

## Appendix to Chapter 6

### ALTERNATIVE PROVISIONS FOR THE DESIGN OF PIPING SYSTEMS

**BACKGROUND:** As currently written, the Provisions do not recognize discrete levels of performance that may be relevant to the seismic design of piping systems, particularly for essential facilities. This Appendix provides preliminary criteria for the establishment of such performance criteria and their use in the assessment and design of piping systems. The performance criteria, from least restrictive to most severe, are: position retention, leak tightness and operability. In particular, the interaction of systems and interface with the relevant piping design standards is addressed.

#### A6.1 DEFINITIONS

**Leak Tightness:** The condition of a piping system characterized by containment of contents, or maintenance of a vacuum, with no discernable leakage.

**Operability:** The condition of a piping system characterized by leak tightness as well as continued delivery, shutoff or throttle of pipe contents flow by means of unimpaired operation of equipment and components such as pumps, compressors and valves.

**Position Retention:** The condition of a piping system characterized by the absence of collapse or fall of any part of the system.

#### A6.2 DESIGN APPROACH

The seismic design of piping systems is determined on the basis of Seismic Design Category,  $I_p$ , and pipe size, as provided in Table A6.2-1. For each case in table A6.2-1, the procedure for seismic qualification is specified in Sec.A.6.5.

Where  $I_p = 1.0$ , the piping system is not criticalcritical and is required to maintain position retention.

Where  $I_p = 1.5$ , the piping system is critical and is required to exhibit leak tightness and may be required to maintain operability.

**Table A6.2-1 Seismic Design Requirements**

Seismic Design Category	$I_p = 1.0$		$I_p = 1.5$	
	Pipe Size $\leq$ 4 inch (SI: 102 mm)	Pipe Size $>$ 4 inch (SI: 102 mm)	Pipe Size $\leq$ 4 inch (SI: 102 mm)	Pipe Size $>$ 4 inch (SI: 102 mm)
B	Interactions (A6.5.2.1)	Interactions (A6.5.2.1)	Bracing (A6.5.2.2) Restraints (A6.5.2.3) Operability <sup>a</sup> (A6.5.2.4) Interactions (A6.5.2.1)	Bracing (A6.5.2.2) Restraints (A6.5.2.3) Operability <sup>a</sup> (A6.5.2.4) Interactions (A6.5.2.1)
C or D	Interactions (A6.5.2.1)	Interactions (A6.5.2.1)	Bracing (A6.5.2.2) Restraints (A6.5.2.3) Operability <sup>a</sup> (A6.5.2.4) Interactions (A6.5.4.2.1)	Analysis (A6.5.2.5) Restraints (A6.5.2.3) Operability <sup>a</sup> (A6.5.2.4) Interactions (A6.5.2.1)
E or F	Bracing (A6.5.2.2) Restraints (A6.5.2.3) Interactions (A6.5.2.1)	Bracing (A6.5.2.2) Restraints (A6.5.2.3) Operability <sup>a</sup> (A6.5.2.4) Interactions (A6.5.2.1)	Analysis (A6.5.2.5) Restraints (A6.5.2.3) Operability <sup>a</sup> (A6.5.2.4) Interactions (A6.5.2.1)	Analysis (A6.5.2.5) Restraints (A6.5.2.3) Operability <sup>a</sup> (A6.5.2.4) Interactions (A6.5.2.1)

<sup>a</sup> Leak tightness is the default requirement. Operability applies only where specified by design.

### A6.3 SYSTEM COEFFICIENTS

**A6.3.1 Deformability.** Piping systems shall be classified as either high-, limited-, or low-deformability systems.

All materials in high-deformability piping systems shall have an elongation at rupture of at least 10 percent at the operating temperature, and pipes and pipe components used in high-deformability systems shall be joined by welding or by bolted flanges.

Systems containing components with an elongation at rupture of less than 10 percent at the operating temperature, or having joints that rely only on friction, shall be classified as low-deformability systems.

Systems that are neither high- nor low-deformability systems shall be classified as limited deformability systems. Systems with threaded connections shall be classified as limited- or low-deformability systems.

**A6.3.2 Seismic Coefficients.** The seismic coefficients  $a_p$  and  $R_p$  are specified in Table 6.4.1 for high-, limited-, and low-deformability piping systems.

### A6.4 SEISMIC DEMAND

**A6.4.1** Seismic demand on a piping system consists of applied forces and relative displacements.

**A6.4.2** Seismic forces shall be determined as specified in Sec. 6.2.6.

**A6.4.3** Seismic relative displacements at points of attachments of pipe restraints to the structure shall be determined as specified in Sec. 6.2.7.

## **A6.5 SEISMIC QUALIFICATION**

**A6.5.1** Elevator system piping shall satisfy the provisions of Sec.6.4.9. ASME B31 pressure piping systems shall satisfy the provisions of the applicable ASME B31 code section. Fire sprinkler systems shall satisfy the provisions of Sec.A6.5.2.6.

**A6.5.2** The seismic qualification of piping systems depends on the Design Approach selected in A6.2.

**A6.5.2.1** Where interactions are specified they shall be evaluated in accordance with Sec.6.2.3.

**A6.5.2.2** Where bracing is specified, the pipe must be seismically restrained. Lateral restraints shall be provided (a) to limit the bending stress in the pipe to yield at the operating temperature and (b) to limit the rotations at articulated joints within the manufacturer limits. Unlike analysis (Sec. A6.5.2.5), bracing does not require a detailed analysis of the piping system; the distance between seismic restraints may be established based on beam approximations of the pipe spans. The effect of seismic restrains on operating loads (thermal expansion and contraction, weight) shall be considered.

**A6.5.2.3** Where restraints are specified, the pipe seismic restraints as well as their welds and anchorage attachment to the structure shall comply with the provisions of Chapters 8 to 12. Supports shall be constructed so that support engagement is maintained considering both lateral and vertical seismic forces.

**A6.5.2.4** Where operability is specified, the equipment and components that must perform an active function that involves moving parts (such as pumps, compressors, fans and valve operators) shall comply with the requirements of Sec.2.4.5.

**A6.5.2.5** Where analysis is specified, the piping system shall be analyzed by static or dynamic methods. The maximum calculated elastic stress due to the earthquake loads and concurrent weight and pressure shall be limited to  $1.5S_Y$  (where  $S_Y$  is the minimum specified material yield stress at normal operating temperature) and the rotations at articulated joints shall be within the manufacturer limits. The analysis shall include the effects of stress intensification factors as determined in the ASME B31 pressure piping code, and corrosion effects.

**A6.5.2.6** Fire protection sprinkler systems shall meet the following requirements:

**A6.5.2.6.1** Fire protection sprinkler systems in Seismic Design Categories A, B and C designed and constructed in accordance with NFPA-13 shall be deemed to satisfy the seismic force and relative displacement requirements of these *Provisions*.

**A6.5.2.6.2** In Seismic Design Categories D, E and F, fire protection sprinkler systems designed and constructed in accordance with NFPA 13 shall also meet the following additional criteria:

1. The spacing of longitudinal sway bracing and transverse sway bracing specified in NFPA 13 Sec. 9.3.5 shall be reduced by multiplying the maximum brace spacing permitted in NFPA 13 Sec. 9.3.5 by  $0.8W_p / F_p$ . The value of  $0.8W_p / F_p$  shall not be taken as greater than 1.0.

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