Seismic Forces Acting on Suspended Equipment

When subjected to an earthquake, Suspended equipment must resist all lateral forces, without regard to their direction. The restraint components for these systems must resist pullout and localized structural failures. Unlike piping and ductwork, there are rarely concerns about the buckling of the equipment. Generally the equipment is assumed to be rugged enough to maintain it shape throughout the seismic event.

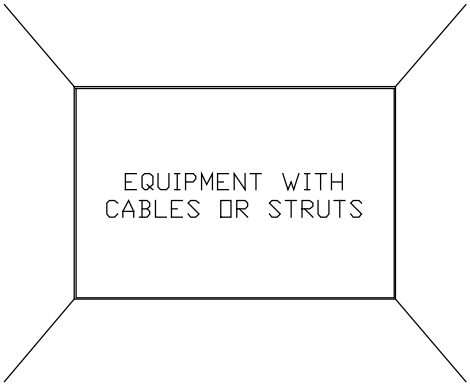
In most cases, equipment is suspended from the deck above on either fixed or isolated hanger rod systems. On more rare occasions the equipment may be bolted directly to the underside of the structure without the inclusion of hanger rods. For the later, the anchorage must be assumed to resist the seismic as well as gravity forces. When mounted on hanger rods, struts or cables are used to absorb the seismic forces.

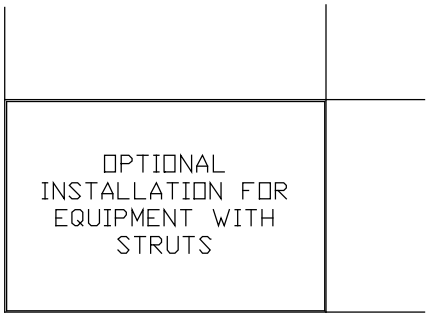
When working with suspended equipment, unlike piping and ductwork, the codes in general do not identify global exemptions. Refer to the code section for specific exemptions, but in general equipment less than 15 pounds in weight does not require the installation of “purpose built” seismic restraint componentry. Conventional attachment is assumed to be adequate.

When installing restraints on hanging equipment, it must be kept from moving in any horizontal direction. The use of cable restraints or struts can induce uplifting forces at their attachment point and if these overcome gravity forces, devices to resist this uplift are also required.

Whether restraining equipment with cables or struts, a minimum of 4 restraints are needed for each piece of equipment. Cables are typically connected to the equipment corners (approx) and run in a direction diagonal to the unit. When looking up at the equipment, each cable should be oriented at approximately 90 degrees to the cables on either side of it creating a “paddle wheel” look with 4 paddles.

When struts are used, they can be oriented like the cables or they can be oriented as shown below.





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The requirement for 4 struts is to prevent the rotation of the equipment that will occur if 2 struts are used that do not line up exactly with the equipment's center of gravity.

Ideally, the restraint members should be at as shallow an angle as possible (mostly horizontal). As the angle becomes steeper (the restraint member becomes more vertical), the vertical forces in the hanger rods increase. At 45 degrees the vertical force equals the horizontal force and at 60 degrees the vertical force is 1.73 times the horizontal force.

The net result is that for cable systems or for struts loaded in tension, the uplift force caused by the cable or strut can be greater than the downward weight load from the equipment. Depending on the support rod length and stiffness, this can cause the support rod to buckle. Rod stiffeners are used to protect against this condition and sizing information is available in Chapter D4 of this manual.

Unlike cables, if struts are used for restraint they can also be loaded in compression. The hanger rod and its anchorage for these applications must be designed to accommodate these combined loads. Hanger rod sizing information is also available in Chapter D4 of this manual.

Proper Use of Force Class Tables when evaluating Hanging Equipment

The Force Class tables presented in Chapter D4 can be used to size cables, struts, hanger rods and stiffeners for equipment as well as for ductwork. Table 1 and 1A (D4.5) tailored with appropriate values for the equipment type (note that this may be different than the values used for piping or ductwork in the same structure) is the first table of interest.

Because this table is based on weight per foot of the piping or ductwork, it requires a modification before being used directly. Using the 10 ft OC spacing table, multiply the values in the weight per ft column by 10 to produce a table that reads directly in pounds. All values within the output portion of the 10 ft OC table remain unchanged.

The total equipment weight can then be compared to the modified values in the weight column and the elevation in the structure to the appropriate elevation column to determine the force class (or lateral restraint in pounds) that is required to properly restrain the equipment.

Tables 2 and 3 (D4.6) deal with piping and ductwork only and are not required when working with equipment.

Tables 4a, b, c all deal with sizing hanger rods, rod anchorage, struts and rod stiffeners. These can be used directly, inputting the weight for the worst case support location and the Force Class as determined above.

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The final Tables (5 and 5a) in section D4.8 of the manual can also be used directly to size cables, anchors and anchorage hardware components based on the Force Class or the lateral restraint force in pounds requirement that was previously determined.

A more detailed explanation of the use of these tables is in section D4.4 of the manual.

SEISMIC FORCES ACTING ON HANGING EQUIPMENT

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