

## Chapter 6

### ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENT DESIGN REQUIREMENTS

#### 6.1 GENERAL

**6.1.1 Scope.** This chapter establishes minimum design criteria for nonstructural components that are permanently attached to structures and for their supports and attachments.

**Exception:** The following components are exempt from the requirements of this chapter.

1. Architectural components in Seismic Design Category B, other than parapets supported by bearing walls or shear walls, where the component importance factor,  $I_p$ , is equal to 1.0.
2. Mechanical and electrical components in Seismic Design Category B.
3. Mechanical and electrical components in Seismic Design Category C where the importance factor,  $I_p$ , is equal to 1.0.
4. Mechanical and electrical components in Seismic Design Category D, E, or F where the component importance factor,  $I_p$ , is equal to 1.0 and both of the following conditions apply:
  - a. flexible connections between the components and associated ductwork, piping, and conduit are provided, and
  - b. components are mounted at 4 ft (1.22 m) or less above a floor level and weigh 400 lb (1780 N) or less.
5. Mechanical and electrical components in Seismic Design Category C, D, E, or F where the component importance factor,  $I_p$ , is equal to 1.0 and both the following conditions apply:
  - a. flexible connections between the components and associated ductwork, piping, and conduit are provided, and
  - b. the components weigh 20 lb (95 N) or less or, for distribution systems, weigh 5 lb/ft (7 N/m) or less.

Design criteria for storage racks, storage tanks, and nonbuilding structures that are supported by other structures are provided in Chapter 14.

Where the individual weight of supported components and nonbuilding structures with periods greater than 0.06 seconds exceeds 25 percent of the total seismic weight  $W$ , the structure shall be designed considering interaction effects between the structure and the supported components.

Testing shall be permitted to be used in lieu of analysis methods outlined in this chapter to determine the seismic capacity of components and their supports and attachments. Thus, adoption of a nationally recognized standard, such as AC-156, is acceptable so long as the seismic capacities equal or exceed the demands determined in accordance with Sec. 6.2.

#### 6.1.2 References

**6.1.2.1 Use of Standards.** Where a reference standard provides a basis for the earthquake-resistant design of a particular type of system or component, that standard may be used, subject to the following conditions:

1. The design earthquake forces shall not be less than those determined in accordance with Sec. 6.2.6.
2. Each component's seismic interactions with all other connected components and with the supporting structure shall be accounted for in the design. The component shall accommodate drifts,

deflections, and relative displacements determined in accordance with the applicable sections of the *Provisions*

**6.1.2.2 Adopted References.** The following references are adopted and are to be considered part of these *Provisions* to the extent referred to in this chapter:

- ASME A17.1 *Safety Code For Elevators And Escalators*, American Society of Mechanical Engineers, 1996.
- ASME B31.1 *Power Piping*, American Society of Mechanical Engineers, 2001.
- ASME B31.3 *Process Piping*, American Society of Mechanical Engineers, 2002.
- ASME B31.4 *Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols*, American Society of Mechanical Engineers, 2002.
- ASME B31.5 *Refrigeration Piping*, American Society of Mechanical Engineers, 2001.
- ASME B31.8 *Gas Transmission and Distribution Piping Systems*, American Society of Mechanical Engineers, 1995.
- ASME B31.9 *Building Services Piping*, American Society of Mechanical Engineers, 1996.
- ASME B31.11 *Slurry Transportation Piping Systems*, American Society of Mechanical Engineers, 1989 (reaffirmed, 1998).
- ASME BPV *Boiler and Pressure Vessel Code*, American Society of Mechanical Engineers, including addenda through 2002.
- IEEE-344 *Recommended Practice for Seismic Qualification of Class I E Equipment for Nuclear Power Generating Stations*, Institute of Electrical and Electronic Engineers, 1987.
- NFPA-13 *Standard for the Installation of Sprinkler Systems*, National Fire Protection Association, 2000, including TIA 02-1 (NFPA 13) (SC 03-7-8 / Log No. 748).

**6.1.2.3 Other references.** The following references are developed within the industry and represent acceptable procedures for design and construction:

- AAMA 501.6 *Recommended Dynamic Test Method for Determining the Seismic Drift Causing Glass Fallout from a Wall System*, American Architectural Manufacturers Association, 2001.
- AC-156 *Acceptance Criteria for Seismic Qualification Testing of Nonstructural Components (AC 156)*, International Conference of Building Officials Evaluation Service, 2000.
- ASHRAE *Handbook, "Seismic Restraint Design,"* American Society of Heating, Ventilating, and Air Conditioning, 1999.
- CISCA 0-2 *Recommendations for Direct-Hung Acoustical Tile and Lay-in Panel Ceilings, Seismic Zones 0-2*, Ceilings and Interior Systems Construction Association, 1991.
- CISCA 3-4 *Recommendations for Direct-Hung Acoustical Tile and Lay-in Panel Ceilings, Seismic Zones 3-4*, Ceilings and Interior Systems Construction Association, 1991.
- SMACNA 95 *HVAC Duct Construction Standards, Metal and Flexible*, Sheet Metal and Air Conditioning Contractors National Association, 1995.
- SMACNA 80 *Rectangular Industrial Duct Construction Standards*, Sheet Metal and Air Conditioning Contractors National Association, 1980.
- SMACNA 98 *Seismic Restraint Manual Guidelines for Mechanical Systems*, Sheet Metal and Air Conditioning Contractors National Association, 1991, including Appendix B, 1998.

### 6.1.3 Definitions

**Appendage:** An architectural component such as a canopy, marquee, ornamental balcony, or statuary.

**Attachments:** Means by which components and their supports are secured and connected to the seismic-force-resisting system of the structure. Such attachments include anchor bolts, welded connections, and mechanical fasteners.

**Base:** See Sec. 4.1.3.

**Component:** See Sec. 1.1.4.

**Construction documents:** See Sec. 2.1.3.

**Deformability:** The ratio of the ultimate deformation to the limit deformation.

**Enclosure:** An interior space surrounded by walls.

**Flexible component:** Component, including its attachments, having a fundamental period greater than 0.06 sec.

**Glazed curtain wall:** A nonbearing wall that extends beyond the edges of the building floor slabs and includes a glazing material installed in the curtain wall framing.

**Glazed partition:** A partition that includes a glazing material installed in its framing.

**Glazed storefront:** A nonbearing wall that is installed between floor slabs, typically including entrances, and includes a glazing material installed in the storefront framing.

**Grade plane:** A reference plane representing the average of the finished ground level adjoining the structure at the exterior walls. Where the finished ground level slopes away from the exterior walls, the reference plane shall be established by the lowest points within the area between the buildings and the lot line or, where the lot line is more than 6 ft (1829 mm) from the structure between the structure and a point 6 ft (1829 mm) from the structure.

**Hazardous material:** See Sec. 1.1.4.

**High deformability element:** An element whose deformability is not less than 3.5 when subjected to four fully reversed cycles at the limit deformation.

**Limit deformation:** Two times the initial deformation that occurs at a load equal to 40 percent of the maximum strength.

**Limited deformability element:** An element that is neither a low deformability nor a high deformability element.

**Low deformability element:** An element whose deformability is 1.5 or less.

**Nonbearing wall:** An exterior or interior wall that does not provide support for vertical loads other than its own weight or as permitted by the building code administered by the authority having jurisdiction.

**Nonbuilding structure:** See Sec. 14.1.3.

**Nonstructural wall:** All walls other than bearing walls or shear walls.

**Owner:** See Sec. 1.1.4.

**Partition:** See Sec. 5.1.2.

**Registered design professional:** See Sec. 2.1.3.

**Rigid component:** Component, including its attachments, having a fundamental period less than or equal to 0.06 sec.

**Seismic Design Category:** See Sec. 1.1.4.

**Seismic Use Group:** See Sec. 1.1.4.

**Special inspector:** See Sec. 2.1.3.

**Structure:** See Sec. 1.1.4.

**Supports:** Those structural members, assemblies of members, or manufactured elements, including braces, frames, legs, lugs, snuggers, hangers, saddles, or struts, that transmit loads between the nonstructural components and the structure.

**Ultimate deformation:** The deformation at which failure occurs and which shall be deemed to occur if sustainable load reduces to 80 percent or less of the maximum strength.

**Utility or service interface:** The connection of the structure's mechanical and electrical distribution systems to the utility or service company's distribution system.

#### 6.1.4 Notation

$A_x$	The torsional amplification factor determined using Eq. 5.2-13
$a_i$	Acceleration at Level $i$ obtained by modal analysis.
$a_p$	The component amplification factor selected, as appropriate, from Table 6.3-1 or 6.4-1.
$b_p$	The width of the rectangular glass.
$c_1$	The clearance (gap) between vertical glass edges and the frame.
$c_2$	The clearance (gap) between horizontal glass edges and the frame.
$D_{clear}$	The relative horizontal (drift) displacement, measured over the height of the glass panel under consideration, which causes initial glass-to-frame contact. For rectangular glass panels within a rectangular wall frame, $D_{clear}$ is given by Eq. 6.3-2.
$D_p$	Relative seismic displacement that the component must be designed to accommodate as defined in Sec. 6.2.7.
$F_p$	The seismic design force applicable to a particular nonstructural component.
$g$	Acceleration due to gravity.
$h$	The average roof height of structure above the base.
$h_p$	The height of the rectangular glass.
$h_{sx}$	Story height used in the definition of the allowable drift, $\Delta_a$ , in Table 4.5-1. Note that $\Delta_a/h_{sx}$ is the allowable drift index.
$I_p$	The component importance factor as prescribed in Sec. 6.2.2.
$K_p$	The stiffness of the system comprising the component and its supports and attachments, determined in terms of load per unit deflection at the center of gravity of the component.
$Q_E$	The effect of horizontal seismic forces. See Sec. 4.1.4.
$R$	Response modification coefficient. See Sec. 4.1.4.
$R_p$	The component response modification factor selected, as appropriate, from Table 6.3-1 or 6.4-1.
$S_{D1}$	The design, 5-percent-damped, spectral response acceleration parameter at a period of 1 second as defined in Sec. 3.3.3.

- $S_{DS}$  The short period spectral acceleration parameter, determined in Sec. 3.3.3.
- $T_p$  The fundamental period of a component (including its supports and attachments) as defined in Sec. 6.4.1.
- $W_p$  Operating weight of a nonstructural component.
- $X$  Height above the base of the upper support attachment (at level  $x$ ).
- $Y$  Height above the base of lower support attachment (at level  $y$ ).
- $z$  The height above the base of the point of attachment of the component, but  $z$  shall not be taken less than 0 and the value of  $z/h$  need not exceed 1.0.
- $\Delta_{aA}$  Allowable story drift for structure A, as defined in Table 4.5-1.
- $\Delta_{aB}$  Allowable story drift for structure B, as defined in Table 4.5-1.
- $\Delta_{\text{fallout}}$  The relative seismic displacement (drift) at which glass fallout from the curtain wall, storefront or partition occurs.
- $\delta_{xA}$  Deflection at level  $x$  of structure A, determined in accordance with Sec. 5.2.6, 5.3.5, or 5.4.3.
- $\delta_{yA}$  Deflection at level  $y$  of structure A, determined in accordance with Sec. 5.2.6, 5.3.5, or 5.4.3.
- $\delta_{yB}$  Deflection at level  $y$  of structure B, determined in accordance with Sec. 5.2.6, 5.3.5, or 5.4.3.
- $\rho$  The redundancy factor as defined in Sec. 4.3.3.

**6.2 GENERAL DESIGN REQUIREMENTS**

Nonstructural components shall satisfy the requirements of this section. In addition to these general requirements, the requirements indicated in Table 6.2-1 shall apply.

**Table 6.2-1 Additional Requirements for Nonstructural Components**

Component Type	<i>Provisions Reference</i>	
	Quality Assurance	Design
Architectural components, including their supports and attachments	2.3.9	6.3
Mechanical and electrical components, including their supports and attachments	2.3.10 2.4.5	6.4

**6.2.1 Seismic Design Category.** For the purposes of this chapter, components shall be assigned to the same Seismic Design Category as the structure that they occupy or to which they are attached.

**6.2.2 Component importance factor.** All components shall be assigned a component importance factor as indicated in this section. The component importance factor,  $I_p$ , shall be taken as 1.5 if any of the following conditions apply:

1. The component is required to function after an earthquake,
2. The component contains hazardous materials, or
3. The component is in or attached to a Seismic Use Group III structure and it is needed for continued operation of the facility or its failure could impair the continued operation of the facility.

All other components shall be assigned a component importance factor,  $I_p$ , equal to 1.0.

**6.2.3 Consequential damage.** The functional and physical interrelationship of components and their effect on each other shall be considered so that the failure of an essential or nonessential architectural, mechanical, or electrical component shall not cause the failure of an essential architectural, mechanical, or electrical component.

**6.2.4 Flexibility.** The design and evaluation of components, supports, and attachments shall consider their flexibility as well as their strength.

**6.2.5 Component force transfer.** Components shall be attached such that the component forces are transferred to the structure. Component attachments that are intended to resist seismic forces shall be bolted, welded, or otherwise positively fastened without consideration of frictional resistance produced by the effects of gravity. A continuous load path of sufficient strength and stiffness between the component and the supporting structure shall be verified. Local elements of the supporting structure shall be designed for the component forces where such forces control the design of the elements or their connections. In this instance, the component forces shall be those determined in Section 6.2.6, except that modifications to  $F_p$  and  $R_p$  due to anchorage conditions need not be considered. The design documents shall include sufficient information concerning the attachments to verify compliance with the requirements of these *Provisions*.

**6.2.6 Seismic forces.** The seismic design force,  $F_p$ , applied in the horizontal direction shall be centered at the component's center of gravity and distributed relative to the component's mass distribution and shall be determined in accordance with Eq. 6.2-1 as follows:

$$F_p = \frac{0.4a_p S_{DS} W_p}{R_p / I_p} \left( 1 + 2 \frac{z}{h} \right) \quad (6.2-1)$$

**Exception:** If the component period,  $T_p$ , is greater than  $T_{flx}$  where  $T_{flx} = (1 + 0.25 z/h) S_{D1} / S_{DS}$ , the value of  $F_p$  may be reduced by the ratio of  $T_{flx} / T_p$ .

In lieu of the forces determined in accordance with Eq. 6.2-1, accelerations at any level may be determined by the response spectrum procedure of Sec. 5.3 with  $R$  equal to 1.0, in which case seismic forces shall be determined in accordance with Eq. 6.2-2 as follows:

$$F_p = A_x \frac{a_i a_p W_p}{R_p / I_p} \quad (6.2-2)$$

$F_p$  is not required to be taken as greater than:

$$F_p = 1.6 S_{DS} I_p W_p \quad (6.2-3)$$

**Exception:** If the component period,  $T_p$ , is greater than  $T_{flx}$  where  $T_{flx} = (1 + 0.25 z/h) S_{D1} / S_{DS}$ , the upper limit value of  $F_p$  may be reduced by the ratio of  $T_{flx} / T_p$ .

and  $F_p$  shall not be taken as less than:

$$F_p = 0.3 S_{DS} I_p W_p \quad (6.2-4)$$

The force  $F_p$  shall be independently applied in each of two orthogonal horizontal directions in combination with service loads. In addition, the nonstructural component shall be designed for a concurrent vertical force  $\pm 0.2 S_{DS} W_p$ . The reliability/redundancy factor,  $\rho$ , and the overstrength factor  $\Omega_o$  are not applicable.

Where wind loads on nonstructural exterior walls or building code horizontal loads on interior partitions exceed  $F_p$ , such loads shall govern the strength design, but the detailing requirements and limitations prescribed in this chapter shall apply.

**6.2.6.1 Allowable Stress Design.** Where an adopted reference provides a basis for the earthquake-resistant design of a particular type of system or component, and the same reference defines acceptance

criteria in terms of allowable stresses rather than strengths, that reference shall be permitted to be used. The allowable stress load combination shall consider dead, live, operating, and earthquake loads. The earthquake loads determined in accordance with the *Provisions* shall be multiplied by a factor of 0.7. The allowable stress design load combinations of ASCE 7 need not be used. The component or system shall also accommodate the relative displacements specified in Section 6.2.7.

**6.2.6.2 Seismic Design Force.** The seismic design force,  $F_p$ , shall be centered at the component's center of gravity and distributed relative to the component's mass distribution and shall be determined in accordance with Eq. 6.2-1.

**6.2.7 Seismic relative displacements.** The relative seismic displacements,  $D_p$ , for use in component design shall be determined in accordance with Eq. 6.2-5 as follows:

$$D_p = \delta_{xA} - \delta_{yA} \quad (6.2-5)$$

$D_p$  is not required to be taken greater than:

$$D_p = (X - Y) \frac{\Delta_{aA}}{h_{sx}} \quad (6.2-6)$$

For two connection points on separate structures, A and B, or separate structural systems, one at level  $x$  and the other at level  $y$ ,  $D_p$  shall be determined in accordance with Eq. 6.2-7 as follows:

$$D_p = |\delta_{xA}| + |\delta_{yB}| \quad (6.2-7)$$

$D_p$  is not required to be taken as greater than:

$$D_p = \frac{X\Delta_{aA}}{h_{sx}} + \frac{Y\Delta_{aB}}{h_{sx}} \quad (6.2-8)$$

The effects of relative seismic displacement shall be considered in combination with displacement caused by other loads as appropriate.

**6.2.8 Component anchorage.** Components shall be anchored in accordance with the requirements of this section and the anchorage shall satisfy the requirements for the parent material as set forth elsewhere in these *Provisions*.

**6.2.8.1 Design forces.** The forces in the connected part shall be determined based on the prescribed forces for the component specified in Sec. 6.2.6. The value of  $R_p$  used in Sec. 6.2.6 to determine the forces in the connected part shall not exceed 1.5 unless:

- a. The component anchorage is designed to be governed by the strength of a ductile steel element, or
- b. The design of anchors in concrete used for the component anchorage is based on Sec. 9.6.4.4.3 whereby post-installed anchors shall be pre-qualified for seismic applications per ACI 355.2-01.

**6.2.8.2 Anchors in concrete or masonry.** Anchors embedded in concrete or masonry shall be proportioned to carry the least of the following:

1. The design strength of the connected part,
2. 1.3 times the force in the connected part due to the prescribed forces, and
3. The maximum force that can be transferred to the connected part by the component structural system.

**6.2.8.3 Installation conditions.** Determination of forces in anchors shall take into account the expected conditions of installation including eccentricities and prying effects.

**6.2.8.4 Multiple anchors.** Determination of force distribution of multiple anchors at one location shall take into account the stiffness and ductility of the connected system and its ability to redistribute loads to other anchors in the group. Designs of anchorage in concrete in accordance with Sec. 9.6 shall be considered to satisfy this requirement.

**6.2.8.5 Power actuated fasteners.** Power actuated fasteners shall not be used for tension load applications in Seismic Design Category D, E, or F unless approved for such loading.

**6.2.9 Construction documents.** Where design of nonstructural components or their supports and attachments is required by these *Provisions* (as indicated in Table 6.2-1), such design shall be shown in construction documents prepared by a registered design professional for use by the owner, building officials, contractors, and inspectors. Such documents shall include a quality assurance plan as required by Sec. 2.2.

### 6.3 ARCHITECTURAL COMPONENTS

Architectural components, and their supports and attachments, shall satisfy the requirements of this section. Appropriate coefficients shall be selected from Table 6.3-1.

**Exception:** Components supported by chains or otherwise suspended from the structure are not required to satisfy the seismic force and relative displacement requirements provided they meet all of the following criteria:

1. The design load for such items shall be equal to 1.4 times the operating weight acting down with a simultaneous horizontal load equal to 1.4 times the operating weight. The horizontal load shall be applied in the direction that results in the most critical loading for design.
2. Seismic interaction effects shall be considered in accordance with Sec.6.2.3.
3. The connection to the structure shall allow a 360-degree range of horizontal motion.

**Table 6.3-1 Coefficients for Architectural Components**

Architectural Component or Element	$a_p^a$	$R_p$
Interior nonstructural walls and partitions <sup>b</sup>		
Plain masonry walls	1.0	1.5
All other walls and partitions	1.0	2.5
Cantilever Elements, unbraced or braced (to structural frame) below their centers of mass	2.5	2.5
Parapets and cantilevered interior nonstructural walls	2.5	2.5
Chimneys and stacks where laterally supported by structures		
Cantilever elements, braced (to structural frame) above their centers of mass		
Parapets	1.0	2.5
Chimneys and stacks	1.0	2.5
Exterior nonstructural walls <sup>b</sup>	1.0	2.5
Exterior nonstructural wall elements and connections <sup>b</sup>		
Wall element	1.0	2.5
Body of wall-panel connections	1.0	2.5
Fasteners of the connecting system	1.25	1.0
Veneer		
High deformability elements and attachments	1.0	2.5
Low deformability elements and attachments	1.0	1.5
Penthouses (except where framed by an extension of the building frame)	2.5	3.5

Ceilings All	1.0	2.5
Cabinets Storage cabinets and laboratory equipment	1.0	2.5
Access floors Special access floors All other	1.0 1.0	2.5 1.5
Appendages and ornamentation	2.5	2.5
Signs and billboards	2.5	2.5
Other rigid components High deformability elements and attachments Limited deformability elements and attachments Low deformability elements and attachments	1.0 1.0 1.0	3.5 2.5 1.5
Other flexible components High deformability elements and attachments Limited deformability elements and attachments Low deformability elements and attachments	2.5 2.5 2.5	3.5 2.5 1.5
<sup>a</sup> A lower value for $a_p$ is permitted where justified by detailed dynamic analysis. The value for $a_p$ shall not be less than 1.0. The value of $a_p$ equal to 1.0 is for rigid components and rigidly attached components. The value of $a_p$ equal to 2.5 is for flexible components and flexibly attached components. <sup>b</sup> Where flexible diaphragms provide lateral support for concrete or masonry walls or partitions, the design forces for anchorage to the diaphragm shall be as specified in Sec. 4.6.2.1.		

**6.3.1 Forces and displacements.** All architectural components, and their supports and attachments, shall be designed for the seismic forces defined in Sec. 6.2.6.

Architectural components that could pose a life-safety hazard shall be designed to accommodate the seismic relative displacements defined in Sec. 6.2.7. Architectural components shall be designed considering vertical deflection due to joint rotation of horizontally cantilevered structural members.

**6.3.2 Exterior nonstructural wall elements and connections.** Exterior nonstructural wall panels or elements that are attached to or enclose the structure shall be designed to accommodate the seismic relative displacements defined in Sec. 6.2.7 and movements due to temperature changes. Such elements shall be supported by means of positive and direct structural supports or by mechanical connections and fasteners in accordance with the following requirements:

1. Connections and panel joints shall allow for a relative movement between stories of not less than the calculated story drift  $D_p$  or 1/2 in. (13 mm), whichever is greater.
2. Connections to permit movement in the plane of the panel for story drift shall be sliding connections using slotted or oversized holes, connections that permit movements by bending of steel, or other connections that provide equivalent sliding or ductile capacity.
3. Bodies of connectors shall have sufficient deformability and rotation capacity to preclude fracture of the concrete or low deformation failures at or near welds.
4. All fasteners in the connecting system such as bolts, inserts, welds, and dowels and the body of the connectors shall be designed for the seismic force  $F_p$  determined by Eq. 6.2-3, using values of  $a_p$  and  $R_p$  taken from Table 6.3-1, applied at the center of mass of the panel.
5. Where anchorage is achieved using flat straps embedded in concrete or masonry, such straps shall be attached to or hooked around reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

Glass in glazed curtain walls and storefronts shall be designed and installed in accordance with Sec. 6.3.7.

**6.3.3 Out-of-plane bending.** Transverse or out-of-plane bending or deformation of a component or system that is subjected to forces as determined in Sec. 6.2.6 shall not exceed the deflection capacity of the component or system.

**6.3.4 Suspended ceilings.** Suspended ceilings shall satisfy the requirements of this section.

**6.3.4.1 Seismic forces.** The weight of the ceiling,  $W_p$ , shall include the ceiling grid and panels; light fixtures if attached to, clipped to, or laterally supported by the ceiling grid; and other components which are laterally supported by the ceiling.  $W_p$  shall not be taken as less than 4 psf (0.2 kN/m<sup>2</sup>).

The seismic force,  $F_p$ , shall be transmitted through the ceiling attachments to the building structural elements or the ceiling-structure boundary.

**6.3.4.2 Industry standard construction.** Unless designed in accordance with Sec. 6.3.4.3, suspended ceilings shall be designed and constructed in accordance with this section.

**6.3.4.2.1 Seismic Design Category C.** Suspended ceilings in Seismic Design Category C shall be designed and installed in accordance with CISCA 0-2, except that seismic forces shall be determined in accordance with Sec. 6.2.6 and 6.3.4.1.

Sprinkler heads and other penetrations in Seismic Design Category C shall have a minimum clearance of 1/4 in. (6 mm) on all sides.

**6.3.4.2.2 Seismic Design Categories D, E, and F.** Suspended ceilings in Seismic Design Category D, E, or F shall be designed and installed in accordance with CISCA 3-4 and the requirements of this section.

1. A heavy-duty T-bar grid system shall be used.
2. The width of the perimeter supporting closure angle shall not be less than 2.0 in. (50 mm). In each orthogonal horizontal direction, one end of the ceiling grid shall be attached to the closure angle. The other end in each horizontal direction shall have a 3/4 in. (19 mm) clearance from the wall and shall rest upon and be free to slide on a closure angle.
3. For ceiling areas exceeding 1000 ft<sup>2</sup> (93m<sup>2</sup>), horizontal restraint of the ceiling to the structural system shall be provided by means of splay wires. The tributary areas of the horizontal restraints shall be approximately equal.

**Exception:** Rigid braces are permitted to be used instead of diagonal splay wires. Braces and the attachments to the structural system above shall be adequate to limit relative lateral deflections at the point of attachment to the ceiling grid to less than 1/4 in. (6 mm) when subjected to the loads prescribed in Sec. 6.2.6.

4. For ceiling areas exceeding 2500 ft<sup>2</sup> (230 m<sup>2</sup>), a seismic separation joint or full height partition that breaks the ceiling into areas not exceeding 2500 ft<sup>2</sup> shall be provided unless structural analyses of the ceiling bracing system for the prescribed seismic forces demonstrate that ceiling system penetrations and closure angles provide sufficient clearance to accommodate the additional movement. Each area shall be provided with closure angles in accordance with Item 2 and horizontal restraints or bracing in accordance with Item 3.
5. Except where rigid braces are used to limit lateral deflections, sprinkler heads and other penetrations shall have a 2 in. (50 mm) oversized ring, sleeve, or adapter through the ceiling tile to allow for free movement of at least 1 in. (25 mm) in all horizontal directions. Alternatively, a swing joint that can accommodate 1 in. (25 mm) of ceiling movement in all horizontal directions is permitted to be provided at the top of the sprinkler head extension.
6. Changes in ceiling elevation shall be provided with positive bracing.

7. Cable trays and electrical conduits shall be supported independently of the ceiling.
8. Suspended ceilings shall be subject to the special inspection requirements of Sec. 2.3.9 of these *Provisions*.

**6.3.4.3 Integral construction.** As an alternative to providing large clearances around sprinkler system penetrations through ceiling systems, the sprinkler system and ceiling grid are permitted to be designed and tied together as an integral unit. Such a design shall consider the mass and flexibility of all elements involved, including: ceiling system, sprinkler system, light fixtures, and mechanical (HVAC) appurtenances. Such design shall be performed by a registered design professional.

**6.3.5 Access floors**

**6.3.5.1 General.** Access floors shall satisfy the requirements of this section. The weight of the access floor,  $W_p$ , shall include the weight of the floor system, 100 percent of the weight of all equipment fastened to the floor, and 25 percent of the weight of all equipment supported by, but not fastened to the floor. The seismic force,  $F_p$ , shall be transmitted from the top surface of the access floor to the supporting structure.

Overturning effects of equipment fastened to the access floor panels also shall be considered. The ability of “slip on” heads for pedestals shall be evaluated for suitability to transfer overturning effects of equipment.

Where checking individual pedestals for overturning effects, the maximum concurrent axial load shall not exceed the portion of  $W_p$  assigned to the pedestal under consideration.

**6.3.5.2 Special access floors.** Access floors shall be considered to be “special access floors” if they are designed in accordance with the following considerations:

1. Connections transmitting seismic loads consist of mechanical fasteners, anchors complying with the requirements of Sec.9.6, welding, or bearing. Design load capacities comply with recognized design codes and/or certified test results.
2. Seismic loads are not transmitted by power actuated fasteners, adhesives, or by friction produced solely by the effects of gravity.
3. The bracing system shall be designed considering the destabilizing effects of individual members buckling in compression.
4. Bracing and pedestals are of structural or mechanical shape produced to ASTM specifications that specify minimum mechanical properties. Electrical tubing shall not be used.
5. Floor stringers that are designed to carry axial seismic loads and are mechanically fastened to the supporting pedestals are used.

**6.3.6 Partitions.** Partitions that are tied to the ceiling and all partitions greater than 6 ft (1.8 m) in height shall be laterally braced to the building structure. Such bracing shall be independent of any ceiling splay bracing. Bracing shall be spaced to limit horizontal deflection at the partition head to be comparable with ceiling deflection requirements as determined in Sec. 6.3.4 for suspended ceilings and Sec. 6.3.1 for other systems.

Glass in glazed partitions shall be designed and installed in accordance with Sec. 6.3.7.

**6.3.7 General.** Glass in glazed curtain walls, glazed storefronts and glazed partitions shall meet the relative displacement requirement of Eq. 6.3-1:

$$\Delta_{\text{fallout}} \geq 1.25 I D_p \text{ or } 0.5 \text{ in. (13mm), whichever is greater.} \tag{6.3-1}$$

$D_p$ , the relative seismic displacement that the glazed curtain walls, glazed storefronts or glazed partitions component must be designed to accommodate (Eq. 6.2-5) shall be determined over the height of the

glass component under consideration.

**Exceptions:**

1. Glass with sufficient clearances from its frame such that physical contact between the glass and frame will not occur at the design drift, as demonstrated by Eq. 6.3-2, shall be exempted from the provisions of Eq. 6.3-1:

$$D_{\text{clear}} \geq 1.25 D_p \quad (6.3-2)$$

Where:

$$D_{\text{clear}} = 2c_1 \left( 1 + \frac{h_p c_2}{b_p c_1} \right)$$

2. Fully tempered monolithic glass in Seismic Use Groups I and II located no more than 10 ft (3 m) above a walking surface shall be exempted from the provisions of Eq. 6.3-1.
3. Annealed or heat-strengthened laminated glass in single thickness with interlayer no less than 0.030 in. (0.76 mm) that is captured mechanically in a wall system glazing pocket, and whose perimeter is secured to the frame by a wet glazed gunable curing elastomeric sealant perimeter bead of 1/2 in. (13 mm) minimum glass contact width, or other approved anchorage system, shall be exempted from the provisions of Eq. 6.3-1.

**6.3.8 Seismic Drift Limits for Glass Components.**  $\Delta_{\text{fallout}}$ , the drift causing glass fallout from the curtain wall, storefront or partition, shall be determined in accordance with AAMA 501.6, or by engineering analysis.

## 6.4 MECHANICAL AND ELECTRICAL COMPONENTS

Mechanical and electrical components, and their supports and attachments, shall satisfy the requirements of this section. Appropriate coefficients shall be selected from Table 6.4-1.

**Exception:** Light fixtures, lighted signs, and ceiling fans not connected to ducts or piping, that are supported by chains or otherwise suspended from the structure, are not required to satisfy the seismic force and relative displacement requirements provided they meet all of the following criteria:

1. The design load for such items shall be 1.4 times the operating weight acting down with a simultaneous horizontal load equal to 1.4 times the operating weight. The horizontal load shall be applied in the direction which results in the most critical loading for design.
2. Seismic interaction effects shall be considered in accordance with Sec. 6.2.3.
3. The connection to the structure shall allow a 360-degree range of horizontal motion.

As an alternative to the analysis methods outlined in this section, testing is an acceptable method to determine the seismic capacity of components, and their supports and attachments. Thus, adaptation of a nationally recognized standard is acceptable so long as the seismic capacities equal or exceed the demands determined in accordance with Sec. 6.2.6 and 6.2.7.

**Table 6.4-1 Coefficients for Mechanical and Electrical Components**

Mechanical or Electrical Component or Element <sup>b</sup>	$a_p^a$	$R_p$
General Mechanical		

Boilers and Furnaces	1.0	2.5
Pressure vessels on skirts and free-standing	2.5	2.5
Stacks	2.5	2.5
Cantilevered chimneys	2.5	2.5
Other	1.0	2.5
Manufacturing and Process Machinery		
General	1.0	2.5
Conveyors (non-personnel)	2.5	2.5
Piping Systems		
High deformability elements and attachments	1.0	3.5
Limited deformability elements and attachments	1.0	2.5
Low deformability elements and attachments	1.0	1.5
HVAC System Component		
Vibration isolated	2.5	2.5
Non-vibration isolated	1.0	2.5
Mounted in-line with ductwork	1.0	2.5
Other	1.0	2.5
Elevator Components	1.0	2.5
Escalator Components	1.0	2.5
Trussed Towers (free-standing or guyed)	2.5	2.5
General Electrical		
Distribution systems (bus ducts, conduit, cable tray)	2.5	5
Equipment	1.0	2.5
Lighting Fixtures	1.0	1.5
<p><sup>a</sup> A lower value for <math>a_p</math> is permitted where justified by detailed dynamic analysis. The value for <math>a_p</math> shall not be less than 1.0. The value of <math>a_p</math> equal to 1.0 is for rigid components and rigidly attached components. The value of <math>a_p</math> equal to 2.5 is for flexible components and flexibly attached components.</p> <p><sup>b</sup> Components mounted on vibration isolators shall have a bumper restraint or snubber in each horizontal direction. The design force shall be taken as <math>2F_p</math> if the nominal clearance (air gap) between the equipment support frame and restraint is greater than 0.25 in. If the nominal clearance specified on the construction documents is not greater than 0.25 in., the design force may be taken as <math>F_p</math>.</p>		

Where design of mechanical and electrical components for seismic effects is required, consideration shall be given to the dynamic effects of the components, their contents, and where appropriate, their supports. In such cases, the interaction between the components and the supporting structures, including other mechanical and electrical components, shall also be considered.

Some complex equipment such as valve operators, turbines and generators, and pumps and motors are permitted to be functionally connected by mechanical links that are not capable of transferring the seismic loads or accommodating seismic relative displacements. Such items may require special design considerations such as a common rigid support or skid.

**6.4.1 Component period.** Where the dynamic response of a mechanical or electrical component (including its supports and attachments) can reasonably be approximated by a spring-and-mass single-degree-of-freedom system, the fundamental period of the component,  $T_p$ , may be determined using Eq. 6.4-1 as follows:

$$T_p = 2\pi \sqrt{\frac{W_p}{K_p g}} \quad (6.4-1)$$

Alternatively, the fundamental period of the component,  $T_p$ , may be determined from experimental test data or by a properly substantiated analysis.

**6.4.2 Mechanical components.** Mechanical components with  $I_p$  greater than 1.0 shall be designed for the seismic forces and relative displacements defined in Sec. 6.2.6 and 6.2.7 and shall satisfy the following additional requirements:

1. Provision shall be made to eliminate seismic impact for components vulnerable to impact, for components constructed of nonductile materials, and in cases where material ductility will be reduced due to service conditions (such as low temperature applications).
2. The possibility of loads imposed on components by attached utility or service lines, due to differential movement of support points on separate structures, shall be evaluated.
3. Where mechanical components contain a sufficient quantity of hazardous material to pose a danger if released and for boilers and pressure vessels not designed in accordance with ASME BPV, the design strength for seismic loads in combination with other service loads and appropriate environmental effects (such as corrosion) shall be based on the following material properties:
  - a. For mechanical components constructed with ductile materials (such as steel, aluminum, or copper), 90 percent of the minimum specified yield strength.
  - b. For threaded connections in components constructed with ductile materials, 70 percent of the minimum specified yield strength.
  - c. For mechanical components constructed with nonductile materials (such as plastic, cast iron, or ceramics), 25 percent of the minimum specified tensile strength.
  - d. For threaded connections in components constructed with nonductile materials, 20 percent of the minimum specified tensile strength.
4. Where piping or HVAC ductwork components are attached to structures that could displace relative to one another and for isolated structures where such components cross the isolation interface, the components shall be designed to accommodate the seismic relative displacements defined in Sec. 6.2.7.

**6.4.3 Electrical components.** Electrical components with  $I_p$  greater than 1.0 shall be designed for the seismic forces and relative displacements defined in Sec. 6.2.6 and 6.2.7 and shall satisfy the following additional requirements:

1. Provision shall be made to eliminate seismic impact between components.
2. Evaluate loads imposed on the components by attached utility or service lines which are also attached to separate structures.
3. Batteries on racks shall have wrap-around restraints to ensure that the batteries will not fall from the rack. Spacers shall be used between restraints and cells to prevent damage to cases. Racks shall be evaluated for sufficient lateral load capacity.
4. Internal coils of dry type transformers shall be positively attached to their supporting substructure within the transformer enclosure.
5. Electrical control panels, computer equipment, and other items with slide-out components shall have a latching mechanism to hold the components in place.
6. Electrical cabinet design shall comply with the applicable National Electrical Manufacturers Association (NEMA) standards. Cut-outs in the lower shear panel that do not appear to have been

made by the manufacturer and are judged to reduce significantly the strength of the cabinet shall be specifically evaluated.

7. The attachments for additional external items weighing more than 100 lb (445 N) shall be specifically evaluated if not provided by the manufacturer.
8. Where conduit, cable trays, or similar electrical distribution components are attached to structures that could displace relative to one another and for isolated structures where such components cross the isolation interface, the components shall be designed to accommodate the seismic relative displacements defined in Sec. 6.2.7.

#### 6.4.4 Supports and attachments

Supports and attachments for mechanical and electrical components shall be designed for the seismic forces defined in Sec. 6.2.6 and shall satisfy the requirements found elsewhere in these *Provisions*, as appropriate, for the materials comprising the means of attachment.

Supports for components shall be designed to accommodate the seismic relative displacements between points of support as determined in accordance with Sec. 6.2.7. Supports for components may be forged or cast so as to form an integral part of the mechanical or electrical component. Attachments between the component and its supports, except where integral, shall be designed to accommodate both the forces and displacements determined in accordance with Sec. 6.2.6 and 6.2.7. Where  $I_p$  is greater than 1.0, the effect of load transfer on the component wall at the point of attachment shall be evaluated.

The following additional requirements shall apply:

1. Supports and attachments that transfer seismic loads shall be constructed of materials suitable for the application and shall be designed and constructed in accordance with a nationally recognized standard specification, such as those listed in Sec. 6.1.2.
2. Seismic supports shall be constructed so that support engagement is maintained.
3. Friction clips shall not be used for anchorage attachment.
4. Oversized plate washers extending to the component wall shall be used at bolted connections through the sheet metal base if the base is not reinforced with stiffeners or is not judged to be capable of transferring the required loads.
5. Where weak-axis bending of cold-formed steel supports is relied on for the seismic load path, such supports shall be specifically evaluated.
6. Components mounted on vibration isolators shall have a bumper restraint or snubber in each horizontal direction, and vertical restraints shall be provided where required to resist overturning. Isolator housings and restraints shall be constructed of ductile materials. (See additional design force requirements in Table 6.4-1.) A viscoelastic pad or similar material of appropriate thickness shall be used between the bumper and components to limit the impact load.
7. Expansion anchors shall not be used for non-vibration isolated mechanical equipment rated over 10 hp (7.45 kW).

**Exception:** Undercut expansion anchors are permitted.

8. The supports for electrical distribution components shall be designed for the seismic forces and relative displacements defined in Sec. 6.2.6 and 6.2.7 if any of the following conditions apply:
  - a. Supports are cantilevered up from the floor;
  - b. Supports include bracing to limit deflection;
  - c. Supports are constructed as rigid welded frames;
  - d. Attachments into concrete utilize non-expanding insets, powder driven fasteners, or cast iron

embedments; or

e. Attachments utilize spot welds, plug welds, or minimum size welds as defined by AISC.

9. For boilers and pressure vessels, attachments to concrete shall be suitable for cyclic loads.

**6.4.5 Utility and service lines.** At the interface of adjacent structures or portions of the same structure that may move independently, utility lines shall be provided with adequate flexibility to accommodate the anticipated differential movement between the ground and the structure. Differential displacements shall be determined in accordance with Sec. 6.2.7.

The possible interruption of utility service shall be considered in relation to designated seismic systems in Seismic Use Group III, as defined in Sec. 1.2.1. Specific attention shall be given to the vulnerability of underground utilities and utility interfaces between the structure and the ground in all situations where the assigned Site Class is E or F and  $S_{DS}$  is greater than or equal to 0.4.

**6.4.6 HVAC ductwork.** Seismic restraints are not required for HVAC ducts with  $I_p$  equal to 1.0 if either of the following conditions is met for the full length of each duct run:

1. HVAC ducts are suspended from hangers, all hangers are 12 in. (305 mm) or less in length as measured from the point of attachment to the duct to the point of attachment on the supporting structure and the hangers are detailed to avoid significant bending of the hangers and their attachments; or
2. HVAC ducts have a cross-sectional area of less than 6 ft<sup>2</sup> (0.6 m<sup>2</sup>).

HVAC duct systems fabricated and installed in accordance with SMACNA 80, SMACNA 95, and SMACNA 98 shall be deemed to satisfy the seismic bracing requirements of these *Provisions*.

Components that are installed in-line with the duct system and have an operating weight greater than 75 lb (334 N), such as fans, heat exchangers, and humidifiers, shall be supported and laterally braced independently of the duct system and such braces shall be designed for the seismic forces defined in Sec. 6.2.6. Appurtenances, such as dampers, louvers, and diffusers, shall be positively attached with mechanical fasteners. Unbraced piping attached to in-line equipment shall be provided with adequate flexibility to accommodate differential displacements.

**6.4.7 Piping systems.** Piping systems shall satisfy the requirements of this section except that elevator system piping shall satisfy the requirements of Sec. 6.4.9.

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

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

**6.4.7.1.1** The spacing of longitudinal sway bracing and transverse sway bracing specified in NFPA 13 Section 9.3.5 shall be reduced by multiplying the maximum brace spacing permitted in NFPA 13 Section 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.

**6.4.7.2 Other piping systems.** Where the seismic design forces and displacements specified in ASME B31.1, ASME B31.3, ASME B31.4, ASME B31.5, ASME B31.8, ASME B31.9, and ASME B31.11 are comparable to those determined using these *Provisions*, the use of these standards for seismic design of piping systems shall be permitted.

**Exception:** Piping systems with  $I_p$  greater than 1.0 shall not be designed using the simplified analysis procedures found in Sec. 919.4.1 (a) of ASME B31.9.

Piping systems with  $I_p$  greater than 1.0 also shall satisfy the following requirements:

1. Under design loads and displacements, piping shall not be permitted to impact other components.
2. Piping shall accommodate the effects of relative displacements that may occur between piping support points on the structure or the ground and other mechanical or electrical equipment or other piping.

Seismic supports for other piping shall be constructed so that support engagement is maintained, and attachments shall be designed in accordance with Sec. 6.2.8.

Seismic supports are not required for other piping systems where one of the following conditions is met:

1. Piping is supported by rod hangers, all hangers in the pipe run are 12 in. (305 mm) or less in length from the top of the pipe to the supporting structure, the hangers are detailed to avoid bending of the hangers and their attachments, and the pipe can accommodate the expected deflections; or
2. High deformability piping is used, provision is made to avoid impact with larger piping or mechanical components or to protect the piping in the event of such impact, and the following size requirements are satisfied:
  - a. In Seismic Design Category D, E, or F, where  $I_p$  is greater than 1.0, the nominal pipe size shall be 1 in. (25 mm) or less,
  - b. In Seismic Design Category C, where  $I_p$  is greater than 1.0, the nominal pipe size shall be 2 in. (51 mm) or less, and
  - c. In Seismic Design Category D, E, or F, where  $I_p$  is equal to 1.0, the nominal pipe size shall be 3 in. (76 mm) or less.

**6.4.8 Boilers and pressure vessels.** Boilers and pressure vessels designed in accordance with ASME BPV shall be deemed to satisfy the seismic force and relative displacement requirements of these *Provisions* provided that the forces and displacements defined in Sec. 6.2.6 and 6.2.7 are used in lieu of the seismic forces and displacements defined in ASME BPV. Supports and attachments for boilers and pressure vessels are still subject to the requirements of these *Provisions*.

**6.4.9 Elevators.** Elevators designed in accordance with the seismic provisions of ASME A17.1 shall be deemed to satisfy the requirements of this chapter except that they also shall satisfy the additional requirements of this section.

**6.4.9.1 Elevators and hoistway structural systems.** Elevators and hoistway structural systems shall be designed for the seismic forces and relative displacements defined in Sec. 6.2.6 and 6.2.7.

**6.4.9.2 Elevator machinery and controller supports and attachments.** Supports and attachments for elevator machinery and controllers shall be designed for the seismic forces and relative displacements defined in Sec. 6.2.6 and 6.2.7.

**6.4.9.3 Seismic switches.** Seismic switches shall be provided for all elevators that operate with a speed of 150 ft/min (46 m/min) or greater, including those which satisfy the requirements of ASME A17.1.

Seismic switches shall provide an electrical signal indicating that structural motions are of such a magnitude that the operation of elevators may be impaired. The seismic switch shall be located at or above the highest floor serviced by the elevator. The seismic switch shall have two horizontal perpendicular axes of sensitivity. Its trigger level shall be set to 30 percent of the acceleration of gravity in facilities where the loss of the use of an elevator is a life-safety issue.

Upon activation of the seismic switch, elevator operations shall comply with the provisions of ASME A17.1. The elevator may be used after the seismic switch has triggered provided that:

1. The elevator shall operate no faster than the service speed,
2. The elevator shall be operated remotely from top to bottom and back to top to verify that it is operable, and

3. The individual putting the elevator back in service shall ride the elevator from top to bottom and back to top to verify acceptable performance.

**6.4.9.4 Retainer plates.** Retainer plates are required at the top and bottom of the car and counterweight.