Forces Transferred Between the Equipment & Restraint

Introduction:

Due to the nature of certain seismically restrained isolators, and certain types of seismic restraints, the forces that are transferred between the equipment and the restraint, and the restraint and the ground are not what would be normally expected from the normal static force analysis. In this document we will discuss the basic types of restraints and isolators, and point out the effects that each will have on the magnitude of the forces transferred.

The newer building codes such as the ***IBC*** Code family and ***TI-809-04*** have mandated design seismic forces that are much larger in magnitude than were previously specified in the older model building codes. This means that the restraints that will be specified, oversized base plates that will be required, and the building structure required to support the equipment with its isolators, and/or restraints will all increase in size and capacity.

Basic Restraint Types:

The most basic types of restraints are those with built in clearance, and those without built in clearance. The following list shows the basic restraint types with the Kinetics Noise Control Models that apply to each.

1.) **Restraints with Built In Clearance: Tri-Axial Restraints – HS-5, HS-7, and FMS; Bi-Axial Restraints – HS-2; Single-Axis Restraint – HS-1.**
2.) **Restraints without Built In Clearance: KSMS**

The restraints with built in clearance are used primarily for three reasons. First this type of restraint is used when free standing steel coil springs are specified for isolation of the equipment. This allows the equipment to move, vibrate, slightly when operating without contacting the restraints. Second they may be used for equipment that is sitting on the floor and has no provisions to allow it to be attached solidly to the building structure, such as mounting feet or a structurally sound base. Third, certain models of this type of restraint, such as the ***HS-1***, may be added after the equipment has been installed and is operational, if there is enough space on the floor or housekeeping pad.

When restraints with built in clearance are used, the engineer, contractor, equipment supplier, and building owner need to be aware that impact forces greatly in excess of the basic code values for the horizontal and vertical seismic forces may be transferred between the equipment and the restraint. These built in clearances allow the equipment to be accelerated relative to the restraint. When the restraint is finally contacted, the equipment has generated an appreciable amount of kinetic energy that must be dissipated in the restraint. If the contact forces are stiff, the impact forces will be large. If

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the contact surfaces are relatively soft, the impact forces will be smaller in magnitude. This phenomenon is discussed in Document T3.1.1 of the Kinetics Vibration Isolation Manual. In this document, a Kinetics Noise Control Model ***HS – 1 – 2000*** was studied. The ***Impact Factor***, I_P, is defined as the ratio of the earthquake acceleration rate divided by the restraint deceleration rate. For a ***500 lb*** piece of equipment, the Impact Factor varied from a high value of ***4.56:1*** with an earthquake input acceleration of ***0.25 g*** to a low value of ***1.62:1*** with an earthquake input acceleration of ***2.00 g***. Please realize that these values are the product of a simplified analysis. However, the physics is sound, and the need to address higher impact forces than the basic code values is adequately demonstrated.

In an effort to address this impact between the equipment and the restraint, the newer codes require that an ***Impact Factor*** of ***2:1*** be applied to the basic computed seismic force. Depending on the design of the restraint and the magnitude of a seismic event, this factor may or may not, be representative of the actual acceleration values encountered in service, however, it is a good point from which to begin.

The equipment manufacturers must to be cognizant of these impact forces as they will affect the reliability of their equipment. They must be considered when designing equipment that will be certified under the provisions of the ***2000 IBC*** for continued operation after an earthquake for facilities that are categorized as essential or hazardous.

For restraints with built in vertical clearance, the forces that resist the overturning of the equipment are concentrated at the corner restraints. This sometimes leads to the necessity to select restraints and/or oversized base plates that seem to be larger than common practice would normally recommend.

The restraints without built in clearance used to mount rigid equipment will not have the impact force issues that the restraints with clearance have. Also, the forces that resist overturning are more-or-less evenly distributed between the restraints. These restraints are equivalent to solid mounting the equipment using the mounting feet provided by the equipment manufacturer. These restraints may also be used in conjunction with the pre-existing mounting feet on the equipment to provide additional restraint as required by the code provisions.

Basic Seismic Isolator Types:

The isolators that utilize steel coil springs fall into two basic types as shown below with Kinetics Noise Control models that typify each type.

1.) **Contained Spring Seismic Isolators: FHS with an Oversized Base Plate; FLS; FLSS; and FMS. In these isolators, when the equipment moves upward, and the vertical restraint is contacted, the spring force *is not* added to the loads in the bolts, anchors, or welds that**

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attach the isolator to the building structure. The spring forces are, thus, tied up in the isolator housing.

2.) **Uncontained Spring Isolators: FHS without an Oversized Base Plate, or any tri-axial restraint arrangement where the isolator is a separate component from the restraint and is supported directly by the building structure. In this type of isolator, when the equipment moves upward and contacts the vertical restraint, the spring force *is* added to the loads in the bolts, anchors, or welds.**

For all of the seismic isolator types listed above, the seismic restraint is a tri-axial type with built in clearance. As such, the previous discussion concerning restraints with built in clearance will apply to these products as well. Also, the forces that resist the overturning of the equipment will tend to be concentrated at the corner isolator locations in a similar fashion.

The Kinetics Noise Control Model ***KRMS Seismic Neoprene Isolator*** falls in to the category of a restraint/isolator assembly without built in clearance. The vertical restraints forces are carried entirely though the housing to the bolts, anchors, or welds attaching the isolator to the building structure. So, it does not fall into either the category of restrained spring, or unrestrained spring. It exhibits the characteristics of both, and must be treated accordingly.

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