

## 6.4 Mechanical, Electrical, and Plumbing Components

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### 6.4.4 Fire Protection piping

#### 6.4.4.1 Suspended Fire Protection Piping

This category covers fire protection sprinkler systems and piping. These systems and piping are subject to the requirements in NFPA 13, *Standard Installation of Sprinkler Systems* (NFPA, 20010a). Fire sprinkler systems may include a number of components besides piping, including pumps, tanks, and control panels. Recommendations for these components are found in the appropriate sections in Chapter 6.

Bracing provisions for fire protection piping were introduced in 1947, making it one of the earliest nonstructural standards to consider lateral bracing. NFPA 13 bracing provisions have developed continuously over time, in response to changes in construction practice and lessons learned from earthquakes. As a result, some fire protection piping systems may appear to be braced, even if installed 50 years ago. Unfortunately, older bracing installations may include features that have been shown to be vulnerable in strong ground shaking.

### Provisions

#### BUILDING CODE PROVISIONS

ASCE/SEI 7–10, *Minimum Design Loads for Buildings*, (ASCE, 2010), Section 13.1.3.1 specifies that systems required for life–safety purposes after an earthquake, such as fire protection systems, be classified as designated seismic systems and designed using a component importance factor,  $I_p$ , of 1.5. Designated seismic systems may require engineering calculations, equipment certification, special inspection, etc. ASCE/SEI 7–10 specifies that fire protection piping conform to NFPA 13, as follows:

- NFPA 13 provides specific requirements for fire suppression systems and piping. Fire protection piping installations conforming to the 2007 or later editions of NFPA 13 may be considered to comply with the requirements of ASCE/SEI 7–10.
- The 2010 edition of NFPA 13 contains prescriptive details and requirements for many aspects of the piping installation, such as hanger size and spacing, clearances between the system and other structural or nonstructural components, and standard bracing installation details. It also contains a simplified method for doing seismic design, based on the concept of “zone of influence,” a method of proportioning forces to bracing

elements that has been in use for decades. Most bracing assemblies for fire protection piping must be listed for a maximum load rating.

## RETROFIT STANDARD PROVISIONS

ASCE/SEI 41–06, *Seismic Rehabilitation of Existing Buildings*, (ASCE, 2007) classifies suspended fire protection piping as both force controlled and displacement controlled. ASCE/SEI 41–06 requires compliance with the anchorage provisions of the standard when the performance level is Life Safety or higher. Rehabilitation, if required, is accomplished by prescriptive approaches to support and bracing, in accordance with NFPA 13.

### Typical Causes of Damage

- Fire protection piping systems are sensitive to both acceleration and deformation. Vulnerable locations include joints, bends, connections to rigidly mounted equipment and risers subjected to significant relative movement between floors.
- Older bracing installations may include details that have performed poorly in past earthquakes, including the use of non–seismically rated power actuated fasteners (shot pins) or drop–in type concrete expansion anchors in bracing applications, which have proven unreliable under seismic loads. Many sprinkler system failures in the 1994 Northridge Earthquake were due to failure of poorly designed braces and brace connections.
- Sprinkler heads are often damaged due to interactions with ceiling systems, especially those with “hard” finishes such as plaster and metal panels. These interactions may also result in impact damage to the ceiling, failure of the sprinkler head, or failure to joints in the piping, with subsequent water damage. Sprinkler heads and sprinkler drops are also damaged by interactions with structural members and other structural braces where inadequate clearance is provided to avoid impact.
- Older systems may lack lateral restraints on the branch lines, which will make the sprinkler heads more vulnerable to interaction with the ceiling system and adjacent structural members.
- Fluids may leak from damaged joints or broken pipe; property losses and business outages are often attributed to fluid leaks from fire suppression piping. Facilities may need to be evacuated if the fire suppression system is compromised.
- Damage to any part of the fire protection system may compromise its functionality. In addition to the piping, pumps, holding tanks, control panels, control sensors, smoke detection equipment, and fire doors must all be operational for the life–safety systems

to function correctly. If a fire breaks out following an earthquake and the fire suppression system is not functional, significant property losses may result.

## DAMAGE EXAMPLES

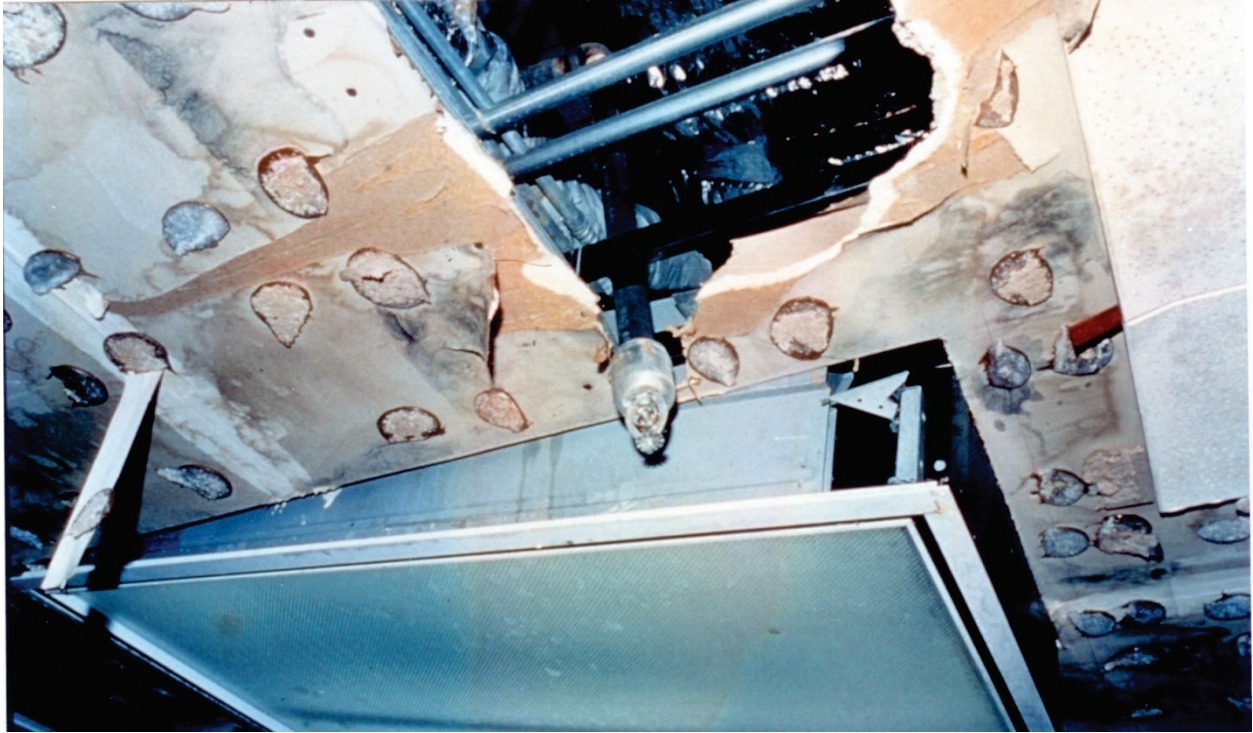


Figure 6.4.4.1-1 Sprinkler pipe ruptured at the elbow joint due to differential motion within the ceiling plenum. Water leakage from broken fire sprinklers and water lines contributed to the decision to close this hospital for several days following the 1994 magnitude-6.7 Northridge Earthquake (Photo courtesy of Robert Reitherman).



Figure 6.4.4.1-2 Wall-mounted pipe restraint failed due to inadequate connection to structural framing in the 2001 magnitude-8.4 Peru Earthquake (Photo courtesy of Eduardo Fierro, BFP Engineers).

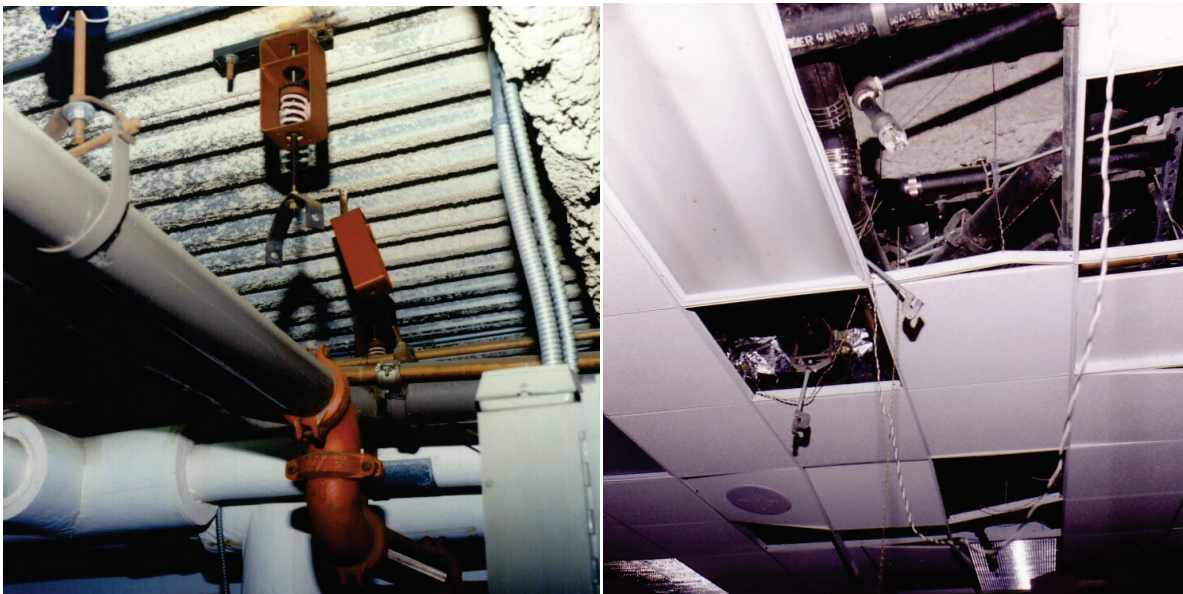


Figure 6.4.4.1-3 Damage to suspended fire protection piping from the 1994 Northridge Earthquake. Failed vibration isolators at left; failed C-clamps without beam clamp restraining straps shown at right (Photos courtesy of Mason Industries).



Figure 6.4.4.1-4 Collapse of water tank at left and broken piping disabled the fire protection system at this power plant in Port-au-Prince and led to the temporary plant closure in the 2010 magnitude-7 Haiti Earthquake (Photo courtesy of Eduardo Fierro, BFP Engineers).



Figure 6.4.4.1-5 Unanchored holding tank slid on concrete pad, breaking fire protection piping and disabling the fire protection system in the 2010 Haiti Earthquake. In this case, the piping was well anchored but the tank was unrestrained (Photo courtesy of Eduardo Fierro, BFP Engineers).



Figure 6.4.4.1-6 Damage to industrial fire protection piping located on jetty in 2001 Peru Earthquake. Longitudinal slip at U-bolt shown at left; this U-bolt still intact but other U-bolts broke and fell off the jetty. Failure of joint coupling and crushing of pipe shown at right (Photo courtesy Eduardo Fierro, BFP Engineers).

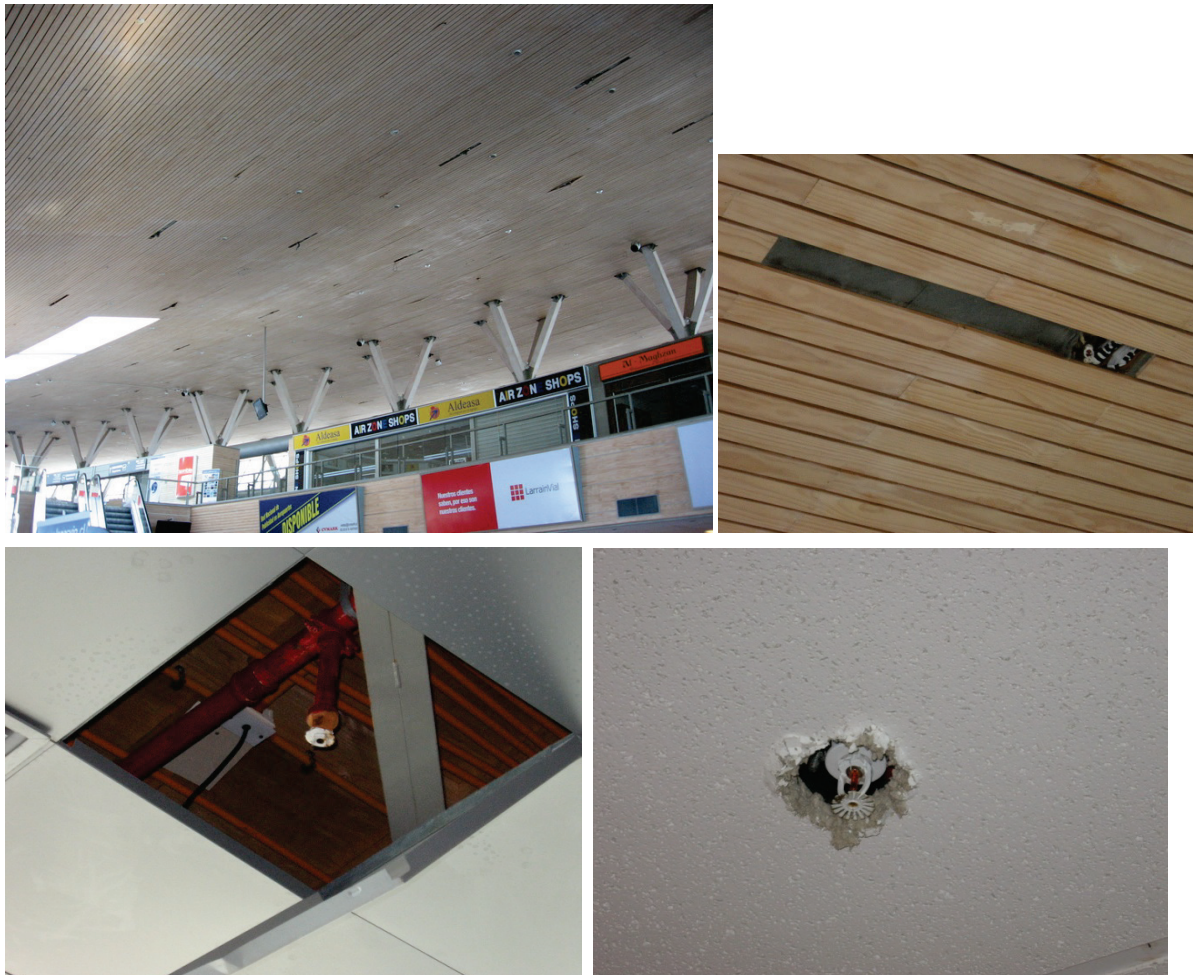


Figure 6.4.4.1-7 Conflicts between the sprinkler heads and several types of ceiling finishes resulted in damage to the ceilings, sprinkler heads and subsequent water damage at the Concepción airport in the 2010 magnitude-8.8 Chile Earthquake (Photos courtesy of Rodrigo Retamales, Rubén Boroschek & Associates).

## Seismic Mitigation Considerations

- Fire suppression systems include many components, all of which must be properly restrained or anchored for the system to function as intended. Pumps, holding tanks, control panels, control sensors, piping and sprinkler heads must all be protected from earthquake damage. In addition to seismic restraints for each component, it is important to check for potential conflicts with other structural and nonstructural elements and for falling hazards.
- Performance of fire protection piping systems that already have some bracing can be improved by addressing the vulnerabilities identified in past earthquakes. Many of these issues have been addressed in the 2010 edition of the NFPA 13 seismic provisions. These include:
  - Limits on the lateral brace spacing on mains and cross-mains to limit bending stresses in the piping, which will reduce the likelihood of leaks.
  - Lateral restraint requirements for branch lines. Laterally restraining the branch lines should reduce the potential for adverse interactions between the sprinkler heads and the ceiling system.
  - The prescriptive allowable fastener load tables have been revised to provide design values consistent with current materials standards. The values in previous editions may be unconservative.
  - The prescriptive values for brace assemblies have been revised. The values in previous editions may be unconservative.
- NFPA 13 Chapter 9 contains many prescriptive bracing details for new installations which may be utilized to retrofit existing systems. As an alternative, seismic restraint details for pressure piping shown in Sections 6.4.3.1 through 6.4.3.8 can be adapted for use with fire protection piping. One significant difference is that components, supports, and seismic restraint hardware for fire protection systems must all be certified (UL listed, FM approved, etc.). This requirement also applies to seismic restraint components for fire protection control panels, pumps, and holding tanks.
- Some proprietary systems are available that reduce the vulnerability of sprinkler heads in suspended ceiling grids. One such system provides flexible sprinkler drops so the sprinkler head can move freely with the ceiling grid (see Figure 6.4.4.1-11); this proprietary system has been shake table tested. Another system is an “integrated” ceiling system where the ceiling grid, acoustical panels, lighting, ducts and air diffusers, and sprinkler piping are all shop assembled in modules; this system alleviates the problem of differential movement of the component parts. These types of solutions

may greatly reduce the seismic vulnerability of sprinkler heads. Check the internet for these and other proprietary systems.

- Two details are included here that are unique to fire protection systems. Figure 6.4.4.1–11 provides one type of detail for a sprinkler drop and Figure 6.4.4.1–12 provides a detail for an end of line restraint required for feeds or cross mains.
- Several engineered seismic bracing systems are commercially available and can be customized for most applications. Check the internet for these proprietary systems and whether they are UL listed, OSHPD approved, FM approved, etc. as required.
- For California schools and essential facilities, DSA Policy 10–01, *Plan Submittal Requirements: Automatic Fire Sprinkler Systems (AFSS)* (California Department of General Services, 2010b), states that as of July 2010, deferred submittals (similar to “design–build” as discussed in Section 5.3.2) for fire protection systems will no longer be accepted. These systems must be submitted as a complete package as part of the initial project submittal.

## MITIGATION EXAMPLES



Figure 6.4.4.1-8 There was no damage to the *fire suppression equipment in this control room in the 2001 Peru Earthquake* because the pump and the control panel were well anchored and the piping had flexible connections with adequate sized wall penetration and no overhead falling hazards (Photo courtesy of Eduardo Fierro, BFP Engineers).

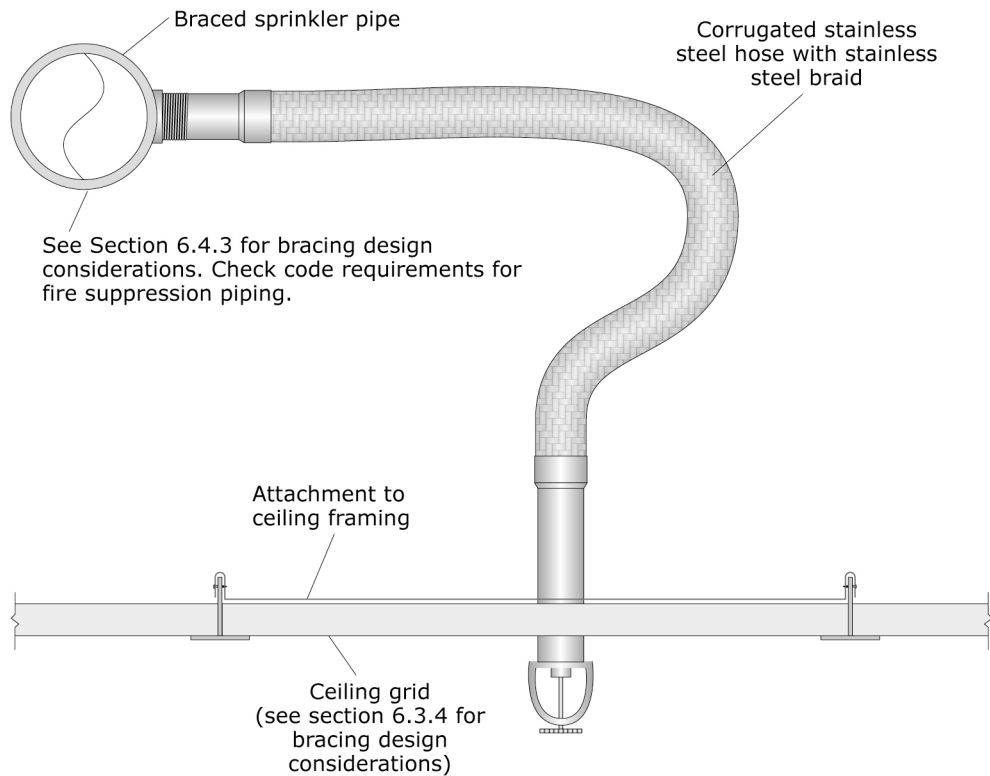


Figure 6.4.4.1-9 Transverse and longitudinal restraints on fire protection distribution line (Photo courtesy of Cynthia Perry, BFP Engineers).



Figure 6.4.4.1-10 Flexible hose between sprinkler line and ceiling allowing the sprinkler head to move with the suspended ceiling without causing damage to the sprinkler system (Photo courtesy of Flexhead).

## MITIGATION DETAILS



**Note:** for seismic design category D, E & F, the flexible sprinkler hose fitting must accommodate at least 1" of ceiling movement without use of an oversized opening. Alternatively, the sprinkler head must have a 2" oversize ring or adapter that allows 1" movement in all directions.

Figure 6.4.4.1-11 Flexible sprinkler drop (ER).

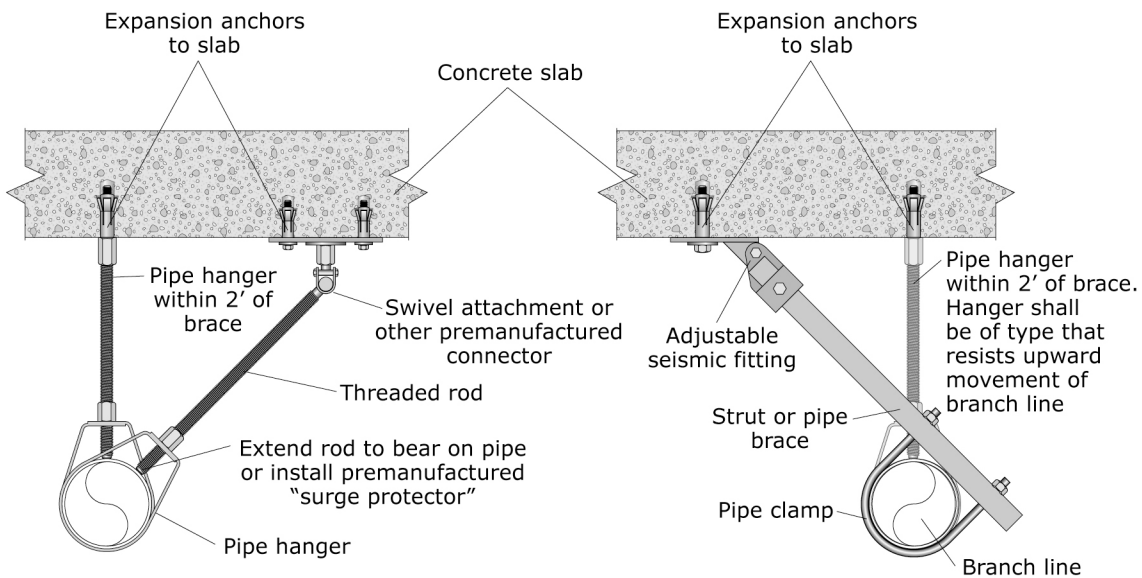


Figure 6.4.4.1-12 End of line restraint (ER).