FIRE PROTECTION PIPING SYSTEMS

S13.1 – Introduction:

Historically the ICC (2000, 2003, 2006, and 2009 IBC) and the NFPA (NFPA 5000) have been competing code writing bodies, and there have been some conflicts between the two. However, ASCE/SEI 7-98, -02, and -05 have been recognized as a reference standard in NFPA-13 which is the standard most often accepted as the code for fire protection systems by local jurisdictions. Therefore, this section will be based on the provisions found in ASCE/SEI 7-05 and NFPA 13 2007 Edition.

S13.2 –ASCE/SEI 7-05 Sections 13.6.8.2 & 13.6.8.3 Fire Protection Piping:

S13.2.1 – Section 13.6.8.2 Seismic Design Category C:

For buildings assigned to Seismic Design Category C, the fire protection sprinkler systems will meet the requirements of Chapter 13 of ASCE/SEI 7-05 if they are designed and constructed in accordance with NFPA 13.

S13.2.2 – Section 13.6.8.3 Seismic Design Categories D through F:

For buildings assigned to Seismic Design Categories D through F, the following requirements for the seismic restraint of fire sprinkler systems must be met.

1. The hangers and seismic restraints of the fire protection piping will meet the requirements of Chapter 13 of ASCE/SEI 7-05 if:
   a. The hangers and seismic restraints are designed and constructed in accordance with NFPA 13.
   b. The hangers and seismic restraints must meet the force and displacement requirements of Sections 13.3.1 and 13.3.2 of ASCE/SEI 7-05.

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2. The piping in the fire protection system must meet the force and displacement requirements of ASCE/SEI 7-05 Sections 13.3.1 and 13.3.2.

13.3 – Design Horizontal Seismic Force:

It is appropriate to discuss the design horizontal seismic force at this point because it will help explain the wording in ASCE/SEI 7-05. From Section S5.0 of this manual, the design seismic force from ASCE/SEI 7-05 is;

$$F_P = \frac{0.4 a_P S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)} \left(1 + 2\frac{z}{h}\right)$$ **Equation S13-1**

The maximum and minimum values for the design horizontal seismic force will be respectively;

$$F_P = 1.6 S_{DS} I_P W_P$$ **Equation S13-2**

$$F_P = 0.3 S_{DS} I_P W_P$$ **Equation S13-3**

Where:

F_P = the design horizontal seismic force acting on a pipe or duct acting at its center of gravity.

S_{DS} = the short period design spectral acceleration.

a_P =the component amplification factor. This factor is a measure of how close to the natural period of the building the natural period of the component is expected is expected to be. Typically this will vary from 1.0 to 2.5, and is specified by component type in ASCE/SEI 7-05 and listed in Table S5-3.

I_P = the component importance factor which be either 1.0 or 1.5.

W_P = the operating weight of the pipe or duct that is being restrained.

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R_P = the response modification factor which usually will vary from 1.0 to 12.0. This factor is a measure of the ability of the component and its attachments to the structure to absorb energy. It is really a measure of how ductile or brittle the component and its attachments are. The values are specified by component type in ASCE/SEI 7-05 and listed in Table S5-3.

z = the structural attachment mounting height of the pipe or duct hanger in the building relative to the grade line of the building.

h = the average height of the building roof as measured from the grade line of the building.

Contrast this to the design horizontal seismic force described in NFPA 13 Section 9.3.5.6.2.

$$F_{pw} = C_P W_{pw}$$ **Equation S13-4**

Where:

F_{pw} = the design horizontal seismic force per NFPA 13

C_P = the seismic coefficient, see Table S13-1 for these values to use with NFPA 13.

$W_{pw} = 1.15 W_P$ The factor of 1.15 that multiplies the weight of the pipe is intended to account for the additional weight of all of the valves, fittings, and other devices in the system that would be attached to the pipe.

It is important to note that according to NFPA 13 Section A.9.3.5.1.3, all horizontal loads in NFPA 13 are given at ASD levels, while all seismic design loads in ASCE/SEI 7-05 are specified at LRFD levels. Recalling that ASD values are 1.4 times lower than LRFD values, comparing Equations S13-1 and S13-4, and ignoring the 1.15 factor that multiplies W_P in NFPA 13 will show that;

$$C_P = \frac{0.4 a_P S_{DS}}{1.4\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{z}{h}\right)$$ **Equation S13-5**

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Table S13-1; Seismic Coefficient Table – ASD Levels [NFPA 13 Table 9.3.5.6.2]

Mapped Short Period Acceleration S_S	Seismic Coefficient C_P ASCE 7-05 Values Have Been Converted to ASD Levels	
	NFPA 13	ASCE 7-05
0.33	0.31	0.24
0.50	0.40	0.33
0.75	0.43	0.43
0.95	0.50	0.51
1.00	0.52	0.52
1.25	0.60	0.60
1.50	0.71	0.71
2.00	0.95	0.95
2.40	1.14	1.14
3.00	1.43	1.43

In Table S13-1, the ASCE 7-05 values have been calculated based on the following information.

1. Site Class D has been assumed as the default Site Class.
2. $I_P = 1.5$ – All fire protection piping systems have been designated as Life Safety Systems by both NFPA 13 and ASCE/SEI 7-05.
3. $a_P = 2.5$ – This value is specified in NFPA 13 Section A.9.3.5.6.1 for steel piping systems.
4. $R_P = 4.5$ – This value is specified in NFPA 13 Section A.9.3.5.6.1 for steel piping systems.
5. $\left(1 + 2\frac{z}{h}\right) = 3$ – The hangers for the fire protection piping are assumed to be attached to the building at or close to the roof line.

Except for the first two instances where S_S is less than or equal to 0.33 and is equal to 0.50 , NFPA 13 and ASCE/SEI 7-05 appear to be in very close agreement as far as the design

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horizontal seismic forces are concerned. This is probably the reason for the provisions in Sections 13.6.8.2 and 13.6.8.3 of ASCE/SEI 7-05. For the purposes of this manual it will be convenient to have the C_P values in Table S13-1 expressed at LRFD levels, see Table 13-2. This will allow the seismic restraints and other components provided by Kinetics Noise Control to be directly selected from the design selection tables in this manual. Keep in mind that the design values in Tables S13-1 and S13-2 will not be valid for the CPVC plastic fire piping.

Table S13-2; Seismic Coefficient Table – LRFD Levels [NFPA 13 Table 9.3.5.6.2]

Mapped Short Period Acceleration S_S	Seismic Coefficient C_P NFPA 13 Values Have Been Converted to LRFD Levels	
	NFPA 13	ASCE 7-05
0.33	0.43	0.34
0.50	0.56	0.47
0.75	0.60	0.60
0.95	0.70	0.71
1.00	0.73	0.73
1.25	0.84	0.83
1.50	0.99	1.00
2.00	1.33	1.33
2.40	1.60	1.60
3.00	2.00	2.00

A safe “Rule of Thumb” to follow for selecting seismic restraints for fire protection piping is, when

$$S_S \le 0.50$$

$$C_P = 0.56$$

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13.4 – Cable Type "Tension Only" Seismic Restraints:

In NFPA 13 seismic restraints are called sway braces, and they must be designed and installed to withstand both tension and compression per NFPA 13 Section 9.3.5.2.1. Typically in the past the seismic restraints that have been specified and designed for NFPA 13 applications have been strut type restraints. However, "tension only" sway bracing is permitted; see NFPA 13 Sections 9.3.5.2.2 and 9.3.5.8.6. This type of bracing refers specifically to cable type seismic restraints. Two cables must be installed for each seismic restraint type and location, one directly opposite the other to fulfill the requirements of NFPA 13 Section 9.3.5.2.1 mentioned above. Also, per NFPA 13 Section 9.3.5.8.1, the restraint cables used for the "tension only" bracing must be tight.

Per NFPA 13 Section 9.3.5.2.2 cable type, "tension only", restraints are to be listed for use on fire suppression piping systems. This listing is typically performed by two recognized agencies, Underwriter's Laboratories (UL) and FM Approvals (Factory Mutual Global).

According to NFPA 13 Sections A9.3.5.2.2 and A9.3.5.3.1, the terms brace assembly and restraint assembly will refer to;

1. The restraint cable assemblies which are made up of the cables and the parts required to make the cable loops or other connections to mounting brackets or other components required to attach the restraint cable assemblies to the building..
2. The mounting brackets or other components required to attach the restraint cable assemblies to the pipe and the building structure.
3. The fasteners required to attach the mounting brackets or components to the pipe and building.

NFPA 13 Section A9.3.5.2.2 states that the use of cable type restraints or "tension only" bracing requires the consideration of the following items.

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1. Corrosion resistance of the restraint assemblies.
2. Pre-stretch of the cable to obtain a verifiable elastic modulus, and to avoid permanent stretch during installation which may produce permanent slack in the cables.
3. The restraints assemblies will require some verifiable means of field identification of the restraint assembly size and capacity, such as color coding.
4. The capacity of all of the components in the restraint assemblies and fields connections to verify and maintain the manufacturer's minimum certified breaking strength.
5. Manufacturer's published product design data/manual and literature to include;
   a. Product design and installation guidelines.
   b. Connection details.
   c. Load calculation procedures.
   d. Maximum horizontal load carrying capacity of the restraint assemblies.
   e. Special tools or precautions needed to ensure proper installation.
6. Manufacturer's restraint assembly shipments should include;
   a. Certification of the maximum breaking strength.
   b. Certification of the proper pre-stretch.
   c. Installation instructions, including notification of any special tools or procedures required to complete a proper installation.
7. A means, device or procedure, to prevent vertical motion under the action of seismic forces, as required.

13.5 – Zone of Influence Defined:

Zone of influence is a term that is peculiar to the seismic restraint of fire protection piping. Each seismic restraint, either transverse or longitudinal, is designed or selected to restrain a certain length of pipe. This length of pipe may have other smaller pipes unrestrained which join it, or are tributary to it, whose weight will also be restrained by the seismic restraints on the larger pipe. It is these smaller unrestrained pipes that compose the zone of influence for the seismic restraints on the larger pipe. This concept will be part of several of the NFPA 13 provisions discussed below.

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The transverse seismic restraints will act as longitudinal seismic restraints for the line which are tributary to that transverse seismic restraint. Conversely, the longitudinal seismic restraints will act as transverse seismic restraints for the line which are tributary to that longitudinal seismic restraint. The concept of the Zone of Influence is illustrated in Figure S13-1 below. For a discussion on Kinetics Noise Control's pipe and duct seismic restraint drawing symbols, please see Section S7-7 of this manual. The transverse seismic restraint shown in the middle of Figure S13.1 restrains the weight of the cross main on either side of the transverse restraint for a distance equal to one half the transverse seismic restraint spacing S_T. The branch lines that are tributary to, intersect, the cross main out to a distance equal to one half the transverse seismic restraint spacing on either side of the transverse restraint, shown in the cloud, are in the zone of influence for that transverse seismic restraint.

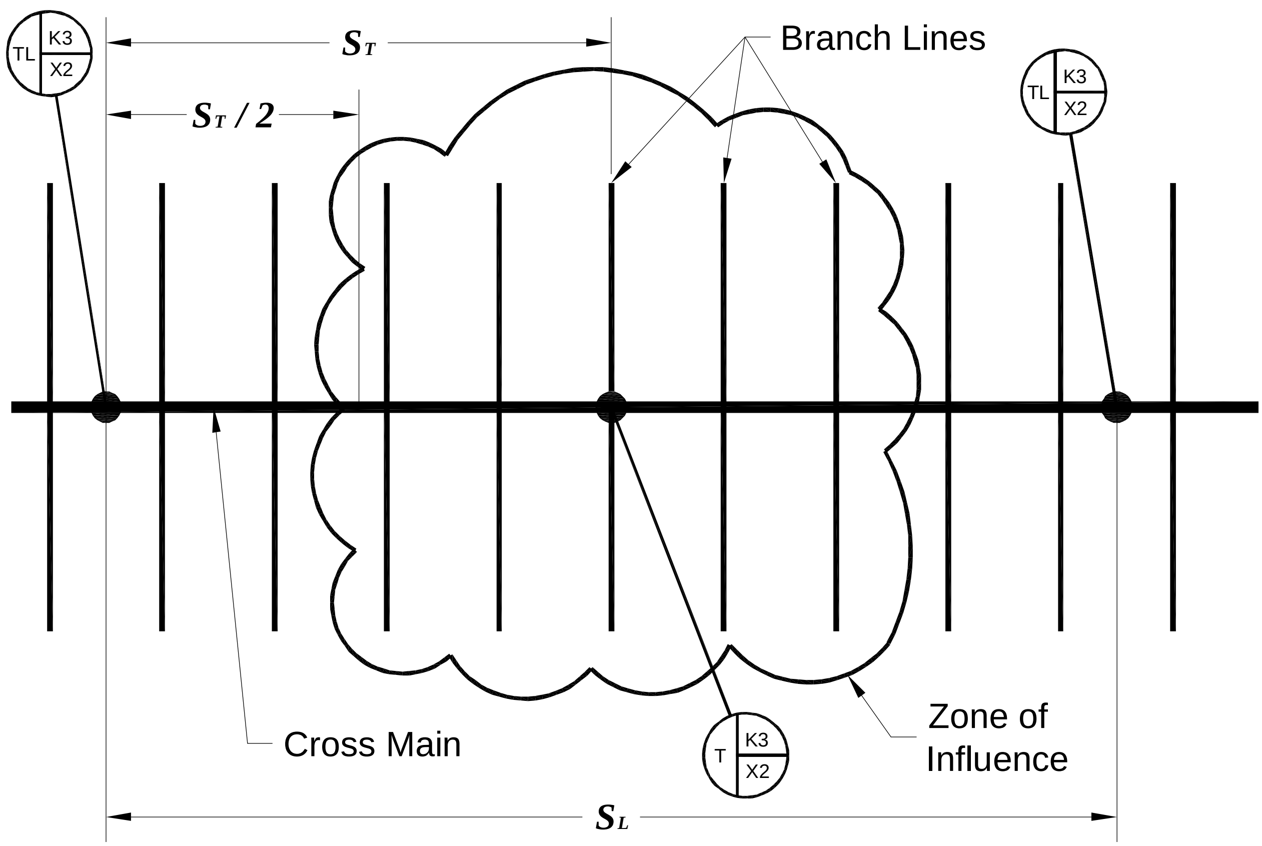

Figure S13-1; Definition of Zone of Influence

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13.6 – Longitudinal Seismic Restraints – NFPA 13 Sections 9.3.5.4, 9.3.5.6, 9.3.5.8, and A.9.3.5.6:

Section 9.3.5.4.1 – Need for Longitudinal Seismic Restraints:

1. Longitudinal seismic restraints are to be provided for all feed and cross main lines. The implication here is that branch lines do not need to have longitudinal seismic restraints. Their weight will fall into the zone of influence for the transverse seismic restraints on the pipe to which they are tributary.
2. The maximum allowable spacing for longitudinal sway bracing is 80 feet. Check the maximum allowable seismic restraint spacing tables for the particular type and size of pipe being used on the project. The actual maximum allowable may be less than 80 feet when buckling of the pipe is considered.

Section 9.3.5.4.2 – Longitudinal Seismic Restraints as Transverse Seismic Restraints:

Longitudinal seismic restraints on one pipe may act as transverse seismic restraints on a connecting pipe if they are located with in 2 feet of the centerline of the connecting pipe, and the weight of the connecting pipe has been included in the capacity calculation for the longitudinal restraint.

Section 9.3.5.4.3 – Length of Free Pipe beyond Last Longitudinal Seismic Restraint:

The distance between the last longitudinal seismic restraint and the end of the pipe can not exceed 40 feet.

Sections 9.3.5.6.5 and A.9.3.5.6.(4).(b) – Consideration of the Zone of Influence:

1. For longitudinal seismic restraints the zone of influence needs to consider all mains whose weight will be tributary to the longitudinal seismic restraints.
2. The selection of longitudinal seismic restraints on cross mains will need to consider only the weight of the cross mains and any tributary mains that fall within the zone of influence for the longitudinal seismic restraints.

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Section 9.3.5.8.5 – Attachment of Longitudinal Restraints to Steel Pipe:

For longitudinal restraints only, the restraints may be attached directly to steel pipe with a weld tab.

13.7 – Transverse Seismic Restraints – NFPA 13 Sections 9.3.5.3, 9.3.5.6, and A.9.3.5.6:

Section 9.3.5.3.1 – Need for Transverse Seismic Restraints:

Transverse seismic restraints must be provided on all feed and cross mains of any size, and on branch lines and other piping with a nominal diameter of 2-1/2 inches and larger. So, branch lines and other piping except feed and cross mains will be exempt from the need for transverse seismic restraint if their nominal diameter is less than 2-1/2 inches.

Sections 9.3.5.3.2 and A.9.3.5.6.(4).(a) – Allowable Transverse Seismic Restraint Spacing Considering the Zone of Influence:

1. The spacing of transverse seismic restraints is not to exceed 40 feet.
2. Up to the maximum spacing specified, the spacing for the transverse seismic restraints is to be selected on the basis of the pipe size and the horizontal design seismic load present in the zone of influence for the transverse seismic restraint. For cross mains, the design horizontal seismic force of all of the branch lines in the zone of influence for the transverse seismic restraint must be added to the design horizontal load of the cross main. For steel piping, the transverse seismic restraint spacing may be selected based on the data in Tables S13-3 and S13-4.
3. For a discussion of the zone of influence, see Section S13.5 of this manual.

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Table S13-3; Maximum Allowable Design Horizontal Seismic Load F_{pw} Due to Tributary Lines in a Zone of Influence in Pounds for Schedule 10 Steel Pipes [NFPA 13 Table 9.3.5.3.2(a)]

Nominal Pipe Size (in)	Transverse Seismic Restraint Spacing S_T (ft)							
	20		25		30		40	
	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
1	120	168	96	134	79	111	56	78
1 1/4	190	266	152	213	125	175	89	125
1 1/2	260	364	208	291	170	238	122	171
2	420	588	336	470	275	385	198	277
2 1/2	690	966	552	773	452	633	325	455
3	1,040	1,456	832	1,165	682	955	489	685
3 1/2	1,380	1,932	1,104	1,546	904	1,266	649	909
4	1,760	2,464	1,408	1,971	1,154	1,616	828	1,159
5	3,030	4,242	2,424	3,394	1,986	2,780	1,425	1,995
6 Over 6	4,350	6,090	3,480	4,872	2,851	3,991	2,046	2,864

Table S13-4; Maximum Allowable Design Horizontal Seismic Load F_{pw} Due to Tributary Lines in a Zone of Influence in Pounds for Schedule 40 Steel Pipes [NFPA 13 Table 9.3.5.3.2(b)]

Nominal Pipe Size (in)	Transverse Seismic Restraint Spacing S_T (ft)							
	20		25		30		40	
	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
1	130	182	104	146	85	119	61	85
1 1/4	230	322	184	258	151	211	108	151
1 1/2	330	462	264	370	216	302	155	217
2	560	784	448	627	367	514	263	368
2 1/2	1,060	1,484	848	1,187	695	973	499	699
3	1,720	2,408	1,376	1,926	1,127	1,578	809	1,133
3 1/2	2,390	3,346	1,912	2,677	1,566	2,192	1,124	1,574
4	3,210	4,494	2,568	3,595	2,104	2,946	1,510	2,114
5	5,450	7,630	4,360	6,104	3,572	5,001	2,564	3,590
6 Over 6	8,500	11,900	6,800	9,520	5,571	7,799	3,999	5,599

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Section 9.3.5.3.3 – Starter Pieces of Pipe:

The provisions of NFPA 13 Section 9.3.5.3.2 do not apply to starter pieces that are nominal diameter of 2-1/2 inches that do not exceed 12 feet in length.

Section 9.3.5.3.4 – Free Length of Pipe beyond Last Transverse Seismic Restraint:

The distance from the last transverse seismic restraint and the end of a pipe can not be more than 6 feet.

Section 9.3.5.3.5 – Transverse Seismic Restraints at the End of Feed or Cross Mains:

The last length of pipe at the end of a feed or a cross main must have a transverse seismic restraint.

Section 9.3.5.3.6 – Transverse Seismic Restraints as Longitudinal Seismic Restraints:

Transverse seismic restraints on one pipe may act as longitudinal seismic restraints on a connecting pipe if they are located with in 2 feet of the centerline of the connecting pipe, and the weight of the connecting pipe has been included in the capacity calculation for the transverse seismic restraint.

Section 9.3.5.3.7 – Transverse Seismic Restraints at Flexible Couplings:

On cross mains that have flexible couplings, including the flexible couplings at grooved type fittings, along their length must have a transverse seismic restraint installed with in 2 feet of every other coupling. The spacing between transverse seismic restraints is not to exceed 40 feet.

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Section 9.3.5.3.8 – The 6″ Rule:

Transverse seismic restraints are not required for pipes that are individually supported by hanger rods that are 6 inches or less in length are measured from the top of the pipe to the attachment point on the building structure.

Section 9.3.5.3.8 – U-Type Hooks:

Where wraparound U-Type hooks of those U-Type hooks that are intended to keep the pipe tight to the supporting structure are permitted to satisfy the requirements for transverse seismic restraints as long as the following provisions are met;

1. The legs are bent out at least 30° from the vertical.
2. The maximum length of the leg and the rod size are capable of carrying the expected seismic loads in accordance with NFPA 13 Tables 9.3.5.8.8(a), 9.3.5.8.8(b), and 9.3.5.8.8(c).

13.8 – Special Requirements for Branch Lines – NFPA 13 Sections 9.3.6 and A9.3.6.4:

The general piping industry uses the terms seismic restraint and seismic bracing interchangeably. NFPA 13, however, makes a clear distinction between seismic restraint and bracing, in particular for branch lines that have a nominal pipe size less than 2-1/2 inches. Seismic braces are intended to not only keep the piping moving with the building during an earthquake, but are also required to absorb all of the horizontal loads associated with the pipe and the lines in its zone of influence. While branch lines smaller that 2-1/2 inches are not required to be braced, they are required to be restrained. The requirements for restraining the branch lines are not as stringent as those for bracing the pipe. So, restraint is a lesser degree of load carrying capacity than bracing. The primary intent of seismically restraining the branch lines is to ensure that there relative position of those branch lines with respect to the building structure is maintained during and after an earthquake. This is because branch lines serve sprinkler heads that are located to protect specific

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areas of a building. Any permanent displacement of sprinkler heads relative to the building structure could result in inadequate coverage of critical areas of the building.

Typically, the hangers or attachments of the branch lines to the building structure are sized and placed to fulfill the seismic restraint requirements of Section 9.3.6 of NFPA 13. This task normally falls to the fire protection design professional. While the feed and cross mains can be restrained with components designed to handle, say, HVAC piping, there are specific hanger and restraint designs and components for branch lines.

Sprigs are vertical runs of pipe off of a branch line with a single sprinkler head attached to them. If a sprig is longer than 4 feet It must have a four way lateral restraint.

13.9 – Fasteners and Attachments– NFPA 13 Sections 9.3.5.9, 9.3.5.11, 9.3.5.12, and 9.3.7:

Sections 9.3.5.9.1, 9.3.5.9.6, and 9.3.5.9.7 – Acceptable Fastener Types and Loads:

The acceptable fastener types are post installed wedge type concrete anchors, post installed undercut anchors, steel bolts connecting to steel structures, through bolts, washers and nut in sawn lumber or glu-lam beams, and lag screws in wood. NFPA 13 Figure 9.3.5.9.1 presents the allowable fastener loads for various brace types and installations. Other fastening methods and anchors are acceptable if they are certified by a registered professional engineer to support the required seismic loads.

Sections 9.3.5.9.3 and 9.3.5.9.4 – Connections to Wood:

Through bolts with washers on each end is the first choice for connections to wood. These may be made with an actual bolt with a washer under the head of the bolt and a washer under the nut. The through bolt connection may also be made using a piece of all thread rod with nuts and

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washers on each end. Washers of sufficient outside diameter should be used to prevent over crushing the wood fibers and loosening the connection.

Lag screws may also be used for making connections to wood. When lag screws are specified, a pilot hole for the screw must be drilled to prevent splitting the wood along the grain lines. The pilot hole may be figured to be 1/8 inch smaller than the root diameter of the screw, or use the data found in Table A4.4-2 of Appendix A4.4 of this manual.

Section 9.3.5.9.5 – Holes for Through Bolts:

All clearance holes for through bolts are to be drilled 1/16 inch larger than the nominal bolt diameter.

Section 9.3.5.11.1 – Attachment to Pipes:

Seismic restraints must be attached directly to feed and cross mains. The restraints may not be attached to the clevis hangers or the hanger rods unless they have been tested and listed for horizontal seismic load carrying capability as well as supporting the dead load of the pipe and water.

Sections 9.3.5.11.2 and 9.3.5.11.3 – Individual Pipe Runs:

Each individual run of pipe must have both transverse and longitudinal seismic restraints. For pipe runs whose length is less than 12 feet, the seismic restraints on adjacent runs of pipe may be used for seismic restraint.

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Section 9.3.5.12 – Differential Motion:

A length of pipe may not be seismically restrained to sections of a building that will be subject to differential motion. This would cause the pipe to be pulled apart as the sections move in opposite directions. A flexible connector is required between the sections of the building subject to differential motion with enough capacity to handle the expected displacements of the two sections of the building.

Section 9.3.7.5 – "C" & "Z" Purlins:

The lips on "**C**" and "**Z**" purlins may not be used as a method of seismic restraint. These are typically light gage roll formed sheet metal parts. Any holes or deformation of the tension flange could have serious structural consequences.

Section 9.3.7.7 – C-Type Clamps:

C-Type clamps used with or without restraining straps are not to be used to attach seismic restraints or braces to the building structure. This includes beam and large flange clamps as well. All of these clamps rely to a greater or less degree on friction to transfer the seismic loads to the building. Also, their geometry is such that torsional loads as a result of, and along with, the horizontal seismic loads may be transferred to building structures incapable of carrying such loads.

Sections 9.3.7.8 and 9.3.7.9 – Powder Shot Pins:

Powder shot pins are not to be used for attaching seismic restraints or braces to the building structure unless specifically listed for the application of resisting lateral earthquake loads. It is imprudent to used powder shot pins in application that place the pin in tension.

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13.10 – Summary:

The NFPA-13 and IBC codes appear to be very close to each other in terms of the restraint selection requirements for piping. However, the actual application and installation of the seismic restraints should follow the guidelines in NFPA 13 since there are many life safety issues with fire protection piping that are not present with HVAC and plumbing piping.

Special Note #1: MEP systems and equipment which have initially been designated I_P**=1.0** which have been suspended above fire protection piping must be re-designated I_P**=1.5**, and restrained accordingly.

Special Note #2: Fire protection design professionals must be consulted concerning the adequacy of the restraint selection and attachment details for and fire protection piping system.

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