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.

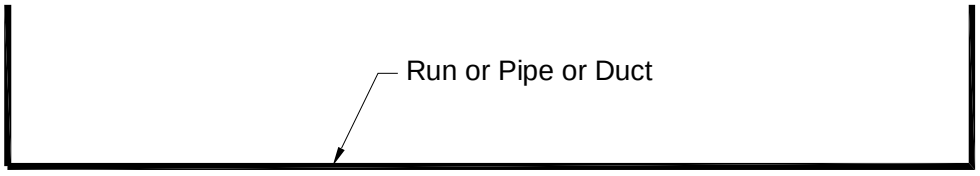

Figure S1-1; RULE #1 – A Run of Pipe or Duct

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 $L_O = 40/16 = 2.5\ ft = 30in$.)

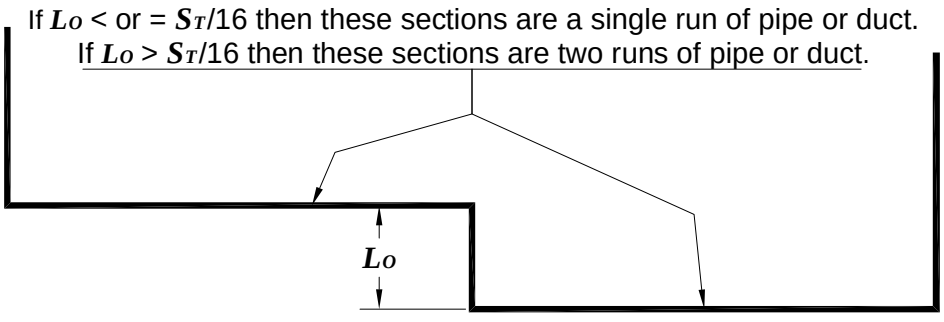

Figure S1-2; RULE #2 – Situation of an Offset in a Pipe or Duct

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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.

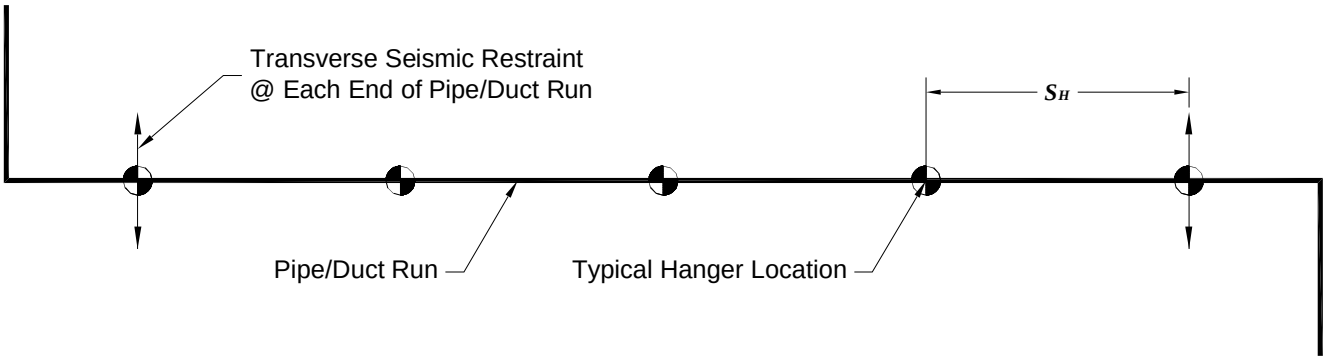

Figure S1-3; RULE #6– Transverse Seismic Restraints

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.

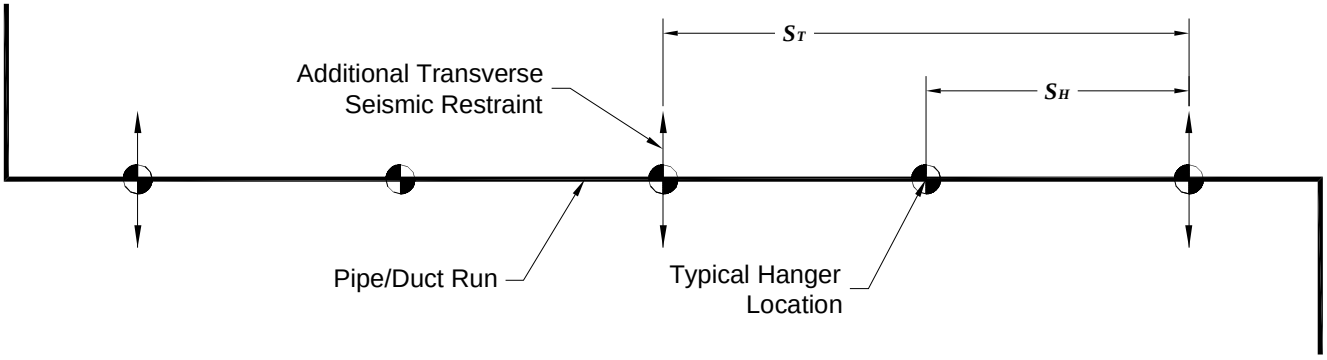

Figure S1-4; RULE #7 – Additional Transverse Seismic Restraints

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.

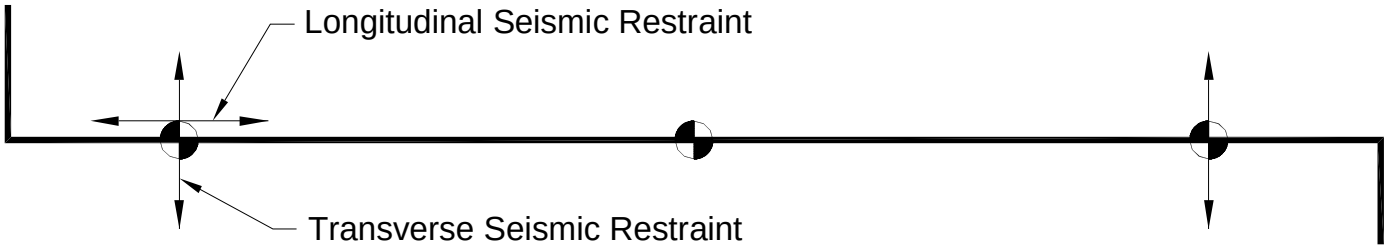

Figure S1-5; RULE #8 – Longitudinal Seismic Restraints

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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.

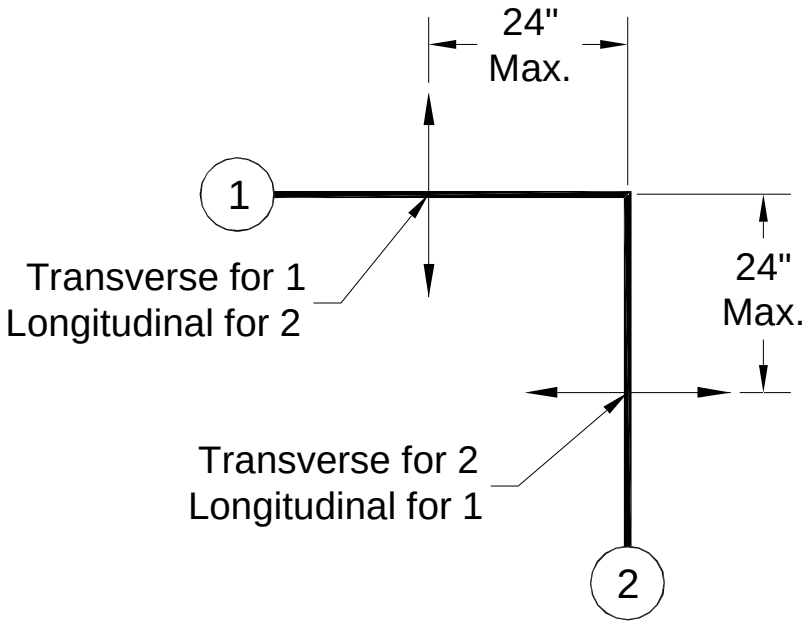

Figure S1-6; Rule #9 – Transverse Seismic Restraints Used as Longitudinal Seismic Restraints at Bends in Pipe and Duct

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.

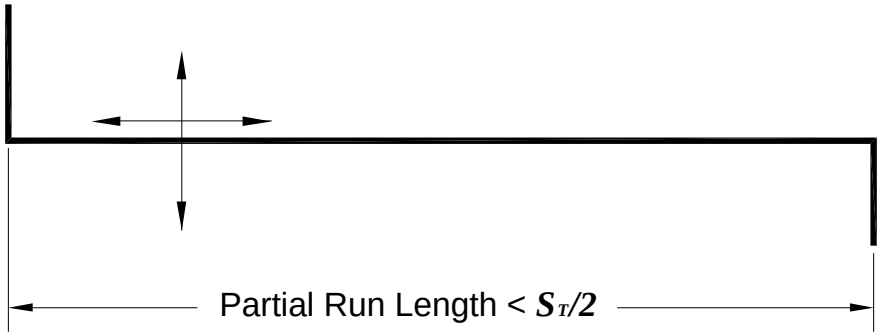

Figure S1-7; Rule #10 – Restraint Requirements for a Partial Run of Pipe or Duct

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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, $L_{SO} \leq S_T/16$, 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.

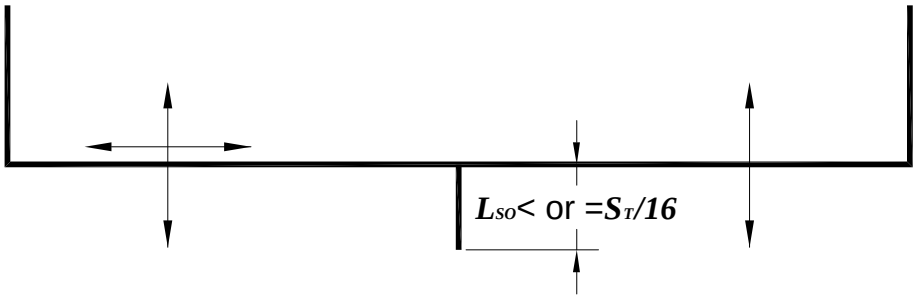

Figure S1-8; Rule # 11 – Restraint of a Pipe or Duct Stub-Out

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 $S_T/2 \leq L \leq S_T$.
2. The lengths of Runs 2, 3, 5, 6, and 7 are $L < S_T/2$.
3. The length of Run 9 is $L \leq S_T/16$.
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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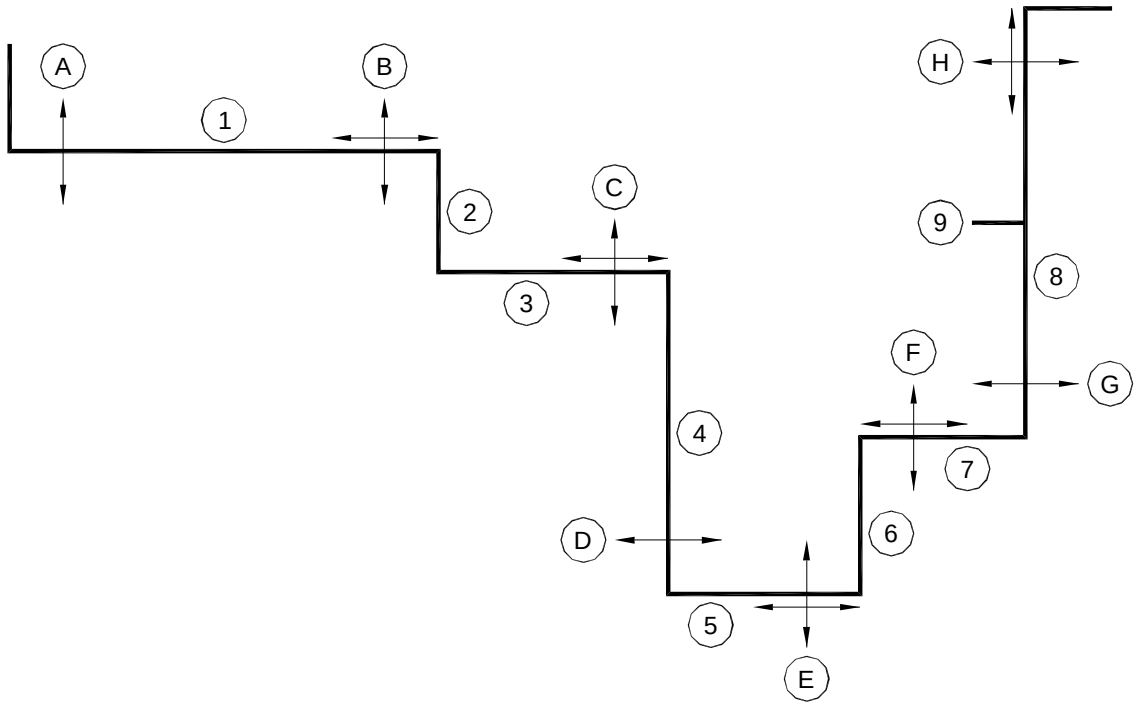

Figure S1-9; Application Example #2 – Restraints for Adjacent Short Sections of Pipe or Duct

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.

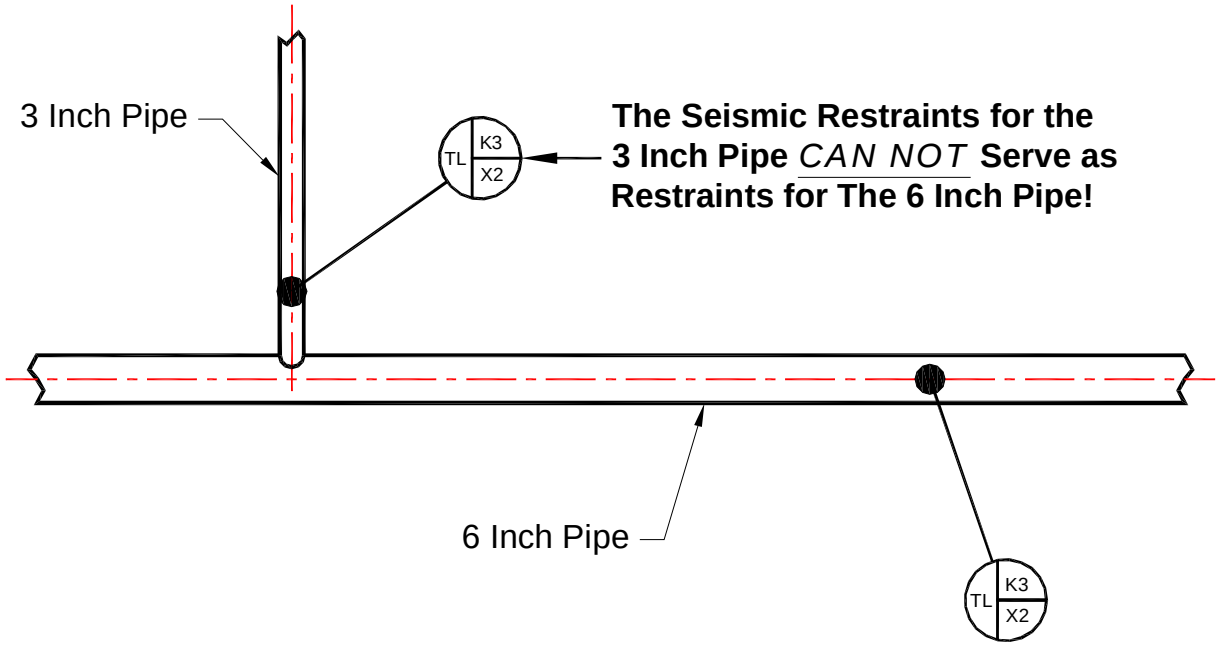

Figure S1-10; Rule #12 – Restraints on Smaller Branch Pipes Can Not Act as Restraints on the Larger Pipe.

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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)

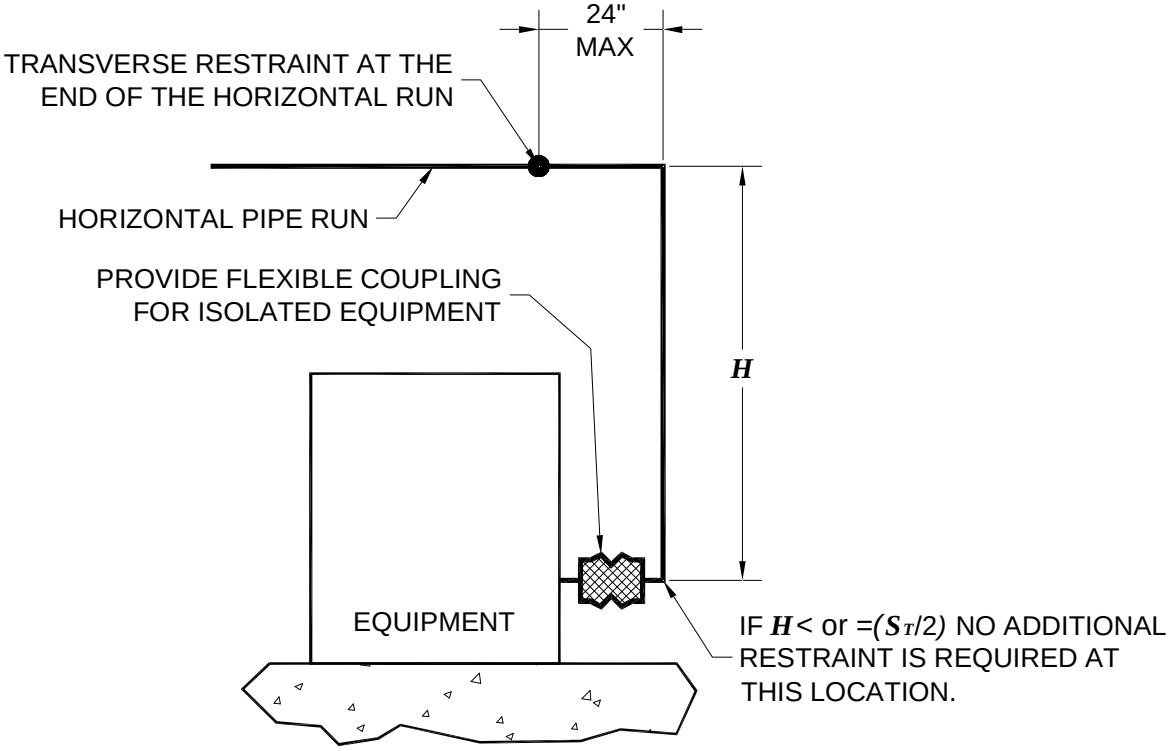

Figure S1-11; RULE #13 & RULE #14 – Vertical Drops for Pipe or Duct

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RULE #15: 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.

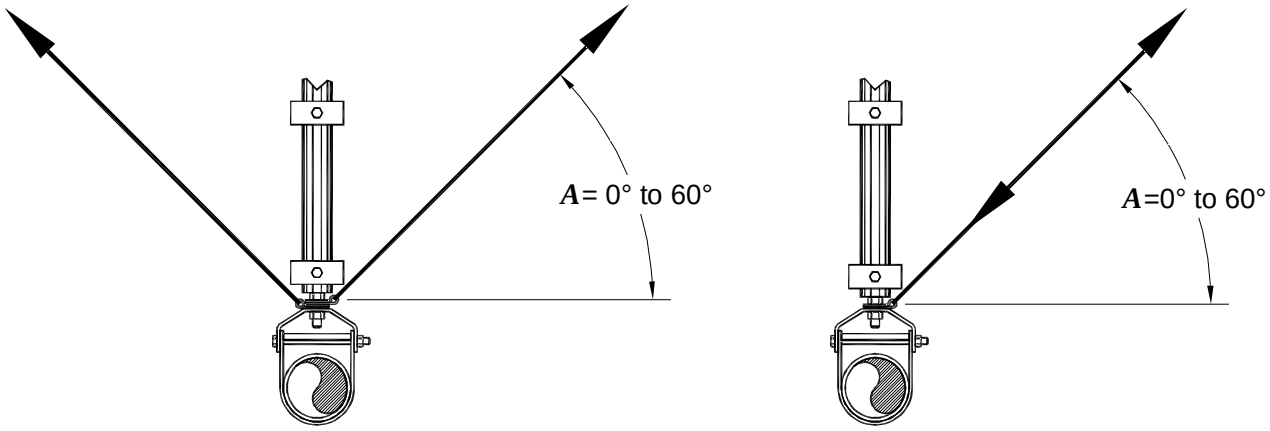

Figure S1-12; RULE #15 – Seismic Restraint Installation Angle for Transverse Restraints

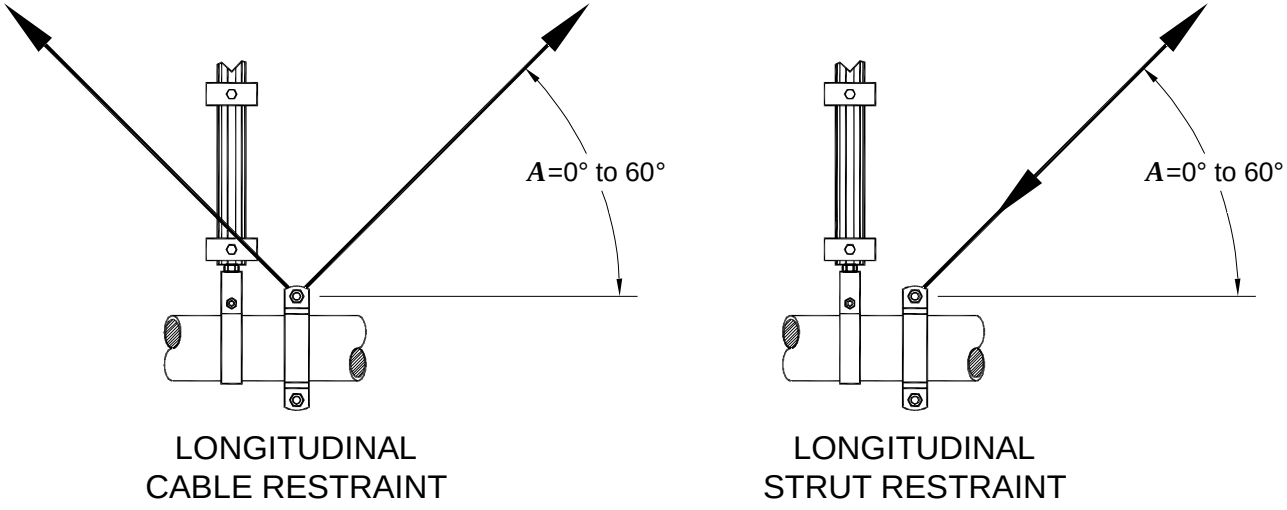

Figure S1-13; RULE #15 – Seismic Restraint Installation Angle for Longitudinal Restraints

RULE #16: 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.

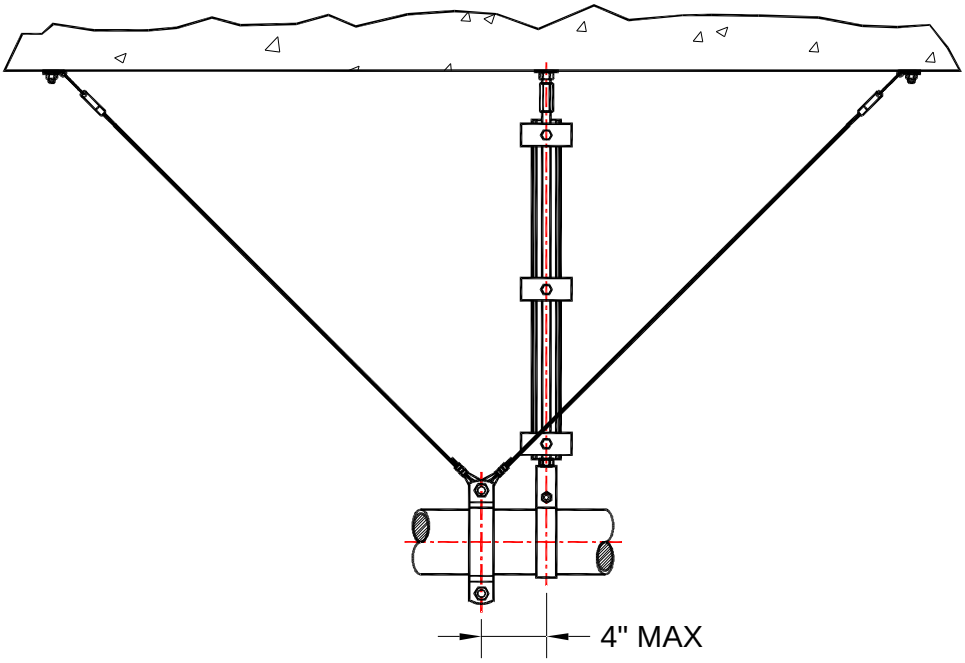

Figure S1-14; Rule #16 – Clevis Hung Pipe with Typical Longitudinal Seismic Cable Restraints

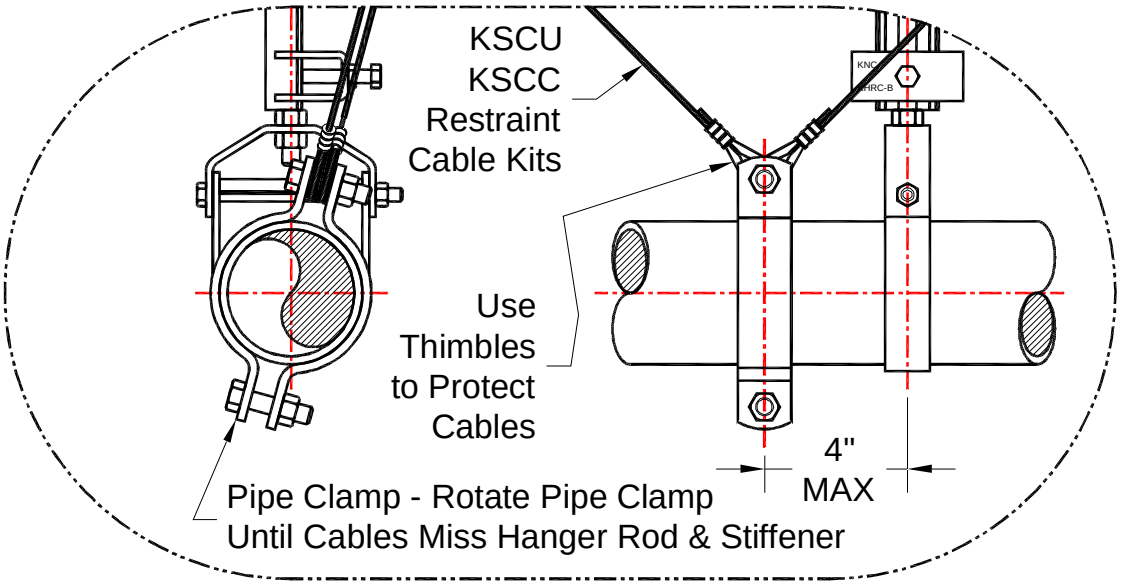

Figure S1-15; Rule #16 – Detail of Typical Longitudinal Cable Restraints for Clevis Hung Pipe

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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.

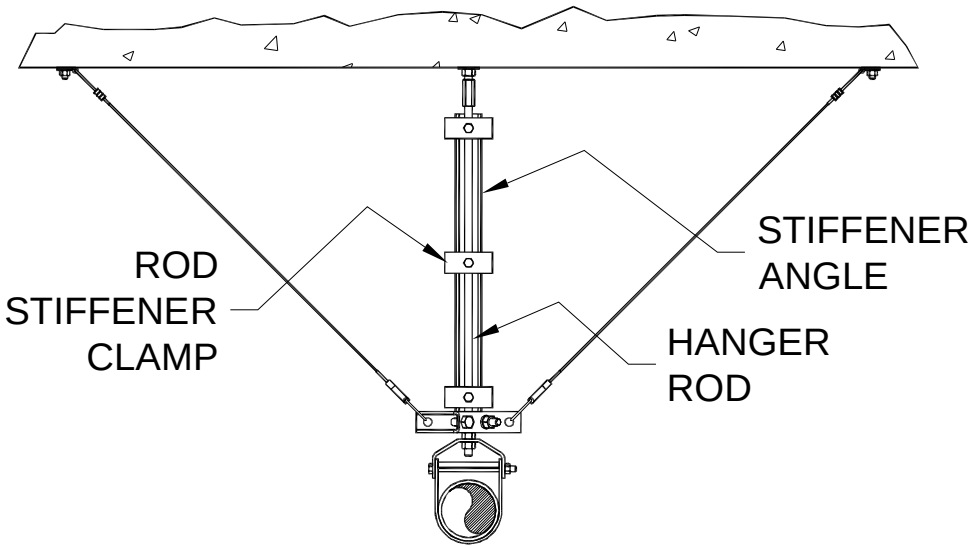

Figure S1-16; Rule #17 – Use of Rod Stiffeners at Seismic Restraint Locations

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.

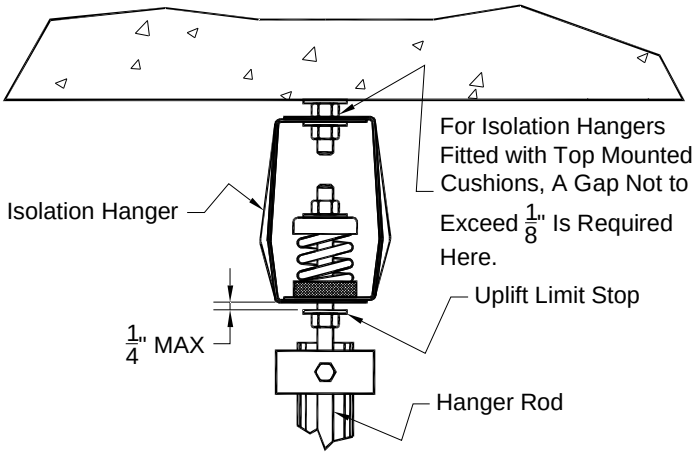

Figure S1-17; RULE #18 – Uplift Limit Stops for Isolation Hangers at Seismic Restraint Locations

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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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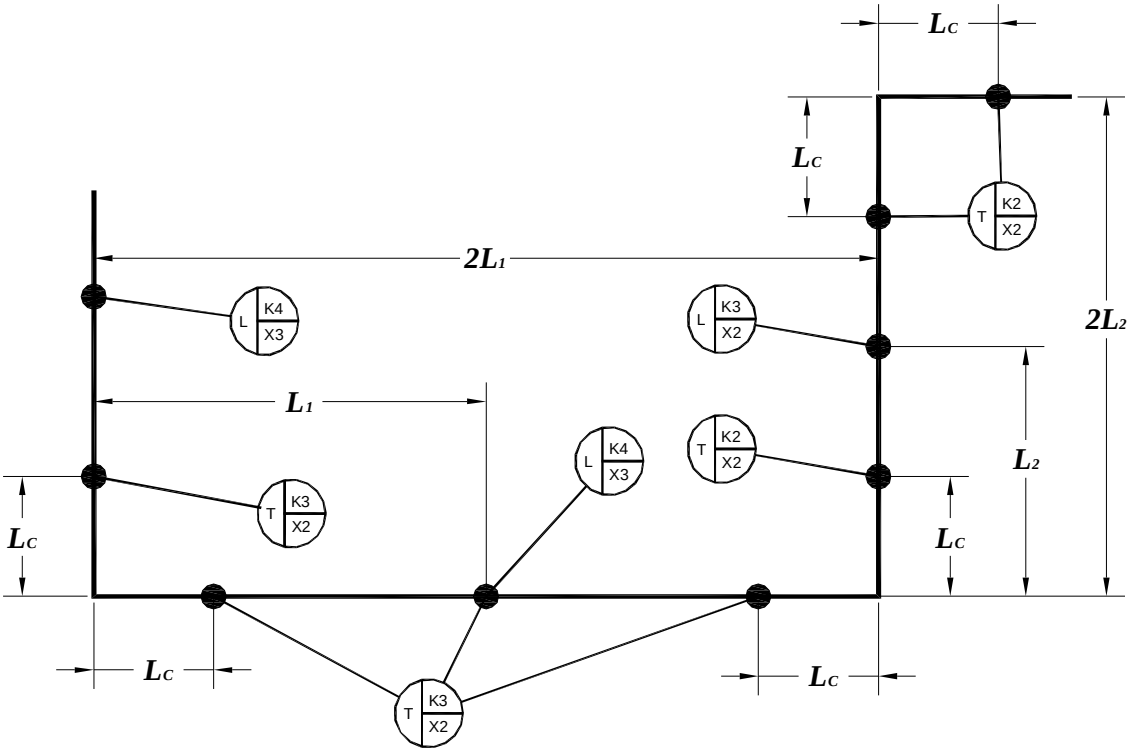

Figure S1-18; Rules #19 & #20 – Typical Seismic Restraint Layout for Domestic Hot & Chilled Water

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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