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New in this revision (older revisions addressed in Section 5.0 Record of Revisions)

Adopted 2021 IBC. Clarified return periods in Table I - 2 notes. Design Basis Document (DBD) eliminated for non-nuclear SSCs, and corresponding requirements moved to Section III. Minor and administrative changes including updated references and definitions.

Please contact the Structural Standards POC for interpretation, variance, and upkeep issues.

SECTION I - GENERAL CRITERIA FOR ALL LANL STRUCTURES

1.0 USE OF THIS CHAPTER

1.1 Purpose

NOTE: Refer to definitions near the end of this document for acronyms and other terms (e.g., Major Modification) used throughout this Chapter.

A. This Chapter of the Los Alamos National Laboratory (LANL) Engineering Standards Manual (ESM) presents structural design criteria that are unique to LANL. The criteria presented herein are in addition to nationally accepted design criteria for structures. In general, the more restrictive provisions of the International Building Code (IBC, version and amendments per ESM Ch 16, IBC Program) and the New Mexico Commercial Building Code (NMAC 14.7.2) shall be the code of record for the design of structures, systems, and components (SSCs) at LANL (see ESM Ch. 1 Section Z10 for details).

B. The edition of the code of record shall be established in project documents for capital projects, or shall be clearly documented in project records for other projects (e.g., minor modifications, etc.) (Requirement 5-1001). In addition, these criteria implement the Natural Phenomena Hazards (NPH) mitigation requirements in Department of Energy (DOE) Order 420.1C, *Facility Safety*, that are applicable to all DOE nuclear and non-nuclear facilities.[1]

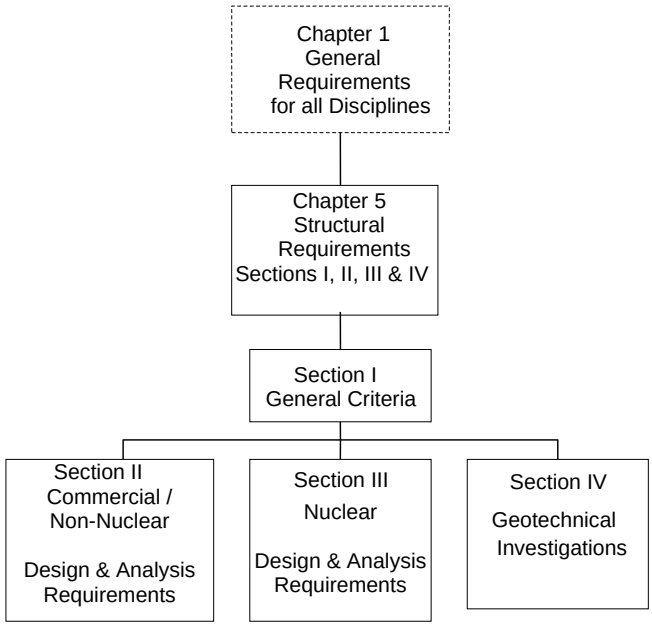
C. This Chapter presents the requirements of the DOE Orders and implementing standards specific to LANL to assist the engineer who may not be familiar with DOE requirements contained in various DOE Orders, Standards, and guidance documents. This Chapter is not intended to replace the DOE requirements; the structural engineer of record (SEOR) is still responsible for compliance with these parent standards. The design organization is responsible for providing the complete design package including drawings, specifications, a design basis document, and other documentation as described in this Chapter. Goals for design basis documentation include:

- Achieve uniformity in documentation for LANL structure designs.
- Provide assurance that LANL-specific loads are addressed.

1.2 Chapter Contents and Conventions

A. *This Chapter consists of four sections. Sections I, II, and III provide the structural design/analysis criteria for SSCs at LANL. Section I provides general guidance, criteria, and background on structural design, quality assurance, and design documentation. Sections II and III provide prescriptive criteria to be used in the actual structural design. The design/analysis of non-nuclear SSCs is addressed in Section II. The design/analysis of Nuclear SSCs (NDC-1–NDC-3[2]) and of facilities with chemical or toxicological hazards exceeding those permitted in non-nuclear facilities is addressed in Section III. Note that some aspects of the design/analysis of NDC-1 and NDC-2 SSCs in Section III are accomplished using the requirements in Section II. Section IV provides geotechnical requirements.*

[1] Section I.3.0 herein provides the definitions of "nuclear" and "non-nuclear" facilities that are applicable throughout this Chapter.
[2] Use of NPH Design Categories NDC-4 and NDC-5 is not expected at LANL; therefore, they're not addressed in this Chapter.



B. Text in regular type indicates mandatory requirements unless prefaced with wording identifying it as guidance or a recommendation. *Italicized* text generally identifies recommended guidance (not mandatory).

C. *Guidance: This Chapter also implements the DOE and LANL policy of a graded approach applied to structural design. Per LANL risk-grading requirements (AP-341-502[3]), facility work is subjected to a level of management control commensurate with the importance of the work to safety, environmental compliance, safeguards and security, programmatic importance, magnitude of hazard, and financial impact.*

At LANL, the graded approach is implemented by Management Levels (ML). The greatest level of management control and rigor is exercised for ML-1 with the least level for ML-4. From a structural design standpoint with respect to safety, ML-1 structures, systems, and components (SSCs) are normally those designated as Safety Class (SC) for Hazard Category (HC) 2 and 3 nuclear facilities or serve to provide protection to the public for non-nuclear facilities. ML-2 SSCs are those designated as Safety Significant (SS) for HC 2 and 3 nuclear facilities or provide worker protection or significant protection against the uncontrolled release of hazardous materials from non-nuclear facilities. ML-3 SSCs are important to safety or other matters but their failure would have only minimal off-site impact. ML-4 SSCs failure is analogous to commonly accepted commercial/industrial risk.

DOE facility design requirements to protect the public, workers, and the environment from the impact of natural phenomena hazards (NPH), which are contained in DOE O 420.1C and DOE-STD-1020-2016, result in the use of the following graded approach:

- *Non-nuclear SSCs are designed for NPH through the assignment of Risk Categories (RCs) as defined in the IBC.*
- *Nuclear SSCs are designed for NPH through the assignment of NPH Design Categories (NDCs) as defined in DOE-STD-1020-2016.*

[3] LANL AP-341-502, Management Level Determination

These Risk Categories and NDCs are discussed in the following section, and they are used in this Chapter for assigning the appropriate structural design requirements. LANL ML designations and requirements must also be included for structure design projects.

NOTE: In the case of seismic hazards, the DOE-STD-1020-2016-based NDC of SSCs is called Seismic Design Category (SDC; SDCs 1 – 5), which is not to be confused with the IBC's Seismic Design Category (SDC; SDCs A – F).

1.3 DOE Natural Phenomena Hazard Mitigation Requirements

A. *Guidance: NPH mitigation objectives defined in Chapter IV of DOE O 420.1C are to ensure that DOE facilities are designed, constructed, and operated so that the general public, workers, and the environment are protected from the impact of NPH. The provisions in the Order apply to DOE sites and facilities and cover all NPH such as seismic, wind, flood, lightning, snow, and volcanic eruption. Where no specific requirements are provided, model building codes or national consensus industry standards shall be used*.

B. SSCs shall be designed, constructed, and operated to withstand the effects of NPH as necessary to ensure the confinement of hazardous material, the operation of essential facilities, the protection of government property, and the protection of life safety for occupants of DOE buildings (Requirement 5-1002). The design and construction of facilities and safety-SSCs shall consider potential damage and failure of SSCs due to both direct and indirect natural phenomena effects, including common cause effects and interactions resulting from failures of other SSCs (Requirement 5-1003).

C. New SSCs, and additions or Major Modifications (a defined term, see Section I.3 "Definitions" herein) to existing SSCs, shall be designed, constructed, and operated to meet the requirements in the previous Subsection (I.1.3.B) (Requirement 5-1004). Any addition or modifications to existing SSCs shall not degrade their performance to the extent that the objectives in this Section cannot be achieved under the effects of natural phenomena (Requirement 5-1005).

1. Regarding existing SSCs, comply with the following:

   a. Prior to performing work in/on non-nuclear facilities, or on SSCs in nuclear facilities, follow NIST GCR 11-917-12/ICSSC RP 8 (or DOE-mandated successor) to determine whether a seismic evaluation is necessary (Requirement 5-1006).

      - If evaluation is necessary, use ICSSC RP 8 to establish the associated requirements, as well as mitigation requirements (if the evaluation indicates such is required).

   b. Nuclear: "Major Modifications" to a nuclear facility's NDC-3 SSCs shall be designed to the same requirements that apply to new nuclear facilities and NDC-3 SSCs, except as permitted in DOE-STD-1020-2016 Section 9.1.1. (Requirement 5-1007).

   c. Nuclear: Work consisting of less than a major modification to a nuclear facility with NDC-3 SSCs shall comply with the same requirements that apply to new nuclear facilities and NDC-3 SSCs, or with those recommended by the Chapter POC (Requirement 5-1008).

      - For new work in/on an existing nuclear facility that is less than the threshold for Major Modification, the decision to follow code of

record criteria, this Section's criteria, or something in-between, shall be based on a graded approach, defined in the LEBC, to the greatest extent possible, except that: (i) in ESM Ch. 16, Section IBC-GEN – *General Building Program Requirements*, Attachment B – *LANL Existing Building/System Code (LEBC)*, references to the IBC structural provisions shall be taken to mean ESM Chapter 5 Section III, and (ii) LEBC provisions for following code of record for minor work are only allowed with approval of the LANL Building Official in consultation with the POC for ESM Chapter 5 (i.e., "automatically approved" within LEBC's "Overall LANL Policy on IEBC Provisions for Code of Record" is not applicable to HC 1–3 nuclear SSCs)

d. Non-nuclear: While, in general, the LANL Existing Building Code (LEBC) requires new work in/on existing facilities to be done to the current LANL Building Code, there are instances when this is not required. For details, refer to ESM Ch. 16 LEBC Section 301.3 *Alteration, addition or change of occupancy — (exception on code of record);* "Overall LANL Policy on IEBC Provisions for Code of Record" heading therein; and 304.3 on seismic evaluation and design.

2. Crosswalk Tables I-1 and I-2 below facilitate the use of this Section in particular, as well as this Chapter in general, and its NPH categorizations (i.e., RCs and NDCs) for work in/on existing facilities that were designed using former NPH categorizations (i.e., Performance Categories, or PCs).

Guidance: The crosswalk tables provide a direct or conservative mapping so that existing facilities undergoing minor modification may utilize this chapter and also other not-yet-updated Conduct of Engineering documents without first completing new NPH category determinations. In some instances, such facilities may be able to reduce conservativism by both confirming SSCs ML determinations and updating NPH determinations to achieve the most appropriate SDC and limit state (LS).

D. The graded approach is implemented by assigning RCs to non-nuclear SSCs and NDCs to nuclear SSCs based on facility characteristics and uses and defining several sets of NPH design/evaluation provisions with increasing conservatism (i.e., producing a decrease in probability of damage or failure to perform the intended safety function).

1. For non-nuclear SSCs, four Risk Categories (RC I – RC IV) are defined in IBC Table 1604.5.

2. For nuclear SSCs, five NDCs (NDC-1 – NDC-5) are defined in DOE-STD-1020-2016; of these, LANL only uses NDC 1–3.[4] NDC-1 and NDC-2 NPH requirements are similar to those of Risk Categories II and IV in the IBC, while NDC-3 applies to LANL's highest risk facilities.

E. *Guidance: Specific design criteria for DOE facilities for each RC/NDC are provided in DOE-STD-1020-2016. These criteria are adopted for design of LANL facilities in this Chapter*.

[4] DOE considers design beyond NDC-3 unlikely (higher-than-NDC-3 NPH requirements approach those for commercial nuclear power plants)

1.4 Crosswalks from PC Categorization to the Current NPH Nomenclature

Table I - 1 Non-Nuclear Facility Designations

Formerly	Now
PC-0	RC I
PC-1	RC II
PC-2	RC IV

NOTES:
1. Basis: Comparison of DOE-STD-1020 historical (2002) definitions to IBC-2021 Table 1604.5 categories.
2. Although Risk Category III exists, there is no PC corollary for it.

Table I - 2 Nuclear SSC Designations (Haz Cat 1–3)

Formerly	Now	
	Seismic NPH[1.a]	Other NPH[1.b]
PC-1	SDC-1, LS A	WDC-1, PDC-1
PC-2	SDC-2, LS B	WDC-2, PDC-2
PC-3	SDC-3, LS C	WDC-3, PDC-3

NOTES:
1. Basis:
   a. Seismic NPH: DOE-STD-1020-2016 Table 3-1; and DOE-HDBK-1220-2017, Appendix A; and DOE-STD-1020-2002 and ASCE 43.
   b. Other NPH design criteria: DOE-STD-1020-2016, Sections 4.1.2 (wind/WDC), 5.5.1 (flood/FDC) and 7.5.4 (precipitation/PDC); and Tables 4-1, 5-3[5] and 7-2.[6]
      i. FDC-1 and FDC-2 only applies to SSCs in/on FDC-1 or FDC-2 facilities; see Ch. 5 Sect. III, NPH Design Category (NDC) -1 and -2 SSCs for more detail.
      ii. On paper, PC-3 ≠ WDC-3, FDC-3, or PDC-3 due to the difference in return period (RP) for design-basis events: 1,000 to 10,000 years for PC-3, and 2,500 to 10,000 years for WDC-3, FDC-3, or PDC-3. However, use of PC-3 **=** WDC-3 and PDC-3 for crosswalk is appropriate since the longer return period associated with these design loads is considered (in ESM Ch. 5 Sect. III). Regarding FDC-3, this load is presently undefined at LANL; thus, for SSCs in low-lying areas, contact POC for ESM Ch. 5 for guidance.
2. Volcanic hazard (i.e., VDC) is presently undefined at LANL; see Section III discussion.
3. LS = Limit State (i.e., limiting acceptable condition of the SSC after the seismic event; refer to Sect. III for details).

1.5 Applicability

A. The requirements of this Chapter shall be applied to the design of new facilities and programmatic SSCs (Requirement 5-1009). Additionally, this Chapter applies to renovation, replacement, modification, maintenance, or rehabilitation projects. Applicability of the provisions of this Chapter is illustrated in Table I - 3.

[5] Table 5-3: Applicable to SSCs not vulnerable to submersion in a design basis flood. If SSC is vulnerable to submersion, refer to DOE-STD-1020-2016 Table 5-2, in which the return periods exceed those of Table 5-3.
[6] Applicable to evaluation of SSCs for the effects of loads resulting from precipitation. Table 7-1 is applicable to evaluating the flooding caused by runoff of the site precipitation.

Table I - 3 Applicability of ESM Chapter 5 to Structural Design

Circumstance	Is Chapter 5 Applicable?
New structures, including replacement of existing facilities, and new SSCs that are Risk Category I (e.g., sheds, sidewalks)	Yes
New non-structural systems & components in new and existing structures, including programmatic equipment	Yes, primarily for anchorage and support design[7]
New anchorage or support for existing systems and components	Yes, for anchorage or bracing only
Renovations, modifications, repairs, alterations, or rehabilitation to existing structural systems and sub-systems	Yes[8]
Existing facility safety basis change	Yes, existing and new SSC shall be evaluated against these criteria
Existing structures analysis/evaluation	Yes

B. The criteria in this Chapter are intended to be used in the design of SSCs by licensed professional engineers (requirements in ESM Chapter 1 Section Z10). Each SSC shall be assigned an RC or NDC (approved by LANL) prior to performance of structural design (Requirement 5-1010). Note that prior to or during the structural design, some SSCs may be reassigned to a higher category due to consequential damage/system interaction effects as discussed in ASCE 7 Chapter 13 and DOE-STD-1020-2016 *Section 2.3.2(b)*. An SSC reassigned to a higher category must be checked against the corresponding higher NPH loads. The appropriate category is a function of the safety or mission importance of the SSC. Criteria presented in this chapter are for:

- RC I–RC IV and NDC-1–NDC-3 SSCs (and structural support and anchorage of the same)

C. This Chapter is not intended for the design of non-structural systems and components. Refer to other chapters of the ESM for criteria that govern the design of electrical and mechanical components. The design requirements for the systems and components such as distribution systems or equipment (other than the support and anchorage) are presented in Chapter 2 (Fire Protection), Chapter 6 (Mechanical), Chapter 7 (Electrical), and others as appropriate. This Chapter does address the structural and seismic analysis/design aspects of fire protection, architectural, mechanical, and electrical equipment, and distribution systems.

[7] This chapter covers the design of supports and anchorage of nonstructural systems and components. This includes complete requirements for the seismic design of those supports and anchorage. In addition, the chapter does provide *some* information and requirements for the seismic design of the systems and components themselves.

[8] Design work on existing non-nuclear SSCs shall be per the International Existing Building Code (IEBC) as amended by LANL; see also LANL ESM Chapter 16, IBC Program (IBC-GEN Attachment B, LANL Existing Building/System Code – LEBC)*. Design work on existing nuclear SSCs follows Section I.1.3.C.

* NOTE: LEBC is based on IEBC. Like ICSSC RP 8 (refer to Section I.1.3.C.1.a), the IEBC includes seismic-evaluation requirements; however, they are based on different criteria. For instance, the ICSSC RP 8 triggers for requiring a seismic evaluation is based on changes to the structure that will increase its life or value (e.g., extensive renovation) or that will increase the risk level of the structure (e.g., a change in occupancy), while IEBC triggers for a seismic evaluation are based on seismic demand increases and/or modifications of to the existing lateral force resisting system. Thus, to ensure that the requirements of both documents are met, at a minimum, the triggers in both documents shall be checked.

D. This chapter presents structural design criteria to be used in the design of structures and component supports against the effects of gravity loads, normal operating loads, NPH loads, and blast loads. The provisions in this chapter for blast are focused on structural design for blast loads. Blast loading criteria will be provided by LANL. These blast loads may result from either planned experiments (as would be the case in/for an experimental facility), or accidents (involving explosives, flammable materials, etc.). Regarding experiments involving explosions, some of them involve a containment structure (to limit explosion effects on the surrounding area); the design of such structures is not within the scope of this chapter.

E. The chapter invokes the minimum antiterrorism requirements as specified by the Department of the Defense (DOD) UFC 4-010-01 (Requirement 5-1011). The applicability of these requirements to a given project will be explicitly stipulated by LANL in the Requirements and Criteria Document (or other LANL-issued document) for the project.[9] *Minimum antiterrorism requirements should be considered for all facilities to the extent it is not cost prohibitive, but particular attention should be paid to antiterrorism requirements for those highly visible facilities and nuclear facilities.*

1.6 Project Records for Structural Design

A. Project Requirements for Structural Designs

1. This Chapter along with applicable building codes, DOE Orders and Standards, and applicable material standards and design manuals provide the basic project requirements for structural design projects. In addition, there are generally project specific design requirements provided by LANL. Project specific requirements may be in the following form:
    - Design bid package including the Request for Proposal (RFP)
    - Project functional requirements.
    - Facility safety analysis reports.
    - Project design criteria
2. All these project requirements shall be referenced, where applicable, in the Project Record Documents (Requirement 5-1012).

B. Project Record Documents

1. Project record documents for structural design shall be prepared considering the concept of a graded approach (Requirement 5-1013). The greatest level of detail and rigor is required in the design and documentation for SSC that are in ML-1 or ML-2 projects or are in systems designated as NDC-3. Lesser level of detail is acceptable for SSCs in ML-3 or ML-4 projects, or in systems designated as RC I – RC IV and NDC-1 or NDC-2. Extensive documentation is generally required for the structural design of new buildings.
2. Since the design of buildings classified as NDC-3 requires an extensive amount of documentation prepared with a high level of detail and rigor, it will typically be performed under scrutiny by LANL and DOE reviewers. On the other hand, there are many LANL structural-design projects that will be relatively simple efforts involving modifications to portions of buildings or installation of new equipment or systems in existing buildings. For these types of projects, it may be possible to

[9] LANL Physical Security (PS) Division will specify (to the LANL Project Manager) whether Project warrants anti-terrorism measures.

adequately document the structural design by drawings with notes along with structural calculations. For all structural design projects, large or small, complex/important or simple, all of the information described in this section must be documented in some manner.

3. The project record documents for structural design to be submitted to LANL shall consist of the following:
    - Design Basis Document (required only for Nuclear SSCs) (Requirement 5-1014)
    - Structural calculations (Requirement 5-1015)
    - Statement of Special Inspections (SSI) (Requirement 5-1016)
    - Structural Design Quality Plan (when required by 1.6.F herein), and Structural Peer Review Plan (when required by 1.6.F herein) (Requirement 5-1017)
    - Specifications (Requirement 5-1018)
    - Construction Drawings (Requirement 5-1019)
4. The review of project record documents is conducted by the LANL ESM Chapter 5 Point of Contact (POC), or their designee, for review and approval.
5. The following subsections provide details on each of the project record documents listed above and, in some instances, the circumstances in which the submission of such records is not required.

C. **Design Basis Document (DBD)**

The Design Basis Document is only required for nuclear SSCs. Refer to Section III.5 for DBD guidelines and requirements.

D. **Structural Calculations**

1. Calculations shall be performed, numbered, and approved in a consistent format and shall include, at a minimum, sections for

- Purpose;
- SSC Background and Mission (including Management Level for the Project and Facility Hazard Categorization and Basis[10]);
- Methodology (including, as applicable, the rationale for (a) selection of the gravity and lateral load-resisting systems, (b) seismic design requirements for nonstructural components and non-building structures, (c) designated seismic systems (DSS) design basis and functionality requirements, (d) calculation of structural demands, and (e) assignment of SSC to NPH risk/design categories);
- Acceptance Criteria (including Design Codes and Standards of Record along with their Edition and Revision Date);
- Unverified Assumptions;
- Assumptions;
- Limitations;
- Calculation Inputs (including material properties; design loads; and geotechnical parameters and recommendations, if applicable);
- Computer Hardware and Software;
- Summary and Conclusions;
- References; and

[10] ML per LANL AP-341-502; HC per LANL SBP111-1

- Calculations (including Member Demand and Capacity Equations/ Calculations, Serviceability and Constructability Design Considerations, and Detailing Requirements, if applicable) (Requirement 5-1020).

a. *Guidance: One acceptable procedure for performing calculations for LANL is detailed in AP-341-605,* Calculations*.*

b. Calculations shall be signed by a Preparer, a Checker or Verifier (that attests to their numerical accuracy), and an Approver (that attests to reasonableness of the theory and assumptions and to the validity of the conclusions reached) (Requirement 5-1021).

c. The Checker and approver may be the same individual but may not be the Preparer (Requirement 5-1022).

d. Calculations shall be performed following a LANL-approved Project Structural Design Quality Plan (SDQP), for details refer to Section I.1.6.F "Project Quality Assurance", and Figure I-2 (Requirement 5-1023).

e. The requirements of the SDQP may be tiered for the various NPH risk/design categories using the graded approach philosophy.

2. Computer analysis:

a. When computer analysis is performed, input and output shall be numbered in a consistent format (which shall be described in the Project SDQP) (Requirement 5-1024).

b. Software shall conform to the requirements in DOE-STD-1020-2016 Section 10.2 (i.e., *Software Quality Assurance*) and LANL requirements (e.g., ESM Chapter 21). (Requirement 5-1025).

c. The documentation for the computer analysis shall be included in the overall calculation, as described above in Numeral 1 (Requirement 5-1026).

d. Preparer, Checker and Approver requirements are as described above in Numeral 1.

e. The documentation for computer analysis shall, at a minimum, include a brief description of the structural model and the loading; figures/graphics showing the model configuration/geometry (e.g., nodes, element types, coordinate system, member/element local axes), applied loads, boundary conditions, and member/element end releases; reactions, deflections, utilization ratios, and member/element forces; and a brief description of how the results of the analysis are applied/used in the design (Requirement 5-1027).

f. The analysis input file and condensed output files directly used to support the analysis results shall be included (Requirement 5-1028).

g. Additional output files may either be included or stored in an electronic format. *Guidance: Computer Input and Output files may be included in Attachments/Appendixes to the Calculation.*

3. Regardless of the way calculations are performed, they shall be sufficiently documented such that a qualified independent third party can easily follow and/or reproduce them (Requirement 5-1029). In the case of a computer

analysis, this means the reviewer can determine that the model is valid and that the results were properly interpreted, and/or use the input file to reproduce the analysis results (Requirement 5-1030).

E. **Statement of Special Inspections**

The details of this document, which includes LANL's version of the IBC's special inspections and test, and structural observation requirements, are given in ESM Chapter 16, *Building Program*.

F. **Project Quality Assurance (QA)**

The following sections describe the QA and peer review requirements for the structural aspects of a project. Project QA and peer review shall be conducted within the framework of a graded approach with increasing level of rigor employed from the lowest-risk non-nuclear facilities through the highest-risk nuclear facilities (Requirement 5-1031).

- For non-nuclear, NDC-1, and NDC-2 SSCs, QA will be achieved through application of the quality-control and quality-assurance requirements of the IBC (and its referenced standards) and no peer review is required (Requirement 5-1032).
- For NDC-3 SSCs, the selected level of rigor of the QA and peer review shall be documented and explained in the project's Structural Design Quality Plan (SDQP) and Structural Peer Review Plan (SPRP), respectively (Requirement 5-1033).

See Figure I – 1 for a template that includes the required elements of an SDQP and SPRP.

1. Structural Design Quality Plan (SDQP):
   a. In addition to the requirements of 10 CFR Part 830 Subpart A, DOE O 414.1D, and LANL SD330 that pertain to HC 1-3 nuclear facilities, to include a Quality Assurance Plan that addresses ASME NQA-1 requirements, structural design requires the implementation and approval of supplemental quality processes prior to the performance of design activities (Requirement 5-1034). The supplemental may be met by addressing the items in the following SDQP and SPRP Sample Template.
   b. The SDQP shall, at a minimum, include provisions for verifying and checking the adequacy of the design either by directly checking the original design and verifying the underlying assumptions, or by use of alternate or simplified calculation methods, performance of a suitable testing program, or by the performance of a design review(s) (Requirement 5-1035).

Structural Design Quality Plan (SDQP)

- QA Requirements for Project (may refer to a manual, rev. and date)
- Project and QA Team Qualifications
- QA Training Requirements
- Design Basis Document Requirements*
- Design Procedures*
- Calculation Requirements (ESM Chapter 1 Section Z10)
- Computer Analysis Requirements (ESM Chapter 1 Section Z10)
- Inspection, Testing, and Observation Requirements*
- Drawing/Specification Requirements (including New Mexico-PE-Stamp requirements)
- Document Control and Records Management
- Design Review and Independent Peer Review*
- Application of Graded Approach for QA Process**
- Work Processes

Structural Peer Review Plan (SPRP)

- Peer Reviewer Qualifications
- Scope of Peer Review Process (When, What, and Where)
- Outline/template of Final Report from Peer Reviewer
- Application of Graded Approach for Peer Review Process**

*Required by DOE-STD-1020-2016 via reference to ASCE 43. Refer to ASCE 43 Sects. 10.1–10.3 for details.
**Must include selected level of rigor and the justification for that selection.

Figure I – 1 SDQP and SPRP Sample Template

2. Structural Peer Review Plan (SPRP)

   a. Qualified LANL staff, or external subject-matter-expert (SME) consultants (hired by LANL), will be engaged to peer review projects that include the design/analysis of NDC-3 SSCs (Requirement 5-1036).

   b. In all cases, the project peer reviewer shall not be engaged in design activities for the project (Requirement 5-1037).

   c. Peer review is in addition to the design review performed in the QA portion of the project and provides an independent evaluation of the design. As indicated above, peer review shall be performed by either internal and/or external personnel with recognized technical credentials concerning the unique features of the design/ analysis (i.e., an SME) (Requirement 5-1038).

   d. *Guidance: The peer review effort may be performed in series or in parallel with the design or analysis process. However, for most projects, it is recommended that peer review should be performed in parallel.*[11]

   e. The SPRP scope and outline (indicated in Figure I-2) shall include the requirements for Structural Calculations, SSI, and Designated Seismic Systems (which are detailed in related sections herein) (Requirement 5-1039).

[11] For large projects, it's recommended that the peer review effort should at least include a review of the DBD, sample calculations performed early in the project, specialized or unique calculations and the final documentation at the end of the project. This enables the peer review effort to have a positive effect on the project throughout and minimizes re-work and surprises at the end of the project.

f. As indicated previously, a graded approach shall be used to ensure the SPRP and its execution are consistent with the complexity of the design, the number of disciplines involved, and the uncertainty in the data (e.g., scope, number and type of SMEs engaged, etc.) (Requirement 5-1040).

g. Peer Review of the proposed design/analysis of SSCs should consider the following elements:

- Applied loads
- Adequacy of model
- Assumptions upon which the model is based
- Use of the results from the analysis
- Appropriateness of the solution technique or analysis software[12]
- Adequacy of horizontal and vertical load paths
- Proper inclusion of the geotechnical investigation into the analysis.

Guidance: Peer Review is not required for non-nuclear, NDC-1, and NDC-2 SSCs, unless Performance-Based procedures or alternative nonprescriptive analysis/testing/evaluation procedures are used for the design of these SSCs and their connections.

G. Specifications

1. A construction specification (Spec) for new SSCs and modifications to existing SSCs shall be prepared to ensure project-specific requirements associated with the structural design are conveyed to contractors, suppliers, and inspectors and are met by the as-built SSCs (Requirement 5-1041). These requirements shall include all of the applicable content in the section templates provided in the LANL Master Specifications (Requirement 5-1042). See ESM Chapter 1 Section Z10 and its Attachment F, *Specifications*, for details and exceptions.

2. The LANL Engineering Standards Program maintains templates for the typical sections needed to assemble a Specification. Most of these templates are intended for use with ML-4, Risk Category I, and Risk Category II projects and SSCs.[13] These templates must be edited to suit the particular project by the SEOR (i.e., author); however, when doing so, the author shall add project-specific requirements and delete only that content that is clearly not applicable (e.g., the author notes in all templates; interior-concrete criteria in template 03 3001 when a project includes only exterior concrete; welding-related content in 05 1000 when a project includes only bolted connections; etc.) (Requirement 5-1043).

   Seismic-related editing guidelines are provided in LANL Master Specifications, STD-342-200 Seismic Spec Section-Editing Guides and Flowchart.

   To seek relief from required content, contact the Engineering Standards Structural POC.

   Specs for projects that involve structural design typically require use of some of the following LANL Master Specification section templates:

Section 01 4000 – *Quality Requirements -Non-nuclear*	Section 01 4000 – *Quality Requirements -Nuclear*

[12] In addition to being technically appropriate, as indicated herein in Structural Calculations, software must comply with ESM Ch. 21.
[13] For higher ML and NPH categories (i.e., ML-1–ML-3, RC-IV, and all NDCs), additional requirements and QA reviews are normally required. The templates include guidance notes regarding these requirements. Additional guidance is provided in ASCE/SEI-43 Section 10.0, Seismic Quality Provisions.

Section 01 8734 – *Seismic Qualification of Nonstructural Components (IBC)*	Section 01 8712 – *Seismic Qualification of Equipment – Nuclear Safety Related*
Section 03 3001 – *Reinforced Concrete*	Section 03 3021 – *Reinforced Concrete – High Confidence*
Section 03 4100 – *Precast Structural Concrete*	
Section 03 6000 – *Grouting*	Section 03 6021 – *Grouting – High Confidence*
Section 04 2220 – *Reinforced Unit Masonry*	
Section 05 0520 – *Post-Installed Concrete and Grouted-Masonry Anchors – Normal Confidence*	Section 05 0521 – *Post-Installed Concrete Anchors – Nuclear Safety*
Section 05 1000 – *Structural Metal Framing*	Section 05 1305 – *Stainless Steel*
Section 05 2100 – *Steel Joist Framing*	Section 05 3000 – *Metal Decking*
Section 05 4000 – *Cold-Formed Metal Framing*	Section 05 5000 – *Metal Fabrications*
Section 05 5213 – *Pipe and Tube Railing*	Section 05 5313 – *Bar Gratings*
Section 13 3419 – *Metal Building Systems [design and construction]*	
Section 22 0548.23 – *Vibration and Seismic Controls for Mechanical Systems*	Section 26 0548.16 – *Seismic Controls for Electrical Systems*
Section 31 2000 – *Earth Moving*	Section 41 2213.13 – *Bridge Cranes*

NOTE: Some projects will need other sections, AND the input of/review by the SEOR for these templates to be properly edited (e.g., Division 01 includes templates on seismic qualification of equipment, Division 11 includes templates involving structural aspects of glovebox design and installation, Division 21 includes templates involving seismic protection of sprinkler piping, etc.). Some of the templates that are listed above cannot be properly edited solely by the SEOR (e.g., 13 3419, 22 0548.23, 26 0548.16, etc.). The proper editing of each and every template referred to in this NOTE is a multi-disciplinary effort.

Refer to Chapter 1 section Z10 Attachment F "Specifications" for general requirements for all specifications and exceptions (e.g., for construction projects below a $300K cost threshold).

H. Construction Drawings

1. Construction drawings for new design and modifications to existing design shall be prepared per the LANL CAD Standards Manual, STD-342-300 (or sketches where allowed). (Requirement 1-1044). A sheet in the project drawing set shall indicate the documents used for the structural design/analysis (e.g., codes, standards, manual) including their edition/revision/publication date (Requirement 5-1045). The typical location for such information is the General Structural Notes on sheet S-0001, which also must include the drawing-content requirements of IBC Section 107, Construction Documents (Requirement 5-1046), Chapter 5 Section II.1.3.A, Live loads, and clearly define the types, grades and properties of materials for each structural element and system (e.g., concrete compressive strength, exposure category, and class; reinforcing steel grade; structural steel grade).

2. LANL Standard Details are available for some types of support-restraint-anchorage. As with Master Specifications, SEOR must edit these templates (Requirement 5-1047).

Available templates include:

ST-G2040-4	Sign Base Detail and Alternate
ST-Z1052	Foundation Support System for Temporary Trailers
ST-D5020-3	Motor Control Center Anchorage
ST-F1033-1	Wall-Mounted Enclosures (I&C)
ST-G4010-38	Square D Three-Phase Transformer Anchorage and Concrete Slabs on Grade

1.7 Designated Seismic Systems (DSS)

A. Components identified as critical to life safety are classified as "designated seismic systems" and are subject to more stringent design and quality assurance requirements. In this standard, for design and qualification purposes, DSS are those nonstructural components (i.e., architectural, electrical, and mechanical components or systems in or on a building or non-building structure) that either (a) perform a seismic hazard mitigating function, based on the results of safety analysis or preliminary hazards analysis, or (b) have a component importance factor, I_p, of 1.5 per ASCE 7 Section 13.1.3.

B. The design, quality, and documentation requirements for DSS vary, depending on whether the component is required to maintain operability, or contain/confine hazardous substances, during and/or after an earthquake, and the nature of the component (i.e., active versus passive). For example, some DSS require qualification/special certification[14], while others only require design for 50% additional seismic force/demand (i.e., I_p = 1.5 versus 1.0).

C. For HC 1–3 nuclear facilities, the functional requirements of important nonstructural components are normally specified in preliminary hazards assessment documents or documented safety analysis. Safety Class (SC), Safety Significant (SS), Defense in Depth (DID), and Other Hazard Controls OHC are the terms used instead of DSS. The design, quality and documentation of such components shall be per the requirements provided in Section III of this Chapter (Requirement 5-1048).

D. For non-nuclear facilities, there may not be associated safety documents that identify DSS and their required functionality. In such cases, the project design team (e.g., LANL Project Management, SEOR, safety analyst, Cognizant System Engineer, etc.) shall identify DSS and their required functionality and document the same per Section I.1.7.E (Requirement 5-1049). As indicated previously, the use of I_p = 1.5 (to determine the seismic demand) might be the only requirement for some DSS, while other DSS might require special certification in addition to use of I_p = 1.5. Refer to ASCE 7 Sections 13.1.3 and 13.2.2 for specific details. *Guidance: The selection/designation of these special SSCs (and the basis for same) should occur during the design-input phase and be captured in the Requirements & Criteria Document (and/or Functional Requirements Document) or similar.*

E. DSS, SC, SS, DID, and OHC components shall be listed as such in the RCD, SSI, and in the DBD for new construction or modifications to existing SSCs where known (Requirement 5-1050). The basis for the functionality/operability requirements shall also

[14] Active or energized mechanical and electrical equipment/component (e.g., fire pump equipment, uninterruptible power supplies) that must remain operable following the design earthquake ground motion are qualified by shake table testing or experience data. The LANL Master Specifications include Division 01 section templates for qualifying nuclear and non-nuclear SSCs.

be provided in the RCD and DBD, as well as which (if any) of the components require special certification (Requirement 5-1051).

Guidance: Indicate DSS, SC, SS, DID, and OHC components on the Drawings and System Design Descriptions to aid facility maintenance.

1.8 Codes and Standards

A. Refer to ESM Chapter 1 Section Z10.7.0 (Code of Record), for the requirements associated with COR.

B. Refer to ESM Chapter 1 Section Z10.8.0 ("Conflicts" and Adequacy), for the requirements pertaining to conflicts between codes, standards, and LANL requirements.

C. Refer to Chapter 1 Section Z10.6.0 ("Clarifications…Non-Conformances"), to deviate from LANL Standards.

D. Refer to ESM Chapter 16 Section IBC-GEN Attachments A and B, LANL Building Code and LANL Existing Building Code, for the adopted editions of codes (e.g., IBC, IEBC, etc.).

E. The edition(s) of the codes and standards used in the design shall be referenced in the DBD and construction drawings *(as noted in the related paragraphs herein*) (Requirement 5-1052). The use of the documents listed under References below (e.g., various codes, standards, reports, papers, etc.) might be necessary to comply with this Chapter.

2.0 ACRONYMS, SYMBOLS, AND SIMILAR

The acronyms, symbols, and the like listed herein are many of the ones used in the sections of this Chapter, to include documents referenced therein. Some examples of items not included in this list are load factors and load-related symbols, the definitions of which can be found in the individual sections in which they are used.

AA – Aluminum Association

AASHTO – American Association of State Highway and Transportation Officials

ACI – American Concrete Institute

ADM – Aluminum Design Manual

AISC – American Institute of Steel Construction

AISI – American Iron and Steel Institute

ANSI – American National Standards Institute

API – American Petroleum Institute

ASCE – American Society of Civil Engineers

ASME - American Society of Mechanical Engineers

ASTM – ASTM International

ASD – Allowable Stress Design

ATC – Applied Technology Council

CE – Carbon Equivalent

CIP – Cast in place

CFR – Code of Federal Regulations

CMAA – Crane Manufacturers Association of America

DBD – Design Basis Document

DBE – Design Basis Earthquake

DOD – Department of Defense

DOD-TM - Department of Defense Technical Manual

DOE G – Department of Energy Guide

DOE O – Department of Energy Order

DOE-STD – Department of Energy Standard

ESM – Engineering Standards Manual

F_μ – Inelastic Energy Absorption Factor

FDD – Facility Design Description

FIMS – Facility Information Management System

ft (') – feet

GIP – geotechnical investigation plan

HC – Hazard Category

HVAC – Heating Ventilation and Air Conditioning

I, I_p – Importance Factor

IBC – International Building Code

ICC – International Code Council

ICC-ES – International Code Council Evaluation Service

IEBC – International Existing Building Code

IEEE – Institute of Electrical and Electronics Engineers

in (") - inches

LANL – Los Alamos National Laboratory

LLNL – Lawrence Livermore National Laboratory

LRFD – Load & Resistance Factor Design

LS – Limit State

mph – miles per hour

ML – Management Level

NDC – NPH Design Category

NEMA – National Electrical Manufacturers Association

NFPA – National Fire Protection Association

NNSA – National Nuclear Security Administration

NPH – Natural Phenomena Hazard

NRC/NUREG – Nuclear Regulatory Commission

OHC – other hazard controls

PI – post-installed

POC – Point-of-Contact

QA – Quality Assurance

R, R_p – Response Modification Coefficient

RC – Risk Category

RFP – Request for Proposal

S_{D1} – Design Spectral Response Acceleration at 1-Second Period

S_{DS} – Design Spectral Response Acceleration at Short Periods

SD – Strength Design

SDC – Seismic Design Category

SDD – System Design Description

SDQP - Structural Design Quality Plan

SF – Scale Factor

SMACNA – Sheet Metal and Air Conditioning Contractors' National Association

SPRP – Structural Peer Review Plan

SSCs – Structures, Systems, and Components

UFC – Unified Facilities Criteria

UHRS – Uniform Hazard Response Spectrum

ϕ – Capacity Reduction Factor

3.0 DEFINITIONS

Anchor – A steel element either cast into concrete or masonry, or post installed into a hardened concrete or masonry member. Including headed bolts, hooked bolts (J- or L-bolt), headed studs, expansion anchors, undercut anchors, etc. Anchors in the context of the ESM also include steel to steel connection elements and welds. Anchors are used to transmit applied loads.

Anchorage – A device or a collection of devices that provide structural support or restraint for systems and components to prevent falling, sliding, overturning, and excessive displacement.

Attachment – The structural assembly, external to the surface of the concrete that transmits loads to or receives loads from the anchor.

Corrosive – A chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the point of contact. A chemical shall be considered corrosive if, when tested on the intact skin of albino rabbits by the method described in DOT 49 CFR, Part 173.137, such chemical destroys or changes irreversibly the structure of the tissue at the point of contact following an exposure period of 4 hours. This term does not refer to action on inanimate surfaces. [IBC 2021]

Exceedance frequency – The annual probability of exceeding a given NPH. For example, at LANL, the 2007 UPSHA has estimated that the mean annual exceedance frequency associated with a peak ground acceleration of 0.47g is 4×10^{-4} or an average return period of 2,500 years.

Exempt – see Seismically Exempt

Existing facility – Refer to IBC definition and any ESM Chapter 16 amendment to same.

Explosives facility – A structure or defined area used for explosives storage or operations. Excluded are explosives presenting only localized, minimal hazards as determined by the Authority Having Jurisdiction. Examples of excluded items may include user quantities of small arms ammunition, commercial distress signals, or cartridges for cartridge actuated tools, etc. [DOE G 420.1-1A]

Facility – One or more building(s) or structure(s), including systems and components, dedicated to a common function (includes operating, non-operating, and facilities slated for decontamination and decommissioning).

Inelastic energy absorption factor (F_μ) – A reduction factor used to reduce demand to account for inelastic behavior. The Inelastic Energy Absorption Factor is a function of the Limit State and the structural system or equipment configuration. See ASCE 43 for more specific details.

Graded approach – the process of ensuring that the level of analysis, documentation, and actions used to comply with a requirement in this part are commensurate with: (1) The relative importance to safety, safeguards, and security; (2) The magnitude of any hazard involved; (3) The life cycle stage of a facility; (4) The programmatic mission of a facility; (5) The particular characteristics of a facility; (6) The relative importance of radiological and nonradiological hazards; and (7) Any other relevant factor.

Hazard – A source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to a person or damage to a facility or to the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation). [DOE-STD-3009-2014]

Hazard categorization (DOE) Evaluation of the consequences of unmitigated releases to classify facilities or operations into the following hazard categories:

- *Hazard Category 1: Has the potential for significant off-site consequences.*
- *Hazard Category 2: Has the potential for significant on-site consequences.*
- *Hazard Category 3: Has the potential for only significant localized consequences.*

DOE-STD-1027 provides guidance and radiological threshold values for determining the hazard category of a facility. DOE-STD-1027-18, Chg 1, *Hazard Categorization of DOE Nuclear Facilities*, interprets Hazard Category 1 facilities as Category A reactors and other facilities designated by the Program Secretarial Officer.

Hazardous material – Any solid, liquid, or gaseous material that is toxic, explosive, flammable, corrosive, or otherwise could adversely affect the health and safety of the public or workers or harm the environment. [DOE-STD-3009-2014]

Health hazard – A classification of a chemical for which there is statistically significant evidence that acute or chronic health effects are capable of occurring in exposed persons. The term "health hazard" includes chemicals that are toxic or highly toxic, and corrosive. [2021 IBC]

High confidence of low probability of failure (HCLPF) – Usually a 90% confidence of a less than 10% probability of failure which results in about a 1% to 2% probability of failure

Highly toxic – A chemical which produces a lethal dose or lethal concentration that falls within any of the following categories:

1. Has a median lethal dose (LD_{50}) of $\leq$ 50 mg per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 g each.
2. Has an LD_{50} of $\leq$ 200 mg per kilogram of body weight when administered by continuous contact for 24 hr (or less if death occurs within 24 hr) with the bare skin of albino rabbits weighing between 2 and 3 kg each.
3. Has a lethal concentration (LC_{50}) in air of $\leq$ 200 parts per million by volume of gas or vapor, or $\leq$ 2 mg per liter of mist, fume, or dust, when administered by continuous inhalation for 1 hr (or less if death occurs within 1 hr) to albino rats weighing between 200 and 300 g each.

Mixtures of these chemicals with ordinary materials, such as water, might not warrant classification as highly toxic. While this system is basically simple in application, any hazard evaluation that is required for the precise categorization of this type of chemical shall be performed by experienced, technically competent persons. [adaptation of 2015 IBC]

Limit state (LS) – The limiting acceptable condition of the SSC. The limit state may be defined in terms of a maximum acceptable displacement, strain, ductility, or stress. The four LSs are as follows per ASCE 43-19 Table 1-2 (for additional details refer to ESM Chapter 5 Section III Appendix D):

A = Short of collapse, but structurally stable

B = Moderate permanent deformation

C = Limited permanent deformation

D = Essentially elastic

Major modification – A modification/change to a DOE nuclear facility that substantially changes the existing safety basis [adaptation of DOE-STD-1189-2016]. Determination is made as detailed in Safety Basis Division Process SBP114-1: *Safety Basis Development for Projects, Attachment C (refer to DOE-STD-1189-2016 Appendix F for Major Modification Determination Examples)*.

Mean annual hazard – The expected (or average) exceedance frequency associated with a given hazard. Future seismic loads are highly variable. For a given site, there is typically, a "mean annual seismic hazard" curve that expresses the average (or expected) value of a ground motion parameter, such as peak ground acceleration, as a function of the probability of exceedance of that variable.

Natural phenomena hazard (NPH) – An act of nature (e.g., earthquake, wind, tornado, flood, precipitation, volcanic eruption, or lightning strike) that poses a threat or danger to workers, the public, or to the environment by potential damage to structures, systems, and components.

New facility – Refer to IBC definition and any ESM Chapter 16 amendment to same.

Non-nuclear facility – Those DOE facilities other than HC 1, 2, or 3 nuclear facilities. These facilities don't have nuclear material above DOE HC 3 thresholds, so they include radiological

facilities[15] and facilities with chemical or toxicological hazards.[16] [adapted from DOE-STD-1020-2016]

Nonstructural Concrete – Any element made of plain or reinforced concrete that is not part of a structural system required to transfer either gravity or lateral loads to the ground. [2021 IBC[17]]

Nuclear facility – DOE HC 1, 2, or 3 nuclear facilities.[18] [adapted from DOE-STD-1020-2016]

Other hazard controls – Refer to definition in ESM Chapter 1 Section Z10 Appendix A.

Peak spectral acceleration – The peak/maximum acceleration response in an acceleration response spectrum. [ASCE 4-16]

Peer review – A formal review process in which an external party (independent from the project) will review the methodology, results, and process by which a design is developed.

Physical hazard – A chemical for which there is evidence that it is a combustible liquid, cryogenic fluid, explosive, flammable (solid, liquid or gas), organic peroxide (solid or liquid), oxidizer (solid or liquid), oxidizing gas, pyrophoric (solid, liquid or gas), unstable (reactive) material (solid, liquid or gas), or water-reactive material (solid or liquid). [2021 IBC]

Positive attachment/connection – Anchors, bolts, welds, screws, and other such fasteners, etc.; not relying on gravity or friction. [adapted from various; e.g., ASCE 7, IBC, SDI, etc.]

Post-installed anchor – An anchor installed in hardened concrete or masonry and used to transmit applied loads to the concrete/masonry. Expansion, adhesive, and undercut anchors are examples of post-installed anchors.

Radiological facility – A DOE facility that contains radioactive material in a quantity less than Hazard Category 3 as defined in DOE-STD-1027-92, Chg. 1. [DOE-STD-1020] (Now termed "Below Hazard Category 3" in DOE-STD-1027-18 Chg 1).

Response modification coefficient (R) – A factor used to reduce the elastic demand of a commercial structure due to the design-basis earthquake, to target the development of the first significant yield (i.e., instead of performing a nonlinear analysis, inelastic effects are accounted for indirectly in the linear analysis methods by means R). R accounts for the displacement ductility demand, R_d, required by the system and the inherent overstrength, Ω, of the seismic force-resisting system (SFRS). R is a function of the structural system configuration (i.e., the SFRS selected for the structure dictates the value of R). [adaptation of ASCE 7-16 Section C12.1]

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[15] Refer to DOE-STD-1020-2016 Section 2.2.3. DOE-HDBK-1220 Section 2.2.3 states, "…IBC 2015 does not explicitly address radiological facilities. The facility should be designated as IBC Risk Category IV unless the technical basis exists for a lower risk category."

[16] DOE-STD-1020-2016 Section 2.2.2 states, "… If the unmitigated failure consequences are such that the equivalent adverse effects are below those for Highly Toxic as defined in 29 CFR 1910.1200, *Toxic and Hazardous Substances,* Appendix A, the SSCs should be designed following IBC-2015 requirements…" First, Part 1910.1200 is called *Hazard Communication*, not *Toxic and Hazardous Substances*. Second, Appendix A to 1910.1200, *Health Hazard Criteria*, doesn't define Highly Toxic. Third, App. A doesn't define '…adverse effects…below those for "Highly Toxic" ...' Fourth, Highly Toxic isn't defined anywhere in 29 CFR 1910 Subpart Z (which includes 1910.1000 – 1910.1450). Fifth, per IBC Commentary, its definition of Highly Toxic is based on 29 CFR 1910.1200. Sixth, per IBC 101.3 and its Commentary, the purpose of the IBC includes providing for the safety of building occupants and fire fighters and emergency responders. Finally, IBC includes and addresses design for hazards that meet or exceed Highly Toxic. Given all these factors, use of the IBC for the design of non-nuclear facilities with chem/toxic hazards complies with DOE-STD-1020-2016.

[17] An exception to this definition is a slab-on-grade or floor that isn't part of a structural system, but is designed to resist gravity loads (e.g., industrial floors designed per ACI 360R, etc.). This exception is necessary because the IBC doesn't define "structural system," and because ACI 318 Section R1.4.8 indicates that industrial floor slabs are akin to structural systems (which are defined subsequently herein).

[18] DOE-STD-1020-2016 Section 2.3.3 includes protection against chemical and toxicological hazards (in DOE HC 1–3 nuclear facilities).

Safety basis – The documented safety analysis and hazard controls that provide reasonable assurance that a DOE nuclear facility can be operated safely in a manner that adequately protects workers, the public, and the environment. [DOE G 420.1-1A]

Safety class structures, systems, and components (SC SSCs) – The SSCs, including portions of process systems, whose preventive or mitigative function is necessary to limit radioactive hazardous material exposure to the public, as determined from safety analyses.. [DOE-STD-1020-2016]

Safety significant SSCs (SS SSCs) – The SSCs which are not designated as SC SSCs, but whose preventative or mitigative function is a major contributor to defense in depth and/or worker safety as determined from safety analyses. [DOE-STD-1020-2016]

Safety SSCs – The set of both the SC SSCs and the SS SSCs. [DOE-STD-1020-2016]

Seismic hazard curves (HC) – Description of the ground motion parameter of interest as a function of annual frequency of exceedance. Peak ground acceleration and spectral accelerations at 0.2 sec and 1 sec natural period plotted as a function of annual frequency of exceedance are common. The seismic hazard curves are determined from a probabilistic hazard assessment following the guidance in ANSI/ANS 2.27 and 2.29.

Seismically Exempt – LANL term for those nonstructural components exempt from seismic design; see ESM Chapter 5, Section II.1.8.C (1613.4).

Spectral acceleration – The maximum acceleration response of a single-degree or freedom oscillator of a known frequency, f, and viscous damping, β, subjected to a prescribed forcing function or earthquake ground motion time history. [ASCE 4-16]

Structural element – Portion of a structure involved in a load path, such as a beam, column, shear wall, diaphragm, brace, anchor or support. [adapted from various places in ASCE 7]

Structural System – Interconnected structural framing (e.g., diaphragms, beams, girders, columns, walls, etc.) and foundation elements (e.g., footings, piles, etc.) designed to resist gravity and/or lateral loads. Some examples of the vertical portion of structural framing are moment frames, braced frames, a combination of moment frames and shear walls, etc. Some examples of the horizontal portion of structural framing are reinforced-concrete roofs/floors, structural steel roof/floor framing, composite steel roof/floor decking, trusses, etc. In ASCE 7, the structural system doesn't include the foundation, while in ACI 318 it does. Structural systems occur in building and nonbuilding structures. They also occur with elevators and hoist ways, which are nonstructural components (ref. ASCE 7 Chapter 13).

Structures, systems, and components (SSCs) – A structure is an element, or a collection of elements, to provide support or enclosure, such as a building, free-standing tanks, basins, dikes, or stacks. A system is a collection of components assembled to perform a function, such as piping, cable trays, conduits, or HVAC. A component is an item of mechanical or electrical equipment, such as a pump, valve, or relay, or an element of a larger array, such as a length of pipe, elbow, or reducer. [ASCE 4-16]

Toxic – A chemical falling within any of the following categories [adaptation of 2021 IBC]:

1. Has a median lethal dose (LD_{50}) of > 50 mg per kg, but $\leq$ 500 mg/kg of body weight when administered orally to albino rats weighing between 200 and 300 g each.
2. Has an LD_{50} of > 200 mg per kg, but $\leq$ 1,000 mg/kg of body weight when administered by continuous contact for 24 hr (or less if death occurs within 24 hr) with the bare skin of albino rabbits weighing between 2 and 3 kg each.

3. Has an LC_{50} in air of > 200 parts per million, but ≤ 2,000 ppm by volume of gas or vapor, or > 2 mg per liter but ≤ 20 mg per liter of mist, fume, or dust, when administered by continuous inhalation for 1 hr (or less if death occurs within 1 hr) to albino rats weighing between 200 and 300 g each.

4.0 REFERENCES[19]

These documents are invoked by reference to the extent applicable. Dates shown are the latest at time of issuance of Section I; however, always use latest contractually required edition (except for those referenced by building code of record used). Most codes and standards are available to LANL from Research Library.

ACI (American Concrete Institute)

- ACI 318-19, "Building Code Requirements for Structural Concrete," Code and Commentary, 2019.
- ACI 349-13, "Code Requirements for Nuclear Safety Related Concrete Structures," Code and Commentary, 2013
- ACI 349.1R-07, "Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures," 2007

AISC (American Institute of Steel Construction)

- AISC 341-16, "Seismic Provisions for Structural Steel Buildings," 2016.
- AISC 360-16, "Specification for Structural Steel Buildings," 2016.
- AISC N690-18, "Specification for Safety-Related Steel Structures for Nuclear Facilities," 2018.
- AISC Steel Design Guide 1, "Base Plate and Anchor Rod Design," 2nd Edition, Second Printing, 2006 (Rev 2014).
- AISC Steel Design Guide 7, "Industrial Buildings, Roofs to Anchor Rods," 3rd Edition, R2019.

AISI (American Iron Steel Institute)

- AISI S100-16, "North American Specification for the Design of Cold-formed Steel Structural Members," 2016 (R2020), with Supplement 2, 2020 Ed.
- AISI S202-20, "Code of Standard Practice for Cold-Formed Steel Framing," 2020.
- AISI S220-20,"North American Standard for Cold-Formed Steel Nonstructural Framing," 2020.
- AISI S240-20, "North American Standard for Cold-Formed Steel Structural Framing, 2020.
- AISI S400-20, "North American Standard for Seismic Design of Cold-Formed Steel Structural Systems," 2020.

ANS (American Nuclear Society)

- ANS-2.26, "Categorization of Nuclear Facility Structures, Systems and Components for Seismic Design," 2004 (R2010), May 2010.

[19] The documents listed are those that are explicitly referenced in the chapter as well as some/many of those that are implicitly referenced (e.g., by way of their being referenced by IBC, etc.).

- ANS 2.27, "Criteria for Investigations of Nuclear Facility Sites for Seismic Hazard Assessments," April 2020
- ANS 2.29, "Probabilistic Seismic Hazard Analysis," April 2020.
- ANS 2.30, "Criteria for Assessing Tectonic Surface Fault Rupture and Deformation at Nuclear Facilities," May 2015 (R2020).

ASCE (American Society of Civil Engineers)

- ASCE 4-16, "Seismic Analysis of Safety Related Nuclear Structures and Commentary," 2016.
- ASCE 7-16, "Minimum Design Loads and Associated Criteria for Buildings and Other Structures," 2017 with Supplement 3.
- ASCE 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members," 2002.
- ASCE 19-16, "Structural Applications of Steel Cables for Buildings," 2016.
- ASCE 41-17, "Seismic Evaluation and Retrofit of Existing Buildings," 2017.
- ASCE 43-19, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities," 2019.
- ASCE 55-16, "Tensile Membrane Structures," 2017.
- ASCE 59-11, "Blast Protection of Buildings," 2011.
- ASCE, "Design of Blast Resistant Buildings in Petrochemical Facilities," Task Committee on Blast Resistant Design, 2010.
- ASCE 58, "Structural Analysis and Design of Nuclear Plant Facilities, Manuals and Reports on Engineering Practice No. 58, 1980.
- ASCE MOP 142, "Structural Design for Physical Security," 2010.

ASME (American Society of Mechanical Engineers)

- ASME NOG-1, "Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)," 2015 (R2020).
- ASME NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications," March 14, 2008 with 2009 addenda.
- ASME NUM-1, "Rules for Construction of Cranes, Monorails, and Hoists (with Bridge, Trolley or Hoist of the Underhung Type)," 2009 (R2016).
- ASME QME-1, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants," 2007.

ASTM International (formerly American Society of Testing Materials)

- ASTM A36-14, "Standard Specification for Carbon Structural Steel," 2014.
- ASTM A53-22, "Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless," 2022.
- ASTM A193-22A, "Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications," 2022.

- ASTM A354-17, "Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners," 2018.
- ASTM A449-14, "Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use," 2014 (R2020).
- ASTM A572-18, "Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel," 2018.
- ASTM A588-15, "Standard Specification for High-Strength Low-Alloy Structural Steel, with 50 ksi [345 MPa] Minimum Yield Point with Atmospheric Corrosion Resistance," 2015.
- ASTM F1554-20, "Standard Specification for Anchor Bolts, Steel, 36, 55, and 105 ksi Yield Strength," 2020.

AWS (American Welding Society)

- AWS D1.1-15, "Structural Welding Code – Steel," 2015.

CISC-ICCA (Canadian Institute of Steel Construction-Institut Canadien De La Construction En Acier)

- "Guide for the Design of Crane-Supporting Steel Structures," 3rd Edition, 2nd Printing, 2017

CFR (Code of Federal Regulations)

- 10 CFR Part 830, "Nuclear Safety Management," 2020.
- 29 CFR Part 1910.109, "Explosives and Blasting Agents," 2017
- 29 CFR Part 1910.1200 Appendix A, "Health Hazard Criteria," 2017

DOD (Department of Defense)

- UFC 4-010-01, "DoD Minimum Antiterrorism Standards for Buildings," Unified Facilities Criteria (UFC), December 12, 2018.

DOE (Department of Energy) Regs, Orders, and Standards

- DOE O 414.1D, "Quality Assurance," 2011, Admin Chg. 2 (2020).
- DOE O 420.1C, "Facility Safety," Change 3 (2019).
- DOE G 420.1-1A, "Nonreactor Nuclear Safety Design Guide for use with DOE O 420.1C, Facility Safety," December 2012.
- DOE-STD-1020-2016, "Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities," December 2016. [referred to as "1020" throughout chapter]
- DOE-STD-1027-2018, "Hazard Categorization of DOE Nuclear Facilities," November 2018, Chg 1 (2019).
- DOE-HDBK-1220-2017, "Natural Phenomena Hazards Analysis and Design Handbook for DOE Facilities," August 2017.
- DOE-STD-1189-2016, "Integration of Safety into the Design Process," December 2016.
- DOE-STD-1212-2019, "Explosives Safety," November 2019, Change Notice No 1 (December 2021).
- DOE-STD-3009-2014, "Preparation of Nonreactor Nuclear Facility Documented Safety Analysis," November 2014.

EPA (Environmental Protection Agency)

- 40 CFR Part 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," 2002.

ICC (International Code Council)

- IBC, "2021 International Building Code"
- IEBC, "2021 International Existing Building Code"

NIST (National Institute of Standards and Technology)

- NIST GCR 11-917-12, "Standards of Seismic Safety for Existing Federally Owned and Leased Buildings/ICSSC Recommended Practice 8 (RP 8)," December 2011.

NRC (U.S. Nuclear Regulatory Commission)

- RG 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)," Revision 3, May 2020.
- RG 1.199, "Anchoring Components and Structural Supports in Concrete," Revision 1, April 2020.

LANL

- Cuesta, I., "Design-Load Basis for LANL Structures, Systems, and Components," LANL Report No.: LA-14165, September 2004.

TMS (The Masonry Society)

- TMS 402, "Building Code for Masonry Structures," Code and Commentary, 2016.
- TMS 602, "Specification for Masonry Structures," Specification and Commentary, 2016.

5.0 RECORD OF REVISIONS

Rev	Date	Description	POC	RM
0	6/28/99	Initial issue in Facility Eng Manual (formerly in Facilities Eng Div Stds).	Doug Volkman, *PM-2*	Dennis McLain, *FWO-FE*
1	2/9/04	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. General revision and improvements.	Mike Salmon, *FWO-DECS*	Gurinder Grewal, *FWO-DO*
2	5/17/06	General revision and improvements; OST became ISD.	Mike Salmon, *D-5*	Mitch Harris, *ENG-DO*
3	10/27/06	Admin changes only. Org and contract reference updates from LANS transition; 420.1A became 420.1B; deleted NM Bldg Code based on 9/18/06 variance. Clarified table. IMP and ISD number changes based on new CoE IMP 341. Master Spec number/title updates.	Mike Salmon, *D-5*	Kirk Christensen, *CENG*
4	6/19/07	Added risk evaluation for projects underway due to increased seismic design basis from 2007 PSHA update (Applicability sections 1.3.B and C).	Mike Salmon, *D-5*	Kirk Christensen, *CENG*

5	11/19/08	Incorporated IBC-2006 & ASCE 7-2005 in place of IBC-2003 & ASCE 7-2002. General revision and improvements.	Mike Salmon, *D-5*	Kirk Christensen, *CENG*
6	6/20/11	Added requirements for Designated Seismic Systems, App A on anchorage, updates for consistency with Section III, updated references.	Mike Salmon, *D-5*	Larry Goen, *CENG*
7	3/27/15	Adopted DOE-STD-1020-2012 and DOE O 420.1C Chg 1, IBC-2015, and RP-8; moved Appendix A anchorage material to Section II App A.	Mike Salmon, *AET-2*	Larry Goen, *ES-DO*
8	03/24/21	Adopted DOE-STD-1020-2016 and DOE O 420.1C Chg 3; other minor clarifications and additions. Many basis footnotes moved to requirements ID document.	Mike Salmon, *ALDFO*	Jim Streit, *ES-DO*
9	03/22/23	Adopted 2021 IBC. Clarified return periods in Table I - 2 notes. Design Basis Document (DBD) eliminated for non-nuclear SSCs, and corresponding requirements moved to Section III. Minor and administrative changes including updated references and definitions.	Carlos Coronado, *ES-SPD*	Michael Richardson, *ES-DO*