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USACE / NAVFAC / AFCEC / NASA	**UFGS-23 05 48.19 (May 2018)**
	Change 2 - 08/20

Preparing Activity: USACE	**Superseding**
	UFGS-13 48 00.00 10 (October 2007)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2023

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SECTION TABLE OF CONTENTS

DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 05 48.19

[SEISMIC] BRACING FOR HVAC

05/18, CHG 2: 08/20

-- End of Section Table of Contents --

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SECTION 23 05 48.19

[SEISMIC] BRACING FOR HVAC
05/18, CHG 2: 08/20

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NOTE: This guide specification covers the requirements for seismic protection of mechanical equipment, ductwork, building piping, and exterior utilities.

This guide specification also covers all HVAC bracing requirements for antiterrorism protection from equipment falling on building occupants in accordance with UFC 4-010-01 DoD Minimum Antiterrorism Standards for Buildings.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Projects only having antiterrorism HVAC bracing requirements with no seismic protection requirements will require significant editing to this UFGS because most of the requirements apply to seismic protection. Projects having both antiterrorism HVAC bracing and seismic protection requirements will require the specification to be edited such that the most stringent of both requirements is met.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

****

PART 1 GENERAL

****

NOTE: The intent of this specification is to provide for adequate resistance to lateral and vertical forces induced by earthquakes for mechanical equipment and systems described herein. The design seismic lateral and vertical forces are in addition to the "normal" gravity forces (weight) acting on the components of a system. This guide specification will be used in conjunction with Section 22 05 48.00 20 MECHANICAL SOUND, VIBRATION, AND SEISMIC CONTROL, 26 05 48.00 10 SEISMIC PROTECTION FOR ELECTRICAL EQUIPMENT, 01 45 35 SPECIAL INSPECTIONS, and 13 48 73 SEISMIC CONTROL FOR MISCELLANEOUS EQUIPMENT

Seismic protection design for anchorage and bracing of all HVAC will be based on UFC 3-301-01 Seismic Design for Buildings for RC I, II, III, and IV facilities, UFC 3-301-02 for RC V facilities, and UFC 4-010-01 DoD Minimum Antiterrorism Standards for Buildings.

The designer has 3 options to provide seismic protection for a project:

1) Issue a contract requiring the Contractor to hire a registered structural engineer to submit the stamped calculations and drawings in accordance with this section. The contracting Officer will "accept" the design but the registered engineer (Engineer of Record) will have final responsibility for the adequacy of the structural members and their connections.

2) Hire an A-E who will use this section and will submit calculations and drawings stamped by a registered structural engineer. The Contracting Officer will "accept" the design but the registered engineer (Engineer of Record) will have final responsibility for the adequacy of the structural members and their connections. One of the disadvantages of this approach may be that the actual equipment dimensions, weights and mounting details may not be known until the equipment is acquired. The structural engineer should be retained during the construction phase to review seismic bracing shop drawings and perform field inspections as part of the final responsibility.

3) Perform the design in house, in which case the Government designer will have final responsibility for the adequacy of the structural members and their connections. One of the disadvantages of this approach may be that the actual equipment dimensions, weights and mounting details may not be known until the equipment is acquired. The

Government designer should be retained during the construction phase to review seismic bracing shop drawings and perform field inspections as part of the final responsibility.

Regardless of who performs the design, this section, properly edited, must be included in the construction documents to allow the Contractor to install the seismic protection features.

****

1.1 REFERENCES

****

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 355.2	(2007) Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary
ACI 355.4	(2011) Qualification of Post-Installed Adhesive Anchors in Concrete (ACI 355.4) and Commentary

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 325	(2017) Steel Construction Manual

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 7-16	(2017; Errata 2018; Supp 1 2018) Minimum Design Loads and Associated Criteria for Buildings and Other Structures

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C105/A21.5	(2018) Polyethylene Encasement for Ductile-Iron Pipe Systems
AWWA C116/A21.16	(2015) Protective Fusion-Bonded Coatings for the Interior and Exterior Surfaces of Ductile-Iron and Gray Iron Fittings
AWWA C153/A21.53	(2019) Ductile-Iron Compact Fittings for Water Service
AWWA C213	(2022) Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M	(2019) Standard Specification for Carbon Structural Steel
ASTM A53/A53M	(2022) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A153/A153M	(2016a) Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A325	(2014) Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
ASTM A490	(2014a) Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
ASTM A500/A500M	(2021a) Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A536	(1984; R 2019; E 2019) Standard Specification for Ductile Iron Castings
ASTM A563	(2021; E 2022a) Standard Specification for Carbon and Alloy Steel Nuts
ASTM A603	(2019) Standard Specification for Zinc-Coated Steel Structural Wire Rope
ASTM D1785	(2015; E 2018) Standard Specification for Poly(Vinyl Chloride) (PVC), Plastic Pipe, Schedules 40, 80, and 120
ASTM D2665	(2014) Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings
ASTM E488/E488M	(2022) Standard Test Methods for Strength

	of Anchors in Concrete Elements
ASTM F891	(2016) Standard Specification for Coextruded Poly (Vinyl Chloride) (PVC) Plastic Pipe with a Cellular Core
ASTM F1554	(2020) Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

FEMA P-414	(January 2004) Installing Seismic Restraints for Duct and Pipe

ICC EVALUATION SERVICE, INC. (ICC-ES)

ICC ES AC156	(2012) Acceptable Criteria for Seismic Certification by Shake-Table Testing of Nonstructural Components
ICC ES AC193	(2012) Acceptance Criteria for Mechanical Anchors in Concrete Elements

INTERNATIONAL CODE COUNCIL (ICC)

ICC IBC	(2021) International Building Code

METAL FRAMING MANUFACTURERS ASSOCIATION (MFMA)

MFMA-4	(2004) Metal Framing Standards Publication

NSF INTERNATIONAL (NSF)

NSF/ANSI 61	(2022) Drinking Water System Components - Health Effects

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA 1981	(2008) Seismic Restraint Manual Guidelines for Mechanical Systems, 3rd Edition

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-301-01	(2019, with Change 1, 2022) Structural Engineering
UFC 3-301-02	(2020) Design of Risk Category V Structures, National Strategic Military Assets
UFC 4-010-01	(2018; with Change 2, 2022) DoD Minimum Antiterrorism Standards for Buildings

VIBRATION ISOLATION AND SEISMIC CONTROL MANUFACTURERS ASSOCIATION (VISCMA)

VISCMA 412	(2014) Installing Seismic Restraints for

1.2 SYSTEM DESCRIPTION

1.2.1 General Requirements

****

NOTE: Designer should verify that specified details do not interfere with the performance of the cathodic protection system (when used) or of the vibration isolation systems.

For systems and equipment in RC V buildings that have a performance objective higher than non-mission critical (NMC), the designer should show a "G" classification for the items under SD-02 Shop Drawings in the SUBMITTALS paragraph. The Engineer of Record (EOR) should review the details of these essential systems and assess their impact on the structural supporting system of the essential building. This also includes Designated Seismic Systems that must remain operational after an earthquake.

Design done by the Contractor must be in accordance with UFC 3-301-01 (UFC 3-301-02 for RC V facilities) and UFC 4-010-01. Loadings determined using UFC 3-301-01 and UFC 3-301-02 are based on strength design; therefore, 2015 IBC, ASCE 7-10, and ASCE/SEI 41-13 should be used to design the steel members in the bracing and anchorage systems.

****

Apply the requirements for seismic protection measures described in this section and on the drawings to the mechanical equipment and mechanical systems both inside and outside of the building along with exterior utilities and systems listed below. Where there is a conflict between the specifications and the drawings, the specifications will take precedence. Accomplish resistance to lateral forces induced by earthquakes without consideration of friction resulting from gravity loads.

1.2.2 Mechanical Equipment

****

NOTE: The designer must ensure that the list below includes all mechanical items to be braced. Delete the items which are not part of the project and add items which are not included in the list.

The lists should be broken out as follows:

For mechanical equipment, components and systems in Risk Category V structures, the designer should provide three separate lists of equipment and systems; non-Mission Critical (NMC), Mission Critical Level 1 (MC-1 equipment and components must be fully operational immediately after a seismic event), or Mission Critical Level 2 (MC-2 equipment and components must be repairable and operable

within 3 days after a seismic event).

For mechanical equipment, components, and systems in Risk Category I, II, III, or IV structures, two separate lists of nonstructural systems/components must be provided; components/systems with Ip = 1.0 and components/systems with Ip = 1.5 (Designated Seismic Systems).

The lists must be specific where more than one list is required.

****

Mechanical equipment to be seismically protected must include the following items to the extent required on the drawings or in other sections of these specifications:

[Equipment/Components with Ip = 1.0]

Boilers and furnaces	Storage Tanks for Oil and Water
Water Heaters	
Expansion Air Separator Tanks	Valves and Fittings for Piping
Heat Exchangers	Steam-fed Kitchen Appliances
Water Chiller Units	Thermal Storage Units
Cooling Towers, Evaporative Coolers, and Fluid Coolers	Air and Refrigerant Compressors
Computer Room Air Conditioners	Air Handling Units
Pumps with Motors	Lab Scrubbers
Large Commercial Dryers	Pollution Control Equipment
Gas Dryers	Split System DX Units
Flash Tanks	Unit Heaters
Accumulator Tank	Exhaust, Return and Misc. Fans
Gas Cylinders	Solar Heating and Hot Water Units
Bridge Cranes and Monorails	Pumps
Air Terminal Units	Unitary HVAC Systems
Humidifiers	Fan Coil Units

Stacks	Instrumentation and Control for HVAC
Duct Mounted Coils	Duct Silencers

[Equipment/Components with Ip = 1.5 (Designated Seismic Systems)
Insert edited list here similar to one above for Ip = 1.0]
[Non-Mission Critical (NMC) Equipment/Components in Risk Category V
Insert edited list here similar to one above for Ip = 1.0]
[Mission Critical Level 1 (MC-1) Equipment/Components in Risk Category V
Insert edited list here similar to one above for Ip = 1.0]
[Mission Critical Level 2 (MC-2) Equipment/Components in Risk Category V
Insert edited list here similar to one above for Ip = 1.0]

1.2.3 Mechanical Systems

****
NOTE: The designer must ensure that the list below includes all piping and mechanical systems which are to be installed or modified. Delete the items which are not part of the project and add items which are not included in the list.
****

Mechanical systems to be seismically protected must include the following items to the extent required on the drawings or in this or other sections of these specifications:

[Mechanical systems with Ip = 1.0]

a. All Piping and Ducts Inside the Building Except as Specifically Stated Below Under "Items Not Covered By This Section".

b. Chilled Water Distribution Systems Outside of Buildings.

c. Steam, Water, Oil, Gas and Fuel Piping Outside of Buildings.

d. All Water Supply Systems Outside of Buildings.

e. Storm and Sanitary Sewer Systems Outside of Buildings.

f. All Process Piping Outside of Buildings.

g. Heat Distribution Systems (Supply, Return, and Condensate Return) Outside of Buildings.

h. Condenser Water and Refrigerant Piping Outside the Building.

i. Pneumatic Tube Distribution System Outside of Buildings.

j. Cold Storage Refrigeration Systems Outside of Buildings.

k. Fuel Storage Tanks Outside of Buildings.

l. Water Storage Tanks Outside of Buildings.

m. Ductwork Outside of Buildings.

n. Stacks.

o. [_____]

[Mechanical systems with Ip = 1.5 (Designated Seismic Systems)
Insert edited list here similar to one above for Ip = 1.0]
[Non-Mission Critical (NMC) Mechanical Systems in Risk Category V
Insert edited list here similar to one above for Ip = 1.0]
[Mission Critical Level 1 (MC-1) Mechanical Systems in Risk Category V
Insert edited list here similar to one above for Ip = 1.0]
[Mission Critical Level 2 (MC-2) Mechanical Systems in Risk Category V
Insert edited list here similar to one above for Ip = 1.0]

1.2.4 Contractor Designed Bracing

****
NOTE: Retain this paragraph when the Contractor will design the bracing. The designer will refer and/or modify the listings above or will list below the equipment and systems to receive seismic bracing. Delete this paragraph when all bracing details and locations are indicated on the drawings and calculations are included in the Design Analysis.
****

Submit copies of the design calculations with the drawings. Calculations must be approved, certified, stamped and signed by a registered Professional Structural Engineer. Calculations must verify the capability of structural members to which bracing is attached for carrying the load from the brace. Design the bracing in accordance with UFC 3-301-01, [UFC 3-301-02], UFC 4-010-01 and additional data furnished by the Contracting Officer. Resistance to lateral forces induced by earthquakes must be accomplished without consideration of friction resulting from gravity loads. UFC 3-301-01 uses parameters for the building, not for the equipment in the building; therefore, corresponding adjustments to the formulas must be required. Loadings determined using UFC 3-301-01 are based on strength design; therefore, AISC 325 Specifications must be used for the design. The bracing for the mechanical equipment designated in paragraph 1.2.2 and systems designated in paragraph 1.2.3 must be developed by the Contractor.

[Provide documentation of an independent design review for mission critical (MC) equipment bracing design. Documentation must be signed by the independent reviewer who must also be a registered structural engineer.]

1.2.5 Items Not Covered By This Section

1.2.5.1 Fire Protection Systems

Install seismic protection of piping for fire protection systems as specified in Sections 21 30 00 FIRE PUMPS, 21 13 13 WET PIPE SPRINKLER SYSTEMS, FIRE PROTECTION, 21 13 16 DRY PIPE SPRINKLER SYSTEMS, FIRE PROTECTION, 21 13 18 PREACTION SPRINKLER SYSTEMS, FIRE PROTECTION, and 21 13 24.00 10 AQUEOUS FILM-FORMING FOAM (AFFF) FIRE PROTECTION SYSTEM.

1.2.5.2 Items Requiring No Seismic Restraints

****
NOTE: Retain only those items found in the project

for this list of pipes and ducts that do not require seismic restraints. For facilities designated as critical, hazardous, or essential with Ip greater than 1.0 or Mission Critical MC Level 1 or 2, delete or edit exceptions for piping and ducts which will require seismic restraint.

****

Seismic restraints are not required for the following items:

a. Gas piping less than 25 mm 1 inch nominal pipe size.

b. Piping in boiler and mechanical equipment rooms less than 32 mm 1-1/4 inches nominal pipe size.

c. All other piping equal to or less than 3inches nominal pipe size.

d. Rectangular air handling ducts less than 0.56 square meters 6 square feet in cross sectional area.

e. Round air handling ducts less than 711 mm 28 inches in diameter.

f. Piping suspended by individual hangers 300 mm 12 inches or less in length from the top of pipe to the bottom of the supporting structural member where the hanger is attached, except as noted below.

g. Ducts suspended by hangers 300 mm 12 inches or less in length from the top of the duct to the bottom of the supporting structural member, except as noted below.

In exemptions f. and g. all hangers must meet the length requirements. If the length requirement is exceeded by one hanger in the run, brace the entire run. Seismically protect interior piping and ducts not listed above in accordance with the provisions of this specification.

Non-critical items may require seismic restraints if adjacent to critical equipment or systems that must remain operational after an earthquake and could be compromised by impact with non-critical adjacent components.

1.3 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project. This includes Designated Seismic Systems and Mission Critical Systems that must remain operational after an earthquake.

For Army projects, fill in the empty brackets

following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Coupling and Bracing

Flexible Couplings or Joints

Equipment Restraint

Contractor Designed Bracing; G[, [_____]]

SD-03 Product Data

Coupling and Bracing; G[, [_____]]

Flexible Couplings Or Joints; G[, [_____]]

Equipment Restraint; G[, [_____]]

Contractor Designed Bracing; G[, [_____]]

Snubbers

Anchor Bolts

Vibration Isolators

SD-05 Design Data

Design Calculations

SD-06 Test Reports

Anchor Bolts; G[, [_____]]

PART 2 PRODUCTS

2.1 GENERAL DESIGN REQUIREMENTS

Submit detailed seismic restraint drawings for mechanical equipment, duct systems, piping systems and any other mechanical systems along with calculations, catalog cuts, templates, and erection and installation details, as appropriate, for the items listed below. Indicate thickness, type, grade, class of metal, and dimensions; and show construction details, reinforcement, anchorage, and installation with relation to the building construction. Calculations must be stamped, by a registered structural engineer, and verify the capability of structural members to which bracing is attached for carrying the load from the brace. Include drawing for Mission Critical Equipment indicating the equipment location in the facility sufficient to be used for the installation. Design must be based on actual equipment and system layout. Design must include calculated dead loads, static seismic loads and capacity of materials utilized for the connection of the equipment or system to the structure. Analysis must detail anchoring methods.

****
NOTE: Appropriate materials for structural supports must be used in corrosive environments. Dissimilar metals must be isolated.
****

2.2 EQUIPMENT RESTRAINT

****
NOTE: Seismic Bracing does not guarantee that the equipment itself is rugged enough to survive earthquake shaking. When a piece of equipment is required to remain operational after an earthquake, include paragraph 3.11 Special Testing for Seismic Resisting Equipment. Roof mounted equipment is especially vulnerable due to building sway during seismic event.
****

Equipment must be rigidly or flexibly mounted as indicated in the specifications and/or drawings depending on vibration isolation requirements as follows below.

Roof mounted equipment such as cooling towers and condensers, both vibration isolated and nonisolated, must have support members designed and anchored to building structural steel or concrete as required for seismic restraint and wind loads.

2.2.1 Rigidly (Base and Suspended) Mounted Equipment

HVAC equipment furnished under this contract must be [rigidly mounted] [rigidly mounted using cast-in-place anchor bolts or post-installed anchors] that are qualified for earthquake loading in accordance with

ACI 355.2 and ACI 355.4. Anchor bolts must conform to ASTM F1554. For any rigid equipment which is rigidly anchored, provide flexible joints for piping, ductwork, electrical conduit, etc., that are capable of accommodating displacements equal to the full width of the joint in both orthogonal directions. Suspended equipment bracing attachments should be located just above the center of gravity to minimize swinging. Use the ratio of the overturning moment from seismic forces to the resisting moment due to gravity loads to determine if overturning forces need to be considered in the sizing of anchor bolts. Provide calculations to verify the adequacy of the anchor bolts for combined shear and overturning.

Roof mounted HVAC equipment roof curbs, framing and attachment to equipment and structure must be designed and braced to withstand seismic loads. [Mission critical base mounted and suspended equipment for Risk Category (RC) V,] Designated Seismic Systems (DSS) assigned to Seismic Design Category (SDC) C, D, E, or F and Risk Category IV components needed for continued operation after an earthquake must have two nuts provided on each anchor bolt.

2.2.2 Nonrigid or Flexibly-Mounted Equipment

****

NOTE: Coordinate this section with Section 22 05 48.00 20 MECHANICAL SOUND, VIBRATION, AND SEISMIC CONTROL.

****

Select vibration isolation devices so that the maximum movement of equipment from the static deflection point is 6 mm1/4 inch. Equipment flexibly mounted on vibration isolators must have a bumper restraint or snubber in each horizontal direction and vertical restraints must be provided where required to resist overturning. Isolator housing and restraints must be constructed of ductile materials. A viscoelastic pad or similar material of appropriate thickness must be used between the bumper and components to limit the impact load. Restraints must be designed to resist the calculated horizontal lateral and vertical forces.

Spring vibration isolators must be seismically rated, restrained isolators for equipment subject to load variations and large external forces. The seismically rated housing must be sized to meet or exceed the force requirements applicable to the project and meet the required isolation criteria. Spring vibration isolator manufacturer's will be a member of VISCMA. Design force, Fp, must be doubled for vibration isolators with an air gap greater than 0.25 inches as specified in ASCE 7-16, Chapter 13. Housed springs must not be used for seismic restraint applications because they cannot resist uplift.

2.3 BOLTS AND NUTS

Hex head bolts, and heavy hexagon nuts must be ASTM A325 or ASTM A490 bolts and ASTM A563 nuts. Provide bolts and nuts galvanized in accordance with ASTM A153/A153M when used underground or exposed to weather.

2.4 FLEXIBLE JOINTS

****

NOTE: Designer should include reference to other specification sections containing provisions for pipe pressure and temperature ratings, if deemed

necessary.
****

Flexible joints must have same pressure and temperature ratings as adjoining pipe. Braided hoses must not be used where there is torsional or axial movement unless manufacturer allows it.

2.4.1 Braided Hose Expansion Joint

Braided hose expansion joint(s) must be installed in the locations indicated on the drawings and as required to accommodate any thermal expansion, contraction or seismic movement of the piping system. Joints must consist of two parallel sections of corrugated metal hose, compatible braid, and 180 degree return bend with inlet and outlet connections. Field fabricated loops are not acceptable. Braided hose expansion joint(s) must be installed in the locations indicated on the drawings and as required to accommodate any thermal expansion, contraction or seismic movement of the piping system. Joints must consist of two parallel sections of corrugated metal hose, compatible braid, and 180 degree return bend with inlet and outlet connections. Field fabricated loops must not be acceptable. Braided hose in a 60 degree flexible V loop arrangement must be used for small diameter pipe connections to coils in variable-air-volume (VAV)terminal units and fan coil units installed in suspended ductwork whether braced or unbraced.

All braided hose expansion joints must be manufactured in accordance with the documented manufacturers weld procedure specifications. The procedure qualification record must be used to document the execution of this procedure and must follow the general "guidelines" of ASME Section IX. Each individual welder must conform to the in-house procedure qualification record and be qualified prior to each production lot. The testing of each individual welder must be documented in a welding procedure qualification record.

****
NOTE: Designer would typically select Type 304 stainless steel for most applications including chilled water, condenser water, heating hot water and steam. Bronze with applicable certifications would typically be selected for potable water and fuel oil service. Type 316 and 321 stainless steel would typically be selected for highly corrosive fluids or surrounding environment.
****

2.4.1.1 Corrugated Hose

Corrugated hose must be [Type [304] [321] [316] stainless steel] [bronze]. Braid must be [Type 304 stainless steel for any series 300 stainless steel hose] [bronze for any bronze hose]. Fittings materials of construction and end fitting type must be consistent with pipe material and equipment/ pipe connection fittings. Copper fittings must not be attached to stainless steel hose.

2.4.1.2 Flexible Hose Expansion Loops

Flexible hose expansion loops must have a factory supplied, hanger / support lug located at the bottom of the 180deg return. [Flexible hose expansion loop(s) must be furnished with a plugged FPT to be used for a

drain or air release vent.] Flexible hose expansion loop(s) must be rated with an operating pressure which is the same as the adjoining pipe. The operating pressure must be based on burst pressure with a 4 to 1 safety factor. [For steam service, the operating pressure must be based on burst pressure with a 8 to 1 safety factor.]

****
NOTE: Flexible expansion joint suitable for liquids under pressure compatible with material and pressure rating of joint.
****

2.4.2 Double Ball Flexible Expansion Joint

Install flexible expansion joints manufactured of ductile iron conforming to the material requirements of ASTM A536 and AWWA C153/A21.53 in the locations indicated on the drawings. Provide foundry certification of material upon request. Each flexible expansion joint must be pressure tested prior to shipment against its own restraint to a minimum of 350 psi (250 psi for flexible expansion joints 2 inch and 30 inches diameter and larger.) A minimum 2:1 safety factor, determined from the published pressure rating, must apply. Factory Mutual Approval for the 3 inch through 12 inch sizes is required. Each flexible expansion joint must consist of an expansion joint designed and cast as an integral part of a ball and socket type flexible joint, having a minimum per ball deflection of: 20°, 2" - 12"; 15°, 14" - 36"; 12°, 42"-48" and 4-inches minimum expansion. Additional expansion sleeves must be available and easily added or removed at the factory or in the field. Both standardized mechanical joint and flange end connections must be available.

2.4.2.1 Internal Surfaces

Line all internal surfaces (wetted parts) with a minimum of 15 mils of fusion bonded epoxy conforming to the applicable requirements of AWWA C213. Sealing gaskets must be constructed of EPDM. The coating must meet NSF/ANSI 61.

2.4.2.2 Exterior Surfaces

Coat exterior surfaces with a minimum of 6 mils of fusion bonded epoxy conforming to the applicable requirements of AWWA C116/A21.16. Include appropriately sized polyethylene sleeves, meeting AWWA C105/A21.5, for direct buried applications.

****
NOTE: Flexible expansion joint gravity drain (non-pressurized) suitable for sanitary drain, waste and vent applications.
****

2.4.3 Double Ball Flexible Expansion Joint Gravity Drain (Non-Pressurized)

Flexible expansion joints gravity drain must be installed in the locations indicated on the drawings and must be manufactured of pvc. All connections whether solvent weld or mechanical must be restrained to allow movement to be transferred to expansion joint. Each ball must allow up to 15 degrees deflection.

End connection outside diameters must be compatible with ASTM D1785,

ASTM D2665 and ASTM F891 PVC pipe and are to be solvent welded.

2.5 SWAY BRACING MATERIALS

****
NOTE: Select Class C galv coating for wire rope where used in coastal environment.
****

Material used for members listed [in this section] [and] [on the drawings], must be structural steel conforming with the following:

a. Plates, rods, and rolled shapes, ASTM A36/A36M.

b. Wire rope, ASTM A603 pre-stretched. [Class B galv coating][Class C galv coating] Ferrule clamps must be qualified by testing for use in seismic applications per VISCMA 412. A minimum of two clamps are required on each end of wire rope.

c. Tubes, ASTM A500/A500M, Grade B.

d. Pipes, ASTM A53/A53M, Grade B.

e. Angles, ASTM A36/A36M.

f. Channels (Struts) with in-turned lips and associated hardware for fastening to channels at random points conforming to MFMA-4

2.6 MULTIDIRECTIONAL SEISMIC SNUBBERS

****
NOTE: Details of multidirectional seismic snubbers will be shown in drawings if paragraph is retained.
****

Install multidirectional seismic snubbers employing elastomeric pads on [floor- or slab-mounted equipment] [and] [large piping] as detailed on drawings. These snubbers must provide 6 mm 1/4 inch free vertical and horizontal movement from the static deflection point. Snubber medium must consist of multiple pads of cotton duct and neoprene or other suitable materials arranged around a flanged steel trunnion so both horizontal and vertical forces are resisted by the snubber medium.

PART 3 EXECUTION

3.1 COUPLING AND BRACING

****
NOTE: Unless otherwise determined by the Contracting Officer, A-E designs must include complete seismic details showing coupling requirements. Government designer should furnish coupling details for Contractor designed systems if required by the project.
****

a. Submit detail drawings, as specified here and throughout this

specification, along with catalog cuts, templates, and erection and installation details, as appropriate, for the items listed. Submittals must be complete in detail; must indicate thickness, type, grade, class of metal, and dimensions; and must show construction details, reinforcement, anchorage, and installation with relation to the building construction.

b. Provide coupling installation conforming to the details shown on the drawings. Provisions of this paragraph apply to all piping within a 1.5 m 5 foot line around outside of building unless buried in the ground. Piping grouped for support on trapeze-type hangers must be braced at the most frequent interval as determined by applying the requirements of this specification to each piping run on the common support.

c. Size bracing components as required for the total load carried by the common supports. Bracing rigidly attached to pipe flanges, or similar, must not be used where it would interfere with thermal expansion of piping.

d. Adjust isolators and restraints after piping systems has been filled and equipment is at its operating weight, following the manufacturer's written instructions.

e. Install cables at a 45-degree slope. Where interference is present, the slope may be minimum of 30 degrees or a maximum of 60 degrees per VISCMA 412.

3.2 BUILDING DRIFT

****

NOTE: Refer to Section 13 48 73 SEISMIC CONTROL FOR MISCELLANEOUS EQUIPMENT to determine the expected drift of the building. Insert the expected drift ratio (in terms of deflection per unit of height) in the blank space.

****

Provide joints capable of accommodating seismic displacements for vertical piping between floors of the building, where pipes pass through a building seismic or expansion joint, or where rigidly supported pipes connect to equipment with vibration isolators. Provide horizontal piping across expansion joints to accommodate the resultant of the drifts of each building unit in each orthogonal direction. For threaded piping, provide swing joints made of the same piping material. For piping with manufactured ball joints the seismic drift must be [0.015] [_____] meters per meter feet per foot of height above the base where the seismic separation occurs; this drift value must be used in place of the expansion given in the manufacturer's selection table.

3.3 FLEXIBLE COUPLINGS OR JOINTS

3.3.1 Building Piping

Provide flexible couplings or joints in building piping at bottom of all pipe risers for pipe larger than 90 mm 3-1/2 inches in diameter. Laterally brace flexible couplings or joints without interfering with the action of the flexible coupling or joint. Cast iron waste and vent piping need only comply with these provisions when caulked joints are used.

Flexible bell and spigot pipe joints using rubber gaskets may be used at each branch adjacent to tees and elbows for underground waste piping inside of building to satisfy these requirements.

3.3.2 Underground Piping

****

NOTE: This paragraph may not be required for some Seismic Design Category structures. The designer will coordinate the requirements for seismic isolation of piping with the structural and civil design drawings to locate flexible connections as required.

The amount of annular space will depend on the stiffness of the foundation assembly and of the surrounding soil, and the distance between the foundation wall and the point outside the building where the pipe is considered to be restrained. The geotechnical engineer will determine the pipe length necessary to provide fixity. As an approximation, a value of 76 mm 3 inches would be necessary for a pipe penetration in a one-story basement in soft soil.

****

Install flexible coupling in underground piping and 100 mm 4 inch or larger conduit, except heat distribution system, where the piping enters the building. Provide couplings that accommodate [_____] mm inches of relative movement between the pipe and the building in any direction. Provide additional flexible couplings where shown on the drawings.

3.4 PIPE SLEEVES

****

NOTE: The designer will determine the amount of differential movement of piping at pipe sleeves passing through non-fire rated walls and partitions and will indicate on the drawings the amount of clearance required between the pipe and the sleeve based on deflection of the pipe between sway braces on either side of the wall.

The designer should avoid pipe penetrations through fire rated assemblies.

****

Size pipe sleeves in interior non-fire rated walls as indicated on the drawings to provide clearances that will permit differential movement of piping without the piping striking the pipe sleeve. Pipe sleeves in fire rated walls must conform to the requirements in Section 07 84 00 FIRESTOPPING.

3.5 SPREADERS

****

NOTE: Refer to UFC 3-301-01 for guidance on separation between pipes and requirements for spreaders.

****

Provide spreaders between adjacent piping runs to prevent contact during seismic activity whenever pipe or insulated pipe surfaces are less than [100][_____] mm [4][_____] inches apart. Apply spreaders at same interval as sway braces at an equal distance between the sway braces. If rack type hangers are used where the pipes are restrained from contact by mounting to the rack, spreaders are not required for pipes mounted in the rack. Apply spreaders to surface of bare pipe and over insulation on insulated pipes utilizing high-density inserts and pipe protection shields in accordance with the requirements of Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

3.6 SWAY BRACES FOR PIPING

Provide sway braces to prevent movement of the pipes under seismic loading. Provide braces in both the longitudinal and transverse directions, relative to the axis of the pipe. Provide sufficient braces for equipment to resist a horizontal force as specified in UFC 3-301-01[UFC 3-301-02] without exceeding safe working stress of bracing components. Provide bracing that does not interfere with thermal expansion requirements for the pipes as described in other sections of these specifications. For seismic analysis of horizontal pipes, the equivalent static force should be considered to act concurrently with the full dead load of the pipe, including contents.

3.6.1 Transverse Sway Bracing

****

NOTE: Piping can be either rigid or flexible. Rigid piping has a period of vibration of 0.06 seconds or less. Piping systems with spacing between braces that exceeds allowable spacing for rigid piping will be deemed flexible and will be designed accordingly.

The designer should provide requirements for bracing PVC pipes.

****

Provide transverse sway bracing for steel and copper pipe at intervals not to exceed those shown on the drawings. All runs (length of pipe between end joints) must have a minimum of transverse bracing at each end. Provide transverse sway bracing for pipes of materials other than steel and copper at intervals not to exceed the hanger spacing as specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE.

3.6.2 Longitudinal Sway Bracing

****

NOTE: Locate longitudinal sway braces on the drawings for systems subject to thermal expansion because indiscriminate placement of sway braces may interfere with expansion requirements.

****

Provide longitudinal sway bracing at 12 m 40 foot intervals unless otherwise indicated. All runs (length of pipe between end joints) must have one longitudinal brace minimum. Construct sway braces in accordance

with the drawings. Do not use branch lines, walls, or floors as sway braces.

3.6.3 Vertical Runs

Run is defined as length of pipe between end joints. Do not brace vertical runs of piping no more than 3 m 10 foot vertical intervals. Braces for vertical runs must be above the center of gravity of the segment being braced. Flexible couplings should be provided at the bottoms of risers for pipes larger than 3.5 in. (89 mm) in diameter. Flexible couplings and expansion joints should be braced laterally and longitudinally unless such bracing would interfere with the action of the couplings or joints. When pipes enter buildings, flexible couplings should be provided to allow for relative movement between the soil and building. Construct all sway braces in accordance with the drawings. Attach sway braces to the structural system. Do not connect to branch lines, walls, or floors.

3.6.4 Clamps and Hangers

Apply clamps or hangers on uninsulated pipes directly to pipe. Insulated piping must have clamps or hangers applied over insulation in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

Hanger rod stiffener angle or strut bracing must be securely attached by a series of attachment clamps manufactured from a one piece metal stamping and must include all require attachment hardware and locking nuts. Attachment clamps made from aluminum or cast iron must not be used in seismic applications. Do not weld vertical braces to hanger rods.

3.7 SWAY BRACES FOR DUCTS

3.7.1 Braced Ducts

Provide bracing details and spacing for rectangular and round ducts in accordance with SMACNA 1981. However, the design seismic loadings for these items must not be less than loadings obtained using the procedures in UFC 3-301-01[UFC 3-301-02]. Bracing must not attach to duct joints. Use shortest screws possible when penetrating ductwork to minimize airflow noise inside duct.

3.7.2 Unbraced Ducts

Attach hangers for unbraced ducts to the duct within 50 mm 2 inches of the top of the duct with a minimum of two #10 sheet metal screws in accordance with FEMA P-414. Use shortest screws possible when penetrating ductwork to minimize airflow noise inside duct. Install unbraced ducts with a 150 mm 6 inch minimum clearance to vertical ceiling hanger wires.

3.8 EQUIPMENT

3.8.1 General

Ensure housekeeping pads have adequate space to mount equipment and seismic restraint devices allowing adequate edge distance and embedment depth for restraint anchor bolts. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength. Install neoprene grommet washers or till the gap

with epoxy on equipment anchor bolts where clearance between anchor and equipment support hole exceeds 0.125 inches.

3.8.2 Controls

Ensure that controls for critical equipment that must remain operational after an earthquake are certified per paragraph 3.11 SPECIAL TESTING FOR SEISMIC-RESISTING EQUIPMENT and are served by emergency power as required.

3.9 ANCHOR BOLTS

3.9.1 Cast-in-Place Anchor Bolts

Use templates to locate cast-in-place bolts accurately and securely in formwork. Anchor bolts must have an embedded straight length equal to at least 12 times nominal diameter of the bolt. Anchor bolts that exceed the normal depth of equipment foundation piers or pads must either extend into concrete floor or the foundation or be increased in depth to accommodate bolt lengths.

3.9.2 Drilled-In Anchor Bolts

****
NOTE: Verify if restrictions exist on the type of drilling equipment to be used for the project.
****

Drill holes with rotary impact hammer drills Drill bits must be of diameters as specified by the anchor manufacturer. Unless otherwise shown on the Drawings, all holes must be drilled perpendicular to the concrete surface. Where anchors are permitted to be installed in cored holes, use core bits with matched tolerances as specified by the manufacturer. Properly clean cored hole per manufacturer's instructions. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Exercise care in coring or drilling to avoid damaging existing reinforcing or embedded items. Notify the COR if reinforcing steel or other embedded items are encountered during drilling. Take precautions as necessary to avoid damaging prestressing tendons, electrical and telecommunications conduit, and gas lines. Unless otherwise specified, do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength. Perform anchor installation in accordance with manufacturer instructions.

3.9.2.1 Wedge Anchors, Heavy-Duty Sleeve Anchors, and Undercut Anchors

Protect threads from damage during anchor installation. Heavy-duty sleeve anchors must be installed with sleeve fully engaged in part to be fastened. Set anchors to manufacturer's recommended torque, using a torque wrench. Following attainment of 10% of the specified torque, 100% of the specified torque must be reached within 7 or fewer complete turns of the nut. If the specified torque is not achieved within the required number of turns, the anchor must be removed and replaced unless otherwise directed by the Engineer.

3.9.2.2 Cartridge Injection Adhesive Anchors

Where approved for seismic application, clean all holes per manufacturer instructions to remove loose material and drilling dust prior to installation of adhesive. Inject adhesive into holes proceeding from the

bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive. Follow manufacturer recommendations to ensure proper mixing of adhesive components. Sufficient adhesive must be injected in the hole to ensure that the annular gap is filled to the surface. Remove excess adhesive from the surface. Shim anchors with suitable device to center the anchor in the hole. Do not disturb or load anchors before manufacturer specified cure time has elapsed.

3.9.2.3 Capsule Anchors

Where approved for seismic application, perform drilling and setting operations in accordance with manufacturer instructions. Clean all holes to remove loose material and drilling dust prior to installation of adhesive. Remove water from drilled holes in such a manner as to achieve a surface dry condition. Capsule anchors must be installed with equipment conforming to manufacturer recommendations. Do not disturb or load anchors before manufacturer specified cure time has elapsed.

Observe manufacturer recommendations with respect to installation temperatures for cartridge injection adhesive anchors and capsule anchors.

3.10 ANCHOR BOLT TESTING

****

NOTE: Expansion and chemically bonded anchors should be tested after installation. Testing every expansion anchor is not necessary or practical; therefore a reasonable rate of testing should be developed depending on the importance of the job. There are two methods of testing: torque wrench and pullout testing. The torque test is easier and cheaper and usually gives a good indication of installation quality; the pullout test gives a better indication of the strength of both expansion and chemically bonded anchors. The torque test does not apply to expansion bolts which are anchored by hammering the sleeve over a cone such as self drilling anchors.

****

Test in place expansion and chemically bonded anchors not more than [24][_____] hours after installation of the anchor, conducted by an independent testing agency; testing must be performed on random anchor bolts as described below.

3.10.1 Torque Wrench Testing

****

NOTE: Delete this paragraph for expansion anchors which are not anchored by an applied torque, such as self drilling anchors.

Torque wrench testing verifies that a torqued expansion anchor has seated properly. If it has not seated, the applied torque on the nut will cause the bolt to twist in the hole. Torque wrench testing does not load the bolt up to allowable load and therefore does not verify the capacity of the

installed bolt.

****

Perform torque wrench testing on not less than [50] [_____] percent of the total installed applied torque expansion anchors and at least [one anchor] [[_____] anchors] for every piece of equipment containing more than [two] [_____] anchors. The test torque must equal the minimum required installation torque as required by the bolt manufacturer. Calibrate torque wrenches at the beginning of each day the torque tests are performed. Recalibrate torque wrenches for each bolt diameter whenever tests are run on bolts of various diameters. Apply torque between 20 and 100 percent of wrench capacity. Reach the test torque within one half turn of the nut, except for 9 mm 3/8 inch sleeve anchors which must reach their torque by one quarter turn of the nut. If any anchor fails the test, test similar anchors not previously tested until [20] [_____] consecutive anchors pass. Failed anchors must be retightened and retested to the specified torque; if the anchor still fails the test it must be replaced.

3.10.2 Pullout Testing

****

NOTE: Pullout testing is expensive and labor intensive because of the apparatus needed to pull on the anchor bolt. Pullout testing determines the tension capacity of the anchor bolt. The amount of load to be applied can vary between 0.5 to 2 times the calculated load, depending on the importance of the bolt. There is not a significant cost difference between testing to 0.5 or 2 times the calculated load; since most anchor bolts have a factor of safety of 4, testing to twice the specified load should not cause any distress. The typical tension failure causes a shear cone to be pulled out of the concrete, the slope of the cone is about a 45 degree angle so there should be nothing on the concrete surface in the vicinity of the bolt to prevent the cone from pulling out. Shear testing is usually not needed unless the bolt is heavily loaded in shear and close to an edge. Select percentage of anchors to be tested. Smaller or more critical installations may warrant a higher percentage of anchors to be tested and a greater penalty for malfunctioning anchors.

****

Test expansion and chemically bonded anchors by applying a pullout load using a hydraulic ram attached to the anchor bolt. Testing must be in accordance with ASTM E488/E488M or ICC ES AC193. At least [10] [_____] percent of each type and size of anchors, but not less than [3] [_____] per day must be tested. Apply the load to the anchor without removing the nut; when that is not possible, the nut must be removed and a threaded coupler must be installed of the same tightness as the original nut. Check the test setup to verify that the anchor is not restrained from withdrawing by the baseplate, the test fixture, or any other fixtures. The support for the testing apparatus must be at least 1.5 times the embedment length away from the bolt being tested. Load each tested anchor to [1] [_____] times the design tension value for the anchor. The anchor

must have no observable movement at the test load. If any anchor fails the test, similar type and size anchors not previously tested must be tested until [10] [_____] percent of those type consecutive anchors pass. Remove and replace failed anchors. Fill empty anchor holes and patch failed anchor locations with high-strength non-shrink, nonmetallic grout.

3.11 SPECIAL TESTING FOR SEISMIC-RESISTING EQUIPMENT

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NOTE: Include this paragraph only for special testing for seismic-resisting equipment and components designated as Mission Critical Level 1 (MC-1) by the building owner and specified by the Structural Engineer. MC-1 equipment and components must be fully operable immediately after a seismic event. This paragraph may also apply to Designated Seismic System (DSS) (assigned to SDC C thru F) equipment and components that must remain operational after an earthquake to function for life safety purposes or is needed for continued operation in a Risk Category IV structure.

This paragraph will be applicable to both new buildings designed according to UFC 3-301-01, UFC 3-301-02, and to existing building seismic rehabilitation designs.

The designer must indicate on the drawings all locations and all components for which special inspection and testing is required for MC-1 equipment.

Some HVAC components are considered rugged and may not require special testing such as motors and motor operators, valves (not in cast-iron housings, except for ductile cast iron), horizontal and vertical pumps (including vacuum pumps), and air compressors

Add any additional requirements as necessary.

****

Equipment and components (including controls) designated as [MC-1 (Mission Critical Level 1] Designated Seismic Systems required to remain operational after an earthquake will be seismic qualified by shake table testing conforming to ICC ES AC156 procedures. The manufacturer is to provide a certification by a fully qualified testing agency for the specific equipment and/or components. Prequalified certifications are acceptable unless noted otherwise.[Seismic component qualification documentation for each piece of equipment must contain the information required in UFC 3-301-02, Section 2-17.2.5 Component Qualification Documentation.]

Mechanical components that are required to be certified must bear permanent marking or nameplates constructed of a durable heat and water resistant material. Nameplates must be mechanically attached to such nonstructural components and placed on each component for clear identification. The nameplate must not be less than 5 inches x 7 inches with red letters 1 inch in height on a white background stating "Certified Equipment." The following statement must be on the nameplate: "This

equipment/component is certified. No modifications are allowed unless authorized in advance and documented in the Equipment Certification Documentation file." The nameplate must also contain the component identification number in accordance with the drawings/specifications and the O&M manuals.

3.12 SPECIAL INSPECTION FOR SEISMIC-RESISTING SYSTEMS AND EQUIPMENT

****

NOTE: Include this paragraph only for special Inspection of seismic-resisting systems that serve Risk Category V Structures; designated seismic mechanical systems and equipment per IBC 1705.12.4; and plumbing and mechanical components per IBC 1705.12.6. The designer must indicate on the drawings all locations and all features for which special inspection is required. This includes indicating the locations of all structural components and connections requiring inspection. Designated Seismic Systems are required to be operational after a design earthquake. MC-1 equipment and components must be fully operable immediately after a seismic event. MC-2 equipment and components must be repairable and operable within 3 days after a seismic event. This paragraph will be applicable to both new buildings designed according to UFC 3-301-01 SEISMIC DESIGN FOR BUILDINGS, and to existing building seismic rehabilitation designs.

****

Perform special inspections for seismic-resisting mechanical systems, equipment and components [for structures assigned to Risk Category V;] designated mechanical seismic systems and equipment per ICC IBC 1705.12.4; and plumbing and mechanical components per ICC IBC 1705.12.6. Periodic special inspections will be conducted on mechanical equipment as required by Section 1705.12 of the International Building Code and paragraph 2-5.4 of UFC 3-301-01. Provide a Statement of Special Inspections and Final Report in accordance with paragraph 2-2.4.3 of UFC 3-301-01.

-- End of Section --