI 7-05 is;

$$F_P = \frac{0.4 a_P S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{z}{h}\right)$$ **Equation S13-1**

The maximum and minimum values for the design horizontal seismic force will be respectively;

$$F_P = 1.6 S_{DS} I_P W_P$$ **Equation S13-2**

$$F_P = 0.3 S_{DS} I_P W_P$$ **Equation S13-3**

Where:

F_P = the design horizontal seismic force acting on a pipe or duct acting 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 is expected to be. Typically this will vary from 1.0 to 2.5, and is specified by component type in ASCE/SEI 7-05 and listed in Table S5-3.

I_P = the component importance factor which be either 1.0 or 1.5.

W_P = the operating weight of the pipe or duct that is being restrained.

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R_P = the response modification factor which usually will vary from 1.0 to 12.0. 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 values are specified by component type in ASCE/SEI 7-05 and listed in Table S5-3.

z = the structural attachment mounting height of the pipe or duct hanger 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.

Contrast this to the design horizontal seismic force described in NFPA 13 Section 9.3.5.6.2.

$$F_{pw} = C_P W_{pw}$$ **Equation S13-4**

Where:

F_{pw} = the design horizontal seismic force per NFPA 13

C_P = the seismic coefficient, see Table S13-1 for these values to use with NFPA 13.

$W_{pw} = 1.15 W_P$ The factor of 1.15 that multiplies the weight of the pipe is intended to account for the additional weight of all of the valves, fittings, and other devices in the system that would be attached to the pipe.

It is important to note that according to NFPA 13 Section A.9.3.5.1.3, all horizontal loads in NFPA 13 are given at ASD levels, while all seismic design loads in ASCE/SEI 7-05 are specified at LRFD levels. Recalling that ASD values are 1.4 times lower than LRFD values, comparing Equations S13-1 and S13-4, and ignoring the 1.15 factor that multiplies W_P in NFPA 13 will show that;

$$C_P = \frac{0.4 a_P S_{DS}}{1.4\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{z}{h}\right)$$ **Equation S13-5**

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Table S13-1; Seismic Coefficient Table – ASD Levels [NFPA 13 Table 9.3.5.6.2]

Mapped Short Period Acceleration S_S	Seismic Coefficient C_P ASCE 7-05 Values Have Been Converted to ASD Levels	
	NFPA 13	ASCE 7-05
0.33	0.31	0.24
0.50	0.40	0.33
0.75	0.43	0.43
0.95	0.50	0.51
1.00	0.52	0.52
1.25	0.60	0.60
1.50	0.71	0.71
2.00	0.95	0.95
2.40	1.14	1.14
3.00	1.43	1.43

In Table S13-1, the ASCE 7-05 values have been calculated based on the following information.

1. Site Class D has been assumed as the default Site Class.
2. $I_P = 1.5$ – All fire protection piping systems have been designated as Life Safety Systems by both NFPA 13 and ASCE/SEI 7-05.
3. $a_P = 2.5$ – This value is specified in NFPA 13 Section A.9.3.5.6.1 for steel piping systems.
4. $R_P = 4.5$ – This value is specified in NFPA 13 Section A.9.3.5.6.1 for steel piping systems.
5. $\left(1 + 2\frac{z}{h}\right) = 3$ – The hangers for the fire protection piping are assumed to be attached to the building at or close to the roof line.

Except for the first two instances where S_S is less than or equal to 0.33 and is equal to 0.50 , NFPA 13 and ASCE/SEI 7-05 appear to be in very close agreement as far as the design

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horizontal seismic forces are concerned. This is probably the reason for the provisions in Sections 13.6.8.2 and 13.6.8.3 of ASCE/SEI 7-05. For the purposes of this manual it will be convenient to have the C_P values in Table S13-1 expressed at LRFD levels, see Table 13-2. This will allow the seismic restraints and other components provided by Kinetics Noise Control to be directly selected from the design selection tables in this manual. Keep in mind that the design values in Tables S13-1 and S13-2 will not be valid for the CPVC plastic fire piping.

Table S13-2; Seismic Coefficient Table – LRFD Levels [NFPA 13 Table 9.3.5.6.2]

Mapped Short Period Acceleration S_S	Seismic Coefficient C_P NFPA 13 Values Have Been Converted to LRFD Levels	
	NFPA 13	ASCE 7-05
0.33	0.43	0.34
0.50	0.56	0.47
0.75	0.60	0.60
0.95	0.70	0.71
1.00	0.73	0.73
1.25	0.84	0.83
1.50	0.99	1.00
2.00	1.33	1.33
2.40	1.60	1.60
3.00	2.00	2.00

A safe "Rule of Thumb" to follow for selecting seismic restraints for fire protection piping is, when

$$S_S \le 0.50$$

$$C_P = 0.56$$

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13.4 – Cable Type "Tension Only" Seismic Restraints:

In NFPA 13 seismic restraints are called sway braces, and they must be designed and installed to withstand both tension and compression per NFPA 13 Section 9.3.5.2.1. Typically in the past the seismic restraints that have been specified and designed for NFPA 13 applications have been strut type restraints. However, "tension only" sway bracing is permitted; see NFPA 13 Sections 9.3.5.2.2 and 9.3.5.8.6. This type of bracing refers specifically to cable type seismic restraints. Two cables must be installed for each seismic restraint type and location, one directly opposite the other to fulfill the requirements of NFPA 13 Section 9.3.5.2.1 mentioned above. Also, per NFPA 13 Section 9.3.5.8.1, the restraint cables used for the "tension only" bracing must be tight.

Per NFPA 13 Section 9.3.5.2.2 cable type, "tension only", restraints are to be listed for use on fire suppression piping systems. This listing is typically performed by two recognized agencies, Underwriter's Laboratories (UL) and FM Approvals (Factory Mutual Global).

According to NFPA 13 Sections A9.3.5.2.2 and A9.3.5.3.1, the terms brace assembly and restraint assembly will refer to;

1. The restraint cable assemblies which are made up of the cables and the parts required to make the cable loops or other connections to mounting brackets or other components required to attach the restraint cable assemblies to the building..
2. The mounting brackets or other components required to attach the restraint cable assemblies to the pipe and the building structure.
3. The fasteners required to attach the mounting brackets or components to the pipe and building.

NFPA 13 Section A9.3.5.2.2 states that the use of cable type restraints or "tension only" bracing requires the consideration of the following items.

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1. Corrosion resistance of the restraint assemblies.
2. Pre-stretch of the cable to obtain a verifiable elastic modulus, and to avoid permanent stretch during installation which may produce permanent slack in the cables.
3. The restraints assemblies will require some verifiable means of field identification of the restraint assembly size and capacity, such as color coding.
4. The capacity of all of the components in the restraint assemblies and fields connections to verify and maintain the manufacturer's minimum certified breaking strength.
5. Manufacturer's published product design data/manual and literature to include;
    a. Product design and installation guidelines.
    b. Connection details.
    c. Load calculation procedures.
    d. Maximum horizontal load carrying capacity of the restraint assemblies.
    e. Special tools or precautions needed to ensure proper installation.
6. Manufacturer's restraint assembly shipments should include;
    a. Certification of the maximum breaking strength.
    b. Certification of the proper pre-stretch.
    c. Installation instructions, including notification of any special tools or procedures required to complete a proper installation.
7. A means, device or procedure, to prevent vertical motion under the action of seismic forces, as required.

13.5 – Zone of Influence Defined:

Zone of influence is a term that is peculiar to the seismic restraint of fire protection piping. Each seismic restraint, either transverse or longitudinal, is designed or selected to restrain a certain length of pipe. This length of pipe may have other smaller pipes unrestrained which join it, or are tributary to it, whose weight will also be restrained by the seismic restraints on the larger pipe. It is these smaller unrestrained pipes that compose the zone of influence for the seismic restraints on the larger pipe. This concept will be part of several of the NFPA 13 provisions discussed below.

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The transverse seismic restraints will act as longitudinal seismic restraints for the line which are tributary to that transverse seismic restraint. Conversely, the longitudinal seismic restraints will act as transverse seismic restraints for the line which are tributary to that longitudinal seismic restraint. The concept of the Zone of Influence is illustrated in Figure S13-1 below. For a discussion on Kinetics Noise Control's pipe and duct seismic restraint drawing symbols, please see Section S7-7 of this manual. The transverse seismic restraint shown in the middle of Figure S13.1 restrains the weight of the cross main on either side of the transverse restraint for a distance equal to one half the transverse seismic restraint spacing S_T. The branch lines that are tributary to, intersect, the cross main out to a distance equal to one half the transverse seismic restraint spacing on either side of the transverse restraint, shown in the cloud, are in the zone of influence for that transverse seismic restraint.

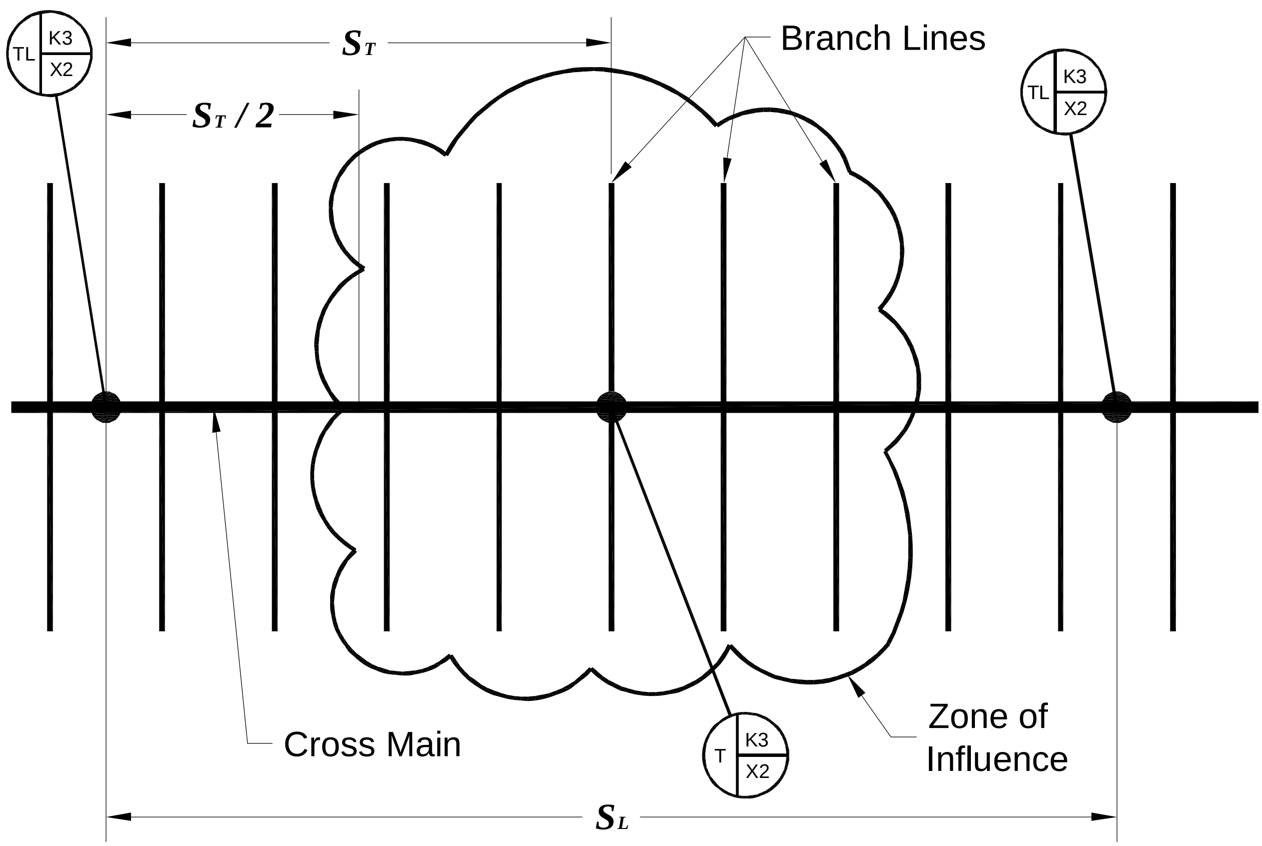

Figure S13-1; Definition of Zone of Influence

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13.6 – Longitudinal Seismic Restraints – NFPA 13 Sections 9.3.5.4, 9.3.5.6, 9.3.5.8, and A.9.3.5.6:

Section 9.3.5.4.1 – Need for Longitudinal Seismic Restraints:

1. Longitudinal seismic restraints are to be provided for all feed and cross main lines. The implication here is that branch lines do not need to have longitudinal seismic restraints. Their weight will fall into the zone of influence for the transverse seismic restraints on the pipe to which they are tributary.
2. The maximum allowable spacing for longitudinal sway bracing is 80 feet. Check the maximum allowable seismic restraint spacing tables for the particular type and size of pipe being used on the project. The actual maximum allowable may be less than 80 feet when buckling of the pipe is considered.

Section 9.3.5.4.2 – Longitudinal Seismic Restraints as Transverse Seismic Restraints:

Longitudinal seismic restraints on one pipe may act as transverse seismic restraints on a connecting pipe if they are located with in 2 feet of the centerline of the connecting pipe, and the weight of the connecting pipe has been included in the capacity calculation for the longitudinal restraint.

Section 9.3.5.4.3 – Length of Free Pipe beyond Last Longitudinal Seismic Restraint:

The distance between the last longitudinal seismic restraint and the end of the pipe can not exceed 40 feet.

Sections 9.3.5.6.5 and A.9.3.5.6.(4).(b) – Consideration of the Zone of Influence:

1. For longitudinal seismic restraints the zone of influence needs to consider all mains whose weight will be tributary to the longitudinal seismic restraints.
2. The selection of longitudinal seismic restraints on cross mains will need to consider only the weight of the cross mains and any tributary mains that fall within the zone of influence for the longitudinal seismic restraints.

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Section 9.3.5.8.5 – Attachment of Longitudinal Restraints to Steel Pipe:

For longitudinal restraints only, the restraints may be attached directly to steel pipe with a weld tab.

13.7 – Transverse Seismic Restraints – NFPA 13 Sections 9.3.5.3, 9.3.5.6, and A.9.3.5.6:

Section 9.3.5.3.1 – Need for Transverse Seismic Restraints:

Transverse seismic restraints must be provided on all feed and cross mains of any size, and on branch lines and other piping with a nominal diameter of 2-1/2 inches and larger. So, branch lines and other piping except feed and cross mains will be exempt from the need for transverse seismic restraint if their nominal diameter is less than 2-1/2 inches.

Sections 9.3.5.3.2 and A.9.3.5.6.(4).(a) – Allowable Transverse Seismic Restraint Spacing Considering the Zone of Influence:

1. The spacing of transverse seismic restraints is not to exceed 40 feet.
2. Up to the maximum spacing specified, the spacing for the transverse seismic restraints is to be selected on the basis of the pipe size and the horizontal design seismic load present in the zone of influence for the transverse seismic restraint. For cross mains, the design horizontal seismic force of all of the branch lines in the zone of influence for the transverse seismic restraint must be added to the design horizontal load of the cross main. For steel piping, the transverse seismic restraint spacing may be selected based on the data in Tables S13-3 and S13-4.
3. For a discussion of the zone of influence, see Section S13.5 of this manual.

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Table S13-3; Maximum Allowable Design Horizontal Seismic Load F_{pw} Due to Tributary Lines in a Zone of Influence in Pounds for Schedule 10 Steel Pipes [NFPA 13 Table 9.3.5.3.2(a)]

Nominal Pipe Size (in)	Transverse Seismic Restraint Spacing S_T (ft)							
	20		25		30		40	
	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
1	120	168	96	134	79	111	56	78
1 1/4	190	266	152	213	125	175	89	125
1 1/2	260	364	208	291	170	238	122	171
2	420	588	336	470	275	385	198	277
2 1/2	690	966	552	773	452	633	325	455
3	1,040	1,456	832	1,165	682	955	489	685
3 1/2	1,380	1,932	1,104	1,546	904	1,266	649	909
4	1,760	2,464	1,408	1,971	1,154	1,616	828	1,159
5	3,030	4,242	2,424	3,394	1,986	2,780	1,425	1,995
6 Over 6	4,350	6,090	3,480	4,872	2,851	3,991	2,046	2,864

Table S13-4; Maximum Allowable Design Horizontal Seismic Load F_{pw} Due to Tributary Lines in a Zone of Influence in Pounds for Schedule 40 Steel Pipes [NFPA 13 Table 9.3.5.3.2(b)]

Nominal Pipe Size (in)	Transverse Seismic Restraint Spacing S_T (ft)							
	20		25		30		40	
	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
1	130	182	104	146	85	119	61	85
1 1/4	230	322	184	258	151	211	108	151
1 1/2	330	462	264	370	216	302	155	217
2	560	784	448	627	367	514	263	368
2 1/2	1,060	1,484	848	1,187	695	973	499	699
3	1,720	2,408	1,376	1,926	1,127	1,578	809	1,133
3 1/2	2,390	3,346	1,912	2,677	1,566	2,192	1,124	1,574
4	3,210	4,494	2,568	3,595	2,104	2,946	1,510	2,114
5	5,450	7,630	4,360	6,104	3,572	5,001	2,564	3,590
6 Over 6	8,500	11,900	6,800	9,520	5,571	7,799	3,999	5,599

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Section 9.3.5.3.3 – Starter Pieces of Pipe:

The provisions of NFPA 13 Section 9.3.5.3.2 do not apply to starter pieces that are nominal diameter of 2-1/2 inches that do not exceed 12 feet in length.

Section 9.3.5.3.4 – Free Length of Pipe beyond Last Transverse Seismic Restraint:

The distance from the last transverse seismic restraint and the end of a pipe can not be more than 6 feet.

Section 9.3.5.3.5 – Transverse Seismic Restraints at the End of Feed or Cross Mains:

The last length of pipe at the end of a feed or a cross main must have a transverse seismic restraint.

Section 9.3.5.3.6 – Transverse Seismic Restraints as Longitudinal Seismic Restraints:

Transverse seismic restraints on one pipe may act as longitudinal seismic restraints on a connecting pipe if they are located with in 2 feet of the centerline of the connecting pipe, and the weight of the connecting pipe has been included in the capacity calculation for the transverse seismic restraint.

Section 9.3.5.3.7 – Transverse Seismic Restraints at Flexible Couplings:

On cross mains that have flexible couplings, including the flexible couplings at grooved type fittings, along their length must have a transverse seismic restraint installed with in 2 feet of every other coupling. The spacing between transverse seismic restraints is not to exceed 40 feet.

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Section 9.3.5.3.8 – The 6″ Rule:

Transverse seismic restraints are not required for pipes that are individually supported by hanger rods that are 6 inches or less in length are measured from the top of the pipe to the attachment point on the building structure.

Section 9.3.5.3.8 – U-Type Hooks:

Where wraparound U-Type hooks of those U-Type hooks that are intended to keep the pipe tight to the supporting structure are permitted to satisfy the requirements for transverse seismic restraints as long as the following provisions are met;

1. The legs are bent out at least 30° from the vertical.
2. The maximum length of the leg and the rod size are capable of carrying the expected seismic loads in accordance with NFPA 13 Tables 9.3.5.8.8(a), 9.3.5.8.8(b), and 9.3.5.8.8(c).

13.8 – Special Requirements for Branch Lines – NFPA 13 Sections 9.3.6 and A9.3.6.4:

The general piping industry uses the terms seismic restraint and seismic bracing interchangeably. NFPA 13, however, makes a clear distinction between seismic restraint and bracing, in particular for branch lines that have a nominal pipe size less than 2-1/2 inches. Seismic braces are intended to not only keep the piping moving with the building during an earthquake, but are also required to absorb all of the horizontal loads associated with the pipe and the lines in its zone of influence. While branch lines smaller that 2-1/2 inches are not required to be braced, they are required to be restrained. The requirements for restraining the branch lines are not as stringent as those for bracing the pipe. So, restraint is a lesser degree of load carrying capacity than bracing. The primary intent of seismically restraining the branch lines is to ensure that there relative position of those branch lines with respect to the building structure is maintained during and after an earthquake. This is because branch lines serve sprinkler heads that are located to protect specific

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areas of a building. Any permanent displacement of sprinkler heads relative to the building structure could result in inadequate coverage of critical areas of the building.

Typically, the hangers or attachments of the branch lines to the building structure are sized and placed to fulfill the seismic restraint requirements of Section 9.3.6 of NFPA 13. This task normally falls to the fire protection design professional. While the feed and cross mains can be restrained with components designed to handle, say, HVAC piping, there are specific hanger and restraint designs and components for branch lines.

Sprigs are vertical runs of pipe off of a branch line with a single sprinkler head attached to them. If a sprig is longer than 4 feet It must have a four way lateral restraint.

13.9 – Fasteners and Attachments– NFPA 13 Sections 9.3.5.9, 9.3.5.11, 9.3.5.12, and 9.3.7:

Sections 9.3.5.9.1, 9.3.5.9.6, and 9.3.5.9.7 – Acceptable Fastener Types and Loads:

The acceptable fastener types are post installed wedge type concrete anchors, post installed undercut anchors, steel bolts connecting to steel structures, through bolts, washers and nut in sawn lumber or glu-lam beams, and lag screws in wood. NFPA 13 Figure 9.3.5.9.1 presents the allowable fastener loads for various brace types and installations. Other fastening methods and anchors are acceptable if they are certified by a registered professional engineer to support the required seismic loads.

Sections 9.3.5.9.3 and 9.3.5.9.4 – Connections to Wood:

Through bolts with washers on each end is the first choice for connections to wood. These may be made with an actual bolt with a washer under the head of the bolt and a washer under the nut. The through bolt connection may also be made using a piece of all thread rod with nuts and

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washers on each end. Washers of sufficient outside diameter should be used to prevent over crushing the wood fibers and loosening the connection.

Lag screws may also be used for making connections to wood. When lag screws are specified, a pilot hole for the screw must be drilled to prevent splitting the wood along the grain lines. The pilot hole may be figured to be 1/8 inch smaller than the root diameter of the screw, or use the data found in Table A4.4-2 of Appendix A4.4 of this manual.

Section 9.3.5.9.5 – Holes for Through Bolts:

All clearance holes for through bolts are to be drilled 1/16 inch larger than the nominal bolt diameter.

Section 9.3.5.11.1 – Attachment to Pipes:

Seismic restraints must be attached directly to feed and cross mains. The restraints may not be attached to the clevis hangers or the hanger rods unless they have been tested and listed for horizontal seismic load carrying capability as well as supporting the dead load of the pipe and water.

Sections 9.3.5.11.2 and 9.3.5.11.3 – Individual Pipe Runs:

Each individual run of pipe must have both transverse and longitudinal seismic restraints. For pipe runs whose length is less than 12 feet, the seismic restraints on adjacent runs of pipe may be used for seismic restraint.

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Section 9.3.5.12 – Differential Motion:

A length of pipe may not be seismically restrained to sections of a building that will be subject to differential motion. This would cause the pipe to be pulled apart as the sections move in opposite directions. A flexible connector is required between the sections of the building subject to differential motion with enough capacity to handle the expected displacements of the two sections of the building.

Section 9.3.7.5 – "C" & "Z" Purlins:

The lips on "**C**" and "**Z**" purlins may not be used as a method of seismic restraint. These are typically light gage roll formed sheet metal parts. Any holes or deformation of the tension flange could have serious structural consequences.

Section 9.3.7.7 – C-Type Clamps:

C-Type clamps used with or without restraining straps are not to be used to attach seismic restraints or braces to the building structure. This includes beam and large flange clamps as well. All of these clamps rely to a greater or less degree on friction to transfer the seismic loads to the building. Also, their geometry is such that torsional loads as a result of, and along with, the horizontal seismic loads may be transferred to building structures incapable of carrying such loads.

Sections 9.3.7.8 and 9.3.7.9 – Powder Shot Pins:

Powder shot pins are not to be used for attaching seismic restraints or braces to the building structure unless specifically listed for the application of resisting lateral earthquake loads. It is imprudent to used powder shot pins in application that place the pin in tension.

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13.10 – Summary:

The NFPA-13 and IBC codes appear to be very close to each other in terms of the restraint selection requirements for piping. However, the actual application and installation of the seismic restraints should follow the guidelines in NFPA 13 since there are many life safety issues with fire protection piping that are not present with HVAC and plumbing piping.

Special Note #1: MEP systems and equipment which have initially been designated I_P**=1.0** which have been suspended above fire protection piping must be re-designated I_P**=1.5**, and restrained accordingly.

Special Note #2: Fire protection design professionals must be consulted concerning the adequacy of the restraint selection and attachment details for and fire protection piping system.

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CONSEQUENTIAL DAMAGE – SWINGING THINGS

S14.1 – Introduction:

This is a single paragraph in ASCE 7-05 that may have far reaching consequences for contractors. This is especially true for those contractors who are on the job site first, and whose systems and/or components may have a code based exemption from the need for seismic restraint. The paragraph is Section 13.2.3 of ASCE 7-05, and reads as follows.

> The function and physical interrelationship of components, their supports, and their effect on each other shall be considered so that the failure of an essential or nonessential architectural, mechanical, or electrical component shall not cause the failure of an essential architectural, mechanical, or electrical component.

In this section, or rule, the nonessential components would have a Component Importance Factor I_P=1.0, and the essential components would have a Component Importance Factor I_P=1.5.

The application of this rule in ASCE 7-05 may require a contractor to go back and install restraints after other systems have been installed. This is a very difficult and expensive process. This section of the Pipe & Duct Seismic Application Manual will discuss the conditions where this rule will apply, and help define the limiting factors for the application of the rule.

S14.2 – Conditions of Application:

There are two basic conditions for which this rule will apply above, and side-by-side.

1. **Above:** In this case the component(s) with a code based exemption from the need for Seismic restraints and Component Importance Factor of either I_P=1.0, or I_P=1.5 are installed above a component or component(s) the have a Component Importance Factor of I_P=1.5. The component(s) which are installed above will need to be restrained to prevent the failure

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of the component(s) with a Component Importance Factor of I_P=1.5 that have been installed below. Examples are given below.

a. Assume a building assigned to Occupancy Category IV, and Seismic Design Category C. A duct whose Component Importance Factor is I_P=1.0 has been installed directly above a cross main for the fire suppression sprinkler system, which has a Component Importance Factor of I_P=1.5. Even though the duct carries a code based exemption from the need for seismic restraint, it would need to be restrained to prevent the possibility of the failure of the fire suppression sprinkler system if the duct should fall.

b. Assume a hospital assigned to Occupancy Category IV, and Seismic Design Category D. A single clevis supported 3″ IPS schedule 40 steel water line with a Component Importance Factor of I_P=1.0 has been installed above a trapeze bar that carries the main feed for the medical gas and vacuum whose Component Importance Factors are I_P=1.5. The single clevis supported 3″ IPS schedule 40 steel water line would need to be restrained to prevent the possible failure of the medical gas and vacuum systems if the 3″ pipe should fall.

2. **Side-by-Side:** Keep in mind that the earthquake will move the building, and the building will drag the components attached to it along with it. Those components that have been adequately restrained per the code will move exactly with the building. That is, there will be no lag between the times the building moves, and when the components begin to move. Those components that have not been restrained will not move with the building, they will be out of phase with the building motion. Impacts can occur in one of two ways. First the building and restrained components can run into the unrestrained components because they can't get out of the way in time. Second, the unrestrained components can be in resonance with the earthquake motion, and their displacements can build up enough so that they swing into the building and/or the restrained components. The big question is how much space to leave between restrained and unrestrained components, and between unrestrained components and the building. The answer is not entirely simple. It will depend on the Site Specific seismic parameters for the project. Estimating these spacings will be the subject of the next section. Some examples are presented below.

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a. Assume a building assigned to Seismic Design Category C. A 2″ IPS natural gas line is installed as being single clevis supported, and is hung so the OD of the pipe is 1 inch away from the structural wall. This pipe would have a Component Importance Factor of I_P=1.5 because it carries a hazardous material, but would have a code based exemption from the need for seismic restraint due to its size. In this case, either the building could "run into" the pipe, or the pipe could swing into the building causing the pipe and/or its hangers to fail. It would require seismic restraint.

b. Assume a building assigned to Seismic Design Category D. There are two pipes which are single clevis supported, and are located side-by-side such that their ODs are 2″ apart. The first pipe is a natural gas line with a Component Importance Factor of I_P=1.5 that is 1-1/2″ IPS. It has been seismically restrained per the code. The second pipe is a 3″ IPS schedule 40 steel water line with a Component Importance Factor of I_P=1.0. It has a code base exemption from the need for seismic restraint. However, the possibility exists that the gas line could "run into" the water line and be damaged, or the water line could swing into the gas line and damage it as the water line displacement builds up during the earthquake. The 3″ IPS water line would need to be restrained as well to prevent damage to the gas line.

S14.3 – Estimating the Allowable Spacing between Objects:

The analysis developed in this section will permit the allowable spacing between an unrestrained component and a building or restrained object, and the allowable spacing between two unrestrained objects to be estimated. The analysis will depend on certain basic assumptions.

1. The run of pipe or duct, when viewed along their long axis, will behave like a simple pendulum of length L.
2. The run of pipe or duct is supported by threaded hanger rods.
3. The hanger rods will behave like flexible members, and have a damping coefficient that is equal to 3% of critical.

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4. The length of the pendulum, L , will be the average length of all of the hanger rods supporting the run of pipe or duct.
5. The simple pendulum formed by the run of pipe or duct will be assumed to be in resonance with the earthquake ground motion.
6. The building itself is relatively small when compared to the portion of the earth's surface that will be excited by the earthquake. Therefore, at this scale, the building will behave like a particle.
7. The simple pendulum formed by the run of pipe or duct and it's hanger rods may be viewed as a single degree of freedom system whose motion is being forced through the attachment point to the building structure by the earthquake motion.
8. The earthquake ground motion will be assumed to be a square wave with constant acceleration in one direction for half the period and then constant acceleration in the opposite direction for half the period.

The motion of the run of pipe or duct may now be described by the following equation which is derived from classical vibration analysis.[1 & 2]

$$X = Y\sqrt{\frac{1+\left(2\xi\frac{T_N}{T}\right)^2}{\left(1-\left(\frac{T_N}{T}\right)^2\right)^2+\left(2\xi\frac{T_N}{T}\right)^2}}$$

Equation S14-1

Where:

X = The displacement of the run of pipe or duct relative to the building.

Y = The displacement of the building attachment point for the hanger rods.

T_N = The natural period of oscillation for the run of pipe or duct.

[1] Beer, Ferdinand P. and Johnston, E. Russel; Vector Mechanics for Engineers: Dynamics 2nd Edition, McGraw-Hill Book Company, Inc., 1972, Pp 832-866.

[2] Thompson, William T.; Theory of Vibration with Application, Prentice-Hall Inc., 1972, Pp 56-62.

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T = the period of the earthquake ground motion.

ξ = the damping coefficient for the Pipe and duct hangers and their attachments. This is assumed to be 3% of the critical damping, or $\xi = 0.03$.

Per the basic assumption number 5; $T = T_N$ or $T_N / T = 1.0$. The radical in Equation S14-1 will now become;

$$\sqrt{\frac{1+\left(2\xi\frac{T_N}{T}\right)^2}{\left(1-\left(\frac{T_N}{T}\right)^2\right)^2+\left(2\xi\frac{T_N}{T}\right)^2}} = \sqrt{\frac{1+(2(0.03)(1.0))^2}{\left(1-(1.0)^2\right)^2+(2(0.03)(1.0))^2}} = 16.6966$$ **Equation S14-2**

Equation S14-1 will now become simply;

$$X = 16.6966Y$$ **Equation S14-3**

Because the building is assumed to behave like a particle with respect to the earth, the displacement of the building at grade level may be expressed as;

$$y = \frac{at^2}{2}$$ **Equation S14-4**

Where:

y = the displacement of the base of the building at grade.

a = the acceleration imparted to the base of the building due to the earthquake ground motion.

t = the time period over which the acceleration acts.

The code based acceleration value that will be used in Equation S14-4 is to be derived from the design horizontal force equation which is the same for all three versions of the IBC.

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$$F_P = \frac{0.4 a_P S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{h}{z}\right)$$ **Equation S14-5**

And;

$$0.3 S_{DS} I_P W_P \leq F_P \leq 1.6 S_{DS} I_P W_P$$ **Equation S14-6**

Where:

F_P = the seismic design horizontal force.

S_{DS} = the spectral acceleration, short (0.2 sec) period. This includes the modification for the Site Class, or the type of soil on which the project has been constructed.

a_P = the component amplification factor. This factor is a measure of how close the natural period of the component is expected to be to the natural period of the building. This factor will vary from 1.0 to 2.5 with 2.5 being the case where the two natural periods are very close.

R_P = the component response modification factor. This factor accounts for the ability of the component and its attachments to absorb energy. The larger this factor, the more able the component and its attachments are to absorb the earthquake energy.

I_P = the component importance factor. This will be either 1.5 or 1.0.

W_P = the operating weight of the component.

z = the height of the structural attachment point for the hanger rods of the components within the building.

h = the average height of the building roof as measured from the grade line of the building.

$\left(1 + 2\frac{z}{h}\right)$ = a term that recognizes that the building structure is flexible, and that the motion at any elevation above grade in the building will exceed the motion at grade level.

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If W_P is dropped from equation S14-5, then what is left is a design acceleration factor that depends on the attachment location in the building. This design acceleration factor has been known in the past as the seismic coefficient, and that seems applicable here as well.

$$C_S = \frac{0.4 a_P S_{DS}}{\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{h}{z}\right)$$ **Equation S14-7**

And;

$$0.3 S_{DS} I_P \le C_S \le 1.6 S_{DS} I_P$$ **Equation S14-8**

Where:

C_S = the seismic coefficient.

Note that at grade line, $z = 0$, therefore;

$$a = \frac{0.4 a_P S_{DS}}{\left(\frac{R_P}{I_P}\right)}$$ **Equation S14-9**

So, the displacement of the hanger rod attachment points for the pipe or duct will be as follows.

$$Y = \frac{at^2}{2}\left(1 + 2\frac{z}{h}\right) = \frac{C_S t^2}{2}$$ **Equation S14-10**

Now then, the maximum time period over which the acceleration can act will be one half of the earthquake period, which has also been assumed to be the natural period of the pendulum

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composed of the pipe or duct and it's supporting hanger rods. For a simple pendulum, the natural period may be estimated by;

$$T_N = T \cong 2\pi \sqrt{\frac{L}{g}}$$ **Equation S14-11**

Where:

g = the acceleration due to gravity, 386.4 in/sec^2.

Then;

$$t = \frac{T_N}{2} = \pi \sqrt{\frac{L}{g}}$$ **Equation S14-12**

Substitute Equation S14-12 into Equation S14-10 to obtain;

$$Y = \frac{\pi^2 C_S L}{2g}$$ **Equation S14-13**

Substituting this result into Equation S14-3 will yield the following.

$$X = \frac{16.6966\pi^2 C_S L}{2g}$$ **Equation S14-14**

This can be reduced even further to;

$$S_{R-U} = X = 0.2132 C_S L$$ **Equation S14-15**

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Where:

S_{R-U} = the minimum safe allowable horizontal spacing between an unrestrained component and a restrained component or the building structure.

For two unrestrained components positioned side-by-side, the minimum safe allowable horizontal spacing between the two objects will be;

$$S_{U-U} = 2X = 0.4265 C_S L$$ **Equation S14-16**

Where;

S_{U-U} = the minimum safe allowable horizontal spacing between two adjacent unrestrained components.

There are times when knowing the angle through which the run of pipe or duct can swing may also be a valuable piece of information. Referenced to the vertical, this angle may be estimated using the following formula.

$$\theta_P = \pm Tan^{-1}\left[\frac{X}{L}\right] = \pm Tan^{-1}\left[0.2132 C_S\right]$$ **Equation S14-17**

Where:

θ_P = the angle through which the unrestrained ruin of pipe or duct will swing from the vertical.

S14.4 – Summary:

1. Consequential damage must be addressed for each project and each piece of equipment, run of pipe, duct, or any other distribution system.
2. Consequential damage from components above and from components and structure located side-by side are defined in Section S14.2 above.

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3. A method of estimating the minimum allowable spacing between adjacent objects is presented in Section S14.3. This method is not easily employed by the either the installing contractor or the inspector. The calculation should be performed by the design professional of record for the system or the system designer.

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ELECTRICAL DISTRIBUTION SYSTEMS

S15.1 – Introduction:

The exemptions mentioned in ASCE 7-05 are actually implied exemptions that are stated as requirements. This section will 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. Also, the component amplification and response modification factors for electrical distribution systems will be tabulated.

S15.2 – "Implied" Blanket Exemption Based on Component Importance Factor I_P

Section 13.6.4 of ASCE 7-05, 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."

ASCE 7-05 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

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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, 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 forces and displacements. 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.

S15.3 – Single Supported Conduit Size Exemption:

There is a size based exemption in ASCE 7-05 Section 13.6.5.5.6a for electrical conduit. They seem to follow the exemptions, in terms size, that are used for piping. 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. For conduit

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weights, see Appendix A8.1. Single supported conduit is restrained in the same fashion as single clevis supported pipe. Note that the seismic restraint products supplied by Kinetics Noise Control do not often work well for wall supported conduit as the wall structures and conduit mounts are counted on for both dead weight support and resisting the seismic loads. Each support point will need to be evaluated for its ability to carry both the dead weight load and the design horizontal seismic force.

S15.4 – Trapeze Supported Electrical Distribution Systems:

Per ASCE 7-05 Section 13.6.5.5.6b, no restraints are required for conduit, bus ducts, or cable trays 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 (146 N/m) or less. This total weight includes not only the conduit, bus duct, or cable trays, but also includes the trapeze bars as well. Trapeze supported electrical distribution systems are restrained in the same way as trapeze supported pipe and duct. It is necessary for the conduit, bus ducts, and cable trays to be attached to the trapeze bars sufficiently to resist the design horizontal seismic forces, both transverse (T) and longitudinal (L).

Cable trays present certain issues when seismic restraints are applied.

1. The construction of certain types of cable trays, such as the "wire basket" type, is designed to carry the dead weight of the cabling over a certain span. They are not necessarily designed to carry the horizontal seismic loads in either the transverse (T) or longitudinal (L) directions over longer spans than the dead weight supports. The manufacturer of the cable trays will need to verify the ability of the cable trays to resist the expected design horizontal seismic forces over the spans specified for the transverse (T) and longitudinal (L) seismic restraint. If the manufacturer of the cable tray hasn't provided transverse (T) and longitudinal (L) load carrying data for their cable trays, assume that the transverse (T) and longitudinal (L) seismic restraint spacings will be equal to the cable tray support spacing.

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2. Cables are typically simply laid in the cable trays. To ensure that the seismic forces are transferred properly to the restraint points, the cables should be strapped either individually or in bundles to the cable tray at regular intervals. A good rule of thumb for the strapping spacing might be one half the cable tray support spacing. This will make sure that the seismic forces are evenly distributed to all of the restraint points.
3. As with the conduit, the seismic restraint products supplied by Kinetics Noise Control do not often work well with wall mounted cable trays. All of the attachments to the wall must be designed to carry both the dead weight and the horizontal seismic forces in the transverse (T) and longitudinal (L) directions.

S15.5 – Seismic Application Factors for Electrical Distribution Systems:

The portion of Table 13.6-1 of ASCE 7-05 relevant to electrical distribution systems is reproduced below.

Table S15-1; Component Amplification and Response Modification Factors for 2006/2009 IBC (ASCE 7-05)

Component	a_P	R_P
Electrical Components	-----	-----
Generators, batteries, inverters, motors, transformers, & other electrical components constructed of high deformability materials	1.0	2.5
Motor control centers, panel boards, switch gear, instrumentation cabinets, and other components with sheet metal framing	2.5	6.0
Communication equipment, computers, instrumentation, & controls	1.0	2.5
Lighting fixtures	1.0	1.5
Other electrical components	1.0	1.5
Distribution Systems	-----	-----
Electrical conduit, bus ducts and, rigidly mounted cable trays	1.0	2.5
Suspended cable trays.	2.5	6.0

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S15.6 – Summary:

1. Single supported conduit and trapeze supported conduit, bus duct, and cable trays are seismically restrained in a manner similar to pipe and duct. The information in this manual pertaining to the restraint of pipe and duct, and the attachment of restraints to pipe, duct, trapeze bars, and the building structure will apply to electrical distribution systems.
2. Unless otherwise specified, use the weights for rigid conduit from Table A8.1-3 when sizing restraints for electrical conduit, both single supported and trapeze supported.
3. Weight per unit length for cable trays and bus duct will need to be supplied by the engineer of record for the electrical distribution system.
4. Unless transverse (T) and longitudinal (L) load carrying capacities are provided by the manufacturer for cable trays and bus ducts locate the transverse (T) and longitudinal (L) seismic restraints at the cable tray and bus duct support points.
5. Strap cables, either individually or in bundles, to the cable tray at a spacing equal to one half the support spacing to spread the seismic loads evenly to all restraint points.
6. The seismic restraint components provided by Kinetics Noise Control are intended to be used with suspended single supported conduit and trapeze supported conduit, cable trays, and bus ducts. They are not easily applied to wall mounted conduit, cable trays, and bus ducts. The wall mounts and their attachments need to be designed and evaluated for both the dead weight load and the design horizontal seismic load. Certification of these mounts and their attachments to the building would need to be by others.

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REQUIRED BASIC PROJECT INFORMATION

S2.1 – 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.

S2.2 – Building Use – Nature of Occupancy:

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 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 the previous 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/SEI 7-05 describes which types of buildings are assigned to which Occupancy Category. Table S2-1 below summarizes the information in Table 1-1 of ASCE/SEI 7-05, 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.

S2.3 – Site Class – Soil Type:

The Site Class is related to the type of soil and rock strata that directly underlies the building site.

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The Site Class ranges from A to F progressing from the stiffest to the softest strata. Table S2-2 lists the various Site Classes and their corresponding strata.

Table S2-1; Building Use vs. Occupancy Category & Seismic Use Group

Occupancy Category 2006/2009 IBC	Seismic Use Group 2000/2003 IBC	Building Use or Nature of Occupancy
I	I	Buildings and structures in which failure would pose a low hazard to human life. These buildings include, but are not limited to: Ø Agricultural buildings and structures. Ø Certain temporary buildings and structures. Ø Minor storage buildings and structures.
II		Buildings and structures that are not listed as Occupancy Category I, III, or IV. Also, cogeneration power plants that do not supply power to the national power grid.
III	II	Buildings and structures, in which failure would pose a substantial hazard to human life, have the potential to create a substantial economic impact, and/or cause a mass disruption of day-to-day civilian life. These buildings include, but are not limited to: Ø Where more than 300 people congregate in one area. Ø Daycare facilities with a capacity greater than 50. Ø Elementary and Secondary school facilities with a capacity greater than 250 and colleges and adult educational facilities with a capacity greater than 500. Ø Healthcare facilities with 50 or more resident patients that do not have surgery or emergency treatment facilities. Ø Jails, prisons, and detention facilities. Ø Power generation stations. Ø Water and sewage treatment facilities. Ø Telecommunication centers. Buildings and structures which are not in Occupancy Category IV which contain enough toxic or explosive materials that would be hazardous to the public if released.
IV	III	Buildings and structures which are designated as essential facilities which include but are not limited to: Ø Hospitals & healthcare facilities with surgical or emergency treatment facilities. Ø Fire, rescue, ambulance, police stations, & emergency vehicle garages. Ø Designated emergency shelters. Ø Facilities designated for emergency preparedness & response. Ø Power generating stations and other public utilities required for emergency response and recovery. Ø Ancillary structures required for the continued operation of Occupancy Category IV buildings and structures. Ø Aviation control towers, air traffic control centers, and emergency aircraft hangers. Ø Water storage facilities and pumping stations required for fire suppression. Ø Buildings and structures required for national defense. Ø Buildings and structures that contain highly toxic and/or explosive materials in sufficient quantity to pose a threat to the public.

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Table S2-2; Site Class vs. Soil Type

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.

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 Class is determined in accordance with Chapter 20 of ASCE/SEI 7-05. 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.

S2.4 – Mapped Acceleration Parameters:

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 short period values are generally used with the 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.

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The Mapped Acceleration Parameters are available in ASCE/SEI 7-05, 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.

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. Equations S2-1 and S2-2 may be used to estimate the Design Spectral Acceleration Parameters.

$$S_{DS} = \frac{2}{3} F_a S_S$$ **Equation S2-1**

And

$$S_{D1} = \frac{2}{3} F_v S_1$$ **Equation S2-2**

Where:

F_a = the short period Site Coefficient which is listed in Table S2-3. The values for F_a which correspond to values of S_S that fall between those listed in Table S2-3 may be obtained through linear interpolation.
F_v = the long period Site Coefficient which is listed in Table S2-4. The values for F_v which correspond to values of S_1 that fall between those listed in Table S2-4 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.

The structural engineer will have the values of S_{DS} and S_{D1} available. It is required to determine the Seismic Design Category for the building, which will be discussed next.

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Table S2-3; Short Period Site Coefficient, F_a

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 S2-4; Long Period Site Coefficient, F_v

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.				

S2.5 – Seismic Design Category:

This parameter is of great importance to everyone involved with pipe and duct. 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 pipes and ducts may be exempted, and which will need to have seismic restraints or bracing selected and installed. 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

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Design Category to which a building or structure is assigned is determined though the use of Tables S2-5 and S2-6.

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.

Table S2-5; Seismic Design Category Based on the Short Period Design Response Acceleration Parameter

Value of S_{DS}	Occupancy Category (Seismic Use Group)		
	I or II (I)	III (II)	IV (III)
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

Table S2-6; Seismic Design Category Based on the Long Period Design Response Acceleration Parameter

Value of S_{D1}	Occupancy Category (Seismic Design Category)		
	I or II (I)	III (II)	IV (III)
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

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For Occupancy I, II, or 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 E. For Occupancy Category IV 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.

S2.6 – Summary:

The following parameters will be required by the design professionals having responsibility for pipe and duct systems in a building, and should be provided by the structural engineer of record.

1. Occupancy Category (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 for pipe and duct.
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 for pipe and duct.

These parameters should be repeated on the drawings for the pipe and duct systems to maintain consistency, and provide this information to contractors and suppliers who may have a need to know.

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PIPE AND DUCT COMPONENT IMPORTANCE FACTOR

S3.1 – Introduction:

Pipe and Duct are categorized in ASCE/SEI 7-05 as non-structural components. There are just two values for the Component Importance Factors for pipe and duct, 1.0 and 1.5. The Component Importance Factor is designated as I_P in the body of the code. All pipe and duct must be assigned a component importance factor. The design professional that has responsibility for the pipe or duct is also responsible for assigning the Component Importance Factor to that pipe or duct.

S3.2 – Criteria for Assigning a Component Importance Factor to Pipe and Duct:

For pipe and duct, the Component Importance Factor (I_P) assigned to the pipe or duct shall be determined as follows.

1. If the pipe or duct is required to remain in place and function for life-safety purposes following and earthquake the importance factor assigned to the pipe or duct shall be 1.5. Some examples of this type of pipe or duct 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 pipe or duct contains or is used to transport hazardous materials a Component Importance Factor of 1.5 shall be assigned to that pipe or duct. Examples are as follows.
   a. Natural gas piping.

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   b. Fuel oil lines.
   c. Ducts used to exhaust laboratory fume hoods.
   d. Boiler and furnace flues.
   e. Ducts that are used to ventilate bio-hazard areas and infectious patient rooms.
   f. Chemical or by-product pipe or duct lines which are required for industrial processes.

3. If the pipe or duct is in or attached to a building that has been assigned to Occupancy 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 pipe or duct. Hospitals, emergency response centers, police stations, fire stations, and etc. fall in Occupancy Category IV. The failure of any pipe or duct could cause the portion of the building it serves to be evacuated and unusable. 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 Category IV.
4. If the pipe or duct that is located in or attached to an Occupancy Category IV facility and its failure would impair the operation of that facility, then a Component Importance Factor of 1.5 shall be assigned to that pipe or duct. This implies that any pipe or duct that could be assigned a Component Importance Factor of 1.0 that is located above pipe, duct or equipment that has been assigned a Component Importance Factor of 1.5 must be reassigned to a Component Importance Factor of 1.5.
5. All other pipe or duct that is not covered under items 1, 2, 3, or 4 may be assigned a Component Importance Factor of 1.0.

S3.3 – Summary:

The Component Importance Factor is very important to the designer responsible for selecting and certifying the seismic restraints for a pipe or duct system. This factor is a direct multiplier for the horizontal seismic design force, which shall be discussed in a later section. If a Component Importance Factor has not been assigned to a run of pipe or duct, the designer responsible for

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selecting the seismic restraints must assume that the Component Importance Factor is equal to 1.5. If the run of pipe or duct actually could 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.

It is in the best interest of the design professionals responsible for the systems that are served by the pipe and duct to properly assign the Component Importance Factors to the pipe and duct. The Component Importance Factor for each pipe and duct system should be clearly indicated on the drawings that are distributed to other design professionals, contractors, suppliers, and building officials.

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CODE BASED EXEMPTIONS FOR PIPE AND DUCT

S4.1 – Introduction:

The International Building Codes (IBC's) allow certain exemptions to be made for pipe and duct from the need for seismic restraint. These exemptions are based on the Seismic Design Category, the Component Importance Factor, and the size and weight, of the pipe or duct. This section will discuss the exemptions that may be applied to pipe and duct and will try to clear up some of the confusion that surrounds several of the exemptions as stated in the IBC.

S4.2 – General Exemptions for Pipe and Duct – ASCE/SEI 7-05 Section 13.1.4:

1. Pipe and duct in or attached to buildings assigned to Seismic Design Categories A or B do not required seismic restraints.
2. Pipe and duct in or attached to buildings assigned to Seismic Design Category C, and which have a Component Importance Factor equal to 1.0, do not required seismic restraint.
3. Pipe and duct that are in or attached to buildings assigned to Seismic Design Categories D, E, or F, that have a Component Importance Factor equal to 1.0, and that weigh 5 lbs/ft or less do not require seismic restraints.

The seismicity of a large portion of the United States is such that items 1 and 2 may be employed to great advantage. A lot of time money and effort may be saved if Seismic Design Category and the Component Importance Factor are known.

S4.3 – Pipe Specific Exemptions (Single Clevis Supported Pipe) – ASCE/SEI 7-05 Section 13.6.8:

The exemptions discussed in this section do not apply to elevator piping or fire protection piping designed in accordance with NFPA 13.

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1. Piping which is supported by hanger rods does not require seismic restraints if all of the following conditions are met.
   a. Hangers in the run of pipe are all 12 in. in length from the top of the pipe top of the pipe to the supporting structure. It should be noted here that the intent of this requirement is that all of the attachments to the supporting structure are at the same elevation. Also, if just one hanger rod exceeds 12 in. in length, the entire run must be seismically restrained. This is commonly referred to as the 12 Inch Rule, see Section S12.0 of this manual for information concerning the implementation of the 12 Inch Rule.
   b. Hangers are detailed and constructed to avoid bending of hangers and their attachments. The implication here is that the attachment of the hanger to the structure needs to be a non-moment generating (free swinging) connection.
   c. There must be sufficient clearance between the piping, to which this exemption is being applied, and surrounding pipe, duct, equipment, and building structure. The pipe needs to be able to swing like a pendulum, without contacting any other components or the building structure.
      i. The attachment to the building structure should be designed to the same level as that called for in ASCE/SEI 7-05 Section 13.6.1. The design load for the piping attachment shall be equal to 1.4 times the operating weight load acting in the downward direction with a simultaneous horizontal load equal to 1.4 times the operating weight. This is in recognition of the fact that the connection of the hanger rod to the building must not only support the weight of the pipe and its contents, but must also be able to resist the cyclic horizontal forces that are required to keep the pipe moving with the building.
2. High deformability piping (welded steel or brazed copper piping) and where provisions are made to avoid impact with adjacent pipe, duct, equipment, or building structure, or to protect the pipe from such impact, may be exempted from the requirement for seismic restraint if the following conditions are met.

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a. The piping is in or attached to a building that is assigned to Seismic Design Categories D, E, or F, and;
   i. The piping has a Component Importance Factor that is equal to 1.5.
   ii. The nominal pipe size is 1.0 in. or less.
b. The piping is in or attached to a building that is assigned to Seismic Design Category C, and;
   i. The piping has a Component Importance Factor that is equal to 1.5.
   ii. The nominal pipe size is 2 in. or less.
c. The Piping is in or attached to a building that is assigned to Seismic Design Categories D, E, or F, and;
   i. The piping has a Component Importance Factor equal to 1.0.
   ii. The nominal pipe size is 3 in. or less.

S4.4 – Pipe Specific Exemptions (Trapeze Supported Pipe) – ASCE/SEI 7-05 Section 13.6.8 per VISCMA Recommendations:

Neither ASCE/SEI 7-05, nor its predecessors, 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 can make the following recommendations on the application of the exemptions in item 2 in the preceding section to trapeze supported pipe, www.viscma.com.

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As with the previous case, the exemptions discussed in this section do not apply to elevator piping or fire protection piping designed in accordance with NFPA 13. The following basic provisions must apply.

1. The hangers must be ASTM A36 all-thread rod.
2. The threads must be roll formed.
3. The pipes must be rigidly attached to the hanger rods.
4. Provisions must be made to avoid impact with adjacent pipe, duct, equipment, or building structure, or to protect the pipe from such impact.

Trapeze supported pipes that meet the preceding provisions may be exempted from the need for seismic restraint if the following additional conditions are met.

1. Trapeze supported piping that is in or attached to a building that is assigned to Seismic Design Category C, and;
    a. The trapeze bar is supported by 3/8-16 UNC, or larger, hanger rods.
    b. The maximum hanger spacing is 10 ft. on center.
    c. The Component Importance Factor is greater than or equal to 1.0.
    d. The maximum nominal pipe size is 2 in.
    e. The total weight supported by the trapeze bar is 15 lbs/ft or less.
2. Trapeze supported piping that is in or attached to a building that is assigned to Seismic Design Category D, and;
    a. The trapeze bar is supported by 1/2-13 UNC, or larger, hanger rods.
    b. The maximum hanger spacing is 10 ft. on center.
    c. The Component Importance Factor is equal to 1.0.
    d. The maximum nominal pipe size is 3 in.
    e. The total weight supported by the trapeze bar is 25 lbs/ft or less.
3. Trapeze supported piping that is in or attached to a building that is assigned to Seismic Design Categories E or F, and;

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   a. The trapeze bar is supported by 1/2-13 UNC, or larger, hanger rods.
   b. The maximum hanger spacing is 10 ft. on center.
   c. The Component Importance Factor is equal to 1.0.
   d. The maximum nominal pipe size is 3 in.
   e. The total weight supported by the trapeze bar is 11 lbs/ft or less.

4. Trapeze supported piping that is in or attached to a building that is assigned to Seismic Design Categories D, E or F, and;
   a. The trapeze bar is supported by 3/8-16 UNC, or larger, hanger rods.
   b. The maximum hanger spacing is 7 ft. on center.
   c. The Component Importance Factor is greater than or equal to 1.0.
   d. The maximum nominal pipe size is 1 in.
   e. The total weight supported by the trapeze bar is 4 lbs/ft or less.

S4.5 – Duct Specific Exemptions – ASCE/SEI 7-05 Section 13.6.7:

There are not as many exemptions for ductwork in the code as there are for pipe, and the ones specifically mentioned are somewhat more restrictive. Seismic restraints are not required for ducts that have a Component Importance Factor equal to 1.0 if either of the following conditions is met for the entire run of the duct.

1. The ducts are suspended from hangers that are 12 in., or less in length, and the hangers have been detailed and constructed to avoid bending of the hangers or their attachments. As with the piping, the attachment of the hangers to the structure should be made with a non-moment generating (free swinging) connector. The connector should be designed to carry 1.4 times the supported weight of the duct in the downward direction, and 1.4 times the supported weight of the duct in the horizontal direction. This in normally referred to as the 12 Inch Rule, see Section S12.0 of this manual for information pertaining to the implementation of this rule.
2. The ducts have a cross-sectional area of less than 6 ft^2.

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ASCE/SEI 7-02 (2003 IBC) and ASCE/SEI 7-05 (2006/2009 IBC) make an interesting statement concerning the fabrication and installation of ductwork, which will be quoted below.

> HVAC duct systems which are fabricated and installed in accordance with standards approved by the authority having jurisdiction shall be deemed to meet the lateral bracing requirements of this section.

The same statement as worded in 2000 IBC reads as follows;

> HVAC duct systems fabricated and installed in accordance with the SMACNA duct construction standards (SMACNA-HVAC and SMACNA –Seismic) and including Appendix B of the SMACNA Seismic Restraint Manual Guidelines for Mechanical Systems shall be deemed to meet the lateral bracing requirements of this section.

As originally published 2000 IBC directly referenced the SMACNA standards as being acceptable for meeting the seismic requirements of the code. The SMACNA Seismic Restraint Guidelines for Mechanical Systems allows the "less than 6 ft^2" for ducts that are assigned a Component Importance Factor Greater Than or equal to 1.0.

The later versions of the code by way of ASCE/SEI 7 documents indicate that it is up to the local authority having jurisdiction over a project to decide whether SMACNA is the approved standard for fabricating and installing the duct systems. Generally speaking, SMACNA is the recognized authority on the design, fabrication, and installation of duct systems, but the designer responsible for selecting the seismic restraints for a duct system needs to check with the local building authorities for verification of the SMACNA standards.

While there are no specific exemptions for duct assigned a Component Importance Factor of 1.5 in ASCE 7-05 or 2006 IBC, 2009 IBC does have the following exemptions for Duct assigned a Component Importance Factor of 1.5 in Section 1613.6.8.

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1. HVAC ducts that are suspended from hangers 12 inches (305 mm) or less in length which have been detailed to avoid significant bending of the hangers or their attachments.
2. HVAC ducts that have a cross-sectional area of less than 6 ft^2 (0.557 m^2).

There is another “exemption”, or rather an allowance, which will reduce the number of restraints a duct system may require. This allowance deals with in-line components such as fans, heat exchangers, humidifiers, VAV boxes, silencers, and etc. These devices may be supported and restrained as part of the duct system if the following conditions are met.

1. They are rigidly, hard, connected to the duct on one or both ends, so that the device moves with the duct.
2. They have an operating weight that is less than or equal to 75 lbs.
3. Appurtenances such as louvers, dampers, diffusers, and etc. are rigidly attached with mechanical fasteners.
4. Piping that serves these devices and is not seismically restrained must be attached to the device with a flexible connector that will handle the expected relative movement between the pipe and the device.
5. Sufficient clearance around the duct and the in-line equipment must be maintained to prevent damage to adjacent components and building structure.

Normally the weight of these in-line devices is small when compared to the weight of the duct being restrained at each restraint location. However, in some cases it may be necessary to include the weight of the device. In these cases the weight of the device should be assumed to be distributed equally over the length of the duct being restrained at each restraint location.

Any seismic restraint exemption that applies to a run of duct also extends to in-line components that are hard connected to the duct on at least one end and that weigh 75 lbs or less. However, if the in-line component weighs more than 20 lbs, and is not hard connected to the duct on at least one end end, it will need to be individually restrained.

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S4.6 – 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 or duct system must assign a 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, and/or all of the duct 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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CODE BASED SESIMIC DESIGN FORCES

S5.1 – Introduction:

The code based horizontal seismic force requirements for pipe and duct are either calculated by the seismic restraint manufacturer as a part of the selection and certification process, or available through a convenient and easy method provided by the manufacturer. Kinetics Noise Control provides online tools that will calculate the horizontal seismic force and make recommendations for the proper seismic restraints for the pipe or duct in question. These tools will be discussed in the next section.

This section 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 pipe or duct and the nature of the seismic forces and the factors that affect them.

S5.2 – Code Based Horizontal Seismic Design Force – ASCE/SEI 7-05 Section 13.3:

The seismic force is a mass, or weight, based force, and as such is applied to the pipe or duct at its center of gravity, which is usually at the center of the cross-section of the pipe or duct. Keep in mind that the earthquake ground motion moves the base of the building first. Then the motion of the building will accelerate the pipe or duct through the hangers. The horizontal seismic force acting on a pipe or duct will be determined in accordance with Equation 13.3-1 of ASCE/SEI 7-05.

$$F_P = \frac{0.4 a_P S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{z}{h}\right)$$ **Equation S5-1**

ASCE/SEI 7-05 defines and upper and lower bound for the horizontal force that is to be applied to the center of gravity of a pipe or duct. The horizontal seismic force acting on a pipe or duct is not required to be greater than;

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$$F_P = 1.6 S_{DS} I_P W_P$$ **Equation S5-2**

And the horizontal seismic force acting on a pipe or duct is not to be less than;

$$F_P = 0.3 S_{DS} I_P W_P$$ **Equation S5-3**

Where:

F_P = the design horizontal seismic force acting on a pipe or duct acting 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 is expected to be. Typically this will vary from 1.0 to 2.5, and is specified by component type in ASCE/SEI 7-05 and listed in Table S5-3.

I_P = the component importance factor which be either 1.0 or 1.5.

W_P = the operating weight of the pipe or duct that is being restrained.

R_P = the response modification factor which usually will vary from 1.0 to 12.0. 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 values are specified by component type in ASCE 7-05 and listed in Table S5-3.

z = the structural attachment mounting height of the pipe or duct hanger 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 **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 **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.

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The weight of the pipe or duct being restrained will depend on the seismic restraint spacing. For the transverse seismic restraints, the weight of the pipe or duct being restrained is;

$$W_P = S_T \sum w_i$$ **Equation S5-4**

For the longitudinal seismic restraints, the weight of the pipe or duct being restrained is;

$$W_P = S_L \sum w_i$$ **Equation S5-5**

Where:

S_L = the longitudinal seismic restraint spacing.

S_T = the transverse seismic restraint spacing.

$\sum w_i$ = the sum of the weights of all of the individual pipes or ducts being restrained over a distance equal to the restraint spacing.

w_i = the weight per foot of an individual pipe or duct over the distance equal to the restraint spacing.

The $\left(1 + 2\frac{z}{h}\right)$ term in Equation S5-1 is recognition of the fact that all buildings and structures become more flexible as they increase in height. That is they are much stiffer 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 to the pipe and duct 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 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.

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The pipe or duct, along with its hangers, will also form a vibrating system with a natural period that depends on the mass of the pipe or duct and the stiffness of the hangers. The component amplification factor (a_P) is a measure of how closely the natural period of the pipe or duct matches the natural period of the building. For $a_P = 1.0$ the natural periods are not close, while for $a_p = 2.5$ the natural period of the pipe or duct is very close to that of the building.

The component response modification factor(R_P)is a measure of how much energy the pipe or duct along with the hanger and attachments can absorb without sustaining crippling damage. A common term used throughout the HVAC industry is fragility. As the term implies, it is concerned with how fragile a component might be. That is, how easily a component may be damaged, and to what degree it might be damaged by a specified load and loading rate. The R_P factor, then, is considered to be an indicator of how fragile a pipe or duct might be. For $R_P = 1.0$ the component is extremely fragile. For $R_P = 12.0$, on the other hand, would be a component that is very robust.

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 S5-1; S5-2, and S5-3 which represent 2000 IBC/ASCE 7-98, 2003 IBC/ASCE 7-02, and 2006/2009 IBC/ASCE 7-05 respectively.

The consensus of opinion appears to be that piping and ductwork, in general, can absorb more energy than had originally been thought. Indeed piping and ductwork that is constructed of highly deformable materials with joints made with welding or brazing can absorb a great deal of energy without sustaining enough damage to cause loss of service. These facts are reflected by the larger values for R_P which will lead to the use of fewer and smaller seismic restraints on a run or pipe or duct.

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Table S5-1; Component Amplification and Response Modification Factors for 2000 IBC (ASCE 7-98)

Component	a_P	R_P
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

Table S5-2; Component Amplification and Response Modification Factors for 2003 IBC (ASCE 7-02)

Component	a_P	R_P
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

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Table S5-3; Component Amplification and Response Modification Factors for 2006/2009 IBC (ASCE 7-05)

Component	a_P	R_P
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

S5.3 – Code Based Vertical Seismic Design Force – ASCE/SEI 7-05 Section 13.3:

ASCE/SEI 7-05 requires that a vertical seismic load be applied to the pipe or duct concurrently with the horizontal seismic load from Equation S5-1. The vertical seismic load acting on the pipe or duct will be;

$$F_V = \pm 0.2 S_{DS} W_P$$ **Equation S5-6**

This force is to be applied in the direction that causes the worst case condition. In this instance it is to be applied downward to the hanger(s) that are closest to the seismic restraint locations. This load will add to the tension load in the hanger generated by the supported weight of the pipe of duct. A check should be performed to make sure that the vertical seismic force does not overload the hanger(s).

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5.4 LRFD versus ASD – ASCE/SEI 7-05 Sections 2.3, 2.4 and 13.1.7

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 S5-1, S5-2, S5-3, and S5-6 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 S5-1 through S5-6 by multiplying the ASD values by 1.4.

S5.5 – Summary:

This section has provided an insight into the way in which the seismic design forces for pipe and duct distribution systems may be computed. It is generally not necessary for a designer to actually run the computations for the seismic design forces. Kinetics Noise Control provides web based computer tools to help the designer responsible for the seismic restraint selection determine the seismic forces that will be acting on the pipe or duct distribution system and to make the proper selection for the seismic restraints. More about the selection process and the web based tools will be said in the following sections.

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ANCHORAGE OF SEISMIC RESTRAINTS FOR PIPE AND DUCT

S6.1 – Introduction:

The 2006/2009 IBC has some strict requirements on the types of attachment hardware to be used to anchor the seismic restraints for pipe or duct to the building structure. This section will discuss these requirements and provide some guidance for interpreting them.

S6.2 – Load Path:

Section 13.4 of ASCE/SEI 7-05 requires that there be a continuous load path of sufficient strength and stiffness between the pipe or duct and the building structure to support the design loads discussed in section S5.0 of this manual. Globally speaking, this load path will be continuous all the way down to the supporting soil structure. The seismic restraints and anchorage hardware provided by Kinetics Noise Control form a part of this continuous load path. The design professional that has responsibility for the pipe or duct must coordinate with the structural engineer of record to ensure that the selected anchorage locations on the building structure will;

1. Have a continuous load path leading to the main building structure and from there to ground. This means that stud walls, unless specifically designed for the purpose, may not be used for anchorage of seismic restraints.
2. Have sufficient strength and stiffness to carry the expected seismic design loads as well as the other normal service loads for which the structure was designed.
3. Have the proper attachment conditions for the type of anchor being used. This is especially critical for post installed concrete anchors which have limiting requirements for concrete strength, anchor embedment, anchor spacing, and anchor distance from the edge of the concrete.

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S6.3 – Post Installed Concrete Anchors:

2006/2009 IBC requires the use of "cracked concrete anchors" when using post installed anchors to attach seismic restraints to the building structure. These anchors are those which have been pre-qualified for seismic applications by testing in accordance with ACI 355.2. Anchors which satisfy the requirements of ACI 355.2 will have an ICC/ES report issued which will specify the following.

1. The IBC code year(s) for which the anchors are qualified.
2. The conditions of use. Whether they are qualified for seismic applications, and if so for which Seismic Design Categories they may be used. Also, the report will indicate whether the anchors may be used in outdoor wet environments, or must be confined to indoor dry applications.
3. The allowable loads, embedment depths, critical spacing, and edge distance.

The concrete anchors supplied by Kinetics Noise Control with their seismic restraint kits meet the requirements of 2006/2009 IBC.

S6.4 – Additional Anchorage Limitations:

There are additional fastener types which may not be used for seismic applications. Some of these are obvious, and some are used regularly without question.

1. Friction Clips – Fasteners which rely on friction for their holding power may not be used for seismic anchorage applications. This is because friction clips require continuous and intimate contact between the friction surfaces for the proper holding forces to be developed. The vibrations introduced by an earthquake may cause this intimate contact to be broken which will lead to slippage in the fastener. Once a friction type clip has begun to slip, it will continue to slide under a much lower force than that which it was designed to resist.

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2. Power Actuated Fasteners – Power actuated fasteners may not be used to resist tensile loads for seismic applications in Seismic Design Categories D, E, or F, unless specifically designed to do so. It is probably good practice to not use power actuated fasteners in Seismic Design Category C as well. A favorite type of this fastener is the powder shot pin. These types of fasteners rely on the elastic nature of the material into which they are driven to provide enough friction force to prevent withdrawal of the fastener under a tensile load. When a vibratory load is introduced, especially in concrete which is weak in tension, these fasteners may tend to "back out' under tensile loads.
3. Beam Clamps w/o Retainer/Safety Straps – Even with a pointed set screw these devices rely strongly on friction to hold their position. If a retainer/safety strap is used with the beam clamp to mechanically prevent it from "walking" off the beam under a cyclic load, and the strap is of adequate size to resist the expected seismic load, then it may be used to anchor the seismic restraint to the structure.

S6.5 – Summary:

1. Be sure there is a continuous load path from the seismic restraint to the building structure. Ultimately the engineer of record must be responsible for the installation of the restraints, and for interfacing with the structural engineer to ensure the validity of the structural connection.
2. Be sure the proper anchor type is being specified for the attachment of the seismic restraint to the building structure.
3. Coordinate with the structural engineer of record to ensure that the structural anchorage points for the seismic restraints have enough strength and stiffness to resist the design seismic loads as well as the other normal service loads.

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SELECTION & LOCATION OF RESTRAINTS FOR PIPE AND DUCT

S7.1 – Introduction:

The actual selection of the seismic restraints and the approximate locations for those restraints along the pipe or duct has typically been done by the supplier of the seismic restraint components. Kinetics Noise Control provides this service to the building industry because we are expected, and in many cases required, to certify that the restraint components that we supply will meet the site specific seismic requirements for the project. As part of the certification process, Kinetics Noise Control will provide tentative restraint selections, quantities, and approximate locations of the seismic restraints for the project in question and then provide a certification letter stating that the restraints will meet the seismic requirements of the project. Keep in mind that the selection, quantities, and indicated locations are tentative and approximate based on the project information submitted to Kinetics Noise Control. Project parameters tend to evolve as the project progresses. Therefore, the number of restraints required may change between the time of submittal and installation. This section will provide the project engineer responsible for the pipe or duct some insight on the selection and application of the seismic restraints for their project.

S7.2 – Information Required for the Selection of Seismic Restraints for Pipe and Duct:

The information required to perform the necessary calculations and make the appropriate selection of seismic restraints for pipe and duct, is described and detailed in Section S2.0 of this manual. For convenience, this required information will be summarized below.

1. Building Occupancy Category – needed to establish the building use.
2. Seismic Design Category – A, B, C, D, E, or F.
3. Design Acceleration Value – either a or b below may be given.
    a. S_S & Soil Type
    b. S_{DS}
4. Component Importance Factor – either 1.0 or 1.5.

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5. The height of the building roof as measured from grade.
6. Elevation of the attachment point for the run of pipe or duct as measured from grade.

S7.3 – Horizontal Force Class:

Since the seismic design force discussed in Section S5.0 acts in a horizontal direction, Kinetics Noise Control has developed a Horizontal Force Class system to rate their seismic restraints for Pipe and Duct and to classify the seismic requirements for projects. This system is defined in Table S7-1 below. The Horizontal Force Class system provides a quick and easy way to select the proper components while being sure that a satisfactory Factor of Safety is being maintained. It simply requires matching the Horizontal Force Class rating of the seismic restraint with the calculated Horizontal Force Class requirement of the pipe or duct.

Table S7-1; Horizontal Seismic Force Class System Designations

Horizontal Force Class	Horizontal Seismic Force Range per Force Class (lbs)
I	$0 \leq F_P \leq 250$
II	$250 < F_P \leq 500$
III	$500 < F_P \leq 1{,}000$
IV	$1{,}000 < F_P \leq 2{,}000$
V	$2{,}000 < F_P \leq 5{,}000$
VI	$5{,}000 < F_P \leq 10{,}000$

S7.4 – Seismic Restraint Kit and Attachment Kit Cross-Reference:

In the discussion that follows various code or “shorthand” symbols will be used to simplify seismic restraint location drawings and calculation documents. These code symbols may be cross-referenced to their respective restraint cable kits and attachment kits as shown in Tables S7-2, S7-3, and S7-4.

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Kinetics Noise Control primarily sells cable type seismic restraints. However, Kinetics Noise Control offers attachment brackets and hardware for the use of strut type restraints. Each restraint cable kit contains enough components to make two complete cable assemblies. This will provide one complete transverse restraint or one complete longitudinal restraint. The attachment kits contain enough hardware to attach two cable restraints to the pipe or duct, and then to the building structure.

Table S7-2; Seismic Restraint Cable Kit vs. Code Cross-Reference

KNC Restraint Kit Code	Restraint Kit Description
K2	KSCU-2 Cable Kit – 2 mm Cable & GRIPPLE HANGFAST No, 2 Connectors
K3	KSCU-3 Cable Kit – 3 mm Cable & GRIPPLE HANGFAST No, 3 Connectors
K4	KSCU-4 Cable Kit – 5 mm Cable & GRIPPLE HANGFAST No, 4 Connectors
K5	KSCU-5 Cable Kit – 6 mm Cable & GRIPPLE Lockable 6 mm Connectors
C1	KSCC-250 Cable Kit – 1/4″ Cable & Saddle + U-bolt Connectors
C2	KSCC-375 Cable Kit – 3/8″ Cable & Saddle + U-bolt Connectors
C3	KSCC-500 Cable Kit – 1/2″ Cable & Saddle + U-bolt Connectors
F	Direct Mounted to Floor or Roof Using Anchor Bolts
W	Direct Mounted to Wall Using Anchor Bolts

Space and structural constraints sometimes make it necessary to use rigid strut restraints instead of cable restraints. Each of the strut restraint kits provided by Kinetics Noise Control will contain enough attachment brackets and hardware for one strut type restraint. The most common materials that are used for rigid strut restraints are structural angles, UNISTRUT® type channels, and pipe. Tables S7-5, S7-6, and S7-7 provide a cross-reference between the Kinetics Noise Control code symbols for the restraint cable kits and struts made from structural angles, UNISTRUT® channel, and pipe respectively. Note that only the KSCU restraint cable kits are supported for strut type restraints using pipe. This is due to the difficulty of attaching the KSCC brackets to the pipe.

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Table S7-3; Structural Concrete/Steel Attachment Kit vs. Code Cross-Reference

KNC Attachment Kit Code	Attachment Kit Description per Restraint Cable Note: Through bolts & nuts of the same size may be used for each kit and code shown below.
X1	(1) 1/4″ Concrete Anchor (with Grommet)
X2	(1) 3/8″ Concrete Anchor (with Grommet)
X3	(1) 1/2″ Concrete Anchor
Y1	(1) 5/8″ Concrete Anchor
Y2	(1) 3/4″ Concrete Anchor
Y3	(1) 7/8″ Concrete Anchor
Z1	(2) 3/8″ Concrete Anchors with Oversized Base Plate
Z2	(4) 3/8″ Concrete Anchors with Oversized Base Plate
Z3	(2) 1/2″ Concrete Anchors with Oversized Base Plate
Z4	(4) 1/2″ Concrete Anchors with Oversized Base Plate

Table S7-4; Structural Wood/Steel Attachment Kit vs. Code Cross-Reference

KNC Attachment Kit Code	Attachment Kit Description per Restraint Cable Note: Through bolts & nuts of the same size may be used for each kit and code shown below.
W1	(1) 1/4″ Lag Screw (with Grommet)
W2	(1) 3/8″ Lag Screw (with Grommet)
W3	(1) 1/2″ Lag Screw
W4	(1) 5/8″ Lag Screw
W5	(1) 3/4″ Lag Screw
W6	(1) 7/8″ Lag Screw
W7	(2) 3/8″ Lag Screws with Oversized Base Plate
W8	(4) 3/8″ Lag Screws with Oversized Base Plate
W9	(2) 1/2″ Lag Screws with Oversized Base Plate
W10	(4) 1/2″ Lag Screws with Oversized Base Plate

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Table S7-5; Seismic Strut Restraint Size per KNC Restraint Code for Structural Steel Angle

KNC Restraint Code	Restraint Cable Kit	Structural Steel Angle Size (in)											
		1 x 1 x 1/8	1 x 1 x 1/4	1-1/2 x 1-1/2 x 1/4	2 x 2 x 1/4	2 x 2 x 3/8	2-1/2 x 2-1/2 x 1/4	2-1/2 x 2-1/2 x 1/2	3 x 3 x 1/4	3 x 3 x 1/2	3-1/2 x 3-1/2 x 1/4	3-1/2 x 3-1/2 x 1/2	4 x 4 x 1/4
		Maximum Strut Length (in)											
K2	KSCU-2	173	205	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
K3	KSCU-3	122	145	197	189	-----	-----	-----	-----	-----	-----	-----	-----
K4	KSCU-4	77	92	125	120	164	153	210	189	-----	-----	-----	-----
K5	KSCU-5	52	61	84	80	110	103	141	127	174	209	-----	-----
C1	KSCC-250	53	63	86	82	113	105	144	130	178	213	-----	-----
C2	KSCC-375	37	44	60	57	78	73	100	90	124	149	203	232
C3	KSCC-500	30	36	49	47	64	60	82	74	101	121	166	190

Table S7-6; Seismic Strut Restraint Size per KNC Restraint Code for UNISTRUT® Profiles

KNC Restraint Code	Restraint Cable Kit	UNISTRUT® Profile			
		P1000	P1001	P5000	P5001
		Maximum Strut Length (in)			
K2	KSCU-2	165	-----	-----	-----
K3	KSCU-3	117	186	179	-----
K4	KSCU-4	74	118	113	160
K5	KSCU-5	49	79	76	108
C1	KSCC-250	51	81	78	110
C2	KSCC-375	34	56	54	77
C3	KSCC-500	16	46	44	62

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Table S7-7; Seismic Strut Restraint Size per KNC Restraint Code for Pipe

KNC Restraint Code	Restraint Cable Kit	Nominal Pipe Size & Schedule						
		1" Sch. 40	1-1/4" Sch. 40	1-1/2" Sch. 40	2" Sch. 10	2" Sch. 40	2-1/2" Sch. 10	2-1/2" Sch. 40
		Maximum Strut Length (in)						
K2	KSCU-2	111	166	210	-----	-----	-----	-----
K3	KSCU-3	79	118	148	188	218	-----	-----
K4	KSCU-4	50	75	94	120	138	168	210
K5	KSCU-5	33	50	63	80	93	113	141

S7.5 – Kinetics Noise Control Pipe & Duct Seismic Restraint Analysis Output:

Using the product information supplied by the customer, Kinetics Noise Control will run a Site Specific seismic analysis for the restraint of pipe or duct. The output of the analysis is based on the weight per foot of the component being restrained. It is not specific to pipe or duct and may be used for both. It is also not specific to single clevis hung pipe or trapeze supported pipe and may be used for both. There are four basic output sheets from the analysis, and they are shown in an example in Tables S7-8 through S7-11.

Currently, the use of the Kinetics Noise Control web based tools for performing the calculations for pipe and duct are limited to employees and representatives of Kinetics Noise Control. The procedure for performing the calculations, selection, and location of seismic restraints for pipe and duct is still under development due to changes in the code and the introduction of new products by Kinetics Noise Control. These web based tools may be made available to design professionals at sometime in the future.

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The site specific selection of seismic restraints and attachment hardware for pipe and duct is based on the restraint cable kit capacities with various attachment kits. These kit capacities are presented in Appendix A1.1 of this manual. These tables will help design professionals of record to verify that the proper selection of restraints and attachment hardware have been made for their specific applications. Also, the data presented in these tables will be pertinent to the discussion which will follow concerning the interpretation of Tables S7-8 through S7-11.

In each of the Tables S7-8 through S7-11 there are columns on the left hand side that give approximate weights per foot for insulated standard steel schedule 40 pipe with water and steam, and for typical rectangular duct that is non-insulated and non-lagged. Appendices A2.1 through A2.5 give the weight per foot for many different types of pipe that are water filled or steam filled, and insulated and non-insulated. Appendices A3.1 through A3.3 give the weight per foot for many different types of duct that are both insulated and non-insulated, and where appropriate with acoustical lagging.

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Table S7-8; Site Specific Seismic Pipe & Duct Horizontal Force Class Example

KINETICS Noise Control

KINETICS NOISE CONTROL
6300 IRELAN PLACE
DUBLIN, OHIO 43017
ph 614-889-0480

Table 1A

Site Specific Horizontal Force Selection Tables 2006 IBC

Horizontal Force Class	
Max Force (lbs)	Force Class
250	I
500	II
1000	III
2000	IV
5000	V
10000	VI

Typ. Lb/Ft Includes Insulation		
Pipe Size	Filled Pipe	Steam Pipe
1	2.91	3.24
1.5	4.67	4.61
2	6.35	5.81
2.5	9.3	8.22
3	12.44	10.35
4	18.34	14.12
5	27.2	20.22
6	35.99	25.36
8	55.84	36.42
10	81.43	49.92
12	106.45	60.48
14	122.88	66.42
16	151.4	75.91
18	182.63	85.41
20	216.59	94.91
24	292.68	113.91

Maximum Rectangular Duct Weight	
Duct Size	Lb/Ft
30 x 30	26
42 x 42	36
54 x 54	47
60 x 60	54
84 x 84	103
96 x 96	129
54 x 28	35
60 x 30	39
84 x 42	74
96 x 48	97
108 x 54	110
120 x 60	121

Instructions for Use

1) Determine the max restraint spacing, from the geometry of the installation but do not exceed values listed in Table 2.
2) Determine the weight of the pipe or duct component(s) from the tables above (adding trapezed items together.)
3) Use the tables at right to determine the Horizontal Force, Force Class, Cable & Attachment Kit Or Kit Type Designator based on the Restraint Spacing
4) For other pipe and duct types see appendices A2.0 and A3.0 of Kinetics Pipe & Duct Application Manual.

(Force Class Units are LRFD [Strength] Based)

Cracked Concrete Anchor (KCCAB) or Through Bolt

Project:	S7.0 Example	KNC#	KN1611
Mapped S_{DS} :	0.25	I_P :	1.5
		R_P :	6
Maximum Installation Angle: 45		Installation Orientation:	BOTH

G's by Building Elevation listed below

Grade	16%	33%	50%	66%	84%	Roof
0.113	0.113	0.113	0.125	0.146	0.166	0.188

Restraints Located 10 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
	Elevation in Structure (% of Total Building Height)						
10	11	11	11	13	15	17	19
25	28	28	28	31	36	42	47
50	56	56	56	63	73	83	94
100	113	113	113	125	146	166	188
150	169	169	169	188	218	249	281
200	225	225	225	250	291	333	375
250	281	281	281	313	364	416	469
300	338	338	338	375	437	499	563

Restraints Located 20 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
	Elevation in Structure (% of Total Building Height)						
10	23	23	23	25	29	33	38
25	56	56	56	63	73	83	94
50	113	113	113	125	146	166	188
100	225	225	225	250	291	333	375
150	338	338	338	375	437	499	563
200	450	450	450	500	583	665	750
250	563	563	563	625	728	831	938
300	675	675	675	750	874	998	1125

Restraints Located 30 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
	Elevation in Structure (% of Total Building Height)						
10	34	34	34	38	44	50	56
25	84	84	84	94	109	125	141
50	169	169	169	188	218	249	281
100	338	338	338	375	437	499	563
150	506	506	506	563	655	748	844
200	675	675	675	750	874	998	1125
250	844	844	844	938	1092	1247	1406
300	1013	1013	1013	1125	1311	1496	1688

Restraints Located 40 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
	Elevation in Structure (% of Total Building Height)						
10	45	45	45	50	58	67	75
25	113	113	113	125	146	166	188
50	225	225	225	250	291	333	375
100	450	450	450	500	583	665	750
150	675	675	675	750	874	998	1125
200	900	900	900	1000	1165	1330	1500
250	1125	1125	1125	1250	1456	1663	1875
300	1350	1350	1350	1500	1748	1995	2250

Restraints Located 60 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
	Elevation in Structure (% of Total Building Height)						
10	68	68	68	75	87	100	113
25	169	169	169	188	218	249	281
50	338	338	338	375	437	499	563
100	675	675	675	750	874	998	1125
150	1013	1013	1013	1125	1311	1496	1688
200	1350	1350	1350	1500	1747	1995	2250
250	1688	1688	1688	1875	2184	2494	2813
300	2025	2025	2025	2250	2621	2993	3375

Restraints Located 80 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
	Elevation in Structure (% of Total Building Height)						
10	90	90	90	100	117	133	150
25	225	225	225	250	291	333	375
50	450	450	450	500	583	665	750
100	900	900	900	1000	1165	1330	1500
150	1350	1350	1350	1500	1748	1995	2250
200	1800	1800	1800	2000	2330	2660	3000
250	2250	2250	2250	2500	2913	3325	3750
300	2700	2700	2700	3000	3495	3990	4500

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Table S7-9; Site Specific Seismic Pipe & Duct Horizontal Seismic Force

KINETICS NOISE CONTROL
6300 IRELAN PLACE
DUBLIN, OHIO 43017
ph 614-889-0480

Table 1

Site Specific Horizontal Force Class Selection Tables 2006 IBC

Horizontal Force Class	
Max Force (lbs)	Force Class
250	I
500	II
1000	III
2000	IV
5000	V
10000	VI

Typ. Lb/Ft Includes Insulation		
Pipe Size	Filled Pipe	Steam Pipe
1	2.91	3.24
1.5	4.67	4.61
2	6.35	5.81
2.5	9.3	8.22
3	12.44	10.35
4	18.34	14.12
5	27.2	20.22
6	35.99	25.36
8	55.84	36.42
10	81.43	49.92
12	106.45	60.48
14	122.88	66.42
16	151.4	75.91
18	182.63	85.41
20	216.59	94.91
24	292.68	113.91

Maximum Rectangular Duct Weight	
Duct Size	Lb/Ft
30 x 30	26
42 x 42	36
54 x 54	47
60 x 60	54
84 x 84	103
96 x 96	129
54 x 28	35
60 x 30	39
84 x 42	74
96 x 48	97
108 x 54	110
120 x 60	121

Instructions for Use

1) Determine the max restraint spacing, from the geometry of the installation but do not exceed values listed in Table 2.
2) Determine the weight of the pipe or duct component(s) from the tables above (adding trapezed items together.)
3) Use the tables at right to determine the Horizontal Force, Force Class, Cable & Attachment Kit Or Kit Type Designator based on the Restraint Spacing
4) For other pipe and duct types see appendices A2.0 and A3.0 of Kinetics Pipe & Duct Application Manual.

(Force Class Units are LRFD [Strength] Based)

Cracked Concrete Anchor (KCCAB) or Through Bolt

Project:	S7.0 Example	KNC#	KN1611
Mapped S_{DS} :	0.25	I_P :	1.5
		R_P :	6
Maximum Installation Angle: 45		Installation Orientation:	BOTH

G's by Building Elevation listed below

Grade	16%	33%	50%	66%	84%	Roof
0.113	0.113	0.113	0.125	0.146	0.166	0.188

Restraints Located 10 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	I	I	I	I	I	I	I
25	I	I	I	I	I	I	I
50	I	I	I	I	I	I	I
100	I	I	I	I	I	I	I
150	I	I	I	I	I	I	II
200	I	I	I	I	II	II	II
250	II	II	II	II	II	II	II
300	II	II	II	II	II	II	III

Restraints Located 20 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	I	I	I	I	I	I	I
25	I	I	I	I	I	I	I
50	I	I	I	I	I	I	I
100	I	I	I	I	II	II	II
150	II	II	II	II	II	II	III
200	II	II	II	II	III	III	III
250	III	III	III	III	III	III	III
300	III	III	III	III	III	III	IV

Restraints Located 30 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	I	I	I	I	I	I	I
25	I	I	I	I	I	I	I
50	I	I	I	I	I	I	II
100	II	II	II	II	II	II	III
150	III	III	III	III	III	III	III
200	III	III	III	III	III	III	IV
250	III	III	III	III	IV	IV	IV
300	IV	IV	IV	IV	IV	IV	IV

Restraints Located 40 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	I	I	I	I	I	I	I
25	I	I	I	I	I	I	I
50	I	I	I	I	II	II	II
100	II	II	II	II	III	III	III
150	III	III	III	III	III	III	IV
200	III	III	III	III	IV	IV	IV
250	IV	IV	IV	IV	IV	IV	IV
300	IV	IV	IV	IV	IV	IV	V

Restraints Located 60 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	I	I	I	I	I	I	I
25	I	I	I	I	I	I	II
50	II	II	II	II	II	II	III
100	III	III	III	III	III	III	IV
150	IV	IV	IV	IV	IV	IV	IV
200	IV	IV	IV	IV	IV	IV	V
250	IV	IV	IV	IV	V	V	V
300	V	V	V	V	V	V	V

Restraints Located 80 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	I	I	I	I	I	I	I
25	I	I	I	I	II	II	II
50	II	II	II	II	III	III	III
100	III	III	III	III	IV	IV	IV
150	IV	IV	IV	IV	IV	IV	V
200	IV	IV	IV	IV	V	V	V
250	V	V	V	V	V	V	V
300	V	V	V	V	V	V	V

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Table 10; Site Specific Seismic Pipe & Duct Cable & Attachment Kit Selection

KINETICS Noise Control

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6300 IRELAN PLACE
DUBLIN, OHIO 43017
ph 614-889-0480

Table 1B

Site Specific Cable & Attachment Kit Selection Tables 2006 IBC

Cracked Concrete Anchor (KCCAB) or Through Bolt

Project:	S7.0 Example	KNC#	KN1611
Mapped S_{DS} :	0.25	I_P :	1.5
		R_P :	6
Maximum Installation Angle: 45		Installation Orientation: BOTH	

G's by Building Elevation listed below

Grade	16%	33%	50%	66%	84%	Roof
0.113	0.113	0.113	0.125	0.146	0.166	0.188

Horizontal Force Class	
Max Force (lbs)	Force Class
250	I
500	II
1000	III
2000	IV
5000	V
10000	VI

Typ. Lb/Ft Includes Insulation

Pipe Size	Filled Pipe	Steam Pipe
1	2.91	3.24
1.5	4.67	4.61
2	6.35	5.81
2.5	9.3	8.22
3	12.44	10.35
4	18.34	14.12
5	27.2	20.22
6	35.99	25.36
8	55.84	36.42
10	81.43	49.92
12	106.45	60.48
14	122.88	66.42
16	151.4	75.91
18	182.63	85.41
20	216.59	94.91
24	292.68	113.91

Maximum Rectangular Duct Weight	
Duct Size	Lb/Ft
30 x 30	26
42 x 42	36
54 x 54	47
60 x 60	54
84 x 84	103
96 x 96	129
54 x 28	35
60 x 30	39
84 x 42	74
96 x 48	97
108 x 54	110
120 x 60	121

Instructions for Use

1) Determine the max restraint spacing, from the geometry of the installation but do not exceed values listed in Table 2.
2) Determine the weight of the pipe or duct component(s) from the tables above (adding trapezed items together.)
3) Use the tables at right to determine the Horizontal Force, Force Class, Cable & Attachment Kit Or Kit Type Designator based on the Restraint Spacing
4) For other pipe and duct types see appendices A2.0 and A3.0 of Kinetics Pipe & Duct Application Manual.

(Force Class Units are LRFD [Strength] Based)

Restraints Located 10 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
25	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
50	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
100	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
150	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-3-375	KSCU-3-375
200	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375
250	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375
300	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-4-500	KSCU-4-500

Restraints Located 20 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
25	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
50	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
100	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375
150	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-4-500	KSCU-4-500
200	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500
250	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500
300	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500

Restraints Located 30 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
25	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
50	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-3-375	KSCU-3-375
100	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-4-500	KSCU-4-500
150	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500
200	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500
250	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCC-250-750	KSCC-250-750
300	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCC-250-750	KSCC-375-750	KSCC-375-750

Restraints Located 40 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
25	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
50	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375
100	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500
150	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500
200	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCC-250-750	KSCC-250-750	KSCC-375-750
250	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCC-250-750	KSCC-250-750	KSCC-375-750	KSCC-375-750
300	KSCC-250-750	KSCC-250-750	KSCC-250-750	KSCC-375-750	KSCC-375-750	KSCC-375-750	-

Restraints Located 60 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
25	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-3-375	KSCU-3-375
50	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-4-500	KSCU-4-500
100	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500
150	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCC-250-750	KSCC-375-750	KSCC-375-750
200	KSCC-250-750	KSCC-250-750	KSCC-250-750	KSCC-375-750	KSCC-375-750	KSCC-375-750	-
250	KSCC-375-750	KSCC-375-750	KSCC-375-750	KSCC-375-750	-	-	-
300	KSCC-375-750	KSCC-375-750	KSCC-375-750	-	-	-	-

Restraints Located 80 ft OC [lbs]

Wt/Ft (Lb)	Elevation in Structure (% of Total Building Height) Grade	16%	33%	50%	66%	84%	Roof
10	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-2-375
25	KSCU-2-375	KSCU-2-375	KSCU-2-375	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-3-375
50	KSCU-3-375	KSCU-3-375	KSCU-3-375	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500
100	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCU-4-500	KSCC-250-750	KSCC-250-750	KSCC-375-750
150	KSCC-250-750	KSCC-250-750	KSCC-250-750	KSCC-375-750	KSCC-375-750	KSCC-375-750	-
200	KSCC-375-750	KSCC-375-750	KSCC-375-750	KSCC-375-750	-	-	-
250	-	-	-	-	-	-	-
300	-	-	-	-	-	-	-

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Table S7-11; Site Specific Seismic Pipe & Duct Cable & Attachment Kit Type Designator

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Table 1C

Site Specific Kit Type Designator Selection Tables 2006 IBC

Horizontal Force Class	
Max Force (lbs)	Force Class
250	I
500	II
1000	III
2000	IV
5000	V
10000	VI

Typ. Lb/Ft Includes Insulation		
Pipe Size	Filled Pipe	Steam Pipe
1	2.91	3.24
1.5	4.67	4.61
2	6.35	5.81
2.5	9.3	8.22
3	12.44	10.35
4	18.34	14.12
5	27.2	20.22
6	35.99	25.36
8	55.84	36.42
10	81.43	49.92
12	106.45	60.48
14	122.88	66.42
16	151.4	75.91
18	182.63	85.41
20	216.59	94.91
24	292.68	113.91

Maximum Rectangular Duct Weight	
Duct Size	Lb/Ft
30 x 30	26
42 x 42	36
54 x 54	47
60 x 60	54
84 x 84	103
96 x 96	129
54 x 28	35
60 x 30	39
84 x 42	74
96 x 48	97
108 x 54	110
120 x 60	121

Instructions for Use

1) Determine the max restraint spacing, from the geometry of the installation but do not exceed values listed in Table 2.
2) Determine the weight of the pipe or duct component(s) from the tables above (adding trapezed items together.)
3) Use the tables at right to determine the Horizontal Force, Force Class, Cable & Attachment Kit Or Kit Type Designator based on the Restraint Spacing
4) For other pipe and duct types see appendices A2.0 and A3.0 of Kinetics Pipe & Duct Application Manual.

(Force Class Units are LRFD [Strength] Based)

Cracked Concrete Anchor (KCCAB) or Through Bolt

Project:	S7.0 Example	KNC#	KN1611
Mapped S_{DS} :	0.25	I_P :	1.5
		R_P :	6
Maximum Installation Angle: 45		Installation Orientation: BOTH	

G's by Building Elevation listed below

Grade	16%	33%	50%	66%	84%	Roof
0.113	0.113	0.113	0.125	0.146	0.166	0.188

Restraints Located 10 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
10	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
25	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
50	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
100	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
150	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K3-X2	K3-X2
200	K2-X2	K2-X2	K2-X2	K3-X2	K3-X2	K3-X2	K3-X2
250	K3-X2	K3-X2	K3-X2	K3-X2	K3-X2	K3-X2	K3-X2
300	K3-X2	K3-X2	K3-X2	K3-X2	K3-X2	K4-X3	K4-X3

Restraints Located 20 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
10	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
25	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
50	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
100	K2-X2	K2-X2	K2-X2	K3-X2	K3-X2	K3-X2	K3-X2
150	K3-X2	K3-X2	K3-X2	K3-X2	K3-X2	K4-X3	K4-X3
200	K3-X2	K3-X2	K3-X2	K4-X3	K4-X3	K4-X3	K4-X3
250	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3
300	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3

Restraints Located 30 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
10	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
25	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
50	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K3-X2	K3-X2
100	K3-X2	K3-X2	K3-X2	K3-X2	K3-X2	K4-X3	K4-X3
150	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3
200	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3
250	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	C1-Y2	C1-Y2
300	K4-X3	K4-X3	K4-X3	K4-X3	C1-Y2	C2-Y2	C2-Y2

Restraints Located 40 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
10	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
25	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
50	K2-X2	K2-X2	K2-X2	K3-X2	K3-X2	K3-X2	K3-X2
100	K3-X2	K3-X2	K3-X2	K4-X3	K4-X3	K4-X3	K4-X3
150	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3
200	K4-X3	K4-X3	K4-X3	K4-X3	C1-Y2	C1-Y2	C2-Y2
250	K4-X3	K4-X3	K4-X3	C1-Y2	C1-Y2	C2-Y2	C2-Y2
300	C1-Y2	C1-Y2	C1-Y2	C2-Y2	C2-Y2	C2-Y2	-

Restraints Located 60 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
10	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
25	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K3-X2	K3-X2
50	K3-X2	K3-X2	K3-X2	K3-X2	K3-X2	K4-X3	K4-X3
100	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3	K4-X3
150	K4-X3	K4-X3	K4-X3	K4-X3	C1-Y2	C2-Y2	C2-Y2
200	C1-Y2	C1-Y2	C1-Y2	C2-Y2	C2-Y2	C2-Y2	-
250	C2-Y2	C2-Y2	C2-Y2	C2-Y2	-	-	-
300	C2-Y2	C2-Y2	C2-Y2	-	-	-	-

Restraints Located 80 ft OC [lbs]

Wt/Ft (Lb)	Grade	16%	33%	50%	66%	84%	Roof
10	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2	K2-X2
25	K2-X2	K2-X2	K2-X2	K3-X2	K3-X2	K3-X2	K3-X2
50	K3-X2	K3-X2	K3-X2	K4-X3	K4-X3	K4-X3	K4-X3
100	K4-X3	K4-X3	K4-X3	K4-X3	C1-Y2	C1-Y2	C2-Y2
150	C1-Y2	C1-Y2	C1-Y2	C2-Y2	C2-Y2	C2-Y2	-
200	C2-Y2	C2-Y2	C2-Y2	C2-Y2	-	-	-
250	-	-	-	-	-	-	-
300	-	-	-	-	-	-	-

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There are several areas of all of Tables S7-8 through S7-11 which are identical.

1. At the top of each table is a header that specifies the type of attachment hardware that has been requested.
2. Directly below this header is an area where the project and site specific information is listed.
3. Immediately below the project and site specific information is a table that lists the code based horizontal seismic acceleration that is to be applied to the pipe or duct in G's as it varies from grade line to roof line of the building. This is the elevation of the attachment point for the pipe or duct in the building. Keep in mind that it is the attachment point for the pipe or duct to which the earthquake displacement or acceleration is applied.
4. Below the acceleration by building elevation table are six tables that are segregated according to the seismic restraint spacing. The listed seismic restraint spacings are 10 ft, 20 ft, 30 ft, 40 ft, 60 ft, and 80 ft. The left hand column is the insulated weight per foot of the pipe, and non-insulated and non-lagged weight per foot of the duct that is being restrained. The column headings across the top of each table are the elevation of the attachment point for the pipe or duct in the building from grade line to roof line as a per cent of the roof line elevation. The contents of these six tables will vary as follows.
    a. Table S7-8: These values are the horizontal seismic force expressed as Horizontal Force Class for each weight per foot and each attachment point elevation within the building. This information may be used to make a conservative selection of seismic restraints and attachment hardware by matching the Horizontal Force Class value from Table S7-8 with the Horizontal Force Class Rating of the seismic restraints listed in Appendix A1.0.
    b. Table S7-9: The values listed in these six tables are the actual horizontal force values computed for each weight per foot and each attachment point elevation within the building. These values are used when trying to optimize the selection of seismic restraints and attachment hardware.
    c. Table S7-10: The information contained in these six tables is the Kinetics Noise Control cable restraint kit and the attachment hardware size, of the type specified in

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the table header, for each weight per foot and each attachment point elevation within the building. These selections are based on the actual horizontal seismic force values from Table S7-9 and the seismic restraint capacity data in Appendix A1.1.

d. Table S7-11: These six tables specify the KNC Restraint Kit Code and the KNC Attachment Kit Code in the order. These are the codes that are used to indicate the capacity of the restraints and attachments to the building structure on the pipe and duct drawings that are reviewed and marked by Kinetics Noise Control.

S7.6 – Maximum Allowable Seismic Restraint Spacing:

Typically, the maximum seismic restraint spacing will be for the longitudinal restraints. The seismic restraint spacing values that have been recommended by SMACNA for both transverse and longitudinal restraints are discussed in Section S11.0 of this manual. The SMACNA Seismic Restraint Manual does not make clear the basis for their recommendations. However, it would appear to be based on a combination of the capacity of the hardware components specified, the stiffness of the system being restrained, and the type of system being restrained. The tables developed by Kinetics Noise Control extract the hardware size from consideration at this point leaving the gross buckling of the pipe or duct along with system data to control the length of pipe that may be restrained. Appendices A6.1 through A6.7 were created to investigate the buckling potential of pipe and duct versus the restrained length of the pipe and duct and the design level seismic acceleration.

A brief review of Appendices A6.1 through A6.5 confirms that the restraint spacing recommendation in the SMACNA Seismic Restraint Manual were, in deed, based on the maximum capacity of the restraints specified, and not on the buckling resistance of the pipe itself. Since system performance is factored independently by Kinetics Noise Control, the maximum un-factored seismic restraint spacing for pipe can be selected based on the tables in Appendices A6.1 through A6.5 for the Maximum Allowable Seismic Restraint Spacing. This is based purely on

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the buckling resistance of the pipe, and includes a Factor of Safety of 2:1 with respect to the applied load.

Special Note: ***For trapeze supported piping, the maximum allowable seismic restraint spacing is to be based on the maximum permitted spacing for the most critical or most sensitive pipe being supported by the trapeze bar*. This is based on keeping the unbraced length of the smallest pipe short enough to prevent buckling. This is a particular problem with copper, PVC, and CPVC pipe since their Modulus of Elasticity is much lower than that for steel pipe. See Sections S11.4 and S11.5 and Appendix 6.0.**

For duct, the seismic restraint spacing recommended by SMACNA for transverse and longitudinal seismic restraints appears to be conservative when compared to the values in Appendices A6.6 and A6.7. Because sheet metal ductwork and connections can vary widely in performance and are less predictable than piping systems, it is prudent to use the SMACNA recommended values listed in Section 11.0 of this manual based on their greater experience with design, construction, and field performance of HVAC duct.

S7.7 – Kinetics Noise Control Pipe & Duct Seismic Restraint Drawing Symbols:

Kinetics Noise Control will accept pipe and duct drawings from their customers to produce drawings showing the proper seismic restraint selections and their locations per project site specific information. These drawings are reviewed by highly trained engineers at Kinetics Noise Control who will then mark the locations for the restraints and indicate the proper restraint to use for each location. These seismic restraint specification and location drawings are then reviewed and signed and sealed by one of Kinetics Noise Control licensed professional engineers. Along with the drawings a signed and seal letter certifying the suitability of the restraints and attachments for the application is also issued by the Kinetics Noise Control licensed professional engineer.

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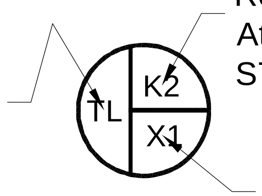
The symbol shown in Figure S7-1 indicates the type of restraint and the capacity of the restraint and the anchorage.

Restraint Type Designation:
T - Transverse Restraint
L - Longitudinal Restraint
TL - Both Transverse & Longitudinal
TT - Two Transverse Restraints -180° Apart & Used Primarily For Riser Applications



KNC Restraint Kit Code: Restraint Capacity Required At This Location, See Table S7-2.

KNC Anchorage Kit Code: Anchorage Capacity Required At This Location, See Tables S7-3 & S7-4.

Figure S7-1; Kinetics Noise Control Restraint Type and Capacity Symbol

The KNC Restraint Kit Codes and the KNC Anchorage Kit Codes are defined in Tables S7-2 and S7-3 respectively. In general, Kinetics Noise Control will attempt to select seismic restraint kits and anchorage kits so that a limited number kits are used for as many locations and restraint types, transverse and longitudinal as possible. There will be cases where it becomes impractical to use the same restraints in all locations on a pipe or duct drawing. In these cases, Kinetics Noise Control will attempt to limit the use of the larger and more expensive components as much as possible. This practice is intended to assist the contractor during installation and may result in a less than optimum restraint selection if cost control is the primary factor. The contractor will make far fewer mistakes during installation if they have a few types restraint and anchorage kits to worry about.

Each transverse restraint (**T**) and longitudinal (**L**) restraint callout represent one pair of restraint cables. For some special cases, an extra pair of restraint cables may be required for a longitudinal restraint location for a duct or trapeze supported pipe run.

The symbols used to indicate the actual locations of the seismic restraints on a run of pipe or duct are shown in Figure S7-2.

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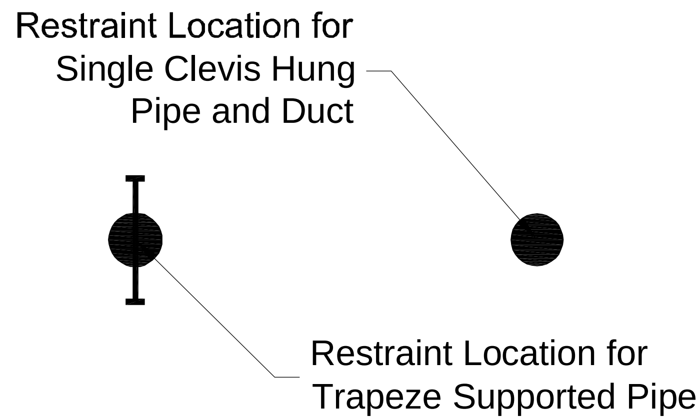

Figure S7-2; Kinetics Noise Control Restraint Location Symbols

For duct or single clevis hung pipe the seismic restraint location is indicated with a single large dot. For trapeze supported pipe, the symbol is an "**I**" shaped bar with a large central dot. The "**I**" shaped bar will extend on either side of the central dot to encompass all of the pipes that are assumed to be supported on the same set of trapeze bars. When two or more pipes run parallel and relatively close together, it is the standard practice of Kinetics Noise Control to assume that all of these pipes are to be supported on the same trapeze bars. This practice allows us to minimize the number of seismic restraint kits and anchorage kits that will be required.

For single clevis hung pipe a typical run of pipe will be marked for seismic restraint and anchorage kits as shown in Figure S7-3. Typically, half of the time, a longitudinal seismic restraint will fall at the same location as a transverse seismic restraint. This is because the spacing for the longitudinal seismic restraints ($\boldsymbol{S_L} \leq 2\boldsymbol{S_T}$) may be up to twice that of the transverse seismic restraints ($\boldsymbol{S_T}$), which will help reduce the total number of restraints required for a run of pipe or duct. For HVAC piping, the transverse seismic restraints may be attached directly to the pipe. They may also be attached to the pipe clevis hanger, or the pipe hanger rod directly above the clevis hanger. For HVAC applications the longitudinal restraints may be attached directly to the pipe. It is also possible for longitudinal restraints to be attached to the clevis hanger or the pipe hanger rod directly above the clevis hanger only if the clevis hanger has been rigidly attached to

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the pipe in such a fashion so as to prevent axial motion. For Fire Protection piping, all seismic restraints must always be attached directly to the pipe.

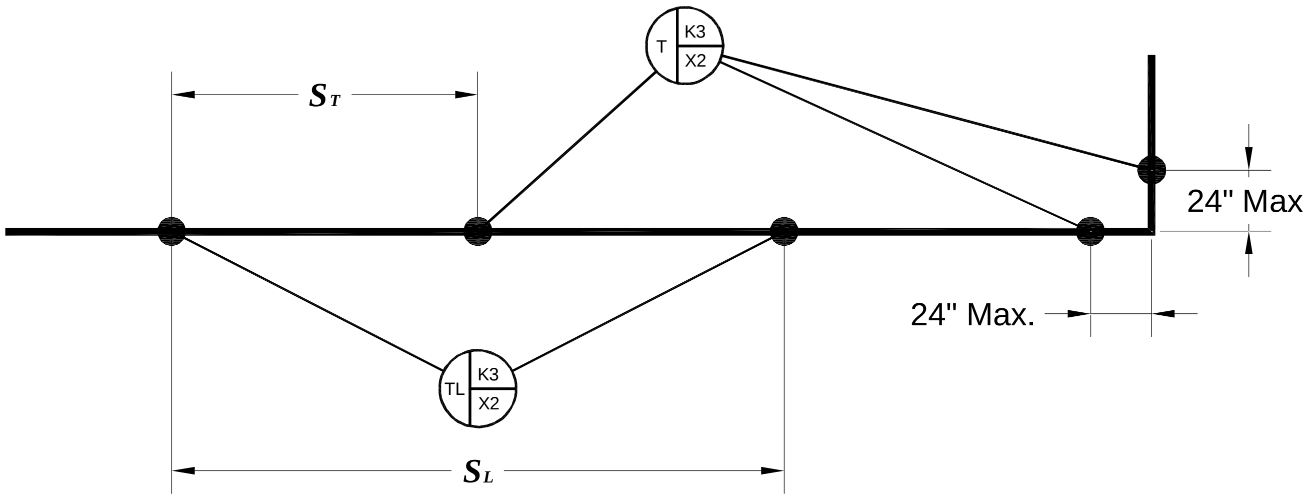

Figure S7-3; Typical KNC Seismic Restraint and Location Callouts for Single Clevis Hung Pipe

Figure S7-4 shows the seismic restraints and locations for a typical run of duct. The locations of the restraints are shown along the centerline of the duct. Rectangular duct is normally supported on trapeze bars which may require special consideration for the actual placement of the restraints. This will be discussed further in a later portion of this section of the manual. The duct must be strong enough to be able to transfer seismic forces along its length between seismic restraint locations. The design of the duct is the responsibility of the HVAC engineer of record. In particular the longitudinal seismic forces which may tend to buckle the sheet metal ducts unless they are rigid enough to resist the buckling loads. If the ducts are supported on trapeze bars, they must be rigidly attached to those trapeze bars to properly transfer the seismic loads to the restraints.

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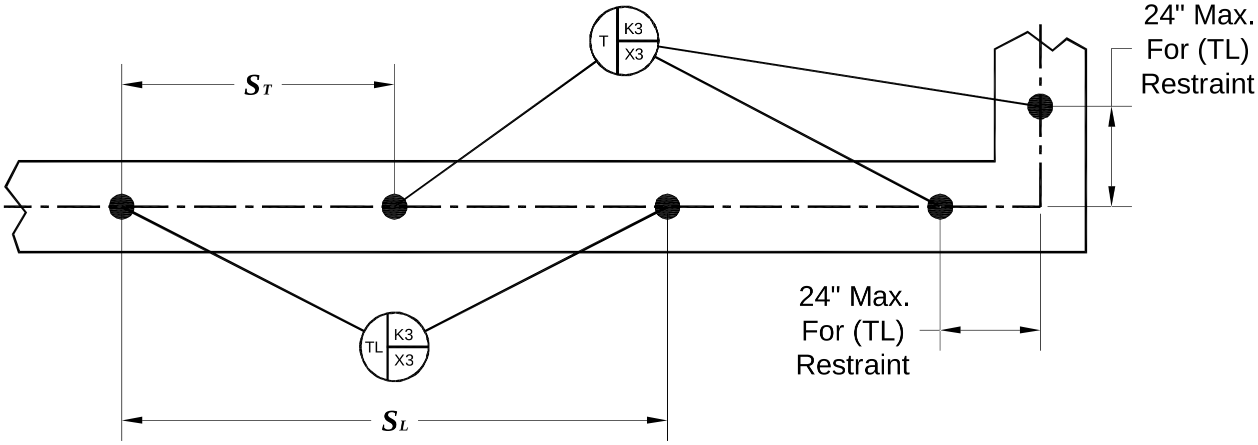

Figure S7-4; Typical KNC Seismic Restraint and Location Callouts for Duct

Typical callouts for seismic restraints and location for trapeze supported pipe are shown in Figure S7-5. Note that the "**I**" shaped bars indicate that the three pipe shown are assumed to be supported on the same set of trapeze bars. The pipes must be rigidly clamped to the trapeze bars to prevent any relative motion between them and the trapeze bar. The dot indicating the location of the seismic restraints is placed on the centerline of the trapeze supported run of pipes. In some cases, special arrangements may be necessary to create a proper longitudinal restraint arrangement. Some of these will be discussed in a later portion of this document.

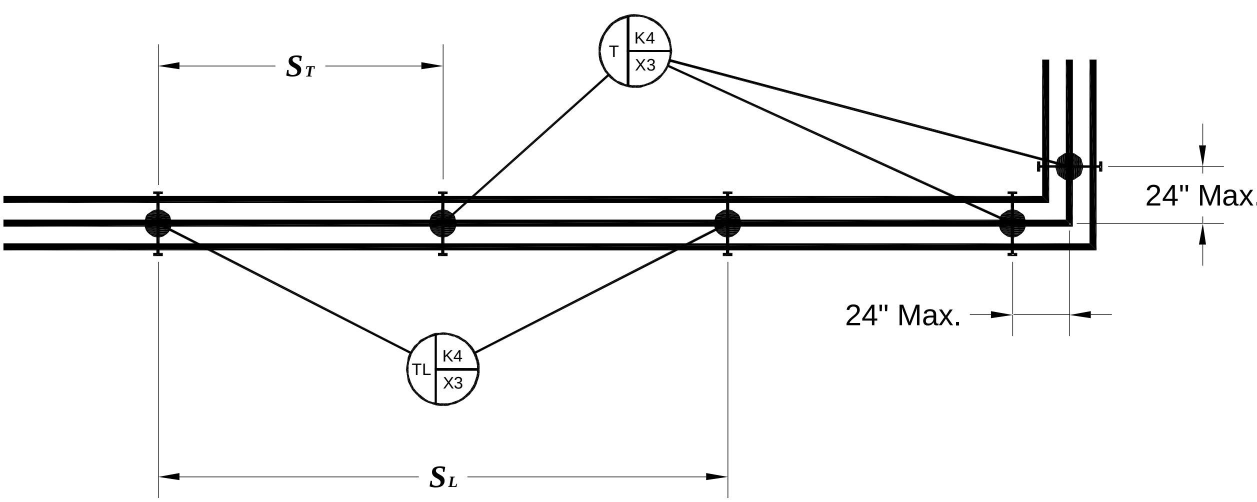

Figure S7-5; Typical KNC Seismic Restraint and Location Callouts for Trapeze Supported Pipe

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In all of the previous examples, the longitudinal seismic restraint spacing has been shown to be twice the transverse seismic restraints spacing. There are often times where it is not possible, or desirable, to have the longitudinal restraint spacing twice that of the transverse restraints for the following reasons.

1. The site and project specific seismic requirements are high enough that restraints of the proper capacity do not exist.
2. The weight of the components being restrained is high enough that restraints of the proper capacity do not exist.
3. There is a desire, or need, to standardize on a particular size or type of restraint device.
4. Connections between pipe segments are not robust enough to transfer longitudinal seismic loads.

A situation of this type is demonstrated in Figure S7-6.

S7.8 – Seismic Restraint and Hanger Locations:

When using cable restraints and rigid strut restraints, the seismic restraint locations must coincide with the hanger locations in order to ensure that there is a clear load path to the structure for any upward reaction loads generated by the horizontal seismic loads. The current standard industry practice is that the seismic restraints for pipe and duct must be located within ±4 inches of the hanger location. Also, the hangers must be rigid members capable of carrying compressive loads.

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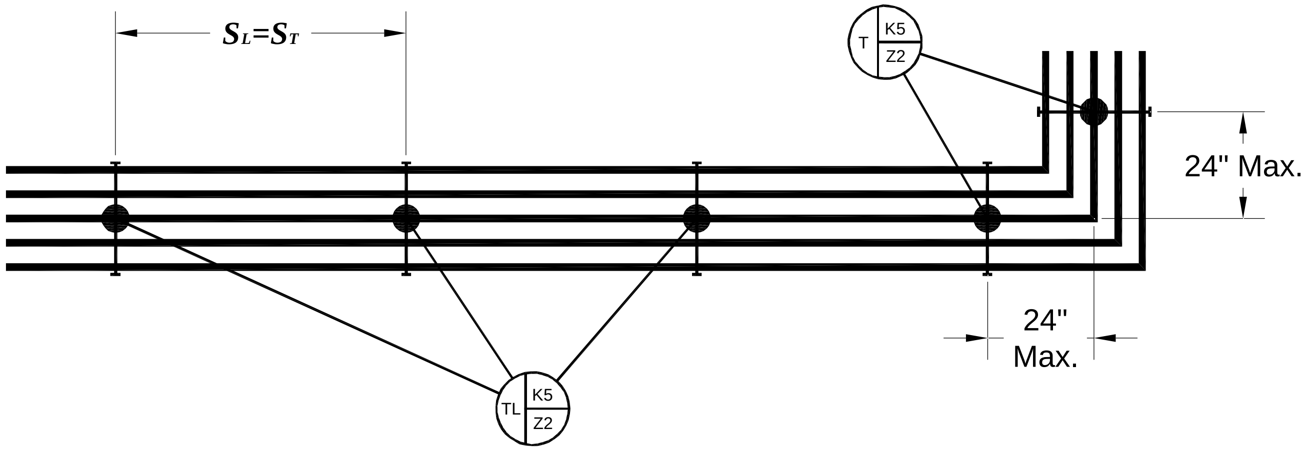

Figure S7-6; Equal Longitudinal and Transverse Seismic Restraint Spacing

Generally speaking, the drawings given to Kinetics Noise Control for marking seismic restraints and locations do not have the hanger locations specified on them. As a result, the locations for seismic restraints indicated on the drawings by Kinetics Noise Control are approximate, and the entire pattern of restraints for a run of pipe or duct must be shifted one way or the other to match the actual hanger spacing. Also, Kinetics Noise Control is rarely provided with the actual hanger spacing that will be used for the runs of pipe or duct for which restraints are to be specified. Actual hanger spacings of 5 ft. or 10 ft. are compatible with the restraint spacings normally used by Kinetics Noise Control. If the actual hanger spacings are not 5 ft. or 10 ft. then the restraint spacing, as installed, must be reduced below the restraint spacing as indicated by Kinetics Noise Control to ensure a acceptable installation. For example, if the actual hanger spacing is 15 ft. and the recommended transverse seismic restraint spacing by Kinetics Noise Control is 20 ft with a recommended longitudinal seismic restraint spacing of 40 ft. The actual transverse restraint spacing must be reduced to 15 ft. and the actual longitudinal restraint spacing must be reduced to 30 ft.

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S7.9 – Longitudinal Seismic Restraints for Trapeze Supported Pipe and Duct:

Trapeze supported pipe and duct require that the longitudinal seismic restraint forces be balanced across the trapeze bar to prevent twisting of the support and bending in the pipe and duct. Figure S7-8 shows three plan views of trapeze supported pipe where the longitudinal seismic restraints are balanced side-to-side. Figure S7-8 shows three plan views of trapeze supported duct with balanced longitudinal restraints.

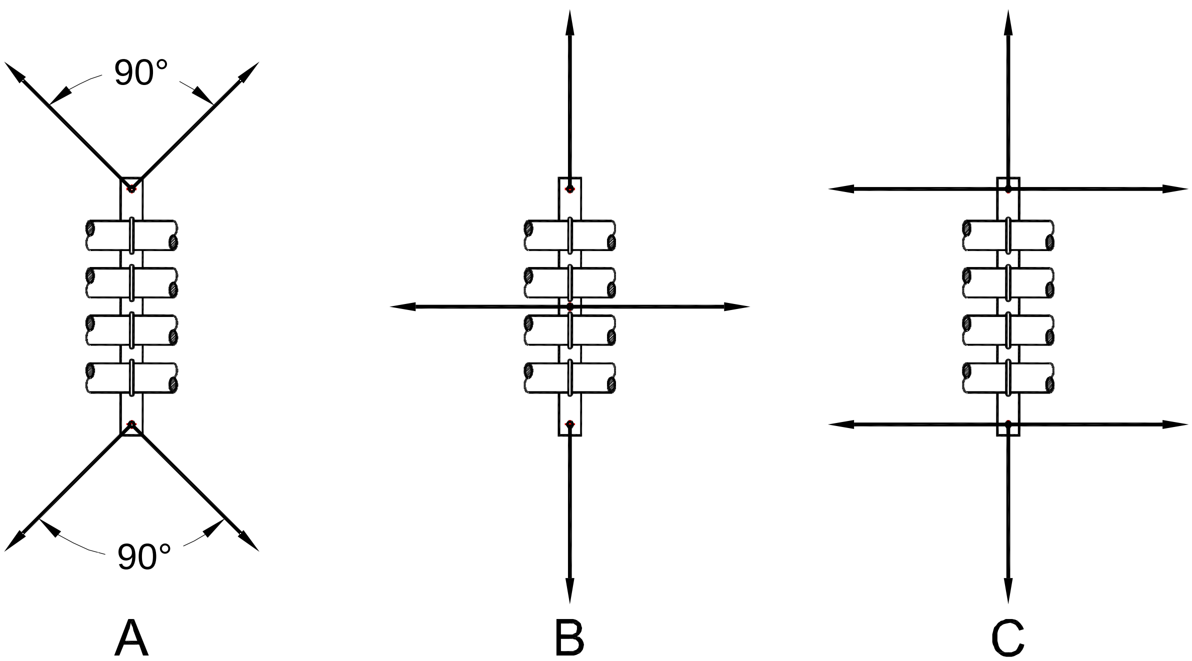

Figure S7-7; Balanced Longitudinal Restraints for Trapeze Supported Pipe

In both Figures S7-7 and S7-8, examples A and B may be achieved with the number of restraint kits, or pairs of restraint cables, which are normally specified by Kinetics Noise Control where transverse and longitudinal restraints are indicated at the same location on the drawing. In order to utilize the fewest possible restraint kits, Kinetics Noise Control assumes that either example A or example B will be followed for trapeze supported pipe and duct where ever transverse and longitudinal seismic restraints are indicated at the same location on the drawings. For example C

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in both Figure S7-7 and S7-8 and extra restraint cable kit will be required for the location indicated on the drawing.

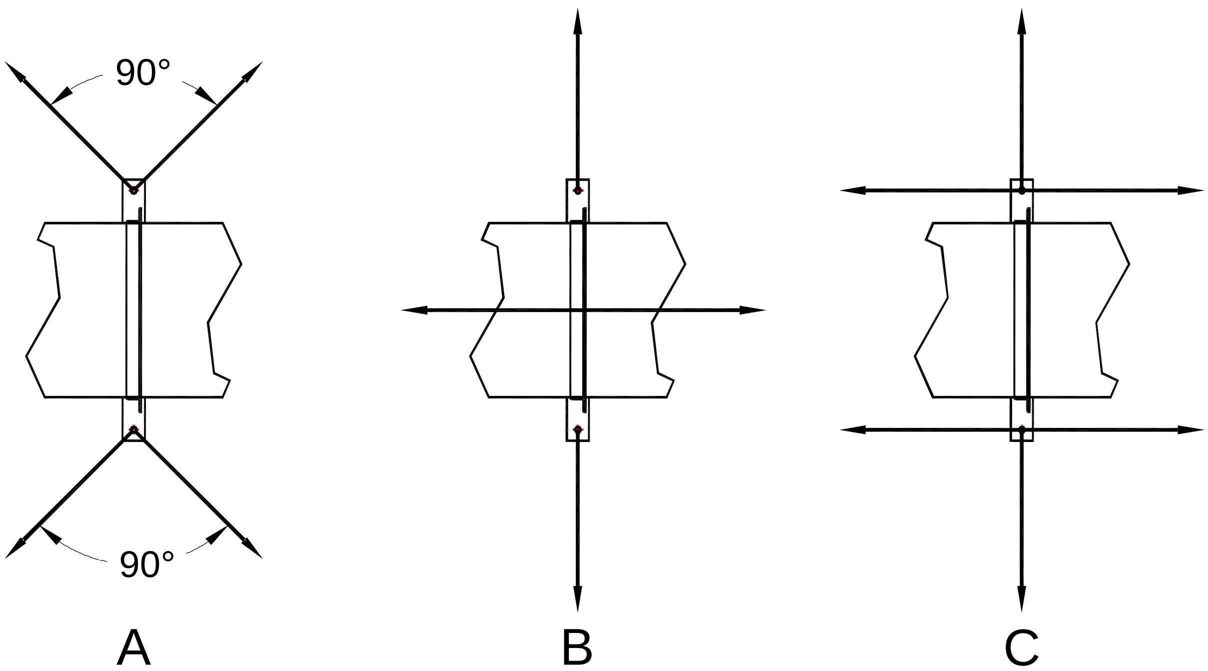

Figure S7-8; Balanced Longitudinal Restraints for Trapeze Supported Duct

S7.10 – Summary:

1. Typical seismic restraint spacings specified by Kinetics Noise Control are 10 ft, 20 ft, 30 ft, 40 ft, 60 ft, or 80 ft. The maximum allowable seismic restraint spacing for piping is specified in Appendices A6.1 through A6.5. The maximum allowable seismic restraint spacing for ductwork is specified the SMACNA Seismic Restraint Manual, and repeated for convenience in Section 11.0 of this manual.
2. For trapeze supported pipe, the maximum allowable seismic restraint spacing is selected based on the smallest pipe size supported by the trapeze bar.
3. Seismic restraint locations are approximate and must coincide with hanger locations ±4 inches.
4. Hangers at seismic restraint locations must be stiff and capable of carrying compressive loads.

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5. If hanger locations do not match the recommended restraint locations and spacings, then the actual installed restraint spacings must be reduced to a value that is a multiple of the hanger spacing, but that is less than the maximum spacing specified by Kinetics Noise Control.
6. For trapeze supported pipe and duct, the longitudinal restraints must be balanced across the trapeze bar.

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HANGER ROD REACTION FORCES & STIFFENER REQUIREMENTS

S8.1 – Introduction:

During an earthquake, the hanger rods are not passive components that just simply support the dead load of the pipe or duct. They must also resist the reaction forces generated by the seismic restraints. First, there is a vertical compressive reaction force with both the strut and cable restraints. Second, there is a tensile reaction force when strut restraints are employed. These compressive and tensile reaction forces may exceed the tensile loads due to the dead weight of the pipe or duct being supported. The compressive reaction forces may be large enough to cause the hanger rod to buckle, and the tensile reaction forces, when added to the dead load being supported, may cause the hanger rod or anchor to fail in tension. When the compressive loads in the hanger rod exceed the buckling strength of the rod, a rod stiffener must be employed to prevent buckling, or a larger hanger rod must be used. When the tensile reaction load plus the dead load exceeds the allowable limit for the hanger rod or anchor, a larger hanger rod or anchor must be used.

This section will examine the nature of the hanger rod reaction forces for both the strut and cable restraints, and outline the basic requirements for the application of rod stiffeners. As will be seen in the discussion that follows, the requirements for hanger rod stiffeners will be very project and location dependent. It will also be noted that seismic restraint reaction forces and the requirements for hanger rod stiffeners will affect only those hanger rods directly connected to or immediately adjacent to the seismic restraints.

S8.2 – Horizontal Force Class:

Since the seismic design force (F_P) discussed in Section S5.0 acts in a horizontal direction, Kinetics Noise Control has developed a Horizontal Force Class system to rate their seismic restraints for Pipe and Duct and to classify the seismic requirements for projects. This system is defined in Table S8-1 below. The Horizontal Force Class system provides a quick and easy way

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to select the proper components while being sure that a satisfactory Factor of Safety is being maintained. It simply requires matching the Horizontal Force Class rating of the seismic restraint with the calculated Horizontal Force Class requirement of the pipe or duct. Also, the Horizontal Force Class system provides a convenient vehicle for a general discussion of hanger rod reaction forces and the requirements for hanger rod stiffeners.

Table S8-1; Horizontal Seismic Force Class System Designations

Horizontal Force Class	Horizontal Seismic Force Range per Force Class (lbs)
I	$0 \le F_P \le 250$
II	$250 < F_P \le 500$
III	$500 < F_P \le 1{,}000$
IV	$1{,}000 < F_P \le 2{,}000$
V	$2{,}000 < F_P \le 5{,}000$
VI	$5{,}000 < F_P \le 10{,}000$

S8.3 – Hanger Rod Size Code and Allowable Load Data:

The hanger rod size code that will be used in this section is a numerical value that corresponds to the basic rod size in eighths of an inch. For instance a 3/8 inch hanger rod will have a hanger rod size code of 3 and a 1 inch hanger rod will have a hanger rod size code of 8. The hanger rod load rating information used in this section was obtained from the following source and is shown in Table S8-2.

MSS SP-58-2002; Pipe Hangers and Supports – Materials, Design, and Manufacture, Manufacturer's Standardization Society; 127 Park Street, NE, Vienna, Virginia 22180; Pg12

The loads are based on an allowable stress of 10,700 psi acting on the minor thread diameter of United National Course threads. Further the loads listed are based on a maximum hanger rod temperature of 650° F.

Table S8-2; Hanger Rod Size Code, Size, and Allowable Load Data

Hanger Rod Code	Hanger Rod Size UNC	Minor Thread Diameter (in)	Area Moment of Inertia (in^4)	Hanger Rod Allowable Load ASD (kips)
3	3/8 - 16	0.2992	0.000393	0.73
4	1/2 - 13	0.4069	0.001346	1.35
5	5/8 - 11	0.5152	0.003458	2.16
6	3/4 - 10	0.6291	0.007689	3.23
7	7/8 - 9	0.7408	0.014783	4.48
8	1 - 8	0.8492	0.025528	5.90
10	1 1/4 - 7	1.0777	0.066216	9.50

S8.4 – Hanger Rod Seismic Reaction Loads with Strut Restraints:

Strut restraints have been employed in the building industry for seismic applications involving pipe and duct for many years. They will be discussed first because of the common usage, and to point out, the not so apparent, limitations to their use. The discussion will start with pipe or duct suspended by single hanger rods and restrained by struts, which is shown in Figure S8-1. Shown in this figure is a single clevis hung pipe. However, the applied forces and reactions can also apply to a duct that is supported by a single hanger rod. The variables in Figure S8.1 will have the following definitions.

A = the seismic restraint installation angle. It is measured from the horizontal and typically has a range of $30^{\circ} \leq A \leq 60^{\circ}$. Occasionally installation angle less than 30° are used, but installation angles greater than 60° are never used.

F_P = the design horizontal seismic force, horizontal seismic force, that is acting at the restraint location. The direction of this force will alternate 180° as the earthquake progresses. This

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horizontal design force is a code mandated figure and is discussed in detail in Section S5.0 of this manual.

F_S = the reaction force acting along the axis of the strut. This will be either compressive or tensile depending on the direction of the seismic force.

F_V = the vertical reaction force due to the design horizontal seismic force acting along the axis of the hanger rod. This force will alternate between tension and compression as the horizontal seismic force changes direction.

W_R = the dead weight of the pipe or duct that is supported by the hanger rod.

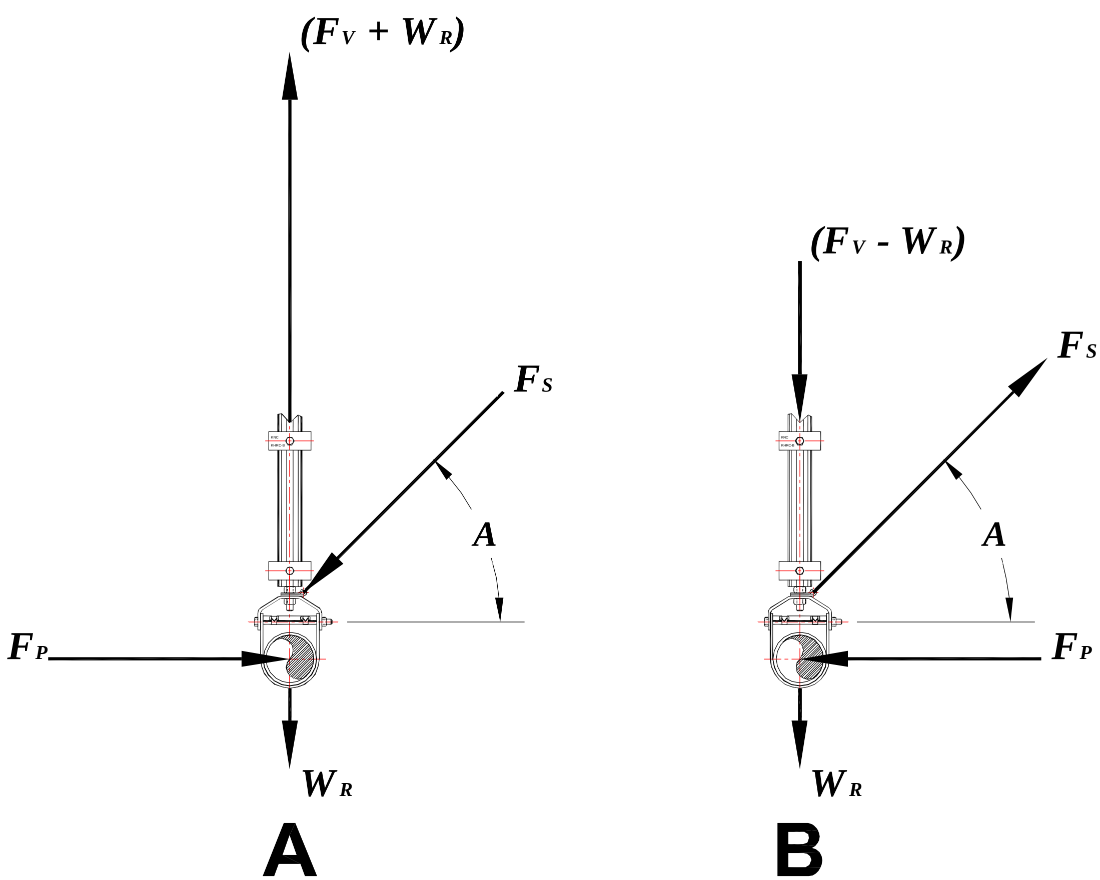

Figure S8-1; Forces Acting on a Strut Restrained Single Hanger Rod Supported Pipe or Duct

The magnitude of the reaction load in the strut restraint may be determined as follows.

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$$F_S = \frac{F_P}{Cos(A)}$$ **Equation S8-1**

The magnitude of the vertical reaction force in the hanger rod will be;

$$F_V = Tan(A)$$ **Equation S8-2**

For a single hanger rod supported pipe or duct, the component weight supported by the hanger rod will be as follows.

$$W_R = S_H w_P$$ **Equation S8-3**

Where:

S_H = the pipe or duct hanger rod spacing, usually given in ft.

w_P = the weight of the pipe or duct, generally expresses as lbs/ft. See Appendices A2.0 and A3.0 for typical values.

In Figure S8-1 in the view marked **A**, the horizontal seismic load is attempting to push the pipe or duct to the right. This produces a compressive reaction load in the strut restraint and causes a vertical tensile reaction load in the hanger rod which adds to the dead weight load already being supported by the hanger rod. In the view marked **B**, the horizontal seismic load attempts to move the pipe or duct to the left. This will produce a tensile reaction force in the strut restraint, and a compressive reaction load in the hanger rod. The dead weight load supported by the hanger rod puts the rod in tension which effectively reduces the overall compressive load to which the hanger rod is ultimately exposed. In many cases the dead load of the pipe or duct will exceed the compressive reaction forces generated by the horizontal seismic force. When this occurs, no rod stiffeners will ever be required at that restraint location. Tables S8-3 and S8-4 present the maximum hanger rod reaction forces for single hanger rod supported pipe or duct with strut restraints and the minimum recommended hanger rod size for each Horizontal Force Class. The design horizontal seismic load used was the maximum value for each Horizontal Force Class. The hanger rod spacing was assumed to be 10 ft, which is a common hanger spacing. For hanger rod spacings other than 10 ft, see Kinetics Noise Control's web based tools for pipe and duct. Table S8.3 assumes an installation angle of 45° and Table S8.4 assumes an installation angle of 60°. Note, as the installation angle increases, the tensile/compressive loads in the hanger rod also increase.

Table S8-3; Maximum Hanger Rod Reactions & Minimum Hanger Rod Size for Single Hanger Rod Supported Pipe and Duct with Strut Restraints – Hanger Spacing = 10 ft. & Installation Angle = 45°

	Horizontal Force Class																	
	I			II			III			IV			V			VI		
Supported Weight (lbs/ft)	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code
5	0.23	0.13	3	0.41	0.31	3	0.76	0.66	4	1.48	1.38	5	3.62	3.52	7	7.19	7.09	10
10	0.28	0.08	3	0.46	0.26	3	0.81	0.61	4	1.53	1.33	5	3.67	3.47	7	7.24	7.04	10
15	0.33	0.03	3	0.51	0.21	3	0.86	0.56	4	1.58	1.28	5	3.72	3.42	7	7.29	6.99	10
25	0.43	-0.07	3	0.61	0.11	3	0.96	0.46	4	1.68	1.18	5	3.82	3.32	7	7.39	6.89	10
50	0.68	-0.32	3	0.86	-0.14	4	1.21	0.21	4	1.93	0.93	5	4.07	3.07	7	7.64	6.64	10
100	1.18	-0.82	4	1.36	-0.64	5	1.71	-0.29	5	2.43	0.43	6	4.57	2.57	8	8.14	6.14	10
150	1.68	-1.32	5	1.86	-1.14	5	2.21	-0.79	6	2.93	-0.07	6	5.07	2.07	8	8.64	5.64	10
200	2.18	-1.82	6	2.36	-1.64	6	2.71	-1.29	6	3.43	-0.57	7	5.57	1.57	8	9.14	5.14	10
250	2.68	-2.32	6	2.86	-2.14	6	3.21	-1.79	6	3.93	-1.07	7	6.07	1.07	10	9.64	4.64	----
300	3.18	-2.82	6	3.36	-2.64	7	3.71	-2.29	7	4.43	-1.57	7	6.57	0.57	10	10.14	4.14	----

1. Negative (-) Compressive reaction forces indicate that ***no rod*** stiffeners will ever be required because the dead weight load of the pipe or duct on the hanger rod exceeds the vertical reaction due to the design horizontal seismic force.

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Table S8-4; Maximum Hanger Rod Reactions & Minimum Hanger Rod Size for Single Hanger Rod Supported Pipe and Duct with Strut Restraints – Hanger Spacing = 10 ft. & Installation Angle = 60°

	Horizontal Force Class																	
	I			II			III			IV			V			VI		
Supported Weight (lbs/ft)	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code
5	0.36	0.26	3	0.67	0.57	3	1.29	1.19	4	2.52	2.42	6	6.24	6.14	10	12.42	12.32	----
10	0.41	0.21	3	0.72	0.52	3	1.34	1.14	4	2.57	2.37	6	6.29	6.09	10	12.47	12.27	----
15	0.46	0.16	3	0.77	0.47	4	1.39	1.09	5	2.62	2.32	6	6.34	6.04	10	12.52	12.22	----
25	0.56	0.06	3	0.87	0.37	4	1.49	0.99	5	2.72	2.22	6	6.44	5.94	10	12.62	12.12	----
50	0.81	-0.19	4	1.12	0.12	4	1.74	0.74	5	2.97	1.97	6	6.69	5.69	10	12.87	11.87	----
100	1.31	-0.69	4	1.62	-0.38	5	2.24	0.24	6	3.47	1.47	7	7.19	5.19	10	13.37	11.37	----
150	1.81	-1.19	5	2.12	-0.88	5	2.74	-0.26	6	3.97	0.97	7	7.69	4.69	10	13.87	10.87	----
200	2.31	-1.69	6	2.62	-1.38	6	3.24	-0.76	7	4.47	0.47	7	8.19	4.19	10	14.37	10.37	----
250	2.81	-2.19	6	3.12	-1.88	6	3.74	-1.26	7	4.97	-0.03	8	8.69	3.69	10	14.87	9.87	----
300	3.31	-2.69	7	3.62	-2.38	7	4.24	-1.76	7	5.47	-0.53	8	9.19	3.19	10	15.37	9.37	----

1. Negative (-) Compressive reaction forces indicate that ***no rod*** stiffeners will ever be required because the dead weight load of the pipe or duct on the hanger rod exceeds the vertical reaction due to the design horizontal seismic force.

Trapeze supported pipe and duct utilizes two hanger rods per support location. Each hanger rod is assumed to carry exactly half of the dead weight load of the pipe or duct. Figure S8-2 shows trapeze supported pipe or duct that is restrained by struts.

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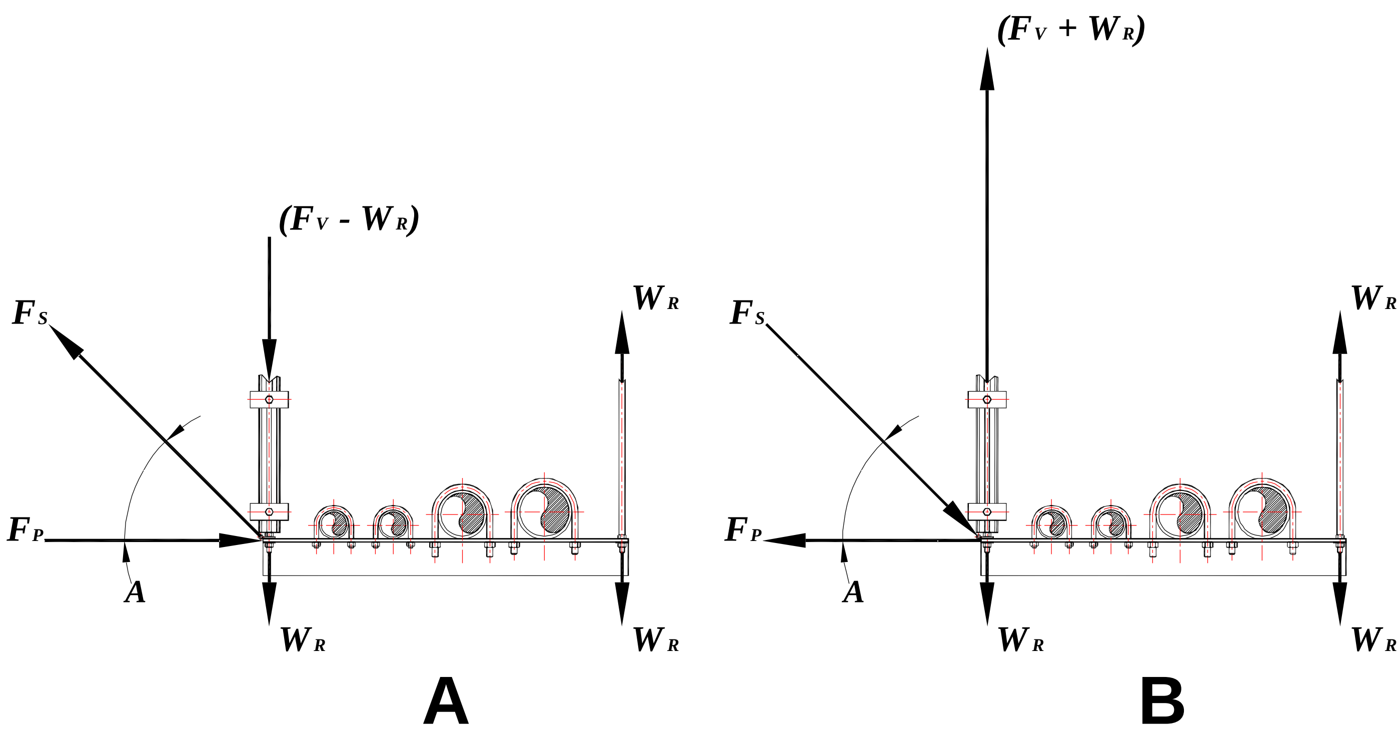

Figure S8-2; Forces Acting on a Strut Restrained Trapeze Supported Pipe or Duct

For both cases in Figure S8-2, the dead weight load supported by each hanger rod will be;

$$W_R = \frac{S_H w_P}{2}$$ **Equation S8-4**

The strut restraint will be placed at or near one of the trapeze bar hanger rods. In both cases for Figure S8-2, the strut restraint is located at the left hand hanger rod. All of the seismic reaction loads will be assumed to pass through the hanger rod closest to the strut restraint. This is a fairly valid assumption since the seismic reaction forces will be like an electric current in that they will find the quickest and easiest path to ground (the building structure).

In Figure S8-2, the view marked **A** shows that the horizontal seismic load is attempting to push the trapeze bar to the right. This produces a compressive reaction load in the strut restraint and causes a vertical tensile reaction load in the left hand hanger rod which adds to the dead weight

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load already being supported by that hanger rod. In the view marked **B**, the horizontal seismic load attempts to move the trapeze bar to the left. This will produce a tensile reaction force in the strut restraint, and a compressive reaction load in the left hand hanger rod. The dead weight load supported by the left hand hanger rod introduces a tensile load into the rod which effectively reduces the overall compressive load to which the hanger rod is subjected. In many cases the dead load of the pipe or duct will exceed the compressive reaction forces generated by the horizontal seismic force. When this occurs, no rod stiffeners will ever be required at that restraint location.

Tables S8-5 and S8-6, for restraint installation angles of 45° and 60° respectively, present the maximum hanger rod reaction forces for trapeze supported pipe or duct with strut restraints and the minimum recommended hanger rod size for each Horizontal Force Class. Again, the horizontal seismic load used was the maximum value for each Horizontal Force Class and the hanger rod spacing was assumed to be 10 ft. For hanger rod spacings other than 10 ft, see Kinetics Noise Control's web based tools for pipe and duct.

Comparing Tables S8-3 and S8-4 to Tables S8-5 and S8-6 will lead to the following conclusions.

1. In many cases, the hanger rod size for trapeze supported pipe or duct may be reduced one rod size from that required for single hanger rod supported pipe or duct for the same supported weight. This is due to the fact that the dead weight load carried by each hanger rod has been reduced by half.
2. Hanger rod stiffeners will be required more often for the trapeze supported pipe and duct than for the single hanger rod supported pipe or duct. This is also due to the reduction in the dead weight load carried by each hanger rod.
3. Use of a 60° installation angle, for both single hanger rod supported and trapeze supported pipe and duct, will place higher loads on the hanger rods potentially causing an increase in the required hanger rod size, and requiring the use of hanger rod stiffeners.

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It should be mentioned here, that, if circumstance s dictate the need for it, only the hanger rod closest to the strut restraint would require a hanger rod stiffener.

Table S8-5; Maximum Hanger Rod Reactions & Minimum Hanger Rod Size for Trapeze Supported Pipe and Duct with Strut Restraints – Hanger Spacing = 10 ft. & Installation Angle = 45°

	Horizontal Force Class																	
	I			II			III			IV			V			VI		
Supported Weight (lbs/ft)	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code
5	0.20	0.15	3	0.38	0.33	3	0.74	0.69	4	1.45	1.40	5	3.60	3.55	7	7.17	7.12	10
10	0.23	0.13	3	0.41	0.31	3	0.76	0.66	4	1.48	1.38	5	3.62	3.52	7	7.19	7.09	10
15	0.25	0.10	3	0.43	0.28	3	0.79	0.64	4	1.50	1.35	5	3.65	3.50	7	7.22	7.07	10
25	0.30	0.05	3	0.48	0.23	3	0.84	0.59	4	1.55	1.30	5	3.70	3.45	7	7.27	7.02	10
50	0.43	-0.07	3	0.61	0.11	3	0.96	0.46	4	1.68	1.18	5	3.82	3.32	7	7.39	6.89	10
100	0.68	-0.32	3	0.86	-0.14	4	1.21	0.21	4	1.93	0.93	5	4.07	3.07	7	7.64	6.64	10
150	0.93	-0.57	4	1.11	-0.39	4	1.46	-0.04	5	2.18	0.68	6	4.32	2.82	7	7.89	6.39	10
200	1.18	-0.82	4	1.36	-0.64	5	1.71	-0.29	5	2.43	0.43	6	4.57	2.57	8	8.14	6.14	10
250	1.43	-1.07	5	1.61	-0.89	5	1.96	-0.54	5	2.68	0.18	6	4.82	2.32	8	8.39	5.89	10
300	1.68	-1.32	5	1.86	-1.14	5	2.21	-0.79	6	2.93	-0.07	6	5.07	2.07	8	8.64	5.64	10

1. Negative (-) Compressive reaction forces indicate that ***no rod*** stiffeners will ever be required because the dead weight load of the pipe or duct on the hanger rod exceeds the vertical reaction due to the design horizontal seismic force.

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Table S8-6; Maximum Hanger Rod Reactions & Minimum Hanger Rod Size for Trapeze Supported Pipe and Duct with Strut Restraints – Hanger Spacing = 10 ft. & Installation Angle = 60°

	Horizontal Force Class																	
	I			II			III			IV			V			VI		
Supported Weight (lbs/ft)	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code
5	0.33	0.28	3	0.64	0.59	3	1.26	1.21	4	2.50	2.45	6	6.21	6.16	10	12.40	12.35	----
10	0.36	0.26	3	0.67	0.57	3	1.29	1.19	4	2.52	2.42	6	6.24	6.14	10	12.42	12.32	----
15	0.38	0.23	3	0.69	0.54	3	1.31	1.16	4	2.55	2.40	6	6.26	6.11	10	12.45	12.30	----
25	0.43	0.18	3	0.74	0.49	4	1.36	1.11	5	2.60	2.35	6	6.31	6.06	10	12.50	12.25	----
50	0.56	0.06	3	0.87	0.37	4	1.49	0.99	5	2.72	2.22	6	6.44	5.94	10	12.62	12.12	----
100	0.81	-0.19	4	1.12	0.12	4	1.74	0.74	5	2.97	1.97	6	6.69	5.69	10	12.87	11.87	----
150	1.06	-0.44	4	1.37	-0.13	5	1.99	0.49	5	3.22	1.72	6	6.94	5.44	10	13.12	11.62	----
200	1.31	-0.69	4	1.62	-0.38	5	2.24	0.24	6	3.47	1.47	7	7.19	5.19	10	13.37	11.37	----
250	1.56	-0.94	5	1.87	-0.63	5	2.49	-0.01	6	3.72	1.22	7	7.44	4.94	10	13.62	11.12	----
300	1.81	-1.19	5	2.12	-0.88	5	2.74	-0.26	6	3.97	0.97	7	7.69	4.69	10	13.87	10.87	----

1. Negative (-) Compressive reaction forces indicate that ***no rod*** stiffeners will ever be required because the dead weight load of the pipe or duct on the hanger rod exceeds the vertical reaction due to the design horizontal seismic force.

S8.5 – Hanger Rod Seismic Reaction Loads with Cable Restraints:

Cable restraints reduce the range of hanger rod reaction forces in half. This is due to the fact that cables are “tension only” restraints. Two cables with the same installation angle and located 180° apart (opposite each other) must be used for the transverse or longitudinal direction at each

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restraint location instead of one rigid strut type restraint that acts in two direction. Thus, where only a transverse or a longitudinal restraint is required, one single pair of cables will be needed with 180° between cables will be need. Where both transverse and longitudinal restraints are required, two pairs of cables will be needed with 90° between cables.

Figure S8-3 shows a single hanger rod supported pipe or duct. In this figure and those which follow;

T = the tensile reaction force generated in the restraint cables due to the horizontal seismic force.

$$T = \frac{F_P}{Cos(A)}$$ **Equation S8-5**

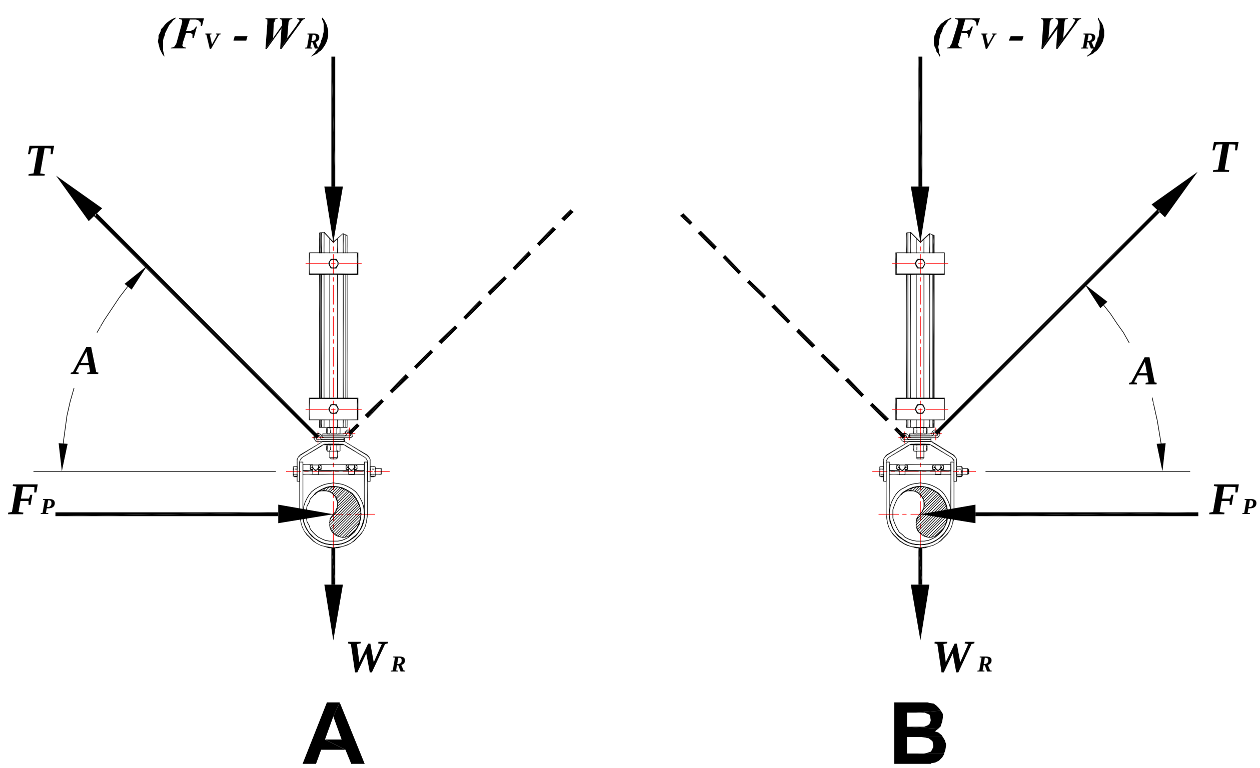

Figure S8-3; Forces Acting on a Cable Restrained Single Hanger Rod Supported Pipe or Duct

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For Figure S8-3, in the view marked **A**, the horizontal seismic load is attempting to push the pipe or duct to the right. This produces a tensile reaction load in the left hand restraint cable, indicated by the heavy solid line with the arrowhead, and causes a vertical compressive reaction load in the hanger rod which deducts from the dead weight load already being supported by the hanger rod. The right hand restraint cable will be slack, which is indicated by the heavy dashed line. In the view marked **B**, the horizontal seismic load is attempting to move the pipe or duct to the left. This will produce a tensile reaction force in the right hand restraint cable, and a compressive reaction load in the hanger rod. The left hand restraint cable will be slack. Notice that the vertical reaction force due to the horizontal seismic force will always act so as to place the hanger rod in compression. As a result, cable restraints will never cause a load condition which places a tensile load in the hanger rod that is greater than the dead weight load of the pipe or duct. The dead weight load supported by the hanger rod puts the rod in tension which effectively reduces the overall compressive load to which the hanger rod is exposed. In many cases the dead weight load of the pipe or duct will be such that the tensile forces exceed the compressive reaction forces generated by the horizontal seismic force. When this occurs, no rod stiffeners will ever be required at that restraint location. Tables S8-7 and S8-8, for restraint installation angles of 45° and 60° respectively, present the maximum hanger rod reaction forces for single hanger rod supported pipe or duct with cable restraints and the minimum recommended hanger rod size for each Horizontal Force Class. As before, the horizontal seismic load used was the maximum value for each Horizontal Force Class and the hanger rod spacing was assumed to be 10 ft. For hanger rod spacings other than 10 ft, see Kinetics Noise Control's web based tools for pipe and duct.

Figures S8-4 and S8-5 present the basic scenarios for trapeze supported pipe and duct with cable restraints. In both cases the horizontal seismic force will produce a tensile reaction force in one of the cables, and a slack condition in the opposite cable. The major difference between the two arrangements is that in the scenario portrayed by Figure S8-4, only one of the hanger rods, the left hand one, will ever see the compressive reaction force due to the horizontal seismic force. For the scenario shown in Figure S8-5, each hanger rods will be exposed to the compressive reaction force due to the horizontal seismic load, depending on the direction of the horizontal seismic load.

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Thus, for the case shown in Figure S8-4, only the left hand hanger rod would need a rod stiffener if it was required, while both hanger rods would need rod stiffeners for the case shown in the Figure S8-5.

Table S8-7; Maximum Hanger Rod Reactions & Minimum Hanger Rod Size for Single Hanger Rod Supported Pipe and Duct with Cable Restraints – Hanger Spacing = 10 ft. & Installation Angle = 45°

	Horizontal Force Class																	
	I			II			III			IV			V			VI		
Supported Weight (lbs/ft)	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code
5	0.05	0.13	3	0.05	0.31	3	0.05	0.66	3	0.05	1.38	3	0.05	3.52	3	0.05	7.09	3
10	0.10	0.08	3	0.10	0.26	3	0.10	0.61	3	0.10	1.33	3	0.10	3.47	3	0.10	7.04	3
15	0.15	0.03	3	0.15	0.21	3	0.15	0.56	3	0.15	1.28	3	0.15	3.42	3	0.15	6.99	3
25	0.25	-0.07	3	0.25	0.11	3	0.25	0.46	3	0.25	1.18	3	0.25	3.32	3	0.25	6.89	3
50	0.50	-0.32	3	0.50	-0.14	3	0.50	0.21	3	0.50	0.93	3	0.50	3.07	3	0.50	6.64	3
100	1.00	-0.82	4	1.00	-0.64	4	1.00	-0.29	4	1.00	0.43	4	1.00	2.57	4	1.00	6.14	4
150	1.50	-1.32	5	1.50	-1.14	5	1.50	-0.79	5	1.50	-0.07	5	1.50	2.07	5	1.50	5.64	5
200	2.00	-1.82	5	2.00	-1.64	5	2.00	-1.29	5	2.00	-0.57	5	2.00	1.57	5	2.00	5.14	5
250	2.50	-2.32	6	2.50	-2.14	6	2.50	-1.79	6	2.50	-1.07	6	2.50	1.07	6	2.50	4.64	6
300	3.00	-2.82	6	3.00	-2.64	6	3.00	-2.29	6	3.00	-1.57	6	3.00	0.57	6	3.00	4.14	6

1. Negative (-) Compressive reaction forces indicate that ***no rod*** stiffeners will ever be required because the dead weight load of the pipe or duct on the hanger rod exceeds the vertical reaction due to the design horizontal seismic force.

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Table S8-8; Maximum Hanger Rod Reactions & Minimum Hanger Rod Size for Single Hanger Rod Supported Pipe and Duct with Cable Restraints – Hanger Spacing = 10 ft. & Installation Angle = 60°

	Horizontal Force Class																	
	I			II			III			IV			V			VI		
Supported Weight (lbs/ft)	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code
5	0.05	0.26	3	0.05	0.57	3	0.05	1.19	3	0.05	2.42	3	0.05	6.14	3	0.05	12.32	3
10	0.10	0.21	3	0.10	0.52	3	0.10	1.14	3	0.10	2.37	3	0.10	6.09	3	0.10	12.27	3
15	0.15	0.16	3	0.15	0.47	3	0.15	1.09	3	0.15	2.32	3	0.15	6.04	3	0.15	12.22	3
25	0.25	0.06	3	0.25	0.37	3	0.25	0.99	3	0.25	2.22	3	0.25	5.94	3	0.25	12.12	3
50	0.50	-0.19	3	0.50	0.12	3	0.50	0.74	3	0.50	1.97	3	0.50	5.69	3	0.50	11.87	3
100	1.00	-0.69	4	1.00	-0.38	4	1.00	0.24	4	1.00	1.47	4	1.00	5.19	4	1.00	11.37	4
150	1.50	-1.19	5	1.50	-0.88	5	1.50	-0.26	5	1.50	0.97	5	1.50	4.69	5	1.50	10.87	5
200	2.00	-1.69	5	2.00	-1.38	5	2.00	-0.76	5	2.00	0.47	5	2.00	4.19	5	2.00	10.37	5
250	2.50	-2.19	6	2.50	-1.88	6	2.50	-1.26	6	2.50	-0.03	6	2.50	3.69	6	2.50	9.87	6
300	3.00	-2.69	6	3.00	-2.38	6	3.00	-1.76	6	3.00	-0.53	6	3.00	3.19	6	3.00	9.37	6

1. Negative (-) Compressive reaction forces indicate that ***no rod*** stiffeners will ever be required because the dead weight load of the pipe or duct on the hanger rod exceeds the vertical reaction due to the design horizontal seismic force.

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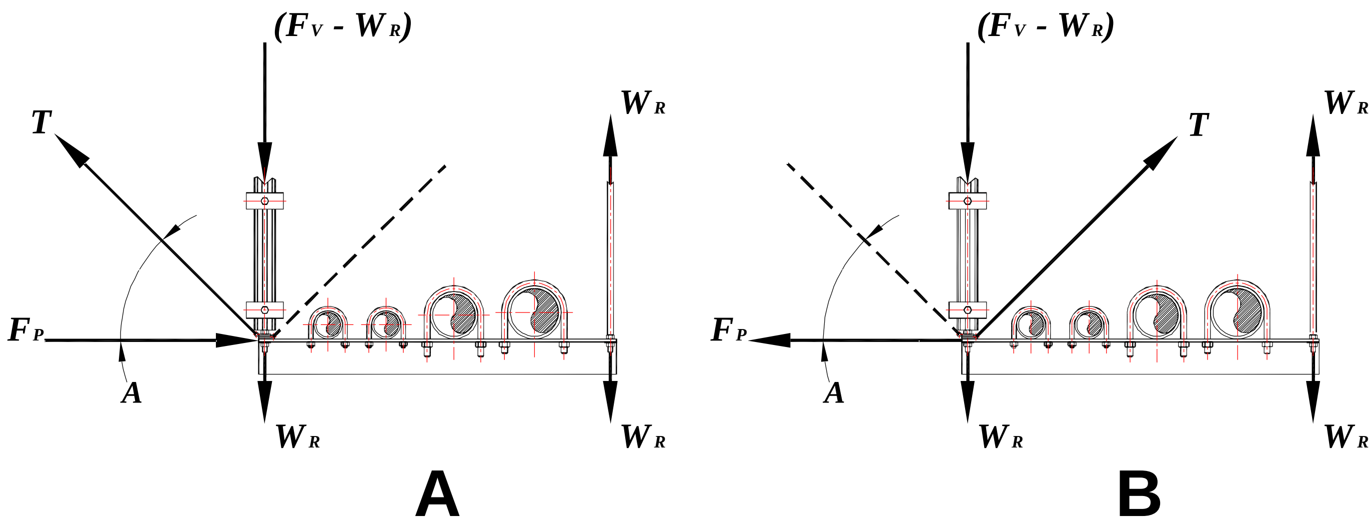

Figure S8-4; Forces Acting on a Cable Restrained Trapeze Supported Pipe or Duct – Both Cable Restraints Attached at One Hanger Rod

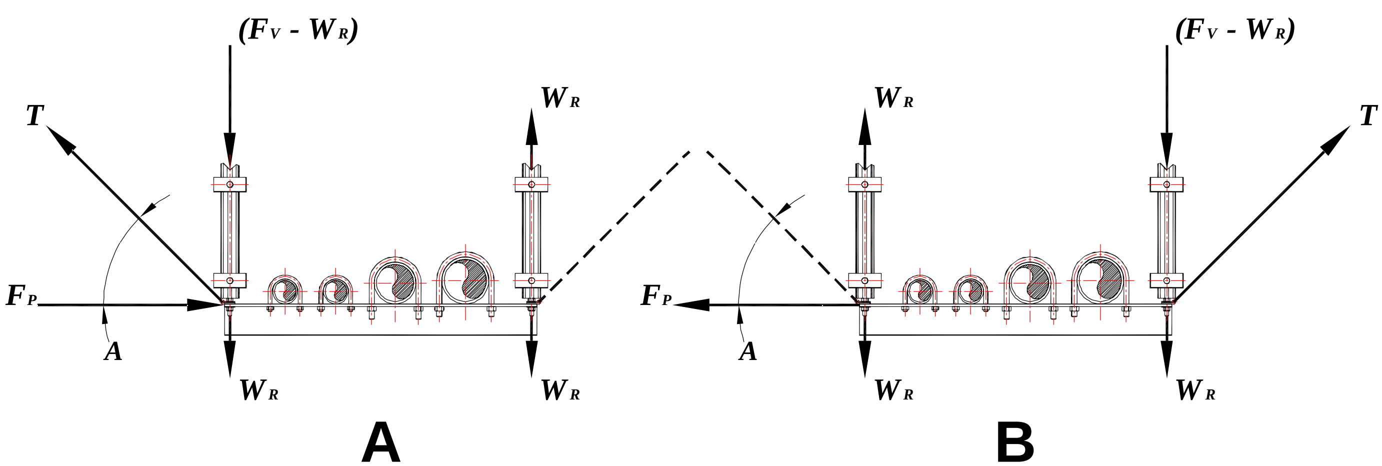

Figure S8-5; Forces Acting on a Cable Restrained Trapeze Supported Pipe or Duct – One Cable Restraints Attached at Each Hanger Rod

Tables S8-9 and S8-10 present the maximum hanger rod reaction forces for trapeze supported pipe or duct with cable restraints and the minimum recommended hanger rod size for each Horizontal Force Class. As with the previous cases, the horizontal seismic load used was the maximum value for each Horizontal Force Class and the hanger rod spacing was assumed to be

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10 ft. For hanger rod spacings other than 10 ft, see Kinetics Noise Control's web based tools for pipe and duct.

Table S8-9; Maximum Hanger Rod Reactions & Minimum Hanger Rod Size for Trapeze Supported Pipe and Duct with Cable Restraints – Hanger Spacing = 10 ft. & Installation Angle = 45°

	Horizontal Force Class																	
	I			II			III			IV			V			VI		
Supported Weight (lbs/ft)	Tensile (kips) ASD	Compressive[1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive[1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive[1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive[1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive[1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive[1] (kips) ASD	Hanger Rod Size Code
5	0.03	0.15	3	0.03	0.33	3	0.03	0.69	3	0.03	1.40	3	0.03	3.55	3	0.03	7.12	3
10	0.05	0.13	3	0.05	0.31	3	0.05	0.66	3	0.05	1.38	3	0.05	3.52	3	0.05	7.09	3
15	0.08	0.10	3	0.08	0.28	3	0.08	0.64	3	0.08	1.35	3	0.08	3.50	3	0.08	7.07	3
25	0.13	0.05	3	0.13	0.23	3	0.13	0.59	3	0.13	1.30	3	0.13	3.45	3	0.13	7.02	3
50	0.25	-0.07	3	0.25	0.11	3	0.25	0.46	3	0.25	1.18	3	0.25	3.32	3	0.25	6.89	3
100	0.50	-0.32	3	0.50	-0.14	3	0.50	0.21	3	0.50	0.93	3	0.50	3.07	3	0.50	6.64	3
150	0.75	-0.57	4	0.75	-0.39	4	0.75	-0.04	4	0.75	0.68	4	0.75	2.82	4	0.75	6.39	4
200	1.00	-0.82	4	1.00	-0.64	4	1.00	-0.29	4	1.00	0.43	4	1.00	2.57	4	1.00	6.14	4
250	1.25	-1.07	4	1.25	-0.89	4	1.25	-0.54	4	1.25	0.18	4	1.25	2.32	4	1.25	5.89	4
300	1.50	-1.32	5	1.50	-1.14	5	1.50	-0.79	5	1.50	-0.07	5	1.50	2.07	5	1.50	5.64	5

1. Negative (-) Compressive reaction forces indicate that ***no rod*** stiffeners will ever be required because the dead weight load of the pipe or duct on the hanger rod exceeds the vertical reaction due to the design horizontal seismic force.

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Table S8-10; Maximum Hanger Rod Reactions & Minimum Hanger Rod Size for Trapeze Supported Pipe and Duct with Cable Restraints – Hanger Spacing = 10 ft. & Installation Angle = 60°

	Horizontal Force Class																	
	I			II			III			IV			V			VI		
Supported Weight (lbs/ft)	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code	Tensile (kips) ASD	Compressive [1] (kips) ASD	Hanger Rod Size Code
5	0.03	0.28	3	0.03	0.59	3	0.03	1.21	3	0.03	2.45	3	0.03	6.16	3	0.03	12.35	3
10	0.05	0.26	3	0.05	0.57	3	0.05	1.19	3	0.05	2.42	3	0.05	6.14	3	0.05	12.32	3
15	0.08	0.23	3	0.08	0.54	3	0.08	1.16	3	0.08	2.40	3	0.08	6.11	3	0.08	12.30	3
25	0.13	0.18	3	0.13	0.49	3	0.13	1.11	3	0.13	2.35	3	0.13	6.06	3	0.13	12.25	3
50	0.25	0.06	3	0.25	0.37	3	0.25	0.99	3	0.25	2.22	3	0.25	5.94	3	0.25	12.12	3
100	0.50	-0.19	3	0.50	0.12	3	0.50	0.74	3	0.50	1.97	3	0.50	5.69	3	0.50	11.87	3
150	0.75	-0.44	4	0.75	-0.13	4	0.75	0.49	4	0.75	1.72	4	0.75	5.44	4	0.75	11.62	4
200	1.00	-0.69	4	1.00	-0.38	4	1.00	0.24	4	1.00	1.47	4	1.00	5.19	4	1.00	11.37	4
250	1.25	-0.94	4	1.25	-0.63	4	1.25	-0.01	4	1.25	1.22	4	1.25	4.94	4	1.25	11.12	4
300	1.50	-1.19	5	1.50	-0.88	5	1.50	-0.26	5	1.50	0.97	5	1.50	4.69	5	1.50	10.87	5

1. Negative (-) Compressive reaction forces indicate that ***no rod*** stiffeners will ever be required because the dead weight load of the pipe or duct on the hanger rod exceeds the vertical reaction due to the design horizontal seismic force.

There are some useful conclusions which may be drawn from the information presented in Tables S8-3 through S8-10.

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1. When cable restraints are used for pipe and duct, the horizontal seismic force does not adversely affect the selection of the hanger rod size. Comparing Tables S8-3 though S8-6 with Tables S8-7 through S8-10 leads to the conclusion that much larger hanger rods may be required to resist the vertical seismic reaction loads plus the dead weight loads of the pipe and duct when strut restraints are used than when cable restraints are used.
2. When strut restraints are used, the hanger rod, in tension, becomes part of the seismic force reaction loop and seismically qualified hardware, especially for post installed concrete anchors, must be specified.
3. When cable restraints are used for trapeze supported pipe and duct, care must be taken where rod stiffeners are required to ensure that the stiffeners are applied to both hanger rods if the cable restraints are attached at both hanger rod locations.
4. When cable restraints are used, selection of the proper hanger rod size is not dependent on the installation angle of the seismic restraints.

S8.6 – Requirements for Hanger Rod Stiffeners:

In the previous discussions in this section, it was pointed out that if the dead weight load supported by the hanger rod exceeded the vertical compressive reaction in the hanger rod due to the horizontal seismic force, then hanger rod stiffeners would never be required at that seismic restraint location. However, where the vertical compressive reaction force due to the horizontal seismic force exceeds the dead weight load of the pipe and duct the need for rod stiffeners will be dependent upon several additional variables, which are listed below.

1. The hanger rod size, minor thread diameter.
2. The hanger rod length.
3. The dead weight being supported by the hanger rod.
    a. The dead weight per foot of the components being supported.
    b. The hanger spacing.
4. The vertical compressive reaction force.

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a. Design horizontal seismic force, Horizontal Force Class value.
b. The seismic restraint installation angle.

Hanger rod stiffeners are structural components that may be clamped to the hanger rod to increase its resistance to buckling. Many different shapes may be used as rod stiffeners, some of the most common through out the industry are listed below with equivalency charts given in Appendix A5.8

1. AISI rolled structural angles
2. Pipe
3. Electrical conduit
4. UNISTRUT® channels (There are several different manufacturers of shapes similar to those provided by UNISTRUT®.)

There are basically three ways to attach the stiffeners to the hanger rod. A clamp is used, or the stiffener is welded to a threaded component such as a coupling nut and then threaded on to the hanger rod, or the stiffener is welded directly to the hanger rod. Kinetics Noise Control, as well as SMACNA and other industry organizations, discourages the practice of welding the stiffener directly to the hanger rod to make this attachment because the root of the hanger rod threads may be damaged, and the material properties of the hanger rod are locally altered. Because the clamps used to attach the stiffener to the hanger rod can not completely prevent the rod from slipping against the stiffener. The possibility exists that the hanger rod may buckle inside the envelope of the stiffener. For this reason, multiple clamps may be required along the length of the hanger rod. Kinetics Noise Control manufactures a two rod stiffener clamps that are used with a wide range AISI rolled structural channels to an equally wide range hanger rod sizes. These clamps are shown in detail in Figures S8-6 and S8-7. The AISI rolled structural angles were chosen because;

1. They are readily available.

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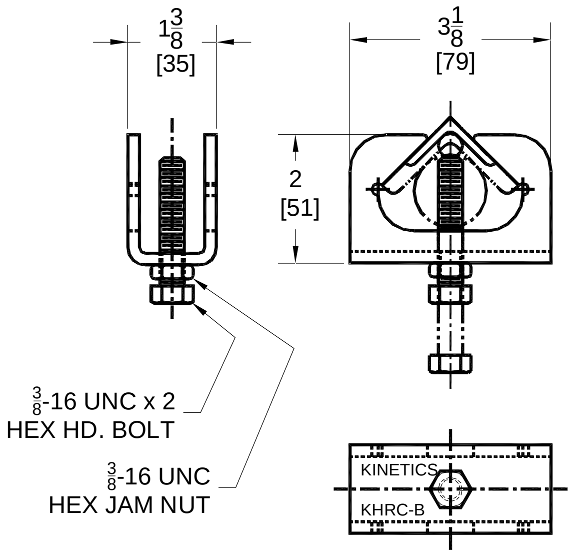
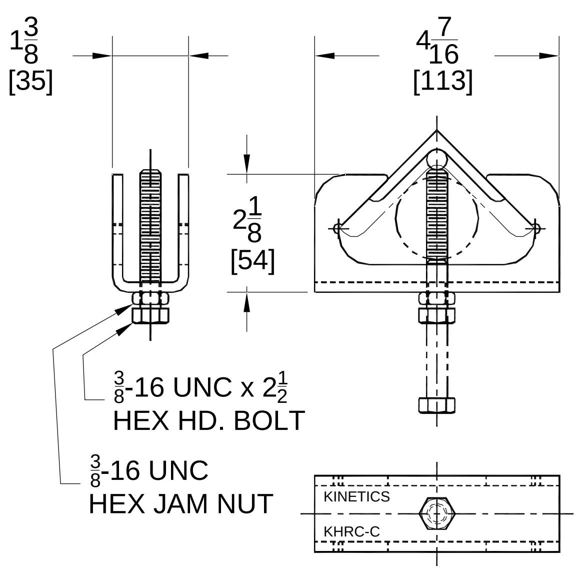
2. Cost – They are relatively cheap when compared to UNISTRUT® channels, and will have costs approximately equal to that of Pipe.
3. They are easier to hold in place while clamping than pipe or conduit.



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

Figure S8-6; Kinetics Noise Control Model KHRC-B Hanger Rod Stiffener Clamp



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

Figure S8-7; Kinetics Noise Control Model KHRC-C Hanger Rod Stiffener Clamp

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A typical hanger rod stiffener installation is shown in Figure S8-8.

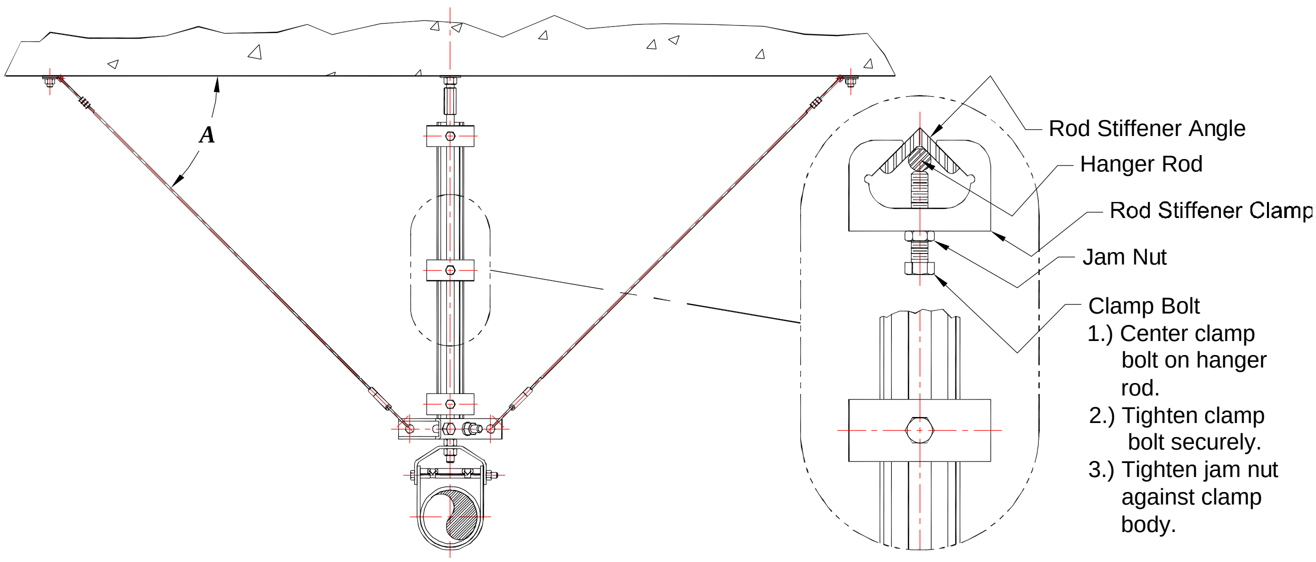

Figure S8-8; Typical Hanger Rod Stiffener Installation

Kinetics Noise Control generated tables or analytical tools recommend hanger rod stiffeners and the number of clamps used based on the following assumptions.

1. The compression members, hanger rods and rod stiffeners, are long relative to their cross-sections. Therefore, Euler's buckling theory will be used for the analysis. Short column and eccentricity effects will not be considered since they introduce unnecessary complications to an already complicated analysis.
2. A 1.5:1 factor of safety with respect to the applied load will be used for all situations to account for unknowns such as eccentricity.
3. The number of hanger rod stiffener clamps used will be based on keeping the free length of hanger rod between each clamp below that which would be prone to buckle under the expected compressive load on the hanger rod.
4. The AISI rolled structural steel angle used for the hanger rod stiffener will be sized carry the entire expected compressive load without buckling.

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Euler's formula for the critical buckling load on a long slender column is given below.

$$P_{CR} = \frac{C_N \pi^2 E I_R}{L^2}$$ **Equation S8-6**

Letting $P_{CR} = N(F_V - W_R)$;

$$N(F_V - W_R) = \frac{C_N \pi^2 E I_R}{L^2}$$ **Equation S8-7**

Where:

C_N = a constant that depends on the end attachment conditions for the hanger rod.

$C_1 = 0.25$ – For a column with one end fixed and one end free.

$C_2 = 1.00$ – For a column with both ends rounded.

$C_3 = 1.20$ – For a column with both ends fixed.

E = the modulus of elasticity of the hanger rod, normally assumed to be $E = 30x10^6\ psi$.

I_R = the area moment of inertia of the hanger rod based on the minor thread diameter.

L = the length of the hanger rod.

N = the Factor of Safety. A factor of safety must always be applied to buckling applications because it is a highly statistical failure mode, and is very difficult to predict accurately; for the purposes of this section and as mentioned above $N = 1.5$.

P_{CR} = the critical buckling load.

Equation S8-7 and the values used for the end condition constants C_N may be found in the following reference.

Shigley, Joseph E., Mischke, Charles R., and Budynas, Richard, G.; Mechanical Engineering Design 7th Edition; Mc Graw-Hill, 2004; Pp 217-220.

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Equation S8-7 may be solved for the critical hanger rod length using the value for C_1. The upper end of the hanger rod is fixed by the anchorage to the structure, and the lower end is free. This is the hanger rod length beyond which a rod stiffener will be required.

$$L_{CR} = \sqrt{\frac{C_1 \pi^2 E I_R}{N(F_V - W_R)}}$$ **Equation S8-8**

Where:

L_{CR} = the critical hanger rod length, or the maximum un-stiffened hanger rod length.

If the hanger rod length is less than this value, then the hanger rod will not require a rod stiffener. The number of rod stiffener clamps that will be required for a particular hanger will be equal to;

$$N_{RC} = \left(\frac{L}{S_{CR}}\right) + 1$$ This value must be rounded up to the next whole number. **Equation S8-9**

Where:

N_{RC} = the number of rod stiffener clamps required at a particular restraint location. For most cases the minimum number of clamps that may be used will be three. For the cases where hanger rods are short, only two clamps may be required. This condition is described below.

S_{RC} = the maximum allowable spacing between rod stiffener clamps based on C_3, which is the end condition constant for a column with both ends fixed. This is the case because both ends of each segment of rod are tightly clamped against the rod stiffener.

$$S_{CR} = \sqrt{\frac{C_3 \pi^2 E I_R}{N(F_V - W_R)}}$$ **Equation S8-10**

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The case where only two hanger rod clamps would be required is defined by the condition where the maximum allowable spacing between hanger rod clamps as calculated by Equation S8-10 is greater than or equal to the length of the hanger rod, or $L \leq S_{RC}$.

A clamp should be placed within 1 inch of each end of the rod stiffener. The remaining clamps will be evenly spaced between the clamps on either end.

The proper AISI angle size to be used for a hanger rod stiffener may be selected by modifying Equation S8-7 as follows.

$$N(F_V - W_R) = \frac{C_2 \pi^2 E I_{Z-Z}}{L^2}$$ **Equation S8-11**

Where:

I_{Z-Z} = the minimum area moment of inertia of the AISI structural angle being used as a hanger rod stiffener. This will be the moment of inertia about the ***Z-Z*** axis, see Figure S8-9.

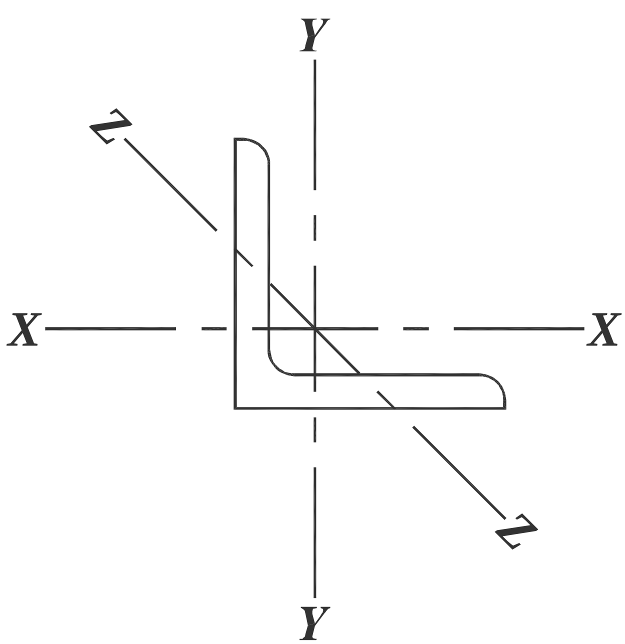

Figure S8-9; Axis Orientation for AISI Rolled Structural Angles with Equal Legs

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The AISI structural angles that are normally recommended by Kinetics Noise Control are listed by rod stiffener code below in Table S8-11. This rod stiffener code is a letter designation A through G. It is now possible to determine the minimum cross-section properties for the rod stiffener angle by solving Equation S8-11 for the area moment of inertia of the rod stiffener angle.

$$I_{Z-Z} = \frac{N(F_V - W_R)L^2}{C_2 \pi^2 E}$$ **Equation S8-12**

The column end condition value of C_2 will apply to this situation. This is because both ends of the rod stiffener angle will act as though they are rounded and free to pivot due to the low relative stiffness of the hanger rod. The value computed with Equation S8-12 should be considered to apply to the minimum required rod stiffener. This computed value for I_{Z-Z} should be compared to those in Table S8-11 and the AISI structural angle whose value for I_{Z-Z} exceeds the calculated value should be selected for the rod stiffener.

The online tools provided by Kinetics Noise Control for selecting hanger rod stiffeners and specifying rod stiffener clamps use this basic procedure. It must be noted here that there may be some hanger rod sizes that will be inappropriate for the higher seismic applications because so many rod stiffener clamps may be required so as to make the installation nearly impossible. Appendix A5.0 will provide tables that may be used for the selection of hanger rod stiffeners and the rod stiffener clamps. These tables can be used for most general cases and allow a fairly quick and easy estimate. They are not intended to replace the on line tools provided by Kinetics Noise Control which are intended to address particular situations more effectively, but are provided to allow the designer and design professionals to make quick estimates sizing selections or estimates.

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Table S8-11; Rod Stiffener Angle Code Designation and Design Data

Rod Stiffener Code	AISI Angle Designation	Weight per Foot (lbs)	Section Area (in^2)	I_{X-X} or I_{Y-Y} (in^4)	Radius of Gyration Z-Z (in)	I_{Z-Z} (in^4)
A	L 1 x 1 x 1/8	0.80	0.234	0.022	0.196	0.0090
B	L 1-1/4 x 1-1/4 x 1/4	1.92	0.563	0.077	0.243	0.0332
C	L 1-1/2 x 1-1/2 x 1/4	2.34	0.688	0.139	0.292	0.0587
D	L 1-3/4 x 1-3/4 x 1/4	2.77	0.813	0.227	0.341	0.0945
E	L 2 x 2 x 1/4	3.19	0.938	0.348	0.391	0.1434
F	L 2 x 2 x 3/8	4.70	1.36	0.479	0.389	0.2058
G	L 2-1/2 x 2-1/2 x 1/4	4.10	1.19	0.703	0.491	0.2869
H[1]	L 2-1/2 x 2-1/2 x 3/8	5.90	1.73	0.984	0.487	0.4103
I[1]	L 2-1/2 x 2-1/2 x 1/2	7.70	2.25	1.230	0.487	0.5336

[1] These rod stiffener angles may be used with the Kinetics Noise Control Model KHRC-C rod stiffener clamp. Not all hanger rod sizes may work with these arrangements. Check with Kinetics Noise Control Engineering for your particular application.

S8.7 – Kinetics On-Line Rod Stiffener Application Tool:

Kinetics Noise Control has developed an on-line analysis tool to assist in the selection of rod stiffeners and the size and number of rod stiffener clamps. The use of this tool will require a KNC number to access previously entered data for selecting seismic restraints for pipe and duct. So at the very least a project will need to have a submittal provided by Kinetics Noise Control for seismic restraints for pipe and/or duct.

To use the web based program:

1. You will need a User Name and a Password supplied by Kinetics Noise Control.
2. Go to the Kinetics Noise Control Web Sit at www.kineticsnoise.com .

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3. Click on Web Programs in the upper right hand corner of the screen.
4. Enter the User Name and Password.
5. Go to Seismic Applications and select Rod Stiffener.
6. Select the year and the Project Code (KNC number) using the pop ups.
7. Enter the restraint location (this is a designation that the user can give to the restraint locations).
8. Select Pipe or Duct.
9. If Pipe is selected, input the number of pipes, and enter the data requested for each pipe using the pop-ups.
10. Enter the requested Hanger Information and Floor Information and Submit.
11. If Duct is selected, input the number of ducts being supported by the same hanger system and enter the requested data for each duct.
12. Enter the requested Hanger Information and Floor Information and Submit.
13. The program output will indicate whether rod stiffeners are required at this restraint location. If they are required, the program will recommend an specific angle size to use as a rod stiffener, and the size and number of clamps required for each hanger rod.

S8.8 – Summary:

1. Use of strut type restraints may dictate the use of larger hanger rods than those normally applied. Whereas, the use of cable restraints imposes no such limitations on the hanger rod size choice.
2. The same comment may be applied to the anchorage of the hanger rods to the building structure. The use of strut restraints require the use of seismically qualified components and potentially much larger than normal post installed concrete anchors or attachment hardware.
3. In instances where the dead weight load of the pipe or duct on the hanger rod exceeds the vertical compressive reaction force due to the horizontal seismic load, no rod stiffeners will ever be required for those restraint locations.

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4. Where net compressive forces are present and if the hanger rod length is less than the critical length calculated with Equation S8-8, a hanger rod stiffener will not be required at that restraint location.
5. Only the hanger rods at the restraint attachment points need to be considered for hanger rod stiffeners.
6. Hanger rod stiffeners should be sized to resist buckling under the maximum expected compressive loads.
7. The hanger rod stiffener is selected from Table S8-11 using the minimum area moment of inertia is defined by I_{z-z} in Equation S8-12.
8. The number of hanger rod clamps should be chosen so that the distance between clamps is less than the maximum allowable spacing between the hanger rod clamps as calculated with Equation S8-10.
9. Refer to Appendix A5.0 and/or Kinetics Noise Control's online tools for size selection information for hanger rod stiffeners.

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EXTREME TEMPERATURE PIPING APPLICATIONS

S9.1 – Introduction:

Piping for extreme temperature applications such as steam lines and cryogenic lines must be treated differently than normal HVAC or plumbing piping. This is due to the fact that the piping will change significantly in length between the as installed condition and the operating condition. The rules for seismically restraining pipe may need to be modified slightly when dealing with extreme temperature applications, as compared to those rules used for more normal applications.

S9.2 – Extreme Temperature Piping Run:

Extreme temperature piping designers want to closely control both the amount and the direction of expansion or contraction in each section of pipe between the installation and operating temperatures. Typically, a section of pipe is joined to adjacent sections through the use of expansion/contraction joints on either end, as shown in Figures S9-1and S9-2 below. The length of the section of pipe between two expansion/contraction joints is designed to be within the range of travel that can be accommodated by the expansion/contraction joint.

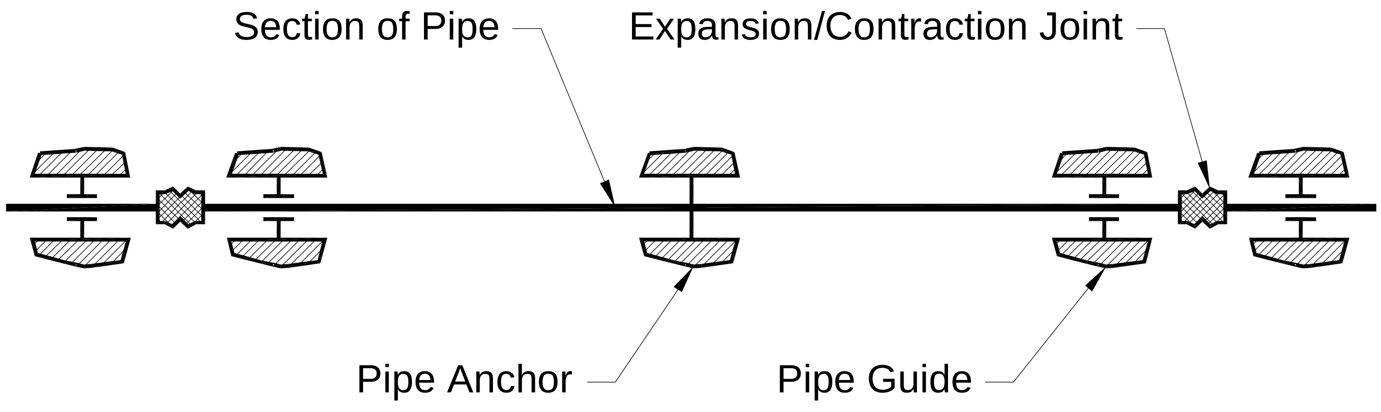

Figure S9-1; Typical Section of Extreme Temperature Piping – Center Anchor

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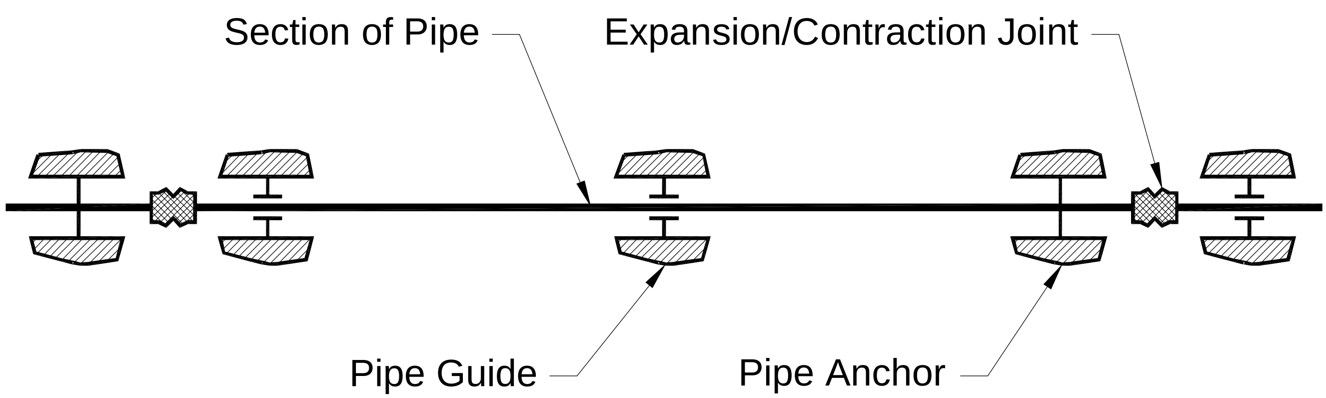

Figure 2; Typical Section of Extreme Temperature Piping – End Anchor

It is common practice, especially with steam lines, to anchor each section pipe to the building structure at one location. The normal anchor location is either in the center of the pipe section or at one end. When the anchor is in the center of the pipe run, the expansion or contraction is divided equally between the expansion/contraction joints on either end of the pipe section. When the anchor is located at one end, the expansion or contraction is taken up by the expansion/contraction joint at the opposite end of the pipe section. Along with an anchor, each section of pipe will require at least two guides that will support the dead weight of the pipe, and still allow the pipe to move with the thermal expansion and contraction.

Each section of pipe between expansion/contraction joints will behave independently from as compared to other interfacing sections when subjected to the earthquake motion. In order to provide adequate seismic restraint, the section of extreme temperature pipe that is located between two expansion/contraction joints will be treated as a full run of pipe. That is, the section of pipe between two expansion/contraction joints must have at least two transverse seismic restraints and at least one longitudinal restraint, per RULE #6 and RULE #8 from Section S1.0.

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S9.3 – Seismic Restraint Locations for Extreme Temperature Piping:

Many steam lines also carry steam at pressures greater than atmospheric, and thus are required to comply with the ASME code for pressure piping. ASCE/SEI 7-05 Section 13.6.8.1, which is a reference document for 2006 IBC, provides an important exemption for pressure piping systems, and is quoted directly below.

> **13.6.8.1 ASME Pressure Piping Systems.** Pressure piping systems, including their supports, designed and constructed in accordance with ASME B31 shall be deemed to meet the force, displacement, and other requirements of this section. In lieu of specific force and displacement requirements provided in ASME B31, the force and displacement requirements of Sections 13.3.1 and 13.3.2 shall be used.

Thus, if documentation showing that the piping system was designed and constructed in accordance with ASME B31 exists, no further seismic restraint is required.

If the piping system was not a pressurized steam system and as such, was not required to b designed and constructed per ASME B31, then additional restraint will be required. For extreme temperature piping it is critical that the longitudinal seismic restraints be located as close to the anchor point as possible. In some cases, if adequately rated for seismic applications, anchors may be used as seismic restraints. This is because as thermal expansion or contraction of the pipe occurs, the further away from the anchor the longitudinal restraints are placed, the greater will be the amount of growth or shrinkage that the longitudinal restraint cables must accommodate. For either expansion or contraction, one restraint cable will become slacker, and the other one will become tighter than is expected in a normal pipe application. Because they are rigid, strut type seismic restraints are not recommended unless they are located immediately adjacent to an anchor. If the longitudinal restraints are located any distance away from the anchor, added tension or compression, driven by the thermal change in pipe length, will be induced in the restraints and can generate failures in either the restraint or the attachment to the pipe and the building.

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Figure S9-3 shows a case where the anchor is located in the center of the pipe section, and the length of the section is such that only one longitudinal restraint will be required. The longitudinal restraint is shown directly on top of the anchor, which is of course not possible. The restraint must be just to the right or left of the anchor. Note also that there are transverse restraints at the guide locations close to the expansion/contraction joints, and one with the longitudinal restraint. The transverse restraints are sized and located along the section of pipe as described in Sections S1.0 and S7.0, where S_T is the transverse restraint spacing. All of the restraints must be located close enough to pipe supports capable of resisting upward motion to counteract the upward reaction forces generated by the restraints. Sometimes the function of the guide is performed by roller supports for the pipe. If this is the case the supports at seismic restraint locations must be fitted with double rollers, on the top and bottom of the pipe, or a hoop strap over the pipe to keep the pipe from being disengaged from the roller by the seismic reaction forces, and to transfer these forces to the building structure.

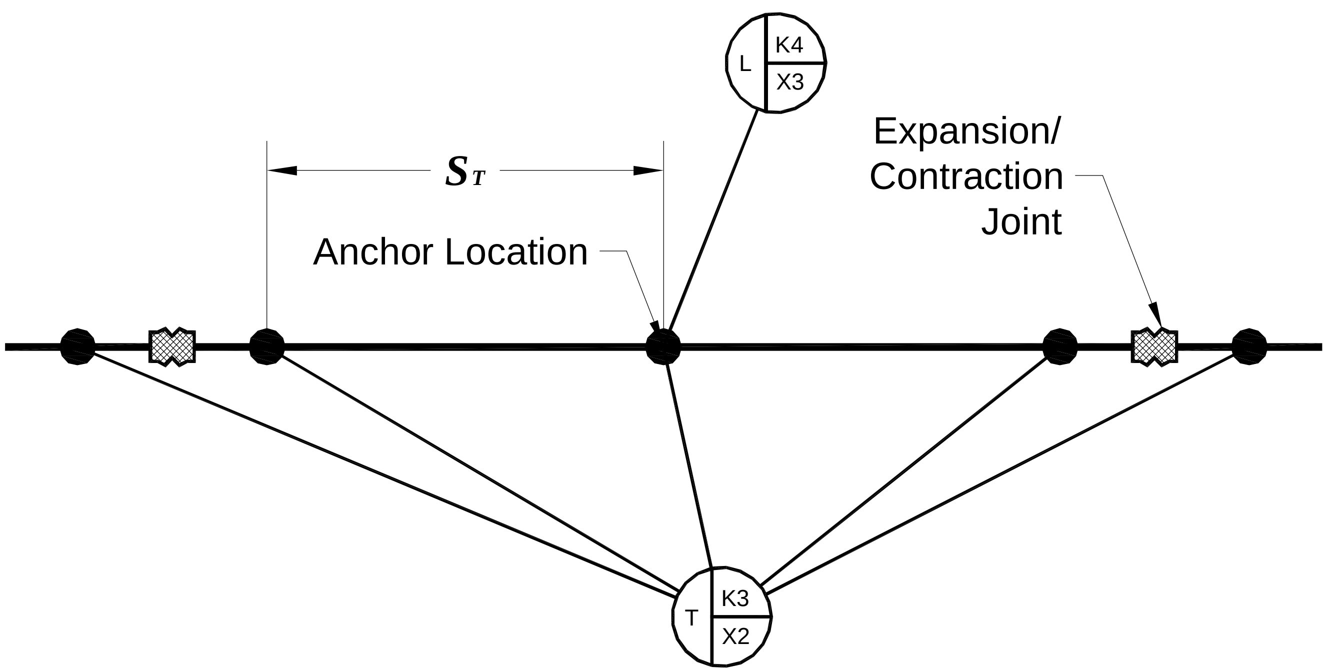

Figure S9-3; Seismic Restraints for Extreme Temperature Pipe with a Center Anchor and One Center Longitudinal Restraint

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Figure S9-4 shows a section of pipe with a central anchor whose length exceeds the maximum allowable spacing for the longitudinal restraints. In this case a longitudinal restraint is located on either side of the anchor. Each longitudinal restraint handles one half of the length of the pipe section between the expansion/contraction joints. If the section of pipe is longer than 160 ft, two longitudinal restraints may still be used provided that the following conditions are met.

1. The requirements for the restraint of the pipe may be met by the seismic restraint components and their anchorage hardware.
2. The compressive force in the pipe that is generated by the design seismic force is below the allowable buckling load of the pipe.

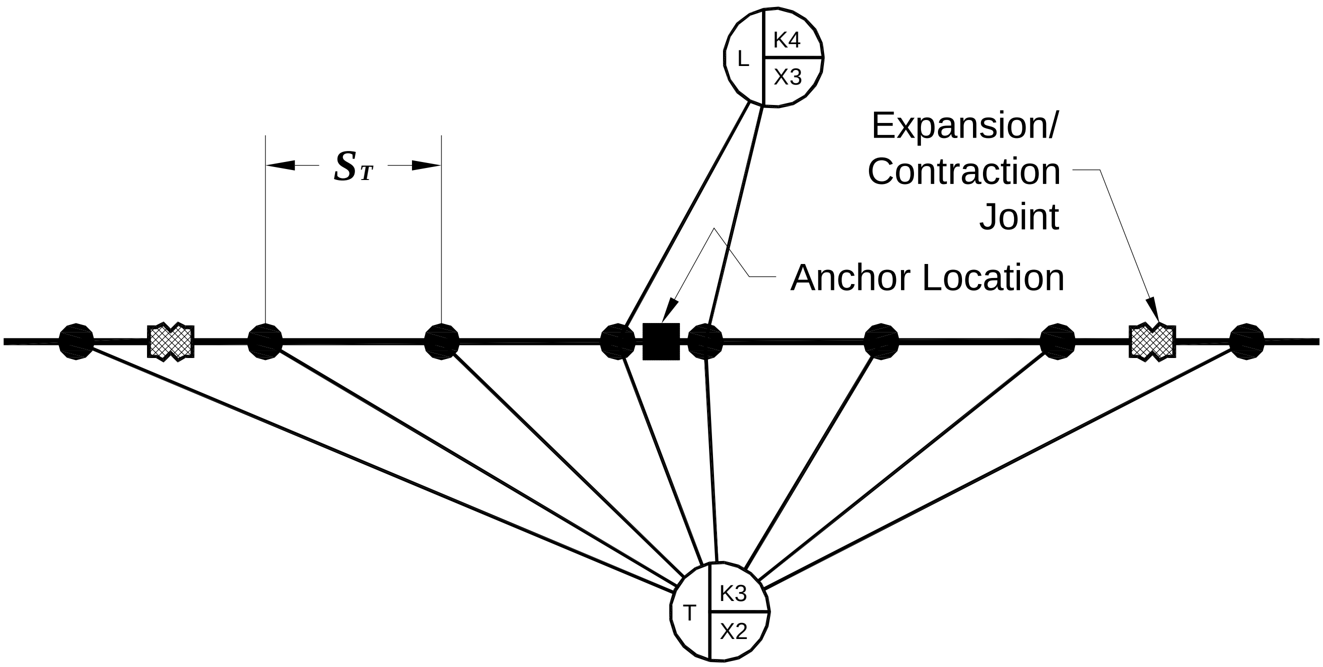

Figure S9-4; Seismic Restraints for Extreme Temperature Pipe with a Center Anchor and Two Center Longitudinal Restraints

Figure S9-5 and S9-6 show the seismic restraint schemes for the case where the section of pipe is anchored on one end. In each case the longitudinal restraint is shown at the anchor location. The actual attachment point to the pipe should be just to the left of the anchor. In both cases, the longitudinal restraints at the anchor must be capable of restraining the entire section of pipe. So,

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for a section of pipe with the anchor at one end, the section length can not exceed 80 ft to 100 ft. Thus, in order to use an end anchor scheme for the expansion/contraction control, the section lengths must be chosen with the seismic restraint requirements for the project in mind.

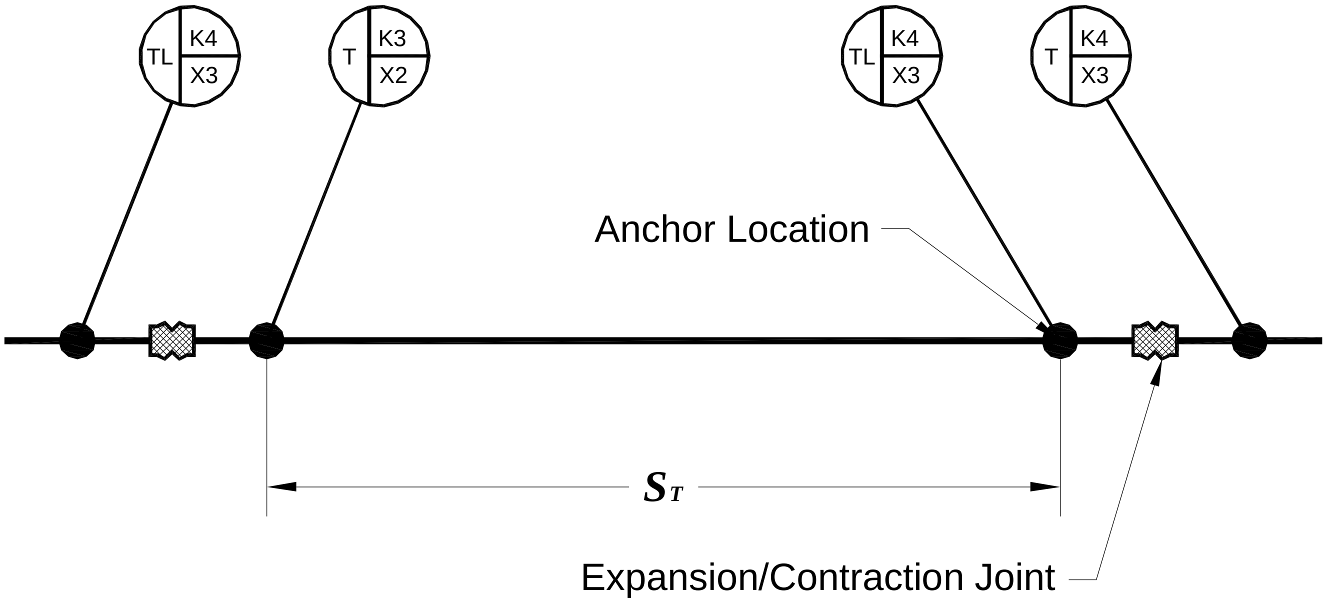

Figure S9-5; First Seismic Restraint Scheme for Extreme Temperature Pipe with One End Anchor

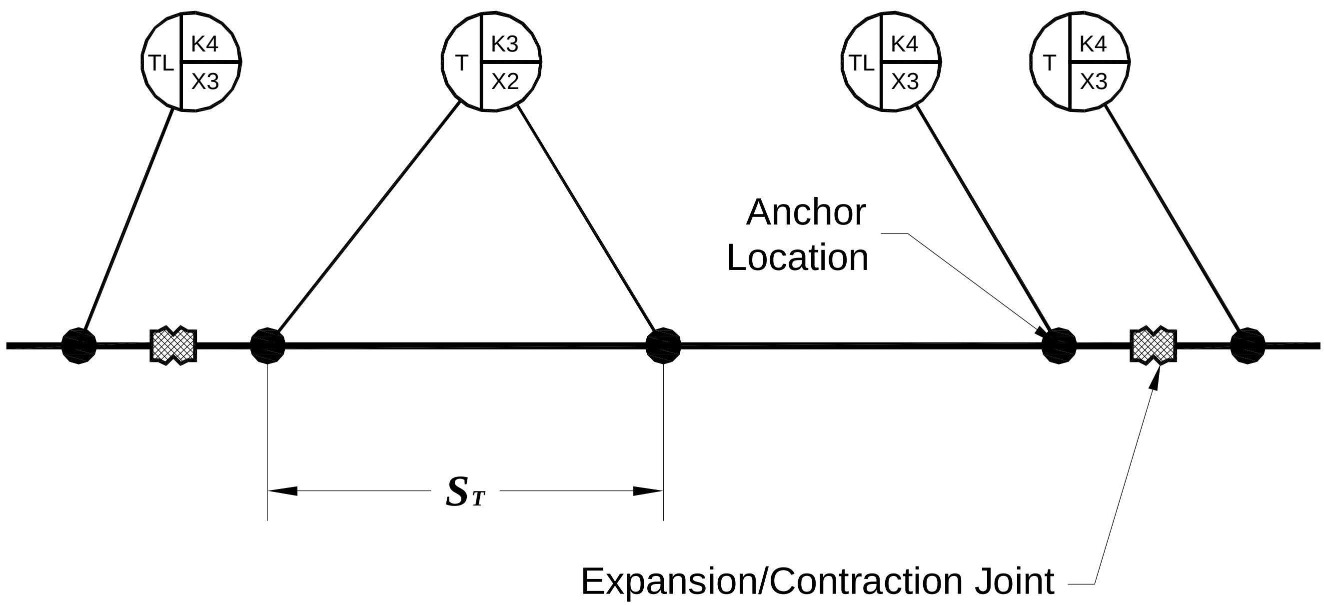

Figure S9-6; Second Seismic Restraint Scheme for Extreme Temperature Pipe with One End Anchor

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S9.4 – Seismic Restraints and Expansion Loops:

Expansion/Contraction joints are sometimes replaced by specially designed “dog-legs” in the pipe that are intended to absorb the expansion and contraction of the long horizontal runs of pipe. Such an expansion/contraction loop is shown in Figure S9-7. This loop would be designed to handle sections of pipe that were anchored in the center.

If the anchor was at one end of the pipe section, one of the guides in Figure S9-7 would be replaced by an anchor, and the anchor would be replaced by a guide as shown in Figure S9-8.

The seismic restraints for the expansion/contraction loop are shown in Figure S9-9. The adjacent to the pipe anchor at the center of the loop there will be both transverse and longitudinal restraints of sufficient capacity to restrain the weight of the entire three legs of the expansion/contraction loop. The ends of both sections of pipe supported with the pipe guides will have transverse seismic restraints located close to the pipe guides.

The seismic restraint scheme for the expansion/contraction loop for extreme temperature pipe with end anchors is shown in Figure S9-10. The guides will have transverse seismic restraints adjacent to them. The anchor at the end of the pipe section will have both transverse and longitudinal restraints adjacent to it. The longitudinal restraint must have enough capacity to restraint both the section of pipe and the expansion/contraction loop.

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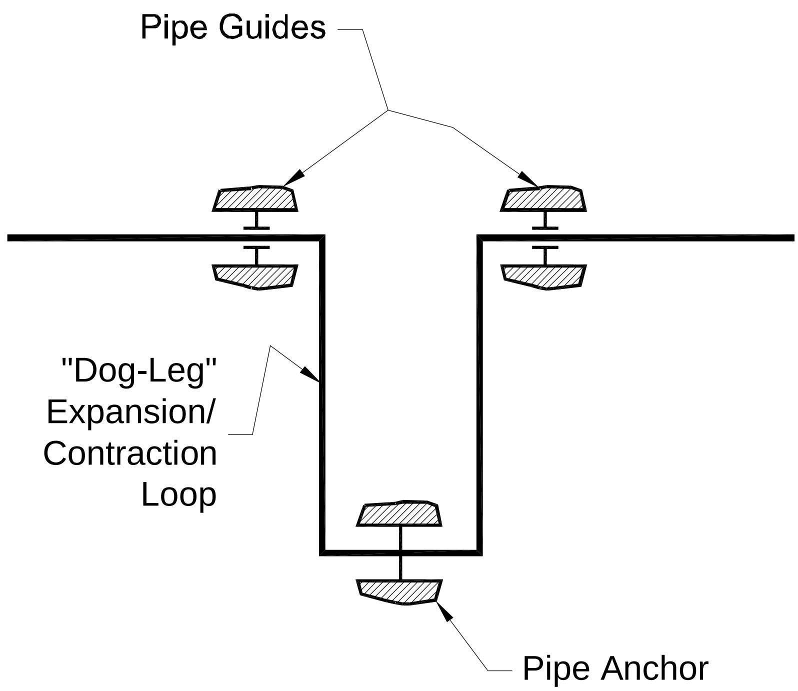

Figure S9-7; Expansion/Contraction Loop for Extreme Temperature Pipe with Center Anchors

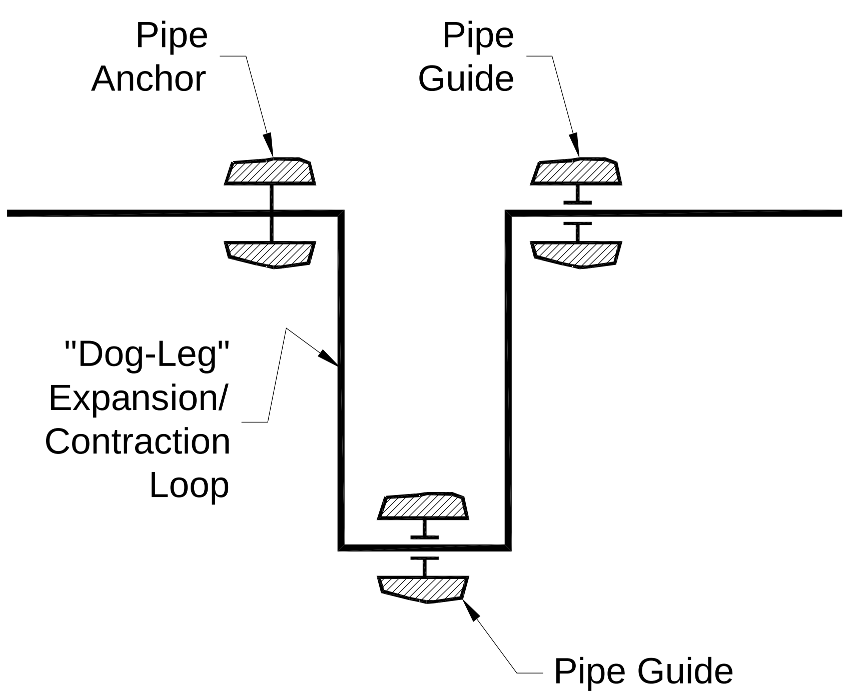

Figure S9-8; Expansion/Contraction Loop for Extreme Temperature Pipe with End Anchors

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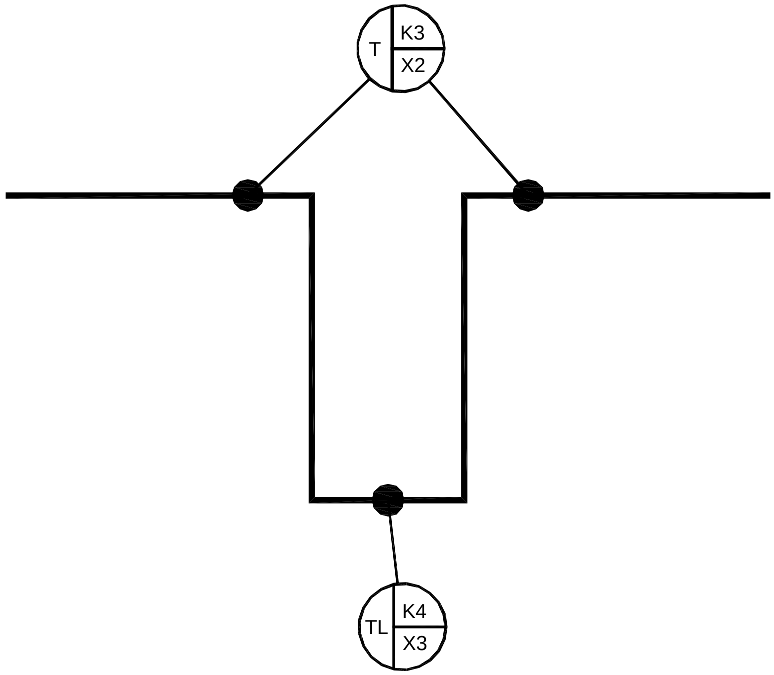

Figure S9-9; Seismic Restraints for Expansion/Contraction Loops for Extreme Temperature Pipe with Center Anchors

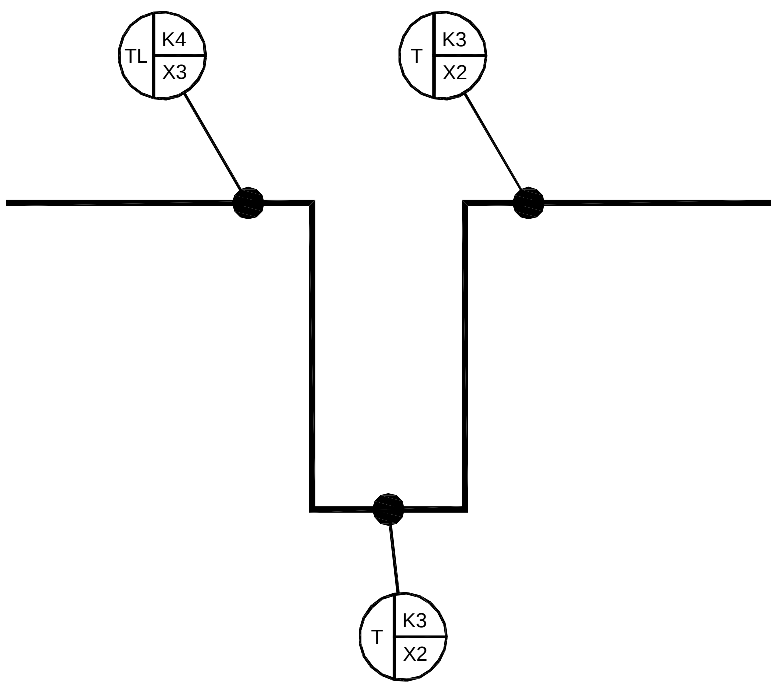

Figure S9-10; Seismic Restraints for Expansion/Contraction Loops for Extreme Temperature Pipe with End Anchors

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S9.5 – Non-Anchored Domestic Hot and Chilled Water Piping:

It is not unusual for domestic hot water piping systems to be designed and installed with no special provisions for anchoring the pipe, or controlling the expansion or contraction that may occur in normal operation of the system. In many cases the pipe sizes are rather small, but may not be small enough to fall under any of the code based exemptions. Whenever a longitudinal seismic restraint is introduced into a run of hot or chilled water piping, an anchor point is established and thermal growth or contraction will occur on either side of the longitudinal restraint location. Transverse seismic restraints that are placed "close" to corners will try to prevent the run of pipe in the other leg from growing or shrinking. This action may over stress the pipe and/or overload the transverse restraint cables that are closest to the corners.

For domestic hot or chilled water piping, the rules for applying longitudinal restraints must be as follows.

1. The longitudinal restraint must be located in the center of the piping run to allow the pipe to experience unrestrained axial growth or shrinkage at the ends of the run. Care must be taken that the restrained length of pipe on each side of the restraint is less than the amount that would cause buckling of the pipe under the expected design horizontal seismic force for the project, see Appendices A6.1, A6.2, and A6.3.
2. If the piping run is long enough that multiple longitudinal restraints are required, an expansion/contraction joint or expansion/contraction loop must be placed between the longitudinal restraints to accommodate the growth or shrinkage of the pipe.
3. When a run of hot or chilled water tees off of a main hot or chilled water line steps must be taken to ensure that the expansion or contraction of the main or the branch line does not place excessive stress on the other.

A typical layout for domestic hot and chilled water might appear as shown in Figure S9-11 below. Note that in the layout, the longitudinal seismic restraints are place in the center of each run. The

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last transverse seismic restraints before each corner are places a specific distance from the corner. This distance is specified in order to allow the pipe to growth or shrink in length along the two legs of the bend without exceeding the allowable stress in the pipe in bending.

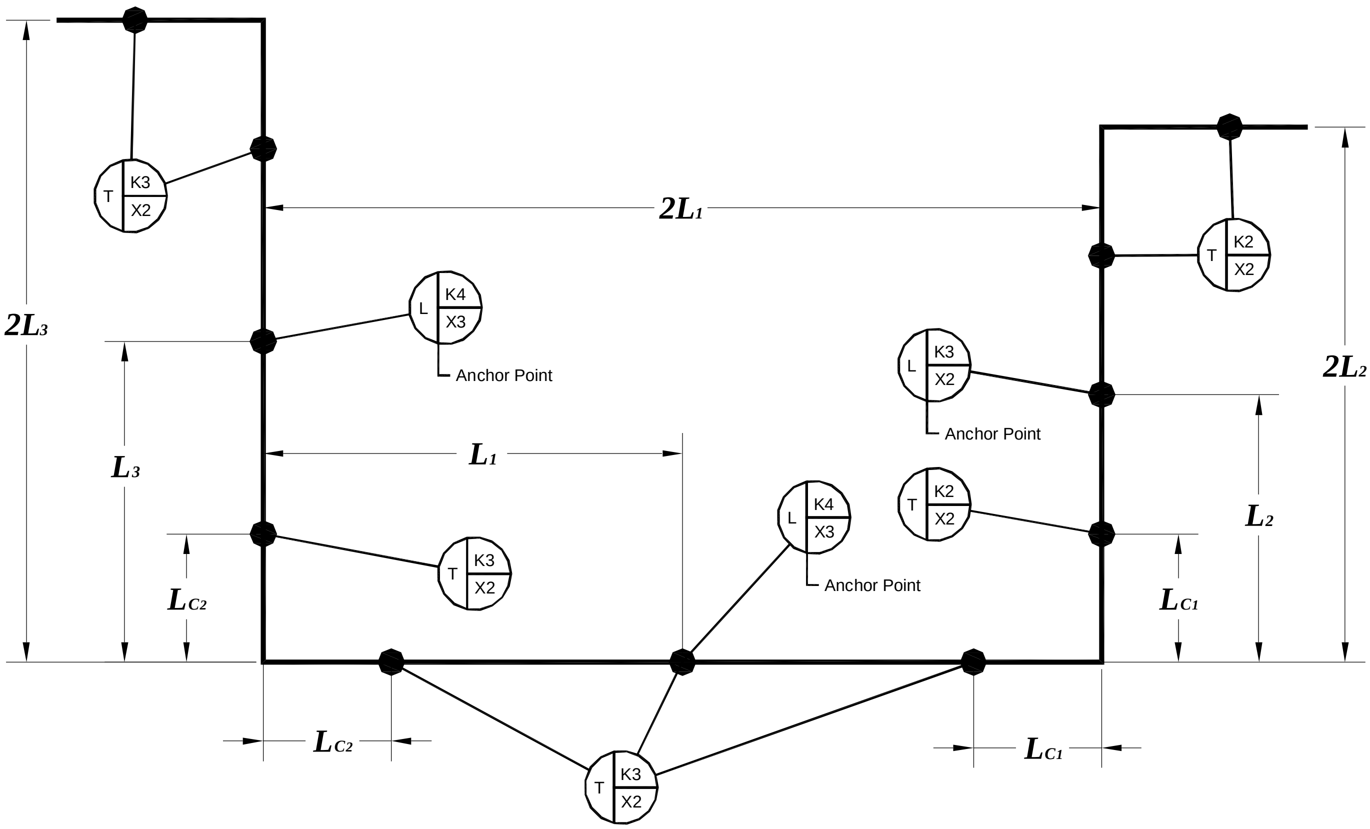

Figure S9-11; Typical Seismic Restraint Layout for Domestic Hot and Chilled Water

The distance from the corners to the first transverse seismic restraint will be determined by;

1. The pipe material.
2. The pipe size.
3. The distance from the longitudinal seismic restraint to the corner.
4. The difference between the installed temperature and the operating temperature of the pipe.

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This length from the corner to the first transverse seismic restraint may be estimated using equation (5) from the 2008 ASHRAE Handbook – HVAC Systems and Equipment; Chapter 45. This equation is repeated in a form that is more applicable to this application.

$$L_C = \sqrt{\frac{3\delta_p D_O E_p}{144 S_A}}$$ **Equation S9-1**

Where:

L_C = the distance from the corner to the first transverse seismic restraint (ft.).

δ_p = the change in length, growth or shrinkage, due to the temperature difference between installation and operating conditions for the length of pipe from the longitudinal seismic restraint and the corner (in.).

D_O = the outside diameter of the pipe or tube (in.).

E_p = the modulus of elasticity for the pipe material (psi).

$E_p = 30x10^6\ psi$ Carbon Steel Pipe

$E_p = 17x10^6\ psi$ Drawn Copper Tubing

$E_p = 4.2x10^5\ psi$ PVC Pipe

$E_p = 3.6x10^6\ psi$ CPVC Pipe

S_A = the allowable stress for the pipe material (psi).

$S_A = 15{,}000\ psi$ Carbon Steel Pipe

$S_A = 9{,}000\ psi$ Drawn Copper Tube

$S_A = 4{,}000\ psi$ PVC 1120 and CPVC 4120 Pipe

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The change in length of the pipe from the longitudinal seismic restraint to the corner may be determined as follows;

$$\delta_p = 12\alpha_p L(\Delta T)$$ **Equation S9-2**

Where:

α_p = the linear coefficient of thermal expansion for the pipe (in./in.°F).

$\alpha_p = 6.31x10^{-6}\ in./in.°F$ Steel Carbon Pipe

$\alpha_p = 9.5x10^{-6}\ in./in.°F$ Drawn Copper Tubing

$\alpha_p = 30.0x10^{-6}\ in./in.°F$ PVC 1120 Pipe

$\alpha_p = 35.0x10^{-6}\ in./in.°F$ CPVC 4120 Pipe

L = the distance from the longitudinal seismic restraint to the corner (ft.)

ΔT = the temperature difference between the installed condition of the pipe and the operating condition of the pipe (°F). This will be positive (+) for domestic hot water pipe and negative (-) for domestic chilled water pipe. Assuming an installation temperature of 60° F, a maximum temperature of 140° F for Domestic hot water, and a minimum temperature of 40° F for domestic chilled water the average temperature differentials may be taken as;

$\Delta T = 80°F$ Domestic Hot Water (Pipe Length Grows)

$\Delta T = 20°F$ Domestic Chilled Water (Pipe Length Shrinks)

Substitution of Equation S9-2 into Equation S9-1 will yield the following result.

$$L_C = 0.5\sqrt{\frac{\alpha_p L\Delta T D_O E_p}{S_A}}$$ **Equation S9-3**

For Standard Steel Pipe:

$L_C = 0.502\sqrt{LD_O}$ Domestic Hot Water **Equation S9-4**

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$L_C = -0.251\sqrt{LD_O}$ Domestic Chilled Water **Equation S9-5**

For Drawn Copper Tubing:

$L_C = 0.599\sqrt{LD_O}$ Domestic Hot Water **Equation S9-6**

$L_C = -0.300\sqrt{LD_O}$ Domestic Chilled Water **Equation S9-7**

For PVC 1120 & CPVC 4120 Pipe:

$L_C = 0.251\sqrt{LD_O}$ Domestic Hot Water **Equation S9-8**

$L_C = -0.125\sqrt{LD_O}$ Domestic Chilled Water **Equation S9-9**

For any particular corner, the value of L_C that is used should be based on the leg with the longest distance from the longitudinal restraint to the corner in question. For instance, referring to Figure S9-11, the value for L_{C1} will be based on L_1 or L_2 whichever is larger, and L_{C2} will be based on the larger of L_1 and L_3. Values for L_C are shown in the tables or Appendix A2.6 for hot or chilled domestic water lines for various pipe sizes and materials. These tables are rather extensive and can be used for special design situations. However, the values in Table S9-1 will be suitable for most applications.

Table S9-1; Basic Corner Distance for Domestic Hot & Cold Water Piping to First Transverse Seismic Restraint for Distances from the Corner to the Longitudinal Restraint Up to and Including 40 ft and Temperature Differences Up to and Including 80° F.

Applicable Pipe/Tubing Size Range (in)	Distance From Corner To Transverse Seismic Restraint L_C (ft)
3/4 to 2-1/2	5
3 to 10	10
11 to 22	15

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S9.6 – Trapeze Supported Extreme Temperature Piping:

There may be occasions when steam line, a chilled water line, or a domestic hot water line will be supported by trapeze bars along with other piping that does not need to meet the seismic restraint requirements for extreme temperature piping, see Figures S9-12 and S9-13 below. Special considerations must be taken into account when restraining the trapeze supported piping where one or more of the supported lines will experience expansion or contraction.

1. When large diameter pipes are being used which have large changes in pipe length due to expansion or contraction for a particular run of pipe, the use of expansion/contraction joints is recommended. This will require the use of pipe anchors and guides as described in Sections S9.2 and S9.3. The trapeze bars and their supports will need to be designed to handle all of the dead loads and thermal loads.
2. When anchors and guides are not used, as in domestic hot water lines and some chilled water lines, the lines must be anchored in one location as discussed in Section S9.5.
    a. The longitudinal seismic restraint that is being used as the anchor may be attached either to the trapeze bar directly or to the pipe.
        i. If the longitudinal seismic restraint is attached to the trapeze bar, Case-1 Figure S9-12, the hot or chilled water pipe must be ***tightly clamped*** to the trapeze bar, and the restraints sized to handle the seismic forces generated by all of the pipes being supported by the trapeze bar.
        ii. If the longitudinal seismic restraint for the hot or chilled water pipe is to be attached, clamped, directly to the hot or chilled water pipe, Case-2 Figure S9-13, it must be located within ±4″ of the trapeze bar, and uplift control must be provided for the pipe at the trapeze bar to transfer the vertical seismic reactions to the trapeze bar hanger rods. See Sections I3.0 and I6.0 for uplift control schemes for extreme temperature piping.
        iii. When a run of hot or chilled water tees off of a main line that is trapeze supported with other pipes, steps must be taken to ensure that the expansion or

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contraction of either the main or the branch line does not excessively stress the other line, or twist the trapeze bar(s) to bend the hanger rods.

b. The hot or chilled water lines must be allowed to expand or contract freely on either side of the longitudinal seismic restraint that serves as the anchor point.

   i. Care must be used to prevent interference at bends with the other pipes being supported by the trapeze bars when the hot or chilled water lines expand or contract.

   ii. Where transverse seismic restraints are located on the hot or chilled water lines, transverse and vertical, uplift control, motion of the pipe must be limited. See Section I6.0 for examples of schemes for limiting transverse and vertical motion while allowing free expansion and contraction of the pipe.

   iii. Rollers or slides may be used to support hot or chilled water lines that experience large amounts of motion, or frequent temperature cycles.

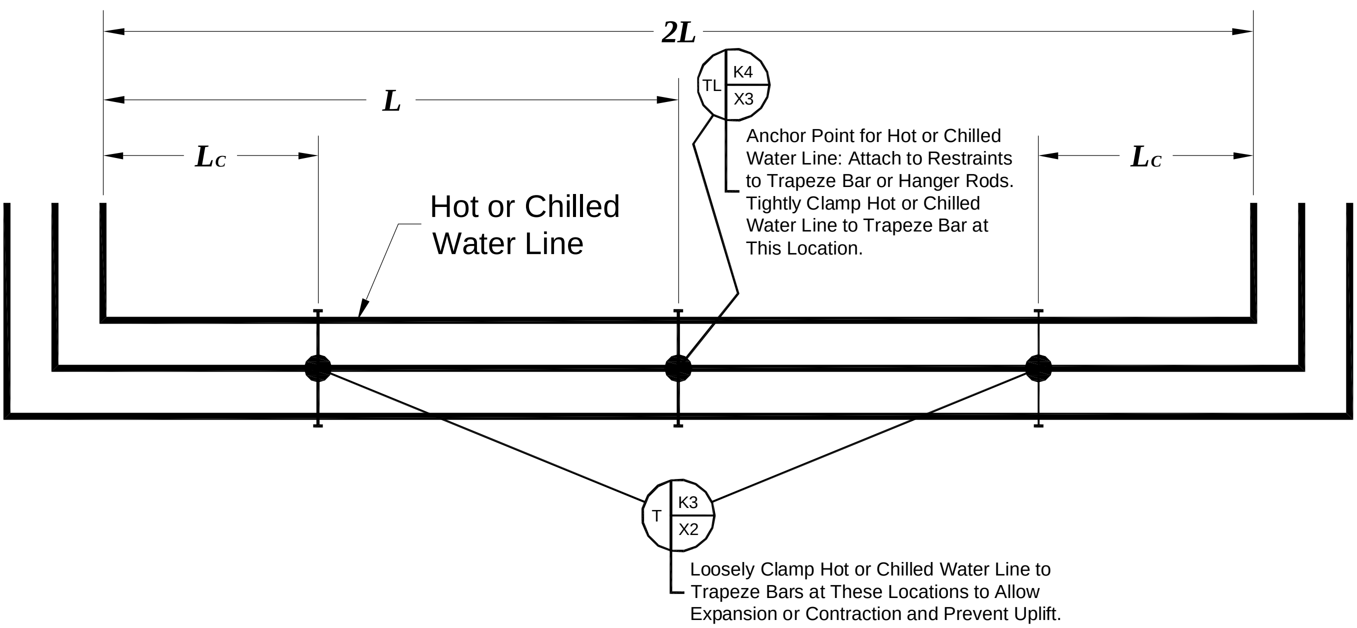

Figure S9-12; Hot or Chilled Water Line Trapeze Supported with Standard Water Lines: Case-1

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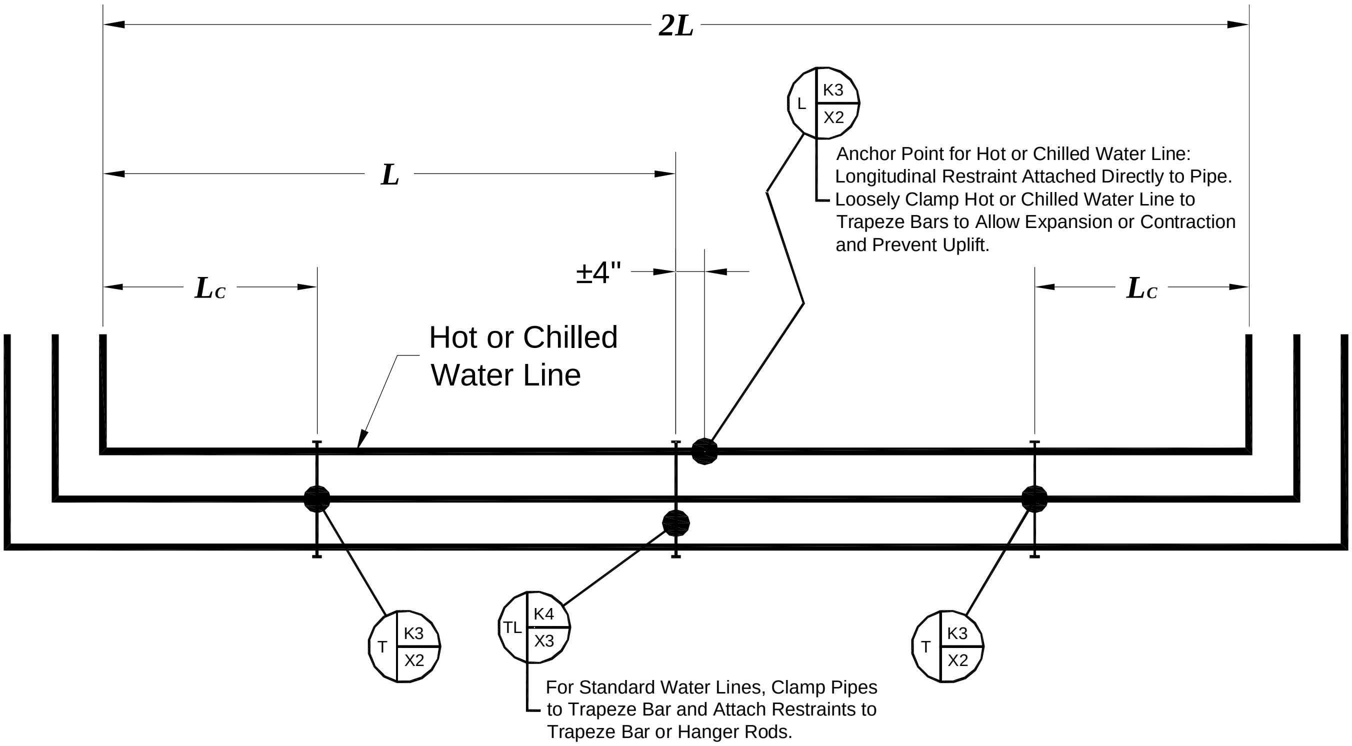

Figure S9-13; Hot or Chilled Water Line Trapeze Supported with Standard Water Lines: Case-2

S9.7 – Additional Transverse Seismic Restraints for Extreme Temperature Piping:

For extreme temperature piping, the run of pipe will have an anchor point either in the middle or at one end as described in the sections above, see figures S9-1 and S9-2. The longitudinal seismic restraint(s) for the run of pipe will be placed at the anchor point, see Figures S9-3 through S9-6. In the case of the domestic hot and chilled water, the longitudinal restraint(s) will be the anchor, see Figure S9-11.

Transverse seismic restraints are typically placed at the anchor point and at the "free" end of the run of pipe where the expansion and contraction are allowed to occur. Additional transverse seismic restraints may be required between the anchor point and the "free" end to prevent buckling of the pipe due to longitudinal seismic forces in the pipe. The proper number or transverse seismic restraints should be selected based on the length of the pipe between the anchor point and the "free" end, and minimum allowable restraint spacing values for the

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appropriate type of pipe as described in Section 8.0 in the tables in Appendices A6.1, A6.4, and A6.5.

S9.8 – Final Comments on Transverse Seismic Restraints for Extreme Temperature Piping:

The transverse seismic restraints will also be affected by the thermal expansion and contraction of the pipe. However, the effects will be to a much smaller degree than those experienced by the longitudinal restraints. Further, the cable type restraints are far less sensitive to the axial motion of the pipe than the strut type restraints. This is due to the geometry of the restraints. The change in length of the restraint for a given change in pipe length is relatively small, and may be compensated for in many cases by larger loops at the ends of the restraint cables, or slotted holes in the brackets used to attach the restraints to the pipe and structure. However, for piping systems that experience very large thermal displacements, the transverse restraints must be mounted to the pipe in such away to accommodate the change in length of the pipe due to the temperature effects. Slider type clevis hangers or roller type clevis hangers are typically used to accommodate larger axial motion. The transverse seismic restraints can be attached to these types of hangers as long as some means, such as a top strap or upper roller, is used to transfer the vertical seismic reaction forces to the hanger.

In Section S1.0, RULE #9, it was stated that is transverse restraints were located within 24 inches, 2 feet, of a corner, that the transverse restraint on one leg could act as the longitudinal restraint on the other leg. This rule ***must not*** be globally applied to extreme temperature piping! Those transverse restraints which are located that close to the corner of an extreme piping run will be subjected to very large displacements which could fail the restraints or their anchorage. The last transverse restraints before the corner must be placed far enough away from the corner that the may grow or shrink as it will without overloading the restraints. This distance from the corner to the first transverse seismic restraints may be estimated using Appendix A2.6, Equation S9-3, or Equations S9-4 through S9-8.

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I1.1 – Seismic Restraint Categories and Types:

Seismic restraints for pipe and duct are generally separated into to two categories.

1. Transverse Seismic Restraints: These act to keep the pipe or duct from swinging side-to-side. They are normally placed so that they act perpendicular, at right angles, to the pipe or duct, as shown in Figure I1-1. These seismic restraints are located at, or very near, the pipe or duct hangers. If the restraints are not attached directly to the hanger, they may be attached to the pipe or duct with in four (4) inches of the hanger location. This is so that any vertical reaction loads from the restraints go to the structure directly through the hanger and not the pipe or duct.

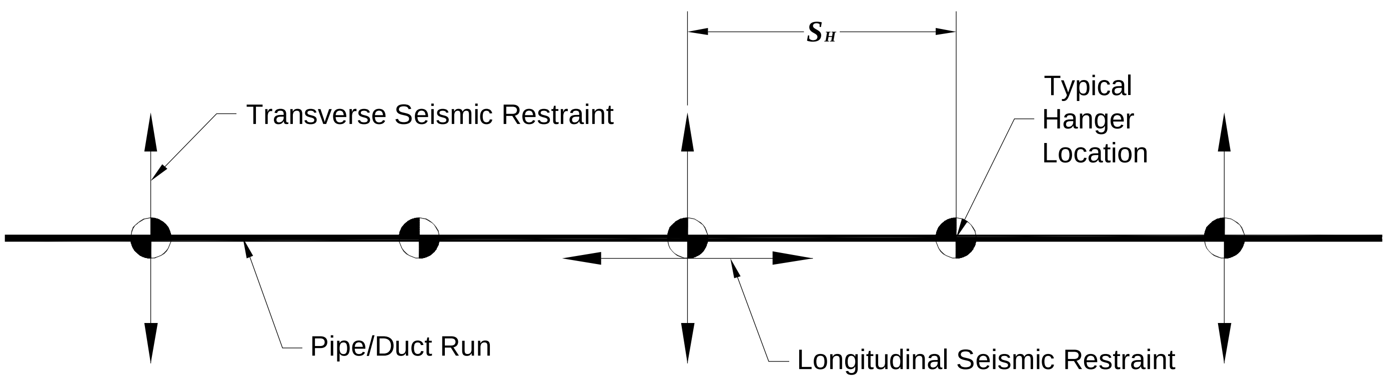

Figure I1-1; Definition of Transverse and Longitudinal Seismic Restraints

2. Longitudinal Seismic Restraints: These act to keep the pipe or duct from swinging back-and –forth along the length of the pipe or duct. Typically, they are placed parallel to, or along, the length of the pipe or duct, as shown in Figure I1-1. The seismic restraints are also located at, or very near, the hanger locations of the pipe or duct for the same reason stated above.

Seismic restraints may be further broken down into two basic types based on the way they work.

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1. Strut Restraints (Rigid Braces) – these restraints carry both tension (pull) and compression (push) loads along the axis of the strut. Only one strut is required to restrain a pipe or duct in one direction, either transverse or longitudinal. These restraints are normally constructed of a structural member with attachment brackets on either end for the structure and the pipe or duct. The common structural members that are used are, AISI rolled angles, pipe, conduit, and UNISTRUT™ channels. ***Caution*** must be used when applying this type of restraint. The seismic forces will produce both tensile and compressive reactions in the hanger rod that may equal or exceed the dead load of the pipe or duct. In other words, the seismic forces acting on the strut restraints may be capable of ***breaking the hanger rod***, or ***pulling the rod anchor out of the structure***. If strut restraints are to be used, the engineer of record needs to be informed. The hanger rods and rod anchors may need to be increased in size and capacity to carry the additional tensile reaction loads in the hanger rod generated by the seismic forces.
2. Cable Restraints (Tension Only Braces) – these restraints can carry only tension (pull) loads along the length of the able. They must be used in pairs where the cables are oriented ~180° apart to keep the pipe or duct from moving back-and-forth. Remember, ***you can't push a rope***, so there must be two cables for each restraint location and direction, transverse and longitudinal. The seismic forces in the restraint cables will produce only compressive reaction loads in the hanger rods.

I1.2 – Drawing Symbols:

On the drawings provided by Kinetics Noise Control the symbols shown in Figure I1-2 are used to indicate the approximate locations of the seismic restraints required for a run of pipe or duct. For duct or single clevis hung pipe the seismic restraint location is shown as a single large dot. For trapeze supported pipe, the symbol used is an "**I**" shaped bar centered on a large dot. The "**I**" shaped bar will extend on either side of the central dot to cover all of the pipes that are assumed to be supported on the trapeze bar.

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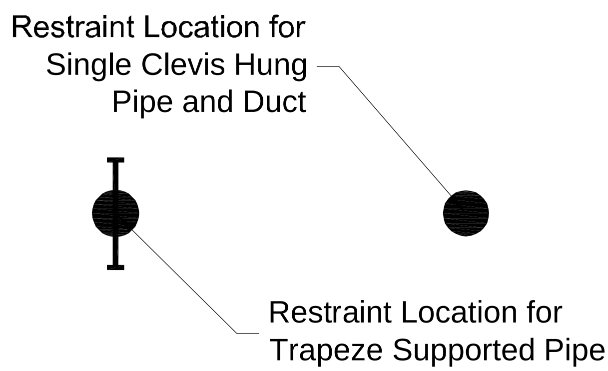

Figure I1-2; Kinetics Noise Control Restraint Location Symbols

The category of the restraint indicated for each location along with the restraint kit and the anchorage (structural attachment) hardware kit for the project's seismic conditions are shown by the symbol in Figure I1-3. The symbol at a location (**T**) indicates that the restraint is a transverse restraint, the symbol (**L**) indicates that the restraint is to be a longitudinal restraint, and symbol (**TL**) indicates that both transverse and longitudinal restraints are required for that location.

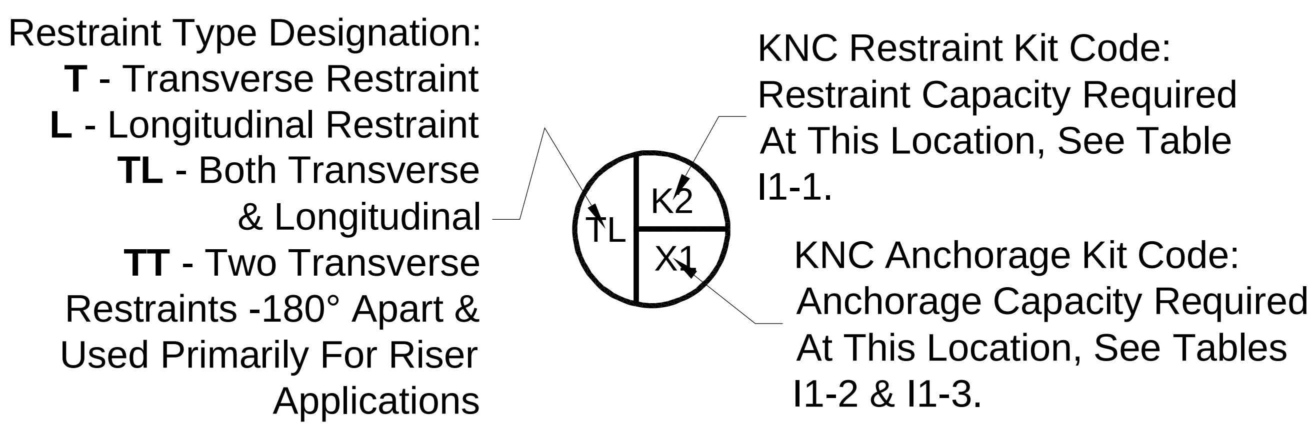

Figure I1-3; Kinetics Noise Control Restraint Kit and Anchorage Kit Symbol

The seismic restraint kits provided by Kinetics Noise Control along with the code designations used on the drawings provided by Kinetics Noise Control are shown in Table I1-1. Each kit contains enough components to make two complete seismic restraint cable assemblies. The brackets supplied with each kit may be used to make one seismic restraint strut assembly with the

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structural member being provided by others. Tables I1-2 and I1-3 list the code designations for the various anchorage kits provided by Kinetics Noise Control for anchorage to concrete/steel and wood/steel respectively. Each anchorage kit will contain enough hardware of the correct size and grade to attach the restraint kit to concrete, steel, or wood. For restraint cable kits the hardware is divided equally between the two cable assemblies. These same hardware kits may also be used with strut restraints that have the same capacity as the cable restraints for which the anchorage kit was recommended.

Table I1-1; Seismic Restraint Cable Kit vs. Code Cross-Reference

KNC Restraint Kit Code	Restraint Kit Description Note: Each kit contains enough components for (2) complete seismic restraint cable assemblies or (1) complete seismic restraint strut assembly with the structural member by others.
K2	KSCU-2 Cable Kit – 2 mm or 1/8″ Cable & Appropriate Connectors
K3	KSCU-3 Cable Kit – 3 mm or 1/8″ Cable & Appropriate Connectors
K4	KSCU-4 Cable Kit – 5 mm Cable 3/16″ & Appropriate Connectors
K5	KSCU-5 Cable Kit – 6 mm or 1/4″ Cable & Appropriate Connectors
C1	KSCC-250 Cable Kit – 1/4″ Cable & Saddle + U-bolt Connectors
C2	KSCC-375 Cable Kit – 3/8″ Cable & Saddle + U-bolt Connectors
C3	KSCC-500 Cable Kit – 1/2″ Cable & Saddle + U-bolt Connectors
F	Direct Mounted to Floor or Roof Using Anchor Bolts
W	Direct Mounted to Wall Using Anchor Bolts

I1.3 – Seismic Restraint Spacings:

This part will discuss the seismic restraint spacings typically used by Kinetics Noise Control. First, the following definitions will be helpful.

S_H = the pipe or duct hanger spacing.

S_L = the calculated spacing for the longitudinal seismic restraints marked as (**L**).

S_T = the calculated spacing transverse seismic restraints marked as (**T**).

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Table I1-2; Structural Concrete/Steel Anchorage Kit vs. Code Cross-Reference

KNC Attachment Kit Code	Anchorage Kit Description per Restraint Cable Kit Note: Through bolts & nuts of the same size may be used for each kit and code shown below.
X1	(2) 1/4″ Concrete Anchor (with Grommet)
X2	(2) 3/8″ Concrete Anchor (with Grommet)
X3	(2) 1/2″ Concrete Anchor
Y1	(2) 5/8″ Concrete Anchor
Y2	(2) 3/4″ Concrete Anchor
Y3	(2) 7/8″ Concrete Anchor
Z1	(4) 3/8″ Concrete Anchors with Oversized Base Plate
Z2	(8) 3/8″ Concrete Anchors with Oversized Base Plate
Z3	(4) 1/2″ Concrete Anchors with Oversized Base Plate
Z4	(8) 1/2″ Concrete Anchors with Oversized Base Plate

Table I1-3; Structural Wood/Steel Anchorage Kit vs. Code Cross-Reference

KNC Attachment Kit Code	Anchorage Kit Description per Restraint Cable Kit Note: Through bolts & nuts of the same size may be used for each kit and code shown below.
W1	(2) 1/4″ Lag Screw (with Grommet)
W2	(2) 3/8″ Lag Screw (with Grommet)
W3	(2) 1/2″ Lag Screw
W4	(2) 5/8″ Lag Screw
W5	(2) 3/4″ Lag Screw
W6	(2) 7/8″ Lag Screw
W7	(4) 3/8″ Lag Screws with Oversized Base Plate
W8	(8) 3/8″ Lag Screws with Oversized Base Plate
W9	(4) 1/2″ Lag Screws with Oversized Base Plate
W10	(8) 1/2″ Lag Screws with Oversized Base Plate

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As mentioned above, the seismic restraint locations must be at, or very near, the pipe or duct hangers. So, the actual seismic restraint spacing will be some multiple of the actual hanger spacing. The longitudinal seismic restraint spacing may be equal to the transverse seismic restraint spacing, or it may be twice the transverse seismic restraint spacing depending on the seismic conditions and the weight per foot of the pipe or duct that is being restrained. The seismic restraint industry has historically relied on the recommendations of SMACNA for specifying the proper seismic restraint spacings. Table I1-4 shows the typical seismic restraint spacings used by Kinetics Noise Control when creating the drawings showing the seismic restraints and their approximate locations for a run of pipe or duct.

Table I1-4; Typical Seismic Restraint Spacings Used by Kinetics Noise Control

Transverse Seismic Restraint Spacing S_T (ft.)	Longitudinal Seismic Restraint Spacing S_L (ft.)	Comments on Maximum Allowable Restraint Spacings
10	10	Maximum Allowable Spacings for Low Deformability (Brittle) Piping.
10	20	Other Optional Spacings Used to Extend the Useful Range of Application for Specific Restraints.
15	30	
20	40	Maximum Allowable Restraint Spacings for Hazardous Gas Piping.
30	60	Maximum Allowable Restraint Spacings for Ductwork.
40	80	Maximum Allowable Restraint Spacings for HVAC & Plumbing Piping.

Kinetics Noise Control makes every possible effort to ensure that their drawings are to the scale indicated, so the approximate restraint locations make be determined on the job site by scaling the drawing. The locations are approximate because the engineers at Kinetics Noise Control have no way of knowing the exact location of the hangers, other components, and structure not shown on the drawings provided to them. As long as the illustrated restraint spacings are not exceeded, the exact location of the restraints along the run of pipe or duct is not critical as long as the restraints coincide with a hanger. This means that in some instances (when restraint spacing is not an even

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multiple of the support spacing), one or two extra restraint kits may be required for a run of pipe or duct.

Many project specifications call for standard hanger spacings of 5 ft. or 10 ft. for all pipe and duct. These hanger spacings work very well with those recommended by SMACNA and Kinetics Noise Control. There are some instances where a different hanger spacing may be required or specified. If for instance the specified hanger spacing was 8 ft. and the transverse and longitudinal restraint spacing specified by Kinetics Noise Control was 20 ft. and 40 ft. respectively, the transverse restraint spacing for the project would be 16 ft. and the project longitudinal spacing would be 32 ft. For this case, extra restraint kits would be required for any pipe or duct runs where the hangers were spaced at 8 ft.

I1.4 – Examples of How Kinetics Noise Control Drawing Symbols are used:

For single clevis hung pipe, a typical run of pipe will be marked for seismic restraint and anchorage kits as shown in Figure I1-4. Notice that every location with a longitudinal seismic restraint will also have a transverse seismic restraint. This is true for virtually all cases of seismic restraint for pipe and duct. The two restraint callouts at the corner are for transverse seismic restraints. If these transverse seismic restraints can be located within 24 in. (2 ft.) of the corner, the transverse restraint in on one leg will serve as the longitudinal restraint on the other leg. Kinetics Noise Control will always assume that a hanger can be placed within 24 in. of the corner and mark the drawings accordingly. If these restraints can not be located close enough to the corner, additional kits may be required to provide restraint in the longitudinal direction for each leg. Note that in all cases the seismic restraint kits will all be K3, KCSU-3. These kits have 1/8″ or 3mm cables with connectors provided by Kinetics Noise Control. The anchorage kits will all be X2, 3/8 in. concrete anchors and 3/8-16 UNC bolts.

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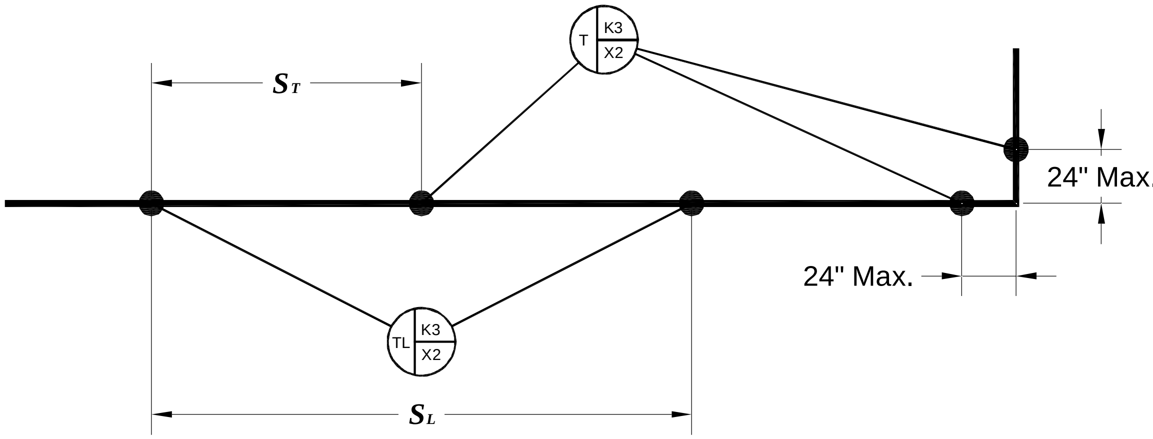

Figure I1-4; Typical Kinetics Noise Control Seismic Restraint Kit and Anchorage Kit, and Location Callouts for Single Clevis Hung Pipe

A typical run of trapeze supported pipe is shown with the approximate locations and callouts for the seismic restraint is shown below in Figure I1-5.

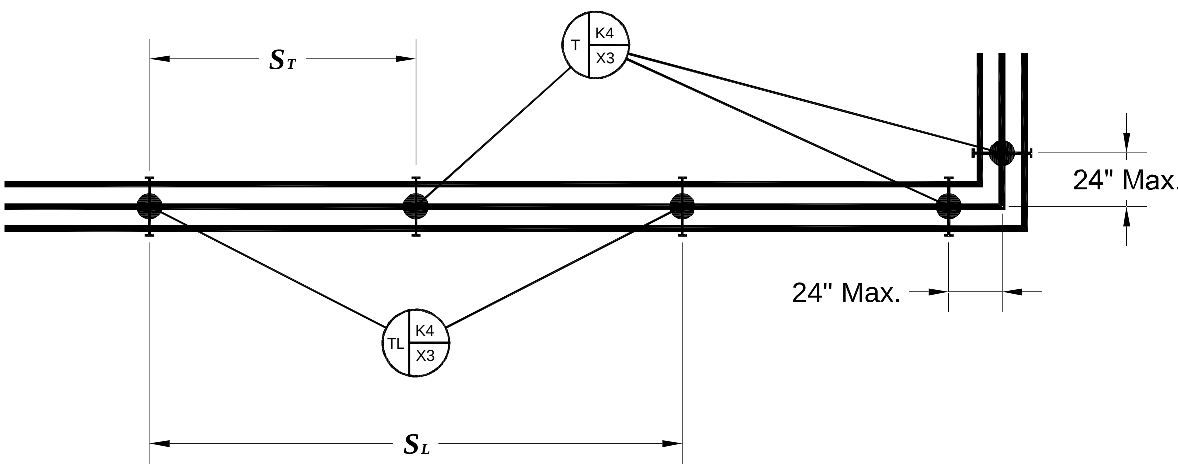

Figure I1-5; Typical Kinetics Noise Control Seismic Restraint Kit and Anchorage Kit, and Location Callouts for Trapeze Supported Pipe

The "**I**" bars indicate that these three pipes are assumed to be supported on the same set of trapeze bars. Unless otherwise instructed, Kinetics Noise Control assumes that runs of pipes that lie parallel and very close together are supported on the same set of trapeze bars. If the actual pipe runs are single clevis hung, more restraints will be required. Note that the restraint kits are

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K4, KSCU-4. These kits contain 5 mm or 3/16″cables and appropriate connectors. The anchorage kits are X3, 1/2 in. concrete anchors and 1/2-13 UNC bolts. The seismic restraint kits and anchorage kits have much higher capacities than the ones called out for the previous example in Figure I1-4. Assuming the two figures are of similar scale and that the pipe sizes are similar, this makes sense. The seismic restraint and anchorage requirements are based on the weight of the pipe or duct that is being restrained, and all other things being equal, three pipes will weight much more than one pipe of a similar size, and will require larger cable and anchors to keep them from swinging side-to-side, or back-and-forth.

For pipe runs supported by trapeze bars, the longitudinal restraints must be arranged to prevent the pipes from being twisted by the seismic forces. In some instances, an extra restraint kit may be required per longitudinal restraint location. This will be discussed further in the next section.

Figure I1-7 shows the seismic restraint callouts and approximate locations for a typical run of duct.

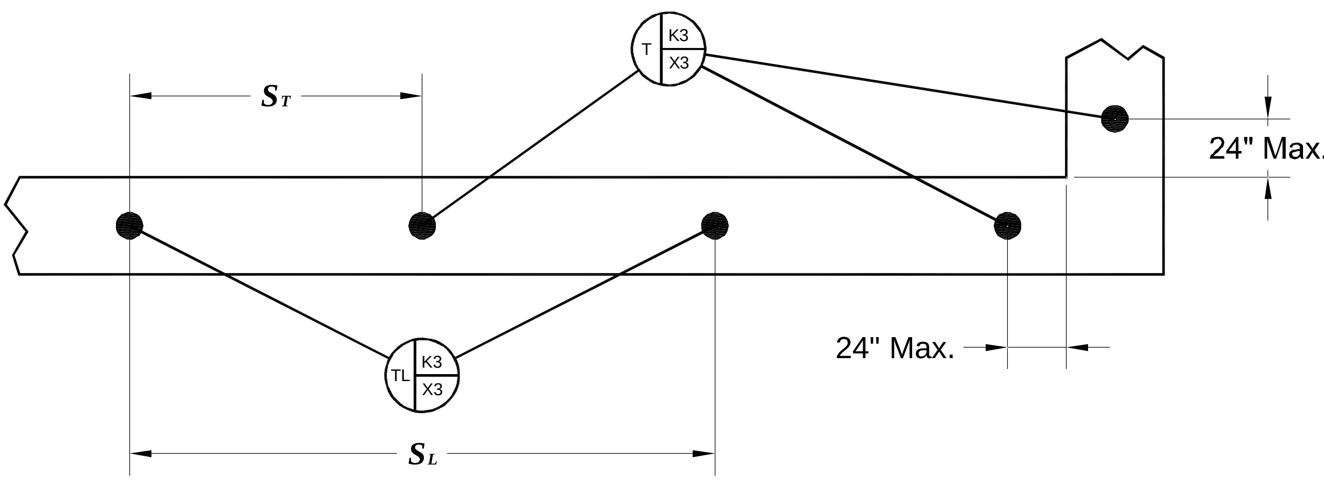

Figure I1-6; Typical Kinetics Noise Control Seismic Restraint Kit and Anchorage Kit, and Location Callouts for Duct

Rectangular duct is normally supported on some type of trapeze bar arrangement. As with the trapeze supported pipe runs, this may require some special arrangements and potentially extra

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cable kits per longitudinal restraint location to keep the duct from being twisted by the seismic forces. See the next part for a more complete discussion of this issue.

I1.5 – Typical Seismic Restraint Arrangements for Single Clevis Hung Pipe:

In this section the basic installation arrangements for pipe and duct will be discussed. This is by no means a complete treatment of the subject. There are many different arrangement for supporting and restraining pipe and duct, and whenever it appears that all of them have been covered a new situation develops that requires new and innovative ways for supporting and restraining the runs of pipe and duct. This section will show just the basic arrangements. More arrangements are shown in a set of drawings, SS-20070950 Sheets A through G, that are sent out with each order shipment of seismic restraint and anchorage kits. If the drawings are not part of the order shipment, or available from the authorized representative of Kinetics Noise Control, they are available directly from Kinetics Noise Control.

Figures I1-7 through I1-9 show single clevis hung pipes with transverse cable restraints. The installation shown in Figure I1-7 is typical for cable restraints. The recommended installation angle for the cable restraints is 45° when measured against the horizontal. Note that a clear distance on either side of the hanger rod approximately equal to the hanger rod length will be required to make the attachment to the roof or floor structure above. Also, between the pipe run attachment and the structural attachment, the cable restraint ***can not*** touch any other component or structure. In normal practice, the installation angle is allowed to vary down to 30° and up to a maximum of 60°. Figure I1-8 is a typical single clevis hung pipe with transverse seismic cable restraints that are installed at 30°. Note that twice as much space on either side of the hanger rod is required for seismic restraints with a 30° installation angle as those seismic restraints which have a 45° installation angle. Installation angles greater than 30° will require increasingly more clear room for installation; which is not normally available in most buildings.

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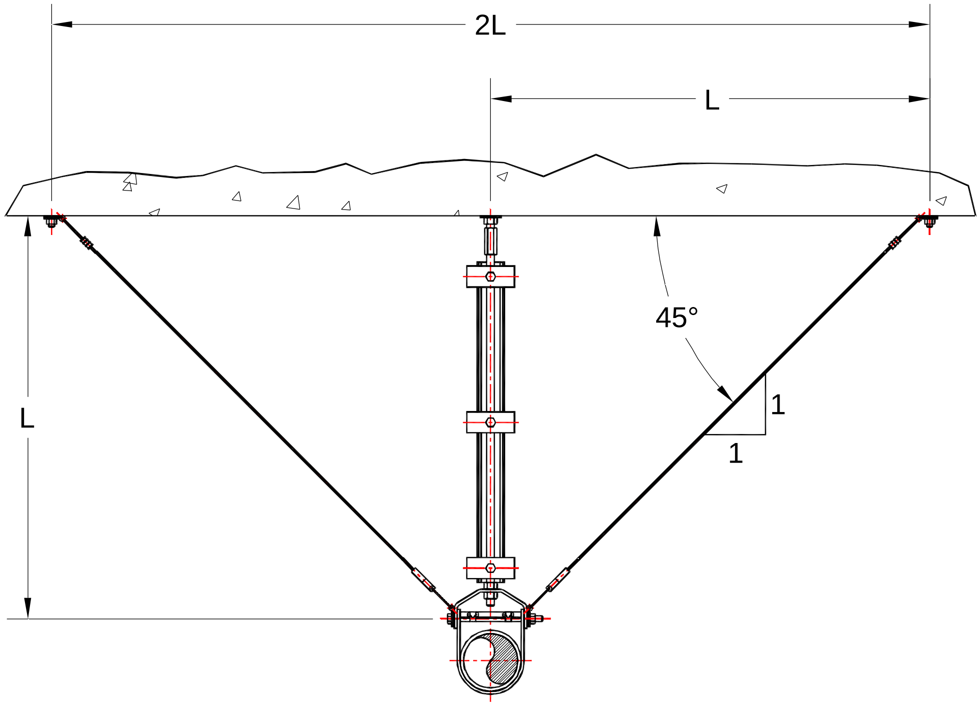

Figure I1-7; Single Clevis Hung Pipe with Typical Transverse Seismic Cable Restraints @ 45°

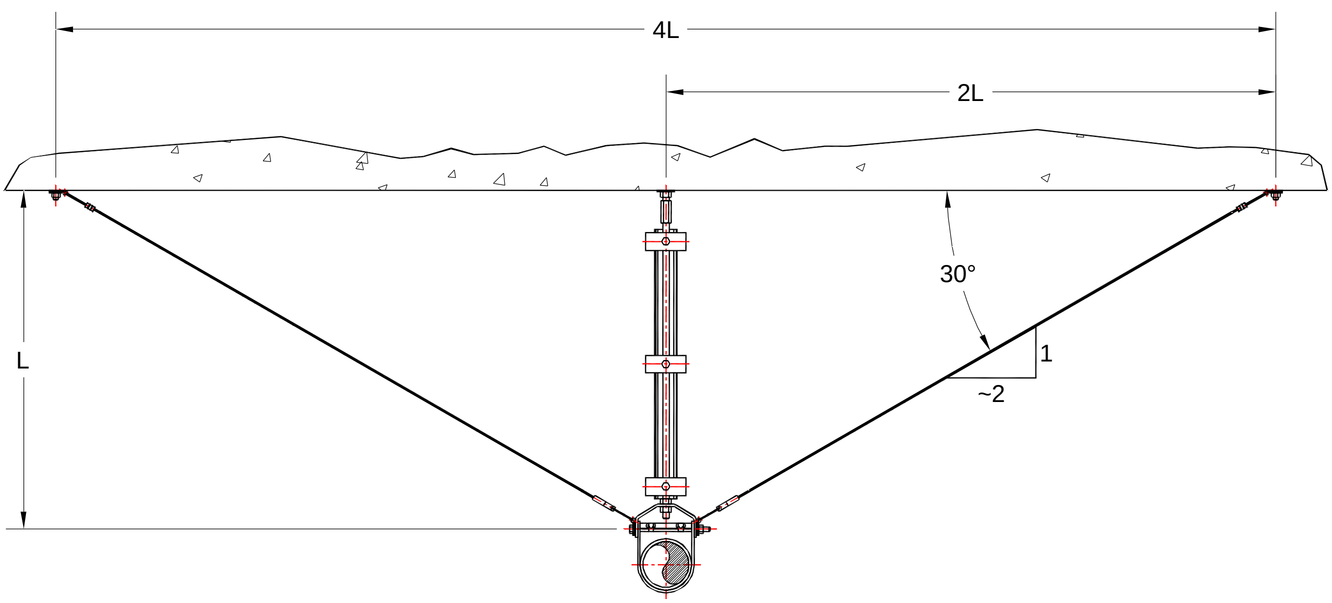

Figure I1-8; Single Clevis Hung Pipe with Typical Transverse Seismic Cable Restraints @ 30°

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Figure I1-9 is a typical single clevis hung pipe with transverse seismic cable restraints that are installed at 60°. Here, half as much space on either side of the hanger rod is required for seismic restraints with a 60° installation angle as those seismic restraints which have a 45° installation angle. No installation angles greater than 60° are permitted as there will be almost no restraint benefit from the cables; the pipe will simply swing side-to-side on the cables and hanger rod with little or no resistance.

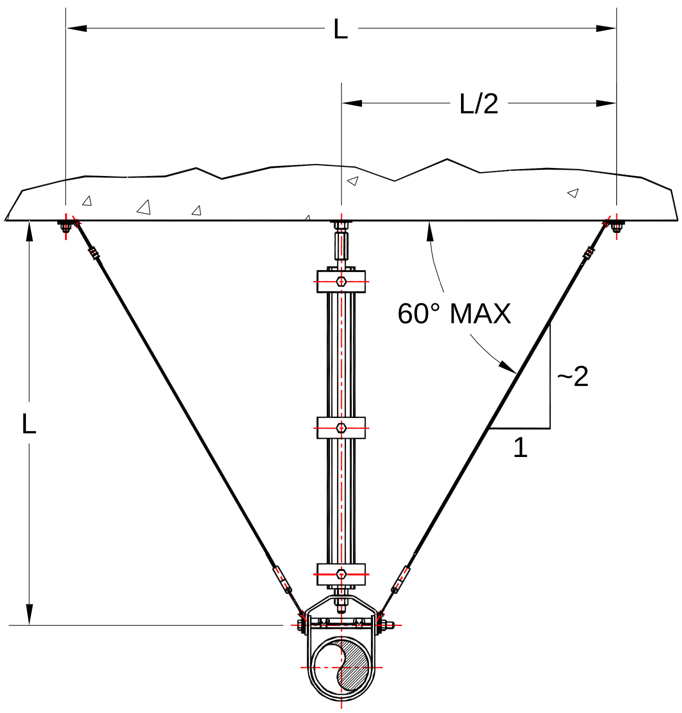

Figure I1-9; Single Clevis Hung Pipe with Typical Transverse Seismic Cable Restraints @ 60°

All three of the cases shown in Figures I1-7 through I1-9 assume that the structural anchorage will be made to the roof or floor structure above. The structural attachment may also be made to walls, beams, and or columns. These attachments will need to be approved by the structural engineer since the roof, floor, walls, columns, and beams were designed without knowledge of the exact placement of the seismic restraints. The use of strut restraints can cut the space required along side the pipe or duct for installing these restraints basically in half, which is probably their one big benefit.

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For single clevis hung pipe, the longitudinal restraints may be installed similar to that shown in Figure I1-10. A more detailed set of views for this arrangement is shown in Figure I1-11.

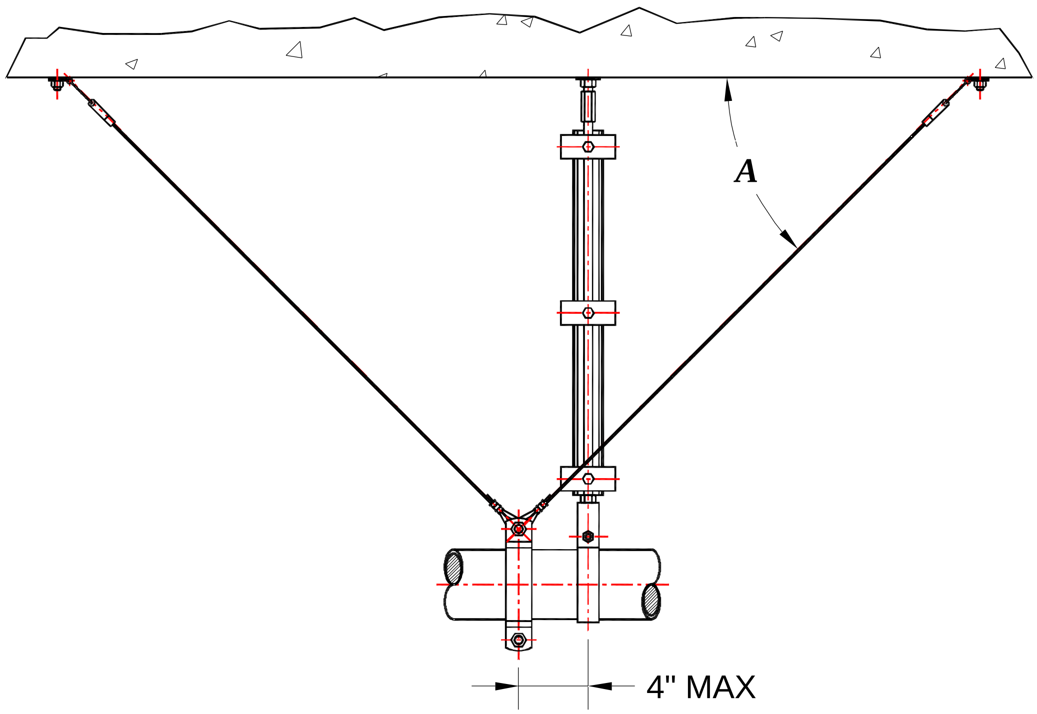

Figure I1-10; Single Clevis Hung Pipe with Typical Longitudinal Seismic Cable Restraints

These two figures show the longitudinal seismic restraints attached directly to the pipe with in 4 inches of the hanger location. The longitudinal restraints may also be attached to the clevis hanger, but some physical means to keep the pipe from sliding back-and-forth in the hanger must be used. Figure I1-11 shows that the pipe clamp is to be rotated slightly to allow the restraints to miss the hanger rod and any rod stiffener that may be in its path. Strut type longitudinal restraints may also be attached to the pipe with a pipe clamp. As with the transverse restraints, the installation angle may vary from 30° up to a maximum of 60°.

If the pipe is insulated it is good practice to clamp directly to the pipe and insulate over the clamp. Clamping seismic restraints to the pipe over the insulation could damage the insulation during installation, and will typically not remain secure during an earthquake.

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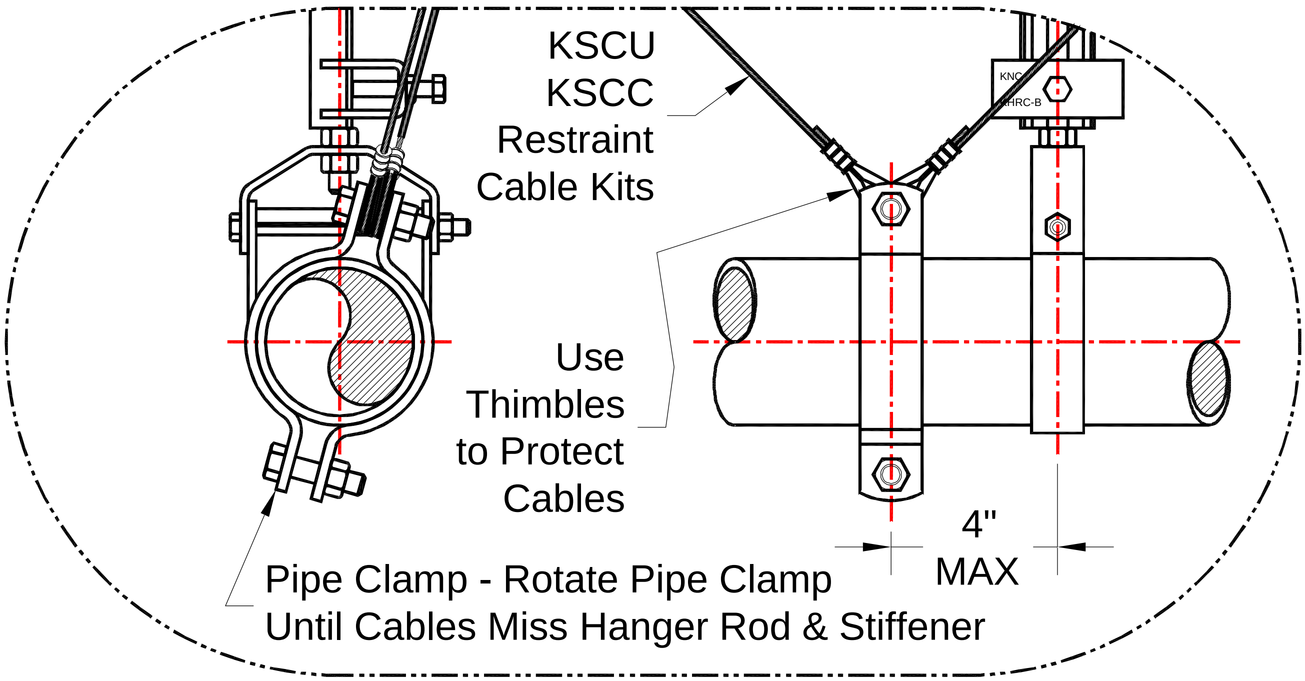

Figure I1-11; Typical Detail of Longitudinal Seismic Cable Restraints for Single Clevis Hung Pipe

I1.6 – Typical Seismic Restraint Arrangements for Trapeze Supported Pipe and Duct:

Typical transverse seismic restraint arrangements for trapeze supported pipe and duct are shown in Figures I1-12 and I1-13 respectively. Many more potential arrangements are shown in drawing SS-20070957 Sheets A1 and A2 provided by Kinetics Noise Control.

How the longitudinal restraints are applied to trapeze supported pipe and duct will determine whether additional restraints are required beyond those indicated in the Material Required List provided by Kinetics Noise Control. As much as practical Kinetics Noise Control design restraint installations that will require the fewest number of restraint kits. The longitudinal restraints for trapeze supported pipe and duct must be installed to balance the loads on the trapeze bar, and pipe or duct. This condition is best illustrated using plan views of the trapeze supported pipe and duct. Figures I1-14 and I1-15 show three plan views each for trapeze supported pipe and duct, respectively, with restraint locations requiring both transverse and longitudinal seismic restraints.

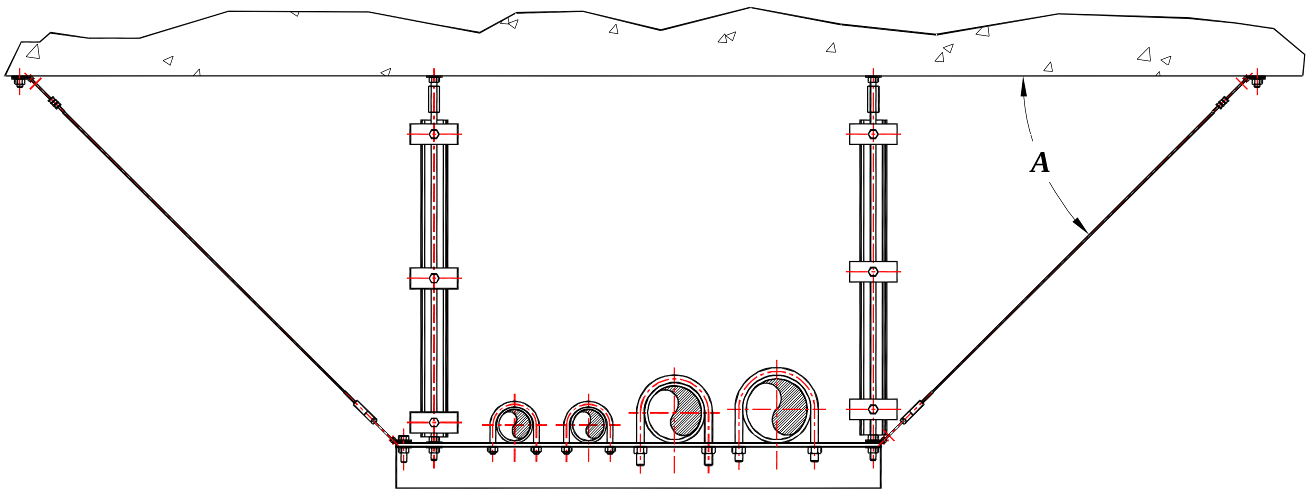

Figure I1-12; Typical Transverse Seismic Restraint Arrangement for Trapeze Supported Pipe

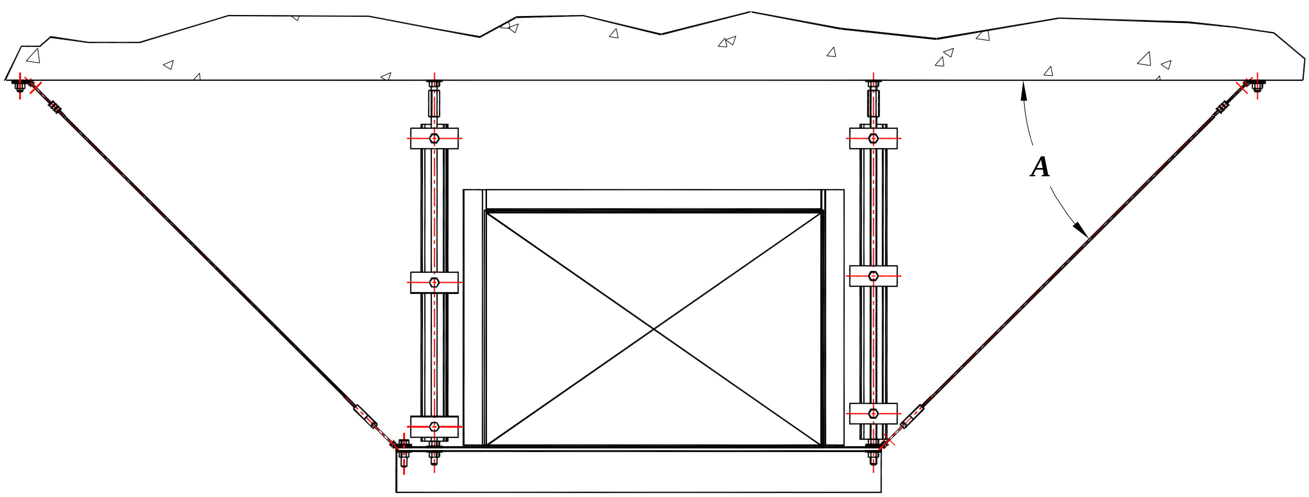

Figure I1-13; Typical Transverse Seismic Restraint Arrangement for Trapeze Supported Duct

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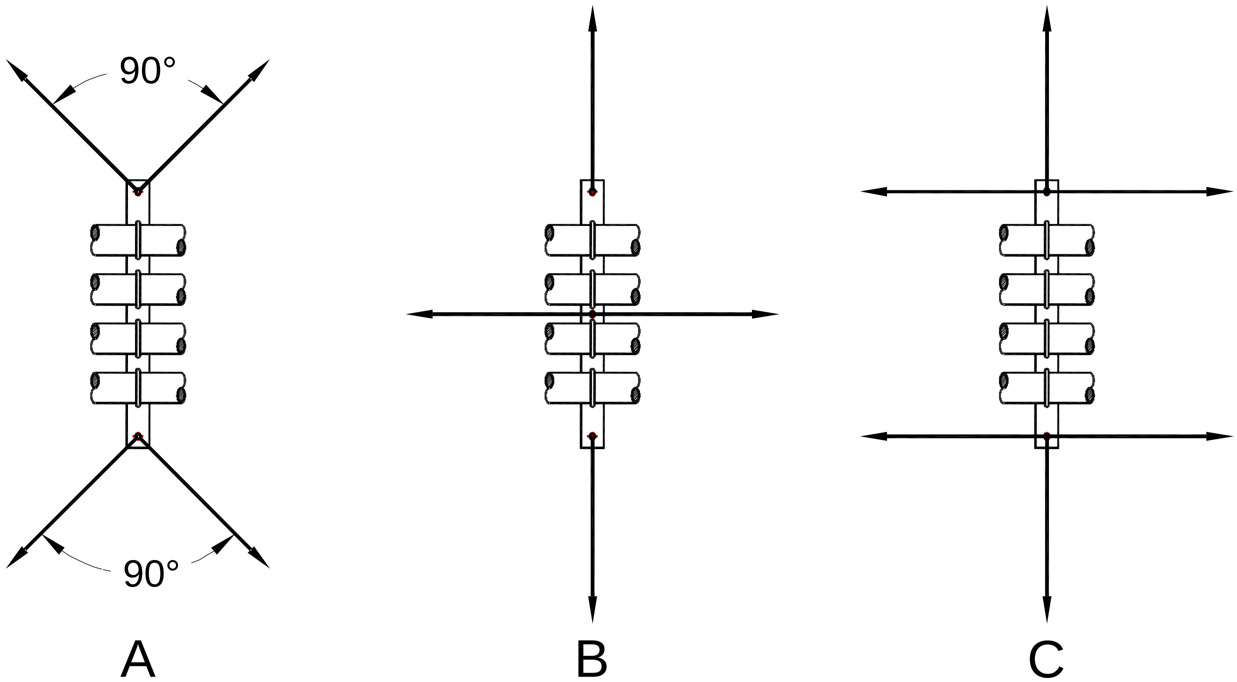

Figure I1-14; Balanced Longitudinal Seismic Restraints for Trapeze Supported Pipe

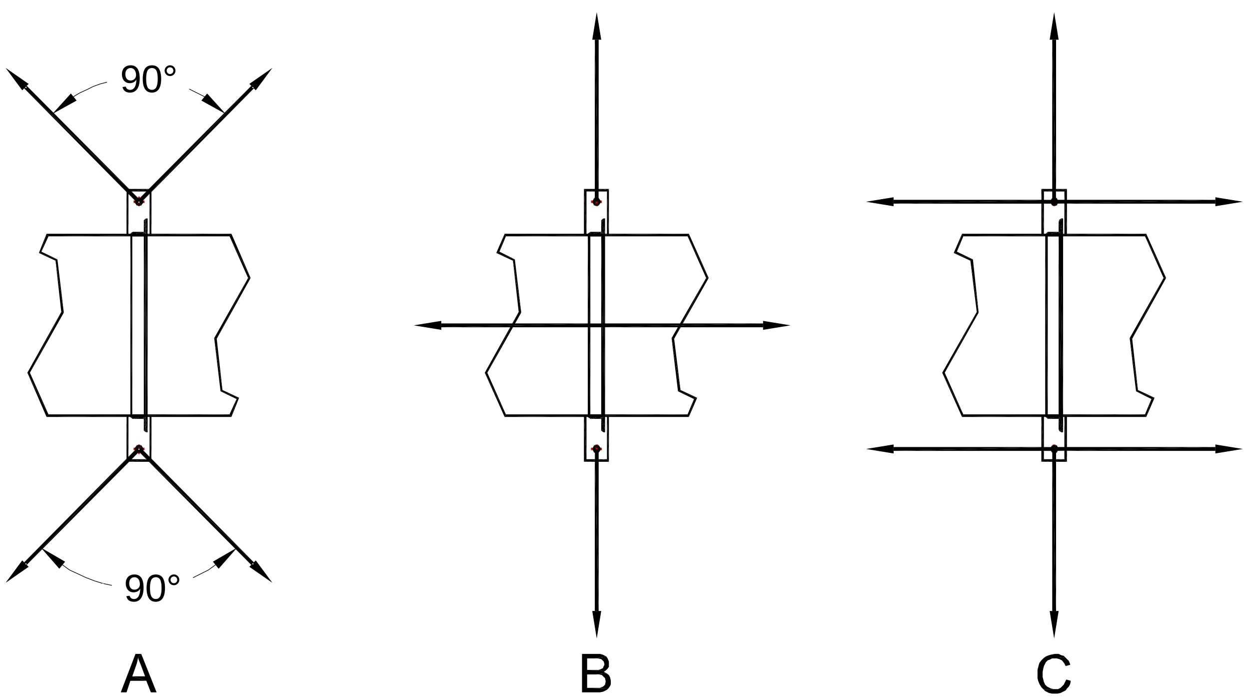

Figure I1-15; Balanced Longitudinal Seismic Restraints for Trapeze Supported Duct

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In Figures I1-14 A & B and Figures I1-15 A & B, the restraint of the trapeze supported pipe and duct may be made with the cable restraint kits which are normally called out and supplied by Kinetics Noise Control. If the installation issues require that arrangements such as the ones shown in Figures I1-14 C and I1-15 C be used, then an extra restraint and anchorage kit will be required for each such location.

I1.7 – Isolated Pipe & Duct:

All of the restraint schematics shown in this manual depict non-isolated pipe and duct. For isolated pipe and duct, the restraints are installed in the same fashion as they are detailed for non-isolated pipe and duct. However, there are special treatments for the isolation hangers that must be followed during the installation to ensure the seismic performance of the system. These treatments are detailed in Figure I1-16.

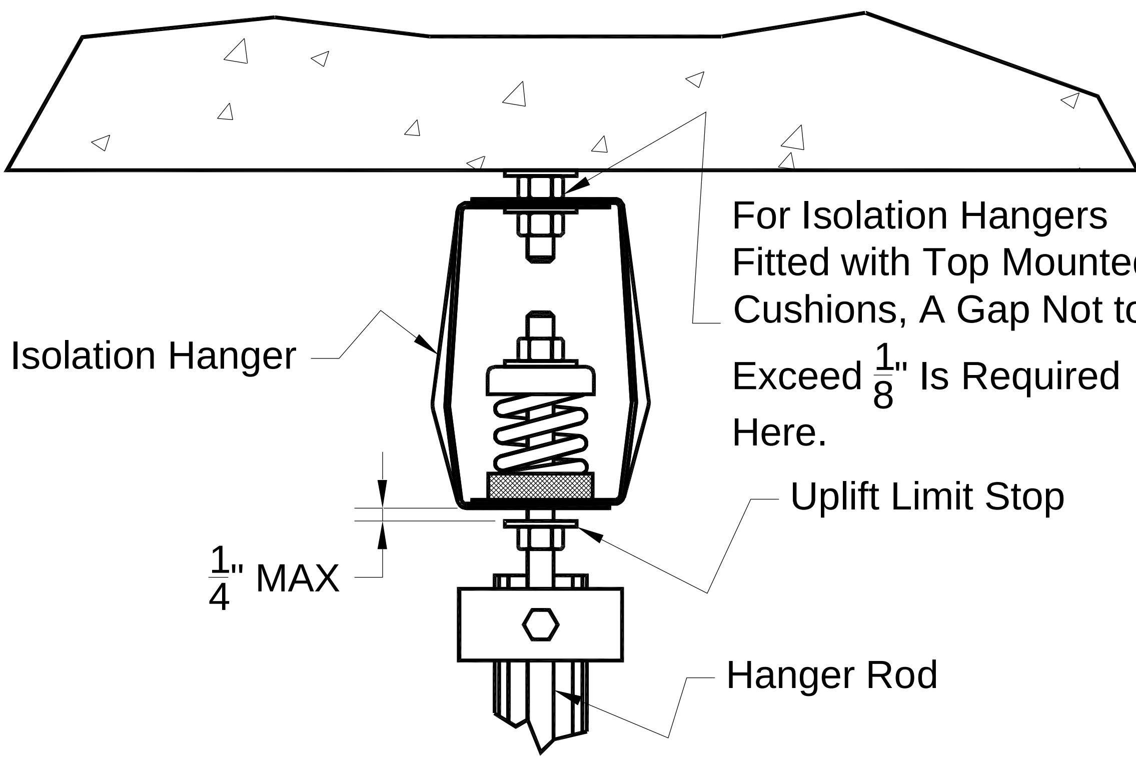

Figure I1-16; Treatments for Isolation Hangers at Seismic Restraint Locations

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The most important treatment from a seismic point of view, see Figure I1-16, is an uplift limit stop applied to the hanger rod just below the isolation hanger. Typically this consists of a nut and washer, as shown, which are adjusted to provide a gap not to exceed one quarter inch between the washer and the bottom of the isolation hanger. When top mounted cushions of neoprene or fiberglass are provided, a gap, not to exceed one eighth inch is required at the top of the isolation hanger. These treatments are valid for all isolated pipe and duct.

For isolated pipe and duct, it is good practice to use only cable type restraints. They provide flexibility and are not as likely to "short out" the isolation hangers. Strut type restraints provide a rigid load path in both tension and compression from the pipe or duct directly to the structure. This will for a continuous transmission path for sound and vibration to travel from the pipe or duct to the structure.

I1.8 – Important Things to Note and Remember:

1. There are two basic categories of seismic restraints.
    a. Transverse Seismic Restraints – perpendicular to the run of pipe or duct.
    b. Longitudinal Seismic Restraints – parallel to the run of pipe or duct.
2. There are two commonly used types of restraints.
    a. Strut Restraints (Rigid Braces) – carry both tension and compression loads along the length of the brace.
        i. ***One strut restraint*** is required at each transverse restraint and each longitudinal restraint.
        ii. Strut restraints ***will*** increase tensile loads in the hangers and anchors, and ***may exceed*** the allowable capacity of the hangers and anchors. Co-ordinate the use of strut restraints with the engineers of record.
        iii. Strut restraints will also create compressive loads in the hangers. Hangers at restraint locations must be capable of carrying compressive (buckling) loads, and may required hanger stiffeners.

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b. Cable Restraints (Tension Only Braces) – carry only tension loads along the length of the cable.

i. ***Two cable restraints*** 180° apart are required for each transverse restraint and each longitudinal restraint.

ii. Cable restraints load the hangers only in compression. The hangers at the restraint locations must be capable of carrying compressive load (buckling) loads and may require hanger stiffeners.

3. Seismic restraints must be located at or very near (within 4 inches) of the pipe and duct hanger locations to directly transfer the compressive reaction loads from the seismic forces to the structure of the building, rather than through the pipe and duct.
4. The recommended installation angle for seismic restraints is 45°, as measured from the horizontal.

a. The maximum allowable installation angle is 60°. Seismic restraints with installation angles greater than 60° will have little or no horizontal restraint capacity.

b. Normally the minimum allowable installation angle is 30°. This is primarily due to space considerations. Smaller installation angles may be used for special cases when required.

5. Anchorage of the seismic restraints to the building structure must be made at locations where the structure is strong enough to carry the seismic loads plus the normal working loads. Co-ordinate the locations and anchorage of all seismic restraints with the structural engineer of record and/or the architect.
6. The seismic restraints ***must not*** touch or interfere with any other component or structure between their attachment point on the pipe or duct run, and their anchorage point on the building structure.
7. Cable restraints and strut restraints ***can not*** be mixed on the same run of pipe or duct. They must all be cable restraints, or they must all be strut restraints.
8. ***For all*** restraint locations and directions, there ***must be*** a hard connection between the pipe or duct and the seismic restraint to prevent movement of the pipe or duct during an

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earthquake. Trapeze supported pipe and duct must be rigidly attached to the trapeze bar if the seismic restraints are attached to the hangers or trapeze bar.

9. For trapeze supported pipe and duct, the longitudinal seismic restraints ***must be*** balanced across the trapeze bar.
10. For isolated pipe and duct special treatments including uplift control are required. These treatments are detailed in Section I1.7.

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PROPER PRIOR PLANNING PREVENTS POOR PERFORMANCE

I2.1 – The Need for a Plan:

The need for seismic restraints on a run of pipe or duct will impact many trades and building design professionals. Typically, the first trade on a project will have little or no trouble installing their pipe or duct and the seismic restraints that may be required. They basically have all of the available space to work with. As the project progresses it becomes more and more difficult to install the various pipe and duct runs, and especially more difficult to install the required seismic restraints. Many times, the last contractor on the project is just plain out-of-luck. If there is enough space to install the pipe or duct, it may be impossible to install the seismic restraints. Heaven forbid that the first contractor on the project find out that seismic restraint will be required for their pipe or duct after everything is installed. They may not be able to even see their pipe or duct from the floor, much less be able to get to it to install the restraints.

So, a plan is needed by the MEP (Mechanical, Electrical, and Plumbing) coordinator for the scheduling of the trades so that the installation of the pipe and duct along with the seismic restraints will be more possible. Also, before each contractor begins the installation of their pipe or duct, they need to walk each run of pipe or duct and determine where the pipe or duct is to be installed relative to other components already in place, what type of seismic restraint will be required for each run, and where the anchorage for the seismic restraint to the building structure will be possible.

This section will provide the MEP coordinator and contractors with guidelines for planning the installation of the seismic restraints for the pipe and duct. These guidelines are in the form of a checklist. They are general and are by no means complete for every project. Since every project has its own special issues that must be dealt with, these guidelines may not address all conditions, but they should be a good start.

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I2.2 – What the MEP Coordinator Needs to Consider:

1. Determine which runs of pipe and duct will require seismic restraint, and which ones won't.
   a. For Seismic Design Categories A and B seismic restraint for pipe and duct is not required by the code.
   b. For Seismic Design Category C, if the pipe or duct has a Component Importance Factor of 1.0, seismic restraint is not required by the code.
   c. For all other cases there may be certain pipe and duct runs that fall under a code exemption or a local jurisdictional exemption. A detailed breakdown of other code based exemptions can be found in Section S-4.0 of the manual.
2. Assume that seismic restraint will be required for the project, there may be instances where a run of pipe or duct that would normally be exempt from the need for restraints would need to be restrained because of its close proximity to equipment or other runs of pipe or duct that do require seismic restraint. A run of pipe or duct that would normally be exempt from seismic restraint will require seismic restraints if;
   a. If it can swing back and for and impact and damage a critical piece of equipment or run of pipe or duct that is seismically restrained.
   b. If a run of pipe or duct that has a Component Importance Factor of 1.0 is installed above a run of pipe or duct that has a component Importance Factor of 1.5, then it must be seismically restrained as thought it had a Component Importance Factor of 1.5.
3. When coordinating between different MEP professionals and trades, give careful consideration to the following.
   a. Position pipe and duct in elevation to allow seismic restraints of adjacent pipe, duct and components to be placed without interference.
   b. Position suspended equipment so that seismic restraints do not interfere with adjacent pieces of equipment, pipe, and duct.
   c. Seismic restraints must be attached directly to building structure that has sufficient capacity to resist the expected seismic loads plus the design service loads.

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d. Equipment in-line with the ductwork may be restrained as part of the ductwork if the following are true.
   i. The in-line equipment weighs 75 lbs, or less.
   ii. At least one end of the in-line equipment is rigidly attached to the duct.
   iii. Piping or other services attached to the in-line equipment are done so with connections that can allow any relative motion to occur without damage.

e. ***Exception* to "d." for duct in buildings assigned to Seismic Design Categories D, E, and F, with a Component Importance Factor equal to 1.0, a cross-sectional area less than 6 ft^2 and in-line equipment weighing more than 20 lbs: *Any restraint exemption that is applicable to the duct is NOT applicable to the in-line equipment which must still be individually restrained!***

4. The following issues must be considered when anchoring the seismic restraints to the building structure.
   a. Component attachments must be connected to the building structure by bolting, welding, or other positive attachment means. The frictional resistance due to the dead weight of the component may not be considered as part of the attachment means.
   b. Post installed concrete anchors should be prequalified in accordance with ACI 355.2. The post installed anchors should have an ICC-ES Report issued for them stating that they are for use with the code that is in force, and in the proper Seismic Design Category.
   c. Power actuated fasteners, such as powder shot pins, may not be used for tension loadings in Seismic Design Categories D, E, or F, unless approved by the code official, Authority having jurisdiction, for those applications.
   d. Friction clips are not permitted for seismic anchorage attachment.
   e. Beam clamps that are used for seismic anchorage attachments must be equipped with retaining straps, also know as retainer straps or safety straps capable of resisting the expected seismic loads.

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I2.3 – What the Contractor Needs to Consider:

By the time the contractor has the final set of plans for the piping and ductwork, the following issues should be decided.

1. The runs of pipe and duct that require seismic restraint.
2. The approximate restraint locations and types, either longitudinal, transverse, or both.
3. The restraint capacity required at each location, and a possible anchorage to the building structure.

Before the pipe or duct is installed, the contractor should walk the run to see if there are any locations where a strut restraint will be required in place of a set of cable restraints. This decision will set the type of restraint for rest of the run. Some of the things that will require the use of strut over cable restraints are;

1. Other pipe or duct runs in the path of one of the restraint cables.
2. Suspended equipment in the path of one of the restraint cables.
3. No competent structure for the attachment of one of the restraint cables to the building.

It is absolutely imperative that seismic restraint cables ***do not*** come in to contact with any other pipe, duct, piece of equipment, or structural component in the path between the component being restrained and the attachment point on the building structure. This is because any seismic activity would place tremendous forces on the component that the seismic restraint cable had been wrapped around, potentially damaging it or the restraint.

2006 IBC requires that there be a clear and well defined load path from the pipe or duct being restrained to the building structure. In general, it is not acceptable to attach seismic restraints to stud walls unless the installation has been approved by the architect and/or structural engineer of record. Some of the stud walls may be load bearing and not have enough extra capacity to handle

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the design seismic loads from a run of pipe or duct. Other stud walls may be non-load bearing walls and not be adequately attached to the load bearing portion of the structure at the top of the wall, and thus not be capable of carrying large loads perpendicular to the wall.

It may be a good idea to install the seismic restraints as the run of pipe or duct is being installed to be sure that the seismic restraints can be placed in the locations that were planned, and that the types of restraints planned for are used. On some jobs, if the contractor waits until the entire pipe or duct run is up to install the restraints, other components may be in the path of the planned restraints, or the building structure may be completely inaccessible.

I2.4 – Final Word on the Use of Strut Type Restraints:

In general the use of strut type restraints over cable type restraints will call for a decrease in the restraint spacing and/or an increase in hanger rod size and hanger rod anchor capacity. Be aware that, if a previously installed run of pipe or duct is being fitted with seismic restraints, and some of the restraint locations require the use of struts rather than cables, all of the existing restraints will need to be changed out to struts and the hanger rod and anchors most likely will need to be increased in size and capacity. Therefore, it is very important to plan ahead to avoid costly surprises.

I2.5 – Summary:

Proper prior planning will indeed lead to the best possible outcome for any project. This planning must be done, not only by the contractor and MEP coordinator, but also by all of the design professionals responsible for the pipe, duct and structure.

It is the close co-ordination of all disciplines and trades that will lead to a smoother execution of a building design. This planning co-ordination is implied in the code, and must be driven from the top down by the building owner and architect.

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CABLE RESTRAINT SCHEMATICS FOR PIPING

I3.1 – Introduction:

This section will present several basic schematics for the seismic cable restraints for single clevis supported pipe. The figures and descriptions in this section will be based on the Kinetics Noise Control drawing SS-20070950 titled Cable Restraint Schematics for Piping – Sheet A. There are several drawings in this specific series. They have been designed to aid the installing contractor with the installation of seismic cable restraints for pipe and duct. Each drawing has a number designation ranging from SS-20070950 through SS-20070959. Also each drawing is also identified by a particular letter designation ranging from Sheet A though Sheet H. Each of the drawings in this series has several views on each sheet designated by a specific letter. Where the figures in this section correspond with those views on the Kinetics Noise Control drawings SS-20070950 through SS-20070959 they will be cross referenced by sheet letter and figure letter, for instance Sheet A – View D.

The schematics in this section are intended to be a quick guide for planning and inspection purposes. The details on making structural connections and pipe attachments for the seismic restraint cables and components are covered in Sections I5.0 and I6.0 respectively. Hanger rod stiffeners may be required at some seismic restraint locations to prevent buckling of the hanger rod when the combination of seismic uplift loads and the reaction forces to the horizontal seismic loads generated at the restraint locations exceed the weight load. They are not addressed in this section, but are covered in Section I8.0. Also, piping supported on isolation hangers is not shown in this document. The seismic restraint schematics and attachments for isolated and non-isolated pipe are identical. However, the isolation hangers must receive special treatments that are described in Section I1.7 of this manual.

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I3.2 – Transverse (T) Cable Restraint Schematics for Clevis Supported Pipe:

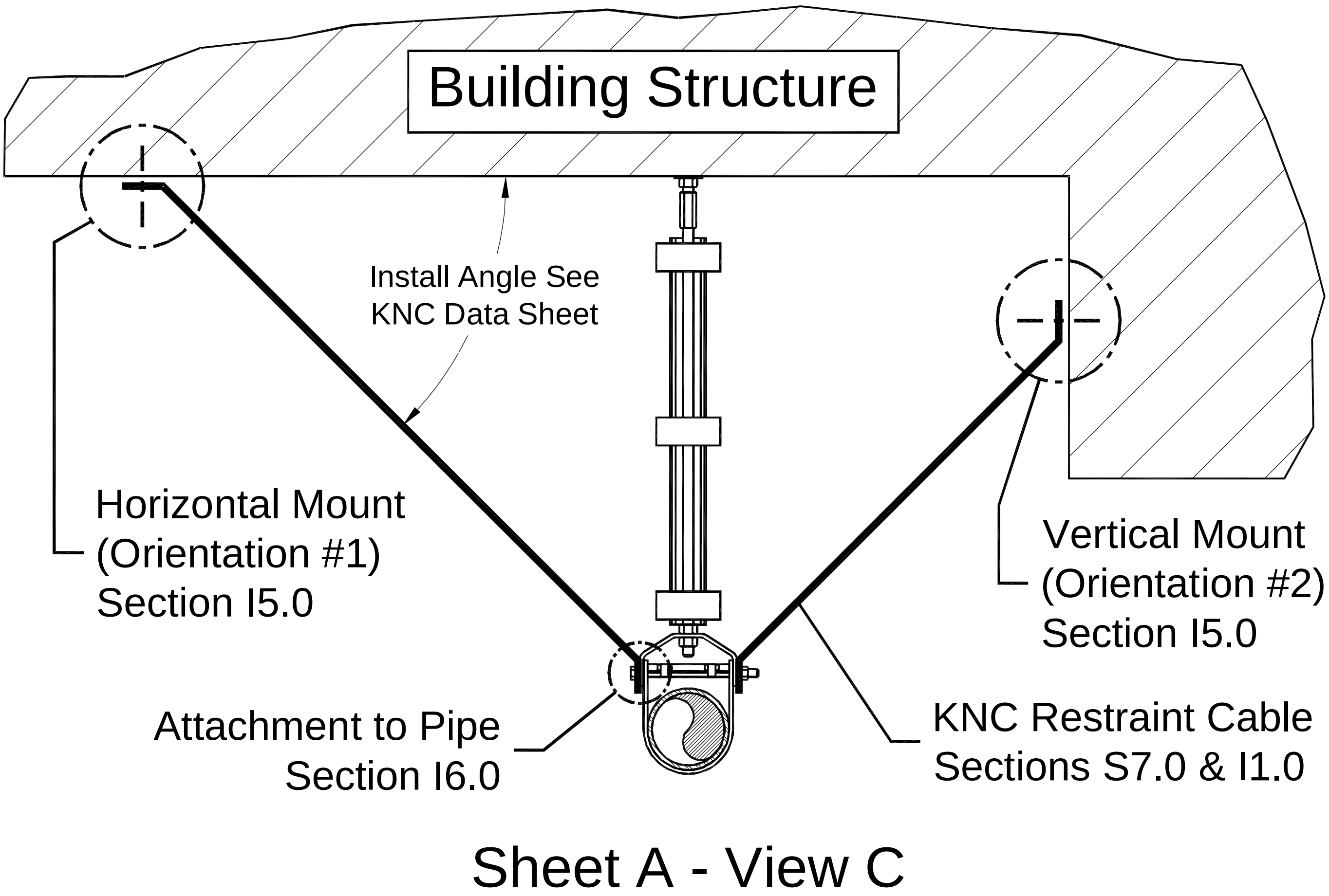

Figure I3-1; Transverse (T) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached to Clevis Hanger

The type of clevis hanger that is represented in Figure I3-1 is a standard adjustable clevis hanger that is typified by the MSS Type-1 detail. This type of hanger is shown in a little more detail in Figure I3-9. This schematic arrangement may also be applied to an adjustable roller hanger MSS Type-43, which is pictured in more detail in Figure I3-10.

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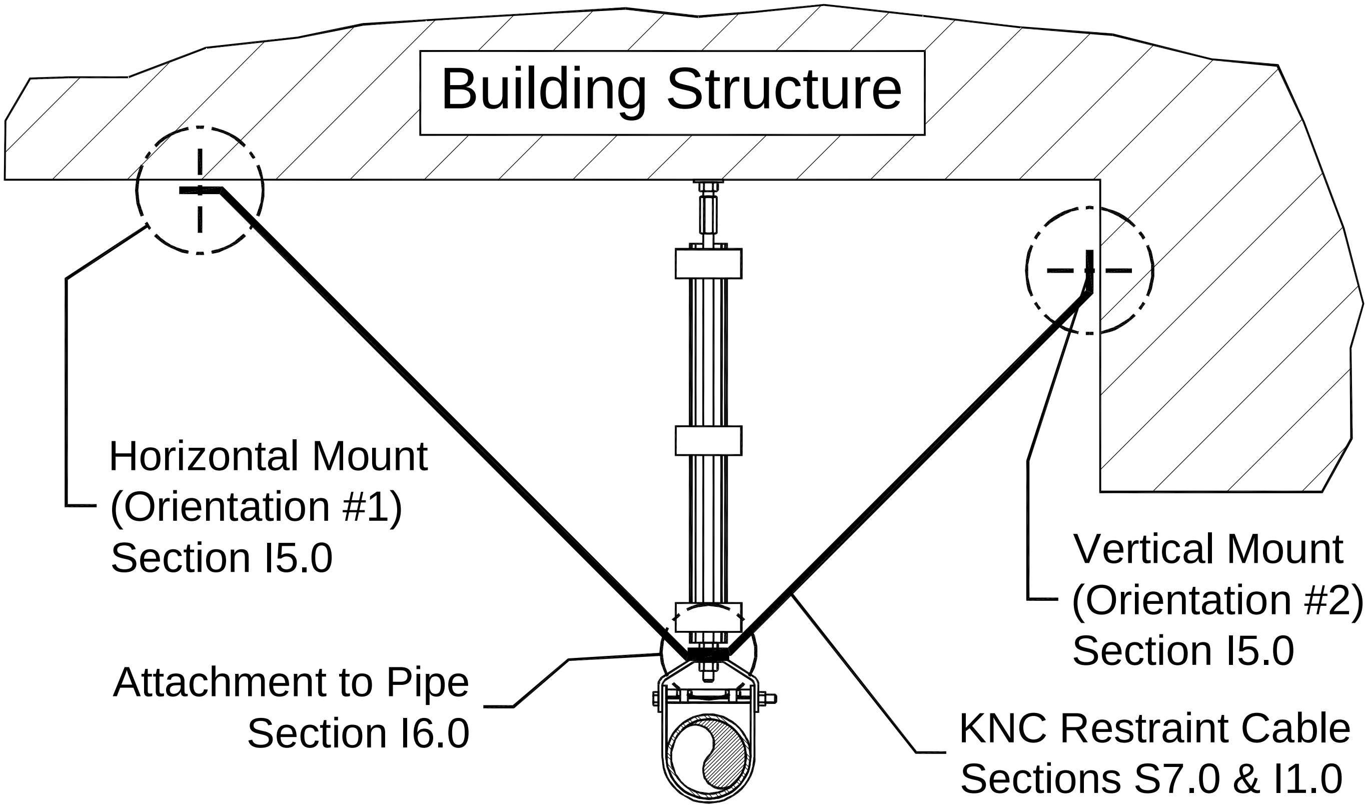

Figure I3-2; Transverse (T) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached to Hanger Rod Immediately Above Clevis Hanger

Occasionally, it makes sense to have the transverse seismic restraints attached to the hanger rod immediately above the clevis hanger. Sometimes there can be access or clearance issues with the clevis hanger. Sometimes the seismic restraints are being retrofitted to piping that is already in place. The Kinetics Noise Control Model KSCA brackets will allow seismic restraints to be retrofit to the hanger rods of clevis supported and trapeze supported pipe. The KSCA brackets must be attached tightly to the rod and tight against the top nut on the clevis hanger or the trapeze support hanger as shown in Section I6.3 of this manual, to prevent bending of the hanger rod.

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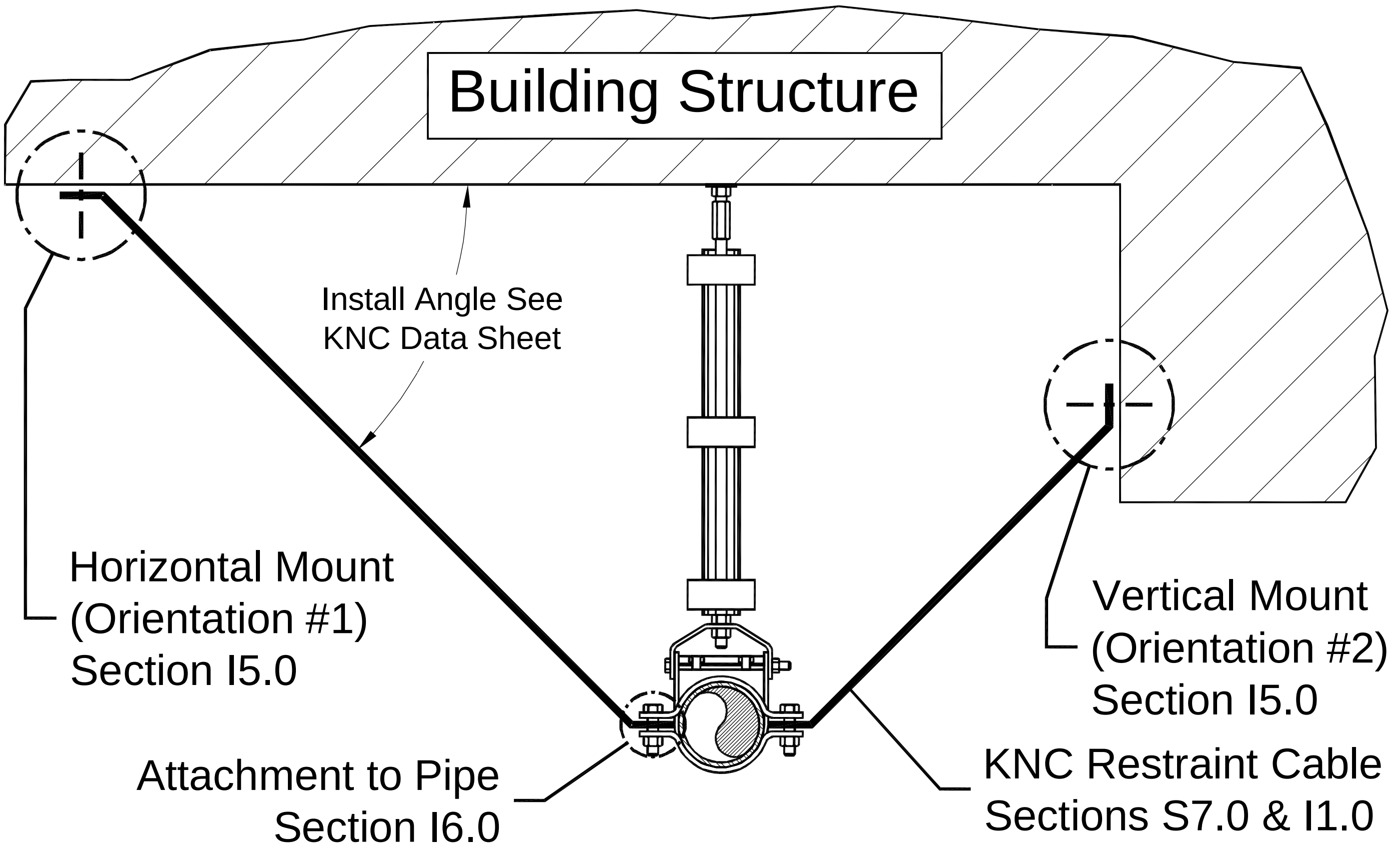

Figure I3-3; Transverse (T) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached to a Pipe Riser Clamp Immediately Adjacent to the Clevis Hanger

For non-insulated pipe, this makes a convenient way to retrofit seismic restraints to piping that is already in place. The clevis hanger and hanger rod are not disturbed by the installation of the seismic restraints. Except in cases where the hanger rods may need to be reinforced with rod stiffeners to resist the seismic uplift forces.

The NFPA requires that the seismic restraints for fire protection piping systems be attached directly to the pipe itself. The pipe riser clamp provides an excellent means of making that attachment to steel pipe.

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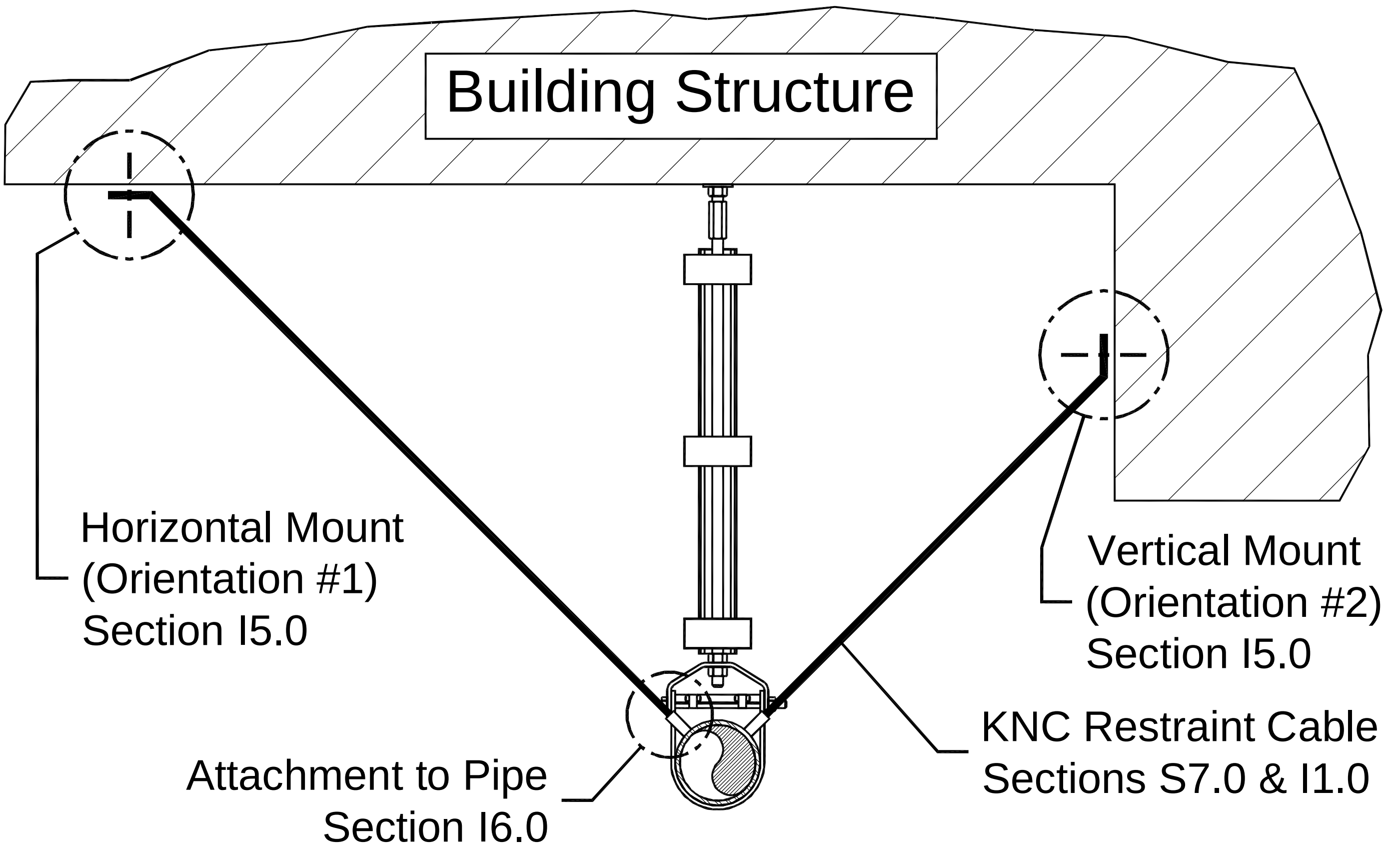

Figure I3-4; Transverse (T) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached Weld to Tabs Immediately Adjacent to the Clevis Hanger

Weld tabs provide a secure means of attaching the seismic restraints to the pipe, especially in high seismic areas where the piping engineer will not allow attachment to the clevis hanger or hanger rod.

The use of weld tabs must be planned for before the pipe is installed and filled. Otherwise, obtaining good welds is nearly impossible due to the heat dissipating properties of the fluid, and the potential orientation of the weld.

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I3.3 – Longitudinal (L) Cable Restraint Schematics for Clevis Supported Pipe:

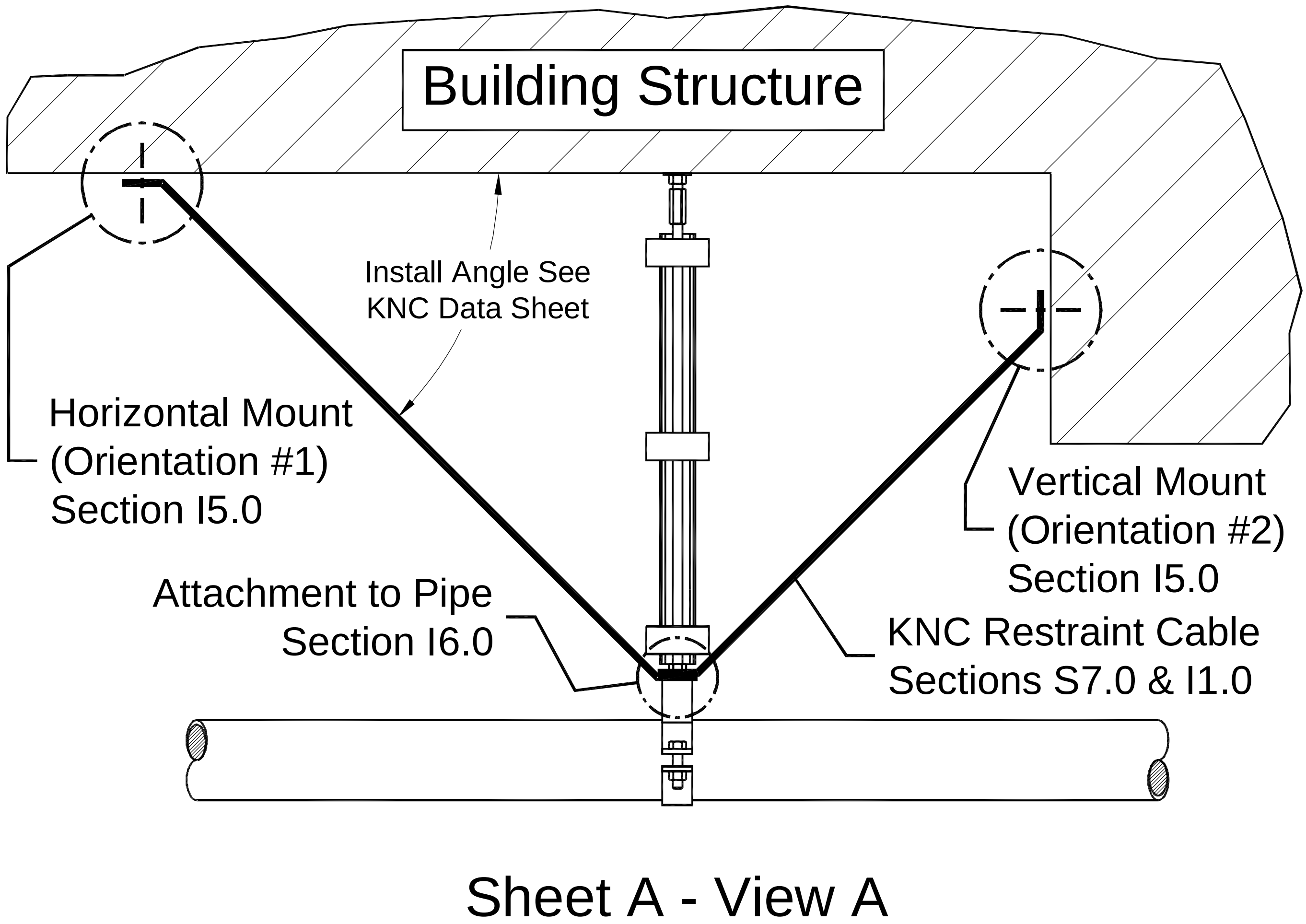

Figure I3-5; Longitudinal (L) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached to a Clamp Type Clevis Hanger

In order for longitudinal seismic restraints to be attached to the clevis hanger or the hanger rod directly above the clevis hanger, the clevis hanger itself ***must*** be a clamping type hanger that firmly secures the pipe in order to transfer the seismic loads from the pipe to the restraints. These are commercially available, but are ***not*** provided by Kinetics Noise Control as part of the standard restraint package..

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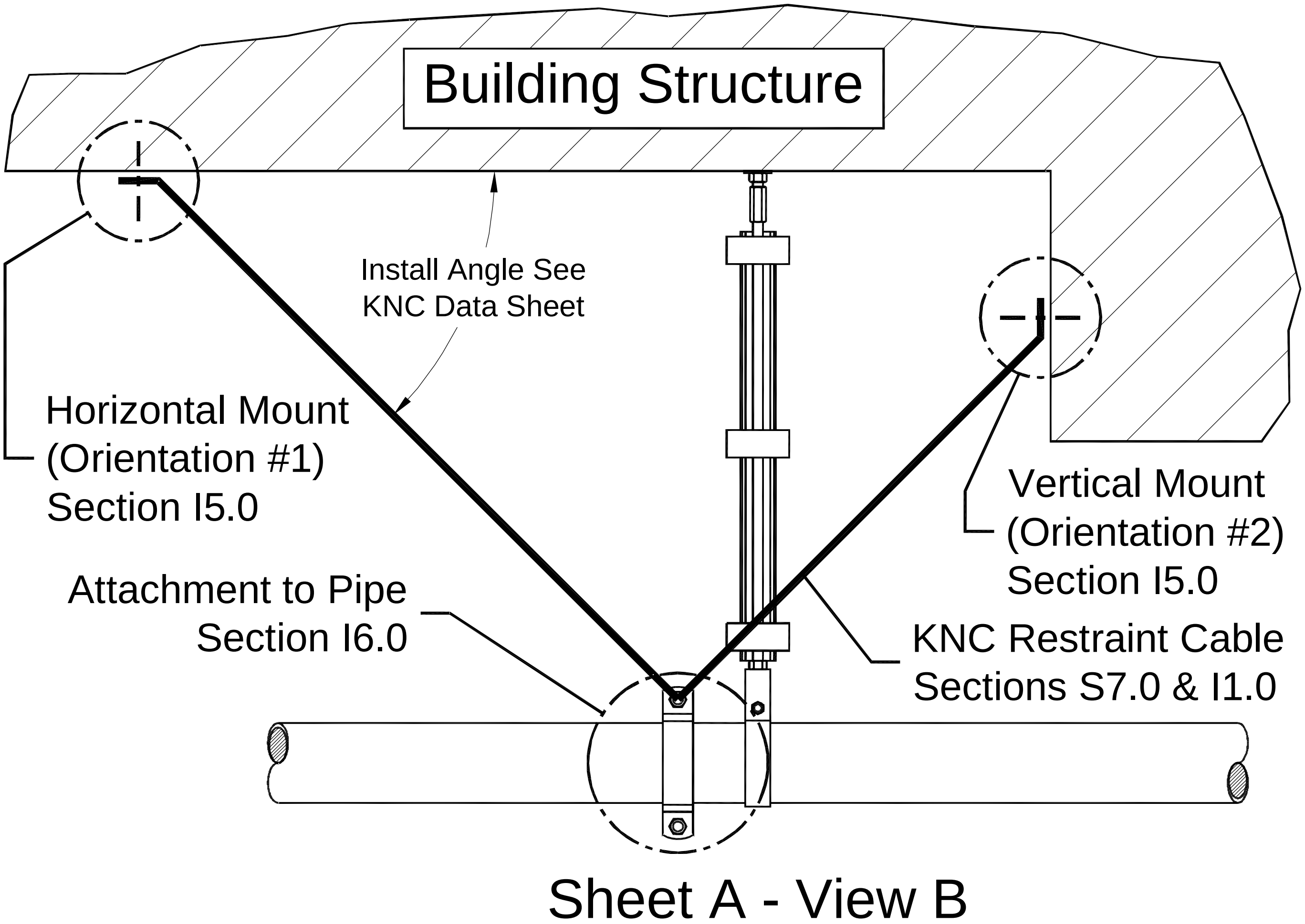

Figure I3-6; Longitudinal (L) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached to a Pipe Riser Clamp Immediately Adjacent to the Clevis Hanger

For this type of installation, a commercially available pipe riser clamp is used to secure the cable restraints to the pipe. The clamp may be rotated slightly to allow the one cable to clear the hanger rod and rod stiffener and clamps, if required. Note that the restraint cables ***must not*** touch the hanger rod, rod stiffener, or the rod stiffener clamps. This could lead to a dangerous overload condition for the hanger rod or damage to the cable during an earthquake.

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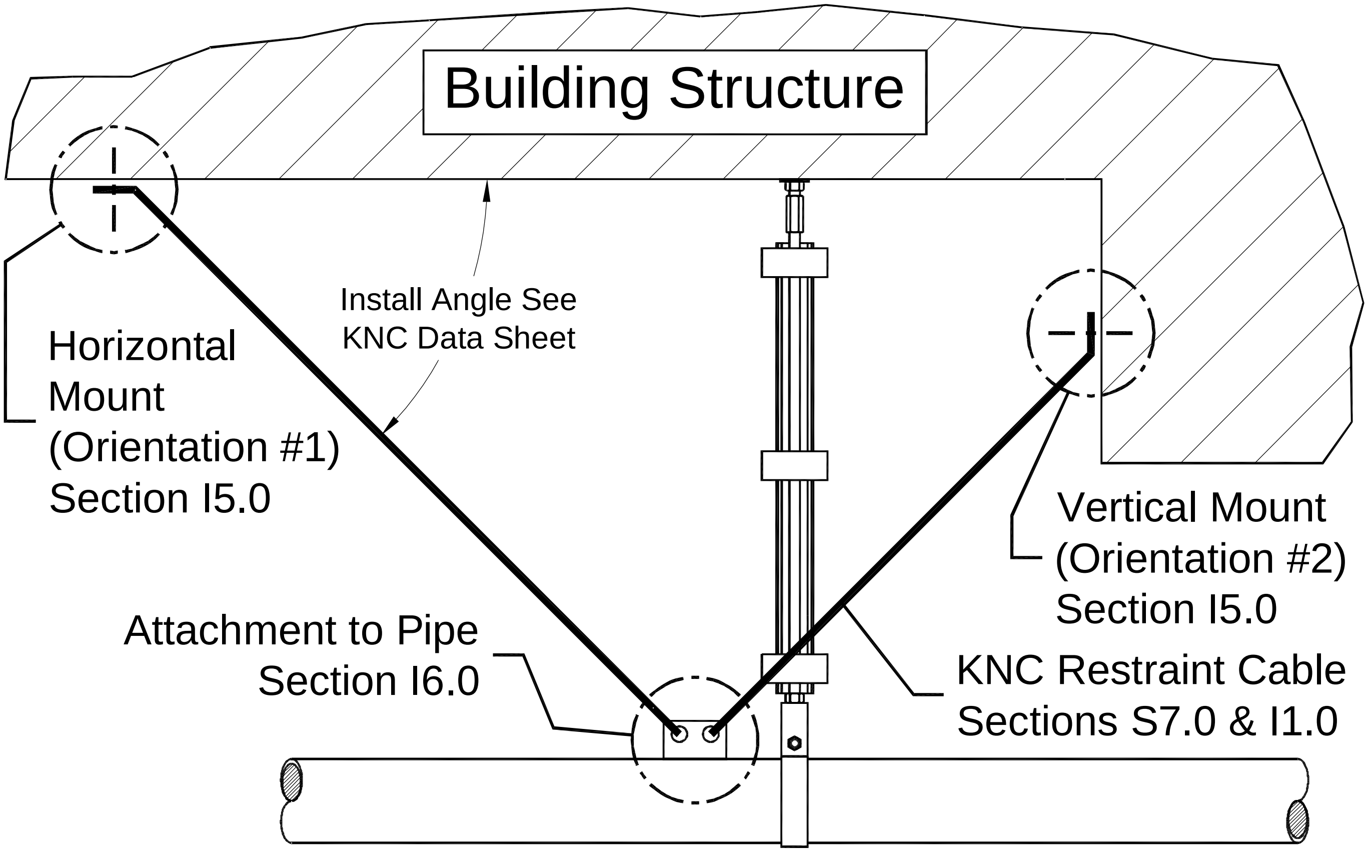

Figure I3-7; Longitudinal (L) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached to Weld Tabs Immediately Adjacent to the Clevis Hanger

As for the transverse restraints, weld tabs provide a secure means of attaching the seismic restraints to the pipe, especially in high seismic areas. The use of weld tabs must be planned for before the pipe is installed and filled. Otherwise, obtaining good welds is nearly impossible due to the heat dissipating properties of the fluid, and the potential orientation of the weld. As with the riser clamps, the restraint cables ***must not*** touch the hanger rod, rod stiffener, or the rod stiffener clamps. This could lead to a dangerous overload condition for the hanger rod or damage the cable during an earthquake.

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I3.4 – Combined Transverse & Longitudinal (TL) Cable Restraint Schematics for Clevis Supported Pipe:

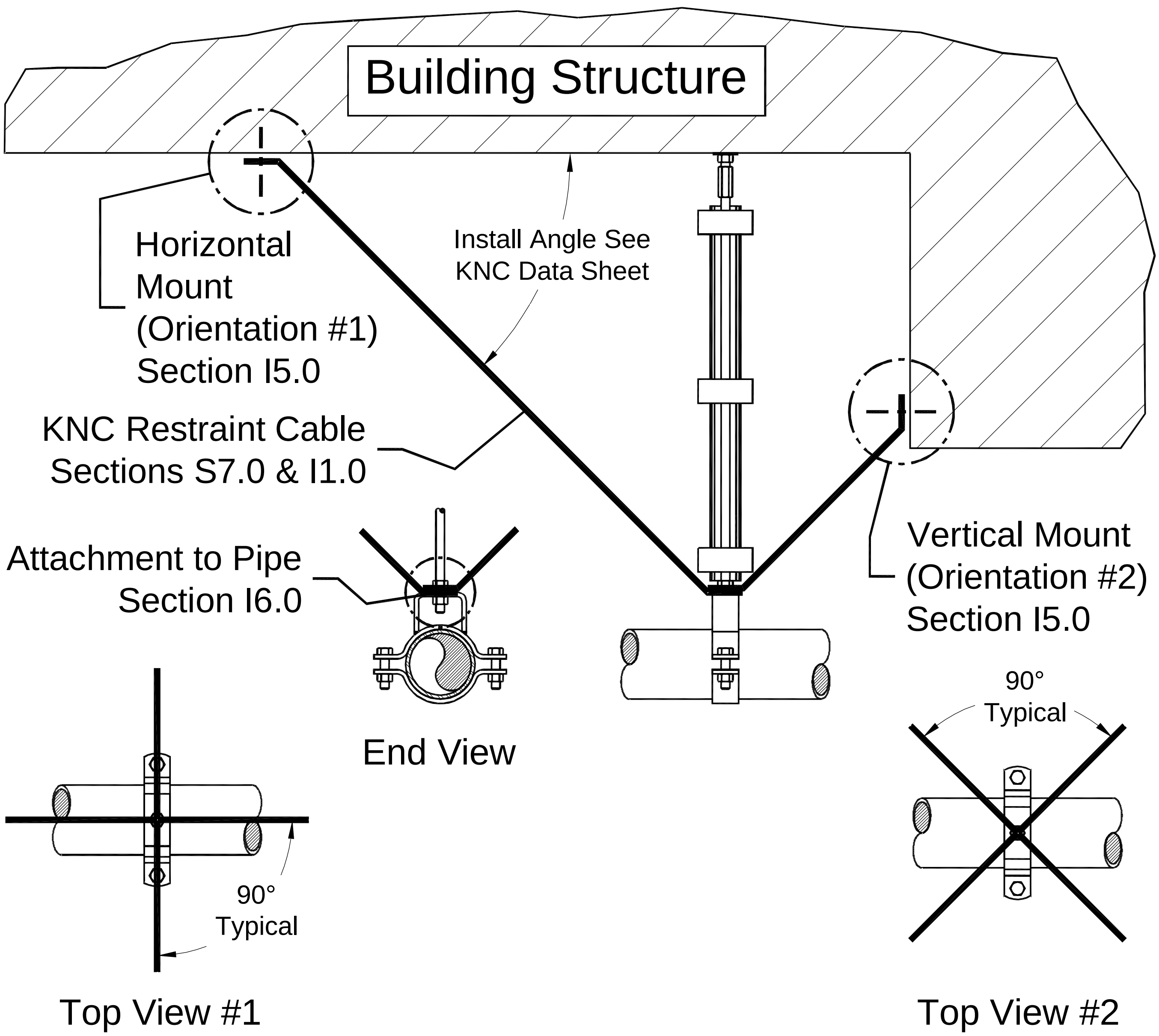

Figure I3-8; Combined Transverse & Longitudinal (TL) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached to a Clamp Type Clevis Hanger

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In order for longitudinal seismic restraints to be attached to the clevis hanger or the hanger rod directly above the clevis hanger, the clevis hanger itself ***must*** be a clamping type hanger that firmly secures the pipe in order to transfer the seismic loads from the pipe to the restraints. These are commercially available, but are not provided by Kinetics Noise Control as part of the standard restraint kit.

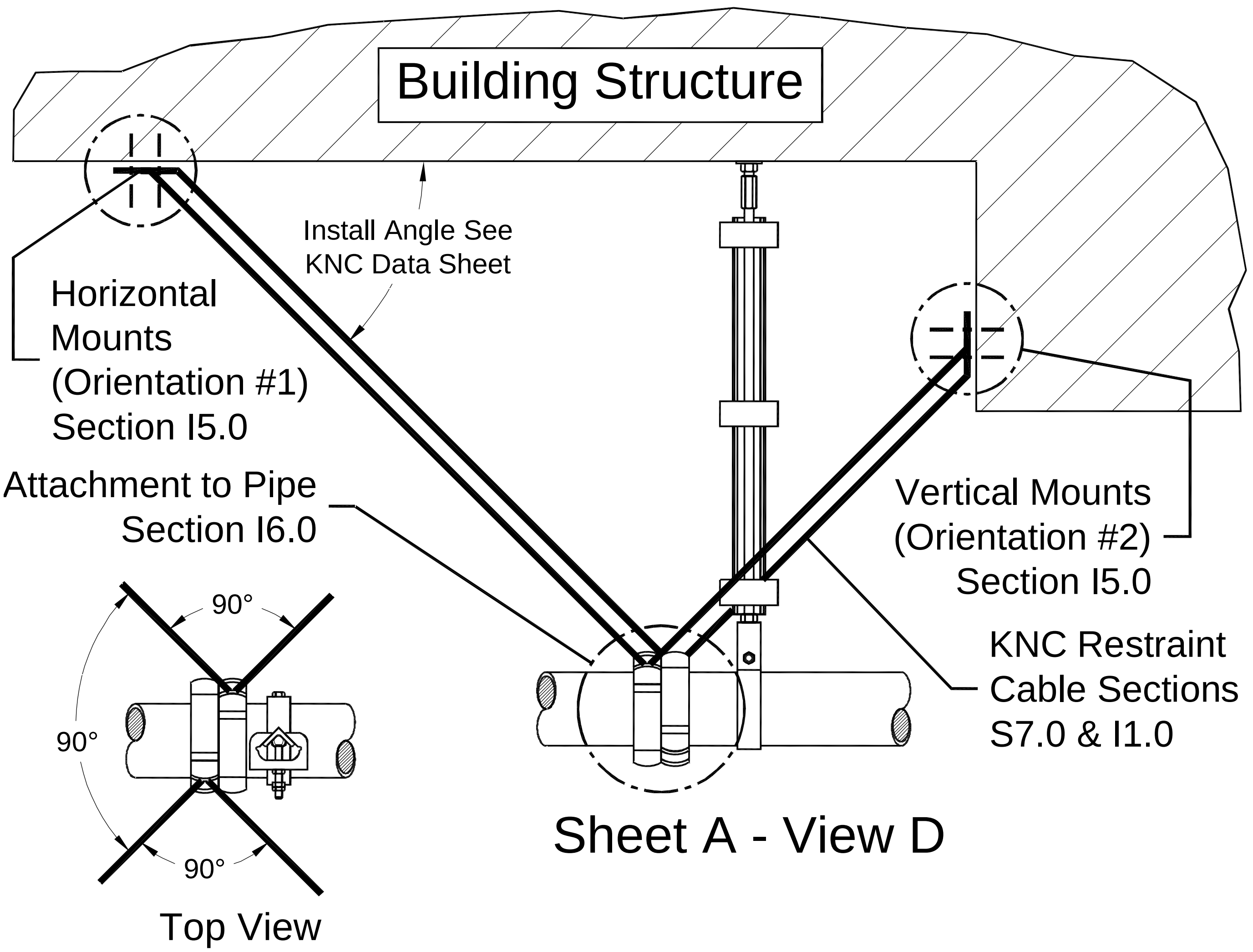

Figure I3-9; Combined Transverse & Longitudinal (TL) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached to Pipe Riser Clamps Immediately Adjacent to the Clevis Hanger

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It is not uncommon to want to use both, the transverse and longitudinal seismic restraints at the same location. The use of riser clamps allows them to be easily attached to the pipe close to a hanger location. The riser clamps can also be replaced with weld tabs as shown in Figure I3-7 above. AS with the independent longitudinal restraints, the restraint cables ***must not*** touch the hanger rod, rod stiffener, or the rod stiffener clamps.

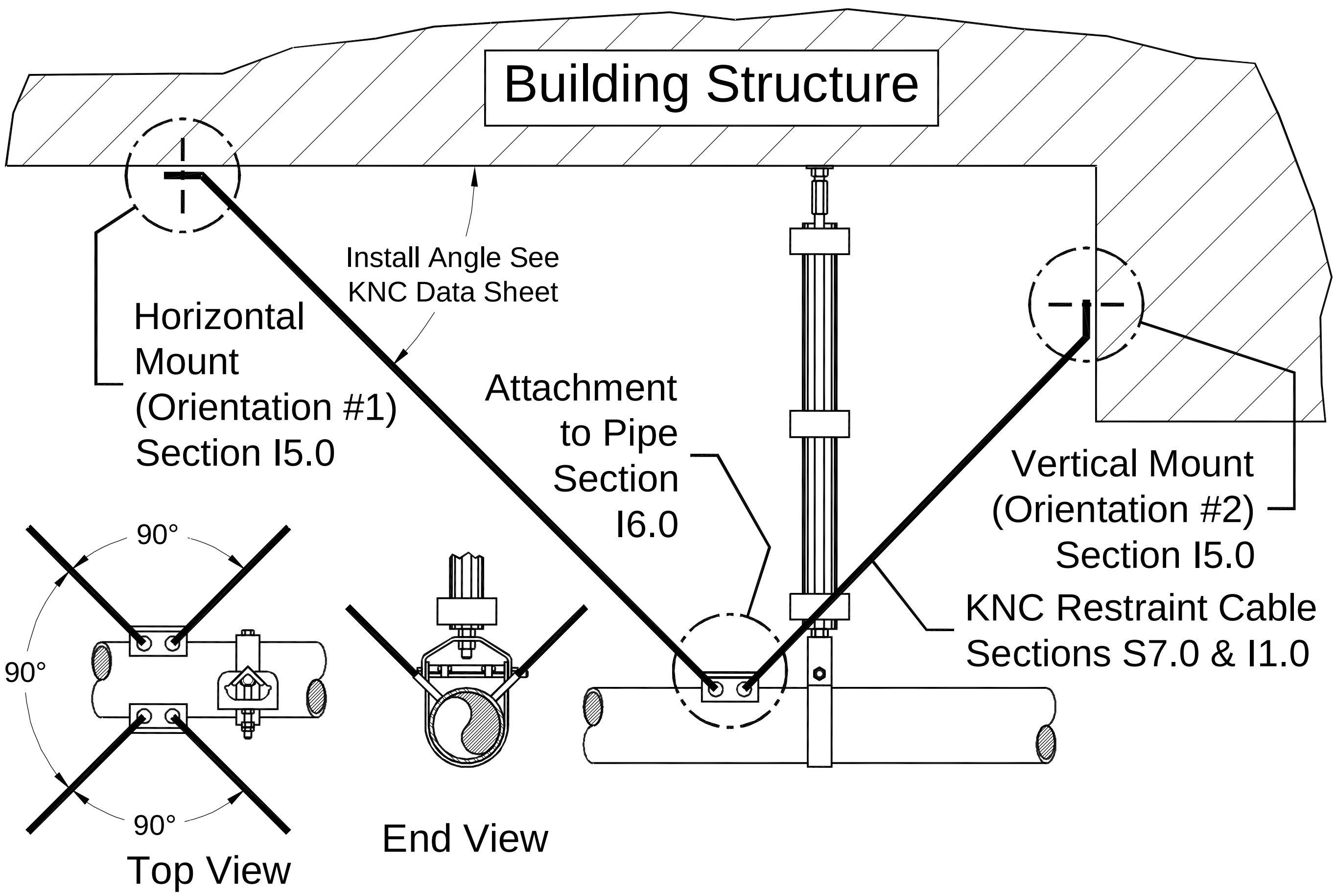

Figure I3-10; Combined Transverse & Longitudinal (TL) Cable Restraint Schematic Arrangement for Single Clevis Supported Pipe – Cable Restraints Attached to Weld Tabs Adjacent to the Clevis Hanger

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I3.5 – Some Common Types of Clevis Hangers:

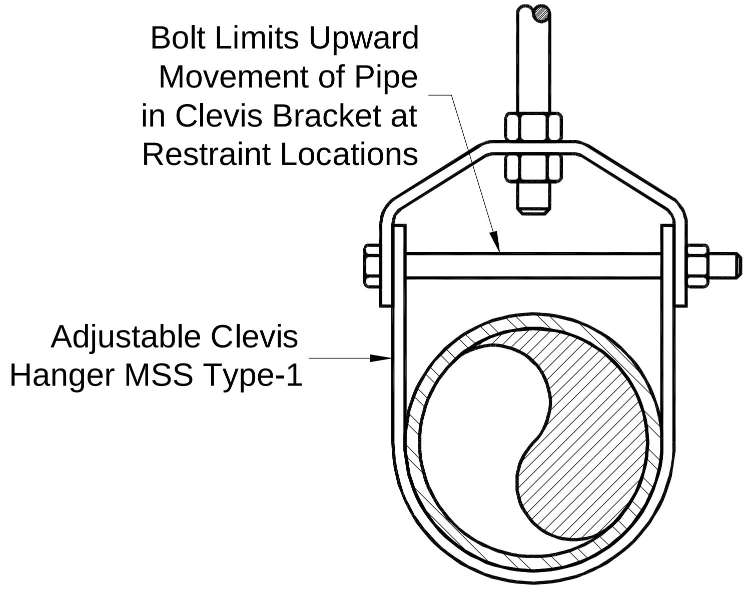

Figure I3-11; Standard Adjustable Clevis Hanger

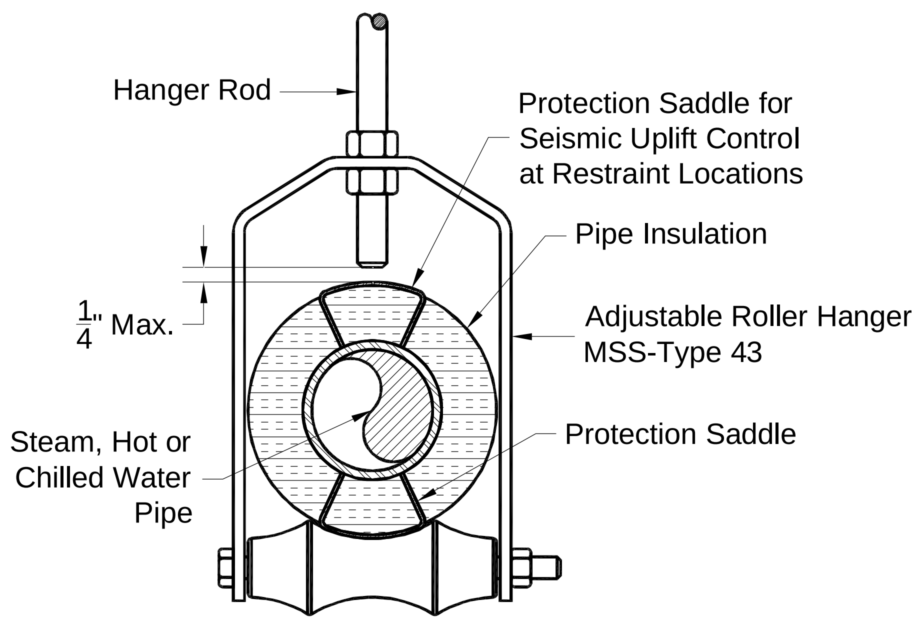

Figure I3-12; Roller Type Clevis Hanger Used for Hot and Cold Fluid Lines

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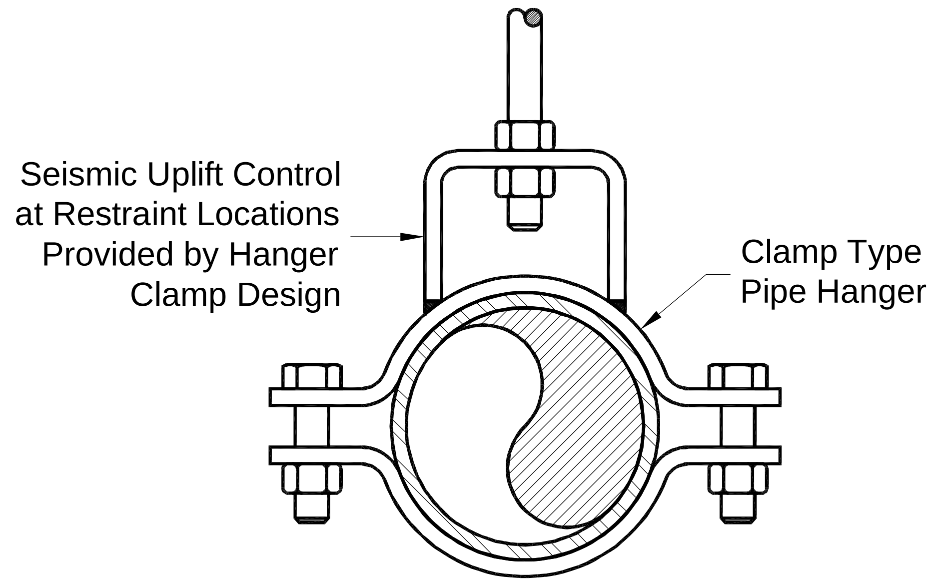

Figure I3-13; Commercially Available Clamp Type Clevis Hanger

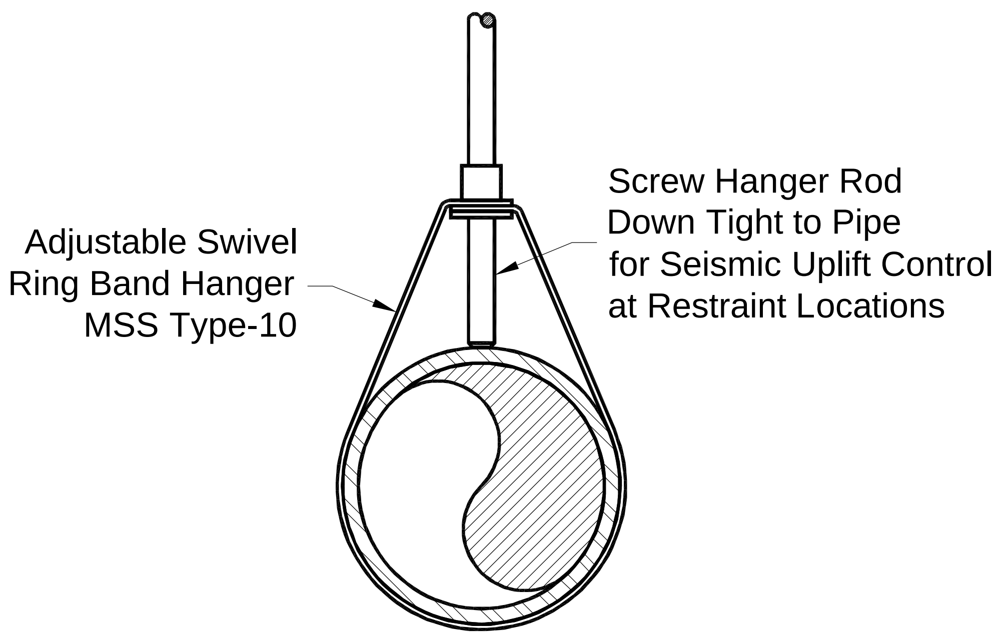

Figure I3- 14; Adjustable Swivel Ring Band Pipe Clevis Hanger – Typically Used for Fire Protection Piping

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I3.6 – Transverse (T) Cable Restraint Schematics for Trapeze Supported Pipe:

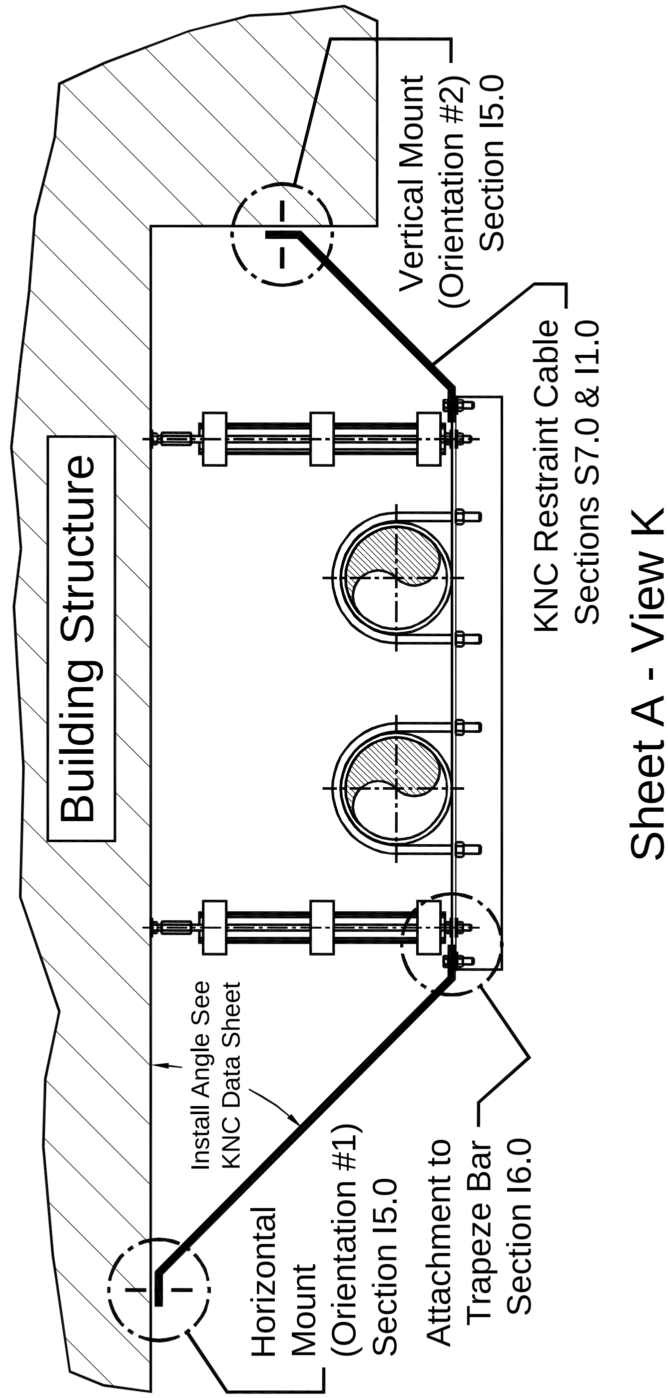

Figure I3-15; Transverse (T) Cable Restraint Schematic Arrangement for Trapeze Supported Pipe – Cable Restraints Attached to Both Ends, or Hanger Rods, of the Trapeze Bar and Directed Outside the Trapeze

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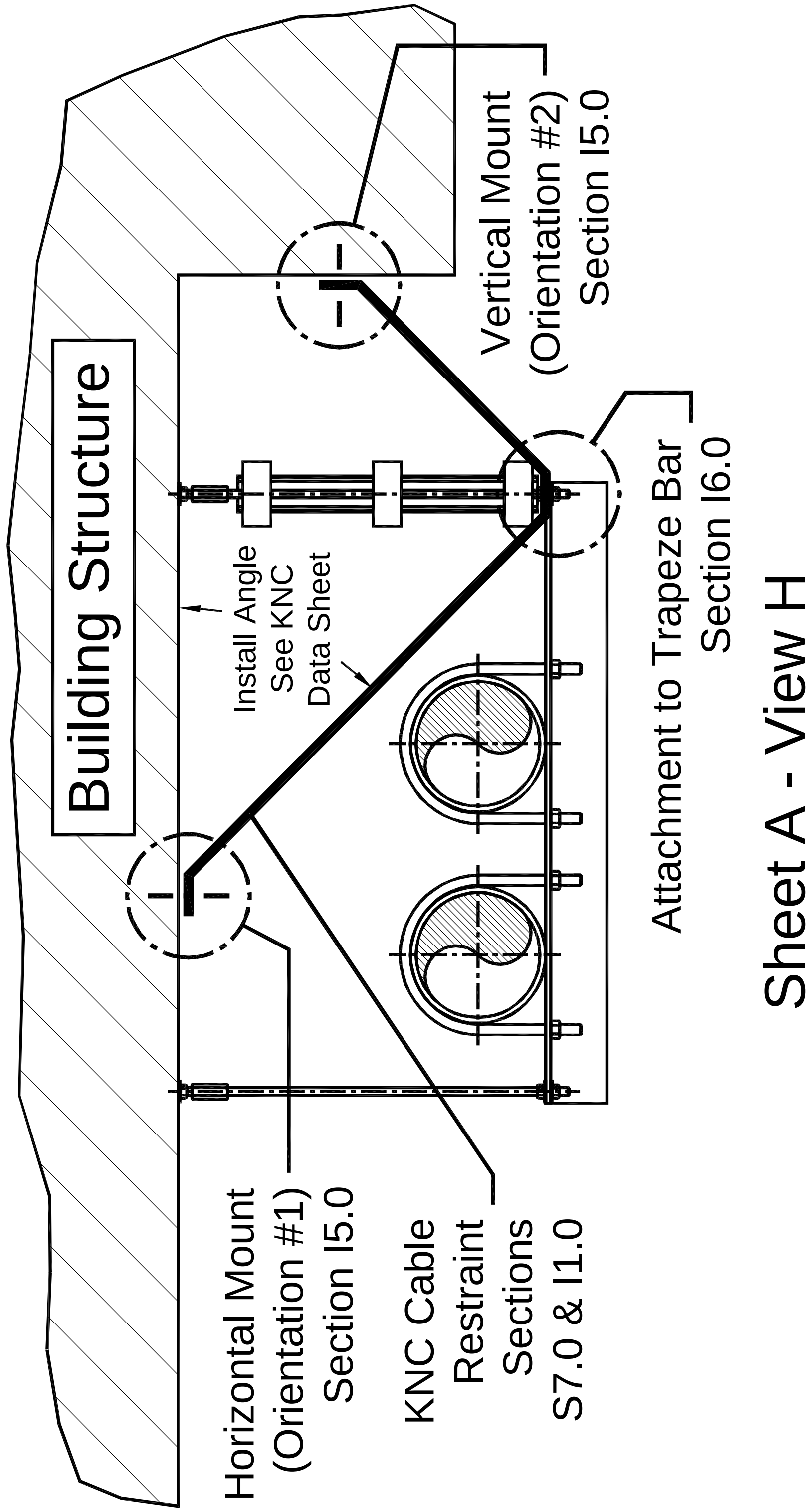

Figure I3-16; Transverse (T) Cable Restraint Schematic Arrangement for Trapeze Supported Pipe – Cable Restraints Attached to One End, or Hanger Rod, of the Trapeze Bar

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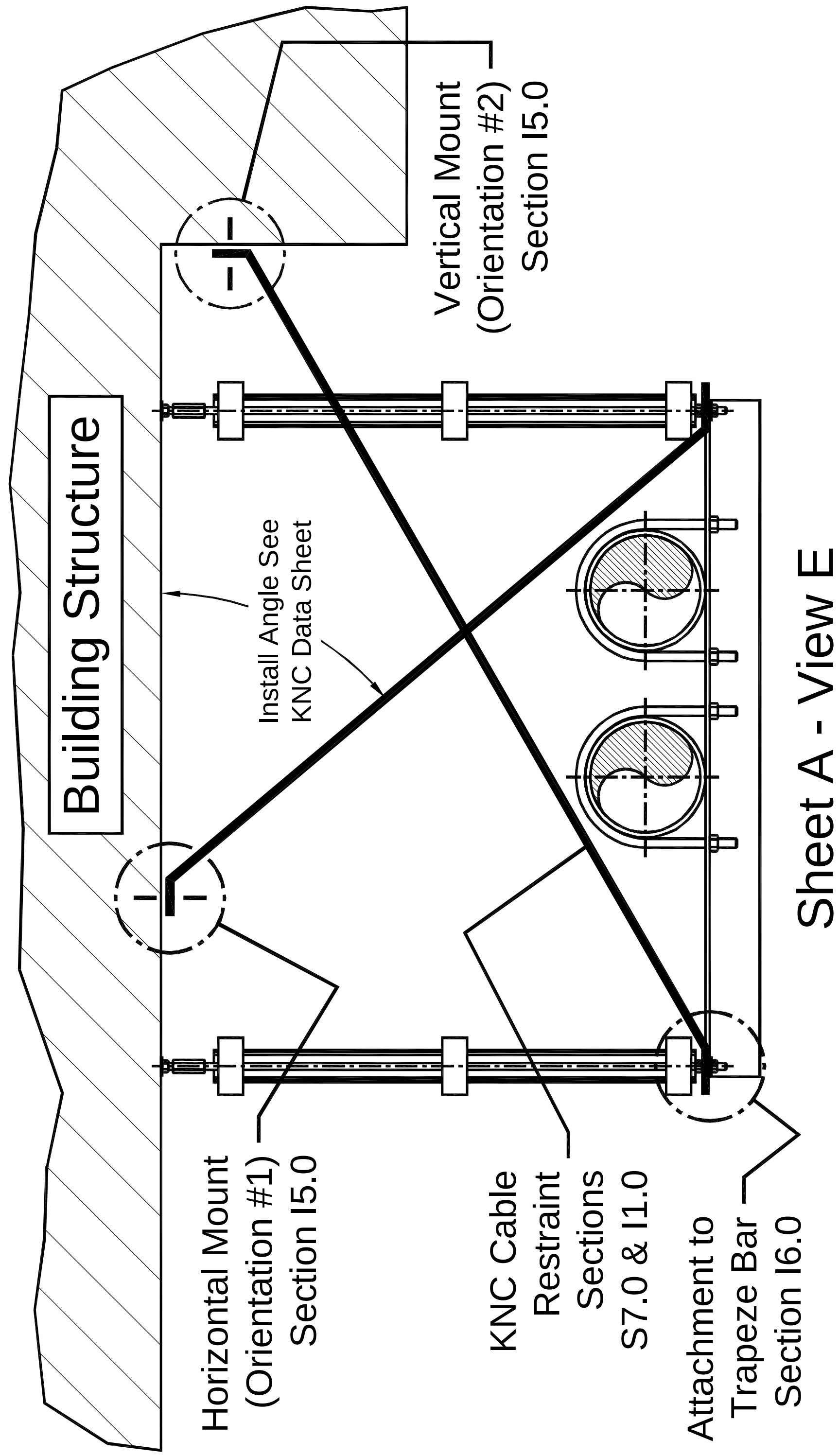

Figure I3-17; Transverse (T) Cable Restraint Schematic Arrangement for Trapeze Supported Pipe – Cable Restraints Attached to Both Ends, or Hanger Rods, of the Trapeze Bar and Directed Inside the Trapeze

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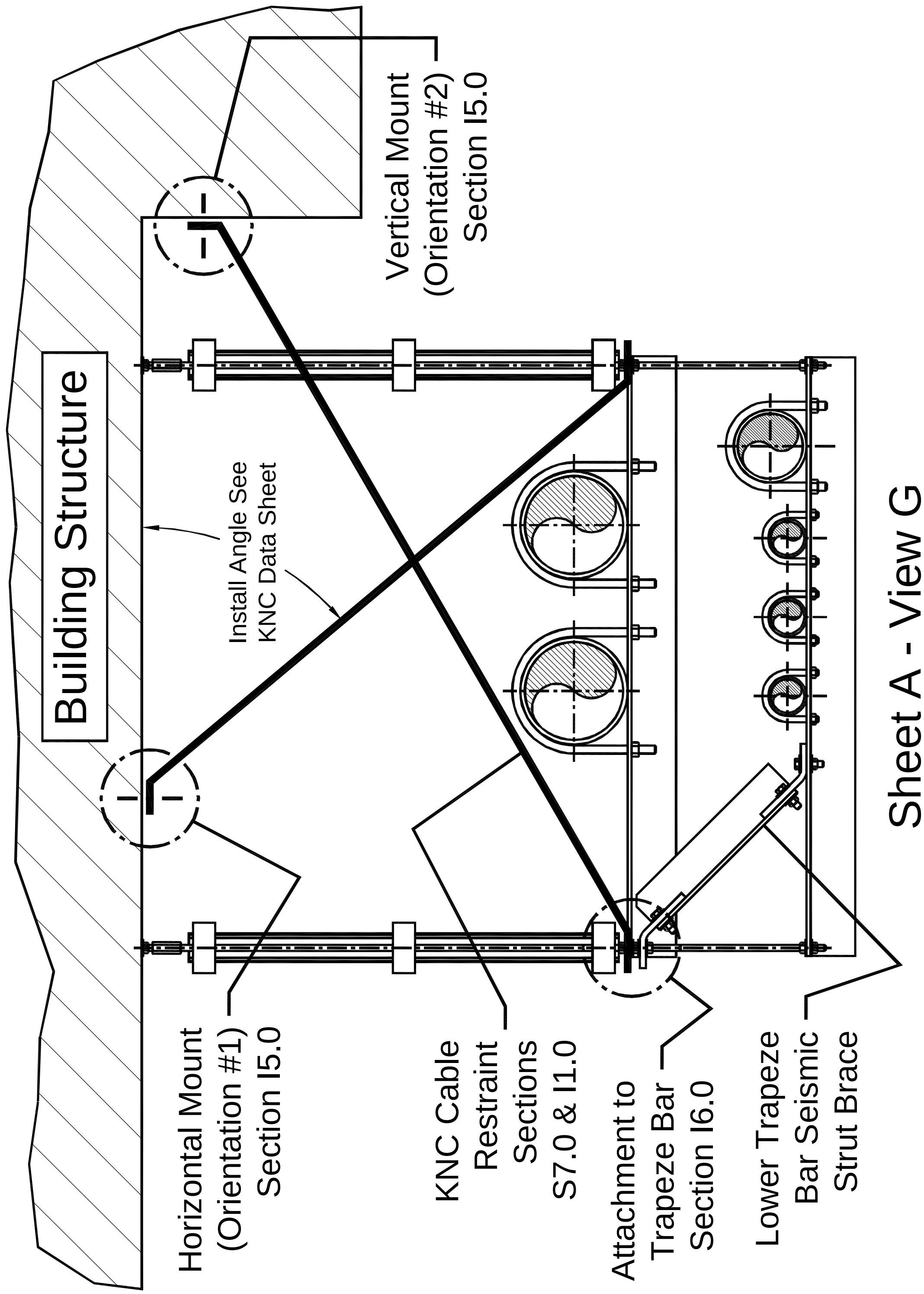

Figure I3-18; Transverse (T) Cable Restraint Schematic Arrangement for Trapeze Supported Pipe – Cable Restraints Attached to Both Ends, or Hanger Rods, of the Trapeze Bar and Directed Inside the Trapeze with a Second Tier Trapeze Support for Additional Pipes.

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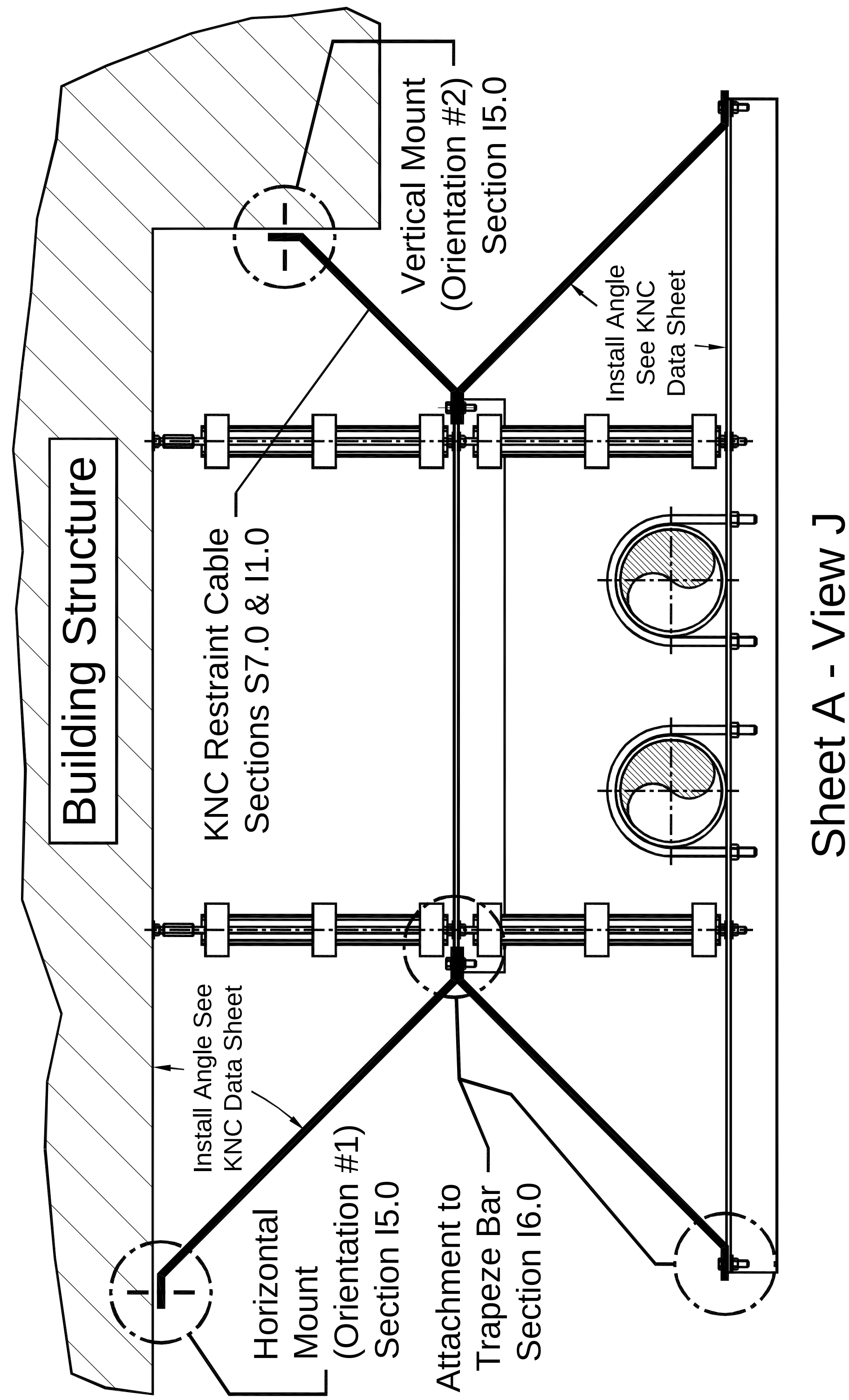

Figure I3-19; Transverse (T) Cable Restraint Schematic Arrangement for Trapeze Supported Pipe – Cable Restraints Attached to Both Ends, or Hanger Rods, of the Trapeze Bar and Directed Outside the Trapeze for Use in Tight Space Situations

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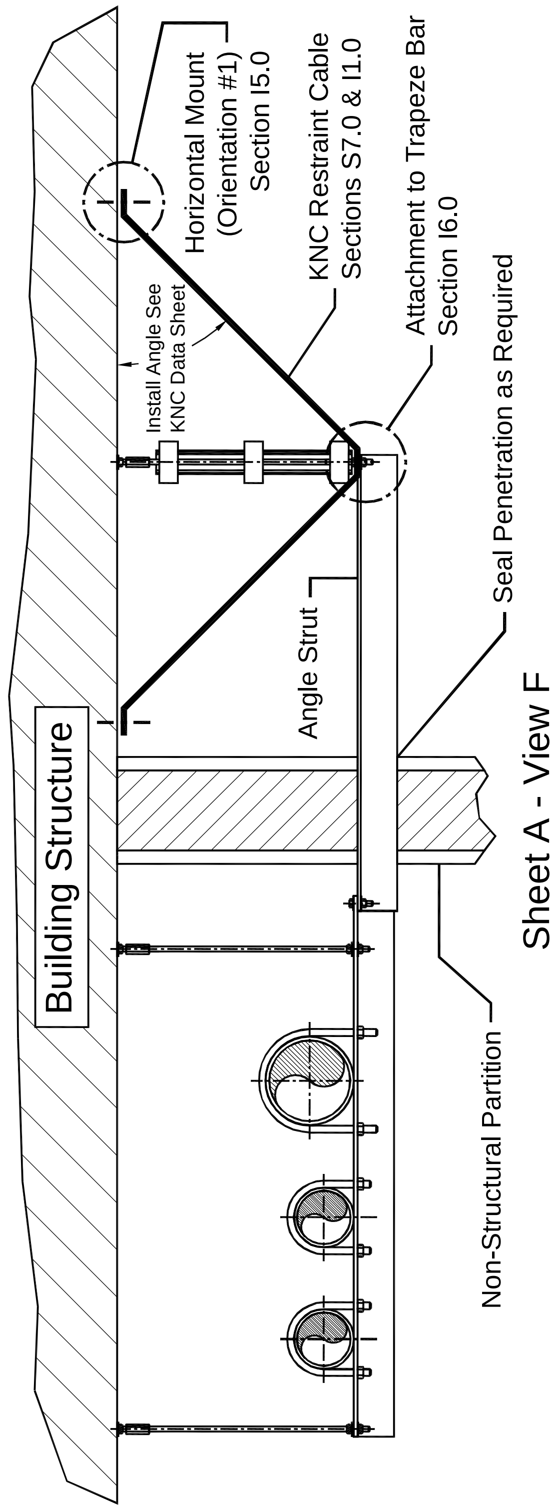

Figure I3-20; Transverse (T) Cable Restraint Schematic Arrangement for Trapeze Supported Pipe – Trapeze Bar Is Too Close to a Wall to Allow a Normal Restraint Arrangement – Obtain Permission from the Structural Engineer and Architect Before Penetrating the Wall

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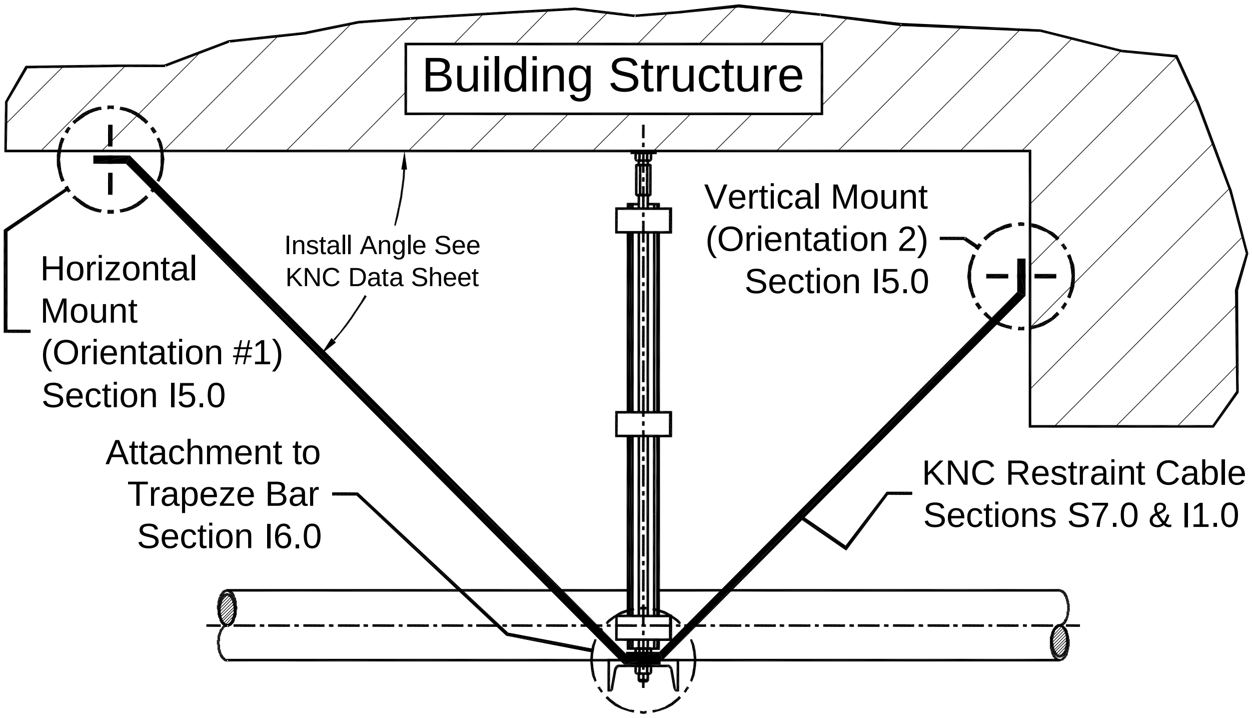
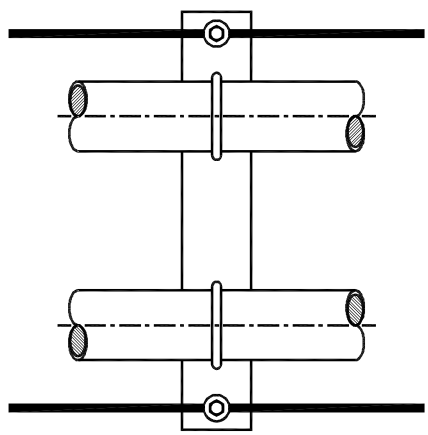
I3.7 – Longitudinal (L) Cable Restraint Schematics for Trapeze Supported Pipe:



Sheet A - View M
Side View Opt. #1



Top View Opt. #1

Figure I3-21; Longitudinal (L) Cable Restraint Schematic Arrangement for Trapeze Supported Pipe – Restraint Forces are Balanced Side-to-Side – Requires One (1) Extra Restraint Cable Kit beyond KNC Material Required List per Longitudinal Restraint Location

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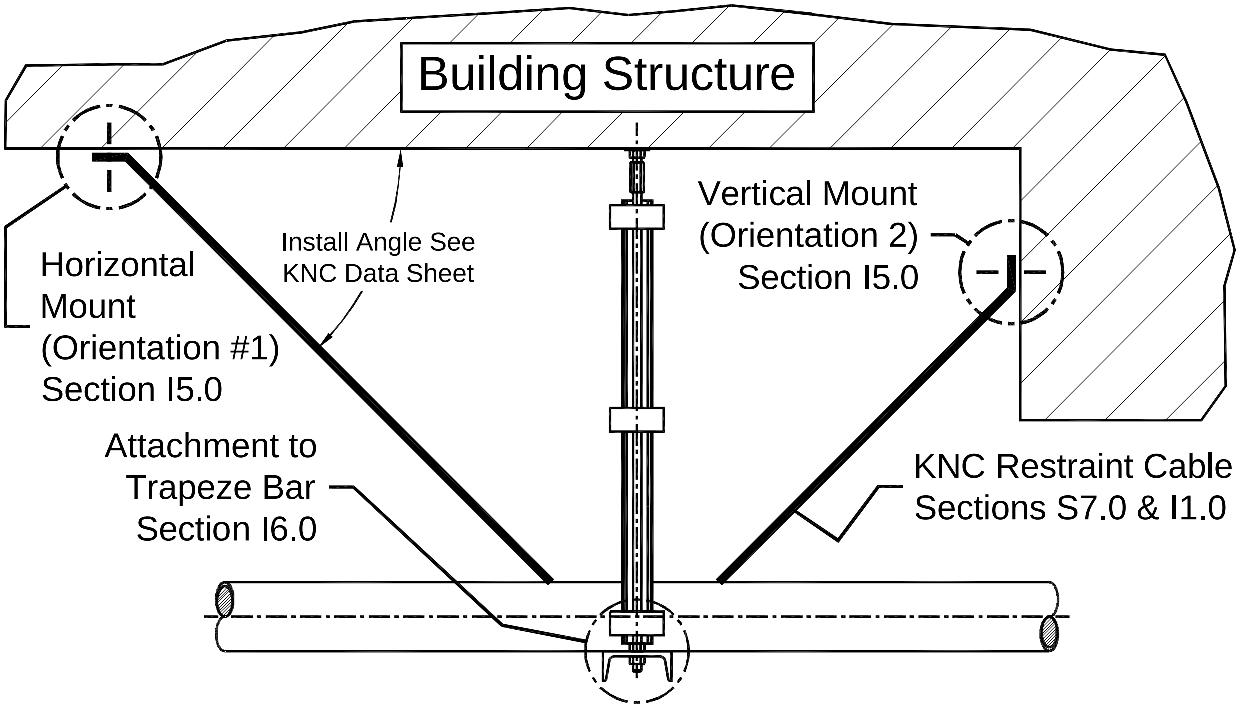
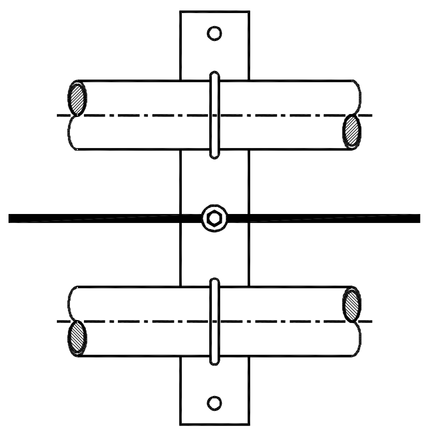


Sheet A - View M
Side View Opt. #2



Top View Opt. #2

Figure I3-22; Longitudinal (L) Cable Restraint Schematic Arrangement for Trapeze Supported Pipe – Restraint Forces are Balanced Side-to-Side – Requires No Addition Cable Kits Other Than Those on the KNC Material Required List per Longitudinal Restraint Location

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I3.8 – Transverse (T) Cable Restraint Schematics for Floor or Roof Mounted Pipe:

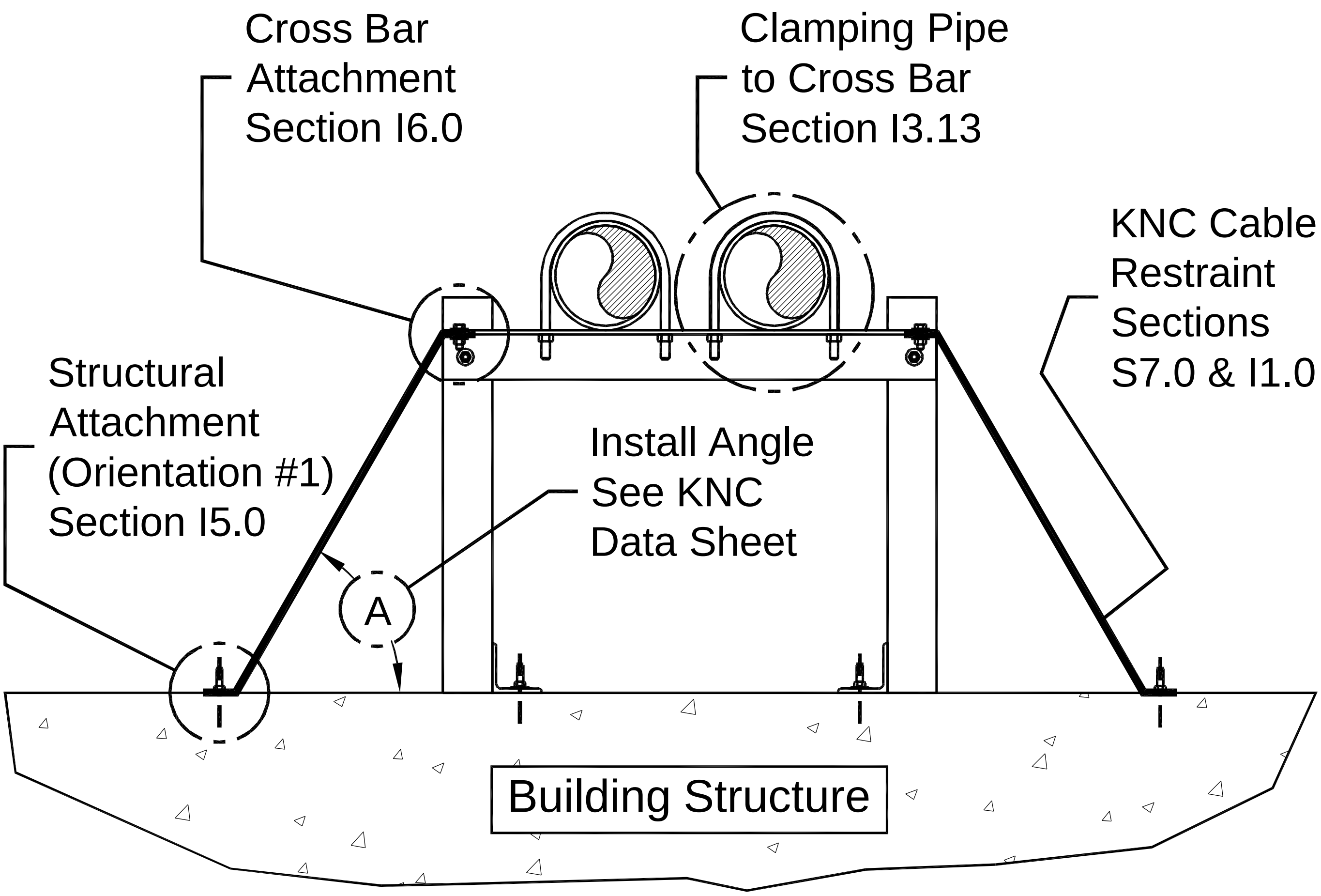

Figure I3-23; Transverse (T) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Pipe – One Restraint Attached to Each Side of the Cross Bar at the Vertical Legs Directed Outward from the Floor Stand

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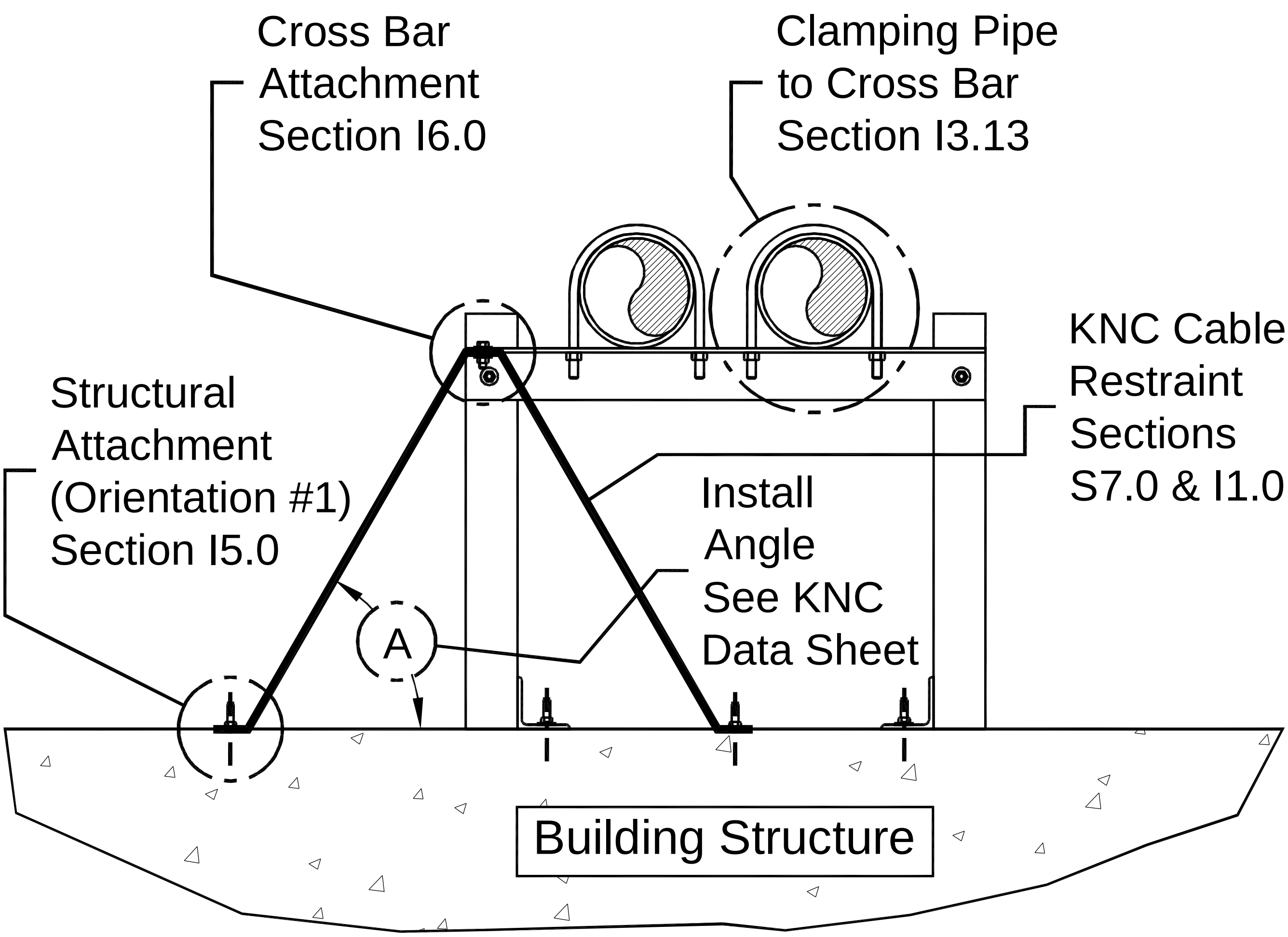

Figure I3-24; Transverse (T) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Pipe – Both Restraints Attached to One Side of the Cross Bar at the Vertical Leg

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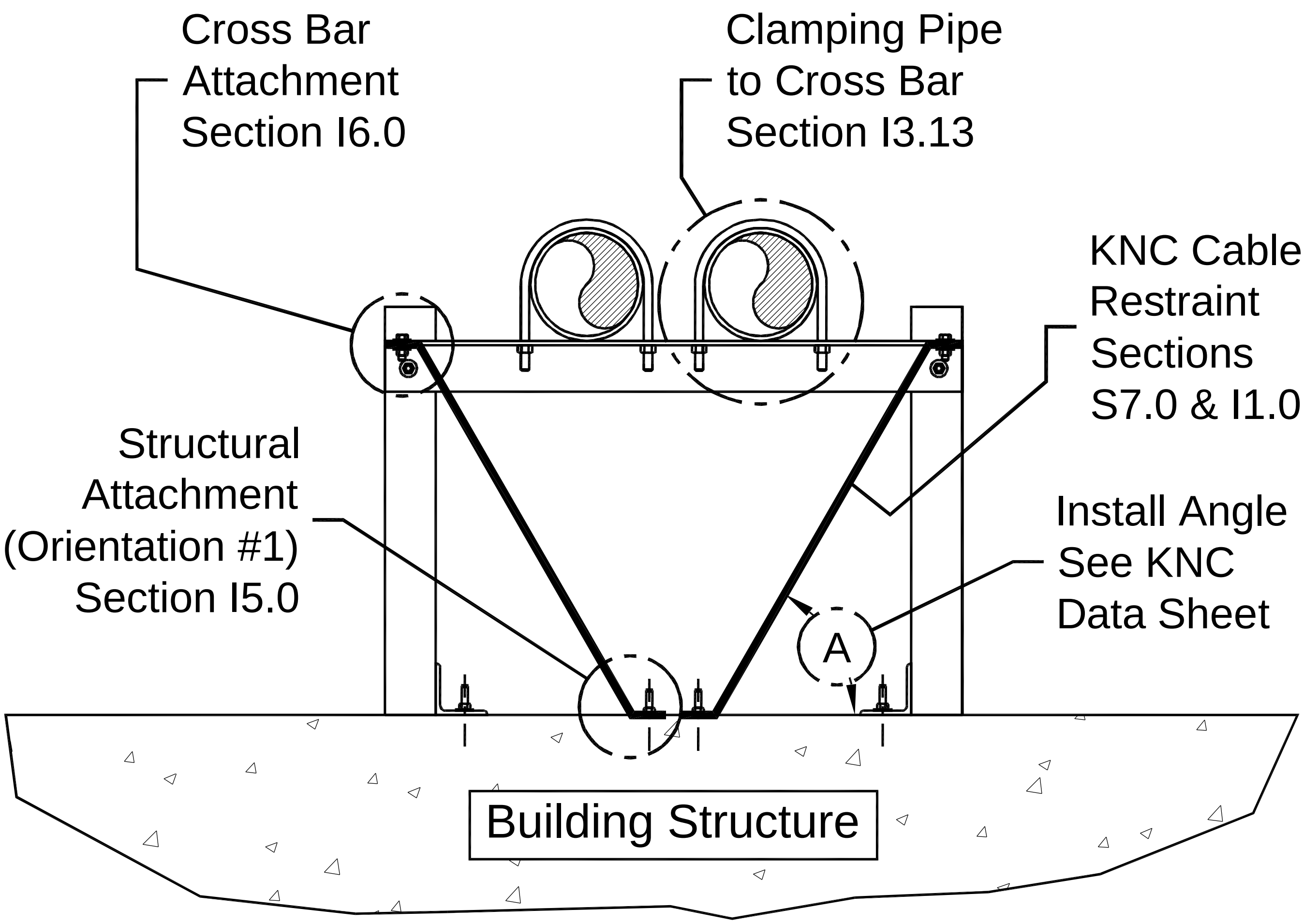

Figure I3-25; Transverse (T) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Pipe – One Restraint Attached to Each Side of the Cross Bar at the Vertical Legs Directed Inward

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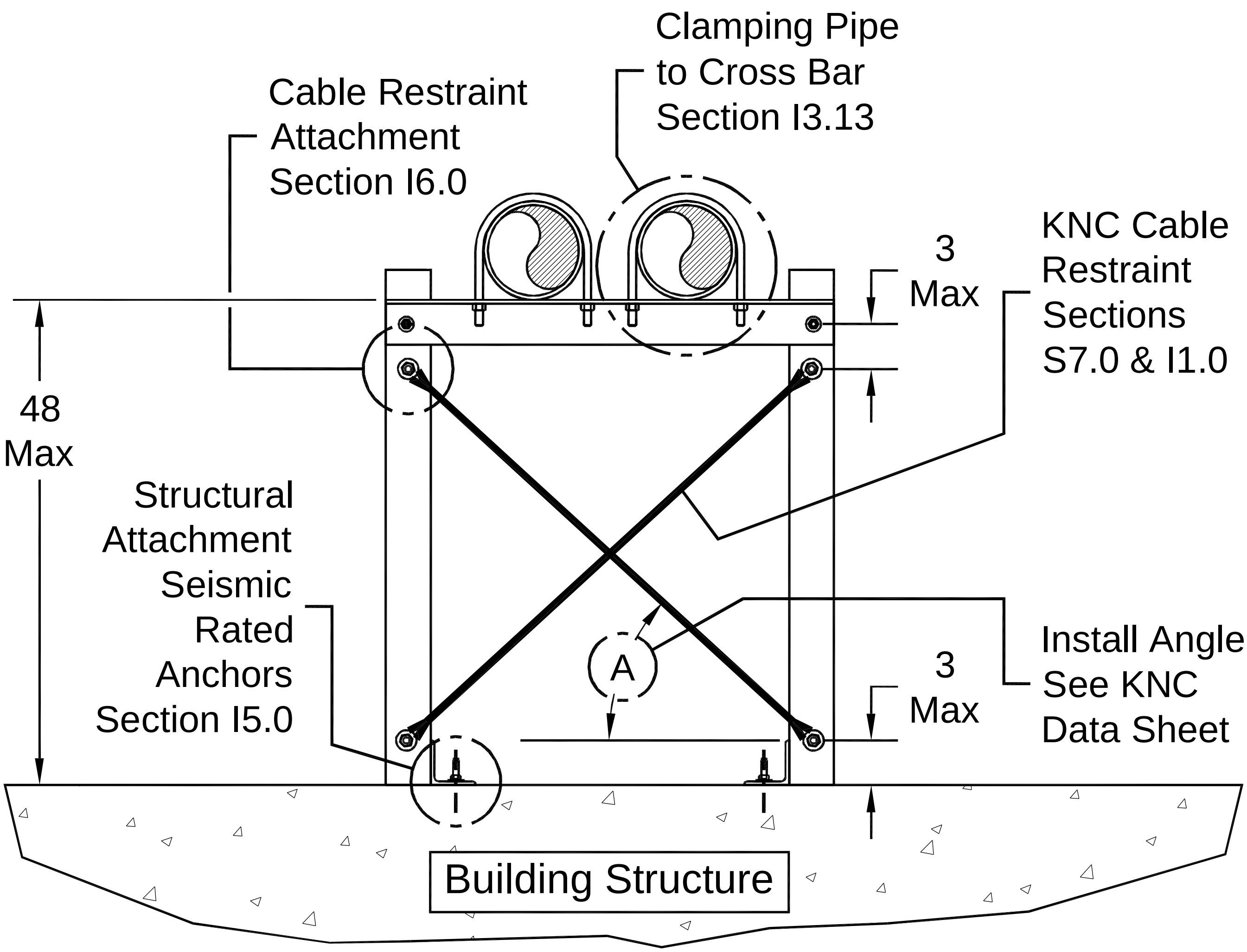

Figure I3-26; Transverse (T) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Pipe – Two Restraints Attached to the Vertical Legs Acting as Cross Braces – The Anchors Attaching the Stand to the Floor Must be Seismically Rated Cracked Concrete Anchors with a Current ICC-ESR Number

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I3.9 – Longitudinal (L) Cable Restraint Schematics for Floor or Roof Mounted Pipe:

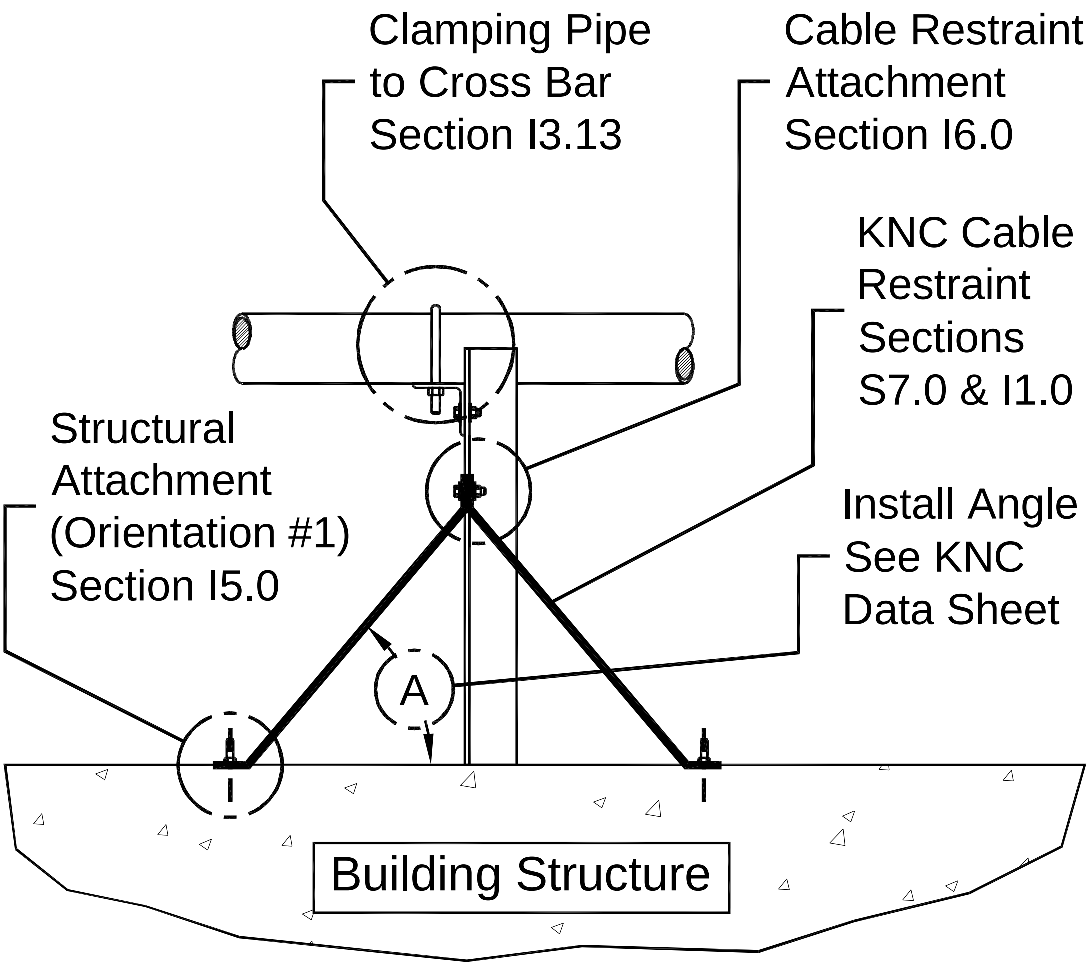

Figure I3-27; Longitudinal (L) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Pipe – Restraints Attached to the Floor Stand or Support

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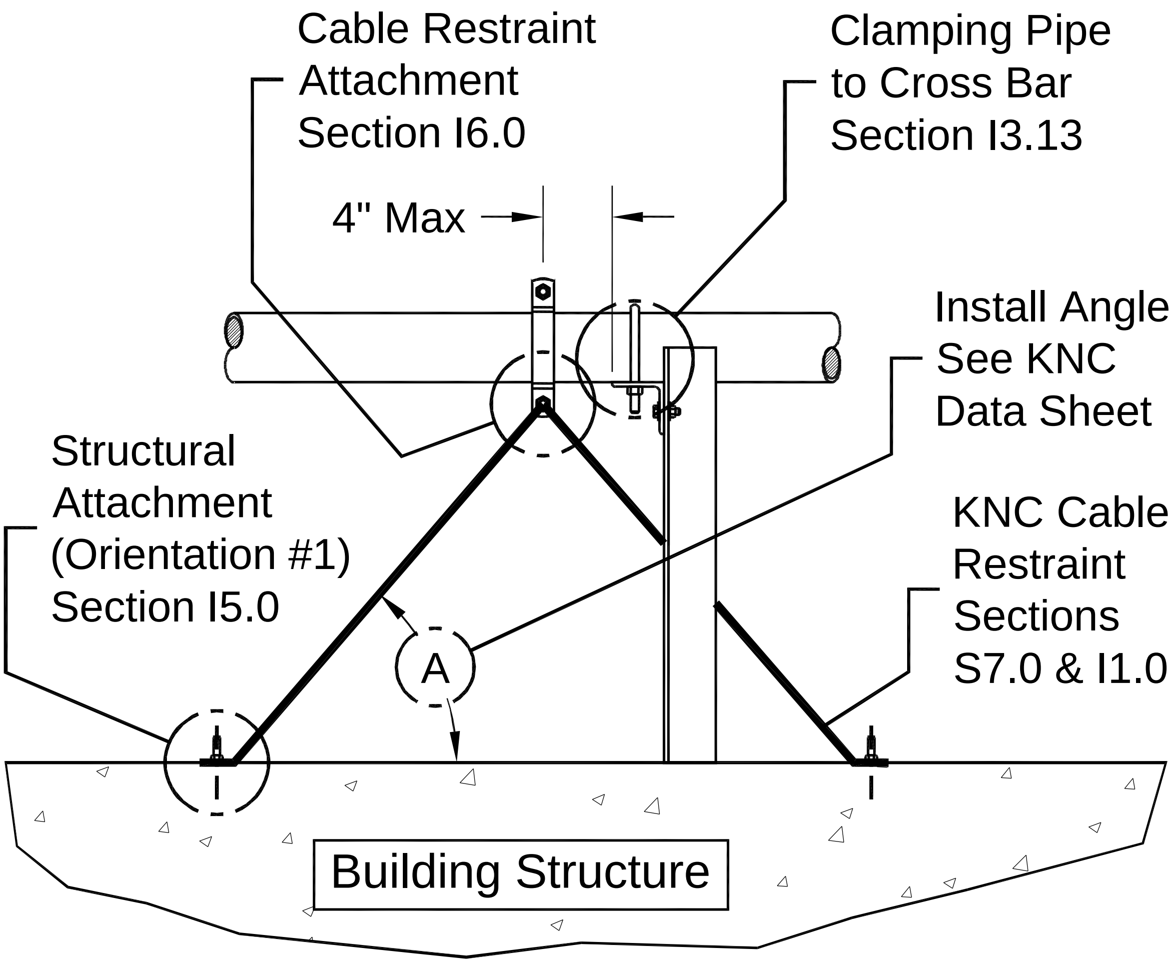

Figure I3-28; Longitudinal (L) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Pipe – Restraints Attached to the Pipe – Each Pipe Must be Individually Restrained

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I3.10 – Combined Transverse & Longitudinal (TL) Cable Restraint Schematics for Trapeze Supported Pipe:

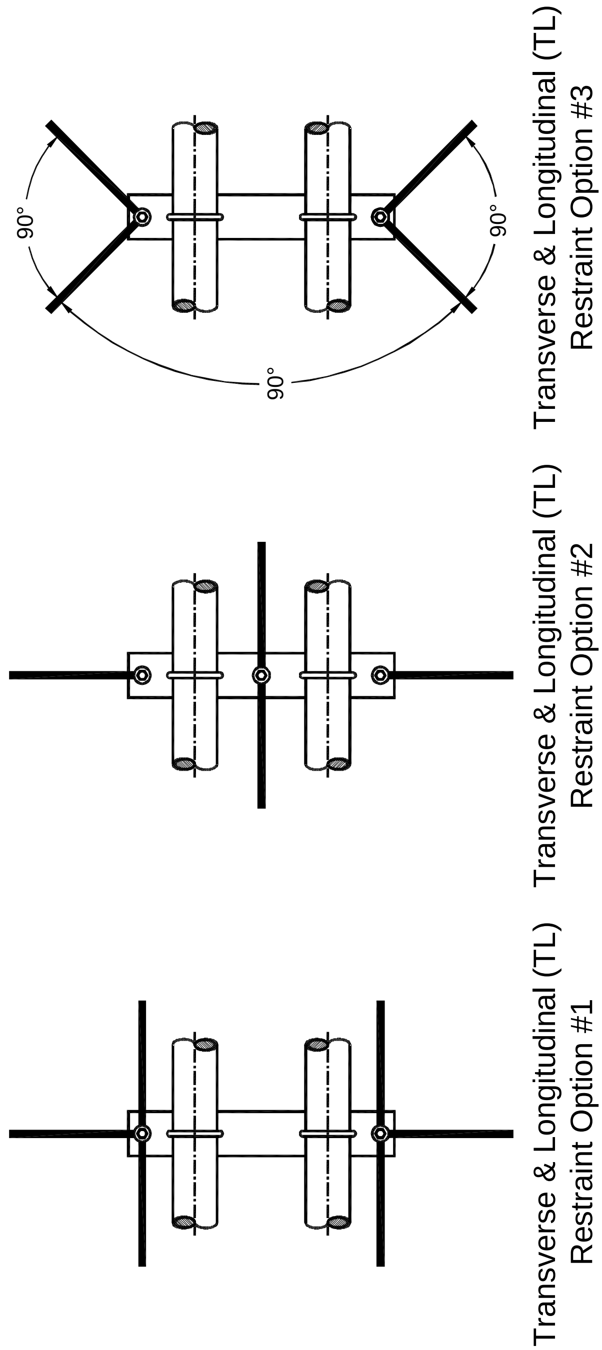

Figure I3-29; Combined Transverse & Longitudinal (TL) Cable Restraint Schematics for Trapeze Supported Pipe – All of the Options Shown Offer Balanced Longitudinal Restraint Forces Side-to-Side – Options #2 and #3 Do Not Require Extra Cable Restraint Kits While Option #1 Does Require One (1) Extra Restraint Cable Kit Beyond Those Listed in the KNC Material Required List per Combined Transverse & Longitudinal Seismic Restraint Location

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I3.11 – Some Common Trapeze Bar Configurations:

The design of trapeze bars used in the support of pipe is varies by trade, the standard used for designing the piping, engineering company, and design requirements. There are no “off the shelf” trapeze bars available as there are clevis hangers. Each trapeze bar is designed for the specific application, and the design of the trapeze bar structural members from which it is constructed are generally specified by the design professional of record for the system being installed.

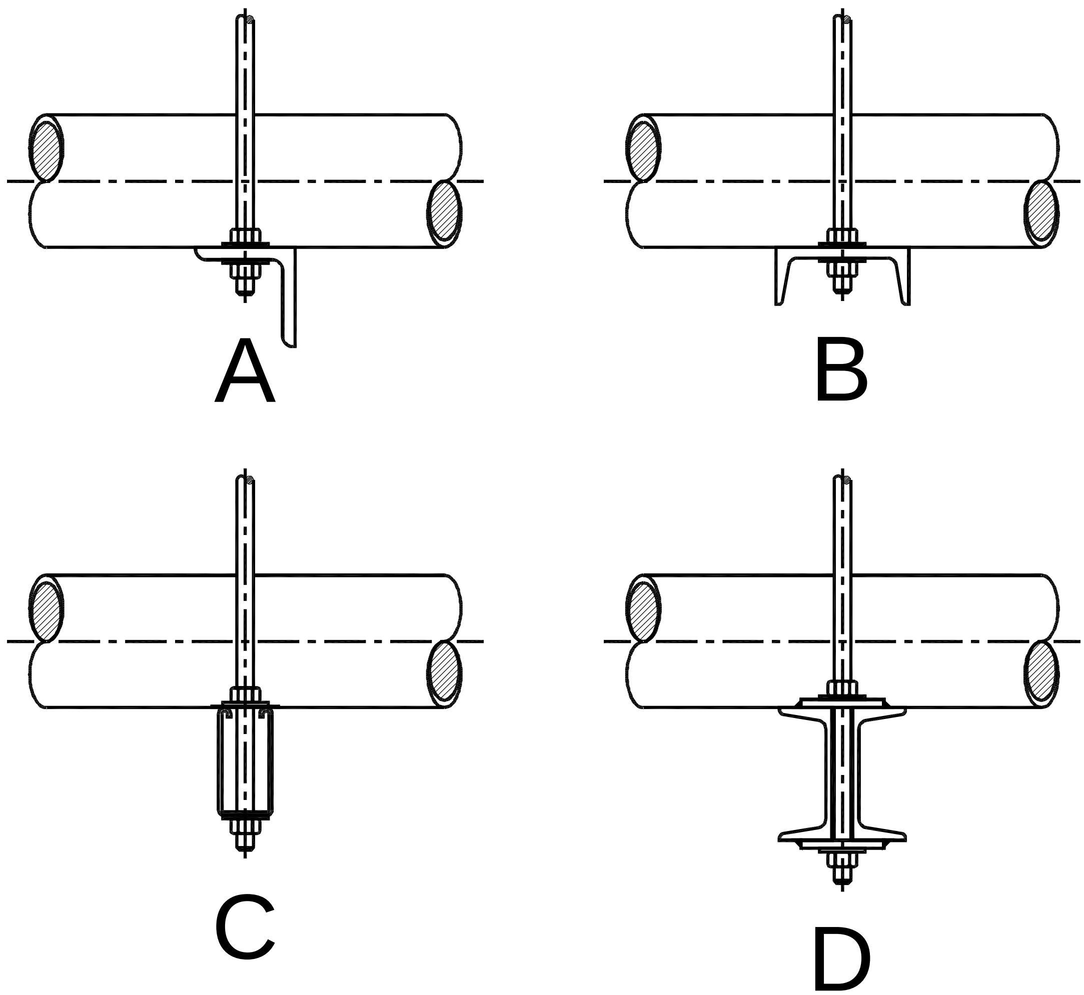

Figure I3-30; Some Common Trapeze Bar Design Configurations Used for Supporting Pipe

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Some common structural members used to construct trapeze bars used for pipe supports are shown in Figure I3-30. Figure I3-30 A is a typical trapeze bar constructed from AISI structural angle that is cut and drilled in the field for the hanger rods and pipe clamps. Figure I3-30 B is a single structural channel that mounted horizontally, and is cut and drilled in the field for the hanger rods and pipe clamps. Figure I3-30 C is a strut channel similar to a UNISTRUT® P5000 which is also cut in the field. Strut channels may be purchased pre-pierced with holes and/or slots to aid in mounting the hanger rods and clamps for the piping. Strut manufacturers also have special pipe clamps that are design to work in the open slot of the strut channel. Figure I3-30 D is a trapeze bar that is made of a weldment consisting of two standard channels back-to-back. In this configuration two drilled plates on welded on each end provide the mounting locations for the hanger rods. Pipe clamps would need to have drilled plates welded to the tops of the channels, or have holes drilled in the flanges of the channels. If the flange holes are used to mount the pipe clamps tapered structural washers should be used against the bottom of the flange to prevent bending of the clamp bolts. This design is used to carry very large and heavy pipes such as chilled water supply and return lines.

I3.12 – Trapeze Bar Design Loads:

Typically trapeze bars are designed to carry the dead weight loads of the pipes that they are supporting, and for non-seismic applications this is more than sufficient. However with the introduction of significant seismic loads, the trapeze bars at the seismic restraint locations may need to become more “beefy” to carry the horizontal seismic loads generated by the pipes they are supporting.

At transverse (T) seismic restraint locations, the seismic loads will act along the trapeze bar, which is its strong direction. The trapeze bar will only need to be strong enough to support the dead weigh load of the pipes, and to not buckle under the transverse seismic loads generated by the pipes that it is supporting.

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At longitudinal (L) and combined transverse & longitudinal (TL) seismic restraint locations, the situation is very different. The longitudinal restraints may be resisting the seismic loads generated by as much as ***eight times*** the length of pipe as they are supporting. The longitudinal seismic forces will act perpendicular to the trapeze bar and will place it in bending. Typically the strong bending direction for a trapeze bar is chosen to resist the dead weight load of the pipe which is acting 9ertically against the bar. As a result, the longitudinal seismic forces are typically applied in the weak bending direction of the trapeze bar. Since the dead weight loads and the longitudinal seismic restraint loads can act concurrently (at the same time), those trapeze bars located at longitudinal seismic restraint locations may require a stronger section to resist the expected load combination. ***This is a situation that should be addressed before the installing contractor is confronted by it in the field***!

Note for Installing Contractors: If a similar trapeze bar design is being used throughout a project, the following situations will warrant a question back to the design professional of record for the system being installed.

1. The project is located in a high seismic area such as;
    a. Los Angeles, CA
    b. San Francisco, CA
    c. Seattle, WA
    d. Portland, OR
    e. Salt Lake City, UT
    f. Memphis, TN
    g. Charleston, SC
2. Large piping is being supported on trapeze bar designs that are also used for smaller pipes.
3. The same trapeze bar design is being used on the top floor and in the basement to carry the same number and size of pipes.

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The seismic design forces acting on the pipe, and the seismic restraint locations and spacings are discussed in the Sections S5.0 and S7.0 respectively. It is the responsibility of the design professional of record for the system being installed to ensure that the trapeze bars at each seismic restraint location are capable of carrying the dead weight loads of the pipe as well as the design seismic loads specified by the code for the project.

I3.13 – "Clamping" the Pipe to the Trapeze Bar – When and How:

When the seismic restraints are attached to either the trapeze bar or the hanger rod(s), the pipes themselves must be clamped, or otherwise positively attached to the trapeze bar to ensure that the seismic loads from the pipes is indeed passed through to the seismic restraints. There can be no relative motion between the pipe and the trapeze bar. Clamps such as U-bolt clamps do rely on friction to hold the pipe in place, but the normal force depends on the torque applied to the nuts rather than the gravity load from the dead weight of the pipe. Therefore, the clamping force may be increased to the point where slippage between the pipe and the trapeze bar is not possible. There are many other types of clamps that may be employed such as the strut type clamps made to work with strut channels such as those manufactured by UNISTRUT® and Cooper B-Line. It is the responsibility of the design professional of record responsible for the system to determine if the clamps specified will be adequate to transmit the expected seismic loads, and to specify the proper torque values required.

When working with steam lines, hot or chilled HVAC water lines, and domestic hot water lines a means to deal with the thermal growth and shrinkage of the pipes must be used that will properly limit the relative movement between the pipe and the trapeze bar at the restraint locations. Pipes such as steam lines and hot or chilled HVAC lines typically are insulated to maintain system thermal efficiency. The insulation presents some particular issues when the relative motion between the pipe and trapeze bar must be kept to zero. Figure I3-31 shows one means of allowing thermal growth or shrinkage while preventing transverse movement of the pipe, and

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providing uplift control. Note, some means of protecting the insulation such as protection saddles must be used to prevent it from being crushed during an earthquake.

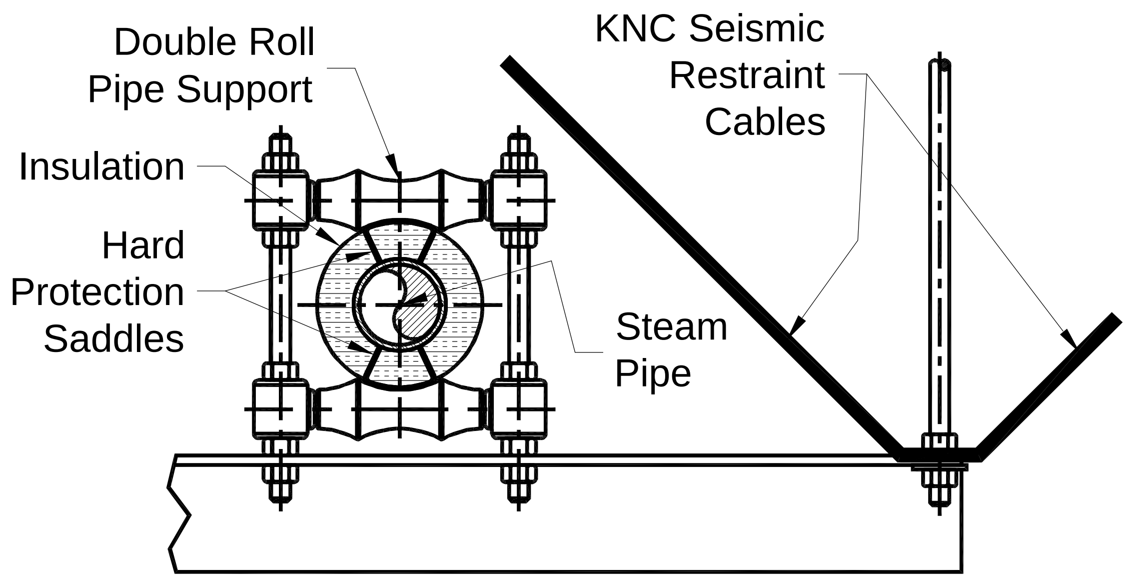

Figure I3-31; Transverse (T) Cable Restraint Location for Trapeze Supported Steam Line – Insulated Steam Pipe Is Trapped in the Transverse Direction and Uplift Is Prevented, While Thermal Growth Is Allowed by a Double Roll Pipe Support

Figure I3-32 shows a hot or chilled HVAC water line supported by a trapeze bar at a transverse seismic restraint location. Here the pipe is loosely restrained to the trapeze bar by a U-Bolt that is slightly wider than the insulation, and is not tightened down. The clearance between the pipe and the U-Bolt must not exceed 1/4″. This arrangement will allow the pipe to grow or shrink without affecting the trapeze bar, or overloading the pipe. Here again, some means of protecting the insulation must be used. Shown in Figure I3-32 are protection saddles, however in lighter seismic conditions, insulation protection shields may serve just as well. Figure I3-33 shows a steam line, or a hot or chilled HVAC water line supported by a trapeze bar at a longitudinal seismic restraint location. Here the pipe is clamped to the trapeze bar firmly enough to prevent slippage between the pipe and the trapeze bar in the longitudinal direction. Great care must be taken that the insulation, and in some cases, the pipe are not crushed when the U-Bolt is tightened down. Typically, there will be only one longitudinal seismic restraint location for this type of pipe per run.

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If more longitudinal seismic restraints are required, expansion/contraction joints will be needed between adjacent longitudinal restraints, see Section S9.0 of this manual.

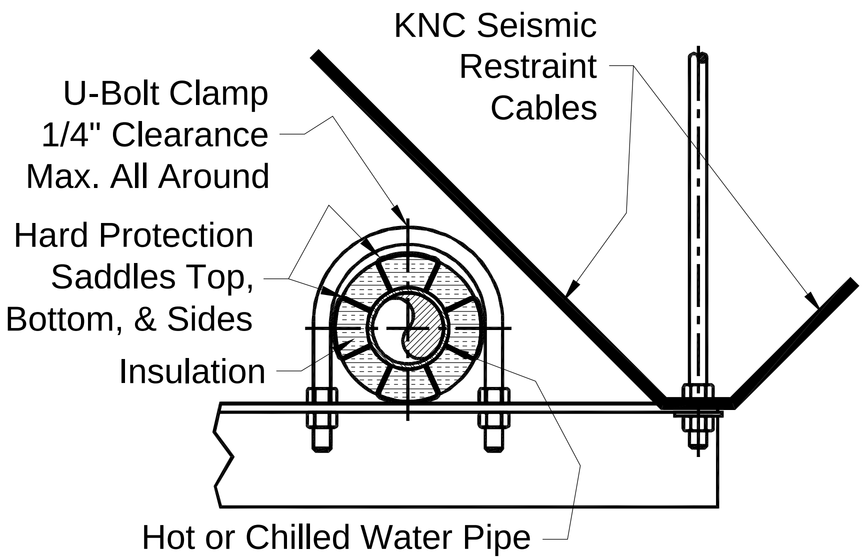

Figure I3-32; Transverse (T) Cable Restraint Location for Trapeze Supported Hot or Chilled Water Line – Insulated Water Pipe Is Trapped in the Transverse Direction and Uplift Is Prevented, While Thermal Growth Is Allowed by a U-Bolt which is Slightly Wider than the Insulation, and which Is Not Tightened Down

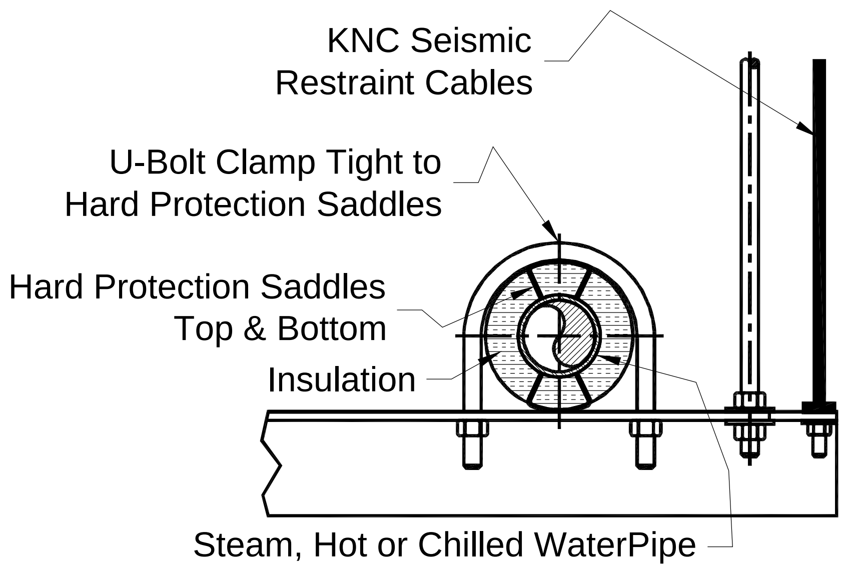

Figure I3-33; Longitudinal (L) Cable Restraint Location for Trapeze Supported Steam Line, or Hot or Chilled Water Line – Insulated Pipe Is Trapped in the Longitudinal Direction and Uplift Is Prevented by a U-Bolt which Fits the Insulation Snuggly, and which Is Tightened Down Sufficiently to Prevent Longitudinal Motion of the Pipe Relative to the Trapeze Bar

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Figures I3-34 and I3-35 show the clamping arrangements for domestic hot water lines to a trapeze bar at the transverse and longitudinal seismic restraint location respectively. Extra care must be taken with domestic hot water piping because the pipes are usually thin wall copper tubing, or are PVC or CPVC. These pipes are easily crushed; therefore, torque values for tightening the U-Bolt clamps on the pipes supported by trapeze bars at longitudinal seismic restraint locations must be closely monitored.

There will probably be only one longitudinal seismic restraint location per run for domestic hot water pipes, and it will typically be located in the middle of the run to balance the thermal growth in the pipe. Also, the last transverse seismic restraint location must be far enough away from a corner so that the pipes do not fail in bending when they grow in service, see Section S9.0 of this manual.

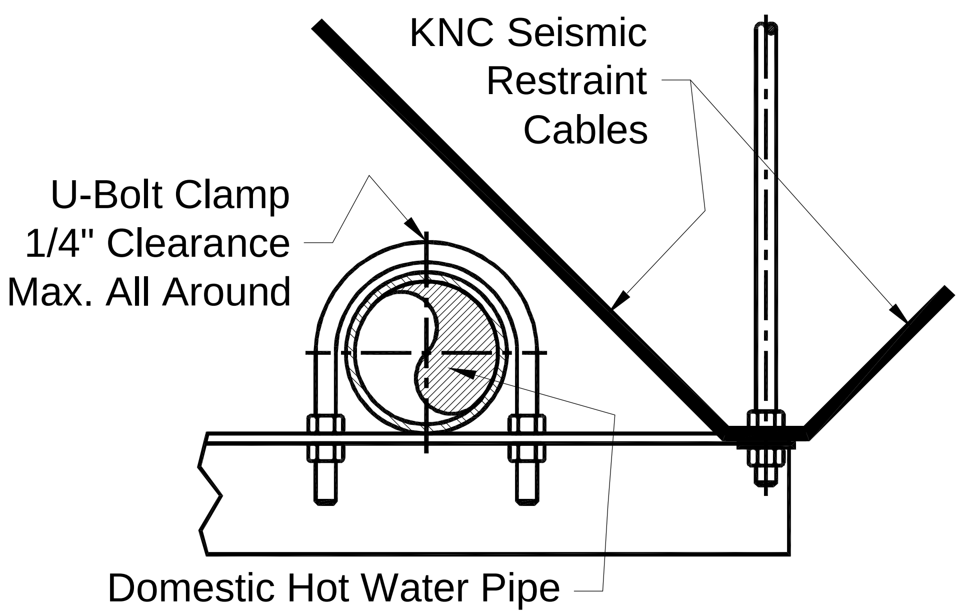

Figure I3-34; Transverse (T) Cable Restraint Location for Trapeze Supported Domestic Hot Water Line – Water Pipe Is Trapped in the Transverse Direction and Uplift Is Prevented, While Thermal Growth Is Allowed by a U-Bolt which is Slightly Wider Than the Pipe, and which Is Not Tightened Down

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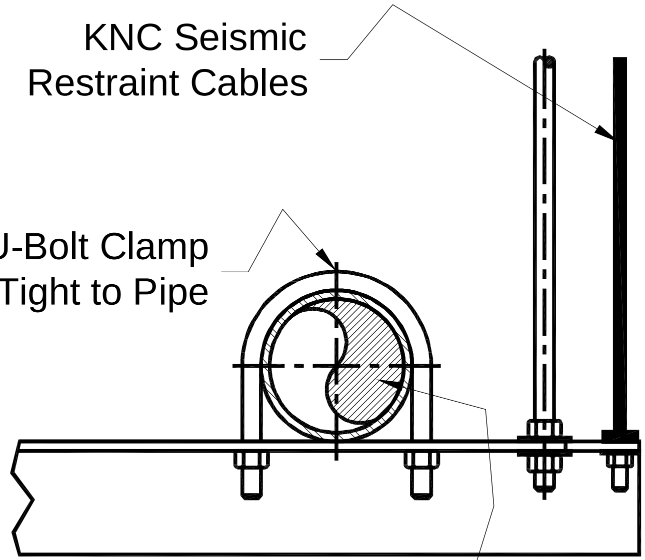

Figure I3-35; Longitudinal (L) Cable Restraint Location for Trapeze Domestic Hot Water Line – Water Pipe Is Trapped in the Longitudinal Direction and Uplift Is Prevented by a U-Bolt Which Fits the Pipe Snuggly, and Which Is Tightened Down Sufficiently to Prevent Longitudinal Motion of the Pipe Relative to the Trapeze Bar

I3.14 – Summary for Seismic Cable Restraints for Piping:

1. The schematics and arrangements presented in this section are intended to be used as guidelines for the installation of seismic restraints for piping. They do not represent fully engineered designs for specific projects. The specific design details of each installation are the responsibility of the design professional of record for the systems that are being installed.
2. A ***minimum of two seismic restraint cables acting 180° apart*** are required for each transverse and each longitudinal seismic restraint location.
3. When locating and specifying seismic restraints for a project, Kinetics Noise Control will list the minimum required number of seismic restraint kits required under ideal conditions for the project. The actual installation circumstances may require additional restraint kits at certain locations.

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4. Clevis hangers, trapeze bars, and hanger rods at seismic restraint locations must be properly sized and specified by the design professional of record for the system to handle the expected seismic forces as well as the dead weight loads from the pipe.
5. Attachment of seismic restraints to the piping, clevis hangers, trapeze bars, and hanger rods must be approved by the design professional of record for the system.
6. For floor or roof mounted pipe where the restraints are installed as shown in Figure I3-26, the anchors attaching the stand or support to the building structure form part of the seismic load path. As such, these anchors must be seismically rated anchors for use in cracked concrete, and must have a current ICC-ESR number.
7. Attachment of seismic restraints to the building structure must be approved by the structural engineer and/or the architect or record.

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CABLE RESTRAINT SCHEMATICS FOR DUCT

I4.1 – Introduction:

This section will present several basic schematics for the seismic cable restraints for duct. The figures and descriptions in this section will be based on the Kinetics Noise Control drawings SS-20070957 and SS-20070958 titled Cable Restraint Schematics for Duct – Sheets A1 and A2 respectively. There are several drawings in this specific series. They have been designed to aid the installing contractor with the installation of seismic cable restraints for pipe and duct. Each drawing has a number designation ranging from SS-20070950 through SS-20070959. Also each drawing is specified by a particular letter designation ranging from Sheet A though Sheet H. The drawing numbers are in no particular order. However, the letter designations are in strict alphabetical order. Each of the drawings in this series has several views on each sheet designated by a specific letter. Where the figures in this section correspond with those views on the Kinetics Noise Control drawings SS-20070950 through SS-20070959 they will be cross referenced by sheet letter and figure letter, for instance Sheet A1 – View H.

The schematics in this section are intended to be a quick guide for planning and inspection purposes. The details on making structural connections and duct attachments for the seismic restraint cables and components are covered in Sections I5.0 and I6.0 respectively. Hanger rod stiffeners may be required at for hanger rods at seismic restraint locations to prevent buckling of the hanger rod under the seismic uplift conditions. They not addressed in this section, but are covered in Section I8.0. Also, duct supported on isolation hangers is not shown in this document. The seismic restraint schematics and attachments for isolated and non-isolated duct are identical. However, the isolation hangers must receive special treatments that are described in Section I1.7 of this manual.

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I4.2 – Transverse (T) Cable Restraint Schematics for Rectangular and Square Duct:

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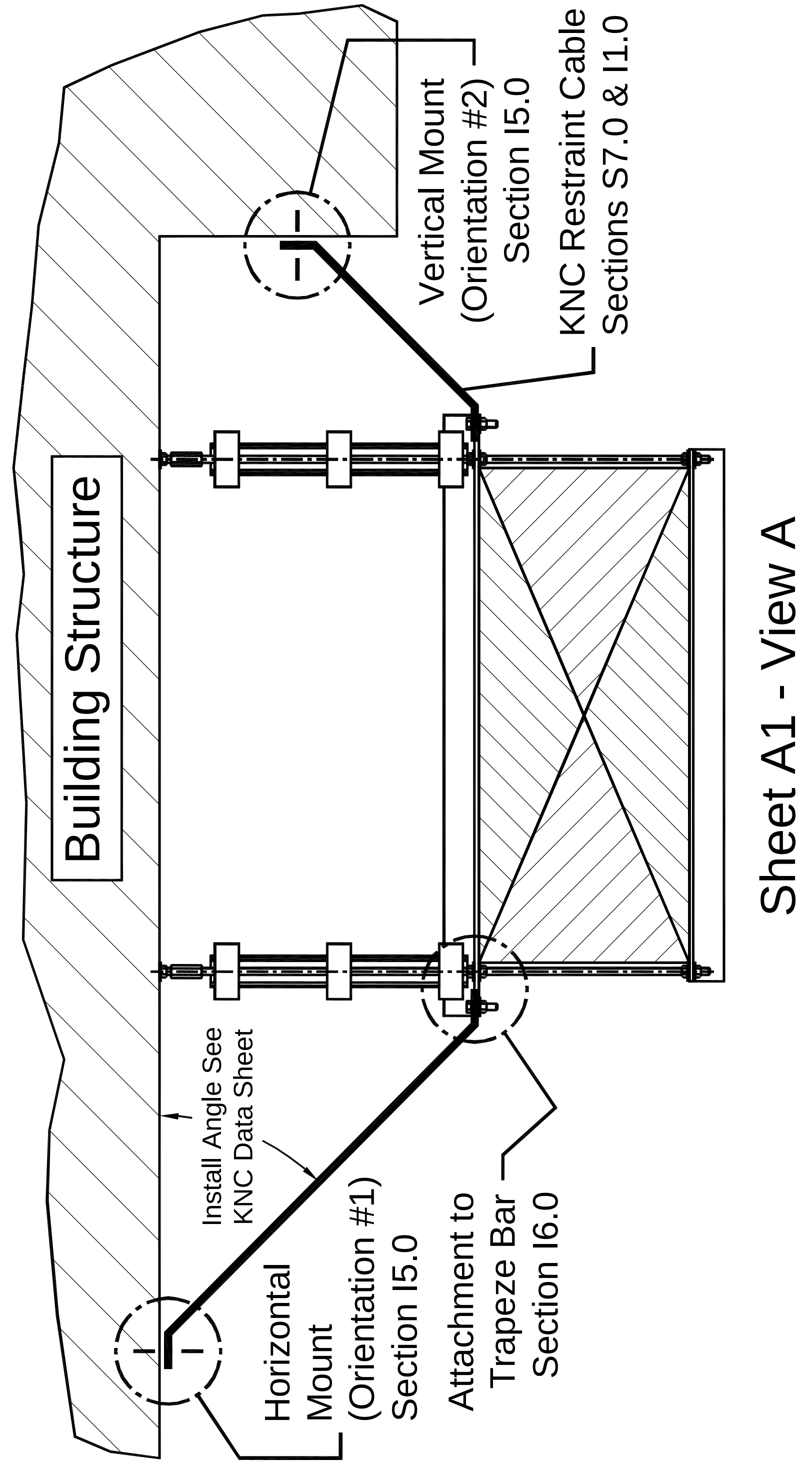

Figure I4-1; Transverse (T) Cable Restraint Schematic Arrangement for Trapped Rectangular Duct – One Restraint at Each Hanger Location Directed Outward from the Top Trapeze Bar

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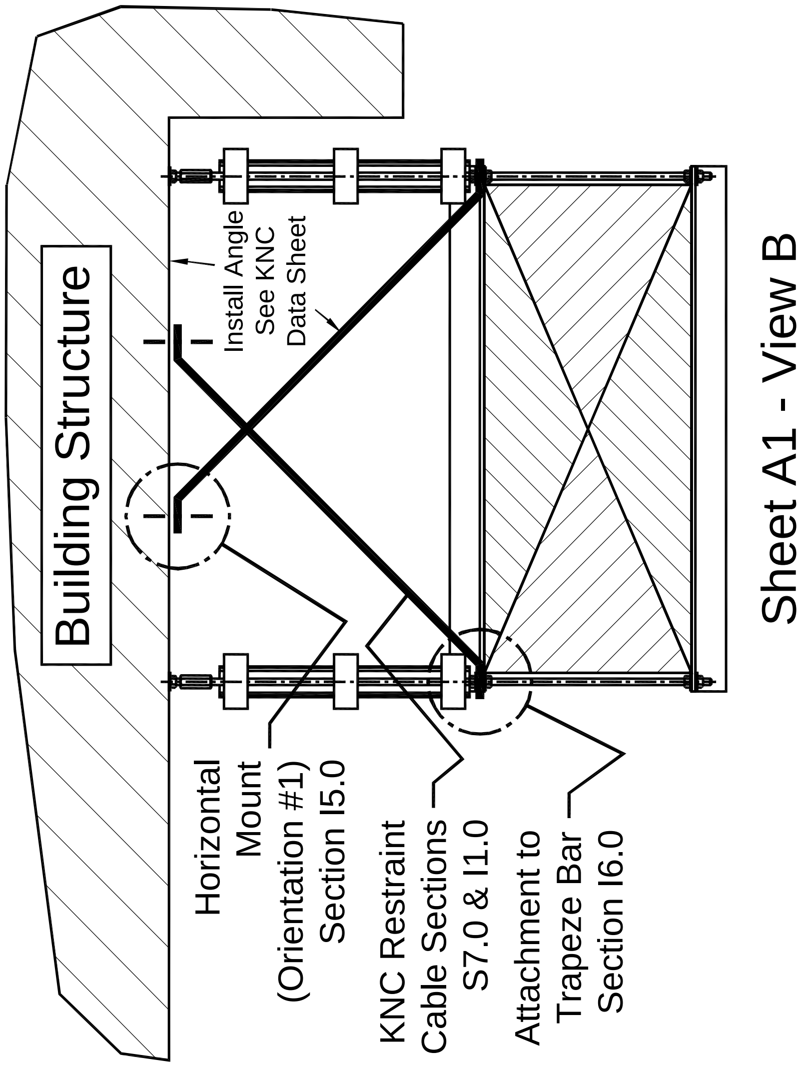

Figure I4-2; Transverse (T) Cable Restraint Schematic Arrangement for Trapped Rectangular Duct – One Restraint at Each Hanger Location Directed Inward & Crossing Over the Top of the Duct from the Top Trapeze Bar

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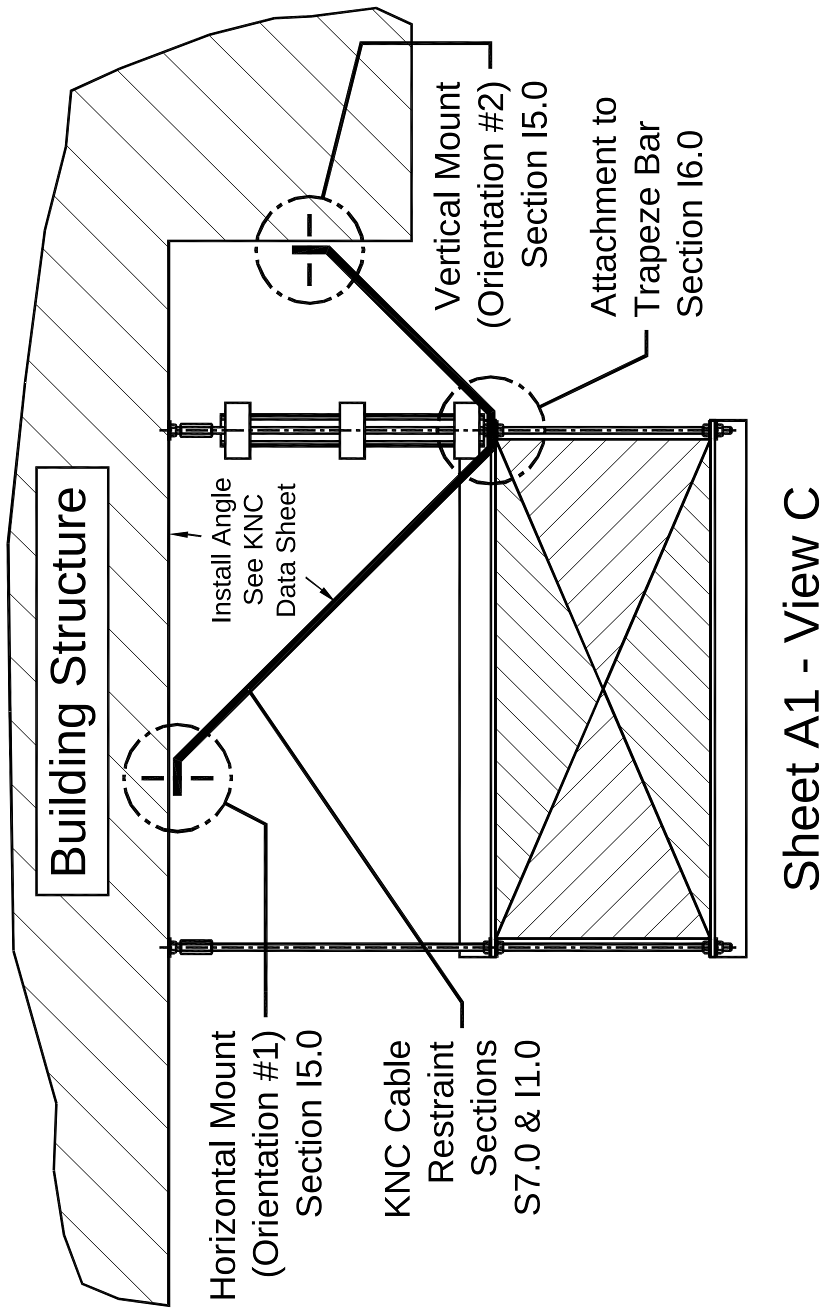

Figure I4-3; Transverse (T) Cable Restraint Schematic Arrangement for Trapped Rectangular Duct – Two Restraints at One Hanger Location with One Restraint Directed Inward & One Restraint Directed Outward from the Top Trapeze Bar

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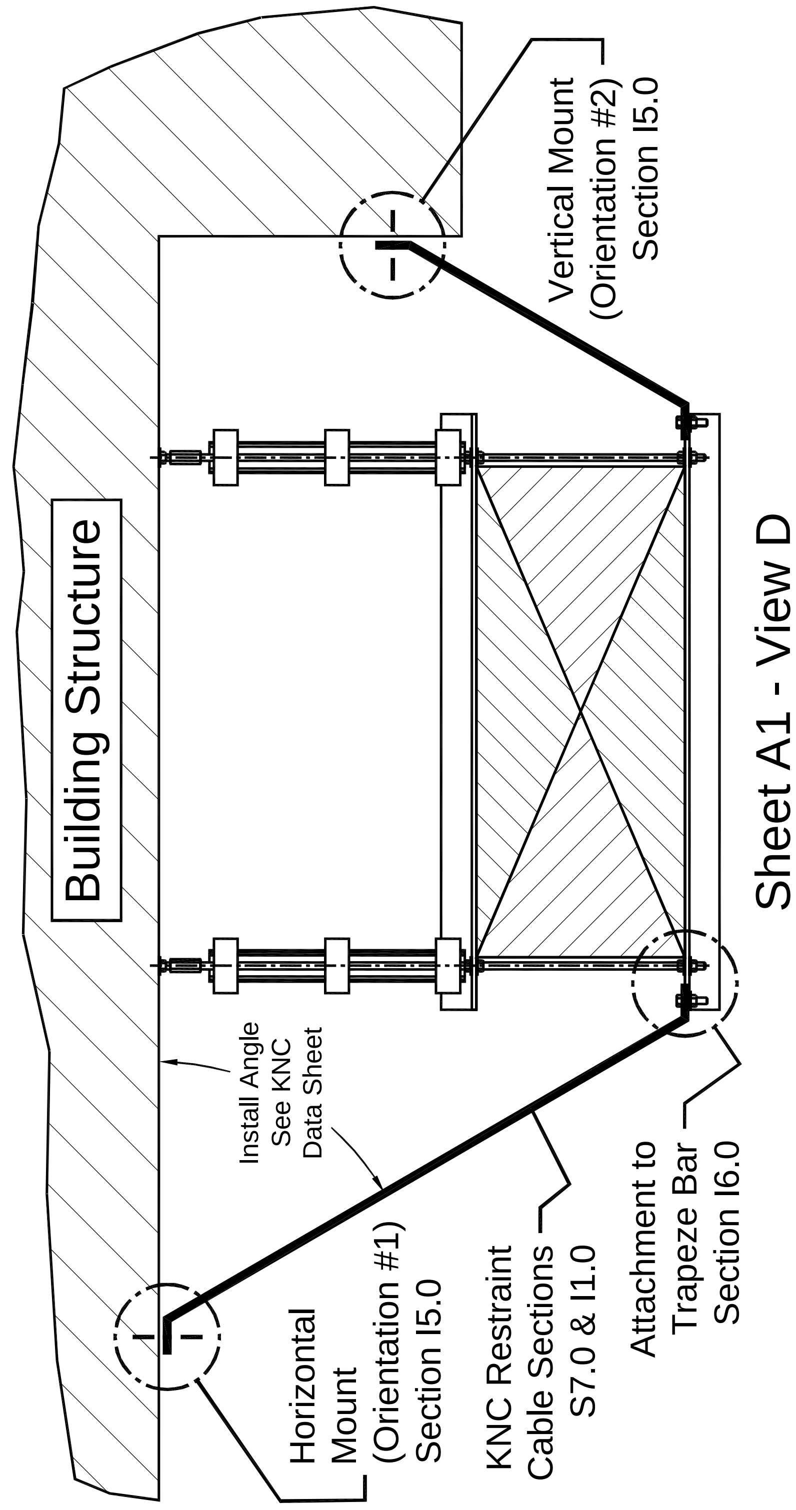

Figure I4-4; Transverse (T) Cable Restraint Schematic Arrangement for Trapped Rectangular Duct – One Restraint at Each Hanger Location Directed Outward from the Bottom Trapeze Bar

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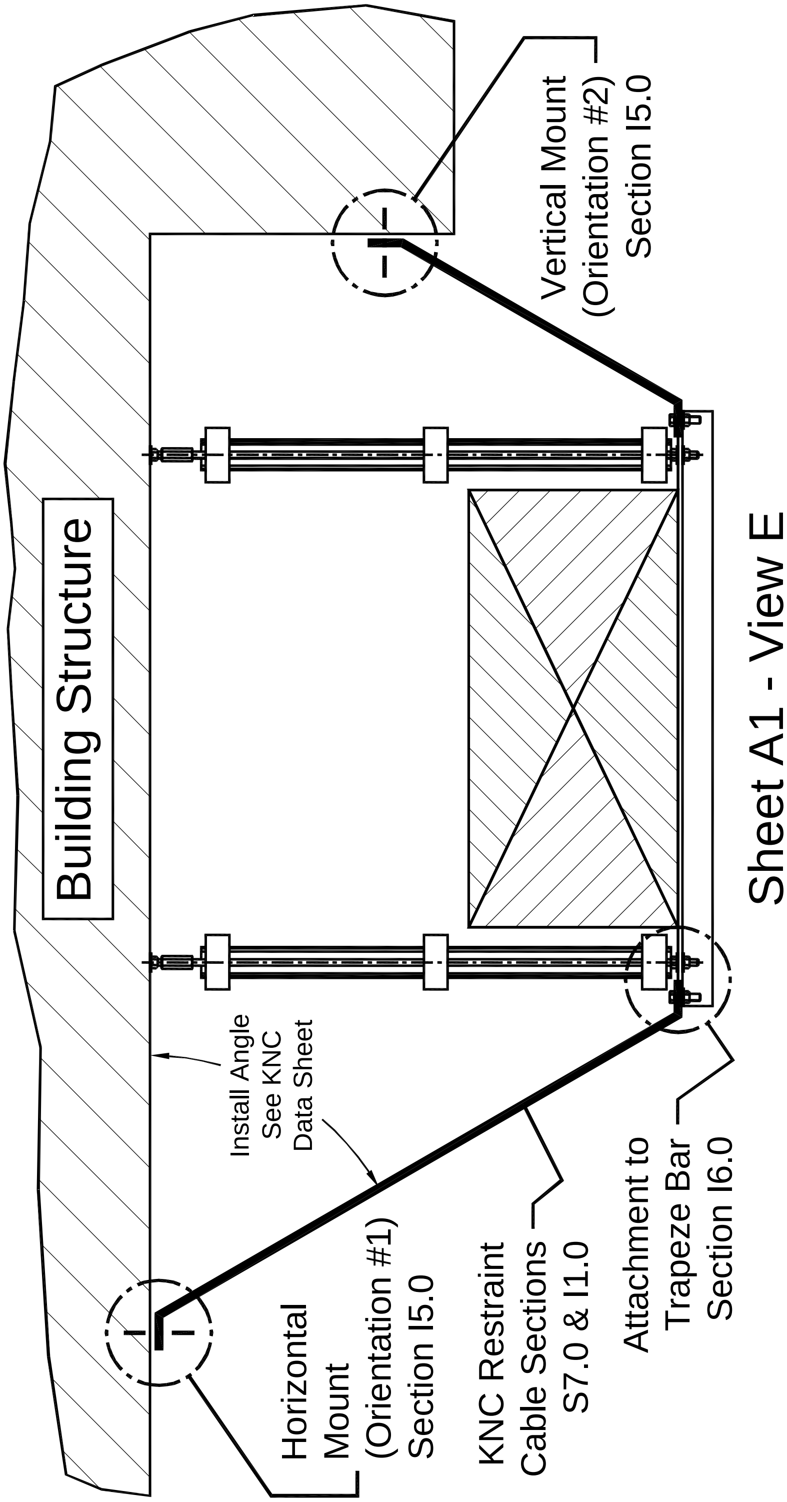

Figure I4-5; Transverse (T) Cable Restraint Schematic Arrangement for Supported Rectangular Duct – One Restraint at Each Hanger Location Directed Outward from the Trapeze Bar

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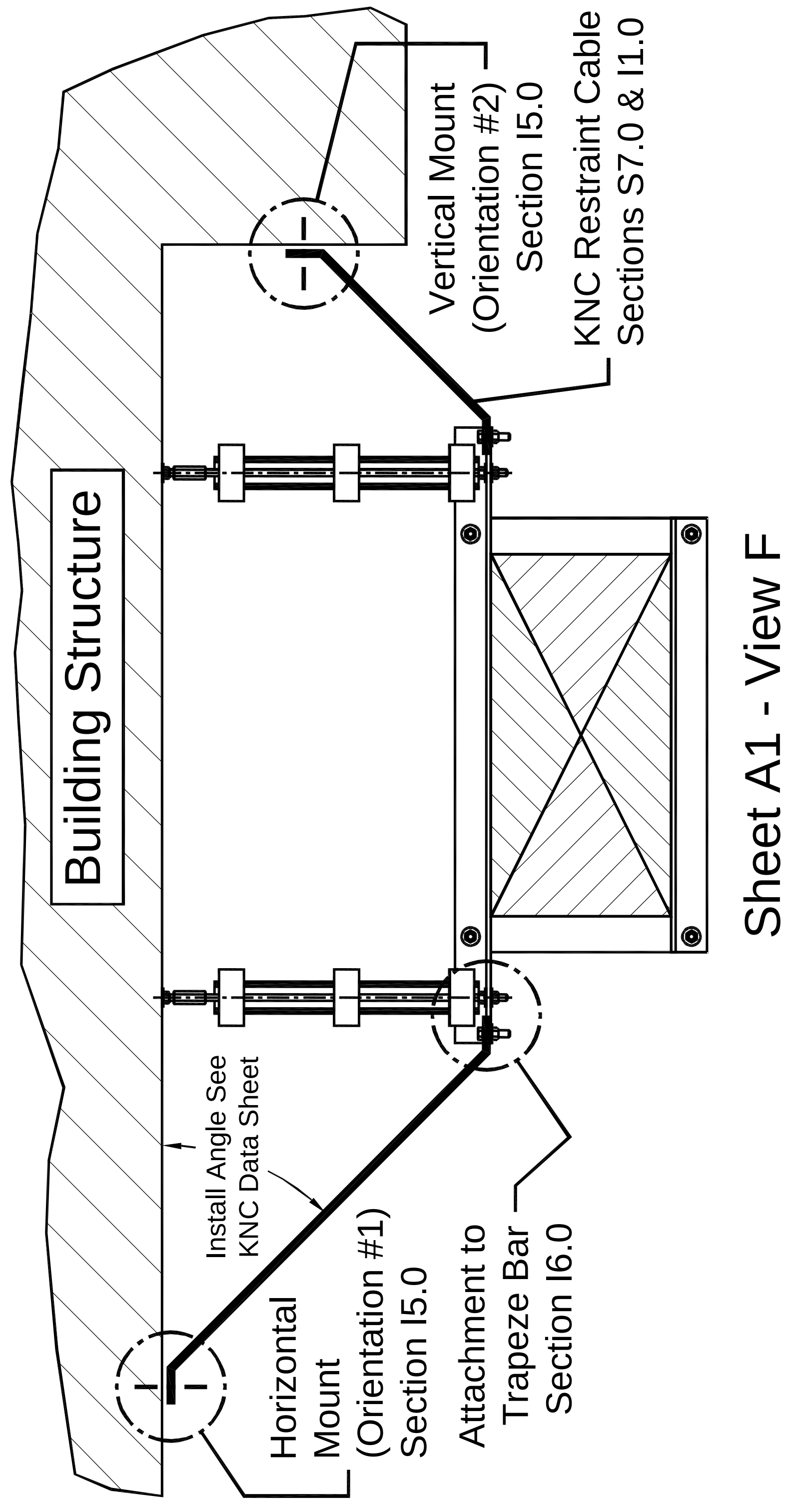

Figure I4-6; Transverse (T) Cable Restraint Schematic Arrangement for Suspended Rectangular Duct – One Restraint at Each Hanger Location Directed Outward from the Trapeze Bar

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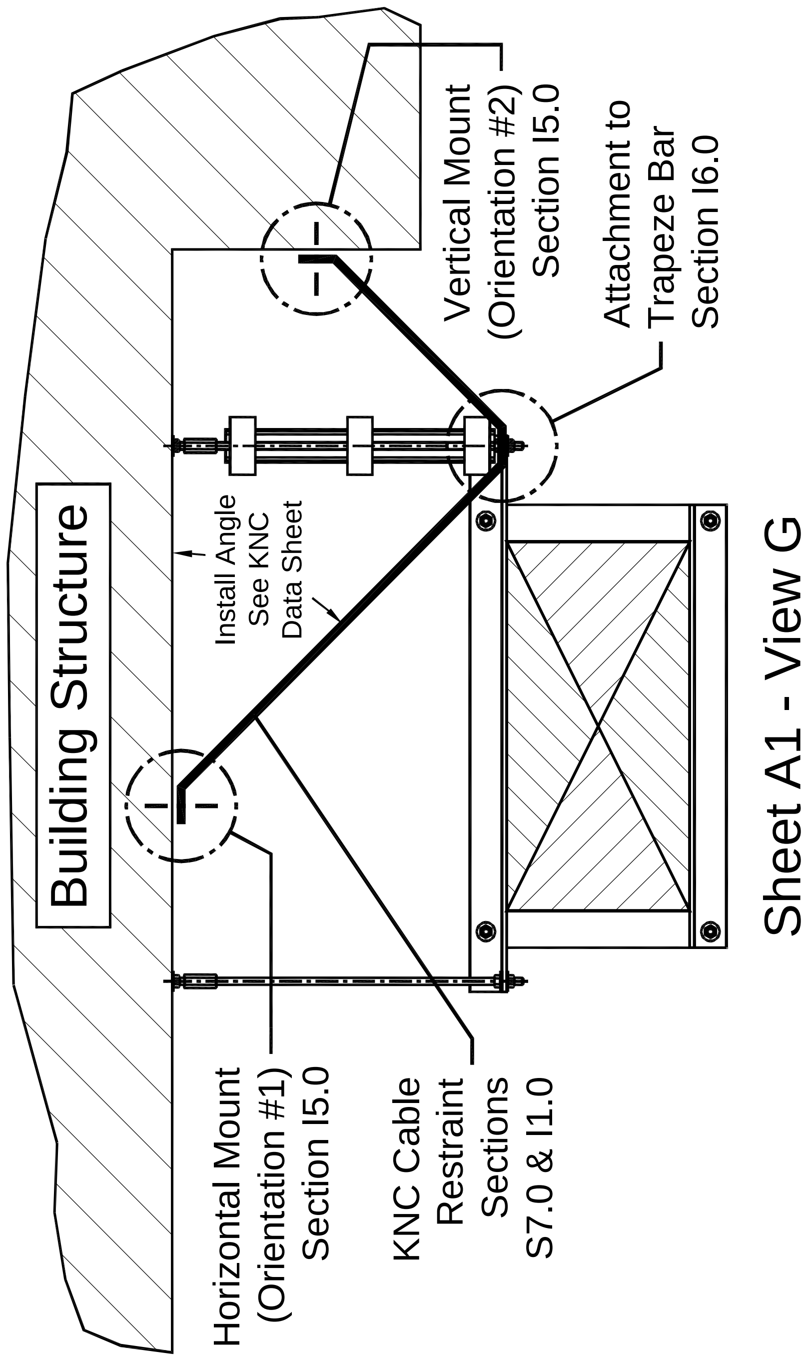

Figure I4-7; Transverse (T) Cable Restraint Schematic Arrangement for Suspended Rectangular Duct – Two Restraints at One Hanger Location with One Restraint Directed Inward & One Restraint Directed Outward from the Trapeze Bar

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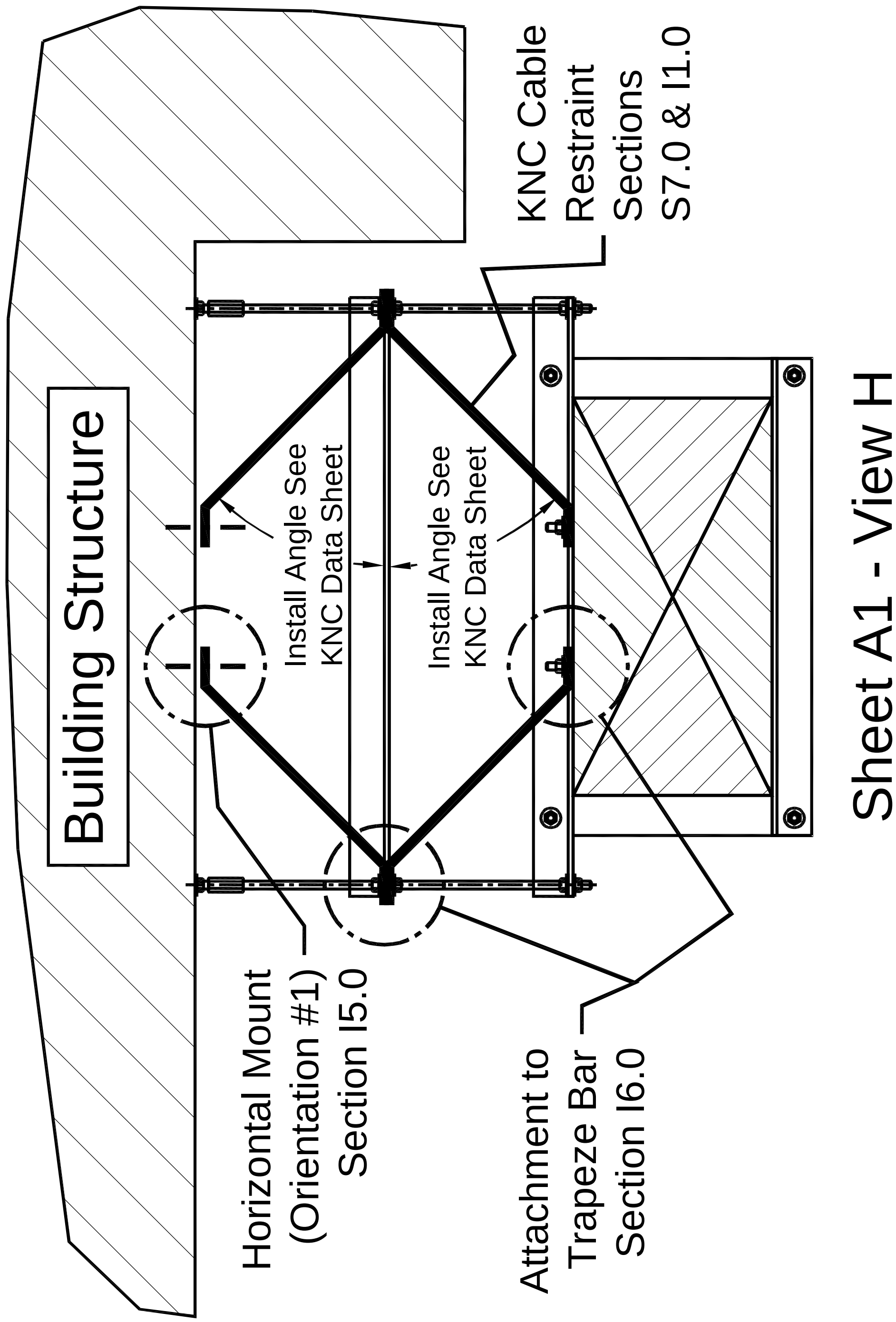

Figure I4-8; Transverse (T) Cable Restraint Schematic Arrangement for Suspended Rectangular Duct – Four Restraints Connected Through an Intermediate Trapeze Bar and Directed Inward from the Intermediate Trapeze Bar – *An Extra Restraint Kit Is Required*

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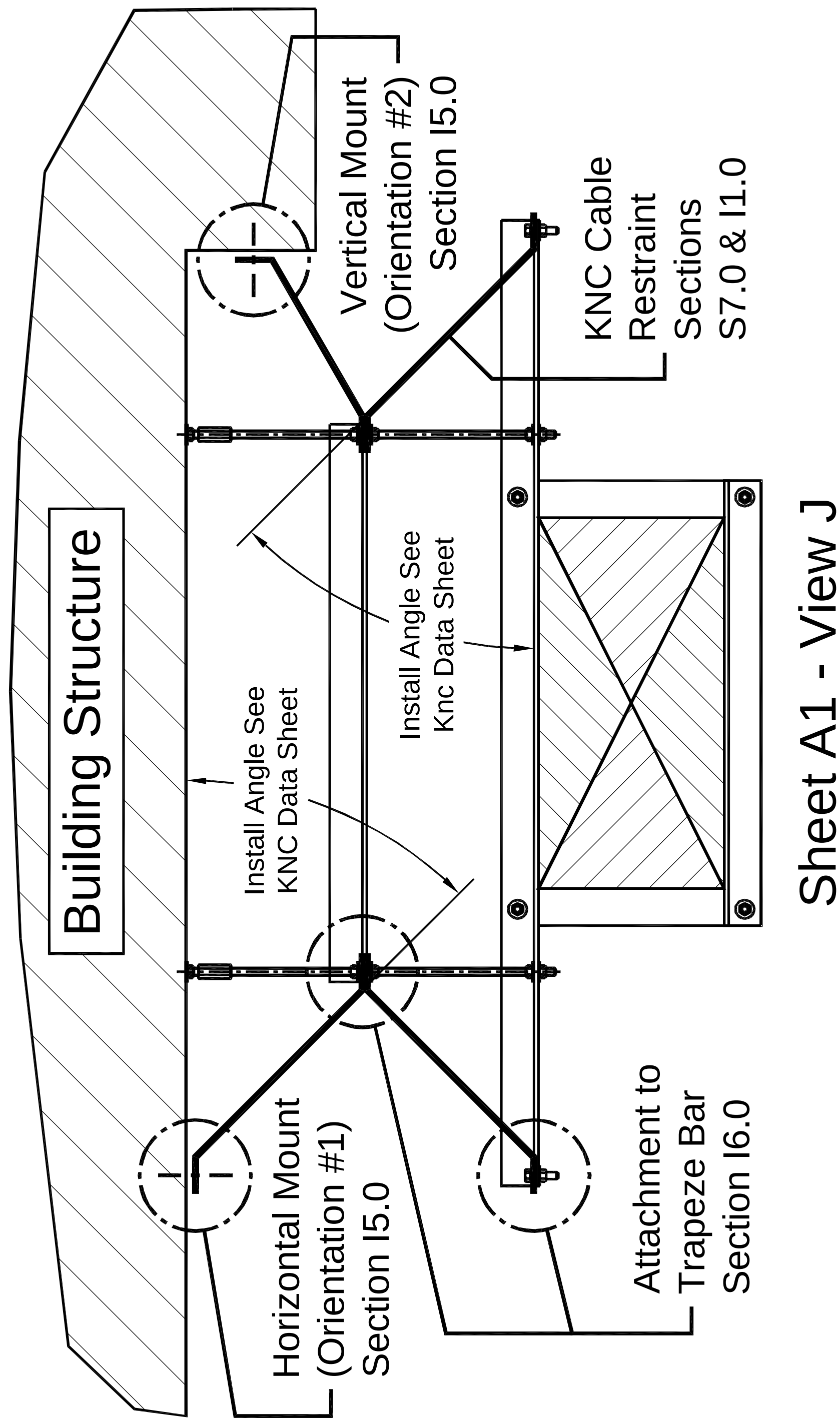

Figure I4-9: Transverse (T) Cable Restraint Schematic Arrangement for Suspended Rectangular Duct – Four Restraints Connected Through an Intermediate Trapeze Bar and Directed Outward from the Intermediate Trapeze Bar – *An Extra Restraint Kit Is Required*

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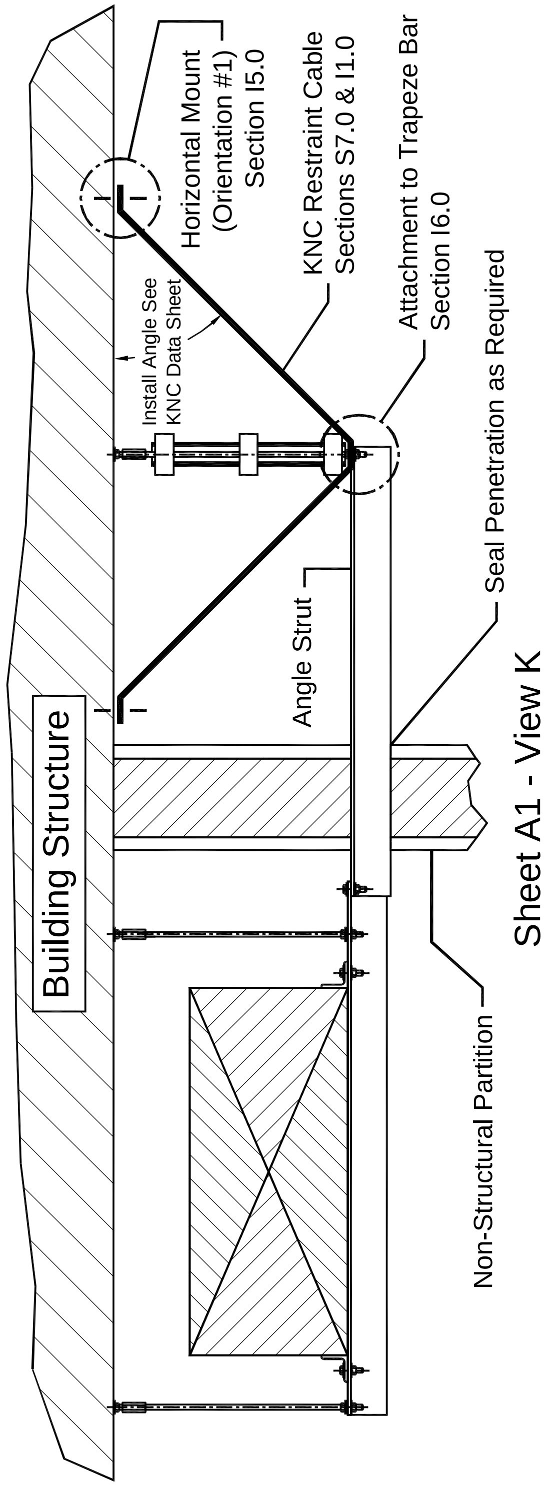

Figure I4-10; Transverse (T) Cable Restraint Schematic Arrangement for Supported Rectangular Duct – Restrained with an Angle Strut Passing Through a Non-Structural Wall Using One Pair of Restraint – Obtain Permission from the Structural Engineer & Architect before Penetrating the Wall

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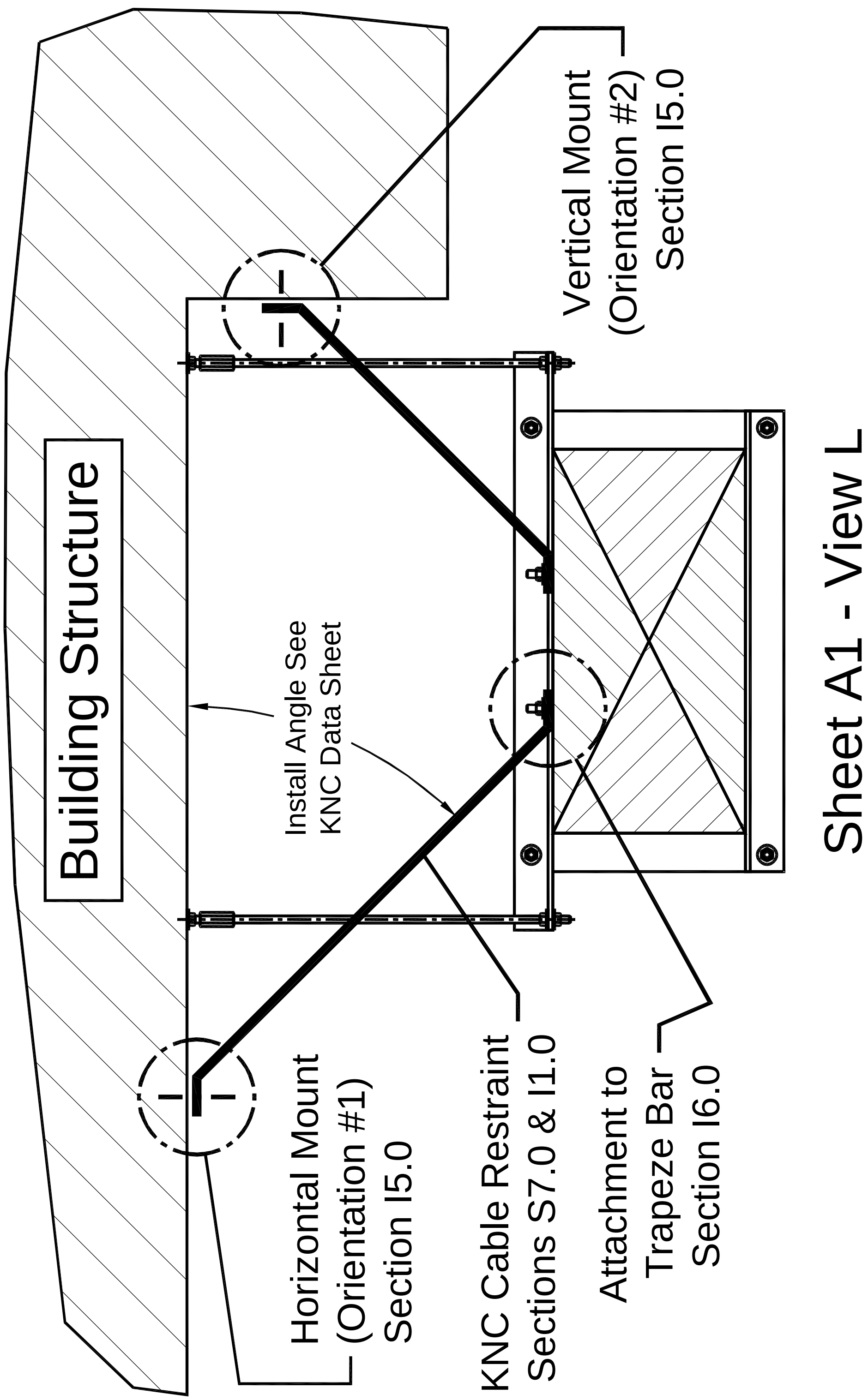

Figure I4-11; Transverse (T) Cable Restraint Schematic Arrangement for Suspended Rectangular Duct – Two Restraints Directed Outward and Attached At or Near the Center of the Trapeze Bar

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I4.3 – Longitudinal (L) Cable Restraint Schematics for Rectangular and Square Duct:

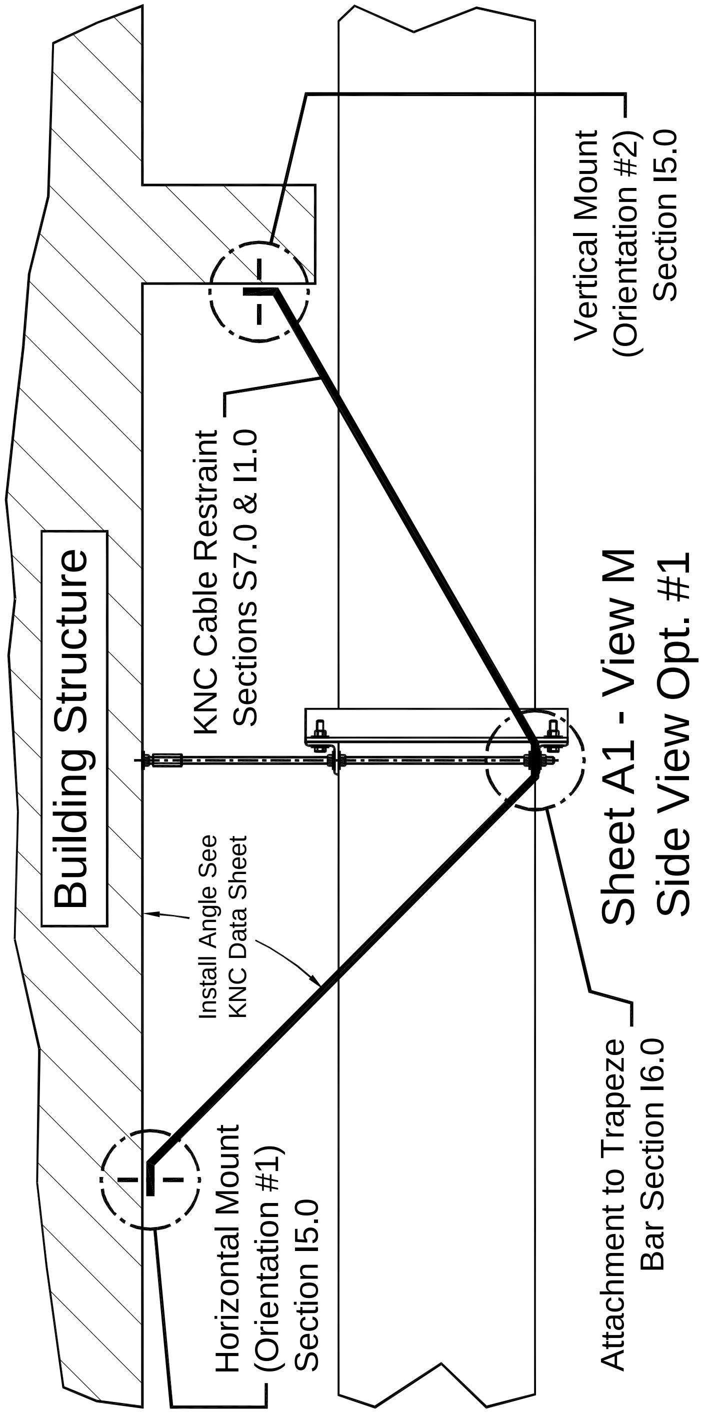

Figure I4-12: Longitudinal (L) Cable Restraint Schematic Arrangement for Rectangular Duct – Restraints Located on Each Side of the Bottom Trapeze Bar – *An Extra Restraint Kit Is Required*

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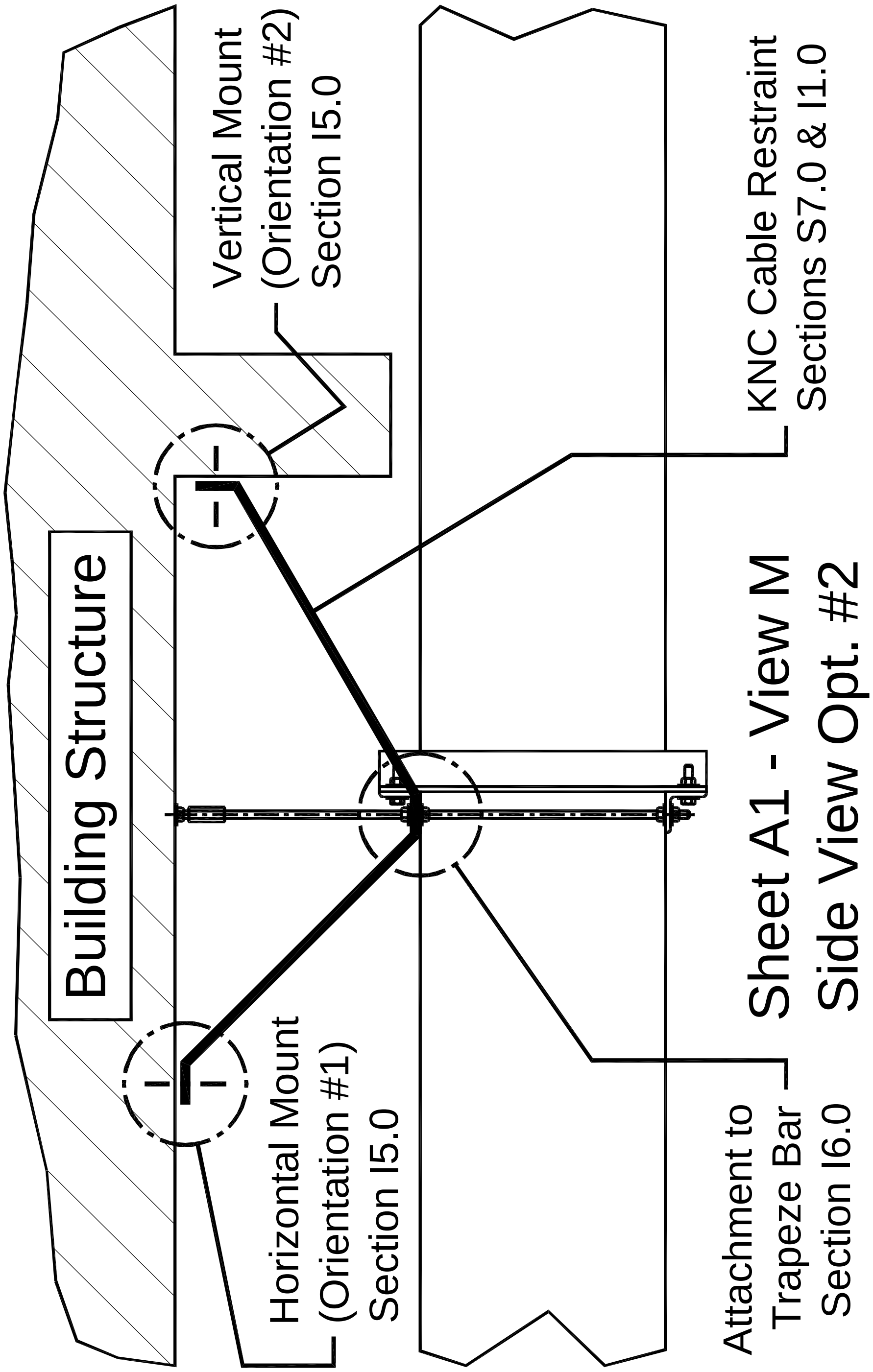

Figure I4-13; Longitudinal (L) Cable Restraint Schematic Arrangement for Trapped Rectangular Duct – 1.) Restraints Located in the Center of the Top Trapeze Bar or 2.) Restraints Located on Each Side of the Top Trapeze Bar – *An Extra Restraint Kit Is Required*

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I4.4 – Transverse (T) Cable Restraint Schematics for Round Duct:

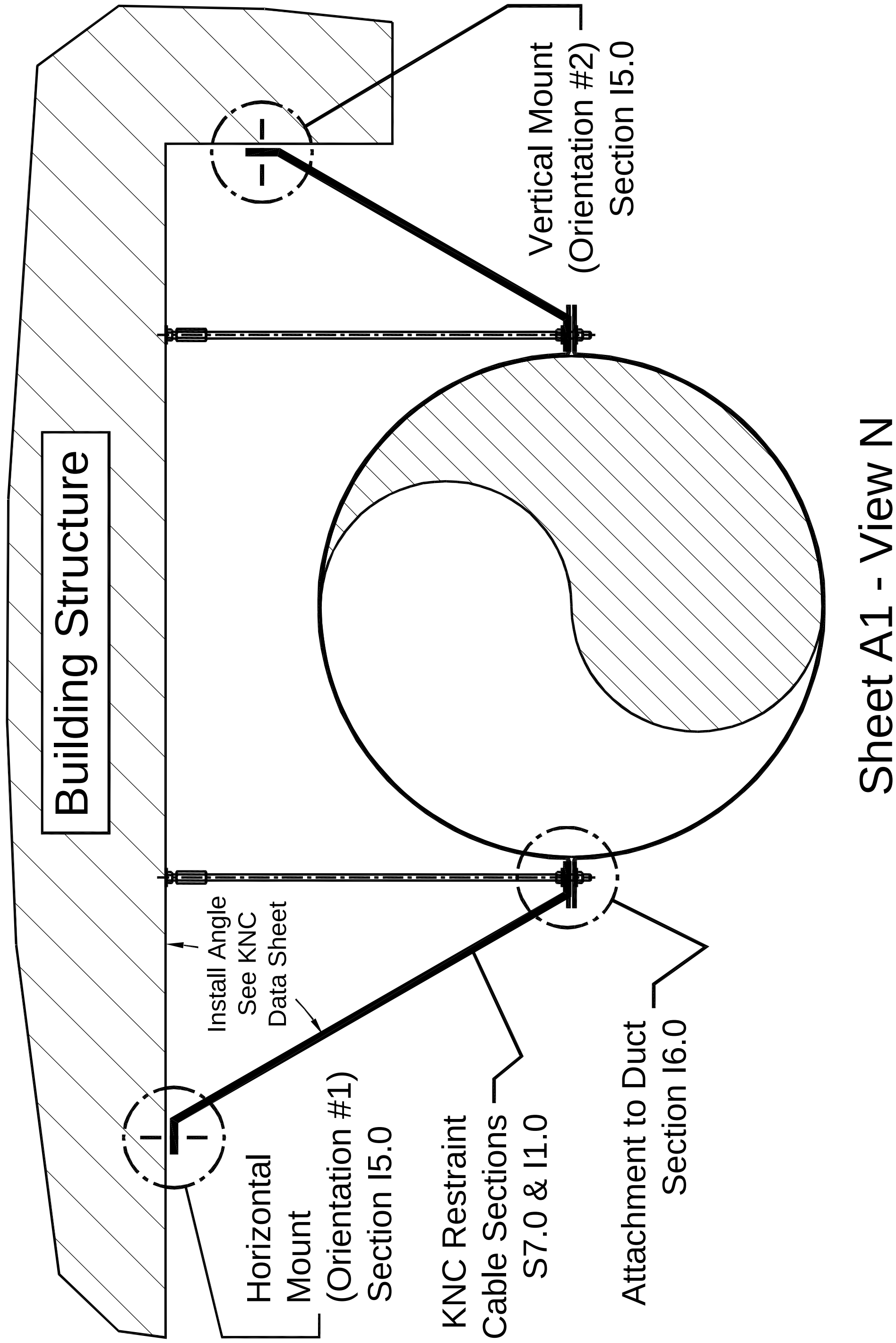

Figure I4-14; Transverse (T) Cable Restraint Schematic Arrangement for Round Duct Supported by Two Hanger Rods – One Restraint at Each Hanger Location Directed Outward

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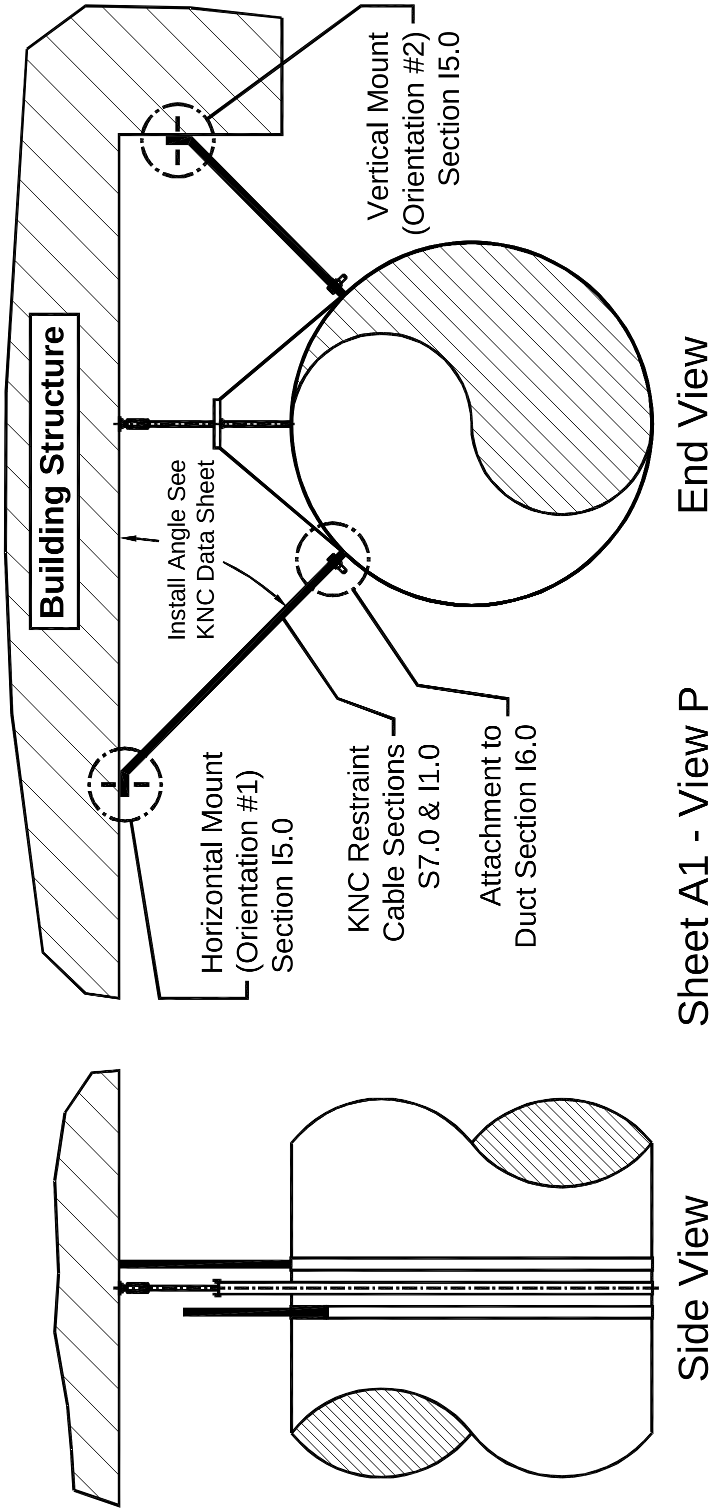

Figure I4-15; Transverse (T) Cable Restraint Schematic Arrangement for Round Duct Supported by One Hanger Rod – Two Restraints Adjacent to Hanger Rod Attached to Band Clamps

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I4.5 – Longitudinal (L) Cable Restraint Schematics for Round Duct:

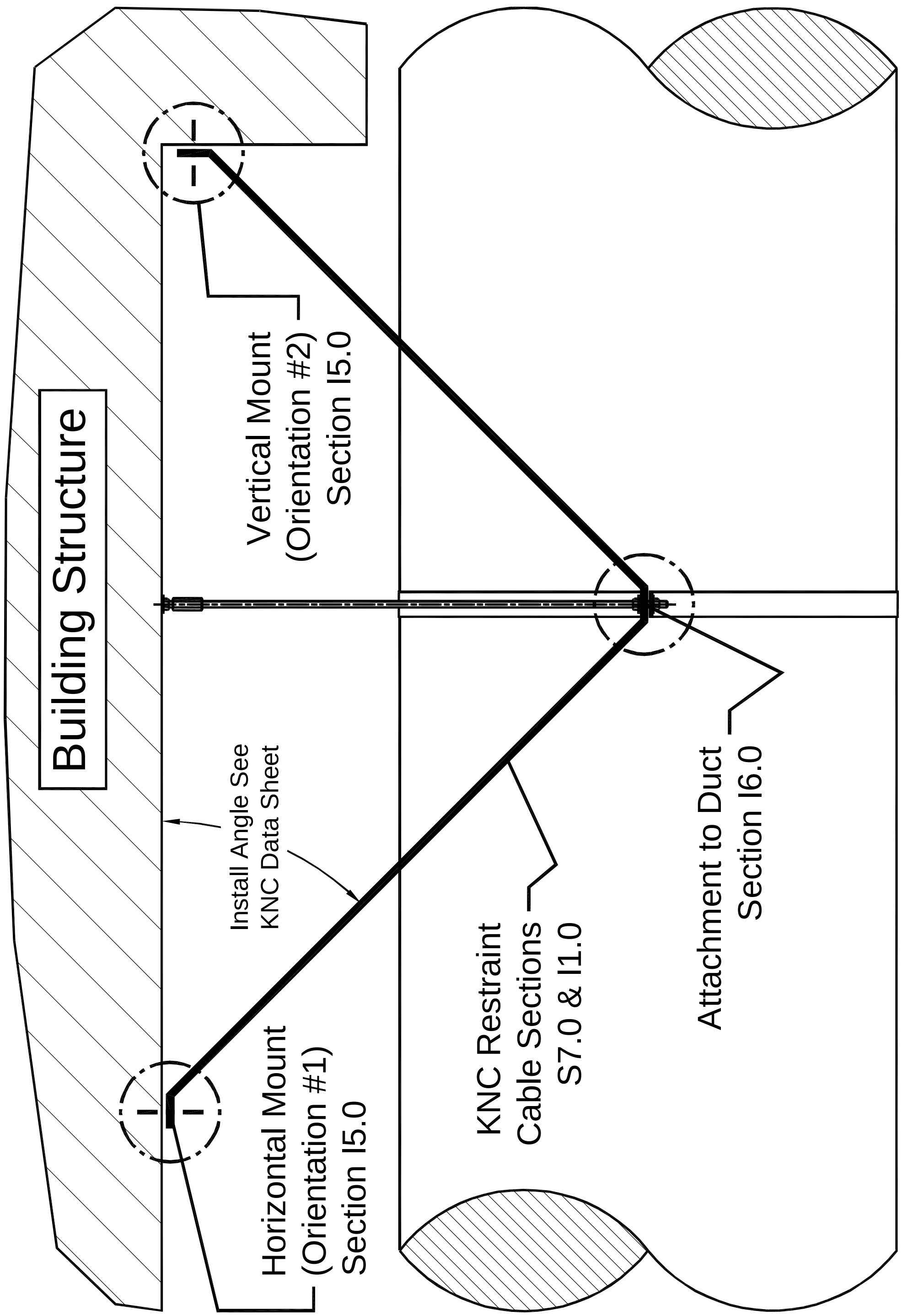

Figure I4-16; Longitudinal (L) Cable Restraint Schematic Arrangement for Round Duct Supported by Two Hanger Rods – Two Restraints at Each Hanger Location – *An Extra Restraint Kit Is Required*

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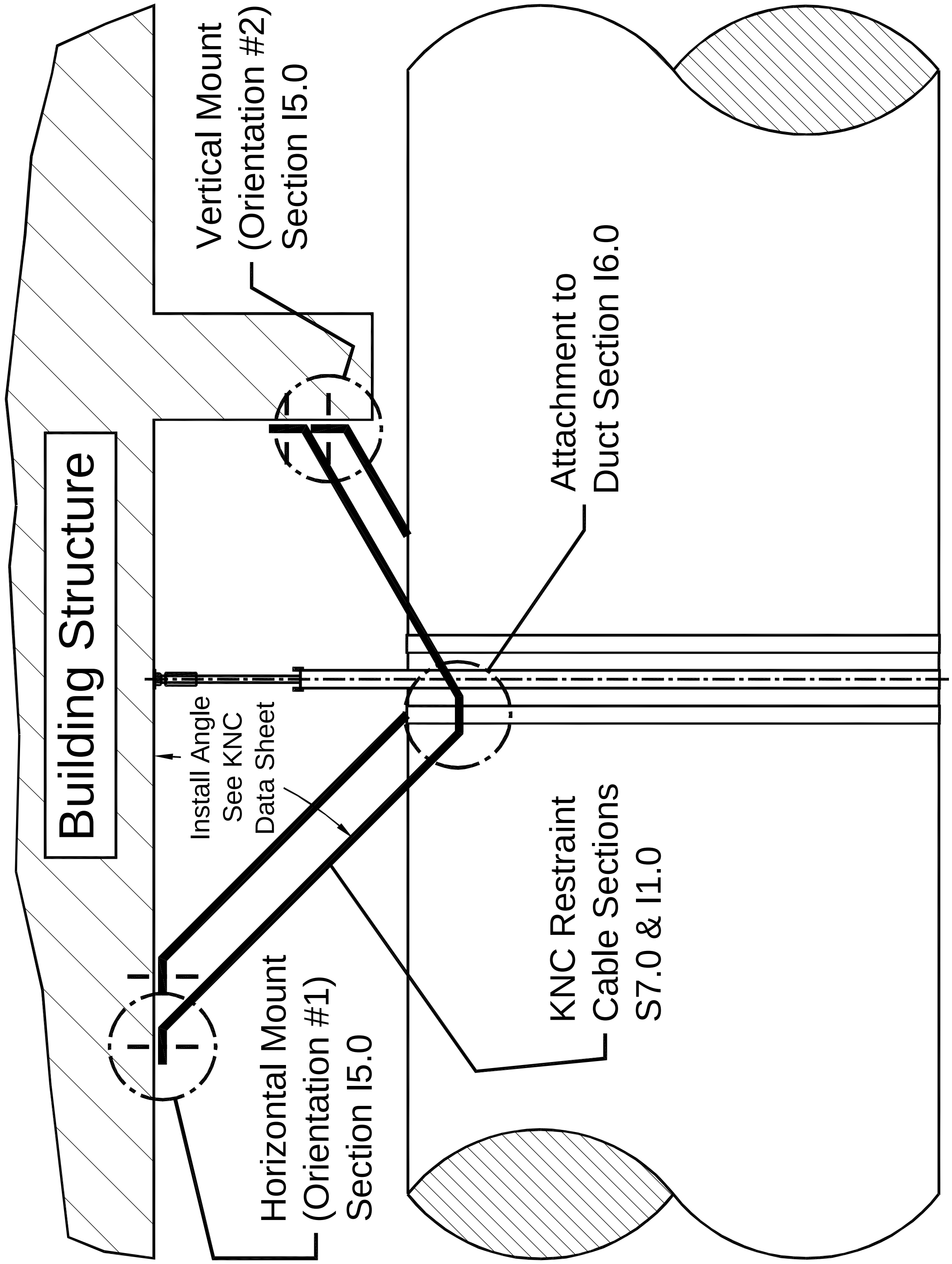

Figure I4-17; Longitudinal (L) Cable Restraint Schematic Arrangement for Round Duct Supported by One Hanger Rod – Two Restraints Adjacent to and on Each Side of the Hanger Rod Attached to Band Clamps – *An Extra Restraint Kit Is Required*

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I4.6 – Transverse (T) Cable Restraint Schematics for Floor or Roof Mounted Duct:

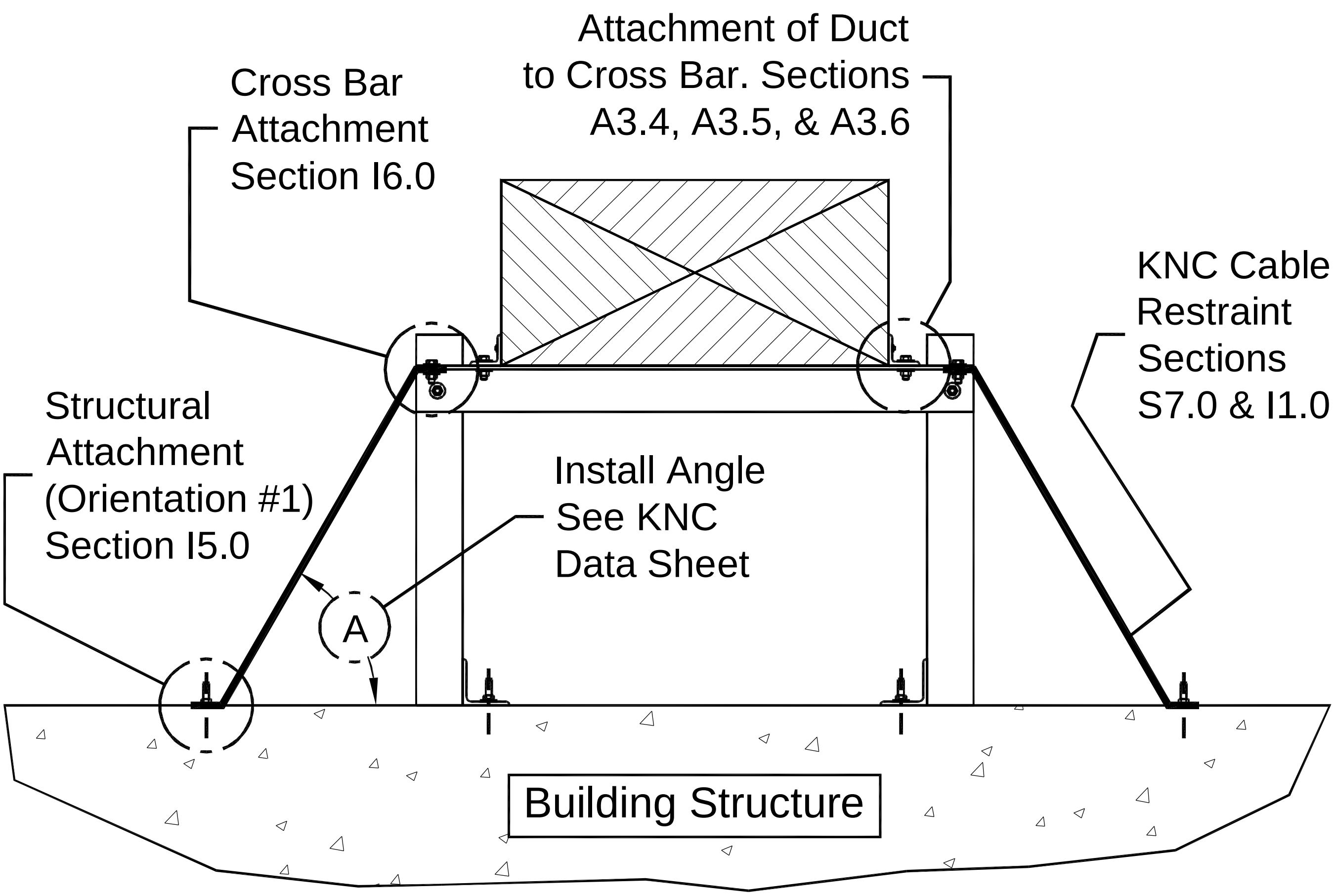

Figure I4-18; Transverse (T) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Duct – One Restraint Attached to Each Side of the Cross Bar at the Vertical Legs and Directed Outward from the Floor Stand

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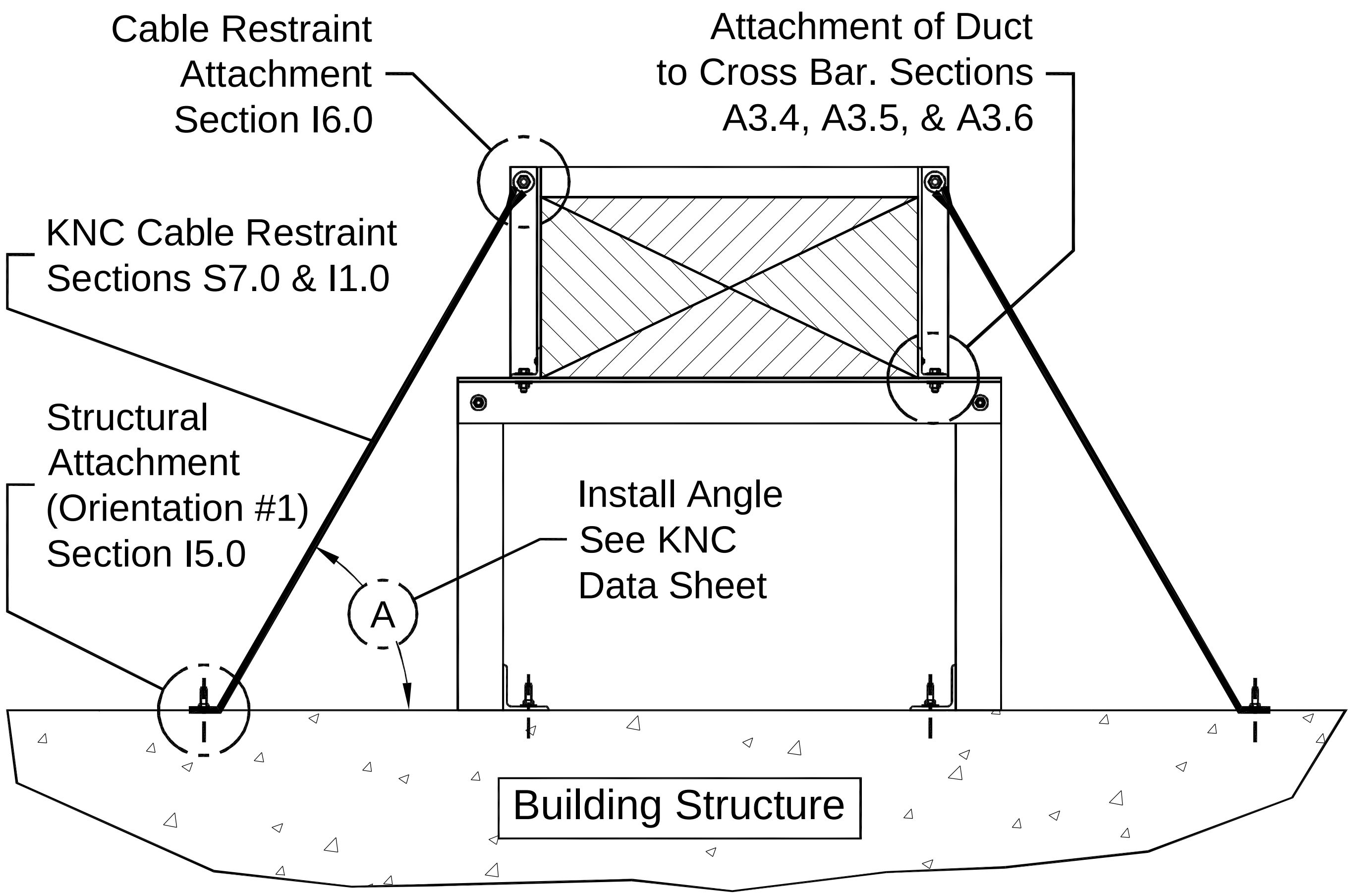

Figure I4- 19; Transverse (T) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Duct – One Restraint Attached to Each Side of the Top of the Duct and Directed Outward from the Floor Stand

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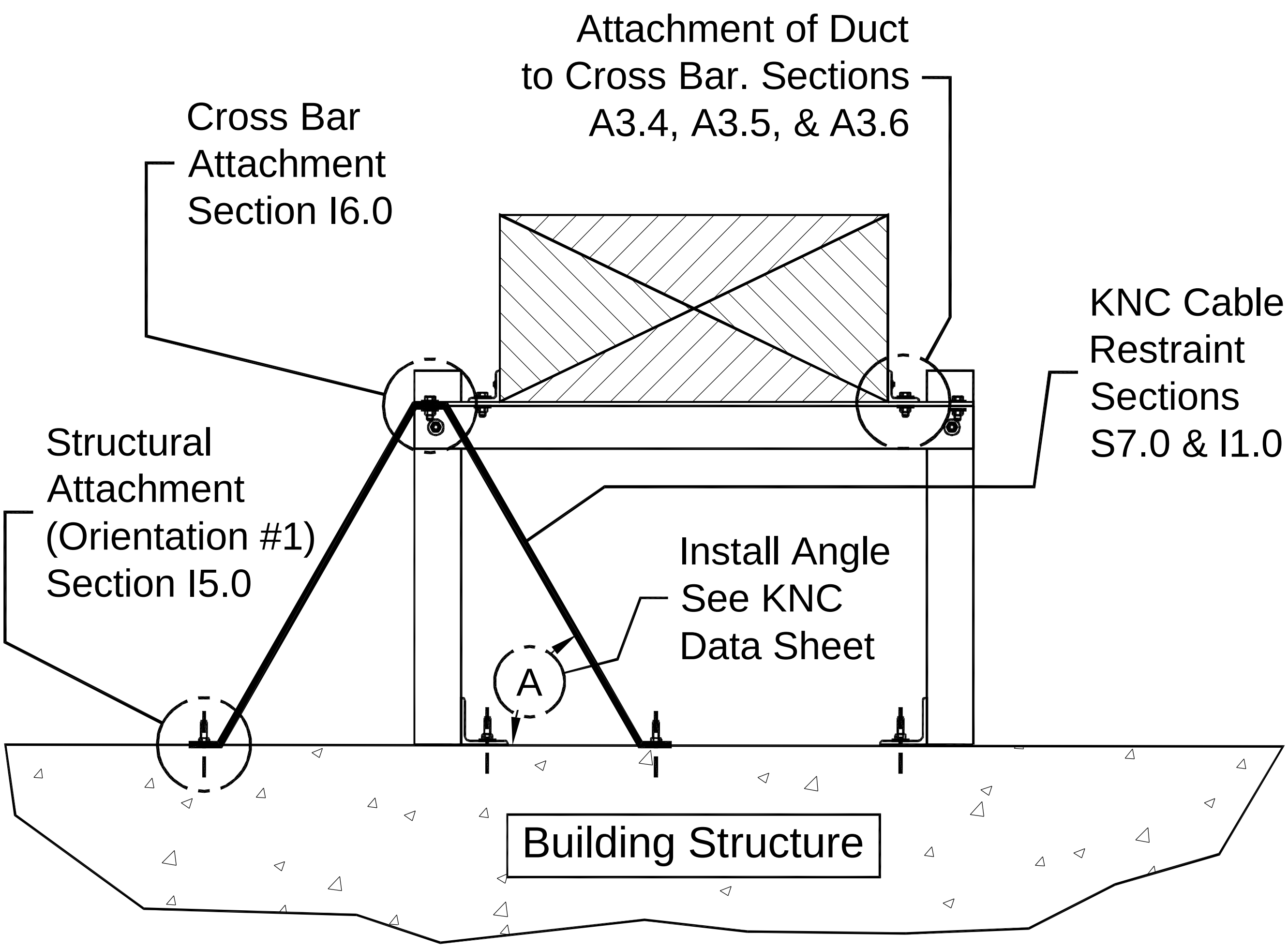

Figure I4-20; Transverse (T) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Duct – Both Restraints Attached to One Side of the Cross Bar at the Vertical Leg

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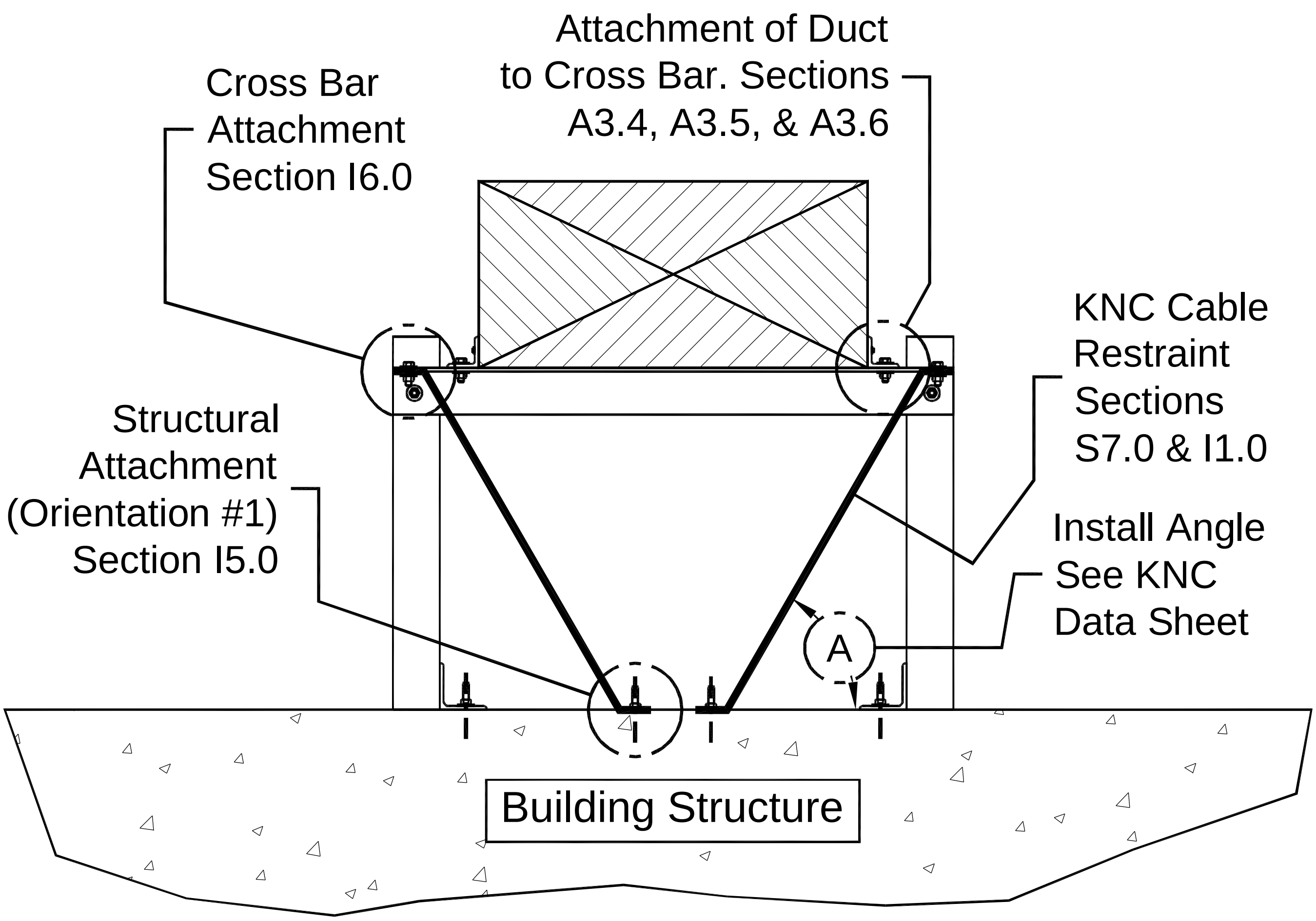

Figure I4-21; Transverse (T) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Duct – One Restraint Attached to Each Side of the Cross Bar at the Vertical Legs and Directed Inward

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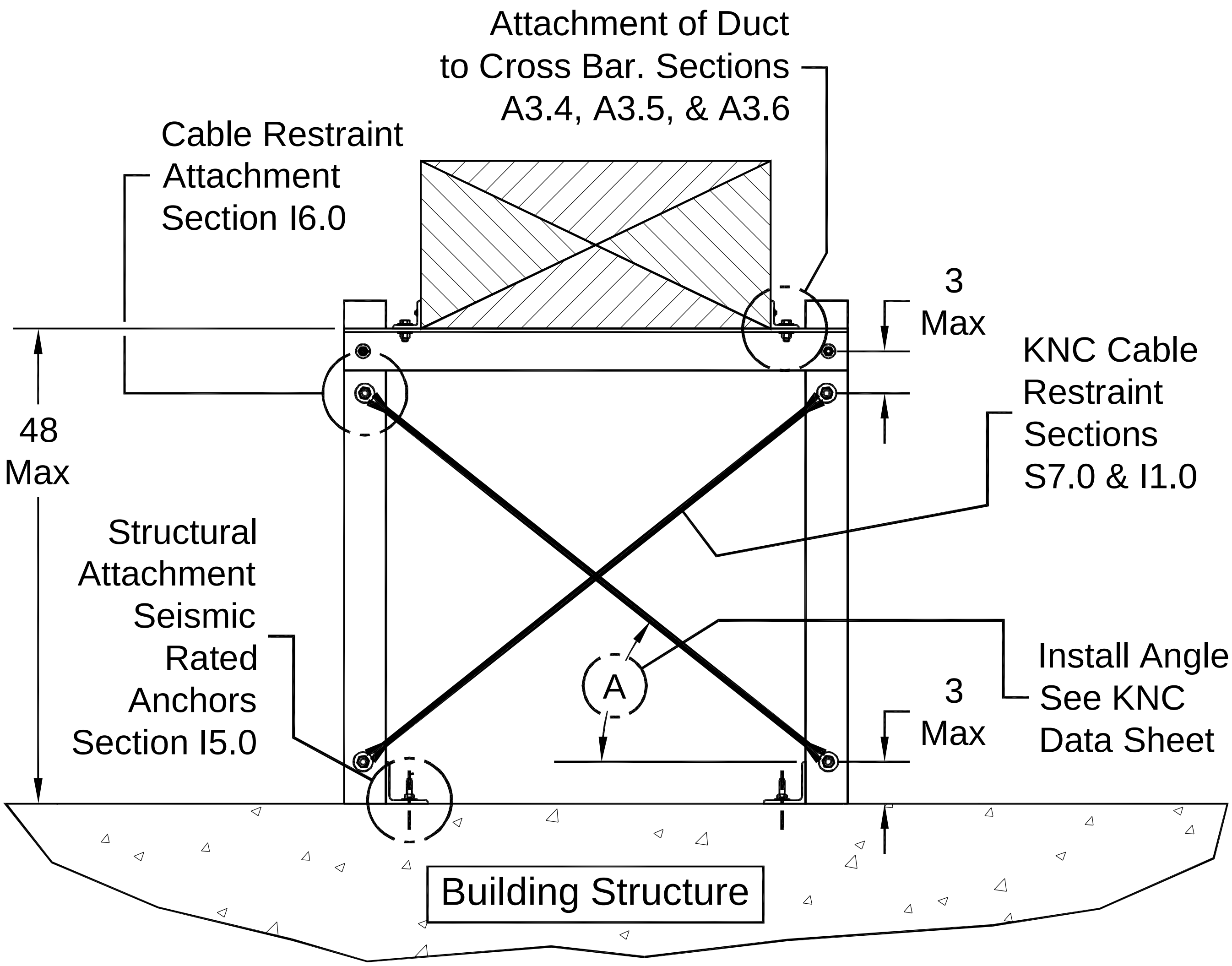

Figure I4-22; Transverse (T) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Duct – Two Restraints Attached to the Vertical Legs Acting as Cross Braces – The Anchors Attaching the Stand to the Floor Must be Seismically Rated Cracked Concrete Anchors with a Current ICC-ESR Number

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I4.7 – Longitudinal (L) Cable Restraint Schematics for Floor and Roof Mounted Duct:

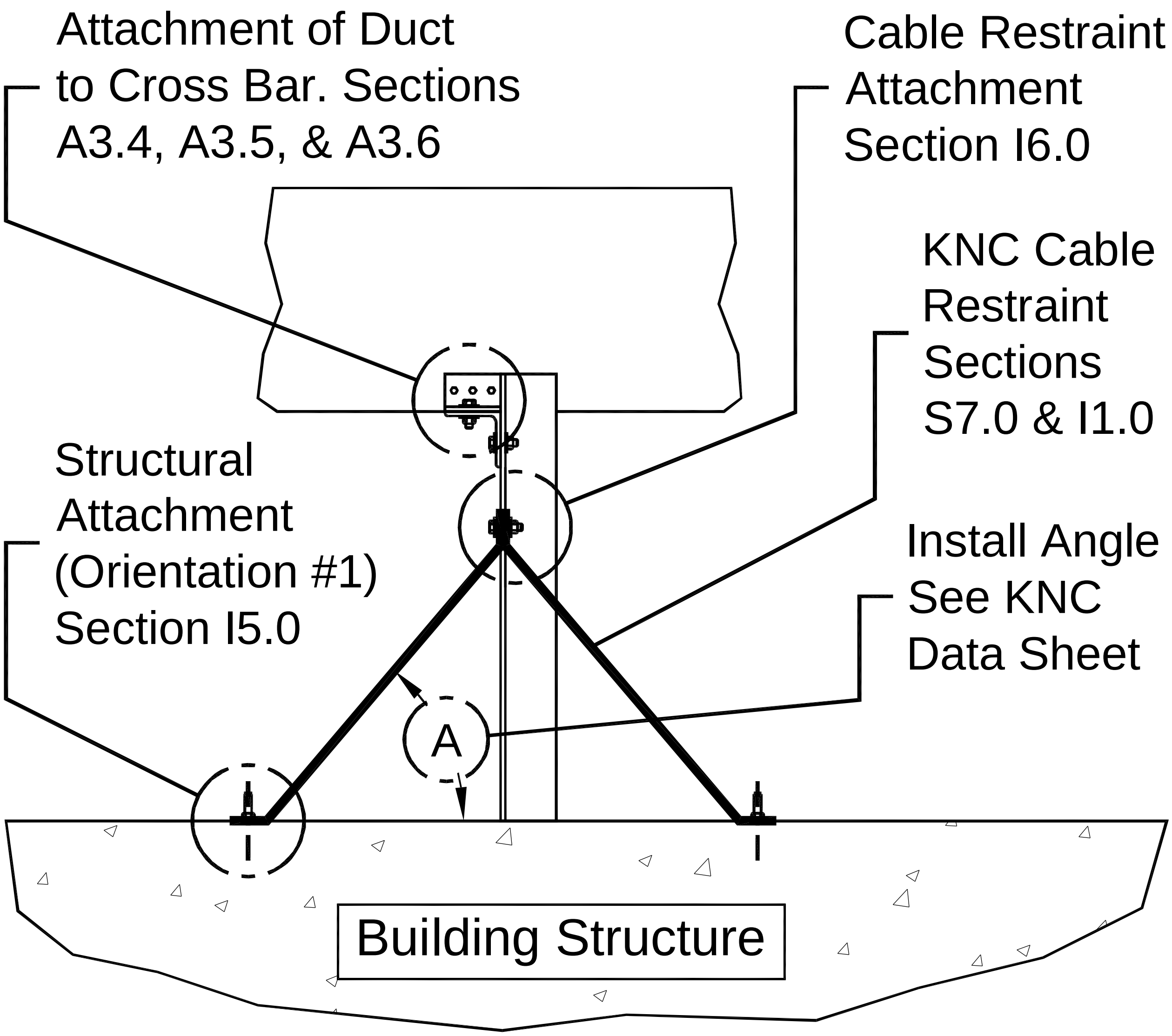

Figure I4-23; Longitudinal (L) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Duct – Restraints Attached to the Floor Stand or Support

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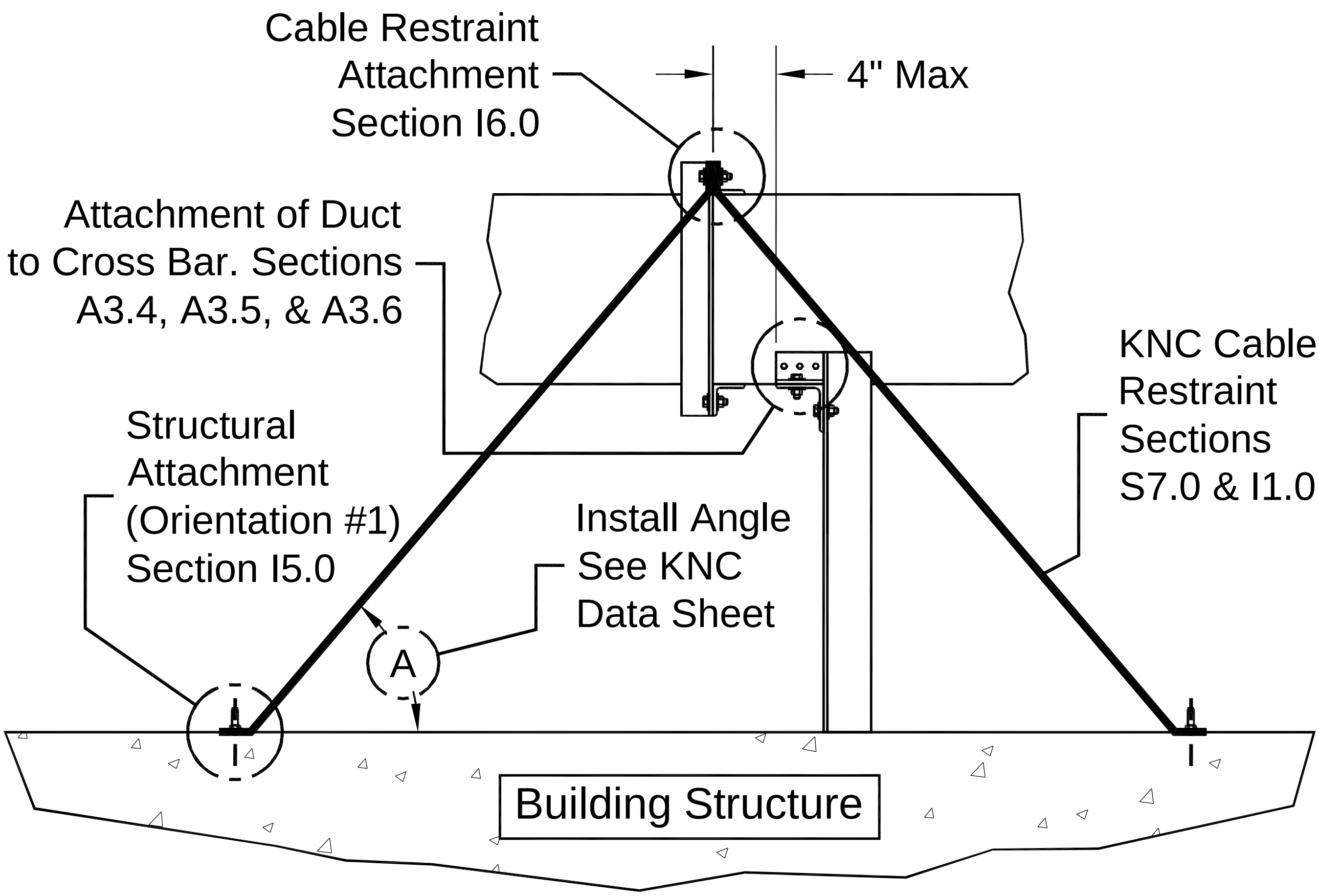

Figure I4-24; Longitudinal (L) Cable Restraint Schematic Arrangement for Floor or Roof Mounted Duct – Restraints Attached to the Duct

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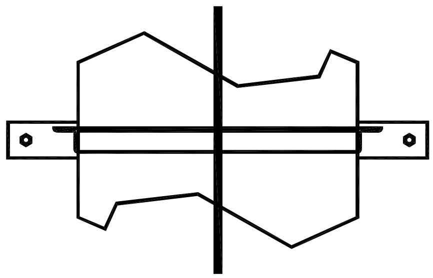
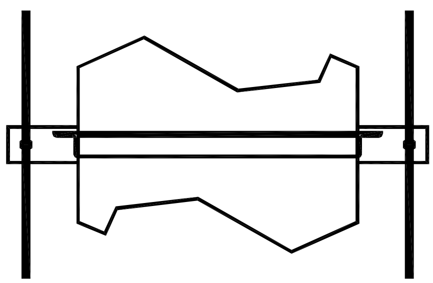
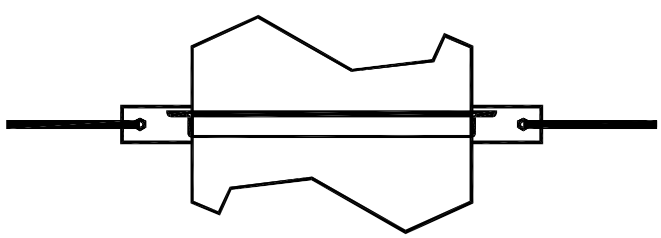
I4.8 – Transverse (T), Longitudinal (L), and Combined (TL) Restraint Plan View Arrangements for Ducts:



Sheet A2 - View A
Longitudinal (L)
Restraint
Plan View
Option #2



Sheet A2 - View A
Longitudinal (L)
Restraint
Plan View
Option #1



Sheet A2 - View A
Transverse (T)
Restraint
Plan View

Figure I4-25; Transverse (T) and Longitudinal (L) Basic Plan View Restraint Arrangements for Duct – Note: The Longitudinal (L) Restraint Cables in Longitudinal Restraint Options #1 & #2 are Arranged to Prevent Twisting of the Duct – *An Extra Restraint Kit Is Required for Longitudinal (L) Restraint Option #1*

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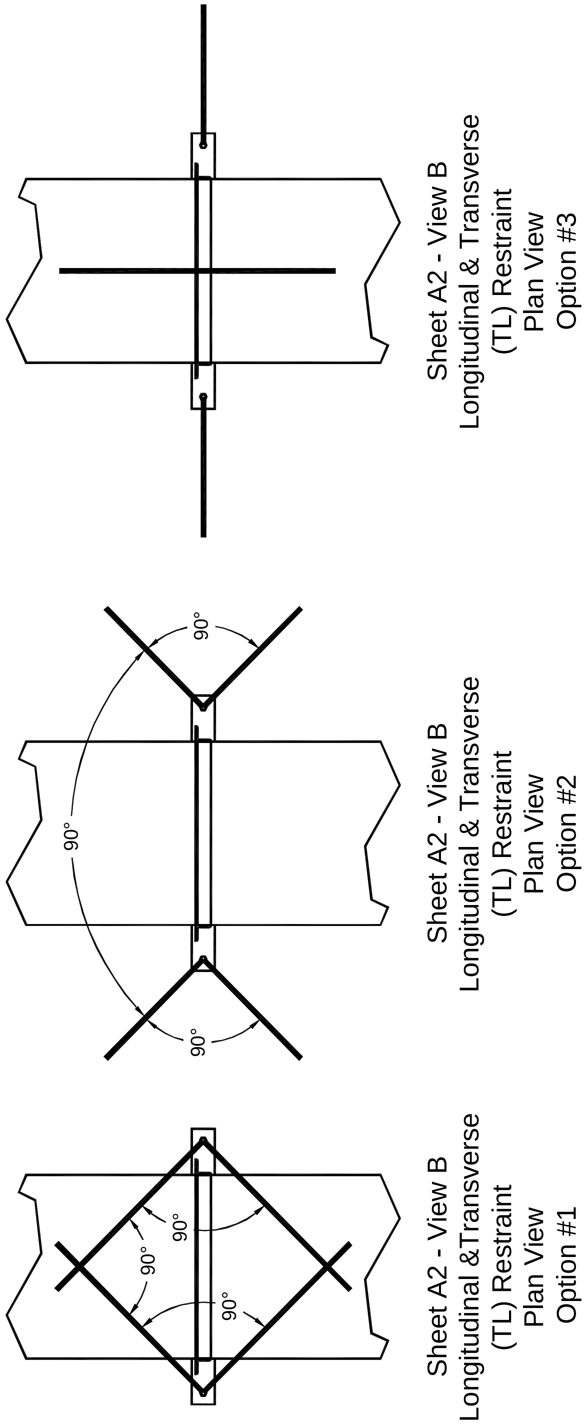

Figure I4-26; Combined Transverse and Longitudinal (TL) Basic Plan View Restraint Arrangements for Duct – Note: The Restraint Cables in Options #1, #2, & #3 are Arranged to Prevent Twisting of the Duct – *An Extra Restraint Kit Is Required for Combined Transverse and Longitudinal (TL) Restraint Options #1 & #2*

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I4.9 – Attachment of Seismic Restraints to Ducts and Trapeze Bars:

It is necessary to have a verifiable positive load path between the duct and the building structure. Duct that is restrained in accordance with the SMACNA "Seismic Restraint Manual – Guidelines for Mechanical Systems" will have this verifiable load path. The methods recommended in this manual by SMACNA are compatible with most forms of sheet metal duct construction techniques, and the seismic requirements of many locations. However, there will be some projects whose seismic requirements exceed the limits published by SMACNA. For these situations, fasteners used to attach the duct to the trapeze bars which are restrained, or the seismic restraints to the duct may be selected based on the information found in Appendices A3.4, A3.5, and A3.6. These fastener selections are based on the Horizontal Force Class for the duct being restrained. This system of Horizontal Force Classes is discussed in Section S7.0 of this manual.

I4.10 – Summary for Seismic Cable Restraints for Duct:

1. The schematics and arrangements presented in this section are intended to be used as guidelines for installation of seismic restraints for duct. They do not represent fully engineered designs for specific projects. The specific design details of each installation are the responsibility of the design professional of record for the systems that are being installed.
2. A ***minimum of two seismic restraint cables acting 180° apart*** are required for each transverse and each longitudinal seismic restraint location.
3. When locating and specifying seismic restraints for a project, Kinetics Noise Control will ***always*** list the minimum required number of seismic restraint kits for each restraint location. The actual installation circumstances may require additional restraint kits at certain locations particularly for trapeze supported duct or round duct supported by two hanger rods to balance the restraint forces from side-to-side on the duct.
4. Hangers and/or hanger rods at seismic restraint locations must be rigid members such as all thread rods in order to be able to transmit seismic uplift reaction forces from the duct to the building structure.

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5. Hangers, trapeze bars, and hanger rods at seismic restraint locations must be properly sized and specified by the design professional of record for the system to handle the expected seismic forces as well as the dead weight loads from the duct.
6. Attachment of seismic restraints to the duct, hangers, trapeze bars, and hanger rods must be approved by the design professional of record for the system.
7. For floor or roof mounted duct where the restraints are installed as shown in Figure I4-22, the anchors attaching the stand or support to the building structure form part of the seismic load path. As such, these anchors must be seismically rated anchors for use in cracked concrete, and must have a current ICC-ESR number.
8. Attachment of seismic restraints to the building structure must be approved by the structural engineer and/or the architect or record.

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STRUCTURAL ATTACHMENTS FOR PIPE AND DUCT RESTRAINTS

I5.1 – Introduction:

This section will present several basic arrangements for attaching seismic cable restraints to the building structure. The figures and descriptions in this section will be based on the Kinetics Noise Control drawings SS-20070951, SS-20070952, and SS-20070953 titled Concrete/Masonry Attachment – Sheet B, Steel Attachment – Sheet C, and Wood Attachment – D respectively. There are several drawings in this specific series. They have been designed to aid the installing contractor with the installation of seismic cable restraints for pipe and duct. Each drawing has a number designation ranging from SS-20070950 through SS-20070959. Also each drawing is specified by a particular letter designation ranging from Sheet A though Sheet H. The drawing numbers are in no particular order. However, the letter designations are in strict alphabetical order. Each of the drawings in this series has several views on each sheet designated by a specific letter. Where the figures in this section correspond with those views on the Kinetics Noise Control drawings SS-20070950 through SS-20070959 they will be cross referenced by sheet letter and figure letter, for instance Sheet C – View M.

Kinetics Noise Control provides attachment kits for their seismic restraint cable kits for pipe and duct. Kinetics Noise Control will, when requested to do so, provide a certification for the products that they sell. This certification will state that the seismic restraint cable and attachment kits will meet the seismic design requirements for the project in question when properly installed at the correct spacing. It is important to keep in mind that this certification ***does not*** extend to the building structure. Kinetics Noise Control is a manufacturer of vibration isolation and seismic restraint devices for the HVAC industry, and as such has no control over the design of the building structure. It is the responsibility of the structural engineer of record, and in some cases the architect of record, to approve the structural connections for the seismic restraints for pipe and duct.

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I5.2 – KSUA Attachment Brackets:

I5.2.1 – 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 I5-1 shows the two KSUA brackets.

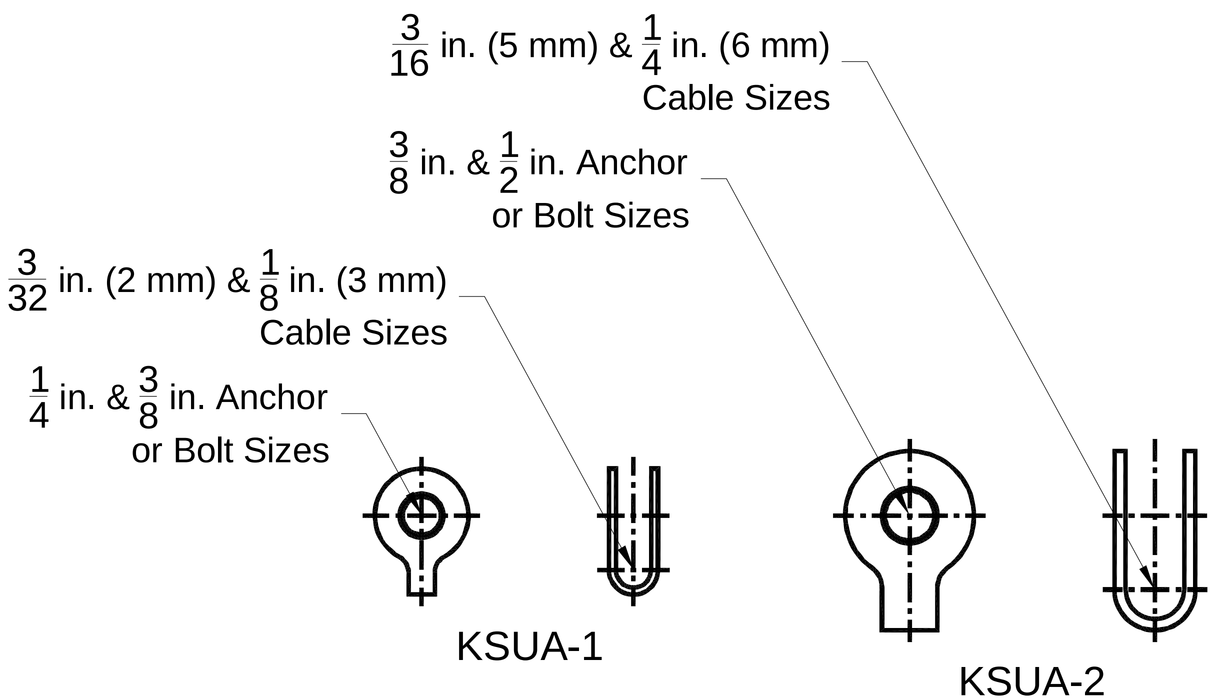

Figure I5-1; Kinetics Noise Control Model KSUA Seismic Restraint Cable Attachment Brackets

Primarily, the KSUA attachment brackets are used with the Kinetics Noise Control Model KSCU Seismic Restraint Cable Kits, which are described in Appendix A1.1. A KSCU seismic restraint cable kit consists of two restraint cables with a loop swaged on one end, two Kinetics provided end connectors, two Kinetics Model KSCA attachment brackets (which will be described in detail in the Section I5.3.1). ***For OSHPD applications thimbles are required for both ends of the restraint cables***.

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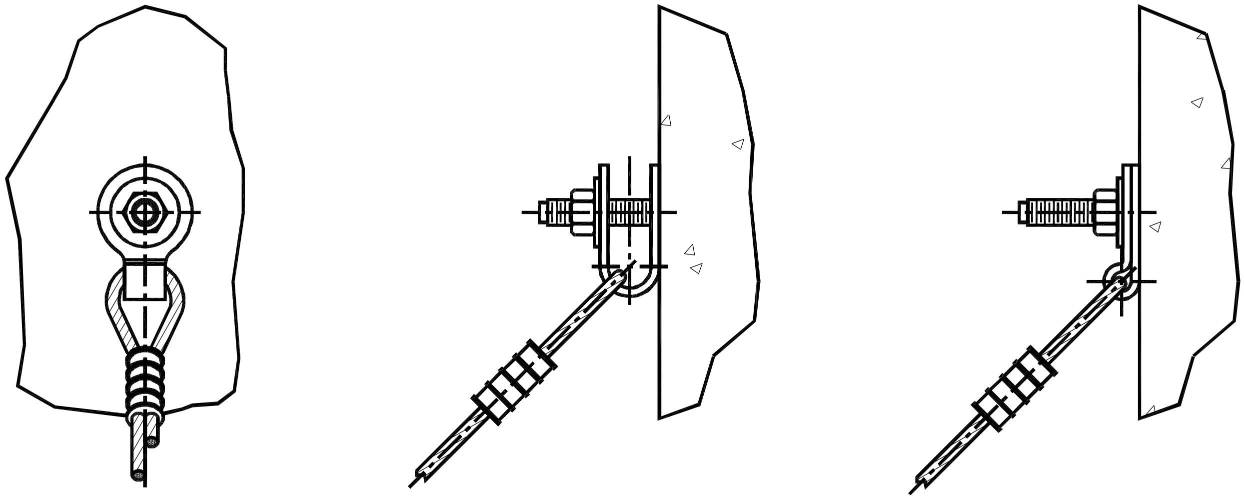

View #1
Front
KSUA - Installed

View #2
Side
KSUA - Open

View #3
Side
KSUA - Closed

Figure I5-2; Installation of Model KSUA Attachment Bracket

The KSUA attachment brackets were designed to be used with the pre-swaged end of the restraint cable, although they can be used on the end of the cable where the loop is made with the Kinetics provided end connector. Figure I5-2 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 pre-swaged end loop of the restraint cable is slipped over one of the legs of the open KSUA bracket; see View #2 Side KSUA – Open in Figure I5-2.
2. The open KSUA bracket is placed over the fastener, with or without a flat washer, and the nut is run down finger tight on the bracket. See View #2 Side KSUA – Open in Figure I5-2 above.
3. 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 completely shut as shown in View # 3 Side KSUA – Closed as shown in Figure I5-2. Squeezing the legs of the KSUA bracket shut

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will form a loop for the restraint cable. The cable should be loose and free to move inside the loop of the KSUA bracket.

I5.2.2 – 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 I5-3 and Table I5-1 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 A307, SAE Grade 2, bolt of the proper size is located on the structural steel and welded as shown in Figure I5-3. Then the cable and KSUA bracket are installed a described in Section I5.2.1.

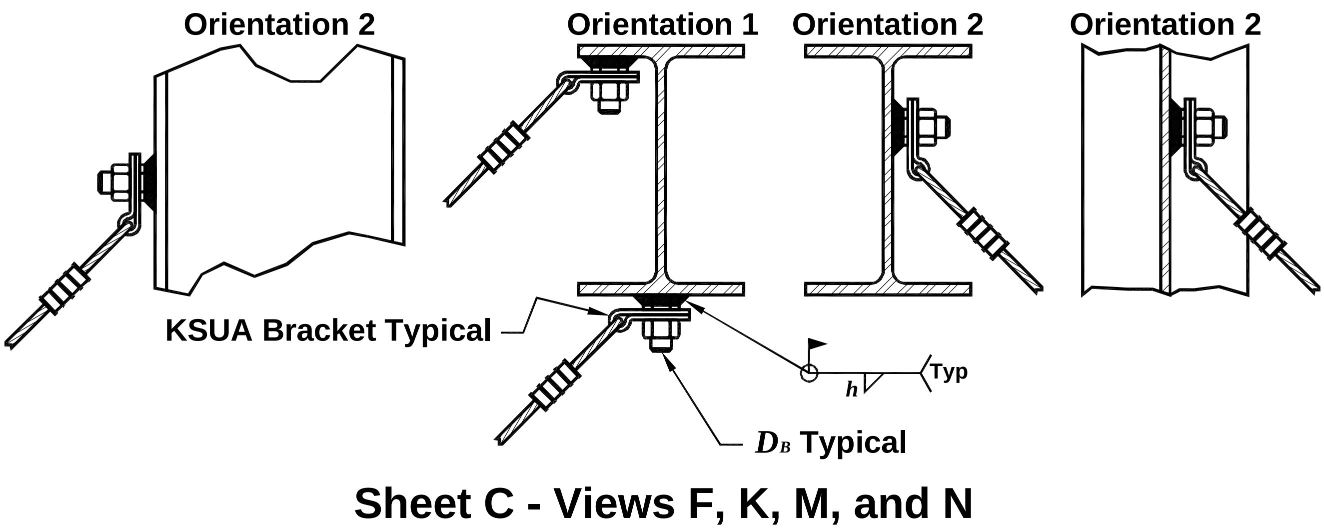

Figure I5-3; Welding KSUA Brackets to Structural Steel

Table I5-1; Bolt and Weld Size for KSUA Bracket Weld Attachment to Structural Steel

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 supplies 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 I5.4. 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***.

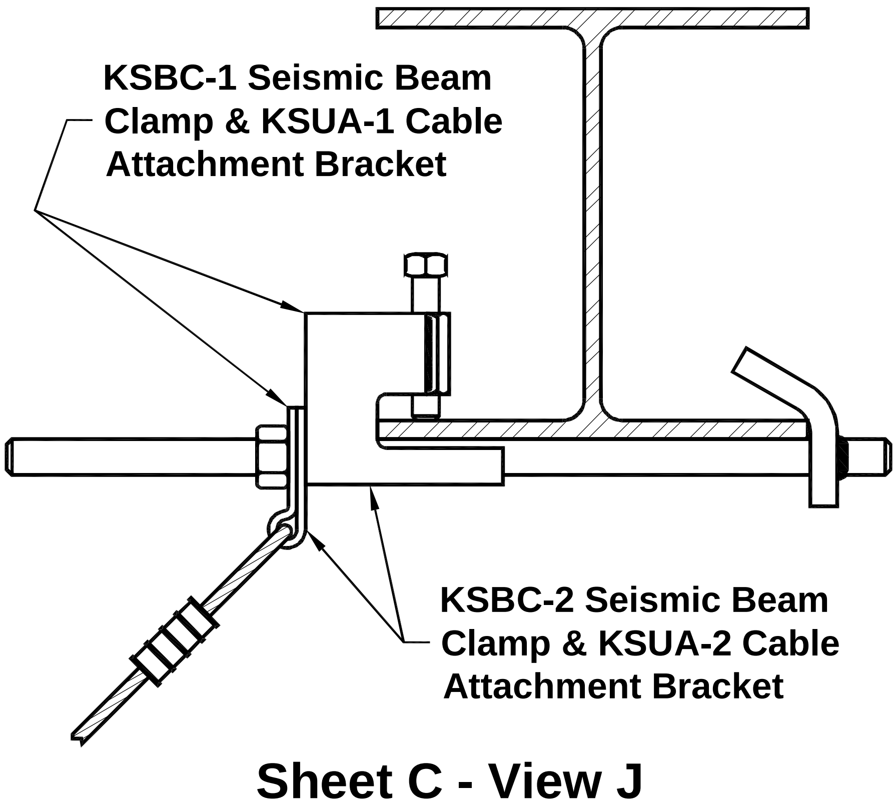

Figure I5-4; Using Model KSBC Seismic Beam Clamps to Attach KSUA Brackets to Structural Steel

KSUA Brackets may be attached to steel open web joists as shown in Figures I5-5, I5-6, and I5-7. These structural elements are normally designed to be as efficient as possible which means that they are designed to carry primarily vertical loads, and are sized to carry just the code mandated loads. If seismic restraints for pipe and duct are to be attached to these open web steel joists as shown in Figures I5-5, I5-6, and I5-7 below, ***it is absolutely necessary for the building structural engineer to approve each attachment point***.

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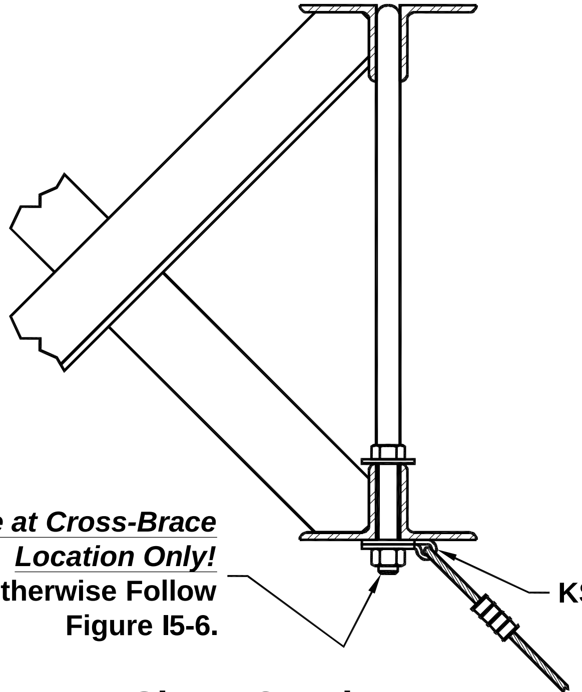
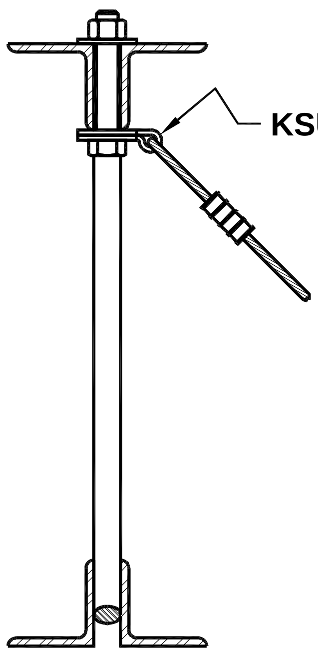


Sheet C - View A

Figure I5-5; Attaching KSUA Brackets to Cross-Braced Open Web Steel Joists



Sheet C - View G

Figure I5-6; Attaching KSUA Brackets to Un-Braced Open Web Steel Joists

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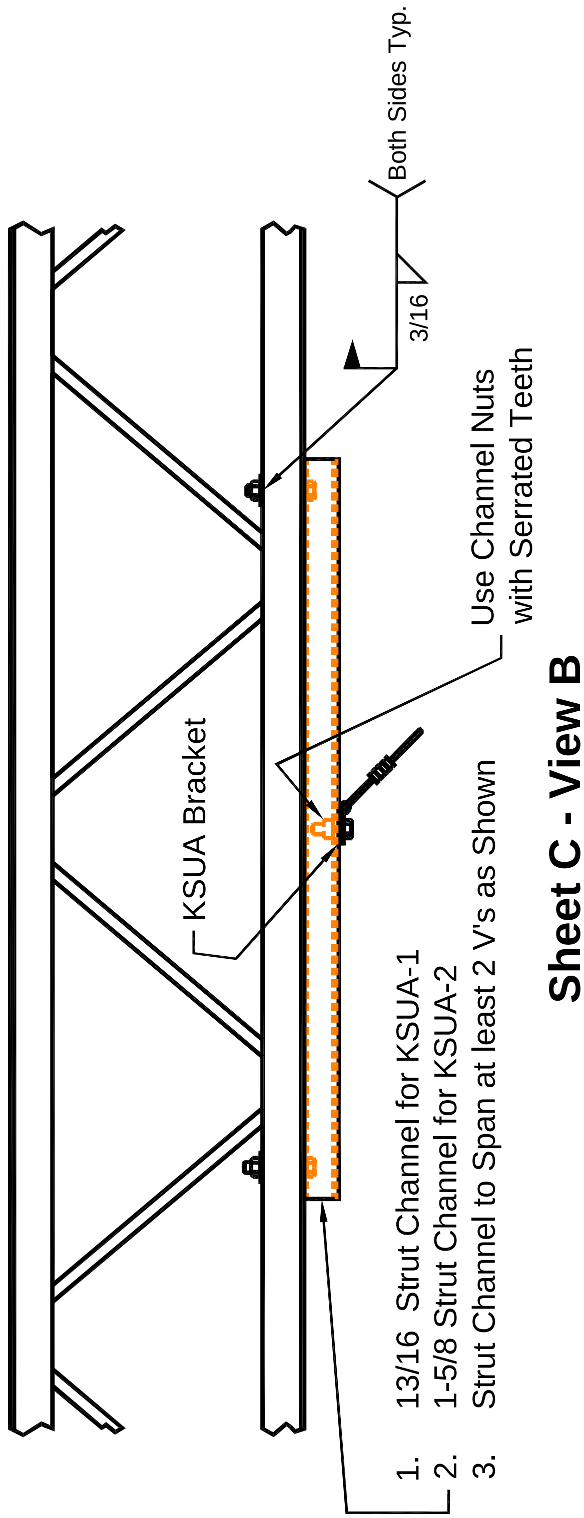

Figure I5-7; Attaching KSUA Brackets to Un-Braced Open Web Steel Joists – Aligned to Joists

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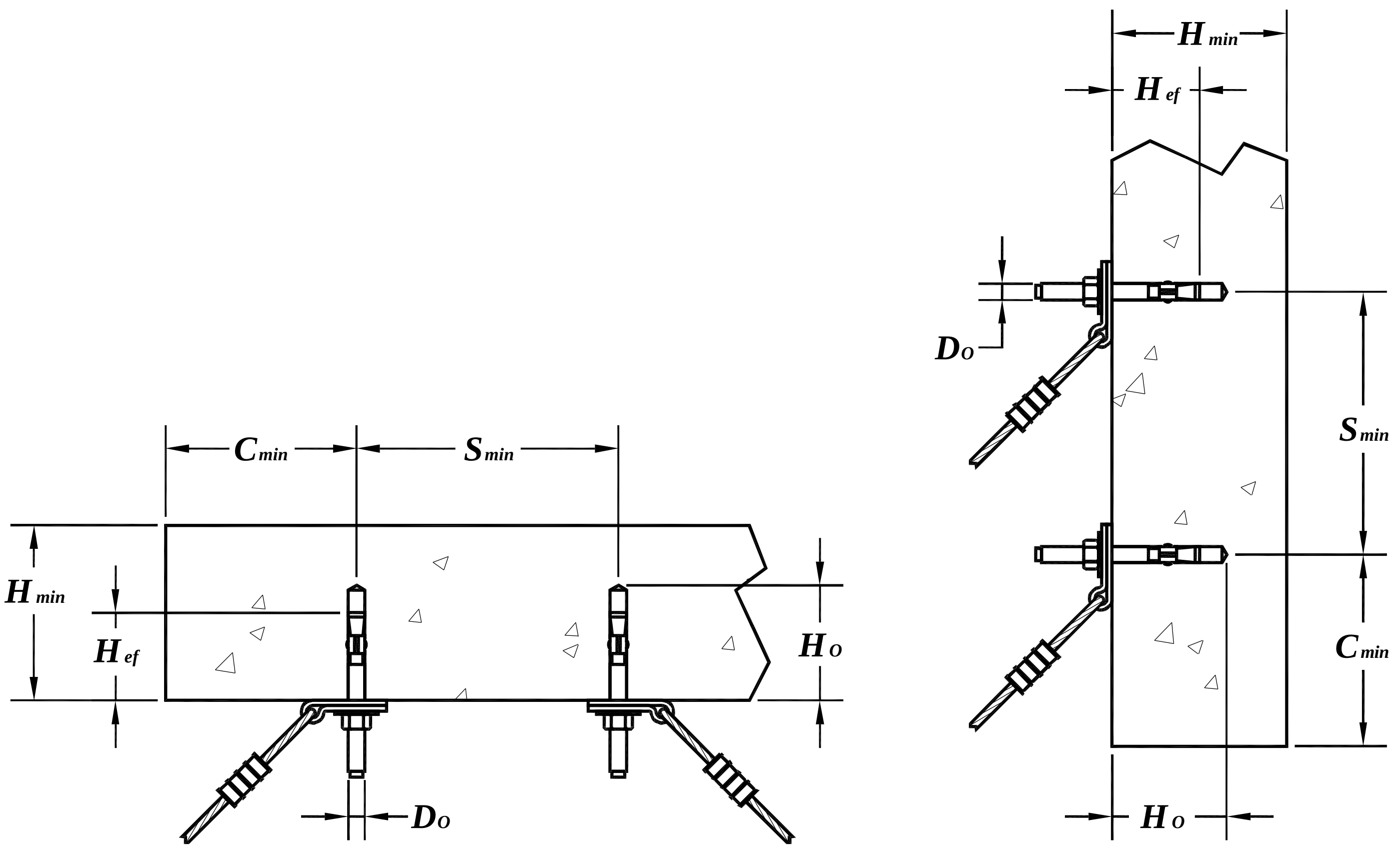
I5.2.3 – KSUA Brackets – Attachment to Concrete:

The typical attachment of seismic cable restraints to concrete using KSUA brackets is shown in Figure I5-8. The critical installation dimensions are listed in Table I5-2.



Orientation 1

Orientation 2

Sheet B - View A

Figure I5-8; Typical KSUA Bracket Installation in Concrete

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Table I5-2; Critical KCCAB Concrete Anchor Installation Dimensions for KSCU Restraint Cable Kits

Anchor & Pilot Hole Size D_O (in)	Pilot Hole Depth H_O (in)	Effective Anchor Embedment H_{ef} (in)	Minimum Concrete Thickness H_{min} (in)	Minimum Anchor Spacing S_{min} (in)	Minimum Anchor Edge Distance C_{min} (in)
3/8	2-5/8	2	4	6	4-3/8
1/2	4	3-1/4	6	9-3/4	7-1/2

The installation dimensions listed in Table I5-2 are the minimum required to achieve the listed capacities for the Model KSCU Seismic Restraint Cable Kits listed in Appendix A1.1, Tables A1.1-3 and A1.1-4.

Figure I5-9 shows a KSUA bracket attached to concrete which has been poured over a corrugated metal deck. Thickest concrete section at the ribs of the decking must meet the Minimum Concrete Thickness from Table I5-2 above. Figure I5-10 shows a KSUA bracket mounted to a strut channel which spans at least two ribs. This arrangement is used when there is not enough concrete thickness for a 1/2″ anchor to be used with a KSUA-2 bracket, or the concrete is a lightweight concrete that produces a lower anchor capacity that what would be expected with normal weight concrete, see Table I5-3 for anchor substitutions for lightweight concrete over metal decking.

Table I5-3; Anchor Substitution for Lightweight Concrete over Metal Decking for KSCU Cable Kits

KNC Anchor Kit Code	Standard Anchor Size (in)	Used With KNC Restraint Kit Code	Cable Size	For Lightweight Concrete over Metal Decking		
				Required Anchor Size (in)	Required Embedment Depth (in)	Required Quantity
X2	3/8	K2	2 mm	3/8	2	1
X2	3/8	K3	3 mm	3/8	2	2
X2	3/8	K4	4 mm	3/8	2	2
X3	1/2	K5[1]	5 mm	5/8	4	1

[1] For use in lightweight concrete poured over metal decking, the KSUA-2 bracket supplied with the K5 (KSCU-5) cable restraint kit will need to be replaced with the Kinetics Noise Control Model KSCC-1 bracket, order P/N 9036608.

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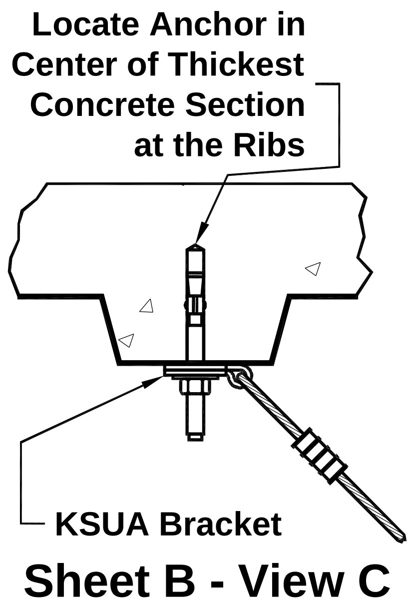

Figure I5-9; KSUA Bracket Attached to Concrete Poured on Corrugated Metal Decking

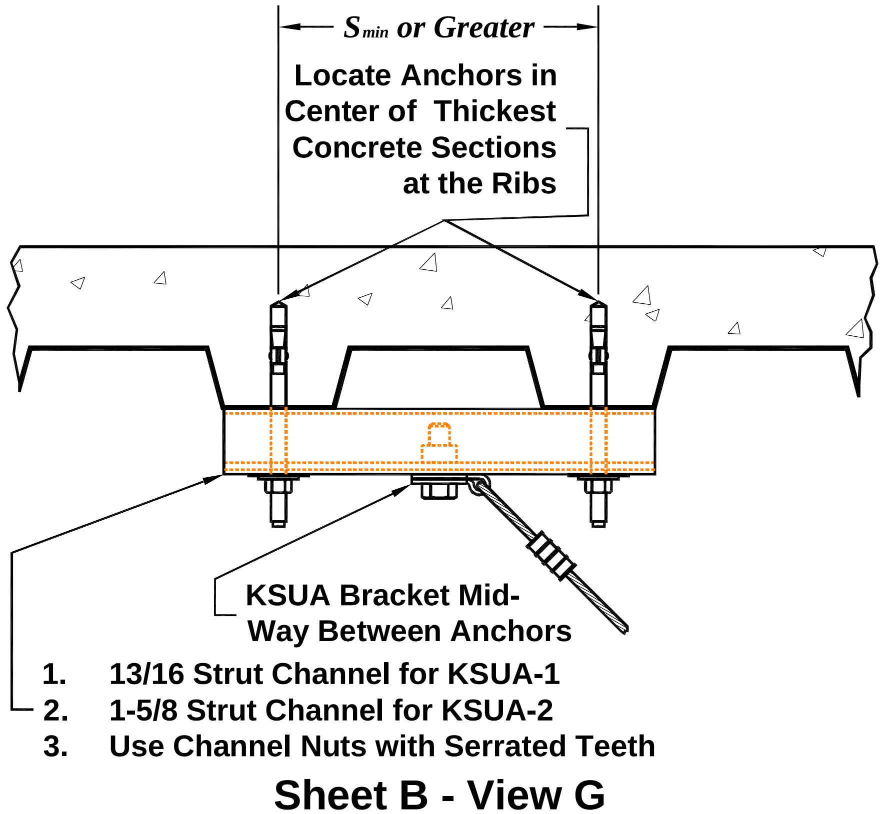

Figure I5-10; KSUA Bracket Attached to Strut Channel Anchored to Concrete Poured on Corrugated Metal Decking

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I5.2.4 – KSUA Brackets – Attachment to CMU Walls:

The concrete used for CMU components is usually a lightweight concrete, and often has fillers and aggregates such as fly ash and bottom ash. Therefore, the strength of this concrete does not match that of normal weight concrete, and may not match that of poured in place lightweight concrete. For this reason, ***attachments for seismic restraints made to CMU walls must be approved by the building structural engineer in advance of installation of the restraints***. When solid masonry blocks are used, the best way to make theses attachments is to use through bolts with load plates on both sides of the wall as shown in Figure I5-11. The capacity of the attachment will be what ever the building structural engineer says that the point load limit for the wall will be. (Up to but not exceeding the cable kit capacity as published by Kinetics Noise Control.)

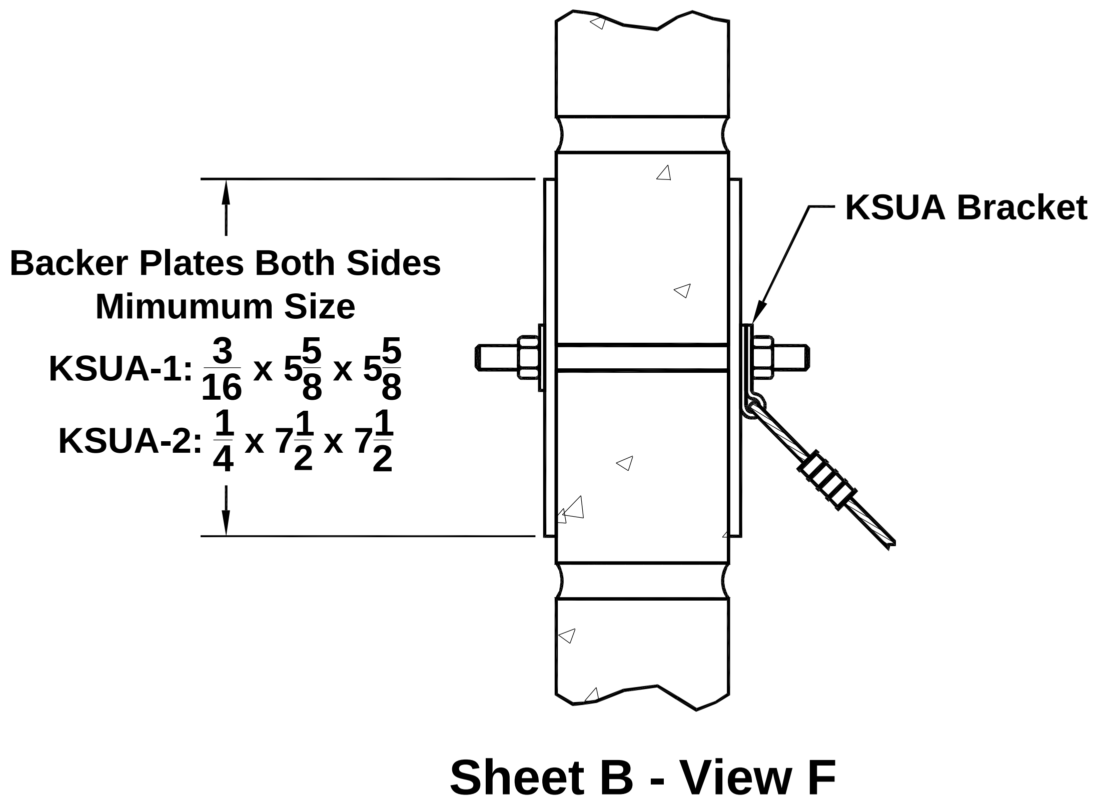

Figure I5-11; KSUA Through Bolt Attachment to a Solid CMU Wall

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Figures I5-12 and I5-13 show attachment methods for hollow CMU walls. ***Here again, the building structural engineer must approve the attachment prior to installation, and indicate the point load limit for the wall***. (Note: In the case of the umbrella type anchor, Figure I5-13, the peak capacity is limited to that of the 3/8" anchor.)

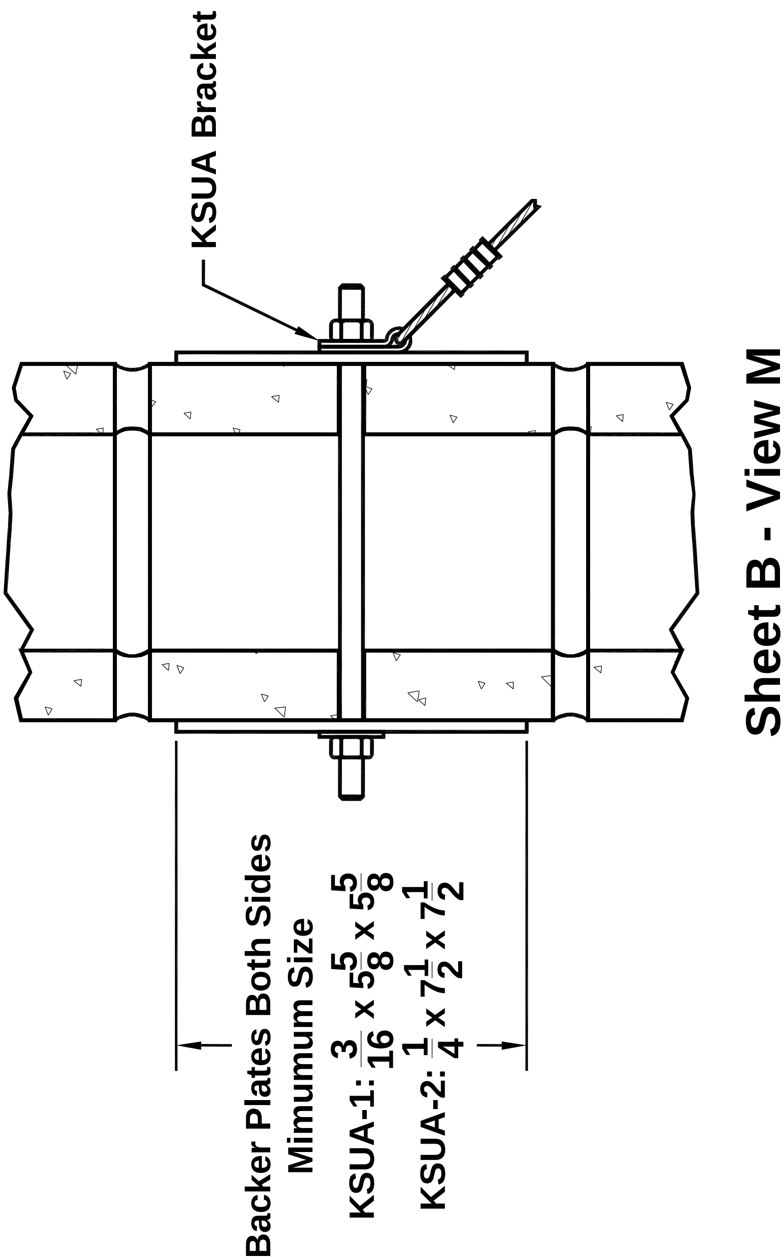

Figure I5-12; KSUA Through Bolt Attachment to a Hollow CMU Wall

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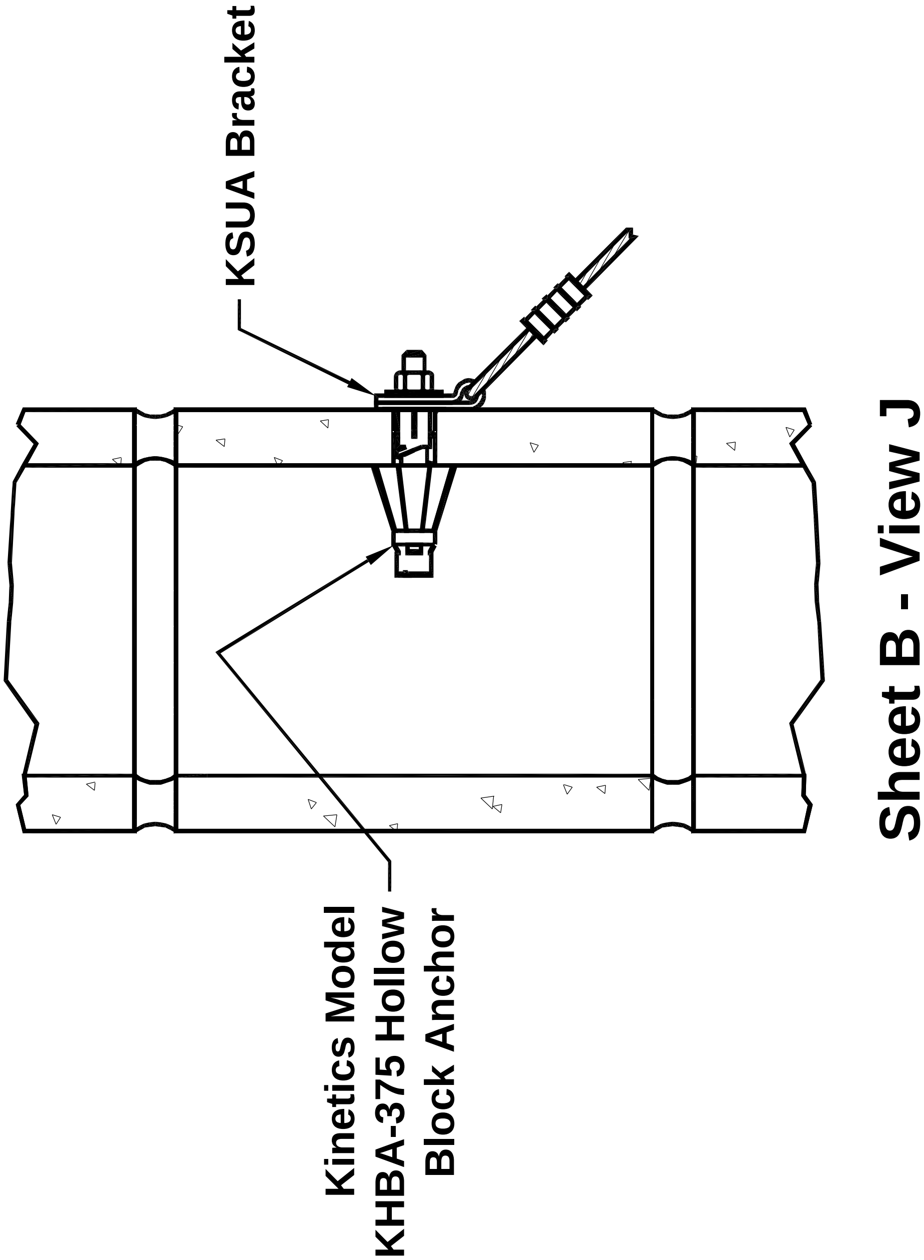

Figure I5-13; KSUA "Umbrella" Type Adhesive Anchor Attachment to a Hollow CMU Wall

Finally, for filled CMU walls, standard wedge type anchors can be used with reduced capacities as shown in Figure I5-14. ***Here also, the building structural engineer must approve the attachment prior to installation, and indicate the point load limit for the wall***.

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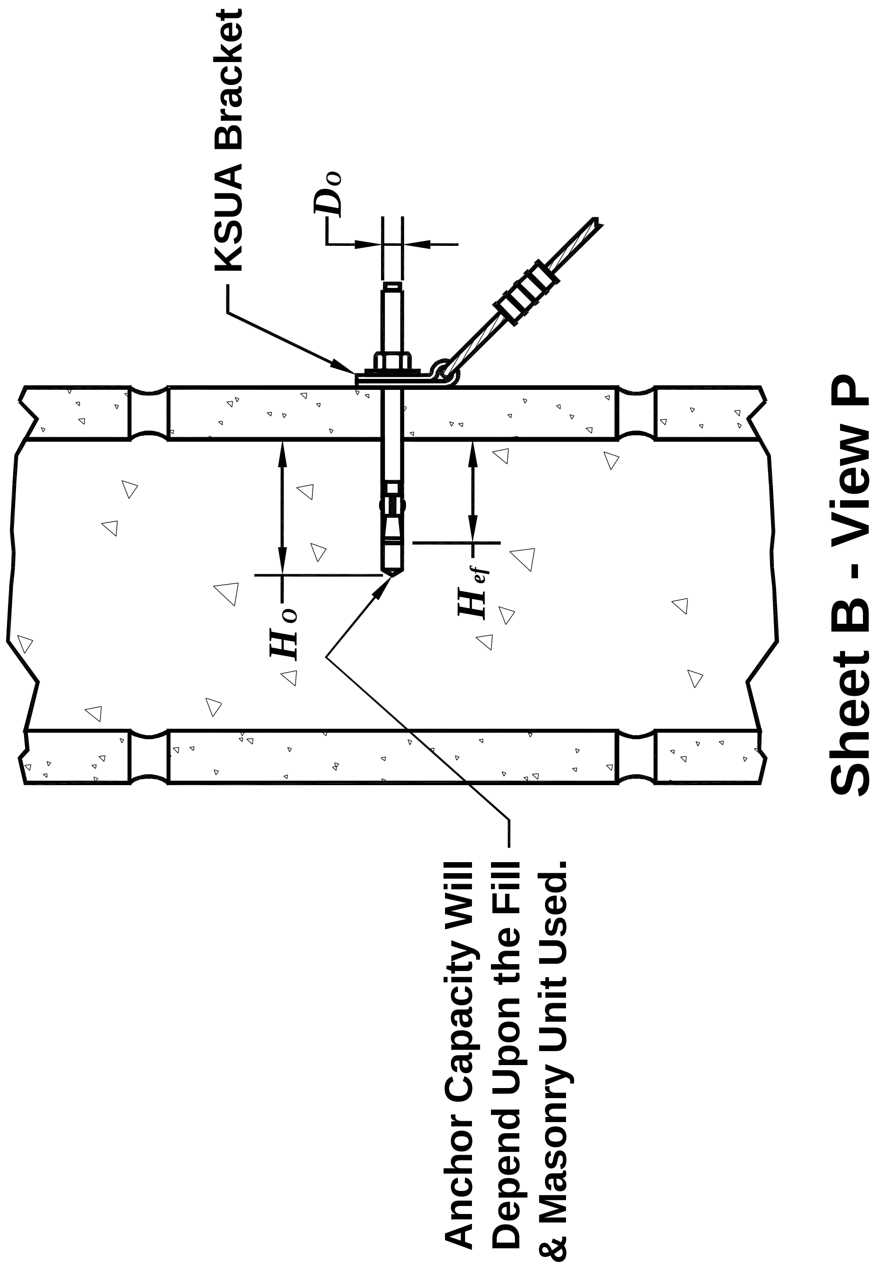

Figure I5-14; KSUA Wedge Type Anchor Attachment to a Filled CMU Wall

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I5.2.5 – KSUA Brackets – Attachment to Wooden Structures:

<u>Attachment of seismic or wind restraints to a wooden structure requires careful coordination with the building structural engineer</u>. While wooden structures tend to perform better during an earthquake than their concrete, masonry, or 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 can not be controlled. The building structural engineer can indicate the proper locations and load capacity limits for each restraint attachment type and location.

Figure I5-15 and Table I5-4 show the typical installation dimensions that will apply to lag screw attachments. For more detailed lag screw data see Appendix A4.4.

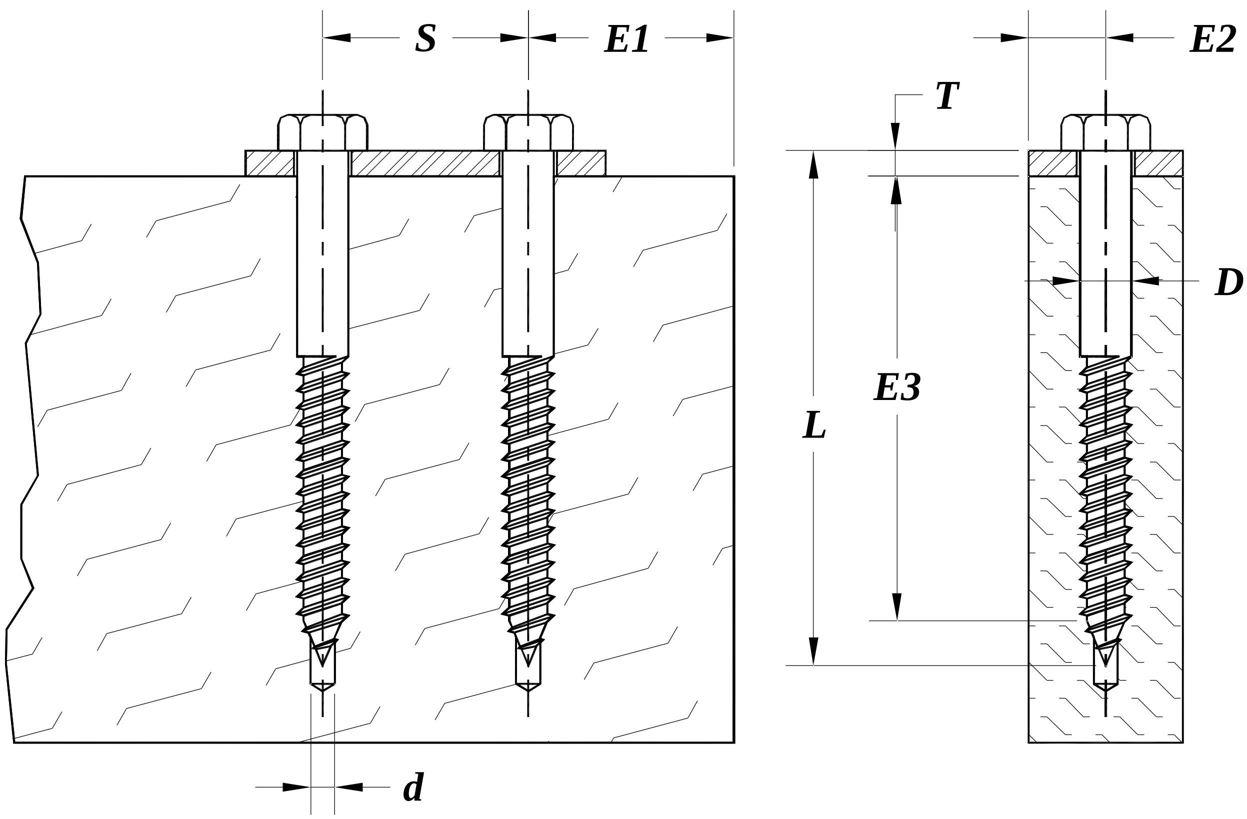

Figure I5-15; Typical Lag Screw Installation Dimensions

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Table I5-4; Lag Screw and Through Bolt Installation Data for Model KSCU Restraint Cable Kits

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				
1/4	1/8	5/32	1	1	3/8	2
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

KSUA brackets installed in Orientation 1 to structural wood are shown in Figure I5-16 for a lag screw attachment and Figure I5-17 for a through bolted attachment.

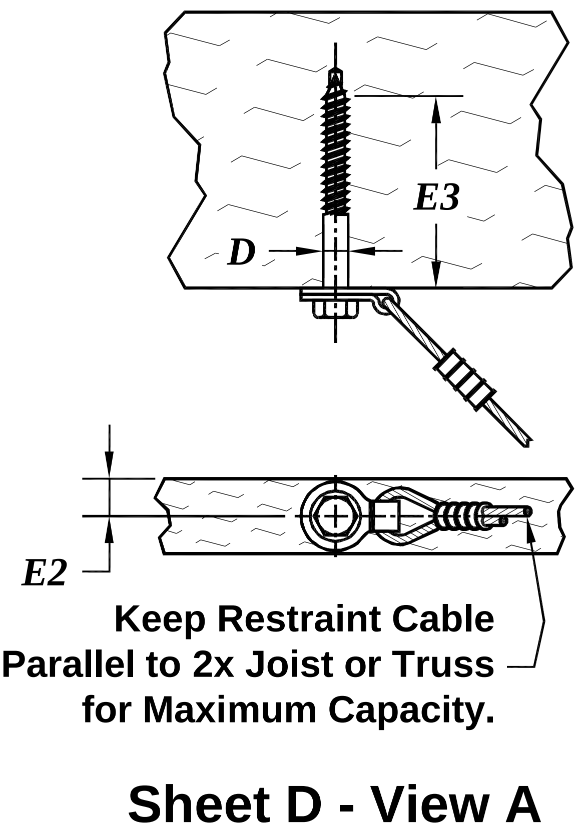

Figure I5-16; KSUA Attached to Wood in Orientation 1 Using a Lag Screw

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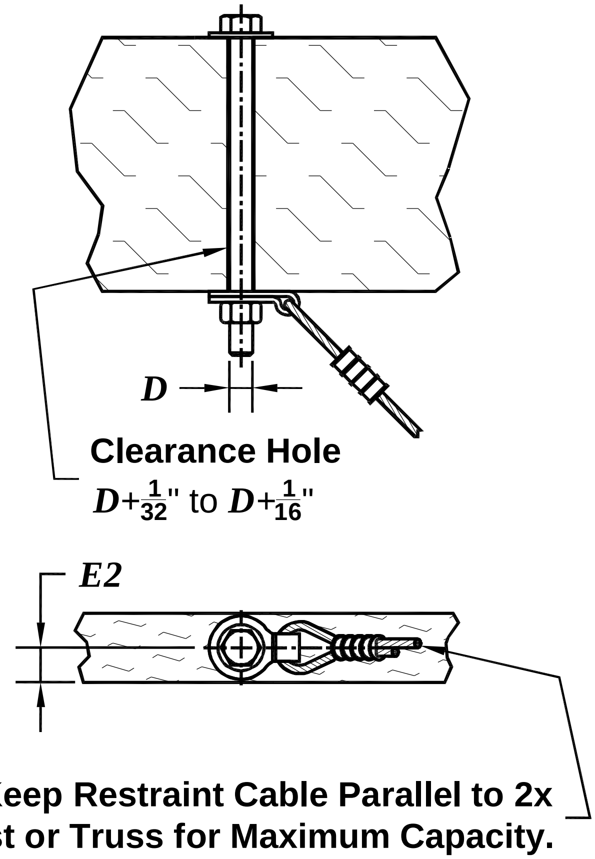

Sheet D - View A

Figure I5-17; KSUA Attached to Wood in Orientation 1 Using a Through Bolt

Special Note: Seismic and wind restraints are not to be attached to the end grain of structural wood!!

KSUA brackets installed in Orientation 2 to structural wood are shown in Figure I5-18 for a lag screw attachment and Figure I5-19 for a through bolted attachment.

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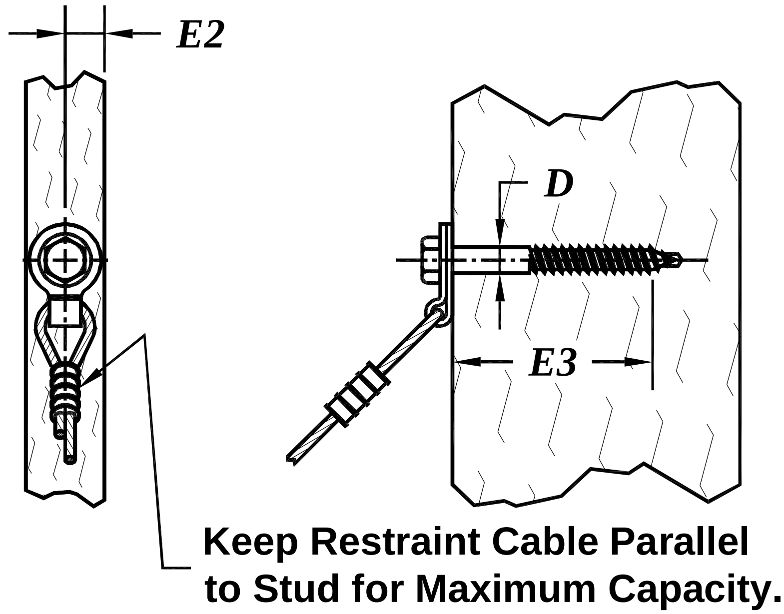

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Figure I5-18; KSUA Attached to Wood in Orientation 2 Using a Lag Screw

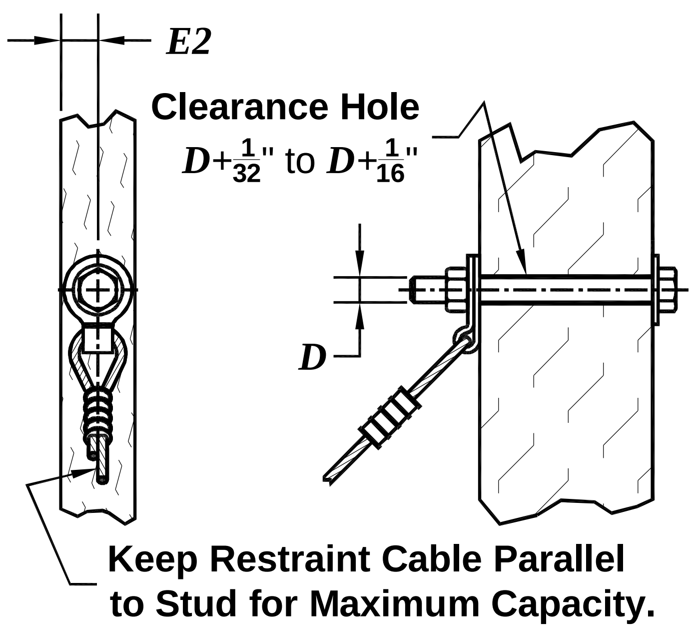

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Figure I5-19; KSUA Attached to Wood in Orientation 2 Using a Through Bolt

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The KSUA bracket may be attached to the sides of wooden joists and beams in Orientation 2 as shown in Figure I5-20 for lag screw attachment and Figure I5-21 for through bolt attachment.

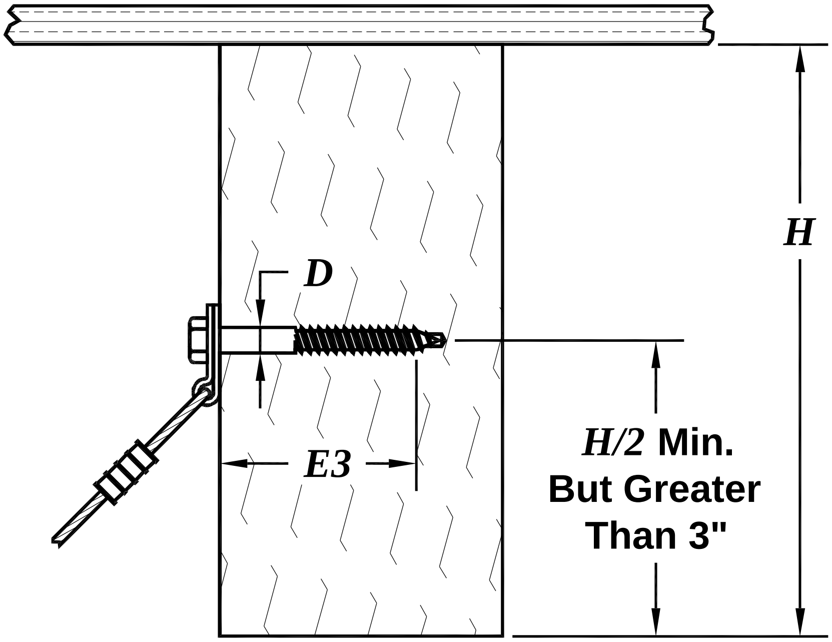

Figure I5-20; KSUA Attached to a Wooden Joist or Beam in Orientation 2 Using a Lag Screw

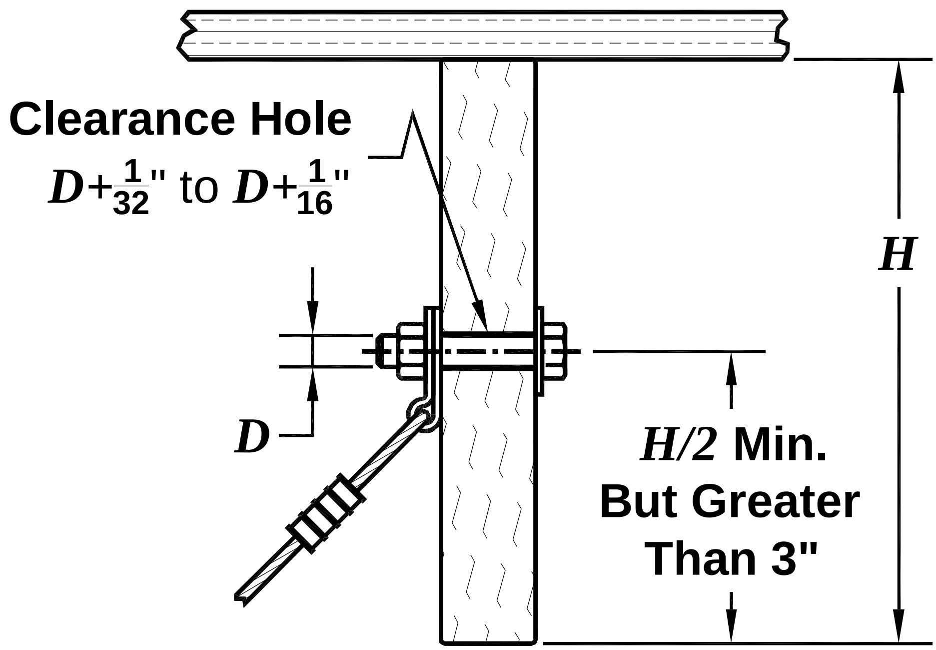

Figure I5-21; KSUA Attached to a Wooden Joist or Beam in Orientation 2 Using a Through Bolt

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I5.3 – KSCA Attachment Brackets:

I5.3.1 – 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. More will be said about this application in Section I6.0 of this manual. 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 I5-22 and I5-23. Notice in Figure I5-22, that the single hole beyond the bend is used for attaching the cable to the bracket. Depending on the angle of the cable when installed, a thimble may be need in this loop to prevent damage to the cable. ***All OSHPD applications require the use of thimbles on both ends of the cable***.

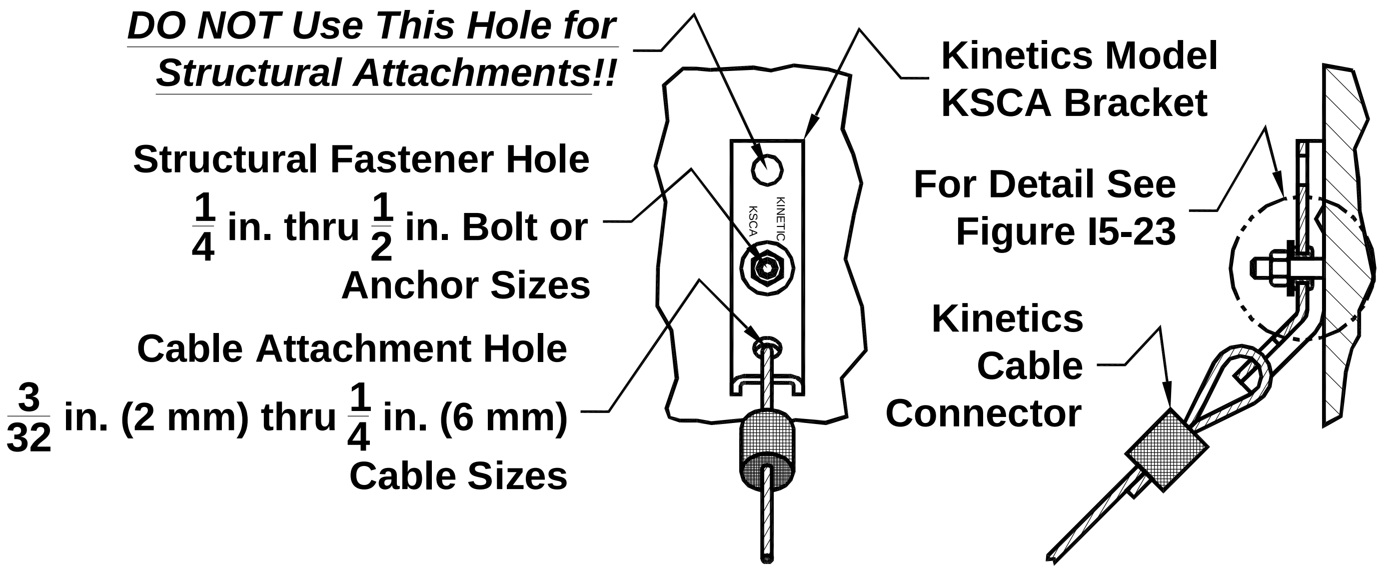

Figure I5-22; General Information for the KSCA Bracket Used for Structural Attachment

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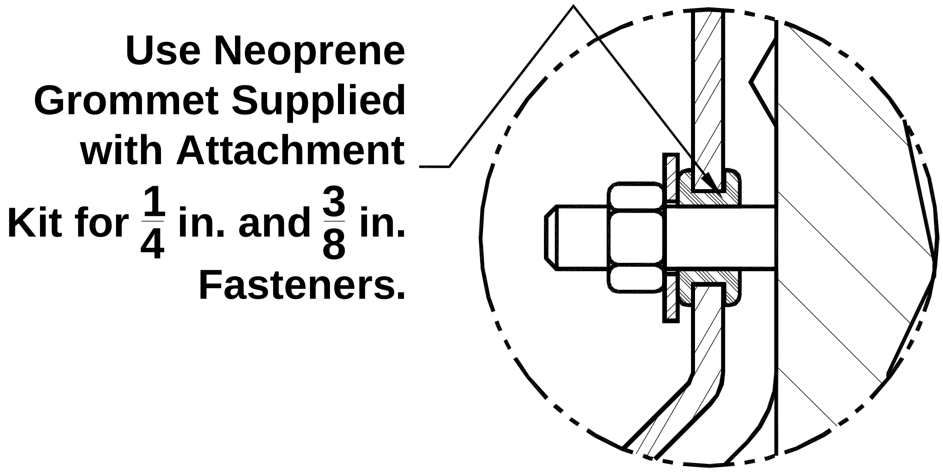

Figure I5-23; Detail of KSCA Bracket When Used with Smaller Bolts/Anchors

I5.3.2 – KSCA Brackets – Attachment to Steel:

KSCA brackets are most easily attached to structural steel by welding, see Figures I5-24 and I5-25. Most structural engineers do not want clearance holes drilled in the structural elements. Figure I5-26 shows the KSCA bracket attached to structural steel AISC W, M, S, or HP shapes without welding.

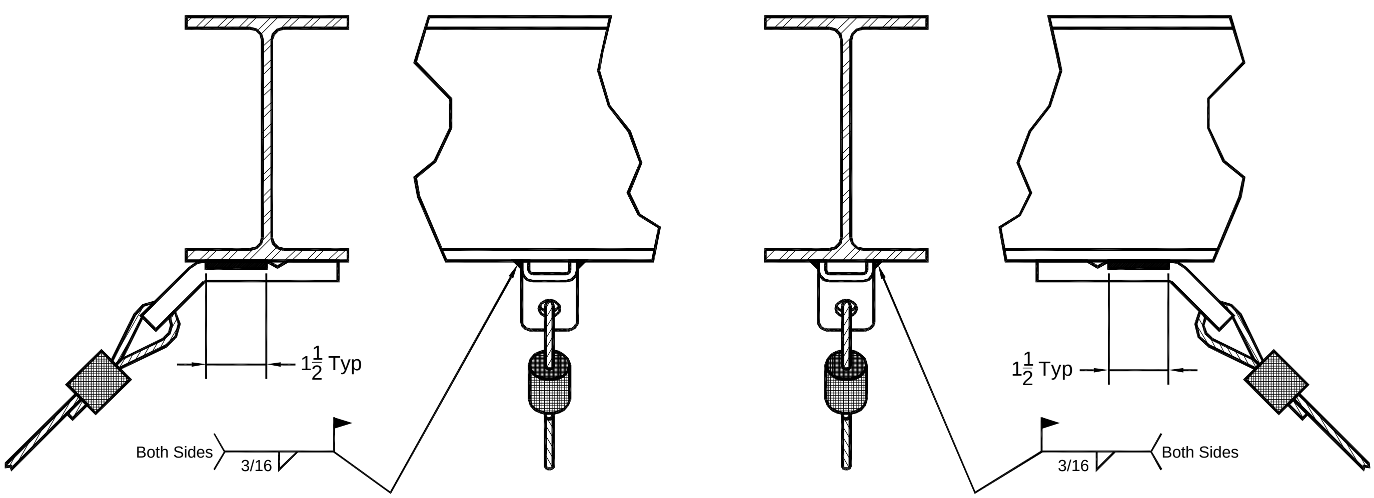

Figure I5-24; KSCA Bracket Welded to Structural Steel in Orientation 1

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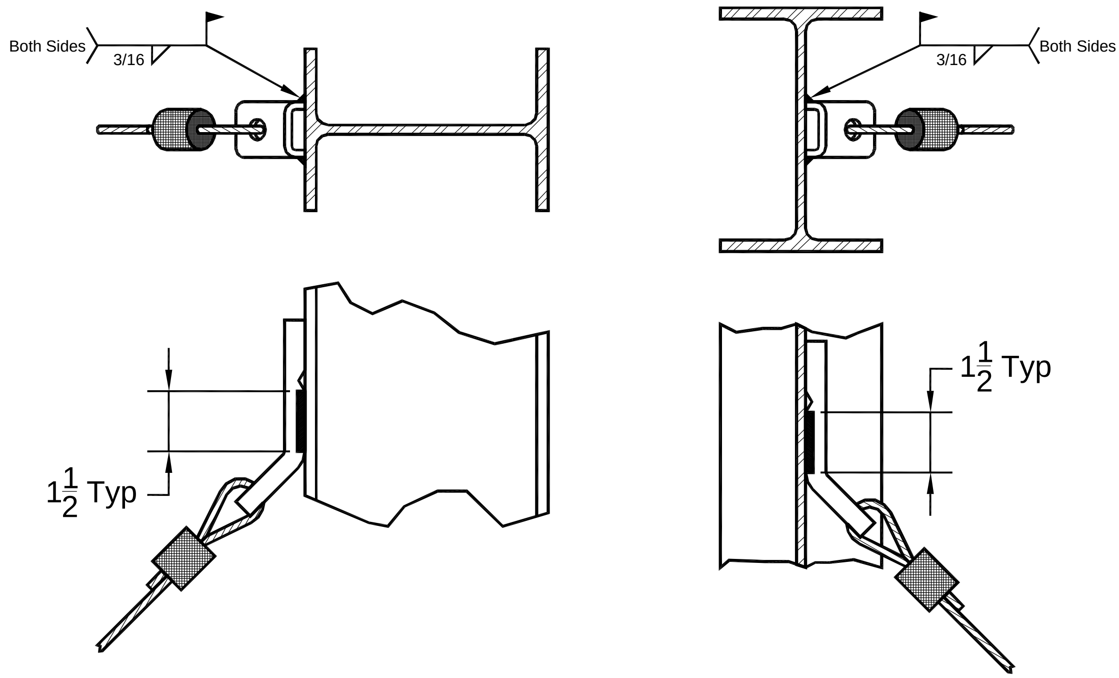

Figure I5-25; KSCA Bracket Welded to Structural Steel in Orientation 2

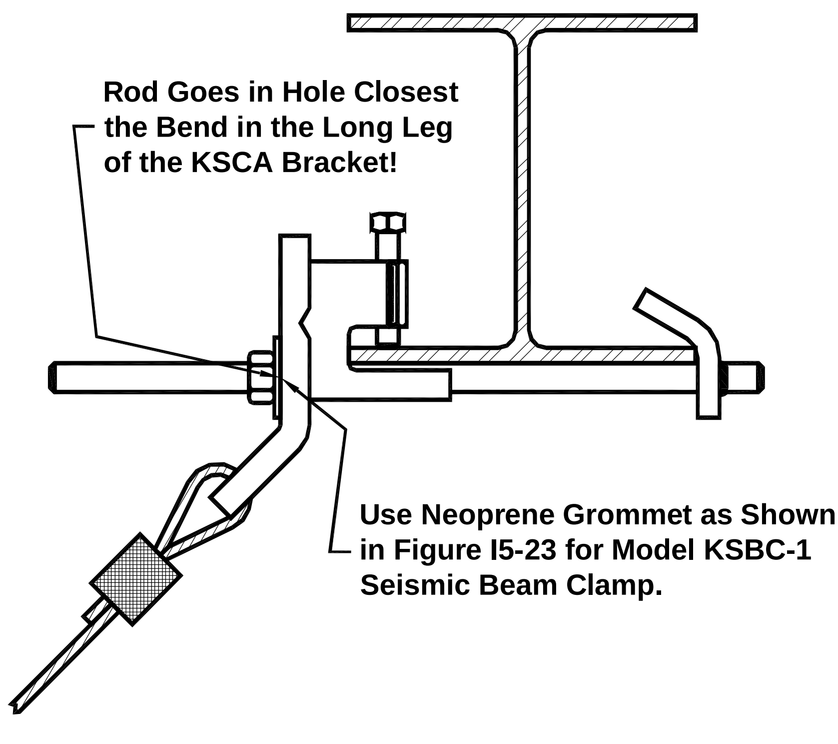

Figure I5-26; Using Model KSBC Seismic Beam Clamps to Attach KSCA Brackets to Structural Steel

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I5.3.3 – 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 I5-27.

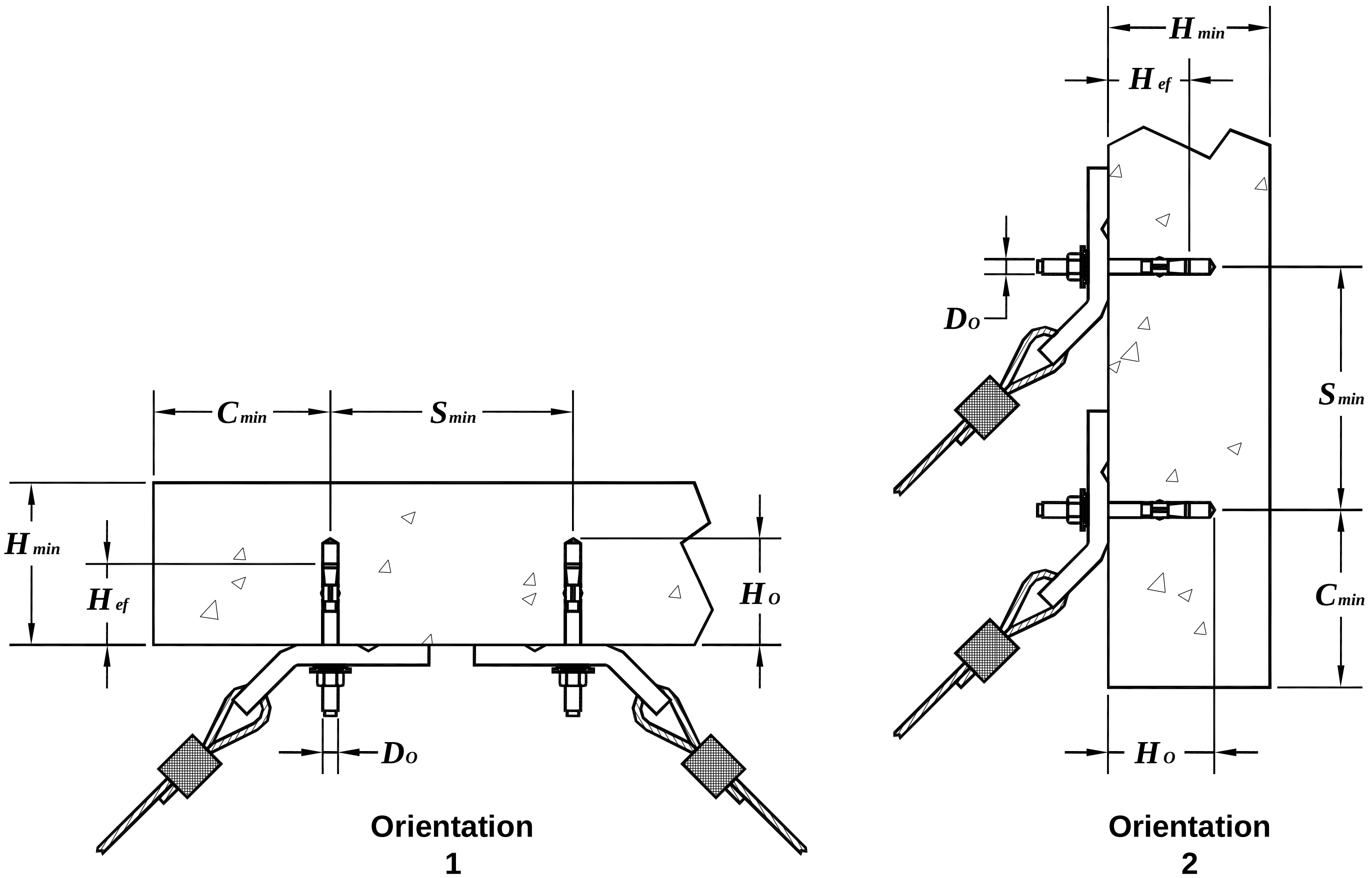

Figure I5-27; Typical KSCA Bracket Installation in Normal Weight Concrete

There may be certain instances where a single anchor with a KSUA bracket or a KSCA bracket will not have enough capacity. Then the KSCUZ2, two concrete anchor, and KSCUZ4, four concrete anchor, kits may be used, shown in Figures I5-28, I5-29, I5-30, and I5-31.

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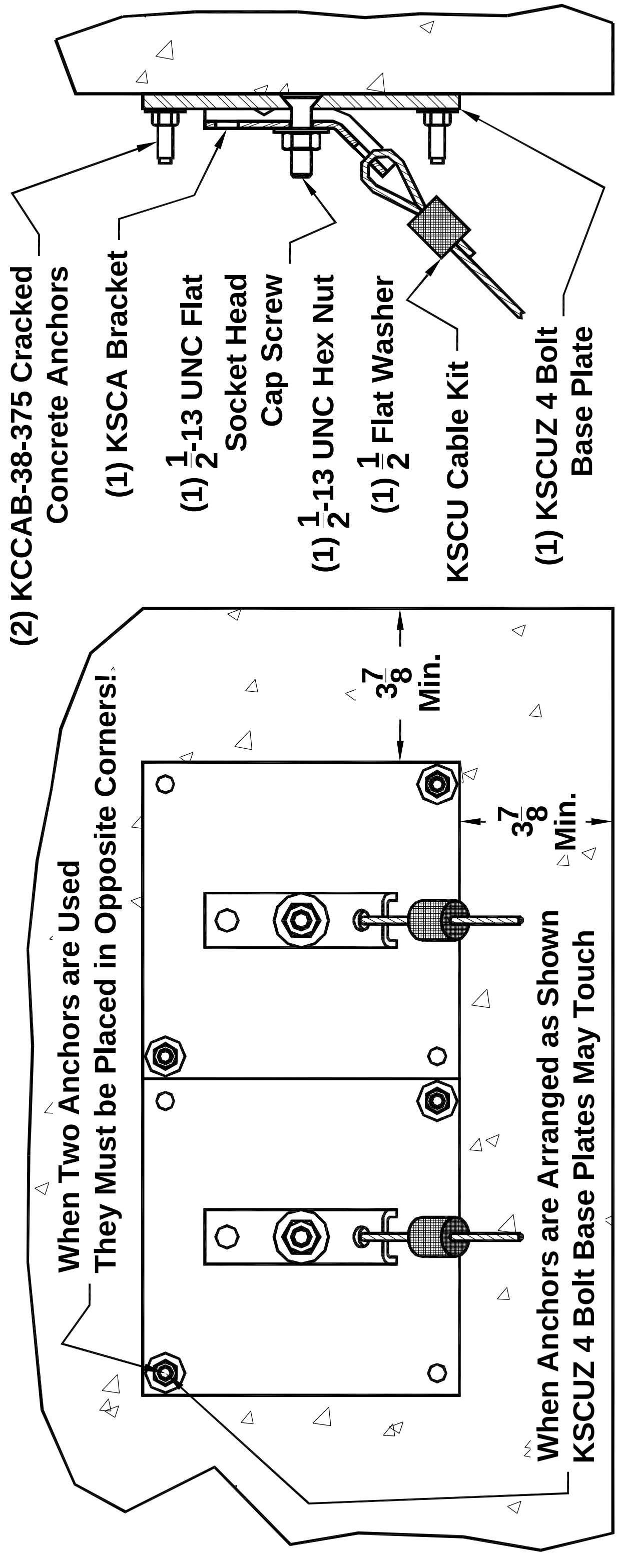

FigureI5-28; Model KSCUZ2 Attachment Kit to Concrete Using the KSCA Bracket – (2) 3/8 Anchors

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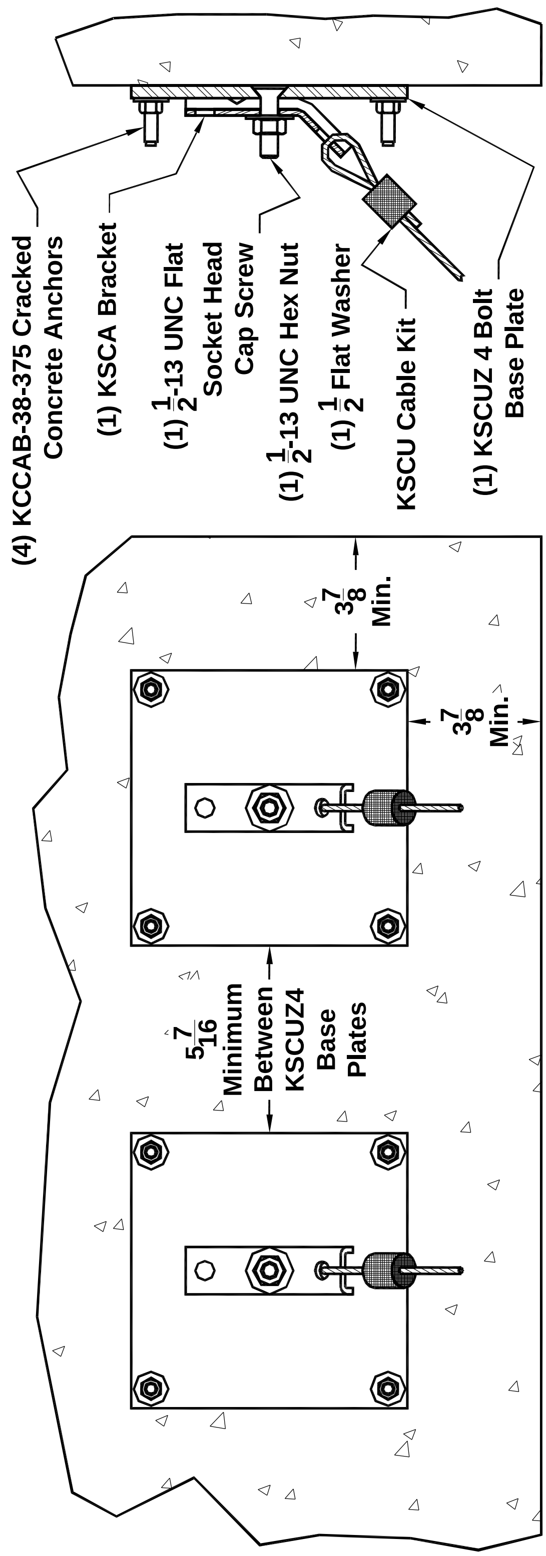

Figure I5-29; Model KSCUZ4 Attachment Kit to Concrete Using the KSCA Bracket – (4) 3/8 Anchors

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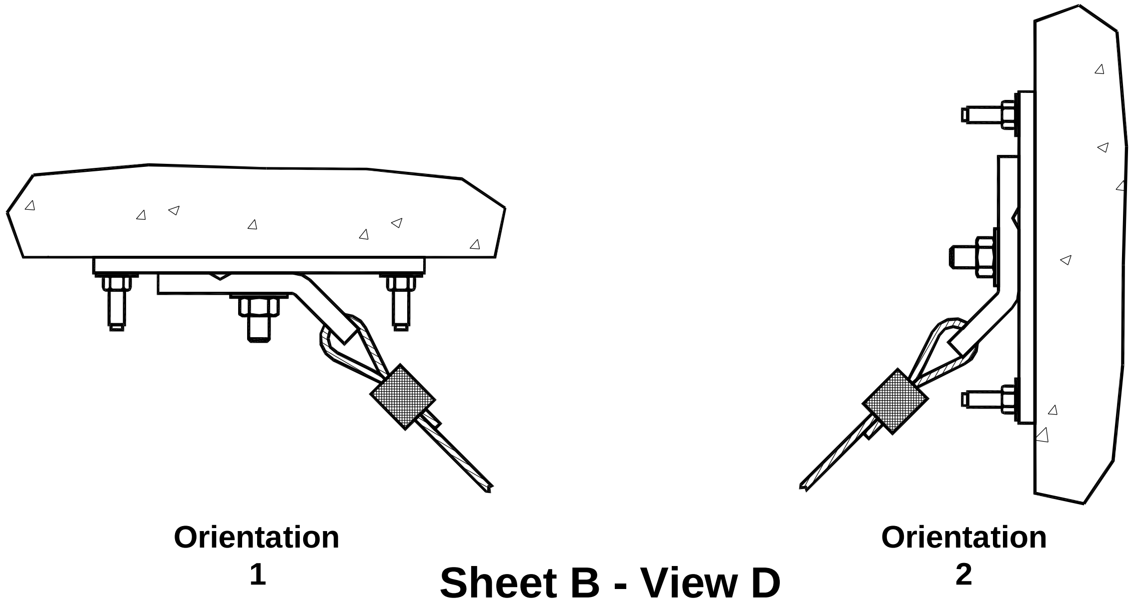

Figure I5-30: Models KSCUZ2 and KSCUZ4 Concrete Attachment Kits for KSCA Brackets in Orientation 1 and Orientation 2

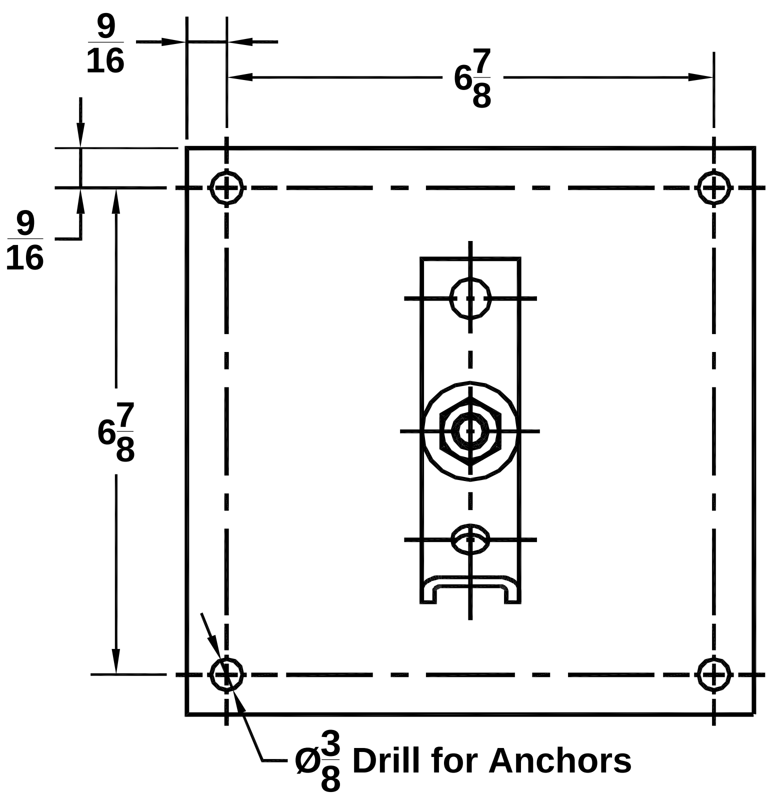

Figure I5-31; Anchor Hole Drill Template for Models KSCUZ2 and KSCUZ4

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I5.3.4 – KSCA Brackets – Attachment to CMU Walls:

The concrete used for CMU components is usually a lightweight concrete, and often has fillers and aggregates such as fly ash and bottom ash. Therefore, the strength of this concrete does not match that of normal weight concrete, and may not match that of poured in place lightweight concrete. For this reason, ***attachments for seismic restraints made to CMU walls must be approved by the building structural engineer in advance of installation of the restraints***. All of the schemes for attaching the KSCA bracket to CMU walls will require the use of a backer plate beneath the KSCA bracket to protect the CMUs. When solid masonry blocks are used, the best way to make theses attachments is to use through bolts with load plates on both sides of the wall as shown in Figure I5-32. The capacity of the attachment will be what ever the building structural engineer says that the point load limit for the wall will be. (Up to but not exceeding the cable kit capacity as published by Kinetics Noise Control.)

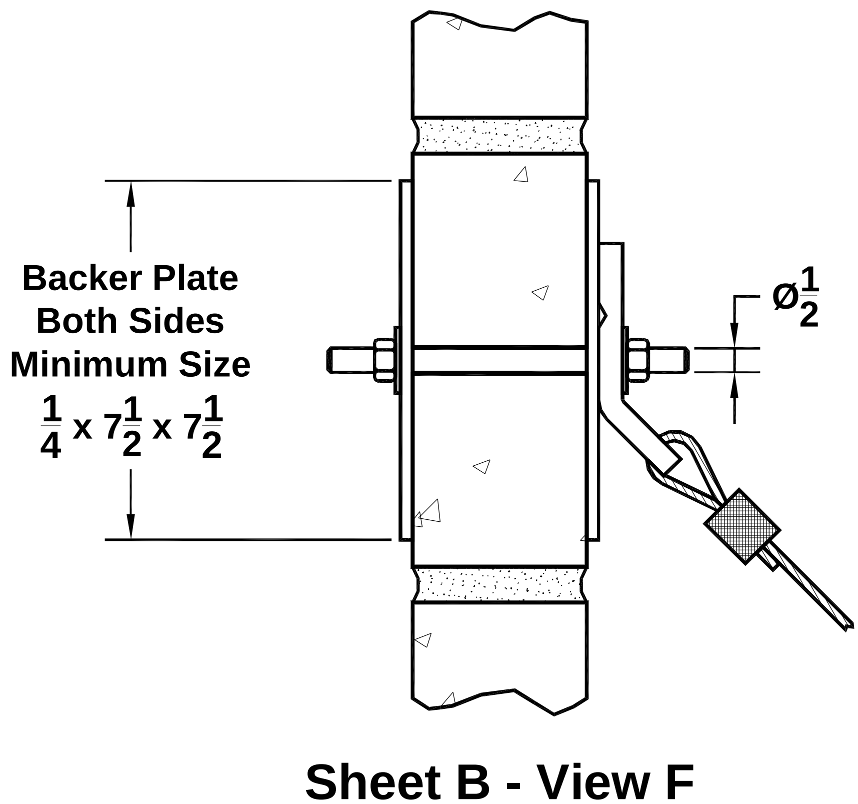

Figure I5-32; KSCA Through Bolt Attachment to a Solid CMU Wall

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Figures I5-33 and I5-34 show attachment methods for hollow CMU walls. ***<u>Here again, the building structural engineer must approve the attachment prior to installation, and indicate the point load limit for the wall</u>***. Also, backer plates beneath the KSCA bracket will be required to protect the CMU. (Note: In the case of the umbrella type anchor, Figure I5-13, the peak capacity is limited to that of the 3/8" anchor.)

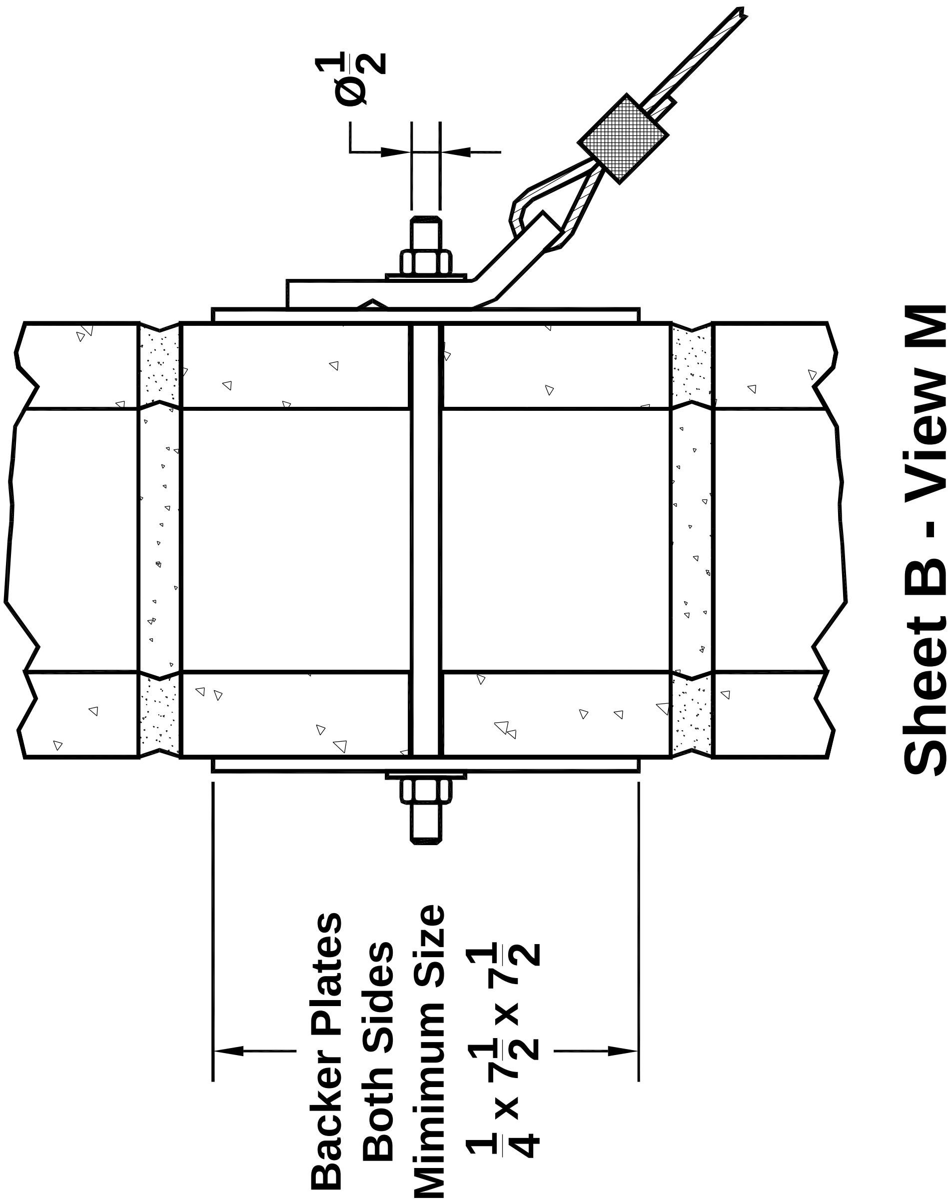

Figure I5-33; KSCA Through Bolt Attachment to a Hollow CMU Wall

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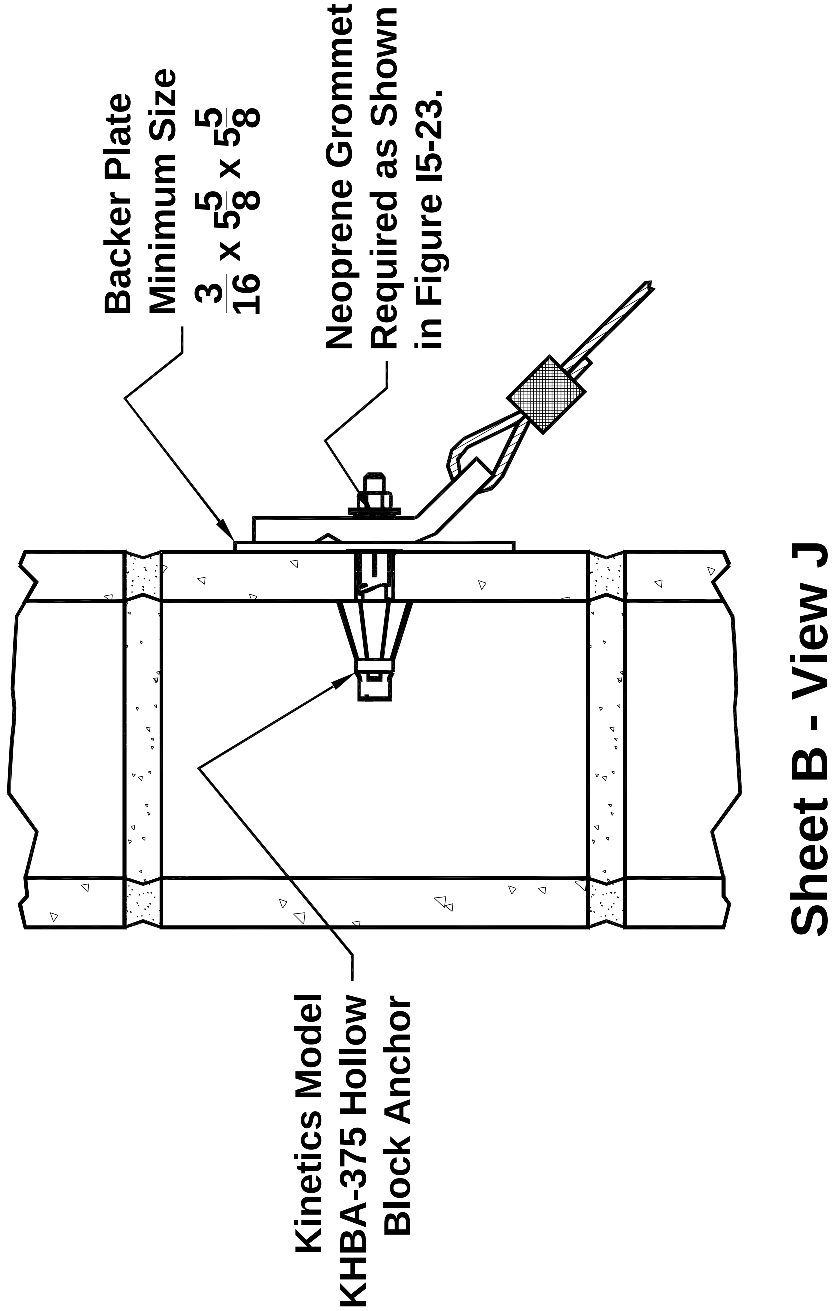

Figure I5-34; KSCA "Umbrella" Type Adhesive Anchor Attachment to a Hollow CMU Wall

Finally, for filled CMU walls, standard wedge type anchors can be used with reduced capacities as shown in Figure I5-35. ***Here also, the building structural engineer must approve the***

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attachment prior to installation, and indicate the point load limit for the wall. As with the other KSCA attachments to CMU walls, a backer plate beneath the KSCA bracket will be required.

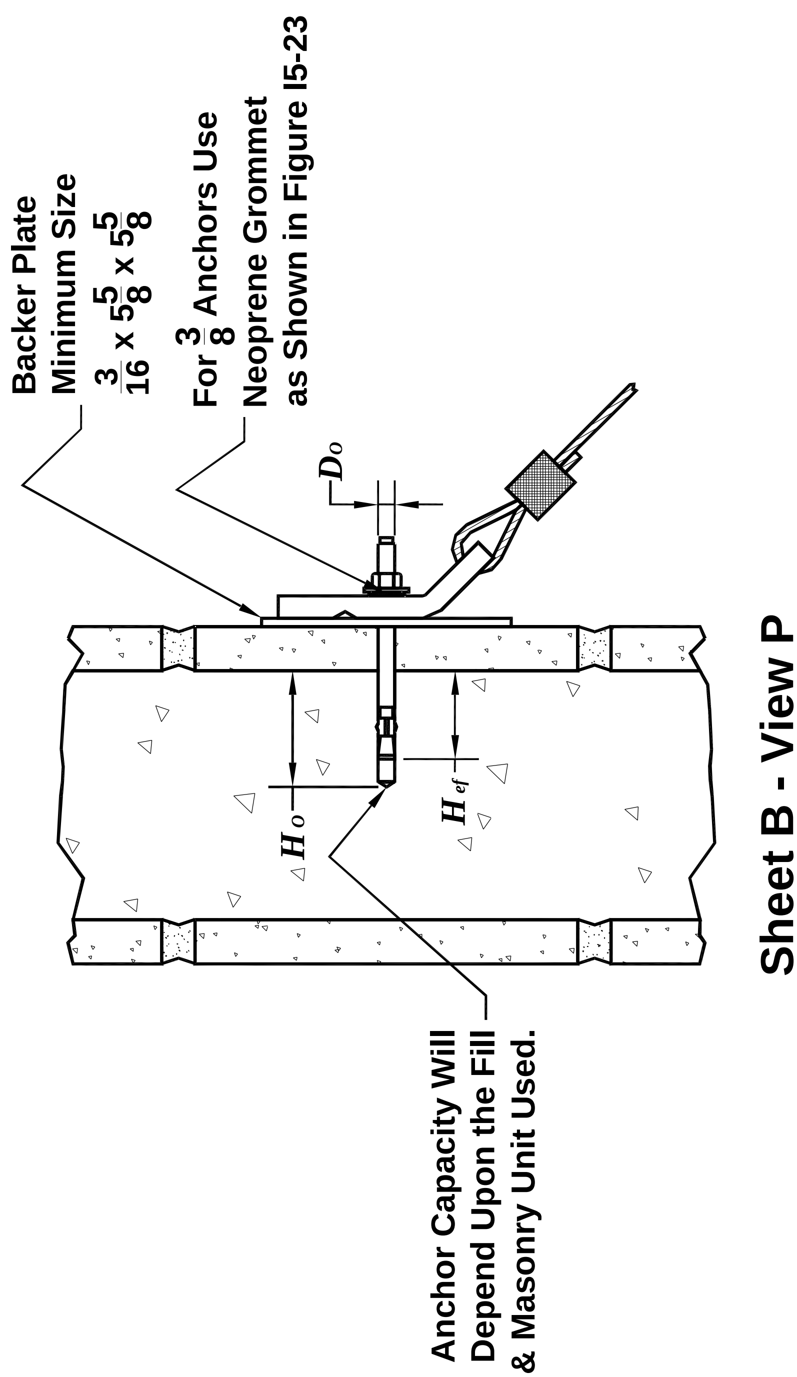

Figure I5-35; KSCA Wedge Type Anchor Attachment to a Filled CMU Wall

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I5.3.5 – 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 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 can not be controlled. The building structural engineer can indicate the proper locations and load capacity limits for each restraint attachment type and location. Figure I5-15 and Table I5-4 show the typical installation dimensions that will apply to lag screw attachments. For more detailed lag screw data see Appendix A4.4. ***KSCA brackets used fro attachment to wood applications will require steel backer plates beneath the KSCA bracket to prevent damage to the wood!*** KSCA brackets installed in Orientation 1 to structural wood are shown in Figure I5-36 for a lag screw attachment and Figure I5-37 for a through bolted attachment.

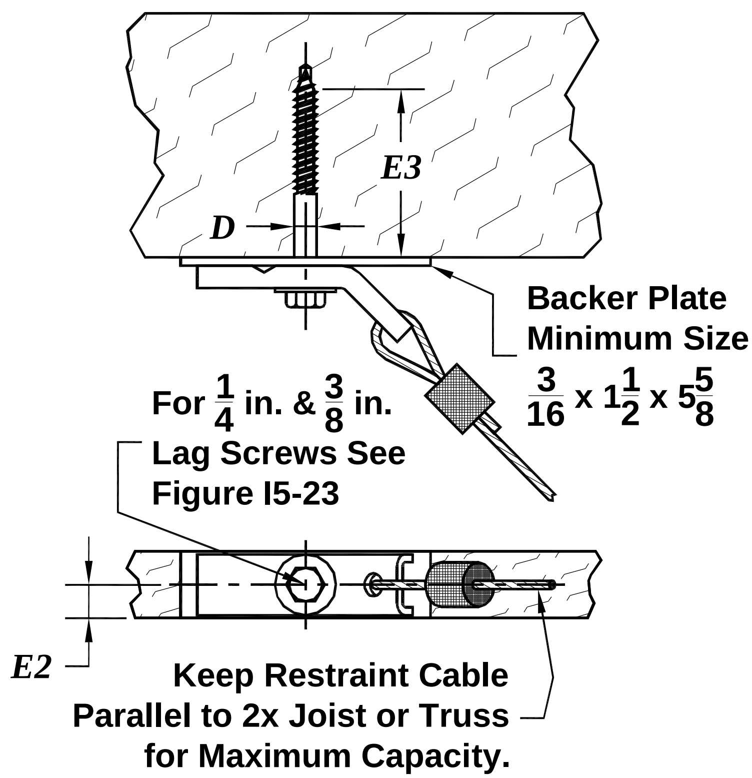

Figure I5-36; KSCA Attached to Wood in Orientation 1 Using a Lag Screw

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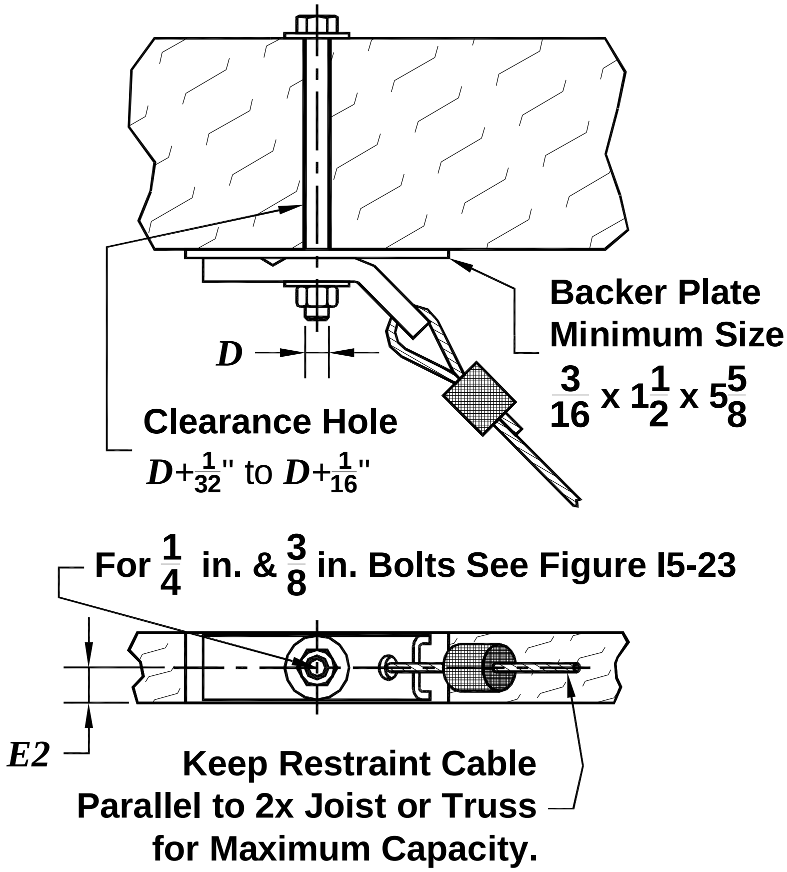

Figure I5-37; KSCA Attached to Wood in Orientation 1 Using a Through Bolt

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 I5-38 for a lag screw attachment and Figure I5-39 for a through bolted attachment.

The KSCA bracket may be attached to the sides of wooden joists and beams in Orientation 2 as shown in Figure I5-40 for lag screw attachment and Figure I5-41 for through bolt attachment.

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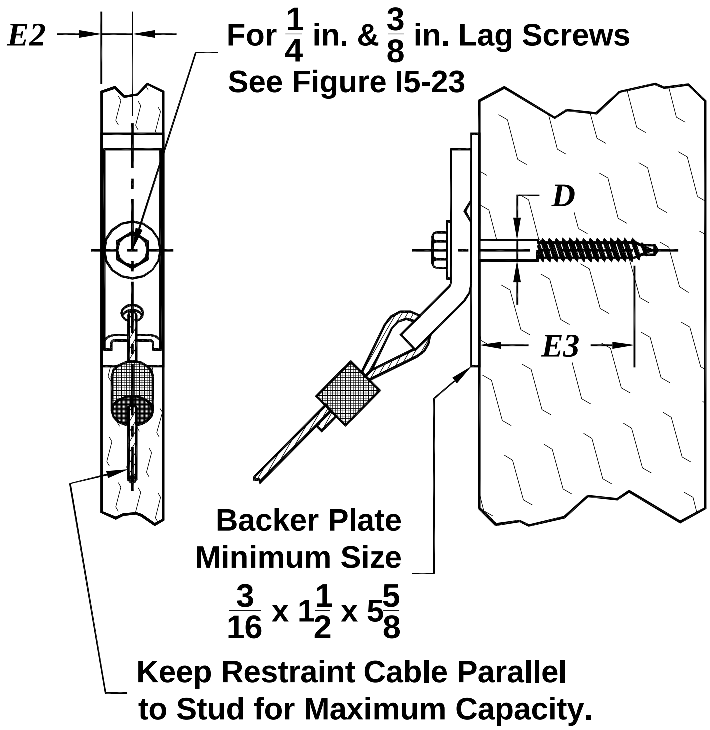

Figure I5-38; KSCA Attached to Wood in Orientation 2 Using a Lag Screw

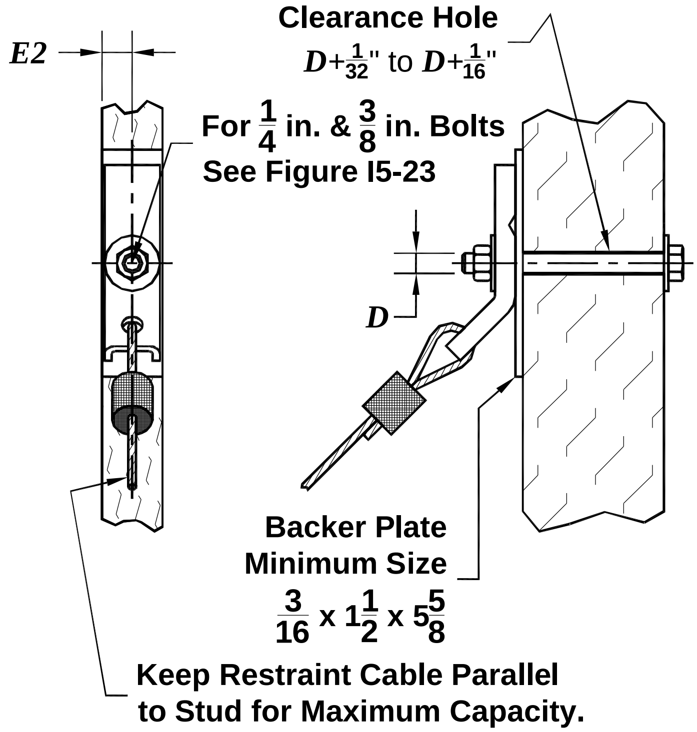

Figure I5-39; KSCA Attached to Wood in Orientation 2 Using a Through Bolt

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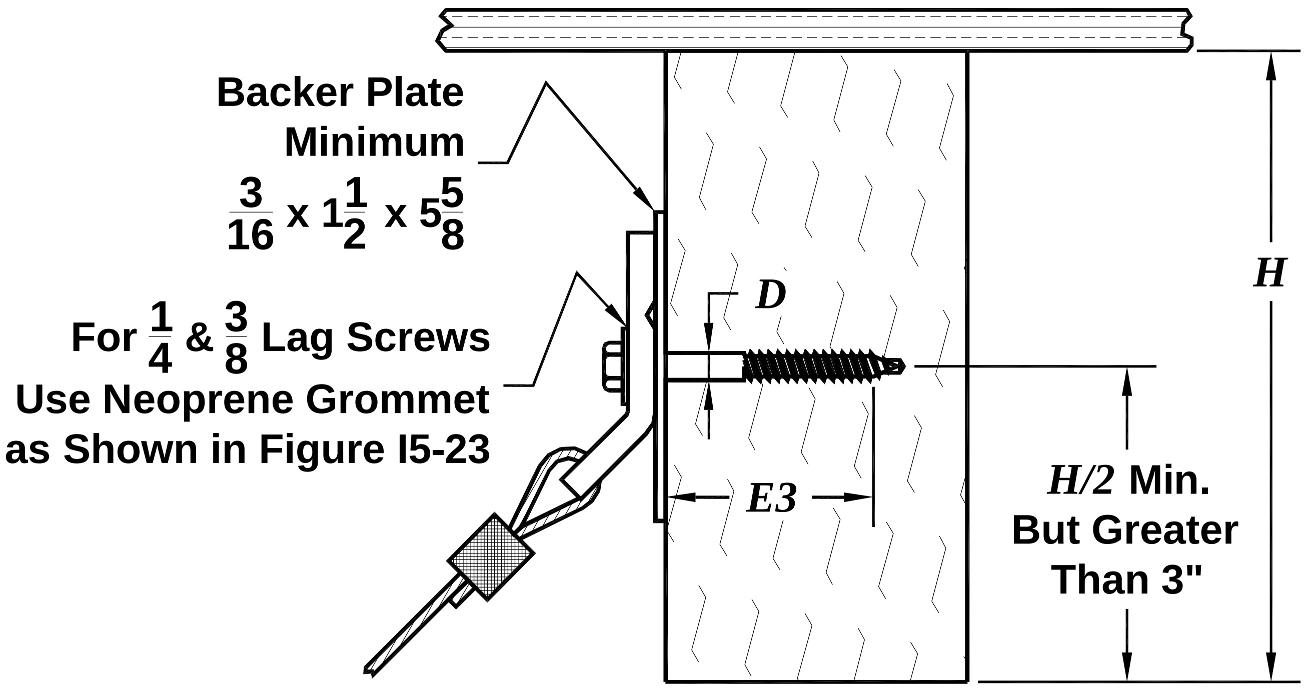

Figure I5-40; KSCA Attached to a Wooden Joist or Beam in Orientation 2 Using a Lag Screw

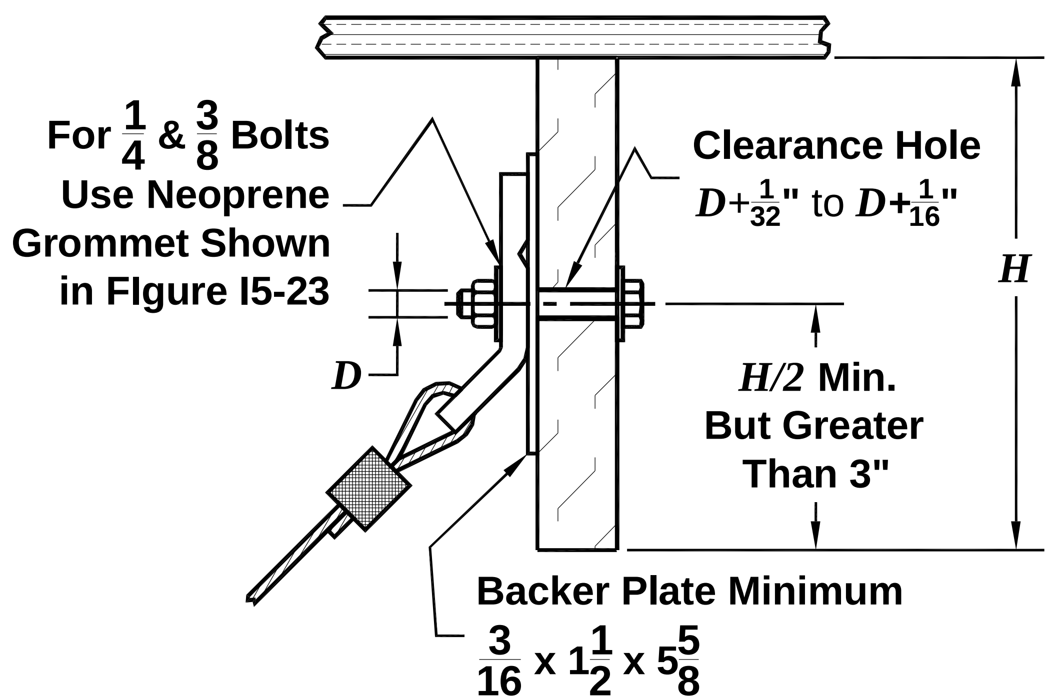

Figure I5-41; KSCA Attached to a Wooden Joist or Beam in Orientation 2 Using a Through Bolt

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The KSCUZ2 and KSCUZ4 attachment kits will allow the KSCA bracket to be mounted to a wooden structural member using two or four lag screws. Figures I5-42 and I5-43 show the KSCUZ2 and KSCUZ4, respectively, mounted to a wooden column.

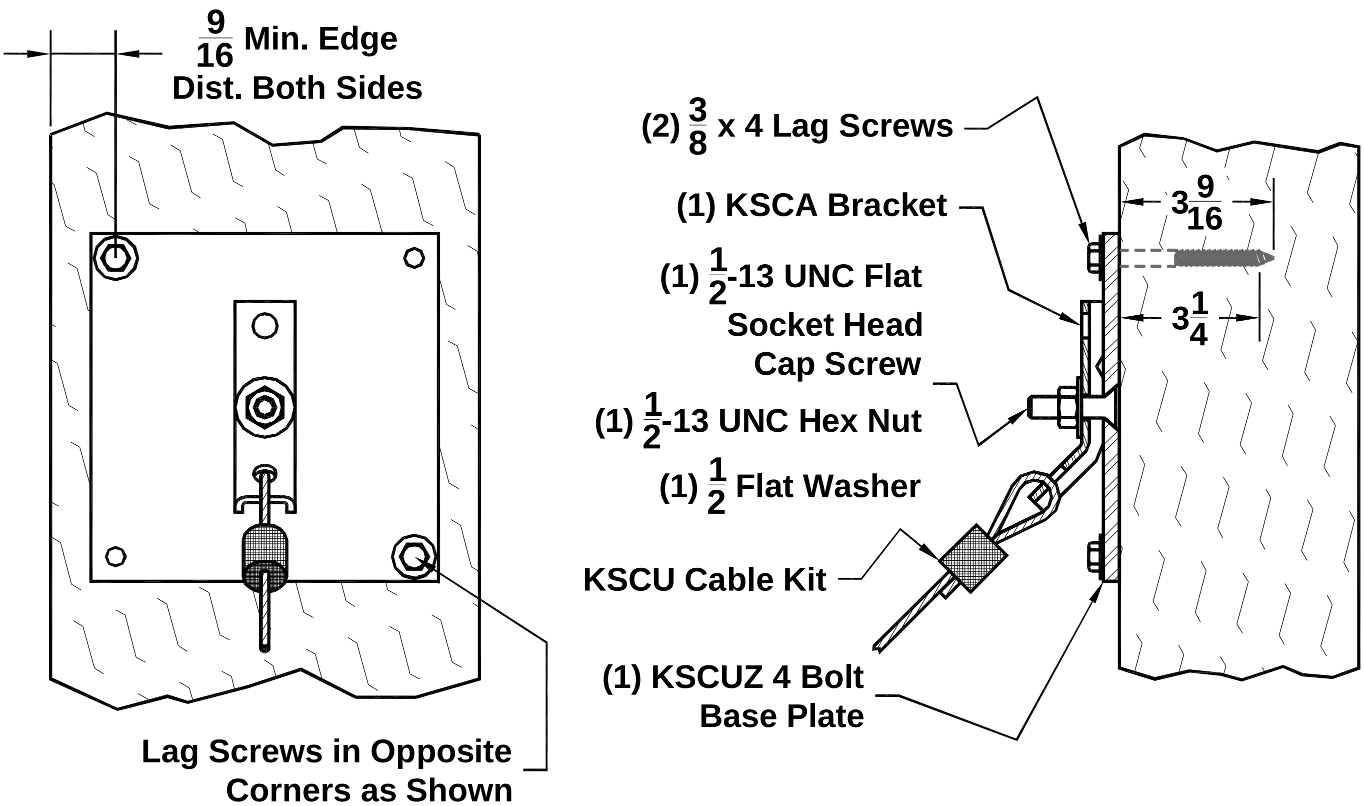

Figure I5-42; Model KSCUZ2 Attachment Kit to a Wooden Column Using the KSCA Bracket – (2) 3/8 Lag Screws

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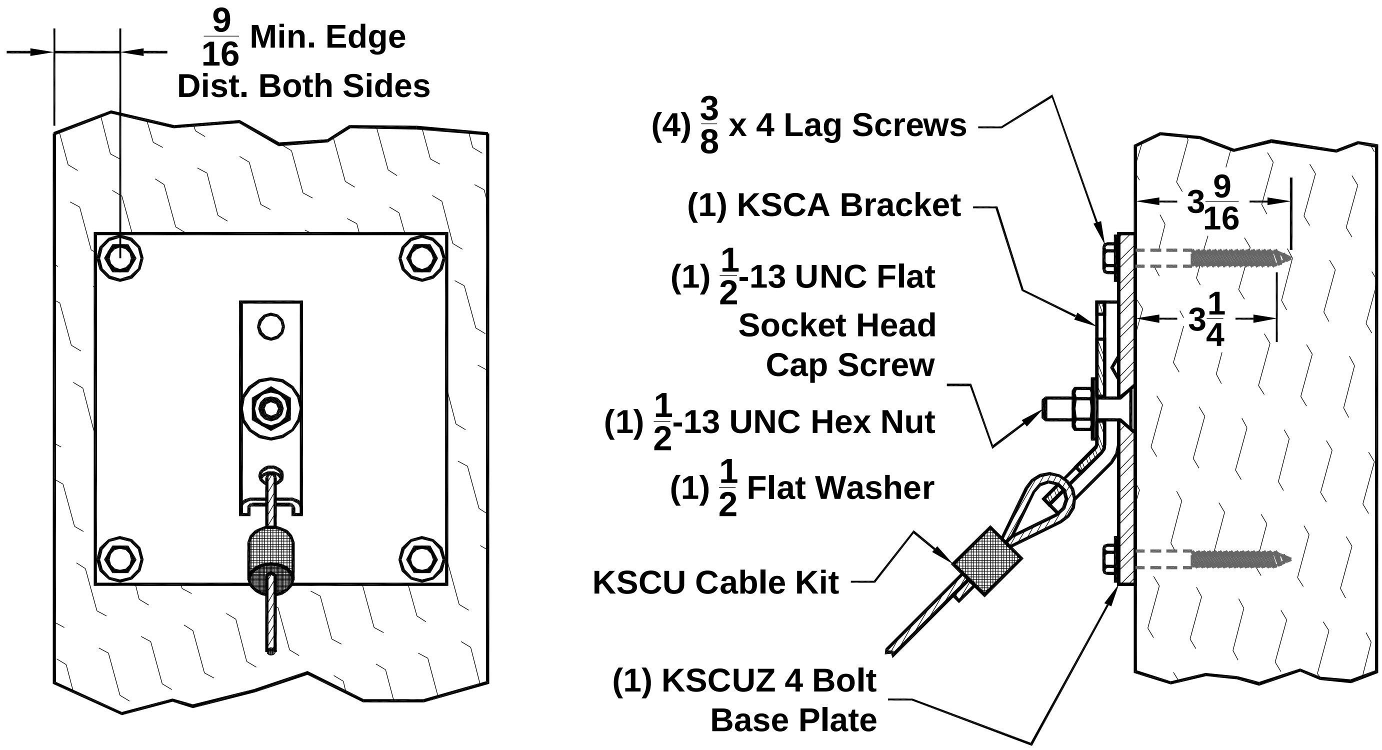

Figure I5-43; Model KSCUZ4 Attachment Kit to a Wooden Column Using the KSCA Bracket – (4) 3/8 Lag Screws

The KSCUZ2 and KSCUZ4 attachment kits will also allow the KSCA bracket to be mounted to a wooden structural beam using two or four lag screws. Figures I5-44 and I5-45 show the KSCUZ2 and KSCUZ4, respectively, mounted to a wooden beam. Figure I5-31 provides the dimensional information to layout the drill pattern for the pilot holes. The pilot drill size is given in Table I5-3 for both hard and soft woods.

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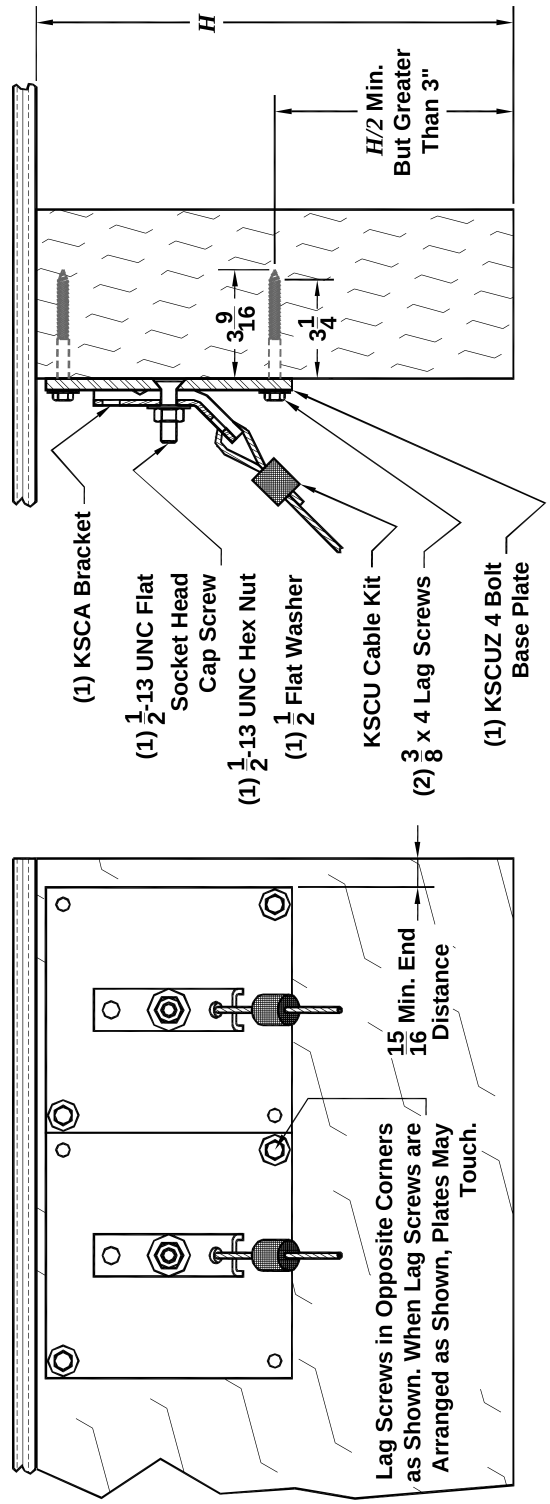

Figure I5-44; Model KSCUZ2 Attachment Kit to a Wooden Beam Using the KSCA Bracket – (2) 3/8 Lag Screws

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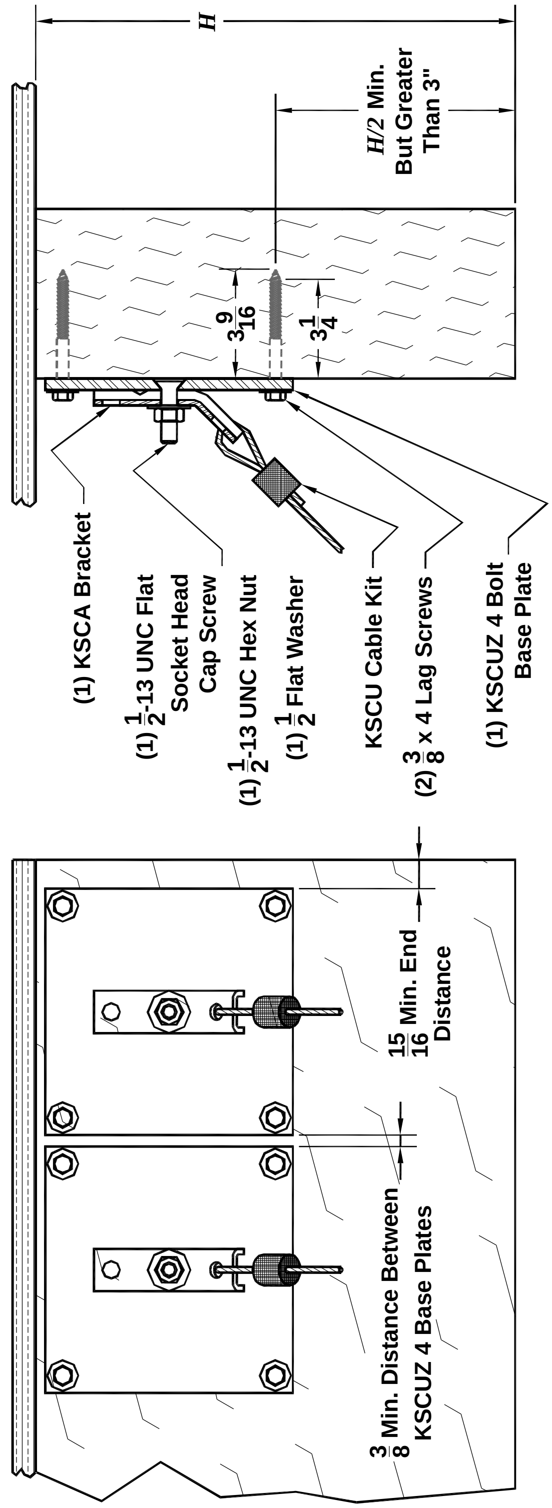

Figure I5-45; Model KSCUZ4 Attachment Kit to a Wooden Beam Using the KSCA Bracket – (4) 3/8 Lag Screws

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I5.4 – KSCC Attachment Brackets:

I5.4.1 – KSCC Brackets – Basic Sizes & Installation:

The Kinetics Noise Control Model KSCC brackets have been designed for use with the larger wire ropes and U-bolt, "Crosby®", type clips. There are currently two KSCC brackets which are described in Figure I5-46.

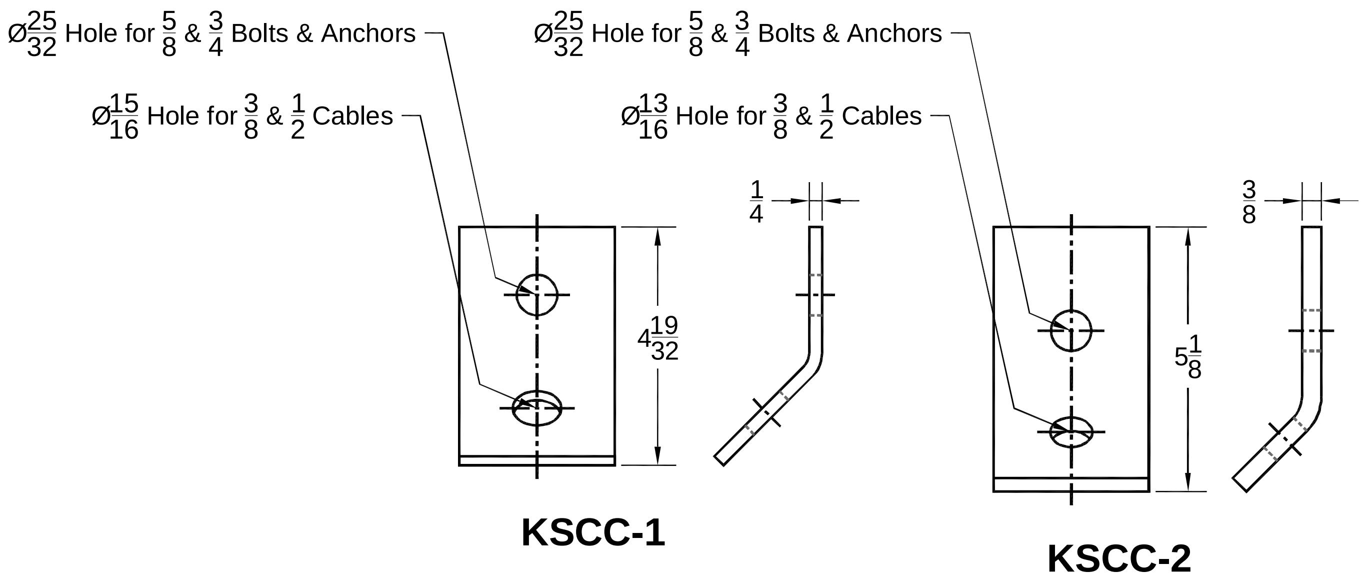

Figure I5-46; Kinetics Noise Control Model KSCC Brackets

A typical KSCC Restraint Cable using a KSCC bracket is shown in Figure I5-47. The details for the U-bolt clip installation may be found in the submittal package or in Appendix A1.1. ***<u>All OSHPD applications require the use of thimbles on both ends of the cable</u>***.

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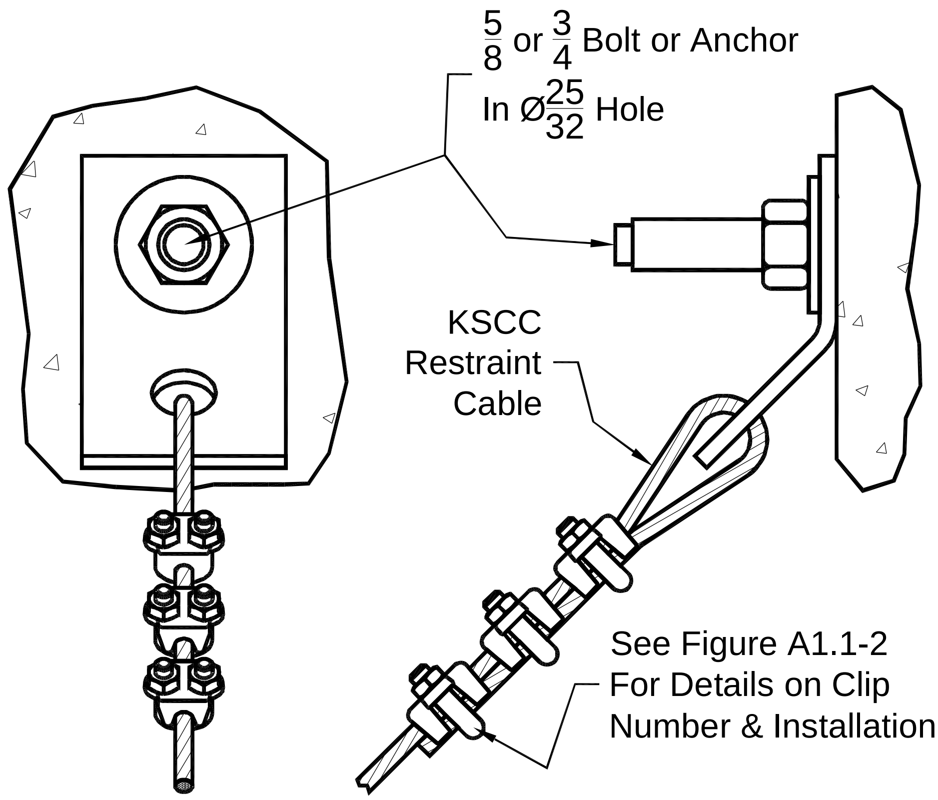

Figure I5-47; Typical Kinetics Noise Control Model KSCC Bracket Installation

I5.4.2 – KSCC Brackets – Attachment to Steel:

Typically, structural engineers do not want bolt clearance holes drilled in structural members that were not sized and selected for this application. So, the KSCC clips may be most readily attached to structural steel by welding as shown in Figures I5-48 and I5-49. Figure I5-50 shows the KSCC brackets attached to structural steel AISI W, M, S, or HP shapes without welding. The pertinent weld information is given in Table I5-5. Figures I5-51, I5-52, and I5-53 show the KSCC brackets attached to steel open web joists.

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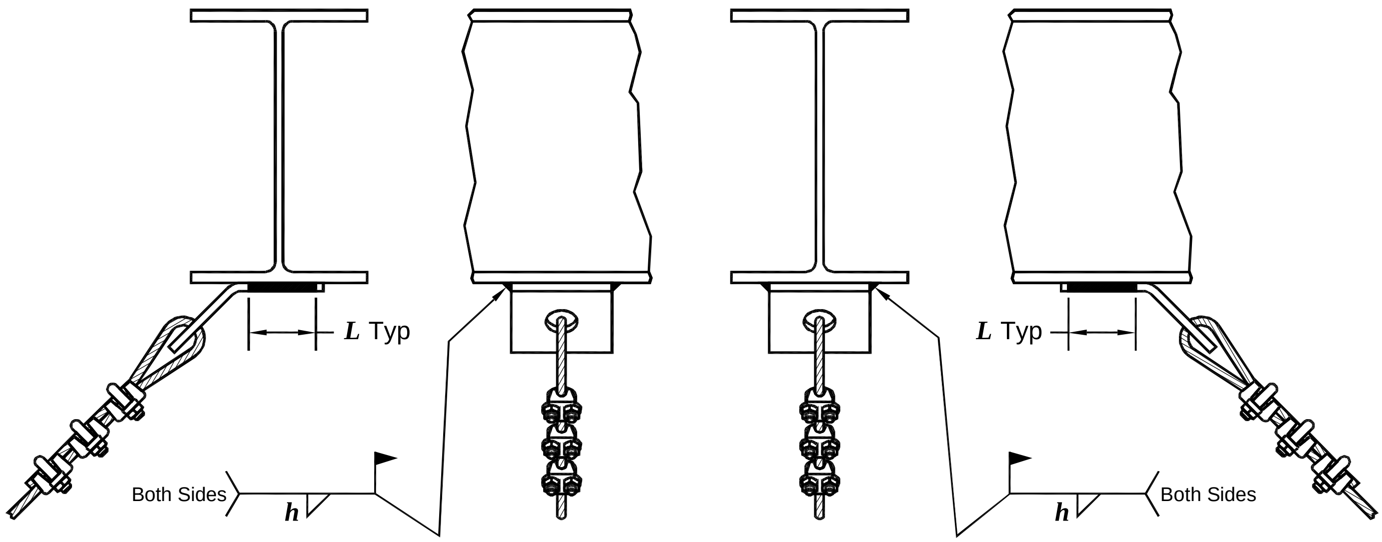
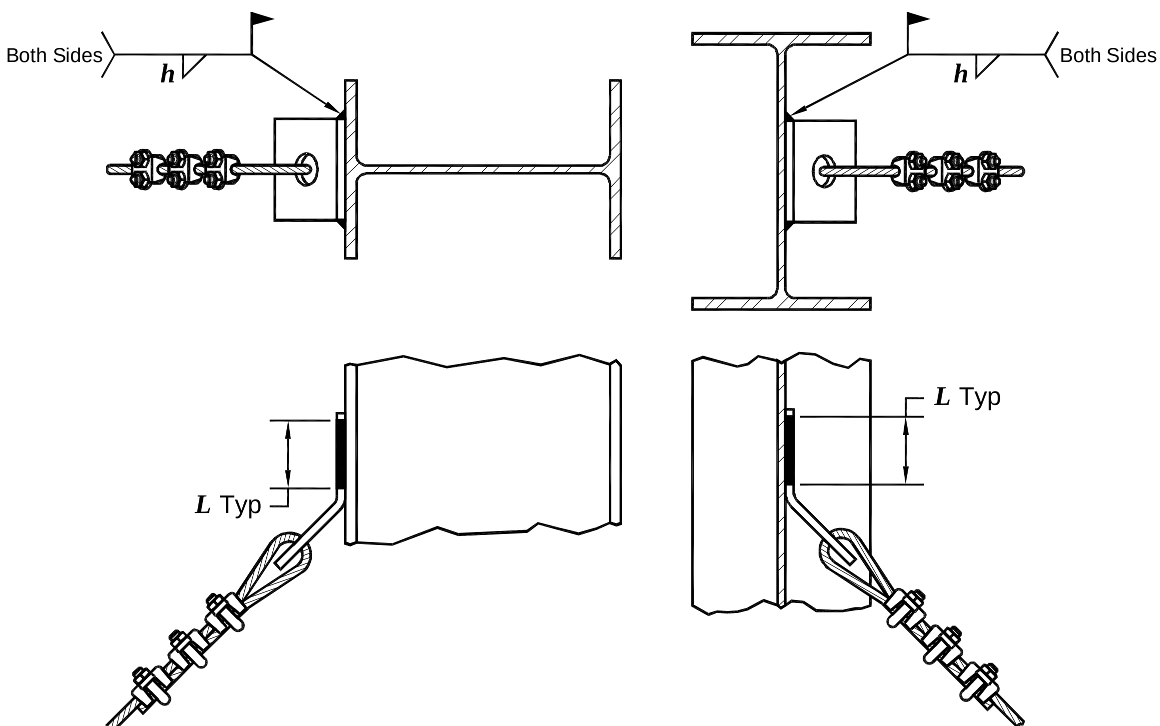


Sheet C - View E

Figure I5-48; KSCC Brackets Welded to Structural Steel in Orientation 1



Sheet C - Views H, P, and Q

Figure I5-49; KSCC Brackets Welded to Structural Steel in Orientation 2

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Table I5-5; Weld Size and Length for KSCC Bracket Weld Attachment to Structural Steel

KSCC Bracket	Weld Size *h* (in)	Weld Length Both Sides *L* (in)
KSCC-1	1/4	2
KSCC-2	5/16	3-1/4

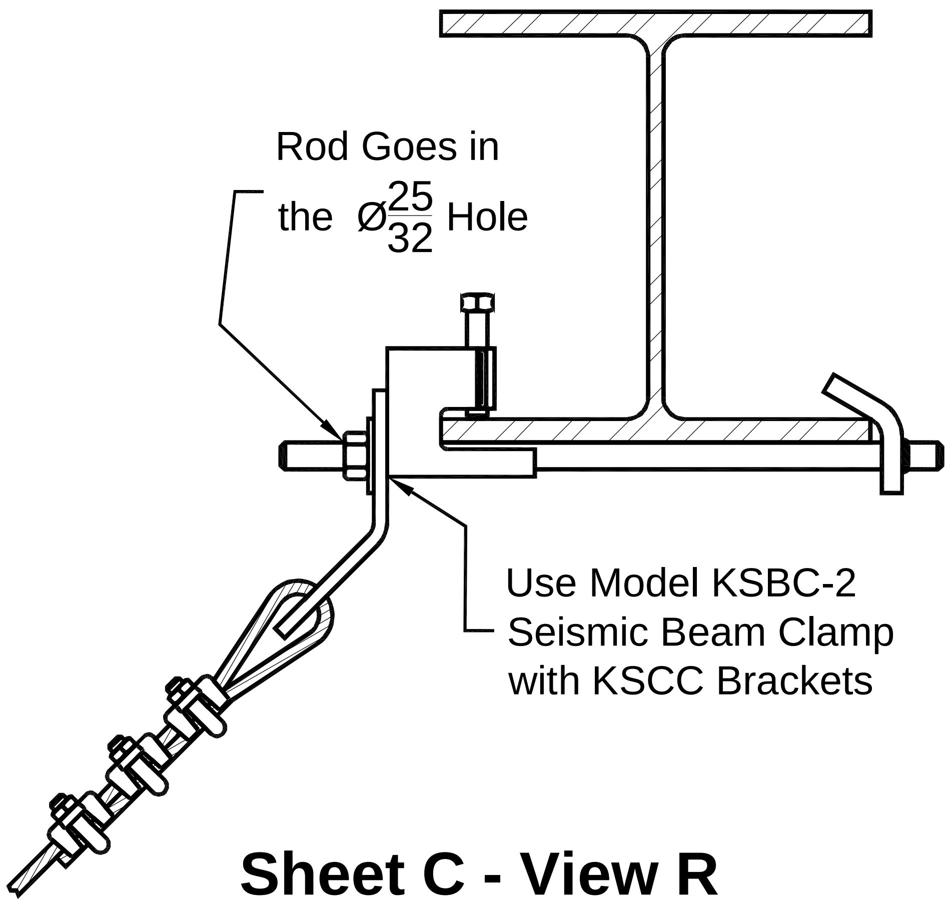

Figure I5-50; Using Model KSBC-2 Seismic Beam Clamps to Attach KSCC Brackets to Structural Steel

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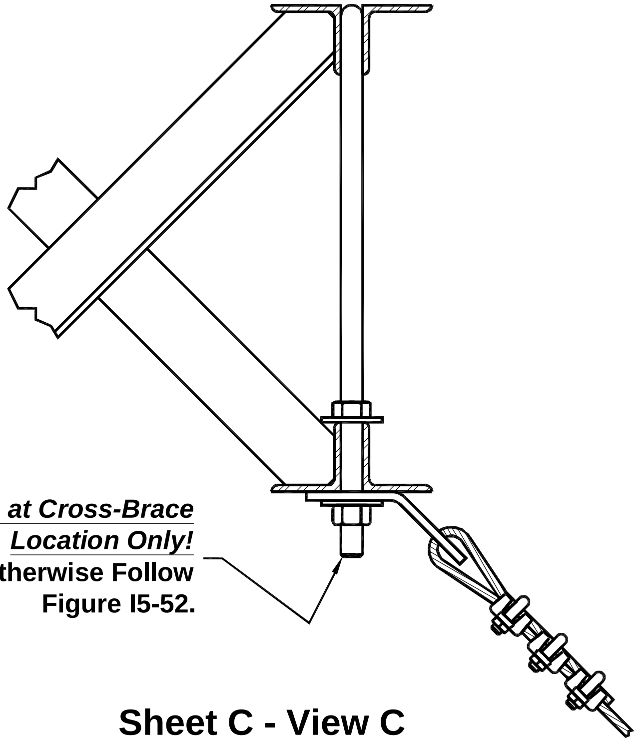

Sheet C - View C

Figure I5-51; Attaching KSCC Brackets to Cross-Braced Open Web Steel Joists

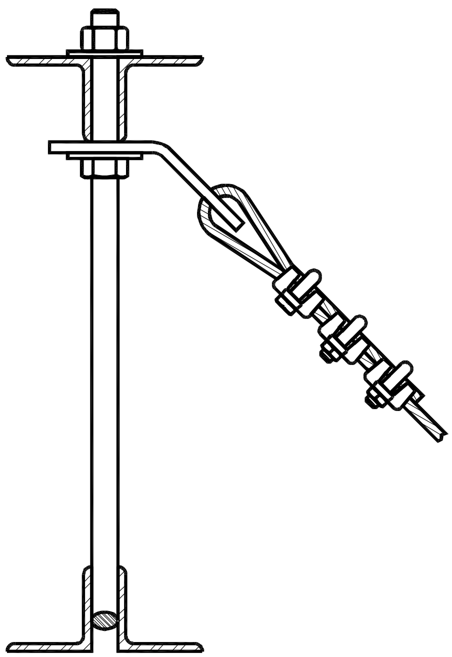

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Figure I5-52; Attaching KSUA Brackets to Un-Braced Open Web Steel Joists

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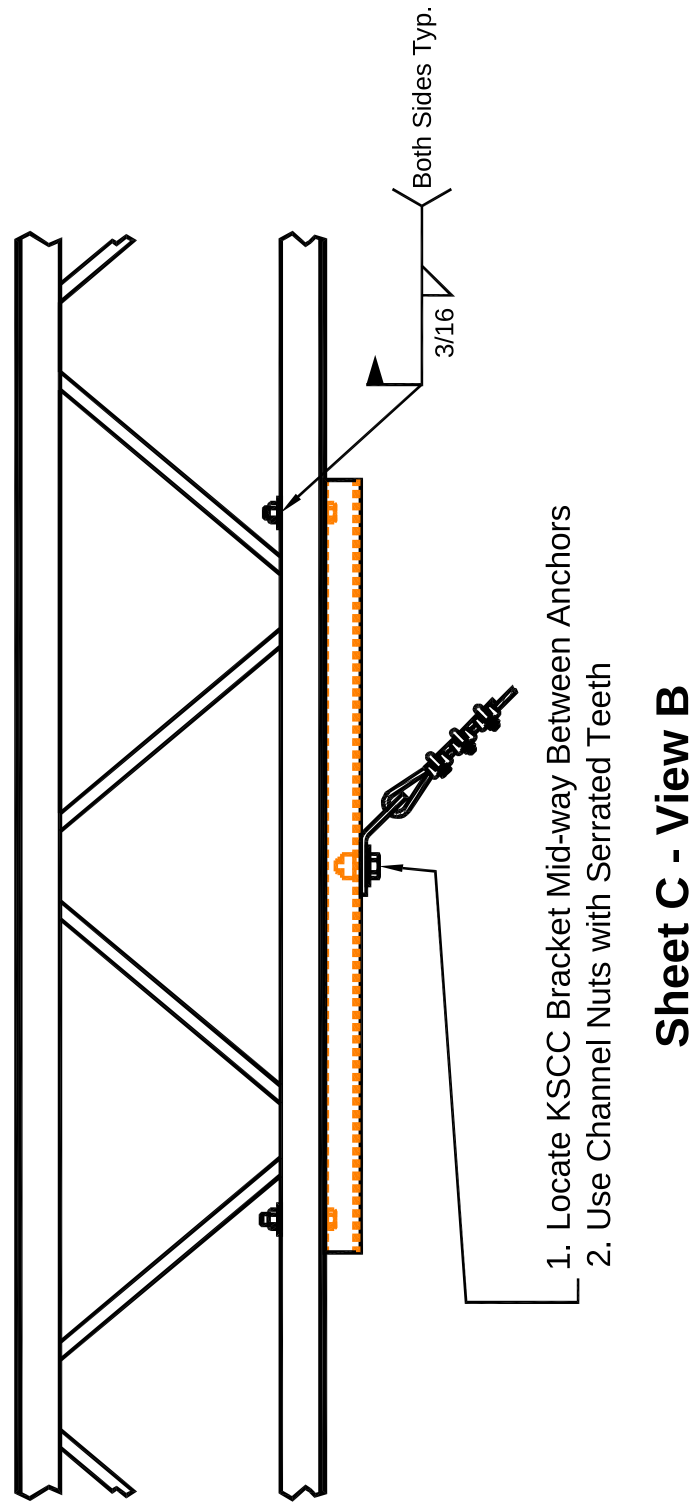

Figure I5-53; Attaching KSCC Brackets to Un-Braced Open Web Steel Joists – Aligned to Joists

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I5.4.3 – KSCC Brackets – Attachment to Concrete:

Model KSCC brackets may be attached to normal weight concrete as shown in Figure I5-54. The installation dimensions indicated in Figure I5-54 are listed in Table I5-6.

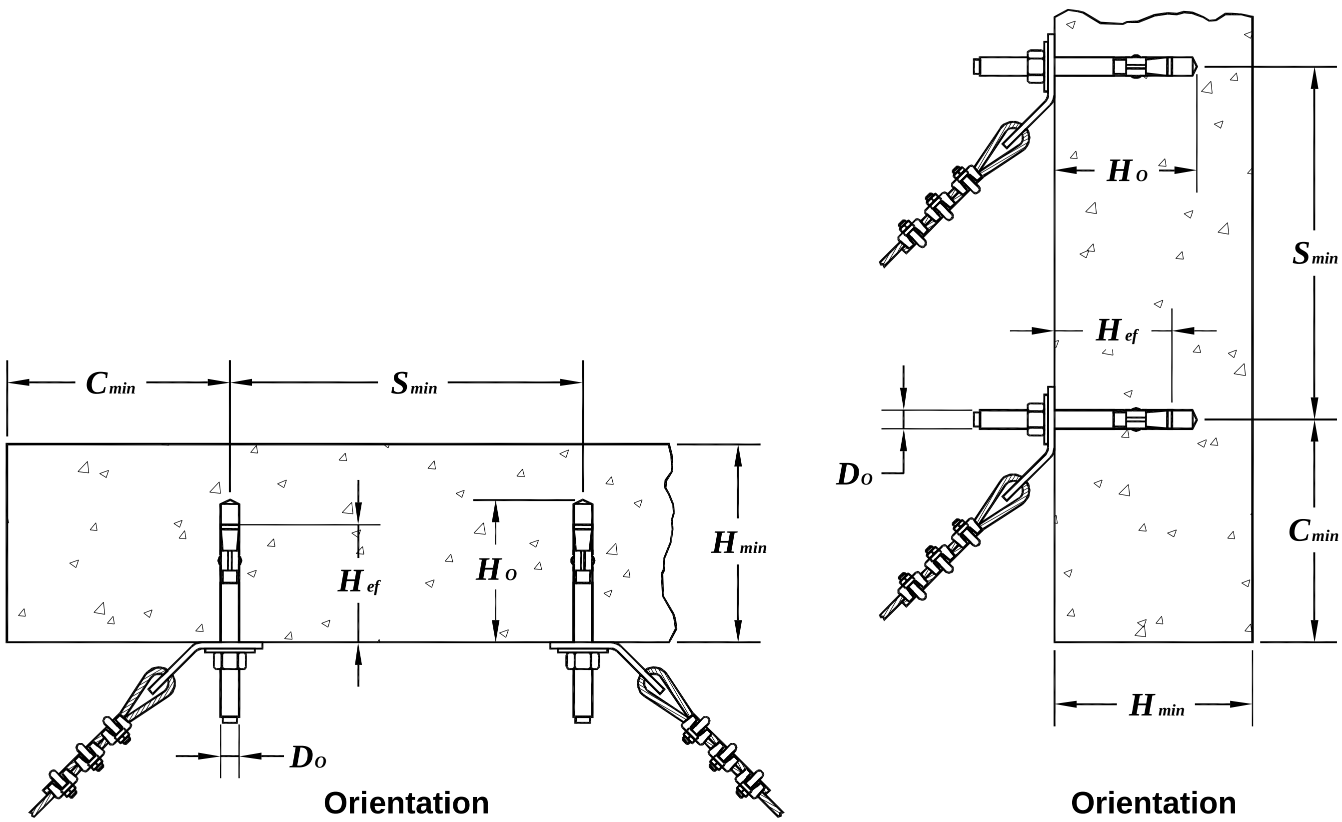

Figure I5-54; Typical KSCC Bracket Installation in Normal Weight Concrete

The installation dimensions listed in Table I5-6 are the minimum requirements to achieve the listed capacities the Model KSCC Seismic Restraint Cable Kits listed in Appendix A1.1, Tables A1.1-3 and A1.1-4 for normal weight concrete.

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Table I5-6; Critical KCCAB Concrete Anchor Installation Dimensions for KSCC Restraint Cable Kits

Anchor & Pilot Hole Size D_O (in)	Pilot Hole Depth H_O (in)	Effective Anchor Embedment H_{ef} (in)	Minimum Concrete Thickness H_{min} (in)	Minimum Anchor Spacing S_{min} (in)	Minimum Anchor Edge Distance C_{min} (in)
1/2	4	3-1/4	6	9-3/4	7-1/2
5/8	4-3/4	4	6	12	8-3/4
3/4	5-3/4	4-3/4	8	14-1/4	9

Figures I5-55 and I5-56 show schemes for attaching the KSCC brackets to concrete which has been poured over corrugated steel decking. The thickest section at the ribs of the decking must meet the Minimum Concrete Thickness from Table I5-6. In the arrangement shown in Figure I5-56, the strut channel must span at least two ribs as shown, see Table I5-7 for anchor substitutions for lightweight concrete over metal decking.

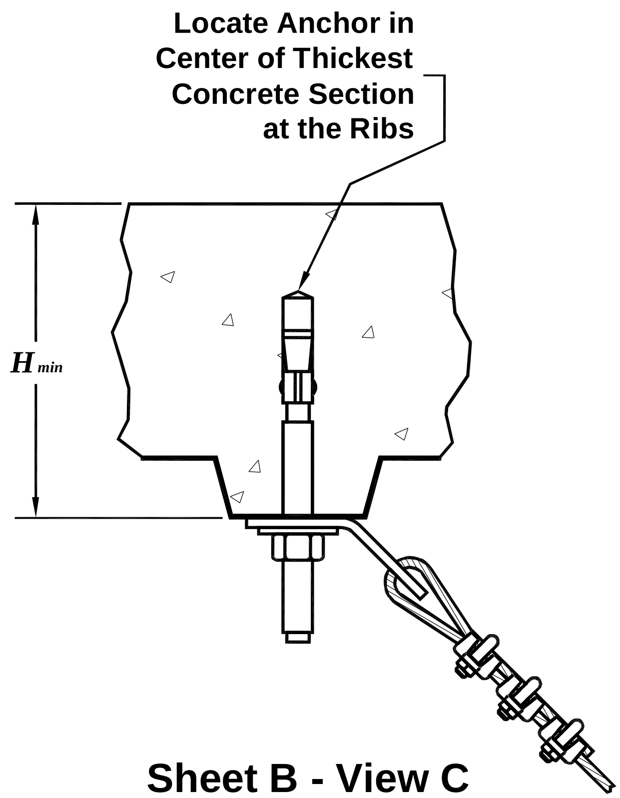

Figure I5-55; KSCC Bracket Attached to Concrete Poured on Corrugated Metal Decking

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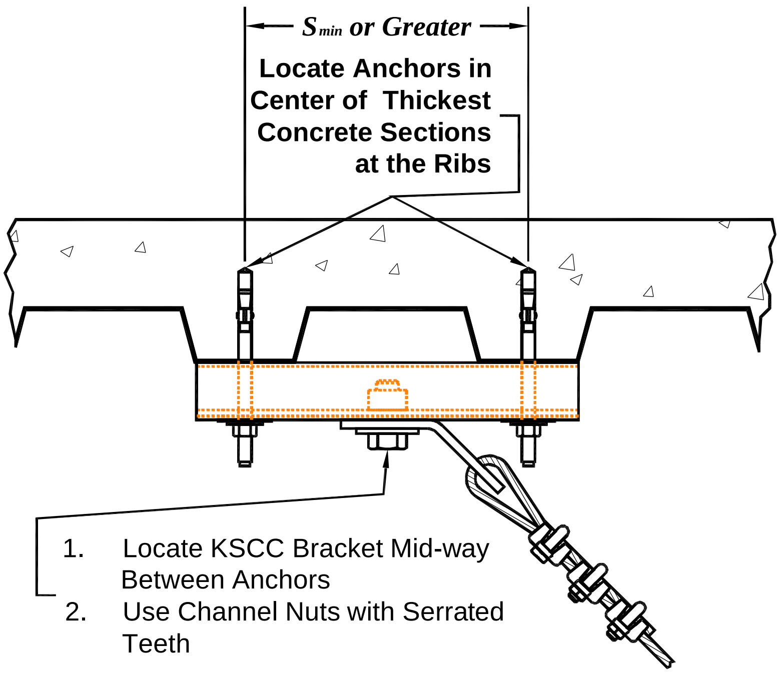
Table I5-7; Anchor Substitution for Lightweight Concrete over Metal Decking for KSCC Cable Kits

KNC Anchor Kit Code	Standard Anchor Size (in)	Used With KNC Restraint Kit Code	Cable Size	For Lightweight Concrete over Metal Decking		
				Required Anchor Size (in)	Required Embedment Depth (in)	Required Quantity
Y!	5/8	K2	1/4 in.	5/8	4	2
Y2	5/8	K3	1/4 in.	5/8	4	4
Y2	5/8	K5	3/8 in.	5/8	4	4



Sheet B - View G

Figure I5-56; KSCC Bracket Attached to Strut Channel Anchored to Concrete Poured on Corrugated Metal Decking

There may be certain instances where the KSCC bracket with a single anchor will not have the required capacity. In those cases, the KSCCZ2, two concrete anchors, or the KSCCZ4, four concrete anchor, kits may be used. These installations, orientations and required bolt template are shown in Figures I5-57, I5-58, I5-59, and I5-60 respectively. Minimum edge distances and spacings must be maintained to generate the full rated capacity of the attachment kits.

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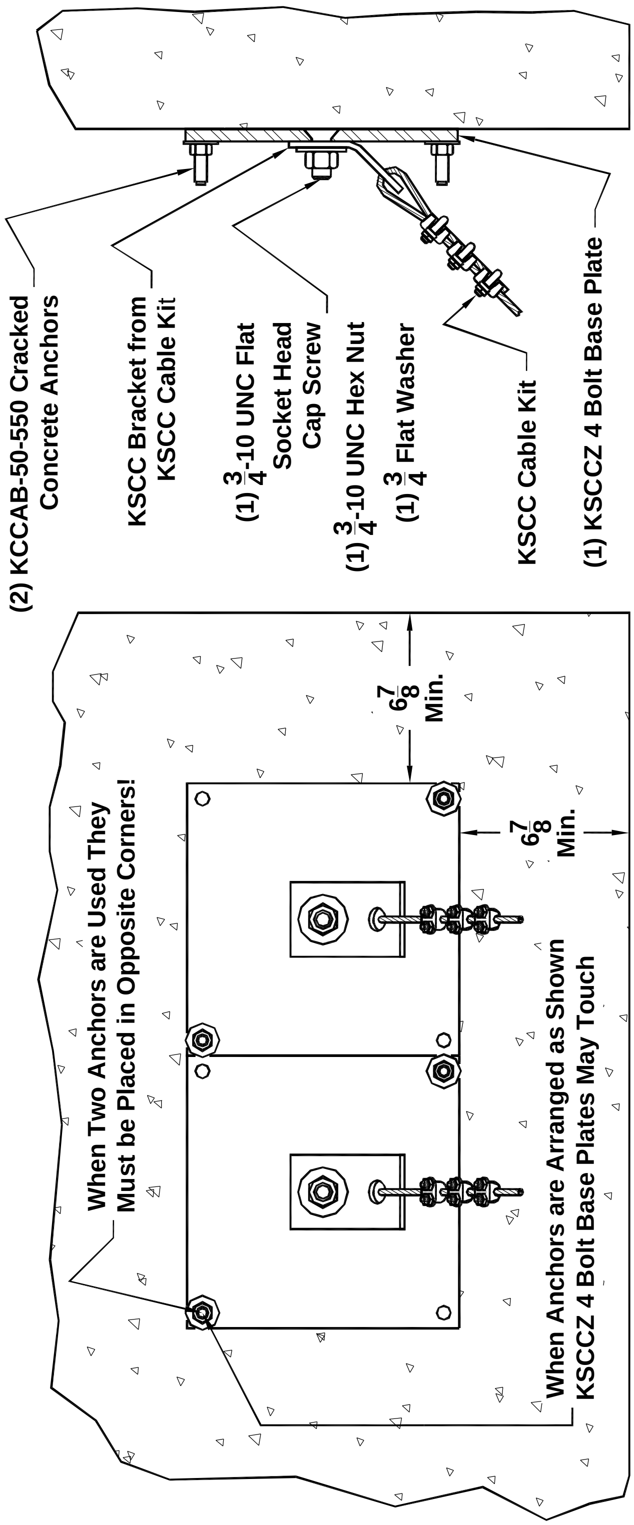

Figure I5-57; Model KSCCZ2 Attachment Kit to Concrete Using the KSCC Brackets – (2) 1/2 Anchors

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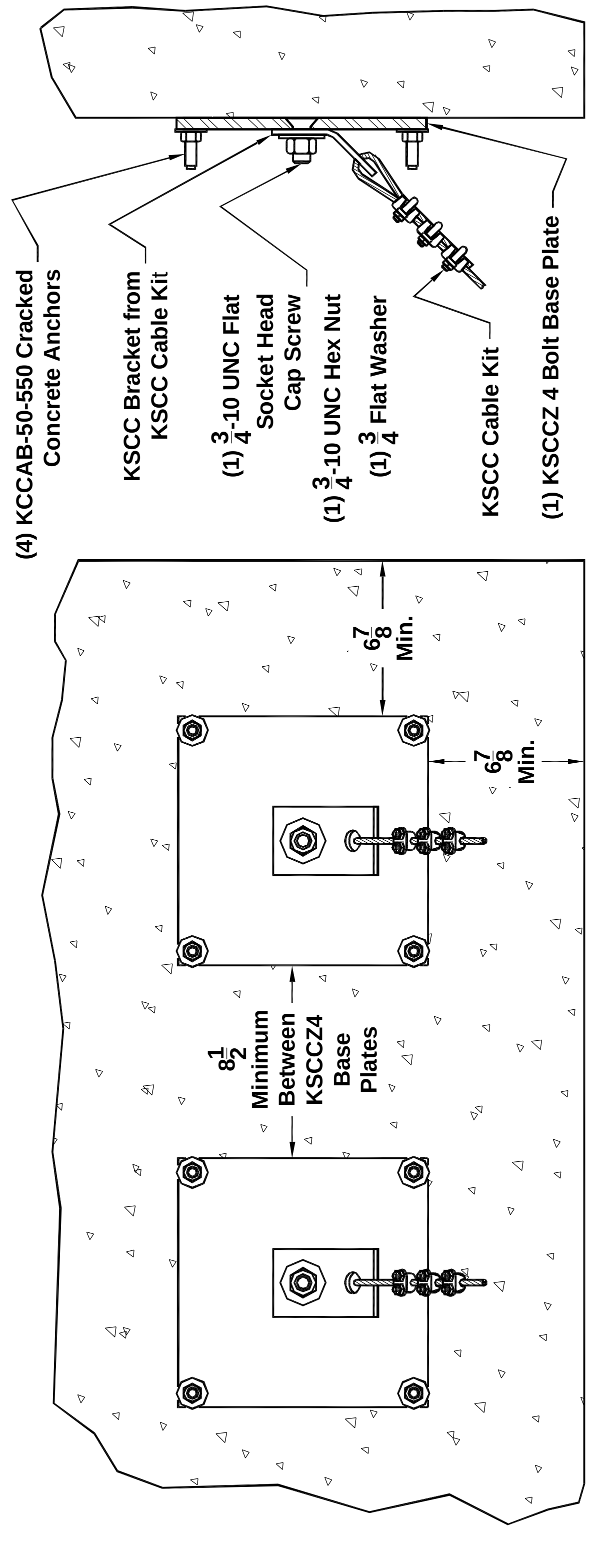

Figure I5-58; Model KSCCZ4 Attachment Kit to Concrete Using the KSCC Brackets – (4) 1/2 Anchors

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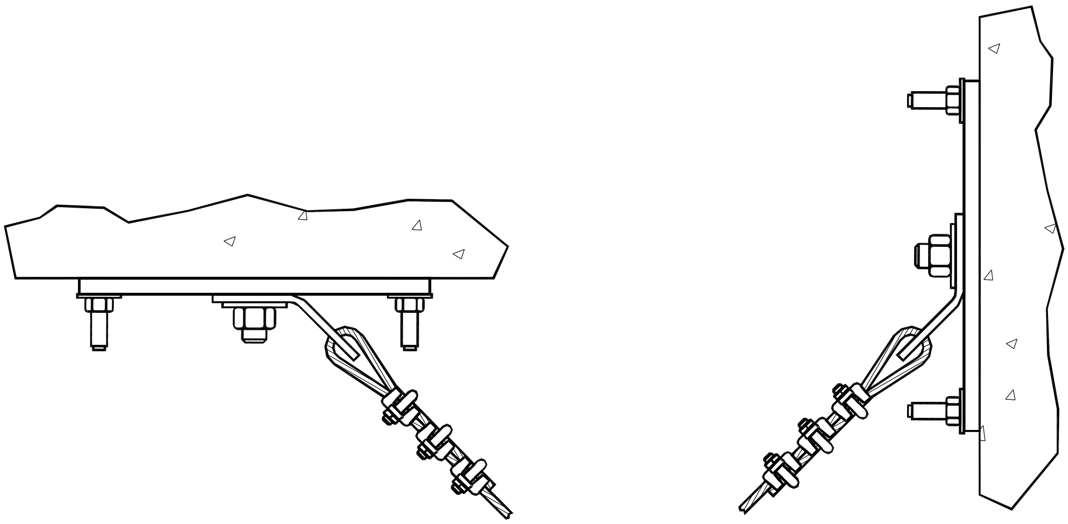

Figure I5-59; Models KSCCZ2 and KSCCZ4 Concrete Attachment Kits for KSCC Brackets in Orientation 1 and Orientation 2

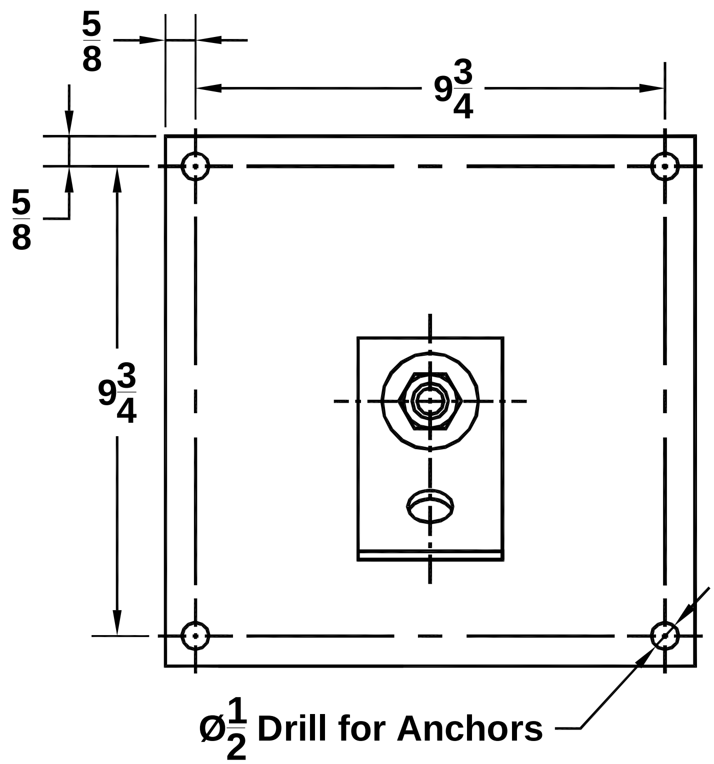

Figure I5-60; Anchor Hole Drill Template for Models KSCCZ2 and KSCCZ4

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I5.4.4 – KSCC Brackets – Attachment to CMU Walls:

The concrete used for CMU components is usually a lightweight concrete, and often has fillers and aggregates such as fly ash and bottom ash. Therefore, the strength of this concrete does not match that of normal weight concrete, and may not match that of poured in place lightweight concrete. For this reason, ***attachments for seismic restraints made to CMU walls must be approved by the building structural engineer in advance of installation of the restraints***. When solid masonry blocks are used, the best way to make theses attachments is to use through bolts with load plates on both sides of the wall as shown in Figure I5-61. The capacity of the attachment will be what ever the building structural engineer says that the point load limit for the wall will be. (Up to but not exceeding the cable kit capacity as published by Kinetics Noise Control.)

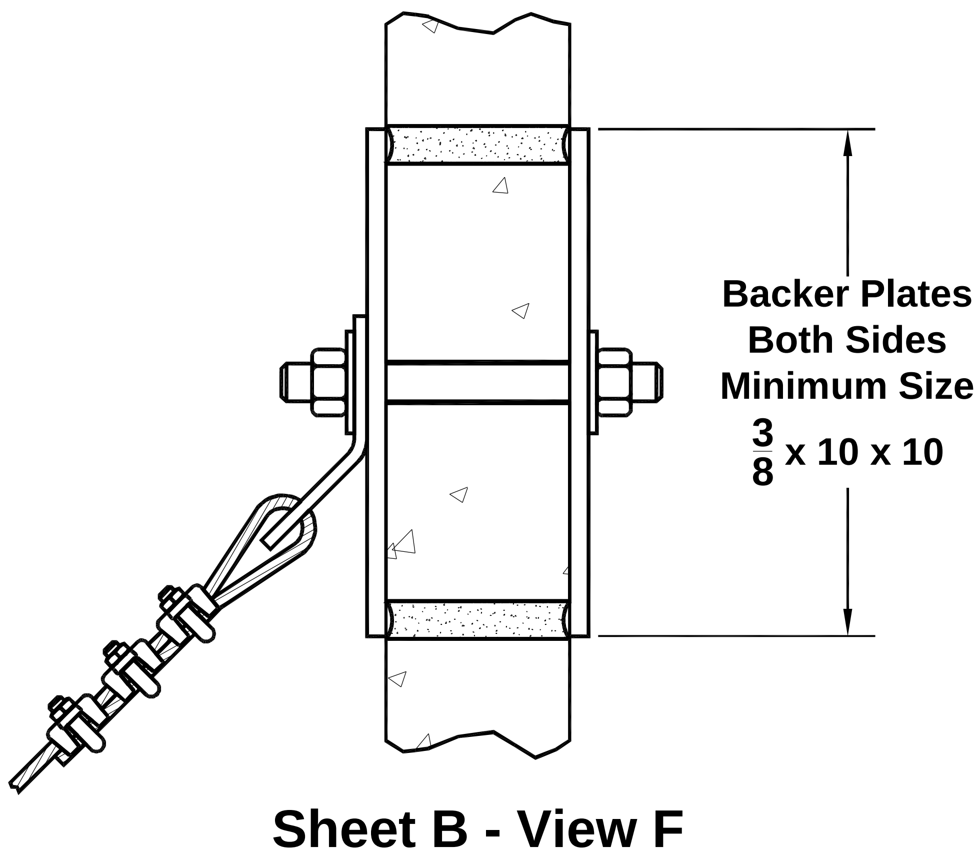

Figure I5-61; KSCC Through Bolt Attachment to a Solid CMU Wall

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Figures I5-62 and I5-63 show attachment methods for hollow CMU walls. ***Here again, the building structural engineer must approve the attachment prior to installation, and indicate the point load limit for the wall***. (Note: In the case of the umbrella type anchor, Figure I5-13, the peak capacity is limited to that of the 3/8" anchor.)

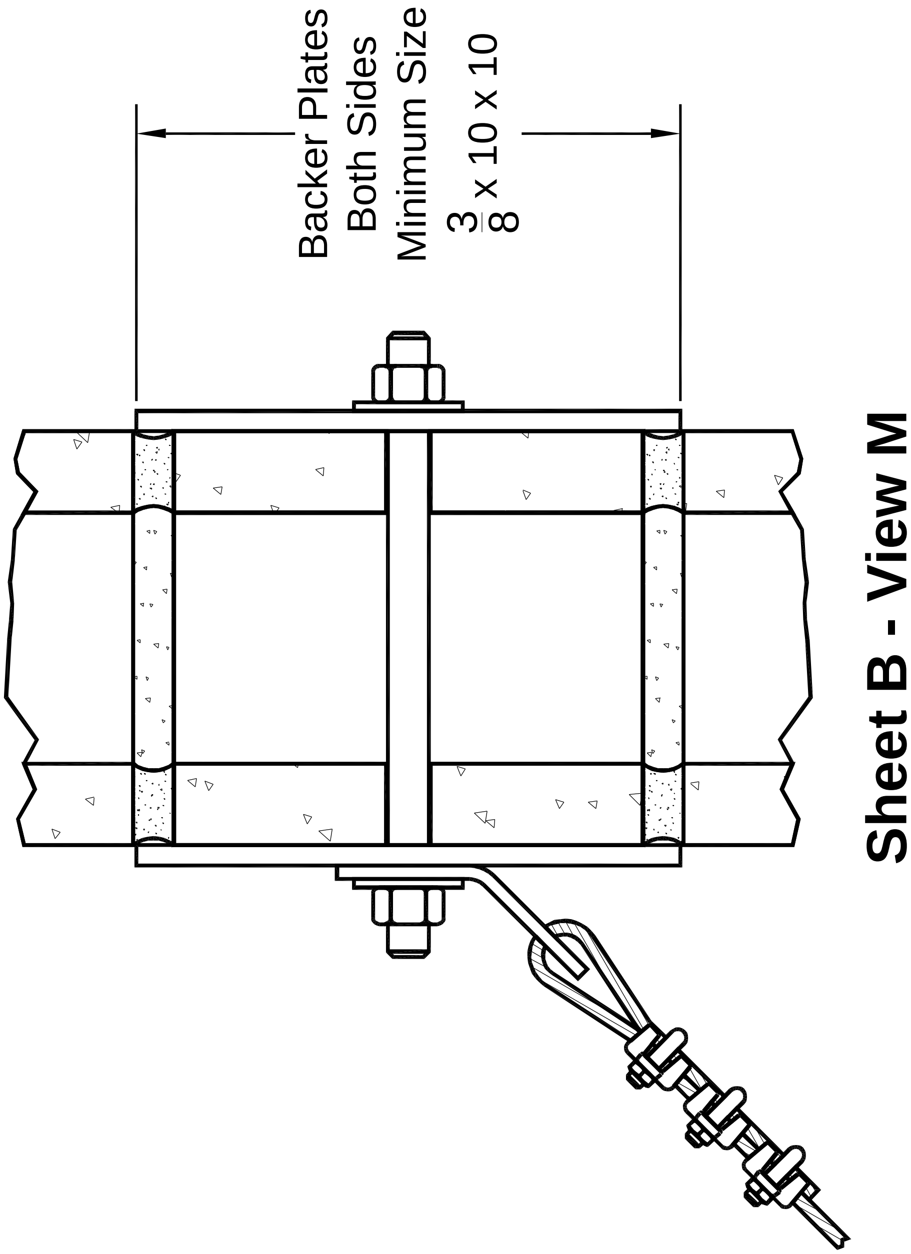

Figure I5-62; KSCC Through Bolt Attachment to a Hollow CMU Wall

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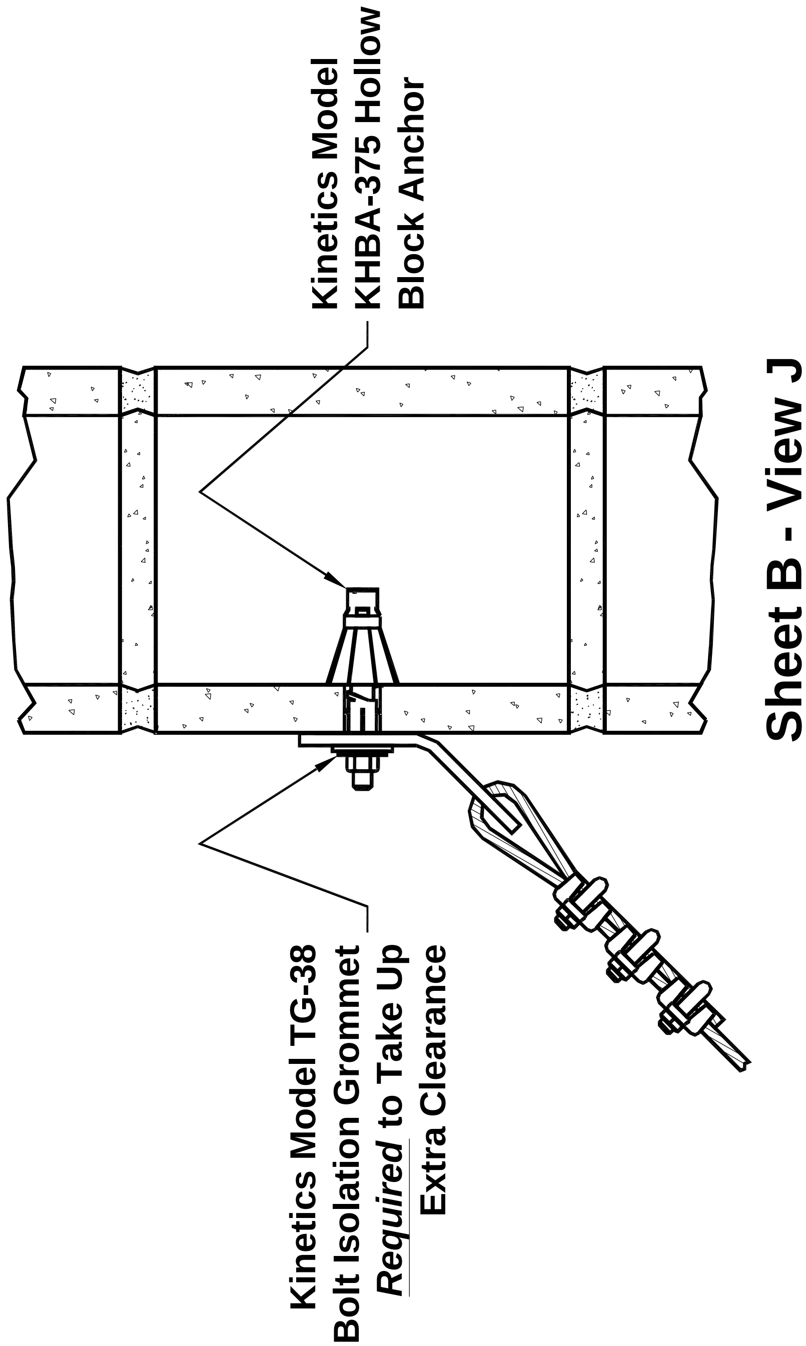

Figure I5-63; KSCC "Umbrella" Type Adhesive Anchor Attachment to a Hollow CMU Wall

Finally, for filled CMU walls, standard wedge type anchors can be used with reduced capacities as shown in Figure I5-64. ***Here also, the building structural engineer must approve the attachment prior to installation, and indicate the point load limit for the wall***.

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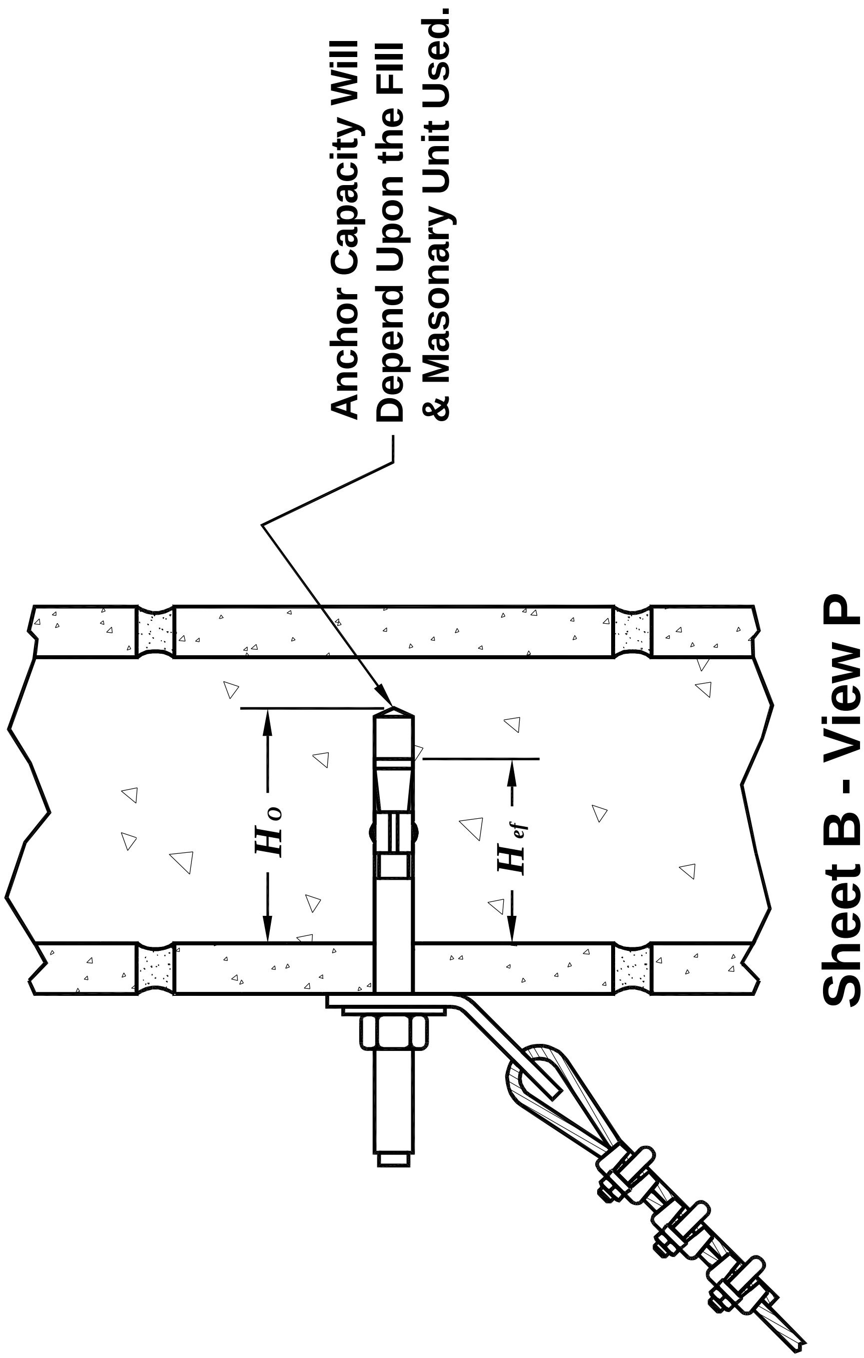

Figure I5-64; KSCC Wedge Type Anchor Attachment to a Filled CMU Wall

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I5.4.5 – KSCC 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 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 can not be controlled. The building structural engineer can indicate the proper locations and load capacity limits for each restraint attachment type and location. Figure I5-15 and Table I5-8 show the typical installation dimensions that will apply to lag screw attachments. For more detailed lag screw data see Appendix A4.4.

Table I5-8; Lag Screw and Through Bolt Installation Data for Model KSCC, Restraint Cable Kits

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				
1/2	15/64	21/64	2	2	3/4	4
5/8	19/64	13/32	2-2/12	2-1/2	15/16	5
3/4	23/64	31/64	3	3	1-1/8	6

Model KSCC brackets installed in Orientation 1 to structural wood using lag screws and through bolts are shown in Figures I5-65 and I5-66 respectively. KSCC brackets attached to structural wood in Orientation 2 using lag screws and through bolts are shown, respectively, in Figures I5-67 and I5-68.

Special Note: Seismic and wind restraints are not to be attached to the end grain of structural wood!!

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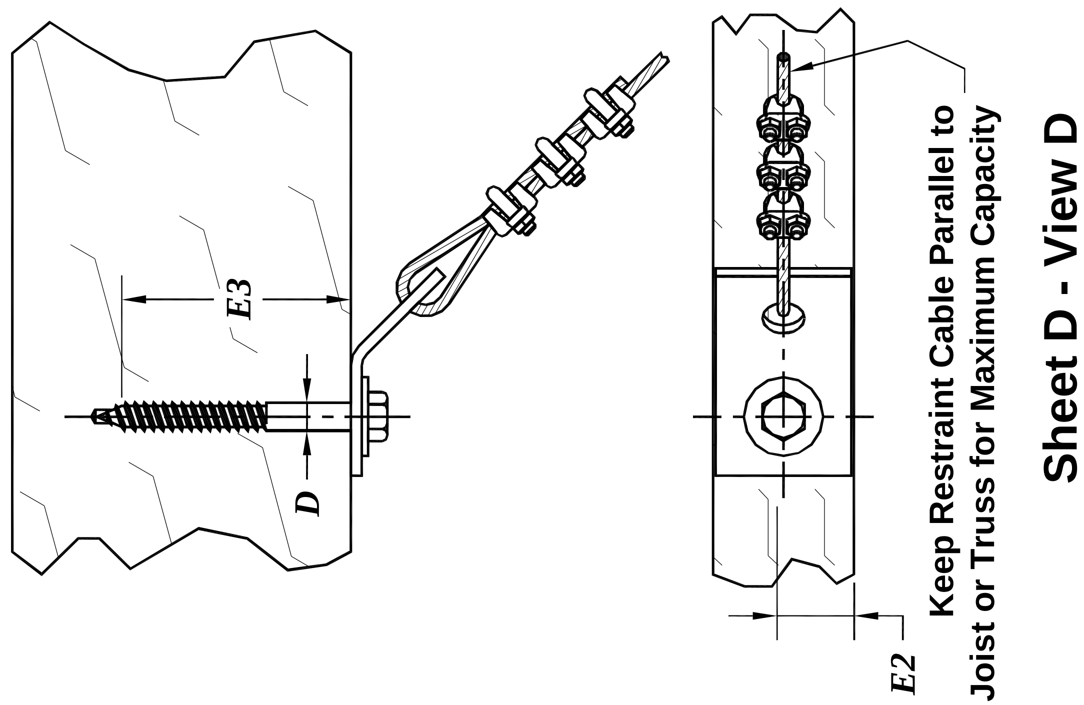

Figure I5-65; KSCC Attached to Wood in Orientation 1 Using a Lag Screw

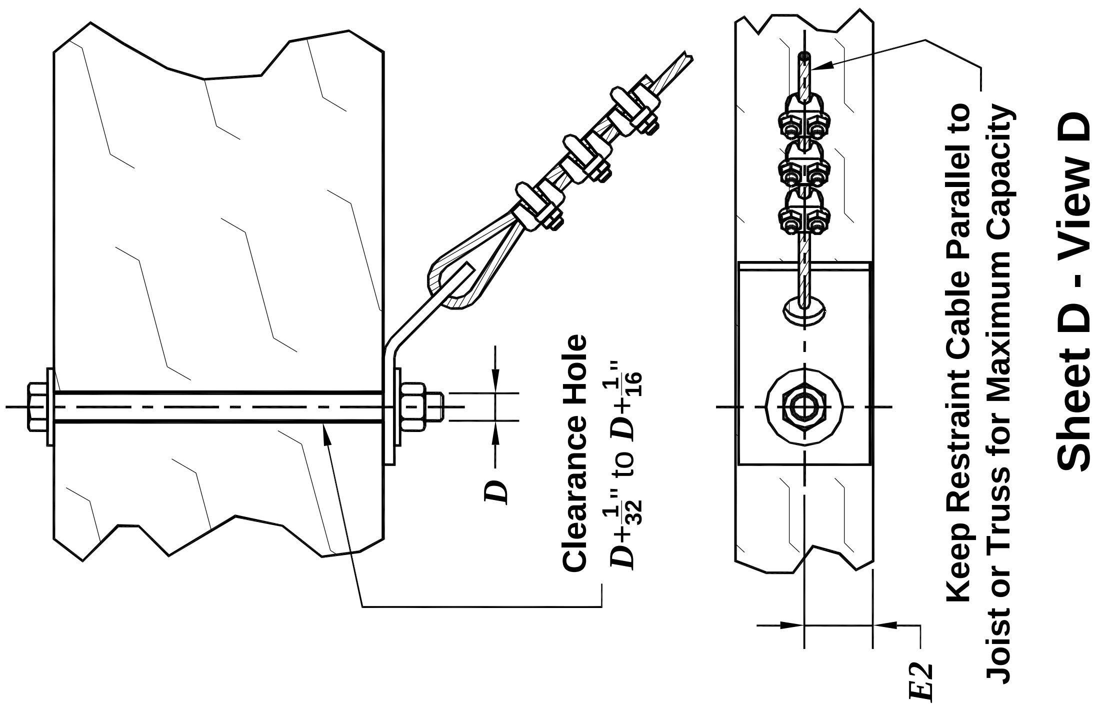

Figure I5-66; KSCC Attached to Wood in Orientation 1 Using a Through Bolt

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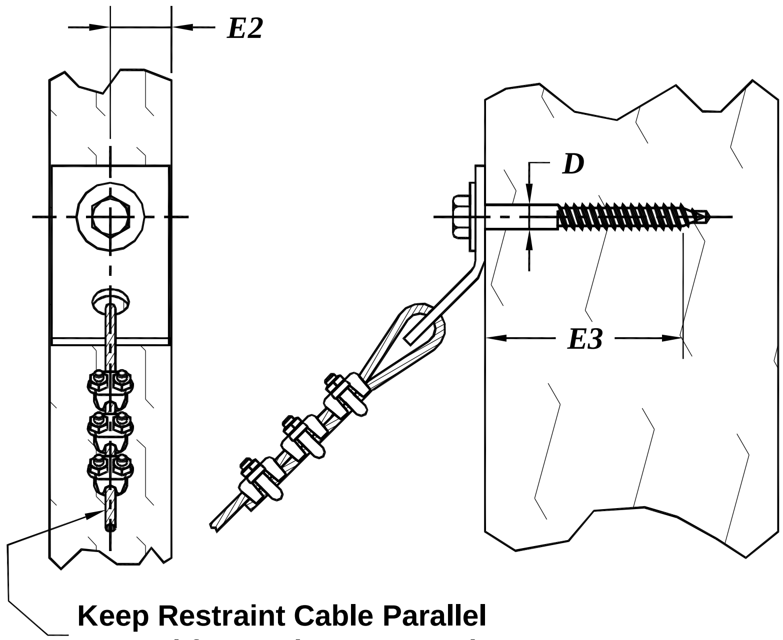
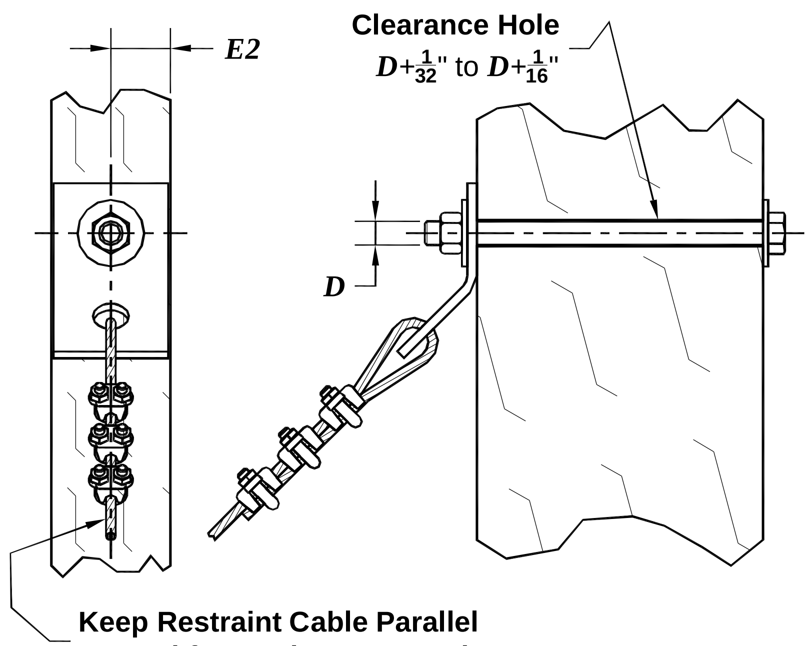


Sheet D - View J

Figure I5-67; KSCC Attached to Wood in Orientation 2 Using a Lag Screw



Sheet D - View J

Figure I5-68; KSCC Attached to Wood in Orientation 2 Using a Through Bolt

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The KSCC bracket may be attached to the sides of wooden joists and beams in Orientation 2 as shown in Figure I5-69 for lag screw attachment and Figure I5-70 for through bolt attachment.

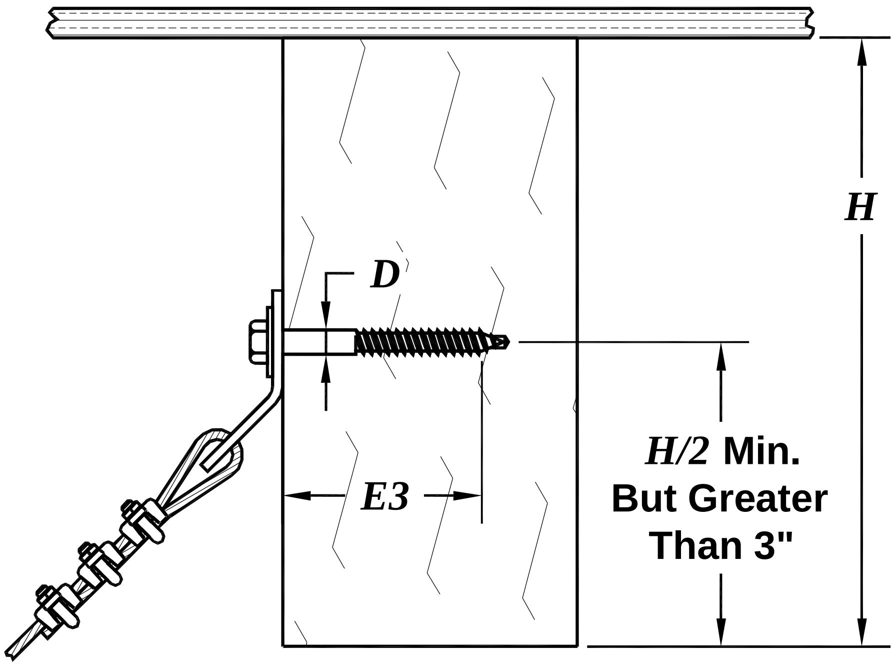
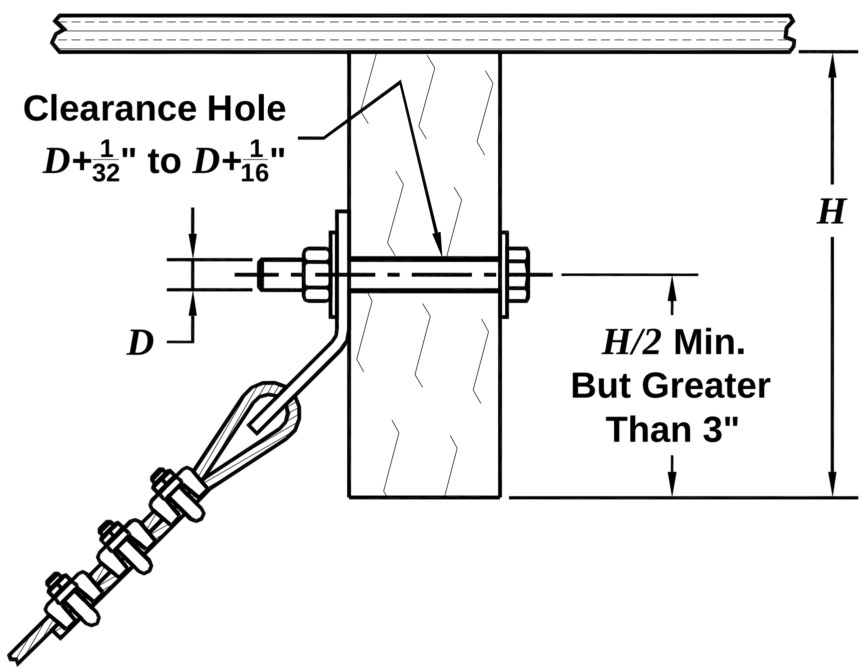


Figure I5-69; KSCC Attached to a Wooden Joist or Beam in Orientation 2 Using a Lag Screw



FigureI5-70; KSCC Attached to a Wooden Joist or Beam in Orientation 2 Using a Through Bolt

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The KSCCZ2 and KSCCZ4 attachment kits will allow the KSCC bracket to be mounted to a wooden structural member, such as a column, using two or four lag screws, as shown in Figures I5-71 and I5-72 respectively.

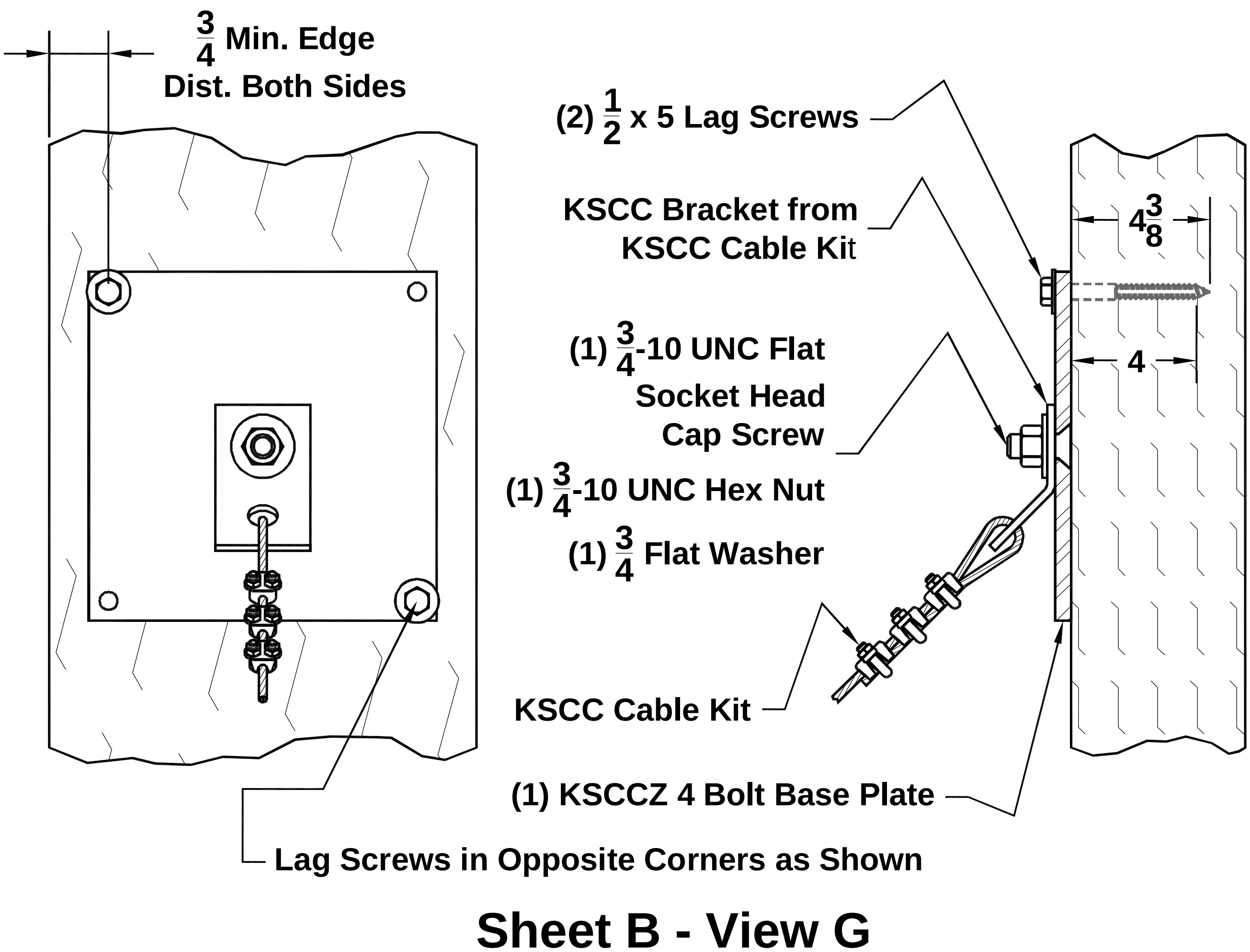

Figure I5-71; Model KSCCZ2 Attachment Kit to a Wooden Column Using KSCC Brackets – (2) 1/2 Lag Screws

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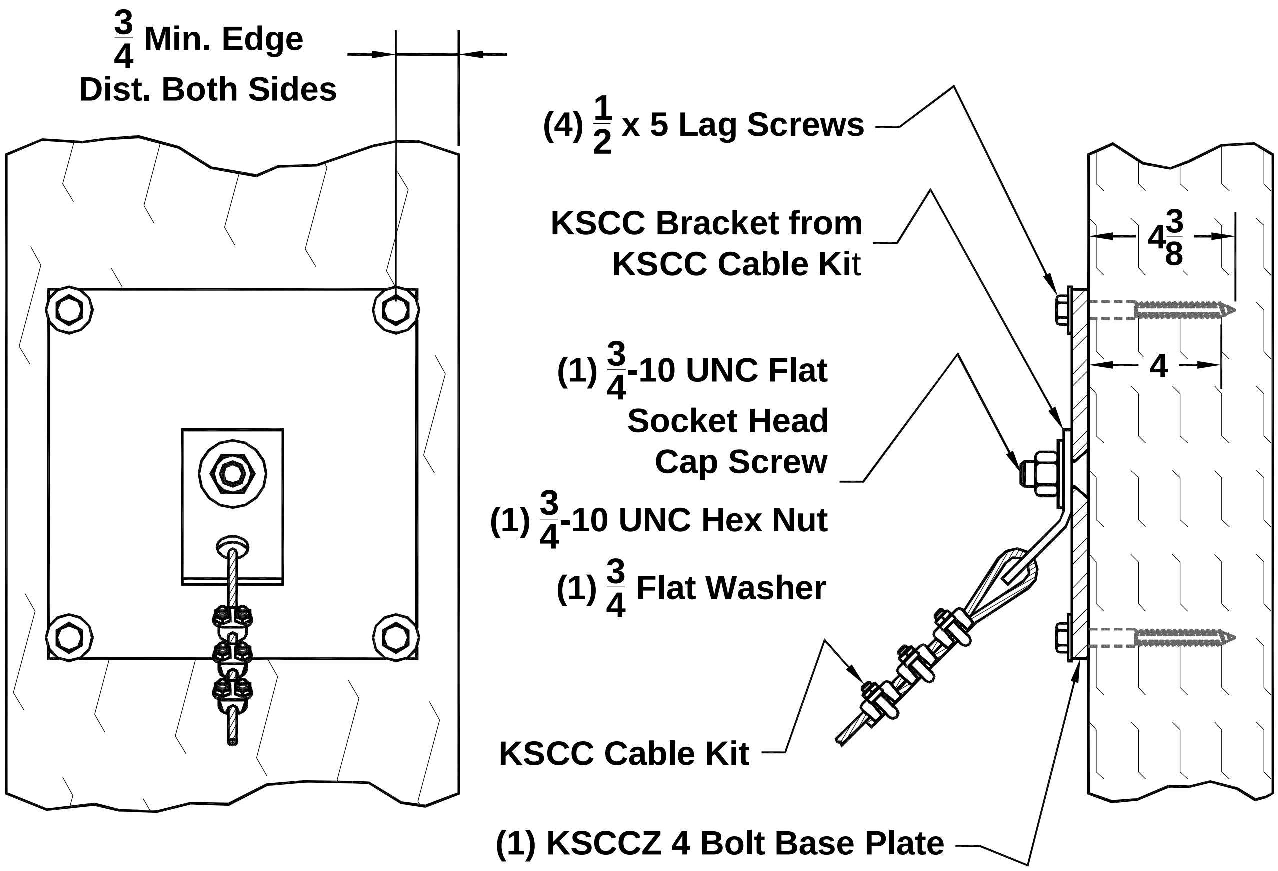

Sheet B - View G

FigureI5-72; Model KSCCZ4 Attachment Kit to a Wooden Column Using KSCC Brackets – (4) 1/2 Lag Screws

The KSCCZ2 and KSCCZ4 attachment kits will also allow the KSCC bracket to be mounted to a wooden structural beam using two or four lag screws. Figures I5-73 and I5-74 show the KSCCZ2 and KSCCZ4, respectively, mounted to a wooden beam. Figure I5-60 provides the dimensional information to layout the drill pattern for the pilot holes. The pilot drill size is given in Table I5-6 for both hard and soft woods.

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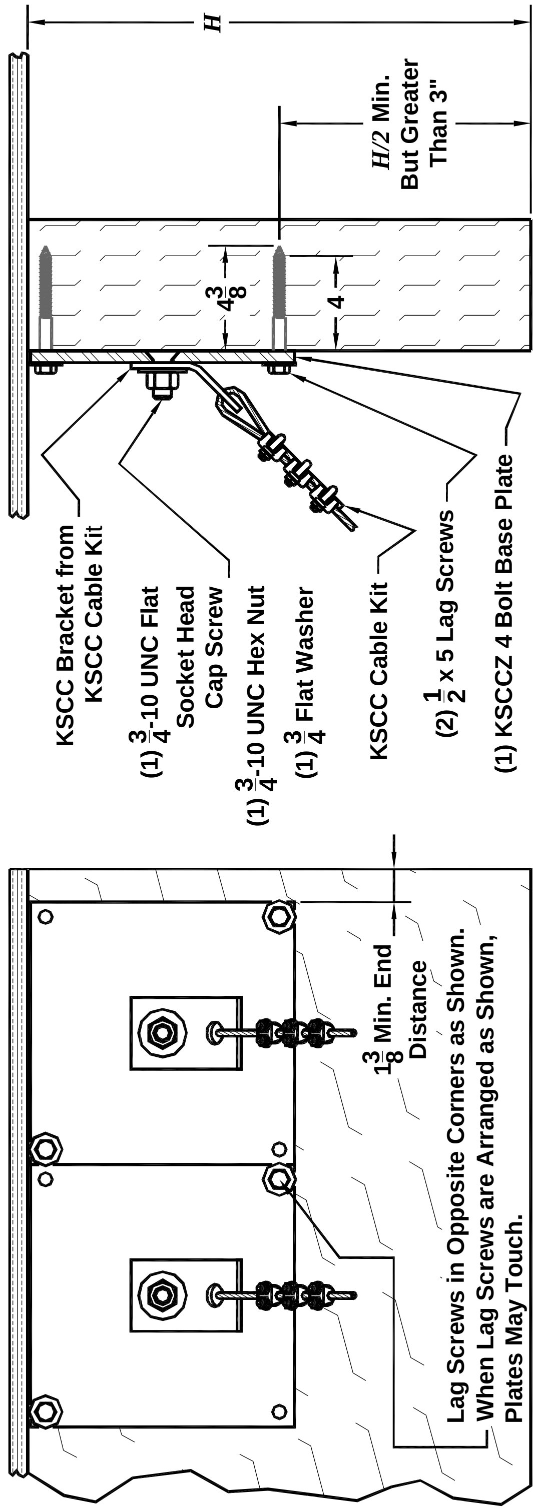

Figure I5-73; Model KSCCZ2 Attachment Kit to a Wooden Beam Using KSCC Brackets – (2) 1/2 Lag Screws

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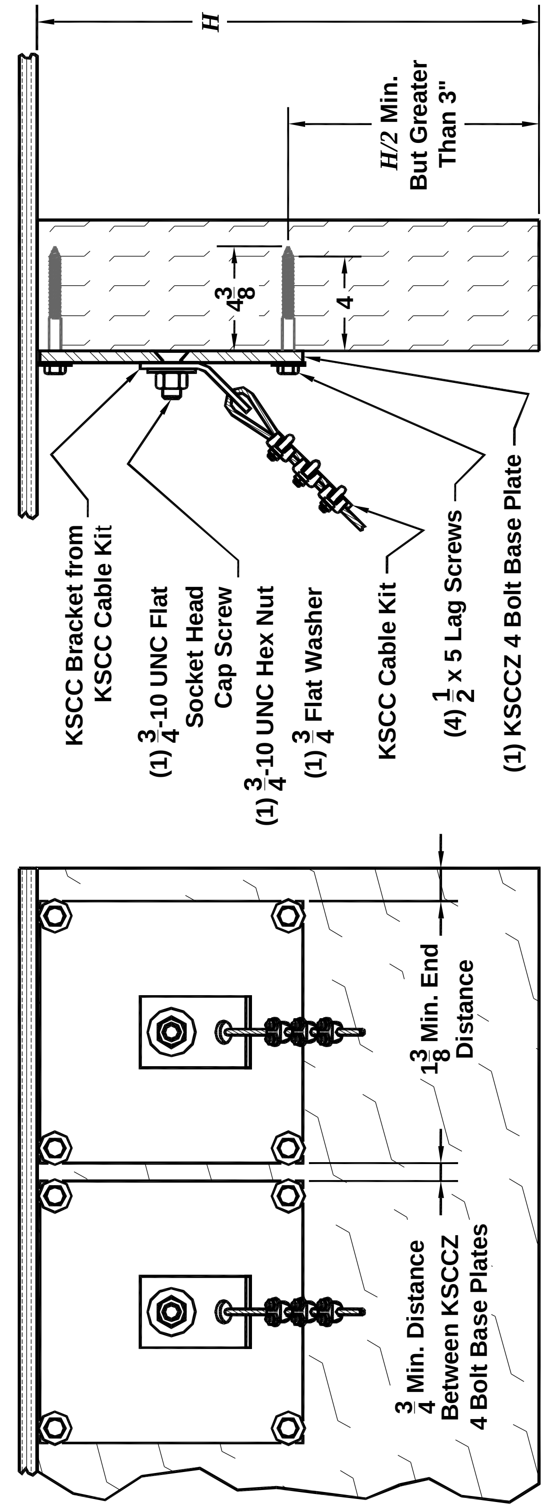

Figure I5-74; Model KSCCZ4 Attachment Kit to a Wooden Beam Using KSCC Brackets – (4) 1/2 Lag Screws

I5.5 – Finishing Touches:

1. Make sure all restraints have two restraint cables 180° apart. Remember: ***You can't push a rope!***
2. Be sure all restraint locations have the proper restraints, transverse (**T**) and/or Longitudinal (**L**) and/or (**TL**), installed per the drawings provided by Kinetics Noise Control or the responsible engineer of record.
3. Make sure all longitudinal (**L**) restraints on trapeze supported pipe and duct are ***balanced***. Seismic forces acting through the longitudinal (**L**) restraints should not twist the pipe or duct through the trapeze bar.
4. All seismic restraints cable must be hand tight as shown in Figure I5-75, and the pipe(s) or duct must be centered.

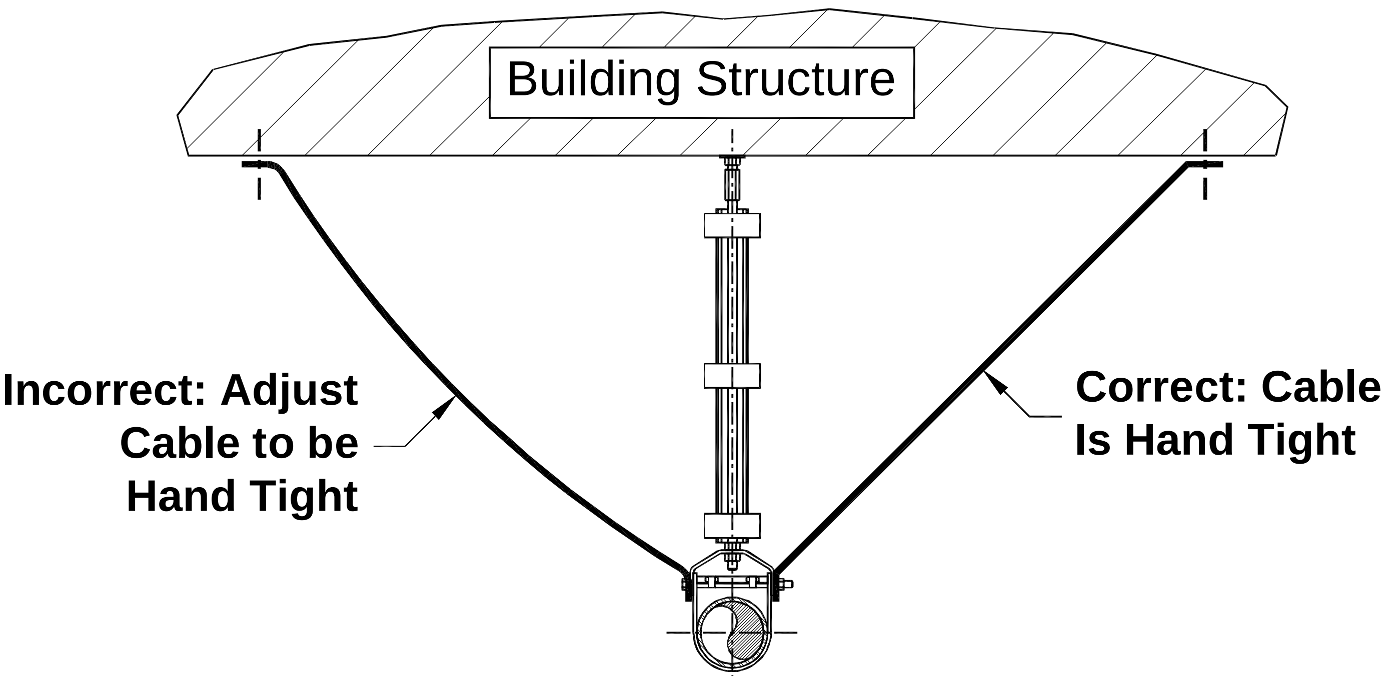

Figure I5-75; All Seismic Restraint Cables must be Hand Tight

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5. Excess seismic restraint cable may be coiled and tied off with tape, plastic or metal wire ties, or tie wire in a fashion that is compatible with the installed environment. For corrosive and damp environments use stainless steel wire ties and tie wire. Excess Cable may be coiled as shown in Figures I5-76 and I5-77 for KSCU and KSCC Seismic Restraint Cable Kits respectively.
6. Finally, if the excess cable is to be removed, ***do not cut off the excess until after the final inspection and approval of the system***.

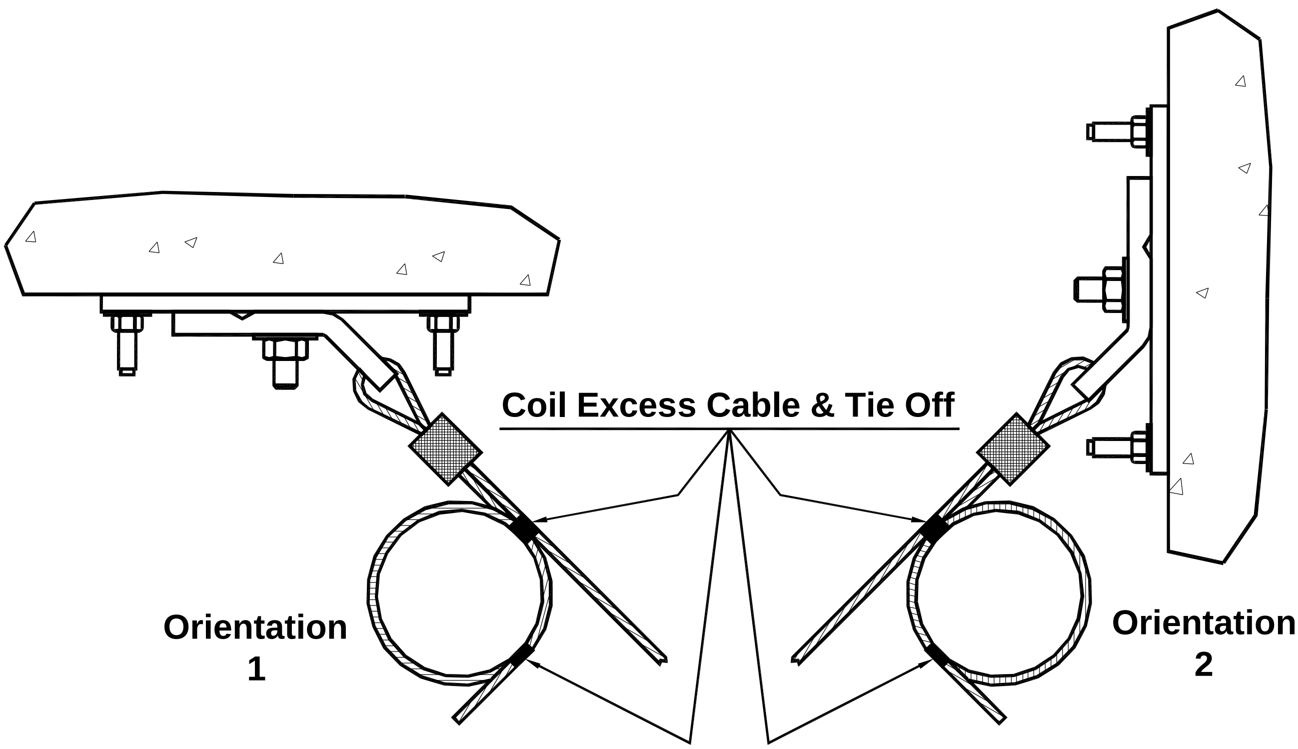

Figure I5-76; Coiling Excess Seismic Restraint Cables for KSCU Cable Kits

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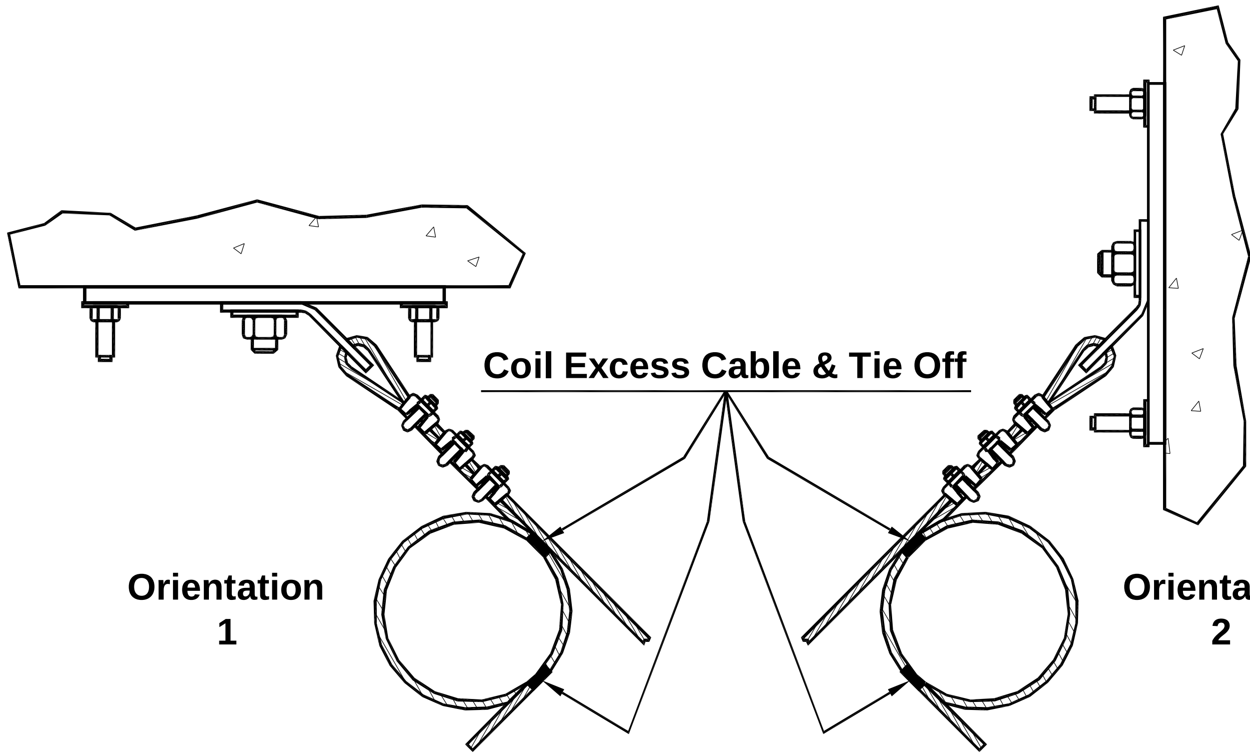

Figure I5-77; Coiling Excess Seismic Restraint Cables for KSCC Cable Kits

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Pipe, Duct, Clevis, and Trapeze Bar Attachments

I6.1 – Introduction:

This section will present several basic arrangements for attaching seismic cable restraints to the building structure. The figures and descriptions in this section will be based on the Kinetics Noise Control drawings SS-20070954, SS-20070955 and SS20070956 titled Attachment to Pipe, Component Attachment Details, and Fire System Restraint Details respectively. There are several drawings in this specific series. They have been designed to aid the installing contractor with the installation of seismic cable restraints for pipe and duct. Each drawing has a number designation ranging from SS-20070950 through SS-20070959. Also each drawing is specified by a particular letter designation ranging from Sheet A though Sheet H. The drawing numbers are in no particular order. However, the letter designations are in strict alphabetical order. Each of the drawings in this series has several views on each sheet designated by a specific letter. Where the figures in this section correspond with those views on the Kinetics Noise Control drawings SS-20070950 through SS-20070959 they will be cross referenced by sheet letter and figure letter, for instance Sheet C – View M.

Kinetics Noise Control provides attachment kits for their seismic restraint cable kits for pipe and duct. Kinetics Noise Control will, when requested to do so, provide a certification for the products that they sell. This certification will state that the seismic restraint cable and attachment kits will meet the seismic design requirements for the project in question when properly installed at the correct spacing. It is important to keep in mind that this certification ***does not*** extend to the building structure. Kinetics Noise Control is a manufacturer of vibration isolation and seismic restraint devices for the HVAC industry, and as such has no control over the design of the building structure. It is the responsibility of the structural engineer of record, and in some cases the architect of record, to approve the structural connections for the seismic restraints for pipe and duct.

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I6.2 – KSUA Attachment Brackets:

I6.2.1 – KSUA Brackets – Basic Sizes & Installation:

Kinetics Noise Control provides several different attachment brackets that can be used to attach the restraint cables to pipe clevises, pipes, duct, and trapeze bar. Figure I6-1 shows the two KSUA brackets.

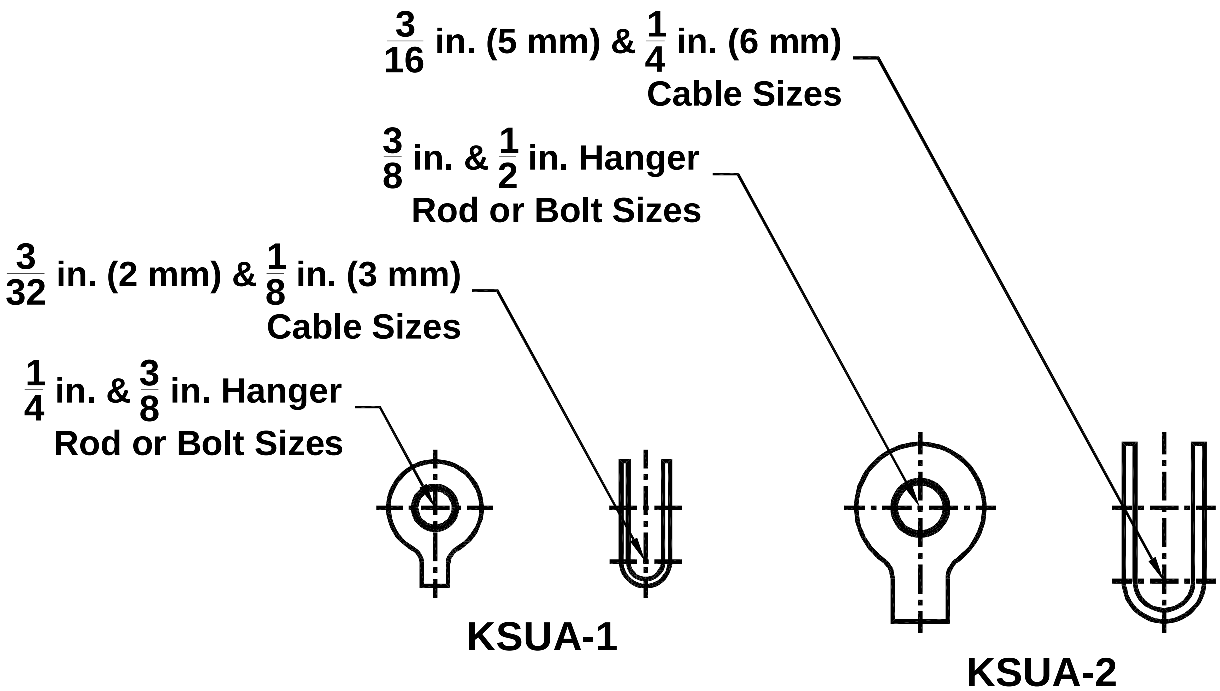

Figure I6-1; Kinetics Noise Control Model KSUA Seismic Restraint Cable Attachment Brackets

Primarily, the KSUA attachment brackets are used with the Kinetics Noise Control Model KSCU Seismic Restraint Cable Kits, which are described in Appendix A1.1. A KSCU seismic restraint cable kit consists of two restraint cables with a loop swaged on one end, two Kinetics provided end connectors, two Kinetics Model KSCA attachment brackets (which will be described in detail in the Section I6.3.1). ***For OSHPD applications thimbles are required for both ends of the restraint cables***.

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The KSUA attachment brackets were designed to be used with the pre-swaged end of the restraint cable, although they can be used on the end of the cable where the loop is made with the Kinetics provided end connector. Figure I6-2 shows the basic installation of the KSUA brackets. The particular installation shown is for attachment to a pipe clevis, although the basic procedure is the same regardless of whether the bracket is being attached to the pipe clevis, the hanger rod, a pipe clamp, or a trapeze bar.

1. The KSUA bracket can be loosely mounted to the clevis hanger as shown in Figure I6-2 End View #1 KSUA – Open.
2. The free end of the restraint cable may be passed through the open loop of the KSUA bracket.
3. Complete the loop in the restraint cable using the Kinetics provided end connector.
4. 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 completely shut as shown in Figure I6-2 End View #3 KSUA – Closed and Side View KSUA – Installed.

If the pre-swaged end loop of the restraint cable is to be used, the cable loop must be slipped over one of the legs of the KSUA bracket before doing Step 1 above.

I6.2.2 – KSUA Brackets – Attachment to a Clevis or Hanger Rod:

For transverse (**T**) restraints only, the KSUA brackets may be attached to the side of a standard, MSS Type 1, clevis hanger or to the hanger rod for a standard clevis hanger as shown in Figures I6-3 and I6-4.

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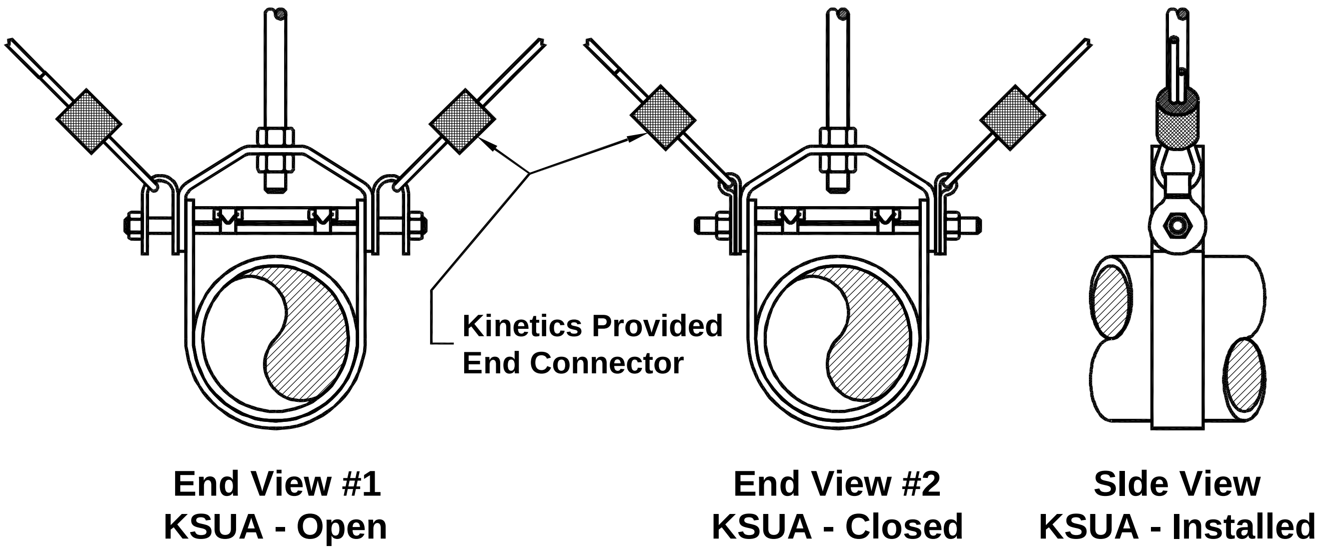
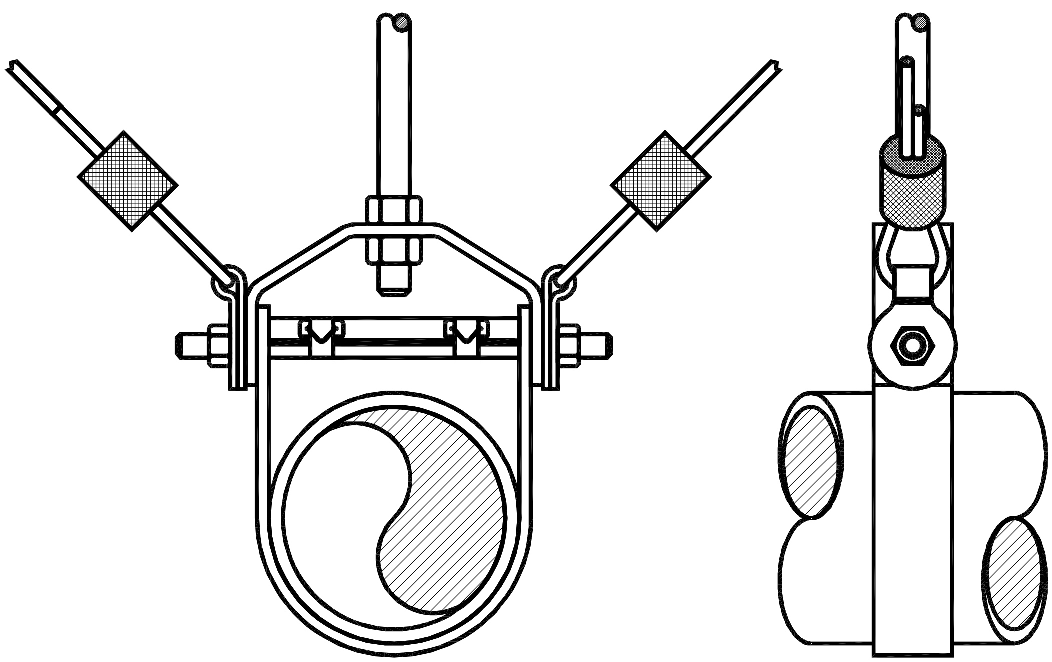


Figure I6-2; Installation of Model KSUA Attachment Bracket



Sheet E - View B

Figure I6-3; KSUA Brackets Attached to the Side of a Standard Clevis Hanger – ***Transverse (T) Restraints Only***

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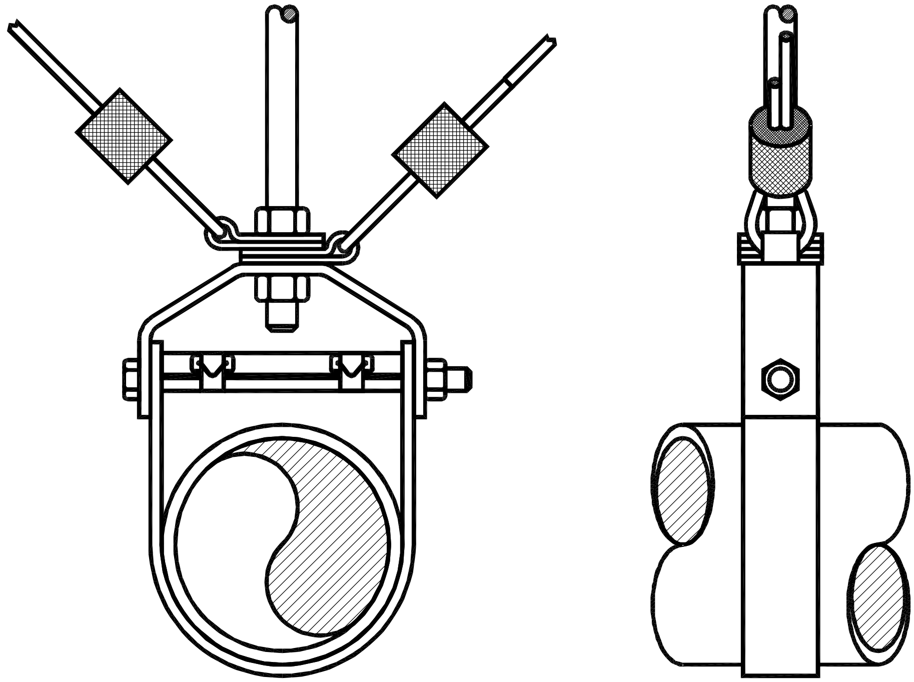

Sheet E - View C

Figure I6-4; KSUA Brackets Attached to the Hanger Rod of a Standard Clevis Hanger –
Transverse (T) Restraints Only

The commercially available clamp type clevis hangers shown in Figure I3-13 may be used with the KSUA brackets. Figure I6-5 shows this type of clevis hanger with transverse (**T**) seismic restraints. Figure I6-6 shows the use of this hanger type with longitudinal (**L**) restraints and Figure I6-7 shows have combined transverse and Longitudinal (**TL**) restraints may be attached to this type of clevis hangers.

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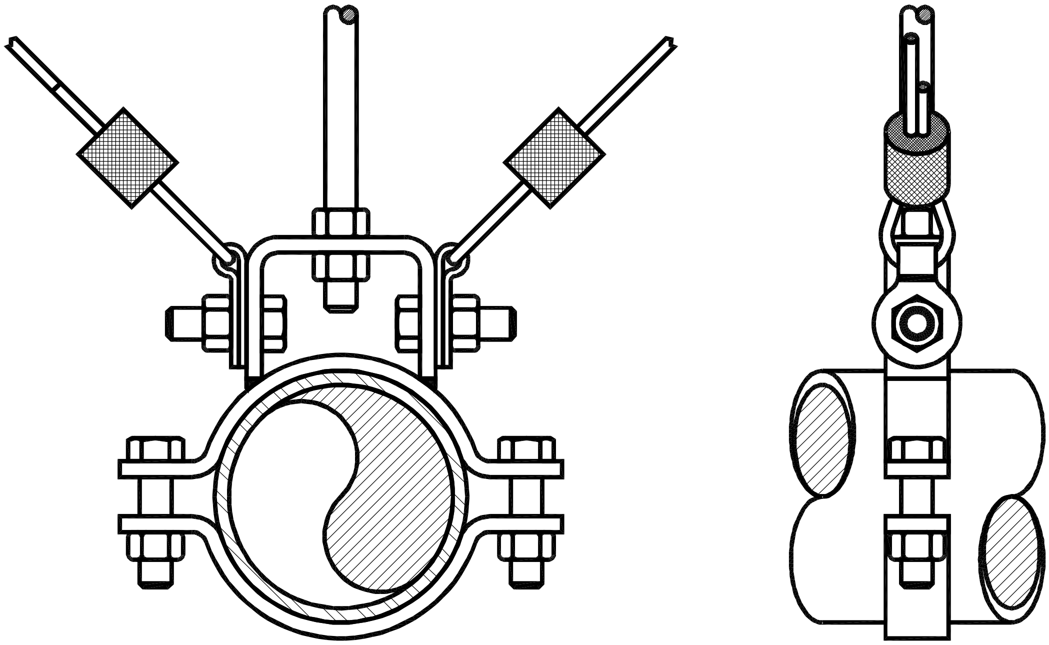

Figure I6-5; KSUA Brackets Attached to a Commercially Available Clamp Type Clevis Hanger – Transverse (T) Restraints

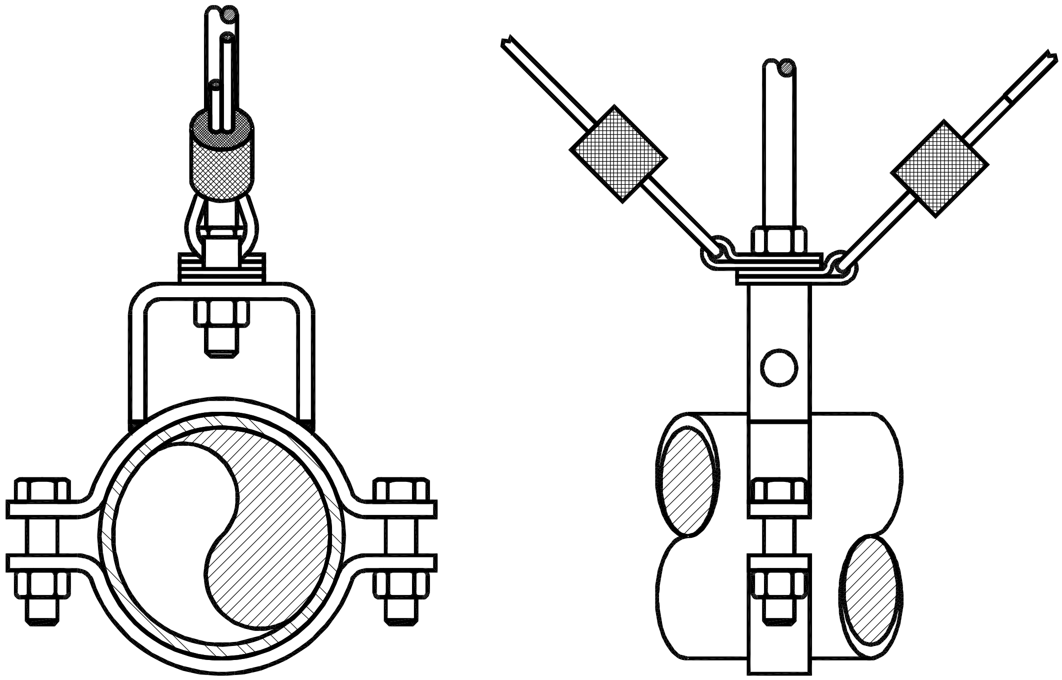

Figure I6-6; KSUA Brackets Attached to the Hanger Rod of a Commercially Available Clamp Type Clevis Hanger – Longitudinal (L) Restraints

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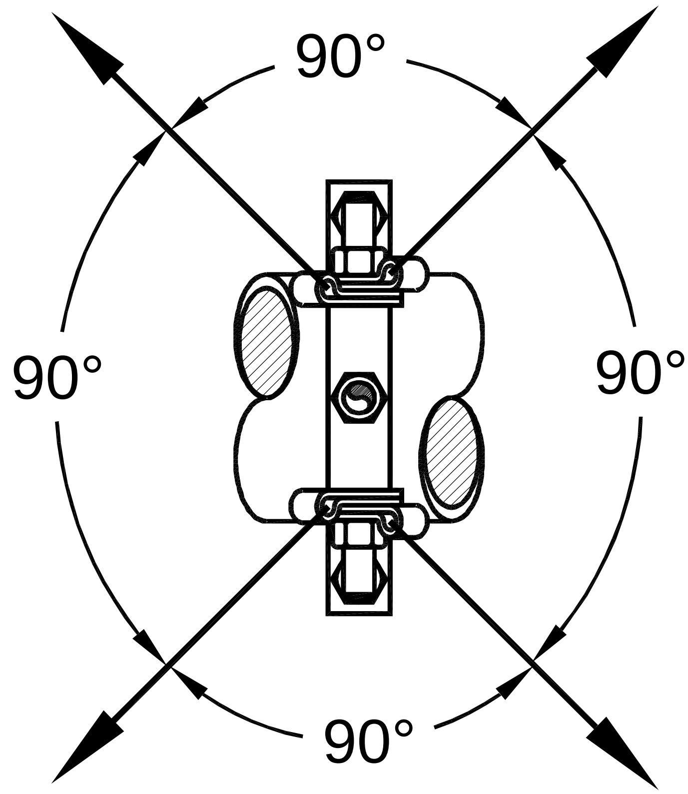

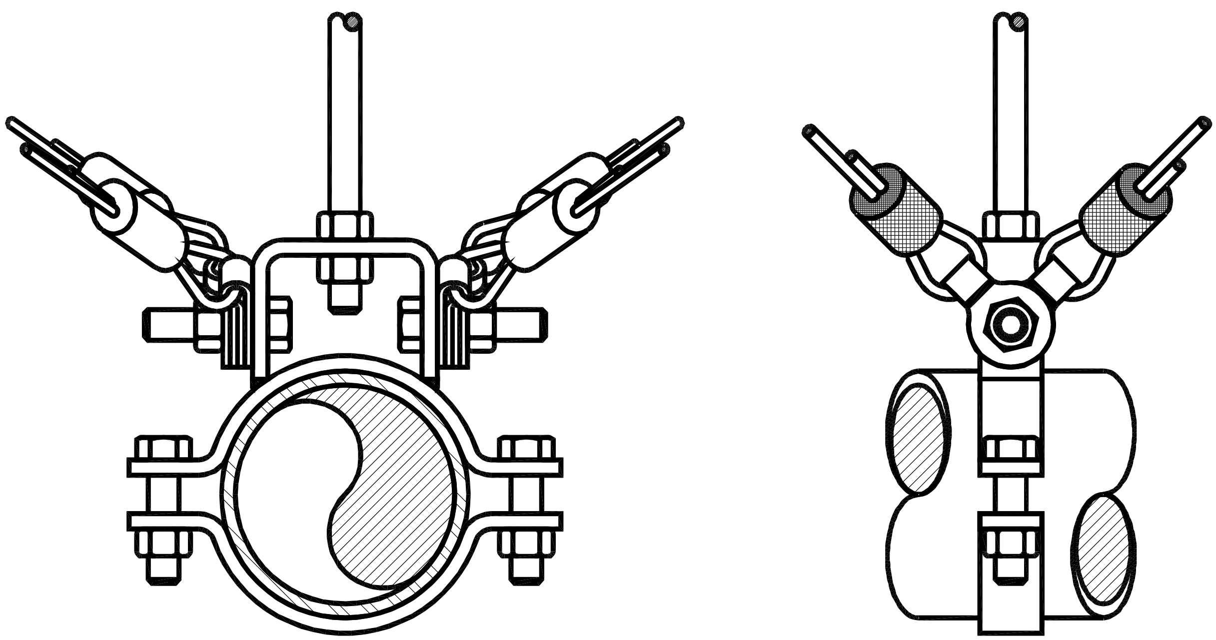

Figure I6-7; KSUA Brackets Attached to a Commercially Available Clamp Type Clevis Hanger – Combined Transverse and Longitudinal (TL) Restraints

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I6.2.3 – KSUA Brackets – Attachment to the Pipe (Fire Protection Piping):

NFPA-13 Section 9.3.5.11.1 requires that all seismic restraints for all feed and cross mains be attached directly to the pipe. Seismic restraints are not to be attached to the clevis hangers for fire protection piping unless the clevis hangers are specifically listed for this type of application. These types of connections may be made using the KSUA-2 bracket and the Kinetics model KFPC Clamp. Figure I6-8 shows the KSUA-2 bracket and KFPC clamp used for a transverse (**T**) restraint, Figure I6-9 shows a longitudinal (**L**) restraint, and Figure I6-10 shows a combination transverse and longitudinal (**TL**) restraint.

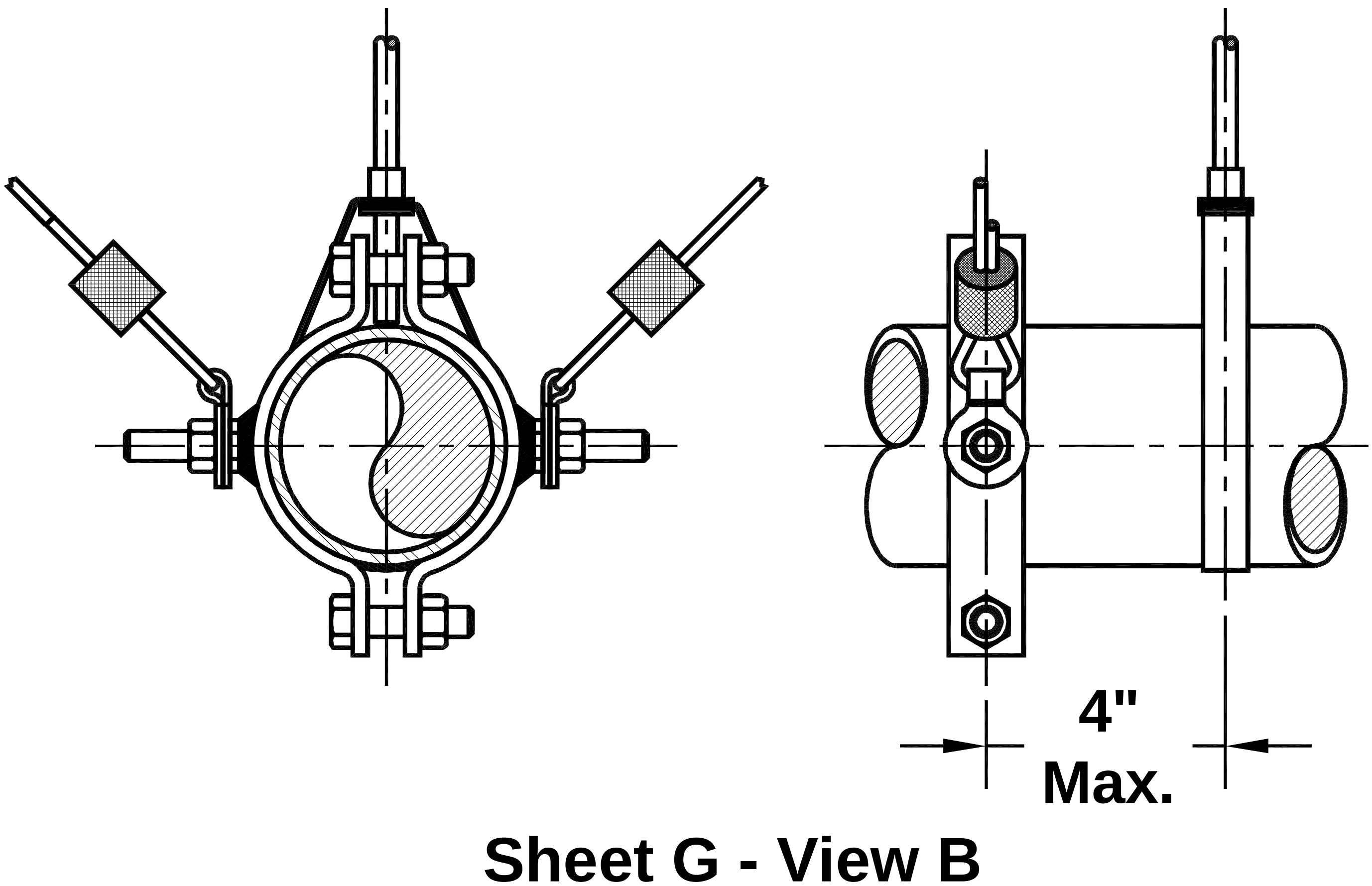

Figure I6-8; KSUA Brackets Attached to a KFPC Clamp (May be Used for Fire Protection Piping) – Transverse (T) Restraints

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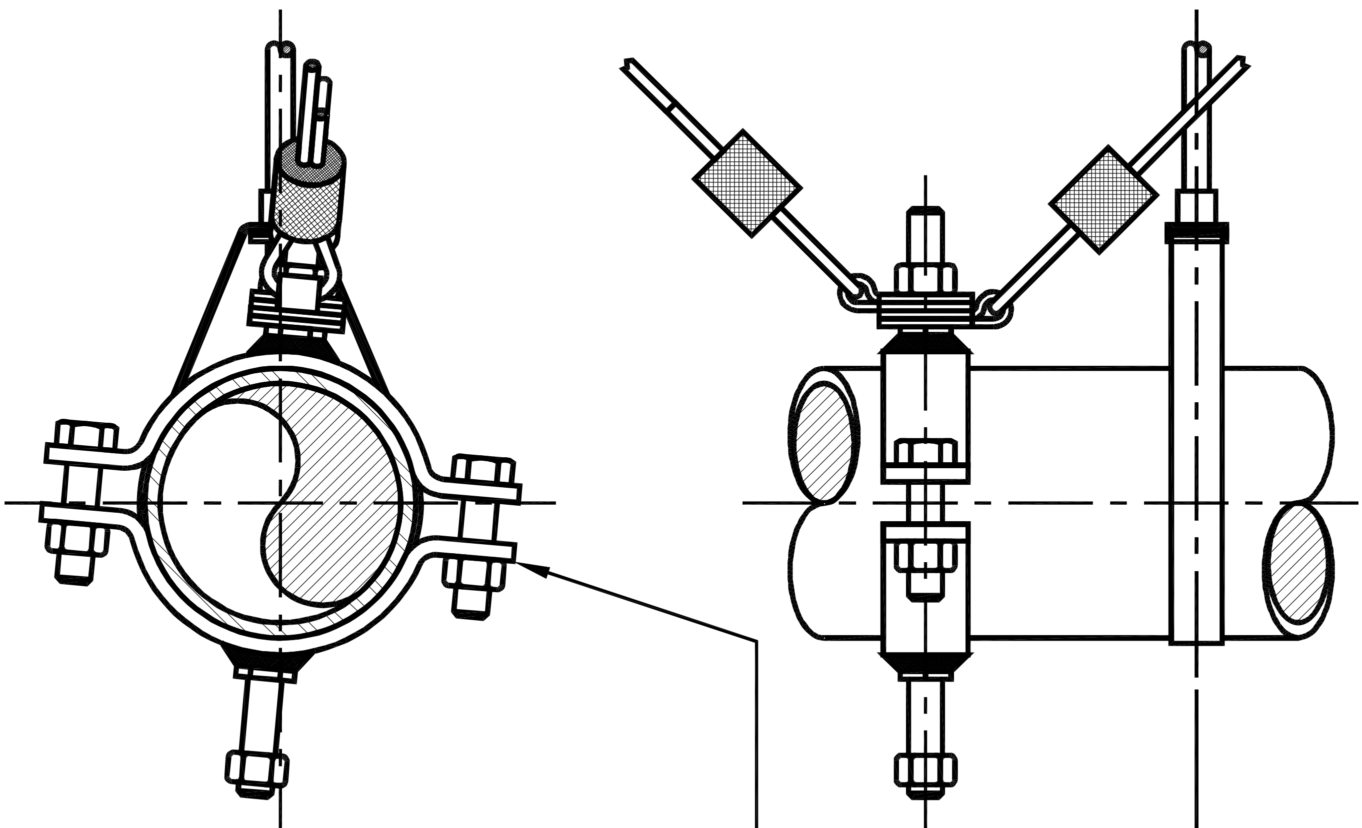

Figure I6-9; KSUA Brackets Attached to a KFPC Clamp (May be Used for Fire Protection Piping) – Longitudinal (L) Restraints

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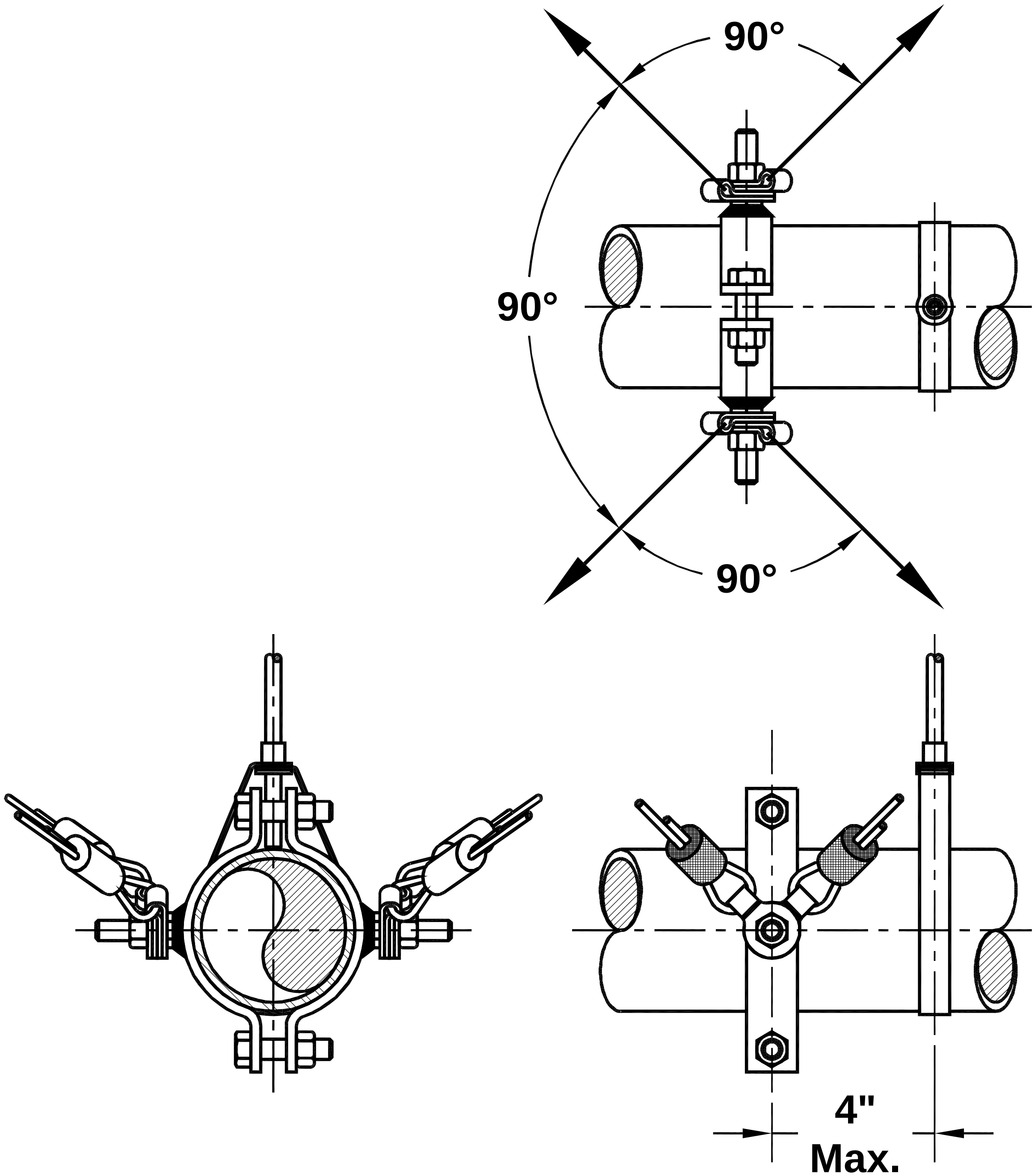

Sheet G - View A

Figure I6-10; KSUA Brackets Attached to a KFPC Clamp (May be Used for Fire Protection Piping) – Combined Transverse and Longitudinal (TL) Restraints

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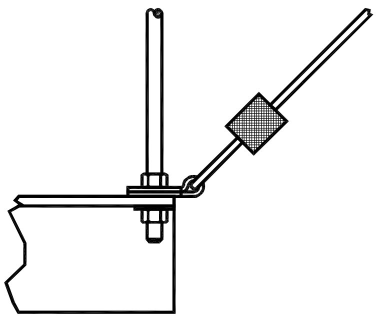
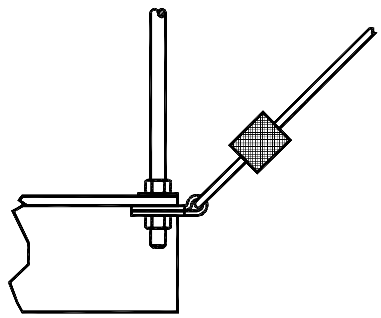
I6.2.4 – KSUA Brackets – Attachment to Trapeze Bars:

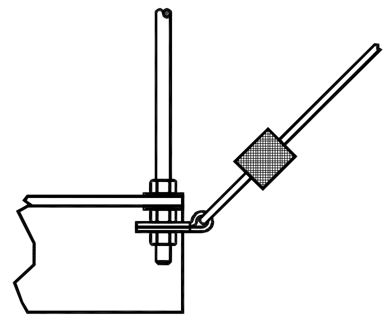
KSUA brackets may be attached to trapeze bars constructed of rolled structural shapes as shown in Figures I6-11(transverse (**T**) restraints), I6-12 (longitudinal (**L**) restraints, and I6-13 (Combined transverse and longitudinal (**TL**) restraints). When one of the bolting surfaces on the structural shape has a taper such the inner leg surface of a C-channel, use a tapered structural washer against this surface to prevent bending in the hanger rods, or bolts.



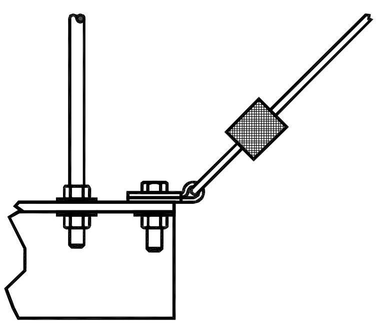
Option #1 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



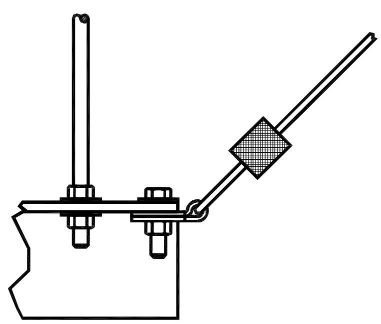
Option #2 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



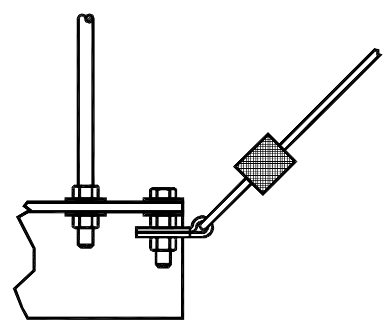
Option #3 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



Option #4 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



Option #5 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



Option #6 Transverse Restraint (T) Typical Both Ends of Trapeze Bar

Sheet F - Views L & M

Figure I6-11; KSUA Brackets Attached to a Rolled Structural Trapeze Bar – Transverse (T) Restraints

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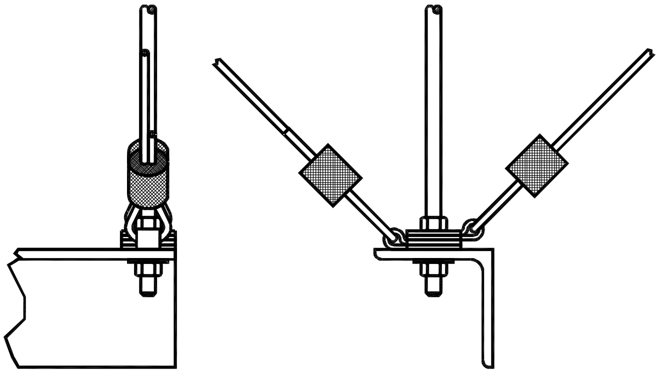
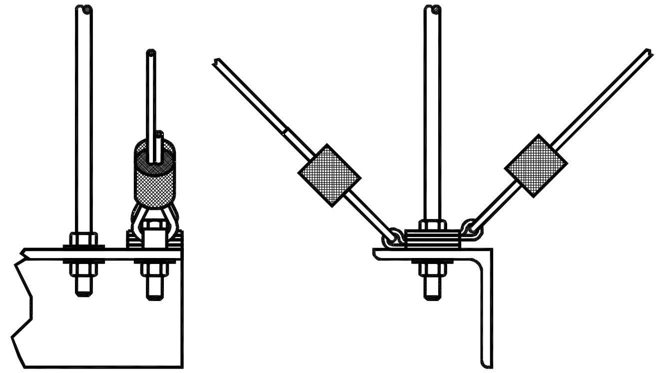
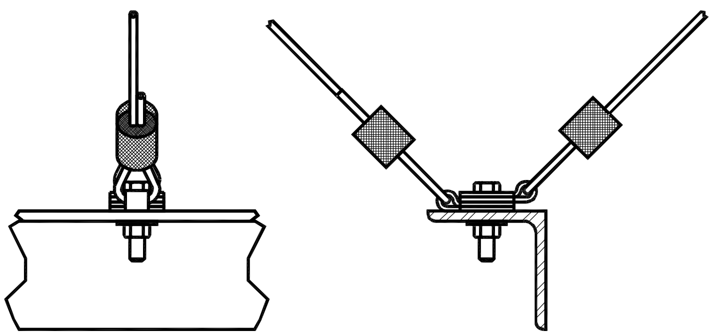


Option #1 Longitudinal Restraint (L)
Typical - Both Ends of Trapeze Bar



Option #2 Longitudinal Restraint (L)
Typical - Both Ends of Trapeze Bar



Option #3 Longitudinal Restraint (L)
At Center of Trapeze Bar

Figure I6-12; KSUA Brackets Attached to a Rolled Structural Trapeze Bar – Longitudinal (L) Restraints

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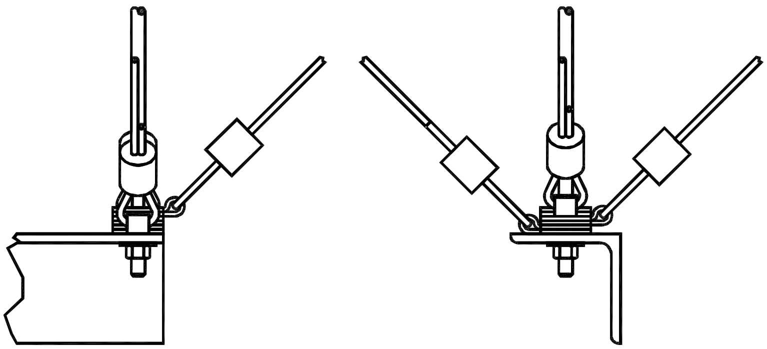
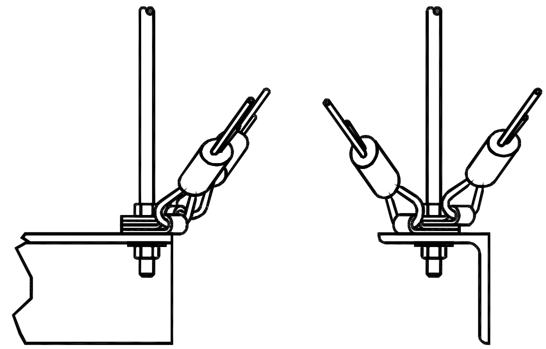
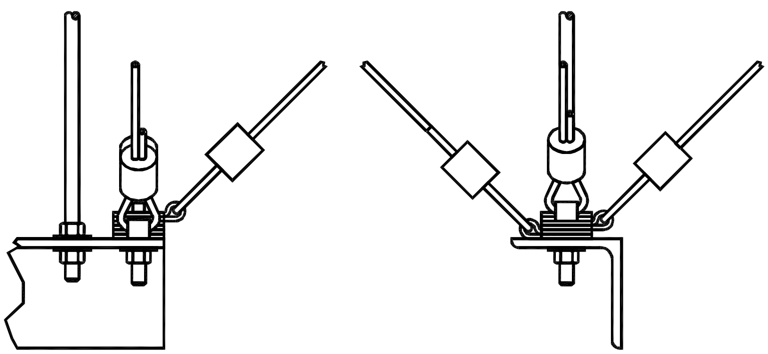


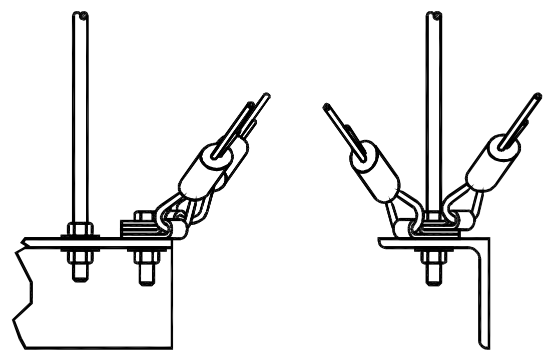
Option #1 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar



Option #2 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar



Option #3 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar



Option #4 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar

Figure I6-13; KSUA Brackets Attached to a Rolled Structural Trapeze Bar – Combined Transverse and Longitudinal (TL) Restraints

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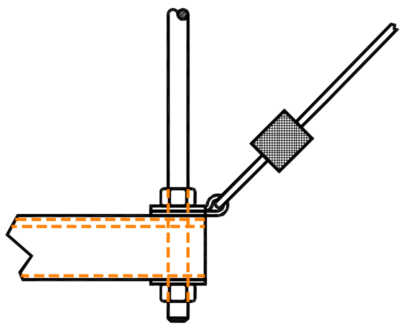
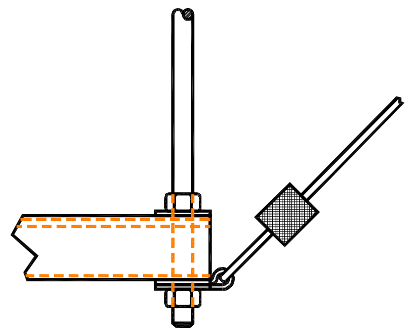
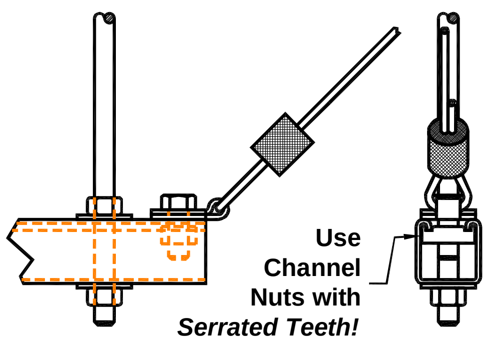
KSUA-2 brackets may be attached to trapeze bars constructed of strut channel as shown in Figures I6-14(transverse (**T**) restraints), I6-15 (longitudinal (**L**) restraints, and I6-16 (Combined transverse and longitudinal (**TL**) restraints). When using strut nuts for making seismic attachments to strut channel trapeze bars, ***use the strut nuts with serrated teeth*** for extra holding ability. Make sure strut channel and strut nuts selected match the restraint capacity of the cable and attachment kits recommended and provided by Kinetics Noise Control.



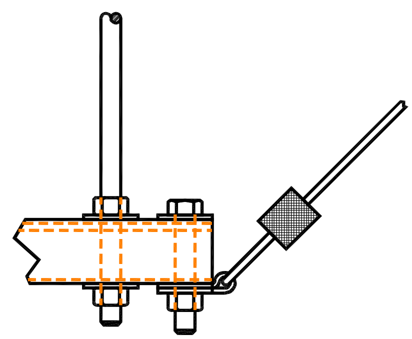
Option #1 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



Option #2 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



Option #3 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



Option #4 Transverse Restraint (T) Typical Both Ends of Trapeze Bar

Sheet F - Views L & M

Figure I6-14; KSUA-2 Brackets Attached to a Strut Channel Trapeze Bar – Transverse (T) Restraints

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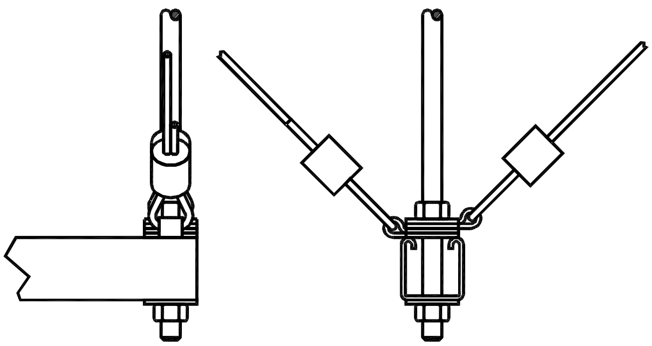
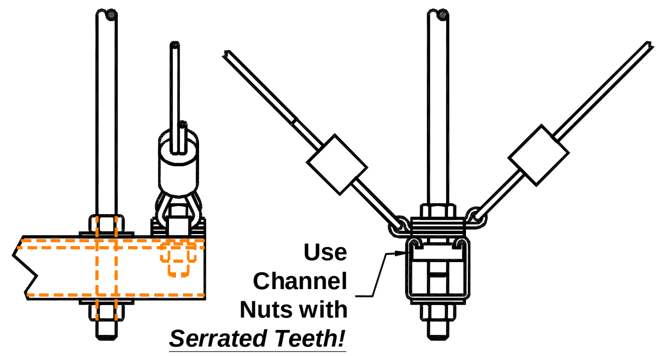
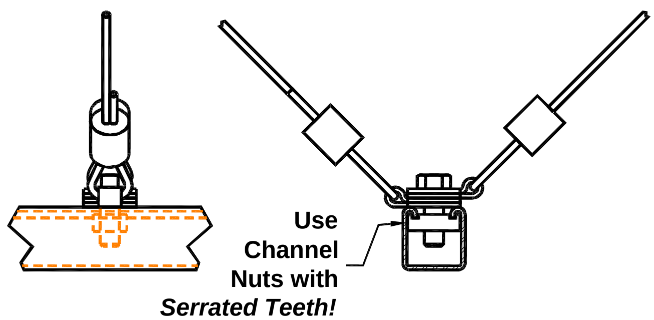


Option #1 Longitudinal Restraint (L)
Typical - Both Ends of Trapeze Bar



Option #2 Longitudinal Restraint (L)
Typical - Both Ends of Trapeze Bar



Option #3 Longitudinal Restraint (L)
At Center of Trapeze Bar

Figure I6-15; KSUA-2 Brackets Attached to a Strut Channel Trapeze Bar – Longitudinal (L) Restraints

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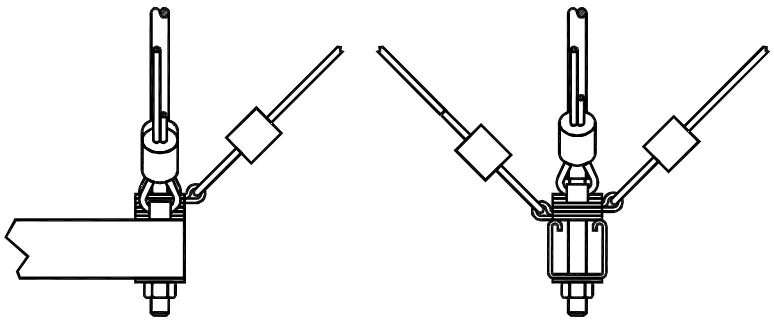
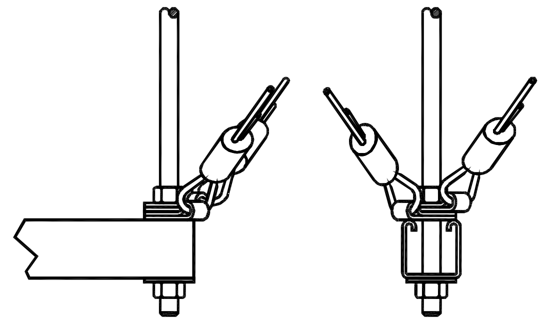
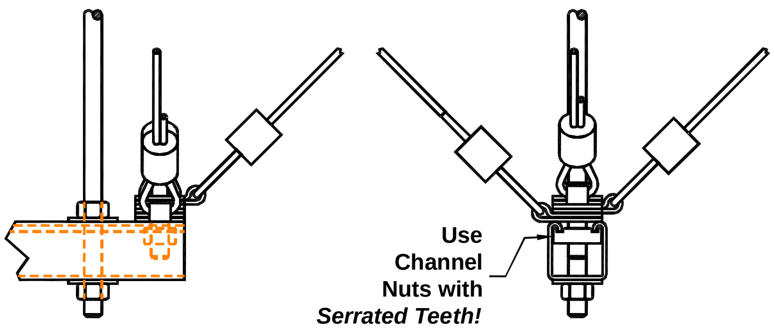


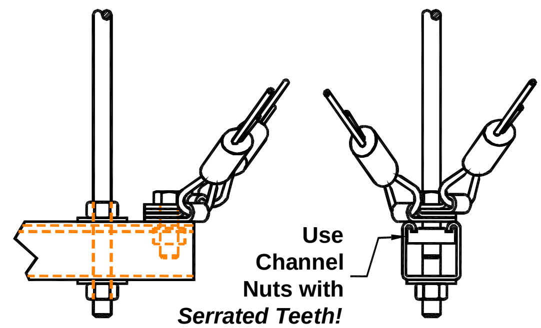
Option #1 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar



Option #2 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar



Option #3 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar



Option #4 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar

Figure I6-16; KSUA-2 Brackets Attached to a Strut Channel Trapeze Bar – Combined Transverse and Longitudinal (TL) Restraints

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I6.3 – KSCA Attachment Brackets:

I6.3.1 – 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 using either two KSCA brackets or one KSCA bracket and a U-Bolt. Figure I6-17 shows the KSCA Bracket. Figure I6-18 shows how the KSCA bracket may be used to clamp the restraint cable kits to hanger rods. Depending on the angle of the cable when installed, a thimble may be need in this loop to prevent damage to the cable. ***All OSHPD applications require the use of thimbles on both ends of the cable***.

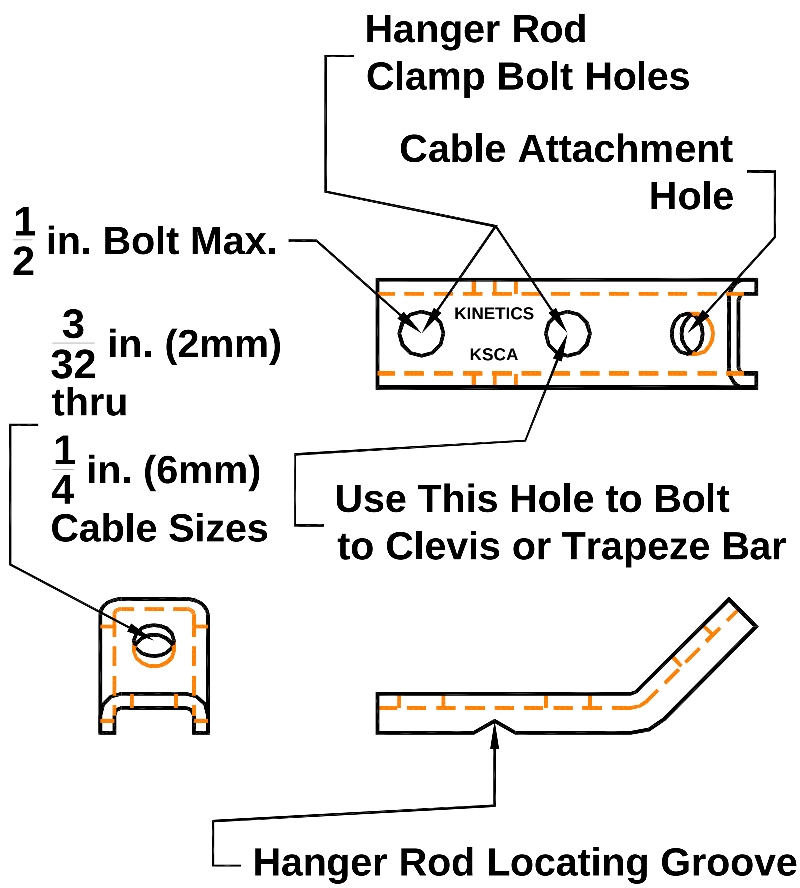

Figure I6-17; Kinetics Noise Control Model KSCA Bracket

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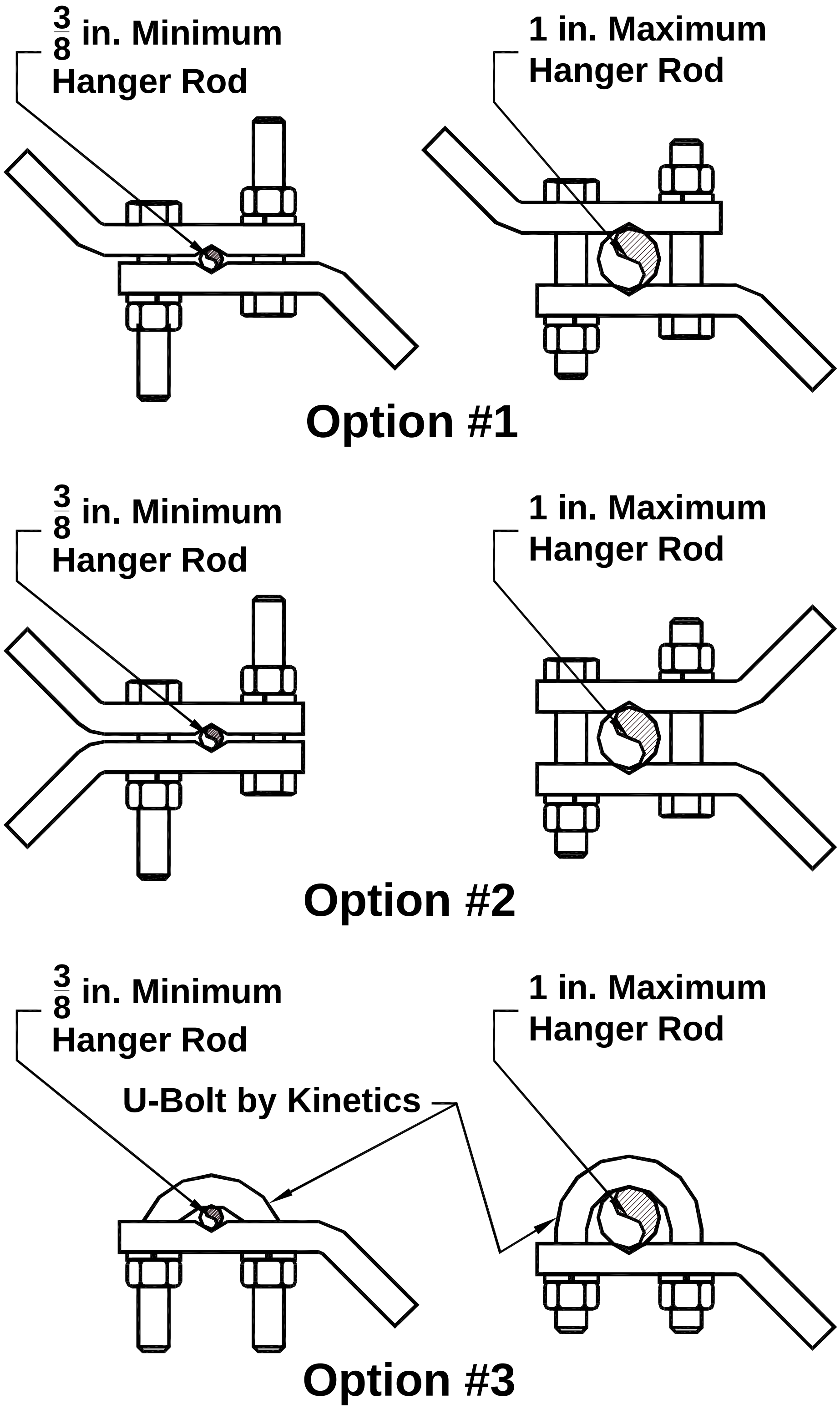

Figure I6-18; Hanger Rod Clamping Options for the KSCA Bracket

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I6.3.2 – KSCA Brackets – Attachment to a Clevis or Hanger Rod:

For transverse (**T**) restraints only, the KSCA brackets may be attached to the hanger rod of a standard, MSS Type 1, or to the side of a standard clevis hanger as shown in Figures I6-19 and I6-20.

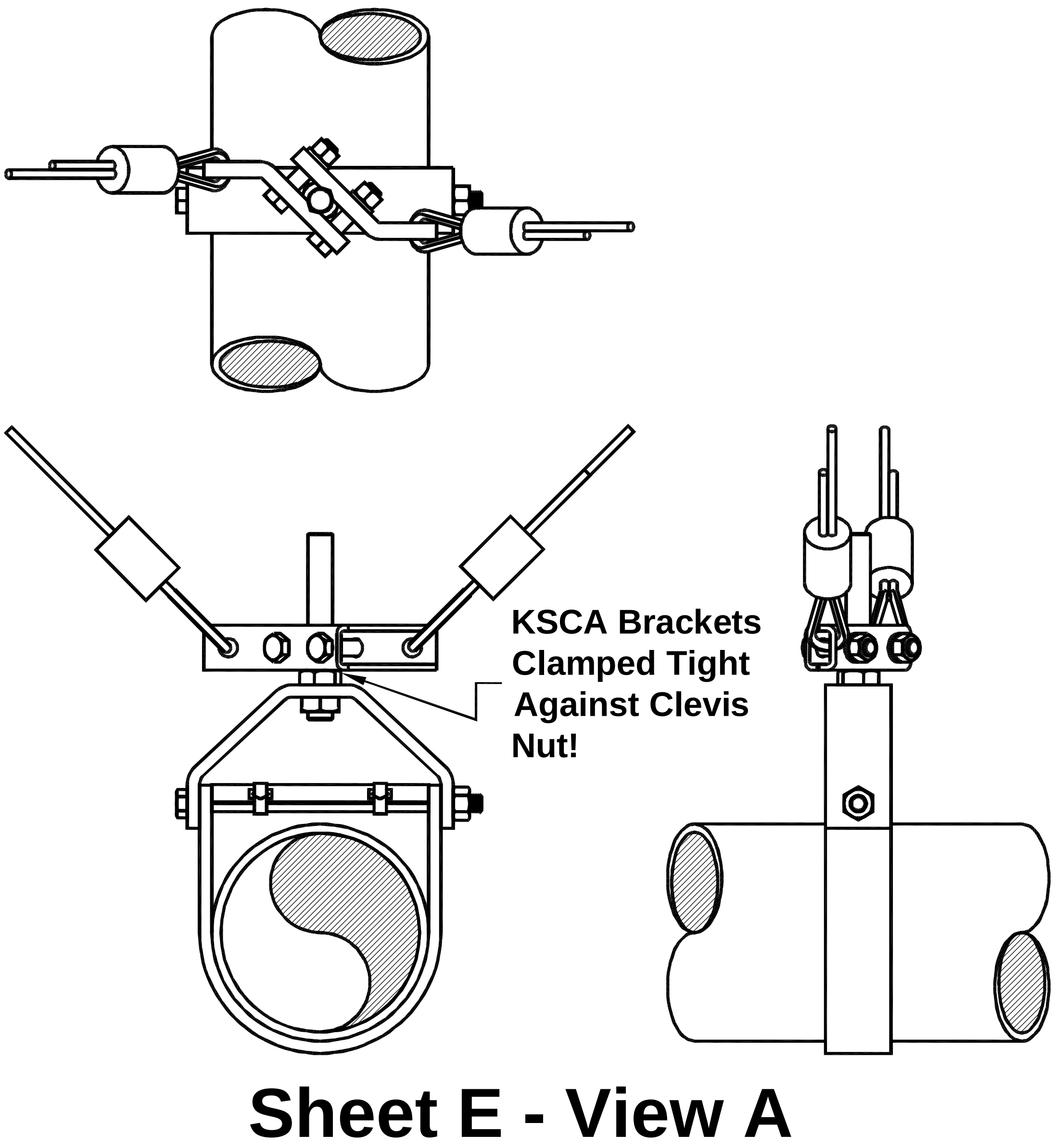

Figure I6-19; KSCA Brackets Attached to the Hanger Rod of a Standard Clevis Hanger – ***Transverse (T) Restraints Only***

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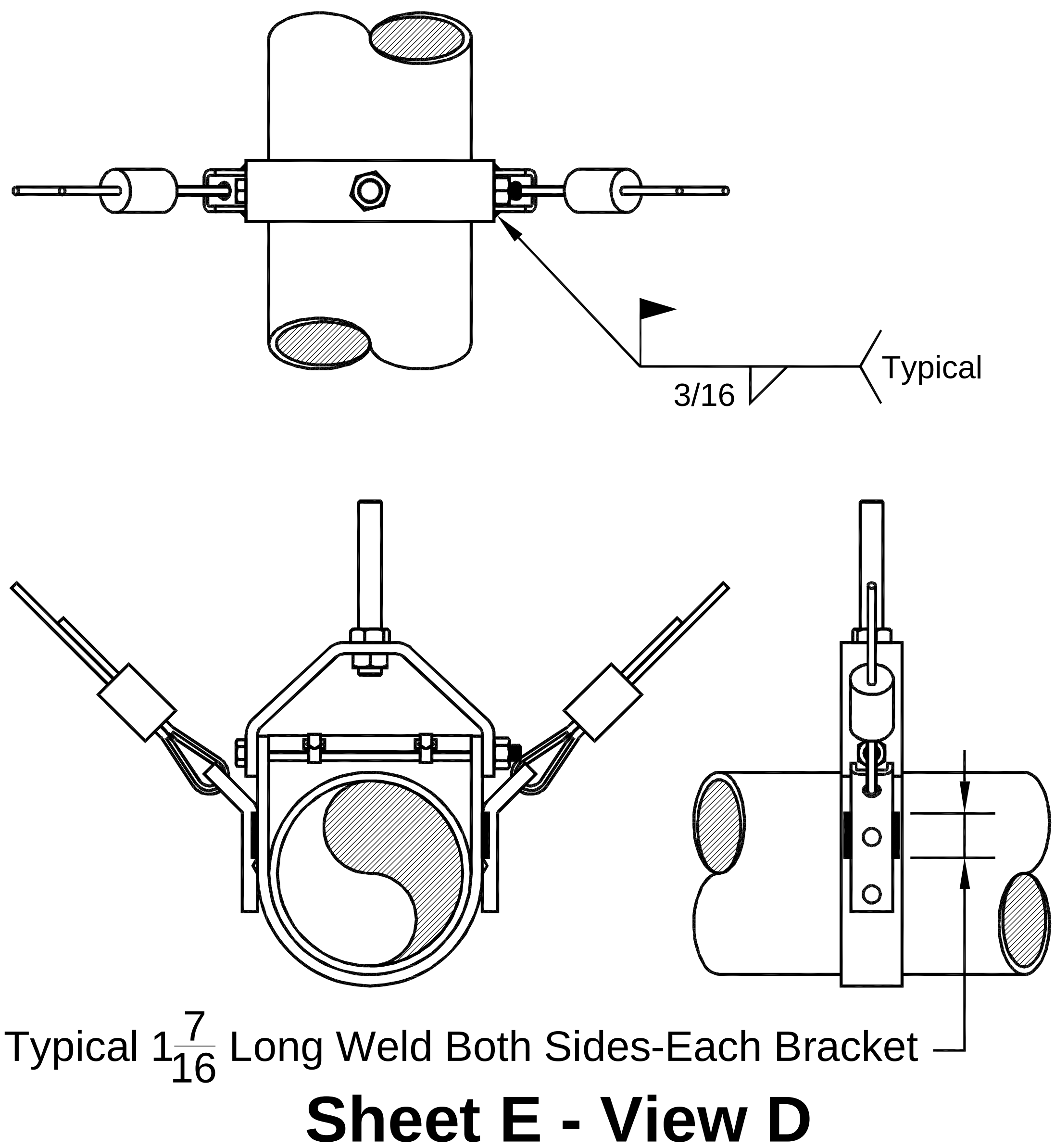

Figure I6-20; KSCA Brackets Attached to the Side of a Standard Clevis Hanger – ***Transverse (T) Restraints Only***

The commercially available clamp type clevis hangers shown in Figure I3-13 may be used with the KSCA brackets. Figure I6-21 shows this type of clevis hanger with transverse (**T**) seismic restraints. Figure I6-22 shows the use of this hanger type with longitudinal (**L**) restraints. Figure I6-23 shows have combined transverse and Longitudinal (**TL**) restraints may be attached to this type of clevis hangers.

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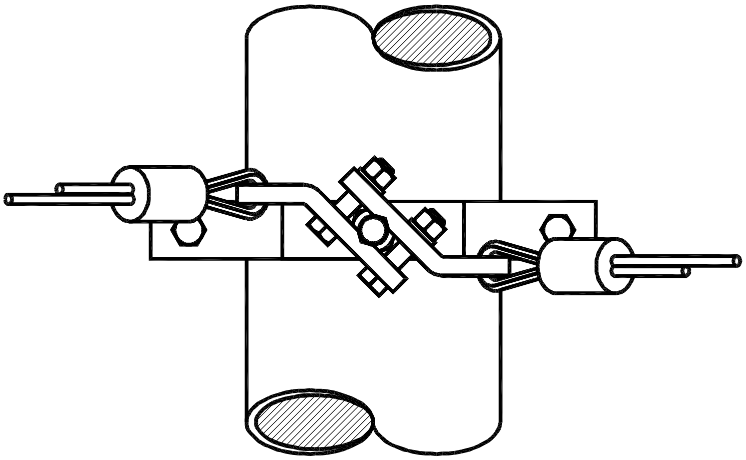

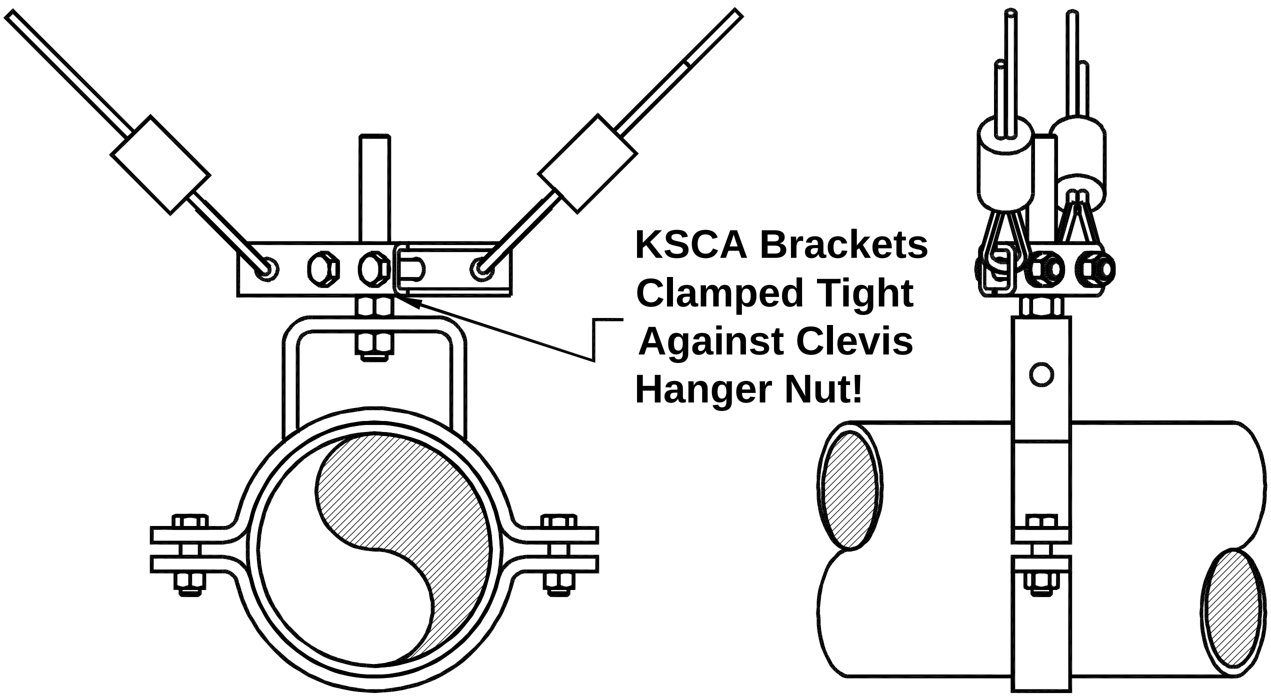

Figure I6-21; KSCA Brackets Attached to the Hanger Rod of a Commercially Available Clamp Type Clevis Hanger – Transverse (T) Restraints

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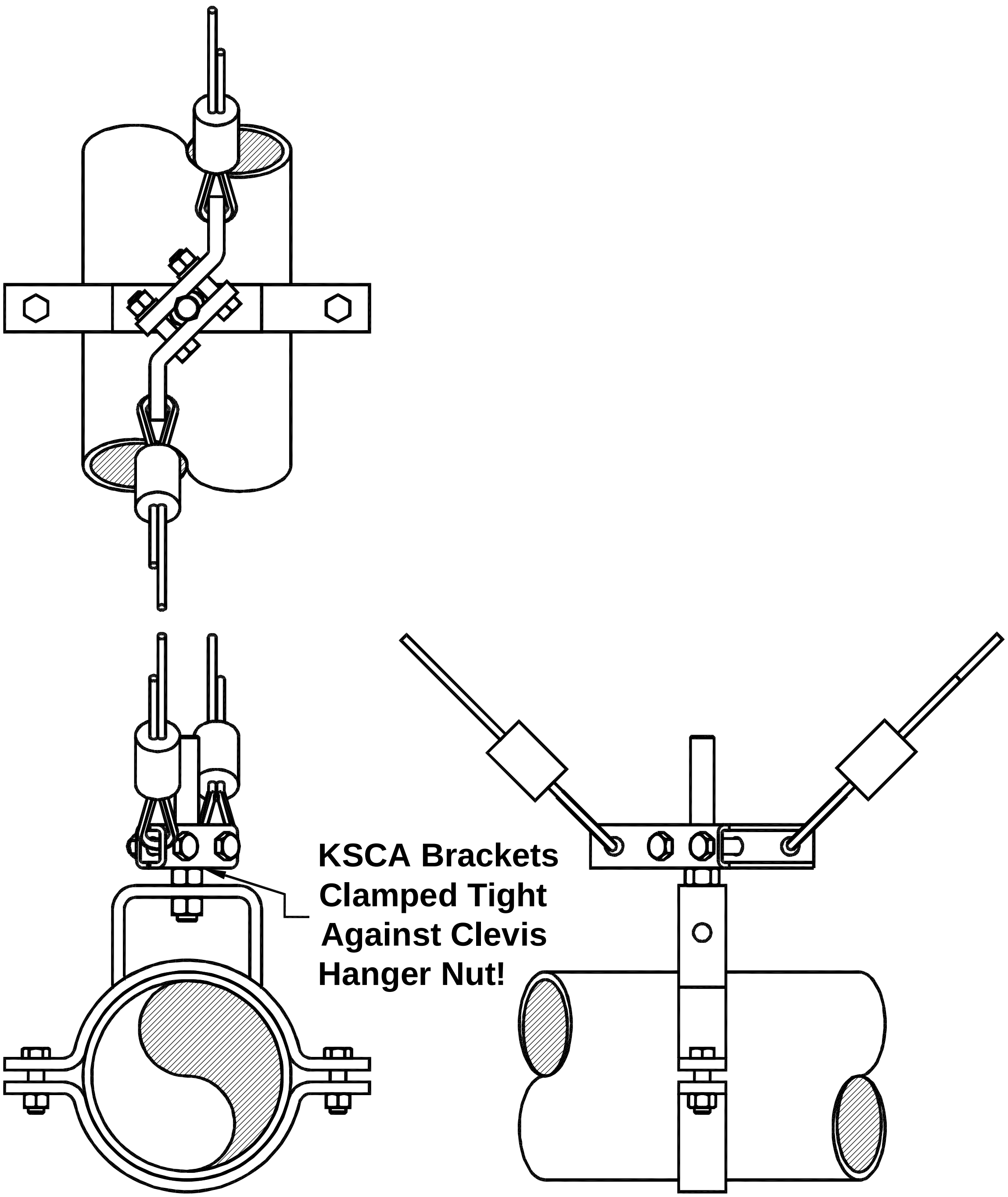

Figure I6-22; KSUA Brackets Attached to the Hanger Rod of Commercially Available Clamp Type Clevis Hanger – Longitudinal (L) Restraints

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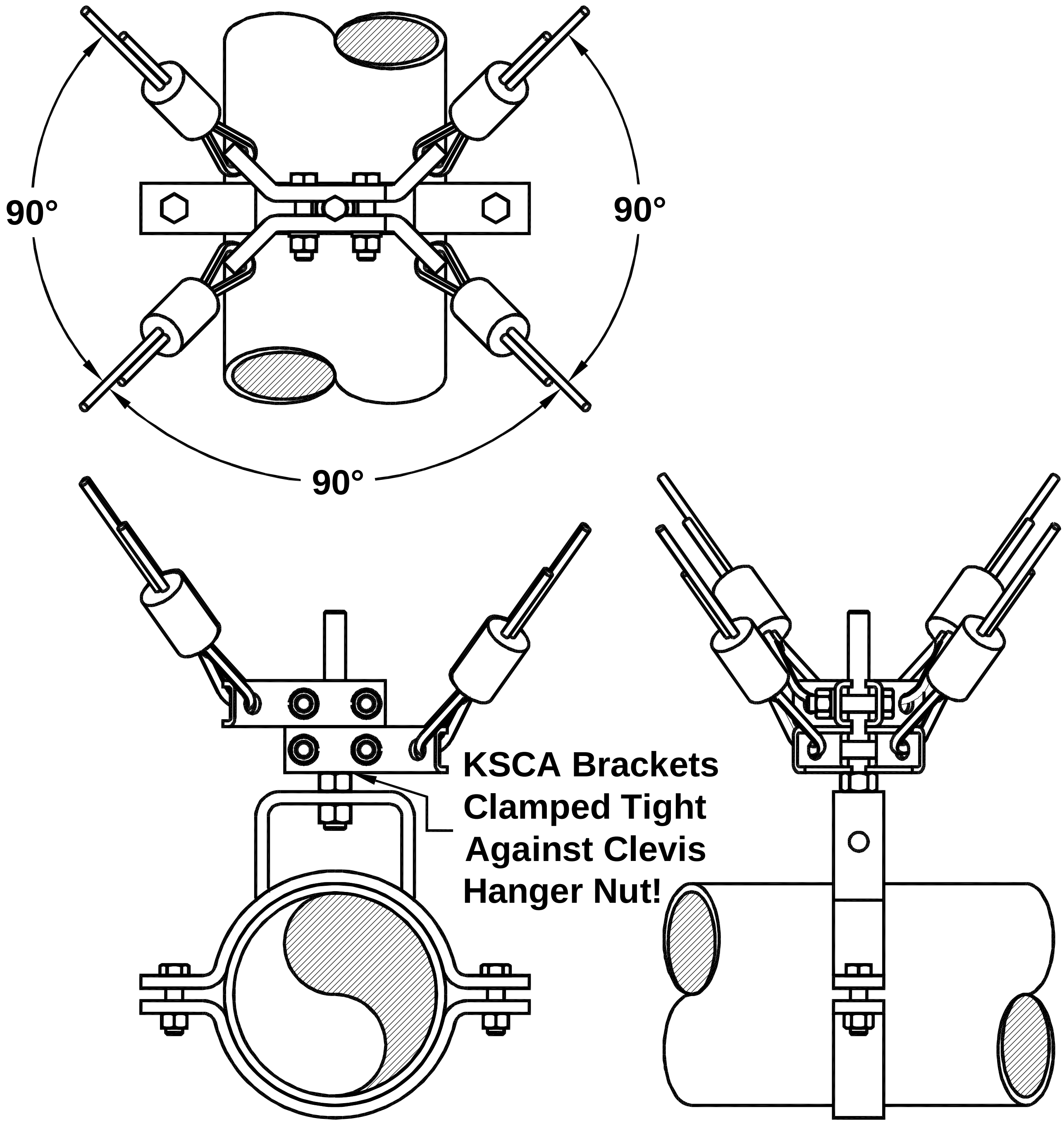

Figure I6-23; KSCA Brackets Attached to the Hanger Rod of a Commercially Available Clamp Type Clevis Hanger – Combined Transverse and Longitudinal (TL) Restraints

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I6.3.3 – KSCA Brackets – Attachment to Trapeze Bars:

KSCA brackets may be attached to trapeze bars constructed of rolled structural shapes as shown in Figures I6-24(transverse (**T**) restraints), I6-25 (longitudinal (**L**) restraints, and I6-26 (Combined transverse and longitudinal (**TL**) restraints).

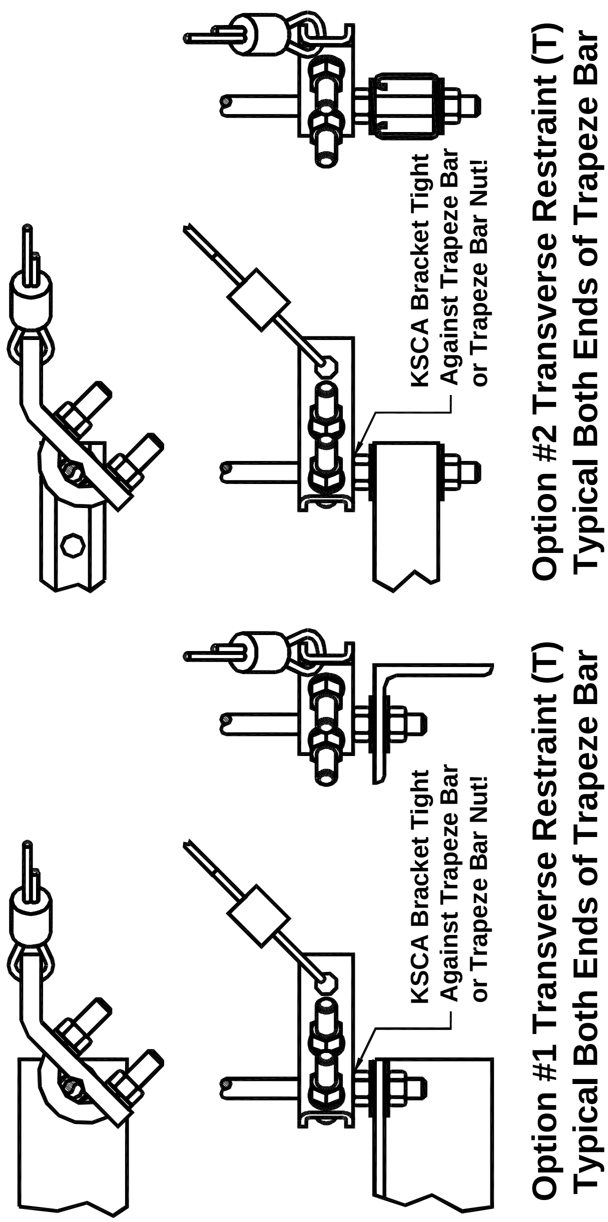

Figure I6-24; KSCA Brackets Used with a Rolled Structural Trapeze Bar & a Strut Channel Trapeze Bar – Transverse (T) Restraints

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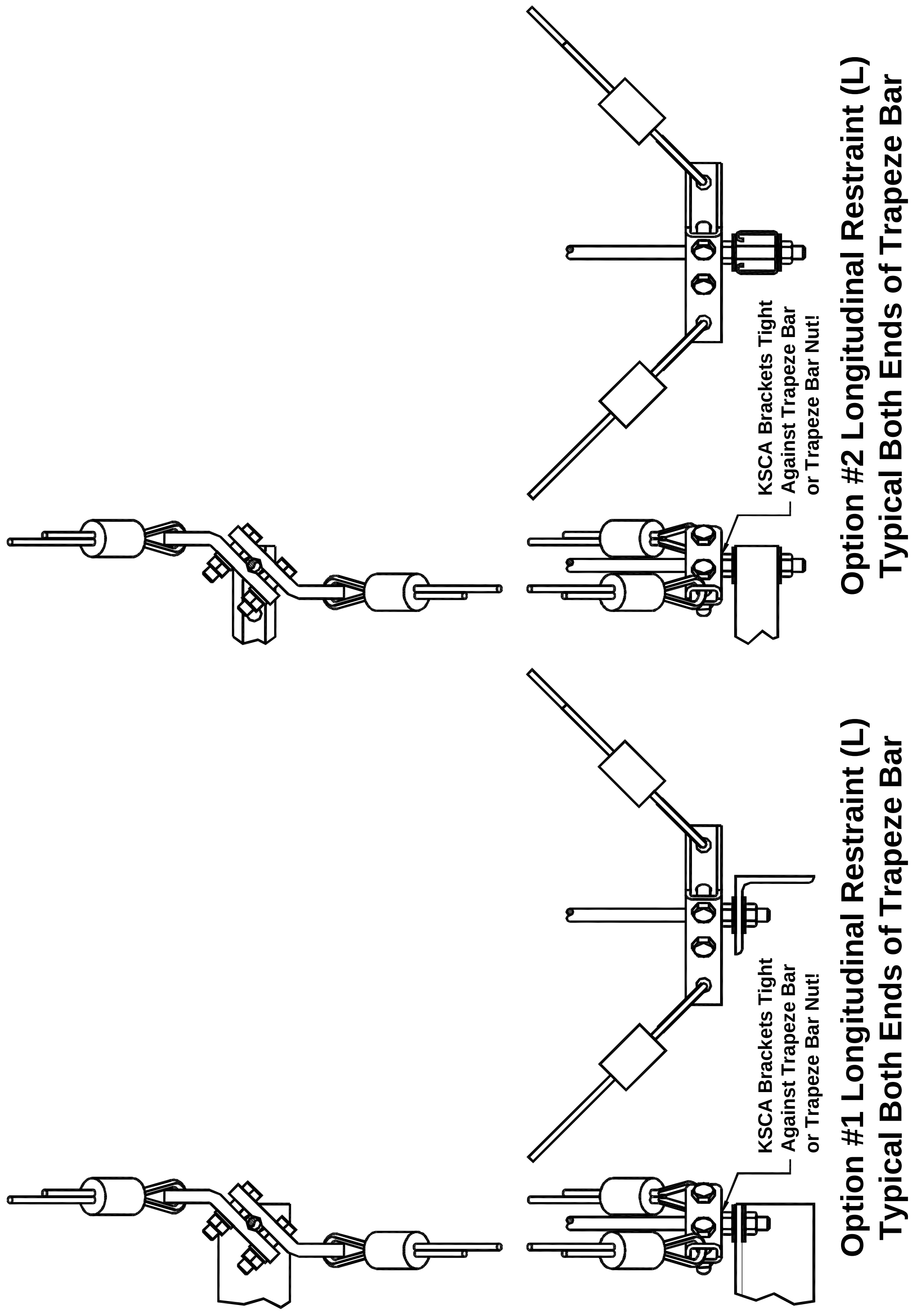

Figure I6-25; KSCA Brackets Used with a Rolled Structural Trapeze Bar & a Strut Channel Trapeze Bar – Longitudinal (L) Restraints

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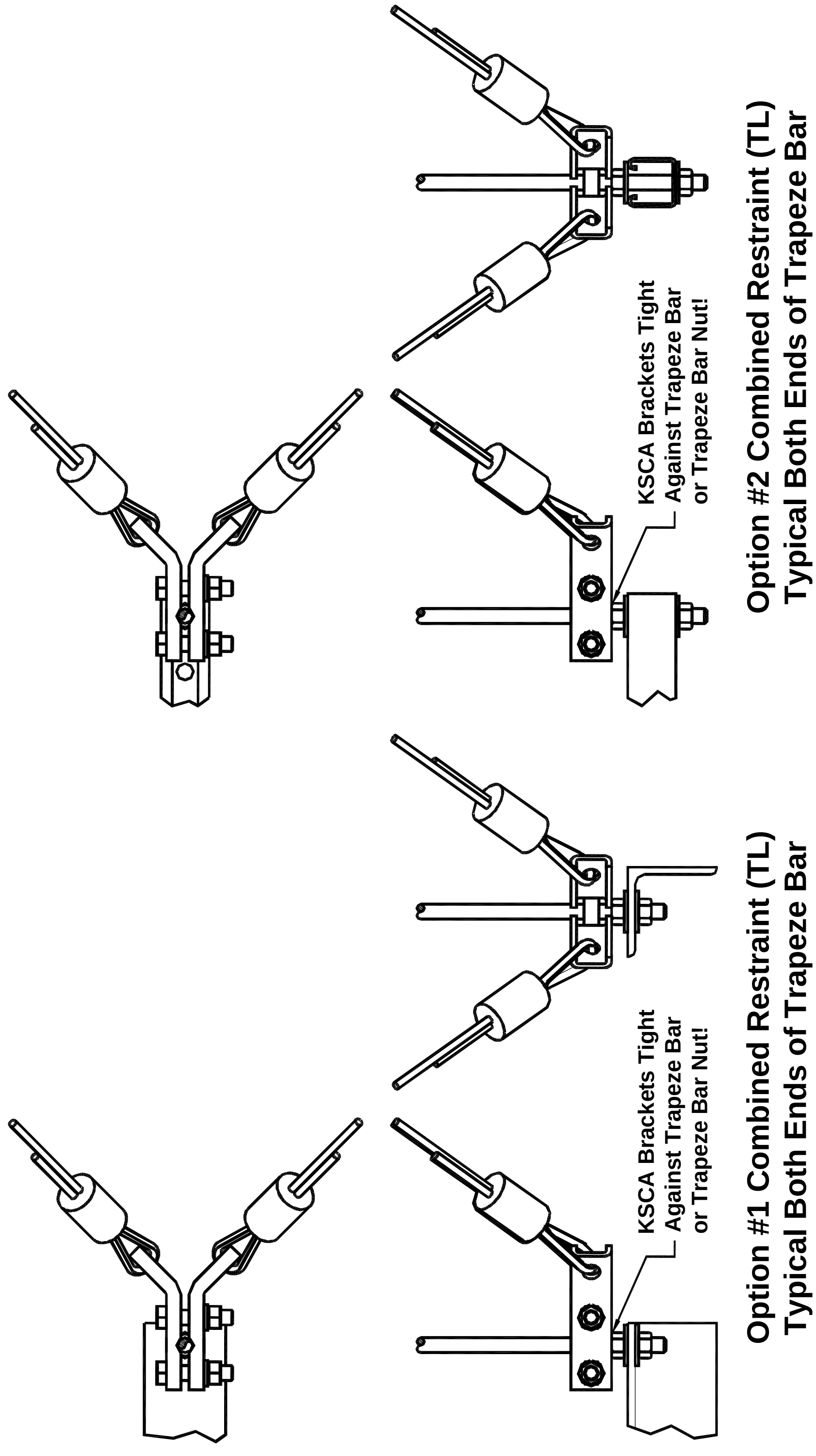

Figure I6-26; KSCA Brackets Used with a Rolled Structural Trapeze Bar & a Strut Channel Trapeze Bar – Combined Transverse & Longitudinal (TL) Restraints

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I6.4 – KSCC Attachment Brackets:

I6.4.1 – KSCC Brackets – Basic Sizes & Installation:

The Kinetics Noise Control Model KSCC-1 and KSCC-2 brackets were designed to be used with the Kinetics Noise Control Model KSCC Seismic Restraint Cable Kits, which are descried in Appendix A1.1. These kits contain two of the KSCC brackets, bulk cable, and the appropriate number of U-Bolt, “Crosby”, clips. These brackets are shown in Figure I6-27, which also indicates the appropriate fasteners and cables that are to be used with each bracket. Depending on the angle of the cable when installed, a thimble may be need in this loop to prevent damage to the cable. ***All OSHPD applications require the use of thimbles on both ends of the cable***.

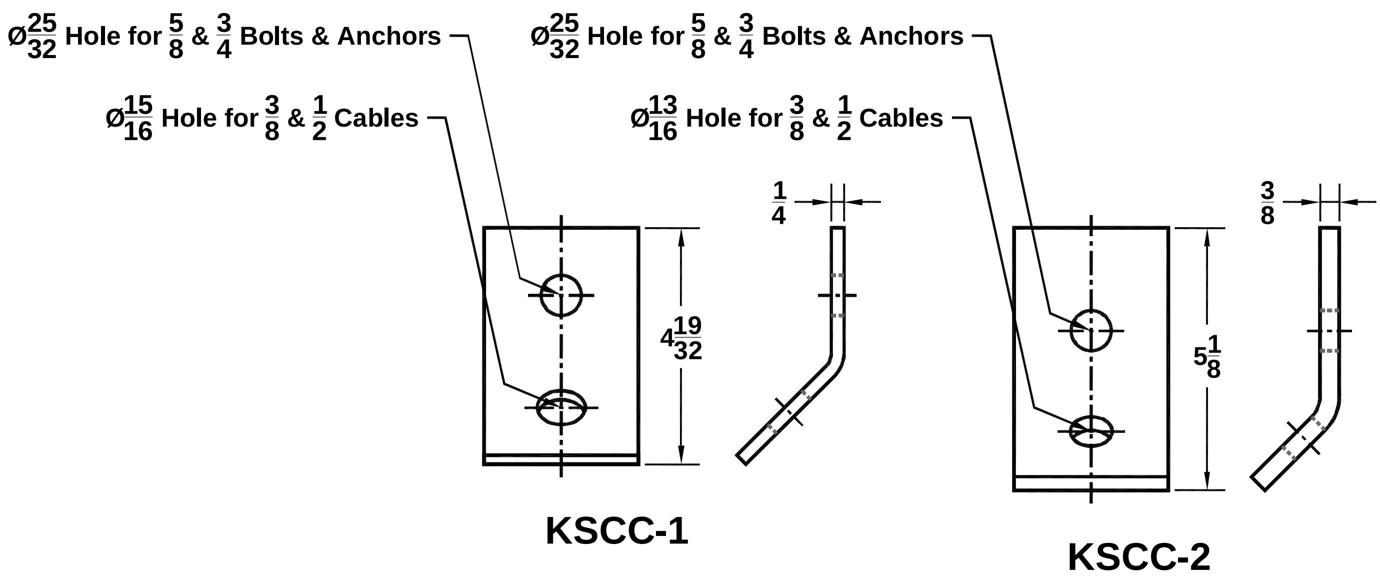

Figure I6-27; Kinetics Noise Control Model KSCC Seismic Restraint Cable Attachment Brackets

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I6.4.2 – KSCC Brackets – Attachment to a Clevis or Hanger Rod:

For transverse (**T**) restraints only, the KSCC brackets may be attached to the side of a standard, MSS Type 1, clevis hanger or to the hanger rod for a standard clevis hanger as shown in Figures I6-28 and I6-29 respectively.

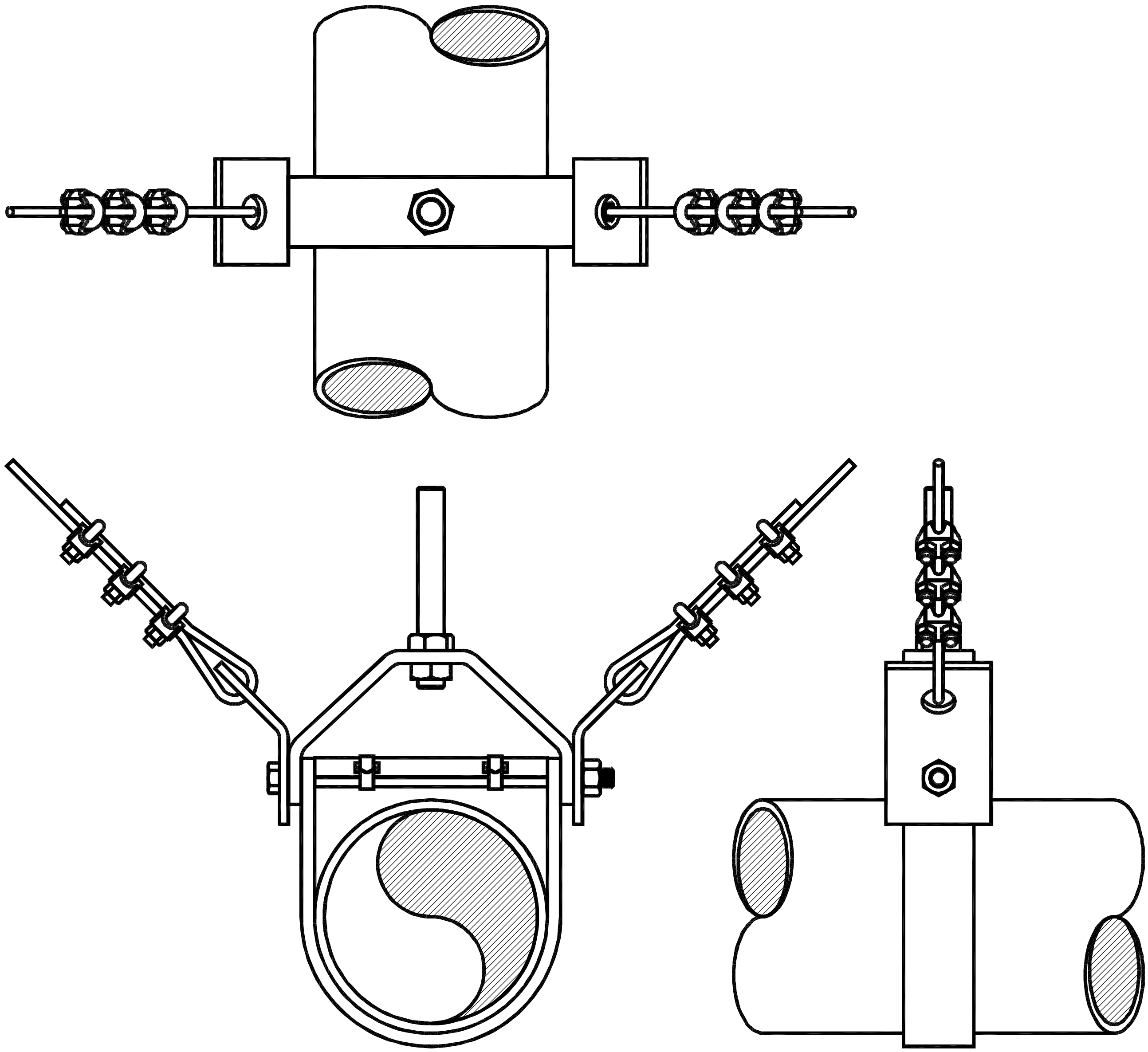

Figure I6-28; KSCC Brackets Attached to the Side of a Standard Clevis Hanger –
Transverse (T) Restraints Only

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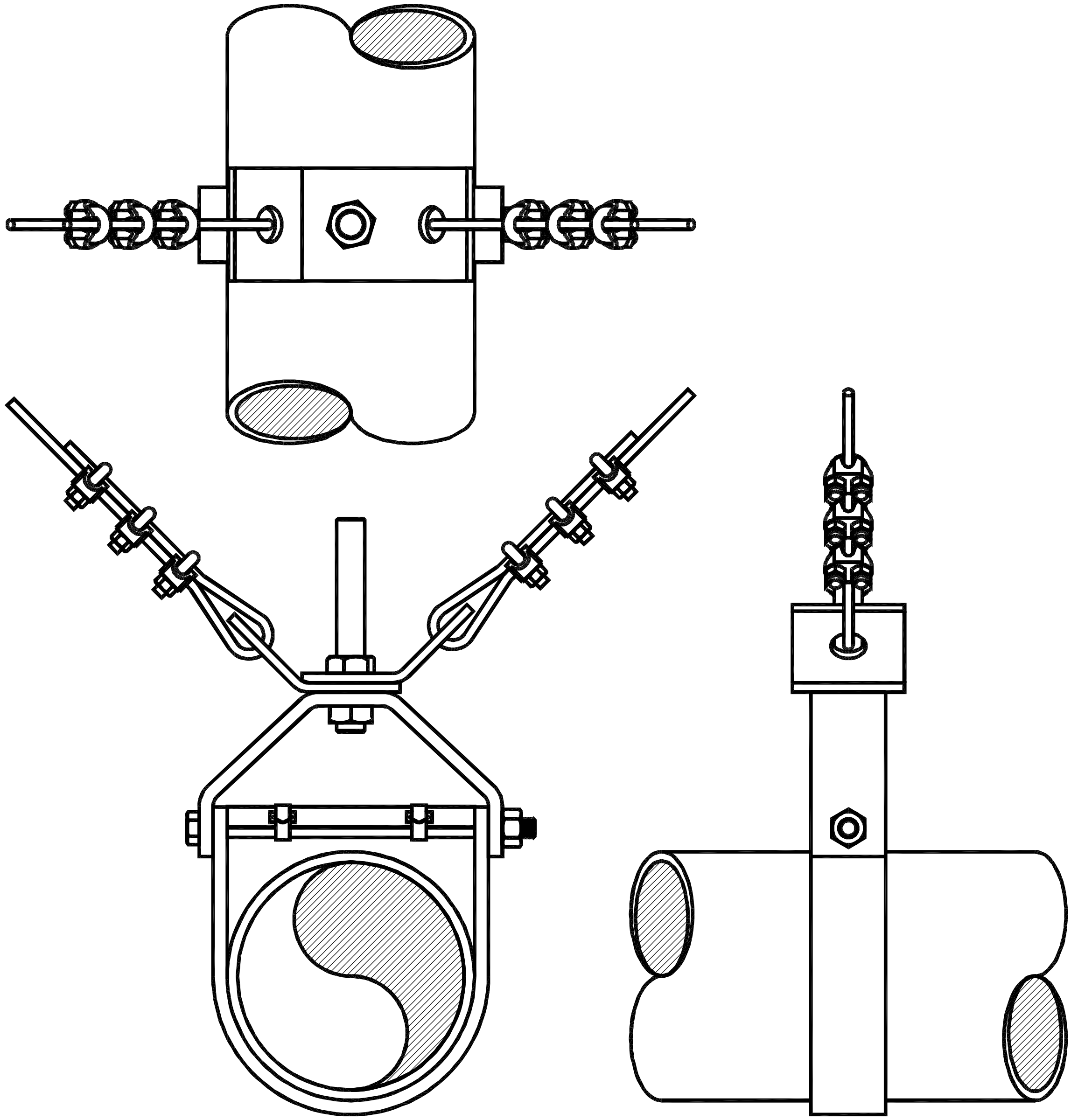

Figure I6-29; KSCC Brackets Attached to the Hanger Rod of a Standard Clevis Hanger –
Transverse (T) Restraints Only

The commercially available clamp type clevis hangers shown in Figure I3-13 may be used with the KSCC brackets. Figure I6-30 shows this type of clevis hanger with transverse (**T**) seismic restraints. Figure I6-31 shows the use of this hanger type with longitudinal (**L**) restraints and

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Figure I6-32 shows have combined transverse and Longitudinal (**TL**) restraints may be attached to this type of clevis hangers.

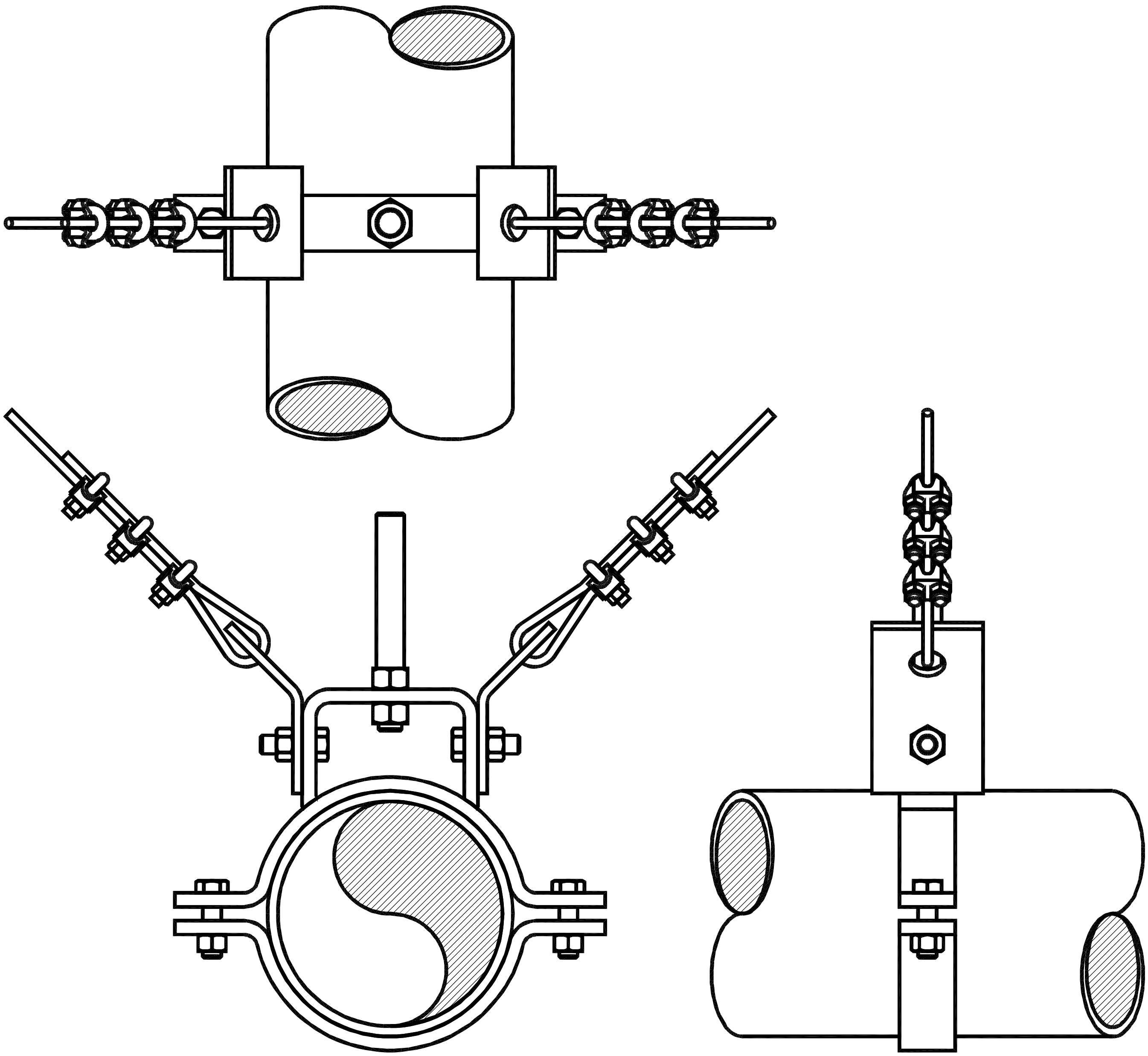

Figure I6-30; KSCC Brackets Attached to a Commercially Available Clamp Type Clevis Hanger – Transverse (T) Restraints

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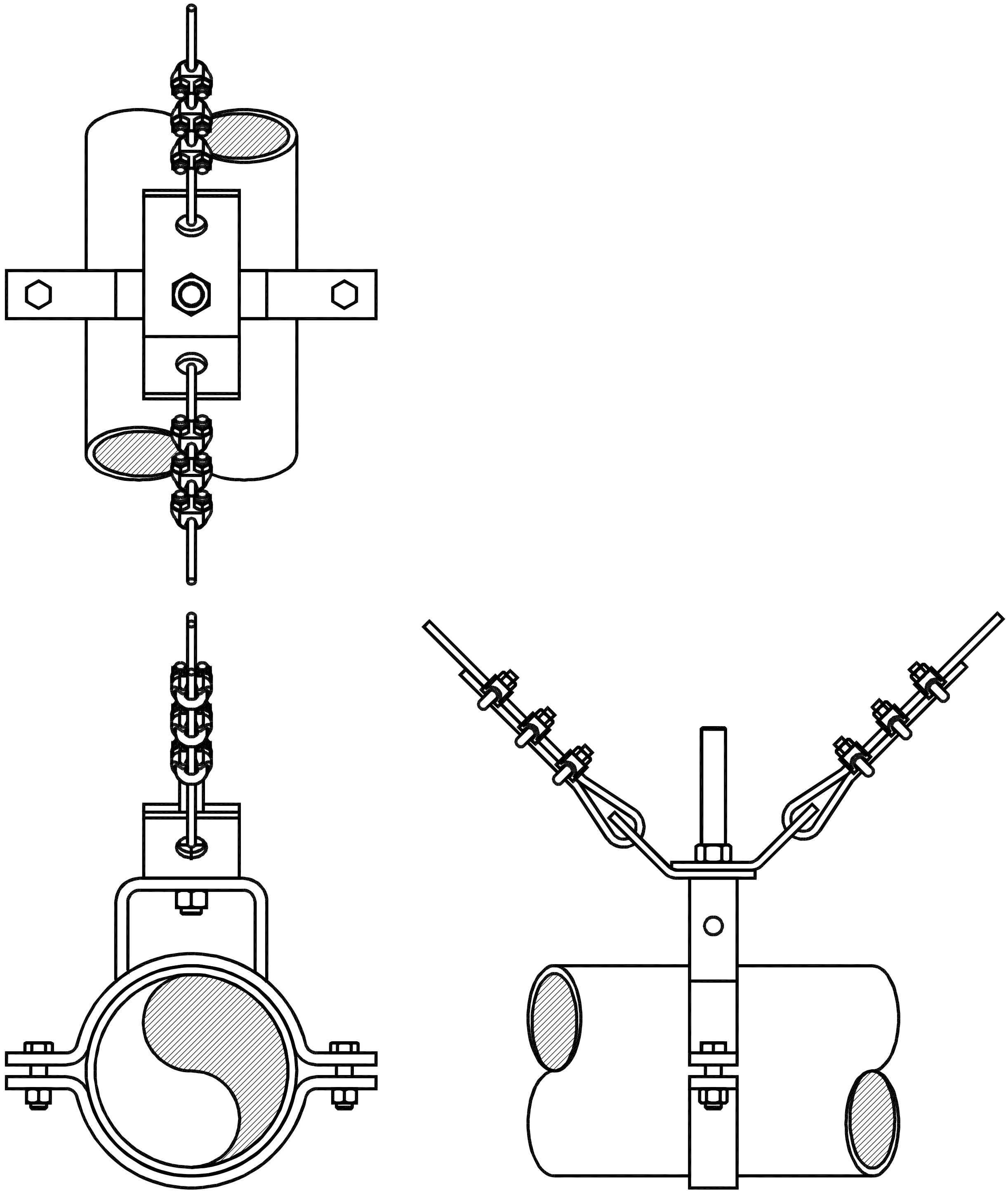

Figure I6-31; KSCC Brackets Attached to the Hanger Rod of a Commercially Available Clamp Type Clevis Hanger – Longitudinal (L) Restraints

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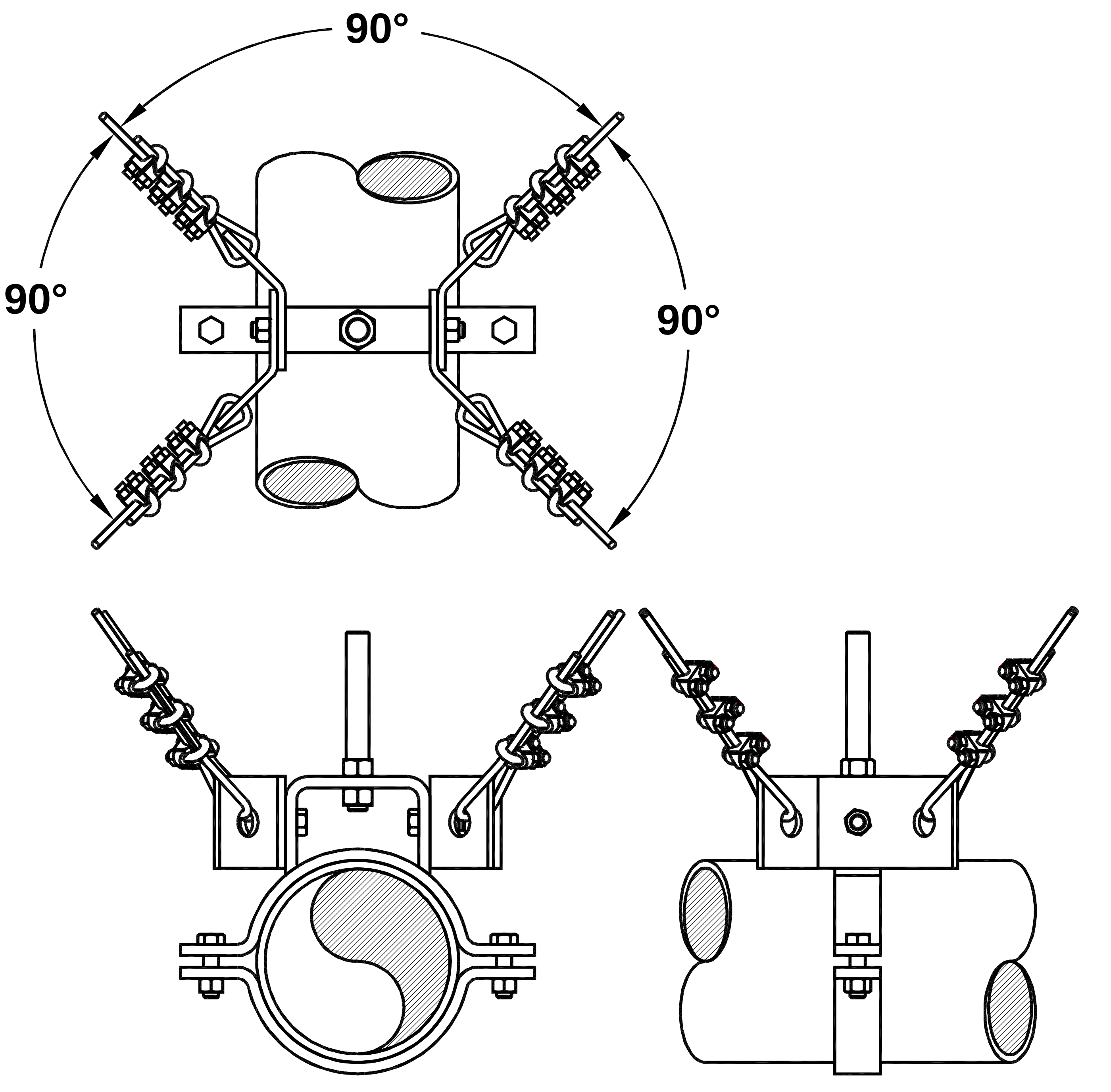

Figure I6-32; KSCC Brackets Attached to a Commercially Available Clamp Type Clevis Hanger – Combined Transverse and Longitudinal (TL) Restraints

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I6.4.3 – KSCC Brackets – Attachment to the Pipe (Fire Protection Piping):

NFPA-13 Section 9.3.5.11.1 requires that all seismic restraints for all feed and cross mains be attached directly to the pipe. Seismic restraints are not to be attached to the clevis hangers for fire protection piping unless the clevis hangers are specifically listed for this type of application. These types of connections may be made using KSCC brackets and the Kinetics model KFPC Clamp. Figure I6-33 shows the KSCC brackets and KFPC clamp used for a transverse (**T**) restraint, Figure I6-34 shows a longitudinal (**L**) restraint, and Figure I6-35 shows a combination transverse and longitudinal (**TL**) restraint.

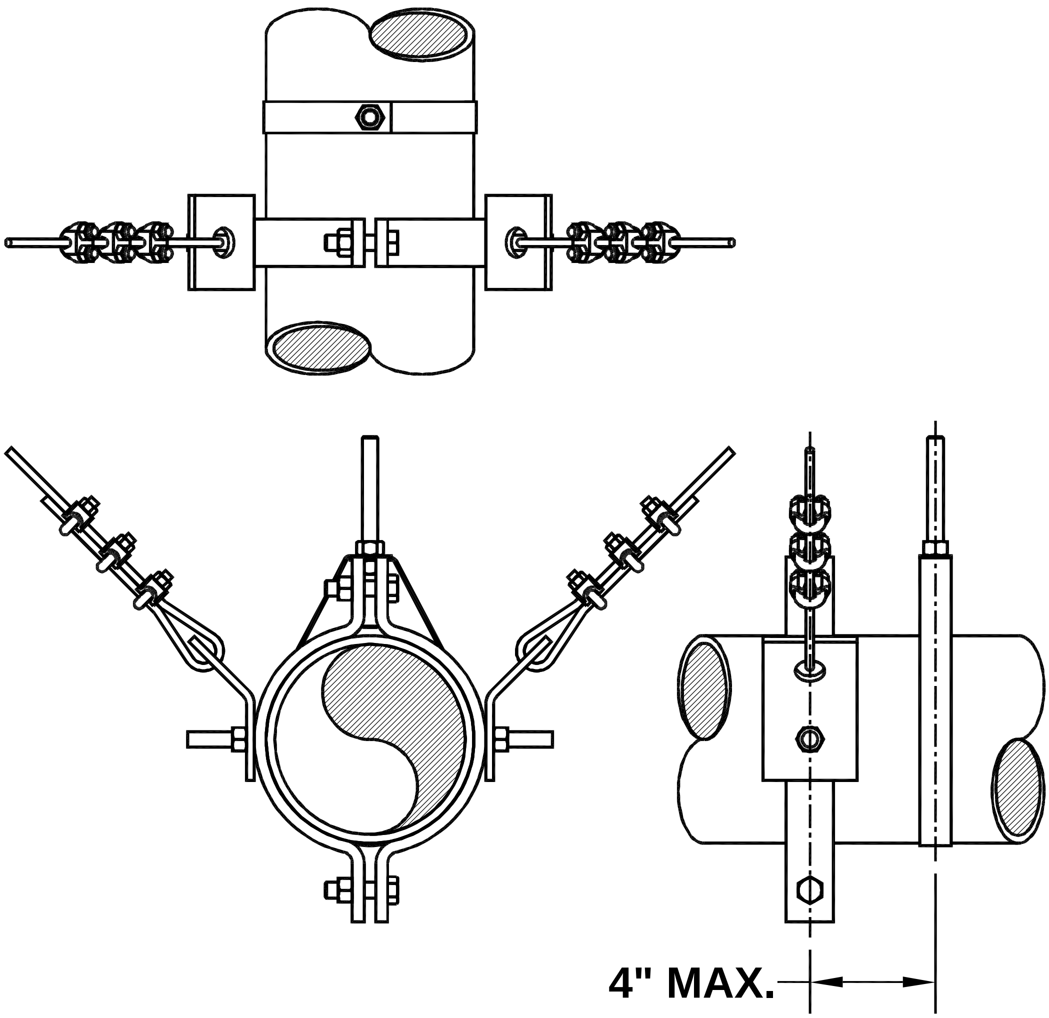

Figure I6-33; KSCC Brackets Attached to a KFPC Clamp (May be Used for Fire Protection Piping) – Transverse (T) Restraints

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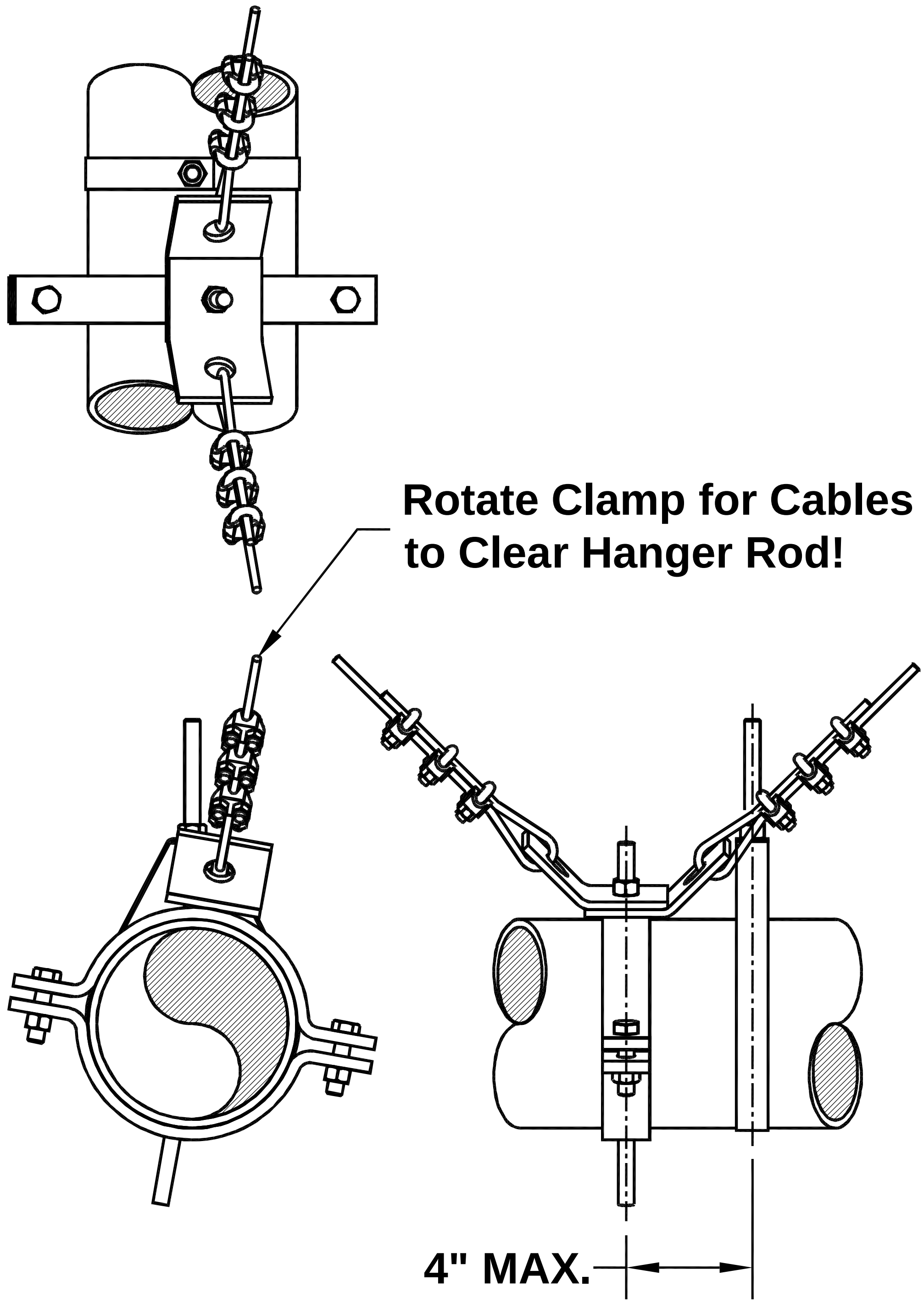

Figure I6-34; KSCC Brackets Attached to a KFPC Clamp (May be Used for Fire Protection Piping) – Longitudinal (L) Restraints

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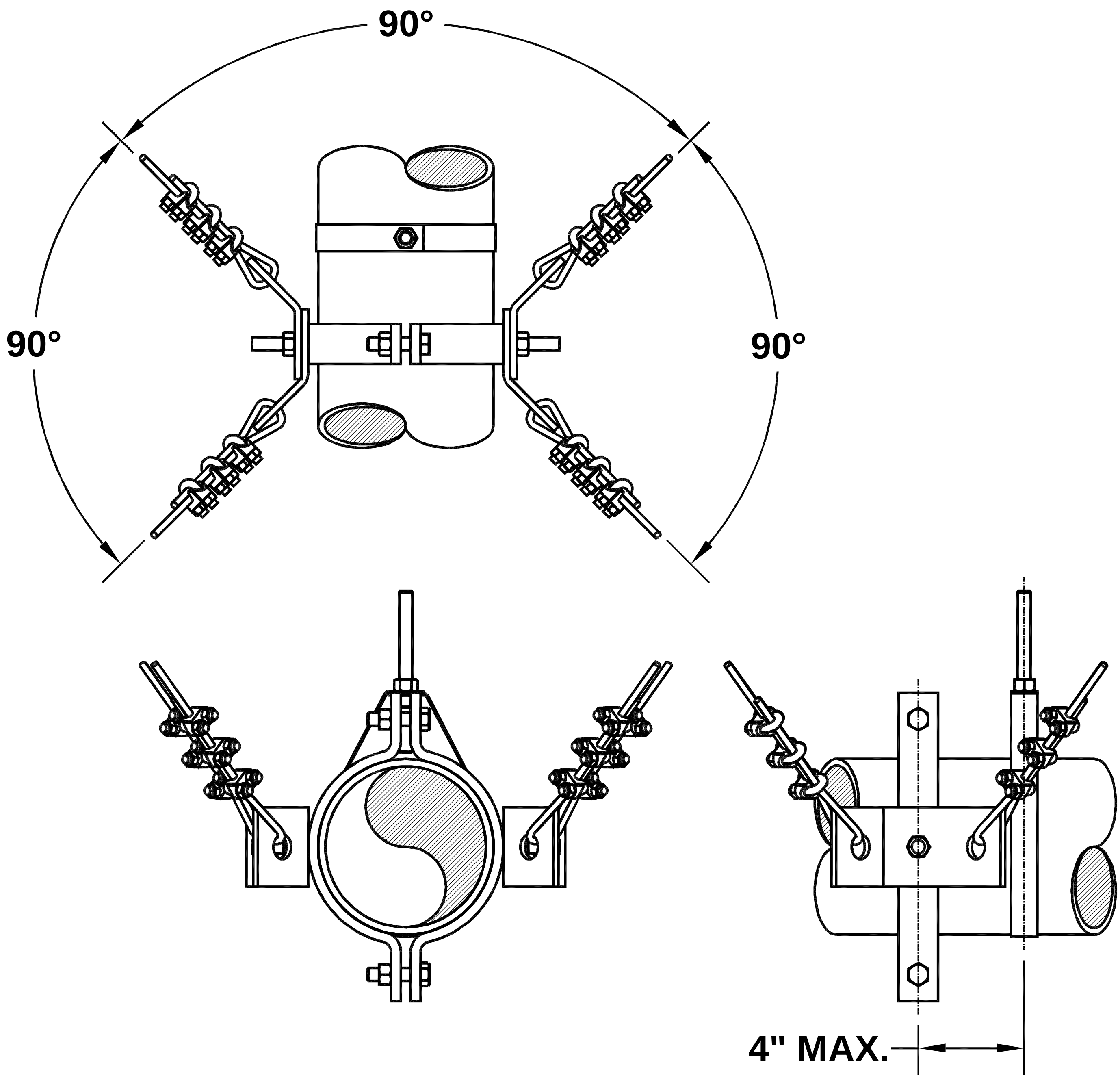

Figure I6-35; KSCC Brackets Attached to a KFPC Clamp (May be Used for Fire Protection Piping) – Combined Transverse and Longitudinal (TL) Restraints

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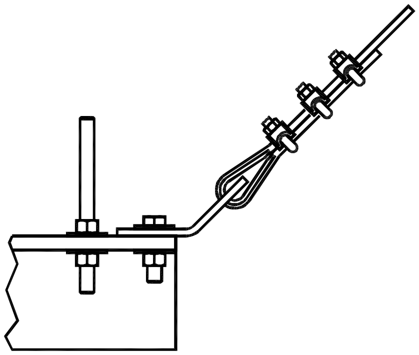
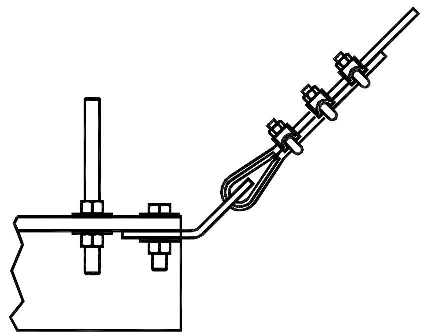
I6.4.4 – KSCC Brackets – Attachment to Trapeze Bars:

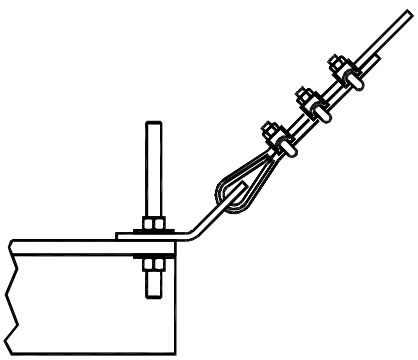
KSCC brackets may be attached to trapeze bars constructed of rolled structural shapes as shown in Figures I6-36 (transverse (**T**) restraints), I6-37 (longitudinal (**L**) restraints, and I6-38 (Combined transverse and longitudinal (**TL**) restraints). When one of the bolting surfaces on the structural shape has a taper such the inner leg surface of a C-channel, use a tapered structural washer against this surface to prevent bending in the hanger rods, or bolts.



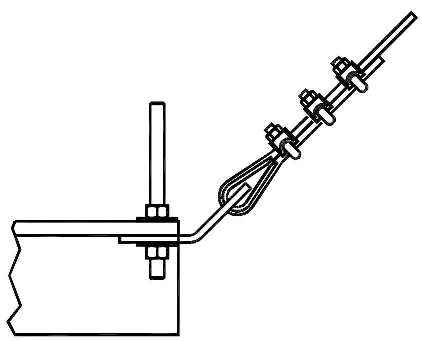
Option #1 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



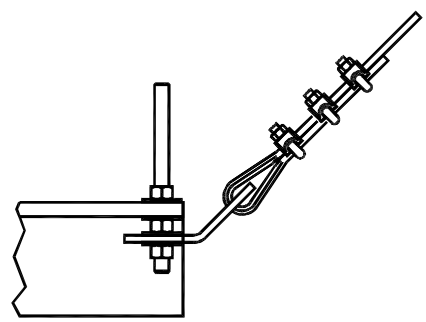
Option #2 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



Option #3 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



Option #4 Transverse Restraint (T) Typical Both Ends of Trapeze Bar



Option #5 Transverse Restraint (T) Typical Both Ends of Trapeze Bar

Sheet F - Views L & M

Figure I6-36; KSCC Brackets Attached to a Rolled Structural Trapeze Bar – Transverse (T) Restraints

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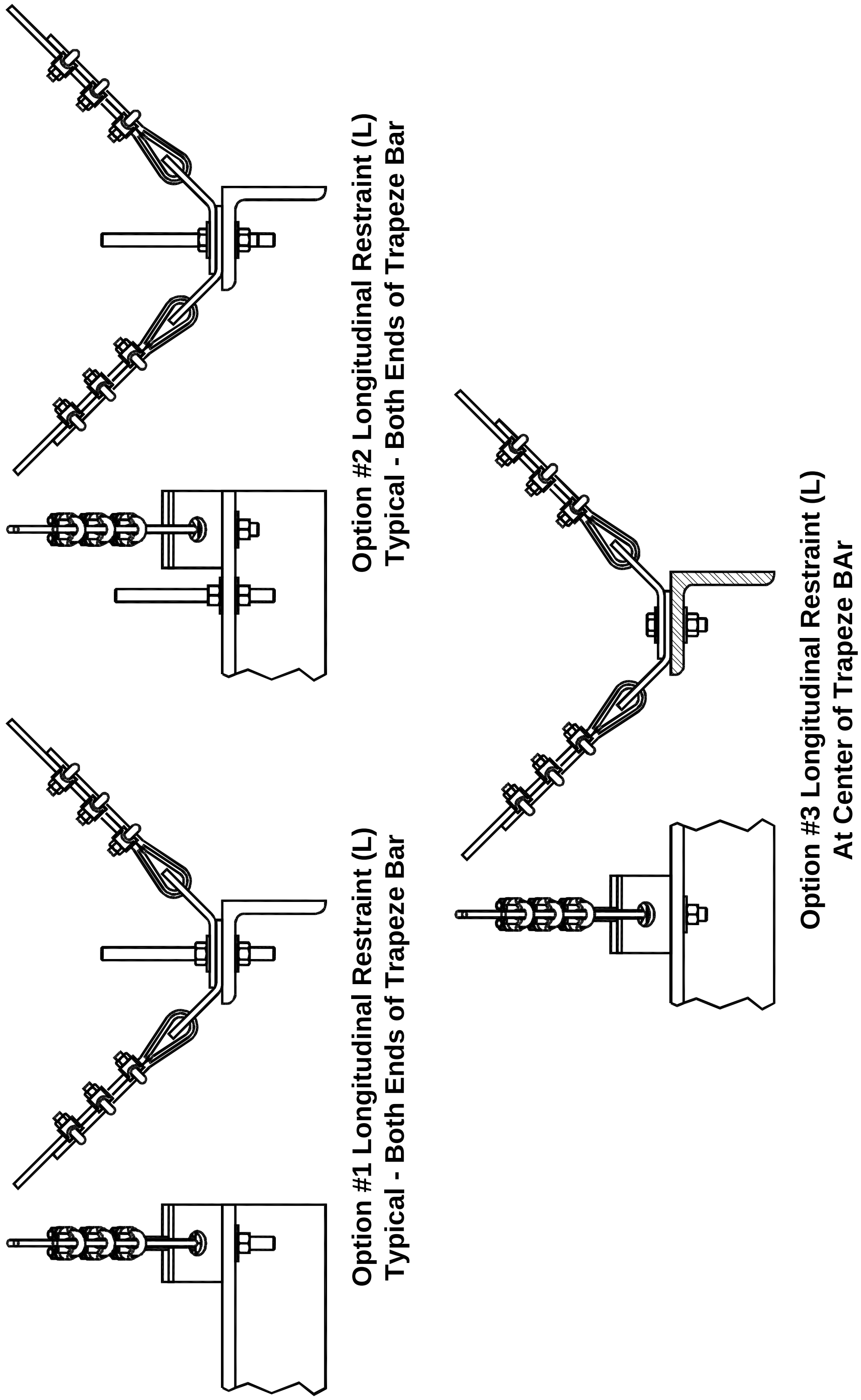

Figure I6-37; KSCC Brackets Attached to a Rolled Structural Trapeze Bar – Longitudinal (L) Restraints

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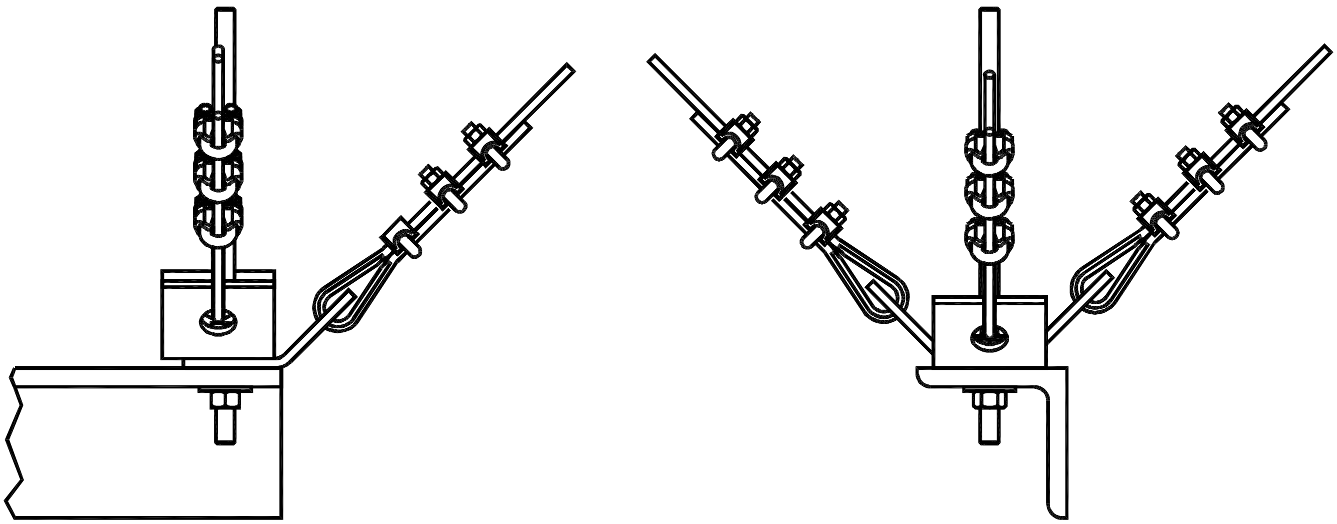
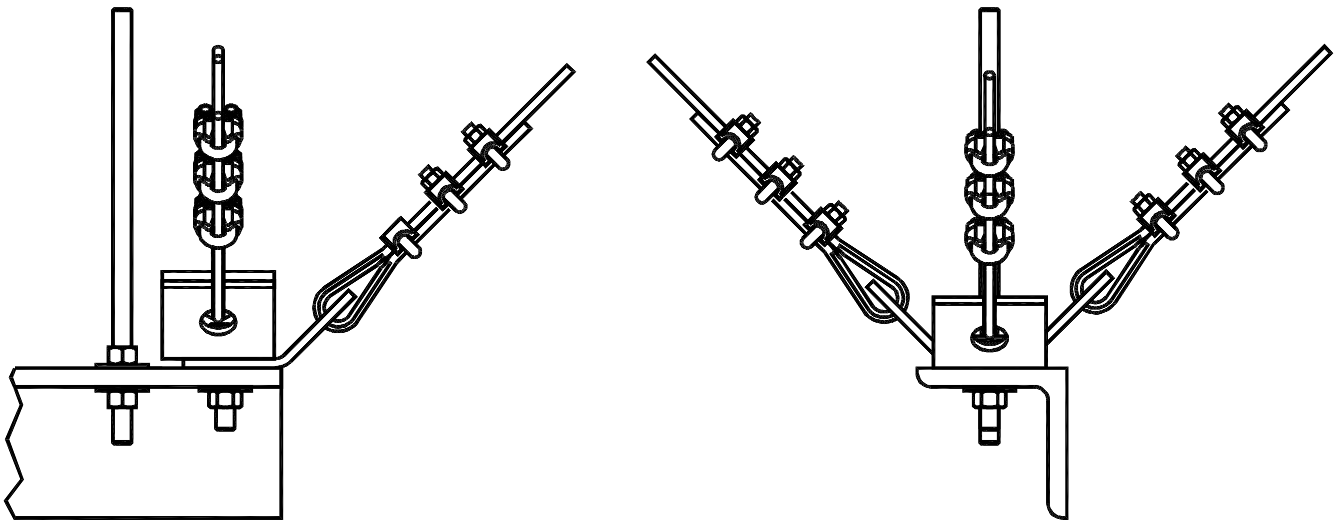


Option #1 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar



Option #2 Combined Restraint (TL)
Typical - Both Ends of Trapeze Bar

Figure I6-38; KSCC Brackets Attached to a Rolled Structural Trapeze Bar – Combined Transverse and Longitudinal (TL) Restraints

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I6.5 – Finishing Touches:

1. Make sure all restraints have two restraint cables 180° apart. Remember: ***You can't push a rope!***
2. Be sure all restraint locations have the proper restraints, transverse (**T**) and/or Longitudinal (**L**) and/or (**TL**), installed per the drawings provided by Kinetics Noise Control or the responsible engineer of record.
3. Make sure all longitudinal (**L**) restraints on trapeze supported pipe and duct are ***balanced***. Seismic forces acting through the longitudinal (**L**) restraints should not twist the pipe or duct through the trapeze bar.
4. All seismic restraints cable must be hand tight as shown in Figure I6-39, and the pipe(s) or duct must be centered.

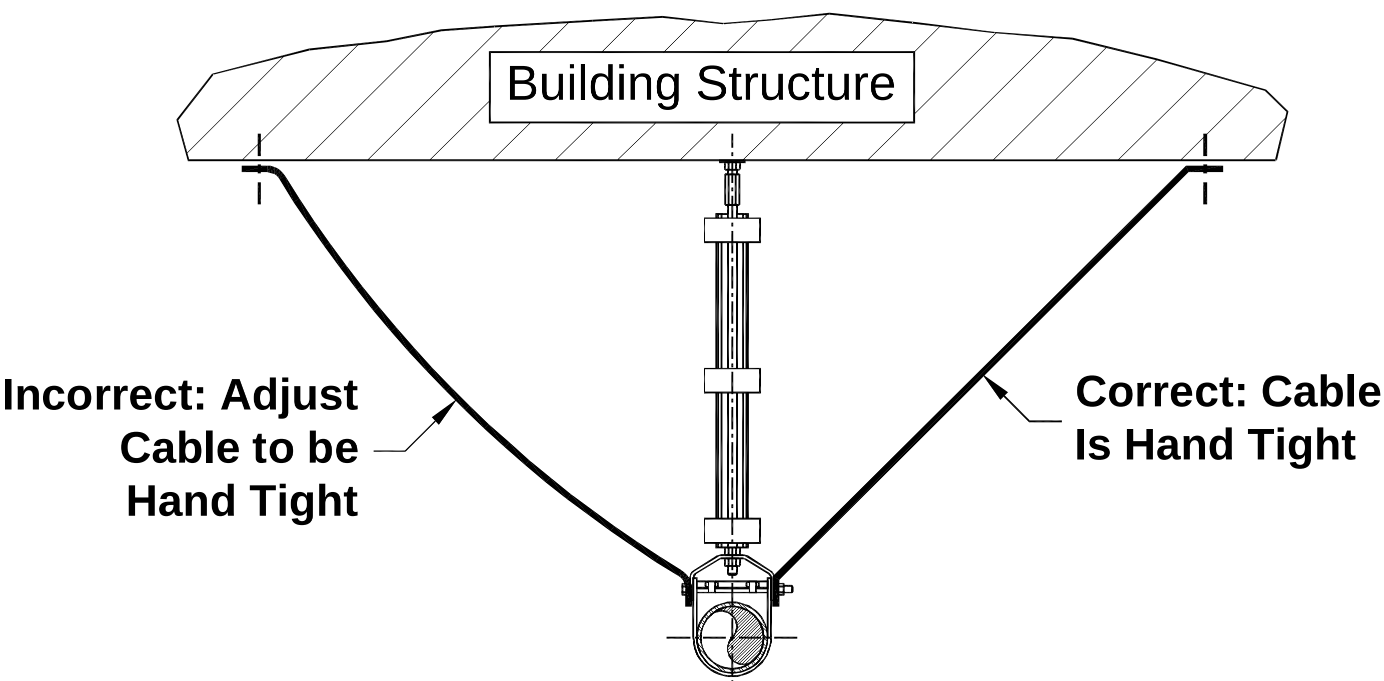

Figure I6-39; All Seismic Restraint Cables must be Hand Tight

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5. Excess seismic restraint cable may be coiled and tied off with tape, plastic or metal wire ties, or tie wire in a fashion that is compatible with the installed environment. For corrosive and damp environments use stainless steel wire ties and tie wire. Excess Cable may be coiled as shown in Figures I6-40 and I6-41 for KSCU and KSCC Seismic Restraint Cable Kits respectively.
6. Finally, if the excess cable is to be removed, ***do not cut off the excess until after the final inspection and approval of the system***.

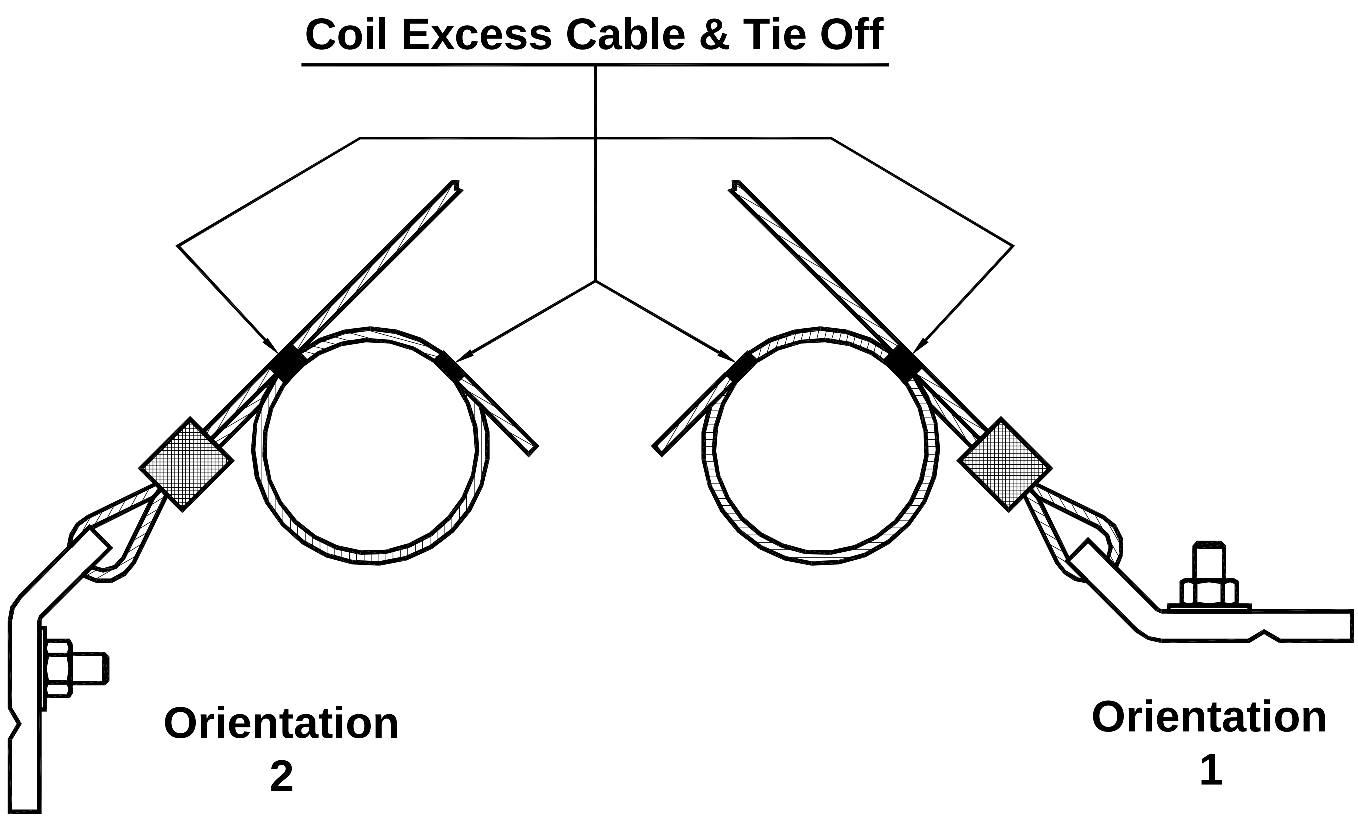

Figure I6-40; Coiling Excess Seismic Restraint Cables for KSCU Cable Kits

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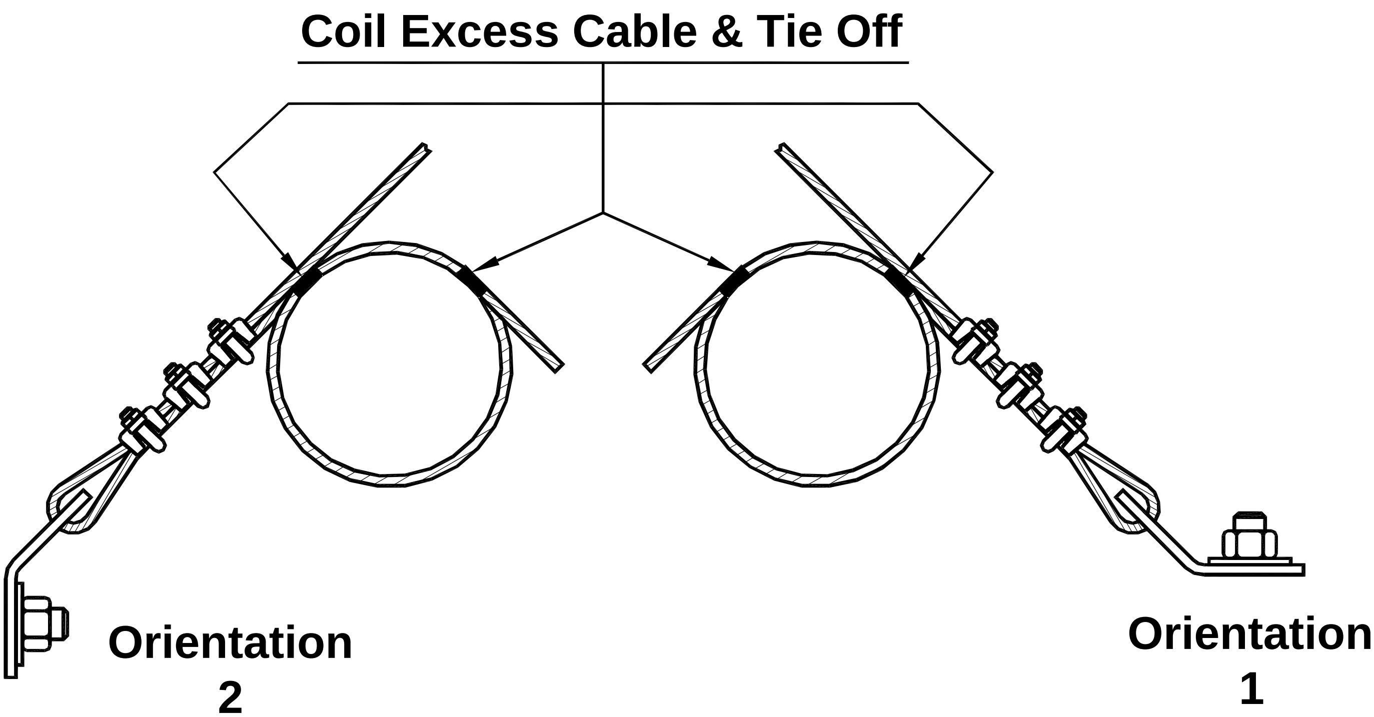

Figure I6-41; Coiling Excess Seismic Restraint Cables for KSCC Cable Kits

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STRUTS & STUFF

I7.1 – Introduction:

Many field installation situations will require the contractor to make a decision to use strut type restraints rather than the cable restraints recommended by Kinetics noise control. Some of these situations will be:

1. Other components directly in the intended path of one of the restraint cables.
2. The pipe or duct is too close to a wall that cannot be penetrated.
3. There is no competent structure for attachment of one of the cable restraints.
4. The specification will not permit cable restraints, also known as tension only braces.

This section is designed to assist the contractor in selecting and installing strut members to be used in conjunction with the brackets and attachment hardware included in the restraint cable kits provided by Kinetics Noise Control to generate strut type restraints with equal capacity to the restraint cable kits. Each KSCU and KSCC Restraint Cable Kit provided by Kinetics Noise Control for any given restraint location will have enough KSCA and KSCC brackets respectively to fabricate strut type restraints for that location. The KSCA bracket is shown in Figure I7-1, and the KSCC brackets are shown in Figure I7-2.

I7.2 – Conditions of Use for Strut Type Restraints:

1. If a run of pipe or duct requires the use of ***even one*** strut type restraint along its length, ***all*** of the restraints on that run of pipe or duct ***must be strut type restraints***.
2. If concrete anchors are used to attach the hanger rods for the pipe or duct to the ceiling or roof structure, they must be anchors approved for use in seismic applications, see ASCE 7-05 Section 13.4.2. Consult with the engineer of record for the system being installed for the specification of the proper anchor.
3. Hanger rod sizes and anchor sizes may need to be increased to handle the additional tensile loads imposed on the hangers by the seismic loads see Section 8.0 of this manual. Consult

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with the engineer of record for the system being installed for the proper hanger rod and/or anchor size for use with strut type restraints.

4. The installation angle for the strut restraints will be limited to 45° by virtue of the design of the KSCA and KSCC brackets.
5. One strut restraint will replace one pair of cable restraints.
6. A web based program available from Kinetics Noise Control at www.kineticsnoise.com may be used to verify the adequacy of hanger rods and hanger rod anchors based on the particulars of the restraint in question.

I7.3 – Using the Restraint Designation Symbol to Select Struts:

Figure I7-1 shows a typical designation symbol for seismic restraints on the drawings produced by Kinetics Noise Control indicating the recommended seismic cable restraint and attachment hardware kits.

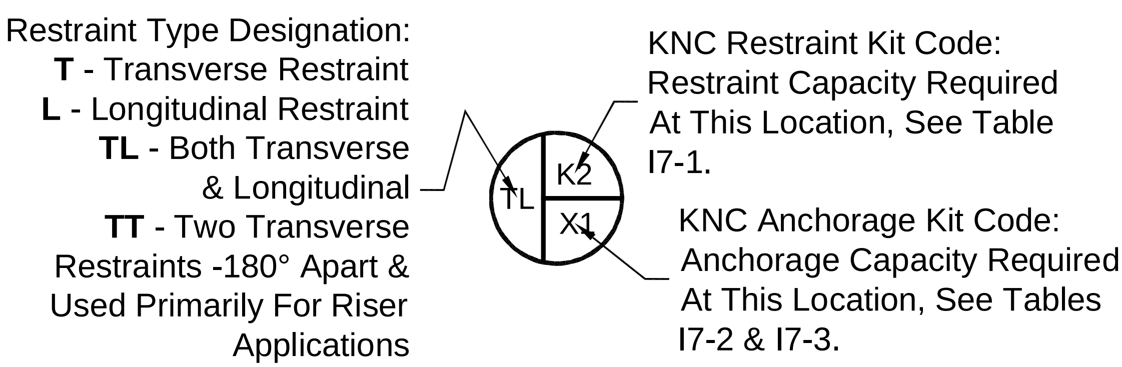

Figure I7-1; Typical Kinetics Noise Control Restraint Kit and Attachment Kit Designation Symbol

The KNC Restraint Codes are described in Table I7-1 and KNC Attachment Kit Codes are described in Tables I7-2 and I7-3. The restraint kit codes in Table I7-1 will be used to select the proper structural shape and size for the material used in the strut type restraint. The attachment kits described in Tables I7-2 and I7-3 will apply to both the cable type restraints and the strut type restraints.

Kinetics Noise Control provides conversion data for three types of structural members that may be used for strut type restraints, rolled structural angle, UNISTRUT® or equal strut channel, and pipe.

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The first type of structural member discussed will be the rolled structural channels. The strut equivalents for Kinetics Noise Control restraint cable kits with rolled structural channel are shown in Table I7-4. This table covers the most readily available and easily handled sizes. Other sizes may be used, but will require analysis by the design professional responsible for the system.

Table I7-1; Seismic Restraint Cable Kit vs. Code Cross-Reference

KNC Restraint Kit Code	Restraint Kit Description
K2	KSCU-2 Cable Kit – 2 mm Cable & GRIPPLE HANGFAST No, 2 Connectors
K3	KSCU-3 Cable Kit – 3 mm Cable & GRIPPLE HANGFAST No, 3 Connectors
K4	KSCU-4 Cable Kit – 5 mm Cable & GRIPPLE HANGFAST No, 4 Connectors
K5	KSCU-5 Cable Kit – 6 mm Cable & GRIPPLE Lockable 6 mm Connectors
C1	KSCC-250 Cable Kit – 1/4″ Cable & Saddle + U-bolt Connectors
C2	KSCC-375 Cable Kit – 3/8″ Cable & Saddle + U-bolt Connectors
C3	KSCC-500 Cable Kit – 1/2″ Cable & Saddle + U-bolt Connectors

Table I7-2; Structural Concrete/Steel Attachment Kit vs. Code Cross-Reference

KNC Attachment Kit Code	Attachment Kit Description per Restraint Cable Note: Through bolts & nuts of the same size may be used for each kit and code shown below.
X1	(1) 1/4″ Concrete Anchor (with Grommet)
X2	(1) 3/8″ Concrete Anchor (with Grommet)
X3	(1) 1/2″ Concrete Anchor
Y1	(1) 5/8″ Concrete Anchor
Y2	(1) 3/4″ Concrete Anchor
Y3	(1) 7/8″ Concrete Anchor
Z1	(2) 3/8″ Concrete Anchors with Oversized Base Plate
Z2	(4) 3/8″ Concrete Anchors with Oversized Base Plate
Z3	(2) 1/2″ Concrete Anchors with Oversized Base Plate
Z4	(4) 1/2″ Concrete Anchors with Oversized Base Plate

Table I7-3; Structural Wood/Steel Attachment Kit vs. Code Cross-Reference

KNC Attachment Kit Code	Attachment Kit Description per Restraint Cable Note: Through bolts & nuts of the same size may be used for each kit and code shown below.
W1	(1) 1/4″ Lag Screw (with Grommet)
W2	(1) 3/8″ Lag Screw (with Grommet)
W3	(1) 1/2″ Lag Screw
W4	(1) 5/8″ Lag Screw
W5	(1) 3/4″ Lag Screw
W6	(1) 7/8″ Lag Screw
W7	(2) 3/8″ Lag Screws with Oversized Base Plate
W8	(4) 3/8″ Lag Screws with Oversized Base Plate
W9	(2) 1/2″ Lag Screws with Oversized Base Plate
W10	(4) 1/2″ Lag Screws with Oversized Base Plate

Table I7-4; Seismic Strut Restraint Size per KNC Restraint Code for Structural Steel Angle

KNC Restraint Code	Restraint Cable Kit	Structural Steel Angle Size (in)											
		1 x 1 x 1/8	1 x 1 x 1/4	1-1/2 x 1-1/2 x 1/4	2 x 2 x 1/4	2 x 2 x 3/8	2-1/2 x 2-1/2 x 1/4	2-1/2 x 2-1/2 x 1/2	3 x 3 x 1/4	3 x 3 x 1/2	3-1/2 x 3-1/2 x 1/4	3-1/2 x 3-1/2 x 1/2	4 x 4 x 1/4
		Maximum Strut Length (in)											
K2	KSCU-2	173	205	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
K3	KSCU-3	122	145	197	189	-----	-----	-----	-----	-----	-----	-----	-----
K4	KSCU-4	77	92	125	120	164	153	210	189	-----	-----	-----	-----
K5	KSCU-5	52	61	84	80	110	103	141	127	174	209	-----	-----
C1	KSCC-250	53	63	86	82	113	105	144	130	178	213	-----	-----
C2	KSCC-375	37	44	60	57	78	73	100	90	124	149	203	232
C3	KSCC-500	30	36	49	47	64	60	82	74	101	121	166	190

The strut equivalents for Kinetics Noise Control restraint cable kits with UNISTRUT® or equal strut channel are shown in Table I7-5. The UNISTRUT® channels listed in Table I7-5 are 1-5/8″ channels. Other sizes may be used, but will require analysis by the design professional responsible for the system.

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Table I7-5; Seismic Strut Restraint Size per KNC Restraint Code for UNISTRUT® Profiles

KNC Restraint Code	Restraint Cable Kit	UNISTRUT® Profile			
		P1000	P1001	P5000	P5001
		Maximum Strut Length (in)			
K2	KSCU-2	165	-----	-----	-----
K3	KSCU-3	117	186	179	-----
K4	KSCU-4	74	118	113	160
K5	KSCU-5	49	79	76	108
C1	KSCC-250	51	81	78	110
C2	KSCC-375	34	56	54	77
C3	KSCC-500	16	46	44	62

The strut equivalents for Kinetics Noise Control restraint cable kits with pipe are shown in Table I7-6. The KSCA and KSCC brackets do not lend themselves well to use with struts fabricated from pipe. Either the pipe would need to be welded to the brackets, or the ends of the pipe would need to be flattened and drilled for bolts. The pipe listed in Table I7-6 covers the most readily available and easily handled sizes. Other sizes may be used, but will require analysis by the design professional responsible for the system.

Table I7-6; Seismic Strut Restraint Size per KNC Restraint Code for Pipe

KNC Restraint Code	Restraint Cable Kit	Nominal Pipe Size & Schedule						
		1" Sch. 40	1-1/4" Sch. 40	1-1/2" Sch. 40	2" Sch. 10	2" Sch. 40	2-1/2" Sch. 10	2-1/2" Sch. 40
		Maximum Strut Length (in)						
K2	KSCU-2	111	166	210	-----	-----	-----	-----
K3	KSCU-3	79	118	148	188	218	-----	-----
K4	KSCU-4	50	75	94	120	138	168	210
K5	KSCU-5	33	50	63	80	93	113	141

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All three of these tables are used in the same manner. The steps required to convert the recommended cable restraint kits to strut type restraints are as follows.

1. Determine the KNC Restraint Codes from the restraint symbol on the drawing for the run of pipe of duct that requires the use of strut type restraints.
2. Determine the approximate length of the structural member required for the strut. Measure from the intended attachment point on the clevis, pipe, duct, or trapeze bar at a 45° angle, 1″ of rise for 1″ of horizontal distance, to the intended anchor point on the structure.
3. Determine the type or structural member that will be used for the strut restraint, rolled structural angle – Table I7-4, UNISTRUT® channel – Table I7-5, or pipe – Table I7-6.
4. Find the row in the table for the selected structural member for the strut that corresponds to the KNC Restraint Code from the drawing symbol, K2 through K5 or C1 through C3.
5. Move across this row until a Maximum Strut Length that exceeds the approximate length required for the strut as measured in step 2 above is found.
6. Move up this column to determine the required size for the structural member to be used for the strut restraint.

I7.4 – Attaching Strut Members to KSCA & KSCC Brackets:

The KSCA bracket is shown in Figure I7-2, and the KSCC bracket is shown in Figure I7-3 below. For each bracket type and size, the appropriate holes are shown in Figures I7-2 and I7-3 for attaching to the strut and the building structure. Always use the strut attachment hardware size indicated in Figures I7-2 and I7-3 to ensure the maximum possible capacity for the strut restraint assembly.

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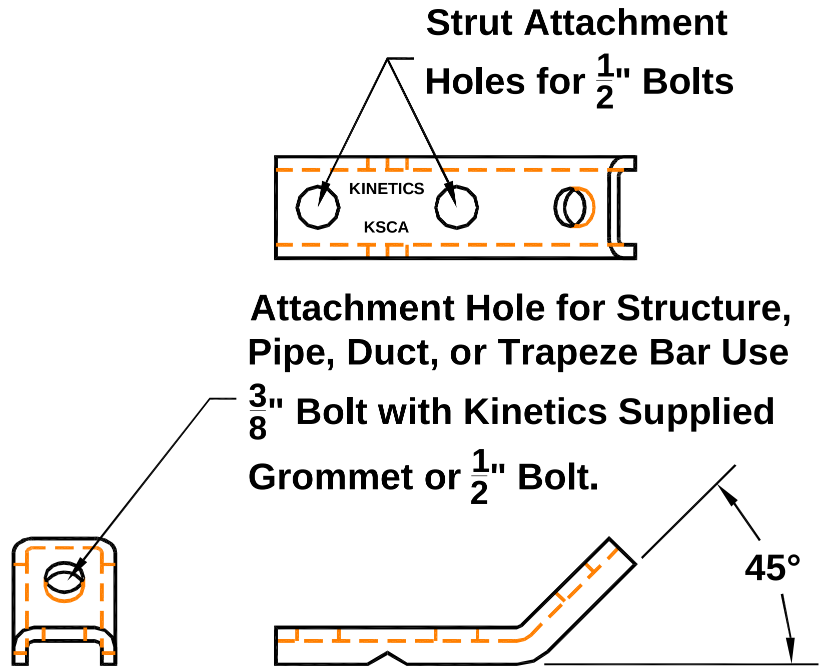

Figure I7-2; KSCA Bracket with Strut and Structure Attachment Holes Identified

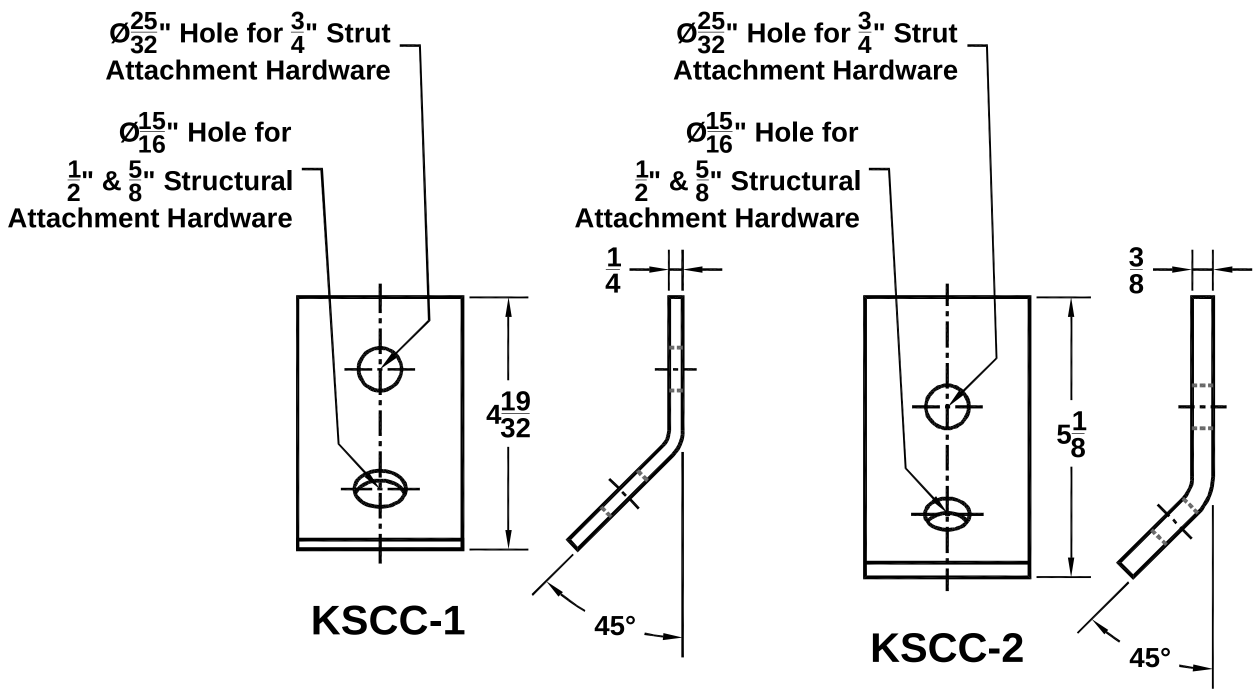

Figure I7-3; KSCC-1 & -2 Brackets with Strut and Structure Attachment Holes Identified

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I7.5 – Attaching Strut Channel to KSCA & KSCC Brackets:

The attachment of strut channel to the KSCA and KSCC brackets is most easily accomplished using bolts and channel nuts. ***Please note the following!***

1. ***Not all strut channels are created equal!*** Different manufacturer's strut channels may have different strengths and capacities. If using other than UNISTRUT® brand strut channel, contact the design professional of record for the system for assistance in selecting the appropriate strut channel for use as seismic strut type restraint. Table I7-5 is based on 1-5/8 UNISTRUT® or equivalent channel.
2. ***Not all channel nuts are created equal!*** Different manufacturer's channel nuts will have different Allowable Pullout Strength and Resistance to Slip values. The channel nuts used in conjunction with Kinetics Noise Control KSCA and KSCC brackets must have serrated teeth to grip the strut channel and maximize the Resistance to Slip rating. Table I7-7 gives the Allowable Pull-Out Strength and Resistance to Slip for strut nut supplied by UNISTRUT®. If another manufacturer's channel nuts are to be used, the design professional of record for the system must ensure that their Allowable Pullout Strength and Resistance to Slip values are consistent with the seismic requirements indicated by Kinetics Noise Control for the application.

Table I7-7; Estimated UNISTRUT® Channel Nut Seismic Capacities – *For Reference Only*

Channel Nut Size	Torque (ft-lbs)	Allowable @ 3:1		Seismic Allowable @ 2:1		Force Class	Compatible Attachment Kits
		Pull-Out Strength (lbs)	Resistance To Slip (lbs)	Pull-Out Strength (lbs)	Resistance To Slip (lbs)		
1/2-13 UNC	50	2,000	1,500	3,000	2,250	IV	X1, X2, X3, Z1
5/8-11 UNC	100	2,500	1,500	3,750	2,250	IV	Y1, Y2, Y3
3/4-10 UNC	125	2,500	1,700	3,750	2,550	IV	Y1, Y2, Y3

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I7.5.1 – KSCA Brackets to Strut Channel:

There are two options available for attaching KSCA brackets to strut channel. These options are shown in Figures I7-4 and I7-5. Both options are based on 1-5/8 strut channel and channel nuts with serrated teeth. Combinations of these two attachment options may be used to create at least six general strut restraint arrangements which are illustrated in Figures I7-6 through I7-11.

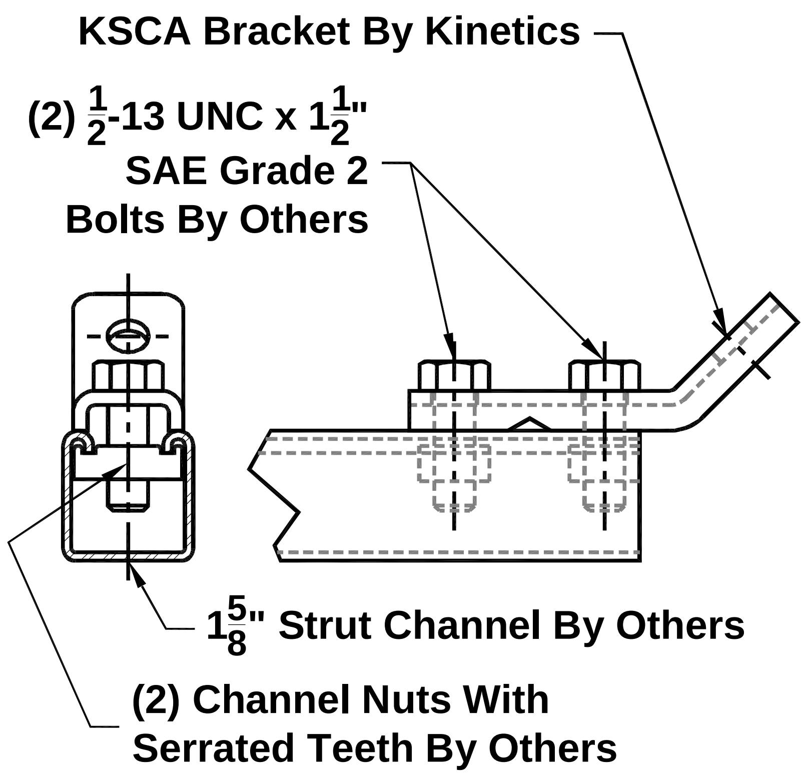

Figure I7-4; Attachment of KSCA Bracket to Strut Channel – Option #1

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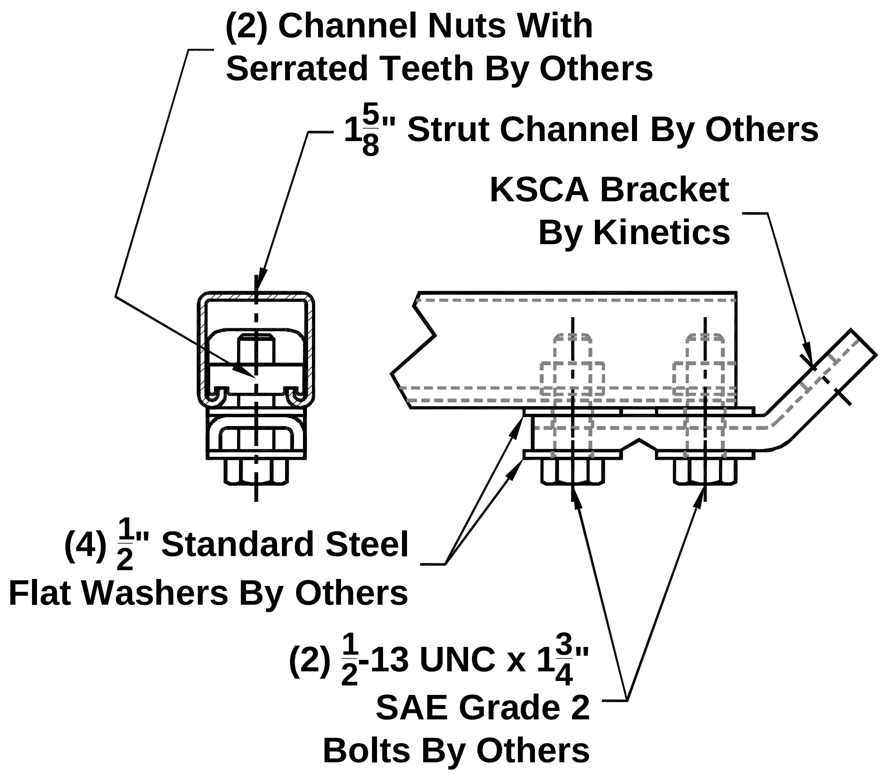

Figure I7-5; Attachment of KSCA Bracket to Strut Channel – Option #2

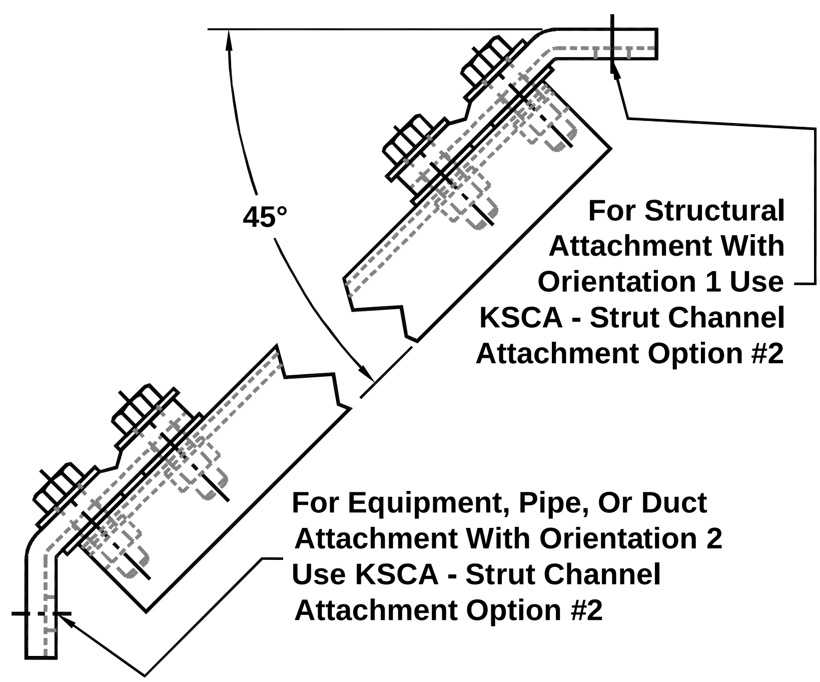

Figure I7-6; Attachment of KSCA Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #1

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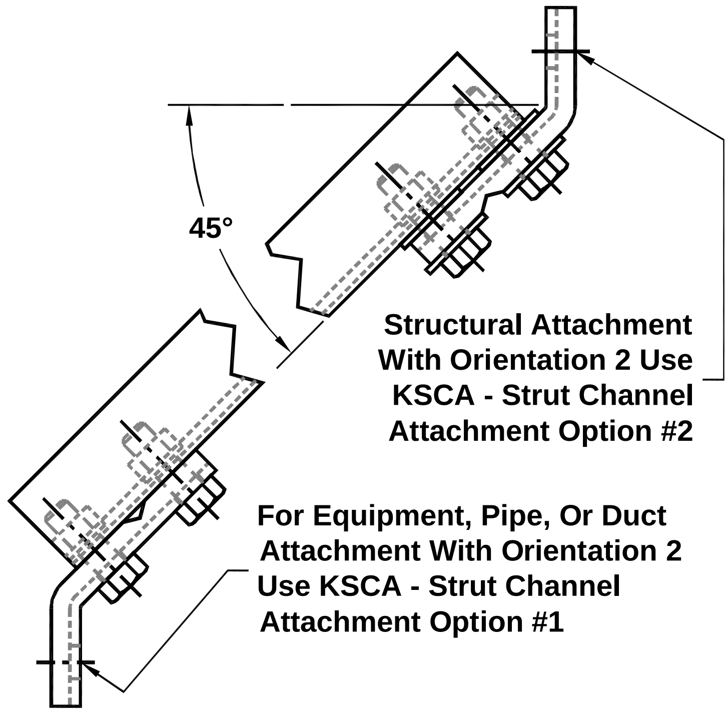

Figure I7-7; Attachment of KSCA Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #2

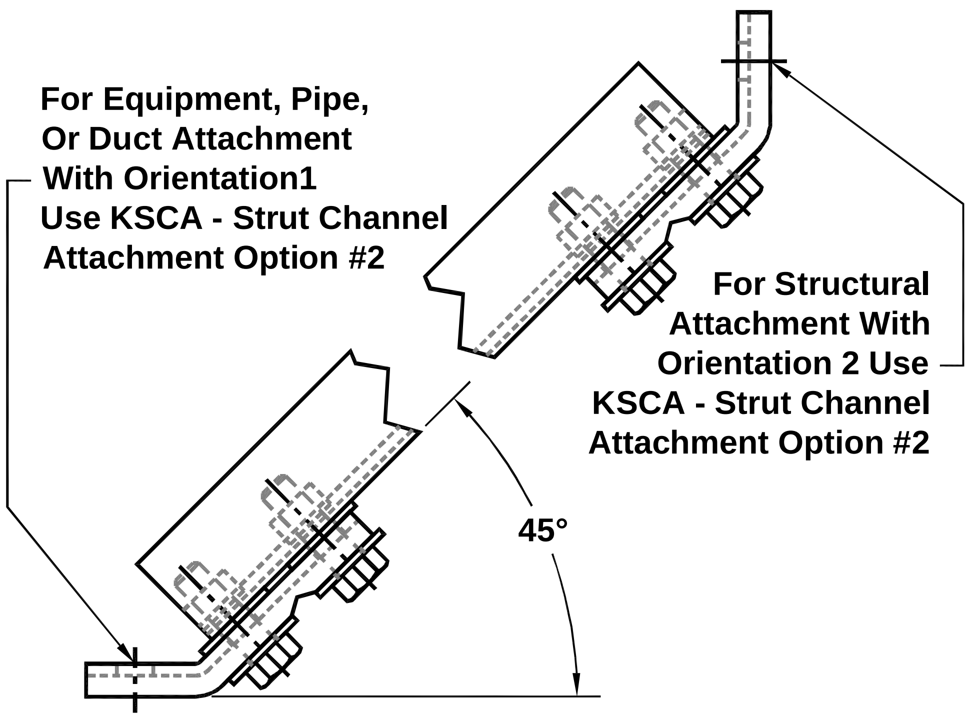

Figure I7-8; Attachment of KSCA Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #3

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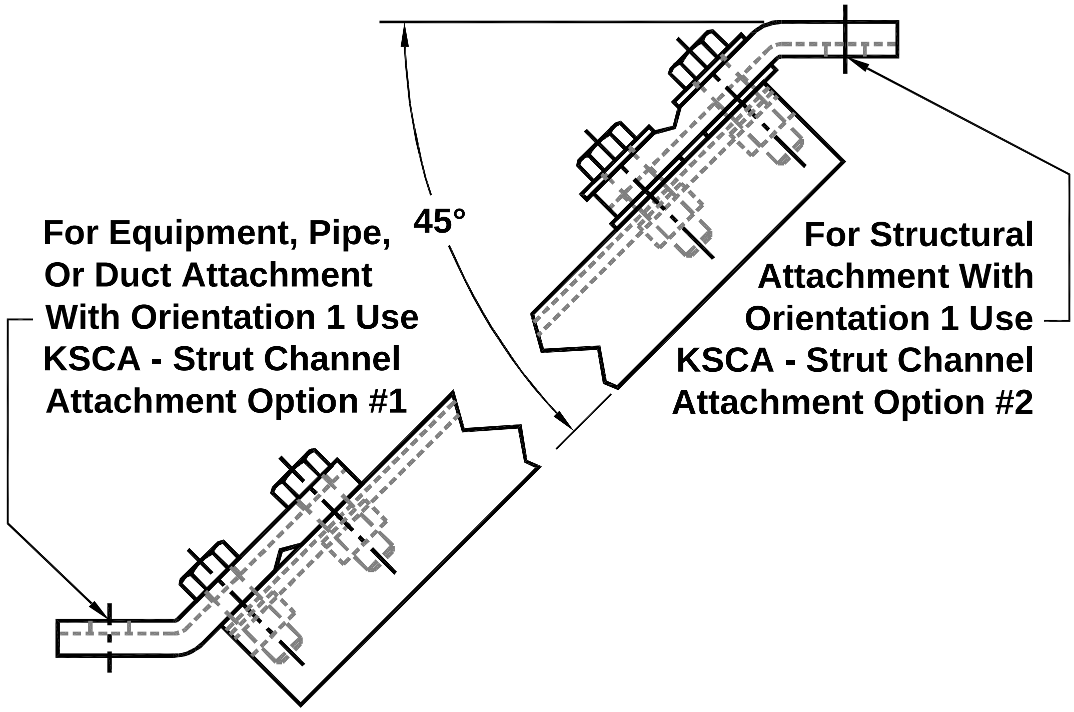

Figure I7-9; Attachment of KSCA Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #4

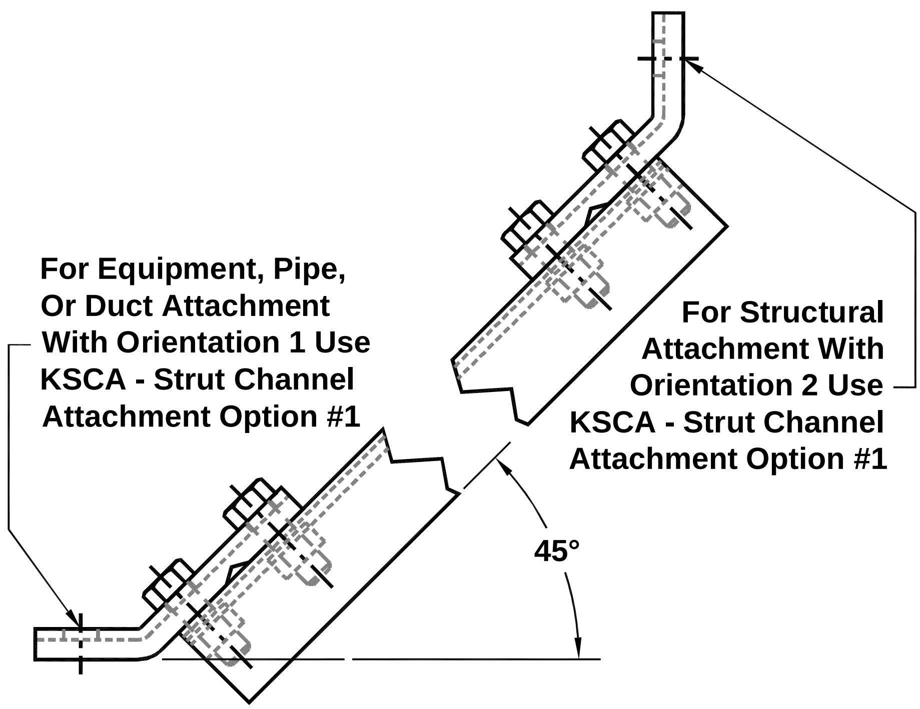

Figure I7-10; Attachment of KSCA Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #5

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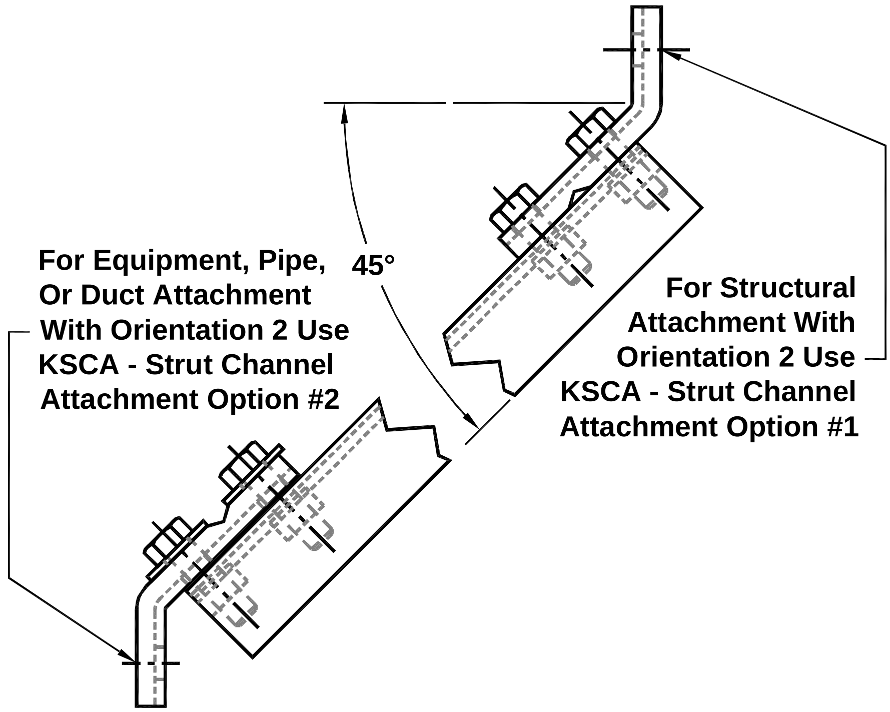

Figure I7-11; Attachment of KSCA Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #6

I7.5.2 – KSCC Brackets to Strut Channel:

There are two options available for attaching KSCC brackets to strut channel. These options are shown in Figures I7-12 and I7-13. Both options are based on 1-5/8 strut channel and channel nuts with serrated teeth. Combinations of these two attachment options may be used to create at least six general strut restraint arrangements which are illustrated in Figures I7-14 through I7-19.

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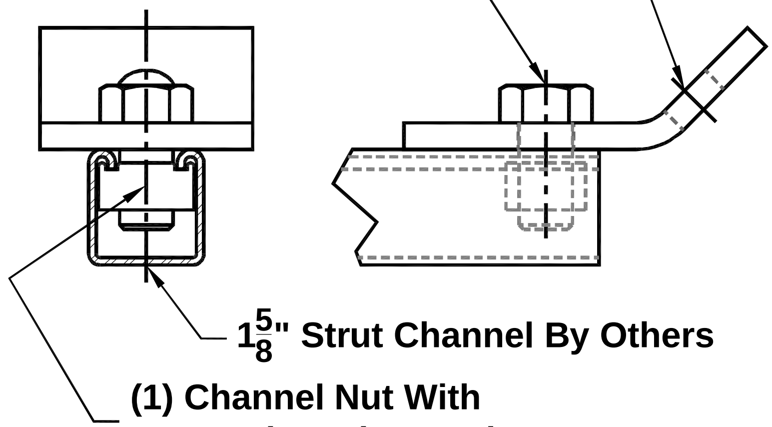

Figure I7-12; Attachment of KSCC Bracket to Strut Channel – Option #1

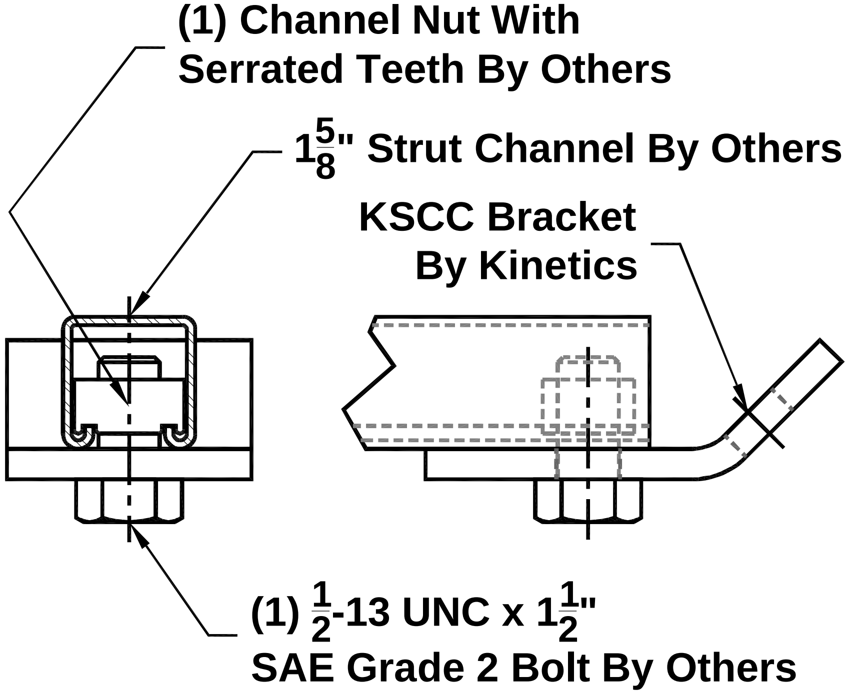

Figure I7-13; Attachment of KSCC Bracket to Strut Channel – Option #2

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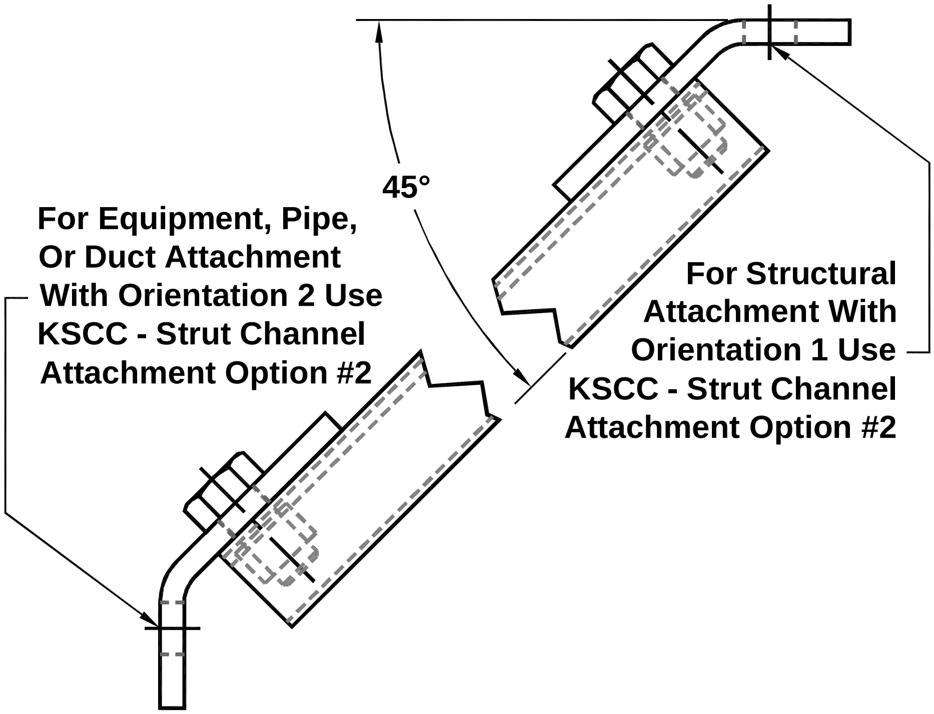

Figure I7-14; Attachment of KSCC Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #1

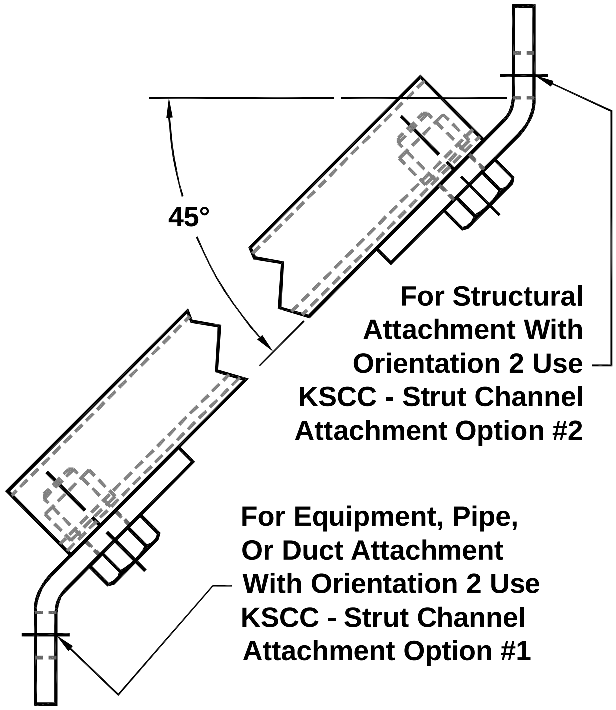

Figure I7-15; Attachment of KSCC Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #2

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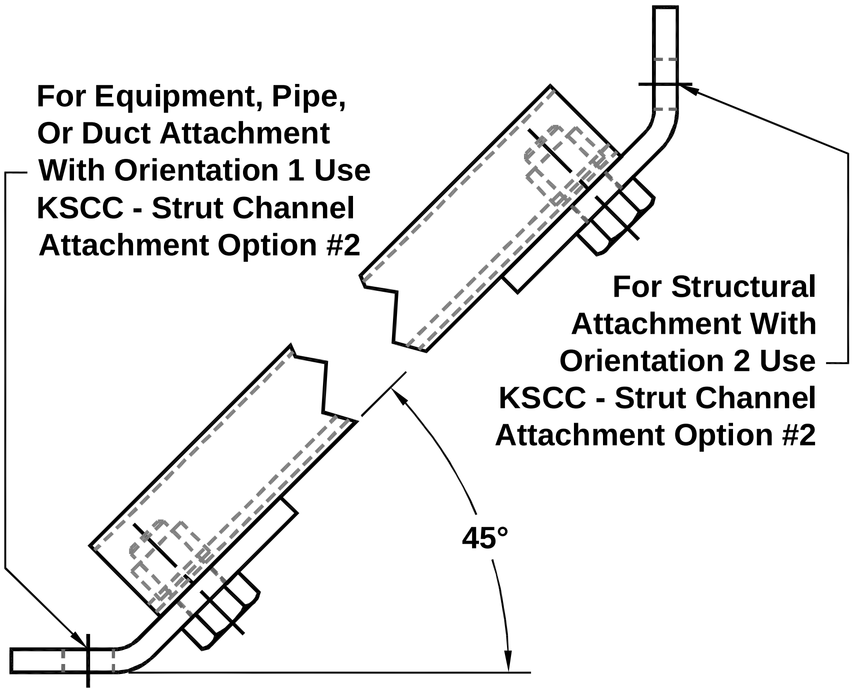

Figure I7-16; Attachment of KSCC Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #3

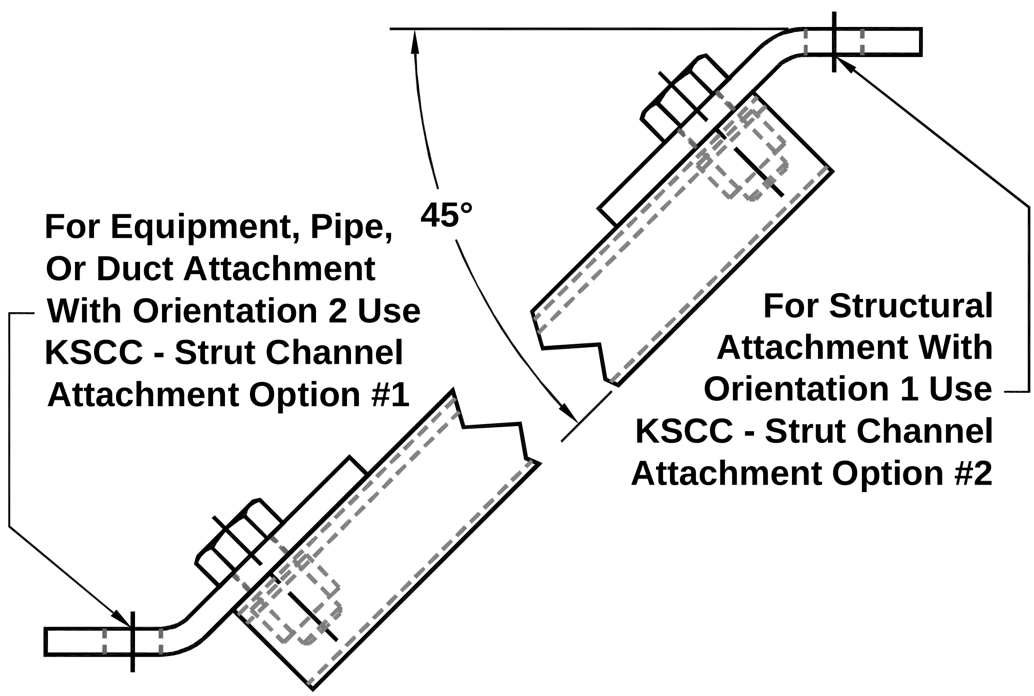

Figure I7- 17; Attachment of KSCC Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #4

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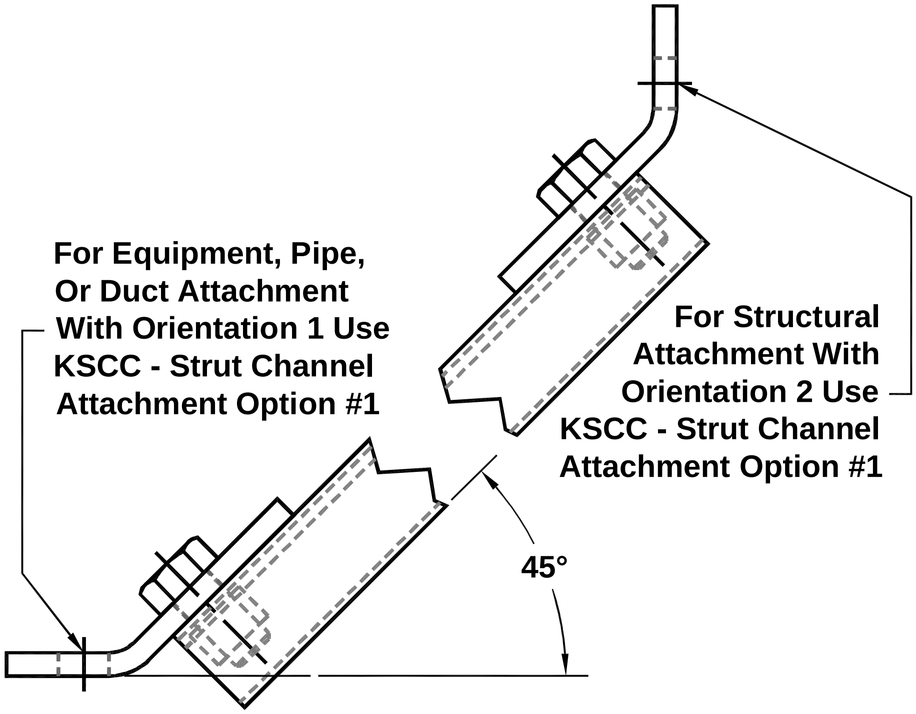

Figure I7-18; Attachment of KSCC Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #5

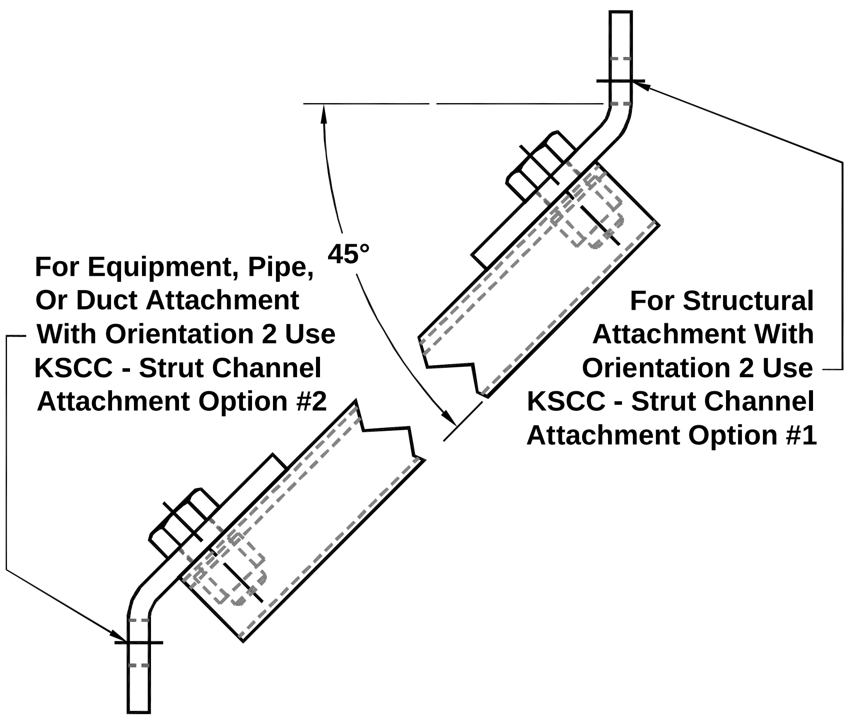

Figure I7-19; Attachment of KSCC Brackets to Strut Channel for Seismic Strut Restraints – General Arrangement #6

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I7.6 – Attaching KSCA & KSCC Brackets to Rolled Structural Angle:

The attachment of rolled structural angle to the KSCA and KSCC brackets is most easily accomplished using bolts, nuts, and washers. The capacities restraints using these attachments will match those of the kits recommended by Kinetics noise control if the following conditions are met.

1. The rolled structural angle to be used for the restraint is properly selected according to the instructions provided in Section I7.2 – Using the Restraint Designation Symbol to Select Struts.
2. The attachment hardware sizes and grades are as specified in Figures I7-20, I7-21, I7-22, I7-23, I7-24, I7-35 and I7-36.

I7.6.1 – KSCA Brackets to Rolled Structural Angle:

There are five workable options available for attaching KSCA brackets to rolled structural angles. These options are shown in Figures I7-20, I7-21, I7-22, I7-23, and I7-24. Options #3, #4, and #5 shown in Figures I7-22, I7-23, and I7-24 may require that the corner of the angle leg be trimmed to eliminate interference with the structure, equipment, pipe, duct, or KSCA bracket. Combinations of the first three attachment options may be used to create at least ten practical general strut restraint arrangements which are illustrated in Figures I7-25 through I7-34.

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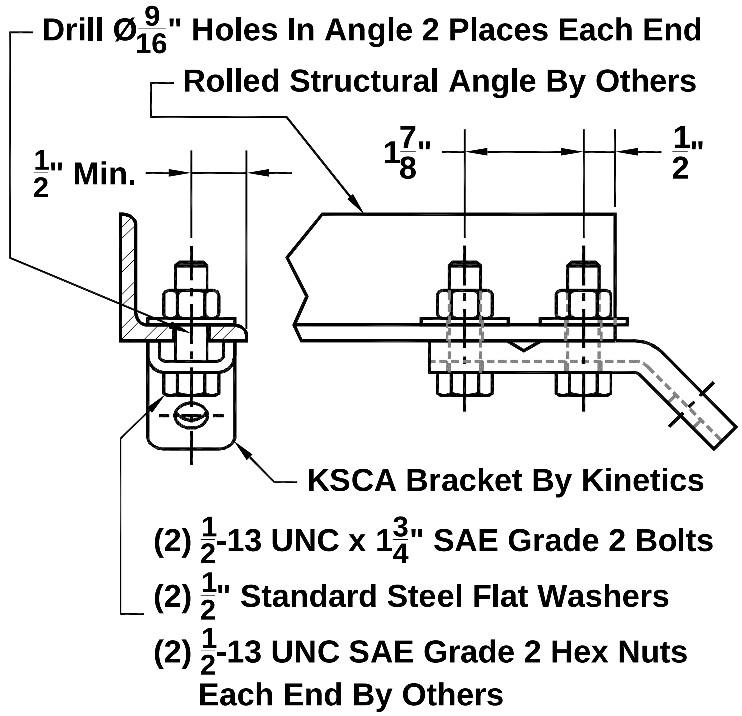

Figure I7-20; Attachment of KSCA Bracket to Rolled Angle – Option #1

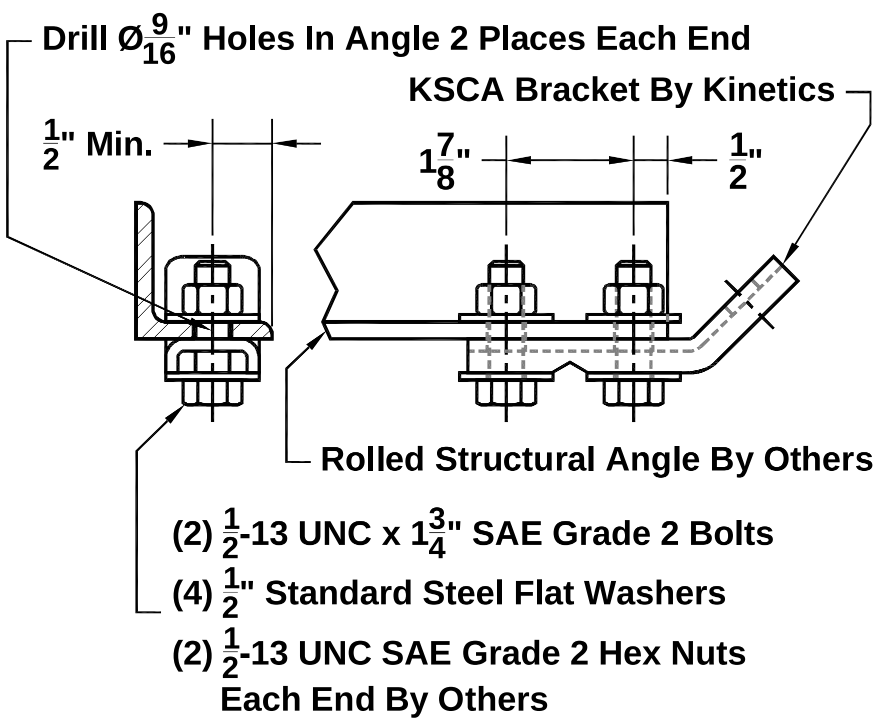

Figure I7-21; Attachment of KSCA Bracket to Rolled Angle – Option #2

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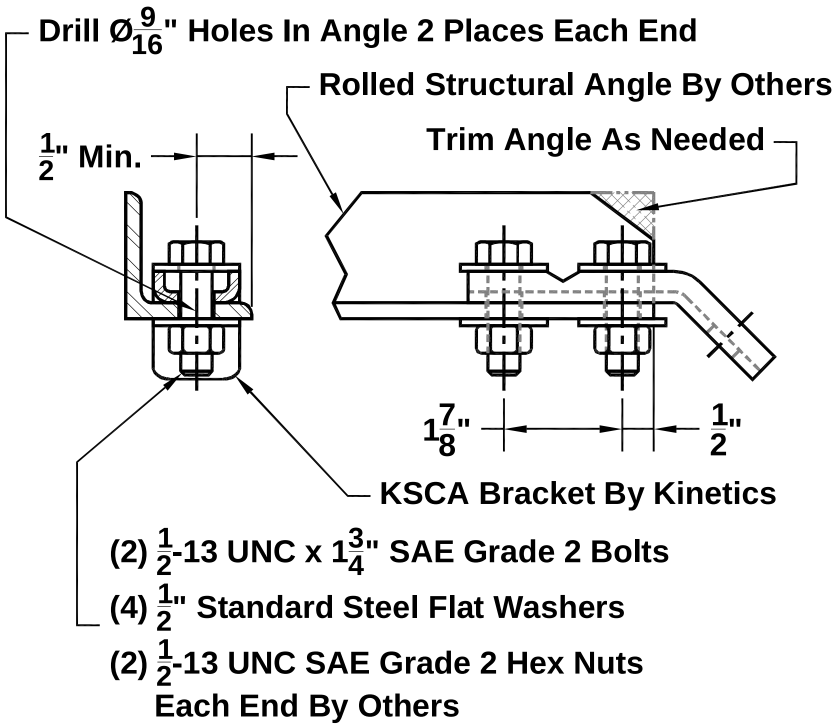

Figure I7-22; Attachment of KSCA Bracket to Rolled Angle – Option #3 *Trim as Angle Needed*

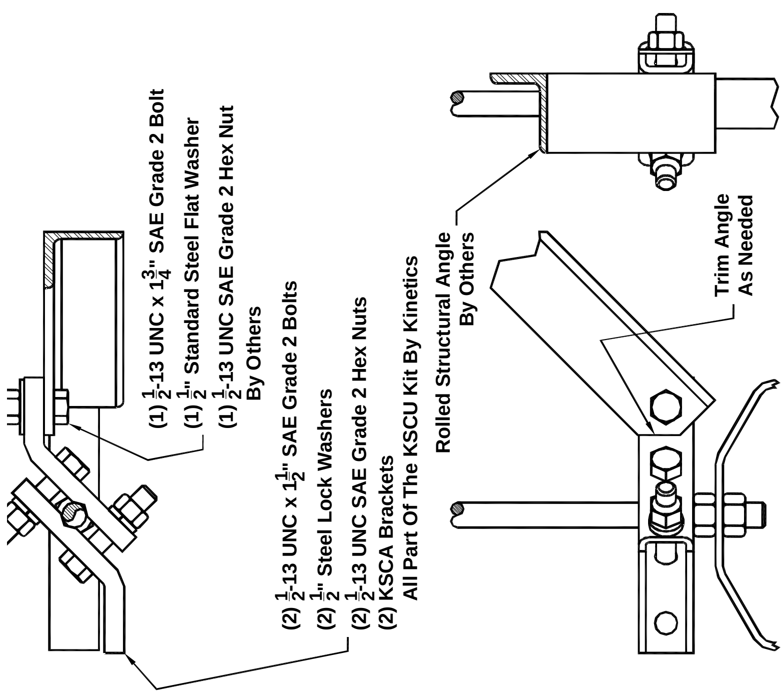

Figure I7-23; Attachment of KSCA Bracket to Rolled Angle for a Clevis Hanger Rod – Option #4 *Trim as Angle Needed*

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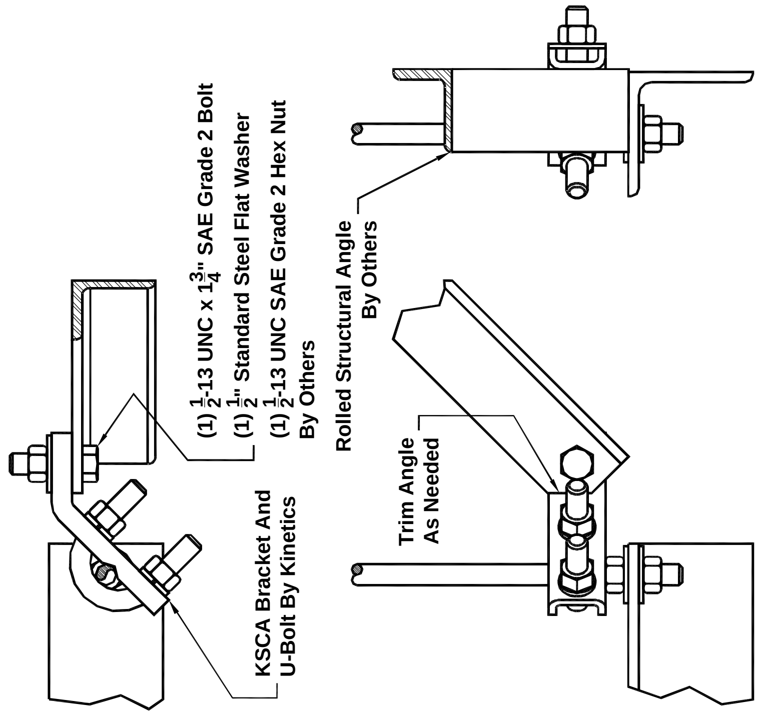

Figure I7-24; Attachment of KSCA Bracket to Rolled Angle for a Trapeze Bar Hanger Rod – Option #5 *Trim as Angle Needed*

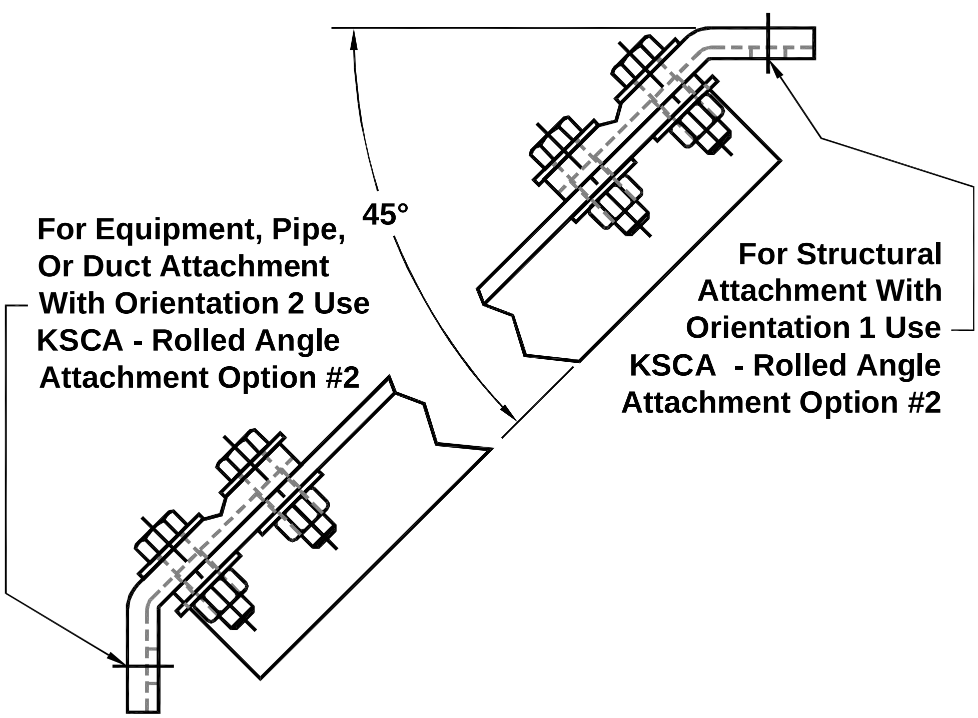

Figure I7-25; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #1

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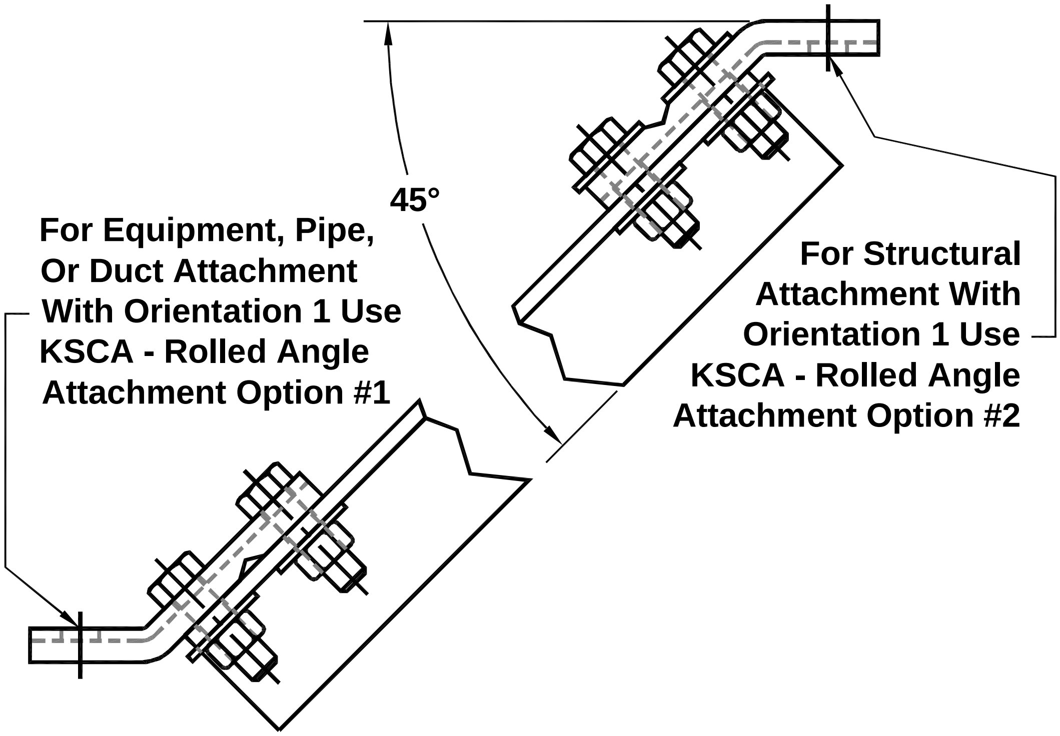

Figure I7-26; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #2

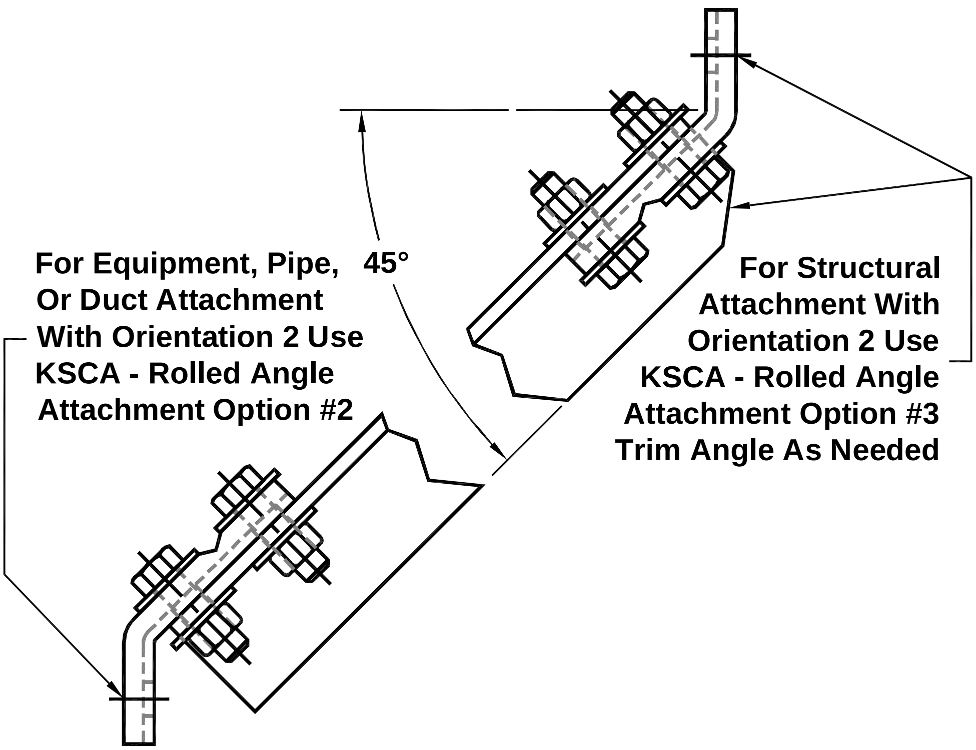

Figure I7-27; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #3

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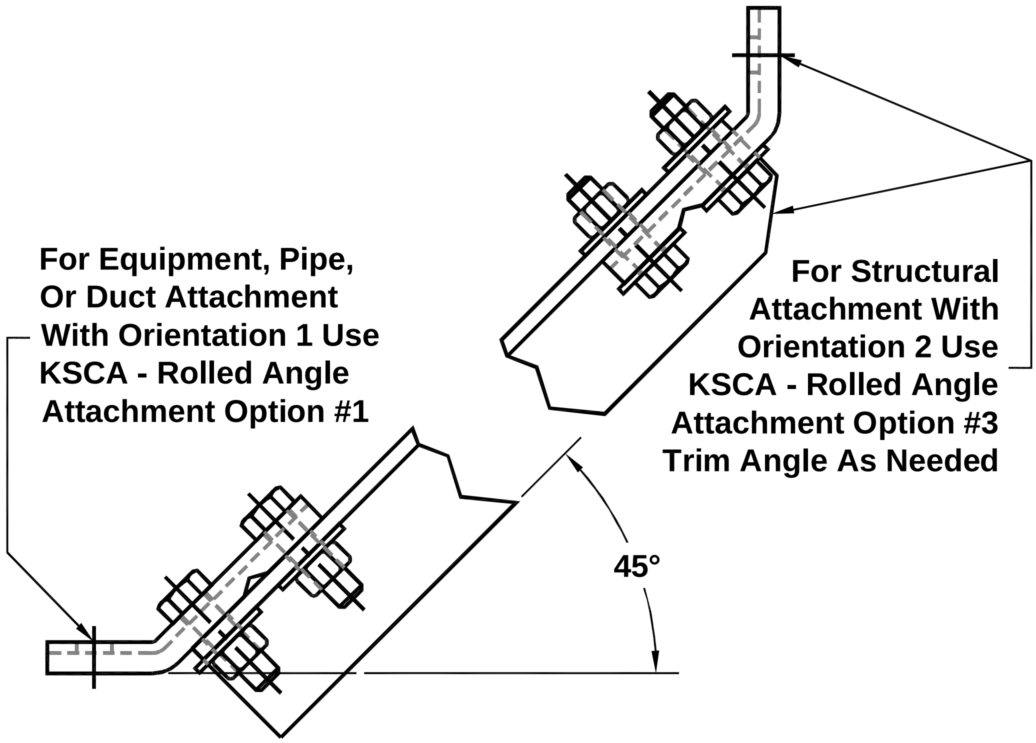

Figure I7-28; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #4

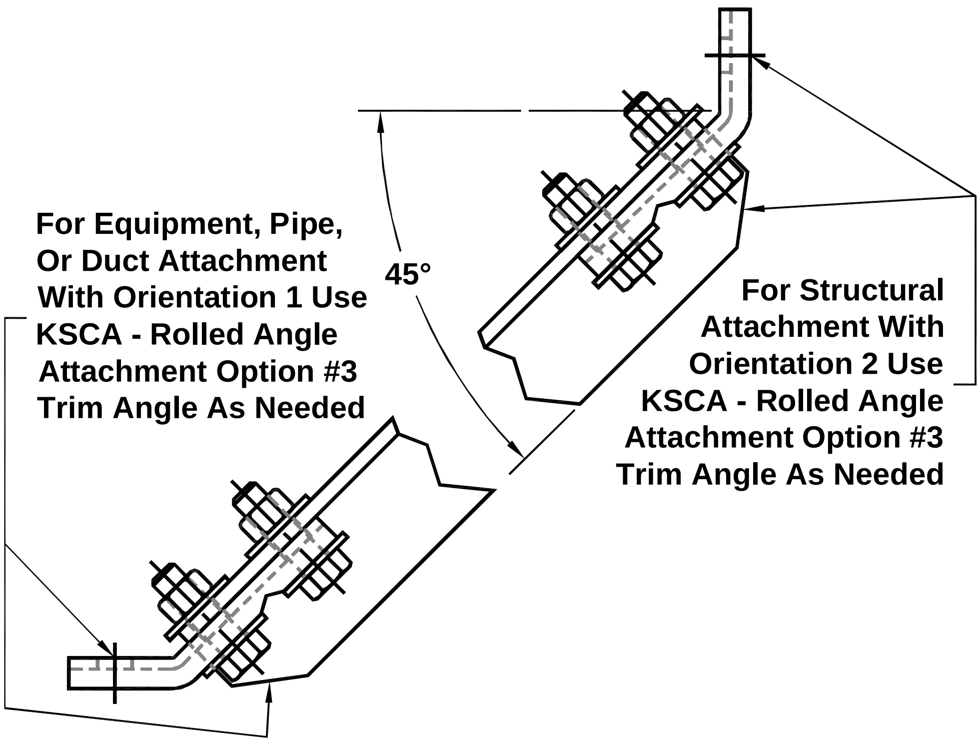

Figure I7-29; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #5

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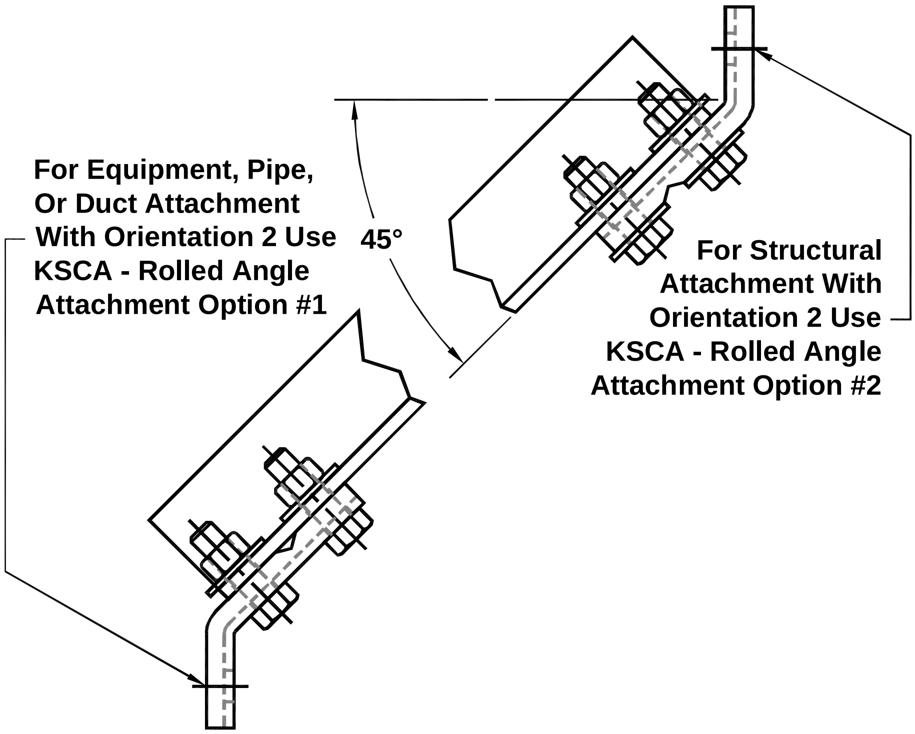

Figure I7-30; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #6

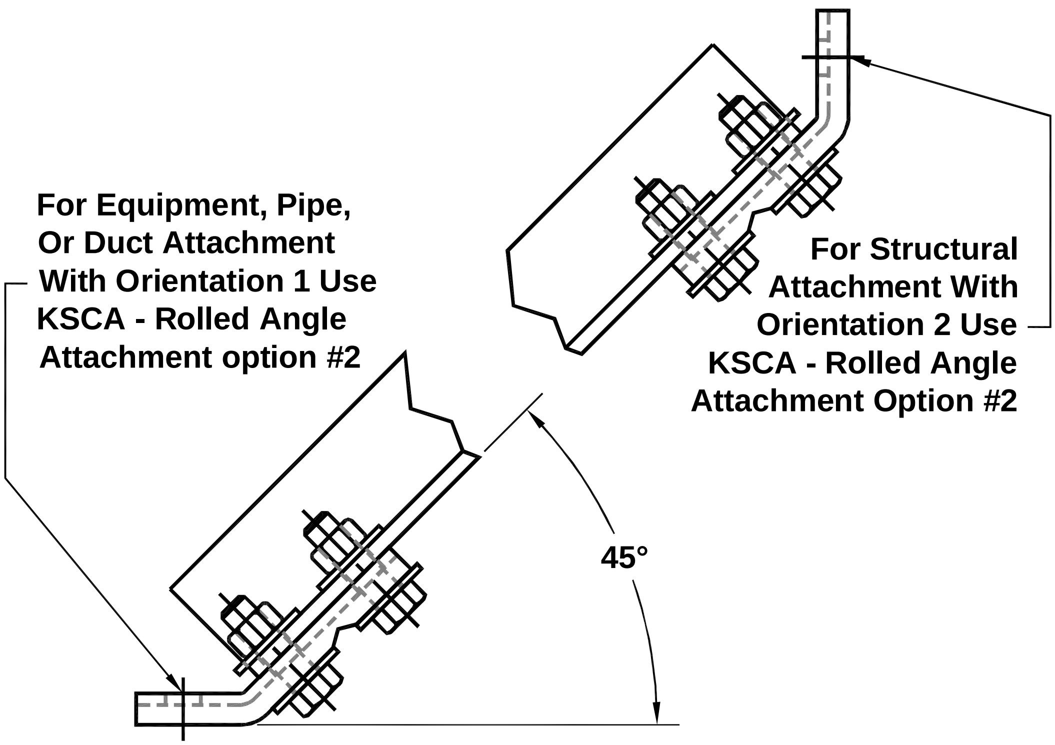

Figure I7-31; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #7

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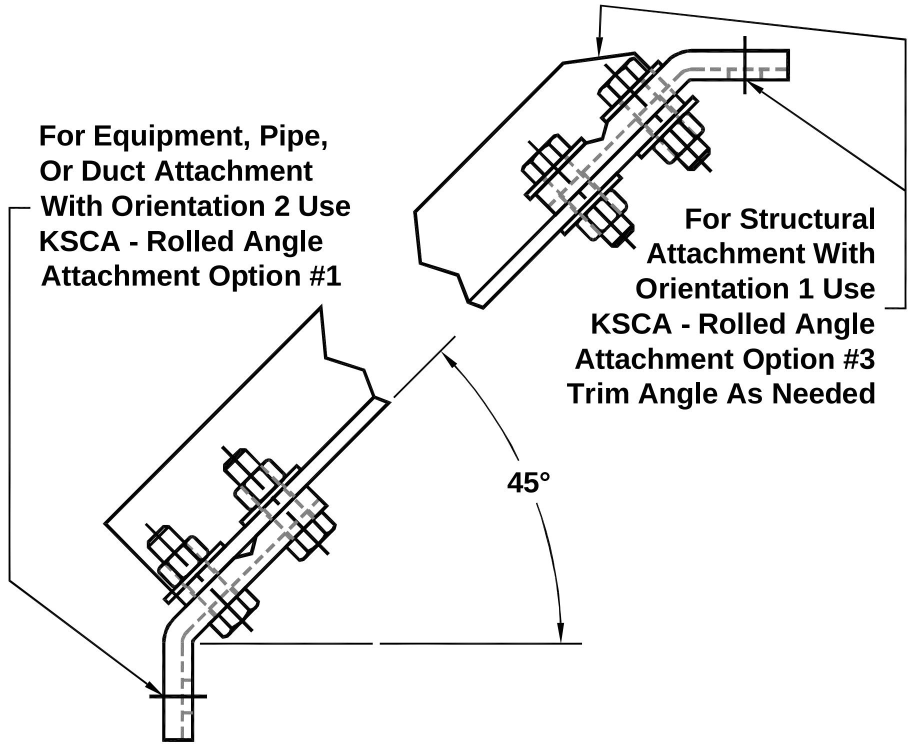

Figure I7-32; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #8

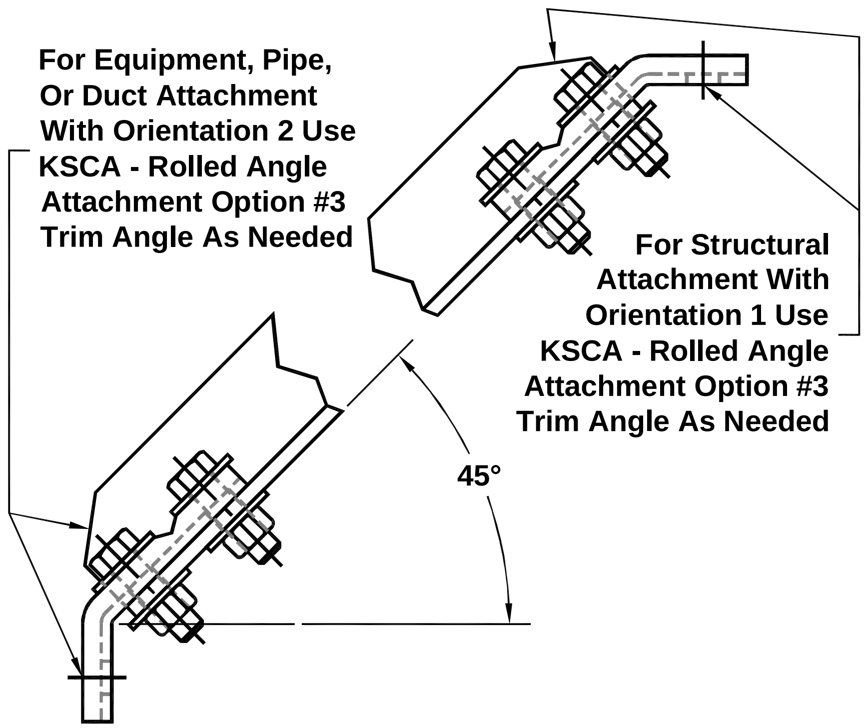

Figure I7-33; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #9

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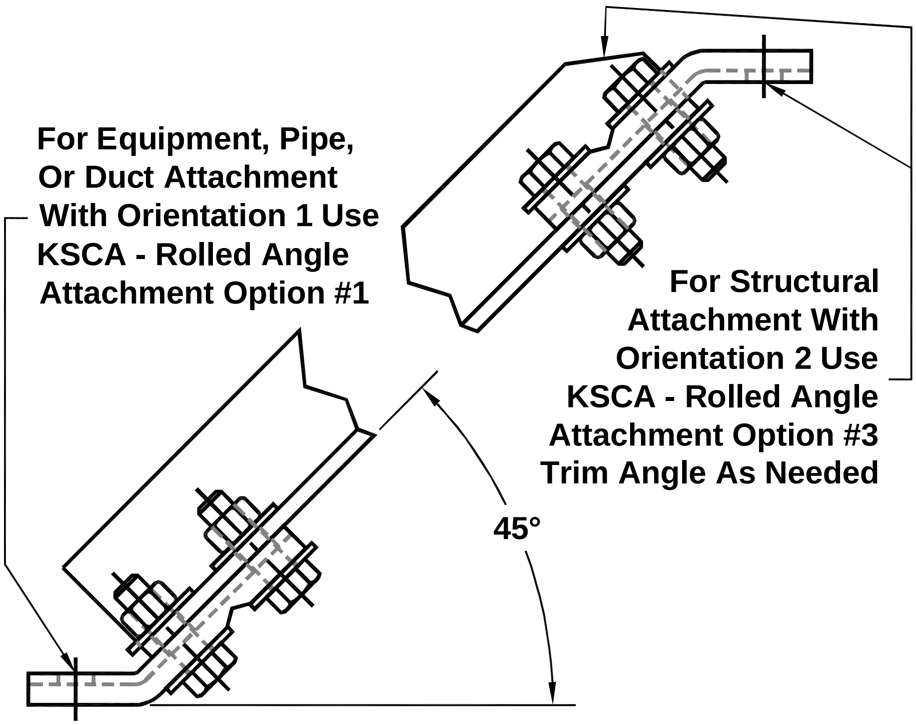

Figure I7-34; KSCA Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #10

I7.6.2 – KSCC Brackets to Rolled Structural Angle:

There are two useful options available for attaching KSCC brackets to rolled structural angles. These options are shown in Figures I7-35 and I7-36. Option #2, shown in Figure I7-36 may require that the corner of the angle leg be trimmed to eliminate interference with the structure, equipment, pipe, or duct. Combinations of these attachment options may be used to create at least eight practical general strut restraint arrangements which are illustrated in Figures I7-37 through I7-44.

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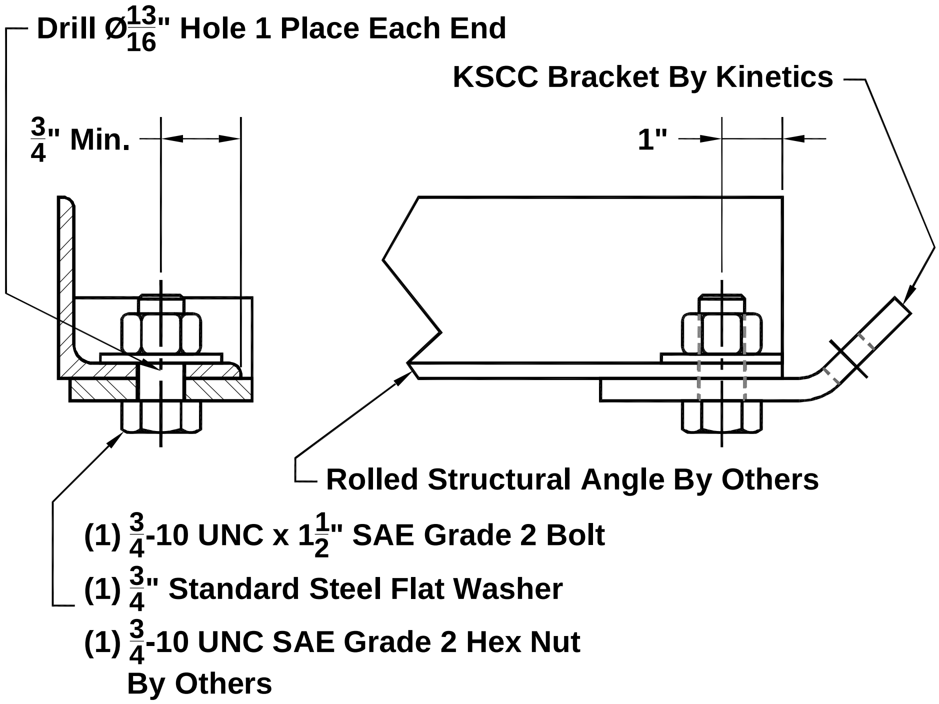

Figure I7-35; Attachment of KSCC Bracket to Rolled Angle – Option #1

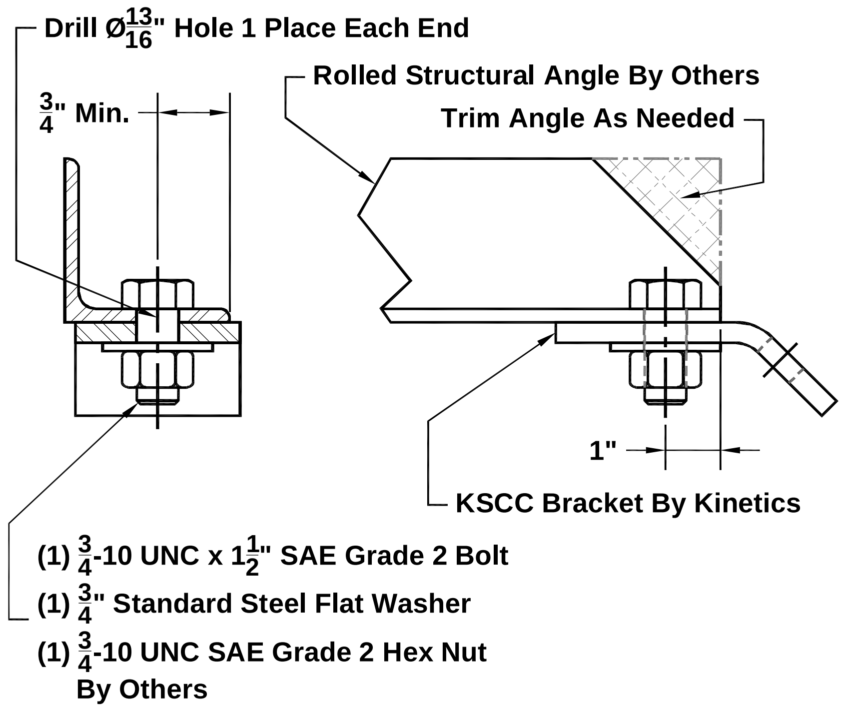

Figure I7-36; Attachment of KSCC Bracket to Rolled Angle – Option #2

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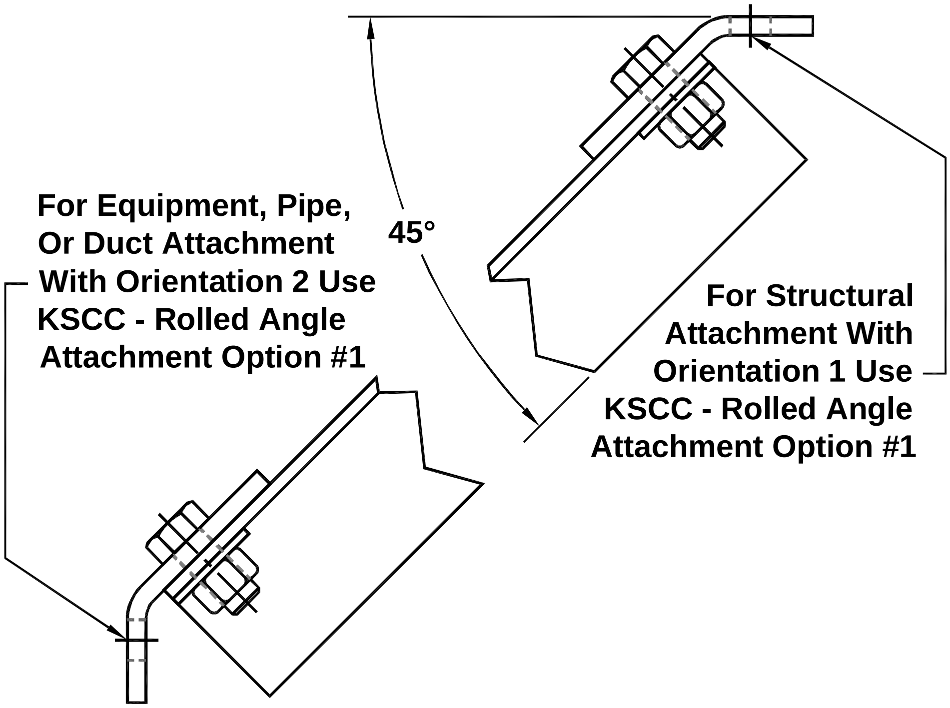

Figure I7-37; KSCC Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #1

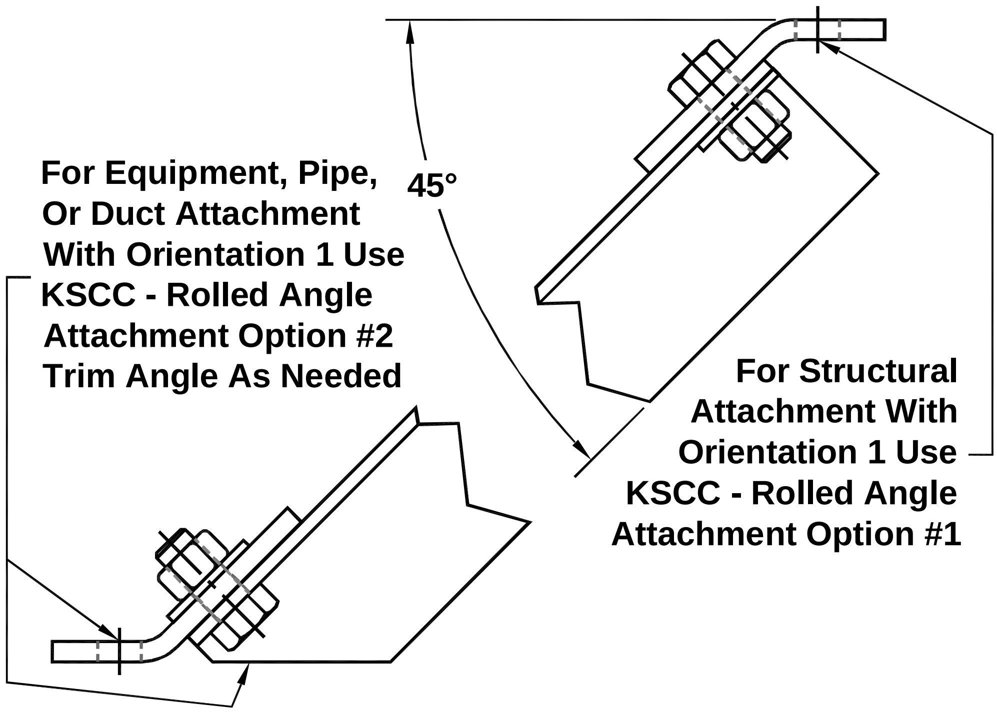

Figure I7-38; KSCC Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #2

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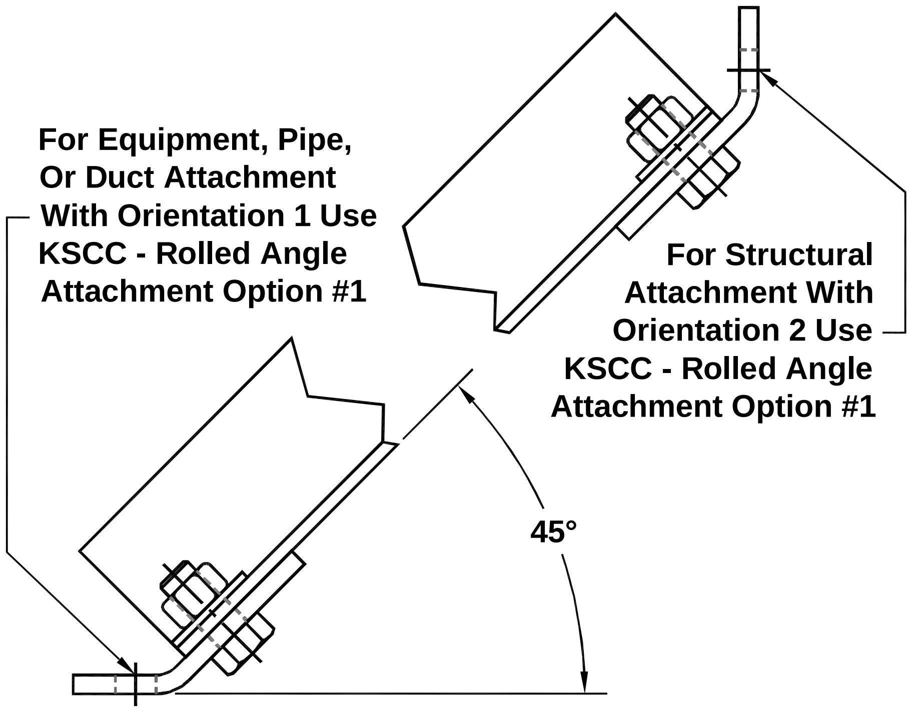

Figure I7-39; KSCC Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #3

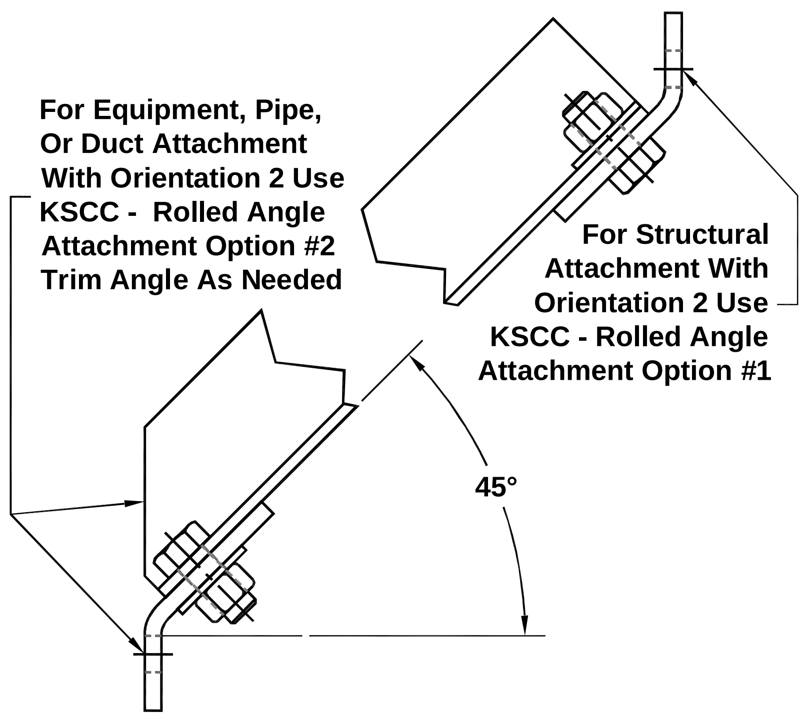

Figure I7-40; KSCC Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #4

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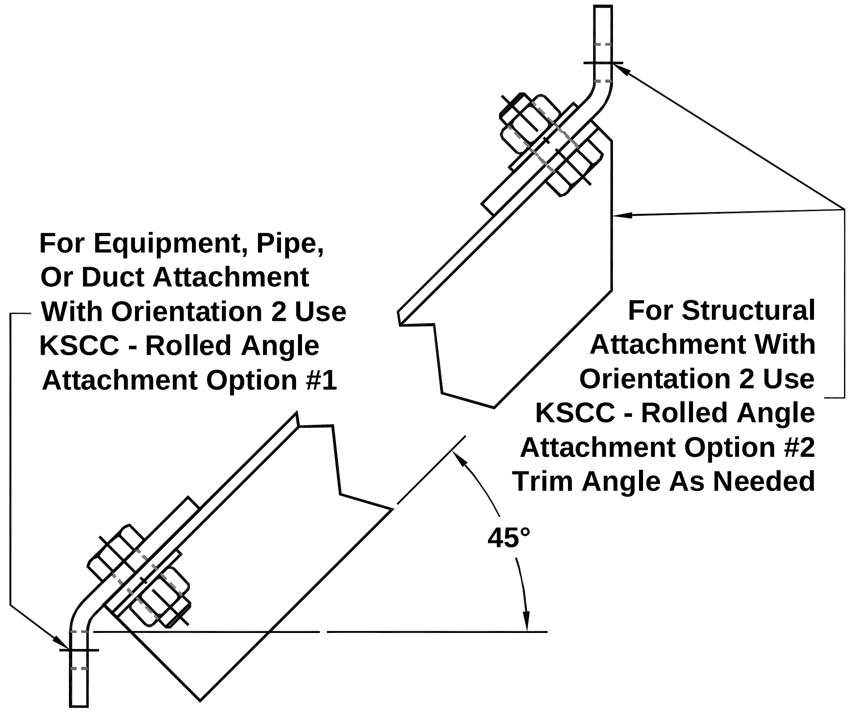

Figure I7-41; KSCC Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #5

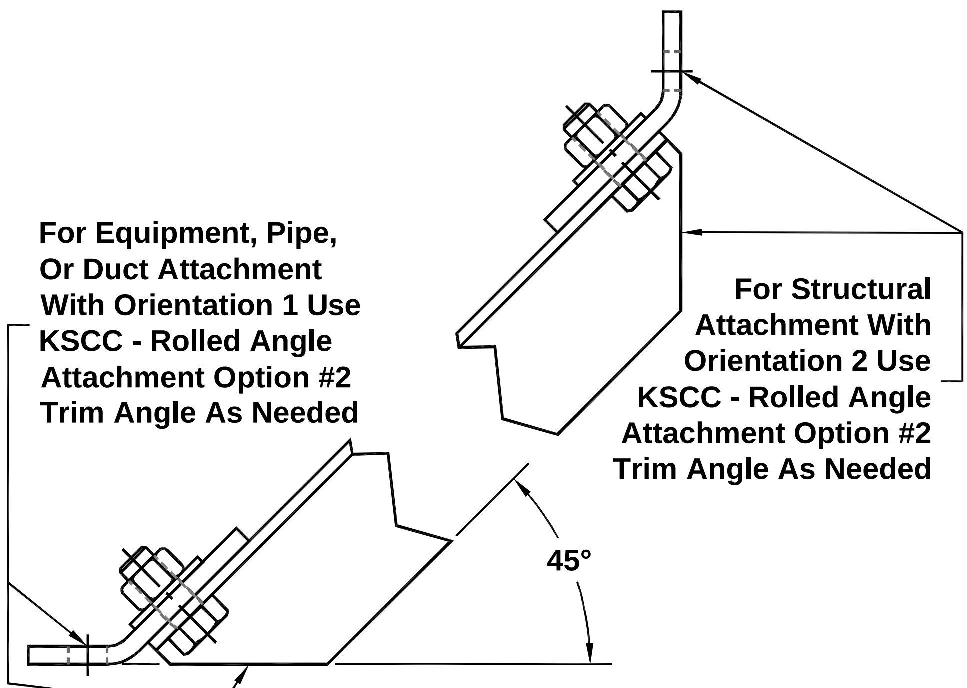

Figure I7-42; KSCC Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #6

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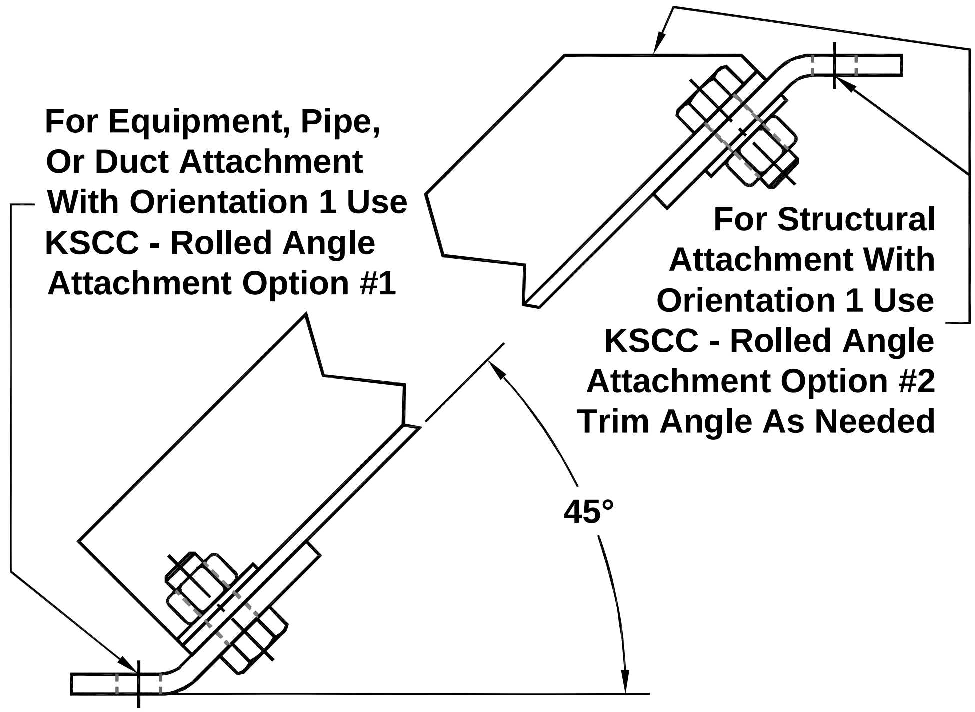

Figure I7-43; KSCC Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #7

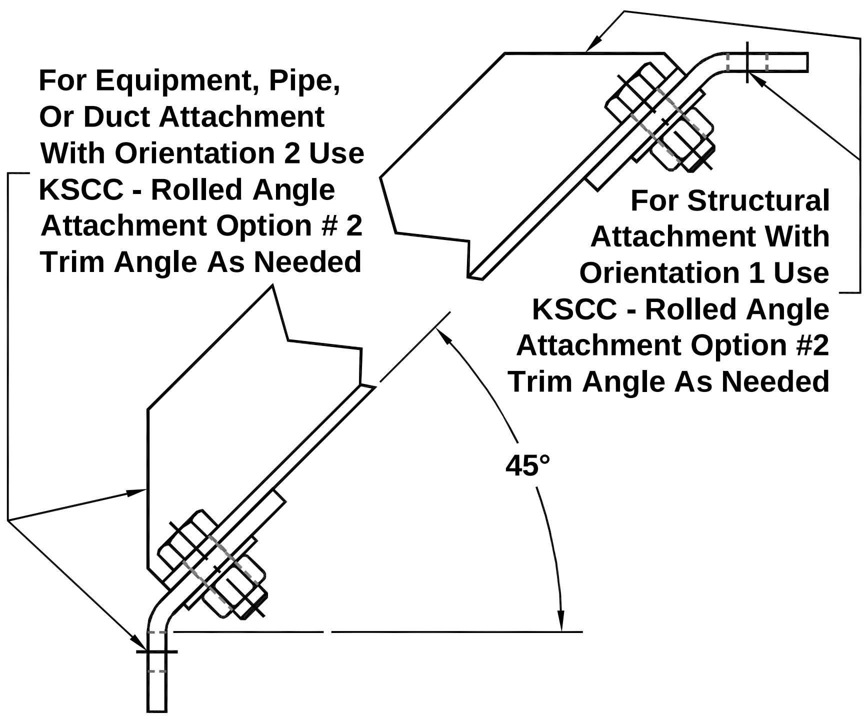

Figure I7-44; KSCC Brackets – Rolled Angle for Seismic Strut Restraints–General Arrangement #8

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I7.7 – Attaching KSCA & KSCC Brackets to Schedule 40 IPS Pipe:

Due to the nature of pipe, it will be difficult to drill the pipe to accurately locate the KSCA and KSCC brackets, and make the attachment using bolts nuts and washers. Kinetics Noise Control recommends that the attachment of the KSCA brackets to schedule 40 IPS pipe be made by welding. The weld attachment details for the KSCA bracket are shown in Figure I7-45. The weld size and length specified will generate the full capacity of the restraints recommended by Kinetics Noise Control when the appropriate schedule 40 IPS pipe has been selected fro Table I7-6 according to the instructions outlined in Section I7.2 – Using the Restraint Designation Symbol to Select Struts. It is not possible to weld the KSCC brackets to the schedule 40 IPS pipes shown in Table I7-6 securely enough to generate the full rated capacity of the restraints recommended by Kinetics Noise Control. This is due to the wall thickness of the pipe, and the possible length of contact between the pipe and the KSCC brackets. ***Therefore, Kinetics Noise Control does not recommend using the KSCC brackets for strut type restraints fabricated from schedule 40 IPS pipe***.

There are four basic general arrangements possible for attaching KSCA brackets to schedule 40 IPS pipe. These options are shown in Figures I7-46, I7-47, I7-48, and I7-49. All of these options may require that the pipe be trimmed to clear the structure, pipe, duct, or trapeze bar.

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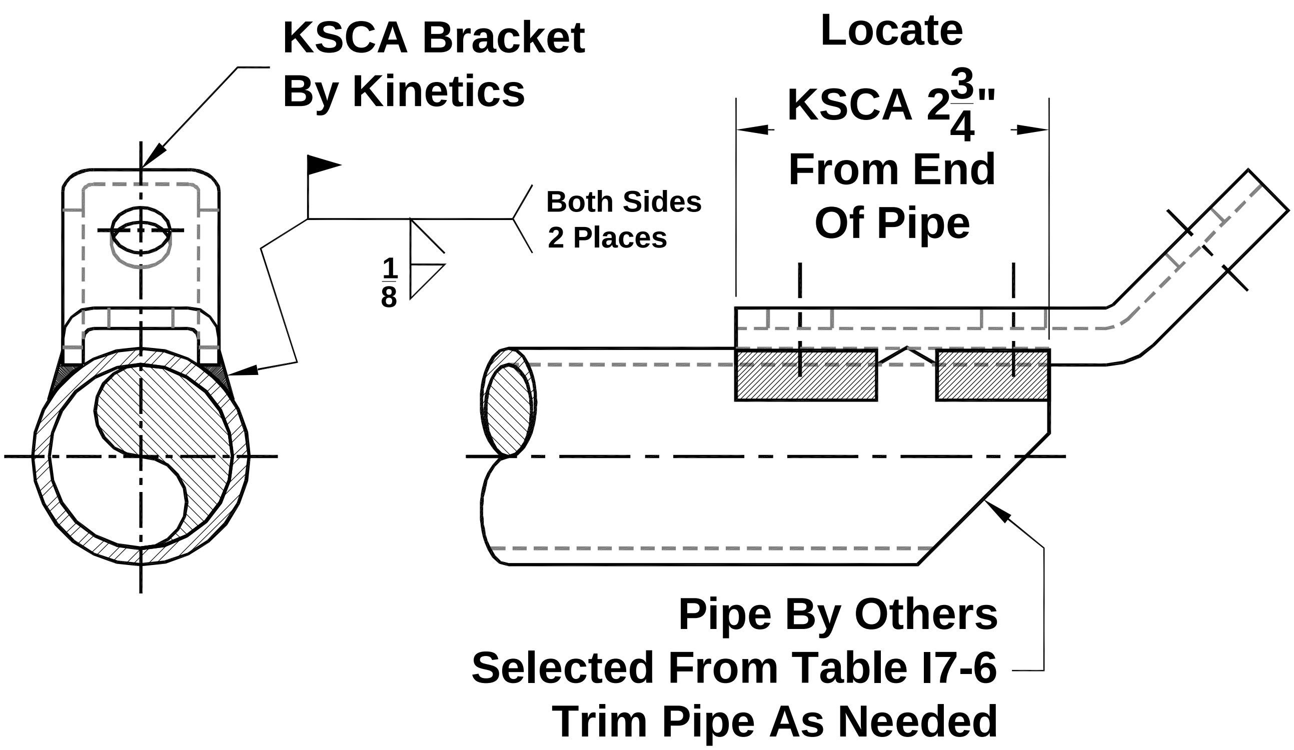

Figure I7-45; Weld Attachment of KSCA Bracket to Schedule 40 IPS Pipe

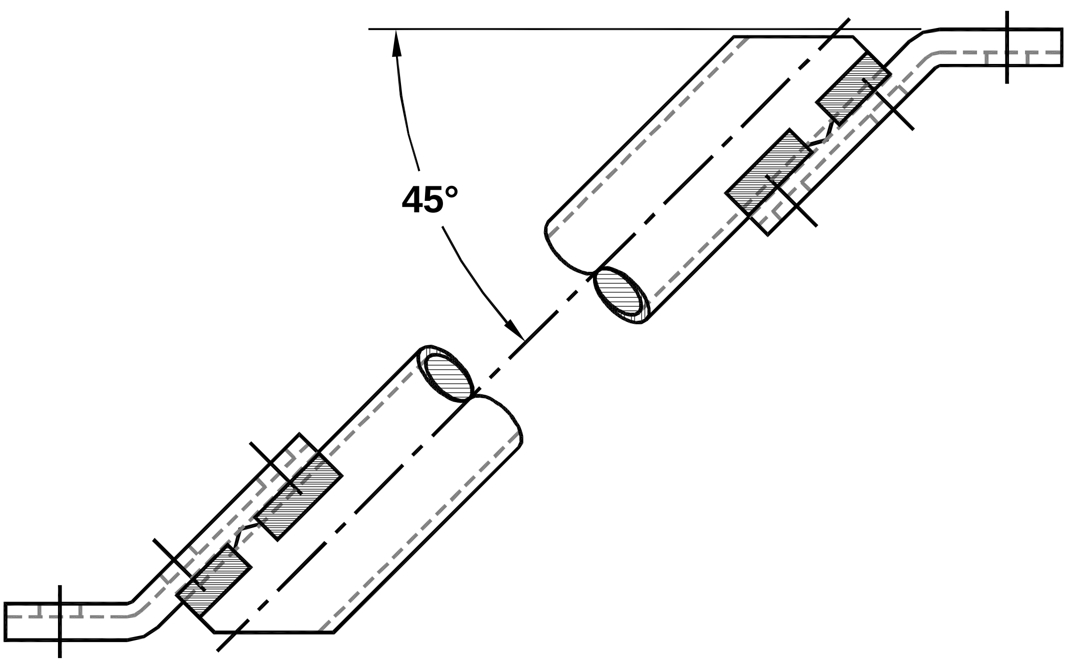

Figure I7-46; KSCA Brackets – Pipe for Seismic Strut Restraints–General Arrangement #1

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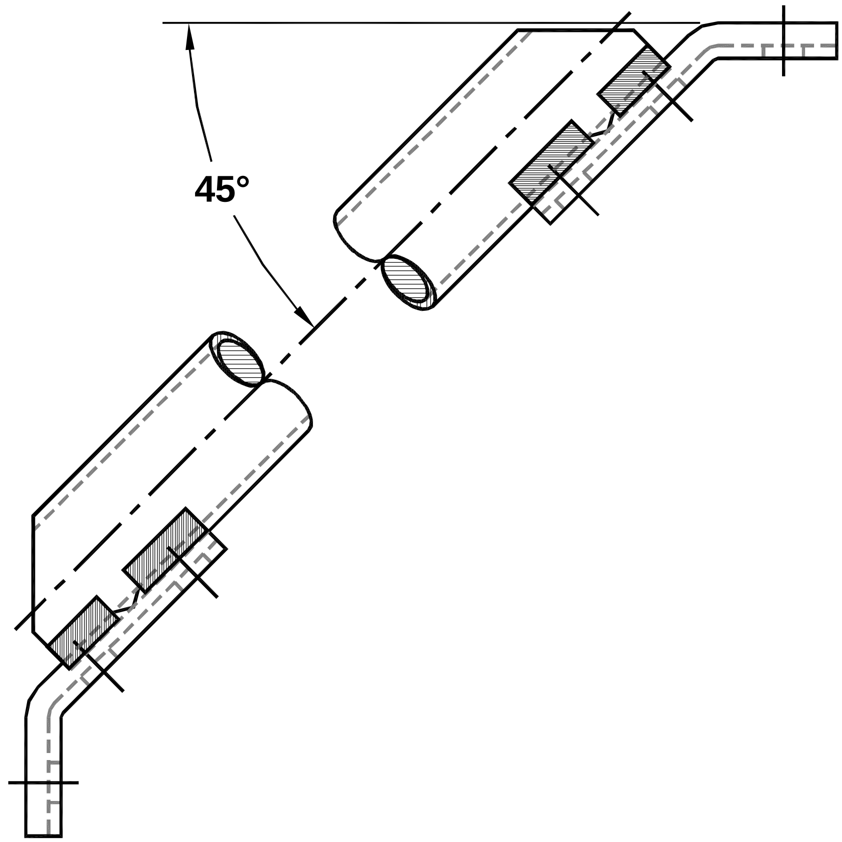

Figure I7-47; KSCA Brackets – Pipe for Seismic Strut Restraints–General Arrangement #2

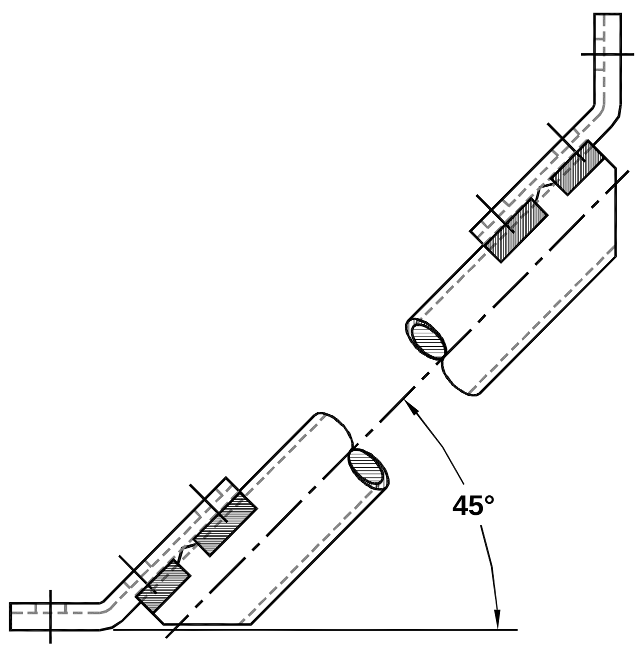

Figure I7-48; KSCA Brackets – Pipe for Seismic Strut Restraints–General Arrangement #3

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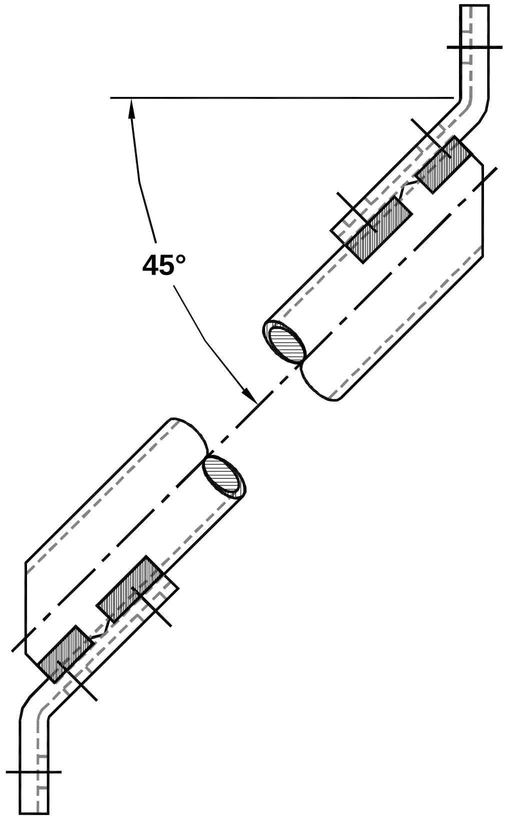

Figure I7- 49; KSCA Brackets – Pipe for Seismic Strut Restraints–General Arrangement #4

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I7.8 – Strut Restraint Schematics for Piping:

Sheet H – View C shown in Figure I7-50 will be typical of the other figures in this section. They refer to the drawing sheet and view on the installation drawings provided by Kinetics Noise Control for each project requiring seismic restraint for pipe and duct systems.

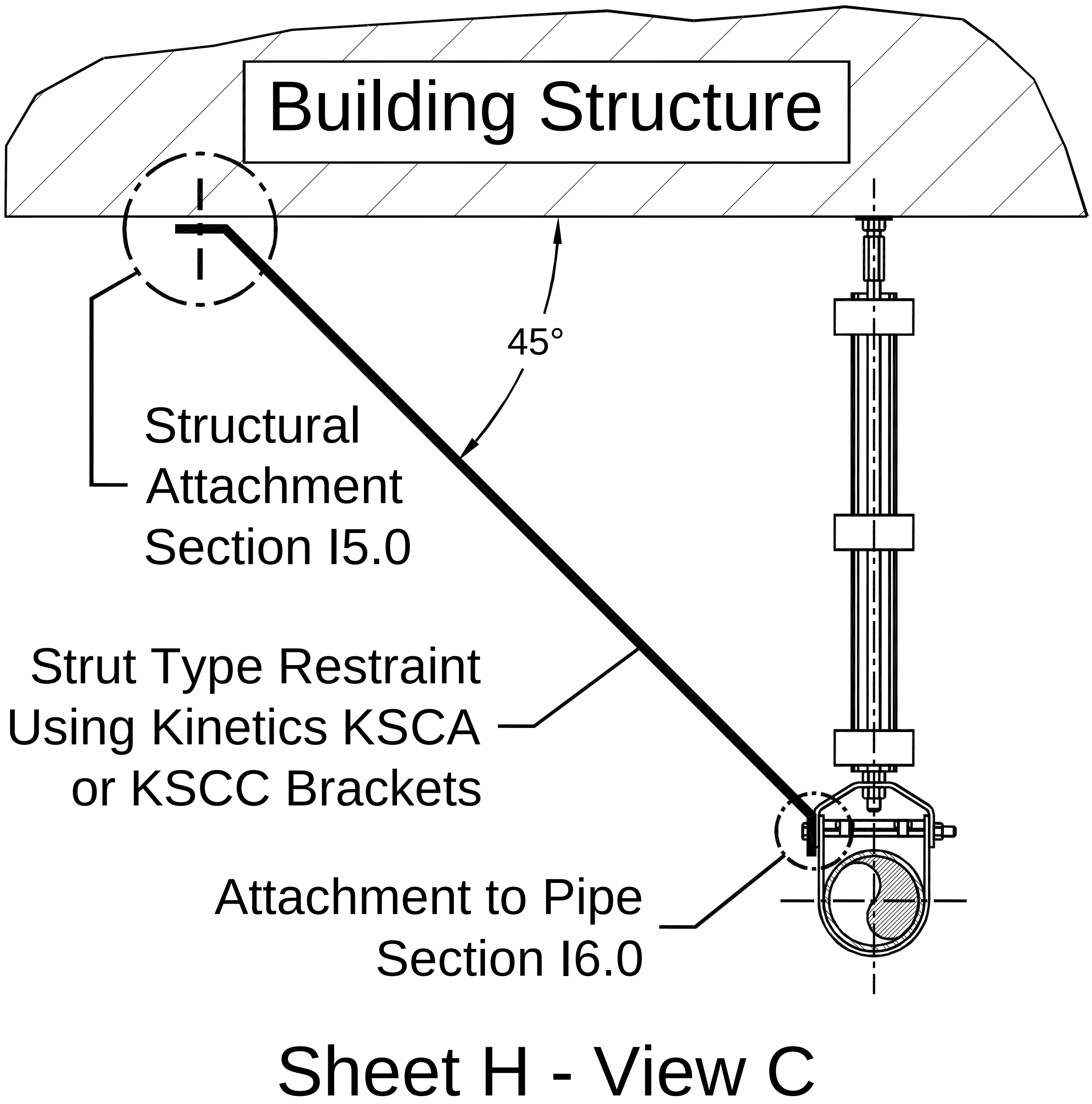

Figure I7-50; Transverse (T) Strut Type Restraint Schematic for Single Clevis Supported Pipe – Strut Type Restraint Attached to Clevis Hanger

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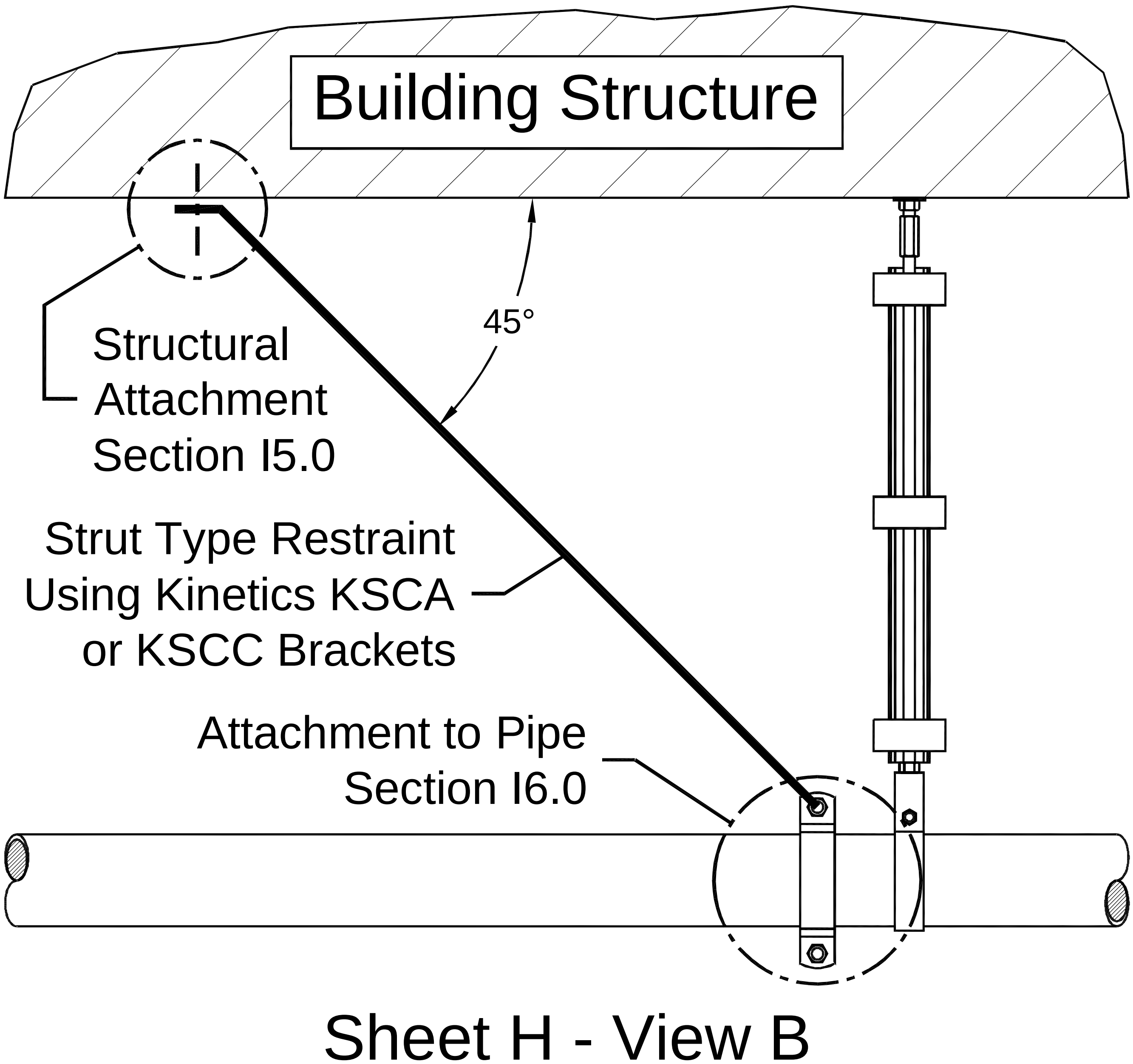

Figure I7-51; Longitudinal (L) Strut Type Restraint Schematic for Single Clevis Supported Pipe – Strut Type Restraint Attached to a Pipe Riser Clamp Immediately Adjacent to the Clevis Hanger

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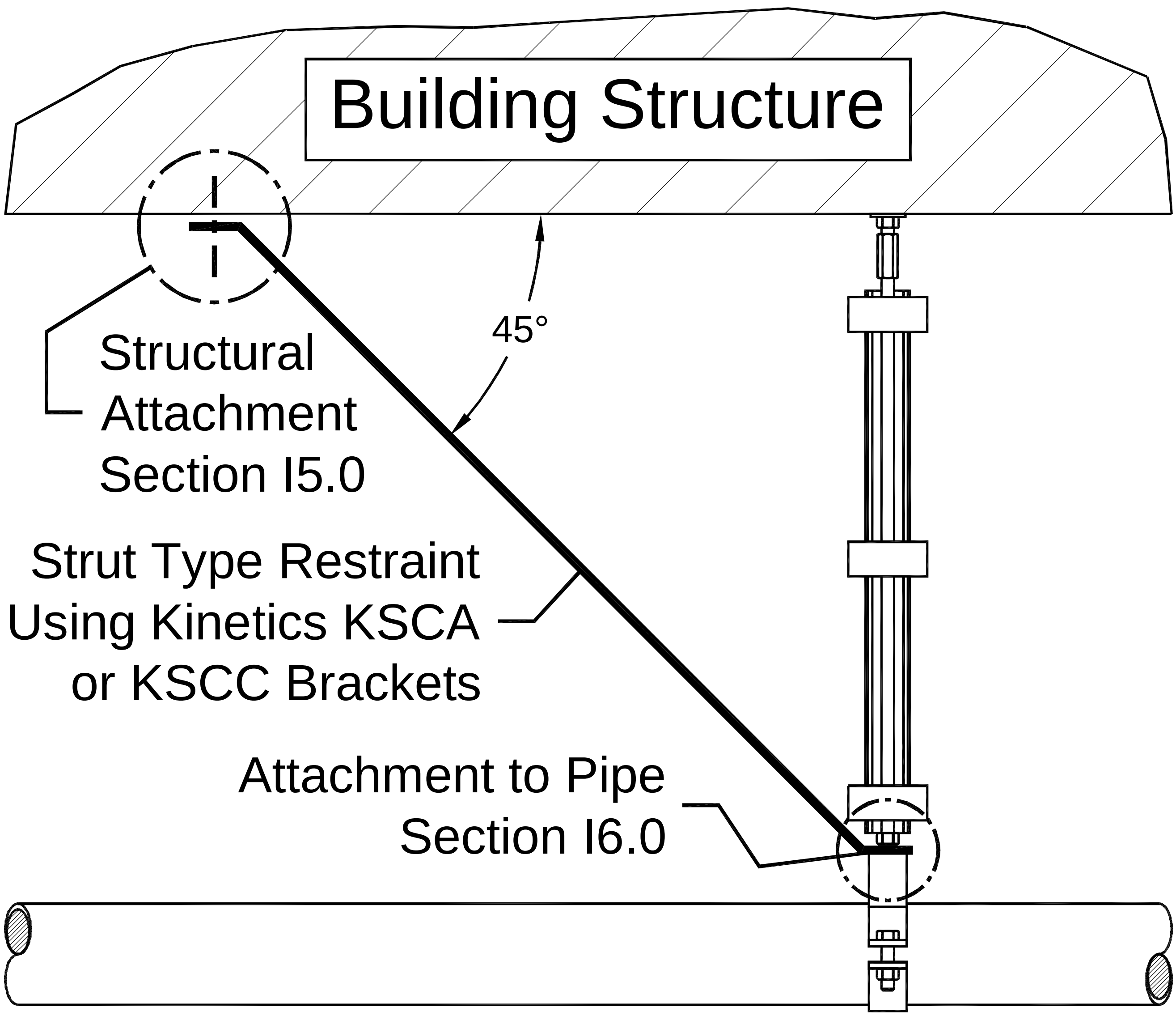

Sheet H - View A

Figure I7-52; Longitudinal (L) Strut Type Restraint Schematic for Single Clevis Supported Pipe – Strut Type Restraint Attached to a Clamp Type Clevis Hanger

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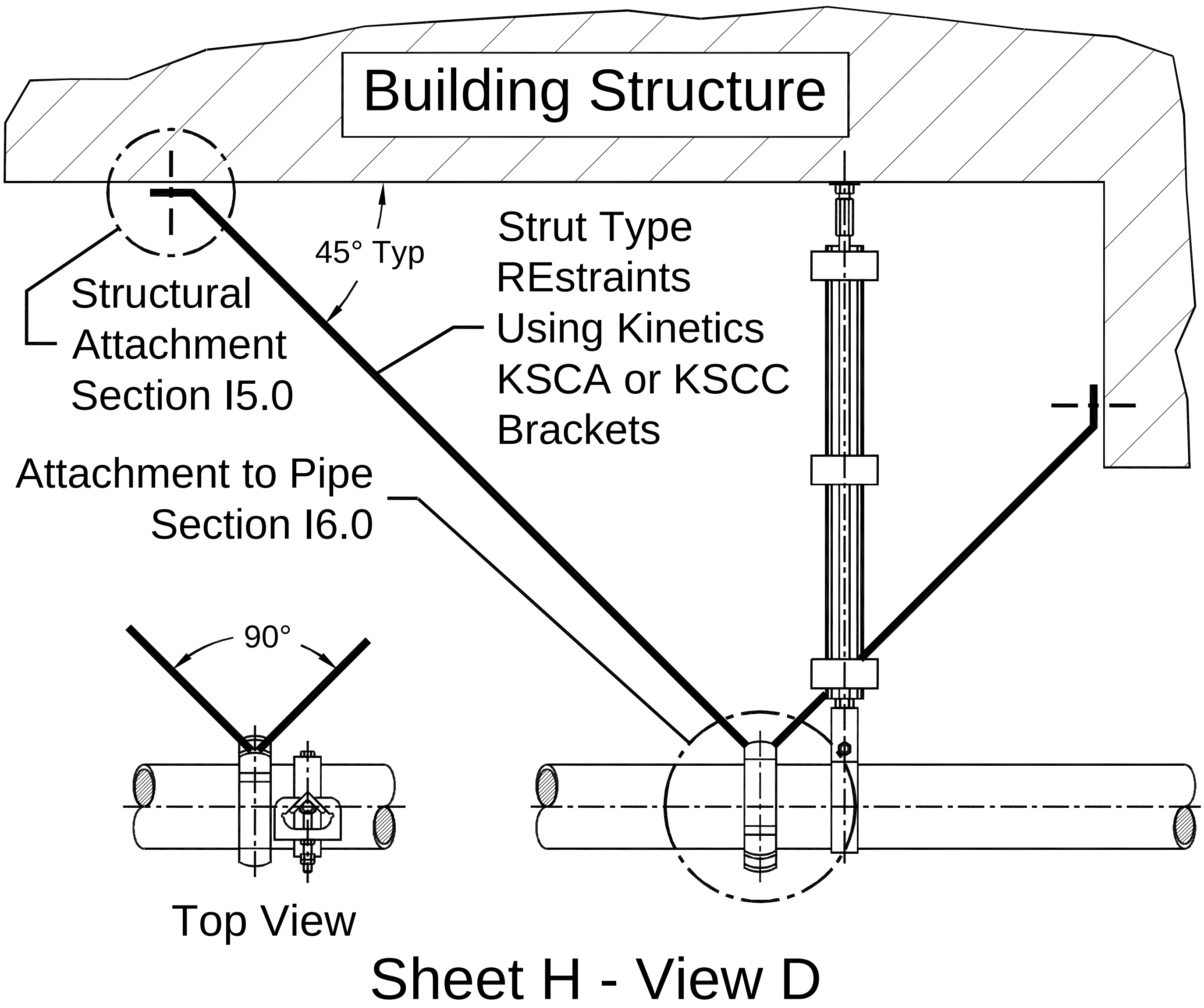

Figure I7-53; Combined Transverse & Longitudinal (TL) Strut Type Restraint Schematic for Single Clevis Supported Pipe – Strut Type Restraints Attached to a Pipe Riser Clamp Immediately Adjacent to the Clevis Hanger

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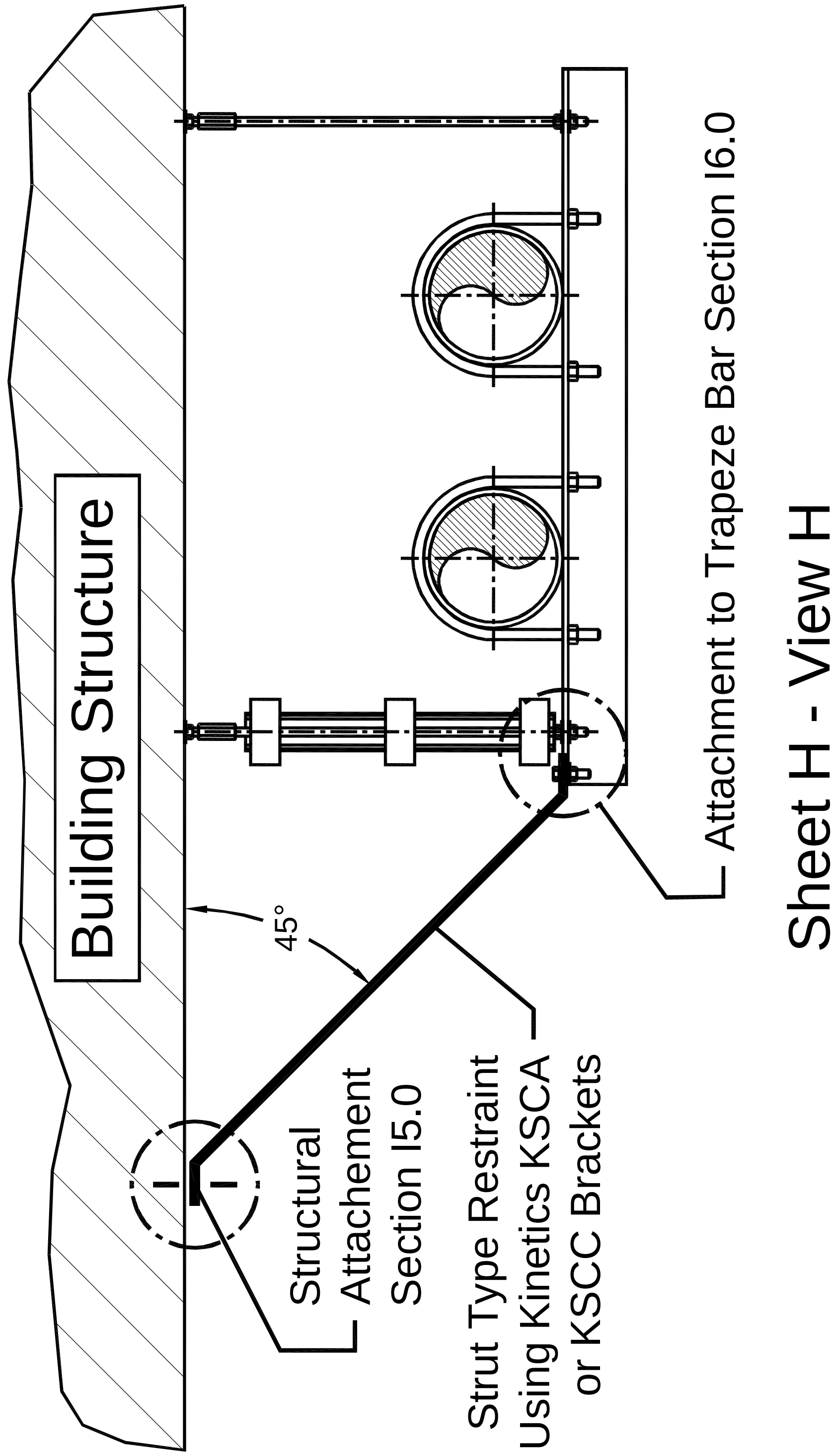

Figure I7-54; Transverse (T) Strut Type Restraint Schematic for Trapeze Supported Pipe – Strut Type Restraint Attached to One End, or One Hanger Rod, of the Trapeze Bar and Directed Outside the Trapeze

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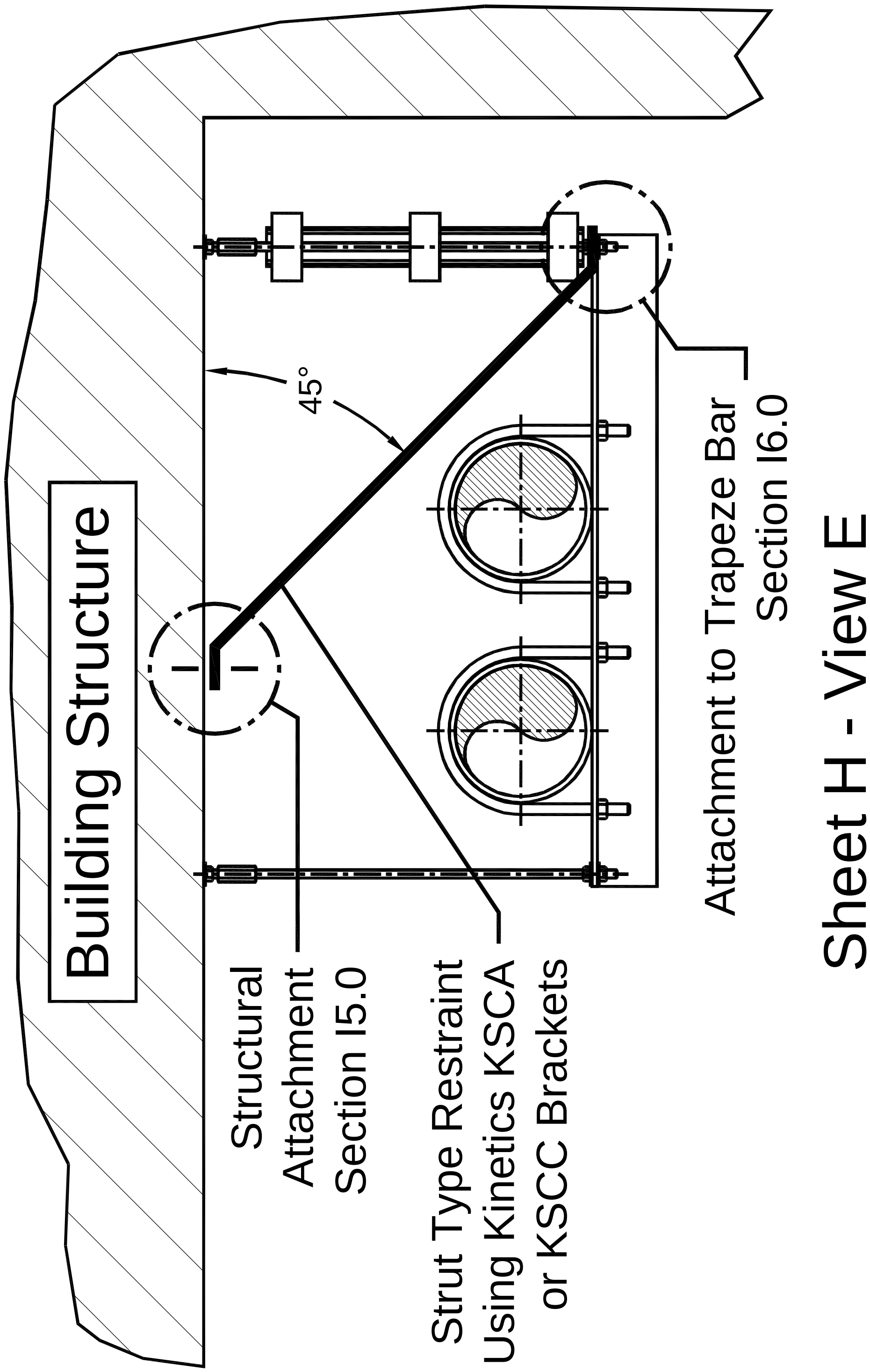

Figure I7-55; Transverse (T) Strut Type Restraint Schematic for Trapeze Supported Pipe – Strut Type Restraint Attached to One End, or One Hanger Rod, of the Trapeze Bar and Directed Inside the Trapeze

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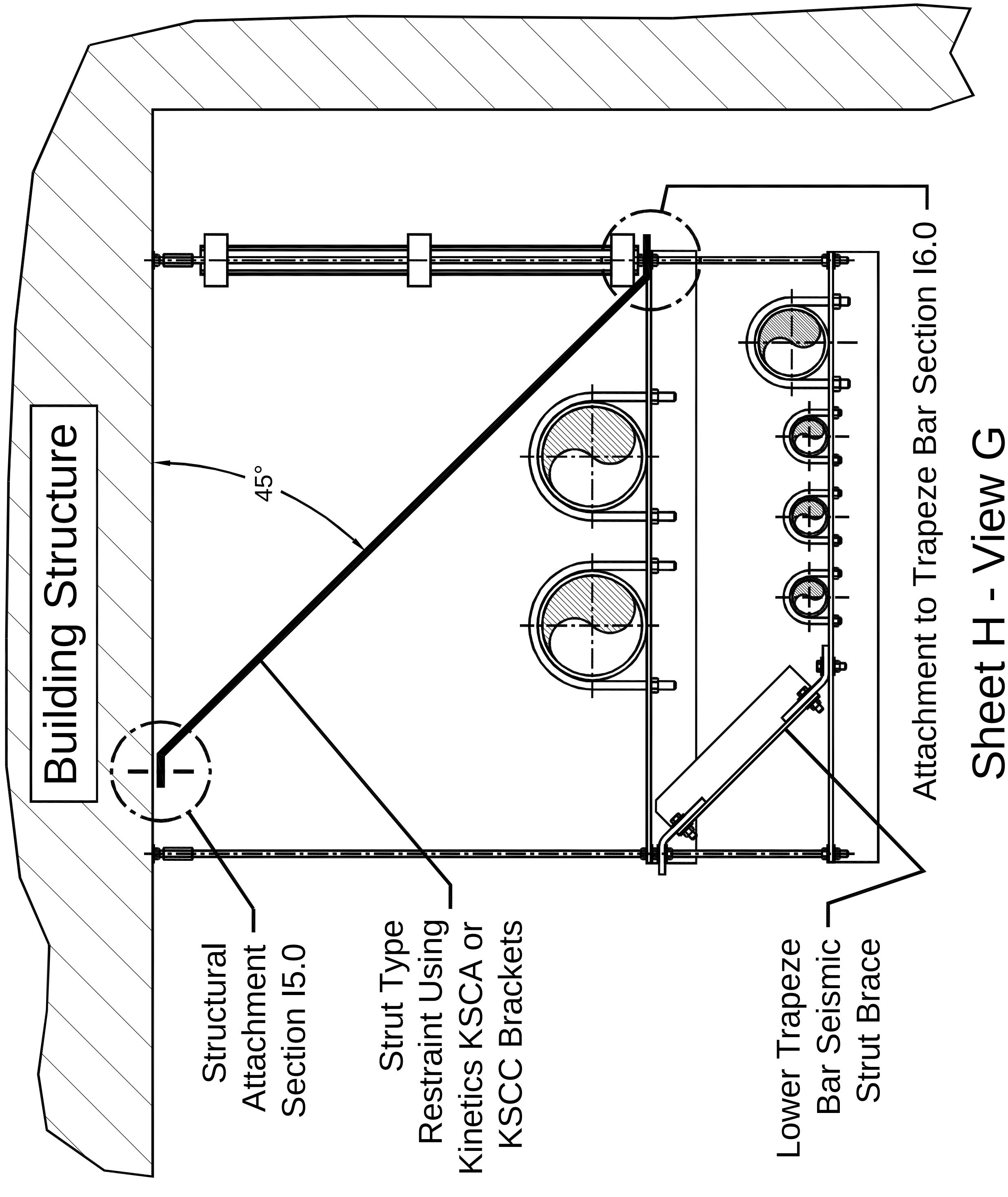

Figure I7-56; Transverse (T) Strut Type Restraint Schematic for Trapeze Supported Pipe – Strut Type Restraint Attached to One End, or One Hanger Rod, of the Trapeze Bar and Directed Inside the Trapeze with a Second Tier Trapeze Support for Additional Pipes

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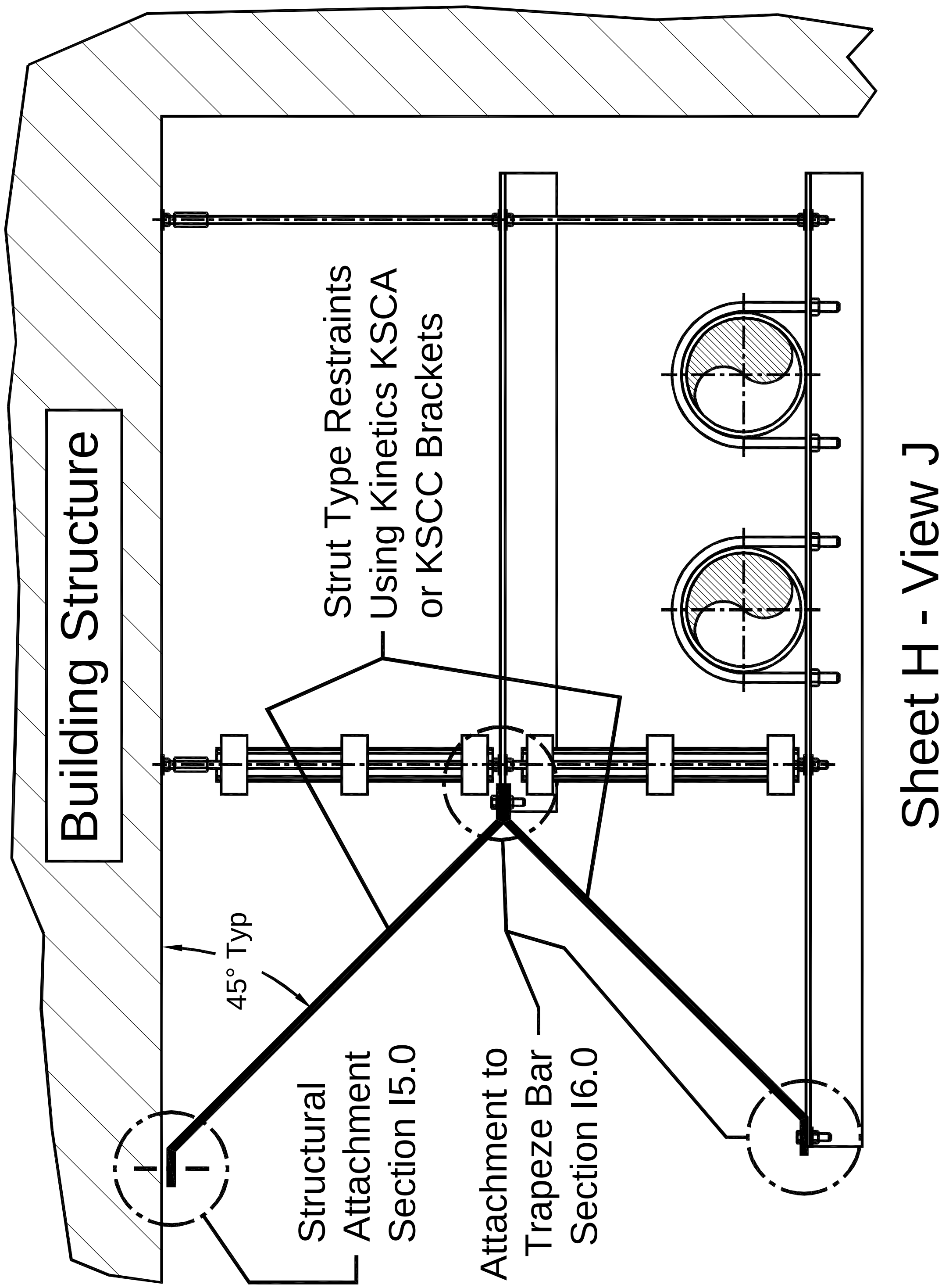

Figure I7-57; Transverse (T) Strut Type Restraint Schematic Arrangement for Trapeze Supported Pipe – Strut Type Restraints Attached to One End, or One Hanger Rod, of the Trapeze Bar and Directed Outside the Trapeze Bar for Use in Tight Space Situations

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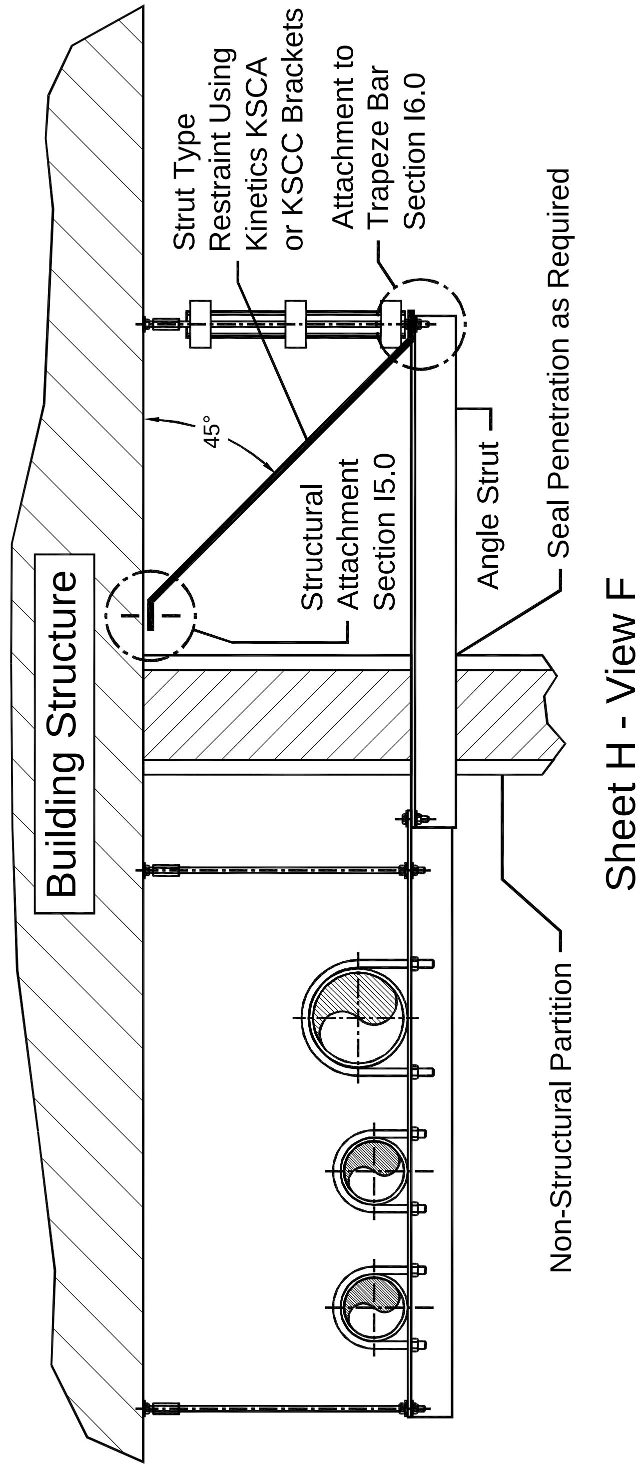

Figure I7-58; Transverse (T) Strut Type Restraint Schematic for Trapeze Supported Pipe – Trapeze Bar is Too Close to a Wall to Allow a Normal Restraint Arrangement – Obtain Permission from the Structural Engineer and Architect Before Penetrating the Wall

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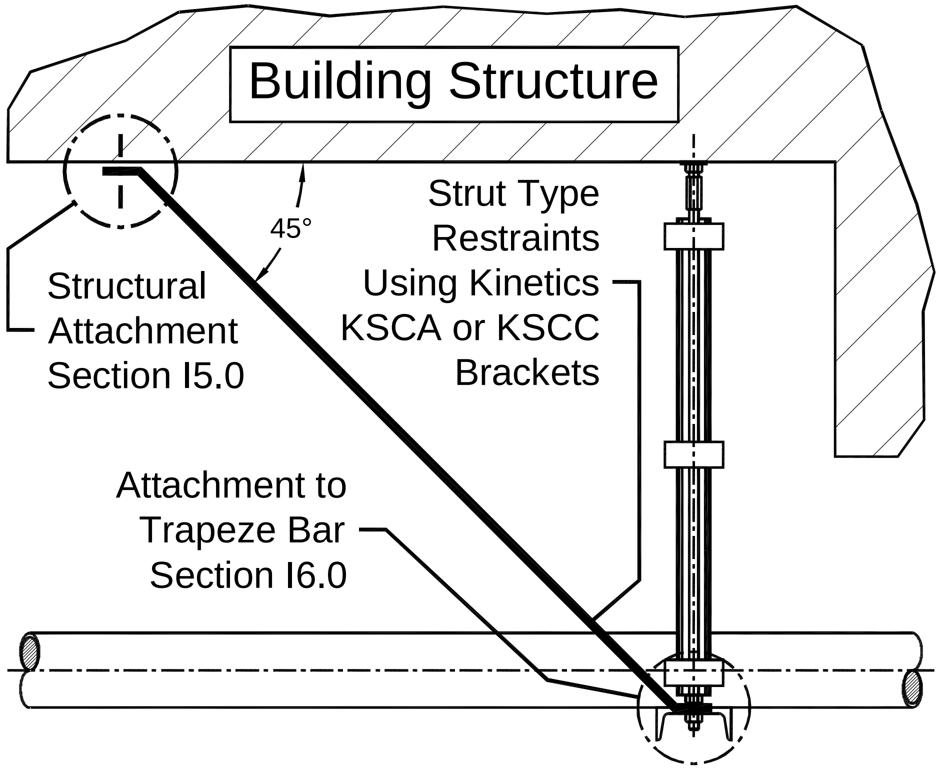

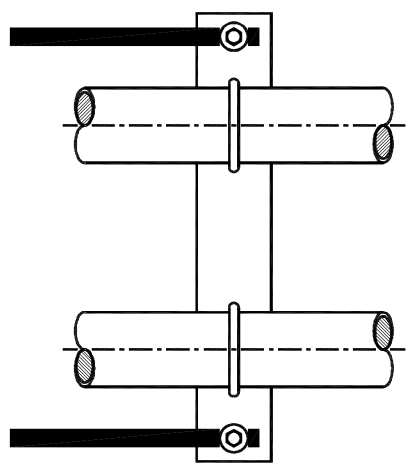

Figure I7-59; Longitudinal (L) Cable Restraint Schematic for Trapeze Supported Pipe – Option #1 – Restraint Forces are Balanced Side-to-Side

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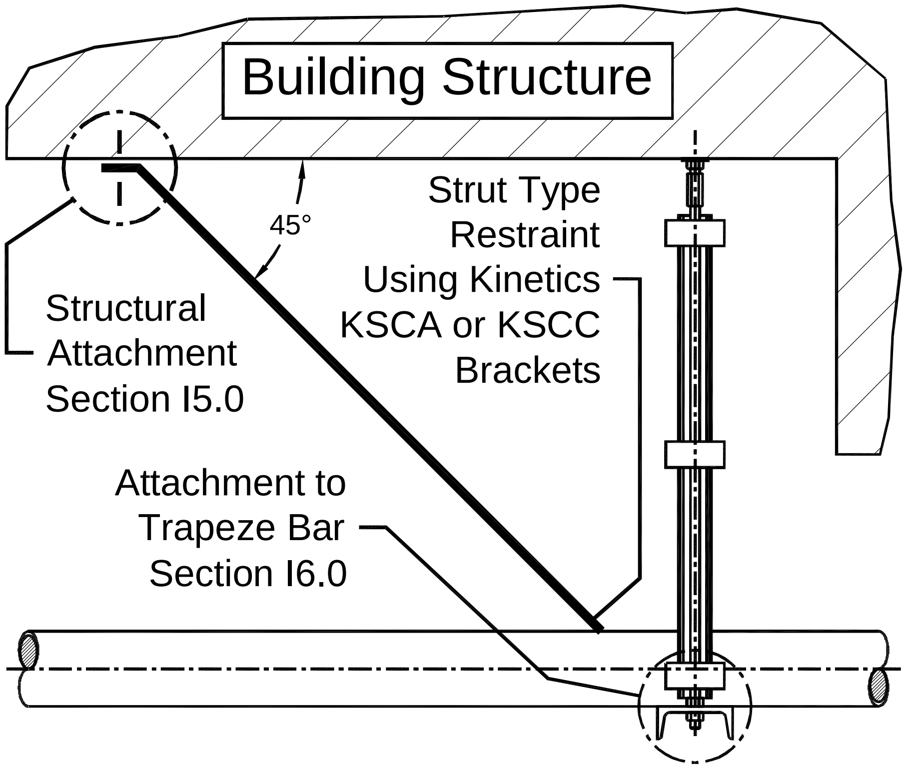
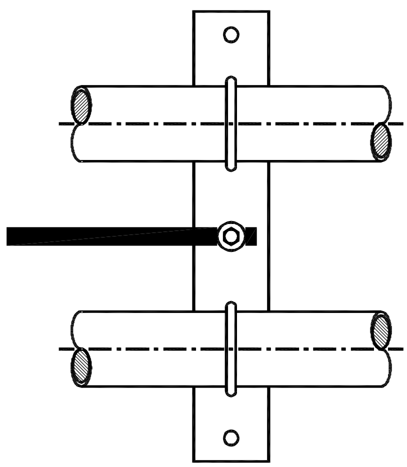


Sheet H - View K
Side View Opt. #2



Top View Opt. #2

Figure I7-60; Longitudinal (L) Cable Restraint Schematic for Trapeze Supported Pipe – Option #2 – Restraint Forces are Balanced Side-to-Side

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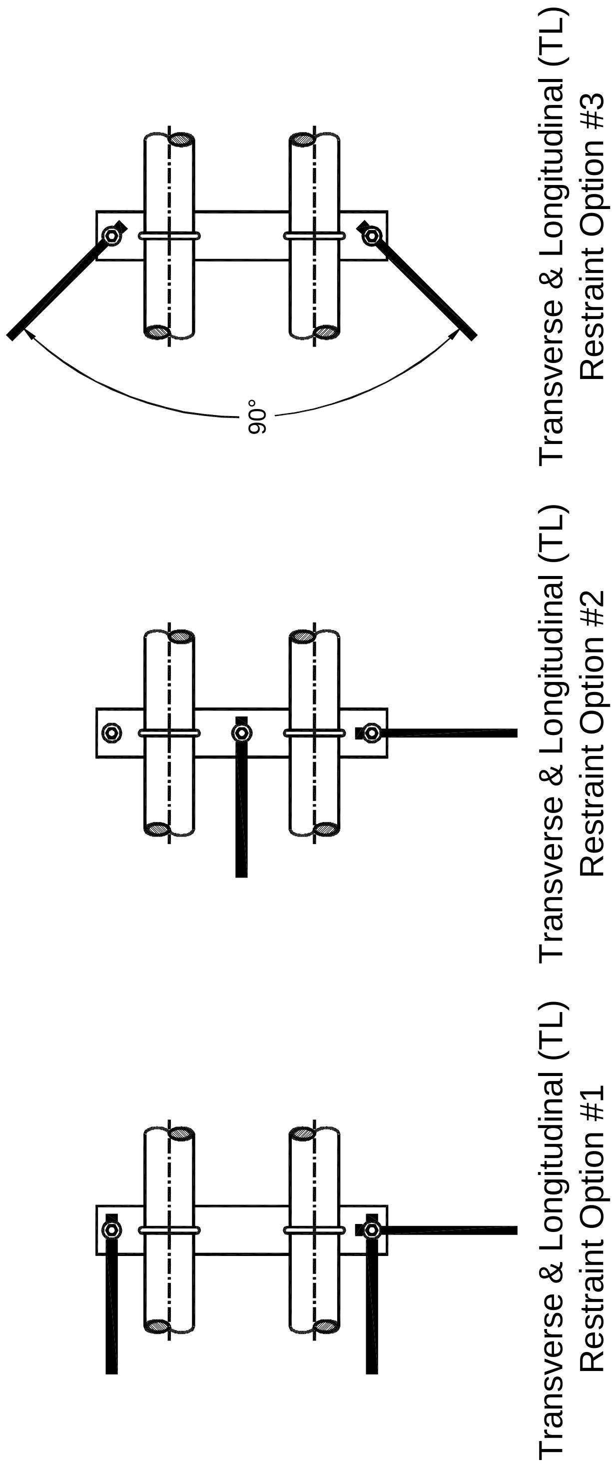

Figure I7-61; Combined Transverse & Longitudinal (TL) Strut Type Restraints for Trapeze Supported Pipe – All of the Options Shown Provide Balanced Longitudinal Restraint Forces Side-to-Side

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I7.9 – Strut Restraint Schematics for Duct:

Sheet H1 – View A shown in Figure I7-62 will be typical of the other figures in this section. They refer to the drawing sheet and view on the installation drawings provided by Kinetics Noise Control for each project requiring seismic restraint for pipe and duct systems.

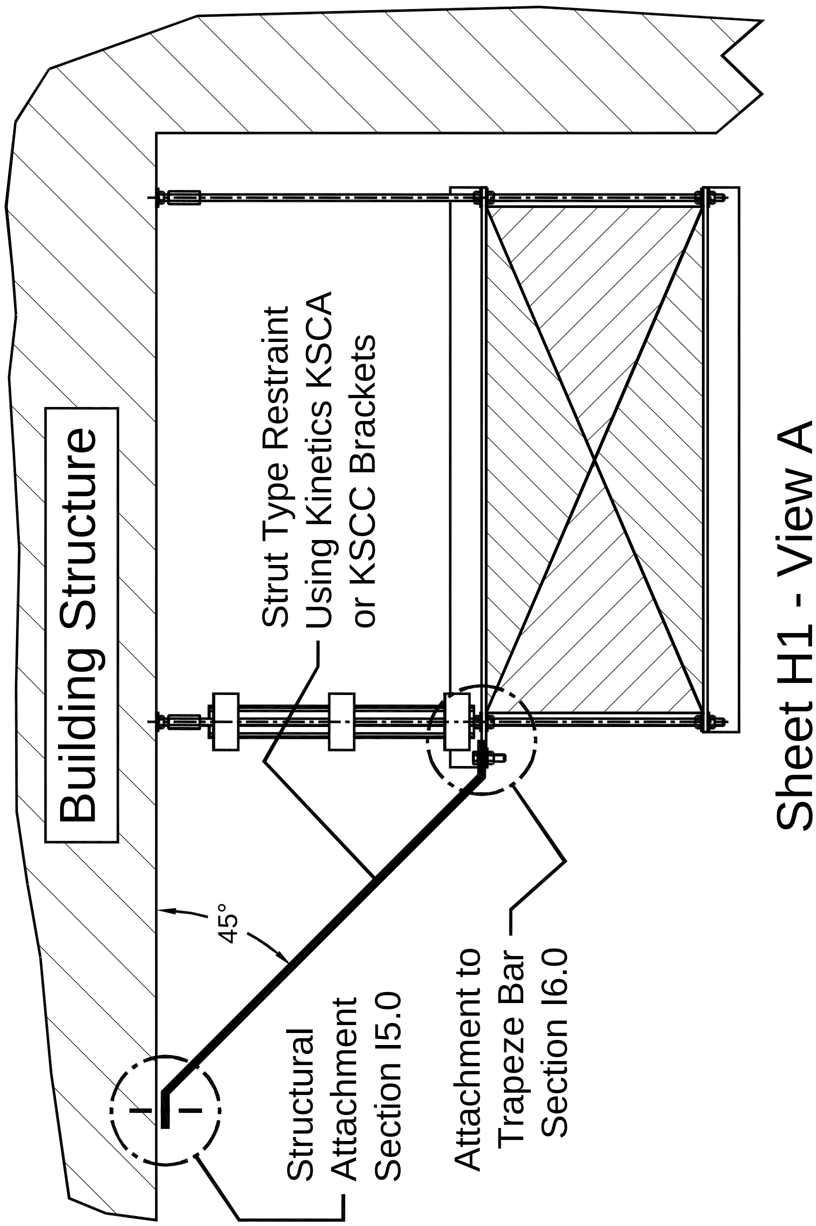

Figure I7-62; Transverse (T) Strut Type Restraint Schematic for Trapped Rectangular Duct – Restraint on Top Trapeze Bar at One Hanger Location Directed Outward from the Trapeze Bar

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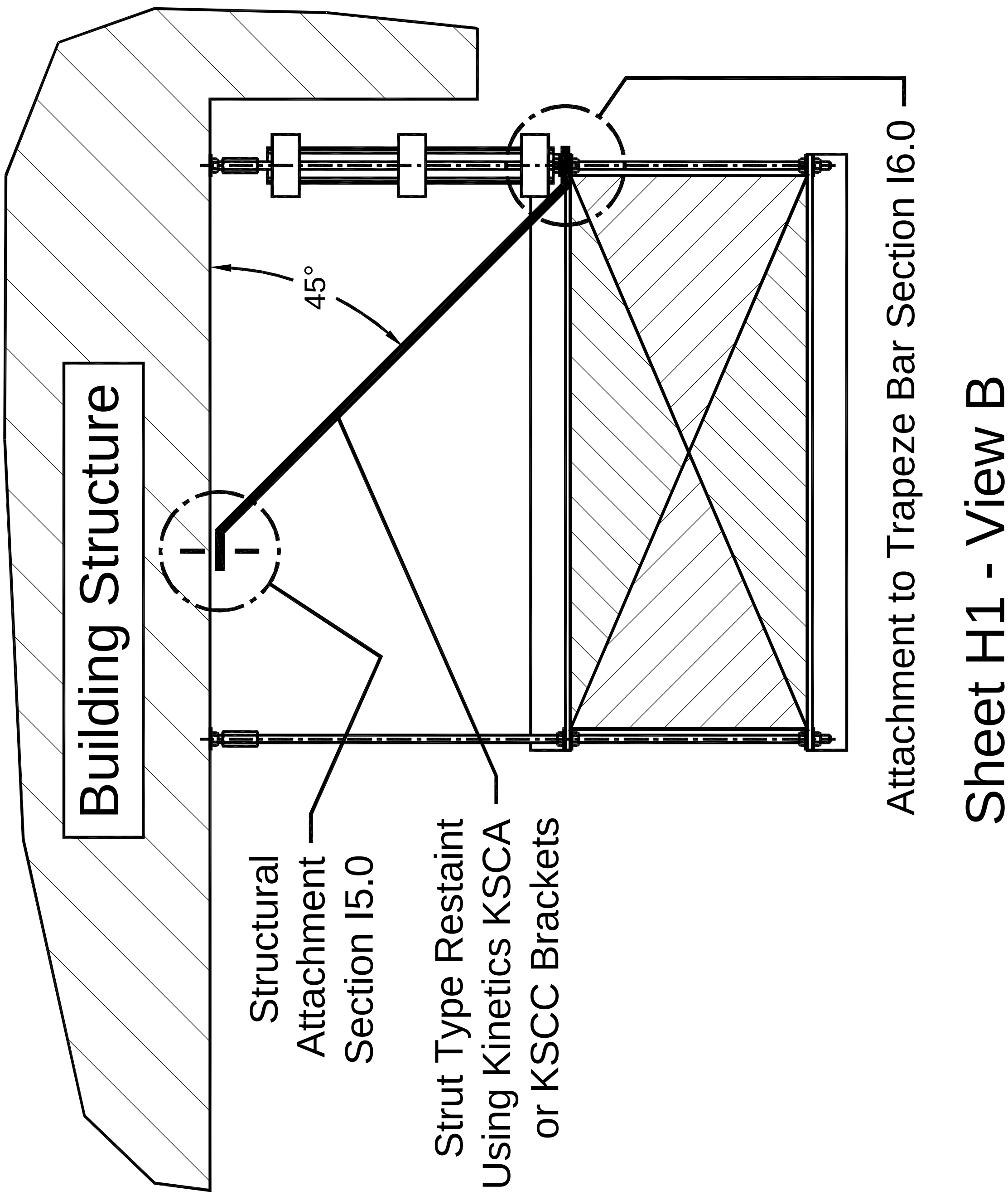

Figure I7-63; Transverse (T) Strut Type Restraint Schematic for Trapped Rectangular Duct – Restraint on Top Trapeze Bar at One Hanger Location Directed Inward Over the Top of the Duct

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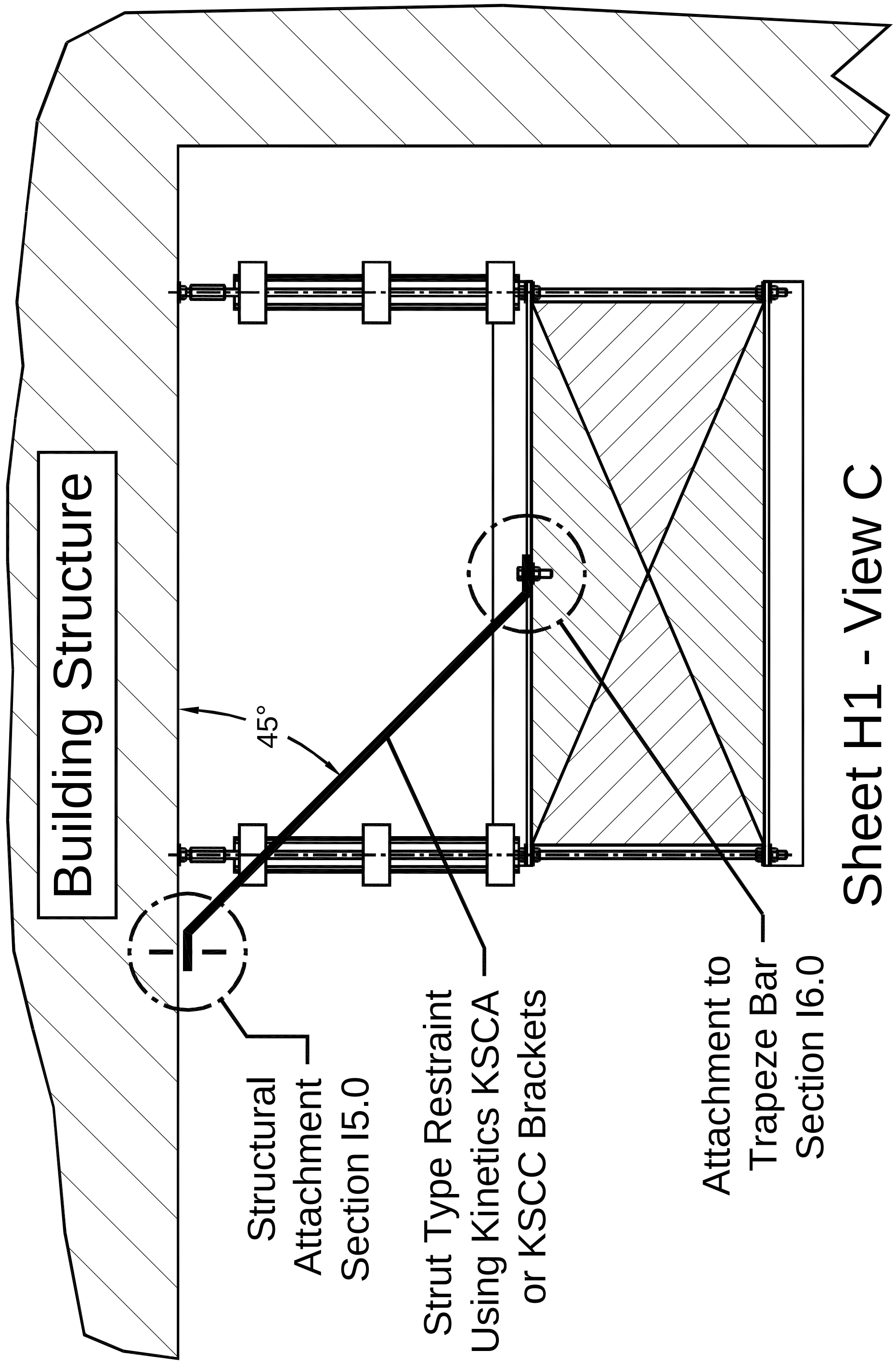

Figure I7-64; Transverse (T) Strut Type Restraint Schematic for Trapped Rectangular Duct – Restraint at the Center of the Top Trapeze Bar and Directed Outward Across the Top of the Duct

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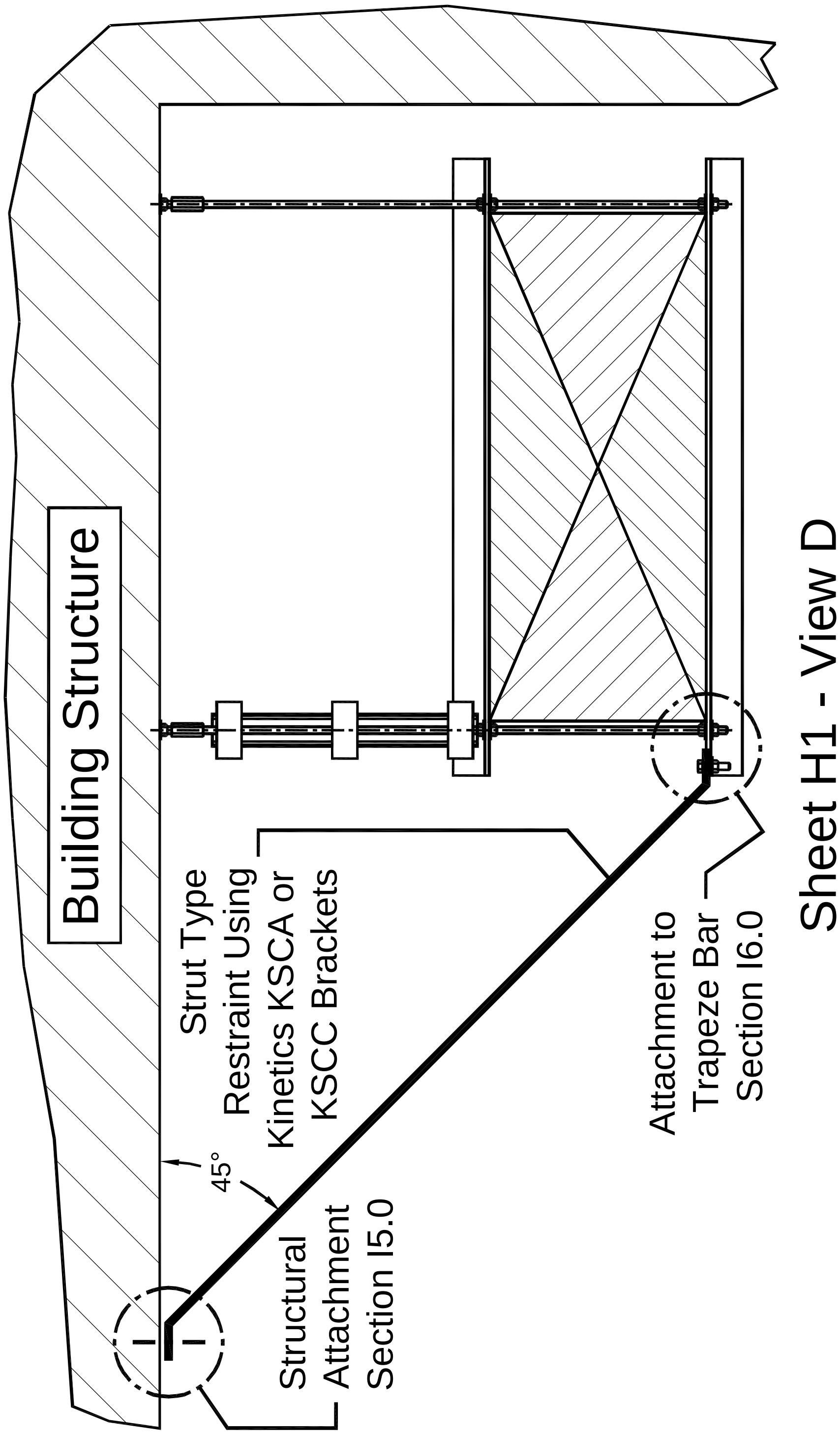

Figure I7-65; Transverse (T) Strut Type Restraint Schematic for Supported Rectangular Duct – Strut Type Restraint Attached to One End, or One Hanger Rod, of the Trapeze Bar and Directed Outward fro the Trapeze Bar

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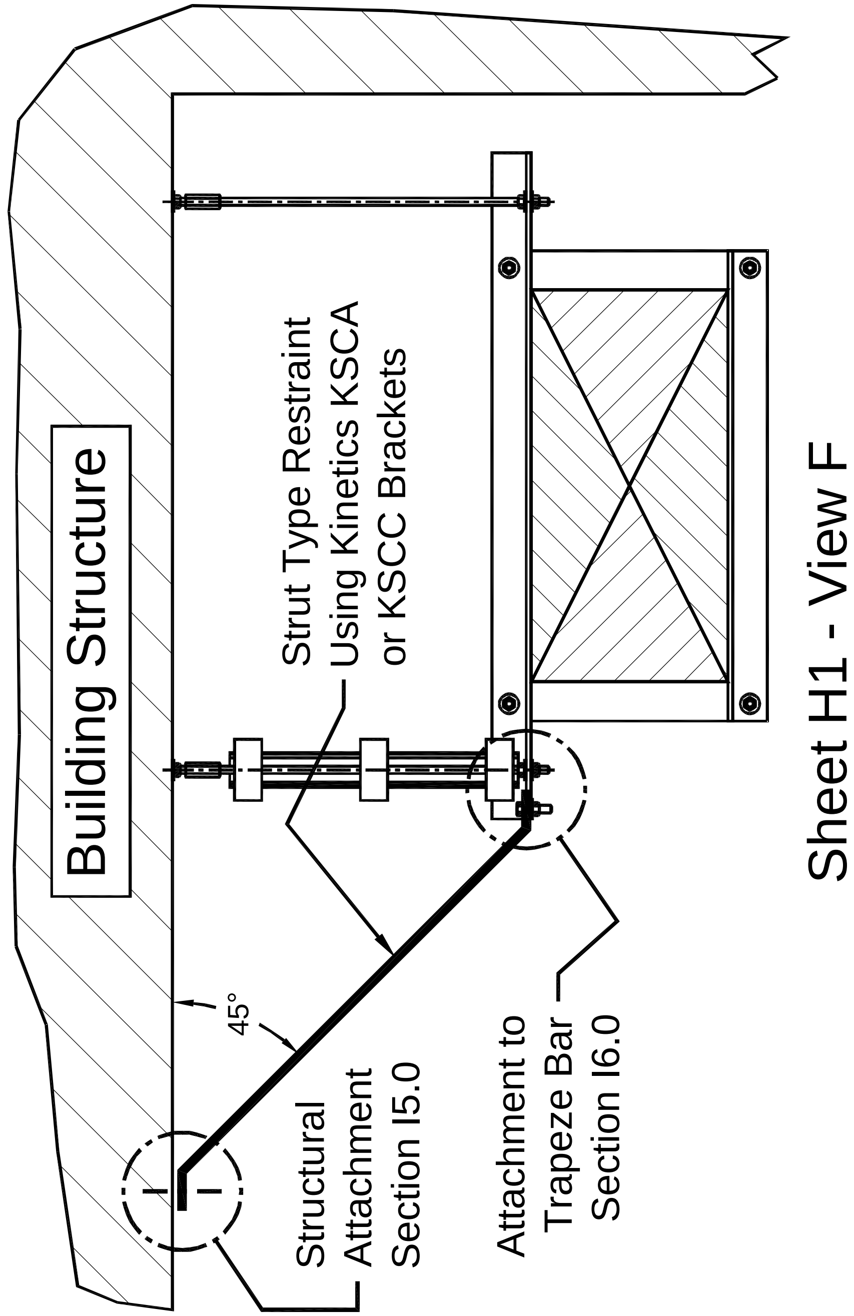

Figure I7-66; Transverse (T) Strut Type Restraint Schematic for Suspended Rectangular Duct – Restraint Attached to One End, or One Hanger Rod, of the Trapeze Bar and Directed Outward from the Trapeze Bar

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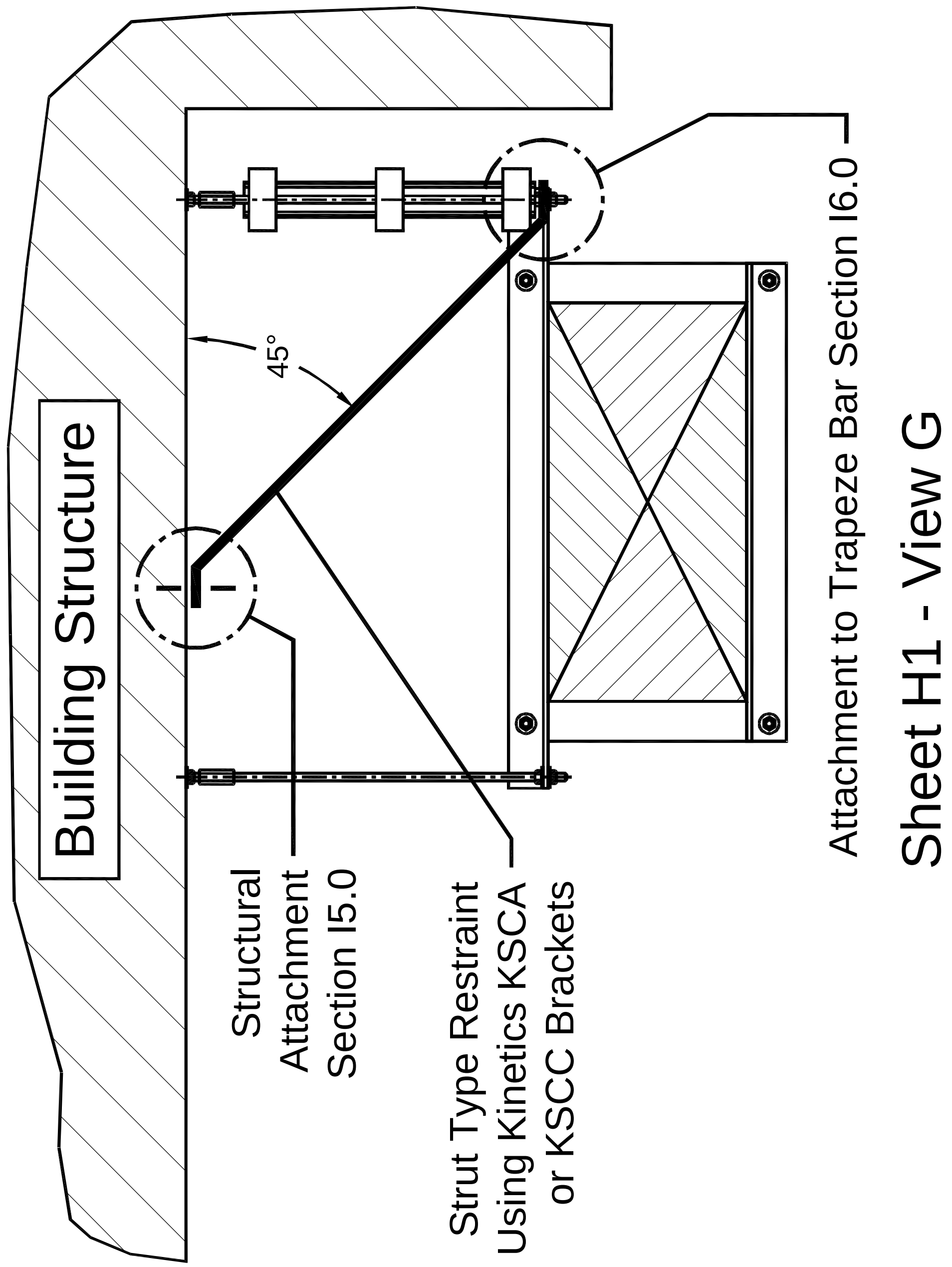

Figure I7-67; Transverse (T) Strut Type Restraint Schematic for Suspended Rectangular Duct – Strut Type Restraint at One Hanger Location and Directed Inward over the Top of the Duct

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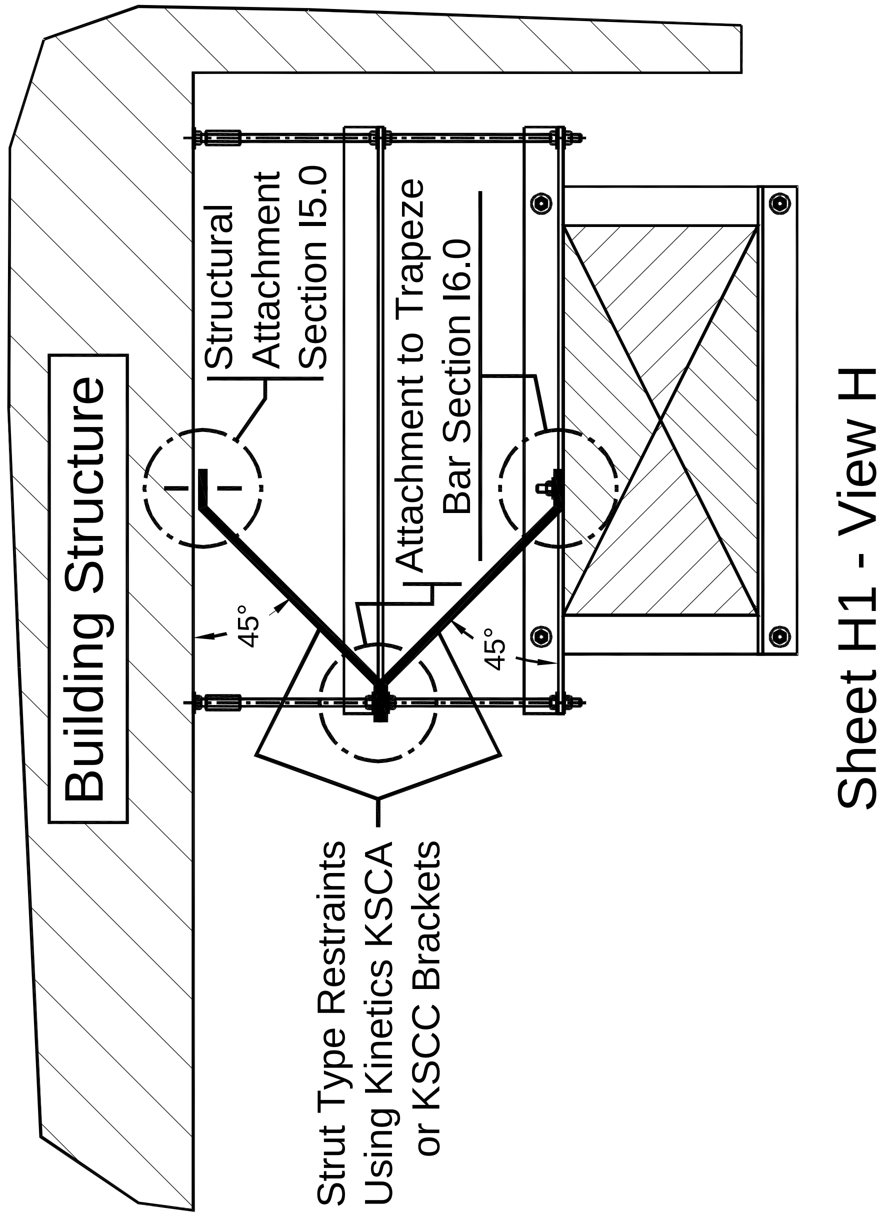

Figure I7-68; Transverse (T) Strut Type Restraint Schematic for Suspended Rectangular Duct – Two Strut Type Restraints Connected Through an Intermediate Trapeze Bar and Directed Inward from the Intermediate Trapeze Bar

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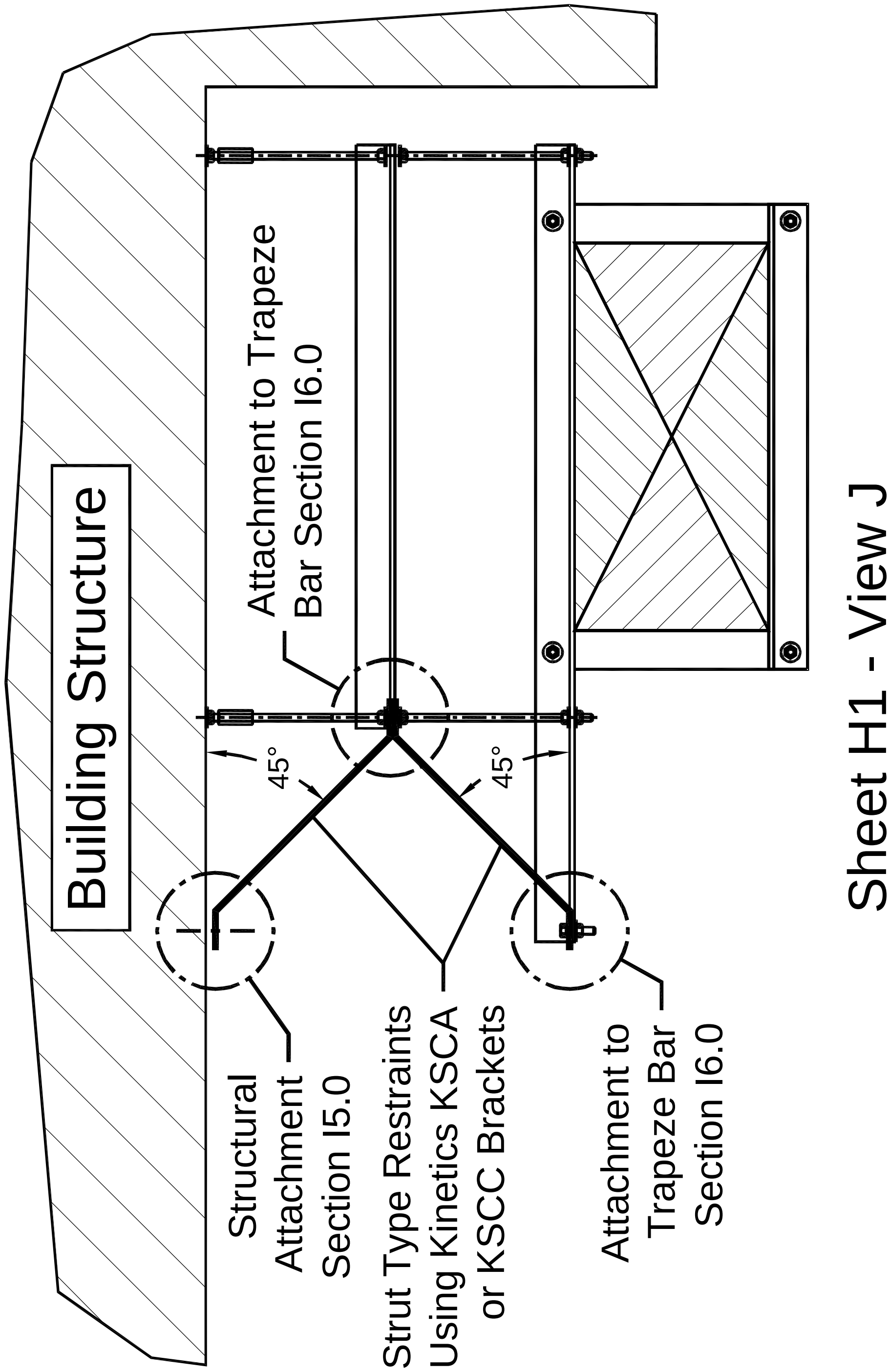

Figure I7-69; Transverse (T) Strut Type Restraint Schematic for Suspended Rectangular Duct – Two Strut Type Restraints Connected Through an Intermediate Trapeze Bar and Directed Outward from the Intermediate Trapeze Bar

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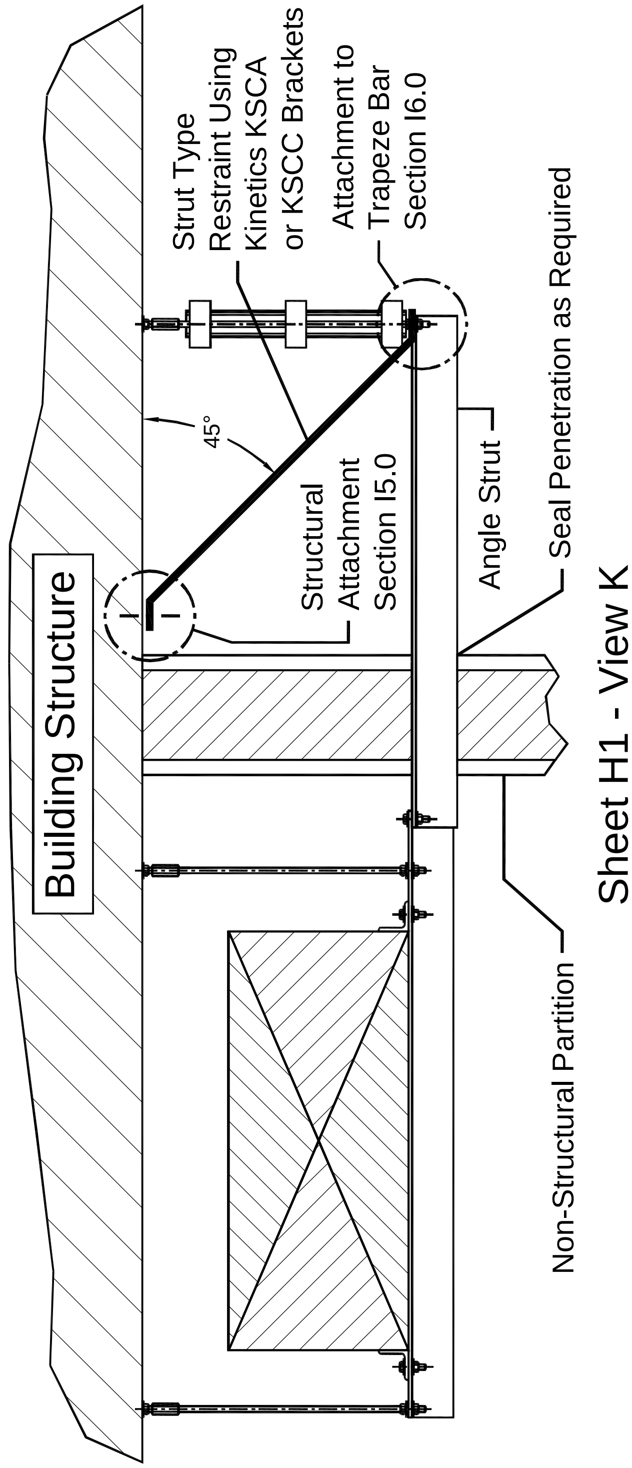

Figure I7-70; Transverse (T) Strut Type Restraint Schematic for Supported Rectangular Duct – Trapeze Bar is Too Close to a Wall to Allow a Normal Restraint Arrangement – Obtain Permission from the Structural Engineer and Architect Before Penetrating the Wall

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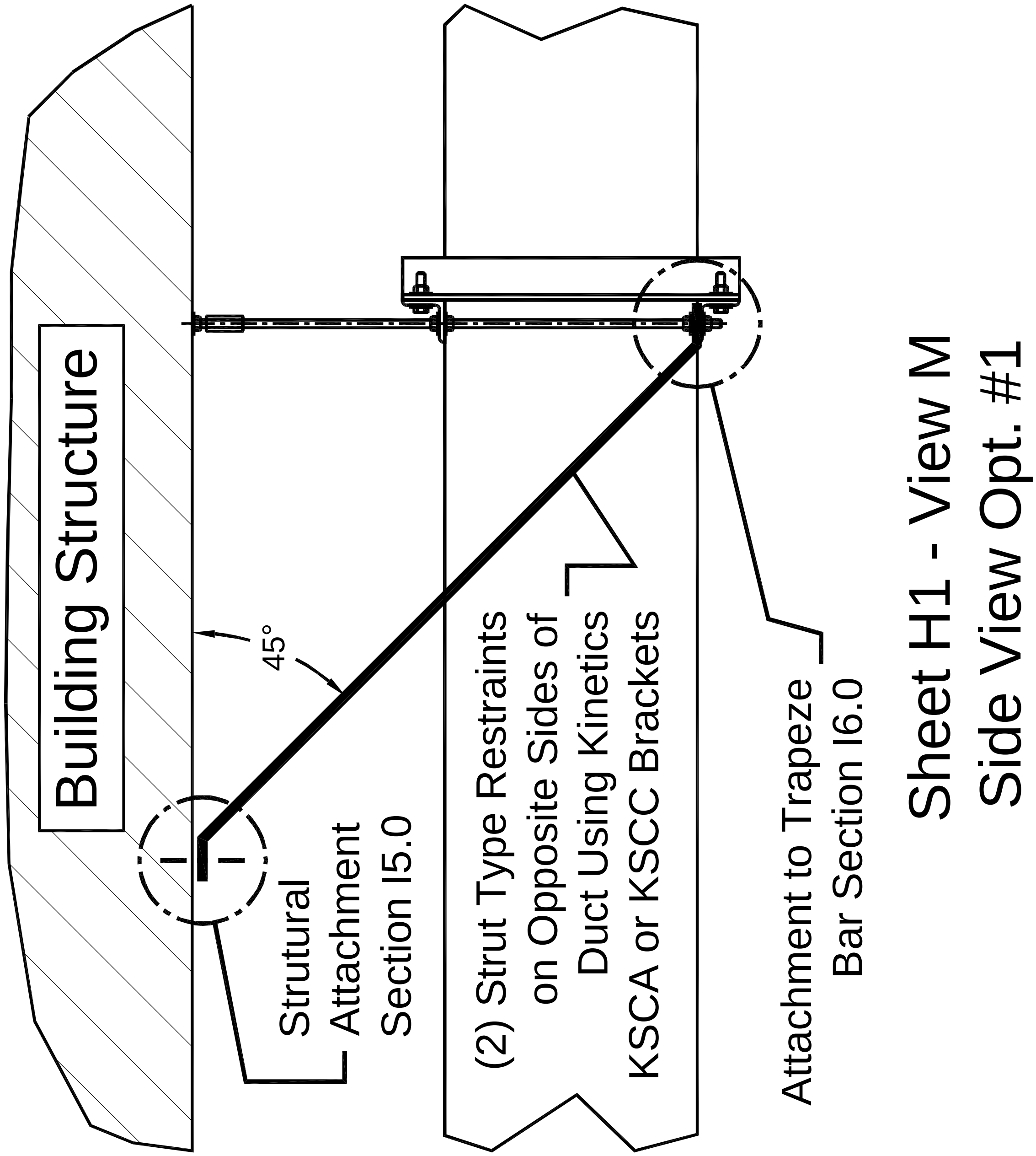

Figure I7-71; Longitudinal (L) Strut Type Restraint Schematic for Rectangular Duct – Restraints Located on Each Side of the Bottom Trapeze Bar

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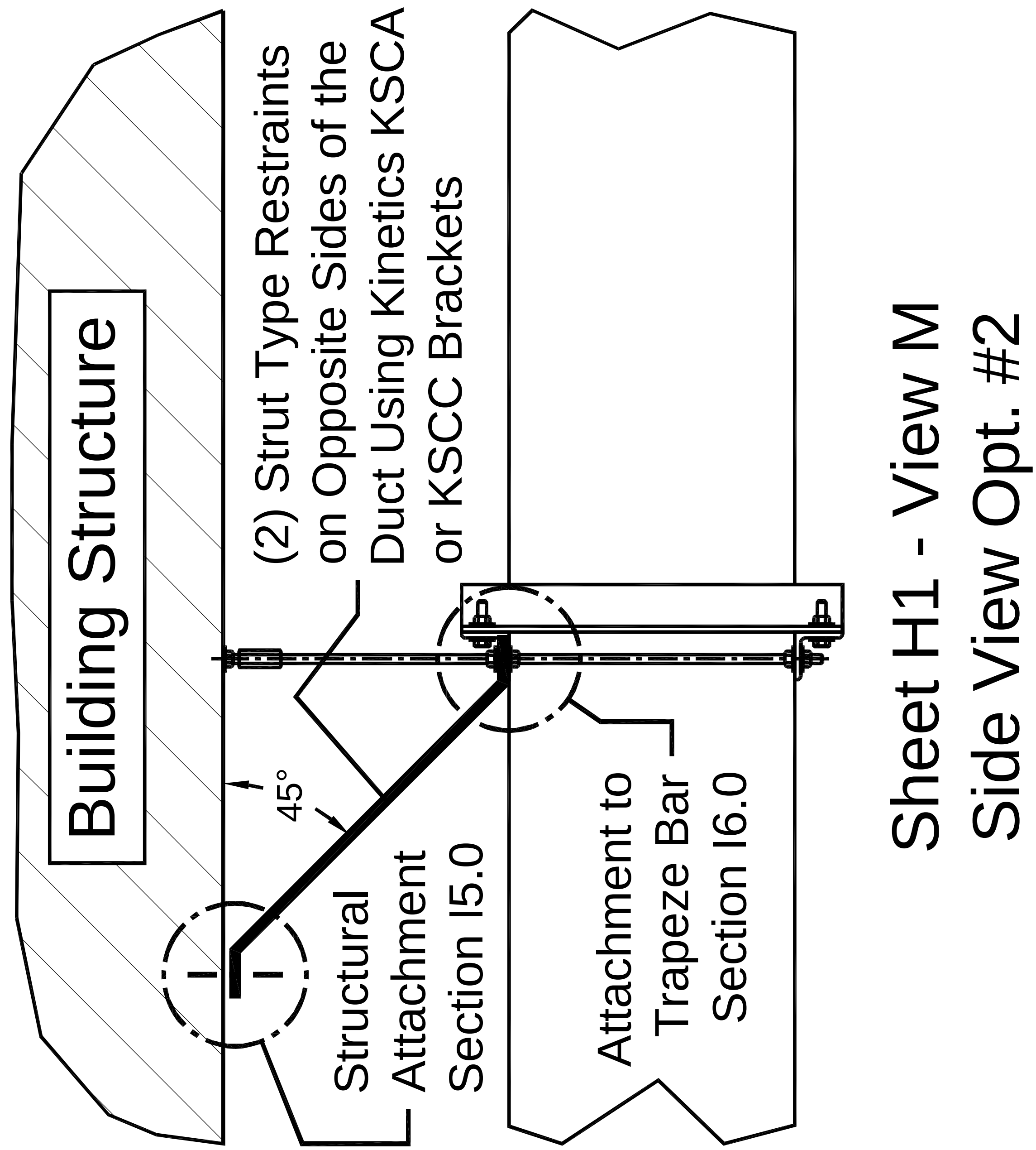

Figure I7-72; Longitudinal (L) Strut Type Restraint Schematic for Trapped Rectangular Duct – One Strut Type Restraints Located in the Center of the Top Trapeze Bar or Two Strut Type Restraints One Located on Each Side of the Top Trapeze Bar

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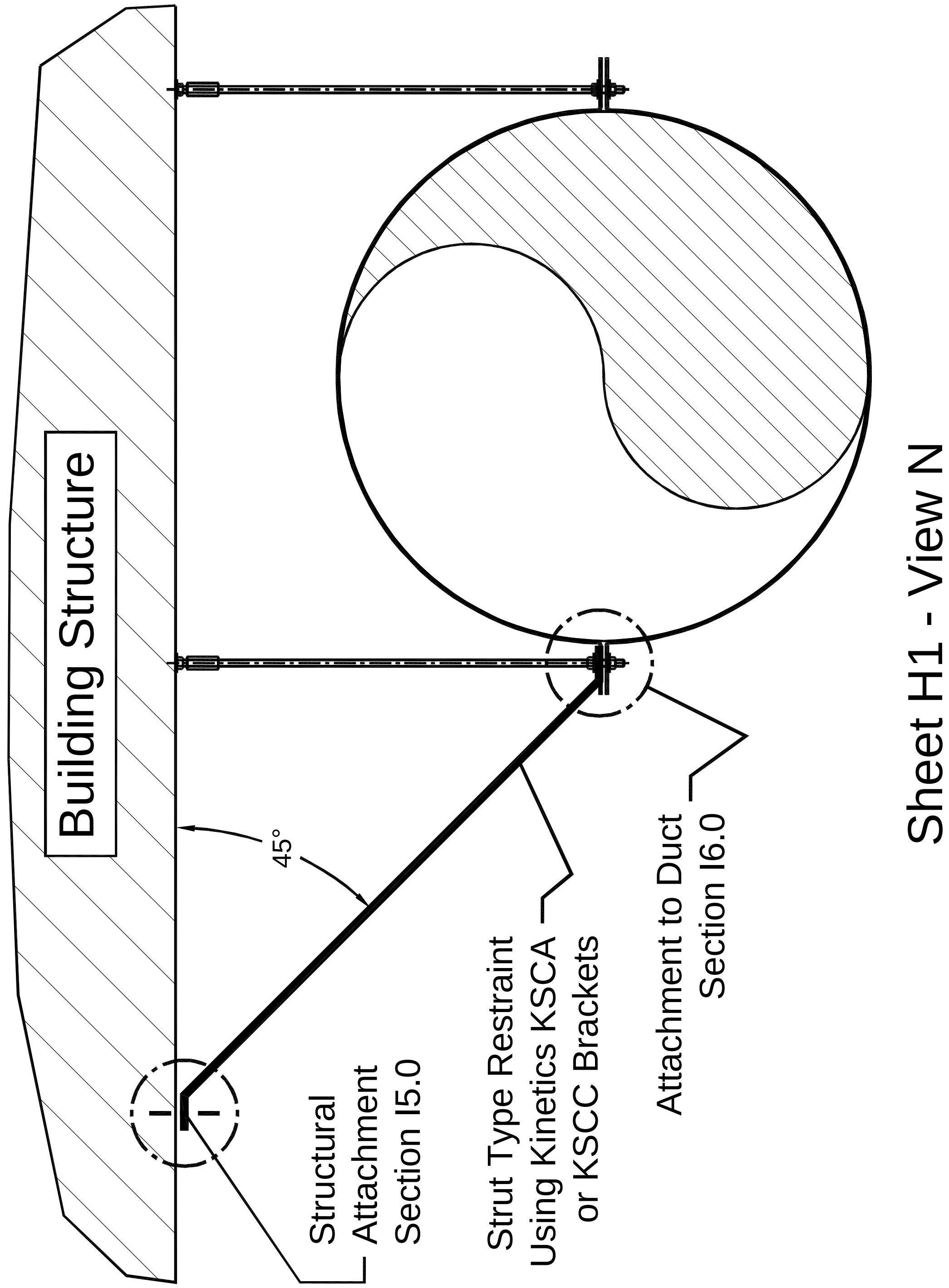

Figure I7-73; Transverse (T) Strut Type Restraint Schematic for Round Duct Supported by Two Hanger Rods

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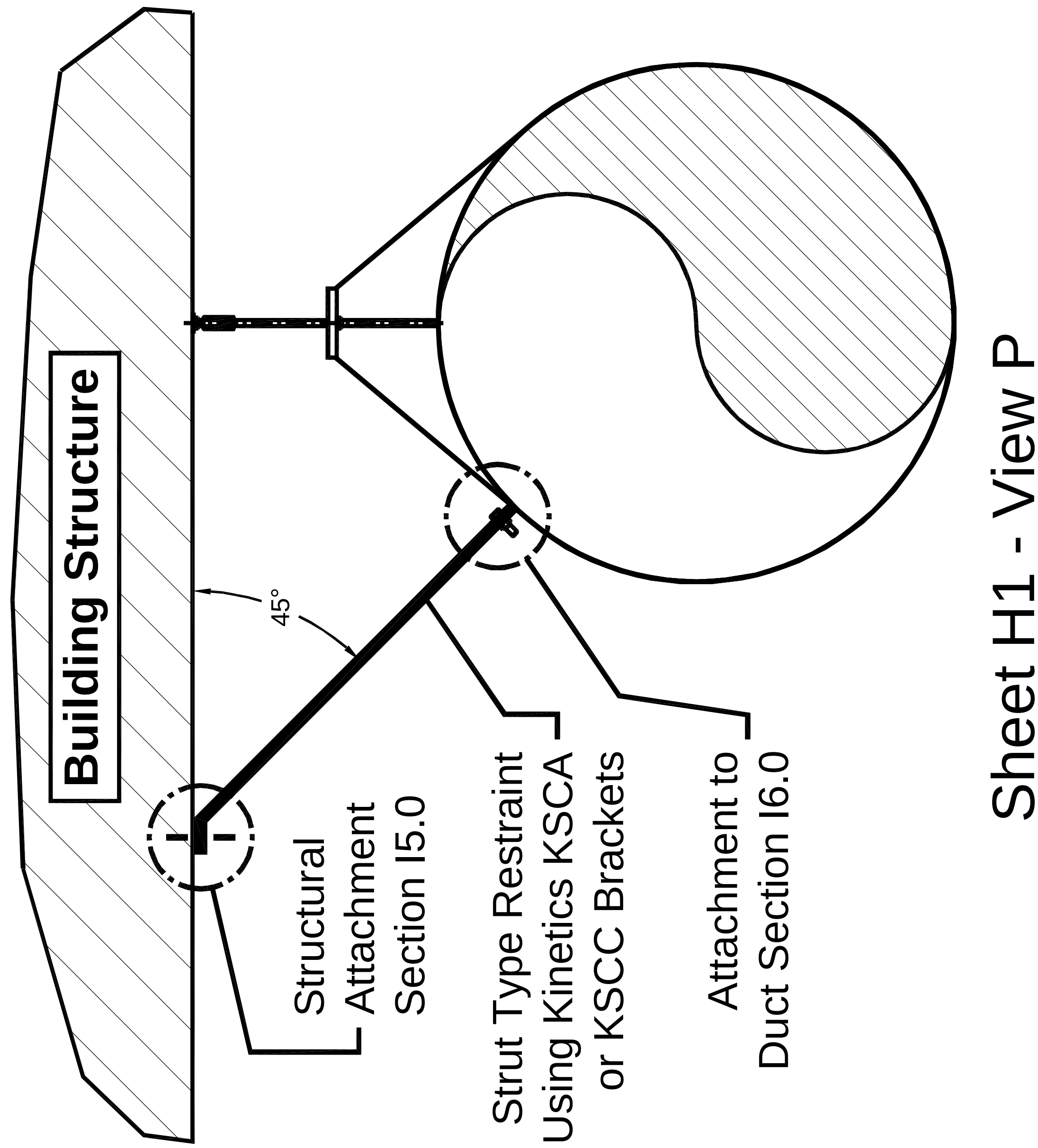

Figure I7-74; Transverse (T) Strut Type Restraint Schematic for Round Duct Supported by One Hanger Rod – Restraint adjacent to Hanger Rod Attached to a Band Clamp

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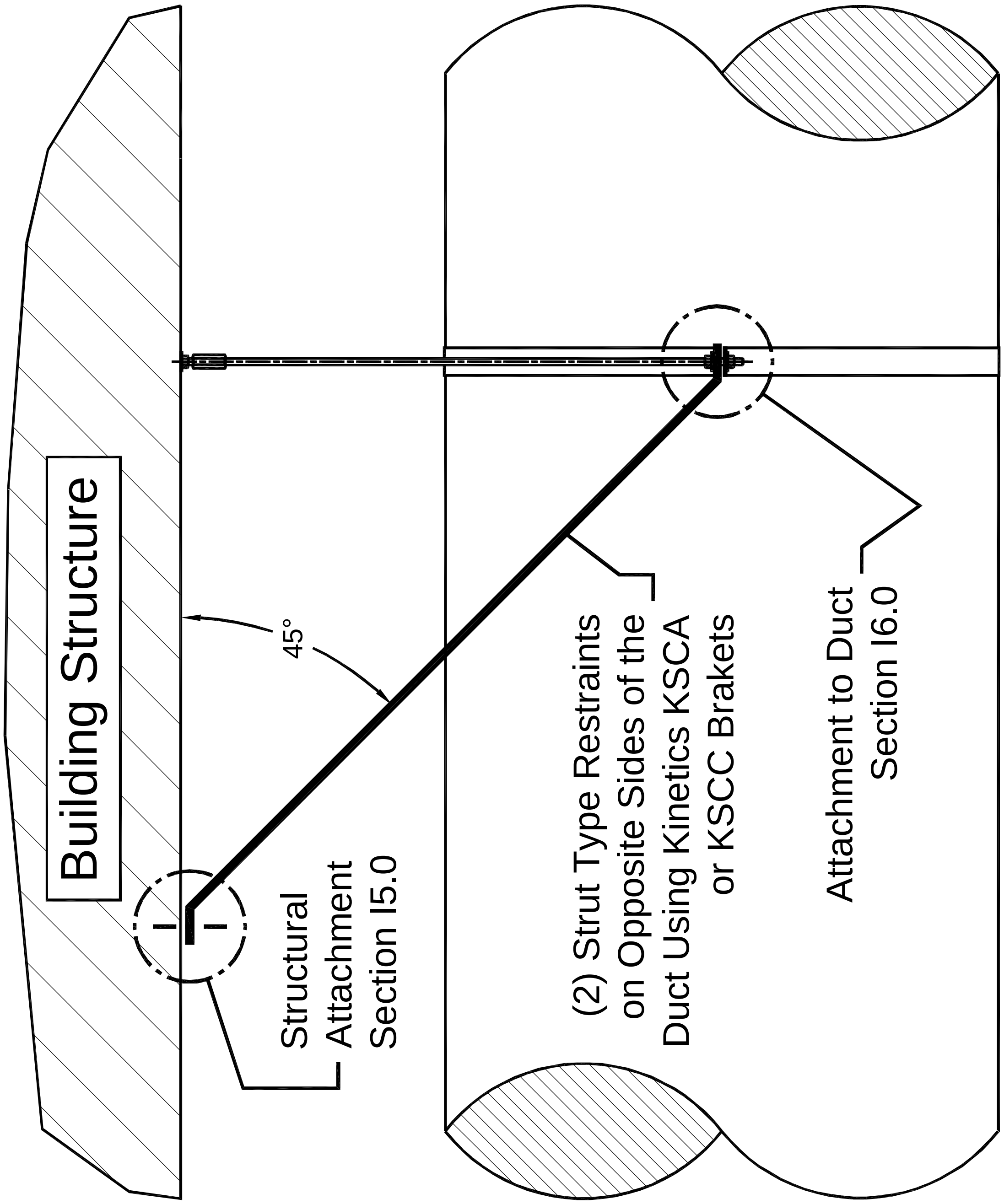

Figure I7-75; Longitudinal (L) Strut Type Restraint Schematic for Round Duct Supported by Two Hanger Rods – One Restraint on Each Side of the Duct

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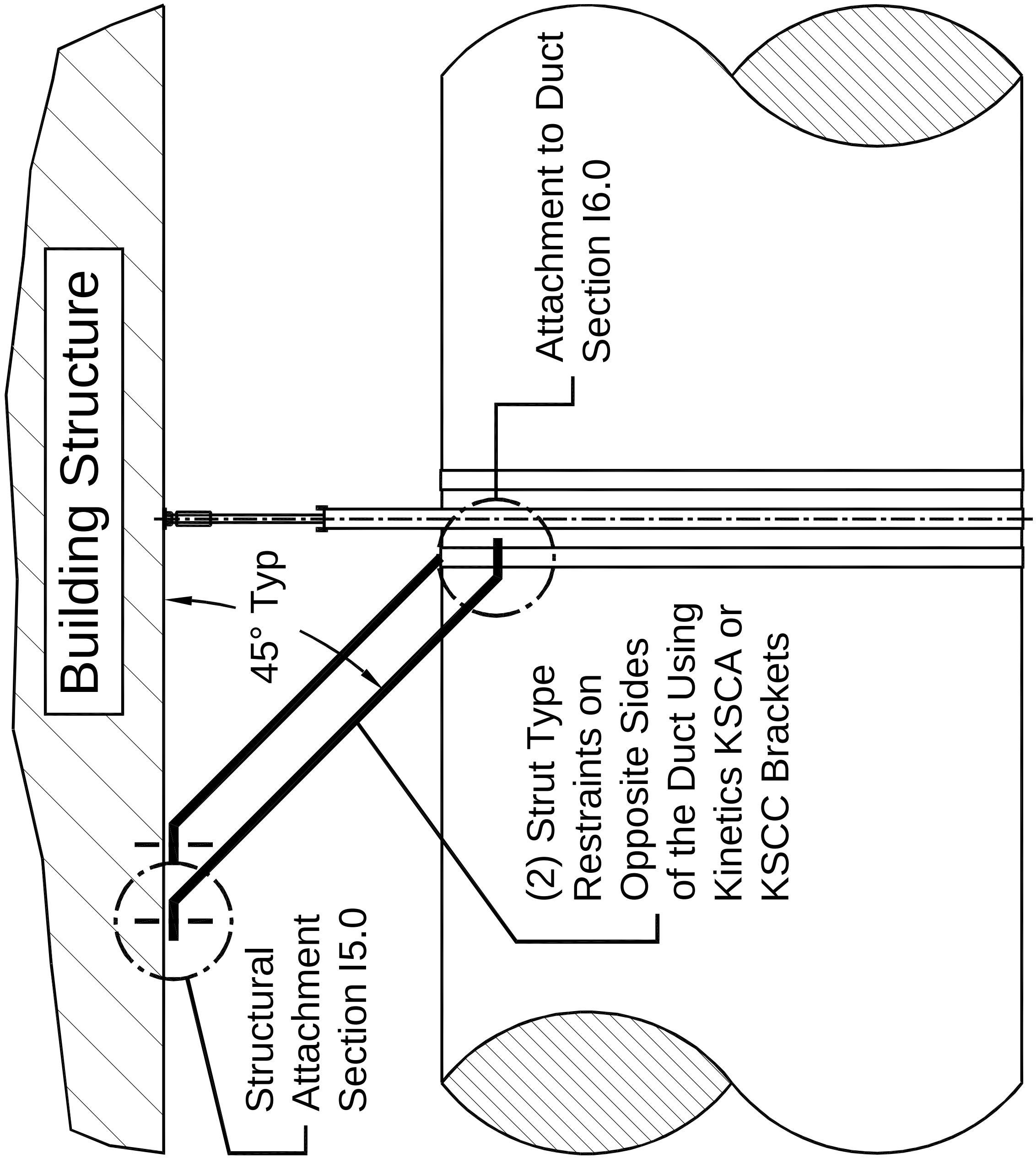

Figure I7-76; Longitudinal (L) Strut Type Restraint Schematic for Round Duct Supported by One Hanger Rod – One Restraint on each Side of the Duct ,Adjacent to the Hanger Rod, and Attached to Band Clamps

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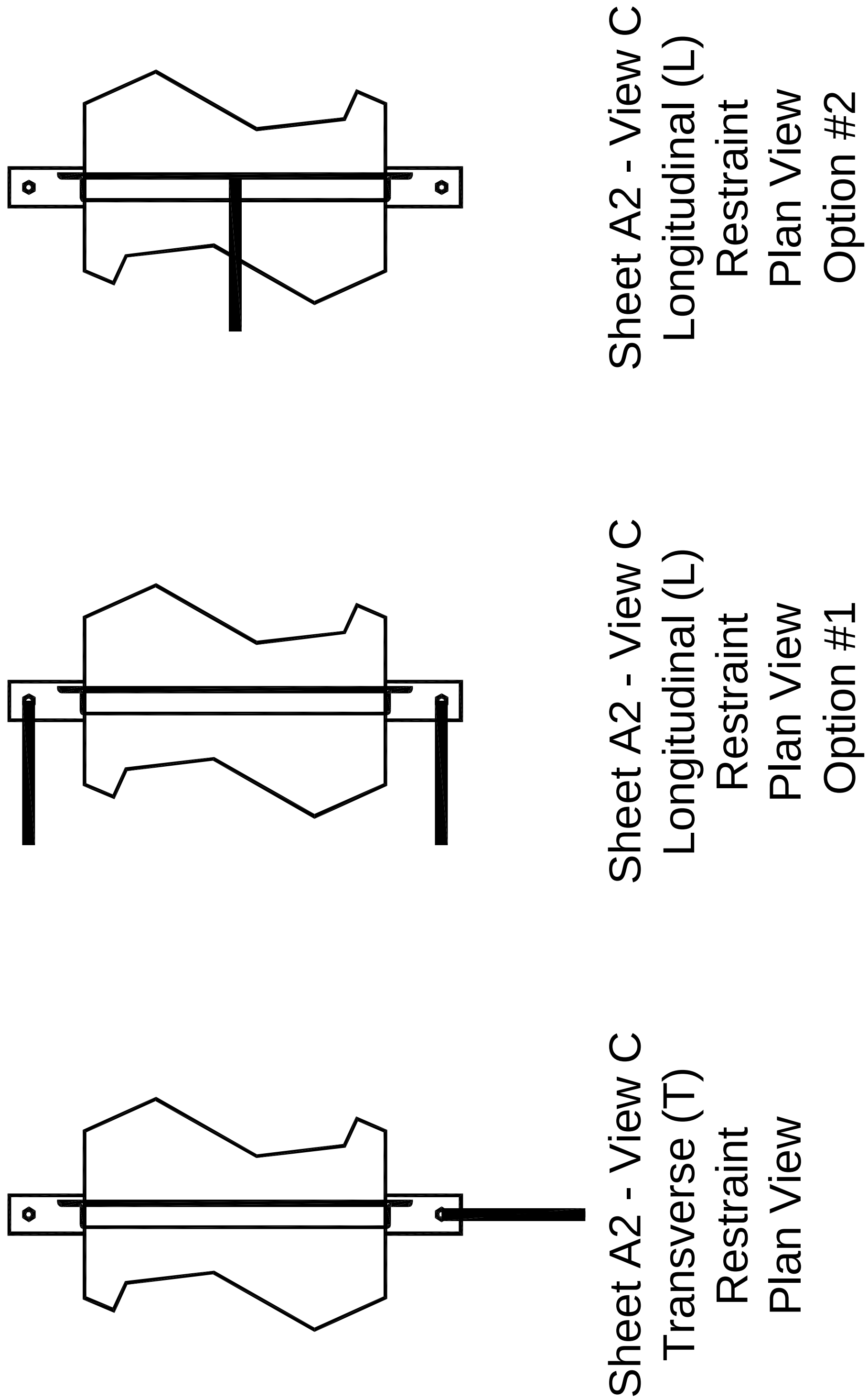

Figure I7-77; Transverse (T) and Longitudinal (L) Basic Plan View Restraint Arrangements for Duct Being Restrained with Strut Type Restraints – Note: The Longitudinal (L) Restraint Cables in Longitudinal Restraint Options #1 & #2 are Arranged to Prevent Twisting of the Duct

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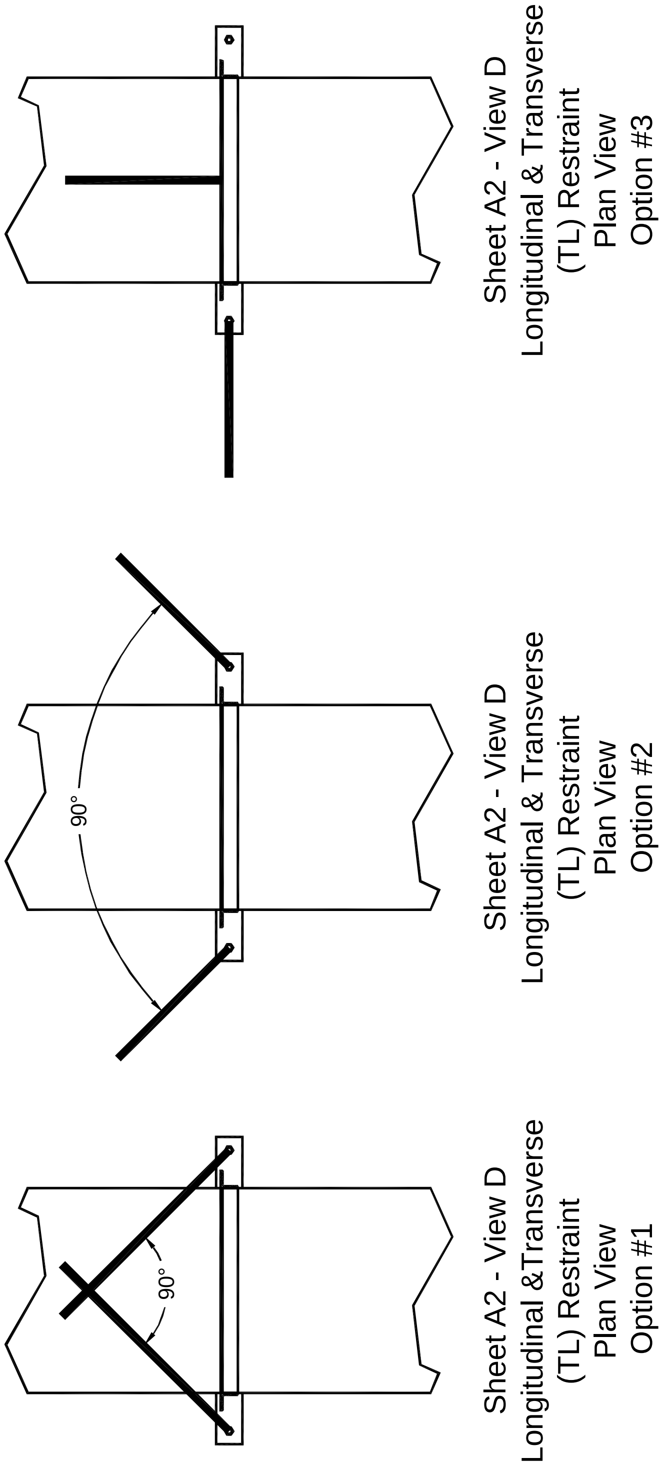

Figure I7-78; Combined Transverse & Longitudinal (TL) Basic Plan View Restraint Arrangements for Duct Being Restrained with Strut Type Restraints – Note: The Restraint Cables in Options #1, #2, & #3 are Arranged to Prevent Twisting of the Duct

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I7.10 – Strut Restraint Schematics for Floor/Roof Mounted Pipe:

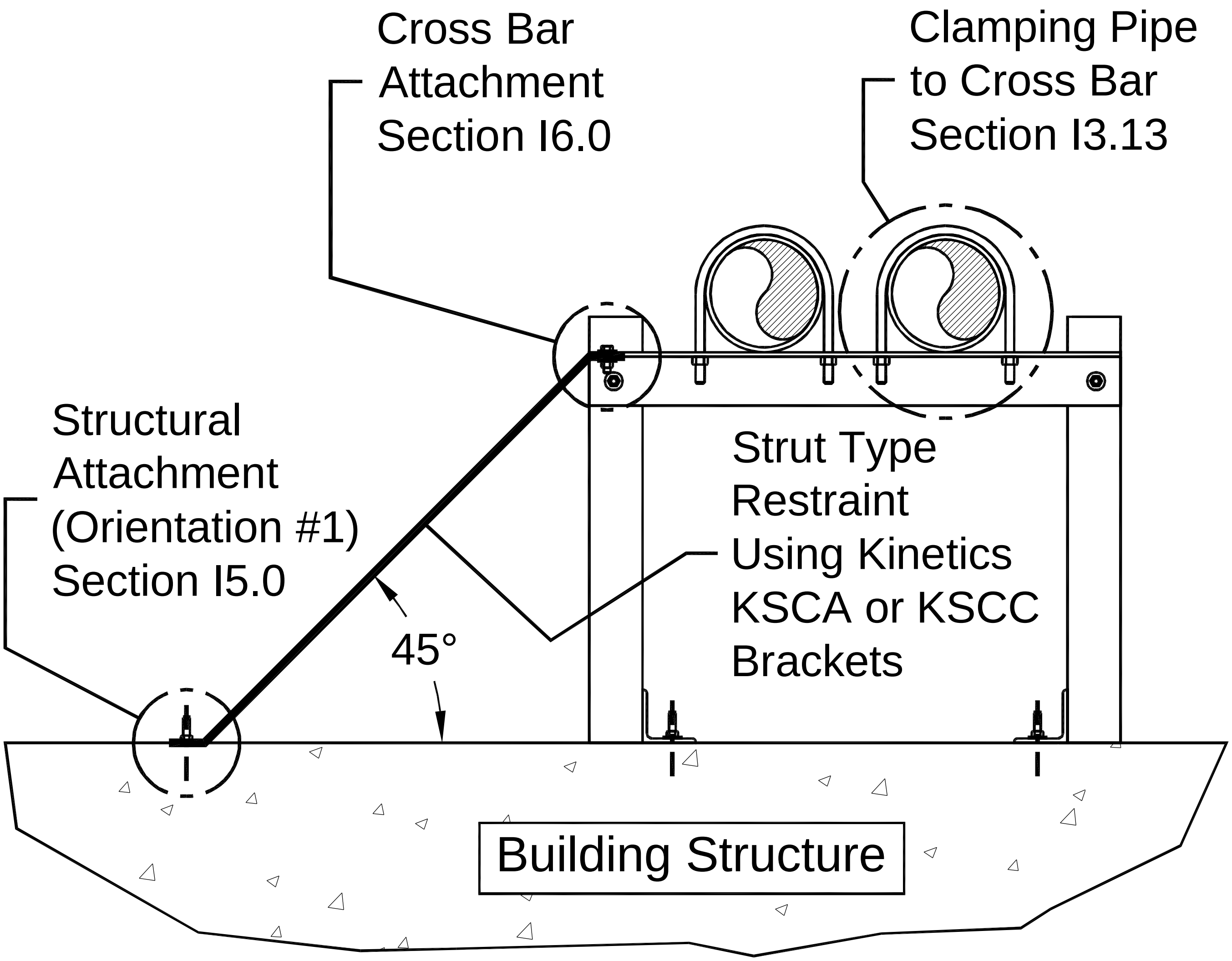

Figure I7-79; Transverse (T) Strut Type Restraint Schematic for Floor/Roof Mounted Pipe – Side Strut at a 45° Angle

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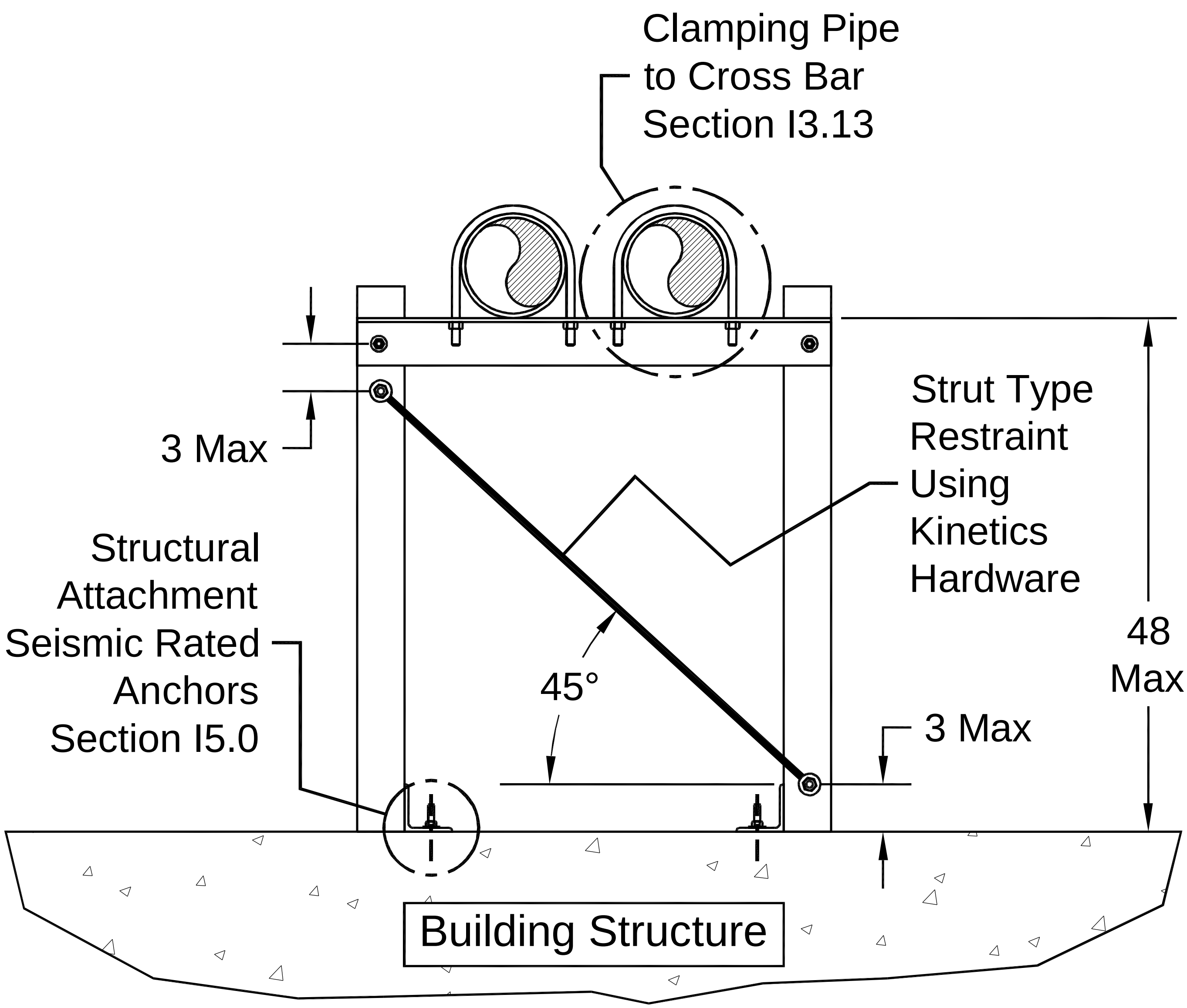

Figure I7-80; Transverse (T) Strut Type Restraint Schematic for Floor/Roof Mounted Pipe – Cross Brace Strut at a 45° Angle

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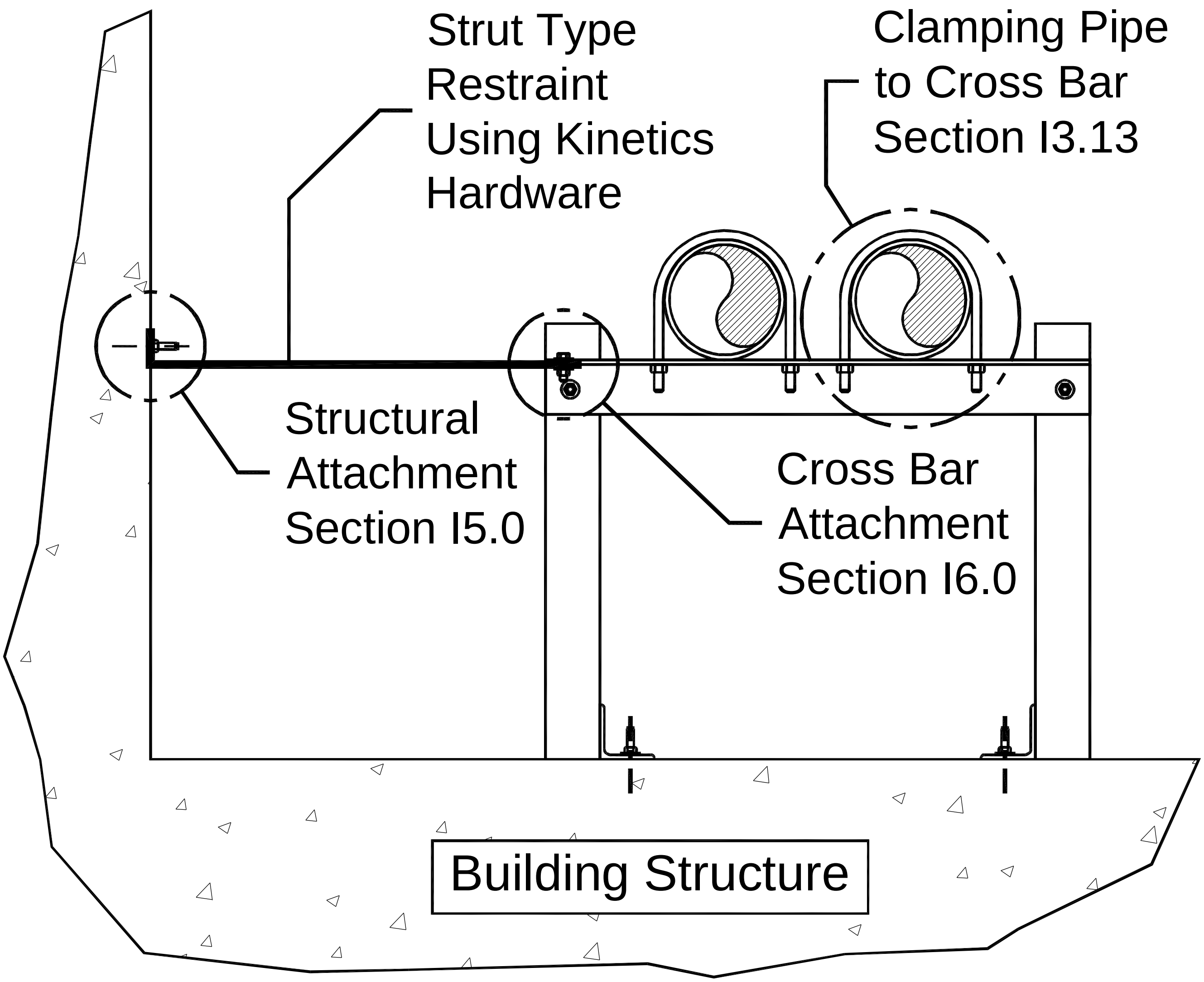

Figure I7-81; Transverse (T) Strut Type Restraint Schematic for Floor/Roof Mounted Pipe – Horizontal Strut

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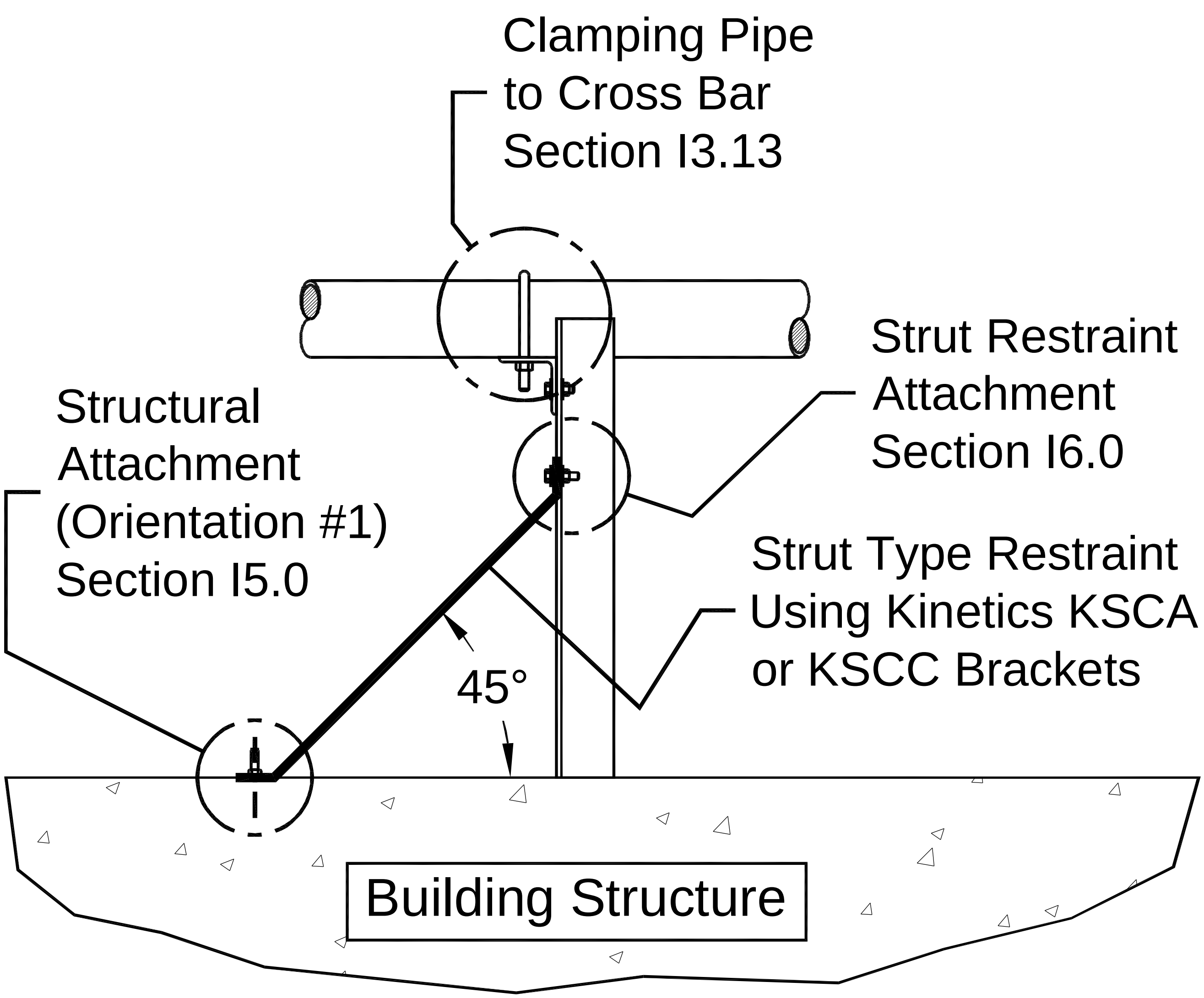

Figure I7-82; Longitudinal (L) Strut Type Restraint Schematic for Floor/Roof Mounted Pipe – Strut Attached to the Floor Stand or Support at a 45° Angle

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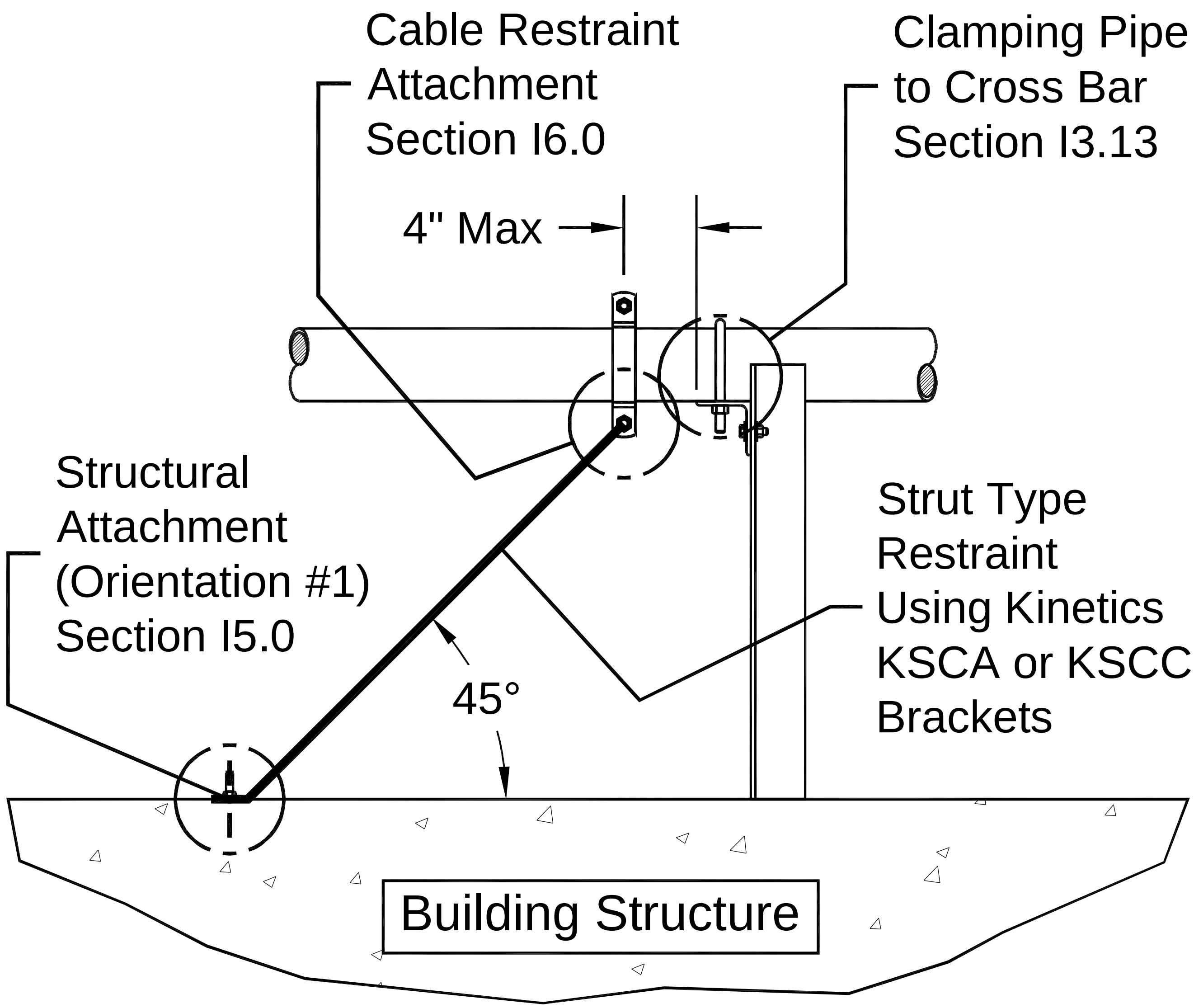

Figure I7-83; Longitudinal (L) Strut Type Restraint Schematic for Floor/Roof Mounted Pipe – Strut Attached to the Duct at a 45° Angle

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I7.11 – Strut Restraint Schematics for Floor/Roof Mounted Duct:

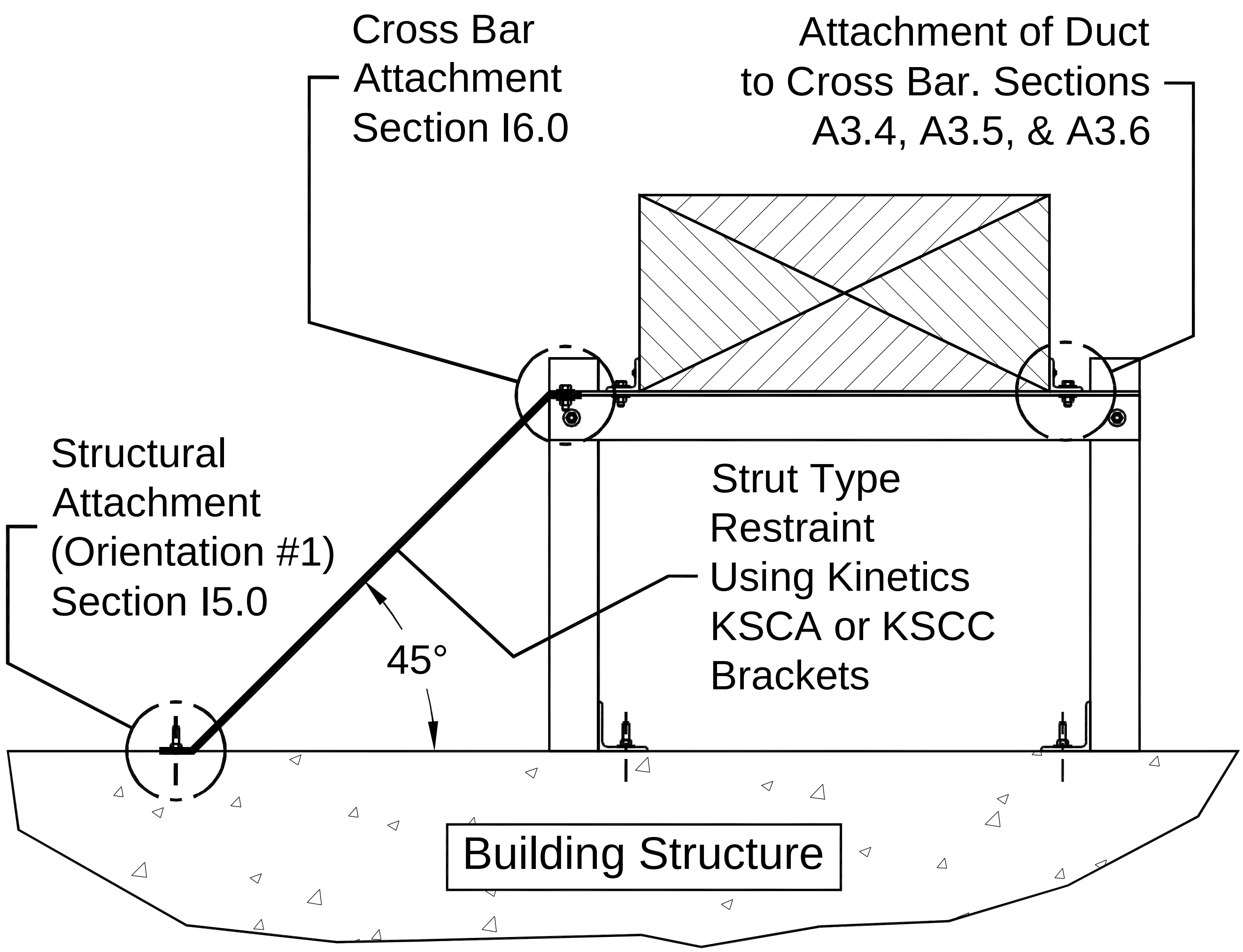

Figure I7-84; Transverse (T) Strut Type Restraint Schematic for Floor/Roof Mounted Duct – Side Strut at a 45° Angle

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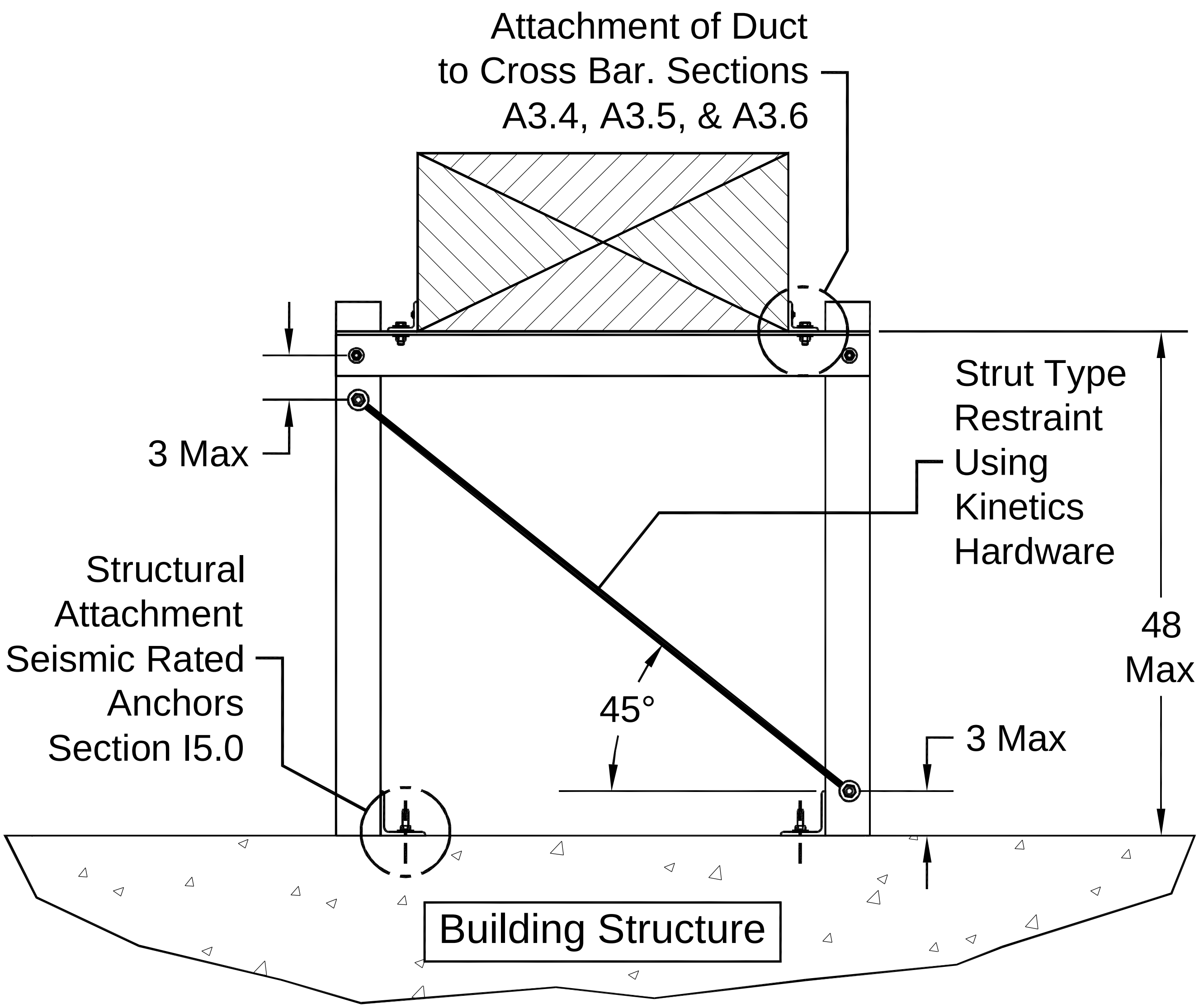

Figure I7- 85; Transverse (T) Strut Type Restraint Schematic for Floor/Roof Mounted Duct – Cross Brace Strut at a 45° Angle

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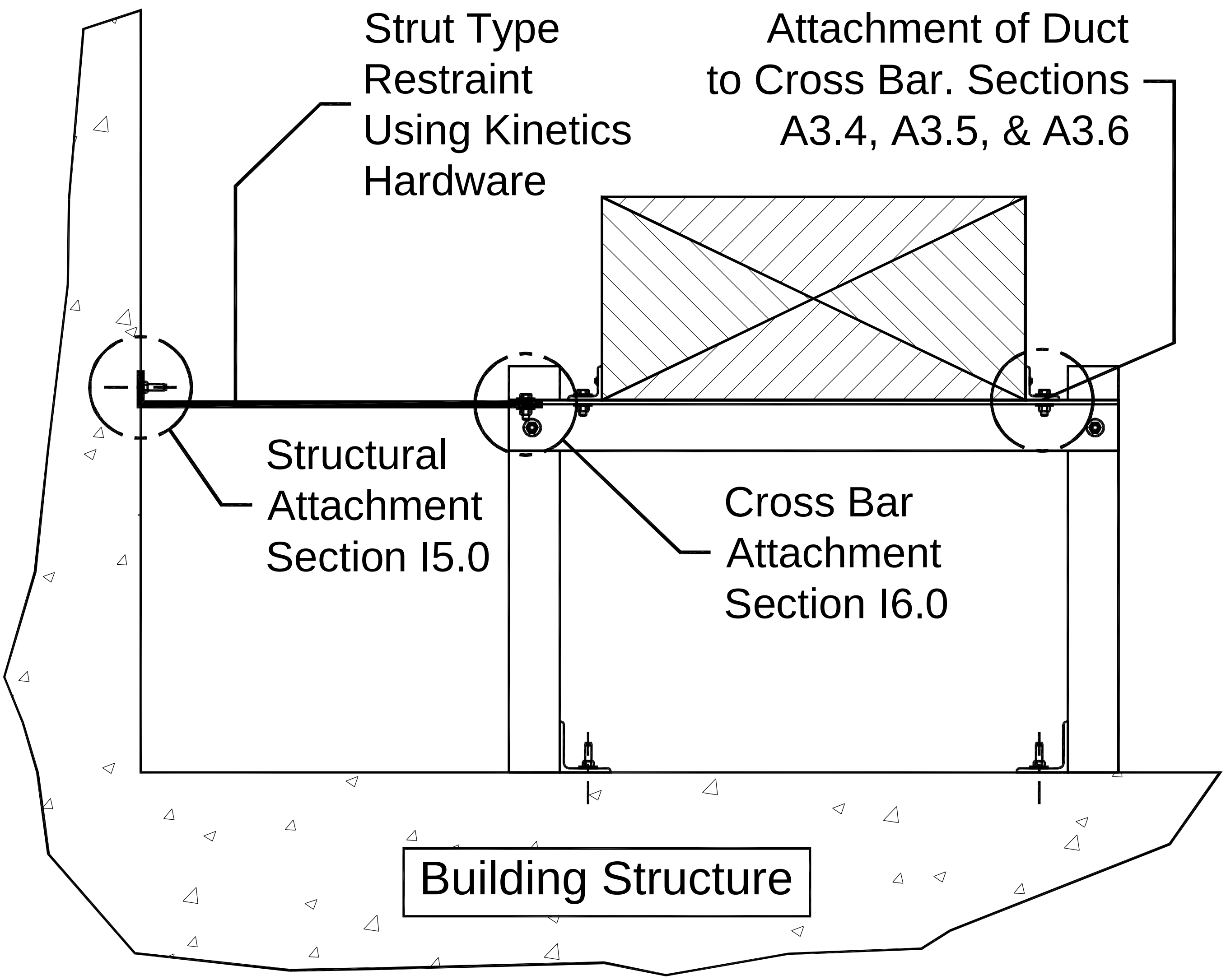

Figure I7-86; Transverse (T) Strut Type Restraint Schematic for Floor/Roof Mounted Duct – Horizontal Strut

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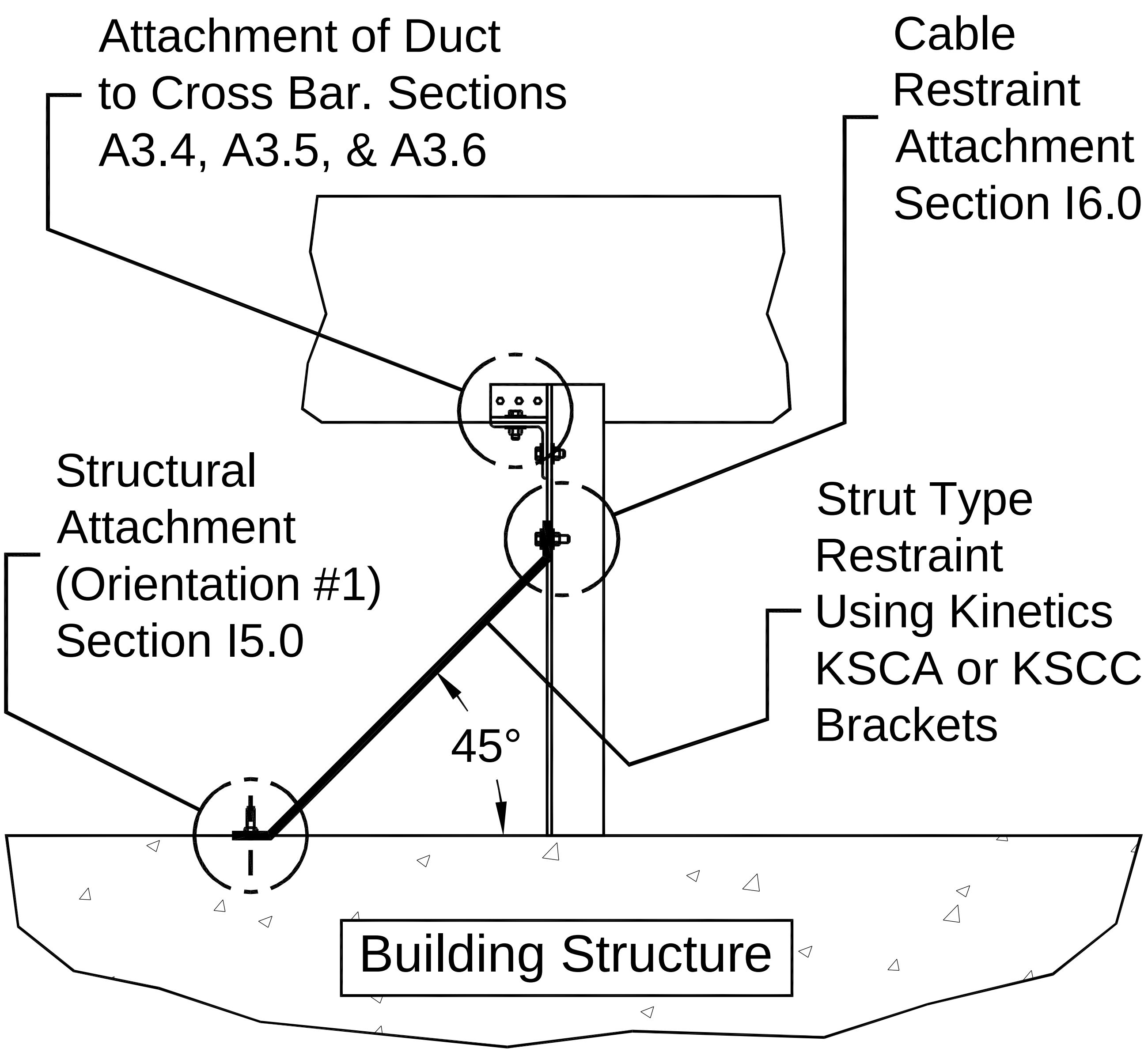

Figure I7-87; Longitudinal (L) Strut Type Restraint Schematic for Floor/Roof Mounted Duct – Strut Attached to the Floor Stand or Support at a 45° Angle

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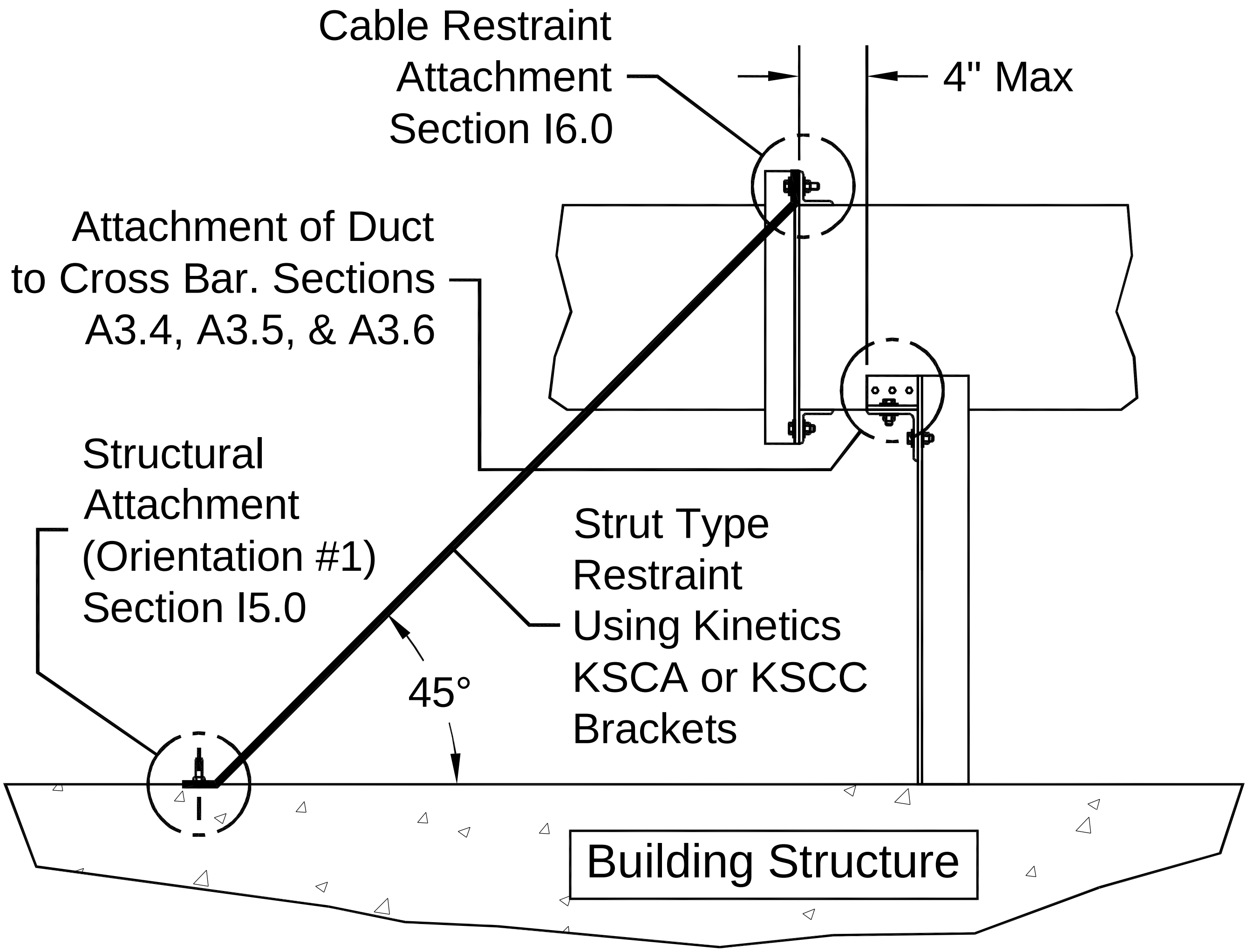

Figure I7-88; Longitudinal (L) Strut Type Restraint Schematic for Floor/Roof Mounted Duct – Strut Attached to the Duct at a 45° Angle

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I7.12 – Summary:

When using strut type restraints instead of cable restraints, it is very important to remember the following items.

1.) One strut type restraint will replace a pair of cable restraints.
2.) Strut type restraints increase the tensile loads on the hanger rods beyond the dead weight of the pipe or duct. ***Hanger rods and hanger attachments to structure may need to be changed!***
3.) When using Kinetics KSCA or KSCC brackets, the strut type restraints must be installed at a 45° angle measured from the horizontal.
4.) If ***one restraint location*** on a run of pipe or duct needs to be a strut type restraint, ***all of the restraints will need to be strut type restraints!***
5.) Help in selecting and evaluating strut sizes, hanger rod s, anchorage, and etc. may be found at www.kineticsnoise.com.

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HANGER ROD STIFFENERS – WHY, WHEN, & HOW

I8.1 – Why are Rod Stiffeners Needed?

Hanger rod stiffeners are used to prevent the buckling of the hanger rods under the compressive reaction loads during an earthquake. Buckling is very difficult to predict, and depends on many factors such as, hanger rod length, hanger rod size, the dead load carried by the hanger rod, the horizontal seismic forces applied to the pipe or duct, and the seismic restraint installation angle. Buckling is also a very dangerous type of failure. It occurs in long slender structural members under compressive load, and it occurs at loads far less than those required to yield the material in the structural member.

It is impractical for the installing contractor to be able to perform the calculations needed to determine if rod stiffeners are required, and to select the proper stiffener element. This section will provide the contractor with some basic tools that can be used to visually determine the need for rod stiffeners. Then the matter can be referred to the engineer of record for the system to have the proper calculations done using the on-line web tools provided by Kinetics Noise Control.

I8.2 – When are Rod Stiffeners Needed?

1. For Seismic Design Categories A & B no seismic restraints, and thus, no rod stiffeners are required for pipe and duct.
2. For Seismic Design Categories C & D, and cable/strut installation angles no greater than 45° as measured from the horizontal, use Tables I8.1 through I8.12. In these tables, N.S.R. means that no rod stiffener is required for the specified hanger rod size and restraint spacing. For all other cases the maximum Unstiffened, or critical, hanger rod length is given for single hanger rod supported pipe & duct, and for trapeze bar supported pipe and duct.
3. For Seismic Design Categories C & D, seismic restraint installation angles greater than 45° as measured from the horizontal, and or Hanger spacings less than 10′, assume that rod stiffeners will be required.

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4. For Seismic Design Categories E & F rod stiffeners will be required for almost all cases, consult with the engineer of record.

Table I8-1; Maximum Unstiffened Hanger Rod Length for Pipe & Duct, Seismic Design Category C, Hanger Spacing is 10′, Restraint Spacing is 10′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	N.S.R.	N.S.R.
1/2	13	N.S.R.	N.S.R.
5/8	23	N.S.R.	N.S.R.
3/4	50	N.S.R.	N.S.R.
7/8	99	N.S.R.	N.S.R.
1	172	N.S.R.	N.S.R.
1 1/4	410	N.S.R.	N.S.R.

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Table I8-2; Maximum Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category C, Hanger Spacing is 10′, Restraint Spacing is 20′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	N.S.R.	34
1/2	13	N.S.R.	39
5/8	23	N.S.R.	47
3/4	50	N.S.R.	48
7/8	99	N.S.R.	48
1	172	N.S.R.	47
1 1/4	410	N.S.R.	49

Table I8-3; Maximum Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category C, Hanger Spacing is 10′, Restraint Spacing is 30′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	N.S.R.	19
1/2	13	N.S.R.	22
5/8	23	N.S.R.	27
3/4	50	N.S.R.	27
7/8	99	N.S.R.	27
1	172	N.S.R.	27
1 1/4	410	N.S.R.	28

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Table I8-4; Maximum Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category C, Hanger Spacing is 10′, Restraint Spacing is 40′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	34	15
1/2	13	39	17
5/8	23	47	21
3/4	50	48	21
7/8	99	48	21
1	172	47	21
1 1/4	410	49	22

Table I8-5; Maximum Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category C, Hanger Spacing is 10′, Restraint Spacing is 60′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	19	11
1/2	13	22	12
5/8	23	27	15
3/4	50	27	15
7/8	99	27	15
1	172	27	15
1 1/4	410	28	16

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Table I8-6; Maximum Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category C, Hanger Spacing is 10′, Restraint Spacing is 80′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	15	9
1/2	13	17	10
5/8	23	21	13
3/4	50	21	13
7/8	99	21	13
1	172	21	13
1 1/4	410	22	13

Table I8-7; Maximum Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category D, Hanger Spacing is 10′, Restraint Spacing is 10′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	N.S.R.	N.S.R.
1/2	13	N.S.R.	N.S.R.
5/8	23	N.S.R.	N.S.R.
3/4	50	N.S.R.	N.S.R.
7/8	99	N.S.R.	N.S.R.
1	172	N.S.R.	N.S.R.
1 1/4	410	N.S.R.	N.S.R.

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Table I8-8; Maximum Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category D, Hanger Spacing is 10′, Restraint Spacing is 20′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	N.S.R.	19
1/2	13	N.S.R.	22
5/8	23	N.S.R.	27
3/4	50	N.S.R.	27
7/8	99	N.S.R.	27
1	172	N.S.R.	27
1 1/4	410	N.S.R.	28

Table I8-9; Maximum Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category D, Hanger Spacing is 10′, Restraint Spacing is 30′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	27	13
1/2	13	31	15
5/8	23	38	19
3/4	50	38	19
7/8	99	38	19
1	172	38	19
1 1/4	410	39	19

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Table I8-10; Max. Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category D, Hanger Spacing is 10′, Restraint Spacing is 40′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	19	11
1/2	13	22	12
5/8	23	27	15
3/4	50	27	15
7/8	99	27	15
1	172	27	15
1 1/4	410	28	16

Table I8-11; Max. Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category D, Hanger Spacing is 10′, Restraint Spacing is 60′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	13	8
1/2	13	15	9
5/8	23	19	12
3/4	50	19	12
7/8	99	19	12
1	172	19	12
1 1/4	410	19	12

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Table I8-12; Max. Unstiffened Hanger Rod Length for Pipe & Duct – Seismic Design Category D, Hanger Spacing is 10′, Restraint Spacing is 80′, and Restraint Installation Angle is 45°

N.S.R. = No Stiffener Required

Hanger Rod Size (in)	Distributed Weight per Hanger Rod (lb/ft)	Critical Hanger Rod Length for Single Hanger Support (in)	Critical Hanger Rod Length for Trapeze Bar Support (in)
3/8	5	11	7
1/2	13	12	8
5/8	23	15	10
3/4	50	15	10
7/8	99	15	10
1	172	15	10
1 1/4	410	16	10

I8.3 – How are Rod Stiffeners Selected and Installed?

The sizing of the rod stiffeners may be accomplished using the techniques outlined in Section S8.0 and Appendices A5.1 through A5.8 of this manual. Section S8.7 outlines the requirements and procedure for using the on-line web Rod Stiffener program provided by Kinetics Noise Control. Sizing rod stiffeners is not a task that should be attempted by the installing contractor in the field, and should be performed by a qualified design professional. The following basic rules will help to determine the need for rod stiffeners.

1. Rod stiffeners only need to be used on hanger rods that carry the reaction loads from seismic restraints.
2. When determining the requirements for rod stiffeners, consider both the transverse (T) and Longitudinal (L) restraints on the run of pipe or duct. Remember, the longitudinal (L) restraints are typically spaced further apart than the transverse (T) restraints and could

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require rod stiffeners when the transverse (T) restraints did not, or require larger rod stiffeners when the transverse (T) restraints also required rod stiffeners.

3. Where hanger rods carry the loads from both Transverse (T) and Longitudinal (L) seismic restraints, the rod stiffeners need to be sized to carry only the reaction loads from the more severe case.

Kinetics Noise Control has designed a series of clamps that are used with standard rolled structural angle to create a rod stiffener system, which are shown in Figure I8-1. The model KHRC-B clamp has been designed to work with hanger rods from 3/8″ to 1-1/8″ in diameter. The model KHRC-C clamp is for use with hanger rods from 3/8″ to 1-1/8″ in diameter. Table I8-13 shows the rolled structural angles recommended for use as rod stiffeners by Kinetics Noise Control, and the model KHRC stiffener clamps to be used with each angle size. The analysis outlined in Section S8.0, and Appendix A5.1, or the on-line web based Rod Stiffener program will indicate which angle and clamp are to be used and how many clamps will be required to properly stiffen the hanger rod.

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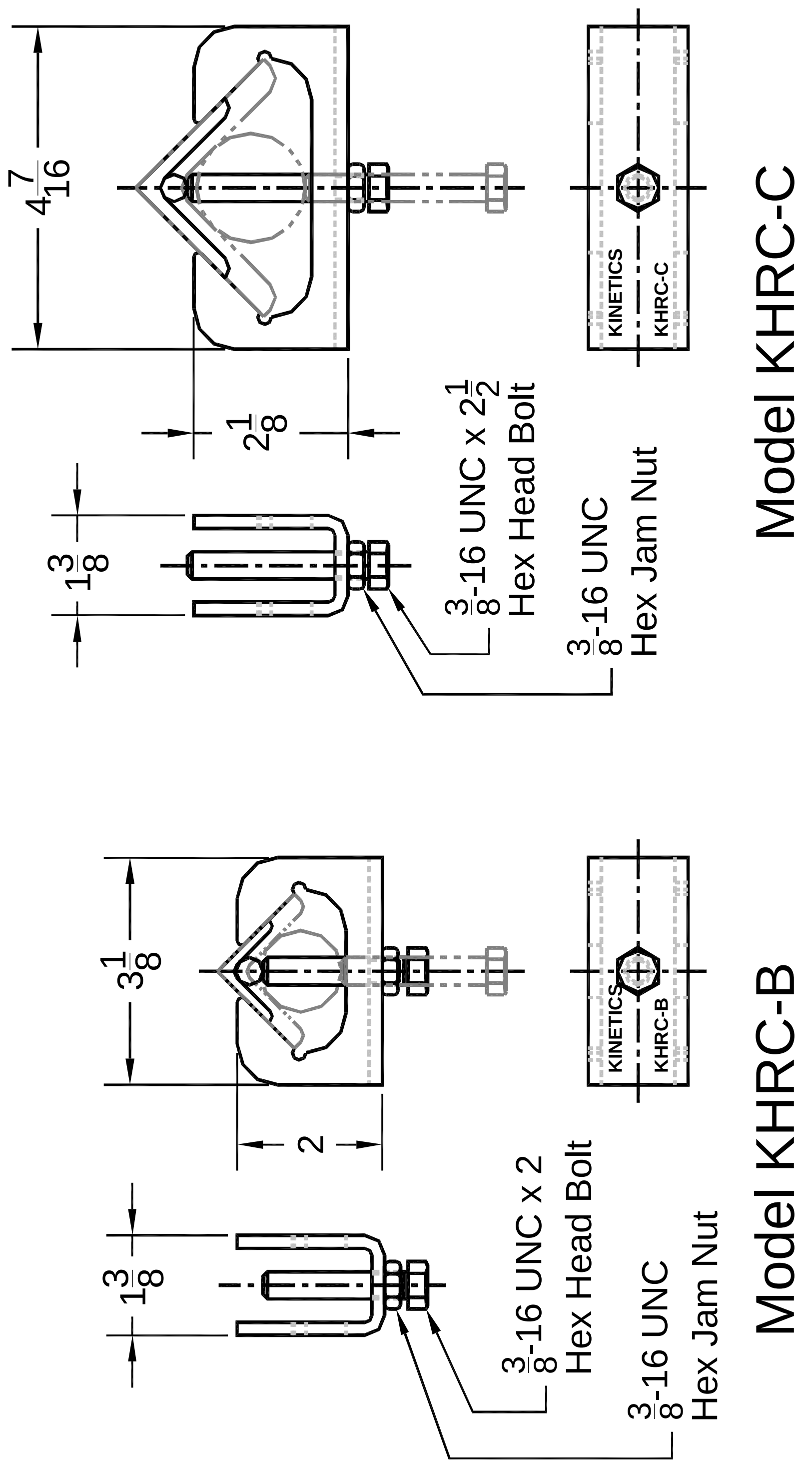

Figure I8-1; Kinetics Noise Control Model KHRC Rod Stiffener Clamps for Use with Rolled Structural Angle

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Table I8-13; Rod Stiffener Angle Code Designation and Model KHRC Rod Stiffener Clamps

Rod Stiffener Code	AISI Angle Designation	Rod Stiffener Clamp Model
A	L 1 x 1 x 1/8	KHRC-B
B	L 1-1/4 x 1-1/4 x 1/4	
C	L 1-1/2 x 1-1/2 x 1/4	
D	L 1-3/4 x 1-3/4 x 1/4	KHRC-C
E	L 2 x 2 x 1/4	
F	L 2 x 2 x 3/8	
G	L 2-1/2 x 2-1/2 x 1/4	
H[2]	L 2-1/2 x 2-1/2 x 3/8	
I[2]	L 2-1/2 x 2-1/2 x 1/2	

[1] The Rod Stiffener Code is used by the Kinetics Noise Control Rod Stiffener Program streamline the specification of the rod stiffener.

[2] These rod stiffener angles may be used with the Kinetics Noise Control Model KHRC-C rod stiffener clamp. Not all hanger rod sizes may work with these arrangements. Check with Kinetics Noise Control Engineering for your particular application.

The basic installation of the rod stiffener clamps is detailed in Figure I8-2, and typical rod stiffener installations are shown in Figures I8-3 through I8-6.

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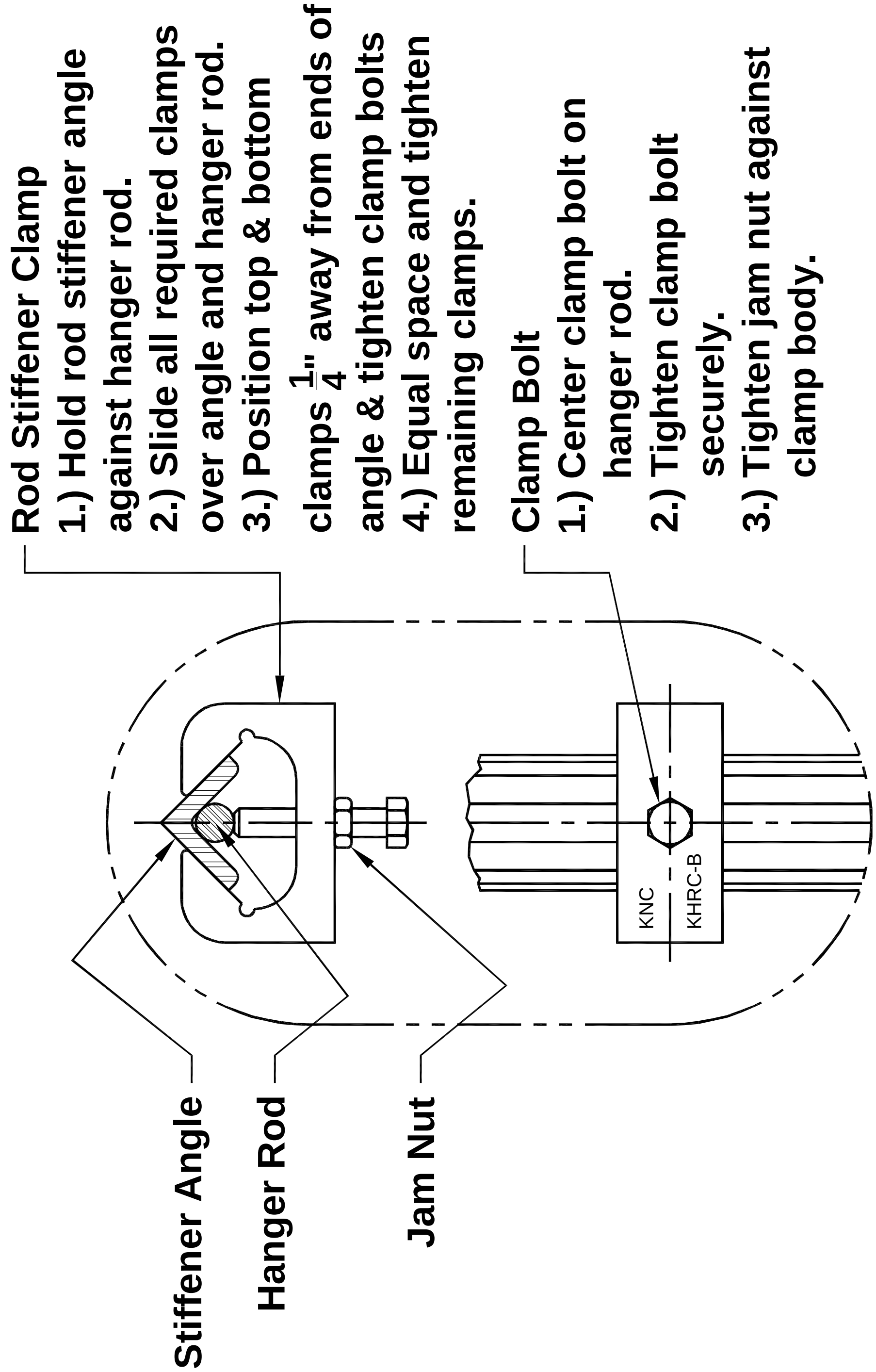

Figure I8-2; Basic Installation of Kinetics Noise Control Model KHRC Rod Stiffener Clamps

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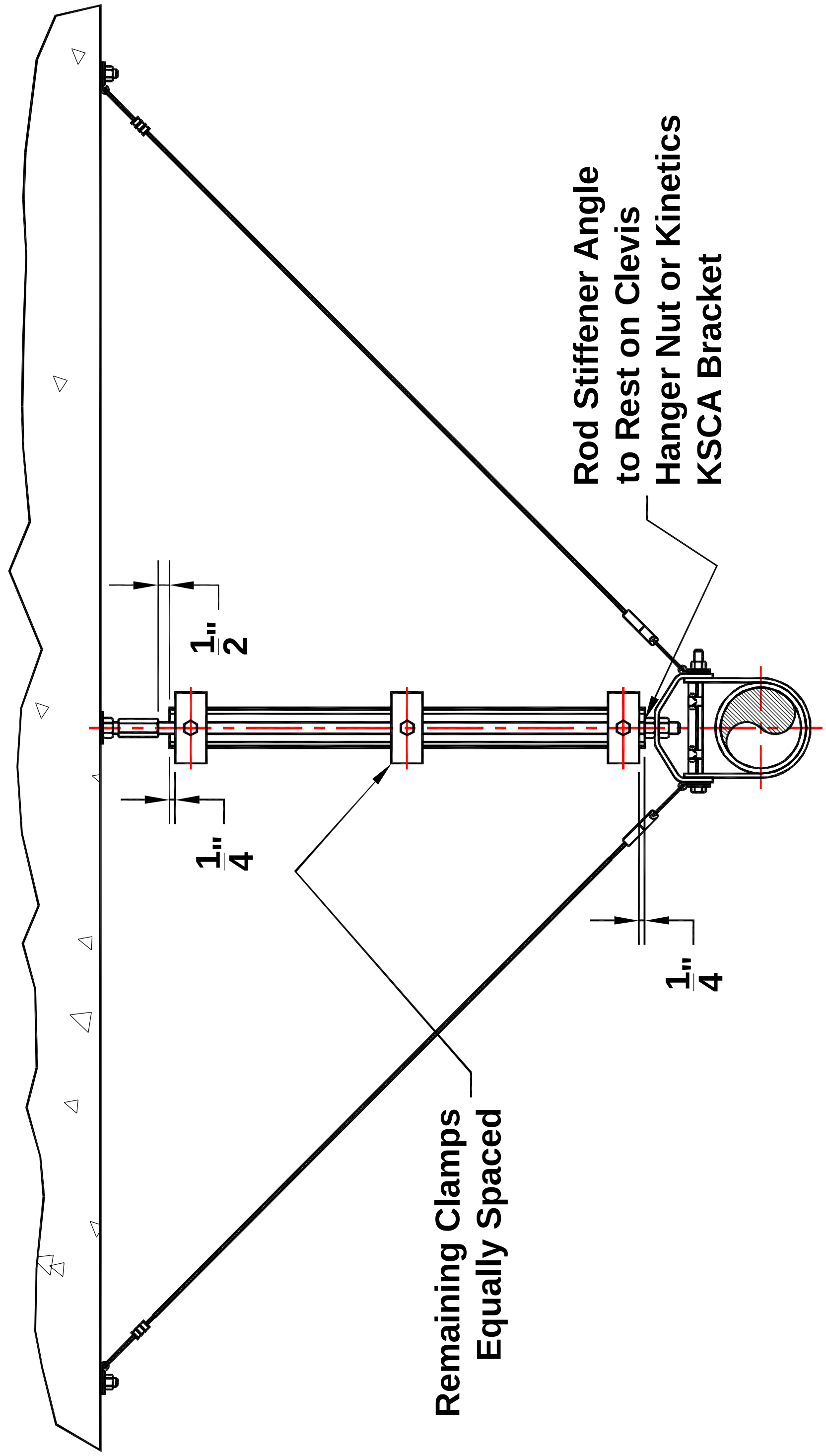

Figure I8-3; Typical Rod Stiffener Installation for Non-Isolated Single Clevis Hung Pipe

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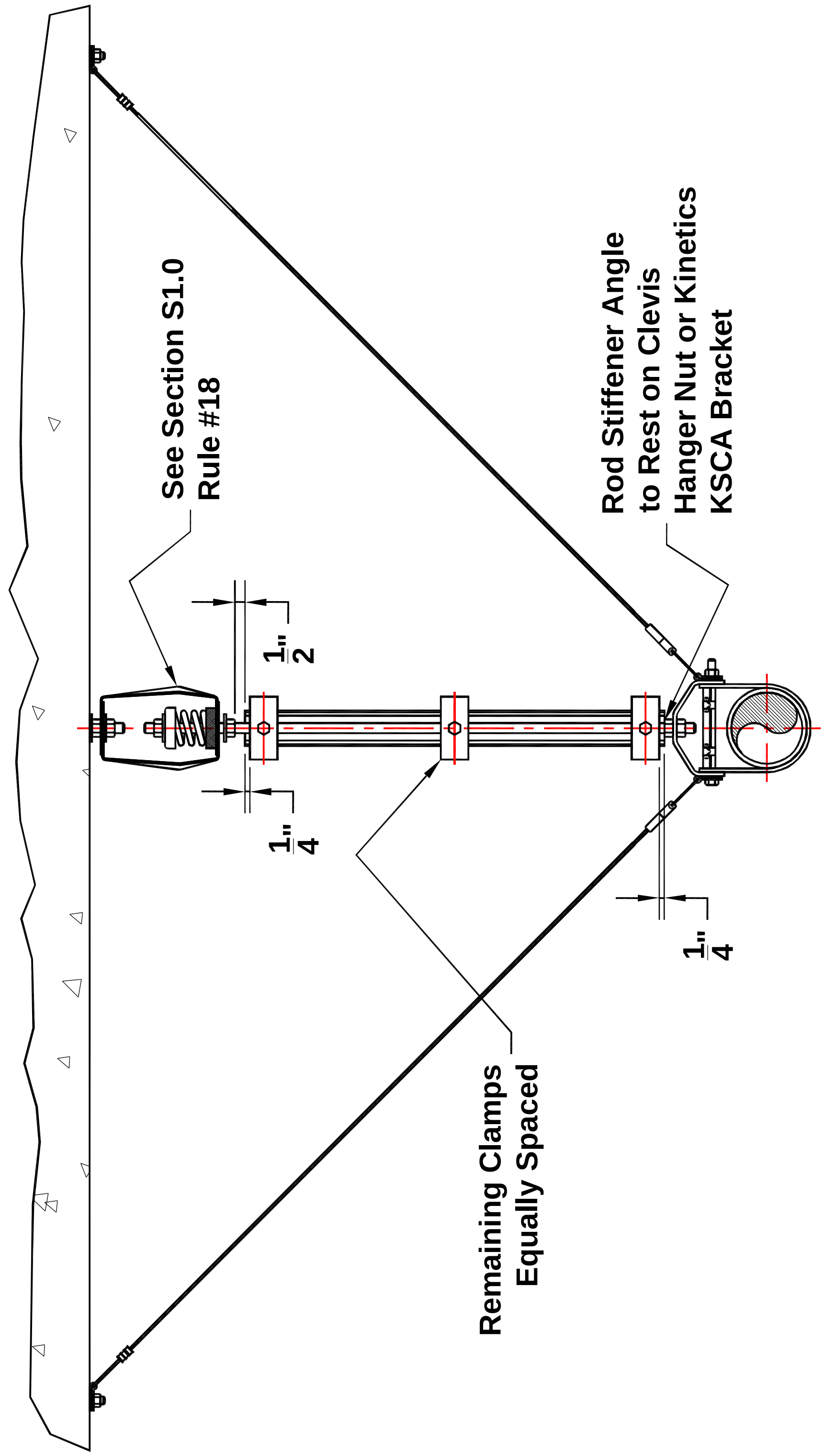

Figure I8-4; Typical Rod Stiffener Installation for Isolated Single Clevis Hung Pipe

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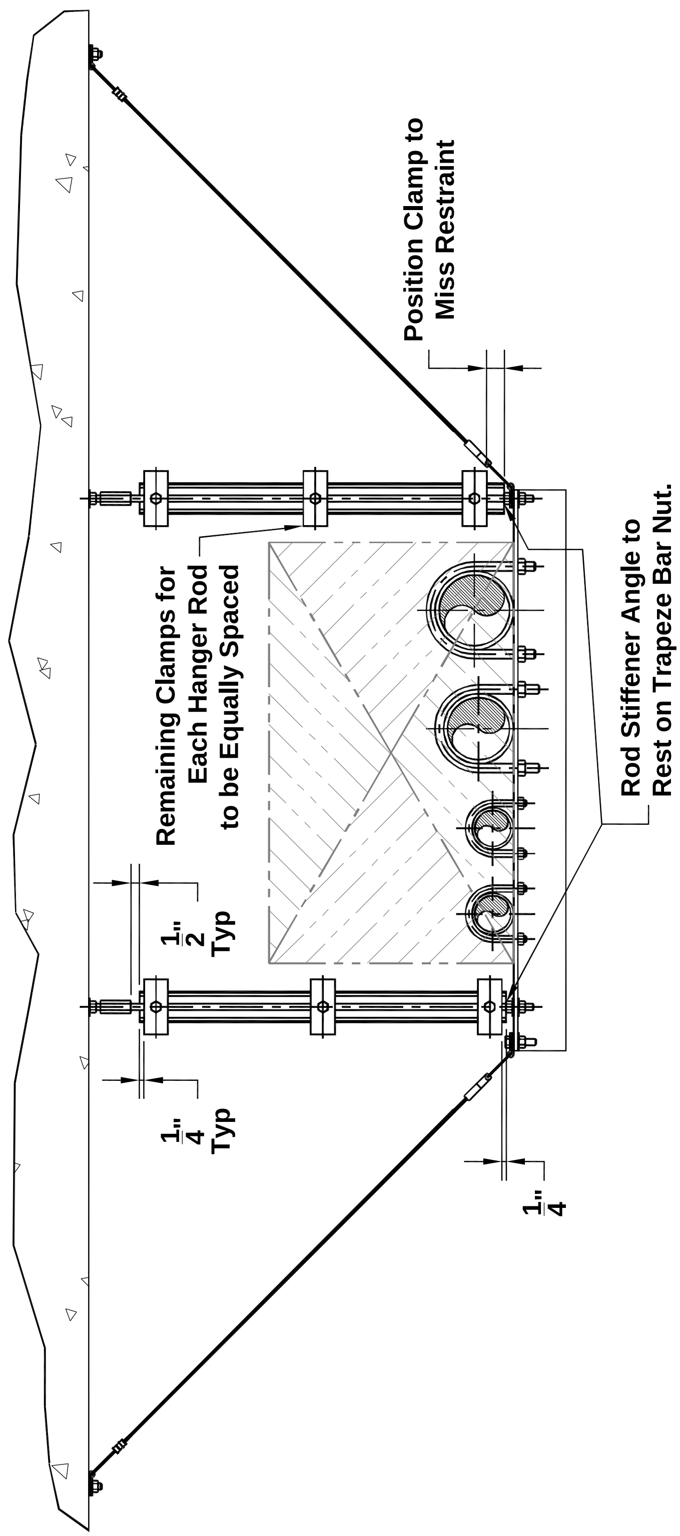

Figure I8-5; Typical Rod Stiffener Installation for Trapeze Supported Pipe & Duct – Two Rods

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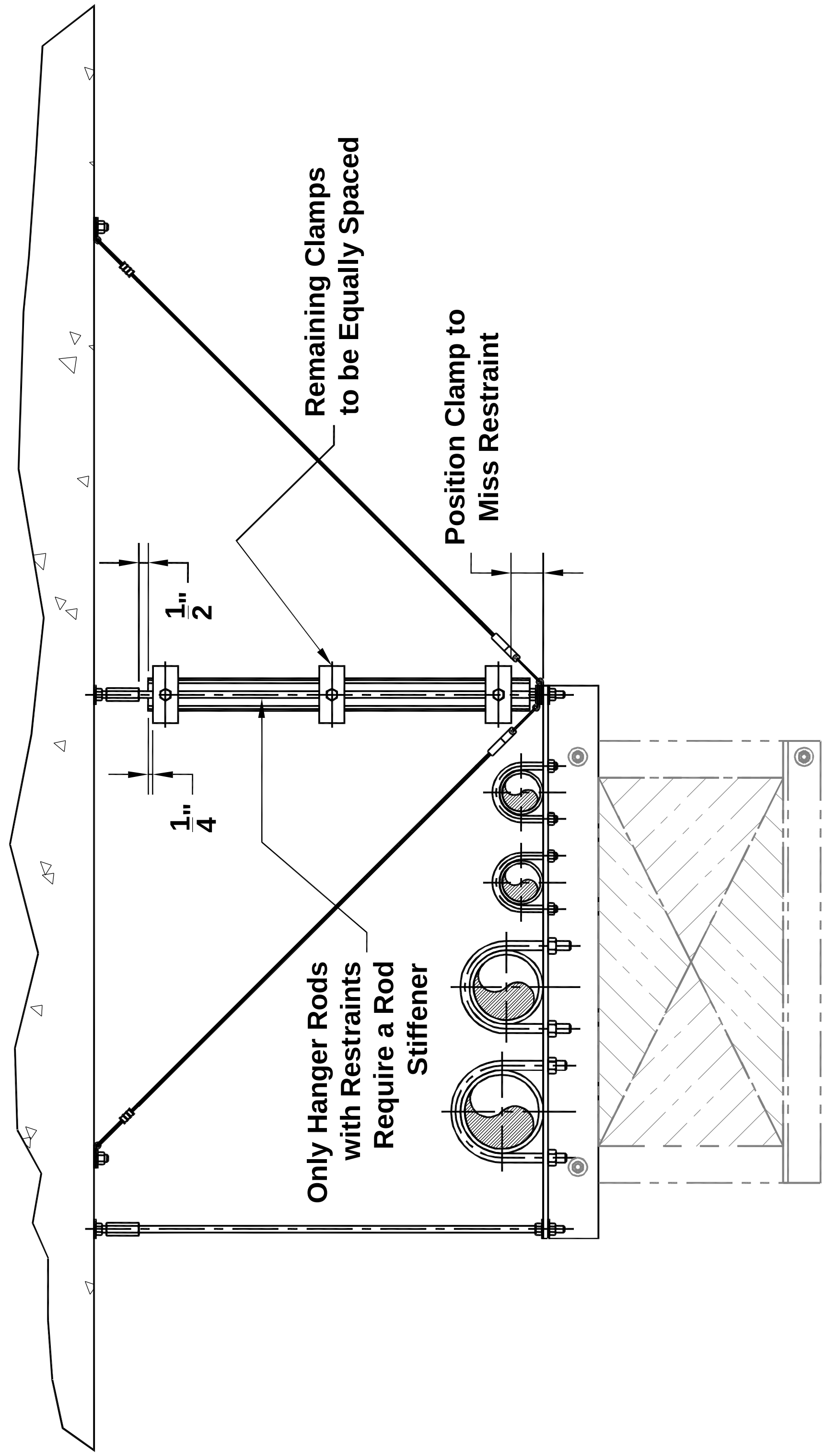

Figure I8-6; Typical Rod Stiffener Installation for Trapeze Supported Pipe & Duct – One Rod

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ELECTRICAL DISTRIBUTION SYSTEMS – CONTRACTOR SUMMARY

The seismic restraints for electrical distribution systems are applied and installed in the same basic way as are those for pipe and duct. The preceding sections in the Installation portion of this manual, Sections I1.0 through I8.0 will apply to the basic restraint installation for electrical distribution systems. There are, however, some points that will need to be considered.

1. Kinetics Noise Control restraint products are designed specifically for suspended distribution systems. The application of these products to wall mounted distribution systems is difficult. Each supported for wall mounted distribution systems should be designed, selected, and analyzed to support both the dead weight load of the distribution system, and the code based design horizontal seismic loads. This should be done by the engineer of record for the distribution system in conjunction with the structural engineer and/or the architect.
2. Sections I1.0 and I2.0 are valuable guides on the basics of seismic restraint planning and installation.
3. Single supported and trapeze supported conduit are treated exactly like single clevis supported and trapeze supported pipe. See Sections I3.0 and I6.0 of this manual for examples of restraint schematics and attachments to hangers and trapeze bars.
4. Trapeze supported bus ducts and cable trays are restrained in a manner similar to duct. See Sections I4.0 and I6.0 of this manual for examples of restraint schematics and attachments to trapeze bars.
5. The structural attachment end of the restraints for conduit, bus ducts, and cable trays is treated exactly like that for pipe and duct. See Section I5.0 of this manual for examples of structural attachments for Kinetics' products.
6. There will be occasions when cable type restraints can not be used due to the close proximity of a wall, or another object. In situations like these, strut type restraints can also be used with conduit, bus ducts, and cable trays. See Section I7.0 of this manual for selecting and applying strut type restraints.

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7. For "long" – small diameter hanger rods, hanger rod stiffeners may be required as they are for pipe and duct. See Section I8.0 of this manual for the use and installation of hanger rod stiffeners.
8. For cable trays – the cables in the trays should be strapped or clamped to the cable trays at a spacing not to exceed one half of the hanger spacing. This will make sure that the seismic loads are evenly distributed to the restraint locations.
9. Cable trays must be properly attached to the trapeze bars with seismic restraints. See Appendices A3.4 and A3.6 for hardware sizes and quantities required to resist seismic loads, and see Appendix A3.5 for weld sizes and lengths required to resist seismic loads.
10. Not all suspended cable trays are supported by trapeze bars. For those which are not supported by trapeze bars contact the manufacturer of the cable tray for the details required to attach seismic restraints to the cable trays.

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KSCU & KSCC SEISMIC RESTRAINT CABLE KIT CAPACITIES

MODEL KSCU RESTRAINT CABLE ASSEMBLY SPECIFICATIONS						
MODEL	**GRIPPLE** CONNECTOR TYPE	WIRE ROPE DIAMETER (mm [in.])	A (in.)	B (in.)	CABLE ASSEMBLY WORKING LOAD LIMIT @ 5:1* (lbs.)	MINIMUM CABLE ASSEMBLY SEISMIC LOAD RATING** (lbs.)
KSCU-2	HANG-FAST No. 2	2 [1/16]	0.69	1.00	100	250
KSCU-3	HANG-FAST No. 3	3 [1/8]	1.75	1.00	200	500
KSCU-4	HANG-FAST No. 4	5 [3/16]	1.88	1.00	495	1,238
KSCU-5	LOCKABLE 6 mm	6 [1/4]	1.81	1.00	1,100	2,750

* Published **GRIPPLE** load rating for suspended overhead components.

** Minimum Cable Assembly Seismic Load Rating is one half of five times the Working Load Limit.

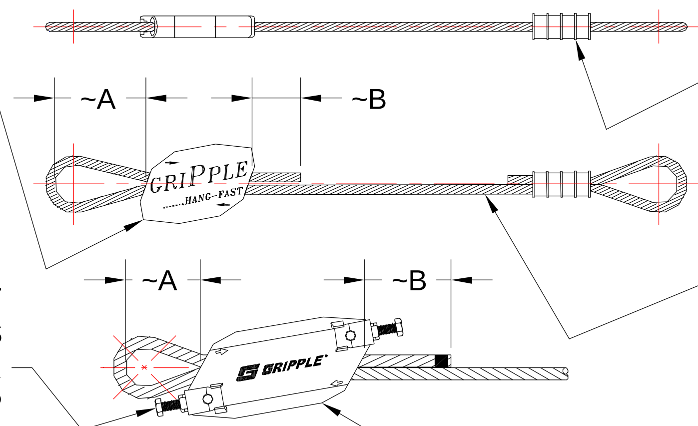

Figure A1.1-1; Model KSCU Restraint Cable Specifications

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MODEL KSCC RESTRAINT CABLE ASSEMBLY SPECIFICATIONS											
MODEL	WIRE ROPE DIAMETER A (in.)	NUMBER OF STRANDS	WIRES PER STRAND	TYPE OF CORE	CABLE TYPE	B (in.)	C (in.)	D (in.)	No. OF CLIPS PER END LOOP	MINIMUM CABLE BREAKING STRENGTH (lbs.)	MINIMUM CABLE ASSEMBLY SEISMIC TENSILE RATING (lbs.)
KSCC-250	1/4	7	19	STRAND	AIRCRAFT	7	3/4	3-3/16	3	7,000	2,625
KSCC-375	3/8	7	19	STRAND	AIRCRAFT	9-1/2	7/8	3-15/16	3	14,400	5,400
KSCC-500	1/2	6	19	IWRC	STANDARD-EIP	15-1/4	1-1/16	4-11/16	4	26,600	9,975

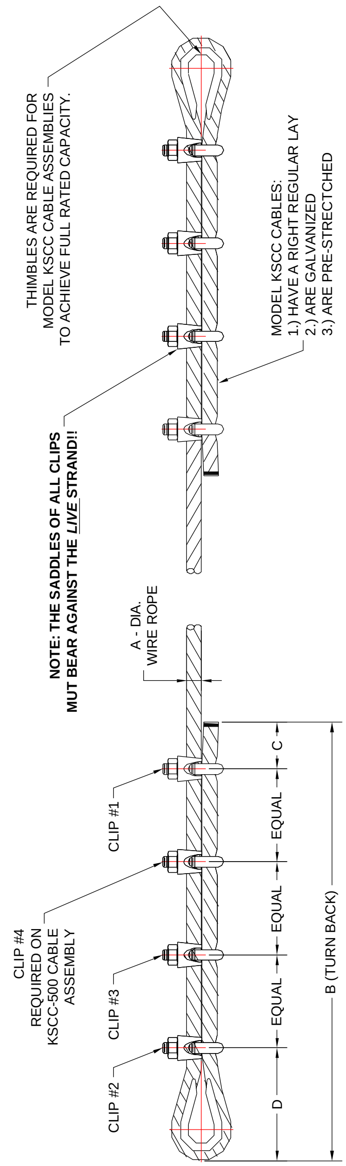

Figure A1.1-2; Model KSCC Restraint Cable Specifications

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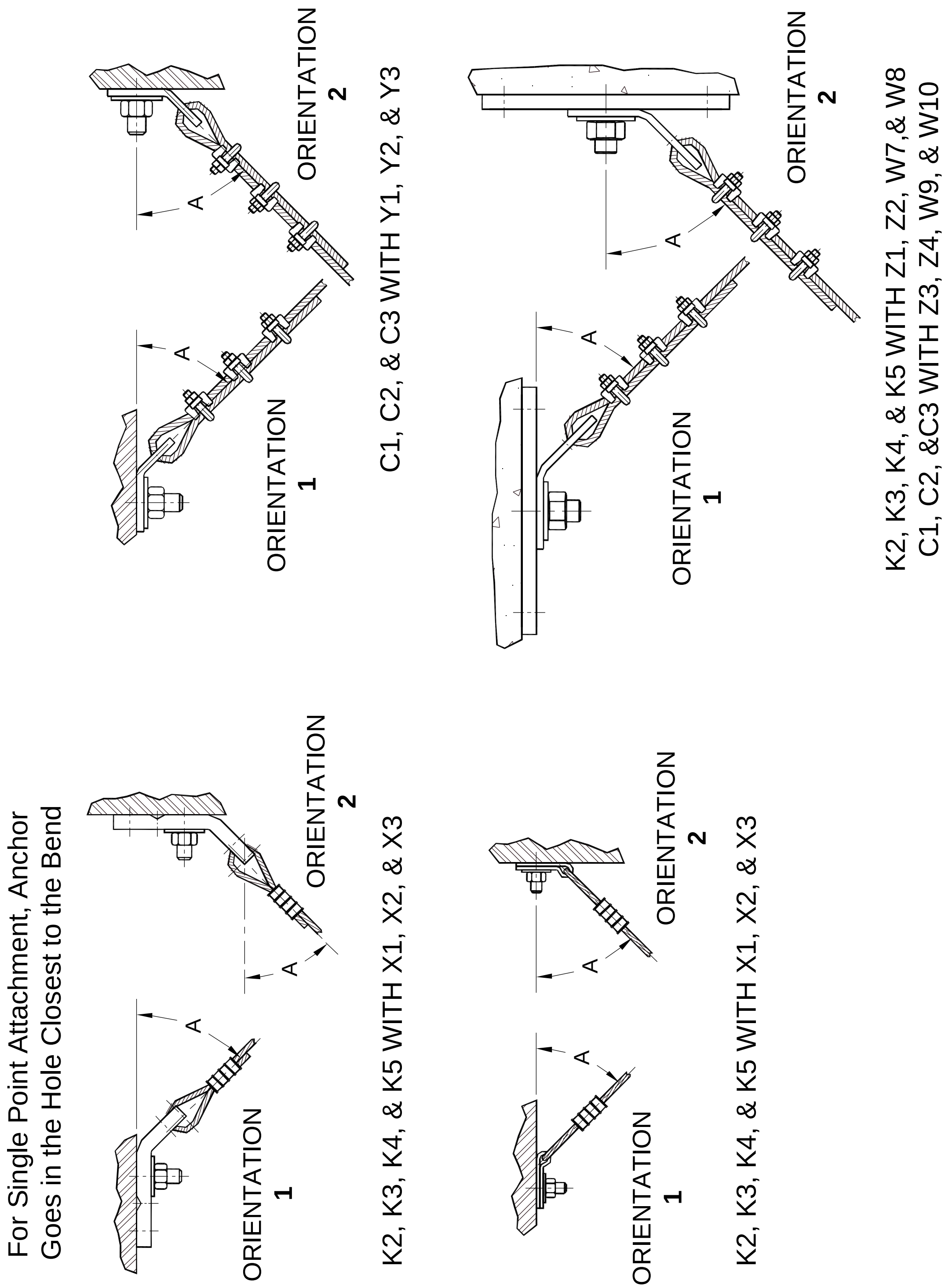

Figure A1-3; Definition of Orientation 1 and Orientation 2 for Bracket Mounting to Structure

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Table A1.1-1; KSCU & KSCC Restraint Cable Kit Capacities for Bolt to Steel Attachment – Orientation 1 (All Listed Forces Are LRFD Values)

KNC Attachment Kit Code	Maximum Cable Angle (°)	KNC Restraint Kit Code													
		K2 KSCU-2		K3 KSCU-3		K4 KSCU-4		K5 KSCU-5		C1 KSCC-250		C2 KSCC-375		C3 KSCC-500	
		Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class
X1 (1) 1/4-20 UNC A307 Bolt	45	247	---	495	---										
	60	175	---	350	---										
X2 (1) 3/8-16 UNC A307 Bolt	45	247	---	495	I	1,226	III								
	60	175	---	350	I	867	II								
X3 (1) 1/2-13 UNC A307 Bolt	45							2,717	IV						
	60							1,672	III						
Y1 (1) 5/8-11 UNC A307 Bolt	45									2,599	IV				
	60									1,838	III				
Y2 (1) 3/4-10 UNC A307 Bolt	45											5,346	V	7,996	V
	60											3,780	IV	4,313	IV
Y3 (1) 7/8-9 UNC A307 Bolt	45														
	60														

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Table A1.1-2; KSCU & KSCC Restraint Cable Kit Capacities for Bolt to Steel Attachment – Orientation 2 (All Listed Forces Are LRFD Values)

		Maximum Cable Angle (°)	KNC Restraint Kit Code													
			K2 KSCU-2		K3 KSCU-3		K4 KSCU-4		K5 KSCU-5		C1 KSCC-250		C2 KSCC-375		C3 KSCC-500	
			Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class
KNC Attachment Kit Code	X1 (1) 1/4-20 UNC A307 Bolt	45	247	---	495	I										
		60	175	---	350	I										
	X2 (1) 3/8-16 UNC A307 Bolt	45	247	---	495	I	1,226	III								
		60	175	---	350	I	867	II								
	X3 (1) 1/2-13 UNC A307 Bolt	45							2,717	IV						
		60							1,672	III						
	Y1 (1) 5/8-11 UNC A307 Bolt	45									2,599	IV				
		60									1,838	III				
	Y2 (1) 3/4-10 UNC A307 Bolt	45											5,346	V	7,996	V
		60											3,780	IV	4,313	IV
	Y3 (1) 7/8-9 UNC A307 Bolt	45														
		60														

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Table A1.1-3; KSCU & KSCC Restraint Cable Kit Capacities for Concrete Attachment – Orientation 1 (All Listed Forces Are LRFD Values)

		Maximum Cable Angle (°)	KNC Restraint Kit Code													
			K2 KSCU-2		K3 KSCU-3		K4 KSCU-4		K5 KSCU-5		C1 KSCC-250		C2 KSCC-375		C3 KSCC-500	
			Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class
KNC Attachment Kit Code	X1[1] (1) KCAB-25	45	182	---	182	---										
		60	111	---	111	---										
	X2 (1) KCCAB-38	45	247	---	380	I	380	I	380	I						
		60	175	---	237	---	237	---	237	---						
	X3 (1) KCCAB-50	45					830	II	830	II						
		60					515	II	515	II						
	Y1 (1) KCCAB-63	45									1,074	III	1,193	III	1,193	III
		60									531	II	655	II	655	II
	Y2 (1) KCCAB-75	45									1,620	III	1,798	III	1,798	III
		60									801	II	987	II	987	II
	Y3[2] (1) KCAB-88	45									1,632	III				
		60									783	II				
	Z1 (2) KCCAB-38	45			495	I	1,160	III	1,160	III						
		60			350	I	696	II	696	II						
	Z2 (4) KCCAB-38	45			495	I	1,226	III	2,319	IV						
		60			350	I	867	II	1,392	III						
	Z3 (2) KCCAB-50	45									2,422	IV	2,375	IV	2,375	IV
		60									1,462	III	1,458	III	1,458	III
	Z4 (4) KCCAB-50	45									2,599	IV	4,750	IV	4,750	IV
		60									1,838	III	2,916	IV	2,916	IV

[1] KNC Attachment Kit Coded X1 is not rated for seismic attachment to concrete for 2003 IBC or 2006 IBC.
[2] KNC Attachment Kit Coded Y3 is not rated for seismic attachment to concrete for 2003 IBC or 2006 IBC.

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Table A1.1-4; KSCU & KSCC Restraint Cable Kit Capacities for Concrete Attachment – Orientation 2 (All Listed Forces Are LRFD Values)

		KNC Restraint Kit Code													
		K2 KSCU-2		K3 KSCU-3		K4 KSCU-4		K5 KSCU-5		C1 KSCC-250		C2 KSCC-375		C3 KSCC-500	
KNC Attachment Kit Code	Maximum Cable Angle (°)	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class
X1[3] (1) KCAB-25	45	182	---	182	---										
	60	162	---	162	---										
X2 (1) KCCAB-38	45	247	---	380	I	380	I	380	I						
	60	175	---	324	I	324	I	324	I						
X3 (1) KCCAB-50	45					830	II	830	II						
	60					714	II	714	II						
Y1 (1) KCCAB-63	45									1,074	III	1,193	III	1,193	III
	60									1,352	III	1,229	III	1,229	III
Y2 (1) KCCAB-75	45									1,620	III	1,798	III	1,798	III
	60									1,838	III	1,854	III	1,854	III
Y3[4] (1) KCAB-88	45									1,632	III				
	60									1,838	III				
Z1 (2) KCCAB-38	45			495	I	1,160	III	1,160	III						
	60			350	I	867	II	972	II						
Z2 (4) KCCAB-38	45			495	I	1,226	III	2,319	IV						
	60			350	I	867	II	1,672	III						
Z3 (2) KCCAB-50	45									2,422	IV	2,375	IV	2,375	IV
	60									1,838	III	1,989	III	1,989	III
Z4 (4) KCCAB-50	45									2,599	IV	4,750	IV	4,750	IV
	60									1,838	III	3,780	IV	3,977	IV

[3] KNC Attachment Kit Coded X1 is not rated for seismic attachment to concrete for 2003 IBC or 2006 IBC.
[4] KNC Attachment Kit Coded Y3 is not rated for seismic attachment to concrete for 2003 IBC or 2006 IBC.

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Table A1.1-5; KSCU & KSCC Restraint Cable Kit Capacities for Attachment to Wood – Orientation 1 (All Listed Forces Are LRFD Values)

		KNC Restraint Kit Code													
		K2 KSCU-2		K3 KSCU-3		K4 KSCU-4		K5 KSCU-5		C1 KSCC-250		C2 KSCC-375		C3 KSCC-500	
KNC Attachment Kit Code	Maximum Cable Angle (°)	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class
W1 (1) 1/4" Lag Screw	45	219	---	219	---										
	60	152	---	152	---										
W2 (1) 3/8" Lag Screw	45	247	---	402	I	443	I	443	I						
	60	175	---	295	I	308	I	308	I						
W3 (1) 1/2" Lag Screw	45					709	II	709	II						
	60					502	II	502	II						
W4 (1) 5/8" Lag Screw	45											1,089	III	1,089	III
	60											759	II	759	II
W5 (1) 3/4" Lag Screw	45									1,411	III	1,475	III	1,475	III
	60									879	II	1,037	III	1,037	III
W6 (1) 7/8" Lag Screw	45									1,822	III				
	60									1,147	III				
W7 (2) 3/8" Lag Screws	45			495	I	1,093	III	1,093	III						
	60			350	I	835	II	835	II						
W8 (4) 3/8" Lag Screws	45			495	I	1,226	III	2,185	IV						
	60			350	I	867	II	1,670	III						
W9 (2) 1/2" Lag Screws	45									1,673	III	1,663	III	1,663	III
	60									1,308	III	1,306	III	1,306	III
W10 (4) 1/2" Lag Screws	45									2,599	IV	3,327	IV	3,327	IV
	60									1,838	III	2,612	IV	2,612	IV

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Table A1.1-6; KSCU & KSCC Restraint Cable Kit Capacities for Attachment to Wood – Orientation 2 (All Listed Forces Are LRFD Values)

KNC Attachment Kit Code		Maximum Cable Angle (°)	KNC Restraint Kit Code													
			K2 KSCU-2		K3 KSCU-3		K4 KSCU-4		K5 KSCU-5		C1 KSCC-250		C2 KSCC-375		C3 KSCC-500	
			Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class	Horizontal Seismic Rating (LRFD) (lbs)	Force Class
	W1 (1) 1/4" Lag Screw	45	219	---	219	---										
		60	155	---	155	---										
	W2 (1) 3/8" Lag Screw	45	247	---	402	I	443	I	443	I						
		60	175	---	264	I	312	I	312	I						
	W3 (1) 1/2" Lag Screw	45					709	II	709	II						
		60					486	I	486	I						
	W4 (1) 5/8" Lag Screw	45											1,089	III	1,089	III
		60											708	II	708	II
	W5 (1) 3/4" Lag Screw	45									1,411	III	1,475	III	1,475	III
		60									950	II	950	II	950	II
	W6 (1) 7/8" Lag Screw	45									1,822	III				
		60									1,207	III				
	W7 (2) 3/8" Lag Screws	45			495	I	1,093	III	1,093	III						
		60			350	I	671	II	671	II						
	W8 (4) 3/8" Lag Screws	45			495	I	1,226	III	2,185	IV						
		60			350	I	867	II	1,343	III						
	W9 (2) 1/2" Lag Screws	45									1,673	III	1,663	III	1,663	III
		60									1,016	III	1,016	III	1,016	III
	W10 (4) 1/2" Lag Screws	45									2,599	IV	3,327	IV	3,327	IV
		60									1,838	III	2,031	IV	2,031	IV

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KSCU & KSCC NON-ISOLATED RESTRAINED WEIGHT CAPACITY

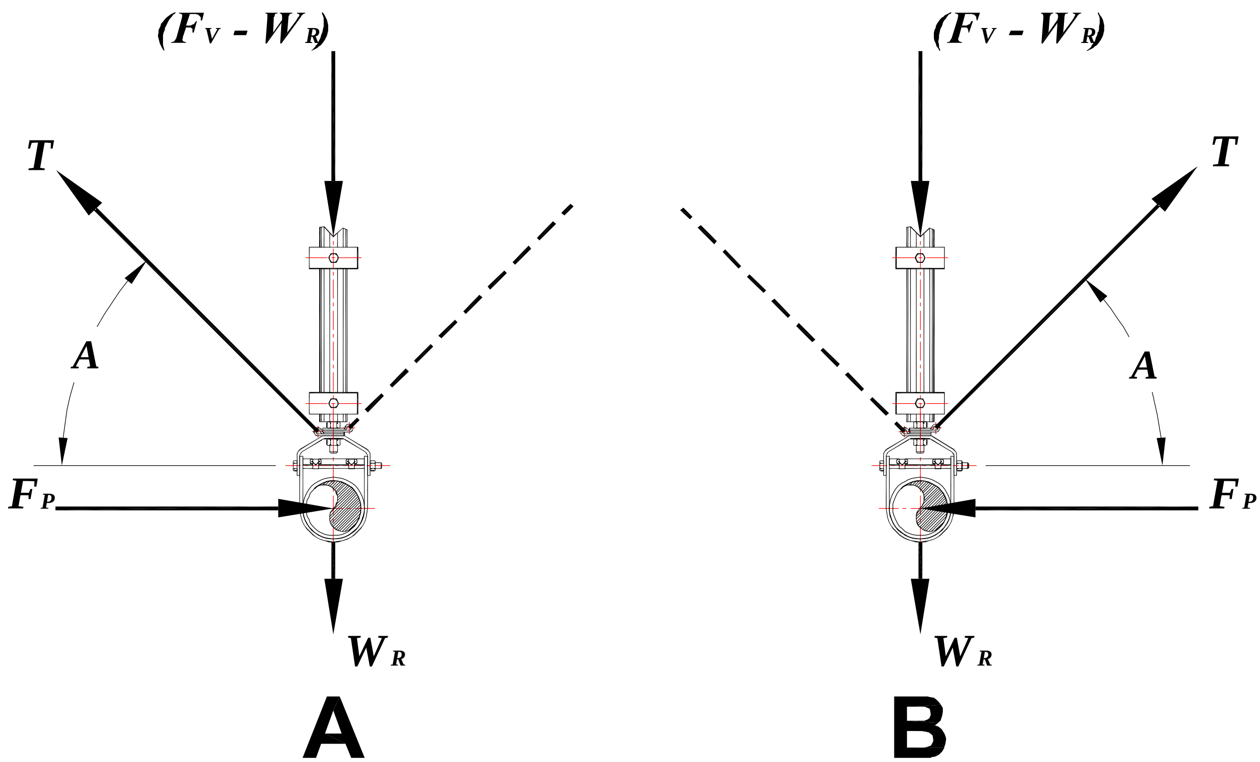

Figure A1.2-1; Forces Acting on a Cable Restrained Single Hanger Rod Supported Pipe or Duct

Introduction:

The purpose of this appendix is to define the capacities of the KSCU and KSCC Seismic Restraint Cable Kits in terms of the building acceleration which they will be able to resist. The capacities expressed in Gs will allow restraints and restraint spacings to be determined when the demand acceleration is known on a particular floor of a building. The basic equation for force and acceleration is given below.

$$F_P = M_R a_E$$ **Equation A1.2-1**

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Where:

F_P = the horizontal seismic force acting on the pipe or duct.

M_R = the mass of the pipe or duct that is being restrained.

a_E = the acceleration of the attachment point of the pipe or duct due to the earthquake acceleration.

The horizontal seismic force may be expressed in terms of the cable tension as follows.

$$F_P = TCos(A)$$ **Equation A1.2-2**

Where:

A = the seismic restraint installation angle measured with respect to the horizontal.

T = the tension in the cable generated by the horizontal seismic force.

The mass of the pipe or duct will be;

$$M_R = \frac{W_R}{g} = \frac{w_R S_R}{g}$$ **Equation A1.2-3**

Where:

S_R = the maximum seismic restraint spacing.

W_R = the weight of the pipe or duct that is being restrained.

g = the acceleration due to gravity.

w_R = the distributed weight of the pipe or duct that is being restrained, see Appendix A2.0 and A3.0.

Then, Equation A1.2-1 may be rewritten as follows.

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$$TCos(A)=\left(\frac{w_R S_R}{g}\right)a_E$$ **Equation A1.2-4**

Let the cable tension be equal to the maximum allowable Seismic Cable Tension Rating (T_A) in **(ASD)** units, and solve for the acceleration.

$$a_E=\frac{gT_A Cos(A)}{w_R S_R}$$ **Equation A1.2-5**

And;

$$G=\frac{a_E}{g}=\frac{T_A Cos(A)}{w_R S_R}=\frac{T_A Cos(A)}{W_R}$$ **ASD** **Equation A1.2-6**

$$G=\frac{a_E}{g}=\frac{1.4T_A Cos(A)}{w_R S_R}=\frac{1.4T_A Cos(A)}{W_R}$$ **LRFD** **Equation A1.2-7**

If the desired G level is known from the code based analysis, then the allowable restrained weight may be computed.

$$W_R=\frac{T_A Cos(A)}{G}$$ **ASD** **Equation A1.2-8**

$$W_R=\frac{1.4T_A Cos(A)}{G}$$ **LRFD** **Equation A1.2-9**

The designation codes for the cable kits and attachment kits provided by Kinetics Noise Control are given in Tables A1.2-1 through A1.2-3.

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Table A1.2-1; Seismic Restraint Cable Kit vs. Code Cross-Reference

KNC Restraint Kit Code	Restraint Kit Description
K2	KSCU-2 Cable Kit – 2 mm Cable & GRIPPLE HANGFAST No, 2 Connectors
K3	KSCU-3 Cable Kit – 3 mm Cable & GRIPPLE HANGFAST No, 3 Connectors
K4	KSCU-4 Cable Kit – 5 mm Cable & GRIPPLE HANGFAST No, 4 Connectors
K5	KSCU-5 Cable Kit – 6 mm Cable & GRIPPLE Lockable 6 mm Connectors
C1	KSCC-250 Cable Kit – 1/4″ Cable & Saddle + U-bolt Connectors
C2	KSCC-375 Cable Kit – 3/8″ Cable & Saddle + U-bolt Connectors
C3	KSCC-500 Cable Kit – 1/2″ Cable & Saddle + U-bolt Connectors
F	Direct Mounted to Floor or Roof Using Anchor Bolts
W	Direct Mounted to Wall Using Anchor Bolts

Table A1.2-2; Structural Concrete/Steel Attachment Kit vs. Code Cross-Reference

KNC Attachment Kit Code	Attachment Kit Description per Restraint Cable Note: Through bolts & nuts of the same size may be used for each kit and code shown below.
X1	(1) 1/4″ Concrete Anchor (with Grommet)
X2	(1) 3/8″ Concrete Anchor
X3	(1) 1/2″ Concrete Anchor
Y1	(1) 5/8″ Concrete Anchor
Y2	(1) 3/4″ Concrete Anchor
Y3	(1) 7/8″ Concrete Anchor
Z1	(2) 3/8″ Concrete Anchors with Oversized Base Plate
Z2	(4) 3/8″ Concrete Anchors with Oversized Base Plate
Z3	(2) 1/2″ Concrete Anchors with Oversized Base Plate
Z4	(4) 1/2″ Concrete Anchors with Oversized Base Plate

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Table A1.2-3; Structural Wood/Steel Attachment Kit vs. Code Cross-Reference

KNC Attachment Kit Code	Attachment Kit Description per Restraint Cable Note: Through bolts & nuts of the same size may be used for each kit and code shown below.
W1	(1) 1/4″ Lag Screw (with Grommet)
W2	(1) 3/8″ Lag Screw
W3	(1) 1/2″ Lag Screw
W4	(1) 5/8″ Lag Screw
W5	(1) 3/4″ Lag Screw
W6	(1) 7/8″ Lag Screw
W7	(2) 3/8″ Lag Screws with Oversized Base Plate
W8	(4) 3/8″ Lag Screws with Oversized Base Plate
W9	(2) 1/2″ Lag Screws with Oversized Base Plate
W10	(4) 1/2″ Lag Screws with Oversized Base Plate

Table A1.2-4; K2 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 45°

Horizontal Acceleration Gs	Attachment Kit Designation					
	X2 (Steel)		**X2** (Concrete)		**W2** (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	988	988	988	988	988	988
0.50	494	494	494	494	494	494
0.75	329	329	329	329	329	329
1.00	247	247	247	247	247	247
1.25	198	198	198	198	198	198
1.50	165	165	165	165	165	165
2.00	124	124	124	124	124	124
3.00	82	82	82	82	82	82

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Table A1.2-5; K3 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 45°

Horizontal Acceleration Gs	Attachment Kit Designation							
	X2 (Steel)		X2 (Concrete)		W2 (Wood)		W7 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	1980	1980	1520	1520	1608	1608	1980	1980
0.50	990	990	760	760	804	804	990	990
0.75	660	660	507	507	536	536	660	660
1.00	495	495	380	380	402	402	495	495
1.25	396	396	304	304	322	322	396	396
1.50	330	330	253	253	268	268	330	330
2.00	248	248	190	190	201	201	248	248
3.00	165	165	127	127	134	134	165	165

Table A1.2-6; K4 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 45°

Horizontal Acceleration Gs	Attachment Kit Designation											
	X3 (Steel)		X3 (Concrete)		Z1 (Concrete)		W3 (Wood)		W7 (Wood)		W8 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	4904	4904	3320	3320	4640	4640	2836	2836	4372	4372	4904	4904
0.50	2452	2452	1660	1660	2320	2320	1418	1418	2186	2186	2452	2452
0.75	1635	1635	1107	1107	1547	1547	945	945	1457	1457	1635	1635
1.00	1226	1226	830	830	1160	1160	709	709	1093	1093	1226	1226
1.25	981	981	664	664	928	928	567	567	874	874	981	981
1.50	817	817	553	553	773	773	473	473	729	729	817	817
2.00	613	613	415	415	580	580	355	355	547	547	613	613
3.00	409	409	277	277	387	387	236	236	364	364	409	409

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Table A1.2-7; K5 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD) Restraint Installation Angle = 45°

Horizontal Acceleration Gs	Attachment Kit Designation													
	X3 (Steel)		X3 (Concrete)		Z1 (Concrete)		Z2 (Concrete)		W3 (Wood)		W7 (Wood)		W8 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	10868	10868	3320	3320	4640	4640	9276	9276	2836	2836	4372	4372	8740	8740
0.50	5434	5434	1660	1660	2320	2320	4638	4638	1418	1418	2186	2186	4370	4370
0.75	3623	3623	1107	1107	1547	1547	3092	3092	945	945	1457	1457	2913	2913
1.00	2717	2717	830	830	1160	1160	2319	2319	709	709	1093	1093	2185	2185
1.25	2174	2174	664	664	928	928	1855	1855	567	567	874	874	1748	1748
1.50	1811	1811	553	553	773	773	1546	1546	473	473	729	729	1457	1457
2.00	1359	1359	415	415	580	580	1160	1160	355	355	547	547	1093	1093
3.00	906	906	277	277	387	387	773	773	236	236	364	364	728	728

Table A1.2-8; C1 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD) Restraint Installation Angle = 45°

Horizontal Acceleration Gs	Attachment Kit Designation											
	Y2 (Steel)		Y2 (Concrete)		Z3 (Concrete)		W6 (Wood)		W9 (Wood)		W10 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	10396	10396	6480	6480	9688	9688	7288	7288	6692	6692	10396	10396
0.50	5198	5198	3240	3240	4844	4844	3644	3644	3346	3346	5198	5198
0.75	3465	3465	2160	2160	3229	3229	2429	2429	2231	2231	3465	3465
1.00	2599	2599	1620	1620	2422	2422	1822	1822	1673	1673	2599	2599
1.25	2079	2079	1296	1296	1938	1938	1458	1458	1338	1338	2079	2079
1.50	1733	1733	1080	1080	1615	1615	1215	1215	1115	1115	1733	1733
2.00	1300	1300	810	810	1211	1211	911	911	837	837	1300	1300
3.00	866	866	540	540	807	807	607	607	558	558	866	866

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Table A1.2-9; C2 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 45°

Horizontal Acceleration Gs	Attachment Kit Designation													
	Y2 (Steel)		Y2 (Concrete)		Z3 (Concrete)		Z4 (Concrete)		W5 (Wood)		W9 (Wood)		W10 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	21384	21384	7192	7192	9500	9500	19000	19000	5900	5900	6652	6652	13308	13308
0.50	10692	10692	3596	3596	4750	4750	9500	9500	2950	2950	3326	3326	6654	6654
0.75	7128	7128	2397	2397	3167	3167	6333	6333	1967	1967	2217	2217	4436	4436
1.00	5346	5346	1798	1798	2375	2375	4750	4750	1475	1475	1663	1663	3327	3327
1.25	4277	4277	1438	1438	1900	1900	3800	3800	1180	1180	1330	1330	2662	2662
1.50	3564	3564	1199	1199	1583	1583	3167	3167	983	983	1109	1109	2218	2218
2.00	2673	2673	899	899	1188	1188	2375	2375	738	738	832	832	1664	1664
3.00	1782	1782	599	599	792	792	1583	1583	492	492	554	554	1109	1109

Table A1.2-10; C3 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 45°

Horizontal Acceleration Gs	Attachment Kit Designation													
	Y2 (Steel)		Y2 (Concrete)		Z3 (Concrete)		Z4 (Concrete)		W5 (Wood)		W9 (Wood)		W10 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	31984	31984	7192	7192	9500	9500	19000	19000	5900	5900	6652	6652	13308	13308
0.50	15992	15992	3596	3596	4750	4750	9500	9500	2950	2950	3326	3326	6654	6654
0.75	10661	10661	2397	2397	3167	3167	6333	6333	1967	1967	2217	2217	4436	4436
1.00	7996	7996	1798	1798	2375	2375	4750	4750	1475	1475	1663	1663	3327	3327
1.25	6397	6397	1438	1438	1900	1900	3800	3800	1180	1180	1330	1330	2662	2662
1.50	5331	5331	1199	1199	1583	1583	3167	3167	983	983	1109	1109	2218	2218
2.00	3998	3998	899	899	1188	1188	2375	2375	738	738	832	832	1664	1664
3.00	2665	2665	599	599	792	792	1583	1583	492	492	554	554	1109	1109

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Table A1.2-11; K2 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 60°

Horizontal Acceleration Gs	Attachment Kit Designation					
	X2 (Steel)		X2 (Concrete)		W2 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	700	700	700	700	700	700
0.50	350	350	350	350	350	350
0.75	233	233	233	233	233	233
1.00	175	175	175	175	175	175
1.25	140	140	140	140	140	140
1.50	117	117	117	117	117	117
2.00	88	88	88	88	88	88
3.00	58	58	58	58	58	58

Table A1.2-12; K3 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 60°

Horizontal Acceleration Gs	Attachment Kit Designation									
	X2 (Steel)		X2 (Concrete)		Z1 (Concrete)		W2 (Wood)		W7 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	1400	1400	948	1296	1400	1400	1180	1056	1400	1400
0.50	700	700	474	648	700	700	590	528	700	700
0.75	467	467	316	432	467	467	393	352	467	467
1.00	350	350	237	324	350	350	295	264	350	350
1.25	280	280	190	259	280	280	236	211	280	280
1.50	233	233	158	216	233	233	197	176	233	233
2.00	175	175	119	162	175	175	148	132	175	175
3.00	117	117	79	108	117	117	98	88	117	117

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Table A1.2-13; K4 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 60°

Horizontal Acceleration Gs	Attachment Kit Designation											
	X3 (Steel)		X3 (Concrete)		Z1 (Concrete)		W3 (Wood)		W7 (Wood)		W8 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	3468	3468	2060	2856	2784	3468	2008	1944	3340	2684	3468	3468
0.50	1734	1734	1030	1428	1392	1734	1004	972	1670	1342	1734	1734
0.75	1156	1156	687	952	928	1156	669	648	1113	895	1156	1156
1.00	867	867	515	714	696	867	502	486	835	671	867	867
1.25	694	694	412	571	557	694	402	389	668	537	694	694
1.50	578	578	343	476	464	578	335	324	557	447	578	578
2.00	434	434	258	357	348	434	251	243	418	336	434	434
3.00	289	289	172	238	232	289	167	162	278	224	289	289

Table A1.2-14; K5 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 60°

Horizontal Acceleration Gs	Attachment Kit Designation													
	X3 (Steel)		X3 (Concrete)		Z1 (Concrete)		Z2 (Concrete)		W3 (Wood)		W7 (Wood)		W8 (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	6688	6688	2060	2856	2784	3888	5568	6688	2008	2008	3340	2684	6680	5372
0.50	3344	3344	1030	1428	1392	1944	2784	3344	1004	1004	1670	1342	3340	2686
0.75	2229	2229	687	952	928	1296	1856	2229	669	669	1113	895	2227	1791
1.00	1672	1672	515	714	696	972	1392	1672	502	502	835	671	1670	1343
1.25	1338	1338	412	571	557	778	1114	1338	402	402	668	537	1336	1074
1.50	1115	1115	343	476	464	648	928	1115	335	335	557	447	1113	895
2.00	836	836	258	357	348	486	696	836	251	251	418	336	835	672
3.00	557	557	172	238	232	324	464	557	167	167	278	224	557	448

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Table A1.2-15; C1 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 60°

Horizontal Acceleration Gs	Attachment Kit Designation											
	Y2 (Steel)		**Y2** (Concrete)		**Z3** (Concrete)		**W6** (Wood)		**W9** (Wood)		**W10** (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	7352	7352	3204	7352	5848	7352	4588	4828	5232	4064	7352	7352
0.50	3676	3676	1602	3676	2924	3676	2294	2414	2616	2032	3676	3676
0.75	2451	2451	1068	2451	1949	2451	1529	1609	1744	1355	2451	2451
1.00	1838	1838	801	1838	1462	1838	1147	1207	1308	1016	1838	1838
1.25	1470	1470	641	1470	1170	1470	918	966	1046	813	1470	1470
1.50	1225	1225	534	1225	975	1225	765	805	872	677	1225	1225
2.00	919	919	401	919	731	919	574	604	654	508	919	919
3.00	613	613	267	613	487	613	382	402	436	339	613	613

Table A1.2-16; C2 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 60°

Horizontal Acceleration Gs	Attachment Kit Designation													
	Y2 (Steel)		**Y2** (Concrete)		**Z3** (Concrete)		**Z4** (Concrete)		**W5** (Wood)		**W9** (Wood)		**W10** (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	15120	15120	3948	7416	5832	7956	11664	15120	5228	3800	5224	4064	10448	8124
0.50	7560	7560	1974	3708	2916	3978	5832	7560	2614	1900	2612	2032	5224	4062
0.75	5040	5040	1316	2472	1944	2652	3888	5040	1743	1267	1741	1355	3483	2708
1.00	3780	3780	987	1854	1458	1989	2916	3780	1307	950	1306	1016	2612	2031
1.25	3024	3024	790	1483	1166	1591	2333	3024	1046	760	1045	813	2090	1625
1.50	2520	2520	658	1236	972	1326	1944	2520	871	633	871	677	1741	1354
2.00	1890	1890	494	927	729	995	1458	1890	654	475	653	508	1306	1016
3.00	1260	1260	329	618	486	663	972	1260	436	317	435	339	871	677

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Table A1.2-17; C3 Restraint Seismic Cable Kit Restrained Weight Capacity (lbs – LRFD)
Restraint Installation Angle = 60°

Horizontal Acceleration Gs	Attachment Kit Designation													
	Y2 (Steel)		**Y2** (Concrete)		**Z3** (Concrete)		**Z4** (Concrete)		**W5** (Wood)		**W9** (Wood)		**W10** (Wood)	
	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2	Orientation 1	Orientation 2
0.25	17252	17252	3948	7416	5832	7956	11664	15908	4148	3800	5224	4064	10448	8124
0.50	8626	8626	1974	3708	2916	3978	5832	7954	2074	1900	2612	2032	5224	4062
0.75	5751	5751	1316	2472	1944	2652	3888	5303	1383	1267	1741	1355	3483	2708
1.00	4313	4313	987	1854	1458	1989	2916	3977	1037	950	1306	1016	2612	2031
1.25	3450	3450	790	1483	1166	1591	2333	3182	830	760	1045	813	2090	1625
1.50	2875	2875	658	1236	972	1326	1944	2651	691	633	871	677	1741	1354
2.00	2157	2157	494	927	729	995	1458	1989	519	475	653	508	1306	1016
3.00	1438	1438	329	618	486	663	972	1326	346	317	435	339	871	677

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STANDARD STEEL PIPE DATA

Table A2.1-1; Non-Insulated Standard Steel Pipe – Water

Nominal Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Water Weight (lb/ft)	Pipe + Water Weight (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	3.60
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	171.79
20	20.000	19.250	78.52	126.12	204.63
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	409.71
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 A2.1-2; Insulated Standard Steel Pipe – Water (85% Magnesia Insulation)

Nominal Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Water Weight (lb/ft)	Insulation Thickness (in)	Insulation Weight (lb/ft)	Pipe + Water + Insulation Weight (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	6.35
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	15.24
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	55.84
10	10.750	10.020	40.44	34.17	1.50	6.81	81.43
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	216.59
22	22.000	21.250	86.52	153.68	1.50	13.07	253.28
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	427.23
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 A2.1-3; Insulated Standard Steel Pipe – Steam (85% Magnesia Insulation)

Nominal Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Steam Weight (lb/ft)	Insulation Thickness (in)	Insulation Weight (lb/ft)	Pipe + Steam + Insulation Weight (lb/ft)
3/4	1.050	0.824	1.13	0.00014	1.50	1.42	2.55
1	1.315	1.049	1.68	0.00022	1.50	1.57	3.24
1 1/4	1.660	1.380	2.27	0.00039	1.50	1.76	4.03
1 1/2	1.900	1.610	2.71	0.00053	1.50	1.89	4.61
2	2.375	2.067	3.65	0.00087	1.50	2.16	5.81
2 1/2	2.875	2.469	5.79	0.00124	1.50	2.43	8.22
3	3.500	3.068	7.57	0.00191	1.50	2.78	10.35
3 1/2	4.000	3.548	9.10	0.00255	1.50	3.06	12.16
4	4.500	4.026	10.78	0.00329	1.50	3.34	14.12
5	5.563	5.047	14.60	0.00517	2.00	5.61	20.22
6	6.625	6.065	18.95	0.00746	2.00	6.40	25.36
8	8.625	7.981	28.52	0.01292	2.00	7.88	36.42
10	10.750	10.020	40.44	0.02037	2.00	9.46	49.92
11	11.750	11.000	45.51	0.02455	2.00	10.20	55.73
12	12.750	12.000	49.51	0.02922	2.00	10.94	60.48
14	14.000	13.250	54.51	0.03562	2.00	11.87	66.42
16	16.000	15.250	62.51	0.04719	2.00	13.35	75.91
18	18.000	17.250	70.51	0.06037	2.00	14.84	85.41
20	20.000	19.250	78.52	0.07519	2.00	16.32	94.91
22	22.000	21.250	86.52	0.09162	2.00	17.80	104.41
24	24.000	23.250	94.52	0.10968	2.00	19.29	113.91
30	30.000	29.250	118.52	0.17359	2.00	23.74	142.43
36	36.000	35.250	142.53	0.25211	2.00	28.19	170.97
42	42.000	41.250	166.53	0.34524	2.00	32.64	199.52
48	48.000	47.250	190.54	0.45297	2.00	37.09	228.08

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FIRE PROTECTION PIPE DATA

Table A2.2-1; Steel Pipe – Threaded or Cut Grooves
{Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Nominal Pipe Size (in)	Pipe Schedule	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)
1	40	1.315	1.049	1.93	0.43	2.36
1 1/4	40	1.660	1.380	2.61	0.75	3.36
1 1/2	40	1.900	1.610	3.12	1.01	4.14
2	40	2.375	2.067	4.20	1.67	5.87
2 1/2	40	2.875	2.469	6.65	2.39	9.04
3	40	3.500	3.068	8.70	3.68	12.39
3 1/2	40	4.000	3.548	10.46	4.93	15.39
4	40	4.500	4.026	12.40	6.34	18.74
5	40	5.563	5.047	16.79	9.97	26.76
6	40	6.625	6.065	21.80	14.40	36.19
8	30	8.625	8.071	28.37	25.50	53.87
10	30	10.750	10.136	39.33	40.21	79.55
12	Standard	12.750	12.000	56.94	56.36	113.30

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Table A2.2-2; Steel Pipe – Welded or Roll-Grooved
{Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Nominal Pipe Size (in)	Pipe Schedule	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)
1	10	1.315	1.097	1.61	0.47	2.08
1 1/4	10	1.660	1.442	2.07	0.81	2.89
1 1/2	10	1.900	1.682	2.40	1.11	3.50
2	10	2.375	2.157	3.03	1.82	4.85
2 1/2	10	2.875	2.635	4.06	2.72	6.77
3	10	3.500	3.260	4.98	4.16	9.14
3 1/2	10	4.000	3.760	5.71	5.53	11.25
4	10	4.500	4.260	6.45	7.10	13.55
5	10	5.563	5.295	8.93	10.97	19.90
6	10	6.625	6.357	10.67	15.82	26.49
8	----------	8.625	8.249	19.46	26.63	46.09
10	----------	10.750	10.374	24.36	42.12	66.48
12	30	12.750	12.090	50.29	57.21	107.50

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Table A2.2-3; *TYPE K* Copper Tubing – ASTM B88
{Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Tube Size (in)	Tube O. D. (in)	Wall Thickness (in)	Tube Weight (lb/ft)	Water Weight (lb/ft)	Tube + Water Weight (lb/ft)
1	1.125	0.065	0.96	0.39	1.35
1 1/4	1.375	0.065	1.19	0.61	1.80
1 1/2	1.625	0.072	1.56	0.86	2.42
2	2.125	0.083	2.37	1.50	3.87
2 1/2	2.625	0.095	3.36	2.32	5.68
3	3.125	0.109	4.59	3.31	7.90
3 1/2	3.625	0.120	5.87	4.48	10.36
4	4.125	0.134	7.47	5.82	13.29
5	5.125	0.160	11.09	9.04	20.13
6	6.125	0.192	15.90	12.90	28.80

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Table A2.2-4; *TYPE L* Copper Tubing – ASTM B88
{Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Tube Size (in)	Tube O. D. (in)	Wall Thickness (in)	Tube Weight (lb/ft)	Water Weight (lb/ft)	Tube + Water Weight (lb/ft)
1	1.125	0.050	0.75	0.41	1.16
1 1/4	1.375	0.055	1.01	0.63	1.64
1 1/2	1.625	0.060	1.31	0.89	2.20
2	2.125	0.070	2.01	1.54	3.55
2 1/2	2.625	0.080	2.84	2.38	5.22
3	3.125	0.090	3.81	3.39	7.21
3 1/2	3.625	0.100	4.92	4.59	9.51
4	4.125	0.114	6.38	5.94	12.33
5	5.125	0.125	8.72	9.30	18.03
6	6.125	0.140	11.70	13.37	25.07

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Table A2.2-5; *TYPE M* Copper Tubing – ASTM B88
{Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Tube Size (in)	Tube O. D. (in)	Wall Thickness (in)	Tube Weight (lb/ft)	Water Weight (lb/ft)	Tube + Water Weight (lb/ft)
1	1.125	0.035	0.53	0.44	0.97
1 1/4	1.375	0.042	0.78	0.65	1.43
1 1/2	1.625	0.049	1.08	0.91	1.99
2	2.125	0.058	1.67	1.58	3.25
2 1/2	2.625	0.065	2.32	2.44	4.76
3	3.125	0.072	3.07	3.48	6.55
3 1/2	3.625	0.083	4.10	4.68	8.79
4	4.125	0.095	5.34	6.06	11.40
5	5.125	0.109	7.63	9.42	17.06
6	6.125	0.122	10.22	13.54	23.76

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Table A2.2-6; BlazeMaster® CPVC Sprinkler Pipe
Manufactured by HARVEL®
{Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Nominal Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)
3/4	1.125	0.874	0.30	0.30	0.60
1	1.375	1.101	0.40	0.47	0.88
1 1/4	1.625	1.394	0.42	0.76	1.18
1 1/2	2.125	1.598	1.17	1.00	2.17
2	2.625	2.003	1.71	1.57	3.28
2 1/2	3.125	2.423	2.32	2.30	4.62
3	6.125	2.950	17.15	3.41	20.56

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CAST IRON SOIL PIPE DATA

Table A2.3-1; Single Hub Service (SV) Weight Cast Iron Soil Pipe - 10′ Length

Size (in)	Weight per Piece (lbs)	Barrel I. D. (in)	Average Pipe Weight (lb/ft)	Water Weight Full (lb/ft)	Pipe + Half Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)
2	41	1.96	4.1	1.3	4.8	5.4
3	60	2.96	6.0	3.0	7.5	9.0
4	79	3.94	7.9	5.3	10.5	13.2
5	100	4.94	10.0	8.3	14.2	18.3
6	124	5.94	12.4	12.0	18.4	24.4
8	181	7.94	18.1	21.5	28.8	39.6
10	260	9.94	26.0	33.6	42.8	59.6
12	346	11.94	34.6	48.5	58.9	83.1
15	525	15.16	52.5	78.2	91.6	130.7

Table A2.3-2; Single Hub Extra Heavy (XH) Cast Iron Soil Pipe - 10′ Length

Size (in)	Weight per Piece (lbs)	Barrel I. D. (in)	Average Pipe Weight (lb/ft)	Water Weight (lb/ft)	Pipe + Half Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)
2	45	2.00	4.5	1.4	5.2	5.9
3	84	3.00	8.4	3.1	9.9	11.5
4	105	4.00	10.5	5.4	13.2	15.9
5	134	5.00	13.4	8.5	17.7	21.9
6	157	6.00	15.7	12.3	21.8	28.0
8	246	8.00	24.6	21.8	35.5	46.4
10	375	10.00	37.5	34.0	54.5	71.5
12	471	12.00	47.1	49.0	71.6	96.1
15	676	15.00	67.6	76.6	105.9	144.2

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Table A2.3-3; Hubless Cast Iron Soil Pipe - 10′ Length

Size (in)	Weight per Piece (lbs)	Barrel I. D. (in)	Average Pipe Weight (lb/ft)	Water Weight (lb/ft)	Pipe + Half Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)
1 1/2	29	1.50	2.9	0.8	3.3	3.7
2	38	1.96	3.8	1.3	4.5	5.1
3	54	2.96	5.4	3.0	6.9	8.4
4	71	3.94	7.1	5.3	9.7	12.4
5	98	4.94	9.8	8.3	14.0	18.1
6	118	5.94	11.8	12.0	17.8	23.8
8	165	7.94	16.5	21.5	27.2	38.0
10	255	10.00	25.5	34.0	42.5	59.5
12	318	11.94	31.8	48.5	56.1	80.3
15	493	15.11	49.3	77.7	88.2	127.0

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PVC & CPVC PIPE DATA

Table A2.4-1; PVC "Solid Wall" Schedule 40 Pipe

Nominal Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Pipe + Half Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)	Insulation Thickness (in)	Pipe + Water + Insulation Weight (lb/ft)
3/4	1.050	0.824	0.20	0.32	0.43	1.0	1.19
1	1.315	1.049	0.30	0.49	0.67	1.0	1.53
1 1/4	1.660	1.380	0.41	0.73	1.05	1.0	2.04
1 1/2	1.900	1.610	0.49	0.93	1.37	1.0	2.44
2	2.375	2.067	0.65	1.38	2.11	1.0	3.36
2 1/2	2.875	2.469	1.03	2.07	3.11	1.0	4.55
3	3.500	3.068	1.35	2.95	4.56	1.0	6.23
3 1/2	4.000	3.548	1.63	3.77	5.91	1.0	7.77
4	4.500	4.026	1.93	4.68	7.44	1.0	9.48
5	5.563	5.047	2.61	6.94	11.28	1.5	15.21
6	6.625	6.065	3.39	9.65	15.91	1.5	20.43
8	8.625	7.981	5.10	15.94	26.78	1.5	32.41
10	10.750	10.020	7.23	24.31	41.40	1.5	48.21
12	12.750	11.938	9.56	33.81	58.06	1.5	65.99
14	14.000	13.126	11.30	40.62	69.94	1.5	78.56
16	16.000	15.000	14.78	53.07	91.35	1.5	101.09
18	18.000	16.876	18.69	67.15	115.61	1.5	126.46
20	20.000	18.814	21.94	82.18	142.41	1.5	154.37
24	24.000	22.626	30.54	117.65	204.77	1.5	218.96

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Table A2.4-2; PVC "Solid Wall" Schedule 80 Pipe

Nominal Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Pipe + Half Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)	Insulation Thickness (in)	Pipe + Water + Insulation Weight (lb/ft)
3/4	1.050	0.742	0.26	0.36	0.45	1.0	1.21
1	1.315	0.957	0.39	0.54	0.70	1.0	1.56
1 1/4	1.660	1.278	0.53	0.81	1.09	1.0	2.08
1 1/2	1.900	1.500	0.65	1.03	1.41	1.0	2.49
2	2.375	1.939	0.90	1.54	2.18	1.0	3.43
2 1/2	2.875	2.323	1.37	2.29	3.20	1.0	4.64
3	3.500	2.900	1.83	3.26	4.69	1.0	6.36
3 1/2	4.000	3.364	2.23	4.16	6.08	1.0	7.94
4	4.500	3.826	2.68	5.17	7.66	1.0	9.70
5	5.563	4.813	3.71	7.65	11.59	1.5	15.52
6	6.625	5.761	5.10	10.75	16.40	1.5	20.92
8	8.625	7.625	7.75	17.64	27.53	1.5	33.17
10	10.750	9.564	11.48	27.05	42.62	1.5	49.43
12	12.750	11.376	15.80	37.82	59.85	1.5	67.77
14	14.000	12.500	18.95	45.54	72.13	1.5	80.75
16	16.000	14.314	24.36	59.23	94.10	1.5	103.83
18	18.000	16.126	30.49	74.74	118.99	1.5	129.84
20	20.000	17.974	36.67	91.65	146.63	1.5	158.59
24	24.000	21.564	52.91	132.04	211.17	1.5	225.36

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Table A2.4-3; CPVC "Solid Wall" Schedule 40 Pipe

Nominal Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Pipe + Half Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)	Insulation Thickness (in)	Pipe + Water + Insulation Weight (lb/ft)
3/4	1.050	0.824	0.22	0.33	0.45	1.0	1.21
1	1.315	1.049	0.33	0.51	0.70	1.0	1.56
1 1/4	1.660	1.380	0.44	0.76	1.09	1.0	2.08
1 1/2	1.900	1.610	0.53	0.97	1.41	1.0	2.48
2	2.375	2.067	0.71	1.44	2.16	1.0	3.41
2 1/2	2.875	2.469	1.12	2.16	3.20	1.0	4.63
3	3.500	3.068	1.47	3.07	4.67	1.0	6.34
3 1/2	4.000	3.548	1.77	3.91	6.05	1.0	7.90
4	4.500	4.026	2.09	4.85	7.61	1.0	9.65
5	5.563	5.047	2.83	7.17	11.50	1.5	15.43
6	6.625	6.065	3.68	9.94	16.20	1.5	20.72
8	8.625	7.981	5.53	16.37	27.21	1.5	32.85
10	10.750	10.020	7.85	24.93	42.02	1.5	48.83
12	12.750	11.938	10.38	34.63	58.88	1.5	66.81
14	14.000	13.126	12.27	41.59	70.91	1.5	79.53
16	16.000	15.000	16.04	54.33	92.62	1.5	102.36
18	18.000	16.876	20.29	68.75	117.22	1.5	128.06
20	20.000	18.814	23.82	84.06	144.29	1.5	156.25
24	24.000	22.626	33.16	120.27	207.39	1.5	221.57

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Table A2.4-4; CPVC "Solid Wall" Schedule 80 Pipe

Nominal Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight (lb/ft)	Pipe + Half Water Weight (lb/ft)	Pipe + Water Weight (lb/ft)	Insulation Thickness (in)	Pipe + Water + Insulation Weight (lb/ft)
3/4	1.050	0.742	0.29	0.38	0.47	1.0	1.23
1	1.315	0.957	0.42	0.58	0.73	1.0	1.59
1 1/4	1.660	1.278	0.58	0.86	1.14	1.0	2.12
1 1/2	1.900	1.500	0.70	1.09	1.47	1.0	2.55
2	2.375	1.939	0.97	1.61	2.25	1.0	3.50
2 1/2	2.875	2.323	1.48	2.40	3.32	1.0	4.76
3	3.500	2.900	1.99	3.42	4.85	1.0	6.52
3 1/2	4.000	3.364	2.42	4.35	6.28	1.0	8.13
4	4.500	3.826	2.90	5.40	7.89	1.0	9.93
5	5.563	4.813	4.03	7.97	11.91	1.5	15.84
6	6.625	5.761	5.54	11.19	16.83	1.5	21.35
8	8.625	7.625	8.41	18.30	28.20	1.5	33.83
10	10.750	9.564	12.47	28.03	43.60	1.5	50.41
12	12.750	11.376	17.16	39.18	61.20	1.5	69.13
14	14.000	12.500	20.57	47.16	73.75	1.5	82.37
16	16.000	14.314	26.45	61.32	96.18	1.5	105.92
18	18.000	16.126	33.10	77.35	121.60	1.5	132.45
20	20.000	17.974	39.82	94.79	149.77	1.5	161.73
24	24.000	21.564	57.44	136.57	215.70	1.5	229.89

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COPPER WATER PIPE DATA

Table A2.5-1; *TYPE K* Copper Tubing – ASTM B88

Tube Size (in)	Tube O. D. (in)	Wall Thickness (in)	Tube Weight (lb/ft)	Water Weight (lb/ft)	Tube + Water Weight (lb/ft)
1/2	0.625	0.049	0.34	0.09	0.44
3/4	0.875	0.065	0.64	0.19	0.83
1	1.125	0.065	0.84	0.34	1.17
1 1/4	1.375	0.065	1.03	0.53	1.56
1 1/2	1.625	0.072	1.36	0.75	2.10
2	2.125	0.083	2.06	1.31	3.36
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

Table A2.5-2; Insulated *TYPE K* Copper Tubing – ASTM B88 (85% Magnesia Insulation)

Tube Size (in)	Tube O. D. (in)	Wall Thickness (in)	Tube Weight (lb/ft)	Water Weight (lb/ft)	Insulation Thickness (in)	Insulation Weight (lb/ft)	Total Weight (lb/ft)
1/2	0.625	0.049	0.34	0.09	1.00	0.60	1.04
3/4	0.875	0.065	0.64	0.19	1.00	0.70	1.52
1	1.125	0.065	0.84	0.34	1.00	0.79	1.96
1 1/4	1.375	0.065	1.03	0.53	1.00	0.88	2.44
1 1/2	1.625	0.072	1.36	0.75	1.00	0.97	3.08
2	2.125	0.083	2.06	1.31	1.00	1.16	4.52
2 1/2	2.625	0.095	2.92	2.02	1.00	1.34	6.28
3	3.125	0.109	3.99	2.88	1.00	1.53	8.40
3 1/2	3.625	0.120	5.11	3.90	1.00	1.72	10.72
4	4.125	0.134	6.49	5.06	1.00	1.90	13.46
5	5.125	0.160	9.64	7.86	1.50	3.69	21.19
6	6.125	0.192	13.83	11.22	1.50	4.24	29.29

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Table A2.5-3; *TYPE L* Copper Tubing – ASTM B88

Tube Size (in)	Tube O. D. (in)	Wall Thickness (in)	Tube Weight (lb/ft)	Water Weight (lb/ft)	Tube + Water Weight (lb/ft)
1/2	0.625	0.040	0.28	0.10	0.39
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	1.43
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

Table A2.5-4; Insulated *TYPE L* Copper Tubing – ASTM B88 (85% Magnesia Insulation)

Tube Size (in)	Tube O. D. (in)	Wall Thickness (in)	Tube Weight (lb/ft)	Water Weight (lb/ft)	Insulation Thickness (in)	Insulation Weight (lb/ft)	Total Weight (lb/ft)
1/2	0.625	0.040	0.28	0.10	1.00	0.60	0.99
3/4	0.875	0.045	0.45	0.21	1.00	0.70	1.36
1	1.125	0.050	0.65	0.36	1.00	0.79	1.80
1 1/4	1.375	0.055	0.88	0.54	1.00	0.88	2.31
1 1/2	1.625	0.060	1.14	0.77	1.00	0.97	2.88
2	2.125	0.070	1.75	1.34	1.00	1.16	4.25
2 1/2	2.625	0.080	2.47	2.07	1.00	1.34	5.88
3	3.125	0.090	3.32	2.95	1.00	1.53	7.80
3 1/2	3.625	0.100	4.28	3.99	1.00	1.72	9.99
4	4.125	0.114	5.55	5.17	1.00	1.90	12.62
5	5.125	0.125	7.59	8.09	1.50	3.69	19.36
6	6.125	0.140	10.17	11.63	1.50	4.24	26.04

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Table A2.5-5; *TYPE M* Copper Tubing – ASTM B88

Tube Size (in)	Tube O. D. (in)	Wall Thickness (in)	Tube Weight (lb/ft)	Water Weight (lb/ft)	Tube + Water Weight (lb/ft)
1/2	0.625	0.028	0.20	0.11	0.31
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

Table A2.5-6; Insulated *TYPE M* Copper Tubing – ASTM B88 (85% Magnesia Insulation)

Tube Size (in)	Tube O. D. (in)	Wall Thickness (in)	Tube Weight (lb/ft)	Water Weight (lb/ft)	Insulation Thickness (in)	Insulation Weight (lb/ft)	Total Weight (lb/ft)
1/2	0.625	0.028	0.20	0.11	1.00	0.60	1.10
3/4	0.875	0.032	0.33	0.22	1.00	0.70	1.34
1	1.125	0.035	0.46	0.38	1.00	0.79	1.63
1 1/4	1.375	0.042	0.68	0.57	1.00	0.88	2.03
1 1/2	1.625	0.049	0.94	0.79	1.00	0.97	2.52
2	2.125	0.058	1.46	1.37	1.00	1.16	3.62
2 1/2	2.625	0.065	2.02	2.12	1.00	1.34	4.93
3	3.125	0.072	2.67	3.02	1.00	1.53	6.48
3 1/2	3.625	0.083	3.57	4.07	1.00	1.72	8.43
4	4.125	0.095	4.65	5.27	1.00	1.90	10.71
5	5.125	0.109	6.64	8.19	1.50	3.69	15.62
6	6.125	0.122	8.89	11.77	1.50	4.24	21.45

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DOMESTIC HOT & CHILLED WATER PIPING CORNER DISTANCE DATA

Table A2.6-1; Corner Distance for Standard Steel Pipe – Domestic Hot & Chilled Water – $\Delta T = 80^\circ F$

Nominal Pipe Size (in)	Pipe O. D. (in)	Distance From Corner to Longitudinal Restraint (ft)			
		10	20	30	40
		Distance from Corner to First Transverse Restraint (ft)			
3/4	1.050	2	2	3	3
1	1.315	2	3	3	4
1 1/4	1.660	2	3	4	4
1 1/2	1.900	2	3	4	4
2	2.375	2	3	4	5
2 1/2	2.875	3	4	5	5
3	3.500	3	4	5	6
3 1/2	4.000	3	4	5	6
4	4.500	3	5	6	7
5	5.563	4	5	6	7
6	6.625	4	6	7	8
8	8.625	5	7	8	9
10	10.750	5	7	9	10
11	11.750	5	8	9	11
12	12.750	6	8	10	11
14	14.000	6	8	10	12
16	16.000	6	9	11	13
18	18.000	7	10	12	13
20	20.000	7	10	12	14
22	22.000	7	11	13	15
24	24.000	8	11	13	16
30	30.000	9	12	15	17
36	36.000	10	13	16	19
42	42.000	10	15	18	21
48	48.000	11	16	19	22

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Table A2.6-2; Corner Distance for PVC 1120 & CPVC 4120 Pipe – Domestic Hot & Chilled Water – $\Delta T = 80°F$

Nominal Pipe Size (in)	Pipe O. D. (in)	Distance From Corner to Longitudinal Restraint (ft)			
		10	20	30	40
		Distance from Corner to First Transverse Restraint (ft)			
3/4	1.050	1	1	1	2
1	1.315	1	1	2	2
1 1/4	1.660	1	1	2	2
1 1/2	1.900	1	2	2	2
2	2.375	1	2	2	2
2 1/2	2.875	1	2	2	3
3	3.500	1	2	3	3
3 1/2	4.000	2	2	3	3
4	4.500	2	2	3	3
5	5.563	2	3	3	4
6	6.625	2	3	4	4
8	8.625	2	3	4	5
10	10.750	3	4	5	5
11	11.750	3	4	5	5
12	12.750	3	4	5	6
14	14.000	3	4	5	6
16	16.000	3	4	5	6
18	18.000	3	5	6	7
20	20.000	4	5	6	7
24	24.000	4	5	7	8

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Table A2.6-3; Corner Distance for Drawn Copper Tubing – Domestic Hot & Chilled Water – $\Delta T = 80°F$

Nominal Pipe Size (in)	Pipe O. D. (in)	Distance from Corner to Longitudinal Restraint (ft)			
		10	20	30	40
		Distance from Corner to First Transverse Restraint (ft)			
1	1.125	2	3	3	4
1 1/4	1.375	2	3	4	4
1 1/2	1.625	2	3	4	5
2	2.125	3	4	5	6
2 1/2	2.625	3	4	5	6
3	3.125	3	5	6	7
3 1/2	3.625	4	5	6	7
4	4.125	4	5	7	8
5	5.125	4	6	7	9
6	6.125	5	7	8	9

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RECTANGULAR DUCT DATA

Table A3.1-1; Maximum Recommended Rectangular Duct Weights for Sizing Seismic Restraints [Maximum Values of Tables A3.1.2 & A3.1.7]

Duct Width (in)	Duct Height (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
28	28	5.4	24
30	30	6.3	26
42	42	12.3	36
54	54	20.3	47
60	60	25.0	54
84	84	49.0	103
96	96	64.0	129
40	20	5.6	26
54	28	10.5	35
60	30	12.5	39
84	42	24.5	74
96	48	32.0	97
108	54	40.5	110
120	60	50.0	121

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Table A3.1-2; Non-Insulated Rectangular Duct: 16 Gage Steel
(*Does Not* Include Reinforcement Steel)

Duct Width (in)	Duct Height (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
28	28	5.4	24
30	30	6.3	26
42	42	12.3	36
54	54	20.3	47
60	60	25.0	52
84	84	49.0	72
96	96	64.0	83
40	20	5.6	26
54	28	10.5	35
60	30	12.5	39
84	42	24.5	54
96	48	32.0	62
108	54	40.5	70
120	60	50.0	78

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Table A3.1-3; Insulated Rectangular Duct: 16 Gage Steel & 1.5 pcf Insulation
(*Does Not* Include Reinforcement Steel)

Duct Width (in)	Duct Height (in)	Duct Area (ft^2)	Bare Duct + 1-1/4″ Insulation Weight (lb/ft)	Bare Duct + 2″ Insulation Weight (lb/ft)	Bare Duct + 3″ Insulation Weight (lb/ft)	Bare Duct + 4″ Insulation Weight (lb/ft)
28	28	5.4	25.6	26.5	27.7	28.8
30	30	6.3	27.4	28.4	29.6	30.9
42	42	12.3	38.4	39.7	41.5	43.2
54	54	20.3	49.4	51.1	53.3	55.6
60	60	25.0	54.9	56.8	59.3	61.8
84	84	49.0	76.8	79.5	83.0	86.5
96	96	64.0	87.8	90.8	94.8	98.8
40	20	5.6	27.4	28.4	29.6	30.9
54	28	10.5	37.5	38.8	40.5	42.2
60	30	12.5	41.2	42.6	44.4	46.3
84	42	24.5	57.6	59.6	62.2	64.8
96	48	32.0	65.9	68.1	71.1	74.1
108	54	40.5	74.1	76.6	80.0	83.4
120	60	50.0	82.3	85.1	88.9	92.6

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Table A3.1-4; Insulated Rectangular Duct: 16 Gage Steel & 3 pcf Insulation (*Does Not* Include Reinforcement Steel)

Duct Width (in)	Duct Height (in)	Duct Area (ft^2)	Bare Duct + 1″ Insulation Weight (lb/ft)	Bare Duct + 2″ Insulation Weight (lb/ft)	Bare Duct + 3″ Insulation Weight (lb/ft)	Bare Duct + 4″ Insulation Weight (lb/ft)
28	28	5.4	26.5	28.8	31.2	33.5
30	30	6.3	28.4	30.9	33.4	35.9
42	42	12.3	39.7	43.2	46.7	50.2
54	54	20.3	51.1	55.6	60.1	64.6
60	60	25.0	56.8	61.8	66.8	71.8
84	84	49.0	79.5	86.5	93.5	100.5
96	96	64.0	90.8	98.8	106.8	114.8
40	20	5.6	28.4	30.9	33.4	35.9
54	28	10.5	38.8	42.2	45.6	49.0
60	30	12.5	42.6	46.3	50.1	53.8
84	42	24.5	59.6	64.8	70.1	75.3
96	48	32.0	68.1	74.1	80.1	86.1
108	54	40.5	76.6	83.4	90.1	96.9
120	60	50.0	85.1	92.6	100.1	107.6

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Table A3.1-5; Insulated Rectangular Duct: 16 Gage Steel & 6 pcf Insulation
(*Does Not* Include Reinforcement Steel)

Duct Width (in)	Duct Height (in)	Duct Area (ft^2)	Bare Duct + 1″ Insulation Weight (lb/ft)	Bare Duct + 2″ Insulation Weight (lb/ft)
28	28	5.4	28.8	33.5
30	30	6.3	30.9	35.9
42	42	12.3	43.2	50.2
54	54	20.3	55.6	64.6
60	60	25.0	61.8	71.8
84	84	49.0	86.5	100.5
96	96	64.0	98.8	114.8
40	20	5.6	30.9	35.9
54	28	10.5	42.2	49.0
60	30	12.5	46.3	53.8
84	42	24.5	64.8	75.3
96	48	32.0	74.1	86.1
108	54	40.5	83.4	96.9
120	60	50.0	92.6	107.6

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Table A3.1-6; Lagged Rectangular Duct: 16 Gage Steel & 5/8″ Gypsum Board Lagging (*Does Not* Include Reinforcement Steel)

Duct Width (in)	Duct Height (in)	Duct Area (ft^2)	Bare Duct + 1 Layer Gypsum Board Weight (lb/ft)	Bare Duct + 2 Layers Gypsum Board Weight (lb/ft)	Bare Duct + 3 Layers Gypsum Board Weight (lb/ft)
28	28	5.4	42.4	60.6	78.8
30	30	6.3	45.4	64.9	84.5
42	42	12.3	63.6	90.9	118.3
54	54	20.3	81.7	116.9	152.0
60	60	25.0	90.8	129.9	168.9
84	84	49.0	127.1	181.8	236.5
96	96	64.0	145.3	207.8	270.3
40	20	5.6	45.4	64.9	84.5
54	28	10.5	62.1	88.7	115.4
60	30	12.5	68.1	97.4	126.7
84	42	24.5	95.4	136.4	177.4
96	48	32.0	109.0	155.9	202.7
108	54	40.5	122.6	175.3	228.1
120	60	50.0	136.2	194.8	253.4

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Table A3.1-7; SMACNA[1] – Maximum Weight for Rectangular Duct

Duct Width (in)	Duct Height (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
30	30	6.3	17
42	42	12.3	29
54	54	20.3	46
60	60	25.0	54
84	84	49.0	103
96	96	64.0	129
54	28	10.5	34
60	30	12.5	39
84	42	24.5	74
96	48	32.0	97
108	54	40.5	110
120	60	50.0	121

[1] SMACNA, Seismic Restraint Manual – Guidelines for Mechanical Systems with Addendum No. 1 2nd Edition; Sheet Metal and Air Conditioning Contractors' National Association, Inc., 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209, 1998.

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ROUND DUCT DATA

Table A3.2-1; Maximum Recommended Round Duct Weights for Sizing Seismic Restraints [Maximum Values of Tables A3.2.2 & A3.2.6]

Duct Diameter (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
30	4.9	20
33	5.9	22
36	7.1	24
48	12.6	33
60	19.6	41
84	38.5	69

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Table A3.2-2; Non-Insulated Round Duct: 16 Gage Steel
(*Does Not* Include Reinforcement Steel)

Duct Diameter (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
30	4.9	20
36	7.1	24
42	9.6	28
48	12.6	33
54	15.9	37
60	19.6	41
66	23.8	45
72	28.3	49
78	33.2	53
84	38.5	57
90	44.2	61
96	50.3	65
102	56.7	69
108	63.6	73

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Table A3.2-3; Insulated Round Duct: 16 Gage Steel & 1.5 pcf Insulation
(*Does Not* Include Reinforcement Steel)

Duct Diameter (in)	Duct Area (ft^2)	Bare Duct + 1-1/4″ Insulation Weight (lb/ft)	Bare Duct + 2″ Insulation Weight (lb/ft)	Bare Duct + 3″ Insulation Weight (lb/ft)	Bare Duct + 4″ Insulation Weight (lb/ft)
30	4.9	21.6	22.3	23.3	24.3
36	7.1	25.9	26.7	27.9	29.1
42	9.6	30.2	31.2	32.6	34.0
48	12.6	34.5	35.7	37.2	38.8
54	15.9	38.8	40.1	41.9	43.7
60	19.6	43.1	44.6	46.5	48.5
66	23.8	47.4	49.0	51.2	53.4
72	28.3	51.7	53.5	55.8	58.2
78	33.2	56.0	57.9	60.5	63.1
84	38.5	60.3	62.4	65.2	67.9
90	44.2	64.7	66.9	69.8	72.8
96	50.3	69.0	71.3	74.5	77.6
102	56.7	73.3	75.8	79.1	82.5
108	63.6	77.6	80.2	83.8	87.3

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Table A3.2-4; Insulated Round Duct: 16 Gage Steel & 3 pcf Insulation
(*Does Not* Include Reinforcement Steel)

Duct Diameter (in)	Duct Area (ft^2)	Bare Duct + 1″ Insulation Weight (lb/ft)	Bare Duct + 2″ Insulation Weight (lb/ft)	Bare Duct + 3″ Insulation Weight (lb/ft)	Bare Duct + 4″ Insulation Weight (lb/ft)
30	4.9	22.3	24.3	26.2	28.2
36	7.1	26.7	29.1	31.5	33.8
42	9.6	31.2	34.0	36.7	39.4
48	12.6	35.7	38.8	41.9	45.1
54	15.9	40.1	43.7	47.2	50.7
60	19.6	44.6	48.5	52.4	56.4
66	23.8	49.0	53.4	57.7	62.0
72	28.3	53.5	58.2	62.9	67.6
78	33.2	57.9	63.1	68.2	73.3
84	38.5	62.4	67.9	73.4	78.9
90	44.2	66.9	72.8	78.6	84.5
96	50.3	71.3	77.6	83.9	90.2
102	56.7	75.8	82.5	89.1	95.8
108	63.6	80.2	87.3	94.4	101.4

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Table A3.2-5; Insulated Round Duct: 16 Gage Steel & 6 pcf Insulation
(*Does Not* Include Reinforcement Steel)

Duct Diameter (in)	Duct Area (ft^2)	Bare Duct + 1-1/4″ Insulation Weight (lb/ft)	Bare Duct + 2″ Insulation Weight (lb/ft)
30	4.9	25.2	28.2
36	7.1	30.3	33.8
42	9.6	35.3	39.4
48	12.6	40.4	45.1
54	15.9	45.4	50.7
60	19.6	50.5	56.4
66	23.8	55.5	62.0
72	28.3	60.6	67.6
78	33.2	65.6	73.3
84	38.5	70.7	78.9
90	44.2	75.7	84.5
96	50.3	80.7	90.2
102	56.7	85.8	95.8
108	63.6	90.8	101.4

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Table A3.2-6; SMACNA[1] – Maximum Weight for Round Duct

Duct Diameter (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
33	5.9	14
36	7.1	16
48	12.6	21
60	19.6	34
84	38.5	69

[1] SMACNA, Seismic Restraint Manual – Guidelines for Mechanical Systems with Addendum No. 1 2nd Edition; Sheet Metal and Air Conditioning Contractors' National Association, Inc., 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209, 1998.

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FLAT OVAL DUCT DATA

Table A3.3-1; Non-Insulated Flat Oval Duct: 16 Gage Steel
(*Does Not* Include Reinforcement Steel)

Duct Height (in)	Duct Width (in)	Duct Flat Width (in)	Duct Area (ft^2)	Duct Weight (lb/ft)
14	60	46	5.5	29
14	66	52	6.1	32
14	72	58	6.7	34
14	78	64	7.3	37
14	84	70	7.9	40
16	48	32	5.0	25
16	54	38	5.6	27
16	60	44	6.3	30
20	36	16	4.4	20
20	48	28	6.1	26
20	60	40	7.7	31
20	72	52	9.4	36
20	84	64	11.1	41
22	36	14	4.8	21
22	48	26	6.6	26
22	60	38	8.4	31
22	72	50	10.3	36
30	72	42	13.7	38
30	78	48	14.9	41
30	84	54	16.2	44

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Table A3.3-2; Insulated Flat Oval Duct: 16 Gage Steel & 1.5 pcf Insulation
(*Does Not* Include Reinforcement Steel)

Duct Height (in)	Duct Width (in)	Duct Area (ft^2)	Bare Duct + 1-1/4″ Insulation Weight (lb/ft)	Bare Duct + 2″ Insulation Weight (lb/ft)	Bare Duct + 3″ Insulation Weight (lb/ft)	Bare Duct + 4″ Insulation Weight (lb/ft)
14	60	5.5	31.1	32.2	33.6	35.0
14	66	6.1	33.8	35.0	36.5	38.1
14	72	6.7	36.6	37.8	39.5	41.2
14	78	7.3	39.3	40.7	42.5	44.3
14	84	7.9	42.1	43.5	45.4	47.3
16	48	5.0	26.1	27.0	28.2	29.4
16	54	5.6	28.9	29.9	31.2	32.5
16	60	6.3	31.6	32.7	34.1	35.6
20	36	4.4	21.7	22.4	23.4	24.4
20	48	6.1	27.2	28.1	29.3	30.6
20	60	7.7	32.7	33.8	35.3	36.8
20	72	9.4	38.1	39.5	41.2	42.9
20	84	11.1	43.6	45.1	47.1	49.1
22	36	4.8	22.2	23.0	24.0	25.0
22	48	6.6	27.7	28.6	29.9	31.2
22	60	8.4	33.2	34.3	35.8	37.3
22	72	10.3	38.7	40.0	41.8	43.5
30	72	13.7	40.8	42.2	44.0	45.9
30	78	14.9	43.5	45.0	47.0	49.0
30	84	16.2	46.2	47.8	49.9	52.0

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Table A3.3-3; Insulated Flat Oval Duct: 16 Gage Steel & 3 pcf Insulation
(*Does Not* Include Reinforcement Steel)

Duct Height (in)	Duct Width (in)	Duct Area (ft^2)	Bare Duct + 1″ Insulation Weight (lb/ft)	Bare Duct + 2″ Insulation Weight (lb/ft)	Bare Duct + 3″ Insulation Weight (lb/ft)	Bare Duct + 4″ Insulation Weight (lb/ft)
14	60	5.5	32.2	35.0	37.8	40.7
14	66	6.1	35.0	38.1	41.2	44.2
14	72	6.7	37.8	41.2	44.5	47.8
14	78	7.3	40.7	44.3	47.8	51.4
14	84	7.9	43.5	47.3	51.2	55.0
16	48	5.0	27.0	29.4	31.8	34.2
16	54	5.6	29.9	32.5	35.1	37.8
16	60	6.3	32.7	35.6	38.5	41.3
20	36	4.4	22.4	24.4	26.4	28.4
20	48	6.1	28.1	30.6	33.1	35.5
20	60	7.7	33.8	36.8	39.7	42.7
20	72	9.4	39.5	42.9	46.4	49.9
20	84	11.1	45.1	49.1	53.1	57.1
22	36	4.8	23.0	25.0	27.0	29.0
22	48	6.6	28.6	31.2	33.7	36.2
22	60	8.4	34.3	37.3	40.4	43.4
22	72	10.3	40.0	43.5	47.0	50.6
30	72	13.7	42.2	45.9	49.6	53.3
30	78	14.9	45.0	49.0	52.9	56.9
30	84	16.2	47.8	52.0	56.3	60.5

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Table A3.3-4; Insulated Flat Oval Duct: 16 Gage Steel & 6 pcf Insulation
(*Does Not* Include Reinforcement Steel)

Duct Height (in)	Duct Width (in)	Duct Area (ft^2)	Bare Duct + 1″ Insulation Weight (lb/ft)	Bare Duct + 2″ Insulation Weight (lb/ft)
14	60	5.5	35.0	40.7
14	66	6.1	38.1	44.2
14	72	6.7	41.2	47.8
14	78	7.3	44.3	51.4
14	84	7.9	47.3	55.0
16	48	5.0	29.4	34.2
16	54	5.6	32.5	37.8
16	60	6.3	35.6	41.3
20	36	4.4	24.4	28.4
20	48	6.1	30.6	35.5
20	60	7.7	36.8	42.7
20	72	9.4	42.9	49.9
20	84	11.1	49.1	57.1
22	36	4.8	25.0	29.0
22	48	6.6	31.2	36.2
22	60	8.4	37.3	43.4
22	72	10.3	43.5	50.6
30	72	13.7	45.9	53.3
30	78	14.9	49.0	56.9
30	84	16.2	52.0	60.5

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SHEET METAL SCREWS REQUIRED FOR DUCT RESTRAINT

Table A3.4-1; Horizontal Seismic Force Class System Designations

Horizontal Force Class	Horizontal Seismic Force Range per Force Class (lbs)
I	$0 \leq F_P \leq 250$
II	$250 < F_P \leq 500$
III	$500 < F_P \leq 1{,}000$
IV	$1{,}000 < F_P \leq 2{,}000$
V	$2{,}000 < F_P \leq 5{,}000$
VI	$5{,}000 < F_P \leq 10{,}000$

Table A3.4-2; Sheet Metal Screws Required for Seismic Attachment for 28 Gage Steel Ducts

Screw Size (Nom. Dia.)	#6 (0.138″)		#8 (0.164″)		#10 (0.190″)		#12 (0.216″)	
Horizontal Force Class	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd
I	112	4	123	4	133	4	140	4
II		5		5		4		4
III		9		9		8		8
IV		18		17		16		15
V		45		41		38		36
VI		90		82		76		72

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Table A3.4-3; Sheet Metal Screws Required for Seismic Attachment for 22 Gage Steel Ducts

Screw Size (Nom. Dia.)	#6 (0.138″)		#8 (0.164″)		#10 (0.190″)		#12 (0.216″)	
Horizontal Force Class	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd
I	207	4	225	4	245	4	259	4
II		4		4		4		4
III		5		5		5		4
IV		10		9		9		8
V		25		23		21		20
VI		49		45		41		39

Table A3.4-4; Sheet Metal Screws Required for Seismic Attachment for 20 Gage Steel Ducts

Screw Size (Nom. Dia.)	#6 (0.138″)		#8 (0.164″)		#10 (0.190″)		#12 (0.216″)	
Horizontal Force Class	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd
I	281	4	307	4	330	4	351	4
II		4		4		4		4
III		4		4		4		4
IV		8		7		7		6
V		18		17		16		15
VI		36		33		31		29

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Table A3.4-5; Sheet Metal Screws Required for Seismic Attachment for 18 Gage Steel Ducts

Screw Size (Nom. Dia.)	#6 (0.138″)		#8 (0.164″)		#10 (0.190″)		#12 (0.216″)	
Horizontal Force Class	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd
I	419	4	455	4	491	4	522	4
II		4		4		4		4
III		4		4		4		4
IV		5		5		5		4
V		12		11		11		10
VI		24		22		21		20

Table A3.4-6; Sheet Metal Screws Required for Seismic Attachment for 16 Gage Steel Ducts

Screw Size (Nom. Dia.)	#6 (0.138″)		#8 (0.164″)		#10 (0.190″)		#12 (0.216″)	
Horizontal Force Class	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd
I	588	4	643	4	690	4	735	4
II		4		4		4		4
III		4		4		4		4
IV		4		4		4		4
V		9		8		8		7
VI		18		16		15		14

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FILLET WELD SIZE & LENGTH FOR DUCT RESTRAINT

Table A3.5-1; Horizontal Seismic Force Class System Designations

Horizontal Force Class	Horizontal Seismic Force Range per Force Class (lbs)
I	$0 \leq F_P \leq 250$
II	$250 < F_P \leq 500$
III	$500 < F_P \leq 1{,}000$
IV	$1{,}000 < F_P \leq 2{,}000$
V	$2{,}000 < F_P \leq 5{,}000$
VI	$5{,}000 < F_P \leq 10{,}000$

Table A3.5-2; Fillet Weld Size and Length Required for Seismic Attachment to Duct and Supports

Fillet Weld Leg Size (in)		1/32	1/16	3/32	1/8	3/16	1/4
Horizontal Force Class	Allow. Weld Shear (LRFD) (psi)	Total Weld Length Req'd (in)	Total Weld Length Req'd (in)	Total Weld Length Req'd (in)	Total Weld Length Req'd (in)	Total Weld Length Req'd (in)	Total Weld Length Req'd (in)
I	26,040	1.00	1.00	1.00	1.00	1.00	1.00
II		1.00	1.00	1.00	1.00	1.00	1.00
III		2.00	1.00	1.00	1.00	1.00	1.00
IV		4.00	2.00	2.00	1.00	1.00	1.00
V		9.00	5.00	3.00	3.00	2.00	2.00
VI		18.00	9.00	6.00	5.00	3.00	3.00

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Notes:

1.) The weld lengths shown in Table A3.5-2 are the minimum total length of weld required to resist the maximum horizontal seismic load for each Horizontal Force Class at each restraint location. The welds must be balance vertically around, and side-to-side across the duct at each restraint location to prevent twisting and warping of the duct. Use the total weld length from Table A3.5-2 for each restraint location plus enough extra weld to balance the amount of weld vertically around, and side-to-side across the duct.

2.) Select Weld leg size based on the thickness of the thinnest member in the weld joint.

3.) Make sure to use the lowest possible current setting that will produce a good weld joint to prevent "burn through" in the duct sheet metal.

4.) The allowable weld shear is based on E60XX weld material.

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ASTM A307 & A325 BOLTS REQUIRED FOR DUCT RESTRAINT

Table A3.4-1; Horizontal Seismic Force Class System Designations

Horizontal Force Class	Horizontal Seismic Force Range per Force Class (lbs)
I	0 ≤ F_P ≤ 250
II	250 < F_P ≤ 500
III	500 < F_P ≤ 1,000
IV	1,000 < F_P ≤ 2,000
V	2,000 < F_P ≤ 5,000
VI	5,000 < F_P ≤ 10,000

Table A3.6-2; ASTM A307 Bolts Required for Seismic Attachment for Steel Ducts

Bolt Size	1/4-20 UNC		3/8-16 UNC		1/2-13 UNC		5/8-11 UNC	
Horizontal Force Class	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd
I	426	2	1,063	2	1,966	2	3,152	2
II		2		2		2		2
III		3		2		2		2
IV		5		2		2		2
V		12		5		3		2
VI		24		10		6		4

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Table A3.6-3; ASTM A325 Bolts Required for Seismic Attachment for Steel Ducts

Bolt Size	1/4-20 UNC		3/8-16 UNC		1/2-13 UNC		5/8-11 UNC	
Horizontal Force Class	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd	Allow. Shear (LRFD) (lbs)	Min. Screws Req'd
I	1,089	2	2,717	2	5,025	2	8,055	2
II		2		2		2		2
III		2		2		2		2
IV		2		2		2		2
V		5		2		2		2
VI		10		4		2		2

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BOLT DATA

Table A4.1-1; ASTM A307 Bolt Capacities (Standard in Cable Kits)

Bolt Size (in)	Thread Minor Diameter (in)	Thread Minor Area (in^2)	Allowable Tensile Load (ASD) (lbs)	Allowable Combined Load (ASD) (lbs)	Allowable Shear Load (ASD) (lbs)	Installation Torque (ft-lbs)
1/4-20 UNC	0.1894	0.0282	609	287	304	4
3/8-16 UNC	0.2992	0.0703	1,519	717	759	13
1/2-13 UNC	0.4069	0.1300	2,809	1,326	1,404	32
5/8-11 UNC	0.5152	0.2085	4,503	2,126	2,251	64
3/4-10 UNC	0.6291	0.3108	6,714	3,170	3,357	113
7/8-9 UNC	0.7408	0.4310	9,310	4,396	4,655	166
1-8 UNC	0.8492	0.5664	12,234	5,776	6,117	250

Table A4.1-2; ASTM A325 Bolt Capacities (Special for Cable Kits When Required)

Bolt Size (in)	Thread Minor Diameter (in)	Thread Minor Area (in^2)	Allowable Tensile Load (ASD) (lbs)	Allowable Combined Load (ASD) (lbs)	Allowable Shear Load (ASD) (lbs)	Installation Torque (ft-lbs)
1/4-20 UNC	0.1894	0.0282	1,555	734	778	8
3/8-16 UNC	0.2992	0.0703	3,881	1,832	1,941	31
1/2-13 UNC	0.4069	0.1300	7,178	3,389	3,589	75
5/8-11 UNC	0.5152	0.2085	11,507	5,433	5,754	150
3/4-10 UNC	0.6291	0.3108	17,158	8,101	8,579	266
7/8-9 UNC	0.7408	0.4310	23,792	11,233	11,896	429
1-8 UNC	0.8492	0.5664	31,264	14,761	15,632	644

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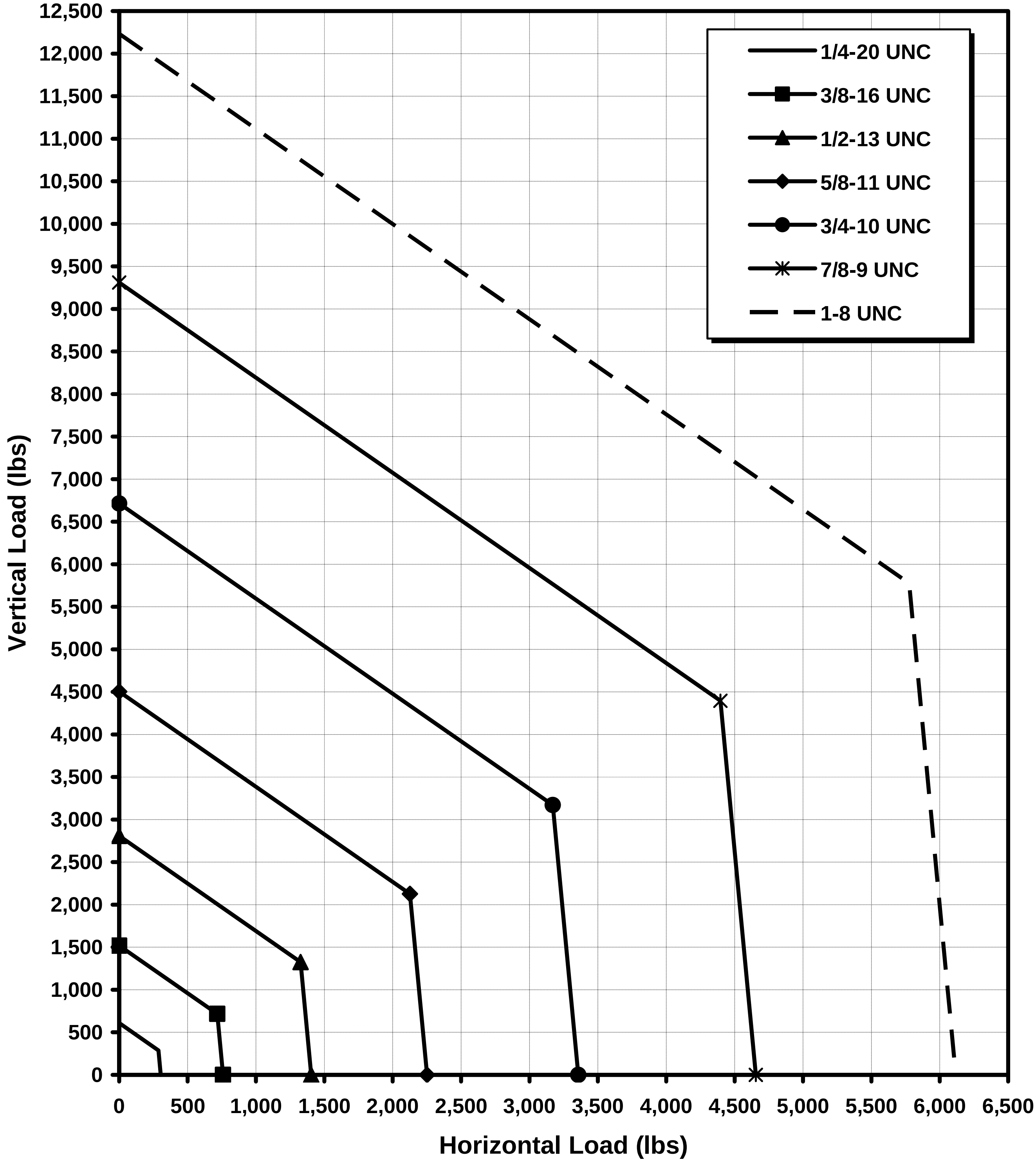

Figure A4.1-1; Seismic Capacity Envelopes for ASTM A307 Bolts

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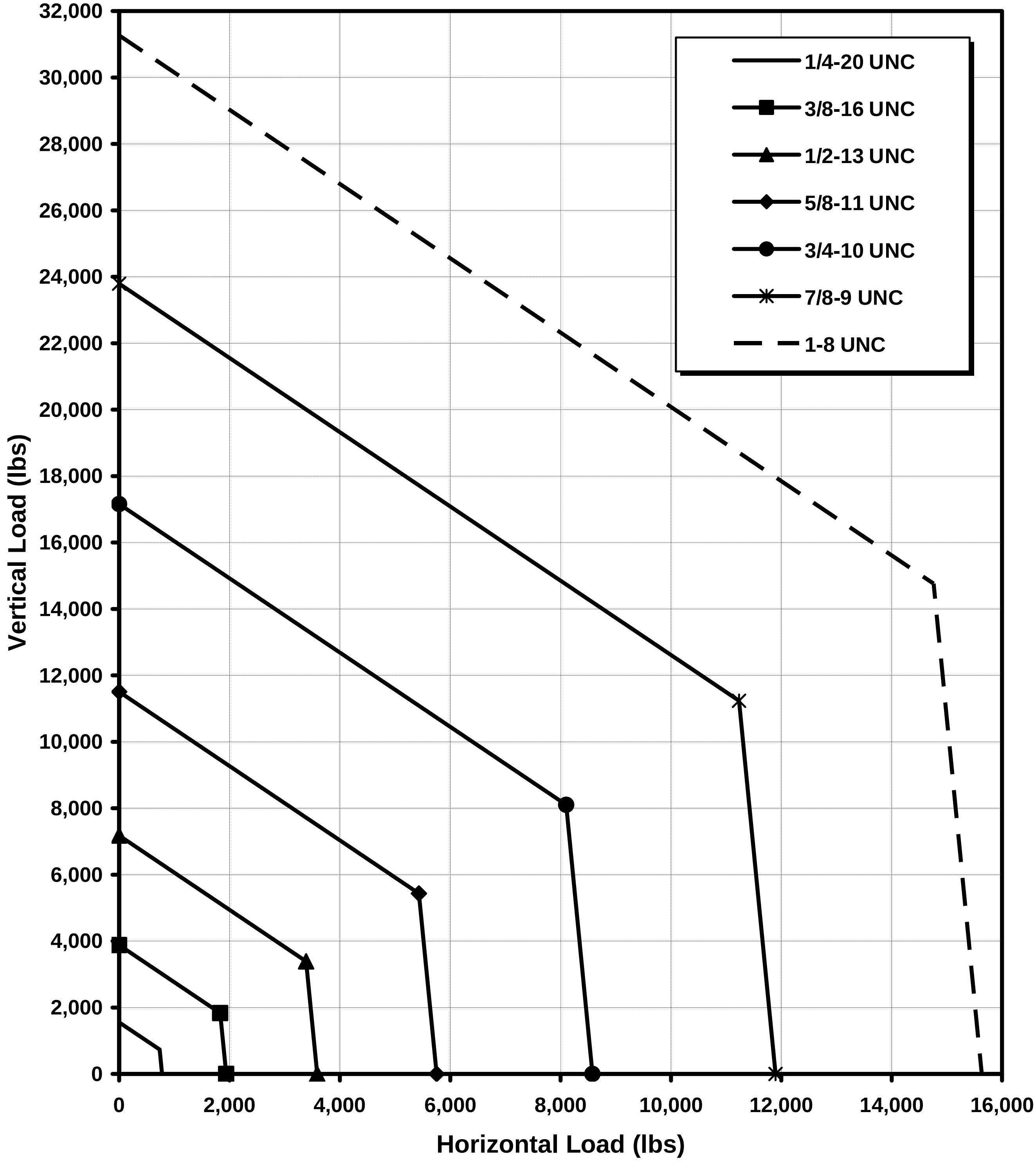

Figure A4.1-2; Seismic Capacity Envelopes for ASTM A325 Bolts

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MODEL KCCAB WEDGE TYPE CONCRETE ANCHOR DATA

Table A4.2-1; Model KCCAB Anchor Capacities – 3,000 psi Normal Weight Concrete – Standard Embedments

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	808	567	922	6	4 3/8	4
1/2	4	3 1/4	1,750	1,251	2,082	9 3/4	7 1/2	6
5/8	4 3/4	4	2,079	1,675	3,430	12	9	6
3/4	5 3/4	4 3/4	3,133	2,525	5,177	14 1/4	11 3/4	8

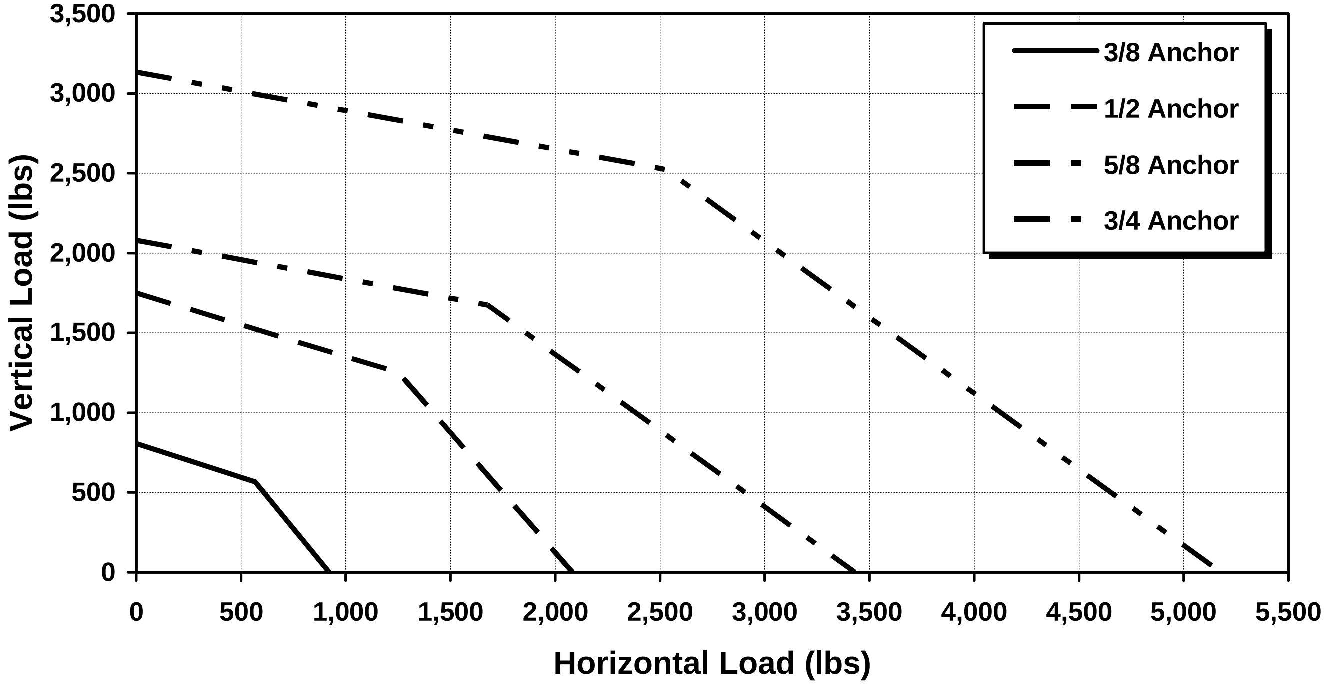

Figure A4.2-1; Seismic Capacity Envelopes for Model KCCAB Concrete Anchors – 3,000 psi Normal Weight Concrete – Standard Embedments

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SHEET METAL SCREW DATA

Table A4.3-1; Allowable Seismic and Wind Loads for Sheet Metal Screws vs. Sheet Metal Gage

Screw Size (Nom. Dia.)	#6 (0.138″)		#8 (0.164″)		#10 (0.190″)		#12 (0.216″)	
Sheet Metal Gage	Allow. Shear (ASD) (lbs)	Allow. Pullout (ASD) (lbs)	Allow. Shear (ASD) (lbs)	Allow. Pullout (ASD) (lbs)	Allow. Shear (ASD) (lbs)	Allow. Pullout (ASD) (lbs)	Allow. Shear (ASD) (lbs)	Allow. Pullout (ASD) (lbs)
28	80	44	88	52	95	61	100	69
22	148	67	161	79	175	92	185	104
20	201	81	219	96	236	112	251	127
18	299	105	325	125	351	145	373	165
16	420	133	459	157	493	183	525	208
14	531	167	632	199	697	231	743	261
12	757	239	900	284	1,044	328	1,187	373

Notes:

1. Minimum screw spacing is three (3) times the nominal screw diameter.
2. These values are based on sheet metal strength of 33,000 psi yield and 45,000 psi tensile.
3. These values have been increased by 33% for seismic and wind applications which produces a Factor of Safety equal to 2.25:1.
4. Use of these values requires a minimum penetration of three (3) clear exposed complete threads through the joined materials.
5. Screw strength must be verified by the supplier of the fasteners.
6. Table data is taken from, *SSMA – Product Technical Information ICBO ER-4943P*; Steel Stud Manufacturer's Association, 2000; Pp 5 & 48.

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LAG SCREW DATA

Notes:

1. *ANSI/AF&PA NDS-1997 National Design Specification for Wood Construction*; American Forest & Paper Association, 1997.
2. Data is for soft wood and engineered wood with a specific gravity of 0.35.
3. ***Do not*** install lag screws into the ***end grain*** of a piece of structural wood for seismic or wind applications!

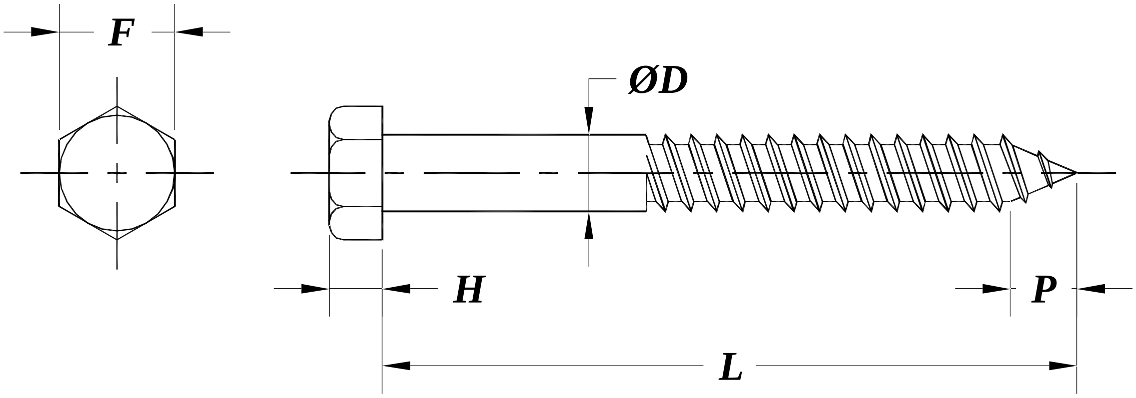

Figure A4.4-1; Typical Lag Screw

Table A4.4-1; Hex Head Lag Screw Dimensional Data – Figure A4.4-1

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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Table A4.4-2; Lag Screw Installation Data – Figure A4.4-2

Lag Screw 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	1	3/8	2	1/8	2-1/2	1/8	5/32
					1/4	2-1/2		
					3/8	3		
					1/2	3		
5/16	1-1/4	1-1/4	15/32	2-1/2	1/8	3	9/32	13/64
					1/4	3-1/2		
					3/8	3-1/2		
					1/2	3-1/2		
3/8	1-1/2	1-1/2	9/16	3	1/8	3-1/2	3/16	1/4
					1/4	4		
					3/8	4		
					1/2	4		
1/2	2	2	3/4	4	1/8	5	15/64	21/64
					1/4	5		
					3/8	5		
					1/2	5		
5/8	2-1/2	2-1/2	15/16	5	1/8	6	19/64	13/32
					1/4	6		
					3/8	6		
					1/2	7		
3/4	3	3	1-1/8	6	1/8	7	23/64	31/64
					1/4	7		
					3/8	8		
					1/5	8		

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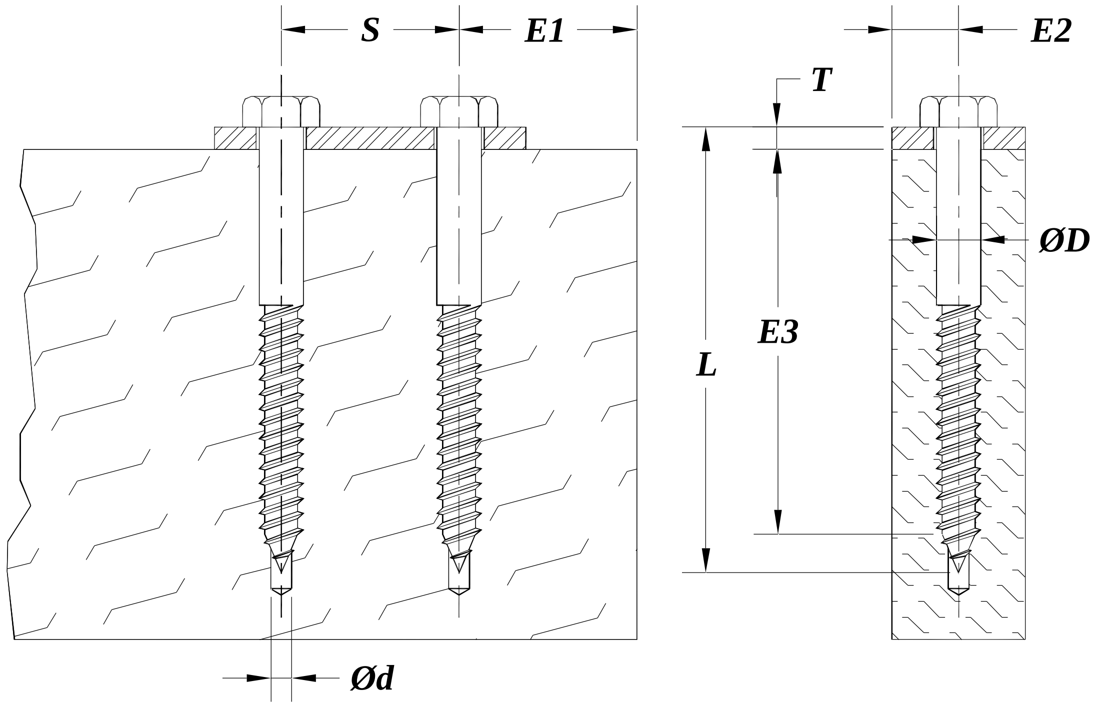

Figure A4.4-2; Typical Lag Screw Installation Dimensions

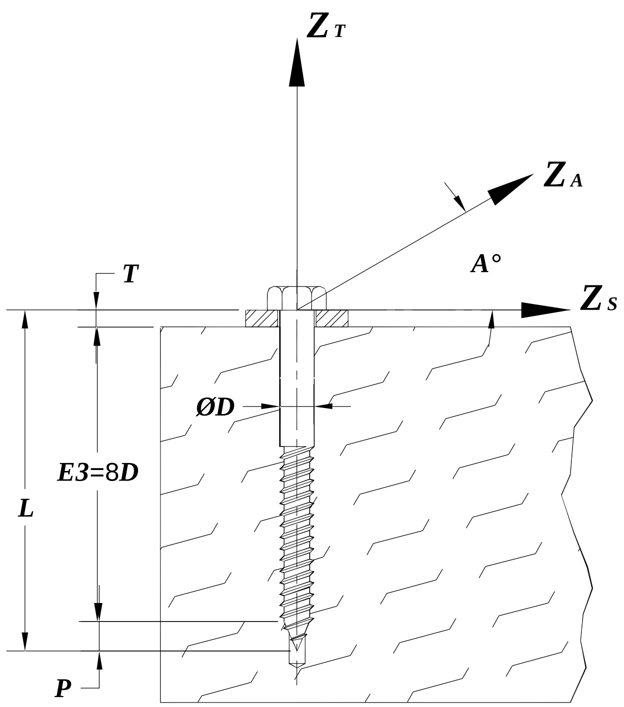

Figure A4.4-3; Lag Screw Loading Diagram

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Table A4.4-3; Allowable Seismic and Wind Loads for Lag Screws – 1/4" Thick Side Plate

Lag Screw Size ΦD (in)	Embed. Depth $E3 = 8D$ (in)	Allow. Tensile Load Z_T (ASD) (lbs)	Allow. Shear Load Z_S (ASD) (lbs)	Load Angle A (deg)	Allow. Comb. Load Z_A (ASD) (lbs)
1/4	2	422	272	0	272
				30	299
				45	331
				60	371
5/16	2 1/2	624	352	0	352
				30	395
				45	450
				60	523
3/8	3	859	416	0	416
				30	478
				45	561
				60	678
1/2	4	1,421	624	0	624
				30	726
				45	867
				60	1,077
5/8	5	2,096	864	0	864
				30	1,013
				45	1,224
				60	1,545
3/4	6	2,880	1,152	0	1,152
				30	1,355
				45	1,646
				60	2,095

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ESTIMATING HANGER ROD STIFFENER REQUIREMENTS

Introduction:

Determining the actual rod stiffener requirements for a specific hanger location on a specific project is beyond the scope of this manual. However, the intent of this appendix is to demonstrate how the rod stiffener requirements may be estimated in a general way for planning and cost estimating purposes.

The need for hanger rod stiffeners, the size of the rod stiffener angle, and the number of clamps used to attach the rod stiffener angle to the hanger rod is dependent on several variables.

1. The horizontal seismic force that is being restrained. This value depends on the design spectral acceleration seismic acceleration, the component importance factor, component amplification and response factors, the weight of the pipe or duct being restrained, the restraint spacing, and the elevation of the hanger rod attachment point in the building with respect to the roof line as measured from grade. In this appendix, the horizontal seismic force will be expressed as a Horizontal Force Class value, see Table A5.1-1. The numerical value assigned to the Horizontal Force Class will be the maximum force value in the range for each Force Class. The Horizontal Force Class number is the force that is applied at each restraint location. It may be computed from the information given in Sections S5.0 and S7.0, or obtained from the online tools provided by Kinetics Noise Control.
2. The hanger rod size. The buckling strength of the hanger rods in this appendix has been determined using the minor thread diameter and assuming that the rods are carbon steel and meet the minimum strength requirements of ASTM A307. The various hanger rod sizes are assigned a numerical code to streamline the data tables in the following sections of this appendix. The hanger rod size code and other hanger rod data are presented in Table A5.1-2.

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Table A5.1-1; Horizontal Seismic Force Class System Designations

Horizontal Force Class	Horizontal Seismic Force Range per Force Class (lbs)
I	$0 \le F_P \le 250$
II	$250 < F_P \le 500$
III	$500 < F_P \le 1{,}000$
IV	$1{,}000 < F_P \le 2{,}000$
V	$2{,}000 < F_P \le 5{,}000$
VI	$5{,}000 < F_P \le 10{,}000$

Table S5.1-2; Hanger Rod Size Code, Size, and Allowable Load Data

Hanger Rod Code	Hanger Rod Size UNC	Minor Thread Diameter (in)	Area Moment of Inertia (in^4)	Hanger Rod Allowable Load ASD (kips)
3	3/8 - 16	0.2992	0.000393	0.73
4	1/2 - 13	0.4069	0.001346	1.35
5	5/8 - 11	0.5152	0.003458	2.16
6	3/4 - 10	0.6291	0.007689	3.23
7	7/8 - 9	0.7408	0.014783	4.48
8	1 - 8	0.8492	0.025528	5.90
10	1 1/4 - 7	1.0777	0.066216	9.50

3. The supported weight of the pipe or duct. This is expressed as a weight per foot. Data for the weight per foot of various pipe and duct may be found in Appendix A2.0 and Appendix A3.0 of this manual respectively.
4. The hanger rod spacing. A 10 ft spacing of the hanger rods was assumed for the tables and analysis in this manual. This is a standard spacing that corresponds well with the usual recommended seismic restraint spacings, see Section S1.0.

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5. Seismic restraint installation angle. In a run of pipe and duct, the restraint installation angle may vary widely form restraint location to restraint location. This appendix provides a set of tables for restraint installation angle ranging from 0° up to and including 45°, Sections A5.2 and A5.4, and a set of tables for restraint installation angles ranging from 45° up to and including 60°, Sections A5.3 and A5.5.
6. Single hanger rod or trapeze supported pipe or duct. This affects the dead weight load carried by each hanger rod which will affect the magnitude of the compressive load that is applied to the hanger rod. The effects of using a single hanger rod or a trapeze to support the pipe or duct is demonstrated in Tables S8-3 through S8-10.

Hanger rod stiffeners may be nearly any rigid structural shape. Some of the components that have historically been used are as follows.

1. AISI rolled structural angles
2. Pipe
3. Electrical conduit
4. UNISTRUT® channels, there are several different manufacturers of shapes similar to those provided by UNISTRUT®

Kinetics Noise Control has chosen to recommend the AISI rolled structural angles for use as hanger rod stiffeners because they give the hanger rod good lateral support, they are readily available, and they provide a great deal of flexibility for use with many hanger rod sizes. Kinetics Noise Control provides two basic models of rod stiffener clamps that cover a wide range of AISI rolled structural angles, and hanger rods. These clamps are shown in Figures A5.1-1 and A5.1-2. These two clamps will allow the use of hanger rods ranging from 3/8 – 16 UNC to 1-1/4 – 7 UNC, and AISI structural angles ranging from L1 x 1 x 1/8 to L2-1/2 x 2-1/2 x 1/4 for normal applications, and up to L2-1/2 x 2-1/2 x 1/2 for certain special applications. To make the tables and specifications easier, an alpha rod stiffener code has been assigned to the AISI structural angles recommended by Kinetics Noise Control. The AISI structural angles suitable for the Models

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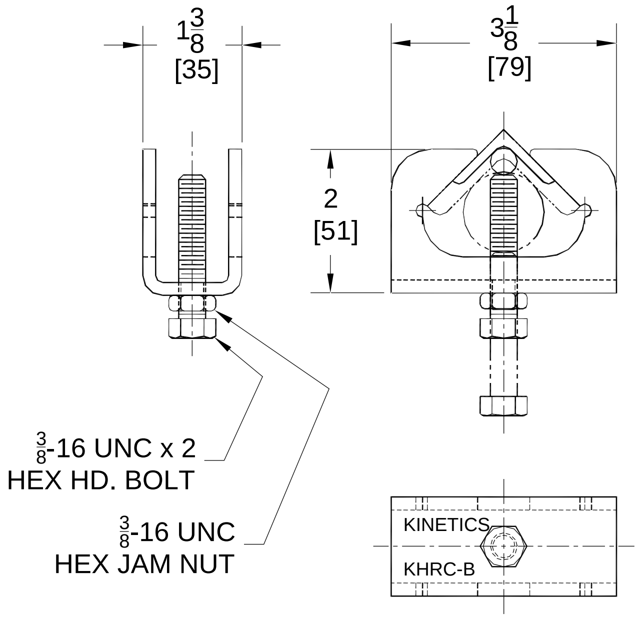
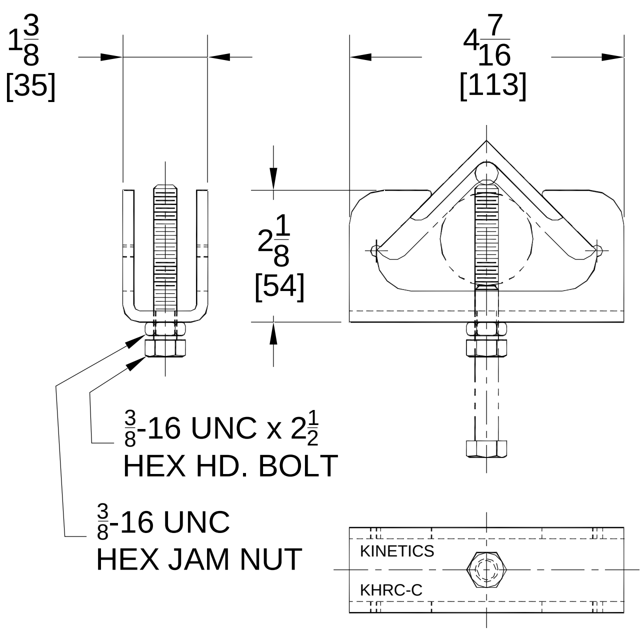
KHRC-B and KHRC-C hanger rod stiffener clamps are list by rod stiffener code letter in Table A5.1-3.



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

Figure A5.1-1; Kinetics Noise Control Model KHRC-B Small Hanger Rod Stiffener Clamp



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

Figure A5.1-2; Kinetics Noise Control Model KHRC-C Large Hanger Rod Stiffener Clamp

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Table A5.1-3; Rod Stiffener Angle Code Designation and Design Data

Rod Stiffener Code	AISI Angle Designation	Weight per Foot (lbs)	Section Area (in^2)	$I_{X\text{-}X}$ or $I_{Y\text{-}Y}$ (in^4)	Radius of Gyration $Z\text{-}Z$ (in)	$I_{Z\text{-}Z}$ (in^4)
A	L 1 x 1 x 1/8	0.80	0.234	0.022	0.196	0.0090
B	L 1-1/4 x 1-1/4 x 1/4	1.92	0.563	0.077	0.243	0.0332
C	L 1-1/2 x 1-1/2 x 1/4	2.34	0.688	0.139	0.292	0.0587
D	L 1-3/4 x 1-3/4 x 1/4	2.77	0.813	0.227	0.341	0.0945
E	L 2 x 2 x 1/4	3.19	0.938	0.348	0.391	0.1434
F	L 2 x 2 x 3/8	4.70	1.36	0.479	0.389	0.2058
G	L 2-1/2 x 2-1/2 x 1/4	4.10	1.19	0.703	0.491	0.2869
H[1]	L 2-1/2 x 2-1/2 x 3/8	5.90	1.73	0.984	0.487	0.4103
I[1]	L 2-1/2 x 2-1/2 x 1/2	7.70	2.25	1.230	0.487	0.5336

[1] These rod stiffener angles may be used with the Kinetics Noise Control Model KHRC-C rod stiifener clamp. Not all hanger rod sizes may work with these arrangements. Check with Kinetics Noise Control Engineering for your particular application.

Example No. 1:

1. CWS – Chilled Water Supply: 8″ insulated schedule 40 steel pipe & a supported weight of 55.84 lbs/ft from Table A2.1-2.
2. Single Hanger Rod Supported: Hanger rod size = 1/2-13 UNC (Hanger Rod Code = 4 from Table A5.1-2).
3. Cable restraints installed @ 45°.
4. Assume 10 ft hanger rod spacing.
5. Horizontal Force Class III
6. Hanger rod length $L = 36$ in.

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A. From Table A5.2-4 the maximum un-stiffened hanger rod length will be $L_{CR} = 11$ in. The actual supported weight falls just over the 50 lb/ft value in the table, therefore, to be safe, the hanger rod will require a stiffener.
B. From Table A5.4-4 the rod stiffener code that will apply is A (L 1 x 1 x 1/8). The actual hanger rod length is less than the maximum allowable angle stiffener length for rod stiffener code A.
C. From Table A5.6-4, the Maximum Rod Stiffener Clamp Spacing for 50 lbs/ft is 40 inches.
D. The number of Model KHRC-B rod stiffener clamps that will be required for this hanger rod is 3. The hanger rod is shorter than the Maximum Rod Stiffener Clamp Spacing.

Example No. 2:

1. CWS & CWR – Chilled Water Supply and Chilled Water Return: 8″ insulated schedule 40 steel pipe & a supported weight of 55.84 lbs/ft each from Table A2.1-2. Total supported weight is 111.68 lbs/ft.
2. Trapeze Supported: Hanger rod size = 3/8-16 UNC (Hanger Rod Code = 3 from Table A5.1-2).
3. Cable restraints installed @ 45°.
4. Assume 10 ft hanger rod spacing.
5. Horizontal Force Class II
6. Hanger rod length $L = 36$ in.

A. From Tables A5.2-9 and A5.4-9 hanger rod stiffeners are not required for:
   a. 3/8-16 UNC hanger rods supporting over 100 lbs/ft in a trapeze arrangement.
   b. Horizontal Force Class II.
   c. Restraint installation angle of 45° or less.

Example No. 3:

1. 54 x 108 rectangular duct with a supported weight of 70 lbs/ft.

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2. Trapeze Supported: Hanger rod size = 3/8-16 UNC (Hanger Rod Code = 3 from Table A5.1-2).
3. Cable restraints installed @ 60°.
4. Assume 10 ft hanger rod spacing.
5. Horizontal Force Class IV
6. Hanger rod length $L = 60$ in.

A. From Table A5.3-11 the 3/8-16 UNC hanger rod is not recommended for a trapeze application for any listed supported load when the Horizontal Force Class is IV and the installation angle is 60°. The first hanger rod that may be used is a #5 rod which is 5/8-11 UNC. The maximum un-stiffened hanger rod length is $L_{CR} = 7$ in.
B. From Table A5.5-11 the rod stiffener code that will apply is C (L 1-1/2 x 1-1/2 x 1/4).
C. From Table A5.7-11, the Maximum Rod Stiffener Clamp Spacing is 16 in.
D. The number of Model KHRC-B rod stiffener clamps that will be required for this hanger rod is $N_{RC} = \left(\frac{L}{S_C}\right) + 1 = \left(\frac{60}{16}\right) = 3.75 = \underline{4}$.

Example No. 4:

1. 44 x 44 square duct with a supported weight of 23.6 lbs/ft.
2. Trapeze Supported: Hanger rod size = 3/8-16 UNC (Hanger Rod Code = 3 from Table A5.1-2).
3. Cable restraints installed @ 60°.
4. Assume 10 ft hanger rod spacing.
5. Horizontal Seismic Design Force @ Restraint Point = 793 lbs (Horizontal Force Class III from Table A5.1-1).
6. Hanger rod length $L = 120$ in.

A. From Table A5.3-10 the 3/8-16 UNC hanger rod is not recommended for a trapeze application for any listed supported load when the Horizontal Force Class is III and the

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installation angle is 60°. The first hanger rod that may be used is a #5 rod which is 5/8-11 UNC. The maximum un-stiffened hanger rod length is $L_{CR} = 10$ in.

B. From Table A5.5-10 the rod stiffener code that will apply is E (L 2 x 2 x 1/4).

C. From Table A5.7-10, the Maximum Rod Stiffener Clamp Spacing is 22 in.

D. The number of Model KHRC-C rod stiffener clamps that will be required for this hanger rod is $N_{RC} = \left(\frac{L}{S_C}\right) + 1 = \left(\frac{120}{22}\right) = 3.75 = \underline{7}$.

Example No. 5:

1. 114 x 50 rectangular duct with a supported weight of 92.4 lbs/ft.
2. Trapeze Supported: Hanger rod size = 1/2-13 UNC (Hanger Rod Code = 4 from Table A5.1-2).
3. Cable restraints installed @ 60°.
4. Assume 10 ft hanger rod spacing.
5. Horizontal Seismic Design Force @ Restraint Point = 3,105 lbs (Horizontal Force Class V from Table A5.1-1).
6. Hanger rod length $L = 120$ in.

A. From Table A5.3-12 the 1/2-13 UNC hanger rod is not recommended for a trapeze application for any listed supported load when the Horizontal Force Class is V and the installation angle is 60°. The first hanger rod that may be used is a #7 rod which is 7/8-9 UNC. The maximum un-stiffened hanger rod length is $L_{CR} = 9$ in.

B. From Table A5.5-12 there is no available rod stiffener for this application and hanger rod length. Reduce restraint spacing to reduce the Horizontal Force Class, or consult with the Kinetics Noise Control for recommendations.

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Example No. 6:

1. Chilled Water Supply: 12″ insulated schedule 40 steel pipe & a supported weight of 106.45 lbs/ft each from Table A2.1-2
2. Single Clevis Supported: Hanger Rod Size = 3/4-10 UNC (Hanger Rod Code = 6 from Table A5.1-2).
3. Cable restraints installed @ 60°.
4. Assume 10 ft hanger rod spacing.
5. Horizontal Seismic Design Force @ Restraint Point = 2,384 lbs (Horizontal Force Class V from Table A5.1-1).
6. Hanger rod length $L = 60$ in.

A. From Table A5.3-6 the 3/4-10 UNC the maximum un-stiffened hanger rod length is $L_{CR} = 7$ in.

B. From Table A5.5-6 the rod stiffener code that will apply is F (L 2 x 2 x 3/8).

C. From Table A5.7-6, the Maximum Rod Stiffener Clamp Spacing is 15 inches.

D. The number of Model KHRC-B rod stiffener clamps that will be required for this hanger rod is $N_{RC} = \left(\frac{L}{S_C}\right) + 1 = \left(\frac{60}{15}\right) = \underline{4}$.

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MAXIMUM UN-STIFFENED HANGER ROD LENGTH FOR 0° ≤ A ≤ 45°

Table S5.2-1; Hanger Rod Size Code, Size, and Allowable Load Data

Hanger Rod Code	Hanger Rod Size UNC	Minor Thread Diameter (in)	Area Moment of Inertia (in^4)	Hanger Rod Allowable Load ASD (kips)
3	3/8 - 16	0.2992	0.000393	0.73
4	1/2 - 13	0.4069	0.001346	1.35
5	5/8 - 11	0.5152	0.003458	2.16
6	3/4 - 10	0.6291	0.007689	3.23
7	7/8 - 9	0.7408	0.014783	4.48
8	1 - 8	0.8492	0.025528	5.90
10	1 1/4 - 7	1.0777	0.066216	9.50

Table A5.2-2; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class I, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	9	18	29	43	60	79	127
10	11	21	33	50	69	91	147
15	13	25	41	61	85	112	180
25	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.2-3; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class II, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	12	19	29	40	52	85
10	--------	12	20	30	42	56	90
15	7	13	22	32	45	59	96
25	8	16	26	38	54	70	114
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.2-4; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class III, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	8	13	19	27	36	58
10	--------	8	13	20	28	37	60
15	--------	8	14	21	29	38	62
25	--------	9	15	22	31	40	66
50	--------	11	18	27	38	50	80
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.2-5; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class IV, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	9	13	19	25	40
10	--------	--------	9	14	19	25	41
15	--------	--------	9	14	19	26	42
25	--------	--------	9	14	20	26	43
50	--------	--------	10	15	22	28	46
100	--------	8	13	19	27	35	57
150	--------	11	18	27	38	50	80
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.2-6; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class V, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	8	12	15	25
10	--------	--------	--------	8	12	16	25
15	--------	--------	--------	8	12	16	25
25	--------	--------	--------	8	12	16	26
50	--------	--------	--------	9	12	16	26
100	--------	--------	--------	9	13	17	28
150	--------	--------	--------	10	14	18	30
200	--------	--------	7	11	15	20	33
250	--------	--------	8	12	17	22	36
300	--------	--------	9	13	19	25	40

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Table A5.2-7; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class VI, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	--------	8	11	18
10	--------	--------	--------	--------	8	11	18
15	--------	--------	--------	--------	8	11	18
25	--------	--------	--------	--------	8	11	18
50	--------	--------	--------	--------	8	11	18
100	--------	--------	--------	--------	9	11	19
150	--------	--------	--------	--------	9	12	19
200	--------	--------	--------	--------	9	12	20
250	--------	--------	--------	7	9	12	20
300	--------	--------	--------	7	10	13	21

Table A5.2-8; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class I, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	9	17	27	41	56	74	120
10	9	18	29	43	60	79	127
15	10	19	31	46	64	84	136
25	12	23	36	55	76	100	161
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.2-9; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class II, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	11	18	28	39	51	82
10	--------	12	19	29	40	52	85
15	--------	12	20	29	41	54	87
25	7	13	21	31	44	57	93
50	8	16	26	38	54	70	114
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.2-10; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class III, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	8	13	19	27	35	57
10	--------	8	13	19	27	36	58
15	--------	8	13	20	28	36	59
25	--------	8	13	20	28	37	61
50	--------	9	15	22	31	40	66
100	--------	11	18	27	38	50	80
150	8	16	26	38	54	70	114
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.2-11; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class IV, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	9	13	19	25	40
10	--------	--------	9	13	19	25	40
15	--------	--------	9	14	19	25	41
25	--------	--------	9	14	19	25	41
50	--------	--------	9	14	20	26	43
100	--------	--------	10	15	22	28	46
150	--------	7	11	17	24	31	51
200	--------	8	13	19	27	35	57
250	--------	9	15	22	31	40	66
300	--------	11	18	27	38	50	80

Table A5.2-12; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class V, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	8	12	15	25
10	--------	--------	--------	8	12	15	25
15	--------	--------	--------	8	12	15	25
25	--------	--------	--------	8	12	16	25
50	--------	--------	--------	8	12	16	26
100	--------	--------	--------	9	12	16	26
150	--------	--------	--------	9	13	17	27
200	--------	--------	--------	9	13	17	28
250	--------	--------	--------	10	13	18	29
300	--------	--------	--------	10	14	18	30

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Table A5.2-13; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class VI, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	--------	8	11	18
10	--------	--------	--------	--------	8	11	18
15	--------	--------	--------	--------	8	11	18
25	--------	--------	--------	--------	8	11	18
50	--------	--------	--------	--------	8	11	18
100	--------	--------	--------	--------	8	11	18
150	--------	--------	--------	--------	8	11	18
200	--------	--------	--------	--------	9	11	19
250	--------	--------	--------	--------	9	11	19
300	--------	--------	--------	--------	9	12	19

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MAXIMUM UN-STIFFENED HANGER ROD LENGTH FOR 45° < A ≤ 60°

Table S5.3-1; Hanger Rod Size Code, Size, and Allowable Load Data

Hanger Rod Code	Hanger Rod Size UNC	Minor Thread Diameter (in)	Area Moment of Inertia (in^4)	Hanger Rod Allowable Load ASD (kips)
3	3/8 - 16	0.2992	0.000393	0.73
4	1/2 - 13	0.4069	0.001346	1.35
5	5/8 - 11	0.5152	0.003458	2.16
6	3/4 - 10	0.6291	0.007689	3.23
7	7/8 - 9	0.7408	0.014783	4.48
8	1 - 8	0.8492	0.025528	5.90
10	1 1/4 - 7	1.0777	0.066216	9.50

Table A5.3-2; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class I, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	7	13	21	31	43	57	92
10	7	14	22	33	46	61	99
15	8	15	24	36	50	66	107
25	10	19	30	45	63	82	133
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.3-3; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class II, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	9	14	21	29	39	63
10	--------	9	14	22	30	40	65
15	--------	9	15	23	31	41	67
25	--------	10	16	24	34	45	72
50	7	13	21	32	44	58	94
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.3-4; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class III, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	10	15	20	27	44
10	--------	--------	10	15	21	27	44
15	--------	--------	10	15	21	28	45
25	--------	--------	10	16	22	29	46
50	--------	7	11	17	24	31	51
100	--------	9	15	22	31	41	66
150	9	16	27	40	56	73	118
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.3-5; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class IV, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	7	10	14	19	30
10	--------	--------	7	10	14	19	31
15	--------	--------	7	10	14	19	31
25	--------	--------	7	10	15	19	31
50	--------	--------	7	11	15	20	33
100	--------	--------	8	12	17	22	36
150	--------	--------	9	13	19	25	40
200	--------	--------	10	16	22	29	47
250	--------	8	13	19	27	36	58
300	--------	11	19	28	39	52	83

Table A5.3-6; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class V, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	--------	9	12	19
10	--------	--------	--------	--------	9	12	19
15	--------	--------	--------	--------	9	12	19
25	--------	--------	--------	--------	9	12	19
50	--------	--------	--------	--------	9	12	20
100	--------	--------	--------	7	9	12	20
150	--------	--------	--------	7	10	13	21
200	--------	--------	--------	7	10	13	22
250	--------	--------	--------	7	10	14	23
300	--------	--------	--------	8	11	14	24

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Table A5.3-7; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class VI, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	--------	--------	8	13
10	--------	--------	--------	--------	--------	8	13
15	--------	--------	--------	--------	--------	8	13
25	--------	--------	--------	--------	--------	8	13
50	--------	--------	--------	--------	--------	8	13
100	--------	--------	--------	--------	--------	8	14
150	--------	--------	--------	--------	--------	8	14
200	--------	--------	--------	--------	--------	9	14
250	--------	--------	--------	--------	7	9	14
300	--------	--------	--------	--------	7	9	15

Table A5.3-8; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class I, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	12	20	30	42	55	89
10	7	13	21	31	43	57	92
15	7	13	21	32	45	59	95
25	7	14	23	35	48	63	102
50	10	19	30	45	63	82	133
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.3-9; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class II, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	8	14	21	29	38	62
10	--------	9	14	21	29	39	63
15	--------	9	14	21	30	39	64
25	--------	9	15	22	31	41	66
50	--------	10	16	24	34	45	72
100	7	13	21	32	44	58	94
150	12	23	38	57	79	104	167
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.3-10; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class III, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	9	14	20	27	43
10	--------	--------	10	15	20	27	44
15	--------	--------	10	15	20	27	44
25	--------	--------	10	15	21	27	45
50	--------	--------	10	16	22	29	46
100	--------	7	11	17	24	31	51
150	--------	8	13	19	27	35	57
200	--------	9	15	22	31	41	66
250	--------	11	18	28	38	51	82
300	9	16	27	40	56	73	118

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Table A5.3-11; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class IV, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	7	10	14	19	30
10	--------	--------	7	10	14	19	30
15	--------	--------	7	10	14	19	31
25	--------	--------	7	10	14	19	31
50	--------	--------	7	10	15	19	31
100	--------	--------	7	11	15	20	33
150	--------	--------	7	11	16	21	34
200	--------	--------	8	12	17	22	36
250	--------	--------	8	13	18	23	38
300	--------	--------	9	13	19	25	40

Table A5.3-12; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class V, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	--------	9	12	19
10	--------	--------	--------	--------	9	12	19
15	--------	--------	--------	--------	9	12	19
25	--------	--------	--------	--------	9	12	19
50	--------	--------	--------	--------	9	12	19
100	--------	--------	--------	--------	9	12	20
150	--------	--------	--------	--------	9	12	20
200	--------	--------	--------	7	9	12	20
250	--------	--------	--------	7	9	13	20
300	--------	--------	--------	7	10	13	21

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Table A5.3-13; Maximum Un-Stiffened Hanger Rod Length: Horizontal Force Class VI, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Un-Stiffened Hanger Rod Length (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	--------	--------	8	13
10	--------	--------	--------	--------	--------	8	13
15	--------	--------	--------	--------	--------	8	13
25	--------	--------	--------	--------	--------	8	13
50	--------	--------	--------	--------	--------	8	13
100	--------	--------	--------	--------	--------	8	13
150	--------	--------	--------	--------	--------	8	14
200	--------	--------	--------	--------	--------	8	14
250	--------	--------	--------	--------	--------	8	14
300	--------	--------	--------	--------	--------	8	14

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AISI ANGLE STIFFENER DATA FOR 0° ≤ A ≤ 45°

Table S5.4-1; Rod Stiffener Angle Code Designation and Design Data

Rod Stiffener Code	AISI Angle Designation	Weight per Foot (lbs)	Section Area (in²)	I_{X-X} or I_{Y-Y} (in⁴)	Radius of Gyration Z-Z (in)	I_{Z-Z} (in⁴)
A	L 1 x 1 x 1/8	0.80	0.234	0.022	0.196	0.0090
B	L 1-1/4 x 1-1/4 x 1/4	1.92	0.563	0.077	0.243	0.0332
C	L 1-1/2 x 1-1/2 x 1/4	2.34	0.688	0.139	0.292	0.0587
D	L 1-3/4 x 1-3/4 x 1/4	2.77	0.813	0.227	0.341	0.0945
E	L 2 x 2 x 1/4	3.19	0.938	0.348	0.391	0.1434
F	L 2 x 2 x 3/8	4.70	1.36	0.479	0.389	0.2058
G	L 2-1/2 x 2-1/2 x 1/4	4.10	1.19	0.703	0.491	0.2869
H[1]	L 2-1/2 x 2-1/2 x 3/8	5.90	1.73	0.984	0.487	0.4103
I[1]	L 2-1/2 x 2-1/2 x 1/2	7.70	2.25	1.230	0.487	0.5336

[1] These rod stiffener angles may be used with the Kinetics Noise Control Model KHRC-C rod stiifener clamp. Not all hanger rod sizes may work with these arrangements. Check with Kinetics Noise Control Engineering for your particular application.

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Table A5.4-2; Maximum Allowable Rod Stiffener Length: Horizontal Force Class I, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	94	174	240	240	240	240	240	240	240
10	108	201	240	240	240	240	240	240	240
15	133	240	240	240	240	240	240	240	240
25	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.4-3; Maximum Allowable Rod Stiffener Length: Horizontal Force Class II, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	62	116	160	203	240	240	240	240	240
10	66	123	170	215	240	240	240	240	240
15	71	131	181	230	240	240	240	240	240
25	84	156	215	240	240	240	240	240	240
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.4-4; Maximum Allowable Rod Stiffener Length: Horizontal Force Class III, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	43	80	110	140	172	206	240	240	240
10	44	82	113	143	177	212	240	240	240
15	45	84	116	148	182	218	240	240	240
25	48	90	124	157	194	232	240	240	240
50	59	110	152	193	237	240	240	240	240
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.4-5; Maximum Allowable Rod Stiffener Length: Horizontal Force Class IV, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	30	55	77	97	120	144	170	203	232
10	30	56	78	99	122	146	172	206	235
15	30	57	79	100	123	148	174	209	238
25	31	58	81	103	127	152	179	215	240
50	34	63	87	111	137	164	194	232	240
100	42	78	107	136	168	201	237	240	240
150	59	110	152	193	237	240	240	240	240
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.4-6; Maximum Allowable Rod Stiffener Length: Horizontal Force Class V, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	18	35	48	61	75	90	106	127	145
10	19	35	48	61	76	91	107	128	146
15	19	35	48	62	76	91	108	129	147
25	19	35	49	62	77	92	109	130	148
50	19	36	50	64	79	95	112	134	152
100	21	39	53	68	84	100	118	142	162
150	22	41	57	73	89	107	127	152	173
200	24	45	62	78	97	116	137	164	187
250	26	49	68	86	106	127	150	179	205
300	29	55	76	96	118	142	168	201	229

Table A5.4-7; Maximum Allowable Rod Stiffener Length: Horizontal Force Class VI, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	13	24	34	43	53	63	75	90	102
10	13	24	34	43	53	64	75	90	103
15	13	24	34	43	53	64	75	90	103
25	13	24	34	43	53	64	76	91	103
50	13	25	34	44	54	65	77	92	105
100	14	26	35	45	56	67	79	94	108
150	14	26	36	46	57	69	81	97	111
200	14	27	38	48	59	71	84	100	114
250	15	28	39	49	61	73	86	103	118
300	15	29	40	51	63	76	89	107	122

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Table A5.4-8; Maximum Allowable Rod Stiffener Length: Horizontal Force Class I, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	88	164	226	240	240	240	240	240	240
10	94	174	240	240	240	240	240	240	240
15	100	186	240	240	240	240	240	240	240
25	119	220	240	240	240	240	240	240	240
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.4-9; Maximum Allowable Rod Stiffener Length: Horizontal Force Class II, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	61	113	156	198	240	240	240	240	240
10	62	116	160	203	240	240	240	240	240
15	64	119	165	209	240	240	240	240	240
25	68	127	175	223	240	240	240	240	240
50	84	156	215	240	240	240	240	240	240
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.4-10; Maximum Allowable Rod Stiffener Length: Horizontal Force Class III, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	42	79	108	138	170	204	240	240	240
10	43	80	110	140	172	206	240	240	240
15	43	81	111	142	174	209	240	240	240
25	45	83	115	146	179	215	240	240	240
50	48	90	124	157	194	232	240	240	240
100	59	110	152	193	237	240	240	240	240
150	84	156	215	240	240	240	240	240	240
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.4-11; Maximum Allowable Rod Stiffener Length: Horizontal Force Class IV, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	29	55	76	97	119	143	169	202	230
10	30	55	77	97	120	144	170	203	232
15	30	56	77	98	121	145	171	205	233
25	30	56	78	99	122	147	173	207	237
50	31	58	81	103	127	152	179	215	240
100	34	63	87	111	137	164	194	232	240
150	37	69	96	122	150	180	212	240	240
200	42	78	107	136	168	201	237	240	240
250	48	90	124	157	194	232	240	240	240
300	59	110	152	193	237	240	240	240	240

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Table A5.4-12; Maximum Allowable Rod Stiffener Length: Horizontal Force Class V, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	18	34	48	61	75	90	106	127	145
10	18	35	48	61	75	90	106	127	145
15	18	35	48	61	75	90	107	128	146
25	19	35	48	61	76	91	107	128	146
50	19	35	49	62	77	92	109	130	148
100	19	36	50	64	79	95	112	134	152
150	20	37	52	66	81	97	115	138	157
200	21	39	53	68	84	100	118	142	162
250	21	40	55	70	86	104	122	146	167
300	22	41	57	73	89	107	127	152	173

Table A5.4-13; Maximum Allowable Rod Stiffener Length: Horizontal Force Class VI, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	13	24	34	43	53	63	75	90	102
10	13	24	34	43	53	63	75	90	102
15	13	24	34	43	53	63	75	90	103
25	13	24	34	43	53	64	75	90	103
50	13	24	34	43	53	64	76	91	103
100	13	25	34	44	54	65	77	92	105
150	13	25	35	44	55	66	78	93	106
200	14	26	35	45	56	67	79	94	108
250	14	26	36	46	56	68	80	96	109
300	14	26	36	46	57	69	81	97	111

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AISI ANGLE STIFFENER DATA FOR 45° < A ≤ 60°

Table S5.5-1; Rod Stiffener Angle Code Designation and Design Data

Rod Stiffener Code	AISI Angle Designation	Weight per Foot (lbs)	Section Area (in²)	$I_{X\text{-}X}$ or $I_{Y\text{-}Y}$ (in⁴)	Radius of Gyration $Z\text{-}Z$ (in)	$I_{Z\text{-}Z}$ (in⁴)
A	L 1 x 1 x 1/8	0.80	0.234	0.022	0.196	0.0090
B	L 1-1/4 x 1-1/4 x 1/4	1.92	0.563	0.077	0.243	0.0332
C	L 1-1/2 x 1-1/2 x 1/4	2.34	0.688	0.139	0.292	0.0587
D	L 1-3/4 x 1-3/4 x 1/4	2.77	0.813	0.227	0.341	0.0945
E	L 2 x 2 x 1/4	3.19	0.938	0.348	0.391	0.1434
F	L 2 x 2 x 3/8	4.70	1.36	0.479	0.389	0.2058
G	L 2-1/2 x 2-1/2 x 1/4	4.10	1.19	0.703	0.491	0.2869
H[1]	L 2-1/2 x 2-1/2 x 3/8	5.90	1.73	0.984	0.487	0.4103
I[1]	L 2-1/2 x 2-1/2 x 1/2	7.70	2.25	1.230	0.487	0.5336

[1] These rod stiffener angles may be used with the Kinetics Noise Control Model KHRC-C rod stiifener clamp. Not all hanger rod sizes may work with these arrangements. Check with Kinetics Noise Control Engineering for your particular application.

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Table A5.5-2; Maximum Allowable Rod Stiffener Length: Horizontal Force Class I, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	68	126	173	220	240	240	240	240	240
10	72	135	186	236	240	240	240	240	240
15	79	146	202	240	240	240	240	240	240
25	98	182	240	240	240	240	240	240	240
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.5-3; Maximum Allowable Rod Stiffener Length: Horizontal Force Class II, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	46	86	119	151	186	223	240	240	240
10	48	89	122	156	192	230	240	240	240
15	49	92	127	161	198	238	240	240	240
25	53	99	137	174	214	240	240	240	240
50	69	128	177	225	240	240	240	240	240
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.5-4; Maximum Allowable Rod Stiffener Length: Horizontal Force Class III, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	32	60	82	105	129	155	183	219	240
10	32	61	84	106	131	157	186	222	240
15	33	62	85	108	133	160	189	226	240
25	34	64	88	112	138	165	195	233	240
50	37	70	96	123	151	181	214	240	240
100	49	91	125	159	196	235	240	240	240
150	87	161	223	240	240	240	240	240	240
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.5-5; Maximum Allowable Rod Stiffener Length: Horizontal Force Class IV, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	22	42	58	73	91	109	128	154	175
10	22	42	58	74	91	109	129	155	176
15	23	42	59	75	92	110	130	156	178
25	23	43	60	76	93	112	132	158	181
50	24	45	62	79	97	117	138	165	188
100	26	49	68	87	107	128	151	181	206
150	30	55	76	97	120	143	169	203	231
200	34	64	88	112	139	166	196	235	240
250	42	79	109	139	171	205	240	240	240
300	61	114	157	200	240	240	240	240	240

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Table A5.5-6; Maximum Allowable Rod Stiffener Length: Horizontal Force Class V, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	14	26	36	46	57	68	81	96	110
10	14	26	36	46	57	68	81	97	110
15	14	26	36	46	57	69	81	97	111
25	14	26	37	47	58	69	82	98	111
50	14	27	37	47	58	70	83	99	113
100	15	28	38	49	60	72	85	102	117
150	15	29	40	51	62	75	88	106	121
200	16	30	41	52	65	78	92	110	125
250	16	31	43	55	67	81	95	114	130
300	17	32	45	57	70	84	100	119	136

Table A5.5-7; Maximum Allowable Rod Stiffener Length: Horizontal Force Class VI, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	--------	18	25	32	40	48	57	68	78
10	--------	18	25	32	40	48	57	68	78
15	--------	18	25	32	40	48	57	68	78
25	--------	18	26	33	40	48	57	68	78
50	--------	19	26	33	41	49	58	69	79
100	--------	19	26	33	41	49	58	70	80
150	--------	19	27	34	42	50	59	71	81
200	--------	19	27	34	42	51	60	72	82
250	--------	20	27	35	43	52	61	73	84
300	--------	20	28	36	44	53	62	75	85

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Table A5.5-8; Maximum Allowable Rod Stiffener Length: Horizontal Force Class I, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	65	122	168	213	240	240	240	240	240
10	68	126	173	220	240	240	240	240	240
15	70	130	179	228	240	240	240	240	240
25	75	140	193	240	240	240	240	240	240
50	98	182	240	240	240	240	240	240	240
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.5-9; Maximum Allowable Rod Stiffener Length: Horizontal Force Class II, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	45	85	117	148	183	219	240	240	240
10	46	86	119	151	186	223	240	240	240
15	47	87	120	153	189	226	240	240	240
25	48	90	125	158	195	234	240	240	240
50	53	99	137	174	214	240	240	240	240
100	69	128	177	225	240	240	240	240	240
150	123	229	240	240	240	240	240	240	240
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.5-10; Maximum Allowable Rod Stiffener Length: Horizontal Force Class III, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	32	59	82	104	128	154	182	217	240
10	32	60	82	105	129	155	183	219	240
15	32	60	83	106	130	156	184	221	240
25	33	61	84	107	132	158	187	224	240
50	34	64	88	112	138	165	195	233	240
100	37	70	96	123	151	181	214	240	240
150	42	78	108	137	169	203	240	240	240
200	49	91	125	159	196	235	240	240	240
250	60	112	154	196	240	240	240	240	240
300	87	161	223	240	240	240	240	240	240

Table A5.5-11; Maximum Allowable Rod Stiffener Length: Horizontal Force Class IV, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	22	42	58	73	90	108	128	153	175
10	22	42	58	73	91	109	128	154	175
15	22	42	58	74	91	109	129	154	176
25	23	42	58	74	92	110	130	155	177
50	23	43	60	76	93	112	132	158	181
100	24	45	62	79	97	117	138	165	188
150	25	47	65	82	102	122	144	172	197
200	26	49	68	87	107	128	151	181	206
250	28	52	72	91	113	135	159	191	218
300	30	55	76	97	120	143	169	203	231

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Table A5.5-12; Maximum Allowable Rod Stiffener Length: Horizontal Force Class V, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	14	26	36	46	57	68	80	96	110
10	14	26	36	46	57	68	81	96	110
15	14	26	36	46	57	68	81	97	110
25	14	26	36	46	57	68	81	97	111
50	14	26	37	47	58	69	82	98	111
100	14	27	37	47	58	70	83	99	113
150	14	27	38	48	59	71	84	101	115
200	15	28	38	49	60	72	85	102	117
250	15	28	39	50	61	74	87	104	119
300	15	29	40	51	62	75	88	106	121

Table A5.5-13; Maximum Allowable Rod Stiffener Length: Horizontal Force Class VI, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Length (in) Rod Stiffener Code for AISI Angles								
	A	B	C	D	E	F	G	H	I
5	--------	18	25	32	40	48	57	68	78
10	--------	18	25	32	40	48	57	68	78
15	--------	18	25	32	40	48	57	68	78
25	--------	18	25	32	40	48	57	68	78
50	--------	18	26	33	40	48	57	68	78
100	--------	19	26	33	41	49	58	69	79
150	--------	19	26	33	41	49	58	69	79
200	--------	19	26	33	41	49	58	70	80
250	--------	19	26	34	41	50	59	70	80
300	--------	19	27	34	42	50	59	71	81

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MAXIMUM ROD STIFFENER CLAMP SPACING FOR 0° ≤ A ≤ 45°

Table S5.6-1; Hanger Rod Size Code, Size, and Allowable Load Data

Hanger Rod Code	Hanger Rod Size UNC	Minor Thread Diameter (in)	Area Moment of Inertia (in^4)	Hanger Rod Allowable Load ASD (kips)
3	3/8 - 16	0.2992	0.000393	0.73
4	1/2 - 13	0.4069	0.001346	1.35
5	5/8 - 11	0.5152	0.003458	2.16
6	3/4 - 10	0.6291	0.007689	3.23
7	7/8 - 9	0.7408	0.014783	4.48
8	1 - 8	0.8492	0.025528	5.90
10	1 1/4 - 7	1.0777	0.066216	9.50

Table A5.6-2; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class I, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	21	39	63	95	117	117	117
10	24	46	73	110	117	117	117
15	30	56	90	117	117	117	117
25	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.6-3; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class II, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	14	26	42	63	88	115	117
10	15	28	45	67	93	117	117
15	16	30	48	72	100	117	117
25	19	35	57	85	117	117	117
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.6-4; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class III, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	9	18	29	43	60	79	117
10	10	18	30	44	62	81	117
15	10	19	31	46	64	84	117
25	11	20	33	49	68	89	117
50	13	25	40	60	83	109	117
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.6-5; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class IV, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	12	20	30	42	55	89
10	7	12	20	30	42	56	90
15	7	13	21	31	43	57	92
25	7	13	21	32	44	58	94
50	7	14	23	34	48	63	102
100	9	17	28	42	59	77	117
150	13	25	40	60	83	109	117
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.6-6; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class V, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	8	12	19	26	34	56
10	--------	8	12	19	26	35	56
15	--------	8	12	19	26	35	56
25	--------	8	13	19	27	35	57
50	--------	8	13	20	27	36	59
100	--------	8	14	21	29	38	62
150	--------	9	15	22	31	41	66
200	--------	10	16	24	34	44	72
250	--------	11	18	26	37	49	79
300	--------	12	20	30	41	54	88

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Table A5.6-7; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class VI, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	9	13	18	24	39
10	--------	--------	9	13	18	24	39
15	--------	--------	9	13	18	24	39
25	--------	--------	9	13	18	24	40
50	--------	--------	9	13	19	25	40
100	--------	--------	9	14	19	25	41
150	--------	--------	9	14	20	26	42
200	--------	--------	10	15	20	27	44
250	--------	--------	10	15	21	28	45
300	--------	--------	10	16	22	29	47

Table A5.6-8; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class I, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	20	37	60	89	117	117	117
10	21	39	63	95	117	117	117
15	23	42	68	102	117	117	117
25	27	50	80	117	117	117	117
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.6-9; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class II, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	14	25	41	61	85	112	117
10	14	26	42	63	88	115	117
15	14	27	43	65	90	117	117
25	15	29	46	69	96	117	117
50	19	35	57	85	117	117	117
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.6-10; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class III, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	9	18	28	43	59	78	117
10	9	18	29	43	60	79	117
15	10	18	29	44	61	80	117
25	10	19	30	45	63	83	117
50	11	20	33	49	68	89	117
100	13	25	40	60	83	109	117
150	19	35	57	85	117	117	117
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.6-11; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class IV, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	12	20	30	42	55	89
10	--------	12	20	30	42	55	89
15	--------	12	20	30	42	56	90
25	7	13	20	31	43	56	91
50	7	13	21	32	44	58	94
100	7	14	23	34	48	63	102
150	8	15	25	38	52	69	112
200	9	17	28	42	59	77	117
250	11	20	33	49	68	89	117
300	13	25	40	60	83	109	117

Table A5.6-12; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class V, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	8	12	19	26	34	56
10	--------	8	12	19	26	34	56
15	--------	8	12	19	26	35	56
25	--------	8	12	19	26	35	56
50	--------	8	13	19	27	35	57
100	--------	8	13	20	27	36	59
150	--------	8	13	20	28	37	60
200	--------	8	14	21	29	38	62
250	--------	9	14	22	30	40	64
300	--------	9	15	22	31	41	66

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Table A5.6-13; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class VI, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 45°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	9	13	18	24	39
10	--------	--------	9	13	18	24	39
15	--------	--------	9	13	18	24	39
25	--------	--------	9	13	18	24	39
50	--------	--------	9	13	18	24	40
100	--------	--------	9	13	19	25	40
150	--------	--------	9	14	19	25	41
200	--------	--------	9	14	19	25	41
250	--------	--------	9	14	20	26	42
300	--------	--------	9	14	20	26	42

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MAXIMUM ROD STIFFENER CLAMP SPACING FOR 45° < A ≤ 60°

Table S5.7-1; Hanger Rod Size Code, Size, and Allowable Load Data

Hanger Rod Code	Hanger Rod Size UNC	Minor Thread Diameter (in)	Area Moment of Inertia (in^4)	Hanger Rod Allowable Load ASD (kips)
3	3/8 - 16	0.2992	0.000393	0.73
4	1/2 - 13	0.4069	0.001346	1.35
5	5/8 - 11	0.5152	0.003458	2.16
6	3/4 - 10	0.6291	0.007689	3.23
7	7/8 - 9	0.7408	0.014783	4.48
8	1 - 8	0.8492	0.025528	5.90
10	1 1/4 - 7	1.0777	0.066216	9.50

Table A5.7-2; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class I, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	15	28	46	68	95	117	117
10	16	30	49	73	102	117	117
15	18	33	53	80	111	117	117
25	22	41	66	99	117	117	117
50	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.7-3; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class II, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	10	19	31	47	65	86	117
10	11	20	32	48	67	88	117
15	11	21	33	50	69	91	117
25	12	22	36	54	75	99	117
50	15	29	47	70	97	117	117
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.7-4; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class III, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	7	13	22	32	45	59	96
10	7	13	22	33	46	60	98
15	7	14	22	33	47	61	99
25	7	14	23	35	48	63	102
50	8	16	25	38	53	70	112
100	11	20	33	49	69	90	117
150	20	37	59	88	117	117	117
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.7-5; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class IV, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	9	15	23	32	42	67
10	--------	9	15	23	32	42	68
15	--------	9	15	23	32	42	68
25	--------	9	15	23	33	43	69
50	--------	10	16	24	34	45	72
100	--------	11	18	27	37	49	79
150	--------	12	20	30	42	55	89
200	7	14	23	35	48	64	103
250	9	18	29	43	60	79	117
300	14	26	42	62	86	114	117

Table A5.7-6; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class V, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	9	14	20	26	42
10	--------	--------	9	14	20	26	42
15	--------	--------	9	14	20	26	42
25	--------	--------	9	14	20	26	43
50	--------	--------	10	14	20	27	43
100	--------	--------	10	15	21	28	45
150	--------	--------	10	15	22	29	46
200	--------	--------	11	16	22	30	48
250	--------	7	11	17	23	31	50
300	--------	7	12	17	24	32	52

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Table A5.7-7; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class VI, *Single Hanger Rod* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	10	14	18	30
10	--------	--------	--------	10	14	18	30
15	--------	--------	--------	10	14	18	30
25	--------	--------	--------	10	14	18	30
50	--------	--------	--------	10	14	18	30
100	--------	--------	7	10	14	19	31
150	--------	--------	7	10	14	19	31
200	--------	--------	7	10	15	19	31
250	--------	--------	7	11	15	20	32
300	--------	--------	7	11	15	20	33

Table A5.7-8; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class I, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	15	27	44	66	92	117	117
10	15	28	46	68	95	117	117
15	16	29	47	71	98	117	117
25	17	32	51	76	106	117	117
50	22	41	66	99	117	117	117
100	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
150	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

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Table A5.7-9; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class II, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	10	19	31	46	64	84	117
10	10	19	31	47	65	86	117
15	10	20	32	47	66	87	117
25	11	20	33	49	68	90	117
50	12	22	36	54	75	99	117
100	15	29	47	70	97	117	117
150	28	52	84	117	117	117	117
200	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
250	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
300	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Table A5.7-10; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class III, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	7	13	21	32	45	59	95
10	7	13	22	32	45	59	96
15	7	13	22	33	45	60	97
25	7	14	22	33	46	61	98
50	7	14	23	35	48	63	102
100	8	16	25	38	53	70	112
150	9	18	28	43	59	78	117
200	11	20	33	49	69	90	117
250	13	25	41	61	85	111	117
300	20	37	59	88	117	117	117

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Table A5.7-11; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class IV, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	9	15	23	31	41	67
10	--------	9	15	23	32	42	67
15	--------	9	15	23	32	42	68
25	--------	9	15	23	32	42	68
50	--------	9	15	23	33	43	69
100	--------	10	16	24	34	45	72
150	--------	10	17	25	35	47	76
200	--------	11	18	27	37	49	79
250	--------	11	19	28	39	52	84
300	--------	12	20	30	42	55	89

Table A5.7-12; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class V, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	9	14	20	26	42
10	--------	--------	9	14	20	26	42
15	--------	--------	9	14	20	26	42
25	--------	--------	9	14	20	26	42
50	--------	--------	9	14	20	26	43
100	--------	--------	10	14	20	27	43
150	--------	--------	10	15	21	27	44
200	--------	--------	10	15	21	28	45
250	--------	--------	10	15	21	28	46
300	--------	--------	10	15	22	29	46

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Table A5.7-13; Maximum Rod Stiffener Clamp Spacing: Horizontal Force Class VI, *Trapeze* Supported Pipe & Duct, 10 ft Hanger Spacing, and an Installation Angle = 60°

Supported Weight (lbs/ft)	Maximum Rod Stiffener Clamp Spacing (in) Hanger Rod Code for UNC Thread Hanger Rods						
	3	4	5	6	7	8	10
5	--------	--------	--------	10	14	18	30
10	--------	--------	--------	10	14	18	30
15	--------	--------	--------	10	14	18	30
25	--------	--------	--------	10	14	18	30
50	--------	--------	--------	10	14	18	30
100	--------	--------	--------	10	14	18	30
150	--------	--------	7	10	14	19	30
200	--------	--------	7	10	14	19	31
250	--------	--------	7	10	14	19	31
300	--------	--------	7	10	14	19	31

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ROD STIFFENER EQUIVALENTS

Kinetics Noise Control provides clamps that may be used with the AISI rolled angles indicated in the tables below. The analysis and selection of rod stiffeners and clamps outlined in Section S8.0 and in Appendices A5.1 through A5.7 of this manual is intended to apply to rod stiffeners made from these rolled angles when used with the Models KHRC-B and KHRC-C Rod Stiffener Clamps. However, Kinetics Noise Control recognizes that other shapes and clamps may be used as hanger rod stiffeners, and that the analysis outlined in Section S8.0 and Appendices A5.1 through A5.7 may apply to these other shapes and clamps. It is the responsibility of the design professional of record to make this determination. As a convenience to other design professionals Kinetics Noise Control has included below Tables A5.8-1 through A5.8-3 to show the equivalencies between the AISI rolled angles used by Kinetics Noise Control and several other shapes commonly available to the various trades.

Table A5.8-1; Rod Stiffener Angle to Pipe Equivalents

Rod Stiffener Code	AISI Angle Designation	$I_{z\text{-}z}$ (in^4)	Schedule 40 Nominal Pipe Size (in)	I (in^4)	Schedule 80 Nominal Pipe Size (in)	I (in^4)
A	L 1 x 1 x 1/8	0.009	1/2	0.017	1/2	0.020
B	L 1-1/4 x 1-1/4 x 1/4	0.033	3/4	0.037	3/4	0.045
C	L 1-1/2 x 1-1/2 x 1/4	0.059	1	0.087	1	0.106
D	L 1-3/4 x 1-3/4 x 1/4	0.095	1 1/4	0.195		
E	L 2 x 2 x 1/4	0.143			1 1/4	0.242
F	L 2 x 2 x 3/8	0.206	1 1/2	0.310		
G	L 2-1/2 x 2-1/2 x 1/4	0.287			1 1/2	0.391
H	L 2-1/2 x 2-1/2 x 3/8	0.410	2	0.666	2	0.918
I	L 2-1/2 x 2-1/2 x 1/2	0.534				

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Table A5.8-2; Rod Stiffener Angle to Conduit Equivalents

<table>
<tr><th>Rod Stiffener Code</th><th>AISI Angle Designation</th><th>$I_{Z\text{-}Z}$ (in^4)</th><th>EMT Steel Conduit</th><th>I (in^4)</th><th>IMC Steel Conduit</th><th>I (in^4)</th><th>Rigid Steel Conduit</th><th>I (in^4)</th></tr>
<tr><td>A</td><td>L 1 x 1 x 1/8</td><td>0.009</td><td>3/4</td><td>0.013</td><td>1/2</td><td>0.011</td><td>1/2</td><td>0.017</td></tr>
<tr><td>B</td><td>L 1-1/4 x 1-1/4 x 1/4</td><td>0.033</td><td rowspan="2">1 1/4</td><td rowspan="2">0.077</td><td rowspan="2">1</td><td rowspan="2">0.059</td><td>3/4</td><td>0.036</td></tr>
<tr><td>C</td><td>L 1-1/2 x 1-1/2 x 1/4</td><td>0.059</td><td>1</td><td>0.084</td></tr>
<tr><td>D</td><td>L 1-3/4 x 1-3/4 x 1/4</td><td>0.095</td><td>1 1/2</td><td>0.120</td><td>1 1/4</td><td>0.125</td><td rowspan="2">1 1/4</td><td rowspan="2">0.187</td></tr>
<tr><td>E</td><td>L 2 x 2 x 1/4</td><td>0.143</td><td rowspan="2">2</td><td rowspan="2">0.248</td><td>1 1/2</td><td>0.204</td></tr>
<tr><td>F</td><td>L 2 x 2 x 3/8</td><td>0.206</td><td rowspan="3">2</td><td rowspan="3">0.434</td><td rowspan="2">1 1/2</td><td rowspan="2">0.298</td></tr>
<tr><td>G</td><td>L 2-1/2 x 2-1/2 x 1/4</td><td>0.287</td><td rowspan="3">2 1/2</td><td rowspan="3">0.623</td></tr>
<tr><td>H</td><td>L 2-1/2 x 2-1/2 x 3/8</td><td>0.410</td><td rowspan="2">2</td><td rowspan="2">0.638</td></tr>
<tr><td>I</td><td>L 2-1/2 x 2-1/2 x 1/2</td><td>0.534</td><td>2 1/2</td><td>1.106</td></tr>
</table>

Table A5.8-3; Rod Stiffener Angle to 1-5/8″ UNISTRUT® Equivalents
Solid Channel: *No Holes* & *No Slots*

<table>
<tr><th>Rod Stiffener Code</th><th>AISI Angle Designation</th><th>$I_{Z\text{-}Z}$ (in^4)</th><th>UNISTRUT Channel</th><th>Min. I (in^4)</th></tr>
<tr><td>A</td><td>L 1 x 1 x 1/8</td><td>0.009</td><td>P4100</td><td>0.026</td></tr>
<tr><td>B</td><td>L 1-1/4 x 1-1/4 x 1/4</td><td>0.033</td><td>P3300</td><td>0.037</td></tr>
<tr><td>C</td><td>L 1-1/2 x 1-1/2 x 1/4</td><td>0.059</td><td rowspan="2">P3000</td><td rowspan="2">0.120</td></tr>
<tr><td>D</td><td>L 1-3/4 x 1-3/4 x 1/4</td><td>0.095</td></tr>
<tr><td>E</td><td>L 2 x 2 x 1/4</td><td>0.143</td><td>P1000</td><td>0.185</td></tr>
<tr><td>F</td><td>L 2 x 2 x 3/8</td><td>0.206</td><td rowspan="2">P5500</td><td rowspan="2">0.334</td></tr>
<tr><td>G</td><td>L 2-1/2 x 2-1/2 x 1/4</td><td>0.287</td></tr>
<tr><td>H</td><td>L 2-1/2 x 2-1/2 x 3/8</td><td>0.410</td><td>P5000</td><td>0.433</td></tr>
<tr><td>I</td><td>L 2-1/2 x 2-1/2 x 1/2</td><td>0.534</td><td>P5501</td><td>0.669</td></tr>
</table>

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MAXIMUM ALLOWABLE RESTRAINT SPACING – STANDARD STEEL PIPE

Table A6.1-1; Max Allowable Restraint Spacing for Non-Insulated Standard Steel Pipe – Empty

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.824	1.1	40	30	30	20	20	20
1	1.315	1.049	1.7	40	40	30	30	30	20
1 1/4	1.660	1.380	2.3	40	40	40	40	30	30
1 1/2	1.900	1.610	2.7	40	40	40	40	30	30
2	2.375	2.067	3.6	40	40	40	40	40	40
2 1/2	2.875	2.469	5.8	40	40	40	40	40	40
3	3.500	3.068	7.6	40	40	40	40	40	40
3 1/2	4.000	3.548	9.1	40	40	40	40	40	40
4	4.500	4.026	10.8	40	40	40	40	40	40
5	5.563	5.047	14.6	40	40	40	40	40	40
6	6.625	6.065	19.0	40	40	40	40	40	40
8	8.625	7.981	28.5	40	40	40	40	40	40
10	10.750	10.020	40.4	40	40	40	40	40	40
11	11.750	11.000	45.5	40	40	40	40	40	40
12	12.750	12.000	49.5	40	40	40	40	40	40
14	14.000	13.250	54.5	40	40	40	40	40	40
16	16.000	15.250	62.5	40	40	40	40	40	40
18	18.000	17.250	70.5	40	40	40	40	40	40
20	20.000	19.250	78.5	40	40	40	40	40	40
22	22.000	21.250	86.5	40	40	40	40	40	40
24	24.000	23.250	94.5	40	40	40	40	40	40

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Table A6.1-2; Max Allowable Restraint Spacing for Non-Insulated Standard Steel Pipe Filled – Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.824	1.4	40	30	30	20	20	20
1	1.315	1.049	2.1	40	40	30	30	20	20
1 1/4	1.660	1.380	2.9	40	40	40	30	30	30
1 1/2	1.900	1.610	3.6	40	40	40	40	30	30
2	2.375	2.067	5.1	40	40	40	40	40	30
2 1/2	2.875	2.469	7.9	40	40	40	40	40	40
3	3.500	3.068	10.8	40	40	40	40	40	40
3 1/2	4.000	3.548	13.4	40	40	40	40	40	40
4	4.500	4.026	16.3	40	40	40	40	40	40
5	5.563	5.047	23.3	40	40	40	40	40	40
6	6.625	6.065	31.5	40	40	40	40	40	40
8	8.625	7.981	50.2	40	40	40	40	40	40
10	10.750	10.020	74.6	40	40	40	40	40	40
11	11.750	11.000	86.7	40	40	40	40	40	40
12	12.750	12.000	98.5	40	40	40	40	40	40
14	14.000	13.250	114.3	40	40	40	40	40	40
16	16.000	15.250	141.7	40	40	40	40	40	40
18	18.000	17.250	171.8	40	40	40	40	40	40
20	20.000	19.250	204.6	40	40	40	40	40	40
22	22.000	21.250	240.2	40	40	40	40	40	40
24	24.000	23.250	278.5	40	40	40	40	40	40

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Table A6.1-3; Max Allowable Restraint Spacing for Insulated Standard Steel Pipe Filled – Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.824	2.1	30	30	20	20	20	15
1	1.315	1.049	2.1	40	40	30	30	20	20
1 1/4	1.660	1.380	2.9	40	40	40	30	30	30
1 1/2	1.900	1.610	3.6	40	40	40	40	30	30
2	2.375	2.067	5.1	40	40	40	40	40	30
2 1/2	2.875	2.469	7.9	40	40	40	40	40	40
3	3.500	3.068	10.8	40	40	40	40	40	40
3 1/2	4.000	3.548	13.4	40	40	40	40	40	40
4	4.500	4.026	16.3	40	40	40	40	40	40
5	5.563	5.047	23.3	40	40	40	40	40	40
6	6.625	6.065	31.5	40	40	40	40	40	40
8	8.625	7.981	50.2	40	40	40	40	40	40
10	10.750	10.020	74.6	40	40	40	40	40	40
11	11.750	11.000	86.7	40	40	40	40	40	40
12	12.750	12.000	98.5	40	40	40	40	40	40
14	14.000	13.250	114.3	40	40	40	40	40	40
16	16.000	15.250	141.7	40	40	40	40	40	40
18	18.000	17.250	171.8	40	40	40	40	40	40
20	20.000	19.250	204.6	40	40	40	40	40	40
22	22.000	21.250	240.2	40	40	40	40	40	40
24	24.000	23.250	278.5	40	40	40	40	40	40

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Table A6.1-4; Max Allowable Restraint Spacing for Insulated Standard Steel Pipe Filled – Steam

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.824	1.9	30	30	20	20	20	15
1	1.315	1.049	1.7	40	40	30	30	30	20
1 1/4	1.660	1.380	2.3	40	40	40	40	30	30
1 1/2	1.900	1.610	2.7	40	40	40	40	30	30
2	2.375	2.067	3.7	40	40	40	40	40	40
2 1/2	2.875	2.469	5.8	40	40	40	40	40	40
3	3.500	3.068	7.6	40	40	40	40	40	40
3 1/2	4.000	3.548	9.1	40	40	40	40	40	40
4	4.500	4.026	10.8	40	40	40	40	40	40
5	5.563	5.047	14.6	40	40	40	40	40	40
6	6.625	6.065	19.0	40	40	40	40	40	40
8	8.625	7.981	28.5	40	40	40	40	40	40
10	10.750	10.020	40.5	40	40	40	40	40	40
11	11.750	11.000	45.5	40	40	40	40	40	40
12	12.750	12.000	49.5	40	40	40	40	40	40
14	14.000	13.250	54.6	40	40	40	40	40	40
16	16.000	15.250	62.6	40	40	40	40	40	40
18	18.000	17.250	70.6	40	40	40	40	40	40
20	20.000	19.250	78.6	40	40	40	40	40	40
22	22.000	21.250	86.6	40	40	40	40	40	40
24	24.000	23.250	94.7	40	40	40	40	40	40

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MAXIMUM ALLOWABLE RESTRAINT SPACING – FIRE PROTECTION PIPING

Table A6.2-1; Maximum Allowable Seismic Restraint Spacing for Steel Water-Filled Pipe – Threaded or Cut Grooves {Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Seismic Coefficient C_P					0.43	0.60	0.73	0.99	1.33	2.00
Pipe Size (in)	Pipe Schedule	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1	40	1.315	1.049	2.4	40	30	30	30	20	20
1 1/4	40	1.660	1.380	3.4	40	40	40	30	30	20
1 1/2	40	1.900	1.610	4.1	40	40	40	30	30	30
2	40	2.375	2.067	5.9	40	40	40	40	40	30
2 1/2	40	2.875	2.469	9.0	40	40	40	40	40	40
3	40	3.500	3.068	12.4	40	40	40	40	40	40
3 1/2	40	4.000	3.548	15.4	40	40	40	40	40	40
4	40	4.500	4.026	18.7	40	40	40	40	40	40
5	40	5.563	5.047	26.8	40	40	40	40	40	40
6	40	6.625	6.065	36.2	40	40	40	40	40	40
8	30	8.625	8.071	53.9	40	40	40	40	40	40
10	30	10.75	10.14	79.5	40	40	40	40	40	40
12	STD	12.75	12.00	113.3	40	40	40	40	40	40

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Table A6.2-2; Maximum Allowable Seismic Restraint Spacing for Steel Water-Filled Pipe – Welded or Rolled Grooves {Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Seismic Coefficient C_P					0.43	0.60	0.73	0.99	1.33	2.00
Pipe Size (in)	Pipe Schedule	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1	10	1.315	1.097	2.1	40	30	30	30	20	20
1 1/4	10	1.660	1.442	2.9	40	40	30	30	30	20
1 1/2	10	1.900	1.682	3.5	40	40	40	30	30	30
2	10	2.375	2.157	4.9	40	40	40	40	30	30
2 1/2	10	2.875	2.635	6.8	40	40	40	40	40	30
3	10	3.500	3.260	9.1	40	40	40	40	40	40
3 1/2	10	4.000	3.760	11.2	40	40	40	40	40	40
4	10	4.500	4.026	18.7	40	40	40	40	40	40
5	10	5.563	5.295	19.9	40	40	40	40	40	40
6	10	6.625	6.357	26.5	40	40	40	40	40	40
8	---	8.625	8.249	46.1	40	40	40	40	40	40
10	---	10.75	10.37	66.5	40	40	40	40	40	40
12	30	12.75	12.09	107.5	40	40	40	40	40	40

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Table A6.2-3; Maximum Allowable Seismic Restraint Spacing for *TYPE K* Water-Filled Copper Tubing – ASTM B88 {Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Seismic Coefficient C_P				0.43	0.60	0.73	0.99	1.33	2.00
Tube Size (in)	Tube O. D. (in)	Tube Wall Thickness (in)	Tube Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1	1.125	0.065	1.3	20	20	20	20	15	15
1 1/4	1.375	0.065	1.8	30	20	20	20	20	15
1 1/2	1.625	0.072	2.4	30	30	30	20	20	20
2	2.125	0.083	3.9	40	30	30	30	20	20
2 1/2	2.625	0.095	5.7	40	40	40	30	30	20
3	3.125	0.109	7.9	40	40	40	40	30	30
3 1/2	3.625	0.120	10.4	40	40	40	40	40	30
4	4.125	0.134	13.3	40	40	40	40	40	30
5	5.125	0.160	20.1	40	40	40	40	40	40
6	6.125	0.192	28.8	40	40	40	40	40	40

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Table A6.2-4; Maximum Allowable Seismic Restraint Spacing for *TYPE L* Water-Filled Copper Tubing – ASTM B88 {Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Seismic Coefficient C_P				0.43	0.60	0.73	0.99	1.33	2.00
Tube Size (in)	Tube O. D. (in)	Tube Wall Thickness (in)	Tube Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1	1.125	0.050	1.2	20	20	20	20	15	15
1 1/4	1.375	0.055	1.6	30	20	20	20	20	15
1 1/2	1.625	0.060	2.2	30	30	20	20	20	20
2	2.125	0.070	3.6	40	30	30	30	20	20
2 1/2	2.625	0.080	5.2	40	40	30	30	30	20
3	3.125	0.090	7.2	40	40	40	40	30	30
3 1/2	3.625	0.100	9.5	40	40	40	40	30	30
4	4.125	0.114	12.3	40	40	40	40	40	30
5	5.125	0.125	18.0	40	40	40	40	40	40
6	6.125	0.140	25.1	40	40	40	40	40	40

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Table A6.2-5; Maximum Allowable Seismic Restraint Spacing for *TYPE M* Water-Filled Copper Tubing – ASTM B88 {Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Seismic Coefficient C_P				0.43	0.60	0.73	0.99	1.33	2.00
Tube Size (in)	Tube O. D. (in)	Tube Wall Thickness (in)	Tube Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1	1.125	0.035	1.0	20	20	20	20	15	15
1 1/4	1.375	0.042	1.4	30	20	20	20	20	15
1 1/2	1.625	0.049	2.0	30	30	20	20	20	20
2	2.125	0.058	3.3	40	30	30	30	20	20
2 1/2	2.625	0.065	4.8	40	40	30	30	30	20
3	3.125	0.072	6.5	40	40	40	30	30	30
3 1/2	3.625	0.083	8.8	40	40	40	40	30	30
4	4.125	0.095	11.4	40	40	40	40	40	30
5	5.125	0.109	17.1	40	40	40	40	40	40
6	6.125	0.122	23.8	40	40	40	40	40	40

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Table A6.2-6; Maximum Allowable Seismic Restraint Spacing for BlazeMaster® CPVC Water-Filled Sprinkler Pipe Manufactured by HARVEL®
{Includes 1.15 Factor Required by NFPA 13 Section 9.3.5.6.1}

Seismic Coefficient C_P				0.43	0.60	0.73	0.99	1.33	2.00
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.874	0.5	10	10	9	8	8	7
1	1.315	1.101	0.8	10	10	10	10	9	8
1 1/4	1.660	1.394	1.2	15	10	10	10	10	9
1 1/2	1.900	1.598	1.6	15	10	10	10	10	10
2	2.375	2.003	2.5	15	15	15	10	10	10
2 1/2	2.875	2.423	3.7	20	15	15	15	10	10
3	3.500	2.950	5.5	20	20	20	15	15	10

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MAXIMUM RESTRAINT SPACING – CAST IRON SOIL PIPE

Table A6.3-1; Maximum Seismic Restraint Spacing for Service (SV) Cast Iron Soil Pipe – Empty

Seismic Coefficient C_S					0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL					D	C	B	A	-----	-----
Pipe Size (in)	Pipe Weight per 10' Section (lbs)	Barrel O. D. (in)	Barrel I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
2	41	2.30	1.96	4.1	40	40	40	30	30	30
3	61	3.30	2.96	6.1	40	40	40	40	40	40
4	79	4.30	3.94	7.9	40	40	40	40	40	40
5	100	5.30	4.94	10.0	40	40	40	40	40	40
6	124	6.30	5.94	12.4	40	40	40	40	40	40
8	181	8.38	7.94	18.1	40	40	40	40	40	40
10	260	10.50	9.94	26.0	40	40	40	40	40	40
12	346	12.50	11.94	34.6	40	40	40	40	40	40
15	525	15.88	15.16	52.5	40	40	40	40	40	40

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Table A6.3-2; Maximum Seismic Restraint Spacing for Service (SV) Cast Iron Soil Pipe – Half Empty

Seismic Coefficient C_S					0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL					D	C	B	A	-----	-----
Pipe Size (in)	Pipe Weight per 10' Section (lbs)	Barrel O. D. (in)	Barrel I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
2	41	2.30	1.96	4.8	40	40	40	30	30	20
3	61	3.30	2.96	7.6	40	40	40	40	40	30
4	79	4.30	3.94	10.5	40	40	40	40	40	40
5	100	5.30	4.94	14.2	40	40	40	40	40	40
6	124	6.30	5.94	18.4	40	40	40	40	40	40
8	181	8.38	7.94	28.8	40	40	40	40	40	40
10	260	10.50	9.94	42.8	40	40	40	40	40	40
12	346	12.50	11.94	58.9	40	40	40	40	40	40
15	525	15.88	15.16	91.6	40	40	40	40	40	40

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Table A6.3-3; Maximum Seismic Restraint Spacing for Service (SV) Cast Iron Soil Pipe – Full

Seismic Coefficient C_S					0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL					D	C	B	A	-----	-----
Pipe Size (in)	Pipe Weight per 10' Section (lbs)	Barrel O. D. (in)	Barrel I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
2	41	2.30	1.96	5.4	40	40	30	30	30	20
3	61	3.30	2.96	9.1	40	40	40	40	30	30
4	79	4.30	3.94	13.2	40	40	40	40	40	40
5	100	5.30	4.94	18.3	40	40	40	40	40	40
6	124	6.30	5.94	24.4	40	40	40	40	40	40
8	181	8.38	7.94	39.6	40	40	40	40	40	40
10	260	10.50	9.94	59.6	40	40	40	40	40	40
12	346	12.50	11.94	83.1	40	40	40	40	40	40
15	525	15.88	15.16	130.7	40	40	40	40	40	40

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Table A6.3-4; Maximum Seismic Restraint Spacing for Extra Heavy (XH) Cast Iron Soil Pipe – Empty

Seismic Coefficient C_S					0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL					D	C	B	A	-----	-----
Pipe Size (in)	Pipe Weight per 10' Section (lbs)	Barrel O. D. (in)	Barrel I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
2	45	2.38	2.00	4.5	40	40	40	40	30	30
3	84	3.50	3.00	8.4	40	40	40	40	40	40
4	105	4.50	4.00	10.5	40	40	40	40	40	40
5	134	5.50	5.00	13.4	40	40	40	40	40	40
6	157	6.50	6.00	15.7	40	40	40	40	40	40
8	246	8.62	8.00	24.6	40	40	40	40	40	40
10	375	10.75	10.00	37.5	40	40	40	40	40	40
12	471	12.75	12.00	47.1	40	40	40	40	40	40
15	676	15.88	15.00	67.6	40	40	40	40	40	40

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Table A6.3-5; Maximum Seismic Restraint Spacing for Extra Heavy (XH) Cast Iron Soil Pipe – Half Empty

Seismic Coefficient C_S					0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL					D	C	B	A	-----	-----
Pipe Size (in)	Pipe Weight per 10' Section (lbs)	Barrel O. D. (in)	Barrel I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
2	45	2.38	2.00	5.2	40	40	40	30	30	30
3	84	3.50	3.00	9.9	40	40	40	40	40	40
4	105	4.50	4.00	13.2	40	40	40	40	40	40
5	134	5.50	5.00	17.7	40	40	40	40	40	40
6	157	6.50	6.00	21.8	40	40	40	40	40	40
8	246	8.62	8.00	35.5	40	40	40	40	40	40
10	375	10.75	10.00	54.5	40	40	40	40	40	40
12	471	12.75	12.00	71.6	40	40	40	40	40	40
15	676	15.88	15.00	105.9	40	40	40	40	40	40

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Table A6.3-6; Maximum Seismic Restraint Spacing for Extra Heavy (XH) Cast Iron Soil Pipe – Full

Seismic Coefficient C_S					0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL					D	C	B	A	-----	-----
Pipe Size (in)	Pipe Weight per 10' Section (lbs)	Barrel O. D. (in)	Barrel I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
2	45	2.38	2.00	5.9	40	40	40	30	30	20
3	84	3.50	3.00	11.5	40	40	40	40	40	30
4	105	4.50	4.00	15.9	40	40	40	40	40	40
5	134	5.50	5.00	21.9	40	40	40	40	40	40
6	157	6.50	6.00	28.0	40	40	40	40	40	40
8	246	8.62	8.00	46.4	40	40	40	40	40	40
10	375	10.75	10.00	71.5	40	40	40	40	40	40
12	471	12.75	12.00	96.1	40	40	40	40	40	40
15	676	15.88	15.00	144.2	40	40	40	40	40	40

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Table A6.3-7; Maximum Seismic Restraint Spacing for Hubless Cast Iron Soil Pipe – Empty

Seismic Coefficient C_S					0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL					D	C	B	A	-----	-----
Pipe Size (in)	Pipe Weight per 10' Section (lbs)	Barrel O. D. (in)	Barrel I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1 1/2	29	1.90	1.50	2.9	40	40	40	30	30	20
2	38	2.35	1.96	3.8	40	40	40	40	30	30
3	54	3.35	2.96	5.4	40	40	40	40	40	40
4	71	4.38	3.94	7.1	40	40	40	40	40	40
5	98	5.30	4.94	9.8	40	40	40	40	40	40
6	118	6.30	5.94	11.8	40	40	40	40	40	40
8	165	8.38	7.94	16.5	40	40	40	40	40	40
10	255	10.56	10.00	25.5	40	40	40	40	40	40
12	318	12.50	11.94	31.8	40	40	40	40	40	40
15	493	15.83	15.11	49.3	40	40	40	40	40	40

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Table A6.3-8; Maximum Seismic Restraint Spacing for Hubless Cast Iron Soil Pipe – Half Empty

Seismic Coefficient C_S					0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL					D	C	B	A	-----	-----
Pipe Size (in)	Pipe Weight per 10' Section (lbs)	Barrel O. D. (in)	Barrel I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1 1/2	29	1.90	1.50	3.3	40	40	30	30	30	20
2	38	2.35	1.96	4.5	40	40	40	40	30	30
3	54	3.35	2.96	6.9	40	40	40	40	40	40
4	71	4.38	3.94	9.7	40	40	40	40	40	40
5	98	5.30	4.94	14.0	40	40	40	40	40	40
6	118	6.30	5.94	17.8	40	40	40	40	40	40
8	165	8.38	7.94	27.2	40	40	40	40	40	40
10	255	10.56	10.00	42.5	40	40	40	40	40	40
12	318	12.50	11.94	56.1	40	40	40	40	40	40
15	493	15.83	15.11	88.2	40	40	40	40	40	40

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Table A6.3-9; Maximum Seismic Restraint Spacing for Hubless Cast Iron Soil Pipe – Full

Seismic Coefficient C_S					0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL					D	C	B	A	-----	-----
Pipe Size (in)	Pipe Weight per 10' Section (lbs)	Barrel O. D. (in)	Barrel I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1 1/2	29	1.90	1.50	3.7	40	40	30	30	30	20
2	38	2.35	1.96	5.1	40	40	40	30	30	30
3	54	3.35	2.96	8.4	40	40	40	40	40	30
4	71	4.38	3.94	12.4	40	40	40	40	40	40
5	98	5.30	4.94	18.1	40	40	40	40	40	40
6	118	6.30	5.94	23.8	40	40	40	40	40	40
8	165	8.38	7.94	38.0	40	40	40	40	40	40
10	255	10.56	10.00	59.5	40	40	40	40	40	40
12	318	12.50	11.94	80.3	40	40	40	40	40	40
15	493	15.83	15.11	127.0	40	40	40	40	40	40

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MAXIMUM RESTRAINT SPACING – PVC & CPVC PIPE

Table A6.4-1; Max Allowable Restraint Spacing for Sched 40 PVC Pipe - Empty

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.804	0.2	15	15	15	15	15	10
1	1.315	1.029	0.3	20	15	15	15	15	15
1 1/4	1.660	1.360	0.4	20	20	15	15	15	15
1 1/2	1.900	1.590	0.5	30	20	20	15	15	15
2	2.375	2.047	0.7	30	20	20	20	15	15
2 1/2	2.875	2.445	1.1	30	30	20	20	20	15
3	3.500	3.042	1.4	40	30	30	20	20	20
3 1/2	4.000	3.521	1.7	40	30	30	30	20	20
4	4.500	3.998	2.1	40	40	30	30	20	20
5	5.563	5.016	2.8	40	40	40	30	30	30
6	6.625	6.031	3.6	40	40	40	40	30	30
8	8.625	7.945	5.4	40	40	40	40	40	40
10	10.75	9.98	7.7	40	40	40	40	40	40
12	12.75	11.89	10.2	40	40	40	40	40	40
14	14.00	13.07	12.1	40	40	40	40	40	40
16	16.00	14.94	15.8	40	40	40	40	40	40
18	18.00	16.81	19.9	40	40	40	40	40	40
20	20.00	18.74	23.4	40	40	40	40	40	40
24	24.00	22.54	32.6	40	40	40	40	40	40

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Table A6.4-2; Max Allowable Restraint Spacing for Sched 40 PVC Pipe – Half Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.804	0.3	15	10	10	10	10	9
1	1.315	1.029	0.5	15	15	10	10	10	10
1 1/4	1.660	1.360	0.8	20	15	15	10	10	10
1 1/2	1.900	1.590	1.0	20	15	15	15	10	10
2	2.375	2.047	1.4	20	20	15	15	15	10
2 1/2	2.875	2.445	2.1	30	20	20	20	15	15
3	3.500	3.042	3.0	30	20	20	20	15	15
3 1/2	4.000	3.521	3.8	30	30	20	20	20	15
4	4.500	3.998	4.8	40	30	20	20	20	20
5	5.563	5.016	7.1	40	30	30	20	20	20
6	6.625	6.031	9.8	40	40	30	30	20	20
8	8.625	7.945	16.2	40	40	40	30	30	20
10	10.75	9.98	24.6	40	40	40	40	30	30
12	12.75	11.89	34.3	40	40	40	40	40	30
14	14.00	13.07	41.1	40	40	40	40	40	30
16	16.00	14.94	53.7	40	40	40	40	40	40
18	18.00	16.81	68.0	40	40	40	40	40	40
20	20.00	18.74	83.2	40	40	40	40	40	40
24	24.00	22.54	119.1	40	40	40	40	40	40

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Table A6.4-3; Max Allowable Restraint Spacing for Sched 40 PVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.804	0.4	15	10	10	10	9	8
1	1.315	1.029	0.7	15	10	10	10	10	9
1 1/4	1.660	1.360	1.1	20	15	10	10	10	10
1 1/2	1.900	1.590	1.4	20	15	15	10	10	10
2	2.375	2.047	2.1	20	15	15	15	10	10
2 1/2	2.875	2.445	3.1	20	20	15	15	15	10
3	3.500	3.042	4.6	30	20	20	15	15	15
3 1/2	4.000	3.521	6.0	30	20	20	20	15	15
4	4.500	3.998	7.5	30	20	20	20	15	15
5	5.563	5.016	11.3	30	30	20	20	20	15
6	6.625	6.031	16.0	40	30	20	20	20	20
8	8.625	7.945	26.9	40	30	30	30	20	20
10	10.75	9.98	41.6	40	40	30	30	30	20
12	12.75	11.89	58.3	40	40	40	30	30	30
14	14.00	13.07	70.2	40	40	40	40	30	30
16	16.00	14.94	91.7	40	40	40	40	30	30
18	18.00	16.81	116.1	40	40	40	40	40	30
20	20.00	18.74	143.0	40	40	40	40	40	40
24	24.00	22.54	205.5	40	40	40	40	40	40

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Table A6.4-4; Max Allowable Restraint Spacing for Insulated Sched 40 PVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.804	1.2	10	9	8	7	6	6
1	1.315	1.029	1.5	10	10	10	9	8	7
1 1/4	1.660	1.360	2.1	15	10	10	10	9	8
1 1/2	1.900	1.590	2.5	15	10	10	10	10	9
2	2.375	2.047	3.4	20	15	10	10	10	10
2 1/2	2.875	2.445	4.6	20	15	15	15	10	10
3	3.500	3.042	6.3	20	20	15	15	15	10
3 1/2	4.000	3.521	7.8	30	20	20	15	15	15
4	4.500	3.998	9.5	30	20	20	20	15	15
5	5.563	5.016	15.3	30	20	20	20	15	15
6	6.625	6.031	20.5	30	30	20	20	20	15
8	8.625	7.945	32.5	40	30	30	20	20	20
10	10.75	9.98	48.4	40	40	30	30	20	20
12	12.75	11.89	66.2	40	40	40	30	30	20
14	14.00	13.07	78.9	40	40	40	30	30	30
16	16.00	14.94	101.5	40	40	40	40	30	30
18	18.00	16.81	126.9	40	40	40	40	40	30
20	20.00	18.74	154.9	40	40	40	40	40	30
24	24.00	22.54	219.7	40	40	40	40	40	40

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Table A6.4-5; Max Allowable Restraint Spacing for Sched 80 PVC Pipe - Empty

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.722	0.3	15	15	10	10	10	10
1	1.315	0.936	0.4	20	15	15	10	10	10
1 1/4	1.660	1.255	0.6	20	20	15	15	10	10
1 1/2	1.900	1.476	0.7	20	20	20	15	15	10
2	2.375	1.913	1.0	30	20	20	20	15	15
2 1/2	2.875	2.290	1.5	30	30	20	20	20	15
3	3.500	2.864	1.9	40	30	30	20	20	20
3 1/2	4.000	3.326	2.4	40	30	30	30	20	20
4	4.500	3.786	2.8	40	40	30	30	20	20
5	5.563	4.768	3.9	40	40	40	30	30	30
6	6.625	5.709	5.4	40	40	40	40	30	30
8	8.625	7.565	8.2	40	40	40	40	40	40
10	10.75	9.49	12.2	40	40	40	40	40	40
12	12.75	11.29	16.8	40	40	40	40	40	40
14	14.00	12.41	20.2	40	40	40	40	40	40
16	16.00	14.21	26.0	40	40	40	40	40	40
18	18.00	16.01	32.5	40	40	40	40	40	40
20	20.00	17.81	39.7	40	40	40	40	40	40
24	24.00	21.42	56.4	40	40	40	40	40	40

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Table A6.4-6; Max Allowable Restraint Spacing for Sched 80 PVC Pipe – Half Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.722	0.4	15	10	10	10	10	9
1	1.315	0.936	0.6	20	15	10	10	10	10
1 1/4	1.660	1.255	0.8	20	15	15	10	10	10
1 1/2	1.900	1.476	1.1	20	20	15	15	10	10
2	2.375	1.913	1.6	20	20	20	15	15	10
2 1/2	2.875	2.290	2.3	30	20	20	20	15	15
3	3.500	2.864	3.3	30	20	20	20	20	15
3 1/2	4.000	3.326	4.3	40	30	20	20	20	20
4	4.500	3.786	5.3	40	30	30	20	20	20
5	5.563	4.768	7.8	40	30	30	30	20	20
6	6.625	5.709	11.0	40	40	30	30	30	20
8	8.625	7.565	18.0	40	40	40	40	30	30
10	10.75	9.49	27.6	40	40	40	40	40	30
12	12.75	11.29	38.5	40	40	40	40	40	40
14	14.00	12.41	46.4	40	40	40	40	40	40
16	16.00	14.21	60.3	40	40	40	40	40	40
18	18.00	16.01	76.1	40	40	40	40	40	40
20	20.00	17.81	93.7	40	40	40	40	40	40
24	24.00	21.42	134.4	40	40	40	40	40	40

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Table A6.4-7; Max Allowable Restraint Spacing for Sched 80 PVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.722	0.5	15	10	10	10	9	8
1	1.315	0.936	0.7	15	10	10	10	10	9
1 1/4	1.660	1.255	1.1	20	15	10	10	10	10
1 1/2	1.900	1.476	1.4	20	15	15	10	10	10
2	2.375	1.913	2.2	20	20	15	15	10	10
2 1/2	2.875	2.290	3.2	20	20	20	15	15	10
3	3.500	2.864	4.7	30	20	20	20	15	15
3 1/2	4.000	3.326	6.1	30	20	20	20	15	15
4	4.500	3.786	7.7	30	30	20	20	20	15
5	5.563	4.768	11.7	40	30	20	20	20	20
6	6.625	5.709	16.5	40	30	30	30	20	20
8	8.625	7.565	27.7	40	40	30	30	30	20
10	10.75	9.49	42.9	40	40	40	40	30	30
12	12.75	11.29	60.2	40	40	40	40	30	30
14	14.00	12.41	72.6	40	40	40	40	40	30
16	16.00	14.21	94.7	40	40	40	40	40	40
18	18.00	16.01	119.7	40	40	40	40	40	40
20	20.00	17.81	147.7	40	40	40	40	40	40
24	24.00	21.42	212.5	40	40	40	40	40	40

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Table A6.4-8; Max Allowable Restraint Spacing for Insulated Sched 80 PVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.722	1.2	10	9	8	7	7	6
1	1.315	0.936	1.6	10	10	10	9	8	7
1 1/4	1.660	1.255	2.1	15	10	10	10	10	9
1 1/2	1.900	1.476	2.5	15	15	10	10	10	10
2	2.375	1.913	3.4	20	15	15	10	10	10
2 1/2	2.875	2.290	4.7	20	20	15	15	10	10
3	3.500	2.864	6.4	30	20	20	15	15	15
3 1/2	4.000	3.326	8.0	30	20	20	20	15	15
4	4.500	3.786	9.8	30	20	20	20	15	15
5	5.563	4.768	15.6	30	30	20	20	20	15
6	6.625	5.709	21.0	40	30	30	20	20	20
8	8.625	7.565	33.4	40	40	30	30	20	20
10	10.75	9.49	49.7	40	40	40	30	30	30
12	12.75	11.29	68.2	40	40	40	40	30	30
14	14.00	12.41	81.2	40	40	40	40	40	30
16	16.00	14.21	104.4	40	40	40	40	40	30
18	18.00	16.01	130.6	40	40	40	40	40	40
20	20.00	17.81	159.7	40	40	40	40	40	40
24	24.00	21.42	226.7	40	40	40	40	40	40

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Table A6.4-9; Max Allowable Restraint Spacing for Sched 120 PVC Pipe - Empty

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.690	0.3	15	15	10	10	10	10
1	1.315	0.891	0.4	20	15	15	10	10	10
1 1/4	1.660	1.204	0.6	20	20	15	15	10	10
1 1/2	1.900	1.423	0.8	20	20	20	15	15	10
2	2.375	1.845	1.1	30	20	20	20	15	15
2 1/2	2.875	2.239	1.6	30	30	20	20	20	15
3	3.500	2.758	2.2	40	30	30	20	20	20
4	4.500	3.574	3.6	40	40	30	30	20	20
6	6.625	5.434	6.9	40	40	40	40	30	30
8	8.625	7.189	10.9	40	40	40	40	40	40

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Table A6.4-10; Max Allowable Restraint Spacing for Sched 120 PVC Pipe – Half Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.690	0.4	15	10	10	10	10	9
1	1.315	0.891	0.6	20	15	10	10	10	10
1 1/4	1.660	1.204	0.9	20	15	15	10	10	10
1 1/2	1.900	1.423	1.1	20	20	15	15	10	10
2	2.375	1.845	1.7	20	20	20	15	15	10
2 1/2	2.875	2.239	2.4	30	20	20	20	15	15
3	3.500	2.758	3.5	30	30	20	20	20	15
4	4.500	3.574	5.8	40	30	30	20	20	20
6	6.625	5.434	11.9	40	40	30	30	30	20
8	8.625	7.189	19.7	40	40	40	40	30	30

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Table A6.4-11; Max Allowable Restraint Spacing for Sched 120 PVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.690	0.5	15	10	10	10	9	8
1	1.315	0.891	0.7	15	15	10	10	10	10
1 1/4	1.660	1.204	1.1	20	15	15	10	10	10
1 1/2	1.900	1.423	1.5	20	15	15	10	10	10
2	2.375	1.845	2.2	20	20	15	15	10	10
2 1/2	2.875	2.239	3.3	30	20	20	15	15	15
3	3.500	2.758	4.8	30	20	20	20	15	15
4	4.500	3.574	7.9	40	30	20	20	20	20
6	6.625	5.434	17.0	40	40	30	30	20	20
8	8.625	7.189	28.5	40	40	40	30	30	20

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Table A6.4-12; Max Allowable Restraint Spacing for Insulated Sched 120 PVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.690	1.2	10	10	8	8	7	6
1	1.315	0.891	1.6	10	10	10	9	8	7
1 1/4	1.660	1.204	2.1	15	10	10	10	10	9
1 1/2	1.900	1.423	2.5	15	15	10	10	10	10
2	2.375	1.845	3.5	20	15	15	10	10	10
2 1/2	2.875	2.239	4.7	20	20	15	15	10	10
3	3.500	2.758	6.5	30	20	20	15	15	15
4	4.500	3.574	10.0	30	20	20	20	20	15
6	6.625	5.434	21.5	40	30	30	20	20	20
8	8.625	7.189	34.1	40	40	30	30	30	20

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Table A6.4-13; Max Allowable Restraint Spacing for Sched 40 CPVC Pipe – Empty

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.804	0.2	15	15	15	15	15	9
1	1.315	1.029	0.4	20	15	15	15	15	15
1 1/4	1.660	1.360	0.5	20	20	15	15	15	15
1 1/2	1.900	1.590	0.6	20	20	15	15	15	15
2	2.375	2.047	0.8	30	20	20	20	15	15
2 1/2	2.875	2.445	1.2	30	20	20	20	20	15
3	3.500	3.042	1.6	40	30	20	20	20	20
3 1/2	4.000	3.521	1.9	40	30	30	20	20	20
4	4.500	3.998	2.3	40	40	30	30	20	20
5	5.563	5.016	3.1	40	40	40	30	30	20
6	6.625	6.031	4.0	40	40	40	40	30	30
8	8.625	7.945	5.9	40	40	40	40	40	30
10	10.75	9.98	8.5	40	40	40	40	40	40
12	12.75	11.89	11.2	40	40	40	40	40	40
14	14.00	13.07	13.2	40	40	40	40	40	40
16	16.00	14.94	17.3	40	40	40	40	40	40
18	18.00	16.81	21.9	40	40	40	40	40	40
20	20.00	18.74	25.7	40	40	40	40	40	40
24	24.00	22.54	35.8	40	40	40	40	40	40

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Table A6.4-14; Max Allowable Restraint Spacing for Sched 40 CPVC Pipe – Half Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.804	0.4	15	10	10	10	9	8
1	1.315	1.029	0.5	15	10	10	10	10	9
1 1/4	1.660	1.360	0.8	20	15	10	10	10	10
1 1/2	1.900	1.590	1.0	20	15	15	10	10	10
2	2.375	2.047	1.5	20	20	15	15	10	10
2 1/2	2.875	2.445	2.2	30	20	20	15	15	15
3	3.500	3.042	3.2	30	20	20	20	15	15
3 1/2	4.000	3.521	4.0	30	20	20	20	20	15
4	4.500	3.998	5.0	30	30	20	20	20	15
5	5.563	5.016	7.3	40	30	30	20	20	20
6	6.625	6.031	10.2	40	30	30	30	20	20
8	8.625	7.945	16.7	40	40	30	30	30	20
10	10.75	9.98	25.4	40	40	40	40	30	30
12	12.75	11.89	35.2	40	40	40	40	30	30
14	14.00	13.07	42.3	40	40	40	40	40	30
16	16.00	14.94	55.3	40	40	40	40	40	40
18	18.00	16.81	70.0	40	40	40	40	40	40
20	20.00	18.74	85.5	40	40	40	40	40	40
24	24.00	22.54	122.3	40	40	40	40	40	40

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Table A6.4-15; Max Allowable Restraint Spacing for Sched 40 CPVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.804	0.5	10	10	10	9	8	7
1	1.315	1.029	0.7	15	10	10	10	9	9
1 1/4	1.660	1.360	1.1	15	15	10	10	10	10
1 1/2	1.900	1.590	1.4	20	15	10	10	10	10
2	2.375	2.047	2.2	20	15	15	10	10	10
2 1/2	2.875	2.445	3.2	20	20	15	15	10	10
3	3.500	3.042	4.7	20	20	20	15	15	10
3 1/2	4.000	3.521	6.1	30	20	20	20	15	15
4	4.500	3.998	7.7	30	20	20	20	15	15
5	5.563	5.016	11.6	30	20	20	20	20	15
6	6.625	6.031	16.3	40	30	20	20	20	20
8	8.625	7.945	27.4	40	30	30	30	20	20
10	10.75	9.98	42.3	40	40	30	30	20	20
12	12.75	11.89	59.3	40	40	40	30	30	20
14	14.00	13.07	71.4	40	40	40	30	30	30
16	16.00	14.94	93.3	40	40	40	40	30	30
18	18.00	16.81	118.0	40	40	40	40	40	30
20	20.00	18.74	145.3	40	40	40	40	40	30
24	24.00	22.54	208.7	40	40	40	40	40	40

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Table A6.4-16; Max Allowable Restraint Spacing for Insulated Sched 40 CPVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.804	1.2	10	9	7	7	6	5
1	1.315	1.029	1.6	10	10	9	8	7	7
1 1/4	1.660	1.360	2.1	15	10	10	10	9	8
1 1/2	1.900	1.590	2.5	15	10	10	10	9	9
2	2.375	2.047	3.4	15	15	10	10	10	10
2 1/2	2.875	2.445	4.7	20	15	15	10	10	10
3	3.500	3.042	6.4	20	20	15	15	10	10
3 1/2	4.000	3.521	8.0	20	20	20	15	15	10
4	4.500	3.998	9.7	30	20	20	15	15	15
5	5.563	5.016	15.5	30	20	20	20	15	15
6	6.625	6.031	20.9	30	30	20	20	20	15
8	8.625	7.945	33.1	40	30	30	20	20	20
10	10.75	9.98	49.2	40	40	30	30	20	20
12	12.75	11.89	67.2	40	40	30	30	30	20
14	14.00	13.07	80.0	40	40	40	30	30	30
16	16.00	14.94	103.0	40	40	40	40	30	30
18	18.00	16.81	128.9	40	40	40	40	30	30
20	20.00	18.74	157.2	40	40	40	40	40	30
24	24.00	22.54	222.9	40	40	40	40	40	40

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Table A6.4-17; Max Allowable Restraint Spacing for Sched 80 CPVC Pipe – Empty

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.722	0.3	15	10	10	10	10	9
1	1.315	0.936	0.5	20	15	10	10	10	10
1 1/4	1.660	1.255	0.6	20	15	15	15	10	10
1 1/2	1.900	1.476	0.8	20	20	15	15	15	10
2	2.375	1.913	1.0	30	20	20	20	15	15
2 1/2	2.875	2.290	1.6	30	20	20	20	20	15
3	3.500	2.864	2.1	40	30	20	20	20	20
3 1/2	4.000	3.326	2.6	40	30	30	20	20	20
4	4.500	3.786	3.1	40	30	30	30	20	20
5	5.563	4.768	4.3	40	40	40	30	30	20
6	6.625	5.709	6.0	40	40	40	40	30	30
8	8.625	7.565	9.1	40	40	40	40	40	30
10	10.75	9.49	13.4	40	40	40	40	40	40
12	12.75	11.29	18.5	40	40	40	40	40	40
14	14.00	12.41	22.2	40	40	40	40	40	40
16	16.00	14.21	28.5	40	40	40	40	40	40
18	18.00	16.01	35.7	40	40	40	40	40	40
20	20.00	17.81	43.6	40	40	40	40	40	40
24	24.00	21.42	61.9	40	40	40	40	40	40

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Table A6.4-18; Max Allowable Restraint Spacing for Sched 80 CPVC Pipe – Half Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.722	0.4	15	10	10	10	9	8
1	1.315	0.936	0.6	15	15	10	10	10	10
1 1/4	1.660	1.255	0.9	20	15	15	10	10	10
1 1/2	1.900	1.476	1.1	20	15	15	15	10	10
2	2.375	1.913	1.7	20	20	15	15	15	10
2 1/2	2.875	2.290	2.5	30	20	20	15	15	15
3	3.500	2.864	3.5	30	20	20	20	15	15
3 1/2	4.000	3.326	4.5	30	30	20	20	20	15
4	4.500	3.786	5.6	40	30	20	20	20	20
5	5.563	4.768	8.2	40	30	30	20	20	20
6	6.625	5.709	11.5	40	40	30	30	20	20
8	8.625	7.565	18.8	40	40	40	30	30	30
10	10.75	9.49	28.8	40	40	40	40	30	30
12	12.75	11.29	40.2	40	40	40	40	40	30
14	14.00	12.41	48.4	40	40	40	40	40	40
16	16.00	14.21	62.9	40	40	40	40	40	40
18	18.00	16.01	79.3	40	40	40	40	40	40
20	20.00	17.81	97.6	40	40	40	40	40	40
24	24.00	21.42	140.0	40	40	40	40	40	40

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Table A6.4-19; Max Allowable Restraint Spacing for Sched 80 CPVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.722	0.5	15	10	10	10	9	8
1	1.315	0.936	0.7	15	10	10	10	10	9
1 1/4	1.660	1.255	1.2	20	15	10	10	10	10
1 1/2	1.900	1.476	1.5	20	15	15	10	10	10
2	2.375	1.913	2.3	20	15	15	15	10	10
2 1/2	2.875	2.290	3.4	20	20	15	15	15	10
3	3.500	2.864	4.9	30	20	20	20	15	15
3 1/2	4.000	3.326	6.4	30	20	20	20	15	15
4	4.500	3.786	8.0	30	20	20	20	20	15
5	5.563	4.768	12.1	40	30	20	20	20	20
6	6.625	5.709	17.1	40	30	30	20	20	20
8	8.625	7.565	28.5	40	40	30	30	20	20
10	10.75	9.49	44.1	40	40	40	30	30	30
12	12.75	11.29	61.9	40	40	40	40	30	30
14	14.00	12.41	74.6	40	40	40	40	30	30
16	16.00	14.21	97.2	40	40	40	40	40	30
18	18.00	16.01	122.9	40	40	40	40	40	40
20	20.00	17.81	151.6	40	40	40	40	40	40
24	24.00	21.42	218.0	40	40	40	40	40	40

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Table A6.4-20; Max Allowable Restraint Spacing for Insulated Sched 80 CPVC Pipe – Full of Water

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Pipe Size (in)	Pipe O. D. (in)	Pipe I. D. (in)	Pipe Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
3/4	1.050	0.722	1.2	10	9	8	7	6	6
1	1.315	0.936	1.6	10	10	10	9	8	7
1 1/4	1.660	1.255	2.1	15	10	10	10	9	8
1 1/2	1.900	1.476	2.6	15	10	10	10	10	9
2	2.375	1.913	3.5	20	15	10	10	10	10
2 1/2	2.875	2.290	4.8	20	20	15	15	10	10
3	3.500	2.864	6.6	20	20	20	15	15	10
3 1/2	4.000	3.326	8.2	30	20	20	15	15	15
4	4.500	3.786	10.0	30	20	20	20	15	15
5	5.563	4.768	16.0	30	20	20	20	20	15
6	6.625	5.709	21.6	40	30	20	20	20	20
8	8.625	7.565	34.2	40	30	30	30	20	20
10	10.75	9.49	50.9	40	40	40	30	30	20
12	12.75	11.29	69.8	40	40	40	40	30	30
14	14.00	12.41	83.2	40	40	40	40	30	30
16	16.00	14.21	107.0	40	40	40	40	40	30
18	18.00	16.01	133.8	40	40	40	40	40	40
20	20.00	17.81	163.6	40	40	40	40	40	40
24	24.00	21.42	232.2	40	40	40	40	40	40

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MAXIMUM RESTRAINT SPACING – COPPER WATER PIPE

Table A6.5-1; Maximum Allowable Seismic Restraint Spacing for *TYPE K* Water-Filled Copper Tubing – ASTM B88

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Tube Size (in)	Tube O. D. (in)	Tube Wall Thickness (in)	Tube Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1	1.125	0.065	1.2	30	20	20	20	20	15
1 1/4	1.375	0.065	1.6	40	30	20	20	20	20
1 1/2	1.625	0.072	2.1	40	30	30	20	20	20
2	2.125	0.083	3.4	40	40	30	30	20	20
2 1/2	2.625	0.095	4.9	40	40	40	30	30	30
3	3.125	0.109	6.9	40	40	40	40	30	30
3 1/2	3.625	0.120	9.0	40	40	40	40	40	30
4	4.125	0.134	11.6	40	40	40	40	40	40
5	5.125	0.160	17.5	40	40	40	40	40	40
6	6.125	0.192	25.0	40	40	40	40	40	40

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Table A6.5-2; Maximum Allowable Seismic Restraint Spacing for *TYPE L* Water-Filled Copper Tubing – ASTM B88

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Tube Size (in)	Tube O. D. (in)	Tube Wall Thickness (in)	Tube Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1	1.125	0.500	3.8	30	20	20	20	15	15
1 1/4	1.375	0.055	1.4	40	30	20	20	20	20
1 1/2	1.625	0.060	1.9	40	30	30	20	20	20
2	2.125	0.070	3.1	40	40	30	30	20	20
2 1/2	2.625	0.080	4.5	40	40	40	30	30	20
3	3.125	0.090	6.3	40	40	40	40	30	30
3 1/2	3.625	0.100	8.3	40	40	40	40	40	30
4	4.125	0.114	10.7	40	40	40	40	40	30
5	5.125	0.125	15.7	40	40	40	40	40	40
6	6.125	0.140	21.8	40	40	40	40	40	40

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Table A6.5-3; Maximum Allowable Seismic Restraint Spacing for *TYPE M* Water-Filled Copper Tubing – ASTM B88

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Tube Size (in)	Tube O. D. (in)	Tube Wall Thickness (in)	Tube Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
1	1.125	0.035	0.8	30	20	20	20	15	15
1 1/4	1.375	0.042	1.2	30	30	20	20	20	15
1 1/2	1.625	0.049	1.7	40	30	20	20	20	20
2	2.125	0.058	2.8	40	40	30	30	20	20
2 1/2	2.625	0.065	4.1	40	40	30	30	30	20
3	3.125	0.072	5.7	40	40	40	40	30	30
3 1/2	3.625	0.083	7.6	40	40	40	40	30	30
4	4.125	0.095	9.9	40	40	40	40	40	30
5	5.125	0.109	14.8	40	40	40	40	40	40
6	6.125	0.122	20.7	40	40	40	40	40	40

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MAXIMUM ALLOWABLE RESTRAINT SPACING – DUCTS

Table A6.6-1; Maximum Allowable Seismic Restraint Spacing for Rectangular Duct (Based on Gross Buckling of the Duct)

Seismic Coefficient C_S				0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL				D	C	B	A	-----	-----
Duct Width (in)	Duct Height (in)	Duct Area (ft^2)	Duct Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
28	28	5.4	24	40	40	40	40	40	40
30	30	6.3	26	40	40	40	40	40	40
42	42	12	36	40	40	40	40	40	40
54	54	20	47	40	40	40	40	40	40
60	60	25	54	40	40	40	40	40	40
84	84	49	103	40	40	40	40	40	40
96	96	64	129	40	40	40	40	40	40
40	20	6	26	40	40	40	40	40	40
54	28	11	35	40	40	40	40	40	40
60	30	13	39	40	40	40	40	40	40
84	42	25	74	40	40	40	40	40	40
96	48	32	97	40	40	40	40	40	40
108	54	41	110	40	40	40	40	40	40
120	60	50	121	40	40	40	40	40	40

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Table A6.6-2; Maximum Allowable Seismic Restraint Spacing for Round Duct (Based on Gross Buckling of the Duct)

Seismic Coefficient C_S			0.25	0.50	0.75	1.00	1.50	2.00
Seismic Hazard Level SHL			D	C	B	A	-----	-----
Duct Diameter (in)	Duct Area (ft^2)	Duct Weight w_p (lb/ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)	Actual Maximum Spacing S_T (ft)
30	4.9	20	40	40	40	40	40	40
33	5.9	22	40	40	40	40	40	40
36	7.1	24	40	40	40	40	40	40
48	13	33	40	40	40	40	40	40
60	20	41	40	40	40	40	40	40
84	38	69	40	40	40	40	40	40

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ELECTRICAL CONDUIT DATA

Table A8.1-1; EMT Electrical Conduit with 40% Copper Fill

Trade Size (in)	Conduit O. D. (in)	Wall Thickness (in)	Conduit Weight (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper Weight (lb/ft)
1/2	0.706	0.042	0.30	0.47	0.77
3/4	0.922	0.049	0.45	0.82	1.28
1	1.163	0.057	0.67	1.34	2.01
1 1/4	1.510	0.065	1.00	2.31	3.31
1 1/2	1.740	0.065	1.16	3.15	4.30
2	2.197	0.065	1.47	5.19	6.66
2 1/2	2.875	0.072	2.15	9.05	11.20
3	3.500	0.072	2.62	13.67	16.30
3 1/2	4.000	0.083	3.46	17.84	21.30
4	4.500	0.083	3.90	22.80	26.70

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Table A8.1-2; IMC Electrical Conduit with 40% Copper Fill

Trade Size (in)	Conduit O. D. (in)	Wall Thickness (in)	Conduit Weight (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper Weight (lb/ft)
1/2	0.815	0.070	0.55	0.55	1.11
3/4	1.029	0.075	0.76	0.94	1.70
1	1.290	0.085	1.09	1.52	2.61
1 1/4	1.638	0.085	1.40	2.62	4.02
1 1/2	1.883	0.090	1.72	3.52	5.24
2	2.360	0.095	2.29	5.72	8.00
2 1/2	2.857	0.140	4.04	8.06	12.11
3	3.476	0.140	4.97	12.40	17.36
3 1/2	3.971	0.140	5.70	16.54	22.24
4	4.466	0.140	6.44	21.27	27.71

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Table A8.1-3; Rigid Electrical Conduit with 40% Copper Fill

Trade Size (in)	Conduit O. D. (in)	Wall Thickness (in)	Conduit Weight (lb/ft)	Copper Weight (lb/ft)	Conduit + Copper Weight (lb/ft)
1/2	0.840	0.104	0.81	0.48	1.30
3/4	1.050	0.107	1.07	0.85	1.92
1	1.315	0.126	1.59	1.37	2.96
1 1/4	1.660	0.133	2.16	2.36	4.52
1 1/2	1.900	0.138	2.59	3.20	5.79
2	2.375	0.146	3.46	5.27	8.73
2 1/2	2.875	0.193	5.50	7.52	13.02
3	3.500	0.205	7.18	11.59	18.77
3 1/2	4.000	0.215	8.65	15.47	24.12
4	4.500	0.225	10.23	19.91	30.14
5	5.563	0.245	13.85	31.24	45.09
6	6.625	0.266	17.98	45.07	63.05

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