TABLE OF CONTENTS

SECTION III - NUCLEAR SSCS DESIGN AND ANALYSIS REQUIREMENTS

New in this revision (older revisions addressed in 7.0 Record of Revisions)

Updated acceptance criteria in Subsection 2.1 to align with ASCE 43 and applicable material codes and standards. Updated flood design guidance in Subsections 1.4.A and 2.2.P in accordance with recommendations from the LANL Natural Phenomena Hazards Assessment, 2025 Update. Revised ACI 349-13 load combination (Eq. 9-5) to align with AISC N690-12 and ACI 349-23; refer to Subsection 2.3.A.1.c for details. Additional minor editorial revisions were made to Subsections 1 through 6.
Updated Appendix A (Design of Anchoring to Concrete) and deleted Appendices B, C, and H incorporating Variance VAR-10745, Alternate Post-Installed Anchors for NDC-3 SSCs.
Revised Appendix E (Design Basis Earthquake Loads) to incorporate updated seismic design parameters from the 2025 LANL PSHA Update, as documented in P-22-016-01-PR-01-AR-01, Rev. 0, *LANL Augmented SSHAC Level 2 Seismic Hazard Update: Ancillary Deliverables* (July 2025), and P-22-016-01-PR-01-FR-01, Rev 0, *Final Report for the LANL Augmented SSHAC Level 2 Seismic Hazard Update* (June 2025).

Please contact the Structural Standards POC (LANL internal) for interpretation, variance, and upkeep issues.

A. This Section provides the minimum requirements for the structural design and analysis of new and existing nuclear structures, systems, and components (SSCs).[1]

B. Abbreviations, notations, and references not defined herein are included in Chapter 5 Subsections I.2 to I.4.

C. DOE-STD-1020-2016: Per DOE Order 420.1C Change 3*, Facility Safety*, the design of new facilities and major modifications[2] must comply with DOE-STD-1020-2016, *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities*.

1. The remainder of this Section refers to DOE-STD-1020-2016 as DOE-STD-1020.

2. The majority of DOE-STD-1020 provisions applicable to nuclear SSCs are not repeated in this Section.[3]

3. ASCE 4 and ASCE 43: LANL amends all DOE-STD-1020 references to ASCE 4-98 to ASCE 4-16 and ASCE 43-05 to ASCE 43-19. Refer to Appendix F for additional details.

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[1] Per DOE-STD-1020-2016, and as indicated in Chapter 5 Section I.3, the nuclear facilities considered herein are DOE Hazard Category 1, 2, and 3 nuclear facilities. In addition to having nuclear materials above DOE HC 3 thresholds, these facilities can also include chemical and/or toxicological hazards.

[2] 10 CFR 830.3 defines major modification as follows: "Major modification means a modification to a DOE nuclear facility that is completed on or after April 9, 2001 that substantially changes the existing safety basis for the facility." DOE-STD-1189-2016, Integration of Safety into the Design Process, provides a process to use to identify major modifications and examples of major modifications.

[3] While this Section does include some of the requirements of DOE-STD-1020 that are applicable to LANL, as well as some related explanations, commentary, etc., users are expected to consult DOE-HDBK-1220-2017 to gain a better understanding of DOE-STD-1020.

4. For the design and construction of non-major modifications, either comply with DOE-STD-1020 or contact the Chapter POC for direction (Requirement 5-3001)[4].

5. The civil engineering systems referred to in the DOE-STD-1020 chapters on flood and precipitation hazards are addressed in ESM Chapter 3, *Civil*.

6. The requirements associated with lightning hazards in DOE-STD-1020 are addressed in ESM Chapter 7, *Electrical*.

7. Per DOE-STD-1020, Section 9.2, for DOE nuclear facilities with safety-related SSCs classified as NDC-3 or higher, natural phenomena hazards (NPH) assessments shall be performed at least once every ten years. The updated NPH and probabilistic seismic hazard analysis (PSHA) assessments for LANL are documented in the following reports:

    a. LANL (2025). Natural Phenomena Hazards Assessment, 2025 Update (referred to as the 2025 LANL NPH Update in this Section).

    b. Slate Geotechnical Consultants (2025). P-22-016-01-PR-01-FR-01, Final Report for the LANL Augmented SSHAC Level 2 Seismic Hazard Update (referred to as the 2025 LANL PSHA Update in this Section).

    c. Slate Geotechnical Consultants (2025). P-22-016-01-PR-01-AR-01, LANL Augmented SSHAC Level 2 Seismic Hazard Update: Ancillary Deliverables (referred to as the 2025 LANL PSHA Ancillary Deliverables in this Section).

D. Table 2-1 in DOE-STD-1020 defines the Natural Phenomena Hazard Design Categories (NDCs) for NDC-1 through NDC-3 based on the unmitigated consequence thresholds associated with radiation and chemical exposure (i.e., Total Effective Dose [TED] and Protective Action Criteria [PAC], respectively) to co-located workers and the public.[5,6]

Using Table 2-1, safety and other SSCs shall be categorized for each natural phenomena hazard (NPH)—seismic (S), wind (W), flood (F), precipitation (P), and volcanic eruption (V)—by assigning to them one of three NPH Design Categories (NDCs): NDC-1, NDC-2, or NDC-3 (Requirement 5-3002).

1. Although NDC-4 and NDC-5 are defined, their likelihood of occurrence at LANL is small enough that they are not addressed herein (Requirement 5-3003).

2. Each NDC applies consistently across all NPHs (Requirement 5-3004)[7].

E. Limit state (LS): The limit state of an SSC for seismic hazard evaluations (i.e., LS A, B, C, or D), and the limiting acceptable deformation, displacement, stress, strain, and

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[4] Guidance: In such cases, following DOE-STD-1020 is the preferred approach; however, in some circumstances a well-justified and documented determination may support the use of the code of record (COR), or an enhanced COR. The COR is discussed in ESM Chapter 1, Section Z10, and in ESM Chapter 16 Building Code Program, as applicable.
[5] Regarding chemical hazards and the associated PACs in Table 2-1, refer to DOE-STD-1020 Section 2.3.3.6 and Chem PACs TEELs (energy.gov).
[6] Despite not being mentioned here, facility workers/building occupants are "accounted for." Refer to Table 2-1 Note 2, and DOE-STD-1020 Section 2.3.3.3.
[7] For example, NDC-1 applies to seismic design category (SDC) SDC-1, wind design category (WDC) WDC-1, etc.

related response parameters for other NPHs, shall be determined in accordance with DOE-STD-1020 Section 2.4 (Requirement 5-3005).

1. For convenience, ANS 2.26 Appendix B, *Examples of Application of Limit States to SSCs*, has been adapted for LANL use and is included herein as Appendix D.

F. The project records, quality control, quality assurance, and construction of nuclear SSCs shall comply with the provisions of Chapter 5 Section I (General Criteria), ESM Chapter 1 (General), ESM Chapter 16 (Building Code Program), and the provisions contained herein (i.e., Chapter 5 Section III) (Requirement 5-3006).

1.0 NDC-1 AND NDC-2 SSCS

1.1 General

A. As indicated previously, NPH-specific design categorization is required by DOE-STD-1020. Therefore, in order for this Subsection (III.1) to be applicable, the design categorization required by the respective portion of DOE-STD-1020 shall have been completed (Requirement 5-3007)[8].

B. Per DOE O 420.1C Chg. 3, in addition to being applicable to the design of Safety Class (SC) SSCs, ACI 349 and AISC N690 must be evaluated for applicability—along with ACI 318 and AISC 360—for the design of Safety Significant (SS) SSCs. Safety Significant SSCs protect the co-located worker; at LANL, Safety Significant SSCs categorized as NDC-3 shall be designed in accordance with ACI 349 and AISC N690. Safety Significant SSCs that fall into the NDC-1 or NDC-2 categories because of the unmitigated consequences shall be designed, at a minimum, to ACI 318 and AISC 360, consistent with the requirements in Section II of this Chapter (Requirement 5-3008).

1.2 Seismic

A. **SDC-1 and SDC-2 SSCs—Buildings/Structures**

1. As applicable, the limit state (LS), determined in accordance with DOE-STD-1020 Section 2.4, shall be adjusted in accordance with DOE-STD-1020 Section 3.1.3 (Requirement 5-3009).

2. SDC-1 and SDC-2 SSCs shall be designed according to the criteria of Chapter 5, Section II, for Risk Category II and Risk Category IV facilities, respectively, and using the response coefficients provided in DOE-STD-1020 Table 3-1. (Requirement 5-3010).

B. **SDC-1 and SDC-2 Non-Facility Equipment** (e.g., Programmatic, Utilities, Infrastructure, Environmental Remediation, etc.) shall be restrained in accordance with Appendix G, *Restraint of Non-Facility Components*, herein (Requirement 5-3011).

1.3 Wind

A. WDC-1 and WDC-2 SSCs

1. WDC-1 and WDC-2 SSCs shall be designed as Risk Category (RC) II and Risk Category IV facilities, respectively, and according to the criteria of Section II of this Chapter (Requirement 5-3012).

[8] For example, in Section III.1.2 "Seismic", it is assumed that the "safety SSCs" and the "other SSCs" applicable to the design-basis seismic event have been categorized in accordance with DOE-STD-1020 Section 3.1.1 and that the categorization indicates that SDC-1 and/or SDC-2 SSCs are applicable.

1.4 Flood

A. FDC-1 and FDC-2 SSCs

1. FDC-1 and FDC-2 SSCs[9] shall be designed such that the following requirements are met[10]:

    a. They shall be able to withstand flood loads resulting from Design Basis Flood Levels (DBFLs)[11] using the load combinations specified in the IBC for Risk Category II and Risk Category IV, respectively; excluding the load factor for the flood load (Requirement 5-3013).

    b. When SSCs that may fail due to water intrusion or submergence cannot be located above the DBFL, consider the mitigation strategies in DOE-STD-1020 Section 5.5.4 (Requirement 5-3014).

1.5 Precipitation

A. PDC-1 and PDC-2 SSCs[12]

1. PDC-1 and PDC-2 SSCs shall be designed as Risk Category II and Risk Category IV facilities, respectively, and according to the criteria of Section II of this Chapter subject to the following changes (Requirement 5-3015):

    a. PDC-2 design rainfall intensity, I, is 2.42 in/hr for a 60-min duration event and 5.82 in/hr for a 15-min duration event (Requirement 5-3016).

1.6 Volcanic Eruption

A. **VDC-1 and VDC-2 SSC** design is not required (Requirement 5-3017).

2.0 NDC-3 STRUCTURES AND STRUCTURAL SYSTEMS

2.1 Acceptance Criteria

A. General

1. The structural demands (e.g., member forces, displacements, stresses, strains) shall be determined using the loads, load combinations, and analysis procedures indicated in this Section (Requirement 5-3018).

2. The design codes/standards listed in Table III-1 are permitted for use (Requirement 5-3019). Design, detailing and determination of capacities shall be in accordance with ASCE 43, and the indicated material design

[9] This requirement applies only to FDC-1 and FDC-2 SSCs located in/on FDC-1 and FDC-2 facilities. It does not apply to FDC-1 and/or FDC-2 SSCs within/on facilities that include FDC-3 SSCs. For FDC-1 and FDC-2 SSCs within facilities that also include FDC-3 SSCs, refer to Section III.2.2.P (Flood Loads). Note that while the FDC of a facility is likely the same as the highest FDC of the SSCs in/on it, the design basis flood level (DBFL) for a facility and its SSCs might differ. Refer to DOE-STD-1020 Section 5.4.2 for details.

[10] Flood design shall comply with DOE-STD-1020 and requires a Probabilistic Flood Hazard Assessment (PFHA), Flood Scenario Analysis (FSA), and, where applicable, a Comprehensive Flood Hazard Assessment (CFHA). The IBC also requires identification of Flood Hazard Areas (FHAs). Refer to Chapter 3 of the 2025 LANL NPH Update, *Analysis of Flooding Hazards and Impacts*, for determination of Design Basis Flood Levels (DBFLs) and associated flood loads for existing LANL nuclear facilities.

[11] A DBFL can be influenced by local precipitation. See Section III.1.5. (Precipitation) herein, and DOE-STD-1020 Figure 5-1.

[12] There are two (2) precipitation related hazards included in DOE-STD-1020 Chapter 7: localized flooding and roof ponding/(over-) loading. Only the latter is addressed herein. To address localized flooding, which can result in water intrusion or submergence of SSCs and/ or structural failure from hydrostatic or hydrodynamic loads, the Design Basis Precipitation Level (DBPL) must be determined from a Probabilistic Precipitation Hazard Assessment (PPHA). Note that the flood hazard caused by local precipitation in DOE-STD-1020 Chapter 7 is related to the flood hazard in DOE-STD-1020 Chapter 5. Refer to DOE-STD-1020 Sections 5.2.2.1, 5.5.3.1, 7.1.1(d) and 7.3.1.

code/standards listed in Table III-1, subject to any applicable amendments made in this Section (Requirement 5-3020).

Table III-1. Material Design Codes and Standards for NDC-3 SSCs

Material	Material Design Code/Standard[13]
Reinforced Concrete	ACI 349*, [14]
Structural Steel	ANSI/AISC N690*
Stainless Steel	ANSI/ASCE 8
Cold Formed Steel	AISI S100
Reinforced Masonry	TMS 402/ACI 530/ASCE 5 (ACI 530)

3. Seismic acceptance criteria for structures and structural systems shall comply with the applicable requirements of ASCE 43, Section 5.2 (Requirement 5-3021)[15].

B. Strength Acceptance Criteria

1. As applicable, the strength requirements and acceptance criteria specified in the applicable material design standards listed in Table III-1 shall be satisfied (Requirement 5-3022).

2. Strength acceptance criteria for seismic loads shall be in accordance with ASCE 43, Section 5.2.2 (Requirement 5-3023).

C. Deformation Acceptance Criteria

1. As applicable, deformation limits, serviceability requirements, and deformation acceptance criteria specified in the applicable material design standards listed in Table III-1 shall be satisfied (Requirement 5-3024).

2. Deformation acceptance criteria for seismic loads shall be in accordance with ASCE 43, Section 5.2.3 (Requirement 5-3025).

2.2 Loads

A. Dead Load (D)

1. Dead loads shall include the weight of all materials of construction incorporated into the building including, but not limited to, walls, floors, roofs, ceilings, stairways, nonstructural components (e.g., ceilings, built-in partitions, finishes, cladding, fixed service equipment, piping, etc.) and other similarly incorporated items, including the weight of cranes (Requirement 5-3026).

    a. For evaluation of seismic response, the dead load and stiffness contributions of nonstructural components shall be considered in accordance with ASCE 4, Sections 3.7 and 4.7 (Requirement 5-3027).

[13] Use the most recent version of the applicable material codes in agreement with the established code of record. Project design documents shall contain the dates for the code of records. Where no code of record is established for the modification of existing facilities, the engineer in responsible charge shall document the revision of the code used for design.

[14] Use of NRC Regulatory Guide (RG) 1.142 in conjunction with ACI 349 is recommended. This regulatory guide provides updates and commentary that supplement ACI 349. Note that RG 1.142 (2020) reflects more current understanding, whereas ACI 349-13 is based on provisions derived from ACI 318-08.

[15] The applicable acceptance criteria under seismic loads depend on the type(s) of analysis performed (i.e., linear and/or nonlinear) and the type of SSC (e.g., structures and structural systems versus nonstructural components and systems).

2. Unit weights of 150 pcf for reinforced concrete and 490 pcf for rolled steel shall be used in the derivation of dead loads (Requirement 5-3028).

3. The dead load used in the design of new facilities shall be based on best estimates of the actual weights comprising it (Requirement 5-3029).

B. Live Load (L)

1. Live loads (L) are not permanently applied to a structure but are likely to occur during its service life, such as loads produced by the use and occupancy of the structure. Live loads shall be determined in accordance with ASCE 7, Chapter 4, and based on project-specific requirements.

C. Crane Loads (C or C_{cr})

1. Determine crane loads (C or C_{cr}) in accordance with Chapter 4.0, Section 4.9 of ASCE 7, and based on project-specific requirements (Requirement 5-3030).

D. Fluid Loads (F)

1. Determine fluid loads — the load due to fluids with well-defined pressures and maximum heights (e.g., fluid in tanks, etc.) — based on project-specific requirements (Requirement 5-3031).

E. Lateral Soil Pressure Loads (H)[16]

1. Underground building walls shall be designed to resist lateral soil pressure loads, assuming steady-state/at-rest conditions, the magnitude of which shall be specified by a geotechnical report approved by a LANL subject matter expert (Requirement 5-3032). A default value of 0.5 for at-rest lateral soil pressure coefficient, K_o, may be used to determine lateral soil pressure loads[17].

2. In determining lateral soil pressure loads, the density of the backfill or native soil, whichever is greater, shall be used (Requirement 5-3033).

3. The lateral soil pressure load magnitude shall be increased if soils with expansion potential are present at the site (based on criteria provided in the project geotechnical report) (Requirement 5-3034).

F. Precipitation Loads (S, R, and D_i)

1. **Snow Loads (S):** Determine snow loads using the procedure prescribed in NRC COL/ESP-ISG-007, *Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures*, and ASCE 7 Chapter 7.0, as amended by the following (Requirement 5-3035)[18]:

   a. The Ground Snow Loads, p_g, due to the Normal Winter Precipitation Event shall be: p_g = 36.6 psf (Requirement 5-3036).[19]

   b. ASCE 7 Section 7.3.3 Importance Factor, I_s, substitute the following text: I_s = 1.0 (Requirement 5-3037).

[16] Refer to Appendix E Section E.C herein for lateral soil pressure loads that result from earthquake.
[17] Average value for K_0 for cohesionless soils per Bowles (Foundation Analysis and Design, 3rd Ed.; Fig. 11-2), and a reasonable value for normally consolidated clays per Winterkorn & Fang (Foundation Engineering Handbook, pp. 488).
[18] Alternative methods for defining the roof snow loads in existing PDC-3 facilities are deemed acceptable, granted it is demonstrated that they meet DOE-STD-1020-2016 requirements and are approved by ESM Chapter 5 POC.
[19] Per ASCE 4-16 Section 3.4.2(c): flat snow roof loads less than 30 psf need not be included as part of the seismic mass.

c. The load due to the Extreme Winter Precipitation Event shall be: 15.9 psf (Requirement 5-3038)[20].

2. **Rain Loads (R):** Determine rain loads using the procedures prescribed in Chapter 8.0 of ASCE 7 as amended by the following (Requirement 5-3039):

   a. PDC-3 design rainfall intensity, I, is 3.05 in/hr for a 60-min duration event and 7.32 in/hr for a 15-min duration event[21] (Requirement 5-3040).

   b. All of the provisions of ASCE 7 Chapter 8 shall be evaluated and complied with (Requirement 5-3041).

   c. Roofs shall have positive drainage and shall be equipped with secondary drains or scuppers (Requirement 5-3042).

3. **Ice Loads (D_i, Atmospheric Ice Weight):** D_i shall be considered for ice-sensitive structures (i.e., structures of relatively small weight and large exterior surface areas, such as lattice structures, guyed masts, open catwalks and platforms, signs, etc.) (Requirement 5-3043). Thus, D_i need not be considered for buildings and building-like structures.

4. Determine D_i using the procedure prescribed in Chapter 10.0 of ASCE 7 as amended by the following (Requirement 5-3044):

   a. Use 0.25 inch for the nominal ice thickness (t) due to freezing rain (Requirement 5-3045).

   b. Use 2.5 for I_i, the importance factor or multiplier on ice thickness (Requirement 5-3046).

   c. The wind load concurrent with ice loading, W_i, shall be based on a 40-mph 3-second-gust wind speed (Requirement 5-3047).

   d. Use 1.0 for I_w, the importance factor for wind on ice-covered SSCs (Requirement 5-3048).

G. **Thermal Loads (T_o[22] and T_a[23])**

1. Determine T_o and T_a, based on the most critical time-dependent or steady-state condition temperature variations that are applicable to the project-specific requirements, (Requirement 5-3049).

2. In the design/analysis of concrete structures, an acceptable approach for considering the effects of T_o and T_a is ACI 349.1R, *Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures* (Requirement 5-3050).[24]

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[20] The extreme winter precipitation load (i.e., the roof load due to the normal winter precipitation event plus the roof load due to the extreme winter precipitation event) is not to be included in the seismic load combinations since these are both extreme events and are to be treated separately, refer to NRC COL/ESP-ISG-007 for guidance.

[21] Rainfall provided here is calculated as the larger between the 1000-year and 2500-year return period intensities reported by NOAA ATLAS 14 and LA-UR-15-29420 Table 4.1 respectively for Los Alamos.

[22] Normal thermal Loads (T_o): Thermal effects and loads encountered during normal operating, start-up, or shutdown conditions.

[23] Abnormal thermal Loads (T_a): Thermal loads generated by the postulated accident, including T_o.

[24] The reason for this allowance is, as indicated at the outset of 349.1R, 349 App. E is intended for nuclear power plant structures, while 349.1R is not restricted to such.

H. Pipe/Equipment Reactions (R_o[25] and R_a[26])

1. Determine R_o and R_a, based on the most critical transient or steady-state condition that is applicable to the project-specific requirements (Requirement 5-3051).

   a. The use of "loads" herein applies to piping and equipment reactions, or related effects (Requirement 5-3052).

I. Operating Basis Earthquake (E_o)

1. The operating basis earthquake (E_o) applies to nuclear power plants and is not applicable at LANL. Refer to ACI 349 Definitions and AISC N690 Glossary for details.

J. Wind Loading (W)

1. Determine wind loads using the procedure prescribed in Chapter 26.0 of ASCE 7 as amended by the following (Requirement 5-3053)[27]:

   a. Modify ASCE 7 Section 26.5.1 as follows:

      26.5.1 Basic Wind Speed. Use a basic wind speed, V, of 120 mph for the determination of wind loads on buildings and other structures (Requirement 5-3054).

   b. Modify ASCE 7 Section 26.7.3 as follows:

      26.7.3 Exposure Categories. Exposure C shall apply for all cases (Requirement 5-3055).

   c. Modify ASCE 7 **Section 26.12.2 Openings**, by adding the following paragraph at the end of the section (Requirement 5-3056):

      Any opening in the building envelope created by a missile breach(s) that exceeds one (1) square foot per 1,000 cubic feet of volume shall be included in the determination of the amount of openings (Requirement 5-3057).

   d. Replace ASCE 7 Section 26.12.3 Protection of Openings, with the following (Requirement 5-3058):

      26.12.3 Straight-Line-Wind Missiles. Structures and structural systems shall be designed to prevent breaching, or else protected from impact, by the following two (2) types of missiles (Requirement 5-3059):

      26.12.3.1 Small/ Lightweight Missile. One-inch-diameter, solid steel sphere, weighing 0.147 lb, 12-mph horizontal velocity, impact height unlimited (Requirement 5-3060).

      26.12.3.2 Medium/ Medium-Weight Missile. ASTM A53 Gr B Pipe 6 Std, 15-feet long, 48-mph horizontal velocity, impact height $\leq$ 30 ft above grade (Requirement 5-3061).

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[25] Normal Pipe/Equipment loads (R_o): pipe reactions during normal operating, start-up or shutdown conditions, based on the most critical transient or steady-state condition.
[26] Abnormal Pipe/Equipment loads (R_a): pipe and equipment reactions generated by the postulated accident, including R_o.
[27] The return period used for calculation of Wind Loads shall not be lower than the associated with IBC 2021 requirements for Risk Category IV structures.

K. Design Basis Earthquake (E, E_s, or E_{ss})

1. Refer to Appendix E of this Section for DBE loads and related requirements (Requirement 5-3062).

L. Tornado Loading (W_t)

1. W_t shall be considered for structures that are to be sealed; however, only with regard to the combination of W_t acting simultaneously with atmospheric pressure change (APC) as described subsequently (Requirement 5-3063).

2. W_t = maximum external pressure acting away from the structure determined using the procedure described in the previous paragraph (III.2.2.L.1), Wind Loading (W), as amended by the following:

   a. Use V = 90 mph (Requirement 5-3064).

3. APC = internal pressure acting outward on the structure shall be taken as 0.2 psi (Requirement 5-3065).

4. Ensure that the structure is designed to withstand whichever of the following two (2) load combinations produces the largest demand (Requirement 5-3066):

   a. ½APC + W_t

   b. APC + ½W_t

M. Differential Pressure (P_a)

1. Determine P_a (i.e., abnormal load generated by a postulated accident) based on the project-specific requirements (Requirement 5-3067).

   a. The use of "load" herein applies to maximum differential pressure load, or related internal moments and forces (Requirement 5-3068).

N. Impulsive and Impact Loads (Y_r, Y_j, Y_m)

1. Determine Y_j, Y_m, and Y_r (i.e., abnormal loads generated by a postulated accident) based on the project-specific requirements (Requirement 5-3069).

   a. The use of "loads" herein applies to the specific type of load as follows (Requirement 5-3070):

      Y_j = Jet impingement load, or related internal moments and forces, on the structure.

      Y_m= Missile impact load, or related internal moments and forces, on the structure.

      Y_r = Loads, or related internal moments and forces, on the structure generated by the reaction of the broken high-energy pipe (during the postulated accident).

2. For additional details on these loads, specific examples of them, how to design for them, etc., refer to ACI 349 and AISC N690.

O. Self-Straining Forces

1. In the design for normal loads, consideration shall be given to the forces due to such effects as ambient temperature change, prestressing, vibration, impact, shrinkage, creep, differential settlement of supports, construction, and testing (Requirement 5-3071).

a. Unless specifically addressed through analysis, the effects of self-straining forces shall be accommodated by placement of relief joints, suitable framing systems, or other details (Requirement 5-3072).

2. Where the structural effects of differential settlement, creep, shrinkage, or expansion of shrinkage-compensating concrete are significant, they shall be included with the dead load, D, in the load-combination equations (Requirement 5-3073). Estimation of these effects shall be based on a realistic assessment of such effects occurring in service (Requirement 5-3074).

P. Flood Loads

1. FDC-3 structures and structural systems shall be designed such that the following requirements are met[28]:

a. They shall be able to withstand flood loads resulting from Design Basis Flood Levels (DBFLs) using the load combinations in ACI 349 and AISC N690 wherein each applicable flood load shall be considered an "Extreme Load" (Requirement 5-3075).

b. When SSCs that may fail due to water intrusion or submergence cannot be located above the Design Basis Flood Level (DBFL), consider the mitigation strategies in DOE-STD-1020 Section 5.5.4 (Requirement 5-3076).

Q. Volcanic Eruption Loads

1. VDC-3 SSC design is not required (Requirement 5-3077).

R. Blast Loads[29]

1. Experimental Blast loads (L_{EB}) shall be determined based on project-specific requirements (Requirement 5-3078)[30]. As necessary/applicable, L_{EB} shall include the blast loading on the outside, or inside, of a building from experimental explosions, and/or the loads that must be resisted by a building from blasts/explosions occurring within experimental-explosion containment structures (Requirement 5-3079). All potential blast effects shall be considered including blast overpressure, gas pressure, fragments, and ground shock (Requirement 5-3080).

2.3 Load Combinations

A. Reinforced Concrete and Reinforced Masonry

1. The load combinations of ACI 349 Chapter 9 shall be used to combine demands for reinforced concrete and masonry structures and structural systems as amended by the following (Requirement 5-3081):

a. The term E_{ss} in ACI 349 Equations 9-6 and 9-9 shall be replaced by E_{ss}/F_{μ}, where F_{μ} is the inelastic energy absorption factor (addressed subsequently herein) (Requirement 5-3082).

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[28] Flood design shall comply with DOE-STD-1020 and requires a Probabilistic Flood Hazard Assessment (PFHA), Flood Scenario Analysis (FSA), and, where applicable, a Comprehensive Flood Hazard Assessment (CFHA). The IBC also requires identification of Flood Hazard Areas (FHAs). Refer to Chapter 3 of the 2025 LANL NPH Update, *Analysis of Flooding Hazards and Impacts*, for determination of Design Basis Flood Levels (DBFLs) and associated flood loads for existing LANL nuclear facilities.

[29] For each applicable load combination, the required strength or ductility of the affected structural elements for the blast loads shall be determined by considering all other applicable concurrently acting loads.

[30] Facility design shall comply with DOE-STD-1212 Chapter 7, *Explosives Facility Design/Site Criteria.*

b. Seismic (E_{ss}), Tornado Wind (W_t) and Extreme Winter Precipitation NPH loads shall be considered "extreme environmental loads" (Requirement 5-3083)[31].

c. Replace ACI 349 equation 9-5 with the following:

$U = 1.2(D + F + R_o) + 1.6H + L + W + T_o$ (9-5)

2. The load combinations in ACI 530 shall not be used for the design of NDC-3 structures and structural systems (Requirement 5-3084).

B. Structural Steel Members, Cold-Formed Steel and Stainless Steel

1. The load combinations of AISC N690 shall be used to combine demands for structural steel, cold-formed steel and stainless steel structure and structural systems as amended by the following (Requirement 5-3085):

a. The term E_s in AISC N690 Equations NB2-6, NB2-9, NB2-15 and NB2-18 shall be replaced by E_{ss}/F_μ, where F_μ is the inelastic energy absorption (addressed subsequently herein) (Requirement 5-3086).

b. Seismic (E_{ss}), Tornado Wind (W_t) and Extreme Winter Precipitation NPH loads shall be considered "extreme environmental loads" (Requirement 5-3087).[32]

c. The AISC N690 "severe environmental load combinations" shall be used for consideration of concurrently-acting D_i and W_i subject to the following modifications: D_i shall be added to D, and W_i shall be taken to be W (Requirement 5-3088).

2. The load combinations in ASCE 8 shall not be used for the design of NDC-3 structures and structural systems (Requirement 5-3089).

3. The load combinations in AISI Standard S100 shall not be used for the design of NDC-3 structures and structural systems (Requirement 5-3090).

C. Inelastic Energy Absorption Factor (F_μ)

1. Determine F_μ in accordance with ASCE 43 Section 5.1.3 (Requirement 5-3091).

2. Use F_μ = 1.0 for masonry and cold-formed steel structural elements (Requirement 5-3092)[33].

3. For stainless steel components, use the same $F_{\mu C}$ values specified for structural steel components in ASCE 43 Section 5.1.3, provided the ductility requirements of DOE-STD-1020 Section 3.6.1 are satisfied (Requirement 5-3093).

2.4 Analysis Procedures

A. Structural analysis shall comply with the applicable material design standards listed in Table III-1 (Requirement 5-3094).

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[31] The load combination for Extreme Winter Precipitation shall be ACI 349 Eq (9-7) with W_t replaced by the Extreme Winter Precipitation load.

[32] The load combination for Extreme Winter Precipitation shall be AISC N690 Eq (NB2-7) with W_t replaced by the Extreme Winter Precipitation load.

[33] A project-specific system energy absorption factor, F_μ, may be developed for these structural elements, provided it meets the performance objectives of ASCE 43. The basis for the selected F_μ shall be fully justified and subject to peer review. Refer to Section C5.1.3.1 for additional guidance.

B. Seismic modeling and analyses shall comply with ASCE 43 and ASCE 4 (Requirement 5-3095).

C. Input motions shall comply with ASCE 43 Chapter 2 and ASCE 4 Chapters 2, 4 and 5, as applicable (Requirement 5-3096).

2.5 Capacities

A. Determine seismic capacities in accordance with ASCE 43 Section 4.2, as amended below (Requirement 5-3097):

1. Section **4.2.2 Reinforced Concrete**. Add the following:
    a. Delete ACI 349 Section 9.2.10 (Requirement 5-3098).
    b. Design of anchorage to concrete in accordance with Appendix A of this Section (Requirement 5-3099).
2. Section **4.2.5 Reinforced Masonry**. Add the following:
    a. Post-installed (PI) anchor bolts shall not be used (Requirement 5-3100).

2.6 Detailing Requirements

A. Comply with all the applicable provisions of ASCE 43 Chapter 6, *Ductile Detailing Requirements* (Requirement 5-3101).

B. Structural steel designs shall allow for/ensure the following (Requirement 5-3102):

1. Each column anchored with a minimum of four (4) anchor rods.
2. Each column base plate assembly, including the column-to-base plate weld and the column foundation, designed to resist a minimum eccentric gravity load of 300 pounds located 18 inches from the extreme outer face of the column in each direction at the top of the column shaft.

2.7 Additional Structural Design Considerations

A. Foundation Design

1. Detailing of NDC-3 building foundations shall meet the following requirements:
    a. Provide a minimum foundation embedment depth of 36 inches below finished grade, unless the foundation bears directly on welded tuff (Requirement 5-3103).
    b. Interconnect all SDC-3 spread footing type foundations using tie beams (Requirement 5-3104).
    c. Design tie beams to resist a minimum horizontal force, in tension or compression, equal to 10 percent of the larger supported column vertical load (Requirement 5-3105).
    d. Additionally, design tie beams to resist bending due to differential settlement, as specified in the project geotechnical report, and due to eccentric column loading on spread footings. These effects shall be considered simultaneously with the horizontal force (Requirement 5-3106).

B. Common-Cause Failure and System Interaction

1. In addition to DOE-STD-1020 Section 2.3.2(b), comply with the requirements and guidance for common-cause failure and system interaction (also referred to as "two-over-one") provided in DOE-STD-1020 Section 3.6.3; this Chapter Subsection I.1.3 (DOE Natural Phenomena Hazard Mitigation Requirements) and Subsection I.1.5 (Applicability); ASCE 43 Section C8.3; and in DOE-HDBK-1220-2017, Appendices A and C.

C. Progressive Collapse

1. Refer to this Chapter Subsection II.1.10, *Section 1618 Minimum Antiterrorism Structural Design Measures* (Requirement 5-3107).

D. Permanent Explosive Facilities and Facilities Containing Explosives, or Those that can be Affected by Such

1. Refer to Section II of this Chapter in Subsection II.1.9, *Section 1617 Accidental Blast Loads* (Requirement 5-3108).

E. Additional Seismic Analysis and Design Considerations

1. Comply with all the applicable provisions of ASCE 43 Chapter 7, *Special Considerations* (Requirement 5-3109).

3.0 NDC-3 NONSTRUCTURAL SYSTEMS AND COMPONENTS

A. In addition to complying with the applicable provisions of DOE-STD-1020, comply with the applicable requirements of this Chapter Subsection I.1.7 *Designated Seismic Systems* (Requirement 5-3110).

B. Seismic modeling, analysis, and qualification of nonstructural systems and components shall comply with the applicable provisions of ASCE 43 and ASCE 4 (Requirement 5-3111).

C. NDC-3 Non-Facility Equipment (e.g., Programmatic, Utilities, Infrastructure, Environmental Remediation, etc.) shall be restrained in accordance with this Section Appendix G, Restraint of Non-Facility Components (Requirement 5-3112).

4.0 EXISTING HC 1 – 3 NUCLEAR FACILITIES WITH NDC-3 SSCs

A. Comply with this Chapter Subsection I.1.3, *DOE Natural Phenomena Hazard Mitigation Requirements* (Requirement 5-3113).

B. In accordance with DOE-STD-1020 Section 3.5.3 use in-structure response spectra (ISRS) to determine seismic demands on equipment. Available ISRS for LANL nuclear facilities are provided on this Chapter website under *Resources*.

5.0 DESIGN BASIS DOCUMENT (DBD)

A design basis document shall be prepared for all nuclear projects (Requirement 5-3114).

A. The DBD shall summarize the structural design basis for the facility and include, at a minimum, the NPH Design Category of the SSCs, design codes of record (including dates and editions), analysis methods (e.g., computer programs and analytical approaches), load definitions, load combinations, load paths (local and global), member capacity equations, and corresponding acceptance criteria (Requirement 5-3115). The DBD shall also describe the design of SSCs, including non-building structures (Requirement 5-3116). A template for a DBD is presented in Figure III-1.

B. The DBD may be used to justify the exclusion of load combinations identified in Sections II and III by demonstrating that such combinations are not applicable or are bounded by other governing load combinations. Once established, the DBD shall remain the structural code of record for the project and **need not be revised** due to subsequent changes to the ESM or referenced standards unless directed by LANL. Refer also to LANL ESM Chapter 1, Subsection Z10.7, *Code of Record*.

- Facility Background and Mission*
- Facility Hazard Categorization and Basis per LANL SBP111-1 (*Facility Hazard Categorization and Documentation*)
- Management Level for the Project per LANL AP-341-502*
- Assignment of SSC as Safety Class (SC), Safety Significant (SS), other hazard controls (OHC), or Defense in Depth (DID) and Assignment of SSC to NPH Risk/Design Categories*
- Listing of Components for which Special Seismic Certification/Qualification is required (i.e., Designated Seismic Systems)
- Rationale for Selection of Gravity and Lateral Load-Resisting Systems
- Facility Siting Considerations (standoff distance from known faults, flood levels, etc.)*
- Facility Geotechnical Investigation (e.g., highlighting recommendations, design parameters and how they are incorporated into selection of foundation depth, foundation design, retaining wall design, as further detailed in Chapter 5 Subsection IV.5)
- Applicable NPH Definition
  - Earthquake (DBE response spectra)
  - Wind (ultimate design/basic wind speed for the applicable risk/design category)
  - Wind Driven Missiles (definition of)
  - Snow (ground load) and Extreme Winter Precipitation
  - Flood and local precipitation (if applicable, or basis for not considering)
  - Other NPH phenomena applicable to the facility design
- Antiterrorism Measures*
- Experimental Explosion Design Considerations
- Accidental Explosion Design Considerations
- LANL ESM Section Revisions/Editions
- Design Codes and Standards of Record (Edition and Rev. Date)
- Seismic design requirements for nonstructural components and non-building structures; including applicability of, and exemptions from, requirements
- Analysis Methodology (used to determine structural demand)
- Member Capacity Equations (not included in design standards/codes, or not commonly used)
- Load Combinations (if applicable, and when provided therein, refer to Chapter 5 Section III)
- Load Path (including validation of local load path between roof deck and attachment to lateral elements and local load path for bracing of seismic lateral-force-resisting-system elements)
- Means of Accounting for Inelastic Behavior During the DBE (in the determination of seismic demand, capacity, and associated detailing)

* This information is typically found in other documents such as the Facility Design Description (FDD), System Design Descriptions (SDD), Functions & Requirements Document (FRD), or Requirements and Criteria Document (RCD), and only a summary (based on these documents) need be included in the DBD.

Figure III - 1 Design Basis Document (DBD) Content

C. In addition to describing the design basis for gravity loads, normal operating loads, and NPH loads, the DBD shall describe the design basis for blast loads and any antiterrorism measures implemented (Requirement 5-3117). Regarding blast loads, the DBD shall also indicate the loads used in design and shall address the methods of analysis and the levels of acceptable blast damage (Requirement 5-3118).

D. An NDC must be assigned to an SSC to establish the appropriate NPH (earthquake, wind, precipitation and flood) design and analysis requirements in DOE-STD-1020-2016.

- On larger projects, NPH design categories will typically be provided to the structural engineer of record (SEOR) by either the leadership of his/her project team or LANL.

- If/when the categories are provided, and related documentation exists (e.g., FDD, SDD, FRD, etc.) the basis/bases for their assignment will likely be summarized therein.
- If the categories are provided, and the bases for their assignment exists, summarize/present the bases in the DBD (Requirement 5-3119).
- If the categories are provided, and the bases for their assignment doesn't exist, the SEOR should state this in the DBD and provide his/her opinion on why the categories were assigned.
- If the categories are not provided, the SEOR shall determine them and indicate the bases for such in the DBD (Requirement 5-3120).

E. A DBD is required for major structural design projects (e.g., new buildings, major modifications to existing buildings, retrofit of several different NDC-3 gloveboxes, etc.) (Requirement 5-3121). For less-significant design projects, the DBD need not be a stand-alone document, rather its contents (described previously) can be included as front matter in the structural calculations.[34] If in doubt, contact the structural POC/designee assigned to review the project record documents.

6.0 QUALITY CONTROL, QUALITY ASSURANCE AND PEER REVIEW

A. Refer to Chapter 5 Subsection I.1.6.F of this Chapter, *Project Quality Assurance* (Requirement 5-3122).

7.0 RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	6/28/99	Initial issue in Facility Eng Manual.	Doug Volkman, *PM-2*	Dennis McLain, *FWO-FE*
1	2/09/04	Incorporated IBC & ASCE 7 in place of UBC 97; incorporated DOE-STD-1020-2002 versus 1994; incorporated concepts from DOE O 420.1A; FEM became ESM, an OST.	Mike Salmon, *FWO-DECS*	Gurinder Grewal, *FWO-DO*
2	5/17/06	Revised load combos since ACI 349 is specified for PC-3 R/C structures and the load factors in the current version of ASCE 7 (used for load combos) are inconsistent with the strength reduction factors in the current version of ACI 349, including new Section 1.1.13 on crane and pipe restraint loads, companion table to go with former Table III-6 (i.e., Table III-6 became Tables III-6 and -7. OST became ISD.	Mike Salmon, *D-5*	Mitch Harris, *ENG-DO*
3	10/27/06	Administrative changes only. Organization and contract reference updates from LANS transition, 420.1A became 1B. Master Spec number/title updates. Became ISD, other administrative changes.	Mike Salmon, *D-5*	Kirk Christensen, *CENG*
4	6/19/07	Incorporated new seismic hazard analysis results into the DBE Response Spectra. Added Appendices A & B for concrete anchor design.	Mike Salmon, *D-5*	Kirk Christensen, *CENG*
5	6/20/11	Major revision. Added 1189 requirements; removed PC-4 requirements; new response spectra.	Mike Salmon, *D-5*	Larry Goen, *CENG*
6	3/27/15	Major revision. Incorporated DOE O 420.1C Chg 1 and DOE-STD-1020-2012 versus 2002. Eliminated historical 10-psf future-floor-DL and, for roofs, 30-psf min roof LL (Lr) and	Mike Salmon, *AET-2*	Larry Goen, *ES-DO*

[34] The majority of LANL structural design projects are of this variety; hence, do not require a stand-alone DBD

		prohibition on LL reduction. Created Apps C & D for LS and DBE loads.		
7	08/28/18	Replaced Drillco Maxi-Bolt with Hilti HDA in App A and B.	Mike Salmon, *AET-2*	Larry Goen, *ES-DO*
8	08/05/19	Added Hilti KB-TZ and HIT-RE 500 V3 to App A, KB-TZ as App. C. App C–D became D–E.	Mike Salmon, *E-1*	James Streit, *ES-DO*
9	03/24/21	Incorporated DOE O 420.1C Chg 3, DOE-STD-1020-2016, and ASCE 4-16 and ASCE 43-19 (adding App F); new App G for programmatic restraint, other minor changes. Many basis footnotes moved to requirements ID document.	Mike Salmon, *ALDFO*	James Streit, *ES-DO*
10	07/19/21	Added Hilti KB-TZ2 to App. A; new App. H for design for same. Crane guidance expanded in App E.	Mike Salmon, *ALDFO*	James Streit, *ES-DO*
11	03/22/23	Subsection III.1 revision adopts ASCE 7-16 and ACI 318-19 for NDC-1 and NDC-2 structures. Precipitation requirements for PDC-1 and PDC-2 structures have been updated to meet IBC 2021. PDC-3 precipitation loads (snow and rainfall) have been increased based on reinterpretation of 1020-2016 requirements and ASCE 7-16 snow and rainfall updates. Design Basis Document (DBD) requirements moved from Subsection I.1.6.C to Subsection III.6. Minor and administrative changes including updated references and definitions.	Carlos Coronado, *ES-SPD*	Mike Richardson, *ES-DO*
12	04/15/26	Updated acceptance criteria in Subsection 2.1 to align with ASCE 43 and applicable material codes and standards. Updated flood design guidance in Subsections 1.4.A and 2.2.P in accordance with recommendations from the LANL Natural Phenomena Hazards Assessment, 2025 Update. Revised ACI 349-13 load combination (Eq. 9-5) to align with AISC N690-12 and ACI 349-23; refer to Subsection 2.3.A.1.c for details. Additional minor editorial revisions were made to Subsections 1 through 6. Updated Appendix A (Design of Anchoring to Concrete) and deleted Appendices B, C, and H incorporating Variance VAR-10745, Alternate Post-Installed Anchors for NDC-3 SSCs. Revised Appendix E (Design Basis Earthquake Loads) to incorporate updated seismic design parameters from the 2025 LANL PSHA Update, as documented in P-22-016-01-PR-01-AR-01, Rev. 0, *LANL Augmented SSHAC Level 2 Seismic Hazard Update: Ancillary Deliverables* (July 2025), and P-22-016-01-PR-01-FR-01, Rev 0, *Final Report for the LANL Augmented SSHAC Level 2 Seismic Hazard Update* (June 2025).	Carlos Coronado, *ES-SPD*	Mike Richardson, *ES-DO*

APPENDIX A: DESIGN OF ANCHORING TO CONCRETE

A.1 Description

A. This Appendix establishes the technical requirements for design and analysis of structural embedments (used to transmit structural loads) in concrete for NDC-3 SSCs.

B. The following embedment types are included: anchors, embedded plates, shear lugs, grouted embedments, and specialty inserts.

1. Cast-in-place (CIP) anchors include headed bolts, threaded and nutted bolts, headed studs, and hooked bolts. Cast-in-place anchors shall conform to ASTM A36, A193, A354 Gr BD, A449, A572, A588, or F1554 (Requirement 5-3123). ASTM F1554 is the preferred material specification in AISC N690. Welding and mechanical properties of headed studs shall comply with AWS D1.1 (per AISC N690) and ESM Chapter 13, *Welding, Joining, and NDE* (Requirement 5-3124).

2. Permitted post-installed (PI) anchors include the Hilti HDA-P and HDA-T undercut anchors (HDA, ESR-1546) (Requirement 5-3125), KB-TZ[1] expansion anchor (KB-TZ, ESR-1917[2]) (Requirement 5-3126), KB-TZ2 expansion anchor (KB-TZ2, ESR-4266) (Requirement 5-3127), and HIT-RE 500 V3 bonded anchor (V3, ESR-3814) (Requirement 5-3128). In addition, other post-installed mechanical anchors may be used provided they meet the qualification requirements of ACI 349-13 and comply with the applicable qualification limitations and conditions of use specified in the anchor's evaluation or qualification report (e.g., ICC-ESR) (Requirement 5-3129) [3,4].

3. Purchase, installation, and testing requirements for NDC-3 anchors:

   a. Refer to LANL Master Specification Section 05 0521 (Requirement 5-3130).

   b. Request LANL STR approval for use of Hilti Undercut anchors HDA-P-DUC, HDA-T-DUC or KB-TZ.[5]

C. Anchors outside the scope of ACI 349 or ASCE 43-19 are not included. Examples include through bolts; multiple anchors connected to a single steel plate at the embedded end of the anchors; direct anchors such as powder or pneumatic actuated nails or bolts; and post-installed anchors intended for commercial, NDC-1, or NDC-2 applications[6].

A.2 Definitions

A. Definitions of anchors per ACI 355.2 and ACI 355.4 apply (Requirement 5-3131).

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[1] Use limited to indoor, dry environment. The nominal strength of KB-TZ anchors shall be reduced by a factor of 0.75 as detailed in Subsection A.11.B.

[2] This ESR is available on this Chapter website under *Resources*.

[3] Where anchors defined herein are to be used for anchorage of safety-related equipment or safety related applications (e.g., Safety Class and Safety Significant SSCs), the vendor shall be listed on the IESL, or proper commercial grade dedication (CGD) shall be performed. Otherwise, procurement of anchors shall be commensurate to the management level of the source SSC.

[4] It is the responsibility of the Engineer of Record (EOR) to confirm anchor availability and project's ability to perform CGD before specifying them in a new design.

[5] Hilti has discontinued production of the HDA-P-DUC and HDA-T-DUC undercut anchors, as well as the KB-TZ expansion anchors. Accordingly, their use in new designs is prohibited unless approved by LANL STR following confirmation of availability in existing LANL inventory.

[6] These anchors are included in this Chapter Section II, Appendix A.

B. Unless noted otherwise, all variable notations (and their definitions) in this appendix follow ACI 349, Appendix D (Requirement 5-3132).

A.3 Applicable Codes and Standards (Requirement 5-3133)

ACI 318	Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary
ACI 355.2	Qualification of Post-Installed Mechanical Anchors in Concrete (ACI 355.2) and Commentary
ACI 355.4	Qualification of Post-Installed Adhesive Anchors in Concrete (ACI 355.4) and Commentary
ACI 349	Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-13) and Commentary

A.4 Applicable Industry Standards

ASME NQA-1	Quality Assurance Requirements for Nuclear Facility Applications, American Society of Mechanical Engineers (Requirement 5-3134)

A.5 LANL Documents

LANL Master Spec Section 03 6021	Grouting–High Confidence (Requirement 5-3135)
LANL Master Spec Section 05 0521	Post-Installed Concrete Anchors Purchase–Nuclear Safety (Requirement 5-3136)
ESM Chapter 13	Welding, Joining, and NDE (Requirement 5-3137)

A.6 Prerequisites for Determining Anchor Design Loads

A. The SEOR shall coordinate with appropriate personnel to determine and document the NPH Design Category (i.e., NDC) of the anchorage and, where NDC = SDC, the Limit State (LS) as well (Requirement 5-3138). The NDC (or SDC + LS) shall be determined by considering both of the following:

1. The safety classification of the item or system being anchored (i.e., its required performance/functionality) (Requirement 5-3139), and

2. System interaction: refer to Section II, Appendix A Subsection A.5.C of this chapter (Requirement 5-3140).

B. Engineering drawings shall indicate the assigned NDC (or SDC + LS) used to design/analyze the anchorage of an SSC(s) (Requirement 5-3141).

A.7 Determining Anchor Design Loads

A. Loads on anchors shall account for baseplate flexibility, eccentricity of connections, and the dynamic (strain rate and low-cycle fatigue)[7] effects of loads and forces (Requirement 5-3142).

[7] Strain-rate effects and low-cycle fatigue under seismic loading are addressed through the testing requirements for seismically qualified post-installed anchors in accordance with ACI 355.2 and ACI 355.4.

A.8 Environmental Conditions

A. Anchors for indoor use in non-aggressive chemical environments may be carbon steel with a zinc electroplating. Anchors for use outdoors, or in aggressive environments, shall be galvanized, or made of stainless steel (Requirement 5-3143).

B. Bonded anchors intended for use in elevated temperature and/or radiation environments shall be qualified in those environments (Requirement 5-3144).

A.9 Requirements for Transfer of Shear Load to Foundations

A. For structures where the eave height exceeds 20 feet, provide shear lugs on base plates of columns in the Seismic force-resisting system, SFRS (Requirement 5-3145). Design the lugs in accordance with ACI 349-23 Section 17.10; and, where there is no conflict, per the recommendations of the most current version of the *AISC Steel Design Guide 1, Base Plate and Anchor Rod Design* (Requirement 5-3146). Where shear lugs are required, they shall be designed to transmit the entirety of shear load in elements of the SFRS to foundation elements (Requirement 5-3147).

A.10 General Design Requirements

A. *Cast-in-place embedments (ref. A.1.B herein) should be used in lieu of post-installed embedments whenever possible, and particularly for resisting heavy loads; and for anchoring rotating, reciprocating, or vibrating equipment such as fans, pumps, and motors. In the event that concrete is already placed due to construction sequencing, contact the Chapter POC for guidance.*

B. Post-installed embedments are used to attach SSCs to hardened concrete where cast-in-place embedments do not exist, or where it is determined to be most effective and efficient to use post-installed embedments. Cases exist where post-installed embedments will be specified prior to concrete placement to allow for release of construction documents (such as where fixture/baseplate details, or locations are not known at the time of drawing issue). The decision to specify post-installed embedments prior to concrete placement should be weighed carefully, considering the amount of construction cost and time required to drill holes, field modify plates, and to avoid cutting rebar.

C. Post-installed embedments and surface-mounted plates are recommended for applications where support requirements are added or modified after concrete placement. Post-installed embedments may be specified on design drawings prior to concrete placement for lightly loaded items where a cast-in-place embedment is not economical.

D. Pretensioning of cast-in-place anchors: Some examples of applications that might require pretension include structures that cantilever from concrete foundations, moment-resisting column bases with significant tensile forces in the anchor rods, or where load reversal/vibration might result in the progressive loosening of the nuts on the anchor rods. Refer to the AISC Steel Construction Manual, *Anchor Rod Nut Installation*; and/or equipment manufacturers' recommendations (i.e., whenever pretensioning is specified for anchors used for rotating or vibrating equipment), for more detail/guidance.

1. Most anchorage applications do not require pretension. In these instances, anchor rod nuts are merely tightened to a snug-tight condition. Snug-tight is defined as tightness attained by a few impacts of an impact wrench, or the full effort of an ironworker with an ordinary spud wrench.

2. When nuts are subject to possible loosening, and pretensioning is not possible/desirable, a locking method should be provided. Acceptable locking

methods include: double nuts or jam nuts, interrupted rod threads, and tack welds (complying with the welding requirements of AISC N690).

E. Use of post-installed anchors shall comply with the following:

1. Post-installed anchors should not be installed through liner plate[8]. Contact the Chapter POC and FDAR for guidance.

2. Post-installed anchor design shall provide for at least ± 1 inch fixture/baseplate and anchor relocation (within fixture/baseplate) to facilitate anchor installation (Requirement 5-3148). Providing for the latter might require over-sizing the fixture (to allow for field drilling of holes). Due consideration shall be given to the location tolerances of the anchors to avoid interferences with rebar.

3. Welding to post-installed anchors is not permitted (Requirement 5-3149).

4. Post-installed anchors shall not be used in masonry walls (Requirement 5-3150). Through-bolting may be an acceptable alternative.

5. A minimum of two (2) post-installed anchors shall be used at each connection (Requirement 5-3151)[9]. One (1) anchor may be used for connecting conduit clamps or for similar installations. *Note: equipment, glove boxes, etc. mounted on four-legged-type frames may have one anchor bolt per leg.*

6. Post-installed anchors shall not be located in the bottom of precast and pre/post-tensioned T-beams stems (Requirement 5-3152). Post-installed anchors into the sides of the T-beam stems shall be designed (prior to installation), and the design must be approved by the SEOR (Requirement 5-3153). And, in such designs, anchors shall not be located closer than 6 inches to pre-/post-tensioning steel (Requirement 5-3154).

A.11 Design Requirements

A. The design strength of cast-in-place and post-installed mechanical anchors shall be determined in accordance with ACI 349-13, Appendix D (Requirement 5-3155).

B. The nominal strength of KB-TZ anchors shall be reduced by a factor of 0.75. Accordingly, for the design of these anchors, modify ACI 349-13 Section D.4.1.1 as follows (Requirement 5-3156):

D.4.1.1 For the design of anchors

$0.75\varphi N_n \geq N_{ua}$ (D-1)

$0.75\varphi V_n \geq V_{ua}$ (D-2)

C. The design strength of bonded anchors and rebar shall be determined in accordance with ACI 349-23 Chapter 17 and the applicable ICC-ES ESR (Requirement 5-3157).

D. All new post-installed (PI) anchor designs shall be based on cracked concrete conditions unless it is analytically demonstrated and documented that the concrete will remain uncracked (i.e., tensile stresses in the concrete do not exceed its tensile strength) under service loads, including wind and seismic forces (Requirement 5-3158).

[8] Liner plate refers to a protective or containment layer, such as steel or lead liner plates used for radiation shielding, liners in tanks, sumps, or containment structures, and corrosion-resistant or waterproofing barriers.

[9] Per Section III.2.6.1 "Detailing Requirements" columns shall be anchored with a minimum of four (4) anchors. Thus, the use of only two (2) PI anchors does not apply to the installation of new structural steel columns.

E. Installation of cast-in or post-installed anchors in plastic hinge regions of beams, columns, walls, slabs or other structural elements is not permitted.

F. Modify ACI 349-13, Appendix D Sections D.4.2.1, D.5.2.6, D.5.3.5, and D.6.2.7, and add Section D.7.4, as follows (Requirement 5-3159):

D.4.2.1 The effect of reinforcement to restrain concrete breakout shall not be considered; therefore, Condition B of Section D.4.4 shall be used (Requirement 5-3160).

D.5.2.6 Use the following $\psi_{c,N}$[10] value: 1.0[11] (Requirement 5-3161).

D.5.3.5 Use the following $\psi_{c,P}$[10] value: 1.0[11] (Requirement 5-3162).

D.6.2.7 Use the following $\psi_{c,V}$[10] value: 1.0[11] (Requirement 5-3163).

D.7.4 In lieu of Sections D.7.1, D.7.2, and D.7.3, the shear-tension interaction expression given in Section RD.7 may be used with $\zeta = 5/3$.

[10] The factors $\psi_{c,N}$, $\psi_{c,P}$, and $\psi_{c,V}$ modify the tensile strength, pullout strength, and shear strength of anchors, respectively, based on the presence or absence of cracks in concrete. Refer to ACI 349 Sections D.5.2.6, D.5.3.6, and D.6.2.7 for additional requirements.

[11] Unless it is analytically demonstrated and documented that the concrete will remain uncracked in accordance with Section A.11.D above.

APPENDIX B: NOT USED

APPENDIX C: NOT USED

APPENDIX D: LIMIT STATE APPLICATION TO SSC EXAMPLES

Adapted for LANL from ANSI/ANS-2.26-2004 (R2010) Appendix B

The selection of a Limit State for structures, systems, and components (SSCs) will depend on SSC component type and the safety function it performs. This appendix provides guidance for selection of a Limit State through use of examples. The examples should not be interpreted as requirements. The selection of the Limit State should be based on the specific safety analysis and the safety function of the SSC. The limit state for an analysis of an existing SSC may be different than the limit state for the design of the same or similar SSC.

SSC Type	Limit State A	Limit State B	Limit State C	Limit State D
Generic	Refer to ESM Chapter 5 Section III body (or ANS 2.26 Section 5) for the definitions of the four Limit States addressed in this table.			
Building structural components	Substantial loss of SSC stiffness and some strength loss may occur, but some margin against collapse is retained so that egress is not impaired; building needs major repair and may not be safe for occupancy until repaired.	Some loss of SSC stiffness and strength may occur, but SSC retains substantial margin against collapse; building may need some repair for operations and occupancy to continue.	The SSC retains nearly full stiffness and retains full strength, and the passive component it is supporting will perform its normal and safety functions during and following an earthquake.	SSC damage is negligible; structure retains full strength and stiffness capacities; building is safe to occupy and retains normal function.
Structures or vessels for containing hazardous material	Applicable to vessels and tanks that contain material that is either not very hazardous or leakage is contained or confined by another SSC to a local area with no immediate impact to the worker. Recovery from a spill may be completed with little risk, but the vessel is not likely to be repairable. Most likely applicable to vessels containing low hazard solids or liquids.	Applicable to vessels and tanks whose contents if released slowly over time through small cracks will either be contained by another SSC or acceptably dispersed with no consequence to worker, public, or environment. Cleanup and repair may be completed expediently. Most likely applicable to moderate-hazard liquids or solids or low-hazard low-pressure gases.	Applicable to low-pressure vessels and tanks with contents sufficiently hazardous that release may potentially injure workers. Damage will be sufficiently minor to usually not require repair.	Content and location of item is such that even the smallest amount of leakage is sufficiently hazardous to workers or the public that leak-tightness must be assured. Most likely applicable to moderate and highly hazardous pressurized gases but may be required for high-hazard liquids. Post-earthquake recovery is assured.

SSC Type	Limit State A	Limit State B	Limit State C	Limit State D
Confinement barriers and systems containing hazardous material (e.g., glove boxes, building rooms, and ducts)	No SSC of this type should be designed to this Limit State.	Barriers could be designed to this Limit State if exhaust equipment is capable of maintaining negative pressures with many small cracks in barriers and is also designed to Limit State D for long-term loads. Safety-related electrical power instrumentation and control if required must also be assured including the loss of off-site power. Localized impact and impulse loads may be considered in this Limit State.	Barriers could be designed to this Limit State if exhaust equipment is capable of maintaining negative pressures with few small cracks in barriers and is also designed to Limit State D for long-term loads. Safety-related electrical power instrumentation and control if required must also be assured including the loss of off-site power. Adequate confinement without exhaust equipment may be demonstrable for some hazardous materials.	Systems with barriers designed to this Limit State may not require active exhaust depending on the contained hazardous inventory and the potential for development of positive pressure. Safety related electrical power, instrumentation, and control, if required, must also be assured including the loss of off-site power.
Equipment support structures, including support structures for pressure vessels and piping, fire suppression systems, cable trays, heating ventilation and air-conditioning ducts, battery racks, etc.	The SSC may undergo substantial loss of stiffness and some loss of strength, and yet the equipment it is supporting may perform its safety functions (normal function may be impaired) following exposure to specified seismic loads; the SSC retains some margin against such failures that may cause systems interactions.	The SSC may undergo some loss of stiffness and strength, and yet the equipment it is supporting may perform its safety functions (normal function may be impaired) following exposure to specified seismic loads; the SSC retains substantial margin against such failures that cause systems interactions.	The SSC retains nearly full stiffness and retains full strength, and the passive equipment it is supporting may perform its normal and safety functions during and following exposure to specified seismic loads.	No SSC of this type should be designed to this Limit State.

SSC Type	Limit State A	Limit State B	Limit State C	Limit State D
Mechanical or electrical SSCs	The SSC must maintain its structural integrity. It may undergo large permanent distortion and yet perform its safety functions; no assurance that the SSC will retain its normal function or will remain repairable.	The SSC must remain anchored, and if designed as a pressure-retaining SSC, it must maintain its leak-tightness and structural integrity. It may undergo moderate permanent distortion and yet perform its safety functions; there is some assurance that the SSC will retain its normal function and will remain repairable.	The SSC must remain anchored, and if designed as a pressure-retaining SSC, it must maintain its leak-tightness and structural integrity. It may undergo very limited permanent distortion and yet perform its normal functions (with little or no repair) and safety functions after exposure to its specified seismic loads.	The SSC remains essentially elastic and may perform its normal and safety functions during and after exposure to its specified seismic loads.
High-efficiency particulate absorber filter assemblies and housings	Assemblies designed to this level should have no nuclear or toxic hazard safety functions.	Assemblies designed to this level should have no nuclear or toxic hazard safety functions.	This Limit State may be expected to be applied to systems categorized as SDC-4 or lower.	N/A at LANL (this Limit State may be expected to be applied to systems classified as SDC-5 and possibly some in SDC-4).
Electrical raceways (cable trays, conduits, raceway channels)	The electrical raceways may undergo substantial distortion, displacement, and loss of stiffness, but the connections (e.g., at the penetrations or at the junction boxes) are very flexible or are such that the cables may still perform their function during and following exposure to specified seismic loads.	The electrical raceways may undergo some distortion, displacement, and loss of stiffness, but the connections (e.g., at the penetrations or at the junction boxes) have some flexibility or are such that the cables may still perform their function during and following exposure to specified seismic loads.	Cable connection (e.g., at the penetrations or at the junction boxes) are rigid or brittle or are such that the electrical raceways may undergo only very limited distortion, displacement, and loss of stiffness during exposure to specified seismic loads before the cable functions are impaired.	Cable connections (e.g., at the penetrations or at the junction boxes) are very rigid or brittle or are such that the electrical raceways may undergo essentially no distortion or loss of stiffness during exposure to specified seismic loads before the cable functions are impaired.
Deformation sensitive SSCs[46]	These types of SSCs should not be designed to this Limit State.	These types of SSCs should not be designed to this Limit State.	Functional evaluation is required when designing to this Limit State. Component testing may be required.	This type of SSC should typically be designed to this Limit State, and testing may be required.

[46] Deformation-sensitive SSCs are defined as those whose safety functions may be impaired if these SSCs undergo deformations within the elastic limit during an earthquake (e.g., a valve operator, a relay, etc.).

Appendix D, Limit State Application to SSC Examples

SSC Type	Limit State A	Limit State B	Limit State C	Limit State D
Anchors and anchor bolts for equipment and equipment support structures	To ensure that system interactions do not occur during an earthquake, no anchors or anchor bolts should be designed to this Limit State. [47]	The anchors or anchor bolts may undergo only moderate permanent distortion without impairing the safety function of the equipment (normal function may be impaired) following exposure to the specified seismic loads.	The anchors or anchor bolts may undergo very limited permanent distortion without impairing the normal and safety functions of the equipment following exposure to the specified seismic loads.	The anchors or anchor bolts need to remain essentially elastic so as not to impair the normal and safety functions of the equipment during and following exposure to the specified seismic loads.
Pressure vessels and piping[48]	Tanks, pressure vessels, and piping systems that do not contain or carry any hazardous fluid, have no safety functions, and whose gross leakage during and following an earthquake will not impact safety. Repair may require replacement of vessel and piping.	Tanks, pressure vessels, and piping systems that can perform their safety function even if they develop small leaks as a result of moderate permanent distortion caused by a design-basis earthquake. In situ repair of vessel may be possible. The safety function of the SSC may include confinement if the radiological release is within prescribed limits.	Tanks, pressure vessels, and piping systems that may have no significant spill and leakage during and following and earthquake. Includes vessels and piping systems that have confinement as a safety function.	Tanks, pressure vessels, and piping systems that are required to have very high confidence of no spills and leakage during and following an earthquake. Includes vessels and piping systems that have containment as a safety function.

[47] Anchor bolts designed to code allowables generally will exceed this Limit State because of conservatism inherent in the standard design procedures (e.g., factor of safety of 4 for expansion anchors). This assumes that appropriate over strength factors of the attached members are considered.
[48] Pressure vessels and piping systems designed to ASME Boiler and Pressure Vessel Code (B&PVC), Section III, Division 1, Service Level D are capable of providing containment function (i.e., Limit State D), even though the code permits stress levels beyond the yield stress. Thus, pressure vessels and piping systems that have confinement as a safety function are permitted to be designed to ASME B&PVC, Section III, Service Level D.

APPENDIX E: DESIGN BASIS EARTHQUAKE LOADS

A. The LANL design basis earthquake response spectra are defined in the free-field at the ground surface.

B. The Horizontal design basis earthquake (DBE) response spectra presented herein correspond to the 5% damped Horizontal Design Response Spectra (DRS) defined in ASCE 43 (2019[49]), Section 2.2, and include the effects of the Scale Factor (SF), as discussed in Sections 14.4.7, 16.1.7 and 17.1.7 of the 2025 LANL PSHA Update. The vertical DRS presented herein were developed by applying vertical-to-horizontal (V/H) ratios to the horizontal uniform hazard response spectra (UHRS). The development of the V/H ratios is discussed in Section 13.3 of the 2025 LANL PSHA Update.

1. The LANL Horizontal and Vertical DBE response spectra for PF-4, CMRR, CMR and WETF are specified in Tables III.E-1 through III.E-4, and Figures III.E-1 through III.E-4.

2. DRS values at intermediate frequencies shall be obtained by log-log interpolation (Requirement 5-3164).

3. DRS at locations other than those specified herein[50] shall comply with the requirements of ASCE 4 Section 2.5 (Requirement 5-3165).

4. Design Response Spectra-Compatible, horizontal and vertical ground, motion histories for PF-4, CMRR, CMR and WETF for SDC-2 and SDC-3 are provided in the 2025 LANL PSHA Ancillary Deliverables report. Their use is permitted upon written approval by the LANL Structural POC and LANL Seismic Program Manager.

C. Lateral soil pressure, H, on embedded structures resulting from earthquake ground shaking shall be calculated using ASCE 4 and shall be included in E (or E_s, or E_{ss}) (Requirement 5-3166). Subsection III.2.2.E, *Lateral Soil Pressure Loads (H)*, herein applies (Requirement 5-3167).

D. Site Limitation: Structures shall not be located within 50 feet of known active faults (Requirement 5-3168). Hazardous waste treatment, storage and disposal facilities must not be located within 200 feet of a fault that has had displacement within the last 11,000 years (Requirement 5-3169).

E. The potential for seismic-induced displacement hazards (i.e., fault rupture) must be assessed on a project-specific basis (Requirement 5-3170). The project-specific plan for addressing fault displacement hazards associated with new construction shall be submitted to the Chapter 5 Point of Contact, or designee, for review and approval prior to the start of design (Requirement 5-3171).

[49] Spectra is based on standards that predate the current ones.

[50] DRS shall be computed at the free surface and, in the case of embedded structures, at the depth of embedment of the structure being considered, as specified for SSI analysis in ASCE 4 Section 5.4.1. Determine DRS at various depths within the site profile in accordance with ASCE 43 Section 2.3, *Method to Define Design Response Spectra at Various Depths in the Site Profile*.

1. A minimum fault displacement of 2 cm (0.8 in.) at the surface shall be used for design (Requirement 5-3172).

F. *Cranes and Seismic Loads (Guidance): ESM Chapter 6 Section D10+E10 paragraph D1090 requires the use of both ASME NOG-1 and ASME NUM-1 for the design of ML-1 and ML-2 cranes, and both of these standards include seismic requirements. ASCE 43 Section 1.4 indicates CMAA has a standard(s) on the seismic design of cranes. At the time of writing, CMAA's Standards Director said the organization does not have standards, publications, or guidance on any aspect of "seismic and cranes." Although AISC Design Guide 7 pertains to industrial buildings, Section 13.6 therein could be of use more broadly; it discusses the contribution of the crane to the seismic mass of the building, interaction between the crane and building, design of cranes that must serviceable after the DBE, etc. Finally, CISC-ICCA's "Guide for the Design of Crane-Supporting Steel Structures" offers suggestions on how to account for interaction of the mass of the crane and the mass of the structure, and for the crane acting as a tie between the crane rails.*

Table III.E-1. PF-4 horizontal and vertical 5% Damped Surface DRS for SDC 2 and SDC 3 developed per ASCE/SEI 43-19[51]

Freq (Hz)	Horizontal DRS SDC-2 (g)	Horizontal DRS SDC-3 (g)	Vertical DRS SDC-2 (g)	Vertical DRS SDC-3 (g)
100	0.126	0.250	0.082	0.168
50	0.123	0.246	0.085	0.175
33.33	0.129	0.255	0.105	0.215
20	0.147	0.271	0.154	0.295
16.67	0.159	0.291	0.166	0.317
13.33	0.177	0.323	0.183	0.353
11.67	0.189	0.341	0.186	0.354
10	0.210	0.376	0.194	0.367
6.67	0.247	0.449	0.171	0.330
5	0.243	0.460	0.131	0.262
4	0.261	0.516	0.119	0.245
3.33	0.267	0.537	0.108	0.223
2.5	0.252	0.514	0.091	0.189
2	0.254	0.527	0.089	0.186
1.33	0.192	0.461	0.070	0.161
1	0.143	0.382	0.056	0.139
0.67	0.087	0.261	0.037	0.105
0.5	0.056	0.174	0.027	0.080
0.33	0.024	0.067	0.014	0.038
0.2	0.008	0.019	0.005	0.012
0.1	0.002	0.004	0.001	0.003

[51] Refer to Section 3 and Table 3.1-1 of P-22-016-01-PR-01-AR-01: *Augmented SSHAC Level 2 Seismic Hazard Update: Ancillary Deliverables*, for details on the development of the DRS presented in this table. For compliance requirements related to the development of DRS for other damping values, refer to ASCE 43-19 Section 2.2.

Table III.E-2. CMRR horizontal and vertical 5% Damped Surface DRS for SDC 2 and SDC 3 developed per ASCE/SEI 43-19[52]

Freq (Hz)	Horizontal DRS SDC-2 (g)	Horizontal DRS SDC-3 (g)	Vertical DRS SDC-2 (g)	Vertical DRS SDC-3 (g)
100	0.126	0.250	0.082	0.168
50	0.123	0.246	0.085	0.175
33.33	0.129	0.255	0.105	0.215
20	0.147	0.271	0.154	0.295
16.67	0.159	0.291	0.166	0.317
13.33	0.177	0.323	0.183	0.353
11.67	0.189	0.341	0.186	0.354
10	0.210	0.376	0.194	0.367
6.67	0.247	0.449	0.171	0.330
5	0.243	0.460	0.131	0.262
4	0.259	0.512	0.119	0.244
3.33	0.264	0.530	0.107	0.220
2.5	0.247	0.504	0.090	0.185
2	0.247	0.513	0.086	0.181
1.33	0.188	0.452	0.068	0.158
1	0.141	0.377	0.055	0.137
0.67	0.087	0.259	0.037	0.105
0.5	0.056	0.174	0.027	0.080
0.33	0.024	0.067	0.014	0.038
0.2	0.008	0.019	0.005	0.012
0.1	0.002	0.004	0.001	0.003

[52] Refer to Section 3 and Table 3.1-2 of P-22-016-01-PR-01-AR-01: *Augmented SSHAC Level 2 Seismic Hazard Update: Ancillary Deliverables*, for details on the development of the DRS presented in this table. For compliance requirements related to the development of DRS for other damping values, refer to ASCE 43-19 Section 2.2.

Table III.E-3. CMR horizontal and vertical 5% Damped Surface DRS for SDC 2 and SDC 3 developed per ASCE/SEI 43-19[53]

Freq (Hz)	Horizontal DRS SDC-2 (g)	Horizontal DRS SDC-3 (g)	Vertical DRS SDC-2 (g)	Vertical DRS SDC-3 (g)
100	0.126	0.270	0.079	0.183
50	0.124	0.266	0.083	0.192
33.33	0.134	0.273	0.106	0.234
20	0.151	0.293	0.148	0.314
16.67	0.165	0.315	0.160	0.334
13.33	0.190	0.360	0.181	0.377
11.67	0.206	0.391	0.186	0.389
10	0.227	0.436	0.192	0.406
6.67	0.280	0.562	0.179	0.396
5	0.313	0.652	0.157	0.358
4	0.319	0.721	0.137	0.331
3.33	0.298	0.729	0.114	0.294
2.5	0.269	0.734	0.095	0.268
2	0.220	0.649	0.076	0.229
1.33	0.152	0.481	0.055	0.177
1	0.118	0.378	0.045	0.147
0.67	0.071	0.232	0.030	0.100
0.5	0.043	0.148	0.021	0.072
0.33	0.020	0.065	0.012	0.038
0.2	0.007	0.019	0.005	0.013
0.1	0.002	0.004	0.001	0.003

[53] Refer to Section 3 and Table 3.1-3 of P-22-016-01-PR-01-AR-01: *Augmented SSHAC Level 2 Seismic Hazard Update: Ancillary Deliverables*, for details on the development of the DRS presented in this table. For compliance requirements related to the development of DRS for other damping values, refer to ASCE 43-19 Section 2.2.

Table III.E-4. WETF horizontal and vertical 5% Damped Surface DRS for SDC 2 and SDC 3 developed per ASCE/SEI 43-19[54]

Freq (Hz)	Horizontal DRS SDC-2 (g)	Horizontal DRS SDC-3 (g)	Vertical DRS SDC-2 (g)	Vertical DRS SDC-3 (g)
100	0.120	0.255	0.076	0.175
50	0.119	0.253	0.080	0.183
33.33	0.129	0.260	0.101	0.223
20	0.147	0.278	0.143	0.296
16.67	0.161	0.298	0.155	0.315
13.33	0.187	0.342	0.177	0.358
11.67	0.201	0.366	0.181	0.364
10	0.214	0.393	0.180	0.367
6.67	0.253	0.497	0.160	0.350
5	0.307	0.612	0.153	0.337
4	0.313	0.677	0.134	0.312
3.33	0.293	0.706	0.113	0.285
2.5	0.244	0.666	0.088	0.244
2	0.199	0.596	0.070	0.212
1.33	0.133	0.440	0.049	0.163
1	0.099	0.322	0.039	0.128
0.67	0.070	0.233	0.031	0.103
0.5	0.043	0.148	0.021	0.073
0.33	0.023	0.076	0.014	0.044
0.2	0.007	0.023	0.005	0.015
0.1	0.002	0.005	0.001	0.003

[54] Refer to Section 3 and Table 3.1-4 of P-22-016-01-PR-01-AR-01: *Augmented SSHAC Level 2 Seismic Hazard Update: Ancillary Deliverables*, for details on the development of the DRS presented in this table. For compliance requirements related to the development of DRS for other damping values, refer to ASCE 43-19 Section 2.2.

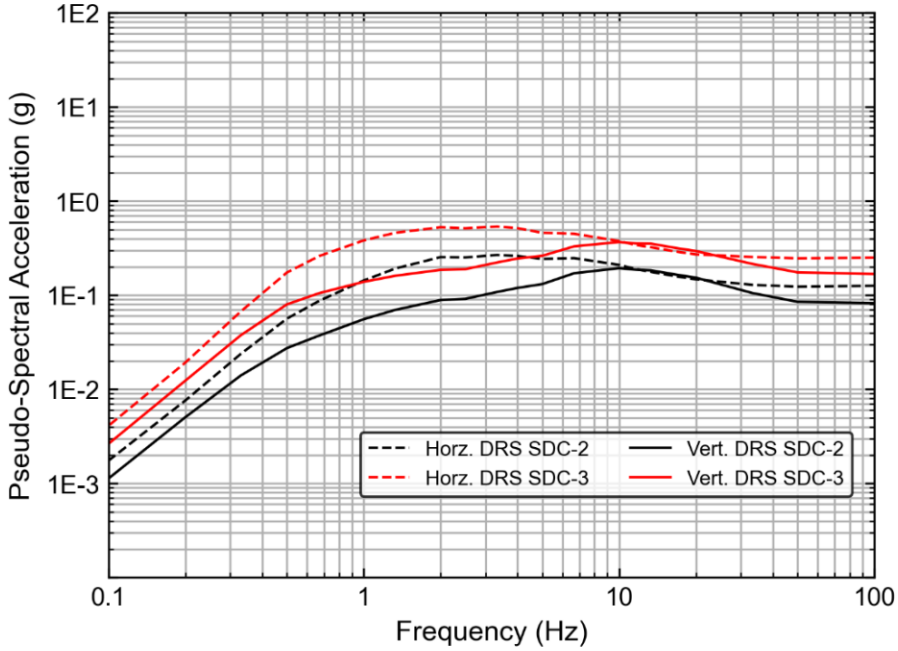

Figure III.E-1. PF-4 horizontal and vertical 5% Damped Surface DRS for SDC 2 and SDC 3 developed per ASCE/SEI 43-19

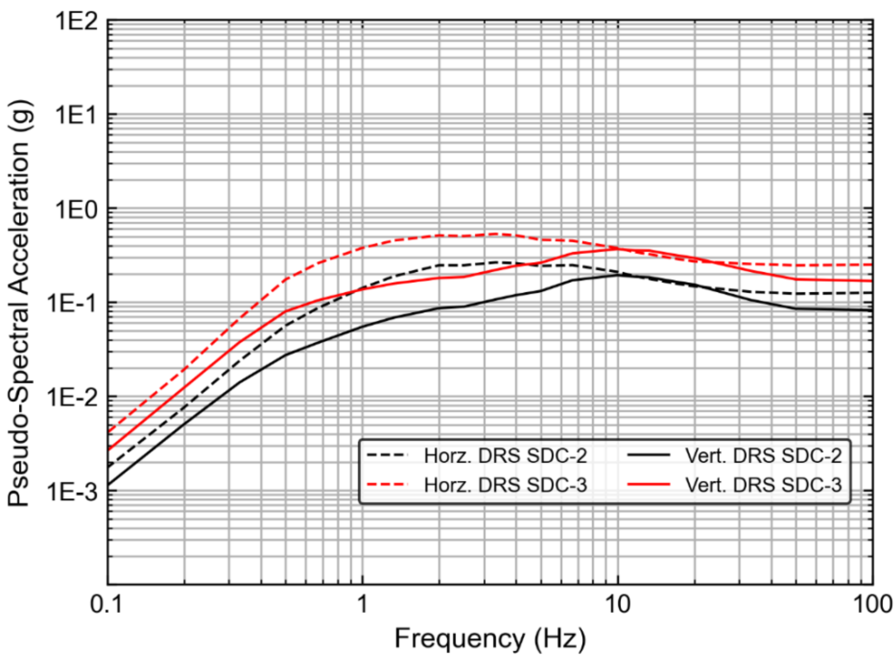

Figure III.E-2. CMRR horizontal and vertical 5% Damped Surface DRS for SDC 2 and SDC 3 developed per ASCE/SEI 43-19

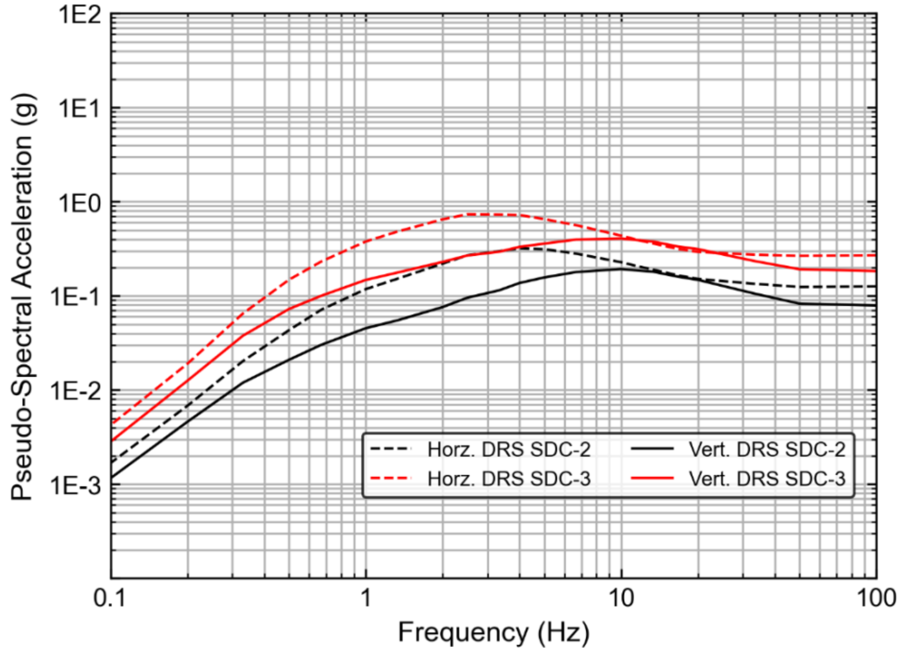

Figure III.E-3. CMR horizontal and vertical 5% Damped Surface DRS for SDC 2 and SDC 3 developed per ASCE/SEI 43-19

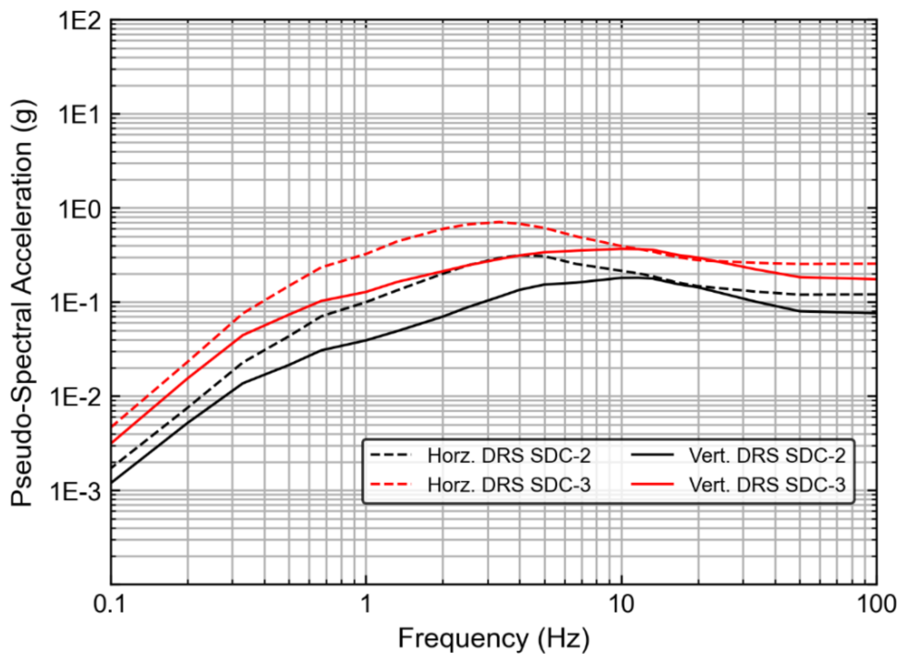

Figure III.E-4. WETF horizontal and vertical 5% Damped Surface DRS for SDC 2 and SDC 3 developed per ASCE/SEI 43-19

APPENDIX F: DOE-STD-1020 AMENDMENTS FOR ASCE 4 AND ASCE 43

As noted early in this document, LANL amends all DOE-STD-1020 ASCE 4 and ASCE 43 edition references from 1998 to 2016 and 2005 to 2019, respectively (Requirement 5-3173). In doing so, a number of minor wording changes to DOE-STD-1020 treatment of ASCE 4 and ASCE 43 are also necessary; these are reflected in the amended DOE-STD-1020 Sections below.

1. Replace "4-98" with "4-16," and "43-05" with "43-19," with the following result:

   3.1.2 SDC-3, SDC-4, and SDC-5 SSCs shall be designed according to the criteria of ASCE/SEI 43-19…and ASCE 4-16 ~~4-98~~…in this Standard.

2. Replace "43-05" with "43-19" with the following result:

   Table 3-1 Note 2 The IBC invokes…as defined in…ASCE/SEI 43-19 …ASCE/SEI 7-10).

3. Replace "43-05" with "43-19," and revise associated verbiage, with the following result:

   3.2.1 For SDC-3 through SDC-5 SSCs, appropriate Target Performance Goals given in ASCE/SEI 43-19 (Table 1-1), and scale factors given in ASCE/SEI 43-19 (Chapter 2 ~~1-2~~), shall be used to determine the DBE response spectrum/acceleration time series applicable for the facility site.

4. Replace "43-05" with "43-19," and revise associated verbiage, with the following result:

   3.3.1 Site characterization…qualifications:

   • Table 1 of ANSI/ANS-2.27-2008 states…characterized.

   • Column 2 of Table 1 of ANSI/ANS-2.27-2008 is labeled "Maximum Considered Earthquake Spectral Response Acceleration." It provides a range of spectral response accelerations for low, moderate and high seismic environments. For DOE purposes, and for consistency with terminology in ASCE/SEI 43-19, this column heading means "Spectral response acceleration at H_D = 1 E-4 annual frequency of exceedance."

5. Replace "4-98" with "4-16," and strike the associated unnecessary verbiage, with the following result:

   3.5.1 For SDC-3 through SDC-5 SSCs, soil-structure interaction analyses may rely on the applicable provisions of ASCE 4-16. The DOE/EM Memo...analysis.

6. Replace "4-98" with "4-16," and "43-05" with "43-19," and strike the associated unnecessary verbiage, with the following result:

   3.5.2 For new facilities, the method of determining design basis seismic ground motion shall satisfy the requirements of Section 2 of ASCE/SEI 43-19 and Section 2 of ASCE 4-16.

7. Replace "4-98" with "4-16," and strike the associated unnecessary verbiage, with the following result:

   3.5.3 The requirements in ASCE 4-16 ~~4-98~~ shall be met in performing dynamic response analyses and generating in-structure response spectra.

8. Replace "43-05" with "43-19" with the following result:

   3.6.4 Seismic qualification of equipment may be performed by testing and/or by using actual earthquake experience or generic shake table test data, subject to the criteria and limitations given in ASCE/SEI 43-19 ~~43-05~~, ASME QME-1…*Energy Facilities*.

APPENDIX G: RESTRAINT OF NON-FACILITY (E.G., PROGRAMMATIC) EQUIPMENT

Restraint (i.e., anchorage and/or bracing) of non-facility (e.g., programmatic, utilities) equipment is required in either of the following two circumstances (Requirement 5-3174)**:**

1. When required by the **manufacturer** for normal operations.[55]
   a. If this is the sole reason restraint is required (i.e., seismic restraint per criterion 2 below not required), then the design need not be per ESM Ch. 5 if the manufacturer provides alternative design requirements (Requirement 5-3175).
2. **In a nuclear facility**, restraint is always required (Requirement 5-3176). The design must be per Section III, the installation and quality control per the appropriate LANL Master Spec Sections, and the QA per ESM Ch.16 (as a minimum) (Requirement 5-3177). There are two exceptions:
   a. **SDC-1 and SDC-2 SSCs.** Subject to the provisions in Sect. III, NDC-1 AND NDC-2 SSCs, Seismic, seismically-exempt equipment (ref. Section II, 1613.5 Amendments to ASCE 7, Add 1613.5.4 Nonstructural Components Exempt from Seismic Design) need not be restrained provided that adverse interactions won't result.***** Non-seismically-exempt equipment might not require restraint provided that adverse interactions won't result*** and** if an alternative method is accepted by the LANL Building Official wherein:
      1) An analysis that indicates the interaction effects of the unrestrained equipment[56] is acceptable at the DBE, or
      2) The equipment will be located in an essentially unoccupied[57] area and is protected as such through administrative or engineering control.

      ***** If equipment is to be unrestrained, adverse interaction with safety SSCs (i.e., Safety Class, Safety Significant, Defense in Depth, or Other Hazard Control[58]) must be considered, documented as part of the design, and, if necessary, prevented (Requirement 5-3178). It is expected that determining the significance of potential interaction effects will require interaction between a structural subject matter expert (SME) and a safety basis SME. For more detail on interactions, refer to Sect. III (*Common-Cause Failure and System Interaction; and App. A, Prerequisites for Determining Anchor Design Loads, System Interaction).*
   b. **SDC-3 SSCs.** If the equipment is to be installed on a floor structure and the provisions of ASCE/SEI 43 Section 7.1, *Rocking and Sliding of Unanchored Rigid Bodies* are met to the satisfaction of the LBO, then seismic restraint is not required.

NOTE for Equipment Outside: Both of the above criteria also apply outside of a building; if the above require an item to be restrained for wind and/or seismic were it inside, then restraint must either be provided or shown/proven unwarranted (Requirement 5-3179). Ref ASCE-7-10 Section 15.1.1, *Nonbuilding Structures*, and Ch. 29, *Wind Loads on Other Structures and Building Appurtenances*.

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[55] Reasons related to performance, functionality, operability, etc. (e.g., motor, centrifuge, certain suspended items/systems, etc.).
[56] E.g., unrestrained from rocking, swaying, overturning, sliding, impact, etc. Also: In all cases, equipment must be anchored if it is permanently attached to utility services (electricity, gas, and water). (ASCE 7 C13.1.1).
[57] I.e., incidental occupancy: occupied for a total of less than 2 hours/day, yearly average (RP 8 exemption 1.3.d utilized herein). Not the same as incidental use (IBC sec. 509 term relating to certain adjunct uses).
[58] Formerly "Other Equipment Important to Safety."

APPENDIX H: NOT USED