CHAPTER D7

PIPING SYSTEMS

TABLE OF CONTENTS

Seismic Forces Acting on Piping Systems — D7.1

Basic Primer for Suspended Piping — D7.2

Pros and Cons of Struts versus Cables — D7.3

Layout Requirements for Piping Restraint Systems

- Requirements for Piping System Restraints (Definitions and Locating Requirements) — D7.4.1
- Ceiling-Supported Pipe Restraint Arrangements — D7.4.2
- Floor- or Roof-Supported Pipe Restraint Arrangements — D7.4.3
- Vertical Pipe Run Restraint Arrangements — D7.4.4
- Axial Restraint of Steam Pipes — D7.4.5

Piping Restraint System Attachment Details

- Transferring Forces (Piping Restraints) — D7.5.1
- Cable Clamp Details — D7.5.2
- Piping Attachment Details — D7.5.3
- Structure Attachment Details for Piping Restraints — D7.5.4
- Non-Moment Generating Connections — D7.5.5
- Connection Options for Awkward Situations — D7.6

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Seismic Forces Acting on Piping Systems

When subjected to an earthquake, piping systems must resist lateral and axial buckling forces, and the restraint components for these systems must resist pullout and localized structural failures.

Most piping systems are suspended from the deck above on either fixed or isolated hanger rod systems. They may be supported singly or there may be several pipes attached to a common trapeze. On some occasions the pipes may run vertically or may be mounted to the floor.

Suspended Systems

Most codes do not require that piping supported on non-moment generating (swiveling) hanger rods 12 in or less in length be restrained. The 12 in length was determined based on the natural frequency of systems supported on the short hanger rods. In practice, it has been found that the vibrations generated by earthquakes do not excite these types of systems and, although the pipes move back and forth somewhat as a result of an earthquake, they do not tend to oscillate severely and tear themselves apart.

There are also exclusions in most codes for small pipes, no matter what the hanger rod length. Again, the basis for this exclusion is based on the post-earthquake review of many installations. It has been found that smaller pipes are light and flexible enough that they cannot generate enough energy to do significant damage to themselves.

For cases where restraints are required, however, the forces involved can be significant. This is due to the difference between the spacing of piping system supports and piping system restraints. Supports for piping systems are typically sized to carry approximately a 10 ft length of piping (in the case of trapezes, multiple pipes each approx 10 ft long). Seismic restraints, on the other hand, are normally spaced considerably further apart with the spacing varying by restraint type, restraint capacity, pipe sizes, and the seismic design load. It is very important to be aware of the impact of the difference in spacing as the wider this spacing, the larger the seismic load when compared to the support load. Guidance in determining restraint spacing requirements is available in Chapter D4 of this manual.

To illustrate this difference, consider a simple example of a single pipe weighing 50 lb/ft being restrained against a 0.2g seismic force with restraints located on 80 ft centers and supports located on 10 ft centers. The load that is applied to the hanger rods by the weight of the pipe is 50 lb/ft x 10 ft or 500 lb each (assuming single rod supports). The horizontal load that occurs at the restraint locations is the total restrained weight (50 lb/ft x 80 ft = 4000 lb) multiplied by the seismic force (0.2g) or 800 lb. Thus the seismic load is larger than the vertical dead load.

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Restraints for suspended systems are normally in the form of cables or struts that run from the pipe up to the deck at an angle. Because of the angle, horizontal seismic loads also generate vertical forces that must be resisted. Therefore, restraint devices must be attached at support locations so that there is a vertical force-resisting member available.

As the angle becomes steeper (the restraint member becomes more vertical), the vertical forces increase. At 45 degrees the vertical force equals the horizontal force and at 60 degrees the vertical force is 1.73 times the horizontal force.

The net result is that for cable systems or for struts loaded in tension, the uplift force at the bottom end of the restraint can be considerably higher than the downward weight load of the pipe. Returning to our example, assume that we have a restraint member installed at a 60 degree angle from horizontal and that the lateral force will load it in tension. In this case, the 800 lb seismic force generates an uplift force of 1.73 x 800 lb or 1384 lb. This is 884 lb more than the support load and, depending upon the support rod length and stiffness, can cause the support rod to buckle. Rod stiffeners are used to protect against this condition and sizing information is available in Chapter D4 of this manual.

Unlike cables, if struts are used for restraint they can also be loaded in compression. In the example above, if the strut were loaded in compression, the 1384 lb load would be added to the support load (trying to pry the hanger rod out of the deck). The total support capacity required would be 1384 lb + 500 lb or 1884 lb. As a consequence, when using struts, the hanger rod must be designed to support 1884 lb instead of the 500 lb maximum generated with cables. Hanger rod sizing information is also available in Chapter D4 of this manual.

Riser Systems

Where piping systems are running vertically in structures, except for the loads directly applied by vertical seismic load components identified in the code, there will be little variation in vertical forces from the static condition. Lateral loads are normally addressed by pipe guides and the spacing between pipe guides is not to exceed the maximum tabulated lateral restraint spacing indicated in the design tables in Chapter D4.

Floor-Mounted Systems

The primary difference between floor- and ceiling-mounted piping systems is that the support loads in the pipe support structure are in compression instead of tension (as in the hanger rods). Although a support column and diagonal cables can be used, a fixed stand made of angle or strut is generally preferred. Rules relating to restraint spacing and the sizing information for diagonal struts are the same as for hanging applications.

However, the support legs need to be designed to support the combined weight and vertical seismic load (for a two-legged stand and the example above, 500 lb / 2 + 1384 lb

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or 1634 lb) in compression (Note: 500 lb / 2 is the load per leg for two legs). The anchorage for the legs needs to be able to withstand the difference between the dead weight and the vertical seismic load (in the example above 1384 lb - 500 lb / 2 or 1134 lb).

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Basic Primer for Suspended Piping

Failures in piping systems resulting from earthquakes have historically resulted in large quantities of water or other materials being dumped into occupied spaces of the building structure. The resulting dollar damage to the building and its contents is often considerably more than the costs of damage to the building structure itself. In addition, failure of the building's mechanical systems can render the structure unoccupiable until the damage is corrected, and result in major problems for the tenants and/or owners.

Because of the impact that failures of these systems have had in the past, design requirements for piping systems have become much more stringent.

Within a building structure, there are multitudes of different kinds of piping systems, each with its own function and requirements. These include potable water, sanitary, HVAC, fire piping, fuel, gas, medical gases, and process systems to name a few. Requirements for the systems vary based on the criticality or hazardous nature of the transported fluid. Code mandated requirements for the restraint of piping systems are addressed in Chapter D2 of this manual (Seismic Building Code Review).

Prior to applying this section of the manual, it is assumed that the reader has reviewed Chapter D2 and has determined that there is indeed a requirement for the restraint of piping. This chapter of the manual is a "how to" guide and will deal only with the proper installation and orientation of restraints and not whether or not they are required by code or by specification.

This chapter also does not address the sizing of restraint hardware. Chapter D4 includes sections on sizing componentry based on the design seismic force and the weight of the system being restrained.

Process piping is not directly associated with building operating systems and often has its own set of requirements. If there are no applicable special requirements, these systems should be restrained in a similar fashion to the building mechanical systems. This manual will not address any special requirements for process piping systems.

Building mechanical systems (potable water, HVAC, sanitary) can normally be grouped together and have similar design requirements. In many cases, requirements for fuel, gas, and medical gasses are more stringent. Refer to the code review chapter (D2) of the manual for applicable design requirements.

Fire piping restraint is normally addressed in the applicable fire code. There is always some requirement for restraint, as triggering a nozzle generates thrust in the piping and must be countered. This thrust may be uni-directional, unlike the loads generated by an earthquake, and can sometimes be countered by unsymmetrical restraint arrangements.

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These types of non-seismic restraints are not addressed in this chapter. To determine the design requirements for seismic applications, refer again back to the code review Chapter D2.

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Pros and Cons of Struts Versus Cables

Both cables and struts have their place in the restraint of piping. In order to minimize costs and speed up installation, the differences between the two should be understood.

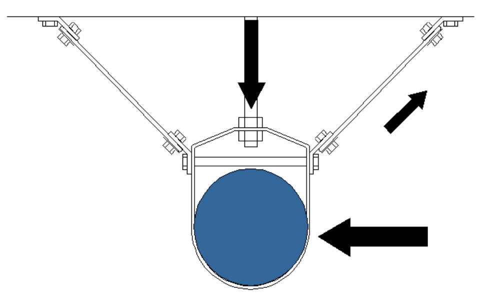
In general, piping restrained by struts will require only 1 brace per restraint location while piping restrained with cables requires that 2 cables be fitted forming an “X” or a “V”. As a trade-off, the number of restraint points needed on a given run of piping will typically be considerably higher for a strut-restrained system than for the cable-restrained system and, generally, strut-restrained systems will be more costly to install.

An added factor to consider when selecting a restraint system is that once a decision is reached on the type to use for a particular run, code requirements state that the same type of system must be used for the entire run (all cable or all strut). Later sections in this chapter will define runs, but for our purposes at present, it can be considered to be a more or less straight section of piping.

The obvious advantage to struts is that, when space is at a premium, cables angling up to the ceiling on each side of a run may take more space than is available. Struts can be fitted to one side only, allowing a more narrow packaging arrangement.

The advantages of cables, where they can be used, are numerous. First, they can usually be spaced less frequently along a pipe than can struts. Second, they cannot increase the tensile forces in the hanger rod that results from the weight load, so rod and rod anchorage capacities are not impacted. Third, they are easily set to the proper length. And fourth, they are well suited to isolated piping applications.

To better explain the differences between the systems, it is necessary to look at how seismic forces are resisted with cables and struts. Shown below are sketches of both cable-restrained and strut-restrained piping.



Cable Restrained

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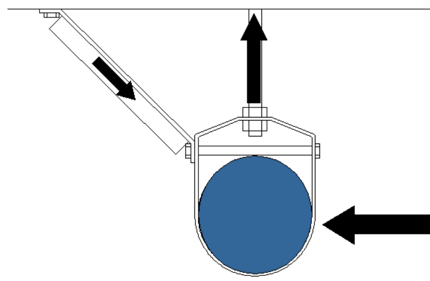

Strut Restrained

The key factor to note is that cables can only be loaded in tension. This means that seismic forces can only generate compressive loads in the pipe hanger rod. Seismic forces can, however, load the strut in compression resulting in a tensile load on the hanger rod.

This tensile load is in addition to any deadweight load that may already be supported by the hanger and is often significantly higher than the original load. This has the potential to rip the hanger rod out of the support structure and must be considered when sizing components.

Because of this added tensile component and the resulting impact on the necessary hanger rod size, most strut manufacturers limit the maximum allowable strut angle (to the horizontal) to 45 degrees. This is lower than typical allowable angles for cables that often reach 60 degrees from the horizontal. Although the tables listed in Chapter D4 of this manual allow the use of higher angles for strut systems, users will find that the penalties in hanger rod size and anchorage will likely make these higher angles unusable in practice. To put this into context, examples will be provided at both 45 degrees and 60 degrees from the vertical to indicate the impact on capacity that results from the angle.

For a 45 degree restraint angle, if we assume a trapeze installation with the weight (W) equally split between 2 supports, the initial tension in each support is 0.5W. Using a 0.25g lateral design force (low seismic area), the total tensile load in a hanger increases to 0.75W for bracing on every support and 1.0W for bracing on every other support, if a strut is used.

For reference, if struts are used in a 60 degree angle configuration (from the horizontal), the tensile force in the hanger rod for all cases increases by a factor of 1.73 *(tan 60)* over that listed in the previous paragraph. This means that the tensile force becomes .94W for bracing on every support and 1.36W for bracing on every other support.

On the other hand, where 0.25g is applicable, buckling concerns in the pipe are such that the spacing between lateral restraints can be as high as 40 ft and for axial restraints, 80 ft. If we were to try to use struts placed at a 40 ft spacing in conjunction with supports

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spaced at 10 ft, the tensile force developed by a seismic event in the rod increases to 1.5W for 45 degree configurations and to 2.23W for 60 degree configurations.

As mentioned earlier, there is no increase in the rod forces for cable restrained systems.

Using real numbers based on a 40 ft restraint spacing and a 60 degree angle configuration, if the peak tensile load in the hanger rod is 500 lb for a cable restrained system, it becomes 2230 lb for an otherwise identical strut restrained system.

A summary of the above data, based on a 500 lb weight per hanger rod (1000 lb per trapeze bar) and including concrete anchorage sizes and minimum embedment is shown below.

Summary of Hanger Rod Tensile Loads based on 500 lb per Rod Weight				
	Tens Force (lb)	Min Rod (in)	Min Anc (in)	Embed (in)
Every Hanger Braced (10')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	750	0.38	0.38	3.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	933	0.50	0.50	4.00
Every other Hanger Braced (20')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	1000	0.50	0.50	4.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	1365	0.50	0.63	5.00
Every fourth Hanger Braced (40')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	1500	0.63	0.63	5.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	2230	0.63	0.75	6.00
Max Spacing between Braces (80')				
Cable Angle = 45	500	0.38	0.38	3.00
Strut Angle = 45	2500	0.75	0.75	6.00
Cable Angle = 60	500	0.38	0.38	3.00
Strut Angle = 60	3960	0.88	1.00	8.00

Note: The above anchorage rating is based on ICBO allowables only. Often the underside of a concrete floor slab is in tension and if this is the case, the anchorage capacity may need to be further de-rated (forcing the need for an even larger hanger rod than is indicated here).

The net result is that the ability to use struts is highly dependent on the hanger rods that are in place. If these were sized simply on deadweight, the added seismic load, even in relatively low seismic areas, can quickly overload them. The only recourse is to either

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replace the hanger rods with larger ones or decrease the restraint spacing to the point at which virtually every support rod is braced.

It should also be noted that the hanger rods in tension become seismic elements. This occurs with struts, but does not with cables. As a result, the system must comply with all of the anchor requirements specified by ICBO. This includes the use of wedge-type anchors and embedment depths that are a minimum of 8 anchor diameters. With larger anchor sizes, floor slab thickness may cause this to become a significant problem.

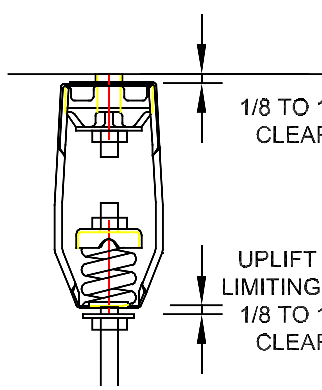
With both cables and struts, the hanger rods can be loaded in compression. As the seismic force increases, it eventually overcomes the force of gravity and produces a buckling load in the hanger rod. It is mandatory in all cases that the rod be able to resist this force.

There is a wide range of variables involved in determining the need for rod stiffeners to resist this buckling load. Factors that impact this need are 1) the magnitude of the compressive force, 2) the weight load carried by the hanger rod, 3) the length of the hanger rod, 4) the diameter of the hanger rod, and 5) the angle between the restraint strut or cable and the horizontal axis.

Tables are included in Chapter D4 of this manual that allow the user to determine if there is a need for a stiffener and to allow the proper selection if required.

Because uplift occurs, some attention must be given to isolated systems. First, when using isolators, the location of the isolation element needs to be at the top end of the hanger rod (close to, but not tight against the ceiling). If placed at the middle of the hanger rod, the rod/isolator combination will have virtually no resistance to bending and will quickly buckle under an uplift load.

Second, a limit stop must be fit to the hanger rod, just beneath the hanger such that when the rod is pushed upward a rigid connection is made between the hanger housing and the hanger rod that prevents upward motion. This is accomplished by adding a washer and nut to the hanger rod just below the isolator (see the sketch below).



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Requirements for Piping System Restraints
Definitions and Locating Requirements

SMACNA has developed a set of restraint placement criteria based on analytical review, practical experience, and historical analysis. The criteria presented in this manual is generally based on the SMACNA criteria, with the only exceptions being an extrapolation of the data to higher seismic force levels and an increase in allowable spacing where restraint hardware capacity (as illustrated in the SMACNA guide) would be exceeded.

With respect to the conceptual restraint arrangement illustrations, the SMACNA concepts are appropriate and are referenced here.

In general, pipes are restrained in lengths called "runs." Therefore before getting into a detailed review of the restraint systems it is imperative that a definition of "run" as well as other key terms be addressed.

Definitions

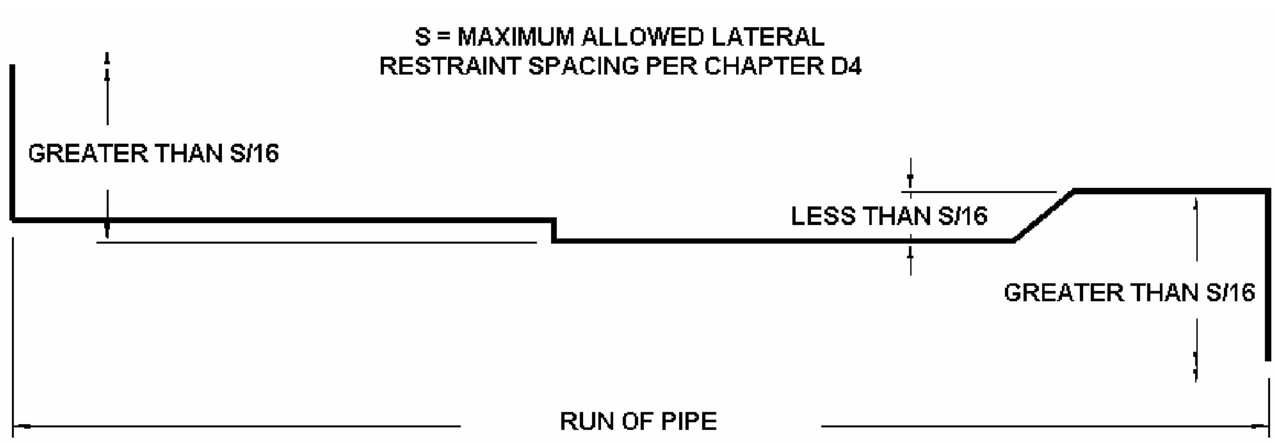
Axial In the direction of the axis of the pipe.

Lateral Side to side when looking along the axis of the pipe.

Pipe Clamp A heavy duty split ring clamp tightened against the pipe to the point that it can be used to control the axial motion of the pipe.

Restraint Any device that limits the motion of a pipe in either the lateral or axial direction.

Run A more or less straight length of pipe where offsets are limited to not more than S/16 where S is the maximum permitted lateral restraint spacing (a function of pipe size and seismic forces) and the total length is greater than S/2. (Note: S dimensions for various conditions are listed in Chapter D4.)



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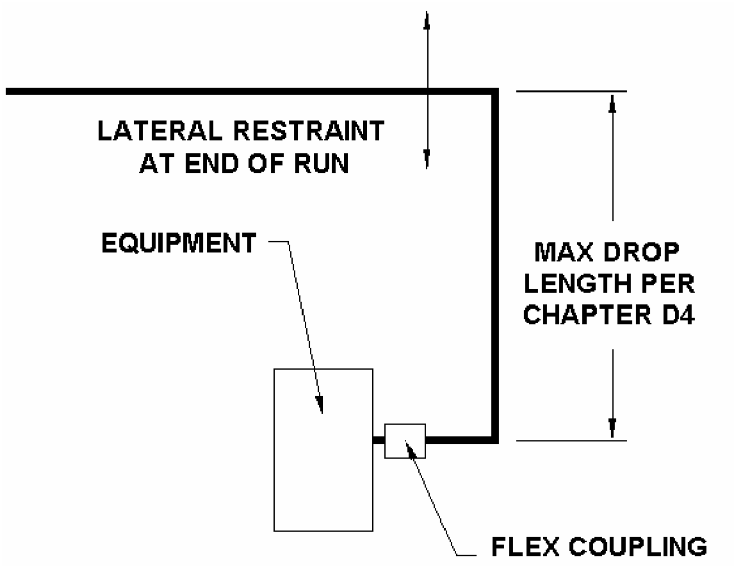
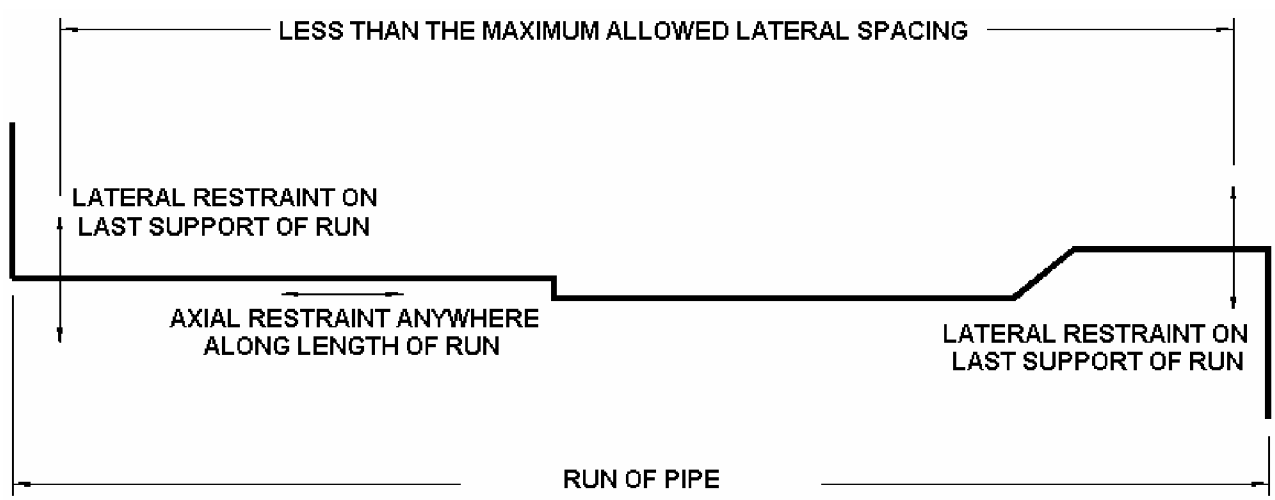
Short Run A run as defined above where the total length is less than S/2 and where it is connected on both ends to other runs or short runs.

Drop A length of pipe that normally extends down from an overhead run of pipe and connects to a piece of equipment, usually through some type of flex connector. The drop can also extend horizontally. In order to qualify as a drop, the length of this pipe must be less than S/2. If over S/2, the length of pipe would be classified as a run.



Restraint Requirements

1) Full runs (Greater in length than S/2) must be restrained in both the axial and lateral direction. If the run is not a short run or a drop, it must, as a minimum, be laterally restrained at the last support location on each end.



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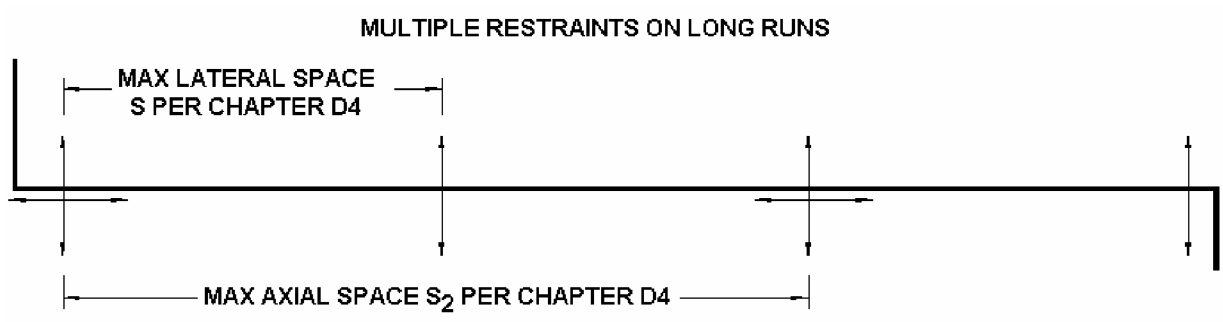
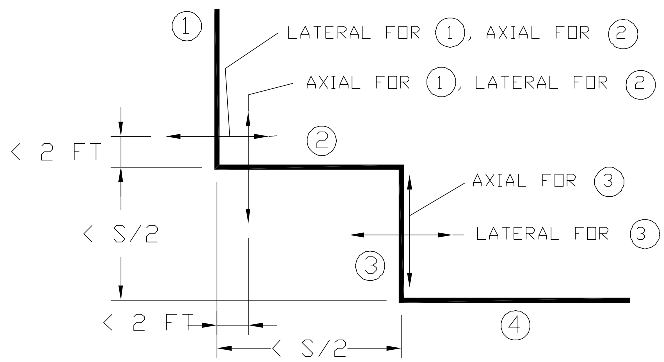
2) If a run is longer than "S", intermediate restraints are required to limit the spacing to that permitted by the building code (see table in Chapter D4).

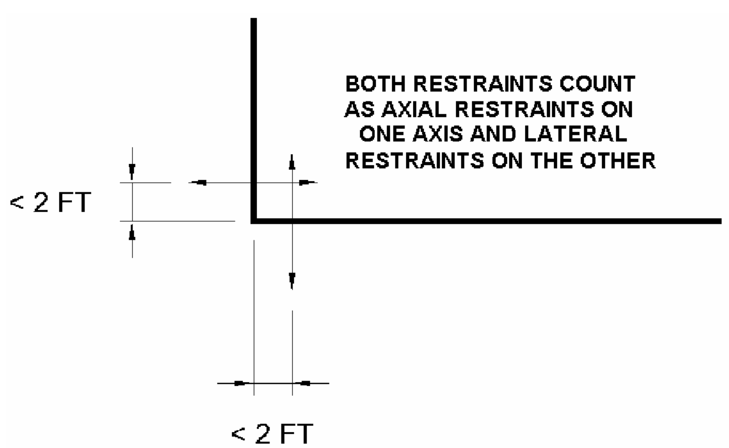


3) Axial restraints attached to the run of piping along its length must be connected using a pipe clamp (as previously defined).

4) Short runs or drops need only have one lateral and one axial restraint.



5) If a lateral restraint is located within 2 feet of a corner (based on a measurement to the pipe centerline), it can be used as an axial restraint on the intersecting run.



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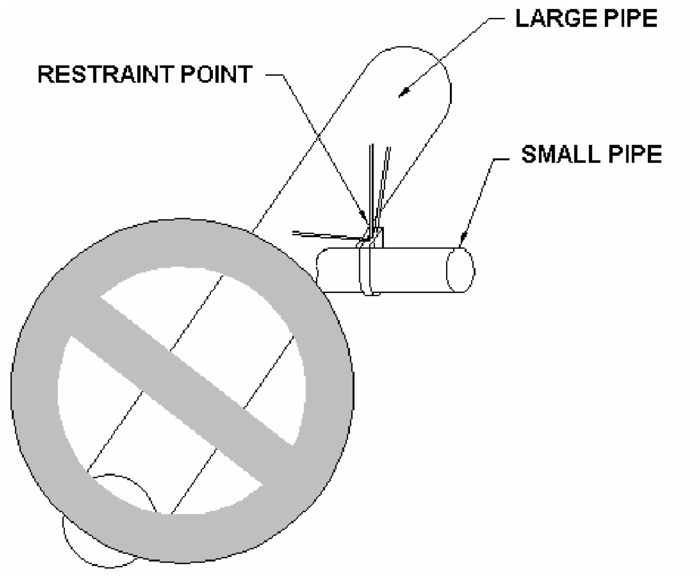
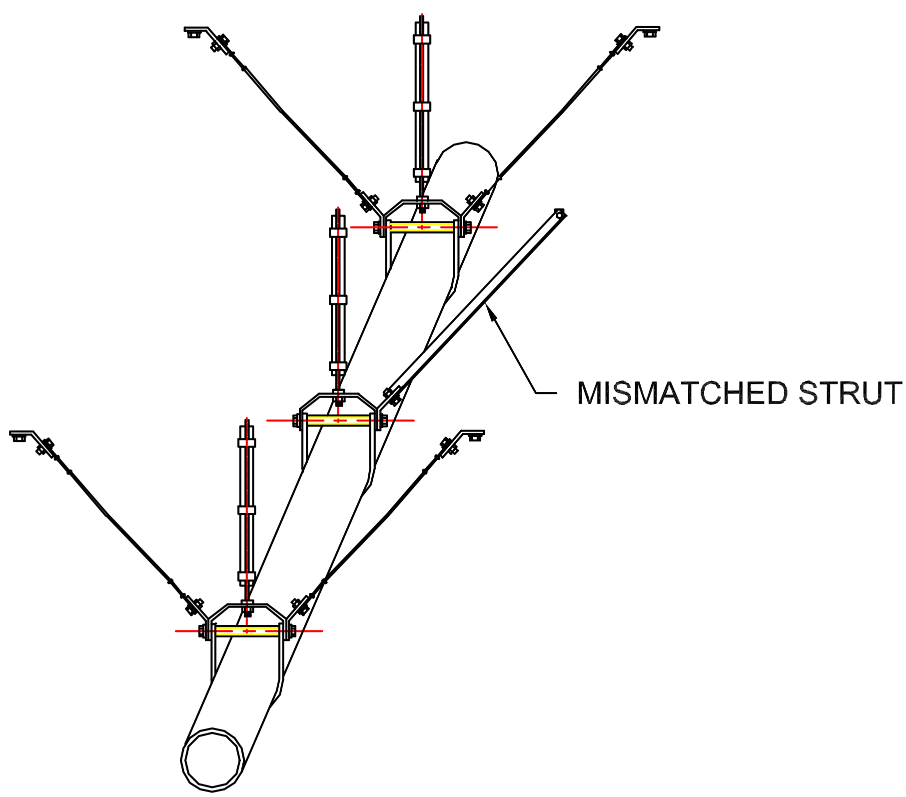
6) Larger pipes cannot be restrained with restraints located on smaller branch lines.



7) Within a run, the type of restraint used must be consistent. For example, mixing a strut with cable restraints is not permitted.



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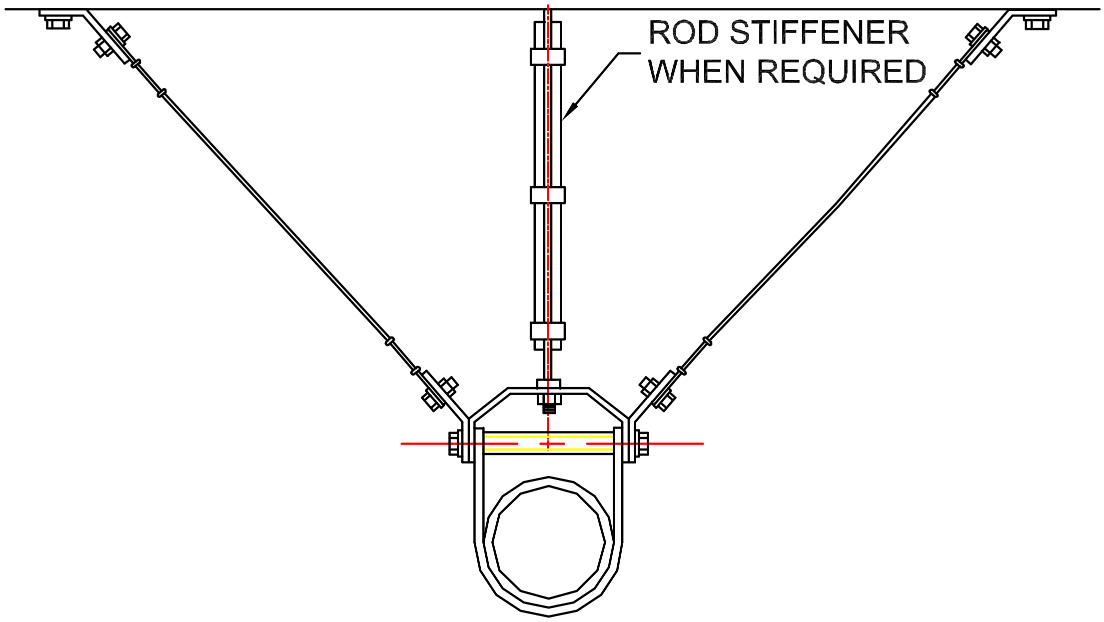
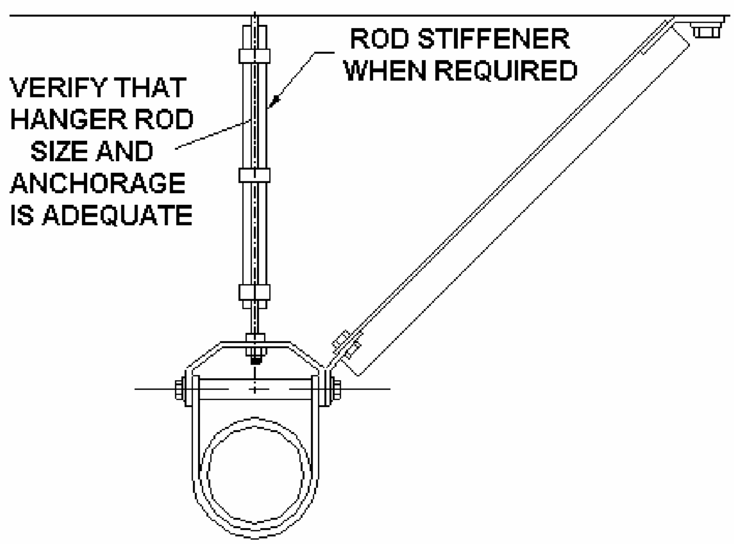
8) With longer hanger rods, rod stiffeners are likely to be required. Refer to the appropriate table in Chapter D4 to determine: (1) if needed, (2) what size stiffener material is appropriate, and (3) how frequently it needs to be clamped to the hanger rod.



9) In addition to possibly requiring rod stiffeners, when struts are used to restrain piping, the size of the hanger rod and its anchorage also become critical. Again refer to the appropriate table in Chapter D4 to determine the minimum allowable size for the hanger rod and anchor.



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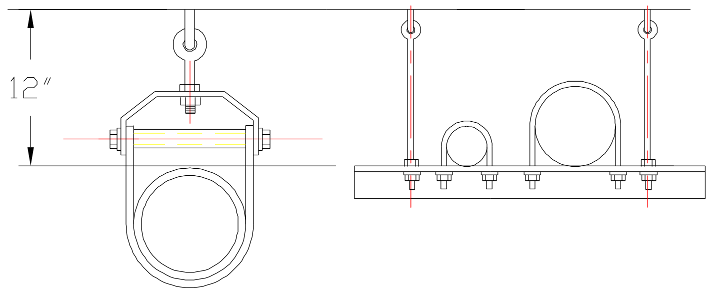
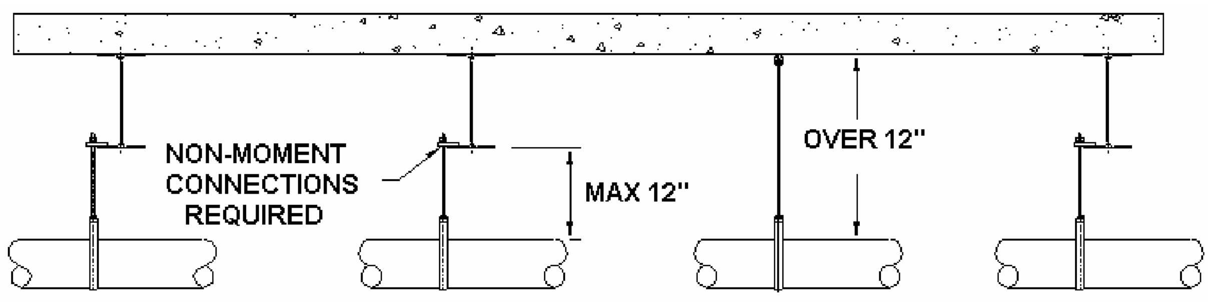
10) In some cases, it may be possible to locate the piping system close enough to the support structure (12") to eliminate the need for restraint. (Refer to the building code review chapter (D2) to determine if this exemption is applicable.) If it is applicable, the 12" dimension is measured as shown below.



11) When using the above rule it is critical that all support locations in a run conform. If even one location exceeds 12", the run cannot be exempted from restraint.



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Ceiling-Supported Pipe Restraint Arrangements

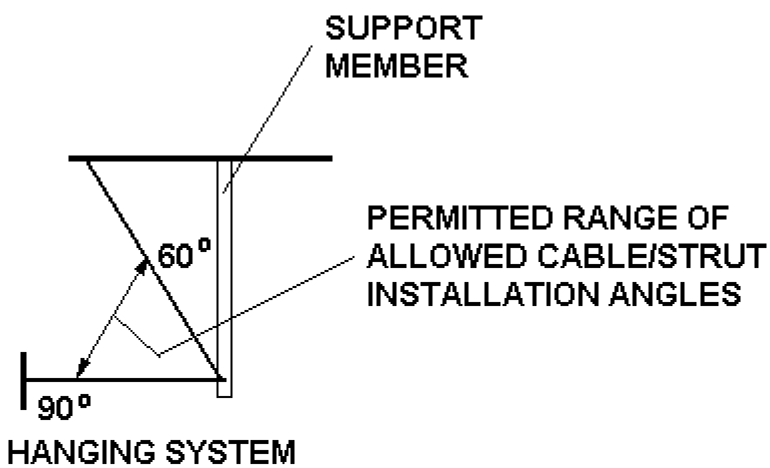
Although the basic principle of diagonal bracing is almost always used to design restraint systems, the actual arrangement of these systems can vary significantly. Despite what looks like substantially different designs, the design forces in the members remain the same, and the same rules apply when sizing components. Illustrated here are many different restraint arrangements, all of which can be used in conjunction with the design "rules" provided in this manual.

Details of the end connections and anchorage hardware are shown in subsequent sections of the manual. It is assumed in this manual that the restraint component is attached to a structural element capable of resisting the design seismic load.

Due to variations in the installation conditions such as structural clearance, locations of structural attachment points, and interference with other pieces of equipment or systems, there will likely be significant benefits to using different arrangements in different locations on the same job.

<u>The only significant caution here is that it is not permissible to mix struts and cables on the same run.</u>

This manual addresses diagonal bracing slopes of between horizontal and 60 degrees from the horizontal. Angles in excess of 60 degrees to the horizontal are not permitted.



When installing restraints, lateral restraints should be installed perpendicular (±10 degrees) to the pipe in plan. Axial restraints should be in line with the pipe, ±10 degrees, again in the plan view. All restraint cables should be aligned with each other. See the sketch below.

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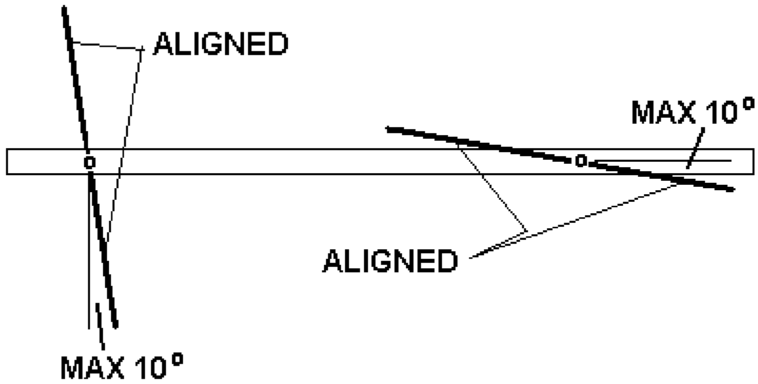

Lateral Restraint **Axial Restraint**

In general, when restraining piping the component actually being restrained is the support device for the pipe. This may be a pipe clevis, a heavy-duty pipe clamp, or a trapeze bar. Because the goal is to restrain the actual pipe, it is necessary that the restrained element be connected to the pipe in such a way as to transfer the appropriate forces between the two. For example, if an axial restraint is installed on a trapeze bar which in turn supports a pipe that is carried by a roller, it is obvious that the axial forces generated by the pipe cannot be restrained by the connection to the trapeze bar, and some other arrangement is needed.

When firmly connecting restraints to piping there are a few general rules that should be followed:

1) A pipe clevis cannot restrain a pipe in the axial direction.
2) If the pipe is wrapped with insulation and an axial restraint is needed, a riser clamp should be tightly clamped to the pipe prior to wrapping it with insulation and the restraint device should penetrate the insulation material.
3) If the pipe is wrapped with insulation and lateral restraint is needed, a hardened insulation material should be fitted at the restraint location.
4) Piping which expands and contracts significantly should include expansion joints or loops between each axially restrained component.
5) Trapeze-mounted piping should be tightly clamped to the trapeze bar.

In addition, when sizing restraint components for multiple pipes, the total weight of all of the restrained piping must be considered.

Hanging Systems Restrained with Cables

Hanging systems may include supports for single pipes or multiple pipes. Single pipes can be supported using clevis hangers but multiple pipes are normally supported on trapeze bars.

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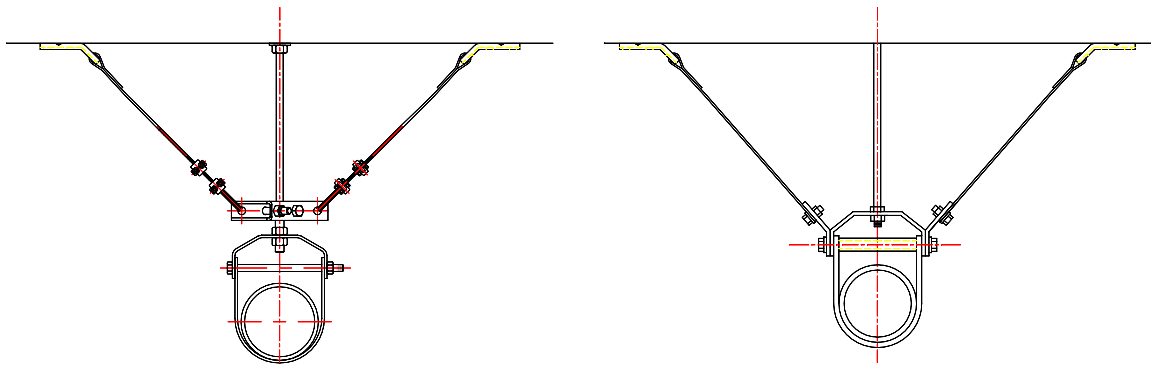
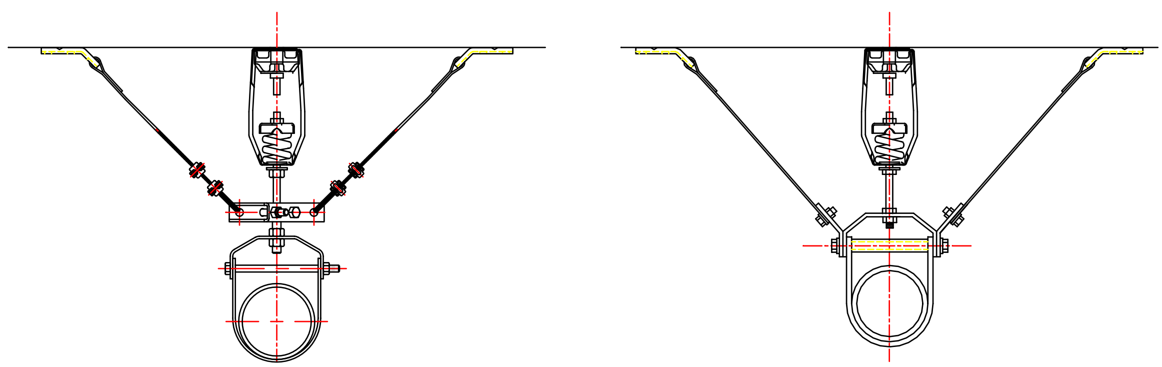
Lateral Restraint Examples

For a cable-restrained pipe supported by a hanger clevis, there are two options for non-isolated installations and two similar options for isolated installations. These options are shown below. Note that the isolator is mounted with minimal clearance to the structure and that a travel limiting washer is fitted to the hanger rod just below the isolator in the isolated arrangements.



Lateral Cable Restraints clamped to Hanger Rod and attached to Clevis Tie Bolt (Non-isolated)



Lateral Cable Restraints clamped to Hanger Rod and attached to Clevis Tie Bolt (Isolated)

There are many options that exist for the arrangements of lateral restraints used in conjunction with trapeze-mounted systems. Shown below are several options for both non-isolated and isolated cable-restrained systems.

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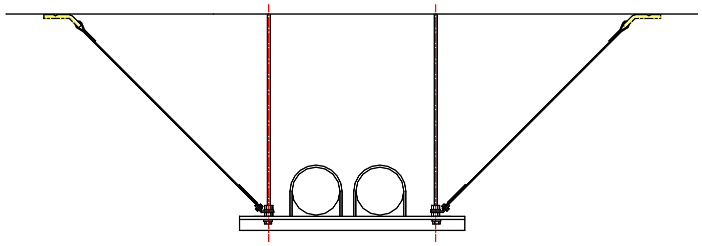
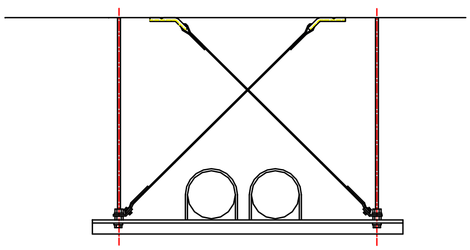
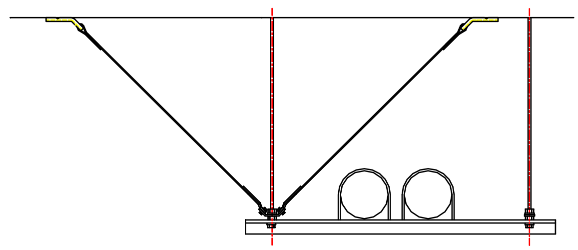
TRAPEZE _/ (TOP)



TRAPEZE X (TOP)

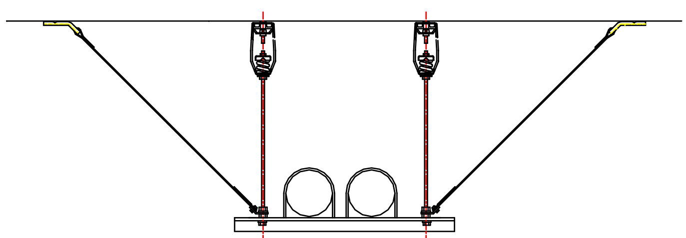


TRAPEZE \/ (TOP)

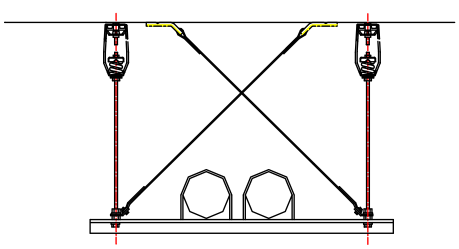


Lateral Cable Restraints Mounted to a Trapeze (Non-isolated)

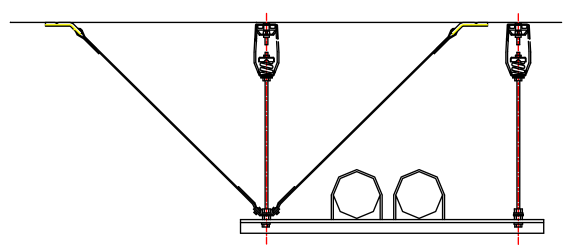
TRAPEZE _/ (TOP)



TRAPEZE X (TOP)



TRAPEZE \/ (TOP)



Lateral Cable Restraints Mounted to a Trapeze (Isolated)

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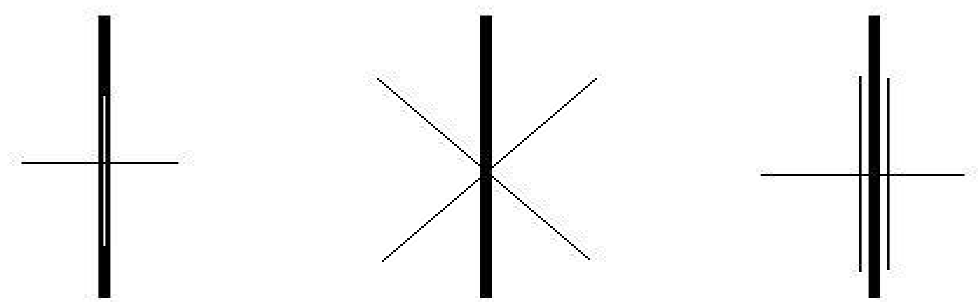
Axial Restraint Examples

Axial restraints cannot be connected to a standard pipe clevis and be expected to work. This is because there is inadequate friction between the clevis hanger and the pipe to transfer the forces in the pipe to the restraint. When axially restraining piping, a trapeze or riser clamp tightly attached to the pipe is the most common connecting device used, although a weld-on tab or connection to a flange is a possibility in some cases. Details on these connections will be addressed in later sections.

If the details of the connection are ignored at this point, general axial restraint arrangements recognized in this manual are illustrated below.

Note: Axial restraints offset from the restrained pipe will generate additional bending forces in the restrained pipe. This is true whether mounted to one end of a trapeze or along side a single pipe rather than directly over its center. Provisions should be made to avoid offsetting axial restraints when restraining a single pipe. This requires either that the restraint be attached to the centerline of the pipe, that the axial restraint be combined with a lateral restraint to form an "X" arrangement or that 2 axial restraints be fitted, one on either side of the pipe (See also the Figure below). (Note that when specifying and providing restraints, KNC assumes one of the 2 former arrangements are used, if the latter case is used, the installation contractor will have to procure and additional restraint set from KNC.) For trapezed systems supporting multiple pipes, a single axial restraint should be located at the approximate center of the trapeze bar or pairs of axial restraints should be installed on each end of the trapeze bar.



Various Acceptable Axial Restraint Arrangements

<u>Hanging Systems Restrained with Struts</u>

It is recommended that struts <u>not</u> be used to restrain isolated piping systems. Struts will generate hard connections between the piping and structure and will greatly reduce the efficiency of the isolation system. Having said that, in some special situations it may be possible to design restraint struts with integral isolation elements, but this is tedious and

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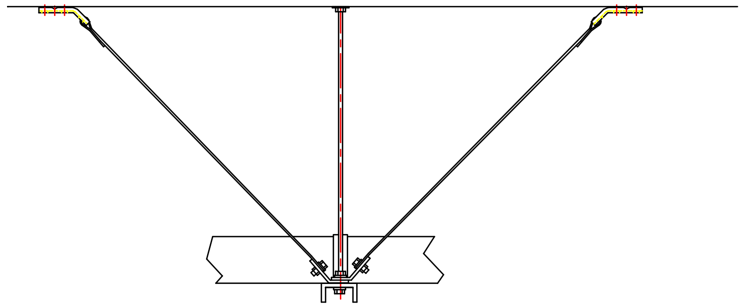
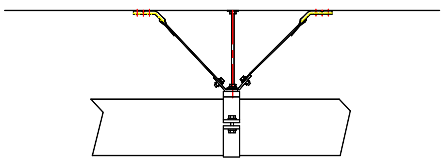
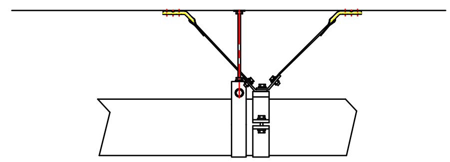
TRAPEZE



RISER CLAMP / SUPPORT

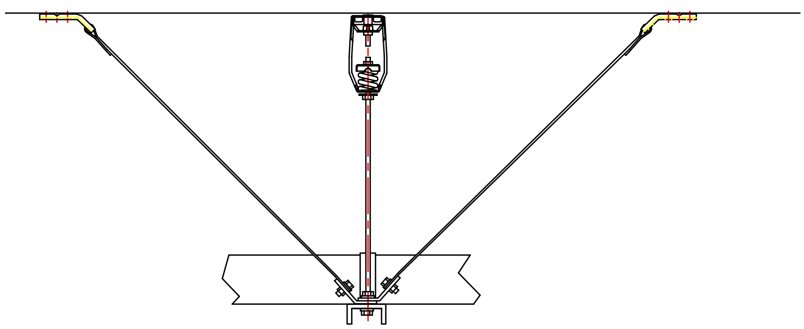


RISER CLAMP
ADJACENT TO SUPPORT

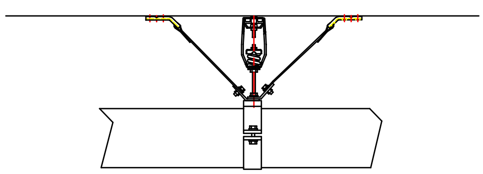


Axial Cable Restraints (Non-isolated)

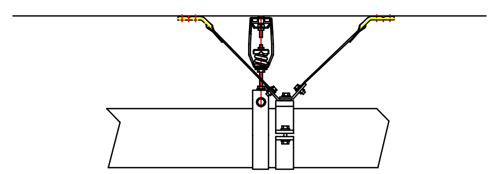
TRAPEZE



RISER CLAMP / SUPPORT



RISER CLAMP
ADJACENT TO SUPPORT



Axial Cable Restraints (Isolated)

CEILING-SUPPORTED PIPE RESTRAINT ARRANGEMENTS

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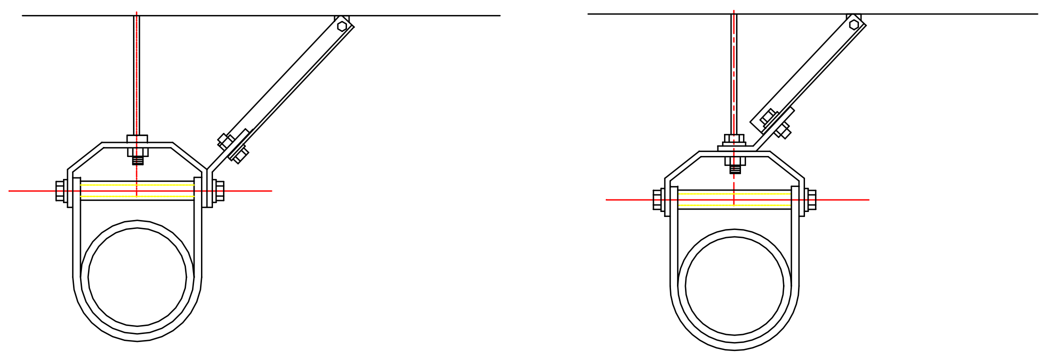
should be avoided unless drastic measures are required.

As with cable restraints, hanging systems may include supports for single pipes or multiple pipes. Single pipes can be supported using clevis hangers, but multiple pipes are normally supported on trapeze bars.

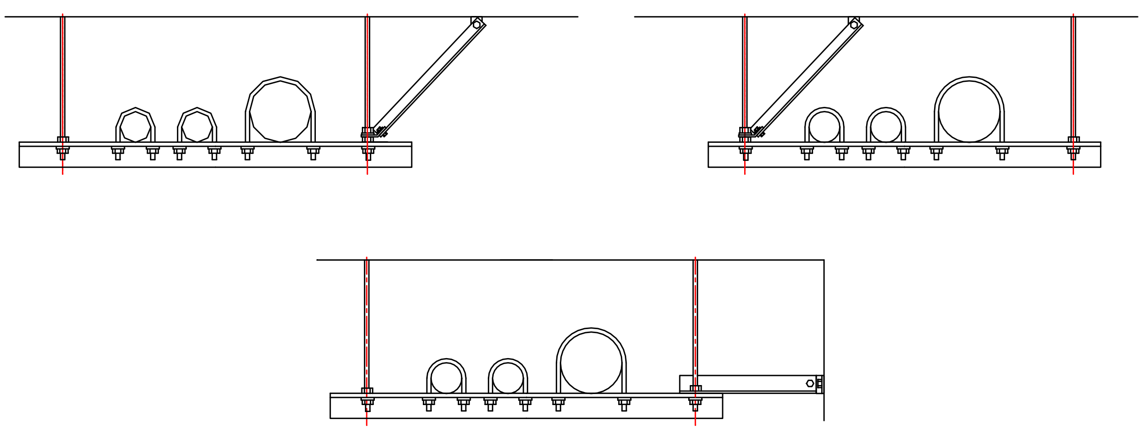
Lateral Restraint Examples

For a strut-restrained pipe supported by a hanger clevis there are two typical options. One is to connect the restraint to the clevis bolt and the other is to connect the restraint to the hanger rod. These are shown below.



Typical Lateral Restraint Strut Arrangements for Clevis-Supported Pipe

Shown below are 3 options for trapeze-supported piping. All are equivalent.



3 Arrangements for Laterally Restrained Trapezes with Struts

Axial Restraint Examples

As with cables, axial restraints using struts cannot be connected to a standard pipe clevis

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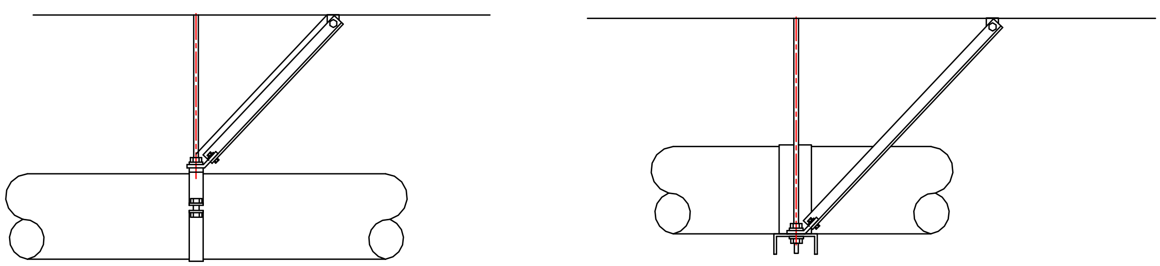
and be expected to work. When axially restraining piping, a trapeze or riser clamp tightly attached to the pipe is the most common connecting device between the restraint strut and the pipe, but occasionally a weld-on tab or connection to a flange can be used. Details on these connections will be addressed in later sections.

Ignoring the details of the connection at this point, common axial restraint arrangements recognized in this manual are illustrated below.

As with the cable restraints, it must be recognized that axial restraints offset from the restrained pipe will generate additional bending forces in the pipe. This is true whether mounted to one end of a trapeze or along side a single pipe rather than directly on its center. Provisions should be made to avoid offsetting axial restraints when restraining a single pipe. This requires either that the restraint be attached to the centerline of the pipe, that the axial restraint be combined with a lateral restraint to form an "X" arrangement or that 2 axial restraints be fitted, one on either side of the pipe. (Note that when specifying and providing restraints, KNC assumes one of the 2 former arrangements are used, if the latter case is used, the installation contractor will have to procure and additional restraint set from KNC.) For trapezed systems supporting multiple pipes, a single axial restraint should be located at the approximate center of the trapeze bar or pairs of axial restraints should be installed on each end of the trapeze bar.

Various Acceptable Axial Restraint Arrangements



Piping Axially Restrained with Struts

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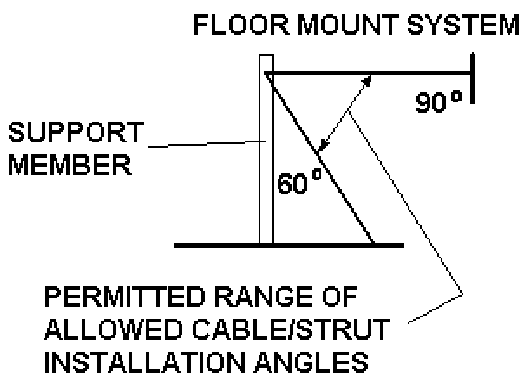
Floor- or Roof-Supported Pipe Restraint Arrangements

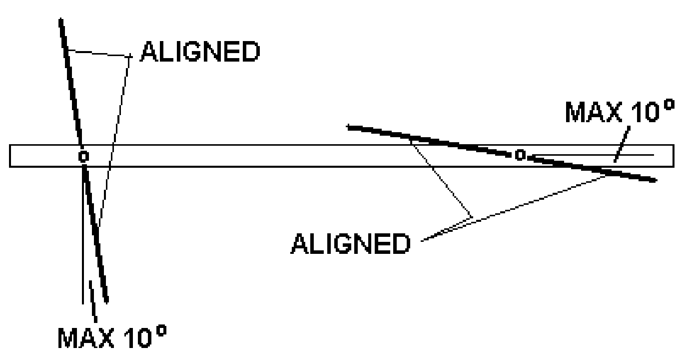
Although the basic principle of diagonal bracing is almost always used to design restraint systems, the actual arrangements of these systems can vary significantly. Despite what looks like substantially different designs, the design forces in the members remain the same, and the same rules apply when sizing components. Illustrated here are many different floor- and roof-mounted restraint arrangements, all of which can be used in conjunction with the design "rules" provided in this manual.

Details of the end connections and anchorage hardware are shown in subsequent sections of this manual. It is assumed in this manual that the restraint component is attached to a structural element capable of resisting the design seismic load.

This manual addresses diagonal bracing oriented between horizontal and 60 degrees from the horizontal. Angles in excess of 60 degrees to the horizontal are not permitted.



When installing restraints, lateral restraints should be installed perpendicular (±10 degrees) to the pipe in the plan view. Axial restraints should be in line with the pipe (±10 degrees) again in the plan view. All restraint cables should be aligned with each other. See the sketch below.



Lateral Restraint **Axial Restraint**

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In general, when restraining piping the component actually being restrained is the support device for the pipe. For floor-mounted equipment this would normally be either a fabricated frame or a trapeze bar. Because the goal is to restrain the actual pipe, it is necessary that the restrained element be connected to the pipe in such a way as to transfer the appropriate forces between the two. For example, if an axial restraint is installed on a trapeze bar which in turn supports a pipe that is carried by a roller, it is obvious that the axial forces generated by the pipe cannot be restrained by the connection to the trapeze bar and some other arrangement is needed.

With respect to firmly connecting restraints to piping, there are a few general rules that should be followed:

1) A pipe carried on a roller cannot be restrained in the axial direction by restraining the support.
2) If the pipe is wrapped with insulation and an axial restraint is needed, a riser clamp should be tightly clamped to the pipe prior to wrapping it with insulation and the restraint device should penetrate the insulation material.
3) If the pipe is wrapped with insulation and lateral restraint is needed, a hardened insulation material should be fitted at the restraint location.
4) Piping which expands and contracts significantly should include expansion joints or loops between each axially restrained component.
5) Trapeze-mounted piping should be tightly clamped to the trapeze bar.

In addition, when sizing restraint components for multiple pipes the total weight of all of the restrained piping must be considered.

Floor- or Roof-mounted Systems Restrained with Cables

Floor- or roof-mounted systems may include supports for single pipes or multiple pipes. Typically, simple box frames are fabricated to support piping, whether it is a single pipe or multiple pipes.

Lateral Restraint Examples

For a cable-restrained pipe support bracket there are four options normally encountered for non-isolated systems and four similar arrangements for isolated systems. These options are shown below. The vertical legs of the support bracket must be sized to carry both the weight load of the supported pipes as well as the vertical component of the seismic forces. Refer to Chapter D4 for more detailed information as to how to size these members.

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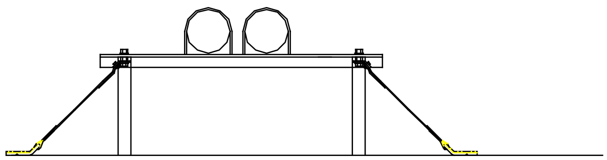
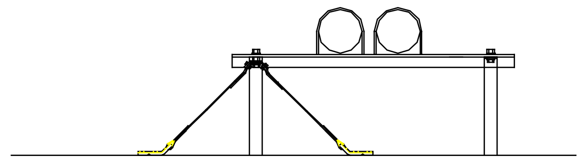
OUTSIDE RESTRAINT



SINGLE LEG RESTRAINT



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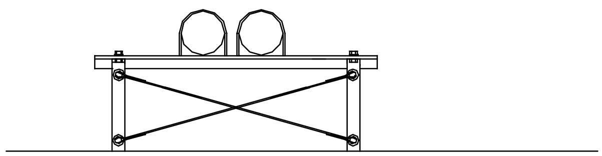

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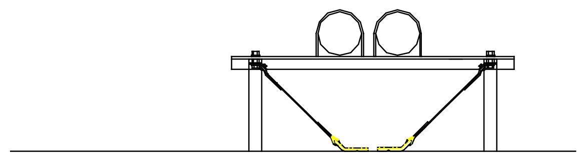
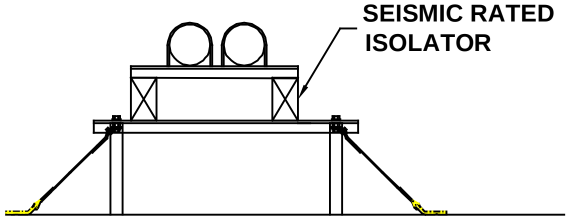


Lateral Cable Restraints used in conjunction with floor-mounted pipe support stands (Non-isolated)

OUTSIDE RESTRAINT



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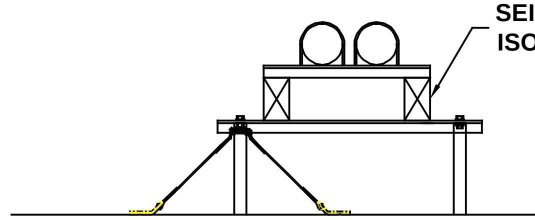

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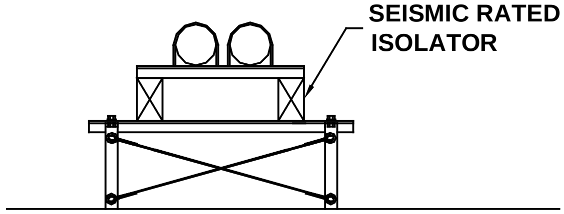
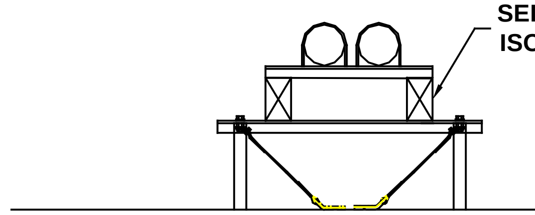


INSIDE RESTRAINT



Lateral Cable Restraints used in conjunction with floor-mounted pipe support stands (Isolated)

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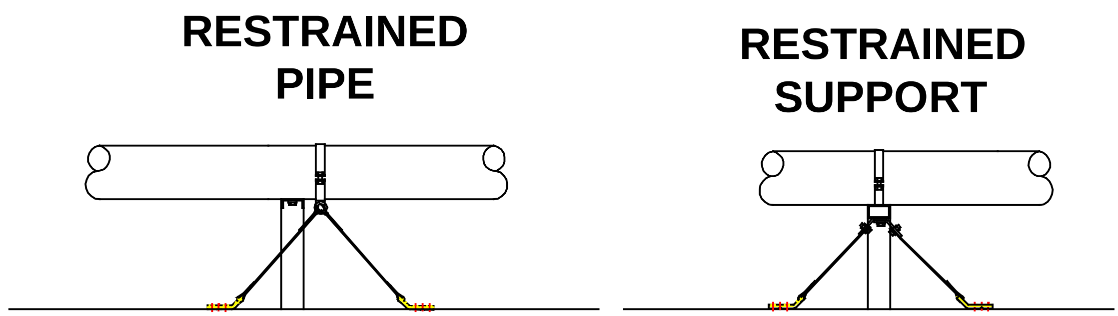
Axial Restraint Examples

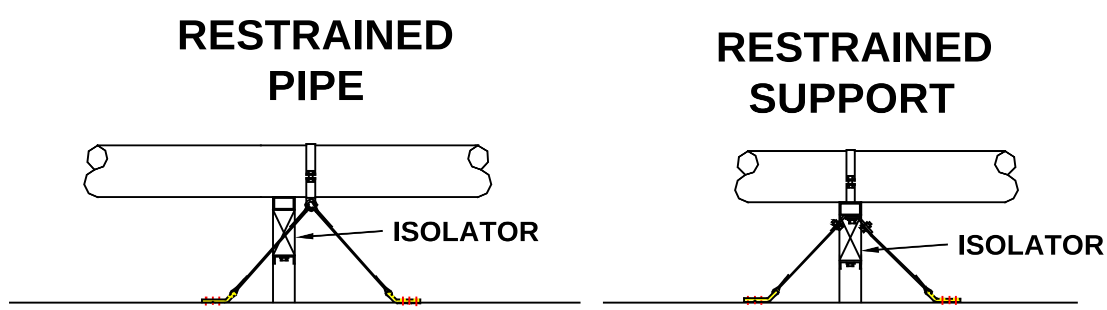
When axially restraining piping, a trapeze or riser clamp tightly clamped to the pipe is the most common connecting device used, although a weld-on tab or connection to a flange is a possibility in some cases. Details on these connections will be addressed in later sections.

If the details of the connection are ignored at this point, general axial restraint arrangements recognized in this manual are illustrated below.

Note: Axial restraints offset from the restrained pipe will generate additional bending forces in the restrained pipe. This is true whether mounted to one end of a trapeze or along side a single pipe rather than directly under its center. When the restraint is offset, the maximum permissible offset from the center of the pipe is 1 pipe diameter. For trapezed systems supporting multiple pipes, a single axial restraint should be located at the approximate center of the trapeze bar or pairs of axial restraints should be installed on each end of the trapeze bar or support frame.



Axial Cable Restraints (Non-isolated)



Axial Cable Restraints (Isolated)

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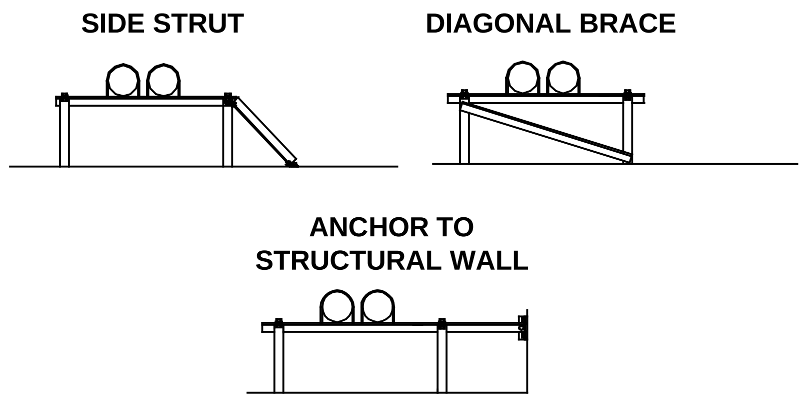
Floor- or Roof-Mounted Systems Restrained with Struts

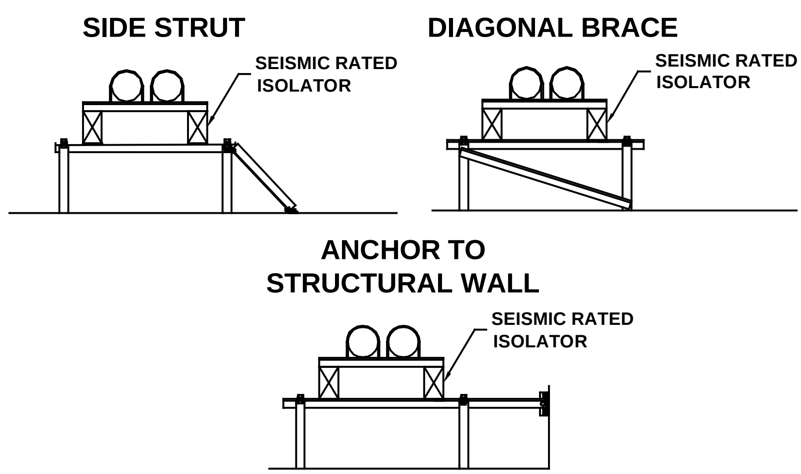
As with cable restraints, floor- or roof-mounted pipe support systems will normally involve a box frame that supports the piping (single or multiple) with some kind of a trapeze bar.

Lateral Restraint Examples

With struts there are three typical configurations. As with the cable systems, these arrangements can be used with or without isolation as shown below.



Typical Lateral Restraint Strut Arrangements for Piping (Non-isolated)



Typical Lateral Restraint Strut Arrangements for Piping (Isolated)

Axial Restraint Examples

When axially restraining piping, a trapeze or riser clamp tightly clamped to the pipe is the most common connecting device between the restraint strut and the pipe, but occasionally

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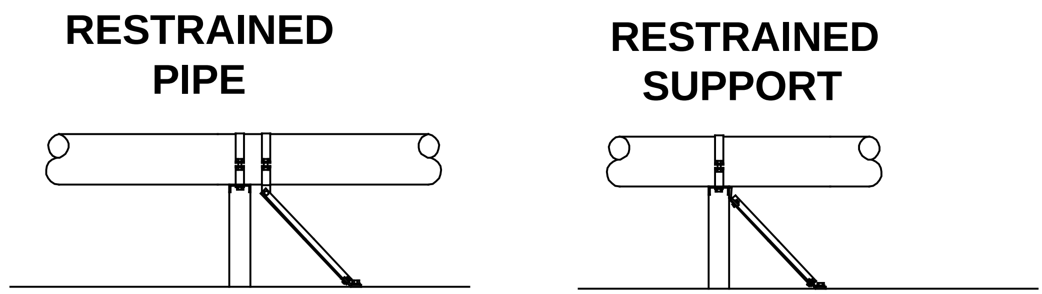
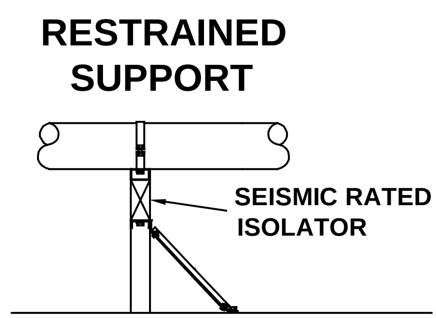
a weld-on tab or connection to a flange can be used. Details on these connections will be addressed in later sections.

Ignoring the details of the connection at this point, common axial restraint arrangements recognized in this manual are illustrated below.

As with the cable restraints, it must be recognized that axial restraints offset from the restrained pipe will generate additional bending forces in the pipe. This is true whether mounted to one end of a trapeze or along side a single pipe rather than directly under its center. When the restraint is offset, the maximum permissible offset from the center of the pipe is 1 pipe diameter. For trapezed systems supporting multiple pipes, a single axial restraint should be located at the approximate center of the trapeze bar or pairs of axial restraints should be installed on each end of the trapeze bar or support frame.



Piping Axially Restrained with Struts (Non-isolated)



Piping Axially Restrained with Struts (Isolated)

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Vertical Pipe Run Restraint Arrangements

Vertical runs of piping need to be restrained in the same manner as horizontal runs. The anchorage provided for the riser system will normally, but not always, have enough capacity to resist the maximum axial seismic load. If anchors were selected based on simple deadweight loads and included little or no overload capacity, the possibility exists that they might have to be upsized to meet the seismic requirements. Because the seismic requirements would be low as compared to the support loads, upsizing anchors by one step is normally more than adequate to meet these requirements. The required capacity of lateral restraints (guides) would, however, be closely linked to the seismic forces.

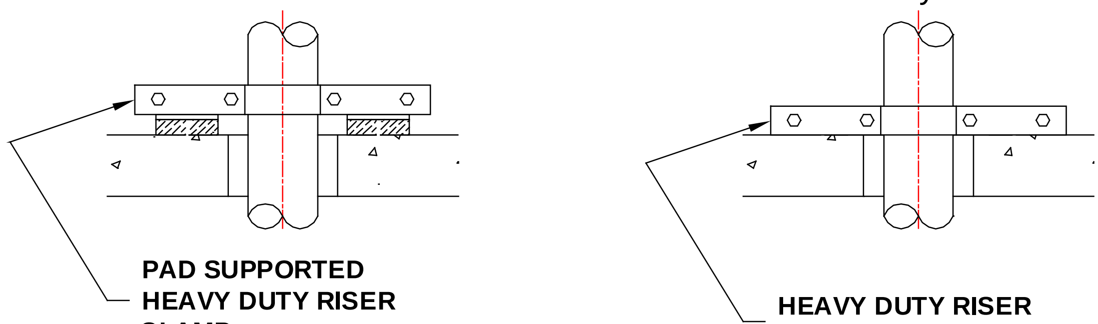
Cables or struts do not normally restrain riser systems. Instead their motion is controlled by special guide and anchor components. In non-seismic applications, these parts are put in place to limit the buckling factors that are generated in the piping by gravity factors. These are very similar to the forces generated in horizontally oriented piping by earthquakes.

Spacing for restraints on risers must meet the same maximum span condition that applies to horizontal runs, but in most instances the spacing used to place these items ignoring seismic concerns will meet this.

Although in conventional designs the spacing between the lateral restraints (or guides) will not normally be an issue, the capacity of the guides must be adequate to withstand the higher seismic forces. Applicable seismic forces for risers are the same as for horizontal runs and more detail on how to determine these can be found in chapter D4.

Typical Axial Restraint Arrangements

Below are illustrations for axial (only) pipe restraints. A simple riser clamp can act as an axial restraint. It need not be attached to the structure to perform the axial restraint function. The same basic arrangement will work for either non-isolated or pad-isolated systems and for attachment to concrete or steel. These do not offer any lateral restraint.



Concrete Supported Axial Restraint for Vertical Pipe Run

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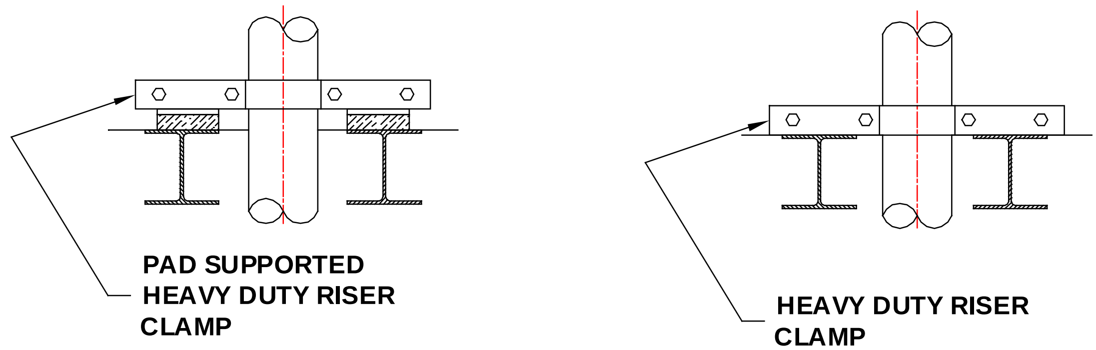
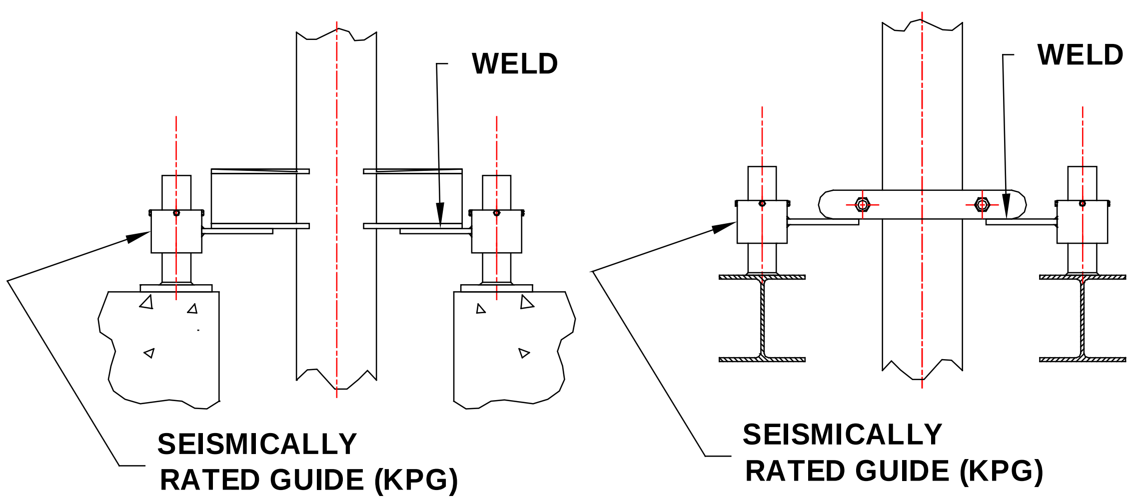


Steel Supported Axial Restraint for Vertical Pipe Run

Typical Lateral Restraint Arrangements

Pipe guides act as lateral restraints only and have a rated force capacity that is based on loads in the horizontal axis. These components do not offer any axial restraint capabilities.

There are two typical guide types. The first includes a component hard mounted to the structure, a mating portion hard mounted to the pipe, and a slip fit connection between the two. This is shown below.



Concrete-Supported Lateral Restraint (Guide) for Vertical Pipe Run

The second type is comprised of a frame with cushioned pads located on the perimeter that bear directly against the pipe itself. This eliminates the need for a direct connection to the pipe. However, if the pipe is insulated, it does require that the insulation be adequately hardened or that a hard shield be provided to prevent damage to the insulation under seismic loads. Typical concrete slab and steel structural examples are shown below.

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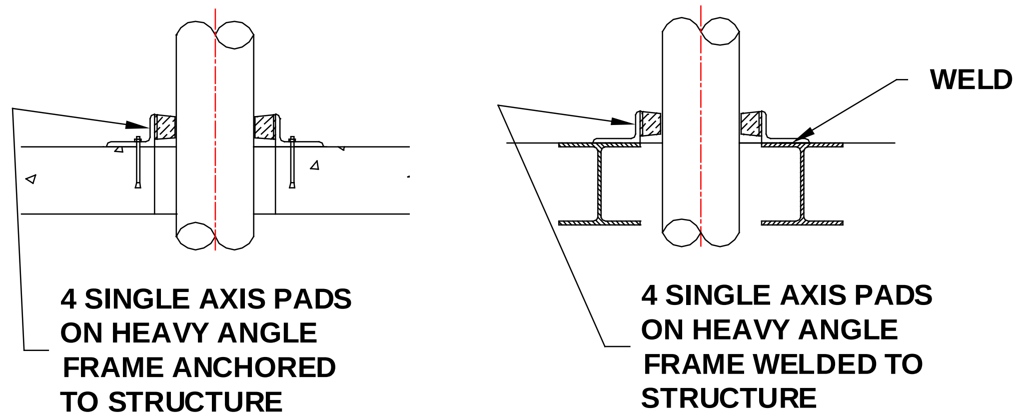
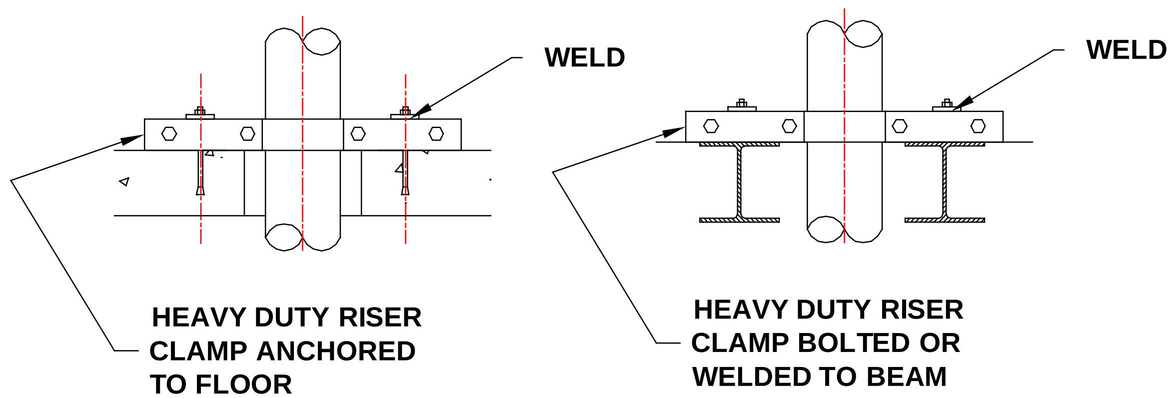


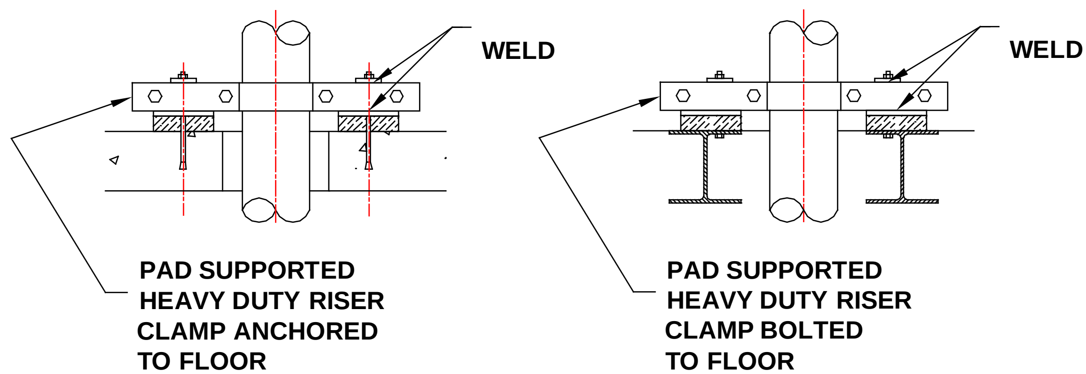
Steel Supported Lateral Restraint (Guide) for Vertical Pipe Run

Combined Lateral and Axial Restraints

In addition to the above details showing independent axial and lateral restraint devices, there are several devices used in vertical runs of pipe that offer both of these together. Anchors for riser systems are the first of these and several types are illustrated below:



Simple Hard-mounted Riser Clamp



Pad-mounted Riser Clamp

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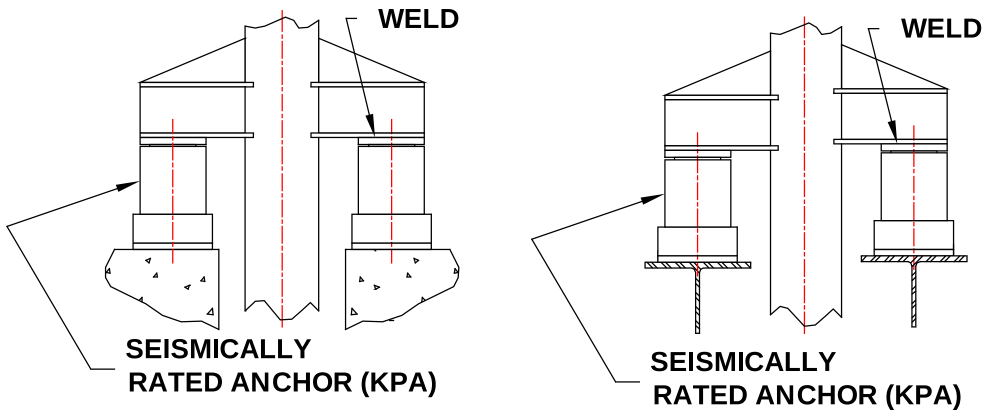
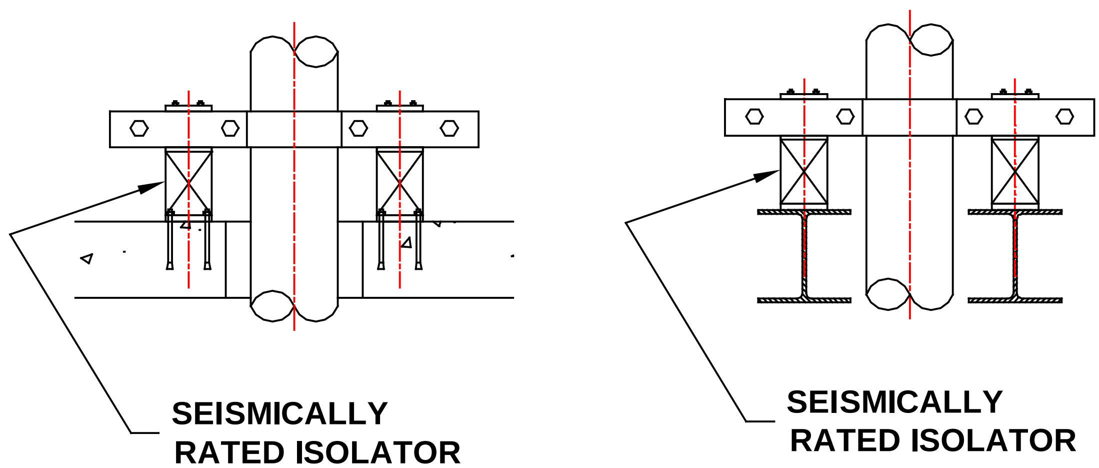


Riser Mounted on Cushioned Rated Anchor

The final combination axial and lateral restraint is a seismically rated, floor-supported isolator.



Riser Piping Mounted on Floor-Mounted Seismically-Rated Isolator

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Email: sales@kineticsnoise.com

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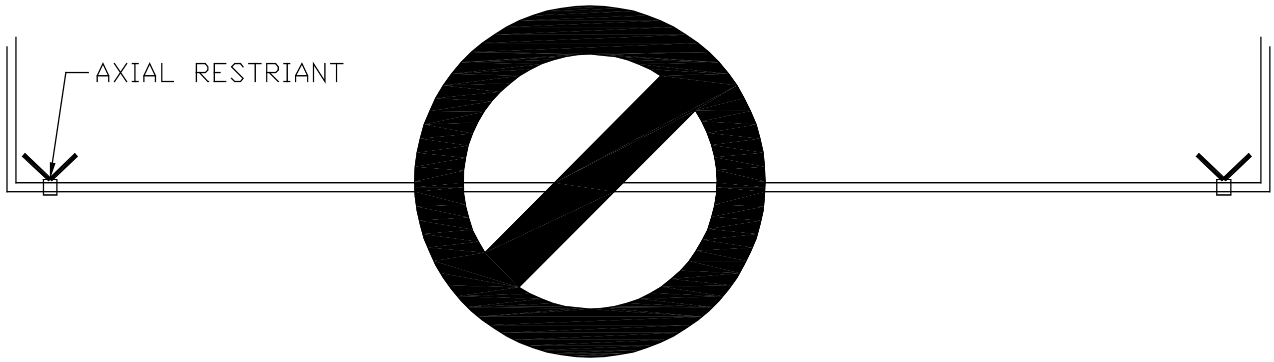
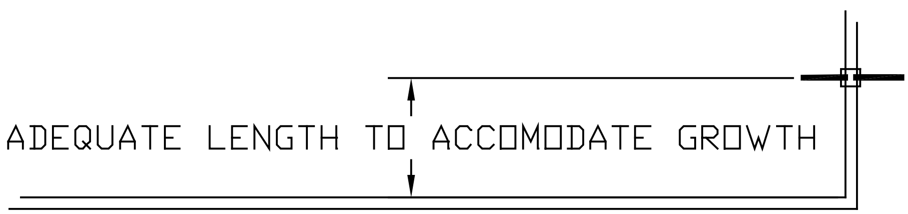
AXIAL RESTRAINT OF STEAM PIPES

The Axial Restraint of Steam Piping raises important design configuration issues. As the pipe length grows with the temperature, the use of more than one restraint on any individual run will resist this growth and will either cause the pipe to buckle or will result in the failure of the restraint. This is unacceptable.



For short runs, a single axial restraint should be used and caution should be exercised to ensure that if restraints are fitted at the junction points of different runs, they do not fall at both ends of the same run. Caution should also be exercised to be sure that there is adequate length between corners and the first lateral restraint on a run to allow for the growth that can occur on the adjacent run.



For long runs that require more than 1 Axial Restraint, a device must be fitted into the run to absorb expansions and contractions between the restraint locations. This can take the form of an expansion loop or an expansion compensator as illustrated below.

If an expansion loop is fitted, the middle leg of the loop requires axial restraint as well. Because this restricts its movement, some caution must be used to ensure that the legs on each side of the loop are adequate to absorb the expansion for their respective runs. If the distance between the loop and the restraints on adjacent runs is approximately the same the system will be balanced and both legs will bend about the same. If the dimensions to the axial restraints vary significantly, the distortion of the two different legs will vary from one another in direct proportion and this should be addressed in design. Kinetics is not responsible for the design of these loops.

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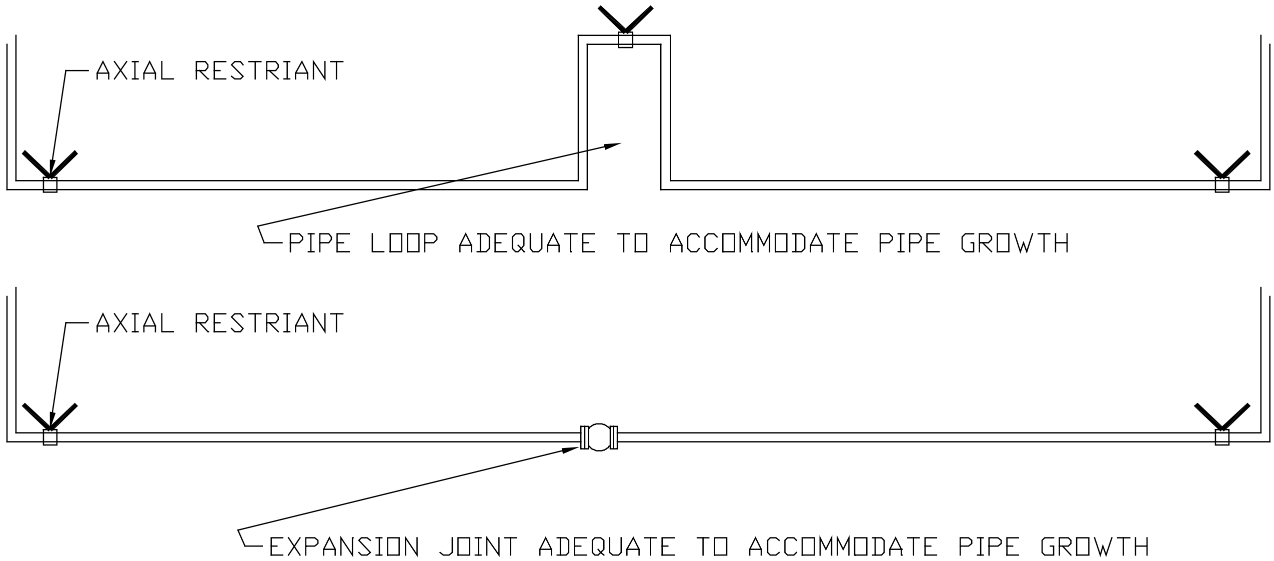

AXIAL RESTRAINT OF STEAM PIPES

PAGE SERIES 2 OF 2

RELEASE DATE: 08/09/04

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Fax: 614-889-0540
World Wide Web: www.kineticsnoise.com
Email: sales@kineticsnoise.com

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Transferring Forces (Piping Restraints)

In order for a restraint system to do its job, all elements of the connections need to be sized and installed properly. Because of the large variety and quantity of interfacing conditions in any given installation, piping, duct, and electrical distribution systems are particularly prone to problems in this area.

The next several sections of this manual will deal with specific components used to clamp cable ends together, or anchor cables or struts to steel members, wood members, and concrete or masonry. There are several types of connections used for each of these conditions, and each type of connection requires some degree of care and understanding to achieve full capacity.

There are a few general rules that apply when adding restraints to systems. These are listed below along with a few comments meant to provide a basic understanding or rationale.

1) Friction generally cannot be counted on when dealing with dynamic, seismic load conditions. Connections, with the following exceptions, should be positive in nature and not require friction to ensure their continued long-term operation.
   Exceptions:
   A) Cable end connections (swaged ends, u-bolts, Gripple clips, and cable nuts can be used with appropriate installation procedures).
   B) Properly installed heavy-duty riser clamps seated against steel pipes or other compression resistant materials.
   C) Toothed strut nuts used in conjunction with a purpose-designed strut material (Unistrut, for example).

   (Rationale: Permitted friction connections have been well researched and deal with a narrow range of applications. In addition, once properly tightened, the components are such that the likelihood of their coming loose as a result of seismic load conditions is very low.)

2) Anchors used for the support of overhead equipment cannot also be used for the anchorage of seismic restraints. *(Rationale: The loads used to size hanger rods and anchors are based on the weight loads generated by the piping system. Seismic forces can increase the tensile loads significantly, and the combination of loads can cause the anchorage to fail.)*

3) Anchors to concrete must comply with minimum edge distance, spacing and slab thickness requirements. To achieve full capacity ratings they must further not be installed into a surface containing significant tensile forces. *(Rationale: All anchorage must be in compliance with ICC allowables for seismic applications. Unless otherwise noted, it is assumed that connections are not made to the underside of structural concrete beams .)*

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4) Screws attached to wood must comply with minimum edge distance, spacing and embedment requirements, and must further not be embedded into the end grain of the wooden member. *(Rationale: All wood anchorage must be in compliance with NDS allowables for seismic applications. Full capacity can only be achieved with adequate embedment, end, and edge distances into the side grain of structural wood members.)*

5) Connections that have the potential to expose open bar joist chords to significant lateral loads are not permitted. *(Rationale: Open joists are notoriously weak in their lateral axis. They are not designed to take loads, particularly on the lower cord, and even light lateral loads can generate buckling and quickly cause catastrophic failure.)*

6) Connections that have the potential to generate significant lateral loads on the weak axis of I-beams or channels used as joists or columns are not permitted unless approved by the structural engineer of record. *(Rationale: Floor or roof support beams are significantly weaker in their minor axis than in their major axis. While they can, under some conditions, withstand some lateral loads, the engineer of record should be consulted to ensure that capacity exists on particular members to withstand the anticipated loads. If these loads are exceeded, catastrophic failures can quickly result.)*

7) Holes should not be added to key structural members without prior authorization from the engineer of record. *(Rationale: The addition of holes, particularly in flanges, can greatly reduce the structural capacity.*

8) The pipe-to-pipe connection can become a critical factor in evaluating the performance of the system. Unless otherwise informed, Kinetics Noise Control assumes connections to be of "medium" deformability as defined by the design code. This is generally appropriate for steel or welded fittings, brazed connections, plastic pipe, and no hub connections. The use of groove-type coupling, cast iron couplings, glass lined pipe, or other non-standard materials will impact this and must be addressed during the design stage. *(Rationale: While generic data is available for some of these materials, it is not for groove-type or other specialty couplings and the specifying agency, prior selecting this type of hardware, must obtain the approval of the coupling manufacturer for its use in a seismic application.)*

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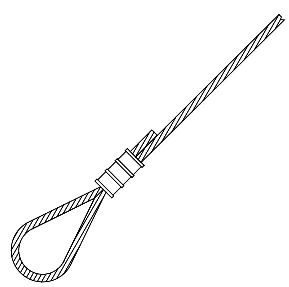
Email: sales@kineticsnoise.com

Cable Clamp Details

There are three different types of cable clamp arrangements that are acceptable for use on Kinetics Noise Control cable restraint systems. These are factory swaged, clamped with U-bolt cable clips, and connections made using seismically rated “Gripple” connectors. Other types of connections have either not been tested, or when tested do not meet the capacity standards required for consistent performance.

Factory-Swaged Connections

When so ordered, one end of a cable assembly can be obtained with a factory-swaged connection. Crimping a zinc-coated copper or a stainless steel sleeve onto a cable loop at the termination point makes these connections. Multiple crimp locations are required with the actual number varying based on the cable size. To obtain a seismic rating, these swaged connections must be performed using the appropriate calibrated hydraulic press and must not use aluminum sleeves. Field-swaged connections and in particular those made using hand crimping tools are not suitable for seismic applications. All Kinetics Noise Control computed seismic certifications are based on capacities obtained from components provided by Kinetics Noise Control. No certifications can be offered on components crimped by others.



Swaged Connector

U-Bolt Cable Clip Connections

For larger cables, as an option to the seismically rated “Gripple” on smaller cables, and where field connections are necessary or desired, U-bolt cable clips can be used. When used, a minimum of three clips is required per connection for sizes up to 3/8” cable. For 1/2” cables a minimum of four clips is required per connection.

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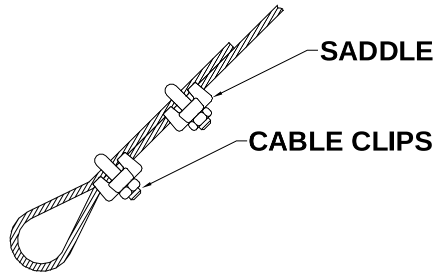
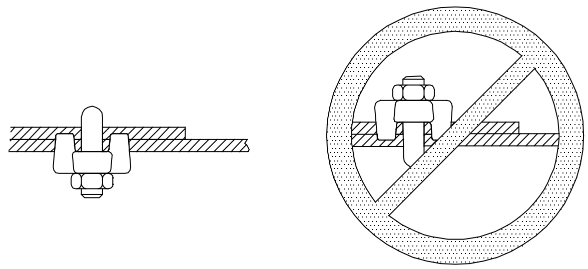


U-Bolt Cable Clips

When fitting cable clips, the saddle side of the clip must always be against the "live" portion of the cable. The "live" side of the cable is the side that does not terminate at the connection, but continues to the clip at the opposite end.



CORRECT INSTALLATION **NOT LIKE THIS**

Failure to orient the clip in the proper fashion will cause premature failure of the cable assembly.

While proper tightening of the clip nuts and adequate turnback (or overlap) length of the cable is important, tests conducted have found that it is not as critical for seismic applications as it is for lifting applications. Reasonable variations from the values listed below have a minimal impact on the capacity of the connection. Below is a table with the desired minimum tightening torques recommended by clip manufacturers, clip quantities, and turnback lengths listed for various sized cables.

Cable Size in Inches	Minimum Number of Clips	Amount of Rope Turnback/Inches	Minimum Torque in Ft. Lbs.
1/8	3	3-3/4	3
3/16	3	3-3/4	4.5
1/4	3	4-3/4	15
3/8	3	6-1/2	30
1/2	4	11-1/2	45

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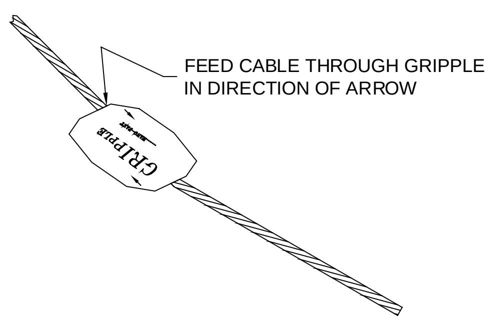
"Gripple" Connections

For smaller cables (up to 5mm (metric) and up to 3/16" (English)), special proprietary "Gripple" connection clips can be used. These clips offer significant benefits in speed of installation and can be used in a large variety of common light-duty applications. When using "Gripple" connectors or "Gripple" restraint connection kits, it is critical that seismically rated components are used. While Kinetics Noise Control offers only seismically rated components, those supplied by others may not be. "Gripple" connectors for sizes in excess of 5mm or 3/16" are not appropriate for seismic installations as they will not seat properly and consistently without the application of a constant tensile load.

Gripple Connector

GRIPPLE Installation Procedure

1) Feed the proper sized cable as provided by Kinetics Noise Control through the Gripple as shown.



2) Loop the cable through the attachment bracket or hardware. If the cable rides against any sharp corners (not counting the hole in the Kinetics Noise Control provided bracket itself) or is subject to excessive vibration in service, fit the Kinetics Noise Control provided thimble in the loop and then feed the cable back through the opposite side of the GRIPPLE.

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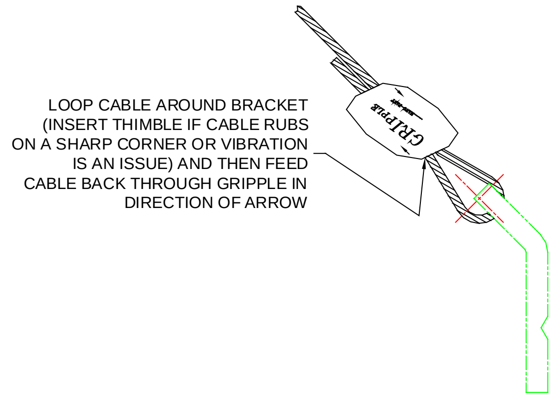
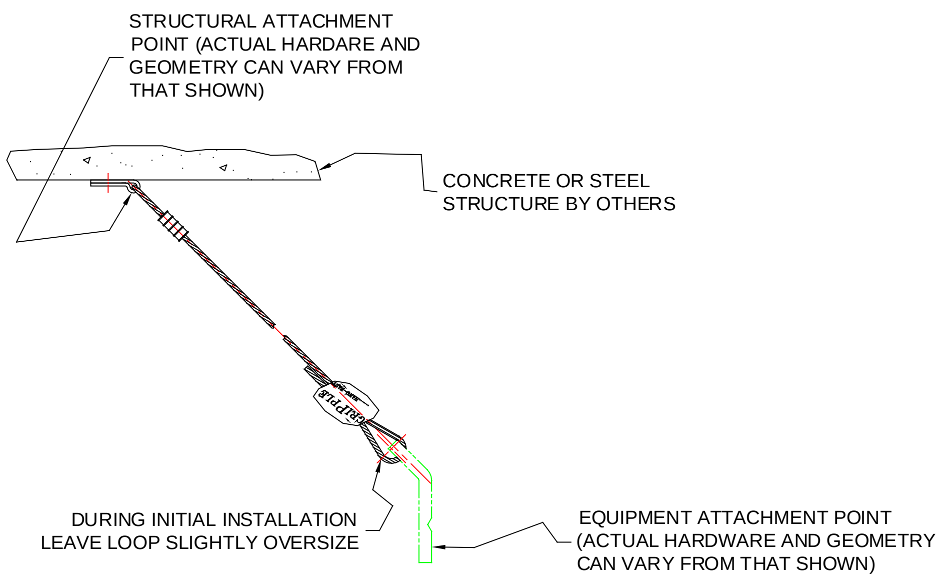
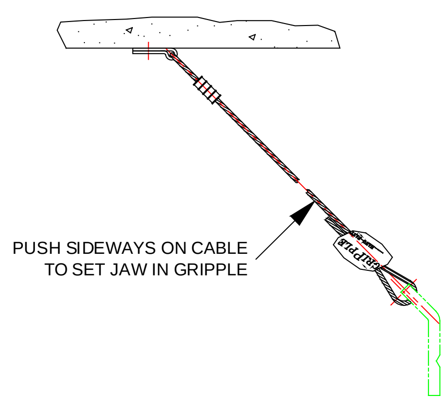


3) Remove the slack from the cable by slipping the cable through the GRIPPLE, but leave the loop slightly oversized to allow later tensioning.



4) Apply a sideways load to the cable by pulling or pushing on it to fully seat the GRIPPLE.



CABLE CLAMP DETAILS

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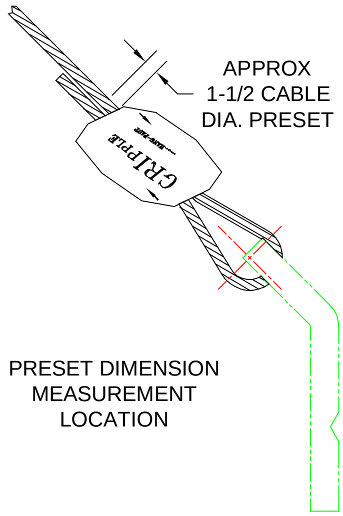
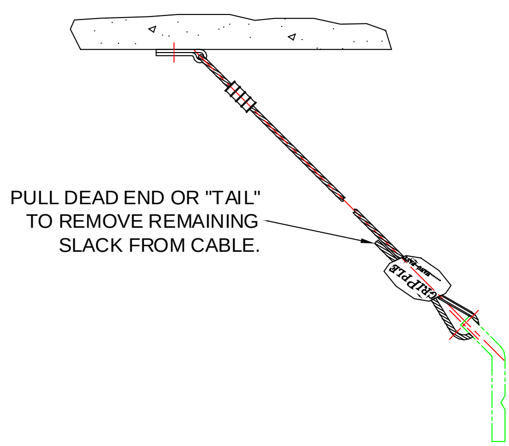
5) When seating the GRIPPLE, jaws will ride up an internal ramp in the GRIPPLE itself and "bite" into the cable. In a properly seated GRIPPLE, the cable will shift approximately 1-1/2 cable diameters (the preset distance) as the jaws engage. If need be, mark the cable to check the preset. This step may be required initially, but once a "feel" for it is obtained, this is no longer necessary. Once the 1-1/2 cable diameter preset dimension has been obtained, the GRIPPLE is adequately seated.



6) Once fully seated, any additional slack should be removed from the cable restraint by pulling on the dead end or "tail" of the cable sticking out of the GRIPPLE. If Isolated, the cables should not be made tight, but should instead be left slightly loose to prevent the transfer of vibrations into the structure. (Slightly loose could be defined as having approx 1/8 to 1/4" of visible sag in the cable – 1/8 for short cables (up to 2 ft), 1/4 for cables longer than that.)



7) The GRIPPLE installation is now complete.

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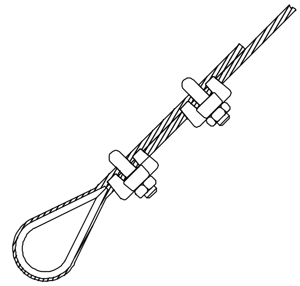
Cable Thimbles

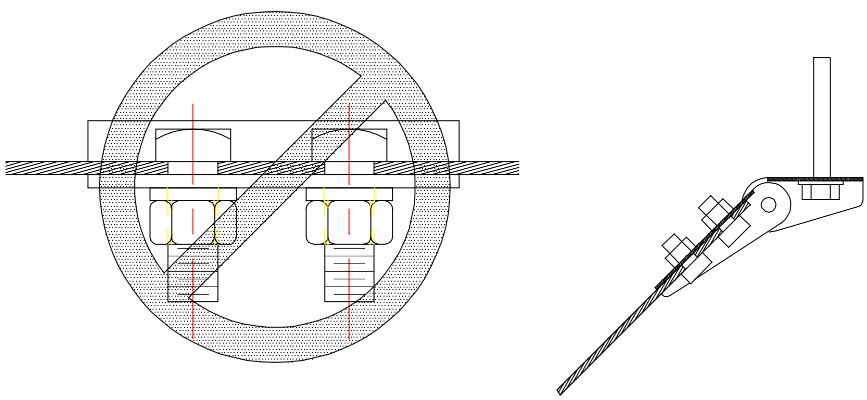
Where sharp corners can bear against the cable loop or where vibration or other dynamic forces can cause the cable loop to abraid, a cable thimble should be used. A cable thimble fit inside the cable loop is shown in the picture below.



Cable Thimble

Unacceptable Connectors

Drilled bolt Cable Connections exhibit undesirable inconsistancies in capacity if precautions are not taken during the assembly process. Undertightening these types of connections results in a loss of frictional capacity while overtightenting cuts into the cable and generates premature cable failures.



Unacceptable Cable Connection Detail and Common Application

If used, the only consistant way to properly install cable connectors of this or similar type is with the use of a torque wrench. Variations of as little as 5 ft-lb of tightening torque can drop the tensile failure load on the cable by 30% or more. Since the use of torque wrenches or other torque-controlled devices in the field is limited, the level of confidence in the capabilities of these connections is lower than desired for critical seismic

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applications.

Because of the extreme sensitivity of the cable pull strength to the tightening torque of the bolt, drilled cable retention bolts have not been found to be acceptable by Kinetics Noise Control for use as connection hardware.

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Piping Attachment Details

Pipes can be supported as independent units or grouped together and supported on a trapeze structure. Restraints can be installed in the same manner. When installing restraints, however, it is critical that (except for horizontally oriented restraint members) they be located in the immediate proximity of a vertical support member as the support is required to absorb vertical forces that are developed during the restraint process.

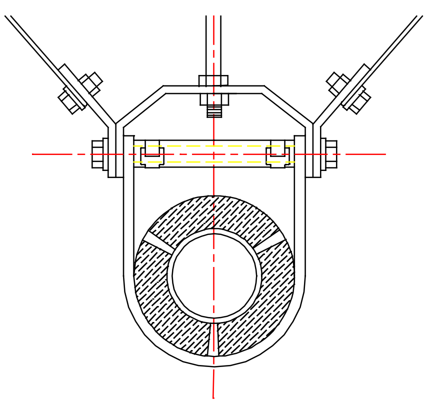
If the piping is isolated, cable restraints should be used in lieu of struts to prevent the transfer of vibration through the strut into the structure. Where cables are illustrated, they can be replaced with a single strut mounted in a similar fashion where appropriate.

Single Pipe Sections Supported on Hangers

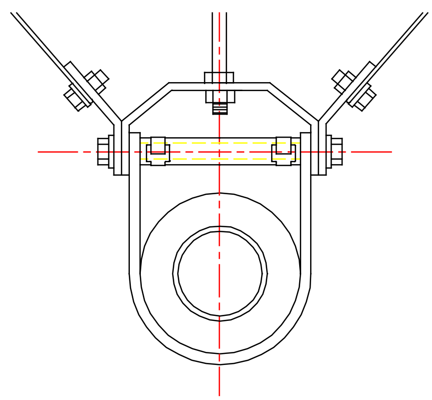
Lateral Restraints

The simplest piping restraint connection is a lateral restraint fit to a single pipe. Because the forces being restrained are at 90 degrees to the pipe axis, there is no requirement for a clamped or otherwise rigid connection between the pipe hanger and the pipe itself. Of concern is the durability of the hardware used, the durability of the pipe insulation (if insulated) and the capacity of the hanger rod to resist the reaction loads generated by the horizontal seismic forces.

Shown below are typical details for clevis hangers fitted with KCHB brace angles and straps (on the cross bolts) and hard insulation (on the pipe). If not insulated, the hardened insulation, blocks, or saddles would not be required.



Side-Restrained Pipe with Wood Insulation Blocks



Side-Restrained Pipe with Hardened Insulation

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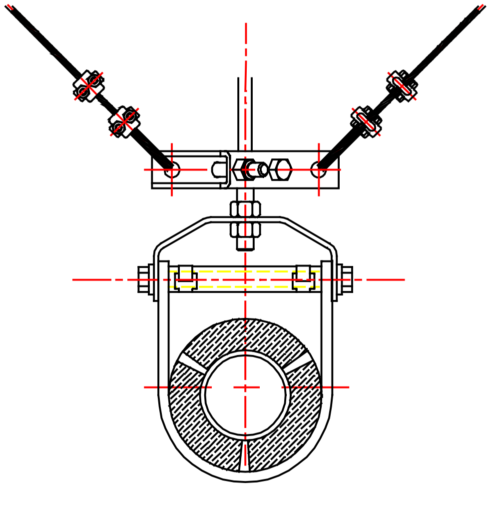
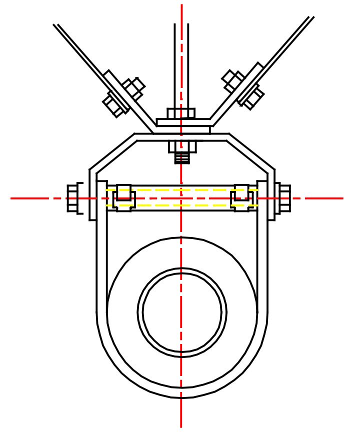




Rod-Restrained Pipe with Wood Insulation Blocks

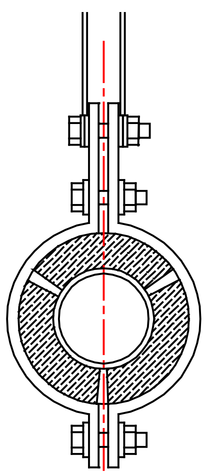
Top-Restrained Pipe with Hardened Insulation

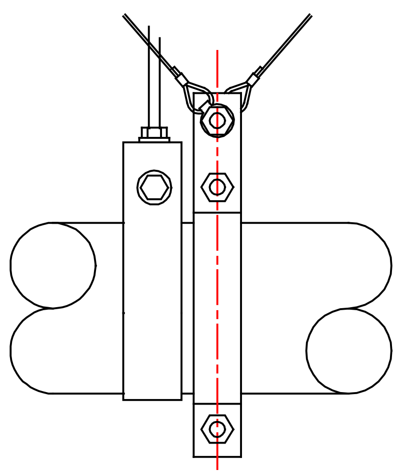
The above description represents the minimum treatment required at each restraint location, and is appropriate whether cable restraints or struts are used.

Axial Restraints

Axial restraints pose more of a problem. Conventional pipe hangers, as shown above, do not have the ability to be clamped tightly enough to the pipe to prevent relative axial motion between the two. In order to ensure that the restraint is rigidly attached to the pipe, a heavy-duty pipe clamp is required, and the tie bolts must be tightened to spec. Three different acceptable types of clamps are shown below.

Again note that the restraints must be located in the immediate vicinity of a vertical support member.





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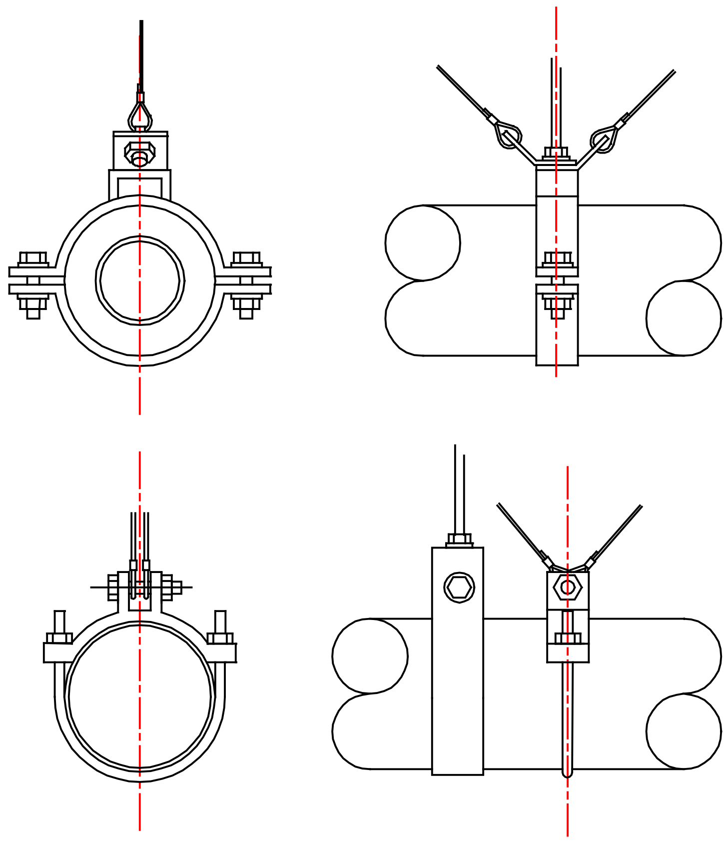

Pipes clamps must be clamped against hard spacers, hardened insulation or directly against the pipe as shown above

Restraint Arrangements for Multiple Pipe Sections Supported on a Trapeze

General Trapeze Design

When restraining multiple pipes of different sizes, the maximum spacing between restraints cannot exceed the worst-case condition for any of the individual pipes. In addition, the restraints must be sized based on the total weight of all of the pipes on the trapeze bar. Some caution should be exercised when selecting the bar to ensure that it has adequate capacity to transfer the load from the pipes to the restraint connections. This is particularly true for some strut arrangements that can be significantly stiffer in the vertical axis than they are in the horizontal (see illustration below.) Because the range of applications for trapeze bars is limitless, details will not be addressed here, but should be reviewed by a competent design professional.

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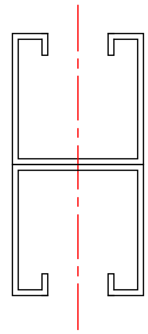


Section that is Stiff Vertically
But Weak Horizontally

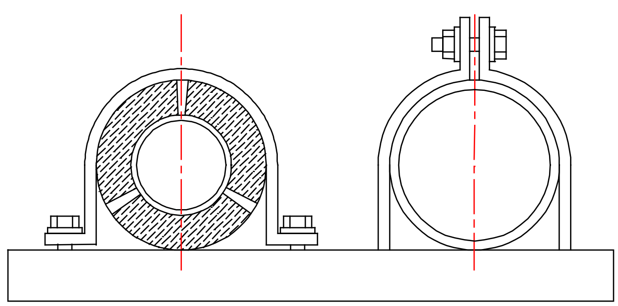
Pipe Connections to Trapeze Bars

When installing restraints, typically not all support points will require treatment. For those trapeze bars that are not restrained either axially or laterally no special pipe connection treatment is required. Where lateral restraint only is provided at a location, motion restraint between the pipes and the trapeze bar only is required in the lateral direction. Where axial restraint is required, the pipe needs to be clamped firmly to the trapeze bar so that it cannot slip through the clamp during a seismic event.

The axial clamps shown here are suitable for both axial and lateral loads, and can be used on all connections. The lateral restraint examples are only appropriate for lateral loads. Note that when controling the axial motion of the pipe, issues relating to expansion and contraction can arise. These issues need to be addressed in the design of the piping system either through the use of expansion loops, frequent doglegs, or expansion couplings.

Axial/Lateral Restraint Trapeze Connections

Below are examples of connections that would be suitable for either axial or lateral load conditions.



Piping Clamped to a Formed Channel-Based Trapeze Bar

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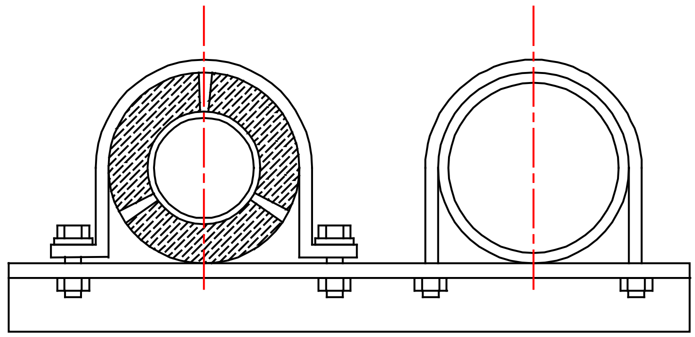
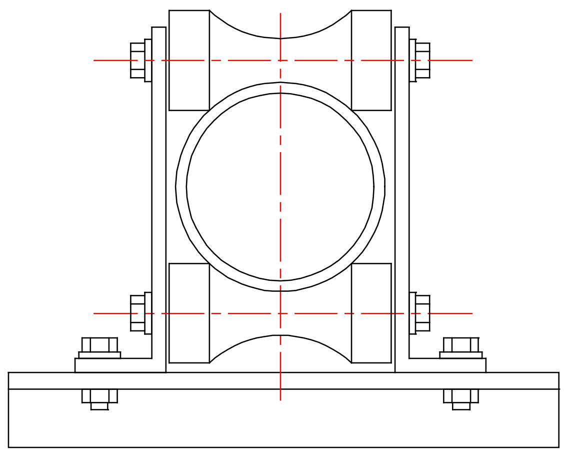


Piping Clamped to an Angle-Based Trapeze Bar

Trapeze Connections Suitable for Lateral Restraint Only

In cases where pipe expansion or contraction must be allowed but lateral restraint is needed, the connection between the pipe and the trapeze must allow motion along the pipe axis. This type of connection cannot transfer an axial restraint force and, as such, can only be used to prevent lateral motion of the piping.



Preferred Lateral Restraint
Trapezed Pipe Mounting Arrangement

Cable and Strut Hardware Attachment Options for use with Single Pipe Hanger Brackets

A typical piping installation begins with suspending the pipes, and then returning later and adding restraints. While this eliminates the need to deal with restraints when actually hanging the pipes, it normally results in more time expended, and possible rework, during the restraint installation phase. Increasing the diameter of hanger rods for strut-restrained systems, relocation or duplication of supports for more accessible restraint installation,

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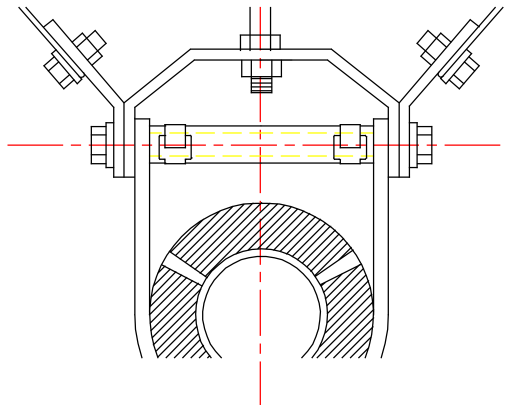
and dismantling and reassembling hanger components to make appropriate connections are the three primary examples of this.

While there is little that can be done from a hardware standpoint to deal with relocation issues, the proper selection of restraint hardware can reduce or eliminate the need to dismantle and reassemble previously installed pipe supports.

Hanger Bracket Reinforcement

When using conventional hangers, the first item required is a spacer bar at the hanger clevis. This serves two functions. The first is to keep the sides of the support from collapsing during a seismic event and the second is to offer a hard surface to work against when attaching and tightening side-mounted restraint brackets and hardware.



Hanger Clevis Showing KSHB Clevis Hanger Brace Fitted on Tie Bolt

The brace shown here can be installed without disassembling any previously installed support hardware.

Cable/Strut Restraint Connection Hardware for Hanger Brackets

Also shown in the above drawing are side-mounted cable attachment brackets. Installation requires the removal and replacement of the tie bolt, which for larger or spring supported pipes can be awkward and time consuming. This is the preferred installation arrangement for CCA mounting clips when used on pipes in excess of 12 inches in diameter.

The CCA mounting clip can be used with either cables or struts, but for struts, the angle between the strut and the ground is limited to 45 degrees. See also the sketches below.

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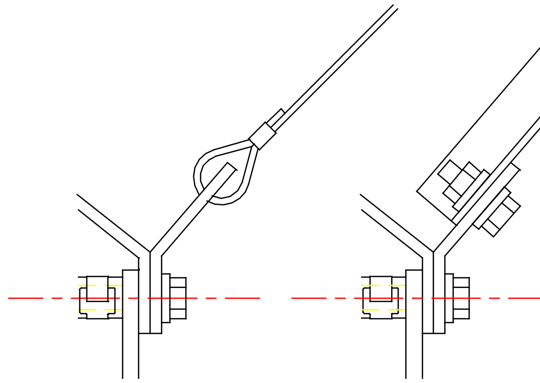
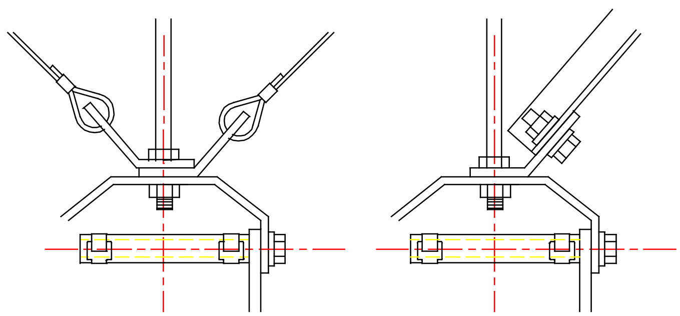


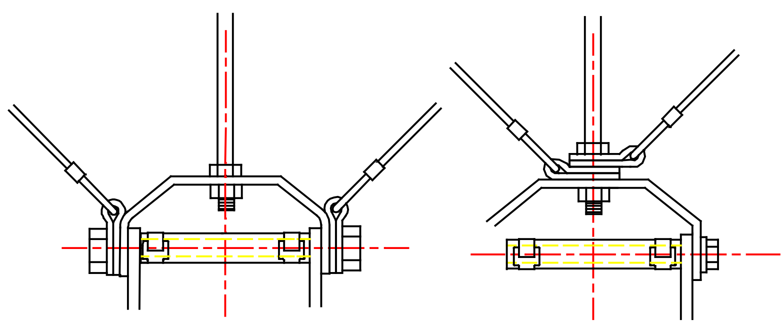
Side-Mounted CCA Clip with Cable and Strut Connections

For piping that is 12 inches in diameter and less, the CCA clip can be top mounted. Unless installed during the initial hanger bracket installation process, this will require the hanger clevis to be disconnected and reinstalled. This installation is virtually the same as the side-mounted arrangement with the exception that the CCA clip attaches to the hanger clevis at the hanger rod location.



Top-Mounted CCA Clip with Cable and Strut Connections

As an option to the CCA clip, a KSCU clip can be used for side- and top-mounted cable restraint applications as shown below.



Top- and Side-Mounted KSUA Clips with Cable Connections

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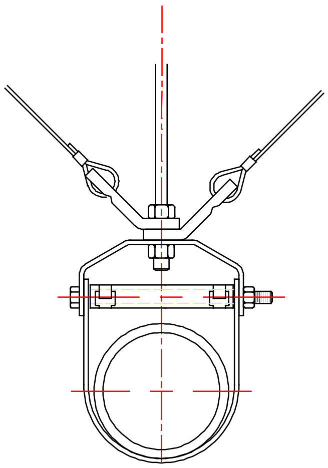
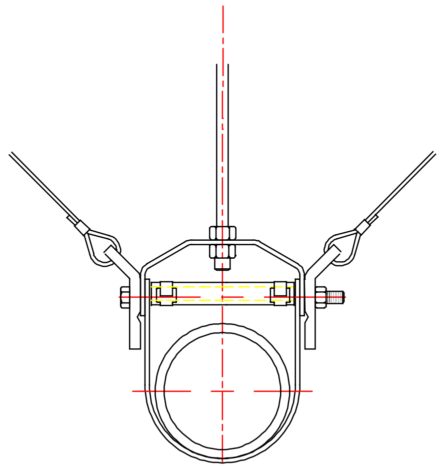
The KSCA is the most versatile clip manufactured by Kinetics Noise Control. It can be mounted in a number of fashions, including both of the above, as well as hanger rod mounted. In the hanger rod-mounted arrangement, no previously installed hardware need be disassembled. This frequently makes it the most time-efficient bracket to install in the field.

While the KSCA is not suitable for extremely heavy-duty applications, it is appropriate for most applications, even up to relatively high "G" load conditions. See the tables in Chapter D4 in this manual for sizing components.

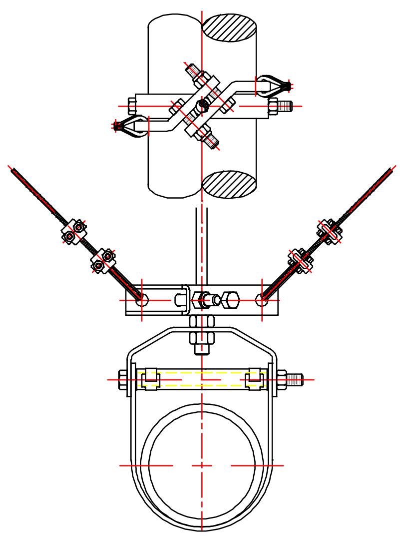


Top Mounted



Side Mounted

Conventional KSCA Cable Restraint Clip Mounting Arrangements



Hanger Rod-Mounted KSCA Cable Restraint Clip

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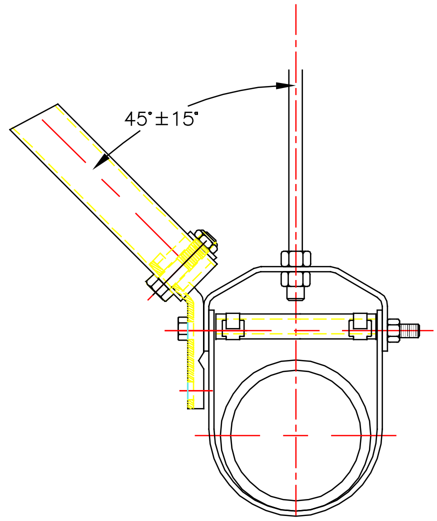
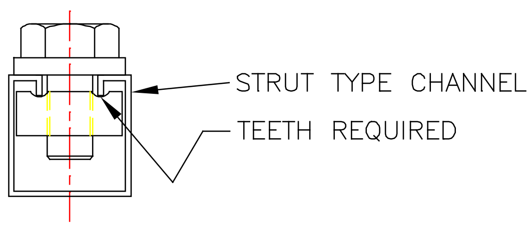


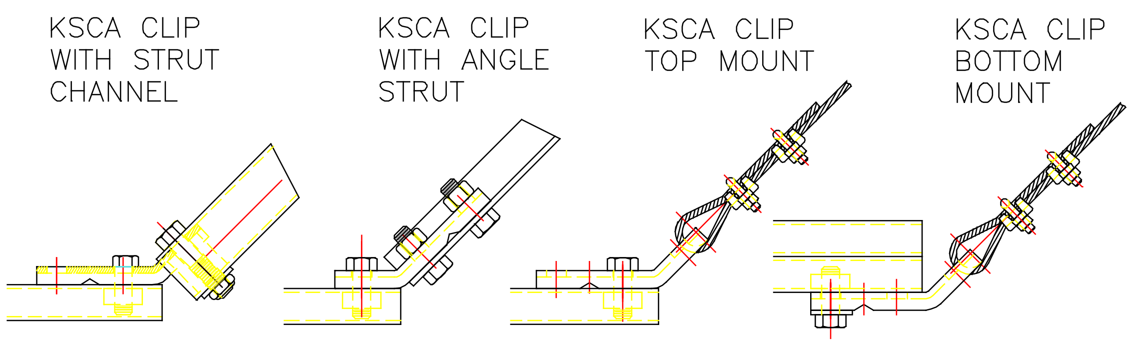
KSCA with Strut Attachment Hardware

Cable/Strut Restraint Connection Hardware for Trapeze Bars

One of the most common materials for trapezed support of piping is formed strut-type channel (ex. Unitstrut). Connections to these materials, if using strut nuts, require the use of toothed nuts. Smooth nuts do not provide adequate resistance against friction and as such are not acceptable. All nuts must be tightened to their full-rated torque.



Shown below are various acceptable methods of mounting restraint hardware to struts.



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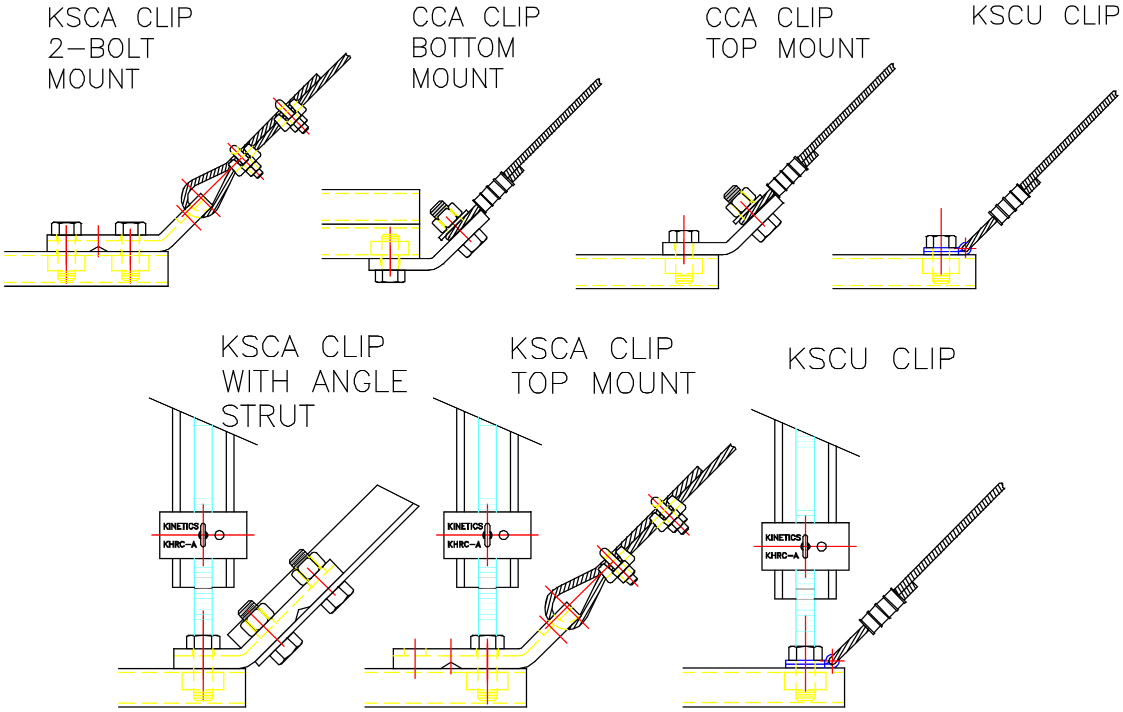
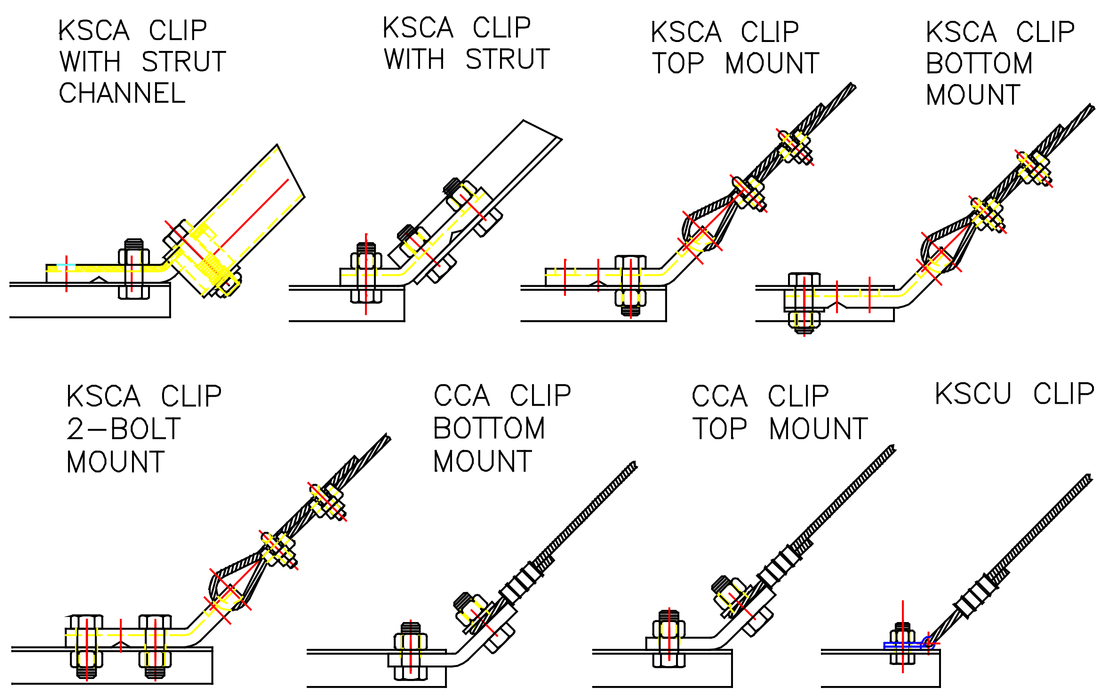


Cable Restraint Bracket to Strut Trapeze Bar Connections (Typical)

Similar types of mounting arrangements can be used with trapeze bars made out of angle or other structural shapes as illustrated below.



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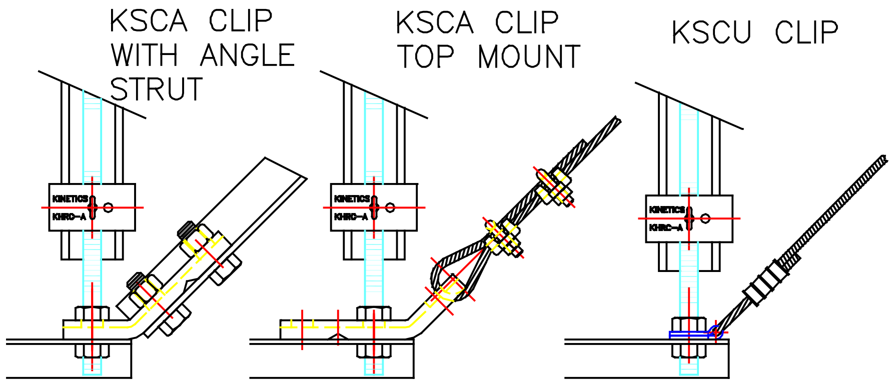
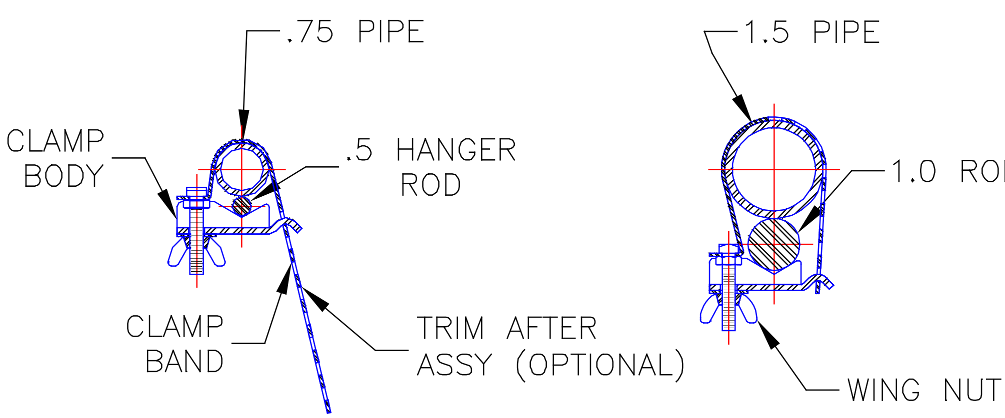


Cable Restraint Bracket to Structural Steel Trapeze Bar Connections (Typical)

<u>Hanger Rod Stiffening Arrangements</u>

In some cases, depending on hanger rod length and the applied seismic force, it may be necessary to protect the hanger rod from the buckling forces that can occur during a seismic event. Chapter D4 includes a section on determining the need for and sizing of the stiffener. When required, either a pipe or an angle can be used as a stiffener and must be clamped tightly to the hanger rod using rod clamps.

Kinetics Noise Control makes clamps for both pipe and angle stiffeners. These are designated the KSRC-P (for pipe) and KSRC-A (for angle). Both are adjustable and can be used over a wide range of hanger rod and stiffener sizes.



KSRC-P Hanger Rod Stiffener Clamp can be used to clamp Rods from .5" to 1.0" Diameter to Pipes from .75" to 1.5" Diameter

Both clamps feature two-part construction and "no tool required" installation. The KSRC-P is comprised of a flexible band punched with a number of slots that is fitted to a clamp body with an integral seat for the hanger rod. Based on the size of the pipe stiffener and the hanger rod, the appropriate slot in the clamp band can be used for preliminary

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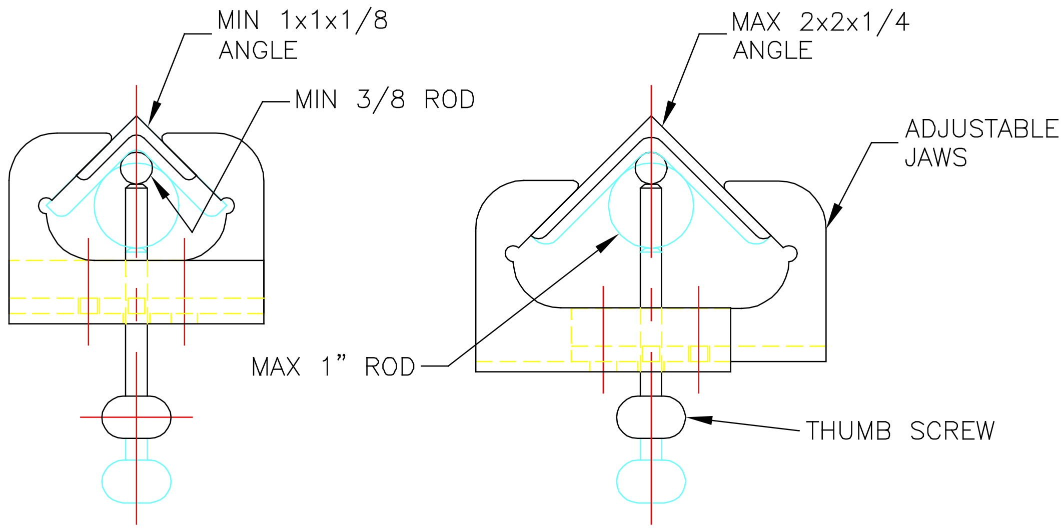
adjustment, with final tightening by means of a wing nut.



KSRC-A Hanger Rod Stiffener Clamp can be used to clamp Rods from .5" to 1.0" Diameter to Angles with Leg lengths from 1 to 2 inches

Shown above is the KSRC-A Clamp. It is made up of two telescoping jaws and a thumbscrew. Preliminary adjustment is made by aligning the appropriate holes in the jaws for the thumb screw, and final tightening is made by tightening the screw.

For both of the above clamps the clamping screws are to be tightened so that they will not come loose in service through vibration. If significant vibration is expected, the use of Loctite or other thread binder is recommended.

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Structural Attachment Details for Piping Restraints

When restraining piping systems to a structure, there are several different construction options that impact the restraint selection. Primary among these are the interface with masonry- or concrete-, steel-, and wood-framed structures. Within each of these are subgroups that can impact the restraint selection as well.

This chapter is broken down into the three main categories listed above, and offers examples of restraint attachment arrangements suitable for each.

While this section addresses local stresses at attachment points, it is critical in any seismic installation that the design professional responsible for the structure as a whole is made aware of the particular attachment points. Locations and estimated loads must be provided and there must be agreement that the addition of these loads will not overload the structure.

In addition, the attachment of this hardware should be done in such a way as to avoid any significant reduction in capacity of the member to which it is being connected.

The authors of this manual in no way assume any liability relative to any limitations on the capacity of the structure to resist the potential forces carried through the restraints or any reduction in capacity of the structure that might result from improper or inappropriate installation of the hardware.

<u>General Installation Issues</u>

Caution should be exercised when using struts for restraint in lieu of cables. A more detailed summary is available earlier in this chapter. The use of struts will more than likely require an increase in the hanger rod size and a decrease in the restraint spacing as compared to cables, and appropriate factors must be used for component selection and placement.

Code requirements also dictate that systems are supported from and restrained to components that do not move in a significantly different fashion during an earthquake. Because structures tend to flex about 1% with respect to height, this would indicate that a relative motion between the floor and ceiling of a 10 ft tall room would be about ½". As a result, attachment of a component to the ceiling and restraint to the floor (or the reverse) is unacceptable. Ideally, the components should be supported from and restrained to the same surface (mount to ceiling/restrain to ceiling). As a worst case, no more than ¼" relative motion should be permitted (which might permit mounting to the ceiling and restraining to a surface near the top of an adjacent structural wall). The stiffer the structure, the more flexibility the installer has in placing restraints.

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When installing restraints there are often opportunities to use the same attachment points used for suspending hanger rods to also connect restraint cables or struts. All hardware size information indicated in this manual is based on independent support and restraint hardware. The use of common connection points is not recommended and, if used, both seismic and support forces along with worst-case safety factors and hardware selection criteria must be included in the evaluation. This is beyond the scope of this document.

Connections to Masonry Structures (Including Concrete)

Masonry structural elements can be either concrete or block. When concrete, they might be poured in place with a removable form, poured over decking, or pre-cast and erected on site. When attaching to masonry, it is important to be aware of the locations of any reinforcing steel that may be embedded in it. It is not permissible to damage the reinforcement.

Damage to the reinforcement will (at best) weaken the structure and can (at worst) result in severe injury or death. Do not under any circumstances drill into a masonry element without first obtaining approval and, second, locating and avoiding any reinforcement components.

All connections that bear the weight (only) of ceiling-mounted components must be rated for a 5:1 safety factor, but may not require seismically approved anchorage hardware. Any connection that must resist only a seismic force must use seismically rated hardware with an inherent 2:1 safety factor. Connections that must withstand both seismic and gravity loads require both seismically rated anchorage and a 5:1 safety factor. Examples of the above are as follows:

	5:1	Seismic Rating
Hanger rod Anchorage for Cable-Restrained System	Yes	No
Restraint Anchor (Strut or Cable System)	No	Yes
Hanger rod Anchorage for Strut-Restrained System	Yes	Yes

Connections into portions of beams or other elements that are loaded in tension will have a reduced capacity as compared to published ratings. These should be avoided, or if unavoidable, should be analyzed independently of the charts and tables published in this document.

All tables used in this document are based on the use of Kinetics Noise Control-supplied seismically rated anchors. Caution should be used to ensure that adequate embedment depth and cover (per local code or anchor manufacturer with a 1” minimum) is provided.

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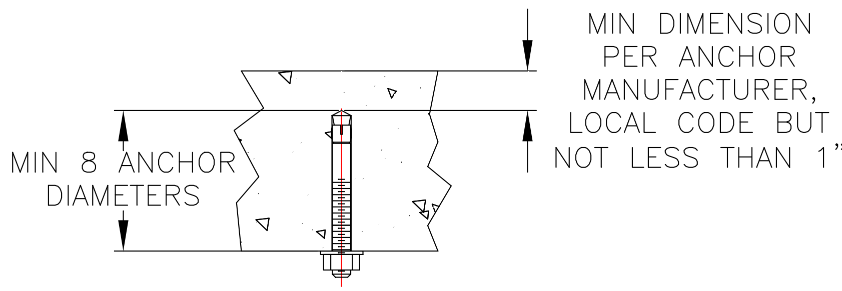
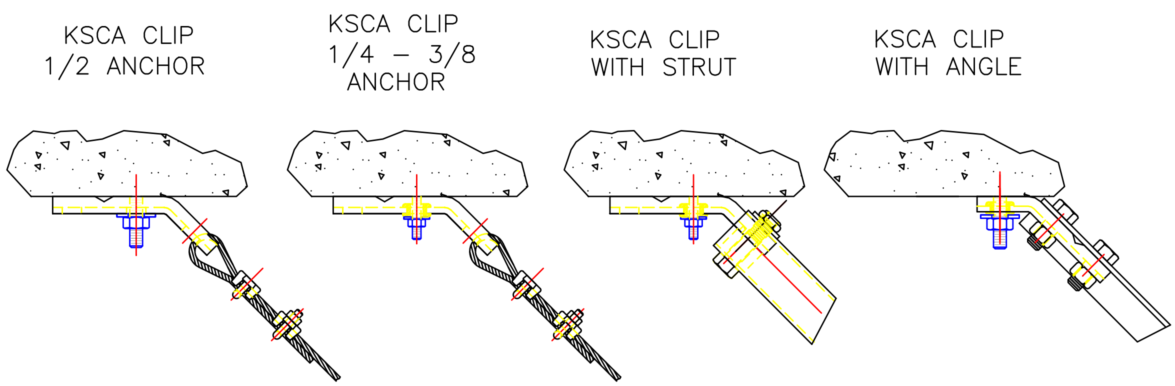


Minimum Anchor Installation Requirements

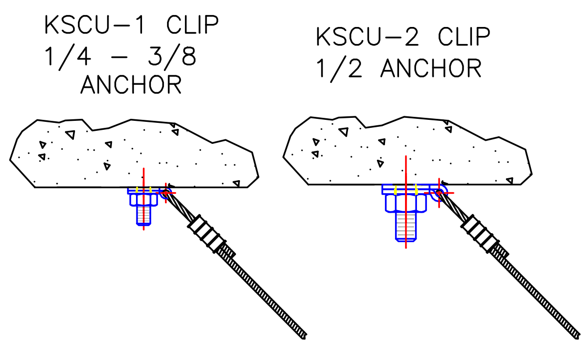
Ceiling Connections

The most efficient connection to the underside of a concrete slab is with a single anchor. Depending on the load requirements and available slab thickness, this may not be practical, and in order to get adequate capacity, multiple anchors may be required.

Single anchor attachments can be made with anchors from ¼" up to ½" using the Kinetics Noise Control KSCA bracket and the KSUA bracket as shown below.



KSCA Clip with Single ¼ to ½ Anchor



KSUA Clips for ¼ Through ½ Anchors

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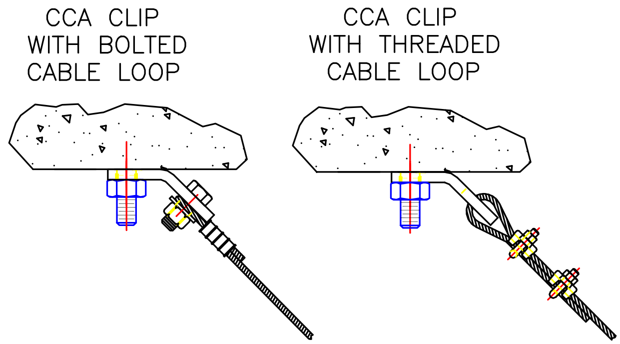
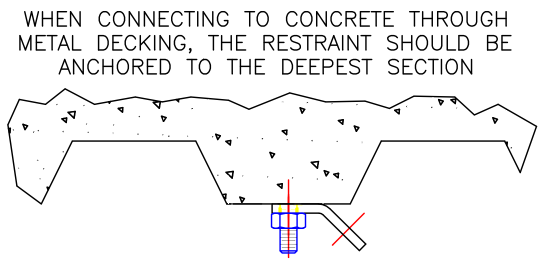
For larger, single-anchor arrangements, the CCA can be used. Depending on the orientation, it can be used with either a 5/8 or 3/4 anchor.



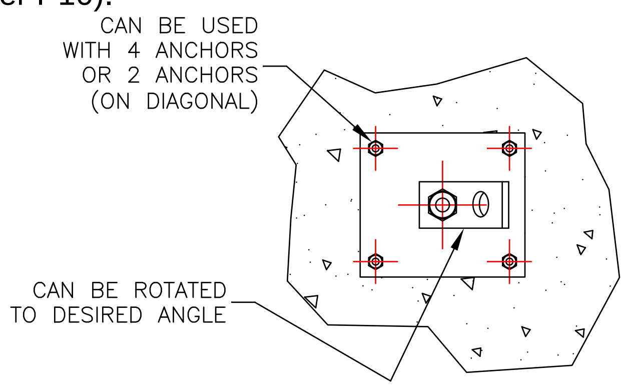
CCA Clips for Single 5/8 and 3/4 Anchors

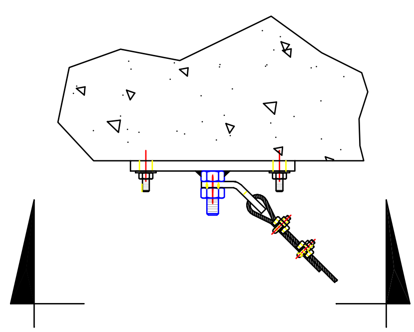
Anchors can be embedded in concrete through the decking as shown below:



Typical Restraint Clip Anchored to Concrete Through Decking

In cases where multiple anchors are required to meet load and/or maximum allowable embedment requirements, a clip fitted with a multiple-anchor embedment plate or a bridging strut member should be used. If using a strut, spacing between anchors must not be less than the allowed spacing per Kinetics Noise Control anchor data tables (Chapter P10).





CCA Clip attached using Kinetics Noise Control 2/4 Bolt Mount Plate

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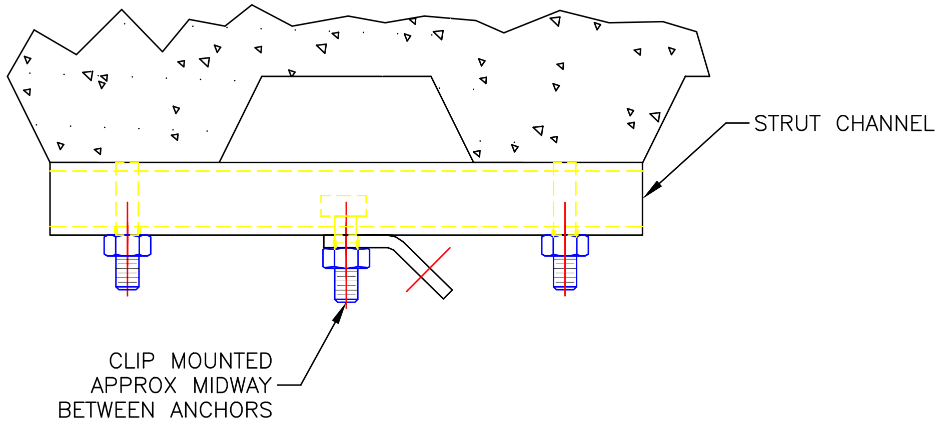
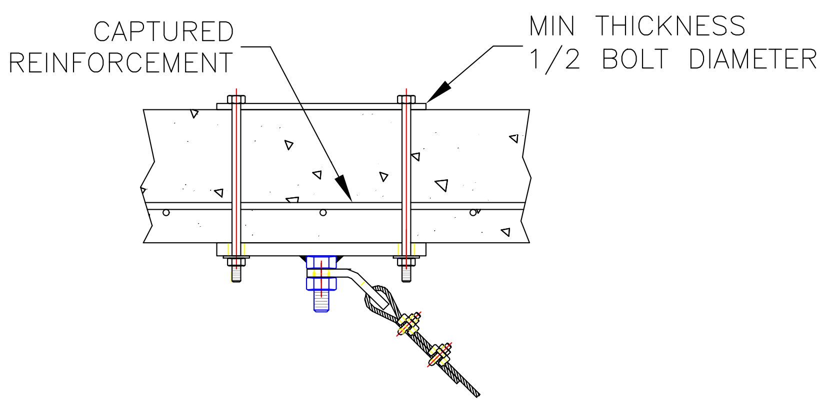


Multiple-Anchor Mounting Using Strut Channel

Under extreme conditions, where the slab to which the restraint is being attached is too thin to achieve the needed capacity with conventional concrete anchors, it may be necessary to bolt through the slab. This method eliminates concerns related to failures due to anchor pullout and allows both the use of the higher through-bolt rating as well as eliminates the penalty factors associated with connections using concrete anchors. Connections made in this manner must bridge over reinforcement steel embedded in the concrete slab as shown below.



Typical Through-Bolted Restraint Attachment Option

<u>Wall and Column Connections</u>

In general, restraint connections to walls and columns made of concrete are very similar to the connections to the ceiling. Wall connections in this group, however, also encompass connections to masonry walls which require some additional attention.

Illustrated below are the wall or column versions of the connections previously shown for the ceiling applications.

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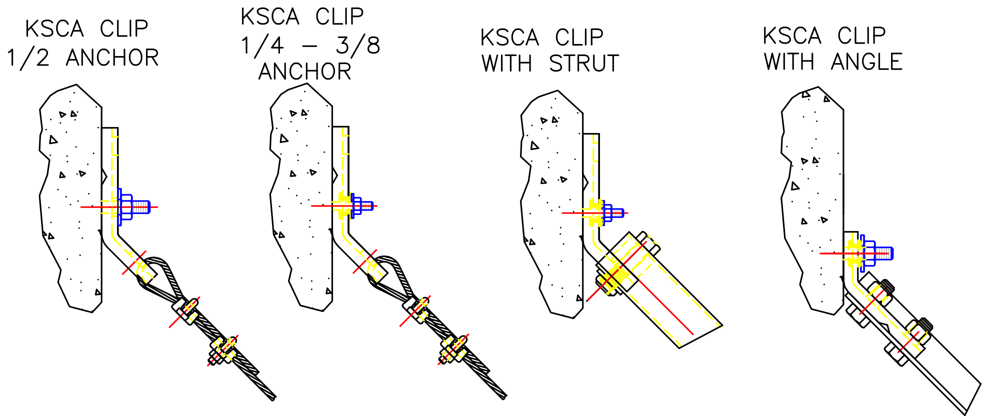
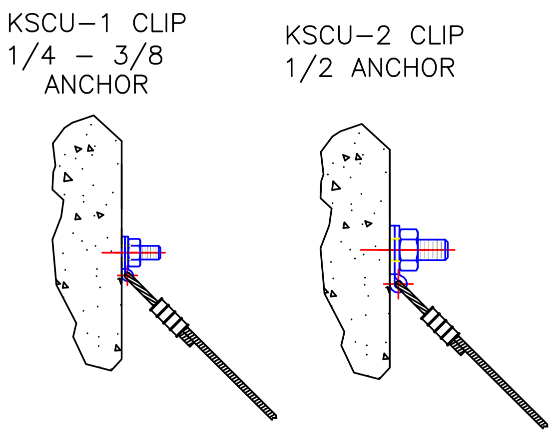
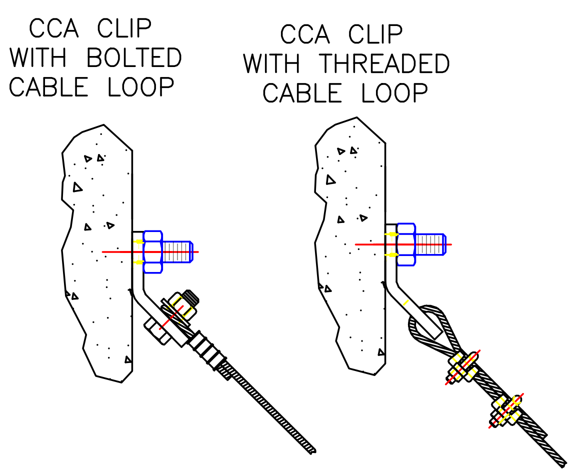


KSCA Clip with Single 1/4 to 1/2 Anchor



KSCU Clips for 1/4 Through 1/2 Anchors



CCA Clips for Single 5/8 and 3/4 Anchors

STRUCTURAL ATTACHMENT DETAILS FOR PIPING RESTRAINTS

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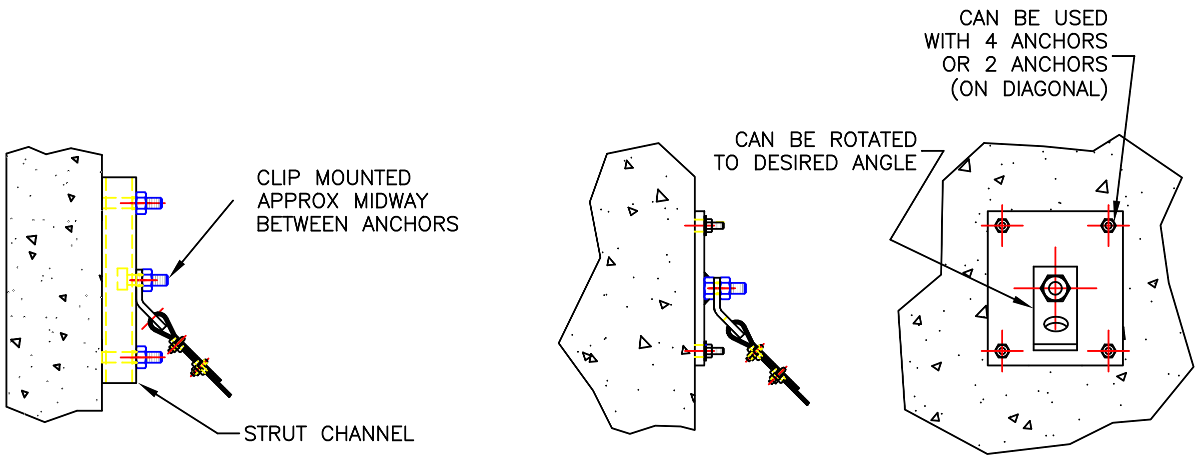
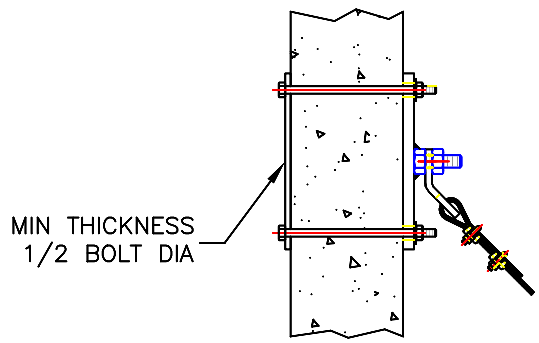


CCA Clip attached using Multiple Bolt Mount Plate and Strut Channel



Through Bolted Connection

Because of the material's lesser strengths, there are limited methods of attachment to masonry block walls. Caution should be exercised to avoid installing wedge-type anchors directly into the mortar used to cement the blocks together.

When used, anchors must penetrate into the core of the masonry unit and achieve adequate embedment into the concrete or grout that fills the cavity. If the blocks are not filled, the use of seismically rated wedge-type anchors should be avoided.

When working with hollow core block walls, restraint components must bolt through either one or both surfaces of the block units. Penetrations through both sides require backer plates of adequate size to distribute stress, while penetrations through one wall are more limited in capacity and must make use of an umbrella or other positive gripping internal element.

Masonry walls used to anchor restraints, as with other structural elements to which restraints are connected, must be reviewed and approved by the design professional of record on the project.

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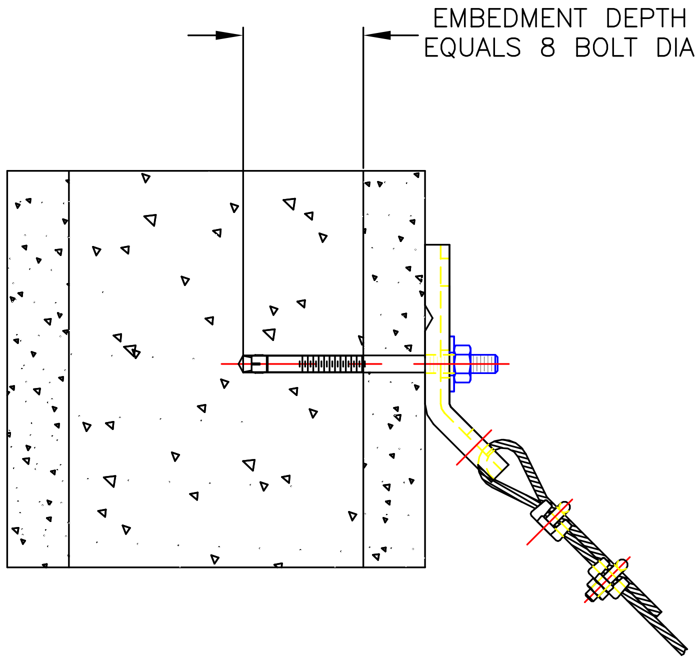
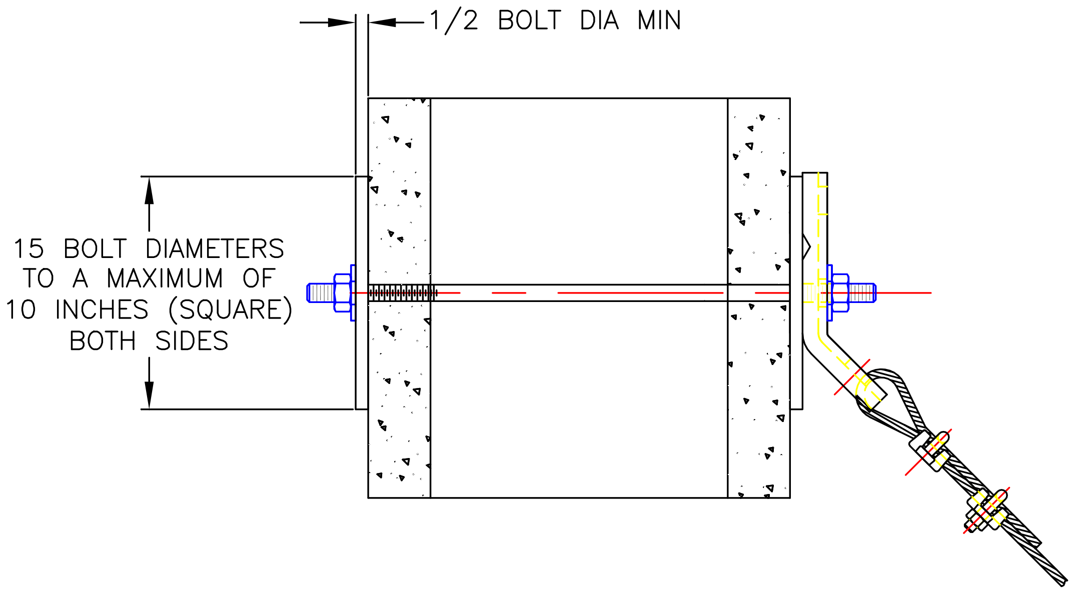
Shown below is an example of a rated anchor embedded into the filled core of a masonry wall unit.



Attachment to filled Masonry Wall with Wedge-Type Anchor



Through-Bolted Connection to a Hollow Block Masonry Wall

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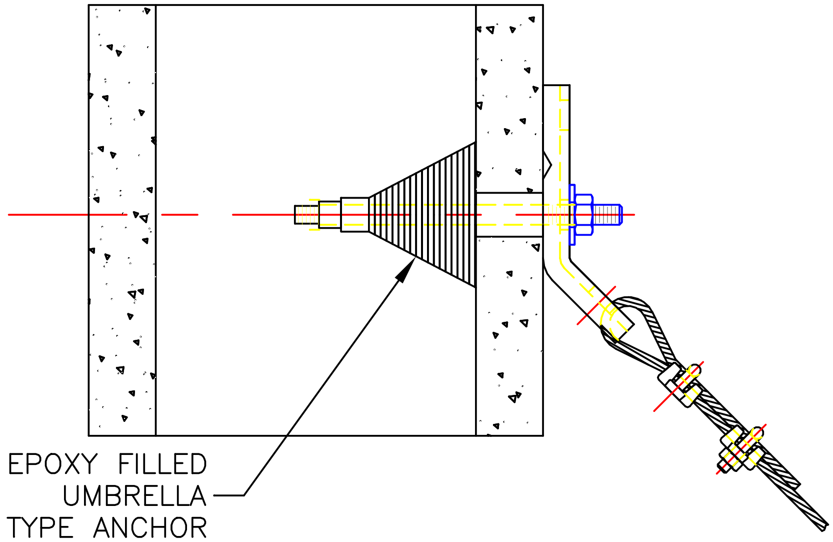

Filled Umbrella-Type Anchor for ¼ and ½ Bolt Sizes

Connections to Steel Structures

Connections can be made to steel building elements by drilling and bolting, clamping (in some instances), or by welding. As most connections are made to hanging components, the most common structural members used as restraint supports tend to be beams and trusses.

Some cautions are appropriate when connecting to these elements, as their primary function is normally to support the floor or roof above, and they are already subject to significant stress. In addition, these elements are oriented such that, while they can withstand high vertical loads, they can be quite weak when horizontal loads are applied to them, especially when the loads are applied at 90 degrees to the beam axis (transverse).

While it is generally safe to make seismic restraint connections near the top of these beams, it is often less convenient than making the attachment at the bottom. Extreme caution must be exercised when connecting to the bottom flange of I-beams and, in particular, open web joists, as frequently a small lateral load applied to these areas can result in a catastrophic failure of the beam. No connections should be made without prior review and approval of the design professional of record.

Assuming approval has been granted for the installation of a restraint at a particular location, welding or clamping the restraint in place is typically the fastest, least invasive method of making the connection. Bolting requires that the structural element be drilled and is normally avoided where possible.

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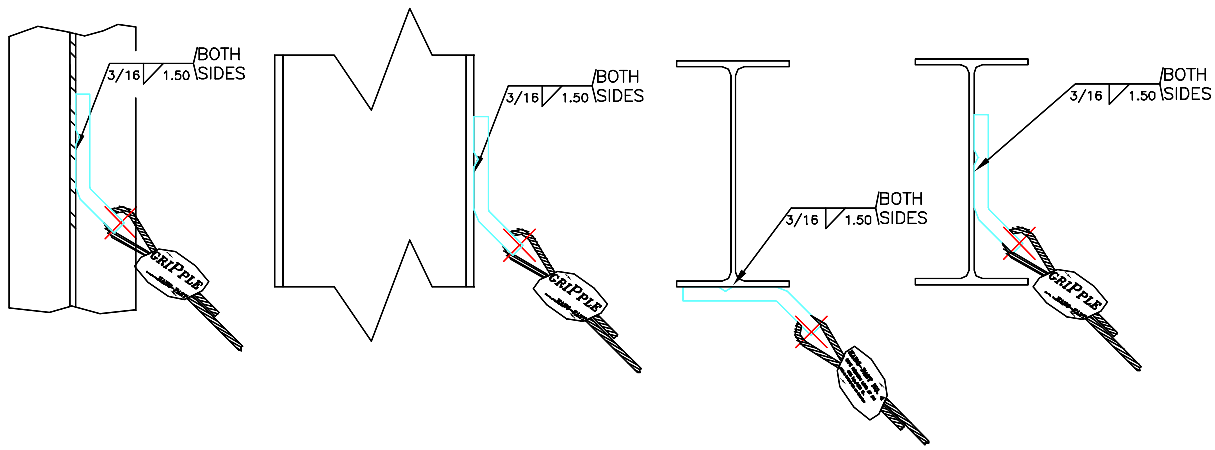
Welded Connections to Beams and Columns

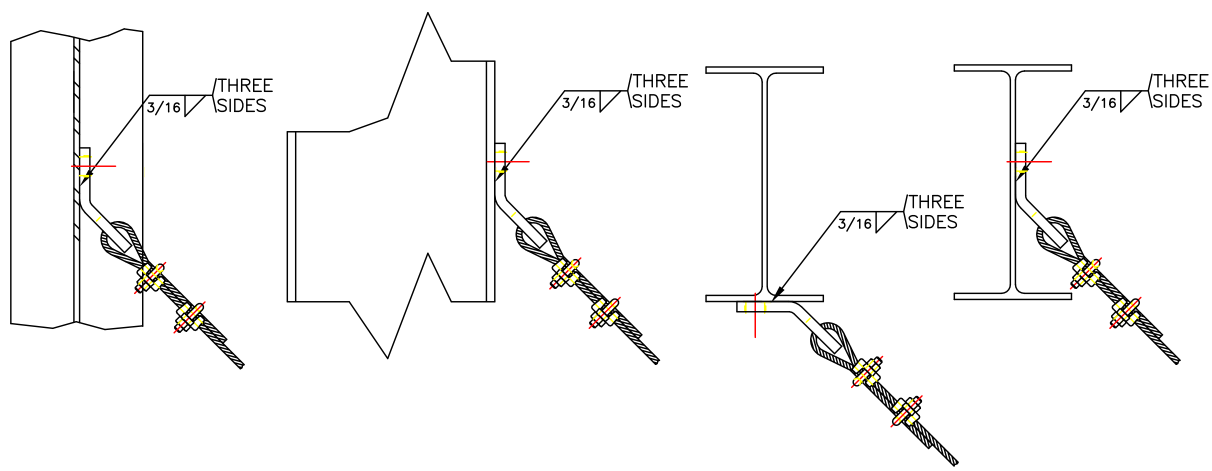
There are two basic methods for making weld attachments. The first is to directly weld a bracket to the structure and the second is to weld a threaded piece of hardware (typically a nut or bolt) to the structure and then attach the bracket to it. Looking first at the direct bracket welding options, the most suitable clips are the KSCA and the CCA.

Below are shown optional weld locations for the KSCA clip mounted to both beams and columns. These same arrangements are appropriate for floor- or roof-mounted connections with the exception that they are inverted.



Weld Data and Orientation for the attachment of the KSCA Clip

The CCA clip can be mounted in a similar fashion.



Weld Data and Orientation for the attachment of the CCA Clip

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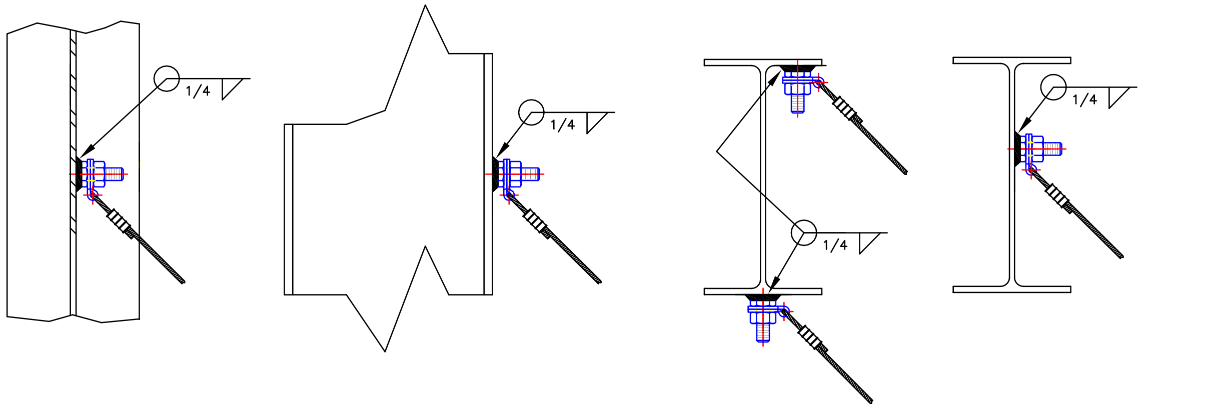
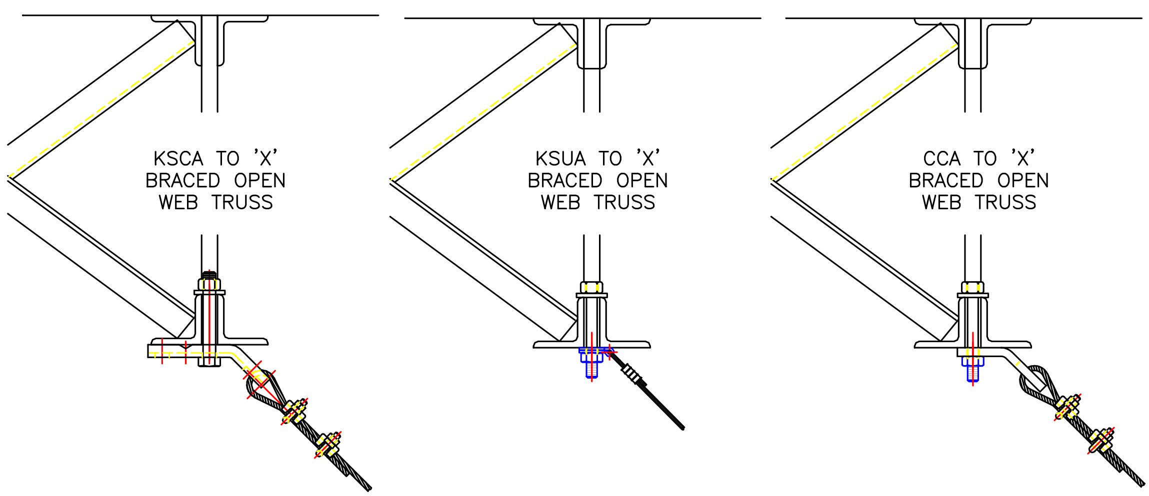
The second type of weld attachment is to weld hardware to the structure and use that to attach the restraint bracket. The KSCU is well adapted to that type of connection.



Weld Data and Orientations for attachment of the KSCU Clip

Bolted Connections to Steel Members

When used, bolted connections to steel structural members are normally made to open web joists or trusses. These are amenable to bolted connections as they have an integral slot, although caution is required to ensure that the addition of the restraint loads will not result in a buckling failure. It is also important to ensure that the load is oriented in such a way as to not cause the attachment bolt to slip in the slot to which it is attached.



Transverse load Connections to "X" Braced Open Web Trusses

It is not recommended that restraints be connected to the bottom flange of an open web truss without substantial "X" bracing in the immediate area of the restraint attachment point. The bracing must be sufficient in nature and adequately connected to the truss to

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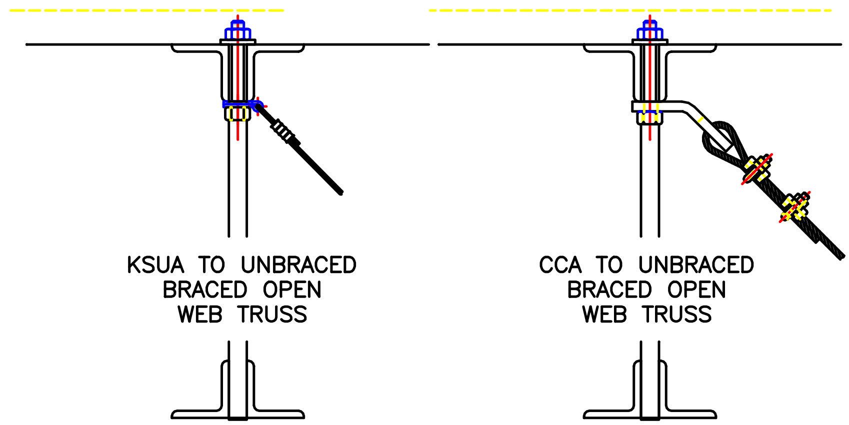
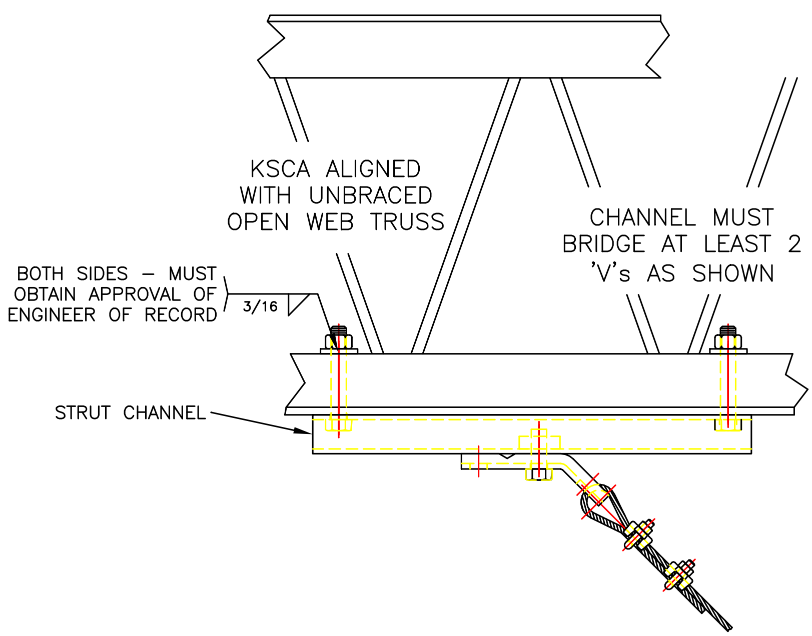
carry all restraint loads to the deck above.



Connections to the Top Chord of an Open Web Truss

“X” bracing is normally not required when restraints are connected to the top chord of an open web truss as long as the truss is adequately tied into the decking and/or floor structure above. This, along with the case below showing loads that are carried parallel to the truss, transfer only minimal stress to the truss itself. Even so, as with the other arrangements, permission should be obtained before making either of these connections.



Bolted Connection to an Open Web Truss for loads parallel to the Truss

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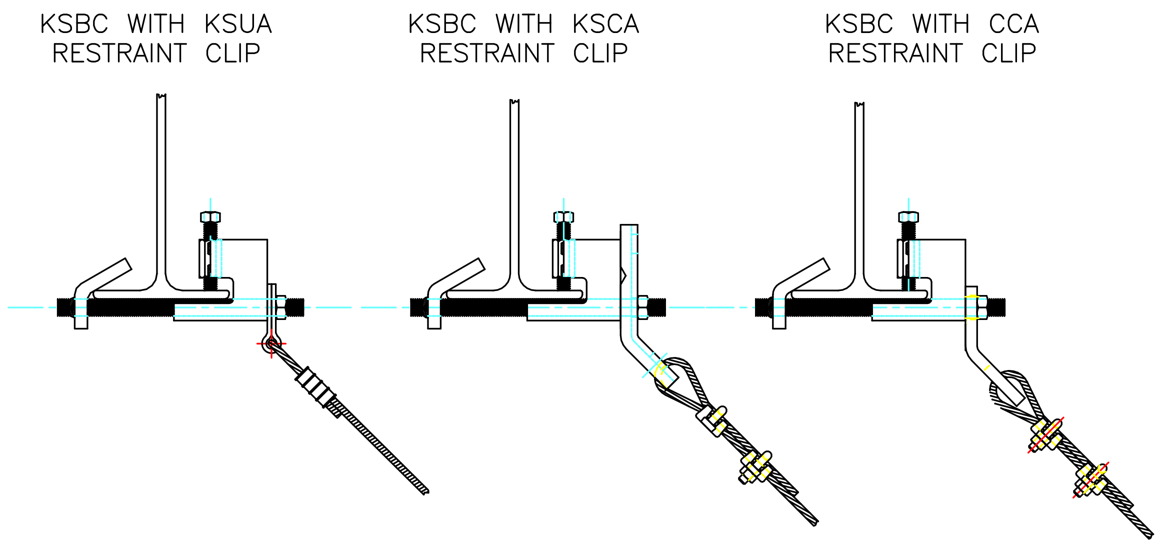
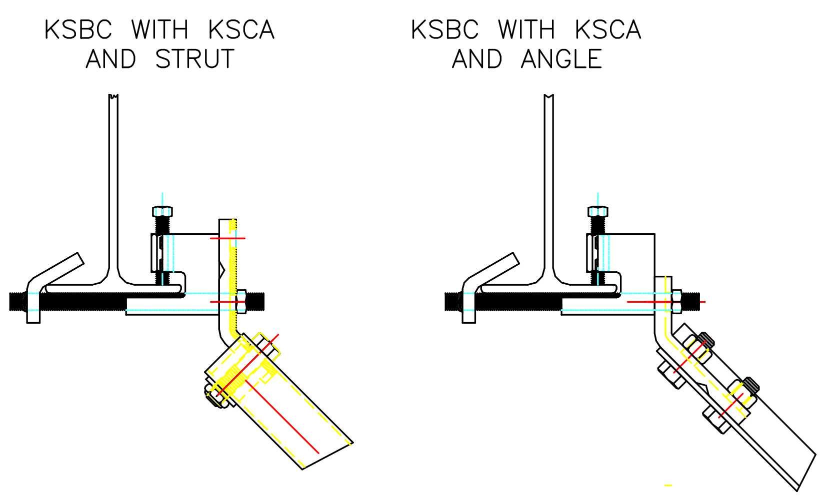
Clamped Connections to Steel Members

Another frequent restraint connection arrangement is to clamp the cable to a beam with a beam clamp. Again it is critical to ensure that the addition of these loads will not result in damage to the beam. The beam clamp selected must have a significant lateral force transferring capacity. Most readily available clamps are intended as supports for vertical loads and have only minimal lateral capacity. As such they are not suitable.

Shown below is Kinetics Noise Control's KSBC beam clamp.



The KSBC Beam Clamp can be mated with a wide range of I-Beams as well as KSUA, KSCA, and CCA Restraint Clips



KSBC Beam Clamps are also compatible with Strut and Angle Bracing

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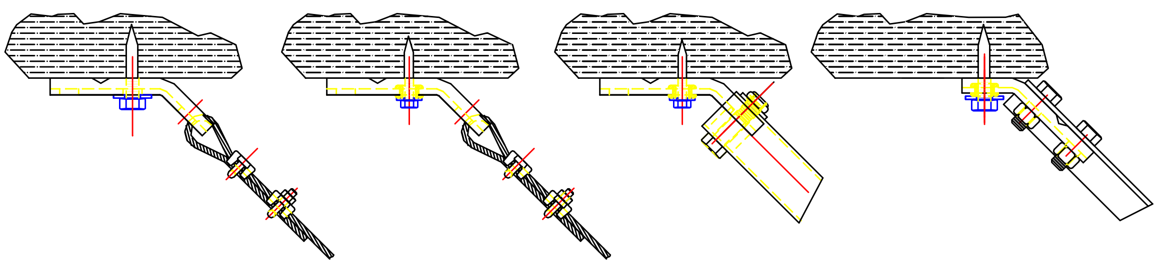
Connections to Wood

<u>Connections to Ceilings and other Horizontal Surfaces</u>

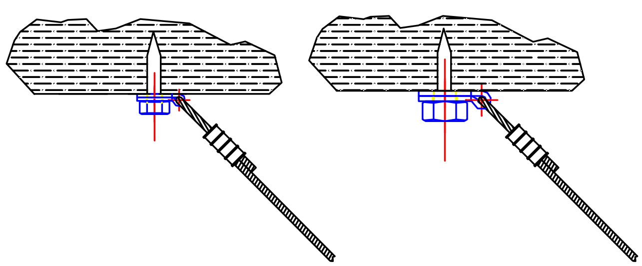
Wood structural members can often create issues when it comes to connecting seismic restraint hardware. Although lag screws are easy to install, adequate depth, end and edge distance issues frequently make them impractical. The option to bolt through a wood member and include a backer plate eliminates the depth issue, but the end and edge distance requirements still must be met. The minimum edge distance is 1.5 bolt diameters and the minimum end distance is seven times the bolt diameter.

The capacity of connections to wood using through bolts and a backer plate is limited only by bolt capacity and the structural capacity of the frame member. Capacities using lag bolts are severely limited, as the pull-out capacity of the lag bolt is much less than that of a through bolt.

Shown below are typical connections to the underside of horizontal surfaces (floor-mounted systems would be the same, but inverted).



KSCA Clip with Single 1/4 to 1/2 Lag Bolt



KSCU Clips for 1/4 Through 1/2 Lag Bolts

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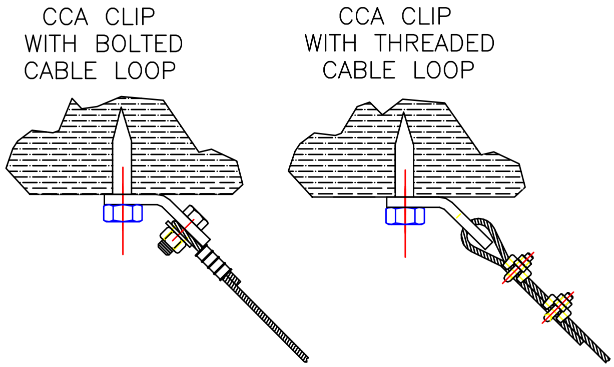
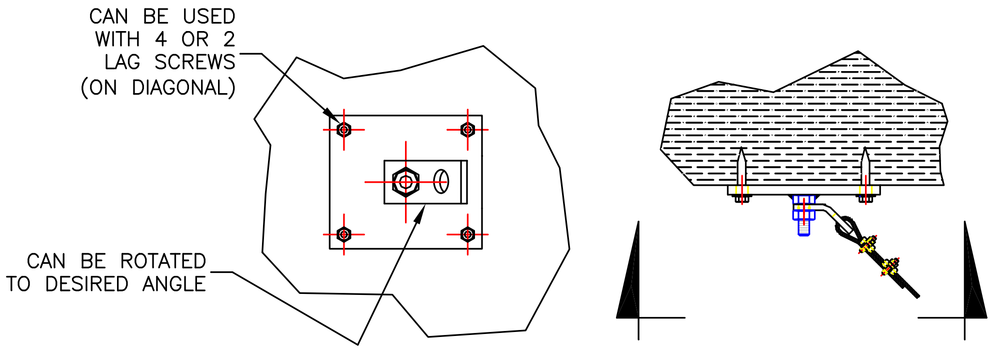


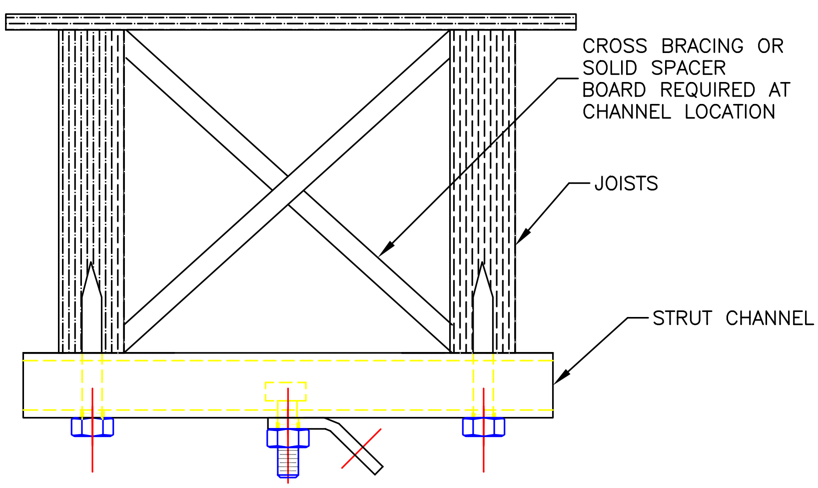
CCA Clip with Lag Bolts 5/8 and 3/4 Diameter

Where loads are such that a single anchor is inadequate, multiple anchors can be used as shown below.



CCA Clip attached using Kinetics Noise Control 2/4 Bolt Mount Plate

As long as adequate resistance to prevent twisting of the joists is provided, it is possible to bridge across multiple joists and install a restraint in between.



Two Anchor Mounting using a Strut Channel

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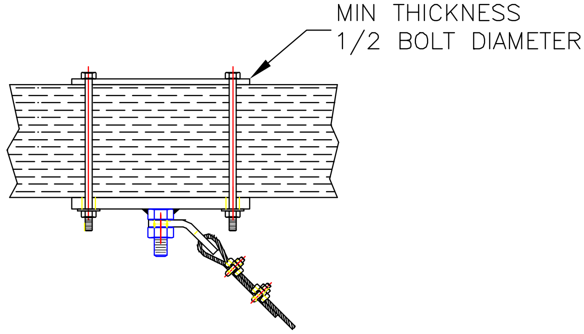
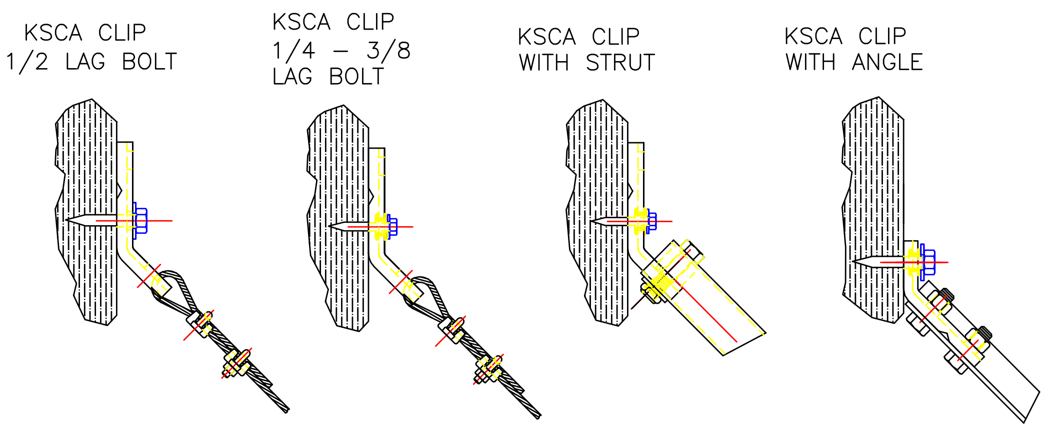
For worst-case conditions, as with concrete anchors, it is possible to bolt through a wood member with a backer plate.



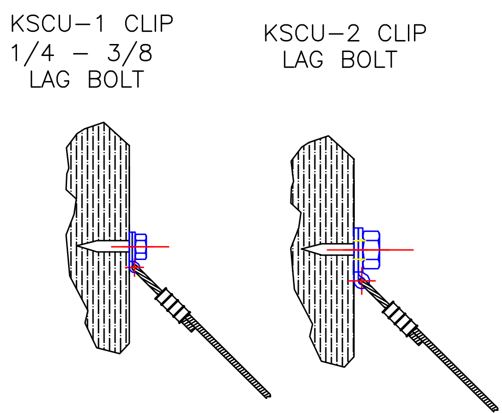
Through-Bolted Application with Backer Plate

Wall and Column Connections

As with concrete anchors, the wall and column connections to wood members are very similar to those for horizontally oriented surfaces. Shown below are typical examples.



KSCA Clips Mounted with Single 1/4 to 1/2 Lag Bolts



KSCU Clips for 1/4 and 1/2 Diameter Lag Screws

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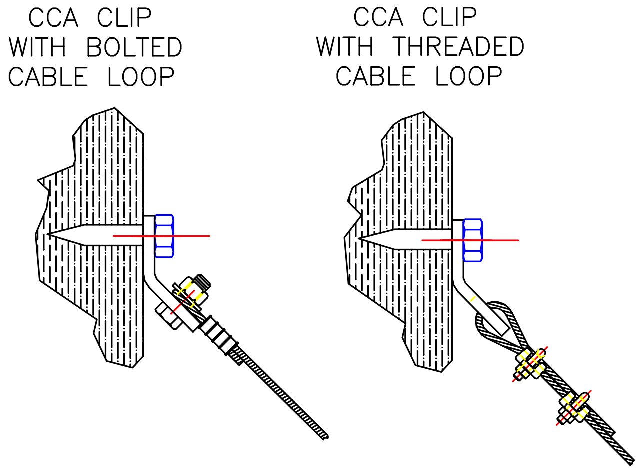
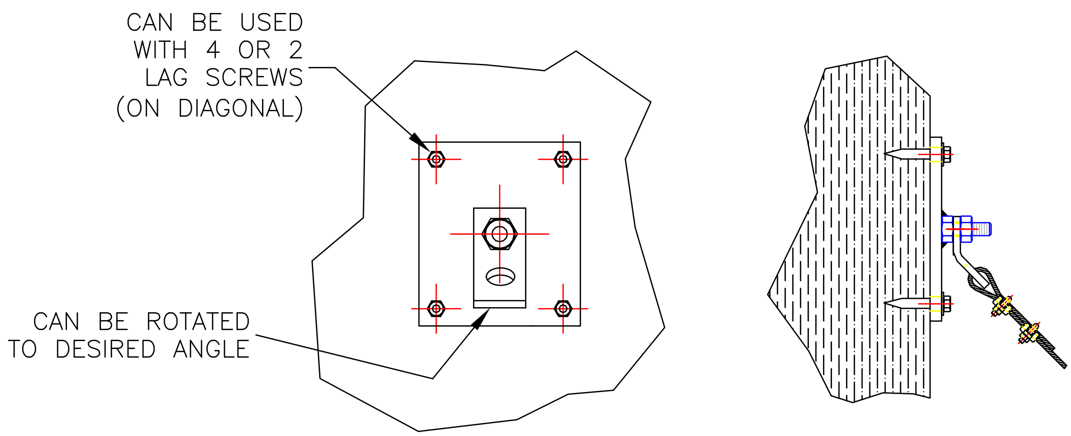
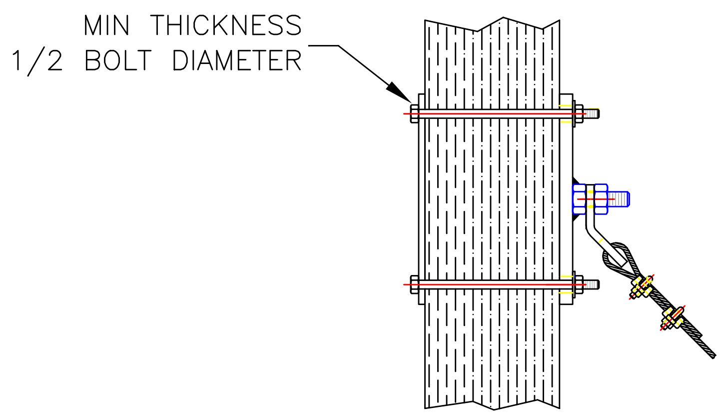


CCA Clip with Lag Bolts 5/8 and 3/4 Diameter



Multiple Bolt Anchor Plate with CCA Clip



Through-Bolted Connection

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Conclusion

This sections attempts to list the bulk of the structural attachment arrangements that are likely to be found in the field. Not all combinations of struts, angles, cables, etc., have been shown for each option. Except for cases where a connection obviously won't fit, the ability to "mix and match" the various end connection combinations shown can be assumed.

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NON-MOMENT GENERATING CONNECTIONS

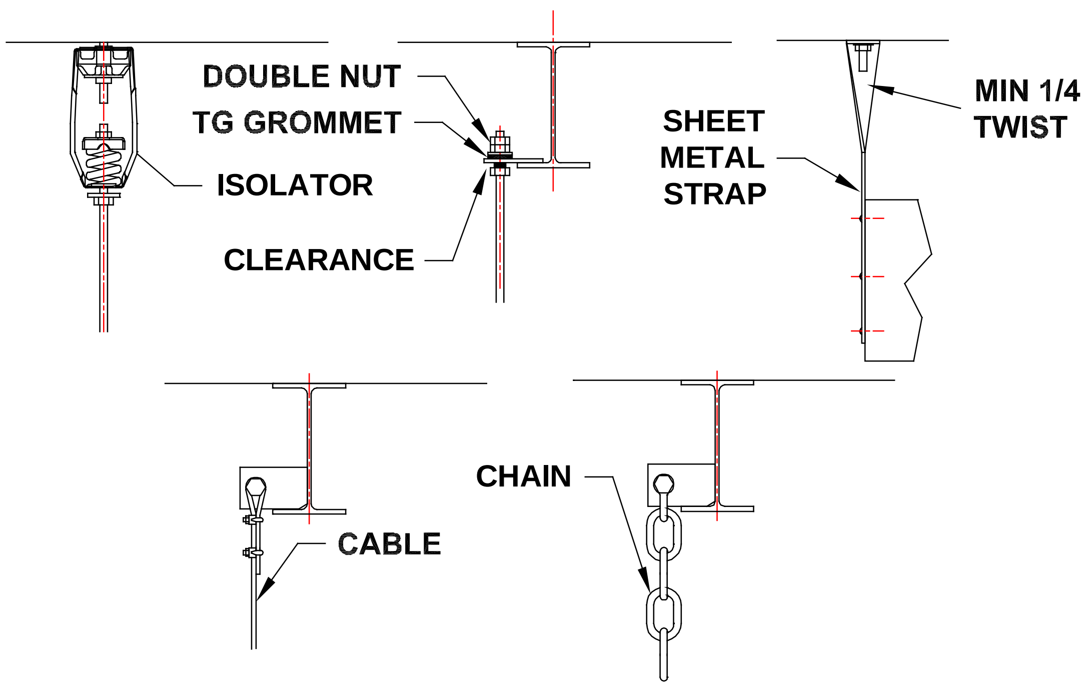
The IBC and 97 UBC codes allow the omission of seismic restraints for most piping, conduit and ductwork runs without regard to size but that are located within 12” of the structure. This figure is 6” for fire sprinkler piping. In order to qualify for this, the following parameters must be met:

1) The length of **all** supports on the run measuring from the top anchorage point to the connection point to the trapeze bar or the top of a singly supported pipe or conduit run must not exceed 12” (6” for fire piping).
2) Unrestrained free travel of the supported system must be such that over the course of its movement, contact is not made with any other system, component or structural element that can result in damage to either the supported system or the object it hit.
3) The top connection to the structure must include a Non-Moment generating connection to prevent damage to the hanger rod or support strap.

A Non-Moment generating connection is any device that would allow a free flexing action of the hanger rod or support strap for an unlimited number of cycles without its being weakened. This motion must be permitted in any direction.

Shown below are typical examples of acceptable Non-Moment generating connections. Any other device that allows the same freedom of motion is equally acceptable.

A hanger rod rigidly embedded into the underside of a concrete structural slab is not.



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Connection Options for Awkward Situations

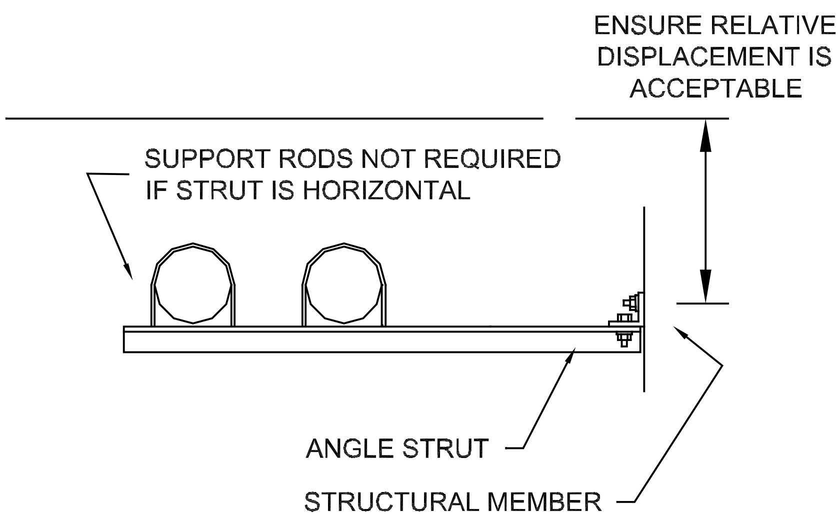
Almost every project will include some areas where installing restraints in a conventional fashion will be difficult. This segment of the manual offers options to consider when confronted with various situations.

Long, Narrow Hallways

Probably the most common issue in the field is how to deal with lateral restraints in long, narrow hallways. Normally there is considerable congestion in these areas and not enough room to angle restraints up to the ceiling structure. Often the walls are not structural and do not offer a surface to which to anchor.

When evaluating halls, the first issue is to determine if either of the walls of the hall is structural. If either wall is structural, it offers a surface to which the restraints can often be attached. For structural walls, any relative displacement issues between the wall and the structure supporting the pipe must be identified. The maximum permitted relative displacement is ¼ inch, which for most structures correspond to a difference in elevation of approximately 2 feet (see also the Structural Attachment Section of this chapter).

Assuming the wall meets both of the above requirements, a lateral restraint can be run either directly over to the wall or up at a slight angle to the wall. Normally this would be done with a strut as shown below.



Trapeze-Mounted Piping Restrained to Structural Wall or Column with a Horizontal Strut

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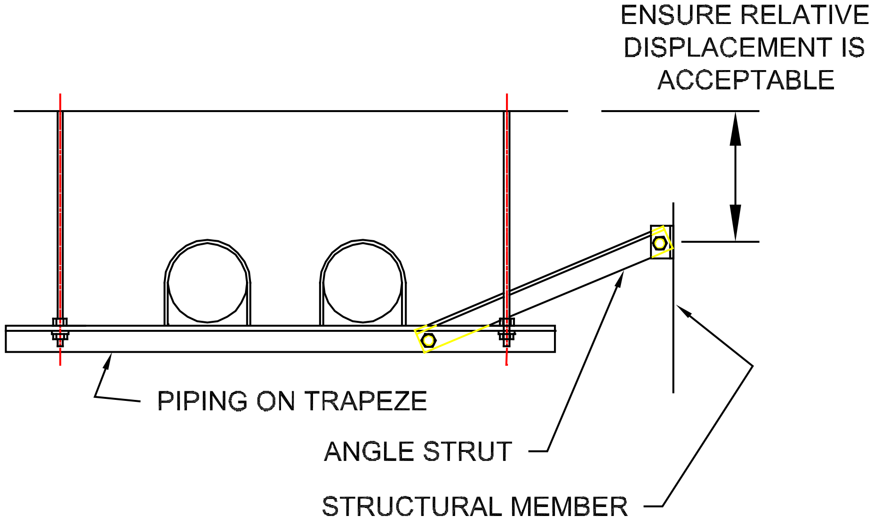
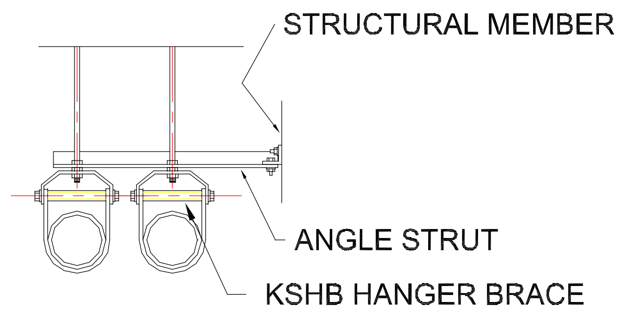


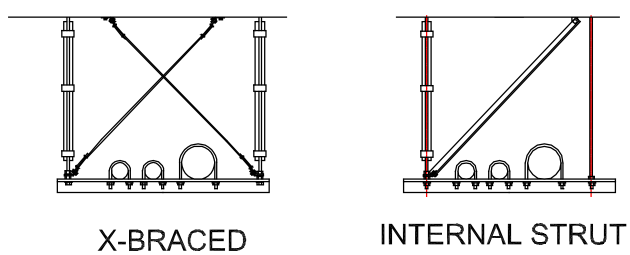
Trapeze-Supported Piping Restrained to Structural Wall or Column with an Sloping Strut



Clevis-Supported Piping Restrained to Structural Wall or Column

For the case where there are no nearby structural connection points or where the nearby structural elements are not suitable, there are several options that can be considered.

The first option is to restrain to the ceiling using “X” bracing or a diagonal strut.



“X” or Diagonally Braced Restraint Arrangement

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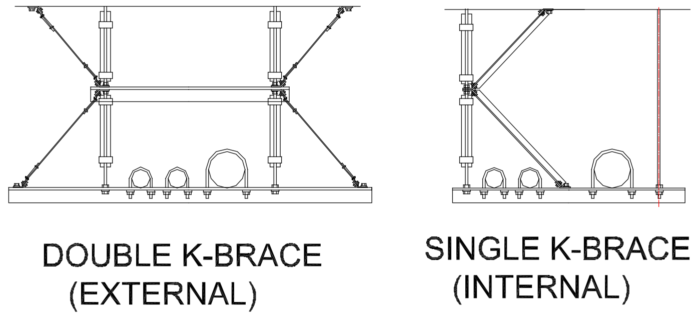
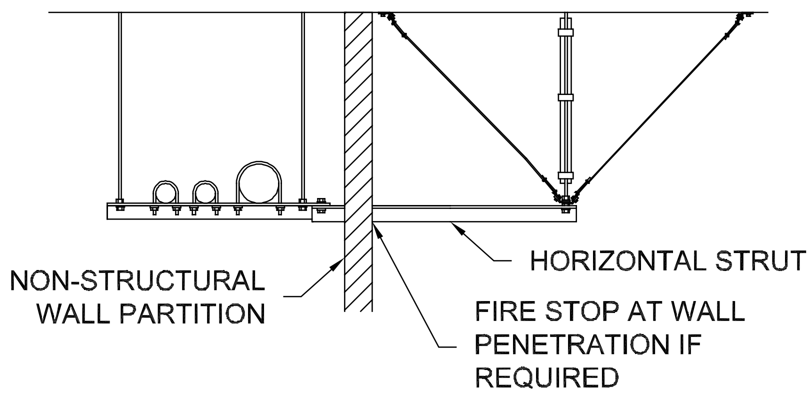
A “K” or double “K” brace can also be used. The “K” can either be located inside the support rods or outside the support rods, but in the case of a double “K”, both sides must be identical (either inside or outside).

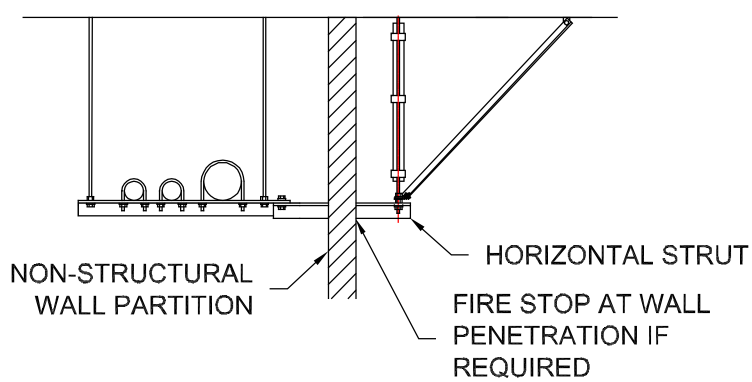


Single and Double “K” Brace Restraint Arrangement

In cases where only non-structural walls limit access for restraint, it is frequently possible to penetrate the non-structural wall and shift the lateral restraint device to the opposite side of the wall or partition as shown here.



Wall Penetration Restraint (Cable)



Wall Penetration Restraint (Strut)

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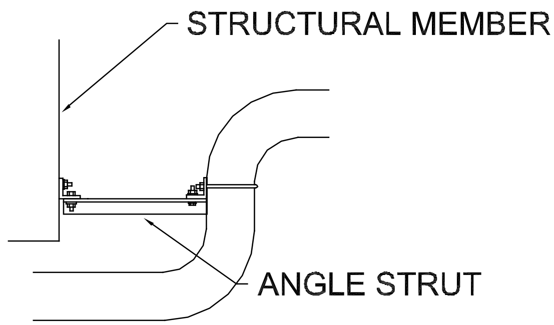
Axial Restraint Strut at a Dogleg

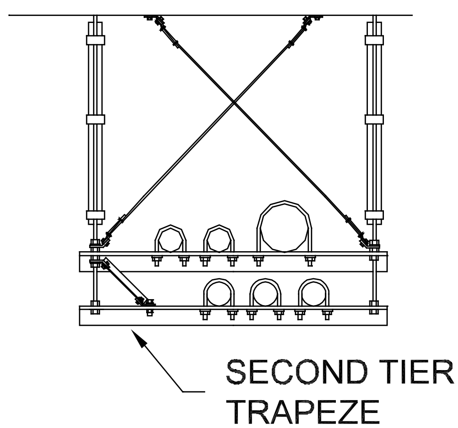
This arrangement is often a convenient way to connect an axial restraint and can occur both in the horizontal and vertical plane. Often it will be found that when installing piping, a jog has been added to a run to avoid running into a column or other structural member. Where this occurs, it offers an easy way to connect an axial restraint.



Axial Restraint Strut at a Dogleg

Piggyback or Double-Tier Restraint

In congested areas, there is often a double layer of piping supported off a single trapeze arrangement. It is possible under some conditions to brace one trapeze bar to the other, and then restrain the second trapeze bar to the structure. If doing this, there are a couple of cautions. First, the restraint capacity for the second trapeze bar must be adequate to restrain the total load from both bars and, second, the piping must be similar in nature and ductility.



Piggyback or Double-Tier Restraint Arrangement

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Restraints for Piping Mounted Well Below the Support Structure

This situation is not easily handled. Past history has shown, and the code is quite clear, that it is not a good idea to support the pipe from one structural element and restrain it using another structural element that will undergo significantly different motions. Restraints fit in this fashion will likely fail or cause the pipe supports to fail. Neither of these outcomes is desirable.

About the only solution to this is to add a support structure for the piping that is located either just above or just below the piping. The piping can then be both attached and restrained to this structure.

The structure can be supported off the floor, off the ceiling, or from structural walls or columns. The support structure must be rigid enough to absorb all of the seismic loads, and particularly the moments, with minimal deformation, transferring pure shear or tensile forces into the supports.

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