

6.4 Mechanical, Electrical, and Plumbing Components

6.4.1 Mechanical Equipment

6.4.1.3 HVAC Equipment with Vibration Isolation

This includes HVAC equipment, typically of sheet metal construction, that is floor-mounted with vibration isolators to prevent the transmission of mechanical vibrations into the building.

Provisions

BUILDING CODE PROVISIONS

Seismic loads for HVAC equipment with vibration isolation are determined using ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures* (ASCE, 2010), Chapter 13. The principal objective is to prevent the component from sliding or overturning.

- ASCE/SEI 7-10 requires anchorage for all equipment in Seismic Design Categories D, E, and F for all equipment weighing over 400 pounds, and items weighing over 20 pounds that are mounted over 4 feet above the floor. Lighter items may be exempt if the component Importance Factor $I_p = 1.0$.
- Items that are exempt from the anchorage requirements noted above are still required to be positively anchored to the structure. The anchorage need not be designed or detailed on the construction documents. Exempt components must be provided with flexible connections between the equipment and associated pipes, ducts, or conduits.
- The seismic design force for vibration isolated equipment is doubled if the “air gap” (the distance between the equipment support frame and the restraint) is greater than 0.25 inches.

RETROFIT STANDARD PROVISIONS

In ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Buildings* (ASCE, 2007), HVAC equipment with vibration isolation is classified as force controlled. ASCE/SEI 41-06 requires compliance with the anchorage provisions of the standard when:

- The performance level is Immediate Occupancy
- The performance level is Life Safety in high seismicity areas, if
 - The item is gas-fired.
 - The item is part of an emergency power system,
 - The items weighs more than 400 pounds and is 6 feet or more in height,

- The item is unanchored, weighs over 100 pounds, is 6 feet or more in height, and is subject to overturning. These items may be exempt if they have a factor of safety greater than 1.5 against overturning when design loads are applied.
- The item weighs over 20 pounds and is mounted over 4 feet above the floor.

Typical Causes of Damage

- Vibration isolated equipment is particularly vulnerable to earthquake damage unless some type of snubbers, bumpers, or vendor-supplied restraints are used. Open and housed springs do not have adequate capacity to resist shear and uplift.
- Vibration isolators tend to amplify seismic response of the equipment. This requires the supporting frames or slabs to have adequate capacity to resist higher forces (Figure 6.4.1.3-3).
- Items can slide, tilt, overturn, or fall.
- Internal components may be damaged by shaking.
- Connections of fuel lines, electrical lines or ductwork may be damaged; machinery may cease to function due to misalignment, failure of the isolators, or internal damage.

DAMAGE EXAMPLES

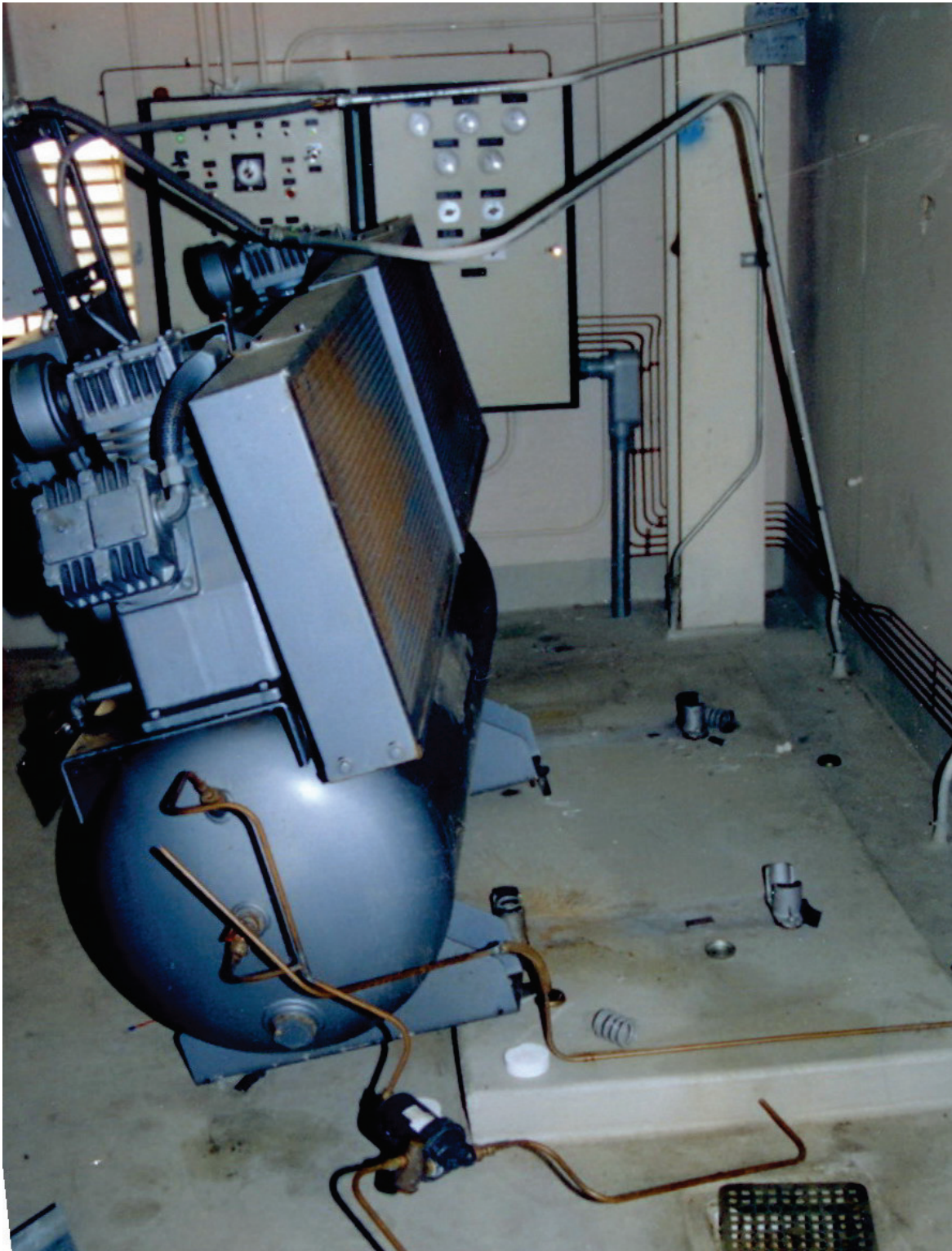


Figure 6.4.1.3-1 Failure of compressor mounted on vibration isolators in the 1994 Northridge Earthquake (Photo courtesy of Wiss, Jenney, Elstner Associates).



Figure 6.4.1.3-2 Failure of pump mounted on three vibration isolators and damage at wall penetration (Photo courtesy of Mason Industries).



Figure 6.4.1.3-3 Failure of an entire support assembly including vibration isolators (Photo courtesy of Mason Industries).



Figure 6.4.1.3-4 Rooftop equipment on isolators collapsed onto skid (Photo courtesy of Mason Industries).

Seismic Mitigation Considerations

- Although the code exempts small components on vibration isolators from design requirements, they should be carefully evaluated, since vibration isolators tend to amplify the seismic response.
- Two methods are used for anchoring floor-mounted equipment on vibration isolators:
 1. Open springs used in conjunction with snubbers or bumpers.

2. Restrained springs with rated capacity to resist the anticipated seismic shear and uplift.

- Rated housed springs with vertical travel limits should be used for seismic restraint applications.
- The “air gap”, or distance between the snubber and the component should be limited to less than 0.25 inches, to avoid significant dynamic amplification when the component contacts the snubber.
- Metal-to-metal contact between snubbers and the supporting frame or between the isolator housing and the mounting bolt to the unit should be avoided. The snubbers should have an elastomeric or resilient surface to lessen the impact effects during strong shaking. For housed springs, an elastomeric grommet will prevent hard surface impact.
- Flexible connections must be provided for fuel lines and piping.
- Refer to FEMA 412 *Installing Seismic Restraints for Mechanical Equipment* (2002) and FEMA 414 *Installing Seismic Restraints for Duct and Pipe* (2004) for additional information and details.
- HVAC equipment or other items required for use in a hospital or essential facility would be classified as designated seismic systems and may require engineering calculations, equipment certification and special inspections. Check with the jurisdiction for specific requirements.

MITIGATION EXAMPLES

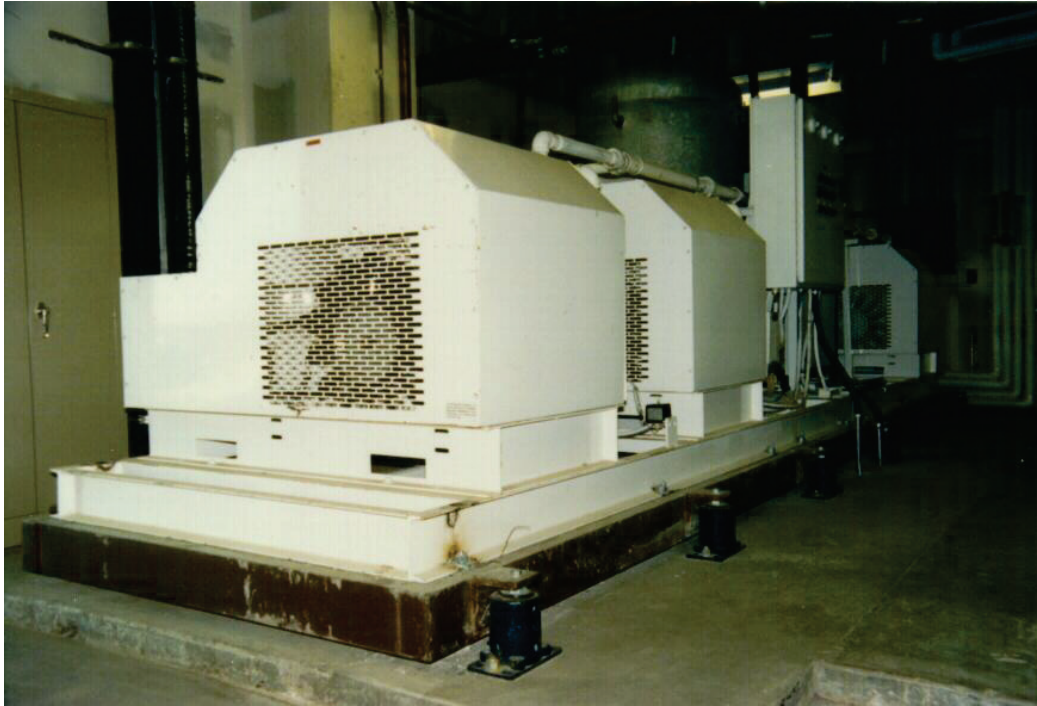


Figure 6.4.1.3-5 Restrainted springs used to support heavy equipment (Photo courtesy of Mason Industries).

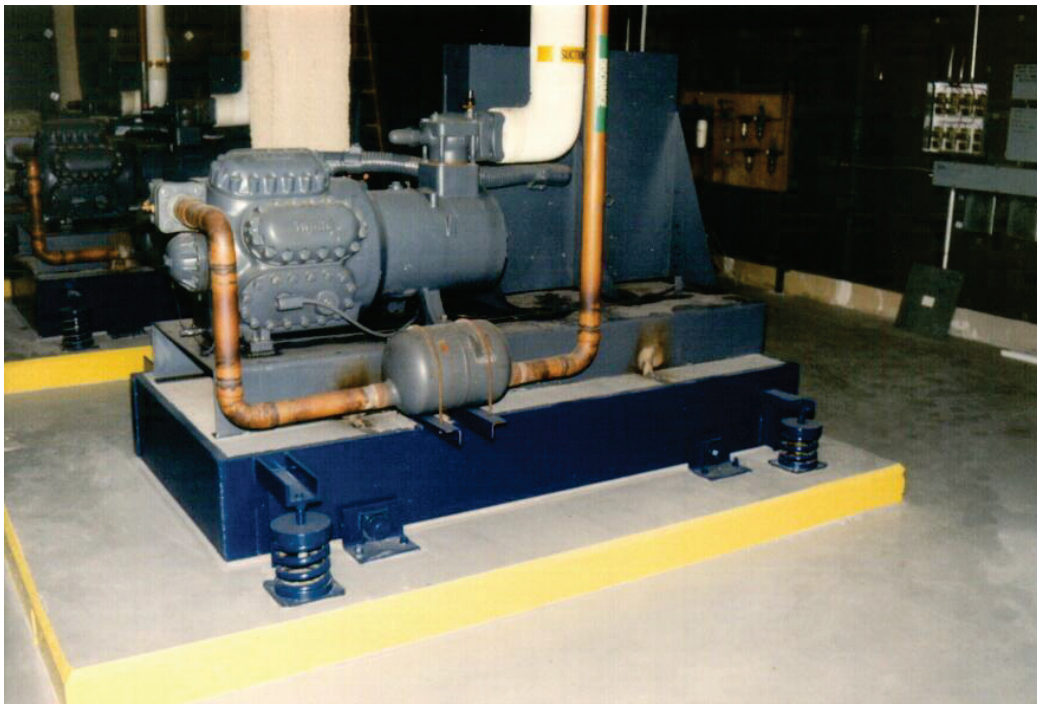
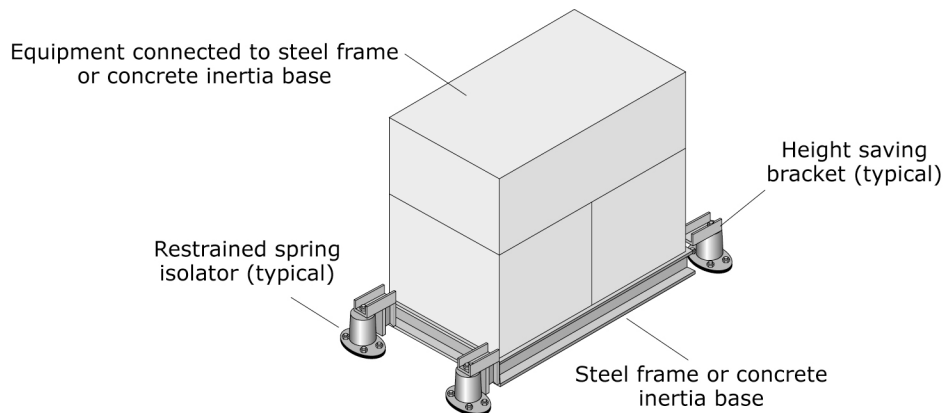


Figure 6.4.1.3-6 Open springs and snubbers used to support equipment (Photo courtesy of Mason Industries).

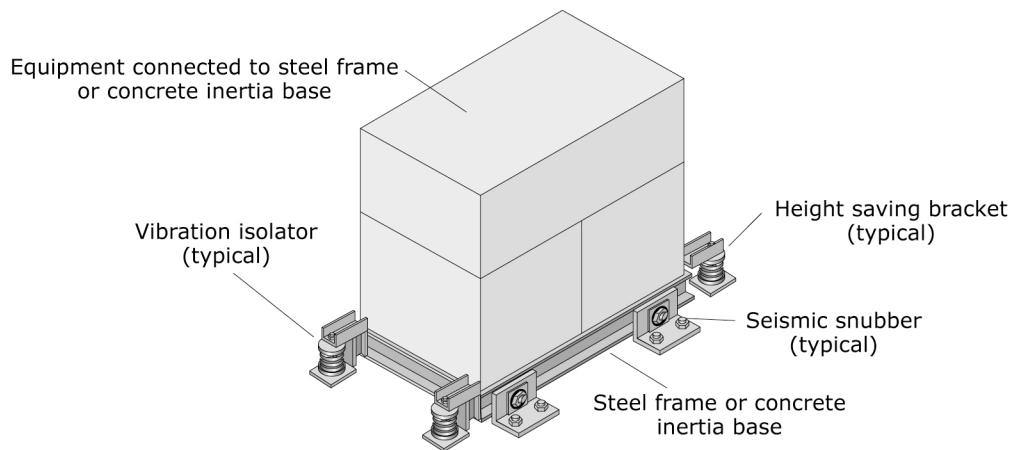


Figure 6.4.1.3-7 Seismic shake table testing of an air-handler unit and vibration isolation restraint system as part of the MCEER-ASHRAE project (Photos courtesy of André Filiatrault, MCEER).

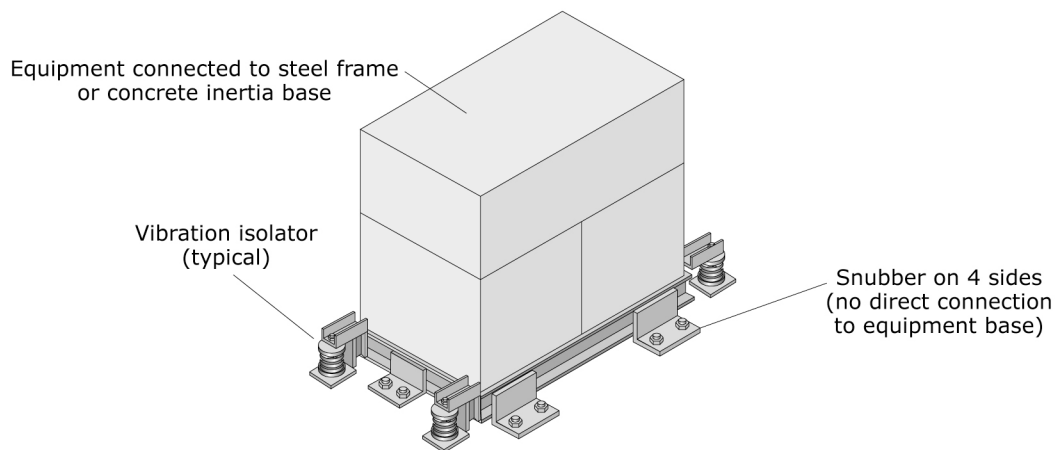
MITIGATION DETAILS



Supplemental base with restrained spring isolators



Supplemental base with open springs and all-directional snubbers



Supplemental base with open springs and one-directional snubbers

Figure 6.4.1.3-8 HVAC equipment with vibration isolation (ER).