

HANGER ROD REACTION FORCES & STIFFENER REQUIREMENTS

S8.1 – Introduction:

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

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

S8.2 – Horizontal Force Class:

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

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

Table S8-1; Horizontal Seismic Force Class System Designations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

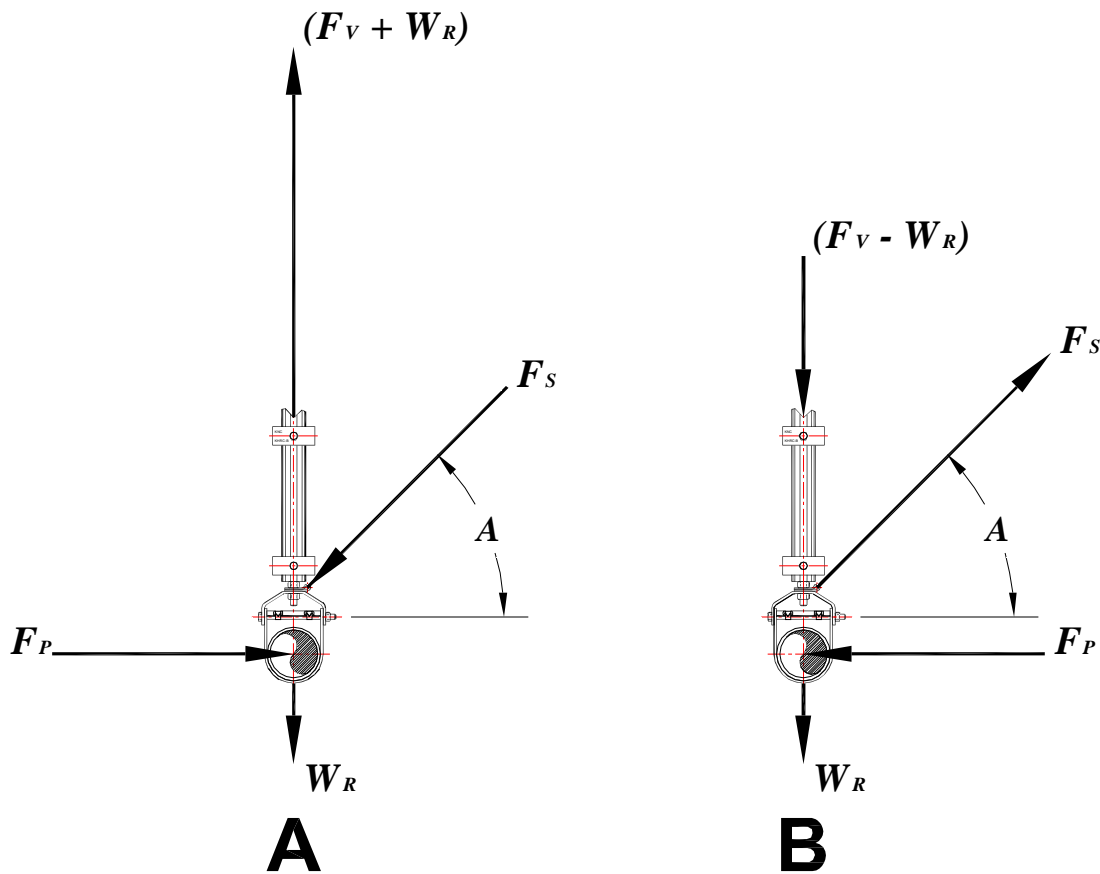


Figure S8-1; Forces Acting on a Strut Restrained Single Hanger Rod Supported Pipe or Duct

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

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$$F_s = \frac{F_p}{\cos(A)}$$

Equation S8-1

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

$$F_v = \tan(A)$$

Equation S8-2

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

$$W_R = S_H w_P$$

Equation S8-3

Where:

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

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

In Figure S8-1 in the view marked **A**, the horizontal seismic load is attempting to push the pipe or duct to the right. This produces a compressive reaction load in the strut restraint and causes a vertical tensile reaction load in the hanger rod which adds to the dead weight load already being supported by the hanger rod. In the view marked **B**, the horizontal seismic load attempts to move the pipe or duct to the left. This will produce a tensile reaction force in the strut restraint, and a compressive reaction load in the hanger rod. The dead weight load supported by the hanger rod puts the rod in tension which effectively reduces the overall compressive load to which the hanger rod is ultimately exposed. In many cases the dead load of the pipe or duct will exceed the compressive reaction forces generated by the horizontal seismic force. When this occurs, no rod stiffeners will ever be required at that restraint location. Tables S8-3 and S8-4 present the maximum hanger rod reaction forces for single hanger rod supported pipe or duct with strut restraints and the minimum recommended hanger rod size for each Horizontal Force Class. The

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design horizontal seismic load used was the maximum value for each Horizontal Force Class. The hanger rod spacing was assumed to be 10 ft, which is a common hanger spacing. For hanger rod spacings other than 10 ft, see Kinetics Noise Control's web based tools for pipe and duct. Table S8.3 assumes an installation angle of 45° and Table S8.4 assumes an installation angle of 60°. Note, as the installation angle increases, the tensile/compressive loads in the hanger rod also increase.

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

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

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

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

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

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

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

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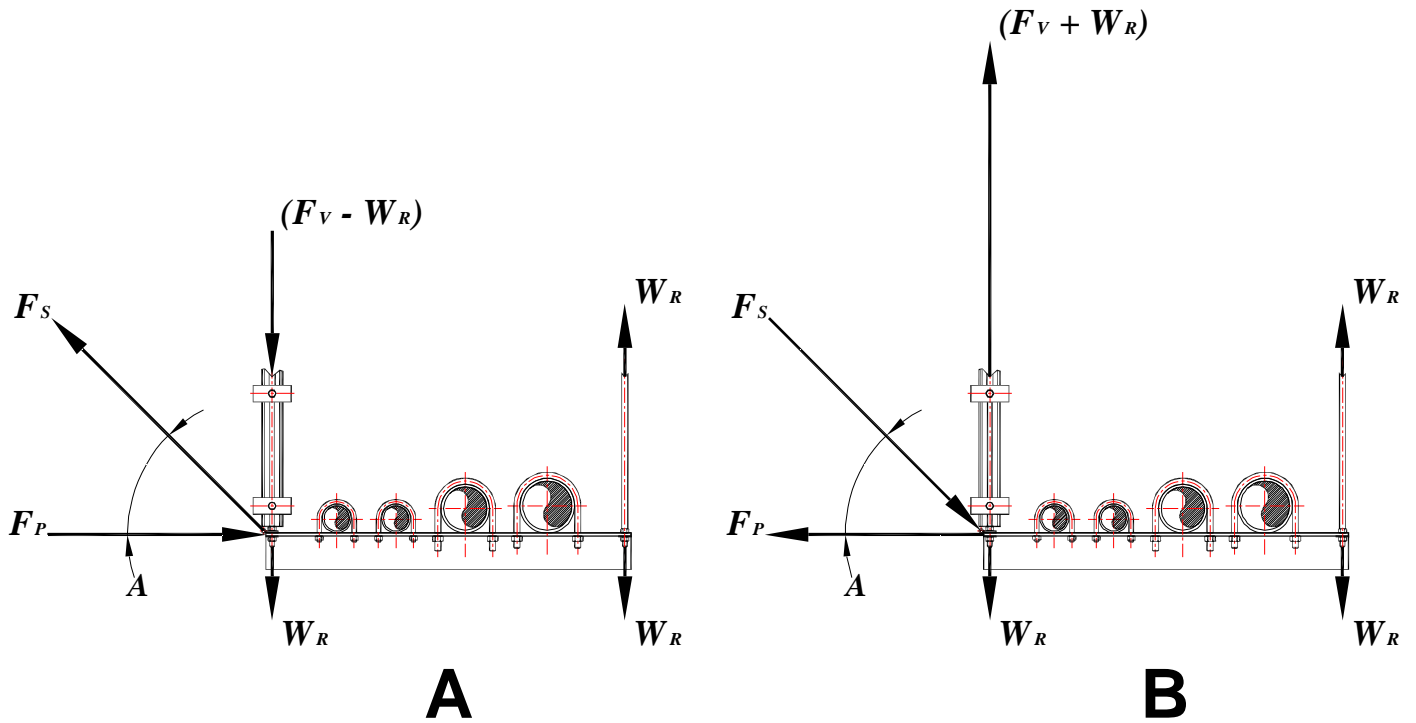


Figure S8-2; Forces Acting on a Strut Restrained Trapeze Supported Pipe or Duct

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$T = \frac{F_P}{\cos(A)}$$

Equation S8-5

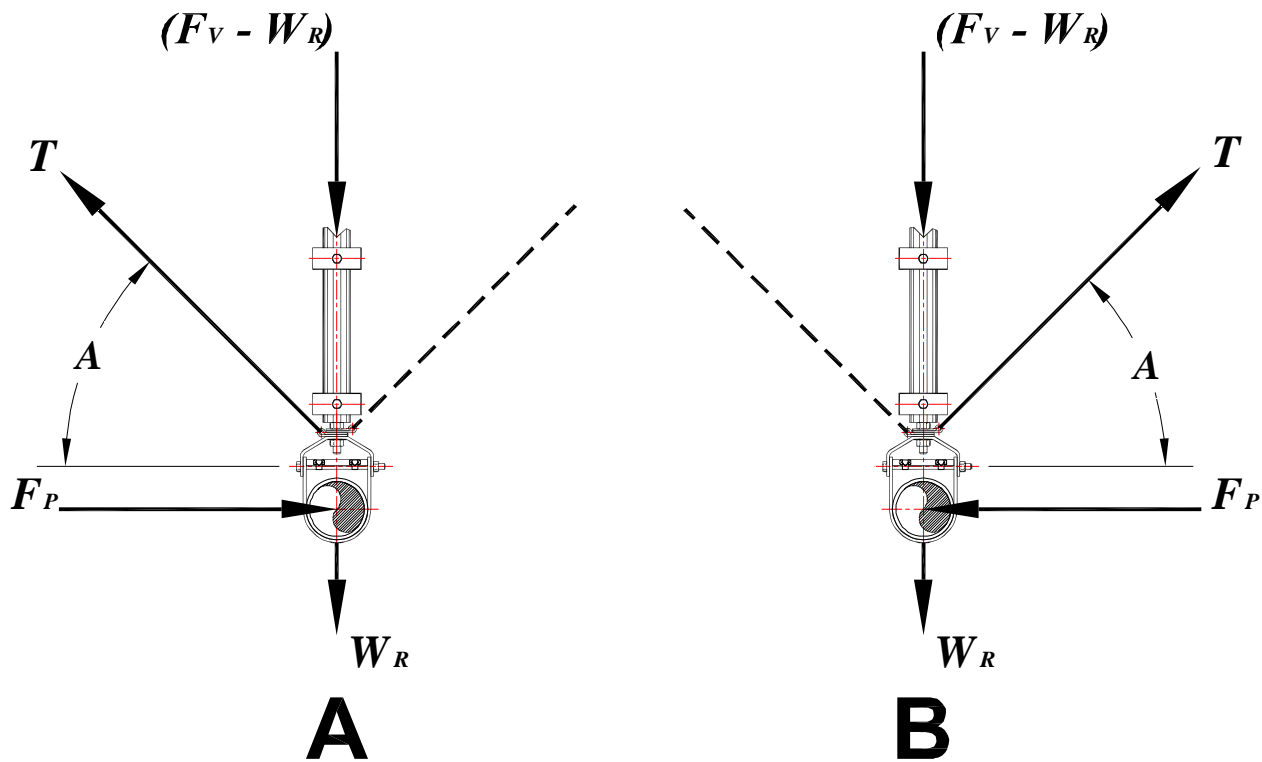


Figure S8-3; Forces Acting on a Cable Restrained Single Hanger Rod Supported Pipe or Duct

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

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

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

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

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

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

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

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

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

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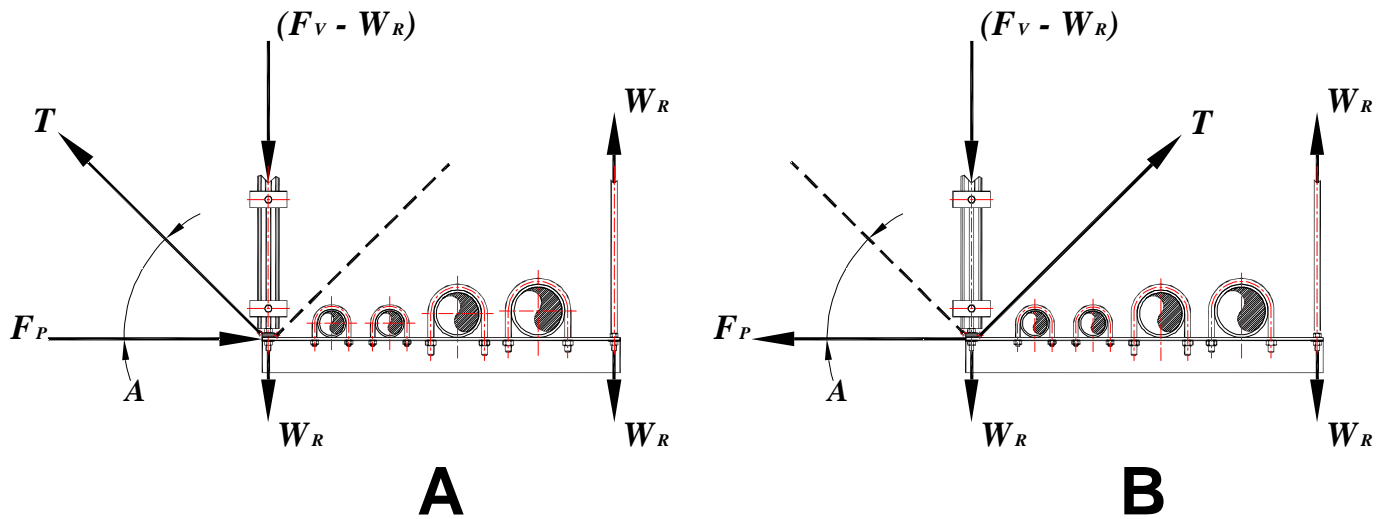


Figure S8-4; Forces Acting on a Cable Restrained Trapeze Supported Pipe or Duct – Both Cable Restraints Attached at One Hanger Rod

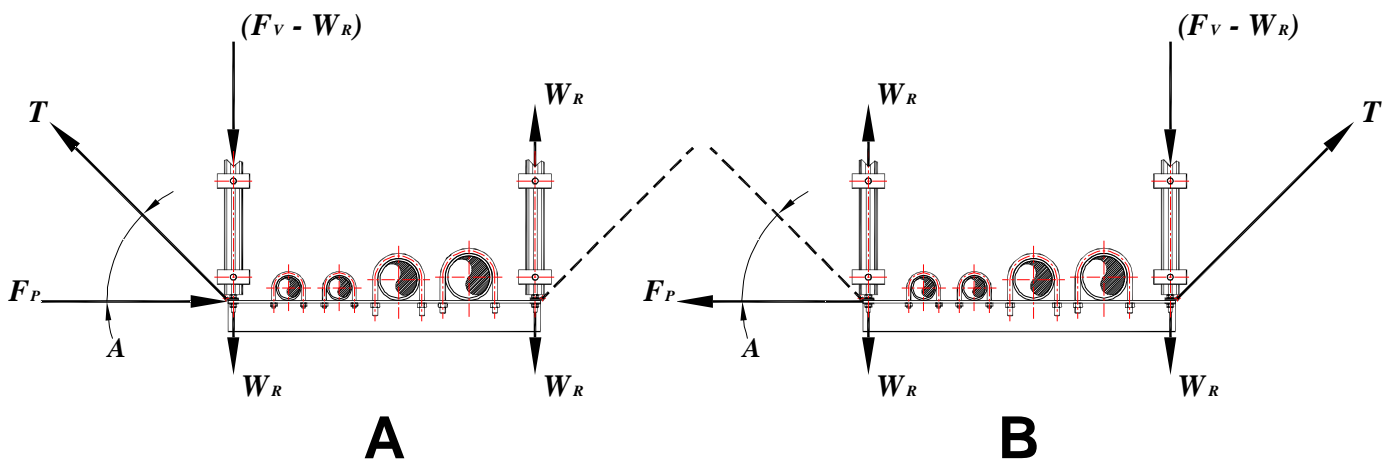


Figure S8-5; Forces Acting on a Cable Restrained Trapeze Supported Pipe or Duct – One Cable Restraints Attached at Each Hanger Rod

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

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

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

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

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

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

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

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

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

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

S8.6 – Requirements for Hanger Rod Stiffeners:

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

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

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

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

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

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

1. They are readily available.

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

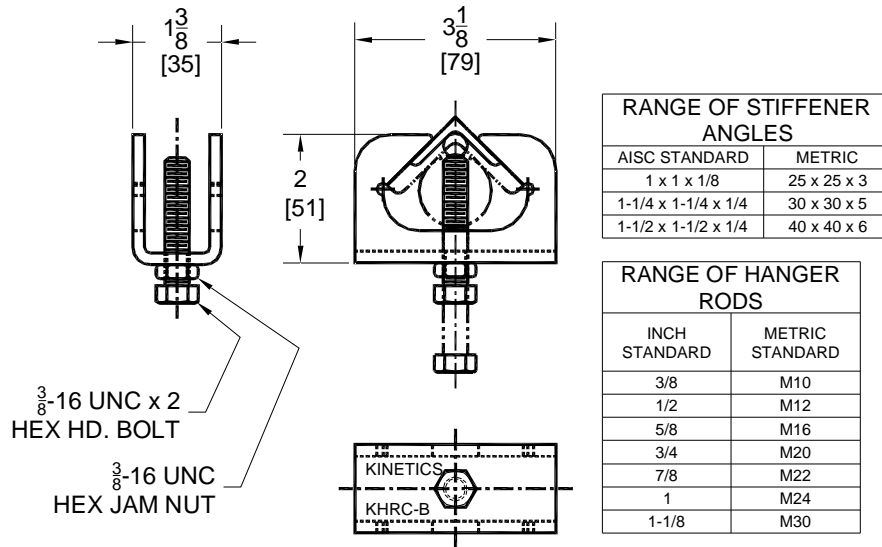


Figure S8-6; Kinetics Noise Control Model KHRC-B Hanger Rod Stiffener Clamp

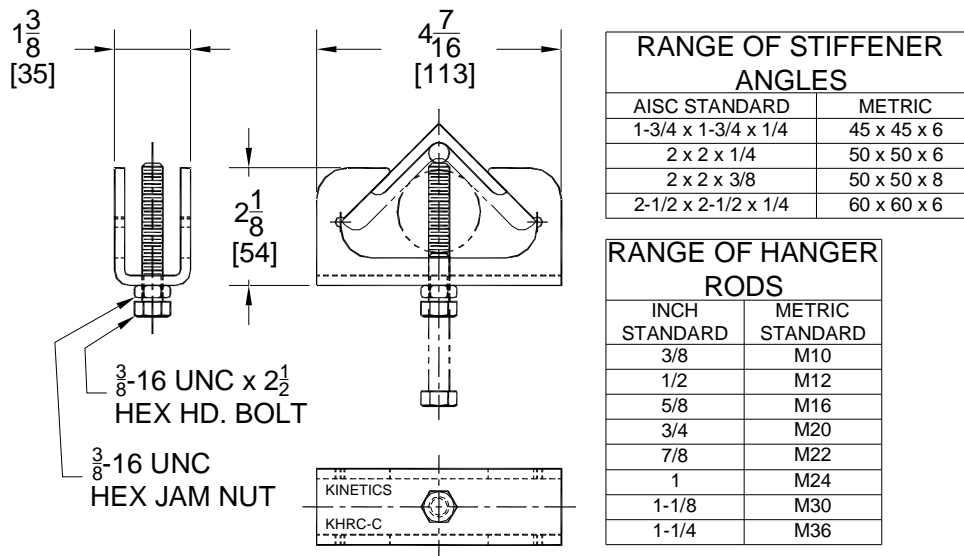


Figure S8-7; Kinetics Noise Control Model KHRC-C Hanger Rod Stiffener Clamp

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

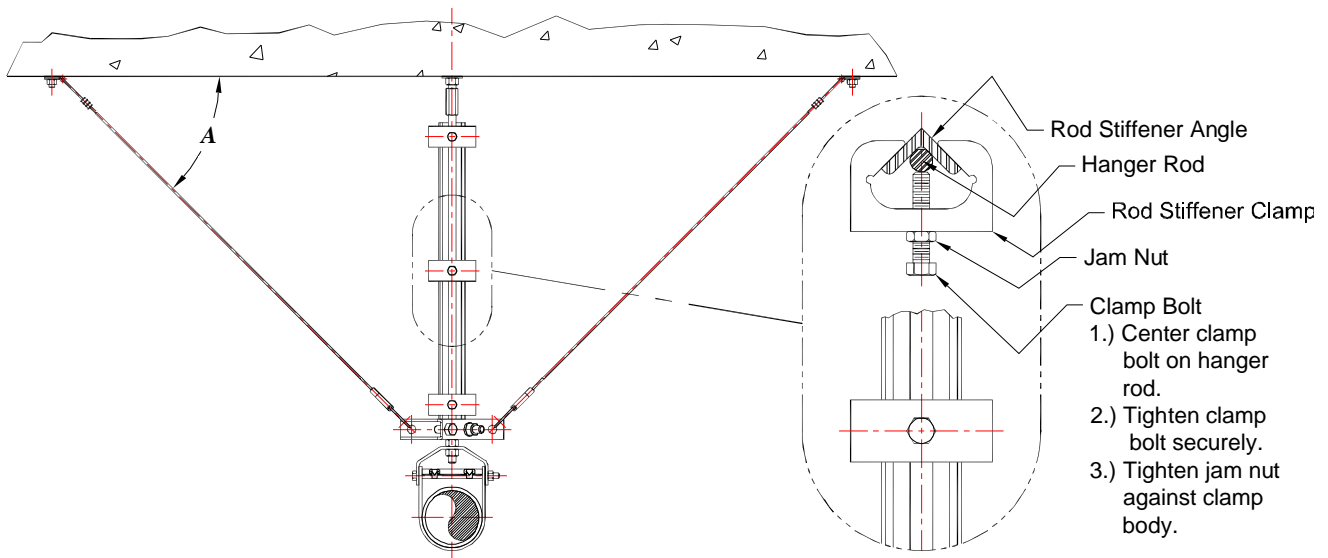


Figure S8-8; Typical Hanger Rod Stiffener Installation

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

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

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

$$P_{CR} = \frac{C_N \pi^2 EI_R}{L^2} \quad \text{Equation S8-6}$$

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

$$N(F_V - W_R) = \frac{C_N \pi^2 EI_R}{L^2} \quad \text{Equation S8-7}$$

Where:

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

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

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

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

E = the modulus of elasticity of the hanger rod, normally assumed to be $E = 30 \times 10^6 \text{ psi}$.

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

L = the length of the hanger rod.

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

P_{CR} = the critical buckling load.

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

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

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

$$L_{CR} = \sqrt{\frac{C_1 \pi^2 EI_R}{N(F_V - W_R)}} \quad \text{Equation S8-8}$$

Where:

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

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

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

Where:

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

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

$$S_{CR} = \sqrt{\frac{C_3 \pi^2 EI_R}{N(F_V - W_R)}} \quad \text{Equation S8-10}$$

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

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

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

$$N(F_V - W_R) = \frac{C_2 \pi^2 EI_{Z-Z}}{L^2} \quad \text{Equation S8-11}$$

Where:

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

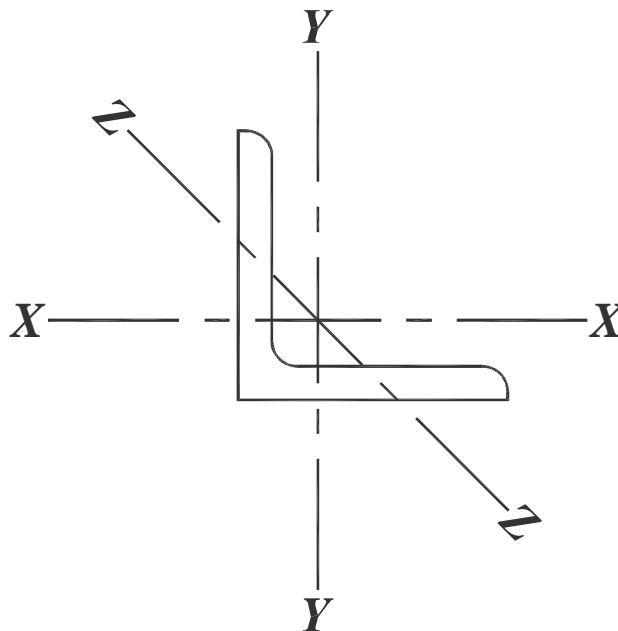


Figure S8-9; Axis Orientation for AISI Rolled Structural Angles with Equal Legs

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

$$I_{z-z} = \frac{N(F_V - W_R)L^2}{C_2\pi^2 E}$$

Equation S8-12

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

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

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

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

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

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

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

To use the web based program:

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

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

S8.8 – Summary:

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

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

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