NFPA 13, 2002 Edition
Seismic Design for Fire Sprinkler Systems

Center for Life Safety Education

American Fire Sprinkler Association
Speaker

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Steven is a principal partner with Scandaliato Design Group, Inc. and a NICET IV Certified Senior Engineering Technician. He has over 19 years experience in fire protection design, covering all types of active and passive life safety systems. Steven has also been involved at every level of construction project management and engineering system design. He serves on the Technical Advisory Committee for the American Fire Sprinkler Association and is a member of the NFPA 13 and 5000/101 Committees. Steven has become a nationally recognized speaker on fire suppression system design and engineering. He is published in several periodicals including articles for the NFPA Journal and Fire Marshals Quarterly and is currently a contributing author to the new text being published by NFPA/SFPE entitled, “Sprinkler Design For Engineers”. Over the last 10 years, he has instructed thousands in contracting and professional associations including the American Fire Sprinkler Association, AIA, Society of Fire Protection Engineers, American Society of Plumbing Engineers and the International Fire Marshals Associations across the country. He is a member of NFPA, SFPE and AFSA.
Agenda

- Seismic Design for Automatic Sprinkler Systems
- Seismic Design and the Codes
- Seismic Design and Shop Drawings
- Seismic Design and Structural Applications
- Practice Example
Seismic Design for Sprinkler Systems

- Automatic Sprinkler Systems
  - History and Development

- Committee Comments on EQ Bracing

- Theory and Purpose for EQ Bracing
Automatic Sprinkler Systems

History and Development

1. Guidance was first included in NFPA in 1947
2. Major modifications following the San Fernando quake in 1971, the Loma Prieta in 1989 and the Northridge in 1994
3. Most of the criteria is found in Chapter 9-3 and the appendix.
4. New federal acts and requirements that have been enacted
Seismic Design for Sprinkler Systems

- Automatic Sprinkler Systems
  - Purpose for Earthquake Bracing
    Overall objective of NFPA 13 to Prevent Damage.
    1. Minimize stresses in piping that would result in damage by providing flexibility and clearances at points where the building is expected to move during an earthquake.
    2. Minimize damaging forces by keeping the piping fairly rigid when supported from a building component expected to move as a unit during an earthquake; such as a floor/ceiling assembly.
Seismic Issues for Sprinkler Systems
Seismic Issues for Sprinkler Systems
Seismic Design for Sprinkler Systems

- Automatic Sprinkler Systems
  - Committee Comments from NFPA and Factory Mutual
  1. See sections 9-3 of the NFPA 13 Handbook
  2. Common sources of water damage were broken or separated overhead sprinkler piping, broken sprinklers due to impact with nearby structural members or other equipment, broken sprinklers or pipe drops due to excessive differential movement between unbraced suspended ceilings and the pipe drops, and broken in-rack sprinkler system piping or sprinklers due to excessive rack movement.
Seismic Design for Sprinkler Systems

- Automatic Sprinkler Systems
  - Committee Comments from NFPA and Factory Mutual

3. In addition to damage from water leakage, fire protection systems are often impaired due to direct damage to the systems, or due to damage to public water supplies or utilities needed for fire protection. Significant impairments to fire protection systems may expose a facility to a severe fire loss following an earthquake.
Seismic Design for Sprinkler Systems

- Automatic Sprinkler Systems
  - Committee Comments from NFPA and Factory Mutual

In evaluating the many incidents of damage, two conclusions are very apparent:

1. Only by providing in a systematic manner the necessary features which incorporate sway bracing, flexibility, clearances and anchorage where needed can a fire protection system be adequately protected to mitigate potential damage from earthquakes.
Seismic Design for Sprinkler Systems

- Automatic Sprinkler Systems
  - Committee Comments from NFPA and Factory Mutual

In evaluating the many incidents of damage, two conclusions are very apparent:

2. Omission of only a few of the critical components necessary for adequate earthquake protection may create conditions where significant earthquake damage may result in substantial water damage.

The necessary shutdown of the system to stop further damage also creates a fire protection system impairment.
Seismic Issues for Sprinkler Systems
Seismic Design for Sprinkler Systems

- Codes
  - Fire Codes

1. UFC
2. IFC
3. NFPA
Seismic Design for Sprinkler Systems

Codes

Building Codes

1. UBC

2. IBC

3. NFPA (5000)
Seismic Design for Sprinkler Systems

Codes

Building Codes

1. IBC 1614: Earthquake Loads – General

Every structure, and portion thereof, shall as a minimum, be designed and constructed to resist the effects of earthquake motions and assigned a seismic design category as set forth in Section 1616.3. Structure determined to be in Seismic Design Category ‘A’ need only comply with Section 1616.4 (structural components only).
Seismic Design for Sprinkler Systems

✓ Codes

✓ Building Codes

Two exceptions exempting sprinkler systems from earthquake protection.

1. Very low ground acceleration (mapped)

2. Building falls into Seismic Design Category A or B which can only be determined after step by step evaluation.
Seismic Design for Sprinkler Systems

ν Codes

ν Building Codes

6 Exceptions:

1. Structures designed in accordance with provisions from ASCE 7 are permitted.

2. Detached on and two family dwellings per Section 101.2 in Seismic Design Categories A, B and C or located where the mapped short-period spectral response acceleration, $S_s$ is less than 0.4g are exempt from the requirements of Sections 1613 through 1622.
Seismic Design for Sprinkler Systems

Codes

Building Codes

6 Exceptions: con’t.

3. The seismic-force-resisting system of wood frame buildings that conform to the provisions of Section 2308 are not required to be analyzed as specified in Section 1616.1.

4. Agricultural storage structures intended only for incidental human occupancy are exempt from the requirements of Sections 1613 through 1623.
Seismic Design for Sprinkler Systems

Codes

Building Codes

6 Exceptions: con’t.

5. Structures located where “mapped” short-period spectral response acceleration, $S_s$, determined in accordance with Section 1615.1 is less than or equal to 0.15g and where the “mapped” spectral response acceleration at 1-second period $S_1$ determined in accordance with Section 1615.1 is less than or equal to 0.04g shall be categorized as Seismic Design Category A. Seismic Design Category A structures need only comply with Section 1616.4.
Codes

Building Codes

6 Exceptions: con’t.

6. Structures located where the short-period “design” spectral response acceleration, $S_s$, determined in accordance with Section 1615.1 is less than or equal to 0.167g and the “design” spectral response acceleration at 1-second period $S_1$ determined in accordance with Section 1615.1 is less than or equal to 0.04g shall be categorized as Seismic Design Category A. Seismic Design Category A structures need only comply with Section 1616.4.
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Codes

- Special Requirements

1. Factory Mutual

2. Federal Government (DOD, DOE, DOT, COE)

3. State & Local AHJ
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Shop Drawings

NFPA Text (Chapter 9.3 ‘02ed)

1. Couplings
2. Separation
3. Clearance
4. Sway Bracing
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Couplings - Section 9.3.1.1 & .2

New section added to 2002.

.1 9.3 does not tell you when it is required. It tells you that when required HOW to design and install it.

.2 System may be exempted if a PE proves that the systems performance with regard to seismic forces will be equal to or greater than that of the building that it is installed in.
Couplings - Section 9.3.2

Listed flexible pipe couplings joining grooved end pipe shall be provided as flexure joints to allow individual sections of piping 2 1/2” (64 mm) or larger to move differentially with the individual sections of the building to which it is attached.

(Continued)
Couplings - Section 9.3.2

Couplings shall be arranged to coincide with structural separations within a building. Systems having more flexible couplings than required here shall be provided with additional sway bracing as required in 9-3.5.3.6. The flexible couplings shall be installed as follows:
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(1) Within 24 in. (610 mm) of the top and bottom of all risers.

Exception No.1: In risers less than 3 ft. (0.9 m) in length, flexible couplings are permitted to be omitted.

Exception No.2: In risers 3 to 7 ft. (0.9 to 2.1 m) in length, one flexible coupling is adequate.
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Note to Detail A: The four-way brace should be attached above the upper flexible coupling required for the riser and preferably to the roof structure if suitable. The brace should not be attached directly to a plywood or metal deck.
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(2) *Within 12 in. (305 mm) above and within 24 in. below the floor in multistory buildings. When the flexible coupling below the floor is above the tie-in main to the main supplying the floor, a flexible coupling shall be provided on the vertical portion of the tie-in piping.
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If dimension is less than 3 ft (0.9 m), flexible fitting is not needed.

(A T-connection fitting with flexible joints can be substituted for elbow.)
Seismic Design for Sprinkler Systems
Seismic Design for Sprinkler Systems
Seismic Design for Sprinkler Systems

(3) On both sides of concrete or masonry walls within 1 ft. of the wall surface. Unless clearance around the pipe is provided in accordance with 9-3.4.
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(4) Within 24 in. of building expansion joints.

(5) Within 24 in. (610 mm) of the top and bottom of drops to hose lines, rack sprinklers and mezzanines, regardless of pipe size.

(6) Within 24 in. (610 mm) of the top of drops exceeding 15 ft. (4.6 m) in length to portions of systems supplying more than one sprinkler, regardless of pipe size.

(7) Above and below any intermediate points of support for a riser or other vertical pipe.
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Separation - Section 9.3.3

Seismic separation assemblies with flexible fittings shall be installed where sprinkler piping, regardless of size, crosses building seismic separation joints above ground level.
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Plan

- 2 ells
- 10 in. (254 mm) long nipple C
- 10 in. (254 mm) long nipple D
- 8 in. (203 mm)
- Normal position
- Fire sprinkler main
- 2 ells and nipple E

Elevation

- Coupling B
- Fire sprinkler main
- Nipple E
- 2 ell lengths
- 8½ in. (216 mm) for 3-in. (76-mm) pipe
- 7½ in. (191 mm) for 2½-in. (63-mm) pipe

Longitudinal movement

- 4 in. (102 mm)

Horizontal Views

- 4 in. (102 mm)
- Normal position
- 8 in. (203 mm)
PLAN

SIZING & DISTANCES SHALL BE PER NFPA 13 SEISMIC REQUIREMENTS

ISOMETRIC

ELEVATION (NOT ROTATED)

SEISMIC SEPERATION ASSEMBLY DETAIL

SCALE: NONE
Nice try!
Clearance - Section 9.3.4

Clearance shall be provided around all piping extending through walls, floors, platforms, and foundations, including drains, fire department connections, and other auxiliary piping.
9.3.4.5 (New – incorporated exceptions) If you do not meet at least one of the following sections, then you must provide a hole that is a minimum of 2” (nominal) larger than the pipe for pipe sizes 1” - 3” and 4” (nominal) larger than the pipe for pipe sizes 4” and larger.

Example: A 2” pipe will require a 4” hole.
A 4” pipe will require a 8” hole.
9.3.5.1.1 The system piping shall be braced to resist both lateral and longitudinal seismic loads and to prevent vertical motion resulting from seismic loads. The structural components to which bracing is attached shall be determined to be capable of carrying the added applied seismic loads.

9.3.5.2.1 Sway braces shall be designed to withstand forces in tension and compression.

9.3.5.2.2.* Tension only bracing systems shall be permitted for use where listed for this service and where installed in accordance with their listing limitations, including installation instructions.
PLAN VIEW

NOTE: REFER TO SPECIFICATIONS, LOOS & CO., INC. MANUAL AND TABLES FOR BRACE SPACING, REQUIRED BRACE LOADS, LOAD CALCULATION PROCEDURES, SIZING, AND ALLOWABLE LOADS ON BRACE ASSEMBLIES AND FASTENERS.

LONGITUDINAL BRACE FOR PIPING and CONDUIT
Seismic Design for Sprinkler Systems

9.3.5.3.1 Lateral sway bracing spaced at a maximum interval of 40 ft. (12.2 m) on center shall be provided on all feed and cross mains regardless of size and all branch lines and other piping with a diameter of 2 1/2 in. (63.5 mm) and larger.

9.3.5.3.2 The distance between the last brace and the end of the pipe shall not exceed 20 ft. (6.1 m). This requirement shall not preclude the use of a lateral brace serving as a longitudinal brace as described in this paragraph.

9.3.5.3.4 The last length of pipe at the end of a feed or cross main shall be provided with a lateral brace.

9.3.5.3.5 Lateral braces shall be allowed to act as longitudinal braces if they are within 24 in. (610 mm) of the centerline of the piping braced longitudinally for lines that are 2 1/2 in. (76 mm) and greater in diameter.
TOLCO FIG. 909 (2)

TOLCO FIG. 1000
"FAST CLAMP"®

TOLCO FIG. 907

3” MAX

4 WAY EARTHQUAKE BRACE

LATERAL/LONGITUDINAL EARTHQUAKE BRACE
Longitudinal brace can serve as lateral brace for cross main if connections are strong enough.

Longitudinal brace needed for Detail A, Figure A-414.4.3.2(a). May be needed for other details to take load off riser brace.

Lateral brace (two-way)

Four-way brace

40 ft (12 m)

40 ft (12 m)
9.3.5.3 Where the spacing of lateral branches is permitted to be up to 50 ft. (7.6 m), the distance between the last brace and the end of the pipe is permitted to be extended to 25 ft. (1.2 m). 

9.3.5.3.7 Lateral sway bracing shall not be required on pipes individually supported by rods less than 6 in (152 mm) long measured between the top of the pipe and the point of attachment to the building structure.
9.3.5.3.6: Where flexible couplings are flexible couplings are installed on mains other than as required in 6-4.2, a lateral brace shall be provided within 24 in. (610 mm) of every other coupling, but not more than 40 ft. (12 m) on center.

9.3.5.3.8: U-type hooks of the wrap-a-round type or those U-type hooks arranged to keep the pipe tight to the underside of the structural element shall be permitted to be used to satisfy the requirements for lateral sway bracing provided the legs are bent out at least 30 degrees from the vertical and the maximum length of each leg and the rod size satisfies the conditions of Tables 9.3.5.8.9 a,b & c.
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9-3.5.4.1 Longitudinal sway bracing spaced at a maximum of 80 ft. (24 m) on center shall be provided for feed and cross mains.

9.3.5.4.2 Longitudinal braces shall be permitted to serve as lateral braces where they are install within 24 in. (609 mm) of the piping that is braced laterally.

9.3.5.4.3 The distance between the last brace and the end of the pipe shall not exceed 40 ft. (12.2 m).
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9.3.5.5*  Risers
9.3.5.5.1  Tops of risers shall be secured against drifting in any direction, utilizing a four-way sway brace.

9.3.5.5.2  Distance between four-way braces for risers shall not exceed 25ft.

9.3.5.5.3  Four-way bracing shall not be required where risers penetrate intermediate floors in multistory buildings where the clearance does not exceed the limits of 9.3.4.
9.3.5.6* Horizontal Force Factors

9.3.5.6.1 Unless the requirements of 9.3.5.6.2 are met, the horizontal loads for braces shall be determined by analysis based on a horizontal force of $F_p = 0.5 \times W_p$, where $F_p$ is the horizontal force factor and $W_p$ is 1.15 times the weight of the water-filled piping.

9.2.5.6.2 Where the use of horizontal force factors other than the horizontal force factor required by 9.3.5.6.1 is required or permitted by the authority having jurisdiction, they shall take precedence.
9.3.5.7 Where the horizontal force factors used exceed 0.5 Wp and the brace angle is less than 45 degrees from vertical or where the horizontal force factor exceeds 1.0 Wp and the brace angle is less than 60 degrees from vertical, the braces shall be arranged to resist the net vertical reaction produced by the horizontal load.
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9.3.5.8* Sway bracing shall be tight. For individual braces, the slenderness ratio \((l/r)\) shall not exceed 300 where \(l\) is the length of the brace and \(r\) is the least radius of gyration. Where threaded pipe is used as part of a sway brace assembly, it shall not be less than Schedule 30. All parts and fittings of a brace shall lie in a straight line to avoid eccentric loading on fittings and fasteners. For longitudinal braces only, the brace shall be permitted to be connected to a tab welded to the pipe in conformance with 3-6.2. For individual braces, the slenderness ratio, \(l/r\), shall not exceed 300 where \(l\) is the length of the brace and \(r\) is the least radius of gyration. For tension-only braces, two tension-only brace components opposing each other must be installed at each lateral or longitudinal brace location. (Cont.)
For all braces, whether or not listed, the maximum allowable horizontal load shall be based on the weakest component of the brace with safety factors. The loads determined in 9.3.5.6 shall not exceed the lesser of the maximum allowable loads provided in Table 9.3.5.8 or the manufacturer’s certified maximum allowable horizontal loads for 30 to 44 degree, 45 to 59 degree, 60 to 89 degree, and 90 degree brace angles. These certified allowable horizontal loads must include a minimum safety factor of 1.5 against the ultimate break strength of the brace components and then be further reduced according to the brace angles.

(Continued)
9.3.5.8.11 Other pipe schedules and materials not specifically included in Table 6-4.5.8 shall be permitted to be used if certified by a registered professional engineer to support the loads determined in accordance with the above criteria. Calculations shall be submitted where required by the authority having jurisdiction.
9.3.5.9* Fasteners

For individual fasteners, the loads determined in 6-4.5.6 shall not exceed the allowable loads provided in Figure 6-4.5.9. The type of fastener used to secure the bracing assembly to the structure shall be limited to those shown in Figure 6-4.5.9. For connections to wood, through bolts with washers on each end shall be used. Holes for through bolts shall be 1/16 in. (1.6 mm) greater than the diameter of the bolt.

(Continued)
9.3.5.9.4 Where it is not practical to install through bolts due to the thickness of the member or inaccessibility, lag screws shall be permitted. Holes shall be pre-drilled 1/8 in. (3.2 mm) smaller than the maximum root diameter of the lag screw.

9.3.5.9.6 Other fastening methods are acceptable for use if certified by a registered professional engineer to support the loads determined in accordance with the criteria in 6-4.5.9. Calculations shall be permitted where required by the authority having jurisdiction.
9.3.5.10 Assemblies

9.3.5.10.1 Sway bracing assemblies shall be listed for a maximum load rating, unless the requirements of 9.3.5.10.2 are met.

9.3.5.10.2 Where sway bracing utilizing pipe, angles, flats, or rods as shown in Table 6-4.5.8 is used, the components do not require listing. Bracing fittings and connections used with those specific materials shall be listed.
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Restraint – 9.3.6

9.3.6.1 Restraint is considered a lesser degree of resisting loads than bracing and shall be provided by use of one of the following:

1. A listed sway brace assembly.
2. A wrap-a-round U-hook satisfying the requirements of 6-4.5.3, Exception Number 3.
3. No.12, 440 lb (200 kg) wire installed at least 45 degrees from the vertical plane and anchored on both sides of the pipe.
4. Other approved means.

(Continued)
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Wire used for restraint shall be located within 2 ft (60 mm) of a hanger. The hanger closest to a wire restraint shall be of a type that resists upward movement of a branch line.

9.3.6.2 The end sprinkler on a line shall be restrained against excessive vertical and lateral movement.

9.3.6.3 Where upward or lateral movement would result in an impact against the building structure, equipment, or finish materials, branch lines shall be restrained at intervals not exceeding 30 ft (9 m).

9.3.6.5* Sprig ups 4 ft (1.2 m) or longer shall be restrained against lateral movement.
9.3.7.1 C-type clamps (including beam and large flange clamps) used to attach hangers to the building structure in areas subject to earthquakes shall be equipped with a retaining strap. The retaining strap shall be listed for use with a C-type clamp or shall be a steel strap of not less than 16 gauge thickness and not less than 1 in (25.4 mm) wide for pipe diameters 8 in (203 mm) or less and 14 gauge thickness and not less than 1 1/4 in (31.7 mm) wide for pipe diameters greater than 8 in (203 mm). The retaining strap shall wrap around the beam flange not less than 1 in (25.4 mm). A lock nut on a C-type clamp shall not be used as a method of restraint. A lip on a “C” or “Z” purlin shall not be used as a method of restraint. Where purlins or beams do not provide an adequate lip to be secured by a retaining strap, the strap shall be through-bolted or secured by a self-tapping screw.
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9.3.7.7  C-type clamps (including beam and large flange clamps), with or without retaining straps, shall not be used to attach braces to the building.

9.3.7.8  Power-driven fasteners shall not be used to attach braces to the building structure, unless they are specifically listed for service in resisting lateral loads in areas subject to earthquakes.

9.3.7.9: In areas where the horizontal force factor exceeds 0.50 Wp, Powder-driven fasteners shall be permitted to attach hangers to the building structure where they are specifically listed for use in areas subject to earthquakes.
Seismic Design for Sprinkler Systems

Seismic Design & Layout

Steps to layout and sizing

1. Determine the distance of the piping from the structure.

2. Choose a brace type/shape from Table 9-3.5.8.9 that the maximum l/r ratio does not exceed 300. Remember, the angle of your braces should be at least 30°. Try to make it 45 or more.

3. Determine the total load applied to each brace in accordance with the examples shown in Figure A-9-3.5.6(e).
Seismic Design for Sprinkler Systems

√ Seismic Design & Layout

√ Steps to layout and sizing

a. The loads on lateral braces on cross mains, add one-half (1/2) the weight of the branch to one-half (1/2) the weight of the portion of the cross main within the zone of influence of the brace. (1,3,6,7)

b. For the loads on longitudinal braces on cross mains, consider only one-half (1/2) the weight of the cross mains and feed mains within the zone of influence. Branchlines do not need to be included. (2,4,5,7,8)
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Seismic Design & Layout

Steps to layout and sizing

c. For the four-way brace at the riser, add the longitudinal and lateral loads within the ZOI of the brace (2,3,5). For the four-way at the top of the riser, half the weight of the riser should be assigned to both the lateral and longitudinal loads as they are separately considered.

4. If the total expected loads are less than the maximums permitted in Table 6-4.5.8 for the particular brace and orientation, go on to step 5. If not, add additional braces to reduce the ZOI.
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✓ Seismic Design & Layout

✓ Steps to layout and sizing

5. Check that fasteners connecting the braces to structural supporting members are adequate to support the expected loads on the braces in accordance with Table 6-4.5.8. If not, again add additional braces or additional means of support.
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A Exercise #1 – Bracing Layout