Design Data for Seismic Applications of Victaulic® Grooved System

The following information is a general reference for using Victaulic products in regions that are prone to seismic forces. Because each system is different, this information is not to be used as a specification for all installations. Professional assistance is a requirement for any application. Published pressures, temperatures, external and/or internal loads, performance standards, and tolerances must never be exceeded.

THE BENEFITS OF VICTAULIC PRODUCTS IN SEISMIC AREAS

Piping systems in earthquake-prone areas can be exposed to forces and deflections beyond normal static conditions. These seismic forces can cause extensive damage when piping systems cannot accommodate these changes. Victaulic components can be used to accommodate seismic forces in the following piping system conditions:

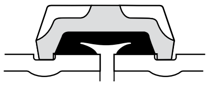
- Code-regulated systems with adequate earthquake bracing
- Unregulated systems with little or no earthquake bracing
- Seismic joint connections between independently-moving sections
- Buried systems

When dealing with any of these applications, each must be considered individually.

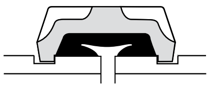
The following information, when used in conjunction with established seismic design practices and requirements, provides an excellent guideline for piping system design.

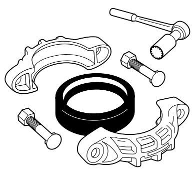
BUILT-IN STRESS RELIEF

STANDARD ROLL GROOVED



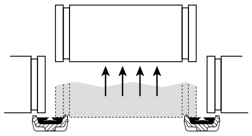
CUT GROOVED





The Victaulic grooved pipe joining method is simple and reliable. The four basic components are the grooved pipe, the housing, the bolts/nuts, and the gasket. The grooved pipe can be prepared with either a roll groove for standard wall and lighter pipe, or a cut groove for standard wall and heavier pipe. Both roll and cut grooved pipe will provide the same pressure rating for standard wall pipe. The coupling housing performs several functions as an integral part of the pipe joint. It fully encloses the elastomer gasket and secures it in position for a proper seal. It also engages the pipe around the full pipe circumference to create a unified joint, along with the advantages of mechanical joining. The bolts and nuts hold the housings together around the pipe. The synthetic elastomer gasket creates a triple seal effect on the pipe ends. A tension seal is created as the gasket is stretched around the pipe, and a compression seal is created as the coupling housings press the gasket onto the pipe. Finally, the sealing lips of the gasket are forced down onto the pipe end when the system is energized. All of these features result in a leak-tight, self-restrained joint.

Victaulic grooved products have provided many successful years of reliable service in seismic applications, including fire protection, HVAC, municipal, and industrial systems. Our couplings are durable and are designed to last the life of the piping system when installed in accordance with our published installation instructions. Our couplings can be quickly and easily assembled and disassembled. This, in combination with a union at every joint, reduces labor costs and permits easy system access for maintenance, repair, component replacement, and retrofits. Also, fittings can be loosely assembled and rotated to line up with mating components before the couplings are tightened. This eases work in tight places and around existing pipe, structures, or equipment.



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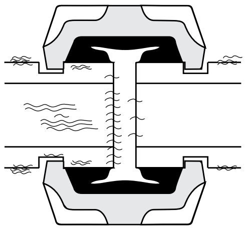
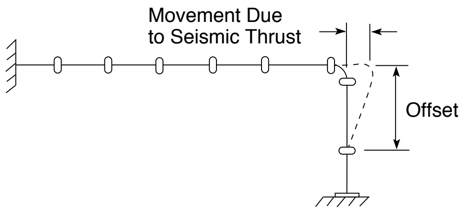


Exaggerated for clarity

The Victaulic system provides many mechanical design features that are useful in systems exposed to earthquake conditions. The flexibility of Victaulic flexible grooved-pipe couplings reduces the transmission of stresses through a piping system, while the gasket damps vibration (refer to Victaulic Submittal 26.04, Vibration Attenuation Characteristics of Victaulic Couplings).

When flexibility is not desired, rigid couplings, such as the Style HP-70 and the Style 07 Zero-Flex®, can be used. Both flexible and rigid couplings provide discontinuity at each joint, which helps minimize pipeline stresses generated during seismic movement.

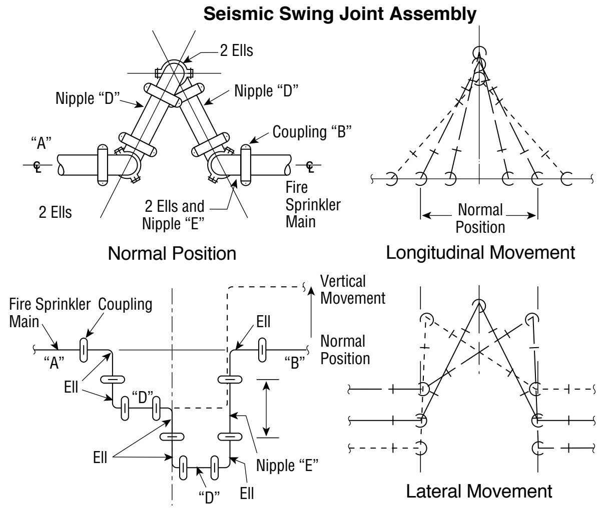
Where design considerations permit, flexible couplings can be used at changes in direction to provide stress relief through deflection for small differential movements.



When large differential movements between piping sections are anticipated, seismic swing joints that are comprised of flexible couplings, pipe nipples, and elbows may be required. Seismic swing joints provide simultaneous movement in all directions. By adding flexibility to the piping system, they help reduce pipe stress and potential system damage.

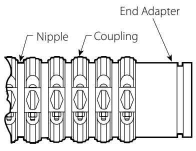
JOB OWNER	CONTRACTOR	ENGINEER
System No. ________	Submitted By ________	Spec Sect ________ Para ________
Location ________	Date ________	Approved ________
		Date ________

Design Data for Seismic Applications of Victaulic® Grooved System



When an in-line device is required, a Victaulic Style 155 Expansion Joint can be used, which incorporates special, precisely grooved nipples (refer to Victaulic Submittal 09.05 for additional information).

STYLE 155 EXPANSION JOINT



Exaggerated for Clarity

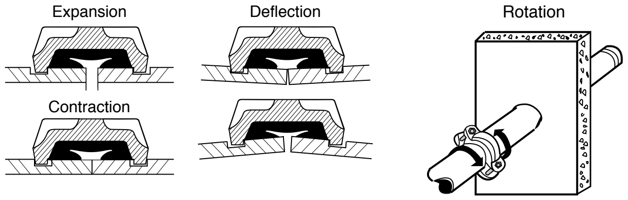
Victaulic grooved products are also suitable for buried applications in seismic areas. The deflection capabilities of flexible couplings will permit a pipeline to continue to function after minor earth movements.

Generally, buried systems do not experience damaging movements, except where they cross or are parallel to a fault line; or where they are located in unconsolidated ground prone to slumps, lurches, or landslides.

To prevent damage by major earth movements, consideration should be given to install pipelines above ground in unstable areas. Providing additional Victaulic flexible couplings will allow greater deflections to occur.

FLEXIBLE COUPLINGS

Flexible couplings for grooved-end pipe allow linear, angular, and rotational movement to occur at pipe joints, while they maintain a positive seal and self-restrained joint. Such performance is achieved through the combination of our elastomeric gasket (which seals the joint) with the housing (which engages the groove without clamping rigidly onto the pipe). These features provide design and installation advantages for piping systems that allow for expansion, contraction, and deflection generated by thermal changes, building/ground settlement, and seismic activity in the pipe. However, these features must be considered when determining hanger/support spacing. Refer to Table 4 in the "Pipe System Bracing Support Guidelines" section in this brochure for additional support information.



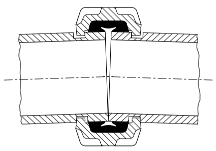


TABLE 1 – FLEXIBLE COUPLING PERFORMANCE

SIZE	Allow. Pipe End Sep. †	Deflect. Fr. CL †		SIZE	Allow. Pipe End Sep. †	Deflect. Fr. CL †		SIZE	Allow. Pipe End Sep. †	Deflect. Fr. CL †	
Nominal Inches Actual mm	In./mm	Degrees per Cplg.	Pipe In./ft./mm/m	Nominal Inches Actual mm	In./mm	Degrees per Cplg.	Pipe In./ft./mm/m	Nominal Inches Actual mm	In./mm	Degrees per Cplg.	Pipe In./ft./mm/m
¾ 26.9	0 - 0.06 0 - 1.6	3° 24′	0.72 60	4½ 127.0	0 - 0.13 0 - 3.2	1° 26′	0.25 21	10 273.0	0 - 0.13 0 - 3.2	0° 40′	0.14 12
1 33.7	0 - 0.06 0 - 1.6	2° 43′	0.57 48	5 141.3	0 - 0.13 0 - 3.2	1° 18′	0.27 22	304.8 mm	0 - 0.13 0 - 3.2	0° 36′	0.13 11
1¼ 42.4	0 - 0.06 0 - 1.6	2° 10′	0.45 38	133.0 mm	0 - 0.13 0 - 3.2	1° 21′	0.28 23	12 323.9	0 - 0.13 0 - 3.2	0° 34′	0.12 10
1½ 48.3	0 - 0.06 0 - 1.6	1° 56′	0.40 33	139.7 mm	0 - 0.13 0 - 3.2	1° 18′	0.28 23	14 355.6	0 - 0.13 0 - 3.2	0° 31′	0.11 9
2 60.3	0 - 0.06 0 - 1.6	1° 31′	0.32 27	152.4 mm	0 - 0.13 0 - 3.2	1° 12′	0.21 17	15 381.0	0 - 0.13 0 - 3.2	0° 29′	0.10 8
2½ 73.0	0 - 0.06 0 - 1.6	1° 15′	0.26 22	6 168.3	0 - 0.13 0 - 3.2	1° 5′	0.23 19	16 406.4	0 - 0.13 0 - 3.2	0° 27′	0.10 8
76.1 mm	0 - 0.06 0 - 1.6	1° 12′	0.26 22	159.0 mm	0 - 0.13 0 - 3.2	1° 9′	0.24 20	18 457.0	0 - 0.13 0 - 3.2	0° 24′	0.08 7
3 88.9	0 - 0.06 0 - 1.6	1° 2′	0.22 18	165.1 mm	0 - 0.13 0 - 3.2	1° 6′	0.23 19	20 508.0	0 - 0.13 0 - 3.2	0° 22′	0.08 7
3½ 101.6	0 - 0.06 0 - 1.6	0° 54′	0.19 16	203.2 mm	0 - 0.13 0 - 3.2	0° 54′	0.16 13	22 559.0	0 - 0.13 0 - 3.2	0° 19′	0.07 6
4 114.3	0 - 0.13 0 - 3.2	1° 36′	0.34 28	8 219.1	0 - 0.13 0 - 3.2	0° 50′	0.18 15	24 610.0	0 - 0.13 0 - 3.2	0° 18′	0.07 6
108.0 mm	0 - 0.13 0 - 3.2	1° 41′	0.35 29	254.0 mm	0 - 0.13 0 - 3.2	0° 43′	0.15 13				

† NOTE: These values are based on standard roll grooved pipe. Figures for standard cut grooved pipe may be doubled. Request 06.01.

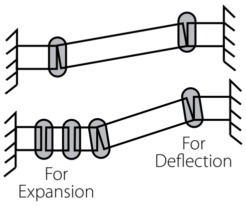
Design Data for Seismic Applications of Victaulic® Grooved System

Linear movement and angular deflection values for flexible, grooved pipe joints are published for each Victaulic style coupling. NOTE: these values are MAXIMUMS for roll-grooved pipe. Double the values if you are using cut-grooved pipe. For design and illustration purposes, reduce these values, according to the following factors, to allow for pipe groove tolerances:

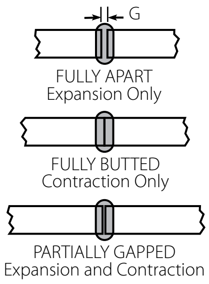
50% for 3½-inch size and smaller

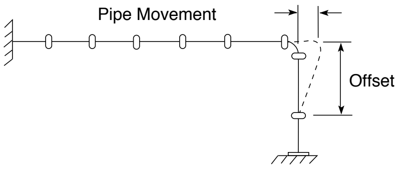
25% for 4-inch size and larger

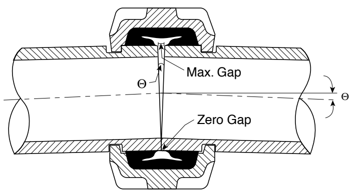
Piping system design for seismic applications requires a careful review of manufacturers' published performance data for piping components, including linear and angular movement tolerances. Couplings for grooved-end pipe do not provide maximum linear and angular movement simultaneously. However, the movement can be accommodated if the system is designed with a sufficient number of joints, in accordance with published design recommendations.



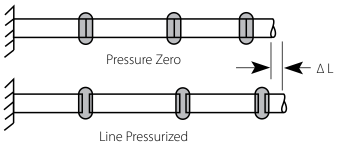
Flexible couplings must be used properly to obtain the desired flexibility, since they do not provide pipe expansion or contraction automatically. Therefore, always consider the best setting for pipe-end gaps. In anchored systems, set the gaps to handle combinations of axial movement and deflection. This can be achieved by assembling the couplings at the mid-point of the maximum available gap (half-way between fully-butted and fully-gapped). In free-floating systems, use directional changes or offsets of sufficient length to accommodate movement without exceeding the deflection values shown in Table 1.

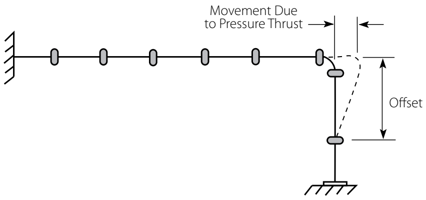






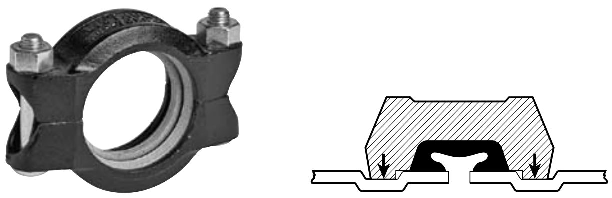
Since flexible couplings permit linear movement, internal pressure can cause pipe growth to accumulate at the end of the run in unanchored systems. The amount of growth is dictated by the position of the pipe ends following installation. Butted pipe ends will allow full growth, while fully gapped pipe ends will allow no growth. Thermal expansion adds to this accumulation. Thus, offsets must be of sufficient length to prevent excess deflection and harmful bending moments at these joints.



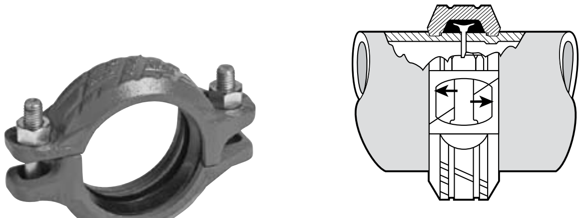


RIGID COUPLINGS

Victaulic rigid couplings provide a rigid joint through mechanical and frictional interlock on the pipe ends. The Style 07 Zero-Flex, Style 005 FireLock®, and the Style HP-70 couplings positively clamp the pipe to resist flexural and torsion loads. This keeps the pipe aligned without deflection during operation.



HP-70 COUPLING



Exaggerated for clarity

STYLE 07 ZERO-FLEX COUPLING

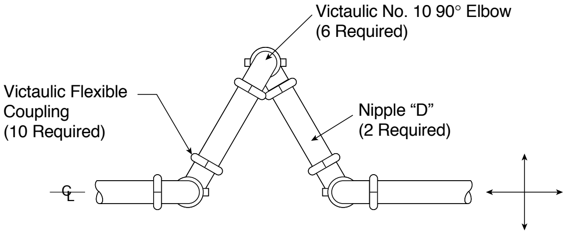
In seismic applications, rigid couplings may be used in any areas where flexibility is not desired, including long, straight runs and 2-inch or smaller-sized branch lines (often where codes do not require flexible couplings). Rigid couplings eliminate the movement that occurs with flexible, grooved joints, and therefore have support and hanging requirements similar to welded systems (corresponding to NFPA 13, ANSI B31.1, and ANSI B31.9). Refer to Submittal 26.01 for additional information on piping support for flexible and rigid couplings. Grooved piping with rigid couplings typically incorporates sway bracing similar to other types of rigid piping systems to minimize the relative movement with respect to the building structure.

Design Data for Seismic Applications of Victaulic® Grooved System

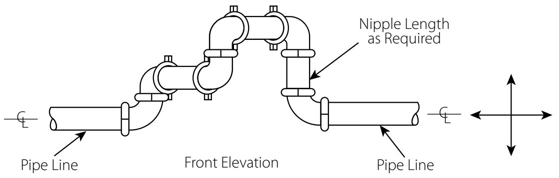
SEISMIC MOVEMENT COMPENSATION DEVICES

Devices or piping configurations that accommodate seismic movement are typically required to isolate independently moving structures, where piping on either side must move separately from the other side. They are designed so that the piping on each side is fixed to the adjacent, respective structure. Various compensation methods are available and include seismic swing joints, loops, offsets, and Style 155 Expansion Joints.

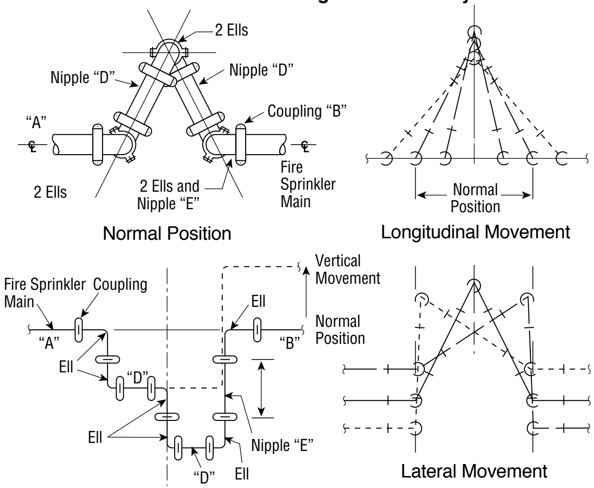
Seismic swing joints are widely accepted for accommodating large pipe movements. Section 6-4.3 of NFPA 13 (1999) states that seismic swing joints are required for all pipe sizes of mains and branches that cross a seismic separation joint above ground. Seismic swing joints are made of flexible couplings, pipe nipples, and grooved elbows similar to the following diagram.



Normal Position



Seismic Swing Joint Assembly



Normal Position

Longitudinal Movement

Lateral Movement

Dimensions for various sizes, depending on movement requirements, are provided in the following table. The amount of available pipe movement must be enough to accommodate the calculated differential earthquake motions. Support recommendations can be found in the next section.

SEISMIC SWING JOINT SIZING CHARTS TO DETERMINE "D" LENGTH FOR IPS CARBON STEEL PIPE

TABLE 2A – ROLL GROOVED PIPE*

SIZE	Dimensions							
			Minimum "D" Length – Inches/millimeters					
Nom. In. Actual mm	Elbow C to E	"E" Length	1"/ 25 mm Mvmt.	2"/ 51 mm Mvmt.	3"/ 76 mm Mvmt.	4"/ 102 mm Mvmt.	5"/ 127 mm Mvmt.	6"/ 152 mm Mvmt.
2 60.3	3.25 83	6.50 165	4 102	14 356	25 635	36 915	47 1194	57 1448
2½ 73.0	3.75 95	7.50 191	4 102	18 458	31 788	45 1143	58 1474	71 1804
3 88.9	4.25 108	8.50 216	4 102	22 559	37 940	53 1347	69 1753	84 2134
4 114.3	5.00 127	10.00 254	4 102	7 178	11 280	16 407	23 585	30 762
5 141.3	5.50 140	11.00 279	6 153	7 178	14 356	22 559	31 788	39 991
6 168.3	6.50 165	13.00 330	6 153	7 178	16 407	26 661	36 915	46 1169
8 219.1	7.75 197	15.50 394	6 153	9 229	22 559	35 889	49 1245	62 1575
10 273.0	9.00 229	18.00 457	8 204	14 356	31 788	48 1220	66 1677	83 2109
12 323.9	10.00 254	20.00 508	8 204	16 407	35 889	54 1372	73 1855	92 2337

*Values were calculated using standard #10 IPS cast grooved elbows. If other elbows are used, "E" length will change accordingly.

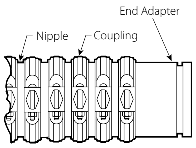
TABLE 2B – CUT GROOVED PIPE*

SIZE	Dimensions							
			Minimum "D" Length – Inches/millimeters					
Nom. In. Actual mm	Elbow C to E	"E" Length	1"/ 25 mm Mvmt.	2"/ 51 mm Mvmt.	3"/ 76 mm Mvmt.	4"/ 102 mm Mvmt.	5"/ 127 mm Mvmt.	6"/ 152 mm Mvmt.
2 60.3	3.25 83	6.50 165	4 102	7 178	11 280	14 356	20 508	25 635
2½ 73.0	3.75 95	7.50 191	4 102	7 178	12 305	18 458	25 635	31 788
3 88.9	4.25 108	8.50 216	4 102	7 178	14 356	22 559	30 762	38 966
4 114.3	5.00 127	10.00 254	4 102	7 178	11 280	14 356	18 458	21 534
5 141.3	5.50 140	11.00 279	6 153	7 178	11 280	14 356	18 458	21 534
6 168.3	6.50 165	13.00 330	6 153	7 178	11 280	14 356	18 458	21 534
8 219.1	7.75 197	15.50 394	6 153	7 178	11 280	14 356	18 458	22 559
10 273.0	9.00 229	18.00 457	8 204	8 204	11 280	14 356	23 585	31 788
12 323.9	10.00 254	20.00 508	8 204	8 204	11 280	16 407	25 635	35 889

*Values were calculated using standard #10 IPS cast grooved elbows. If other elbows are used, "E" length will change accordingly.

Design Data for Seismic Applications of Victaulic® Grooved System

Victaulic Style 155 Expansion Joints are a combination of couplings and specially machined short pipe nipples that provide pipeline expansion and contraction and are ideal for lateral pipe movement. The nipples are precisely grooved to provide full linear allowance at each joint.



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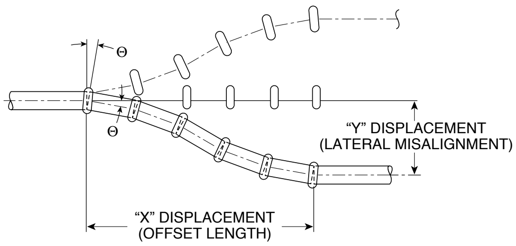
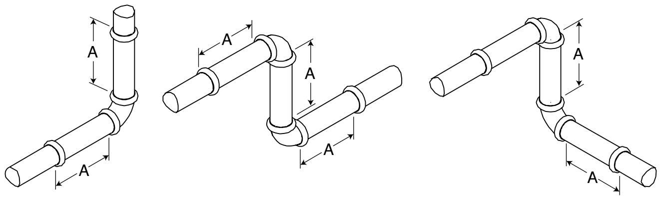


The movement characteristics of flexible couplings provide linear movement and angular deflection for offsets. This can be beneficial for applications where small amounts of pipe movement compensation are required from an in-line configuration. In accordance with Victaulic specifications and code requirements, the configuration must be supported properly. Special techniques may be required to achieve this support while providing the desired movement.

Victaulic flexible couplings, grooved elbows, and grooved pipe ends can be assembled in L-type or Z-type offset configurations to achieve movement through deflection at each flexible coupling. The minimum required pipe lengths adjacent to the elbows can be calculated by using published information for deflection values of flexible couplings (see Table 1), as shown in the following examples. The equations provide the minimum nipple lengths ("A") required to achieve the required movement in all three directions. In applications where only two directions of movement are required, the layouts can be optimized with shorter lengths. Please contact Victaulic for details. Note that the specified length must be able to move freely in order to ensure proper operation. Local code requirements and feasibility must be evaluated to verify whether the layout is practical.



L-Type **Z-Type** **Z-Type**

EXAMPLE FOR L TYPE LAYOUT

A = (√2) x (required movement) / (coupling capability)

TABLE 3A – ROLL GROOVED PIPE

SIZE	Cplg. Deflect. Cap.	Cplg. Design Deflect.	Minimum "A" Length (feet/m) for L Type Offset			
Nom. In. Actual mm	in/ft mm/m	in/ft mm/m	1"/ 25 mm Mvmt.	2"/ 51 mm Mvmt.	3"/ 76 mm Mvmt.	4"/ 102 mm Mvmt.
2 60.3	0.32 27	0.16 13	8.9 2.7	17.7 5.4	26.6 8.1	35.4 10.8
2½ 73.0	0.26 22	0.13 11	10.9 3.3	21.8 6.6	32.7 10.1	43.6 13.3
3 88.9	0.22 18	0.11 9	12.9 3.9	25.8 7.9	38.6 11.8	51.5 15.7
4 114.3	0.34 28	0.25 21	5.7 1.7	11.4 3.5	17.0 5.2	22.7 6.9
5 141.3	0.27 23	0.20 17	7.1 2.2	14.2 4.3	21.3 6.5	28.3 8.6
6 168.3	0.23 19	0.17 14	8.4 2.6	16.7 5.1	25.0 7.6	33.3 10.1
8 219.1	0.18 15	0.15 11	9.5 2.9	18.9 5.8	28.3 8.6	37.8 11.5
10 273.0	0.14 12	0.10 9	14.2 4.3	28.3 8.6	42.5 13.0	56.6 17.3
12 323.9	0.12 10	0.09 8	15.8 4.8	31.5 9.6	47.2 14.4	62.9 19.2

TABLE 3B – CUT GROOVED PIPE

SIZE	Cplg. Deflect. Cap.	Cplg. Design Deflect.	Minimum "A" Length (feet/m) for L Type Offset			
Nom. In. Actual mm	in/ft mm/m	in/ft mm/m	1"/ 25 mm Mvmt.	2"/ 51 mm Mvmt.	3"/ 76 mm Mvmt.	4"/ 102 mm Mvmt.
2 60.3	0.63 27	0.32 13	4.4 1.3	8.8 2.7	13.3 4.1	17.7 5.4
2½ 73.0	0.52 22	0.26 11	5.4 1.6	10.9 3.3	16.3 5.0	21.8 6.6
3 88.9	0.43 18	0.22 9	6.4 2.0	12.9 3.9	19.3 5.9	25.7 7.8
4 114.3	0.67 28	0.50 21	2.8 0.9	5.7 1.7	8.5 2.6	11.3 3.4
5 141.3	0.54 23	0.40 17	3.5 1.1	7.1 2.2	10.6 3.2	14.1 4.3
6 168.3	0.45 19	0.33 14	4.3 1.3	8.6 2.6	12.9 3.9	17.1 5.2
8 219.1	0.35 15	0.26 11	5.4 1.6	10.9 3.3	16.3 5.0	21.8 6.6
10 273.0	0.28 12	0.21 9	6.7 2.1	13.5 4.1	20.2 6.2	26.9 8.2
12 323.9	0.23 10	0.17 8	8.3 2.5	16.6 5.1	25.0 7.6	33.3 10.2

Design Data for Seismic Applications of Victaulic® Grooved System

EXAMPLE FOR Z TYPE LAYOUT

A = (required movement) / (coupling capability)

TABLE 3C – ROLL GROOVED PIPE

SIZE	Cplg. Deflect. Cap.	Cplg. Design Deflect.	Minimum "A" Length (feet/m) for Z Type Offset					
Nom. In. Actual mm	in/ft mm/m	in/ft mm/m	1"/ 25 mm Mvmt.	2"/ 51 mm Mvmt.	3"/ 76 mm Mvmt.	4"/ 102 mm Mvmt.	5"/ 127 mm Mvmt.	6"/ 152 mm Mvmt.
2 60.3	0.32 27	0.16 13	6.3 1.9	12.5 3.8	18.8 5.7	25.0 7.6	31.3 9.5	37.5 11.4
2½ 73.0	0.26 22	0.13 11	7.7 2.3	15.4 4.7	23.1 7.0	30.8 9.4	38.5 11.7	46.2 14.1
3 88.9	0.22 18	0.11 9	9.1 2.8	18.2 5.5	27.3 8.3	36.4 11.1	45.5 13.9	54.6 16.6
4 114.3	0.34 28	0.25 21	4.0 1.2	8.0 2.4	12.0 3.7	16.0 4.9	20.0 6.1	24.0 7.3
5 141.3	0.27 23	0.20 17	5.0 1.5	10.0 3.0	15.0 4.6	20.0 6.1	25.0 7.6	30.0 9.1
6 168.3	0.23 19	0.17 14	5.9 1.8	11.8 3.6	17.7 5.4	23.6 7.2	29.5 9.0	35.3 10.8
8 219.1	0.18 15	0.13 11	7.7 2.3	15.4 4.7	23.1 7.0	30.8 9.4	38.5 11.7	46.2 14.1
10 273.0	0.14 12	0.10 9	10.0 3.0	20.0 6.1	30.0 9.1	40.0 12.2	50.0 15.2	60.0 18.3
12 323.9	0.12 10	0.09 8	11.2 3.4	22.3 6.8	33.4 10.2	44.5 13.6	55.6 16.9	66.7 20.3

TABLE 3D – CUT GROOVED PIPE

SIZE	Cplg. Deflect. Cap.	Cplg. Design Deflect.	Minimum "A" Length (feet/m) for Z Type Offset					
Nom. In. Actual mm	in/ft mm/m	in/ft mm/m	1"/ 25 mm Mvmt.	2"/ 51 mm Mvmt.	3"/ 76 mm Mvmt.	4"/ 102 mm Mvmt.	5"/ 127 mm Mvmt.	6"/ 152 mm Mvmt.
2 60.3	0.63 53	0.32 27	3.2 1.0	6.3 1.9	9.4 2.9	12.5 3.8	15.7 4.8	18.8 5.7
2½ 73.0	0.52 43	0.26 22	3.9 1.2	7.7 2.3	11.6 3.5	15.4 4.7	14.5 4.4	23.1 7.0
3 88.9	0.43 36	0.22 18	4.6 1.4	9.1 2.8	13.7 4.2	18.2 5.5	22.8 6.9	27.3 8.3
4 114.3	0.67 56	0.50 42	2.0 0.6	4.0 1.2	6.0 1.8	8.0 2.4	10.0 3.0	12.0 3.7
5 141.3	0.54 45	0.40 33	2.5 0.8	5.0 1.5	7.5 2.3	10.0 3.0	12.5 3.8	15.0 4.6
6 168.3	0.45 38	0.33 28	3.1 0.9	6.1 1.9	9.1 2.8	12.2 3.7	15.2 4.6	18.2 5.5
8 219.1	0.35 29	0.26 22	3.9 1.2	7.7 2.3	11.6 3.5	15.4 4.7	19.3 5.9	23.1 7.0
10 273.0	0.28 23	0.21 18	4.8 1.5	9.6 2.9	14.3 4.4	19.1 5.8	23.9 7.3	28.6 8.7
12 323.9	0.23 19	0.17 14	5.9 1.8	11.8 3.6	17.7 5.4	23.6 7.2	29.5 9.0	35.3 10.8

SYSTEM BRACING/SUPPORT GUIDELINES

Government reports indicate that the differential motions that exist in an un-braced system during an earthquake tend to cause failure of rigid fittings and junctions, especially threads. Victaulic flexible grooved systems can allow differential motions to occur without excessive stress to the pipe or coupling. Victaulic publishes the amount of deflections and allowable pipe movements of flexible couplings in all applicable literature (see Table 1).

Various codes require that the systems be adequately braced against earthquake forces. In addition, pipes cannot be fastened to independently moving structures, such as a wall and a ceiling, or a ceiling and a floor, without installing a movement compensation device. Nor can pipe on one side of the device be fastened to the opposing structure. A system that is braced properly will move with the structure with controlled or limited additional stress to the pipe or Victaulic components.

Local codes should be consulted to determine whether un-braced systems are permitted within the given seismic zone. During an earthquake, un-braced systems may sway unpredictably in response to ground motions. The amount of sway (amplitude) and acceleration will depend upon the severity of the disturbance, the natural frequency of the piping system, and the amount of vibration damping in the system.

Connections between system components and equipment in independently moving sections of a structure may also require bracing. The independently moving sections may include walls, ceilings, fixed equipment, piping, separate buildings, etc. Ground motions (up to 10 inches) are possible at the epicenter of earthquakes. Government reports confirm the failure of components that cannot accommodate these movements.

Seismic bracing and piping supports are utilized in piping systems to prevent excessive movement during a seismic occurrence, which could result in excessive stresses to the piping system if not properly braced. Piping supports for a Victaulic grooved piping system must limit pipe movements so they do not exceed the recommended allowable deflections, pipe end movements, and end loads. NFPA 13 covers these systems and requires sprinkler systems to be protected to minimize or prevent pipe breakage in areas subject to earthquakes. This is accomplished through two techniques:

1) Make the piping flexible, where necessary (flexible couplings)

2) Attach the piping directly to the building structure for minimum relative movement (sway bracing)

Sway bracing is intended to brace main sprinkler piping so that it will withstand a horizontal force equal to 50% of the weight of the water-filled piping. A piping system designed to withstand this force without breakage or permanent deformation is considered reasonably safe from the effects of seismic forces.

The use of a multiplier has also been incorporated into calculations to adjust this value for specific geographical areas where higher or lower seismic accelerations are expected. This multiplier may be as low as 0.4 or as high as 2.4. The use of this multiplier is subject to the requirements of the local building code.

"Two-way" bracing prevents piping from oscillating in one direction (lateral or longitudinal), while "four-way" bracing provides simultaneous lateral and longitudinal bracing action. Lateral movement refers to side-to-side pipe movement (perpendicular to run), while longitudinal movement refers to in-line movement (parallel to run). Vertical loads are not frequently considered in bracing calculations, since the upward component is typically assumed to be incorporated into design safety factors. In all cases, sway bracing must be connected directly to the building structure. "Four-way" sway bracing is typically used at the top of a riser.

Generally, branch lines are not laterally braced, except for where movement could damage other equipment. Additionally, branch movement is limited by bracing the mains. Typically, design guides do not require seismic bracing for 2-inch and smaller lines because the piping is considered durable enough to withstand seismic forces without damage. Instead, the branches incorporate restraints (smaller bracing) for lateral and vertical control. Restraints are also used at the ends to minimize the whipping action of the branch lines at these locations. Sway bracing is typically required for 2½-inch and larger branch lines. Consult the local code for specific requirements.

Design Data for Seismic Applications of Victaulic® Grooved System

Seismic separation assemblies using flexible couplings (i.e. seismic swing joints) are typically required for all pipe sizes when the aboveground piping crosses between independently moving building segments. Our experience has shown that the first adjacent length of pipe on each side of the grooved seismic swing joint should be rigidly attached to the corresponding structure with adequate bracing. The swing joint must be supported in a manner that will not prohibit proper operation during an earthquake. Non-restraining hangers should be incorporated to support the grooved elbows and pipe nipples of the assembly. NOTE: Code requirements take precedence over these recommendations.

Section 6-4.4.1 of NFPA 13 (1999) stipulates that the diameter of holes, where pipe passes through walls or other obstructions, must be as follows:

- 2 inches larger than pipe 3½ inches and smaller
- 4 inches larger than pipe 4 inches and larger.

This standard also stipulates that the piping must have at least two inches of clearance around other structural members that are not penetrated or used to support the piping. Exceptions to this include piping that passes through gypsum or other non-fire-related material and when flexible couplings are within 1 foot of each side of the wall or obstruction. When the applicable building code requires that the annular space around the piping be filled, a flexible sealant, such as mastic, must be used.

This criteria defines the method by which sprinkler systems are protected from seismic movements under NFPA 13. Other piping systems will have varying installation requirements to provide for earthquake conditions, depending on the specific system; its proximity to seismic zones; the level of seismic zone; and conformance to local, state, and/or national codes. Therefore, each system must be reviewed on an individual basis to determine the support mechanism and the proper incorporation of flexible and rigid couplings.

Factory Mutual provides design steps for sway bracing in Data Sheet 2-8, Earthquake Protection for Water-based Fire Protection Systems, which states the following:

Step 1: *Lay out sway bracing locations with respect to the sprinkler piping and to the structural members to which the bracing will be attached.*

Step 2: *Calculate the seismic design load requirements for each sway bracing location.*

Step 3: *Select the proper sway bracing shape, angle of attachment, size, and maximum length based on the horizontal design load requirement.*

Step 4: *Select the proper attachment method for the sway bracing to the structure and to the piping.*[1]

Systems installed with Victaulic rigid couplings can be supported and braced for seismic occurrences in a similar way to threaded and welded systems. The hanger spacing requirements for Victaulic rigid couplings are in accordance with standard industry codes for threaded and welded systems. These nationally recognized codes are ANSI B31.1 Power Piping Code, ANSI B31.9 Building Services Code and NFPA 13 Sprinkler Systems.

Victaulic Company's pipe support recommendations for both flexible and rigid systems can be found in the following Tables 4A through 4C. The tables show the suggested maximum span between pipe supports for horizontal straight runs of standard-weight steel pipe that carry water or similar liquids.

RIGID SYSTEMS

For Victaulic rigid coupling Styles 07, 307, HP-70, 005, and others, the Maximum Hanger Spacing below may be used.

TABLE 4A

PIPE SIZE	Suggested Maximum Span Between Supports Feet/meters					
Nominal Inches / Actual mm	Water Service			Gas or Air Service		
	*	†	‡	*	†	‡
1 33.7	7 2.1	9 2.7	12 3.7	9 2.7	9 2.7	12 3.7
1¼ 42.4	7 2.1	11 3.4	12 3.7	9 2.7	11 3.4	12 3.7
1½ 48.3	7 2.1	12 3.7	15 4.6	9 2.7	13 4.0	15 4.6
2 60.3	10 3.1	13 4.0	15 4.6	13 4.0	15 4.6	15 4.6
3 88.9	12 3.7	15 4.6	15 4.6	15 4.6	17 5.2	15 4.6
4 114.3	14 4.3	17 5.2	15 4.6	17 5.2	21 6.4	15 4.6
6 168.3	17 5.2	20 6.1	15 4.6	21 6.4	25 7.6	15 4.6
8 219.1	19 5.8	21 6.4	15 4.6	24 7.3	28 8.5	15 4.6
10 273.0	19 5.8	21 6.4	15 4.6	24 7.3	31 9.5	15 4.6
12 323.9	23 7.0	21 6.4	15 4.6	30 9.1	33 10.1	15 4.6
14 355.6	23 7.0	21 6.4	15 4.6	30 9.1	33 10.1	15 4.6
16 406.4	27 8.2	21 6.4	15 4.6	35 10.7	33 10.1	15 4.6
18 457.0	27 8.2	21 6.4	15 4.6	35 10.7	33 10.1	15 4.6
20 508.0	30 9.1	21 6.4	15 4.6	39 11.9	33 10.1	15 4.6
24 610.0	32 9.8	21 6.4	15 4.6	42 12.8	33 10.1	15 4.6

* Spacing corresponds to ANSI B31.1 Power Piping Code.

† Spacing corresponds to ANSI B31.9 Building Services Piping Code.

‡ Spacing corresponds to NFPA 13 Sprinkler Systems.

FLEXIBLE SYSTEMS

For coupling Styles including 75, 77, and others.

Standard, grooved-type couplings allow angular, linear, and rotational movement at each joint to accommodate expansion, contraction, settling, vibration, noise, and other piping system movement. These features provide advantages in designing piping systems but must be considered when determining hanger and support bracing and location.

Design Data for Seismic Applications of Victaulic® Grooved System

Maximum Hanger Spacing
For straight runs without concentrated loads and where full linear movement is required.

TABLE 4B

PIPE SIZE	Pipe Length in Feet/meters									
Nominal Inches Actual mm	7 2.1	10 3.0	12 3.7	15 4.6	20 6.1	22 6.7	25 7.6	30 9.1	35 10.7	40 12.2
	*Average Hangers per Pipe Length Evenly Spaced									
¾ – 1 26.9 – 33.7	1	2	2	2	3	3	4	4	5	6
1 ¼ – 2 42.4 – 60.3	1	2	2	2	3	3	4	4	5	5
2 ½ – 4 73.0 – 114.3	1	1	2	2	2	2	2	3	4	4
5 – 8 141.3 – 219.1	1	1	1	2	2	2	2	3	3	3
10 – 12 273.0 – 323.9	1	1	1	2	2	2	2	3	3	3
14 – 16 355.6 – 406.4	1	1	1	2	2	2	2	3	3	3
18 – 24 457.0 – 610.0	1	1	1	2	2	2	2	3	3	3
28 – 42 711.0 – 1067.0	1	1	1	1	2	2	2	3	3	3

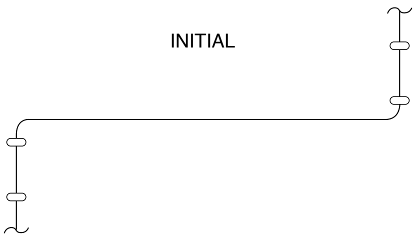
*No pipe length should be left unsupported between any two couplings.

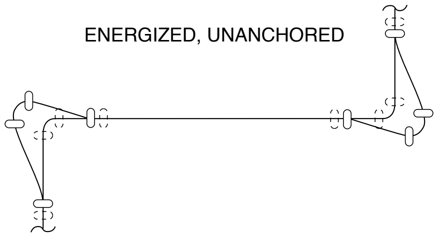
Maximum Hanger Spacing
For straight runs without concentrated loads and where full linear movement is not required.

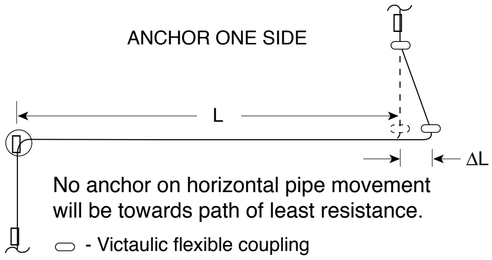
TABLE 4C

PIPE SIZE RANGE Nominal Inches Actual mm	Suggested Maximum Span Between Supports Feet/meters
¾ – 1 26.9 – 33.7	8 2.4
1 ¼ – 2 42.4 – 60.3	10 3.0
2 ½ – 4 73.0 – 114.3	12 3.7
5 – 8 141.3 – 219.1	14 4.3
10 – 12 273.0 – 323.9	16 4.9
14 – 16 355.6 – 406.4	18 5.5
18 – 30 457.0 – 762.0	20 6.1
32 – 42 813.0 – 1067.0	21 6.4

The system designer should note that flexible couplings installed with partial gaps or fully-butted pipe ends will allow the pipe to expand fully when the system is energized. Strategically placed anchors will contain the energized system between the anchors. Also, pipe guides and proper pipe support will help to prevent angular deflection at the joints that would otherwise reduce the amount of linear movement capable at each joint.

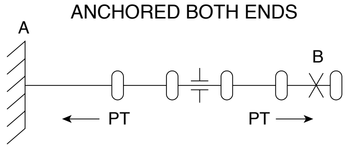




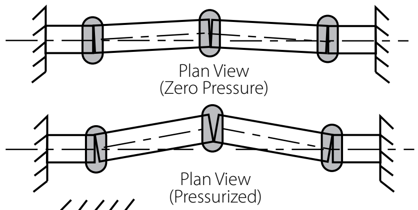


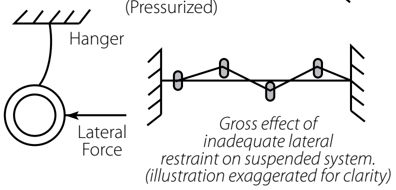
No anchor on horizontal pipe movement will be towards path of least resistance.

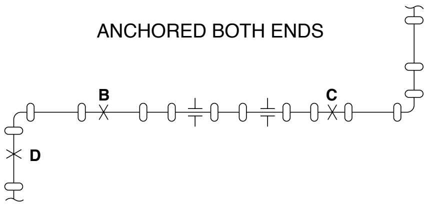
- Victaulic flexible coupling
- Anchor
- Assumed or proposed anchor



Unrestrained, deflected joints will straighten under axial pressure thrusts and other forces that act to pull pipes apart. If deflection is desired, anchors or lateral resistance must be applied to the lines to help maintain joint deflection. Lateral forces will always act upon deflected joints due to internal pressure. A fully-deflected joint will not provide linear movement that is normally available at the joint. Conversely, angular deflection at fully-butted or fully-gapped joints is not possible, unless the pipe ends can shorten and grow, as required. Partially deflected joints will provide some portion of linear movement.







Flexible couplings can provide deflection at branch connections and offsets to accommodate anticipated pipe movement. Offsets must be

Design Data for Seismic Applications of Victaulic® Grooved System

long enough to provide sufficient deflection to prevent harmful bending moments, which would be induced at the joints of the offset. NOTE: If the pipes were to expand due to thermal changes, additional pipe growth would also take place at the ends.

SEISMIC CALCULATIONS

Victaulic grooved products have consistently demonstrated the ability to withstand considerable forces during earthquakes. When exposed to bending forces, they have remained intact. A bending moment will occur when the joint deflects beyond its maximum allowable angular deflection. Where these deflections are anticipated, additional flexible couplings should be installed to accommodate this movement. Several agencies, such as ASTM and Underwriters Laboratories (UL), have established methods for qualification of bending loads. However, the following is a list of the minimum bending moments that Victaulic products must withstand to obtain a UL Listing. UL established the minimum bending moment requirements through the following method from UL Standard 213, Rubber Gasketed Fittings for Fire Protection:

The bending moments are calculated based on twice the weight of the water filled pipe over twice the maximum distance between supports specified in the Standard for Installation of Sprinkler Systems, NFPA 13.2

This UL standard is one of several publications for bending moment requirements. ASTM F-1476 is another standard that provides bending loads based on hanger spacing, etc. The couplings are tested only to the respective bending moment shown, and factor of safety is built into these values. All bending moments were applied at their maximum UL pressure rating. These values are provided as information only and must not be used for design purposes. However, they can be compared to minimum theoretical values required by various building codes to demonstrate the actual capabilities versus design requirements.

MINIMUM REQUIRED BENDING MOMENT AT COUPLING ON STANDARD WALL PIPE

TABLE 5

COUPLING SIZE Nominal In. Actual mm	Bending Moment ft-lb N • m	COUPLING SIZE Nominal In. Actual mm	Bending Moment ft-lb N • m
1 33.7	300 407	6 168.3	7085 9600
1 ¼ 42.4	420 569	8 219.1	11304 15317
1 ½ 48.3	810 1098	10 273.0	16785 22744
2 60.3	1150 1558	12 323.9	22950 31098
2 ½ 73.0	1770 2398	14 355.6	27450 37195
3 88.9	2426 3287	16 4006.4	35843 48568
3 ½ 101.6	3013 4083	18 457.0	45360 61463
4 114.3	3645 4939	20 508.0	54742 74176
5 141.3	5238 7098	24 610.0	77670 105244

The following static analysis equations and resulting values demonstrate the capabilities of Victaulic products in seismic conditions. The results provided in the following tables show that properly assembled Victaulic grooved couplings exceed the performance requirements to which threaded and welded piping systems currently conform for use in pre-approved seismic systems. In addition, Victaulic has a 75-year history of successful use of these products in commercial building applications, mining, municipal, industrial, oilfield, and fire protection. These results are in accordance with the requirements of the latest revision of the California Building Code. Section 1630B.2 states that piping, ducting, conduit systems, and connections that are constructed of ductile materials may use the values of Cp from Table 16B-0. Victaulic grooved coupling housings are constructed of durable ductile iron that is dual certified to ASTM A395, Grade 65-45-15 and ASTM A536, Grade 65-45-12. ASTM A395 is the formulation commonly referenced in ASTM B31 codes for ductile iron pressure-containing components, while ASTM A536 is a widely accepted formulation used in modern castings.

INTERNATIONAL BUILDING CODE (2000)

Seismic forces calculated in accordance with IBC are determined as follows:

$$F_p = (0.4 a_p S_{DS} W_p)\,\frac{l_p}{R_p}\left(1 + 2\,\frac{z}{h}\right)$$

which can be simplified to the following equation based on the maximum value of Fp:

$$F_p = 1.6_{DS} l_p W_p$$

where

F_p is the design lateral force for non-structural components.

S_{DS} is design spectral response acceleration (0.33, based on S_{DS} = $2F_aS_s/3$, where F_a = 2.5 for worst case soft soil and $S_s = 0.2_s$ for worst case spectral acceleration).

I_p is importance factor (1.5 for critical facility).

W_p is component operating weight.

When required, the vertical component of the force is calculated by:

$$F_p v = 0.25_{DS} W_p$$

The following chart provides results using the first simplified equation as a general case.

STANDARD WALL CARBON STEEL PIPE SINGLE SPAN, SIMPLE SUPPORT

TABLE 6

SIZE Nominal In. Actual mm	Wp lb/ft kg/m	Fp lb/ft kg/m	M ft-lb N•m	Safety Factor*
2 60.3	5.1 7.6	4.0 6.0	800 1084	1.44
2 ½ 73.0	7.9 11.8	6.3 9.4	1260 1707	1.41
3 88.9	10.8 16.1	8.6 12.8	1720 2331	1.41
4 114.3	16.3 24.3	12.9 19.2	2580 3496	1.41
6 168.3	31.5 46.9	25.0 37.2	5000 6775	1.42
8 219.1	50.2 74.7	39.8 59.2	7960 10786	1.42
10 273.0	74.6 111.0	59.1 87.9	11820 16016	1.42
12 323.9	98.6 146.7	78.1 116.2	15620 21165	1.47
14 355.6	114.3 170.1	90.5 134.7	18100 24526	1.52
16 406.4	141.7 210.8	112.2 167.0	22440 30407	1.60
18 457.0	171.8 255.6	136.1 202.5	27220 36884	1.67
20 508.0	204.6 304.4	162.0 241.1	32400 43902	1.69
24 610.0	278.4 414.3	220.5 328.1	44100 59756	1.76

*Safety factor is based on comparison of calculated bending moment (M) to UL minimum required bending moment which all Listed Victaulic couplings must withstand.

Design Data for Seismic Applications of Victaulic® Grooved System

CALIFORNIA BUILDING CODE (BASED ON 1997 UNIFORM BUILDING CODE)

$$F_p = 0.4\, C_a\, I_p\, W_p$$

or, to consider the higher accelerations which occur on upper elevations of a structure,

$$F_p = (a_p\, C_a\, I_p / R_p)\,(1 + 3h_x / h_r)\, W_p$$

where

F_p is the design lateral force for nonstructural components.

a_p is component amplification factor (1.0 for piping).

C_a is the seismic coefficient (between 0.06 and 0.44, depending on seismic acceleration zone and soil profile).

I_p is the importance factor (1.5 for essential facility).

R_p is the response modification factor (3.0 for piping).

h_x is component elevation (components on upper elevations receive more accelerations than lower floors).

h_r is roof elevation.

W_p is distributed load of the pipe (weight per foot of pipe and water).

The following chart provides results using the first equation as a general case, with C_a of 0.44 (worst case) and I_p of 1.5.

STANDARD WALL CARBON STEEL PIPE SINGLE SPAN, SIMPLE SUPPORT

TABLE 7

SIZE Nominal In. Actual mm	Wp lb/ft kg/m	Fp lb/ft kg/m	M ft-lb N•m	Safety Factor*
2 60.3	5.1 7.6	1.4 2.1	270 366	4.26
2½ 73.0	7.9 11.8	2.1 3.1	418 566	4.23
3 88.9	10.8 16.1	2.9 4.3	570 772	4.26
4 114.3	16.3 24.3	4.3 6.4	860 1165	3.50
6 168.3	31.5 46.9	8.3 12.4	1664 2255	4.26
8 219.1	50.2 74.7	13.3 19.8	2650 3591	4.27
10 273.0	74.6 111.0	19.7 29.3	3938 5336	4.26
12 323.9	98.6 146.7	26.0 38.7	5206 7054	4.41
14 355.6	114.3 170.1	30.2 44.9	6036 8179	4.55
16 406.4	141.7 210.8	37.4 55.7	7482 10138	4.79
18 457.0	171.8 255.6	45.4 67.6	9072 12293	5.00
20 508.0	204.6 304.4	54.0 80.4	10802 14637	5.07
24 610.0	278.4 414.3	73.5 109.4	14700 19919	5.28

*Safety factor is based on comparison of calculated bending moment (M) to UL minimum required bending moment which all Listed Victaulic couplings must withstand.

1999 ASHRAE (BASED ON 1994 UNIFORM BUILDING CODE)

$$F_p = Z\, I\, C_p\, W$$

where

F_p is total design lateral seismic force (actually recalculates distributed load for piping system).

Z is seismic zone factor (0.4 based upon worse case seismic zone 4).

I is importance factor (1.5 based on essential facility).

C_p is horizontal force factor (0.75 for rigidly mounted pipe). (NOTE: resiliently mounted equipment, such as spring-mounted hangers, uses a Cp of 2.0).

W is distributed load (weight per foot of pipe and water).

STANDARD WALL CARBON STEEL PIPE SINGLE SPAN, SIMPLE SUPPORT

TABLE 8

SIZE Nominal In. Actual mm	Wp lb/ft kg/m	Fp lb/ft kg/m	M ft-lb N•m	Safety Factor*
2 60.3	5.1 7.6	2.3 3.4	460 623	2.50
21/2 73.0	7.9 11.8	3.5 5.2	708 959	2.50
3 88.9	10.8 16.1	4.9 7.3	970 1314	2.50
4 114.3	16.3 24.3	7.3 10.9	1467 1988	2.48
6 168.3	31.5 46.9	14.2 21.1	2833 3839	2.50
8 219.1	50.2 74.7	22.6 33.6	4522 6127	2.50
10 273.0	74.6 111.0	33.6 50.0	6712 9095	2.50
12 323.9	98.6 146.7	44.4 66.1	8871 12020	2.58
14 355.6	114.3 170.1	51.4 76.5	10285 13936	2.66
16 406.4	141.7 210.8	63.8 94.9	12752 17279	2.81
18 457.0	171.8 255.6	77.31 115.0	15461 20950	2.93
20 508.0	204.6 304.4	92.07 137.0	18414 24951	2.97
24 610.0	278.4 414.3	125.29 186.4	25058 33954	3.10

*Safety factor is based on comparison of calculated bending moment (M) to UL minimum required bending moment which all Listed Victaulic couplings must withstand.

SEISMIC TESTING OF VICTAULIC PRODUCTS

The performance of the Victaulic grooved-end piping system under seismic conditions was evaluated in a series of tests conducted by ANCO Engineers, Inc., an independent laboratory that specializes in seismic evaluations of products. The tests were conducted to assess the structural and functional integrity of Victaulic products during seismic loading for a major electric utility that was considering the use of grooved piping at one of its nuclear plant sites. The tests included flexible and rigid couplings, tees, elbows, reducers, and caps, as well as roll-grooved and cut-grooved pipe in 1 – 6-inch nominal sizes.

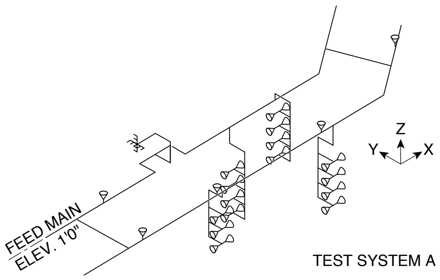


Figure 1

Design Data for Seismic Applications of Victaulic® Grooved System

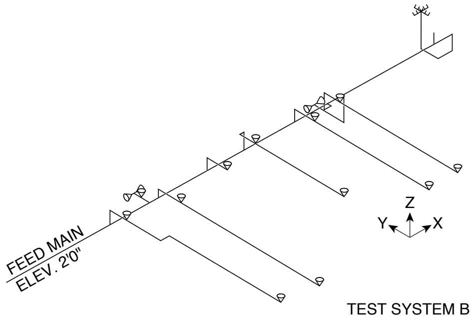


Figure 2

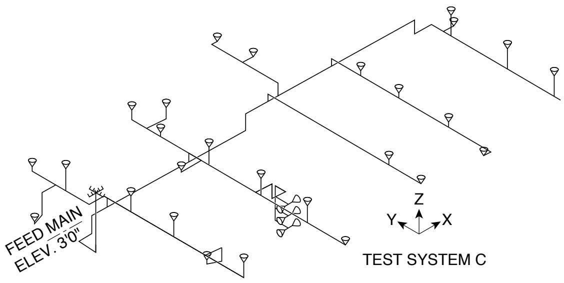


Figure 3

The laboratory used computerized data monitoring control and acquisition systems, plus servo-hydraulic actuators and feedback controls to conduct the tests. Three test segments (A, B, and C shown in figures 1, 2, and 3) were constructed on a shake table that measured 45-feet long by 14-feet wide and 14-feet high. Four linked actuators – two longitudinal and two transverse units – generated the pitch, roll, and yaw motions of earthquake activity.

Each simulated disturbance lasted 30 seconds, including a 5-second rise, 20 seconds of strong motion, and 5 seconds of delay time.

The tests simulated 13 different scenarios:

- Three less-than-operating-basis earthquakes (OBE) to establish the relationship between shake table drive signal gains and computed test response spectra (TRS)
- Six OBEs
- Two safe-shutdown earthquakes (SSE)
- An earthquake scaled to 1.2 times SSE levels
- One scaled to 1.4 times SSE levels

The test system main feed line resonant frequencies ranged from 1.92 Hz (Y direction) to 40.6 Hz (Z direction). Shake-table input acceleration averaged 1.5g in each principal direction during the OBE tests, 2.25g during the SSE tests, and 2.9g under the highest-level (H-L) conditions (upward ground accelerations of up to 1.8g were recorded during the Northridge earthquake). The following table shows response accelerations in "G"s for the main feed lines of systems A, B, and C in directions X, Y, and Z during OBE, SSE, and H-L testing. These results apply only to Victaulic products and do not represent the performance capabilities of competitors' grooved products.

TABLE 9

	Operating-Basis Earthquake (OBE) Tests			Safe-Shutdown Earthquake (SSE) Tests			Highest Level (H-L) Tests		
	X	Y	Z	X	Y	Z	X	Y	Z
A	1.9	3.1	1.4	2.6	4.7	2.4	3.1	5.0	3.3
B	1.5	6.9	3.5	2.3	8.9	5.0	2.9	14.1	5.4
C	2.4	0.9	2.6	3.9	1.4	5.0	4.0	1.4	4.0

The 6.9g Y-direction result for System B during OBE testing reflected the use of a hard stop on the piping to simulate lack of rattle space near that location. Additionally, the highest-level test produced displacements in System B of +/-5.0" in the X direction and +1.6"/-6.0" in the Y direction. The previously mentioned hard stop limited the +Y direction displacement. The same test displaced System C +/-0.35" in the X direction and +/-3.5" in the Y direction.

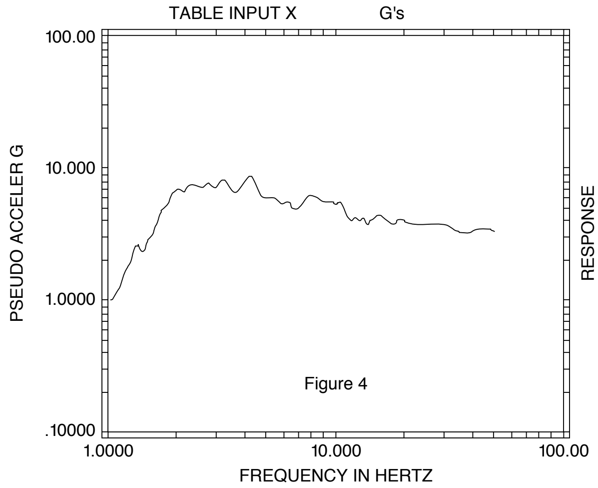


Figure 4

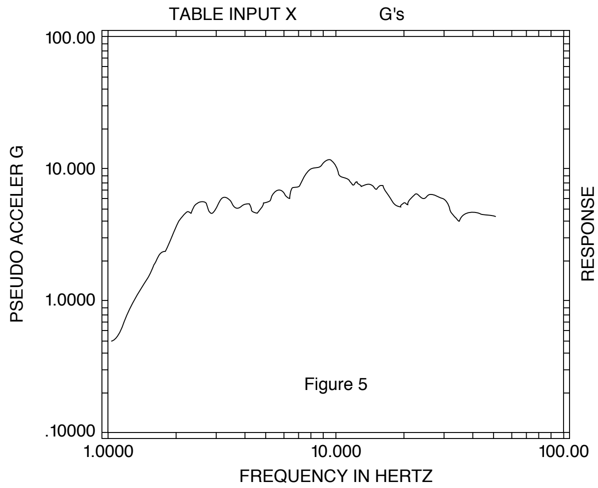


Figure 5

Design Data for Seismic Applications of Victaulic® Grooved System

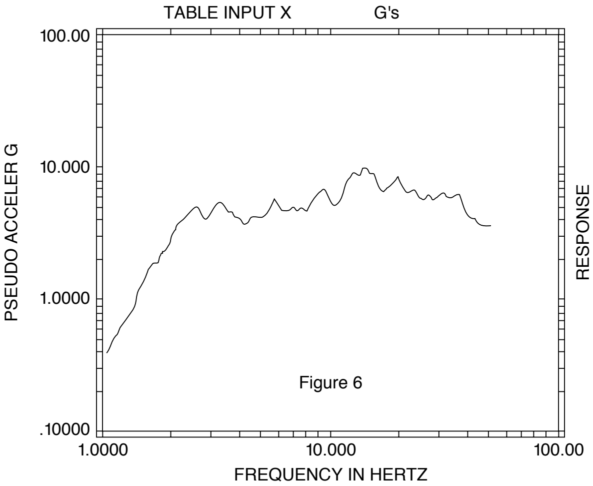


Figure 6

The severity of input motion is best described in terms of Test Response Spectra (TRS), which was calculated from measured test input motions. Figures 4, 5, and 6 are the TRS for the highest level event, which is impressively high. In the opinion of ANCO Engineers, Inc., few, if any, nuclear power plant sites would have higher Required Response Spectra (RRS) as design criteria above 1.5 Hz.

Post-test inspection by the laboratory of the Victaulic fittings and couplings revealed no abrasion, cracks, deformation, or damage of any kind, indicating it could continue to perform its intended function. Hydro-tests after the first OBE test demonstrated that these Victaulic components maintained functionality during and after the simulation, thereby substantiating their reliability under seismic conditions.

SUMMARY

Victaulic grooved products have consistently demonstrated the ability to withstand earthquakes when used on fire protection, HVAC, municipal, and industrial applications in seismic-active areas. Recognition of their inherent seismic accommodation characteristics by national and international organizations further attests to the superior design features of Victaulic grooved products. When properly used and installed in accordance with published requirements, Victaulic grooved products will provide durable pipe joints in seismic areas.

SEISMIC COMPATIBLE CONFIGURATION CAN BE EASILY INSULATED.

LOOP IS "Z" SHAPED TO ABSORB SEISMIC MOVEMENT.

DHEN-5XCTGQ

Seismic Testing Program

Test Summary

Seismic Testing was completed on 4"/DN100, 8"/DN200, and 16"/DN400 Victaulic grooved mechanical pipe couplings and fittings installed on standard wall carbon steel pipe. The testing proved that Victaulic couplings are most suitable for use on piping systems subjected to earthquakes. The test program was developed in accordance with an internationally recognized current shake table standard for testing nonstructural building components. The piping assemblies were subjected to input amplitudes of ±3"/76mm in both x and y horizontal directions, input accelerations of up to 1.3g and a frequency range of 1.3 to 33Hz. Braced rigid and flexible sections performed flawlessly under the test conditions which saw peak accelerations of the piping to be recorded at over 7g's. The water filled assemblies were pressurized to 200 psi/1375 kPa for the duration of all tests and no pressure loss or leakage was noted during or after any of the tests.

Victaulic Company

Victaulic, founded in 1925, is the world leader in mechanical pipe joining systems. Victaulic introduced a radical concept in joining pipe—a mechanical bolted coupling that would engage into grooves and uses an elastomer gasket to seal the joint.

The grooved piping method, which dramatically reduces the amount of installation time as compared to welding, threading or flanging is used extensively in HVAC, plumbing, fire protection, mining, industrial utilities, oilfield piping, plus water and wastewater systems.

Victaulic products are found in major landmarks and buildings the world over. With the ability to provide both rigid and flexible joints the Victaulic system provides design versatility not found on other types of pipe joining systems

Victaulic in Seismic Conditions

The use of Victaulic flexible grooved couplings in areas subject to seismic events has been traced back to the early 1940's where they were used to provide stress relief at equipment connections. Since that time grooved products have become a standard joining method due to their unique design benefits in being able to provide both rigid and flexible pipe joints based upon a specific system's design requirements. Victaulic products have had many years of successful performance in areas that have experienced seismic events such that they have become the standard method for joining pipe on many projects in seismic areas. There have also been a number of in-house and third party tests performed in order to qualify the performance capabilities of Victaulic products when subjected to adverse conditions such as seismic events, shipboard piping systems and high pressure cycling. The results of these various tests have proven the reliability and integrity of Victaulic products under these adverse conditions.

Purpose of Testing

Victaulic realized the need for state of the art testing on our products in order to demonstrate conformance to new code requirements and prove they provide a sustainable system that will withstand the forces generated during a seismic event and maintain system integrity when subjected to real time seismic events. Testing was designed to provide analytical data in support of the successful "real-world" performance during past earthquakes.

Piping or building damage occurs due to differential movement between the pipe and the building; and at locations where the piping crosses a building seismic joint, where piping crosses between two separate structures, or piping is supported or fixed to independent support structures within a building, (IE: supported from the roof truss then drops into racks). The former is addressed, within a given "structural area", by fixing the pipe (seismically bracing) to the building structure so it moves in concert with the building. Bracing and clearances must be designed for the specified seismic accelerations and amplitudes of movement. The latter is addressed, where piping crosses from one "structural area" to another. Piping should be installed with a flexible component (seismic isolation assembly) sufficient to accommodate the differential movement that will occur between pipes that are joined but supported from or anchored to different "seismic structures". The flexible element permits these structures and the piping attached to each structure to move independently within the building, without damaging each other, or other equipment, during the seismic event.

The goal of this testing was to demonstrate the suitability of Victaulic Grooved Mechanical Couplings and Fittings to be used to install and maintain operational integrity of piping systems during seismic events. The test program was designed to show seismic performance in two conditions sited above. First, testing was conducted to prove that rigid or flexible Victaulic couplings installed on code compliant braced piping will maintain full performance when subjected to seismic events. Second, testing was conducted to confirm the ability of our flexible couplings in seismic swing joints or in offset pipe configurations, to provide sufficient freedom of movement in order to accommodate the differential movement of pipe between structures or at building seismic separation joints.

Seismic Tests

ATLSS Testing Facility

Lehigh University's ATLSS Lab, Advanced Technology for Large Structural Systems a national engineering research center, was chosen to perform the required testing. The ATLSS Center is a member of the Network for Earthquake Engineering Simulation (NEES), established by the US National Science Foundation as a national networked collaboration of geographically-distributed, shared-use experimental research equipment sites. The Lehigh NEES Equipment Site was developed with the capabilities to perform real-time testing using effective force method, pseudo-dynamic testing method, or the pseudo-dynamic hybrid testing method for the testing of large-scale structural components, structural subassemblages, and superassemblages under earthquake excitations. Thus it is well suited to perform and analyze simulated real-time multi-direction earthquake effects on piping systems. Victaulic and Lehigh consulted with an internationally recognized designer and supplier of seismic bracing systems, who provided the design support for the hanging and bracing of the pipe test assemblies.

Test Requirements

The test program was developed in accordance with current shake table testing standards. Artificial ground motions were developed for this test program. These randomly generated ground motions were generated to satisfy a specified minimum response spectra.

The ICC Evaluation Service, Inc. report AC156 "Acceptance Criteria for Seismic Qualification by Shake-table Testing of Nonstructural Components and Systems" was used to develop the testing protocol. This document establishes the minimum requirements for shake-table tests of non-structural components which includes piping. This document specifies a minimum response spectra that is derived from the code specified nonstructural component design seismic load. The response spectrum of the input motion to the shake testing was greater than the minimum spectrum specified in AC156.

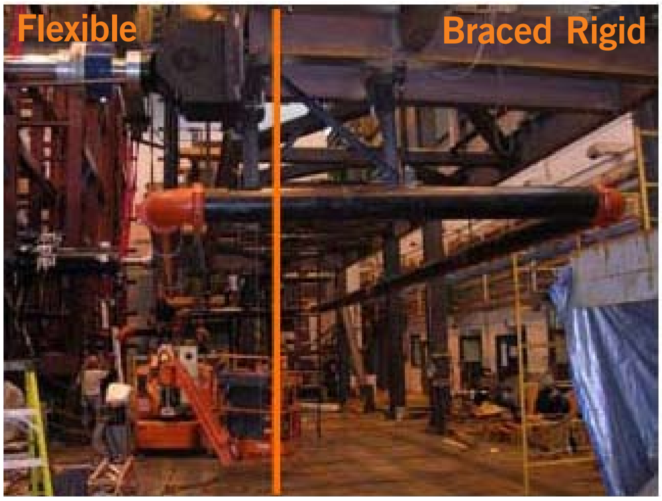
The minimum response spectra specified in AC156 were based upon the seismic design loads specified in the current building codes. The 2006 International Building Code (IBC) was used for this test program. The IBC 2006 references seismic loads as specified in ASCE 7-05 "Minimum Design Loads for Buildings and Other Structures" by the American Society of Civil Engineers. The design of the piping and other nonstructural components was based on the equivalent static load method, similar to that used for building design.

Test Configuration

A test configuration was developed that could accommodate a large pipeline and impose the required motions. The tests required the capability of imposing large accelerations, displacements and velocities on the piping and couplings. A horizontal truss was designed to serve as a rigid diaphragm or "building ceiling" from which the piping would be supported. The seismic motion was imposed on this "ceiling" which in turn was transferred to the piping. Three NEES actuators were used to impose the seismic motion required in both the longitudinal and transverse directions. To record all pertinent test data accelerometers, displacement sensors, and strain gauges were strategically placed in pre-determined locations to provide an accurate record of the testing program.

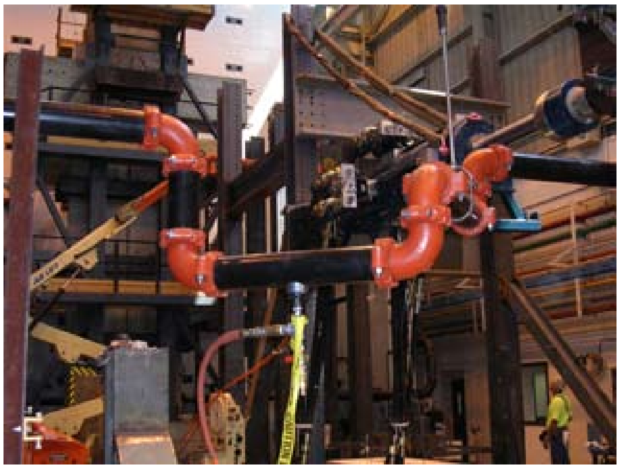
The piping layout consisted of a 40'/ 12m run (consisting of two 20'/6m pipe lengths) with a 90° elbow and then a 10'/3m run on either end, all joined with Victaulic Style 07 or W07 rigid couplings. This section of piping was seismically braced in accordance with standard industry code requirements and was referred to as the "braced rigid zone". On each end of the "braced rigid zone" there was a "flexible zone" comprised of a Victaulic seismic isolation assembly. These displacement assemblies were then connected to the ATLSS reaction wall that allowed no movement. Therefore, movement of the piping in the "rigid zone" generated relative displacements in the seismic isolation assemblies.

Rigid Zone Piping

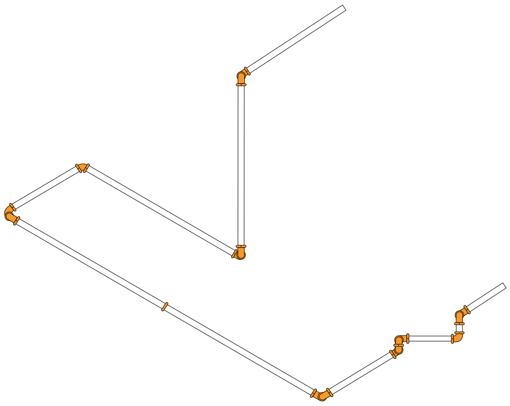


Seismic Tests

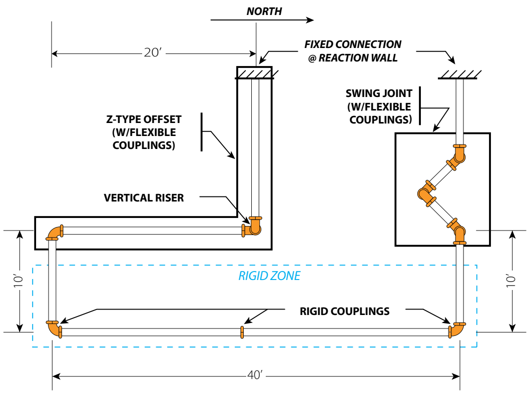
Seismic Swing Joint



Seismic Loop



Seismic Loop- Rigid/Flexible Zones



Two different seismic isolation assemblies were utilized, one on each end of the "rigid zone". One assembly was a Z-Type offset configuration and the other was a seismic swing joint. Both of these configurations used the deflection and rotational characteristics of Victaulic Styles 77 and W77 flexible couplings to accommodate the differential piping movement between the "rigid zone" and the reaction wall.

4"/DN100 Test Assembly

8"/DN200 Test Assembly

16"/DN400 Test Assembly

Seismic Tests

Three pipe sizes were selected for testing: 4"/DN100, 8"/DN200 and 16"/DN400. Each size was tested individually as a complete layout. A number of tests were performed on each piping assembly to demonstrate the ability of Victaulic couplings to handle a variety of seismic demands. The same couplings and pipe were used for all three tests. These tests included a static displacement test, sinusoidal sweep test and shake tests. The piping was water filled and pressurized to 200 psi/1375 kPa throughout the duration of all tests.

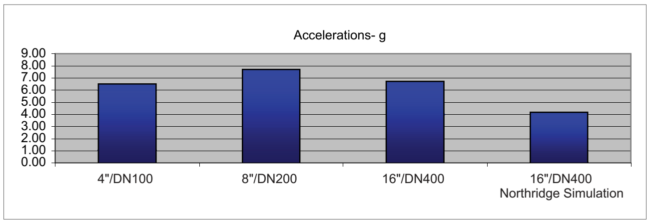
The static displacement test subjected each assembly to ± 4"/102mm of movement in both x and y horizontal directions. The sinusoidal sweep test subjected each assembly to a sinusoidal acceleration record with a frequency range from 1.3Hz to 33Hz. The shake tests subjected each assembly to three levels of seismic motion. The maximum inputs during the shake tests were ± 3"/76 mm of horizontal movement and 1.3g acceleration.

Two additional tests were performed. The first involved the 8"/DN200 piping assembly. Following the shake tests, the rigid couplings were replaced with flexible couplings and all tests performed again. The second involved the 16"/DN400 piping assembly. Following the standard program tests, a real-time multi-directional hybrid simulation of the Northridge Earthquake was performed. This testing was performed in order to study the response of the piping system installed in a three story building subjected to a real earthquake. Two tests were performed during this testing. First the assembly was subjected to ½ of the calculated amplitude of the Northridge Earthquake. Second, the assembly was subjected to 1.07 times the calculated amplitude.

Test Results

Performance of the Victaulic couplings was excellent. There was no evidence of any pipe joint leakage throughout all of the tests. The 200 psi/1375 kPa internal pressure was always maintained. The piping and couplings exhibited a very robust behavior even after the failure of a large number of seismic bracing elements.

The peak accelerations recorded per assembly were as follows:



4"/DN100 Assembly – 6.51g
8"/DN200 Assembly – 7.70g
16"/DN400 Assembly – 6.71g
16"/DN400 Northridge Earthquake Simulation – 4.17g

The performance of the seismic isolation assemblies was also excellent. All differential motions were accommodated. It should be noted that the loads measured in the actuators were very low which indicates that the stiffness of the isolation assemblies was minimal. This is desirable in minimizing the loads and stresses induced to seismic braces or anchor points.

Richter scale Values

While many of us associate the "Richter Scale" with earthquakes, the "Richter Scale" is a measurement of the energy released during the seismic event and not a building or piping system design tool. It is a useful tool for comparing relative strengths of different seismic events, but cannot be used to directly predict the motion or forces that a particular building or piping system will experience during seismic movements.

Structural engineers design buildings and piping systems to withstand displacements and accelerations caused by seismic ground motion which is not solely based on the energy released, but also on factors such as site soil properties, building type/construction, and proximity to the earthquake epicenter and others. The movements of the buildings themselves and the infrastructure within the buildings may vary considerably from a given ground motion due to the building size and shape, construction method (e.g., steel, concrete, wood-frame), natural frequencies and specific locations within the building. Piping systems are designed and implemented per the displacements and forces specified by the structural engineer. These design parameters are a function of the natural frequencies of the building, site seismicity, and the proposed location of the piping system within the structure. It is for this reason that our testing parameters were based on a frequency range encompassing historical recordings and accelerations that were above the typical values recorded, and not based on any "Richter Scale" value, nor can the test parameters be correlated to any specific "Richter Scale" value.

The magnitude of accelerations/displacements expected to be caused by a given earthquake at a given site is not only a function of the amount of energy released (the Richter magnitude), it is also a function of the following:

1. Distance to the epicenter (smaller distance means larger forces/displacements)
2. Soil condition (softer soil often means larger forces/displacements)
3. Building type (the construction type and height/width of the building affects the natural frequency which changes how the building/piping will respond to the earthquake)

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