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# RECORD OF REVISIONS

| Rev | Date | Description | POC | OIC |
|---|---|---|---|---|
| 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 O 420.1C/Chg 1, DOE-STD-1020-2012, IBC-2015, and RP-8; moved Appendix A anchorage material to Section II App A. | Mike Salmon, *AET-2* | Larry Goen, *ES-DO* |

**Contact the Structural Standards POC**
for upkeep, interpretation, and variance issues

| | |
|---|---|
| **Ch. 5, Section I** | **Structural POC/Committee** |

This Chapter is online at http://engstandards.lanl.gov/

# 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.). 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.

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 engineer 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.

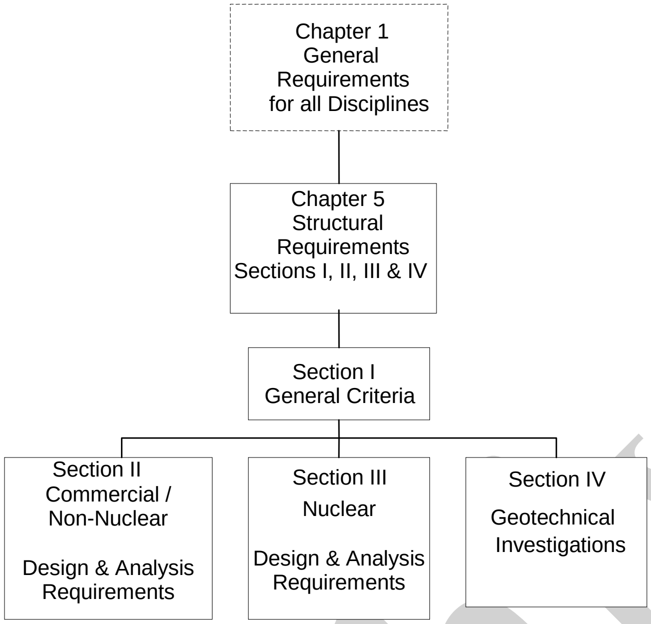
### 1.2 Chapter Contents and Conventions

A. *This Chapter consists of four sections. Sections I, II, and III provide the structural design and 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 more prescriptive criteria to be used in the actual structural design. The design /analysis of non-nuclear SSC, and of facilities with insignificant chemical or toxicological hazards*[1]*, are addressed in Section II. The design and analysis of NDC-1 - NDC-3*[2] *SSC and of facilities with biological or significant chemical or toxicological hazards are addressed in Section III. Note that some aspects of the*

[1] Facilities with insignificant chemical or toxicological hazards are those facilities that have chemical or toxicological hazards that are not significant per DOE-STD-1020-2012 paragraphs 2.1.5 and 2.3.9. Also see definition of “significant chemical or toxicological hazard” herein (in Subsection 3.0).

[2] Use of NDC-4 and -5 categories is not expected at LANL so not addressed in this Chapter.

*design/analysis of NDC-1 and NDC-2 SSC in Section III are accomplished by utilization of Section II. Section IV provides geotechnical requirements.*




B. Text in regular type indicates mandatory requirements unless prefaced with wording identifying it as guidance or a recommendation. *Italicized* text 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 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 SSCs are normally those designated as safety class 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 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 SSC failure is analogous to commonly accepted industrial risk.*



[3] LANL AP-341-502, Management Level Determination and Identification of Quality Assurance and Maintenance Requirements.

*DOE requirements for the design for NPH, which are contained in DOE O 420.1C and DOE-STD-1020, result in the use of a 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 (and Appendix A of DOE-STD-1189).*
  - *Similar applies to SSCs with significant biological, chemical, or toxicological hazards. If biological, chemical, or toxicological hazards are not significant then the SSCs are treated as non-nuclear.*

*These RCs 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, the 1020-based NDC is called Seismic Design Category (SDC). This SDC is not to be confused with the IBC's Seismic Design Category (SDC).*

## 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, and lightning. Where no specific requirements are specified, 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.[4] The design process shall consider potential damage and failure of SSCs due to both direct and indirect natural phenomena effects, including common cause effects and interactions from failures of other SSCs.

C. New SSCs, and additions or Major Modifications (a defined term, see Definitions) to existing SSCs, shall be designed, constructed, and operated to meet the requirements in the previous paragraph. 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.

1. Regarding existing SSCs, the following shall be complied with:

a. RP 8: Prior to doing work in/on non-nuclear facilities, or on SSCs in nuclear facilities, follow NIST GCR 11-917-12 /ICSSC RP 8[5] (or successor) to determine whether a seismic evaluation is necessary.

- If it is, use RP 8 to establish the evaluation requirements and any mitigation requirements if the evaluation indicates such is required.

[4] NPH mitigation design requirements are presented in Ch IV of DOE 420.1C.
[5] RP 8 mandated by DOE-STD-1020-2012 (2.1.4, 9.0, 9.4.1)

b. Major Modifications to a nuclear facility's NDC-3 SSCs shall be designed in accordance with the same requirements that apply to new nuclear facilities and NDC-3 SSCs. See DOE-STD-1020 (*2012 paragraph 9.1*) for more detail.

c. Prior to doing work consisting of a non-major modification to a nuclear facility with NDC-3 SSCs, and NPH other than seismic, comply the requirements for evaluation and mitigation associated with the non-seismic NPH in DOE-STD-1020 (*2012 paragraph 9.4.2-4*).

2. The Table I-1 crosswalks facilitate the use of this Section in particular, as well as this Chapter in general, and its NPH categorizations (i.e., RC and NDC) for work in/on existing facilities that have only the former NPH categorizations (i.e., Performance Category, or PC). *Guidance: The crosswalks provide a direct or conservative mapping so that existing facilities undergoing minor modification may utilize this chapter and also other not-yet-updated ESM documents without first completing new NPH category determinations. In some instances, such facilities may be able to reduce conservativism by both confirming SSC ML determinations and redoing NPH determinations to achieve the most appropriate SDC/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). For non-nuclear SSCs, four RCs are defined in the IBC, ranging from RC I through RC IV. For nuclear SSCs, five NDCs are defined in DOE-STD-1020, ranging from NDC-1 through NDC-5; of these, LANL only uses NDC 1-3.[6] NDC-1 and NDC-2 NPH requirements are similar to those of the higher RCs 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. These criteria are adopted for design of LANL facilities in this Chapter*.

## 1.4 Crosswalks from PC Categorization to the Current NPH Nomenclature

**Table I - 1a Non-Nuclear Facility Designations**

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

NOTES:

1. Basis: ESM Ch. 5 Sect. II, rev. 6, para. 1.1.1; and Occupancy Category therein = RC.
2. Although RC III exists, there is no PC-corollary for it.
3. While, in general, the LANL Existing Building Code (LEBC) requires new work in/ on existing facilities to be done in accordance with the LANL Building Code, there are instances in which such is not required. For details, refer to ESM Ch. 16, Sect. IBC-GEN, Att. B (LEBC), "Overall LANL Policy on IEBC Provisions for Code of Record."

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

**Table I - 2b 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, para. 3.1.2; and DOE-HDBK-TBD, App. A; and DOE-STD-1020-2002 and ASCE 43.
   b. Other NPH: DOE-STD-1020, Sect. 4.0 (WDC), and paras. 5.5.5 (FDC) and 7.5.4 (PDC); and Tables 4-1, 5-2B and 7-2.
      i. FDC-1 and FDC-2 only applies to SSCs in/on FDC-1 or FDC-2 facilities; see Ch. 5 Sect. III, Para. H 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 years for former, and 2,500 years for the latter group. However, use of PC-3 = WDC-3 and PDC-3 for crosswalk is appropriate since the longer RP 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., the condition of the SSC after the seismic event; ref. Ch. 5 Sect. III).
4. For new work in/on an existing 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:
   a. In the LEBC, references to the IBC structural provisions shall be taken to mean ESM Chapter 5 Section III, and
   b. 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 N/A to HC 1 – 3 nuclear SSCs).

## 1.5 Applicability

A. The requirements of this Chapter shall be applied to the design of new facility and programmatic SSCs. Additionally, this Chapter applies to renovation, replacement, modification, maintenance, or rehabilitation projects. Applicability of the provisions of this Chapter is illustrated in Table I - 2.

**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 RC I (e.g., sheds, sidewalks) | Yes |

| | |
|---|---|
| New non-structural systems & components in new and existing structures, including programmatic equipment | Yes, 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 per ESM Chapter 1 Section Z10). Each SSC shall be assigned an RC/NDC by LANL prior to performance of structural design. Note that prior to/during the course of 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 / DOE-STD-1020 (*2012 para 5.5.3.9*). 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 are presented in this chapter for:

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

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

[7] This chapter primarily 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 in accordance with the International Existing Building Code (IEBC) as amended by LANL; see also LANL ESM Chapter 16, IBC Program (IBC-GEN Att B, LEBC)*. Design work on existing nuclear SSCs follows para. 1.3.C herein.

* NOTE: LEBC is based on IEBC. Like RP 8 (ref. 1.2.C herein), the IEBC includes seismic-evaluation requirements; however, they are quite different. To begin with, the RP 8 trigger for requiring an evaluation is cost-based, while that in IEBC is area-based. Thus, in order to ensure that the requirements of both documents are complied with, it is likely (in most instances) that, at a minimum, the triggers in both documents be checked.

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. The applicability of these requirements to a given project will be explicitly stipulated by LANL[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 HC 2 or 3 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 of these project requirements shall be referenced, where applicable, in the Project Record Documents.

### B. Project Record Documents

1. Project record documents for structural design shall be prepared considering the concept of a graded approach where the level of detail and rigor is consistent with the importance to safety, mission importance, and project cost. 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 SSC 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 close 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 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.

[9] LANL Physical Security (PS) Division will specify (to the LANL Project Manager) whether anti-terrorism measures shall be included in a project.

3. The project record documents for structural design to be submitted to LANL shall consist of the following:

   - Design Basis Document (DBD)
   - Structural calculations
   - Statement of Special Inspections (SSI)
   - Structural Design Quality Plan (if present), and Structural Peer Review Plan (if present)
   - Specifications
   - Construction Drawings

4. The review of project record documents is conducted by the LANL Engineering Standards Chapter 5 Point of Contact (POC), or his/her designee, for review and approval.

5. In what follows, details on each of the project record documents are provided and, in some instances, the circumstances in which submission is not required.

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

1. The DBD provides a summary of the specific facility structural design basis and shall include the NPH RC(s) or NDC(s) of the SSCs being designed, design codes of record (dates and editions), methods (computer codes, analytical methods), load definition, load combinations, load path (local and global), member capacity equations, and corresponding applicable acceptance criteria. The DBD shall describe the design of the SSCs (to include non-building structures). A template for a DBD is presented in Figure I - 1.

2. The DBD may be used to eliminate load combinations (indicated in Sections II and III) from consideration by showing that they are either not applicable or bounded by other load combination equations. Once the DBD is established, **it does not** have to be revisited during the project duration for changes or updates to the ESM or the referenced standards unless directed by LANL. Also, see LANL ESM Chapter 1 Section Z10 on 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, Safety Significant, or Important to Safety, 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 Structural
- Facility Siting Considerations (standoff distance from known faults, flood levels, etc.)*
- Facility Geotechnical Investigation (e.g., highlight content of recommendations and how they are incorporated into foundation design, etc.)
- Applicable NPH Definition
  - Earthquake (DBE ground response spectra)
  - Wind (basic wind speed for the applicable risk /design category)
  - Wind Driven Missiles (definition of)
  - Snow (ground load)
  - Flood and local precipitation (if applicable, or basis for not considering)
  - Etc.
- 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 to, requirements
- Analysis Methodology (used to determine structural demand)
- Member Capacity Equations (not included in design standards / codes, or not commonly used)
- Load Combinations (may refer to Chapter 5 of the ESM)
- 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), Functional & Requirements Document (FRD), or Requirements & Criteria Determination (RCD), and only a brief summary (based on these documents) need be included in the DBD.

**Figure I - 1 Design Basis Document (DBD) Template**

3. 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. 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.

4. An RC or NDC must be assigned to an SSC to establish the appropriate NPH (earthquake, wind, and flood) design and analysis requirements as put forth in DOE-STD-1020. This standard provides design/analysis criteria for all NPH Risk and Design Categories (i.e., RC I – RC IV, and NDC-1 – NDC-3).

   - NPH risk/design categories will be provided to the structural engineer by either the leadership of his/her project team or LANL.
   - The assignment of risk/design categories may be summarized when a safety analysis report exists that contains the detailed information. The assignment of risk/design categories shall be presented in detail when a separate document, such as a safety analysis report, does not present the basis for assignment of risk/ design categories.
   - The basis for assignment of risk/design categories to SSC shall be either summarized or presented in detail in the DBD.

5. 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.). For less significant design projects, the DBD need not be a stand-alone document, rather its contents (described previously) can merely be included as front matter in the structural calculations.[10] If in doubt, contact the POC/designee referred to in paragraph 1.5.B.4.

D. **Structural Calculations**

1. Calculations shall be performed, numbered, and approved in a consistent format and shall include, at a minimum, sections for Purpose and Objective, Methodology and Acceptance Criteria, Assumptions, Design Input, References, Calculations, and Summary and Conclusions. *One acceptable procedure for performing calculations for LANL is AP-341-605[11]*. Calculations shall be signed by a Preparer, a Checker (that attests to numerical accuracy), and an Approver (attests to reasonableness of the theory and assumptions and to the validity of the conclusions reached). The Checker and approver may be the same individual but not the Preparer. Calculations shall be performed following a LANL-approved Project SDQP (refer to 1.5.F and Figure I-2 herein). The requirements of the SDQP may be tiered for the various NPH risk/design categories by the graded approach philosophy.

2. Computer analysis: When computer analysis is performed, input and output shall be numbered in a consistent format (which shall be described in the Project SDQP). Analyses shall conform to the requirements in LANL ESM Chapter 1 Section Z10 (*paragraphs 7.3.F.4 and Z1020.A*). The documentation for the computer analysis shall be included in the overall calculation, as described above. *Computer Input and Output files may be included in Attachments/Appendixes to the Calculation.* Preparer, Checker and Approver requirements are as described above. The documentation for computer analysis shall, at a minimum, include a brief description of the structural model, the loading, a figure showing the model configuration (with control nodes shown along with the most limiting structural components /members), and how the results of the analysis are applied. The analysis input file and condensed output

---

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

[11] "Engineering Calculations," LANL AP-341-605

files directly used to support the analysis results shall be included. Additional output files may either be included or stored in an electronic format.

3. Regardless of the manner in which calculations are performed, they shall be sufficiently documented such that an independent third party can easily follow and /or reproduce them. 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 take the input file and reproduce the analysis results.

E. **Statement of Special Inspections**

1. The details of this document, which includes LANL's version of the IBC's special inspection and test and structural observation requirements are given in ESM Chapter 16, IBC 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.[12]

- For non-nuclear SSCs, QA will be achieved solely through application of the quality-control and quality-assurance requirements of the IBC (and its referenced standards) and no peer review is required.
- For all nuclear SSCs (NDC-1 – NDC-3), the selected level of rigor of the QA shall be documented and explained in the project Structural Design Quality Plan (SDQP).
- For high-hazard nuclear SSCs (NDC-3)[13], the selected level of rigor of the peer review shall be documented and explained in the project Structural Peer Review Plan (SPRP).

See Figure I - 2 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 DOE O 414.1D and LANL SD330 that pertain to HC 1-3 nuclear facilities, to include a Quality Assurance Plan that addresses NQA-1 requirements, structural design necessitates supplemental quality processes be implemented and approved prior to the performance of design activities. The supplemental can be met by addressing the items in the template (Fig. I-2).

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).

[12] Sect. 10 of DOE-STD-1020-2012 and its draft HDBK
[13] For low-hazard nuclear SSCs (i.e., NDC-1 and NDC-2), no peer review is required

**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

**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**

*DOE-STD-1020 requires that projects involving SDC-3 SSCs meet the QA requirements of ASCE/SEI 43 (Sect. 9.3), as applicable, in addition to those stipulated in para. 1.5.F.1 herein. ASCE 43 Sect. 9.3 contains specific minimum requirements pertaining to DBDs and Design Procedures.
**Must include selected level of rigor and the justification for that selection.

**Figure I - 2 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 and analysis of NDC-3 SSCs. In all cases, the project peer reviewer shall not be engaged in design activities for the project. 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. However, an Independent Review of an ML-1 – ML-3 calculation (required by AP-341-605) is not required in addition to a peer review.[14] 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 and analysis (i.e., an SME). 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.*[15] The

[14] In other words, since a project that requires peer review will, by definition, have its calculation(s) independently reviewed, a second Independent Review (required by the LANL calculation procedure) is unnecessary.
[15] For large projects, it is 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

SPRP scope and outline (indicated in Fig. I-2) will include the requirements for Structural Calculations, SSI, and Designated Seismic Systems (ref. 1.5.D, 1.5.E, and 1.6, respectively, herein).

b. 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.).

c. 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[16]
- Adequacy of horizontal and vertical load paths
- Proper inclusion of the geotechnical investigation into the analysis

G. **Specifications:**

1. A construction specification (Spec) for new design and modifications to existing design shall be prepared such that any/all project-specific requirements necessary for the structural design/analysis (of the applicable SSCs) to be achieved/ realized. These requirements shall include all of the applicable content in the section templates provided in the LANL Master Specifications Manual. See ESM Chapter 1 Section Z10 Attachment F for details.

2. The LANL Engineering Standards Program maintains templates for the typical sections needed to assemble a Spec. Most of these templates are intended for use with ML-4, RC-I and RC-II projects and SSCs, respectively[17]. 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 5001 when a project includes only bolted connections; etc.). To seek a variance for the deletion of required content, contact the Engineering Standards Structural POC.

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

Section 03 3001 – Reinforced Concrete
Section 03 3021 – Reinforced Concrete – High Confidence
Section 03 4100 – Precast Structural Concrete
Section 03 6000 – Grout
Section 04 2220 – Reinforced Unit Masonry

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minimizes re-work and surprises at the end of the project.

[16] In addition to being technically appropriate, as indicated herein in para. 1.5.D.2, software must comply with ESM Ch. 1 Sect. Z10 (*paras. 7.3.F.4 and Z1020*).

[17] For higher ML and NPH categories (i.e., ML-1 – ML-3, RC-III and RC-IV, and all NDCs), additional requirements and QA reviews are normally required. The templates include guidance on this in the Author Notes. Additional guidance is in ASCE/SEI-43 Section 9.0, Seismic Quality Provisions.

Section 05 0521 – Post-Installed Concrete Anchors – High Confidence
Section 05 0520 – Post-Installed Concrete and Grouted-Masonry Anchors – Normal Confidence
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 5350 – Gratings and Floor Plates
Section 13 3419 – Metal Building Systems [design and construction]
Section 13 4800 – Sound, Vibration, and Seismic Control
Section 22 0548 – Vibration and Seismic Controls for Plumbing Piping and Equipment
Section 26 0548 – Vibration and Seismic Controls for Electrical Systems
Section 31 2000 – Earth Moving
Section 41 2213.13 – Bridge Cranes
Section 41 2225 – Hoist and Trolleys

*NOTE: Some projects will need other sections, AND the input of/ review by the SEOR in order for these templates to be properly edited (e.g., Division 21 includes some templates involving seismic protection of sprinkler piping, Division 11 includes some templates involving structural aspects of glovebox design and installation, etc.). And, on a related note, some of the templates that are listed can't be properly edited solely by the SEOR (e.g., 13 3419, 13 4800, 22 0548, 26 0548). The proper editing of each and every template referred to in this NOTE requires a multi-disciplinary effort.*

H. **Construction Drawings**

1. Construction drawings for new design and modifications to existing design shall be prepared in accordance with the LANL Drafting Manual. A sheet in the project drawing set shall indicate the documents used for the structural design /analysis (e.g., codes, standards, manuals, etc.) including their edition /revision/ publication date. The typical location for such is the General Structural Notes on sheet S-0001, which also must include the drawing-content requirements of IBC Section 1603.

2. LANL Standard Details exist for some aspects of anchorage design. As with Master Specifications, SEOR must edit these templates.

   Available templates include:

   ST-Z1052 Foundation Support System for Temporary Trailers

   ST-B1081 Metal Stairs [external to buildings]

   ST-D5020 Motor Control Center Anchorage

   ST-F1033 Wall-Mounted Equipment

   ST-TBD on server rack anchorage (future, may be ST-D6010)

## 1.7 Designated Seismic Systems (DSS)

A. DSS are those nonstructural components (i.e., parts of an architectural, electrical, and mechanical system(s) within or without 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) Require design in accordance with Chapter 13 of ASCE 7 and for which the component importance factor, Ip is greater than 1.0 in accordance with ASCE 7 (*Section 13.1.3*).

B. The design, quality and documentation requirements for DSS vary, depending upon 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, while others merely require design for 50% more seismic force /demand (i.e., Ip = 1.5 versus 1.0).

C. For HC 1 – 3 nuclear facilities, the functional requirements of important nonstructural components (safety class/SC, safety significant/SS, and OEITS/other equipment important to safety are the terms used instead of DSS) are normally specified in preliminary hazards assessment documents or documented safety analysis. The design, quality and documentation of such components shall be in accordance with the requirements provided in Section III of this Chapter.

D. For non-nuclear facilities, there may not be associated safety documents that identify DSS and their required functionality. In such cases, it is up to the project design team (e.g., LANL Project Management, SEOR, safety analyst, Cognizant System Engineer, etc.) to identify DSS and their required functionality and document same per the following paragraph. As indicated previously, the use of Ip = 1.5 (to determine the seismic demand) might be all that is required for some DSS, while other DSS might require special certification in addition to 50% more demand. Refer to ASCE 7 (*Ch 13 paras 13.1.3 and 13.2.2*) for more detail. *Guidance: The selection/designation of these special SSCs (and bases 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, and SC, SS, and OEITS components shall be listed in the SSI (per 1.5.E herein), and in the DBD for new construction or modifications to existing SSCs. The basis for the functionality requirement shall also be provided in the DBD, as well as which (if any) of the components require special certification. *Guidance: Also indicating these on the Drawings and possibly System Design Descriptions will aid facility maintenance.*

## 1.8 Codes and Standards

A. Refer to ESM Chapter 1 Section Z10 Code of Record heading for the requirements associated with COR.

B. Refer to ESM Chapter 1 Section Z10 “Conflicts” and Adequacy heading for the requirements pertaining to conflicts between codes, standards, and LANL requirements.

C. Refer to Chapter 1 Section Z10 heading for interpretation, variances, etc. to the LANL Standards.

D. Refer to ESM Chapter 16 Section IBC-GEN, Attachment A for the 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 1.5.C and 1.5.H*). The use of the documents listed under References below (e.g., various codes, standards, reports, papers, etc.) might be necessary in order to comply with this Chapter.

## 2.0 Acronyms and Notations[18]

The following is a list of acronyms, notation, symbols, and shortened titles used in this Chapter. Load-related symbols and factors are defined in Sections II and III.

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

ASME – American Society of Mechanical Engineers

AWS – American Welding Society

BLEVE – Boiling Liquid Expanding Vapor Explosion

BNL – Brookhaven National Laboratory

CE – Carbon Equivalent

CIP – Cast in place

CFR – Code of Federal Regulations

DBD – Design Basis Document

DBE – Design Basis Earthquake

DOD – Department of Defense

DOD-TM - Department of Defense Technical Manual

DOE G – Department of Energy Guideline

DOE M – Department of Energy Manual

DOE O – Department of Energy Order

DOE-STD – Department of Energy Standard

ESM – Engineering Standards Manual

$F_\mu$ – Inelastic Energy Absorption Factor

FDD – Facility Design Description

FEMA – Federal Emergency Management Agency

FIMS – Facility Information Management System

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



[18] The acronyms and notations listed herein are not intended to be only/all of those used in this chapter, nor are they intended to be all of those that might be required by the documents referenced in this chapter. Rather the listing is merely intended to include some of the more commonly used acronyms and notations in the chapter and in the documents referenced in it.

IEEE – Institute of Electrical and Electronics Engineers

IMP – Implementation procedure

ISD – Implementation Support Documents

LANL – Los Alamos National Laboratory

LANS – Los Alamos National Security, LLC

LLNL – Lawrence Livermore National Laboratory

LRFD – Load & Resistance Factor Design

ML – Management Level

NASPEC – North American Specification

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

OEITS – other equipment important to safety

PI – Post-installed

POC – Point of Contact

QA – Quality Assurance

R, $R_p$ – Response Modification Coefficient

RC – Risk Category

RFP – Request for Proposal

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

$S_{DS}$ – Peak Response Spectral Acceleration (0.2 Second Period)

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

TEMA – Tubular Exchanger Manufacturers Association

UFC – Unified Facilities Criteria

UHRS – Uniform Hazard Response Spectrum

$\phi$ – 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 2015]

**Exceedance frequency** – The annual probability of exceeding a given ground motion. For example, at LANL, the 2007 UPSHA[19] has estimated that the mean exceedance frequency associated with a peak ground acceleration of 0.47g is 4 x $10^{-4}$ (i.e., 1/2500) or an average return period of 2,500 years.

**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 ($F_\mu$)** – 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 detail.

**Graded approach** – A process by which the level of analysis, documentation, and actions necessary to comply with requirements are commensurate with: the relative importance to safety, safeguards, and security; the magnitude of any hazard involved; the life cycle stage of a facility; the programmatic mission of a facility; the particular characteristics of a facility; and 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 personnel (workers or the public), damage to an operation, or damage to the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation).

**Hazard categorization** – 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-1027-92 provides guidance and radiological threshold values for determining the hazard category of a facility. DOE-STD-1027-92, Chg 1, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, interprets Hazard Category 1 facilities as Category A reactors and other facilities designated as such by the Program Secretarial Officer. [DOE G 420.1-1A]

**Hazardous material** – Any solid, liquid, or gaseous material that is radioactive, toxic, explosive, flammable, corrosive, or otherwise physically or biologically threatening to health. [DOE G 420.1-1A]

**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. [2015 IBC]

[19] Refer to the URS Corp. document contained in Miscellaneous References herein.

**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 an $LD_{50}$ 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:

**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-1189-2008]. Determination is made through a checklist (see SBP114-1, *Safety Basis Development for Projects, Att 2).*

**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.

**Nonreactor nuclear facility** – Those facilities, activities or operations that involve, or will involve, radioactive and/or fissionable materials in such form and quantity that a nuclear or a nuclear explosive hazard potentially exists to workers, the public, or the environment, but does not include accelerators and their operations and does not include activities involving only incidental use and generation of radioactive materials or radiation such as check and calibration sources, use of radioactive sources in research and experimental and analytical laboratory activities, electron microscopes, and x-ray machines. [DOE G 420.1-1A]

**Other equipment important to safety** – Refer to ESM Chapter 1 Section Z10 definition.

**Peak spectral acceleration** – The maximum acceleration response that a prescribed forcing function can produce in a single degree of freedom oscillator (independent of the natural frequency of the oscillator).

**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). [2015 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. Expansion, adhesive, and undercut anchors are examples of post-installed anchors.

**Response modification coefficient (R)** – A factor used to reduce demand (that would be generated by a commercial structure behaving elastically due to the design-basis earthquake) to target the development of the first significant yield. It accounts for the displacement ductility demand required by the system and the inherent overstrength of the seismic force-resisting system (SFRS). R is a function of the structural system configuration (i.e., the SFRS selected for use dictates the value of R). [adaptation of ASCE 7-10 Expanded Commentary on Ch. 12]

**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** – A category for facilities or SSCs identified by a safety analysis whose importance to safety is to prevent or mitigate potential adverse consequences to the general public or the environment.

**Safety significant** – A category for facilities or SSCs identified by a safety analysis whose importance to safety is a preventative or mitigative function that is a major contributor to defense-in-depth and /or to prevent or mitigate potential adverse consequences to the facility workers or occupants.

**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 second 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.

**Significant chemical or toxicological hazard** – A dose applied to /received by a facility worker, collocated worker, or the public that warrants protection (in the form of SSCs) against the hazard. The NPH categorization of the SSCs (e.g., RC-II, NDC-2, etc.) is based on the dose and the unmitigated consequences of SSC failure. The methodology for the categorization should be consistent with DOE-STD-1189 (i.e., Appendix B for collocated workers and the public, and Appendix C for facility workers) and direction from the responsible program office. [adapted from DOE-STD-1189 Appendices, and DOE-STD-1020]

**Spectral acceleration** – The maximum acceleration response of a single-degree or freedom oscillator of a known frequency, f and viscous damping, $\beta$, subjected to a prescribed forcing function or earthquake ground motion time history.

**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]

**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.

**Toxic** – A chemical falling within any of the following categories [adaptation of 2015 IBC]:

1. Has a median lethal dose ($LD_{50}$) of > 50 mg per kg, but ≤ 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 ≤ 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 $LD_{50}$ 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[20]

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 edition (except for those referenced by building code of record used).

**ACI (American Concrete Institute)**

- ACI 318, "Building Code Requirements for Structural Concrete," Code and Commentary, 2014.
- ACI 349, "Code Requirements for Nuclear Safety Related Concrete Structures," Code and Commentary, 2013
- ACI 349.1R, "Reinforced Concrete Design for Thermal Effects on Nuclear Power Plan Structures," 2007
- TMS 402 and 602/ACI 530 and 530.1/ASCE 5 and 6, "Building Code Requirements for Masonry Structures," and "Specification for Masonry Structures," respectively, 2013.

**AISC (American Institute of Steel Construction)**

- AISC 341 – Seismic Provisions for Structural Steel Buildings, including Supplement 1, 2010.
- AISC 360 – Specification for Structural Steel Buildings, 2010.

[20] 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.).

**AISI (American Iron Steel Institute)**

- AISI S100, "North American Specification for the Design of Cold-formed Steel Structural Members," 2012.
- AISI S110/S1, "Standard for Seismic Design of Cold-Formed Steel Structural Systems—Special Moment Frames," 2007 with Supplement 1, dated 2009 (R2012).
- AISI S200, "North American Standard for Cold-Formed Steel Framing – General Provision," 2012.
- AISI S210,"North American Standard for Cold-Formed Steel Framing - Floor and Roof System Design," (R2012)
- AISI S211/S1, "North American Standard for Cold-Formed Steel Framing - Wall Stud Design," 2007 including Supplement 1, dated 2012 (R2012).
- AISI S212, "North American Standard for Cold-Formed Steel Framing - Header Design," 2007 (R2012).
- AISI S213/S1, "North American Standard for Cold-Formed Steel Framing – Lateral Design," 2007, with Supplement 1, dated 2009 (R2012).
- AISI S214, "North American Standard for Cold-Formed Steel Framing - Truss Design," 2012.

**ANSI/AISC (American National Standards Institute/ American Institute of Steel Construction)**

- ANSI/AISC N690, "Specification for Safety-Related Steel Structures for Nuclear Facilities, 2012.

**ANSI/ANS (American National Standards Institute/American Nuclear Society)**

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

**ASCE (American Society of Civil Engineers)**

- ASCE 4, "Seismic Analysis of Safety Related Nuclear Structures and Commentary," 1998.
- ASCE 7, "Minimum Design Loads for Buildings and Other Structures with Supplement No. 1," 2010.
- ASCE 8, "Specification for the Design of Cold-Formed Stainless Steel Structural Members," 2014.
- ASCE 19, "Standard Guidelines for the Structural Applications of Steel Cables for Buildings," 2009.
- ASCE 41, "Seismic Evaluation and Retrofit of Existing Buildings," 2013.
- ASCE 43, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities," 2005.
- ASCE 59, "Blast Protection of Buildings," 2011.
- ASCE, "Design of Blast Resistant Buildings in Petrochemical Facilities," Task Committee on Blast Resistant Design, 1997.

- ASCE, "Structural Analysis and Design of Nuclear Plant Facilities, Manuals and Reports on Engineering Practice No. 58, 1980.
- ASCE, "Structural Design for Physical Security, State of the Practice," 1999.American Society of Civil Engineers.

**ASME (American Society of Mechanical Engineers)**

- NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications," March 14, 2008 with 2009 addenda.
- QME-1, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants," 2007.

**ASTM International (formerly American Society of Testing Materials)**

- ASTM G 57, "Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method," 2006.

**DOD (Department of Defense)**

- UFC 3-340-01, "Design and Analysis of Hardened Structures for Conventional Weapons Effects," Unified Facilities Criteria (UFC), 2002.
- UFC 4-010-01, "DoD Minimum Antiterrorism Standards for Buildings," Unified Facilities Criteria (UFC), October 8, 2003.
- UFC 4-010-02, "DoD Minimum Antiterrorism Standoff Distances for Buildings, Unified Facilities Criteria (UFC), January 2007.
- UFC 3-340-02, "Structures to Resist the Effects of Accidental Explosions, Unified Facilities Criteria (UFC), December 2008.

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

- 10 CFR Part 830, "Nuclear Safety Management," 2006.
- DOE O 414.1D, "Quality Assurance," 2011, Admin Chg. 1 (2013).
- DOE O 420.1C, "Facility Safety," Change 1 (2015).
- DOE G 420.1-1A, "Nonreactor Nuclear Safety Design Guide for use with DOE O 420.1C, Facility Safety," December 2012.
- DOE M 440.1-1A, "Explosive Safety Manual," 2006.
- DOE-STD-1020, "Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities," December 2012.
- DOE-HDBK-TBD, "Natural Phenomena Hazards Analysis and Design Handbook for DOE Facilities," October 2014 draft.
- DOE-STD-1189, "Integration of Safety into the Design Process," March, 2008.
- DOE/EH-0545, "Seismic Evaluation Procedure for Equipment in the US DOE Facilities," March 1997.

**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, "2015 International Building Code," Copyright 2014, First Printing May 2014.
- IEBC, "2015 International Existing Building Code," Copyright 2014, First Printing May 2014.

**ICC-ES (Evaluation Service) AC (Acceptance Criteria)** (reference only; bases for ES Reports)

- AC01, "Expansion Anchors in Masonry Elements," August 2013
- AC58, "Adhesive Anchors in Masonry Elements," August 2013.
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