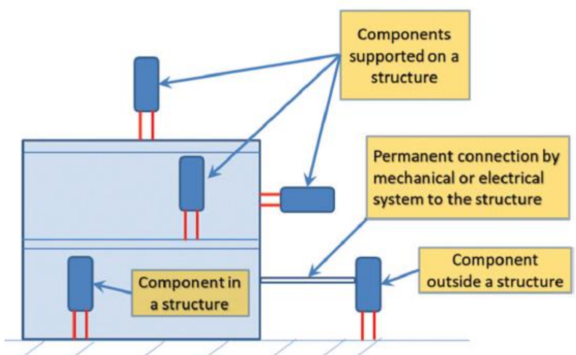
SEISMIC DESIGN GUIDE FOR ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS FOR RC V STRUCTURES

This guide addresses the seismic design requirements for nonstructural components in facilities considered to be national strategic military assets assigned to Risk Category (RC) V. The nonstructural components in these facilities require a significantly different design approach than those in RC I, II, III, and IV structures. RC V structures need to be designed to ensure that their mission-critical nonstructural components remain elastic through MCE_R ground motions, and that their installed equipment remains operational immediately following MCE_R ground motions. As such, the design seismic forces for RC V structures are much higher than they are for structures assigned to other RC's.

UFC 3-301-02 Chapter 2 provides modifications to provisions of the 2024 *International Building Code* (IBC) and ASCE 7-22, *Minimum Design Loads for Buildings and Other Structures*, that are applicable to RC V structures. Where conflicts between the 2024 IBC or ASCE 7-22 and UFC 3-301-02 arise, the UFC controls.

Chapter 13 of ASCE 7-22 provides minimum design requirements for architectural, mechanical, electrical, and other nonstructural systems and components, recognizing use of the structure, occupant load, the need for operational continuity, and the interrelation of structural, architectural, mechanical, electrical, and other nonstructural components. Note that, unless specified, all the Section and Table numbers in this design guide refer to ASCE 7-22.

The requirements for seismic design of nonstructural components apply to the nonstructural component and its supports and attachments, regardless of whether it is within or supported by a building or nonbuilding structure, or if it is outside of a structure.



Possible locations of nonstructural components.
(Source: ASCE 7-22 Commentary)

STEP 1 Do you have an RC V Structure?

According to UFC 3-301-01 Table 2-2, RC V structures include facilities designed as national strategic military assets, including, but not limited to:

- Key national defense assets (e.g. National Missile Defense facilities) without geographically separated redundant capability.
- Facilities involved in operational missile control, launch, tracking, or other critical defense capabilities.
- Emergency backup power-generating facilities required for primary power for Category V occupancy.
- Power-generating stations and other utility facilities required for primary power for Category V occupancy, if emergency backup power generating facilities are not available
- Facilities involved in storage, handling, or processing of nuclear, chemical, biological, or radiological materials, where structural failure could have widespread catastrophic consequences.

STEP 2 Designation for Nonstructural Components

The structural engineer, in consultation with functional risk representatives designated by the AHJ, must classify all architectural, mechanical, and electrical components, as Mission-Critical Level 1 (MC-1), Mission-Critical Level 2 (MC-2), or Non-Mission-Critical (NMC), as shown in the following table.

Classifications of Nonstructural Components, including Important Details

Mission-Critical Level 1 (MC-1) Components	• Components that are critical to the mission of the facility and must be operational immediately following the MCE_R ground shaking. • If the failure of an MC-2 or NMC component can cause the failure of an MC-1 component, then the MC-2 or NMC component must be designated as MC-1. • All systems in RC V facilities designated as MC-1 must be considered part of the Designated Seismic System. • Both components and their supports must remain elastic.
Mission-Critical Level 2 (MC-2) Components	• Components that may incur minor damage that would be reparable with parts stocked at or near the facility within a 3-day period, by on-site personnel, following the MCE_R ground shaking. • If the failure of an NMC component can cause the failure of an MC-2 component, then the NMC component must be designated as MC-2. • Component supports must remain elastic during the MCE_R-induced building motions, while limited inelastic component response is permitted.
Non-Mission-Critical (NMC) Components	• Components that may incur damage in the MCE_R ground shaking. • NMC components must be designed so they will not cause falling hazards or impede facility egress. • Inelastic deformations are permitted in both component and support response

STEP 3 Check if the Nonstructural Component is Exempted from Design Requirements in Chapter 13

All nonstructural components in RC V structures shall be designed by ASCE 7-22 Chapter 13 as modified by UFC 3-301-02. No exemptions shall apply.

STEP 4 Consideration of Seismic Design Category for the Nonstructural Component

According to UFC 3-301-02 Section 2-15.4, the requirements of ASCE 7-22 Section 11.6, Seismic Design Category, do not apply to RC V structures.

However, where ASCE 7-22 Chapter 13 requirements are based on the SDC of a structure, determine SDC assuming RC to be IV.

Step 4a – Determine the Seismic Design Category (SDC) for the structure assuming RC IV.

Structures must be assigned a seismic design category in accordance with Section 11.6.

Seismic Design Category for RC IV Structures

Value of S_{DS}	SDC[1,2]	Value of S_{D1}	SDC[1,2]
$S_{DS} < 0.167$	A	$S_{D1} < 0.067$	A
$0.167 \leq S_{DS} < 0.33$	C	$0.067 \leq S_{D1} < 0.133$	C
$0.33 \leq S_{DS} < 0.50$	D	$0.133 \leq S_{D1} < 0.20$	D
$0.50 \leq S_{DS}$	D	$0.20 \leq S_{D1}$	

[1]SDC shall be the worst based on S_{DS} and S_{D1}.
[2]Risk Category IV structures located where the mapped spectral response acceleration parameter at 1-s period, S_1, is greater than or equal to 0.75 shall be assigned to Seismic Design Category F

Step 4b – Determine the Seismic Design Category (SDC) for the nonstructural component.

A nonstructural component shall be assigned to the same seismic design category as:

1. The structure that it occupies or is supported by, or
2. The structure to which it is permanently connected by mechanical or electrical systems, or
3. For parts of an egress system, the structure it serves.

If an egress system serves more than one structure, the highest SDC of the structures served must be used.

STEP 5 DESIGN BASIS

Step 5a – Determine effective seismic weight, W of the supporting structure

W is the weight of the structure plus that of any contents that could, with a high degree of probability, be attached to the structure at the time of the earthquake. In addition to the dead load of the structure, ASCE 7-22 Section 12.7.2 requires that the following loads be included in the effective seismic weight, W:

Description	Include Seismic Weight
Areas of storage (other than public garages and open parking structures)	25 percent of floor live load (not needed where the inclusion of storage loads adds no more than 5% of the seismic weight at that level)
Buildings with partitions	10 psf or actual weight, whichever is greater
Buildings with roofs designed for snow	Where flat roof snow loads are greater than 45 psf, 15 percent of the uniform design snow load, regardless of actual roof slope
Permanent equipment	100 percent of operating weight
Buildings with roof gardens	100 percent of the weight of landscaping and other materials
Buildings containing fluids and bulk material	Weight of fluids and bulk material expected to be present during normal use.

Step 5b – Weight of the nonstructural component < 20% of combined effective seismic weight of the supporting structure and the nonstructural component.

Go to Step 6.

Step 5c – Weight of the nonstructural component ≥ 20% of the combined effective seismic weight of the supporting structure and the nonstructural component.

1. Determine the fundamental period, T_p, of the nonstructural component, including its supports and attachments to the structure

$$T_p = 2\pi \sqrt{\frac{W_p}{K_p g}}$$

where
W_p= Component operating weight,
K_p= Combined stiffness of the component, supports, and attachments, determined in terms of load per unit defection at the center of gravity of the component.

Alternatively, T_p can be determined from experimental test data or by a properly substantiated analysis.

Component period is used to classify components as rigid (T_p ≤ 0.06 s) or flexible (T_p> 0.06 s).

2. Determine the fundamental period of the supporting structure, T (including the lumped weight of the nonstructural component)

3. If $T_p/T < 0.5$ or $T_p/T > 2$, the supporting structure shall be designed in accordance with the requirements of Chapter 12 or Section 15.5, as appropriate. For design of nonstructural components go to Step 6.

Otherwise, go to Step 5d.

Step 5d – Perform structural analysis of the combined system

Perform structural analysis of the combined system accounting for stiffness, boundary conditions, material properties, and other structural characteristics of both the nonstructural component and the supporting structure. The nonstructural component and its attachments and the supporting structure must be designed for forces and displacements in accordance with Chapter 12 for nonstructural components in building structures or in accordance with Section 15.5 for nonstructural components in nonbuilding structures. The R-value for the combined system must be taken as the lesser of: 0.40$\left[\frac{C_{AR}}{R_{po}}\right]$ of the nonstructural component or the R-value of the supporting structure.

The nonstructural component and its attachments should be designed for forces and displacements resulting from the combined analysis. For other design criteria, Chapter 13 should be followed.

STEP 6 GENERAL DESIGN REQUIREMENTS FOR NONSTRUCTURAL COMPONENTS

All architectural, mechanical, and electrical components must be designed for the in-structure horizontal and vertical response spectra developed in UFC 3-301-02 Section 2-17.4.4. Designs must include bracing, anchorage, isolators, and energy dissipation devices, as appropriate, for all components, in addition to the components themselves. Motion amplification through component supports must be determined and accommodated in design. Additionally, these components, their supports, and attachments must comply with the sections referenced in Table 13.2-1.

Unless specifically noted otherwise in UFC 3-301-02, any ASCE 7-22 Chapter 13 provision that is specific to RC IV structures must also be applied to RC V structures.

ASCE 7-22 Table 13.2-1. Applicable Requirements for Architectural, Mechanical, and Electrical Components: Supports and Attachments.

Nonstructural Components, their Supports, and Attachments	General Design Requirements (Section 13.2)	Force and Displacement Requirements (Section 13.3)	Attachment Requirements (Section 13.4)	Architectural Component Requirements (Section 13.5)	Mechanical and Electrical Component Requirements (Section 13.6)
Architectural components and supports and attachments for those components	X	X	X	X	
Mechanical and electrical components	X	X	X		X
Supports and attachments for mechanical and electrical components	X	X	X		X

The applicable requirements must be satisfied by one of the following:

1. Project-specific design and documentation submitted for approval to the Authority Having Jurisdiction (AHJ) after a review of the nonstructural component design is performed by an independent licensed professional engineer with at least 15 years of experience in the theory and application of nonlinear seismic analysis and structural behavior under extreme cyclic loads (see Step 13); or

2. Submittal of the manufacturer's certification that the component is seismically qualified by at least one of the following:

a) Analysis, or
b) Testing in accordance with Section 13.2.6
c) Experience data in accordance with Section 13.2.7

As an alternative to the analytical requirements of Sections 13.3 through 13.6, testing and experience data can be used to determine the seismic capacity of components and their supports and attachments.

Seismic qualification by testing must be based on a nationally recognized testing procedure acceptable to the AHJ. Seismic qualification by experience data must be based on nationally recognized procedures acceptable to the AHJ.

UFC 3-301-01 Section 13.2.3 endorses the following nationally recognized testing procedures:

1. The requirements of the International Code Council Evaluations Service (ICC-ES), *Acceptance Criteria for Seismic Qualification by Shake-Table Testing of Nonstructural Components*, ICC-ES AC156, November 2020.
2. The CERL *Equipment Fragility and Protection Procedure* (CEFAPP), USACERL Technical Report 97/58, Wilcoski, J., Gambill, J.B., and Smith, S.J., March 1997. The test motions, test plan, and results of this method require peer review.
3. For power substation equipment only, Institute of Electrical and Electronics Engineers (IEEE), *Recommended Practices for Seismic Design of Substations*, IEEE 693-2018.

The substantiated seismic capacities from the above alternative procedures must be equal to or greater than the seismic force and displacement demands determined in accordance with Section 13.3.1 and 13.3.2.

STEP 7 CONSTRUCTION OF IN-STRUCTURE HORIZONTAL AND VERTICAL RESPONSE SPECTRA

Provisions of ASCE 4-16 Section 6, *Input for Subsystem Analysis*, apply for the construction of in-structure response spectra needed for the analysis of accelerations and displacements for installed architectural, mechanical, and electrical components. In-structure response spectra must be developed from models of the primary structure subjected to MCE_R ground motions. Frequency interval of the response spectra is to be set based on ASCE 4-16 Section 6.2.2. However, the lower-bound frequency is to be set at 0.1 Hz. Increments above 34 Hz are to be at 3 Hz and increments below 0.5 Hz are to be at 0.10 Hz.

Exception: In the application of ASCE 4-16 Section 6, those provisions that relate to spectra-to-spectra analysis in Section 6.2.1.2 do not apply.

STEP 8 DETERMINE HORIZONTAL SEISMIC DESIGN FORCE, F_p

The horizontal seismic design force, F_p, should be applied at the component's center of gravity and distributed according to the component's mass distribution. Seismic forces are to be computed using the MCE_R ground motion parameters. The procedure used for the force calculation will depend on the classification of the component.

The directions of F_p used must be those that produce the most critical load effects on the component, the component supports and attachments. Alternatively, it is permitted to use the more severe of the following two load cases:

- Case 1: A combination of 100% of F_p in any one horizontal direction and 40% of F_p in a perpendicular horizontal direction applied simultaneously.
- Case 2: The combination from Case 1 rotated 90 degrees.

Step 8a – Determine Component Operating Weight, W_p

Operating weight is the total weight of a component when it is in use, including the weights of such things as an operator, fuel, and any additional equipment or tools required for its operation.

Step 8b – Determine Fundamental Period of Nonstructural Component, T_p, including its supports and attachment to the structure

Already determined in Step 5c.

For MC-1 components go to Step 8c.
For MC-2 components go to Step 8d.
For NMC components go to Step 8e.

Step 8c – Determine F_p for MC-1 Components

Forces for MC-1 components are to be determined by response spectrum analysis or equivalent static analysis, using as input the in-structure response spectra determined in accordance with UFC 3-301-02 Section 2-17.4.4 (see Step 7). MC-1 components and their supports must remain elastic. MC-1 component forces are to be determined using UFC 3-301-02 Equation 2-4, with R_p for both components and supports set to 1.0.

$$F_p = \frac{a_{ip} W_p}{R_p} = a_{ip} W_p$$

UFC 3-301-02 Equation 2-4

where
a_{ip}= component spectral response acceleration in a given direction, at the fundamental period of the component.
R_p = component response modification factor, which is equal to 1.0 for MC-1 components.

Step 8d – Determine F_p for MC-2 Components

Forces for MC-2 components are to be determined by response spectrum analysis or equivalent static analysis, using as input the in-structure response spectra developed in accordance with UFC 3-301-02 Section 2-17.4.4 (see Step 7). MC-2 component supports must remain elastic, while limited inelastic component response is permitted. MC-2 component forces are to be determined using UFC 3-301-02 Equation 2-4, with R_p for supports set to 1.0, and R_p for components as specified in UFC 3-301-02 Tables 2-2 and 2-3.

$$F_p = \frac{a_{ip} W_p}{R_p}$$

UFC 3-301-02 Equation 2-4

UFC 3-301-02 Table 2-2 R_p Values for MC-2 Architectural Components

Architectural Component	R_p
Interior nonstructural walls and partitions	2½
Cantilever elements (unbraced or braced to structural frame below its center of mass)	
Parapets and cantilever interior nonstructural walls	2½
Chimneys where laterally braced or supported by the structural frame	2½
Cantilever elements (braced to structural frame above its center of mass)	
Parapets	2½
Chimneys	2½
Exterior nonstructural walls	2½
Exterior nonstructural wall elements and connections	
Wall element	2½
Body of wall panel connections	2½
Fasteners of the connecting system	1
Veneer	
Limited deformability elements and attachments	2½
Low-deformability elements and attachments	1½
Penthouses (except where framed by an extension of the building frame)	3½
Ceilings	
All	2½

Architectural Component	R_p
Cabinets	
Permanent floor-supported storage cabinets more than 6 ft (1,829 mm) tall, including contents	2½
Permanent floor-supported library shelving, book stacks, and bookshelves more than 6 ft (1,829 mm) tall, including contents	2½
Laboratory equipment	2½
Access floors	
Special access floors (designed in accordance with Section 13.5.7.2)	2½
All other	1½
Appendages and ornamentations	2½
Signs and Billboards	3
Other rigid components	
High-deformability elements and attachments	3½
Limited-deformability elements and attachments	2½
Low-deformability materials and attachments	1½
Other flexible components	
High-deformability elements and attachments	3½
Limited-deformability elements and attachments	2½
Low-deformability materials and attachments	1½
Egress stairs and ramp fasteners and attachments	2½

UFC 3-301-02 Table 2-3 R_p Values for MC-2 Mechanical and Electrical Components

Mechanical and Electrical Components	R_p
Air-side HVACR, fans, air handlers, air conditioning units, cabinet heaters, air distribution boxes, and other mechanical components constructed of sheet metal framing	6
Wet-side HVACR, boilers, furnaces, atmospheric tanks and bins, chillers, water heaters, heat exchangers, evaporators, air separators, manufacturing or process equipment, and other mechanical components constructed of high-deformability materials	2½
Air coolers (fin fans), air-cooled heat exchangers, condensing units, dry coolers, remote radiators and other mechanical components elevated on integral structural steel or sheet metal supports	3
Engines, turbines, pumps, compressors, and pressure vessels not supported on skirts and not within the scope of Chapter 15	2½
Skirt-supported pressure vessels not within the scope of Chapter 15	2½
Elevator and escalator components	2½
Generators, batteries, inverters, motors, transformers, and other electrical components constructed of high-deformability materials	2½
Motor control centers, panel boards, switch gear, instrumentation cabinets, and other components constructed of sheet metal framing	6
Communication equipment, computers, instrumentation, and controls	2½
Roof-mounted stacks, cooling and electrical towers laterally braced below their center of mass	3
Roof-mounted stacks, cooling and electrical towers laterally braced above their center of mass	2½
Lighting fixtures	1½
Other mechanical or electrical components	1½
VIBRATION-ISOLATED COMPONENTS AND SYSTEMS	
Components and systems isolated using neoprene elements and neoprene isolated floors with built-in or separate elastomeric snubbing devices or resilient perimeter stops	2½
Spring-isolated components and systems and vibration-isolated floors closely restrained using built-in or separate elastomeric snubbing devices or resilient perimeter stops	2
Internally isolated components and systems	2
Suspended vibration-isolated equipment including in-line duct devices and suspended internally isolated components	2½
DISTRIBUTION SYSTEMS	
Piping in accordance with ASME B31 (2001, 2002, 2008, and 2010), including in-line components with joints made by welding or brazing	12
Piping in accordance with ASME B31, including in-line components, constructed of high- or limited-deformability materials, with joints made by threading, bonding, compression couplings, or grooved couplings	6
Piping and tubing not in accordance with ASME B31, including in-line components, constructed of high-deformability materials, with joints made by welding or brazing	9
Piping and tubing not in accordance with ASME B31, including in-line components, constructed of high- or limited-deformability materials, with joints made by threading, bonding, compression couplings, or grooved couplings	4½
Piping and tubing constructed of low-deformability materials, such as cast iron, glass, and nondutile plastics	3
Ductwork, including in-line components, constructed of high-deformability materials, with joints made by welding or brazing	9
Ductwork, including in-line components, constructed of high- or limited-deformability materials with joints made by means other than welding or brazing	6
Ductwork, including in-line components, constructed of low-deformability materials, such as cast iron, glass, and nonductile plastics	3
Electrical conduit and cable trays	6
Bus ducts	2½
Plumbing	2½
Pneumatic tube transport systems	6

Step 8e – Determine F_p for NMC Components

ASCE 7-22 Equation 13.3-7 must be used for NMC component force calculations. Inelastic deformations are permitted in both component and support response. In applying ASCE 7-22 Equation 13.3-7, the values of C_{AR} and R_{po} specified in ASCE 7-22 Tables 13.5-1 and 13.6-1 are to be used. I_p is to be taken as 1.0, in lieu of the importance factors listed in ASCE 7-22 Sections 13.1.3.

$$F_p = I_p W_p a_i \left[\frac{C_{AR}}{R_{po}}\right] = W_p a_i \left[\frac{C_{AR}}{R_{po}}\right]$$

ASCE 7-22 Equation 13.3-7

where the peak in-structure floor acceleration determined in accordance with UFC 3-301-02 Section 2-17.4.4 is to be substituted for the term a_i, the acceleration at level i. The value of a_i should be taken as the mean of the maximum values of accelerations at the center of mass of the support level, obtained from analysis for each of the ground motions in the suite.

Step 8f – Determine Component Resonance Ductility Factor, C_{AR}, and Component Strength Factor, R_{po}

C_{AR} and R_{po} for architectural components are provided in Table 13.5-1 and for mechanical components are provided in Table 13.6-1.

C_{AR} for mechanical and electrical equipment mounted on equipment support structures or platforms must not be less than component resonance ductility factor used for the equipment support structure or platform.

STEP 9 DETERMINE VERTICAL SEISMIC DESIGN FORCE

The component, including its supports and attachments, must be designed for a concurrent vertical seismic design force, $E_v = 0.2S_{MS}D$, where D is the effect of dead load.

EXCEPTION: The concurrent vertical seismic force need not be considered for lay-in access floor panels and lay-in ceiling panels.

ASCE 7-22 mandates the use of the vertical response spectrum of Section 11.9 only in the design of nonbuilding structures Sensitive to Vertical Ground Motions, Section 15.1.4. The section specifically mentions tanks, vessels, hanging structures, and nonbuilding structures incorporating horizontal cantilevers. UFC 3-301-01 Section 1605.1.2 identifies the following as being particularly sensitive to vertical ground motion:

Building Structures:

- horizontal or nearly horizontal structural members spanning 65 ft or more
- horizontal or nearly horizontal cantilever components longer than 16 ft
- horizontal or nearly horizontal prestressed components
- building components, excluding foundations, in which demands due to gravity loads exceed 80% of the nominal strength of the component
- horizontal structural elements supporting discontinuous vertical elements of the gravity load-resisting system
- base-isolated structures

Nonbuilding Structures:

- long-span roof structures (e.g., stadiums or high-bay aircraft maintenance hangars aircraft maintenance hangar header truss)
- electric power generation facilities

In view of the above, it is felt that vertical earthquake effect on nonstructural components can be adequately represented by $0.2S_{MS}D$. S_{MS} replaces the usual S_{DS} because the RC V structures being discussed must be designed to remain elastic in MCE_R ground motion.

STEP 10 — DETERMINE SEISMIC RELATIVE DISPLACEMENTS, D_p

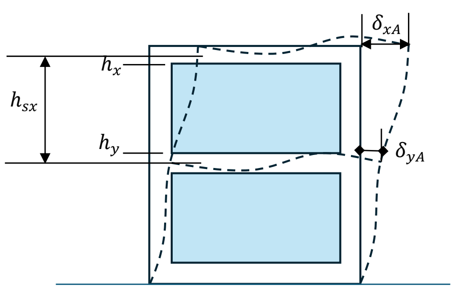
The effects of seismic relative displacements must be considered in combination with displacements caused by other loads, as appropriate. The seismic relative displacement given in Equation 13.3-8 is the calculated elastic relative displacement, D_p, times the Importance Factor, I_e. As per UFC 3-301-02 Section 2-15.3.1, for RC V structures, I_e, is equal to 1.0. The calculation of relative displacements will depend upon whether the component is attached to points on the same structure or to connection points on separate structures.

Displacements within Structure

For two connection points on the same structure A or the same structural system, one at a height h_x and the other at a height h_y

$$D_p = \delta_{xA} - \delta_{yA}$$

δ_{xA} = elastic displacement at building level x of structure A computed under MCE$_R$ earthquake forces.
δ_{yA} = elastic displacement at building level y of structure A computed under MCE$_R$ earthquake forces.



Structure A

For structures where the story drift associated with the MCE$_R$ earthquake displacement does not exceed the allowable story drift, Δ_a, for RC IV structures defined in Table 12.12-1, D_p is not required to be taken as greater than

$$D_p = \frac{(h_x - h_y)\Delta_{aA}}{h_{sx}}$$

where Δ_{aA} is the allowable story drift for structure A. As per UFC 3-301-02 Section 2-16.9.1, for RC V structure, allowable story drifts should be taken from Table 12.12-1 assuming the structure as RC IV. h_{sx} is the story height used in the definition of the allowable drift, Δ_a.

Allowable Story Drift, Δ_a

Structure	Risk Category IV
Structures, other than masonry shear wall structures, four stories or less above the base as defined in Section 11.2, with interior walls, partitions, and ceilings that have been designed to accommodate the drifts associated with the MCE$_R$ Earthquake Displacements	$0.015h_{sx}$
Masonry cantilever shear wall structures[b]	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$
All other structures	$0.010h_{sx}$

[a] There shall be no drift limit for single-story structures in which the interior walls, partitions, and ceilings have been designed to accommodate story drifts associated with the MCE$_R$ Earthquake Displacement. The structural separation requirement of Section 12.12.3 is not waived.

[b] Structures in which the basic structural system consists of masonry shear walls designed as vertical elements cantilevered from their base or foundation support that are so constructed that moment transfer between shear walls (coupling) is negligible.

Where performance requirements for installed equipment or other nonstructural features require smaller allowable drifts than those permitted by this Step, the smaller drifts govern.

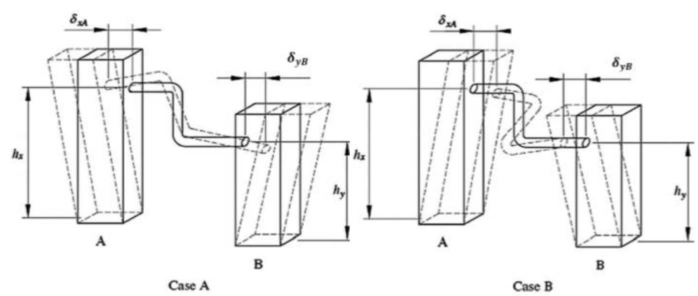
Displacements between Structures

For two connection points on separate structures A and B or separate structural systems, one at height h_x, and the other at a height h_y, D_p must be determined as

$$D_p = |\delta_{xA}| + |\delta_{yB}| \le \left[\frac{h_x\Delta_{aA}}{h_{sx}} + \frac{h_y\Delta_{aB}}{h_{sy}}\right]^*$$

*the limit applies only to structures where story drifts associated with MCE$_R$ Earthquake Displacement do not exceed the allowable story drift, assuming the structure is RC IV.

A component or system connected to two structures must accommodate horizontal movements in any direction, as illustrated in Figure below.



Displacement between structures.
(Source: ASCE 7-22 Commentary)

STEP 11 — LOAD COMBINATIONS

In load combinations involving seismic load effects, the combined effect, E, of horizontal (Section 12.4.2.1) and vertical earthquake-induced forces (Step 9) needs to be computed using the procedures outlined in UFC 3-301-02. ASCE 7-22 Sections 12.4.2 and 12.4.3 address the determination of the combined seismic load effect, E, and the combined seismic load effect including overstrength, E_m.

$$E = \rho F_p \pm E_v = F_p \pm 0.2S_{MS}D$$

- ρ = 1 for nonstructural components
- Effects of Horizontal Seismic Design Forces, F_p determined in Step 8
- Vertical Seismic Design Forces, determined in Step 9

E_m is the maximum seismic load effect and is required for the design of certain elements critical to the seismic load paths.

$$E_m = \Omega_{op}F_p \pm 0.2S_{MS}D$$

Ω_{op} is the component overstrength factor listed in Tables 13.5-1 and 13.6-1. $\Omega_{op}F_p$ represents the actual forces that may be experienced by a nonstructural component, its attachments or supports as a result of the MCE$_R$ level ground motion. E_m is used in the additive and the counteractive load combinations the same way as E.

For masonry and concrete anchors where nonductile anchorage in concrete and masonry is used, the anchorage overstrength factor, Ω_{op}, given in Tables 13.5-1 and 13.6-1 must be used.

Nonstructural components, including their supports and attachments, must comply with Section 1.3, and designed for load combinations of Section 2.3 (strength design). Note that only strength design load combinations are permitted for RC V structures (see UFC 3-301-02 Section 2-5 on Load Combinations).

Where the effects of nonseismic loads on nonstructural components exceed those due to F_p, the nonseismic load effects must govern the strength design, but the detailing requirements and limitations prescribed in Section 13.5 and 13.6 must still apply.

STEP 12 Design of Component Anchorage and Attachment

The design force in the attachment must be determined based on the forces and displacements calculated for the component in Steps 8 through 11. The determination of forces in attachments must take into account the expected conditions of installation, including eccentricities and prying effects. Where there are multiple attachments at one location, the design force from the component must be distributed to each attachment taking into account:

- the stiffnesses of the component, the component supports, the attachments, and the structure,
- the ductility of an MC-2 or NMC component,
- the ductility of NMC component supports and the attachments, and
- the ability of the attachment to redistribute loads to other attachments in the group.

A continuous load path of sufficient strength and stiffness between the component and supporting structure must be provided. Local elements of the structure, including connections, must be designed and constructed for the effects of component forces where they control the design of these elements.

Component attachments must be bolted, welded, or otherwise positively fastened without depending on frictional resistance produced by effects of gravity.

Anchors in Concrete

Anchors in concrete must be designed in accordance with Chapter 17 of ACI 318-19. Where nonductile anchorage to concrete is used to satisfy ACI 318-19 Section 17.10.5.3 (d), the anchorage overstrength factor, Ω_{op}, given in Tables 13.5-1 and 13.6-1 must be used.

In structures assigned to SDC C or higher, post-installed mechanical anchors in concrete are required to be prequalified for seismic applications in accordance with ACI 355.2 or other approved qualification procedures. Post-installed adhesive anchors in concrete in structures assigned to SDC C, D, E, or F are required to be prequalified for seismic applications in accordance with ACI 355.4 or other approved qualification procedures.

Anchors in Masonry

Anchors in masonry must be designed in accordance with TMS 402-22. Additionally, at least one of the following must be satisfied in structures assigned to SDC C or higher.

a. Anchors in tension are designed to be governed by the tensile strength of a ductile steel element.
b. Anchors are designed for the maximum load that can be transmitted to the anchors from a ductile attachment, considering both material overstrength and strain hardening of the attachment.
c. Anchors are designed for the maximum load that can be transmitted to the anchors by a non-yielding attachment.
d. Anchors are designed for the maximum load obtained from design load combinations that include F_p, where the effect of horizontal seismic design force, F_p, is multiplied by Ω_{op} as given in ASCE 7-22 Tables 13.5-1 and 13.6-1.

In structures assigned to SDC C or higher (assuming the structure as RC IV), post-installed anchors in masonry are required to be prequalified for seismic applications in accordance with approved qualification procedures.

Use of Power-Actuated Fasteners must comply with the requirements of Section 13.4.5

Use of Friction Clips must comply with the requirements of Section 13.4.6

STEP 13 Requirements for Mechanical and Electrical Component Supports

Mechanical and electrical component supports include structural members, braces, frames, skirts, legs, saddles, pedestals, cables, guys, stays, snubbers, tethers, and elements forged or cast as a part of the component. Section 13.6.4 outlines design and detailing requirements of mechanical and electrical component supports, as well as equipment support structures and platforms. Here is a summary of the requirements:

1. If supports designed in accordance with ASME B31, NFPA 13, or MSS SP-58 are used, they must be designed by load rating (i.e., testing) or for seismic design forces calculated in Steps 8 and 9.
2. The supports must be designed to accommodate seismic relative displacements calculated in Step 10.
3. The means by which the supports are attached to the component must be designed for seismic forces and relative displacements. The local region of the support attachment point must be evaluated for the effect of load transfer on the component wall.
4. Materials for support and means of attachment must be in conformance with nationally recognized standards.
5. Seismic supports must be constructed to maintain engagement. Reinforcement (e.g., stiffeners or Belleville washers) is required for bolted connections through sheet metal equipment housings. Weak-axis bending of cold-formed steel supports requires specific evaluation. Components on vibration isolators need appropriate restraints and materials to limit impact loads.
6. Equipment support structures and platforms must be designed for seismic forces and relative displacements determined in Steps 8 through 10. The selected seismic force-resisting system (SFRS) for equipment support structures and platforms should conform to the types in UFC 3-301-02 Table 2-1.
7. NMC Distribution system supports are assigned a component resonance ductility factor, C_{AR}, from Table 13.6-1, based on the type of support system. Seismic loads for distribution system supports and trapeze assemblies must be based on the weight of the distribution system tributary to the supports, including fittings and in-line components.

For buildings that are assigned to RC IV, guidance on the design of lighting fixtures is found in Section C-3.4 of UFC 3-301-01. The guidance may also be useful for RC V structures.

STEP 14	CONSEQUENTIAL DAMAGE – SEISMIC INTERACTION EFFECTS

The functional and physical interrelationship of components, their supports, and their effects on each other must 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. Where not otherwise established by analysis or test, required clearances for sprinkler system drops and sprigs must not be less than those specified in Section 13.2.4.1.

STEP 15	REQUIREMENTS FOR ARCHITECTURAL COMPONENTS

All architectural components, and their supports and attachments, must be designed for seismic forces calculated in Step 8, applied at center of mass of the component.

Architectural components that could pose life-safety hazard must be designed to accommodate the seismic relative displacement calculated in Step 10. They must be designed considering vertical deflection caused by joint rotation of cantilever structural members.

Transverse or out-of-plane bending of a component or system must not exceed the out-of-plane deflection capability of the component or system.

Strength and ductility requirements for architectural components

Type of Component	Strength and Ductility Requirements
Suspended components or components supported by chains **Section 13.5.1**	Need not satisfy seismic force and relative displacement requirements if they meet all of the following criteria: • The components are designed for a gravity load of 1.4 times the operating weight with a simultaneous lateral load of 1.4 times the operating weight. The lateral load should be applied in the direction that results in the most critical load effect. • Seismic interaction effects are considered (Step 14) • Connection allows for 360-degree range of motion in horizontal plane.
Exterior Nonstructural Wall Elements and Connections **Section 13.5.3**	• In addition to seismic relative displacement, the component must accommodate movements due to temperature changes. • Connections and panel joints must allow for D_p, or 0.5 in. (13 mm), whichever is greater. • Connections with threaded steel rods or bolts: ○ Threaded rods or bolts must be made of low-carbon or stainless steel. Cold-worked carbon steel rods must meet or exceed ASTM F1554 Grade 36 requirements. Grade 55 rods are also permitted if they meet Supplement 1 (of ASTM F1554) requirements. ○ Threaded rods in connections accommodating drift through sliding mechanisms in slotted or oversized holes must have length(clear distance between nuts or threaded bolts)-to-diameter ratios of 4 or less, with slots or holes proportioned to accommodate full design story drift in each direction. Nuts must be finger-tight, with measures to prevent loosening. ○ Connections accommodating story drift by bending of threaded rods must satisfy $$\frac{\left(\frac{L\ (\text{clear length as above})}{d\ (\text{rod diameter})}\right)}{D_p} \geq 6\left(\frac{1}{\text{in.}}\right)$$ • The connecting member itself shall have sufficient ductility and rotation capacity to preclude fracture of the concrete or brittle failures at or near welds. • Forces should be calculated for the connecting system which includes the connections between the wall panels or elements and the structure, and the interconnections between wall panels or elements. • Flat straps used for anchorage must be attached or hooked around reinforcing steel or terminated such that they transfer the forces to reinforcing steel.
Glass in glazed curtain walls, glazed storefronts, and glazed partitions **Sections 13.5.4, 13.5.9**	Glass in glazed curtain walls, glazed storefronts, and glazed partitions shall meet the relative displacement requirement of Equation 13.5-2: $$\Delta_{fallout} \geq 1.25\, D_p$$ ASCE 7-22 Equation 13.5-2 or 0.5 in., whichever is greater, where $\Delta_{fallout}$ is the seismic relative displacement (drift) at which the glass fallout from the curtain wall occurs, which must be determined in accordance with AAMA 501.6 or by engineering analysis. D_p is the relative displacement over the height of the glass component under consideration. Glass need not comply with the above requirement if it meets one of the three exceptions listed in Section 13.5.9.1. Glazing Sealants, when used, must conform to the requirements of the standards listed in Table 13.5-2.
Suspended Ceilings	In addition to the provisions of ASCE 7-22 Section 13.5.6, as modified by UFC 3-301-01, suspended ceilings are to be designed to resist seismic effects using a rigid bracing system, where the braces are capable of resisting tension and compression forces, or diagonal splay wires, where the wires are installed taut. Particular attention should be paid in walk-down inspections (see Section 2-18.4) to ensure splay wires are taut. Positive attachment is required to be provided to prevent vertical movement of ceiling elements. Vertical support elements need to be capable of resisting both compressive and tensile forces. Vertical supports and braces designed for compression must have a slenderness ratio, Kl/r, of less than 200. Additional guidance on suspended ceiling design is provided in Section C-2.2.8 of UFC 3-301-01.
Access Floors	Follow ASCE 7-22 Section 13.5.7. Access floor components that have $I_p > 1.0$ must meet the requirements of Special Access floors (Section 13.5.7.2). Additional requirements concerning certification is provided in UFC 3-301-01 Section 13.5.7.
Partitions	Section 13.5.8 provides requirements for lateral bracing of partitions tied to the ceiling or exceeding 6 ft (1.8 m) in height. Such bracing should be independent of ceiling lateral force bracing and spaced to limit horizontal deflection at the partition head, aligning with ceiling deflection requirements. However, there are exceptions to this requirement.
Egress Stairs and Ramps	Egress stairs and ramps that are not part of the seismic force-resisting system (SFRS) of the structure to which they are attached must be detailed to accommodate seismic relative displacement determined in Step 10, including diaphragm deformation, in accordance with Section 13.5.10.

Type of Component	Strength and Ductility Requirements
Penthouses and Rooftop Structures	Penthouses and rooftop structures must be designed in accordance with Section 13.5.11, except for those framed by an extension of the building frame, which should be designed according to Chapter 12 requirements as modified by UFC 3-301-02. The seismic force-resisting system for penthouses and rooftop structures shall conform to one of the types indicated in UFC 3-301-02 Table 2-1.
Bridges, Cranes, and Monorails	Structural supports for NMC crane systems in buildings or structures assigned to SDC C, D, E, and F should be designed for F_p with $\left[\frac{C_{AR}}{R_{po}}\right] = 1$. Crane rail connections must be designed for the forces resulting from $\left[\frac{C_{AR}}{R_{po}}\right] = 1.15$. Refer to UFC 3-301-01 Section 13.6.14 for more requirements. Further guidance on the design of these systems can be found in Section C-3.5 of UFC 3-301-01.

STEP 16 Requirements for Mechanical and Electrical Components

Dynamic effects of the components, their contents, and their supports and attachments should be considered. Where such effects are pronounced, the interaction between the components and the supporting structure, including other mechanical and electrical components must also be evaluated.

Strength and ductility requirements for mechanical and electrical components

Type of Component	Strength and Ductility Requirements
Mechanical Components	
All mechanical components	• Components that are vulnerable to impact or are made of nonductile materials (MC-1 component) or where the ductility may decrease due to service conditions (MC-2 and NMC components) must not experience seismic impact. • The possibility of loads imposed on components by attached utility or service lines, caused by differential movement of support points on separate structures, must be evaluated. • Piping or HVACR ductwork components attached to structures that could displace relative to one another or where such components cross isolation interface for isolated structures must be designed to accommodate seismic relative displacements.
HCACR equipment	HVACR equipment qualified in accordance with the requirements of Chapters 1 through 10 of ANSI/AHRI Standard 1270 (I-P) or ANSI/AHRI Standard 1271 is deemed to meet the special certification requirements for designated systems, provided the requirements in Section 13.6.2.1 are met.
HVACR ductwork	HVACR and other duct systems not designed to carry toxic, highly toxic, or flammable gases or not used for smoke control need not be designed for seismic forces and relative displacements if they meet the exceptions in Section 13.6.6
Piping systems	Piping and tubing systems must comply with the requirements of Section 13.6.7. Piping systems that satisfy the exceptions in Section 13.6.7.3 need not be designed for seismic forces. Note these exceptions do not apply to elevator system piping.
	ASME pressure piping systems must satisfy the requirements of Section 13.6.7.1. Fire protection sprinkler piping must satisfy the requirements of Section 13.6.7.2. Elevator system piping must satisfy the requirements of Section 13.6.11.
Boilers and Pressure Vessels	Boilers and Pressure Vessels can be designed either for seismic forces and displacements in Sections 13.3.1 and 13.3.2 or in accordance with ASME BPVC. For more requirements refer to Section 13.6.10.
Elevators	For buildings that are assigned to RC V, seismic switches are not permitted to be used. Elevator system design for RC V buildings must ensure elevator operability at accelerations computed from building response analysis. Additional guidance on the design of elevator systems is found in Section C-3.3 of UFC 3-301-01.
Rooftop Solar Panels	UFC 3-301-01 Section 13.6.12 deletes the exception in ASCE 7-22 Section 13.6.12 related to ballasted solar panels. Ballasted systems are specifically disallowed by UFC 3-110-03, *Roofing.*
All other mechanical components	Refer to Section 13.6.13.
Electrical Components	
All electrical components	These components must be designed for the seismic forces and relative displacements determined in Steps 8 through 10 and satisfy the additional requirements given in Section 13.6.3.
Light fixtures, lighted signs, and ceiling fans not connected to ducts or piping, supported by chains or suspended from the structure	These components need not be designed for seismic forces and relative displacements determined in Steps 8 though 10 if they meet all of the following criteria: • The components are designed for a gravity load of 1.4 times the operating weight with a simultaneous lateral load of 1.4 times the operating weight. The lateral load should be applied in the direction that results in the most critical load effect. • Seismic interaction effects are considered (Step 14) • Connection allows for 360-degree range of motion in the horizontal plane.
Utility and service lines	Utility and service lines must have the flexibility to accommodate the differential movement between moving structures or portions that they are connected to. The possible interruption of utility lines in designated seismic systems of RC V structures must be considered. Underground utilities need specific attention. For more requirements, refer to Section 13.6.9
Distribution Systems: Conduit, Cable Tray, and Raceways	Cable trays and raceways shall be designed for seismic forces and seismic relative displacements determined in Steps 4 through 6. Design for the seismic forces and relative displacements shall not be required for MC-2 or NMC components, where: • flexible connections or other assemblies are provided between the cable tray or raceway and associated components to accommodate the relative displacement, • the cable tray or raceway is positively attached to the structure, and • one of the requirements of Exception 1 to Section 13.6.5 is met.

Type of Component	Strength and Ductility Requirements
	MC-2 or NMC conduit greater than 2.5 in. (64 mm) trade size and attached to panels, cabinets, or other equipment subject to seismic relative displacement, D_p , shall be provided with flexible connections or designed for seismic forces and seismic relative displacements determined in Steps 4 through 6. Design for the seismic forces and relative displacements shall not be required for conduit where the conduit is less than 2.5 in. However, across seismic joints, design for displacements shall be required for conduit, cable trays, and raceways without consideration of conduit size.
Other electrical components	Refer to Section 13.6.13

STEP 17 Special Certification Requirements for Designated Seismic Systems

Designated Seismic Systems: Those nonstructural components that require design in accordance with ASCE 7-22 Chapter 13. This designation applies to systems that are required to be operational following the MCE_R. All systems in RC V facilities designated as MC-1 must be considered part of the Designated Seismic System.

Designated seismic systems assigned to SDC C and above should be certified as follows:

Active mechanical and electrical equipment	• Active mechanical and electrical equipment that must remain operable following the MCE_R earthquake ground motion shall be certified by the manufacturer as operable.
	• Active parts and energized components:
	  ○ must be certified exclusively on the basis of approved shake table testing using a nationally recognized testing standard such as ICC-ES 156 (when shake table testing is performed as the basis of certification, the Required Response Spectra (RRS) are not permitted to be derived using ICC-ES AC156), or
	  ○ must be shown to be inherently rugged by comparison with similar seismically qualified components. Evidence of such comparison must be reviewed and accepted by a registered design professional (see Step 19) and then submitted to the AHJ for approval.
	• Active mechanical and electrical equipment cannot be certified through analysis.

Nonactive components	• Analysis can be used to certify these components and the seismic demand for NMC components in Step 8 should be calculated for $\left[\frac{C_{AR}}{R_{po}}\right]$=2.5. • For NMC components with period, $T_p \leq 0.06$ secs, as calculated in Step 5c, $\left[\frac{C_{AR}}{R_{po}}\right]$ can be taken as 1.0.
Components with hazardous substances	These components must be certified as maintaining containment following MCE_R earthquake ground motion by: • Analysis, or • Approved shake table testing, or • Experience data.

	Evidence demonstrating compliance with this requirement must be reviewed and accepted by a registered design professional (see Step 19) and submitted to the AHJ for approval.

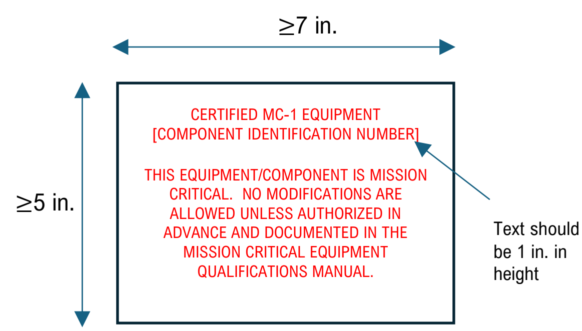
UFC 3-301-02 provides more certification requirements which are:

2-17.7 - Component Certification and Operations & Maintenance (O&M) Manual

All MC-1 and MC-2 equipment qualification documentation, as outlined in UFC 3-301-02 Section 2-17.2.5, must be maintained in a file identified as "Mission Critical Components and Equipment Qualifications Manual" that is to be a part of the Operations & Maintenance Manual that is turned over to the Authority Having Jurisdiction. The project specifications should require the Operations & Maintenance Manual to state that replaced or modified components need to be qualified per the original qualification criteria.

2-17.8 - Component Identification Nameplate

All MC-1 and MC-2 equipment must bear permanent marking or nameplates constructed of a durable heat and water-resistant material. Nameplates must be mechanically attached to all nonstructural components and placed on the component for clear identification. The nameplate must not be less than 5" x 7" with red letters 1" in height on a white background stating MC-1 or MC-2 as appropriate. The following statement must be on the nameplate: "This equipment/component is Mission Critical. No modifications are allowed unless authorized in advance and documented in the Mission Critical Equipment Qualifications Manual." The nameplate must also contain the component identification number in accordance with the drawings/specifications and the O&M manual. Continuous piping, and conduits must be similarly marked as specified in the contract documents.



STEP 18 Construction Documents

According to UFC 3-301-02 Section 2-3.1, construction documents for architectural, mechanical, and electrical components must be prepared by a Registered Design Professional for all buildings assigned to RC V.

Component Qualification Documentation

The seismic qualification documentation for each piece of equipment must contain the following as a minimum:

1. An engineering submittal containing the following:
   a. Design calculations and complete description of the equipment or component with cut sheets or photographs containing all germane data including fastening requirements, welds, post-installed anchors, and so forth.
   b. Development of the in-structure response demand for vertical and horizontal shaking.
   c. For MC-1 components, development of the response capacity (fragility curve) for vertical and horizontal shaking.
   d. Design of the anchorage, including anchor qualifications, calculations indicating forces predicated on the seismic loads, and capacity of the anchors.

e. A drawing indicating the equipment/component and location in the facility, sufficient to be used for the installation.

All of the above elements must be checked and signed by the designer and the nonstructural component design reviewer (UFC 3-301-02 Section 2-1.2 and Step 19). The designer must affix his/her Professional Engineer seal on the cover page. The cover page must identify the equipment/component and the performance category (MC-1 or MC-2).

2. Documentation of the independent design review mentioned in Item 1.

3. The Department of Energy (DOE) Screening Evaluation Worksheet (SEWS) of the installed MC-1 equipment/component. Documentation of the Special Inspection of any post-installed anchorages or Special Inspection of components identifying the Special Inspector. Consideration must be given to the installed condition and proximity to adjacent structures and components to avoid pounding effect.

   The appropriate DOE SEWS can be obtained from the DOE web site at: https://ehss.energy.gov/au/seismic/. Other evaluation worksheets can be used upon approval by the Authority Having Jurisdiction.

4. For MC-1 components, documentation of the independent "walk-down" inspection of the equipment in the final installed condition.

STEP 19 — NONSTRUCTURAL COMPONENT DESIGN REVIEW

A review of the nonstructural component design (including anchorage) must be performed by an independent licensed professional engineer with at least 15 years of experience in the theory and application of nonlinear seismic analysis and structural behavior under extreme cyclic loads. Previous design experience must be commensurate in complexity to the project being reviewed. Selection of the independent nonstructural component design reviewer is subject to the review and approval of the AHJ and the reviewer must be retained by the A/E design firm (DBB) or the General Contractor (DB). The structural and nonstructural component design review may be conducted by the same independent reviewer subject to the already noted qualifications. The nonstructural component design review should occur prior to commissioning and should include, but not necessarily be limited to, the following:

1. Review of in-structure response data and confirmation that any recommendations made by the Structural Design Reviewer have been incorporated into the in-structure response.
2. Review of component qualifications to confirm proper in-structure response was utilized.
3. Upon completion of design review of all documentation, the reviewer must perform a walk-down inspection of the project and confirm the following:
   a. Component installations are in their submitted and approved location.
   b. Identification nameplates are installed as specified in UFC 3-301-02 Section 2-17.8
   c. Component qualification documentation has been incorporated into the Operations & Maintenance Manual as specified in UFC 3-301-02 Section 2-17.7.

ABBREVIATIONS

AAMA	American Architectural Manufacturers Association
ACI	American Concrete Institute
AHJ	Authority Having Jurisdiction
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BPVC	Boilers and Pressure Vessels
CEFAPP	CERL Equipment Fragility and Protection Procedure
CERL	Construction Engineering Research Laboratory
DB	Design-Build
DBB	Design-Bid-Build
DoD	Department of Defense
DOE	Department of Energy
IBC	International Building Code
ICC	International Code Council
ICC-ES	International Code Council - Evaluation Services
IEEE	Institute of Electrical and Electronics Engineers
MC	Mission-Critical
MCE_R	Risk-Targeted Maximum Considered Earthquake
MSS	Manufacturers Standardization Society
NFPA	National Fire Protection Association
NMC	Non-Mission-Critical
RC	Risk Category
RRS	Required Response Spectra
SDC	Seismic Design Category
SEWS	Screening Evaluation Worksheet
SFRS	Seismic Force-Resisting System
O&M	Operations & Maintenance
TMS	The Masonry Society
UFC	Unified Facilities Criteria
USACERL	U.S. Army Construction Engineering Research Laboratory