Civil/ Structural Engineering

Qualification Standard

Reference Guide

APRIL 2006

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PURPOSE

The purpose of this reference guide is to provide a document that contains the information required for a National Nuclear Security Administration (NNSA) technical employee to successfully complete the Civil/Structural Engineering Functional Area Qualification Standard. In some cases, information essential to meeting the qualification requirements is provided. Some competency statements require extensive knowledge or skill development. Reproducing all the required information for those statements in this document is not practical. In those instances, references are included to guide the candidate to additional resources.

SCOPE

This reference guide has been developed to address the competency statements in the March 2004 edition of DOE-STD-1182-2004, Civil/Structural Engineering Functional Area Qualification Standard. Competency statements and supporting knowledge and/or skill statements from the qualification standard are shown in contrasting bold type, while the corresponding information associated with each statement is provided below it. The qualification standard for the civil/structural engineer contains 11 competency statements. This reference guide will address all the competencies in the standard.

Every effort has been made to provide the most current information and references available as of April 2006. However, the candidate is advised to verify the applicability of the information provided.

Please direct your questions or comments related to this document to the Training and Development Department, NNSA Service Center.

TECHNICAL COMPETENCIES

1. Civil/structural engineering personnel shall demonstrate an expert-level knowledge of the civil/structural engineering related sections and/or requirements of the following DOE Directive and Guides.

- **DOE O 420.1B, Facility Safety**
- **DOE G 420.1-1, Nonreactor Nuclear Safety Design Criteria and Explosive Safety Criteria Guide for use with DOE O 420.1, Facility Safety**
- **DOE G 420.1-2, Guide for the Mitigation of Natural Phenomena Hazards (NPH) for DOE Nuclear Facilities and Non-Nuclear Facilities**

a) Describe the purpose, scope, and application of requirements detailed in the listed Directive and associated Guides.

DOE O 420.1B, Facility Safety
The objectives of DOE O 420.1B are to establish facility and programmatic safety requirements for the Department of Energy (DOE), including the NNSA, for the following:

- Nuclear and explosives safety design criteria
- Fire protection
- Criticality safety
- NPH mitigation
- The system engineer program

Except for the exclusions in paragraph 3c of this Order, this Order applies to all DOE elements with responsibility for DOE-owned or DOE-leased facilities. (See attachment 1 of the Order for a complete list of DOE elements as of the date of the Order. The Order automatically applies to DOE elements created after that date.) Except for the exclusions in paragraph 3c, the requirements in this Order apply to the types of DOE facilities established in the applicability paragraphs of each chapter of this Order. The requirements in this Order are applicable to Department employees. Failure to include comparable requirements in contracts does not relieve Department employees of responsibilities in the Order. The NNSA Administrator will ensure that NNSA employees and contractors comply with their respective responsibilities under this Order.

DOE G 420.1-1, Nonreactor Nuclear Safety Design Criteria and Explosive Safety Criteria Guide for use with DOE O 420.1, Facility Safety
DOE G 420.1-1 provides guidance on the application of the requirements of DOE O 420.1, Facility Safety, section 4.1, Nuclear and Explosives Safety Design Criteria, to nonreactor nuclear facilities and explosives facilities. The following guidelines were established for the development of this Guide.

DOE G 420.1-1 provides guidance on implementing the requirements stated in DOE O 420.1, section 4.1, as they apply to the design aspects for nuclear safety of nonreactor nuclear facilities and the safety requirements for explosives facilities. The guide does not establish requirements.

Safety analyses performed in accordance with DOE-STD-3009-94 establish the identification, function, and performance of safety structures, systems, and components (SSCs), and must be conducted early in the design process.

DOE G 420.1-2, Guide for the Mitigation of Natural Phenomena Hazards (NPH) for DOE Nuclear Facilities and Non-Nuclear Facilities
This DOE implementation guide was approved by the DOE Office of Nuclear Safety Policy and Standards and is available for use by all DOE elements and their contractors.

This document provides guidance in implementing the NPH mitigation requirements of DOE O 420.1, Facility Safety, section 4.4, Natural Phenomena Hazards Mitigation. This guide does not establish or invoke any new requirements. Any apparent conflicts arising from the NPH guidance would defer to the requirements in DOE O 420.1.

This Guide is to be used with DOE O 420.1; the current/latest versions of the NPH DOE Standards 1020, 1021, 1022, 1023, and 1024; and Interagency Committee on Seismic Safety in Construction (ICSSC) standards/guides RP 1, 2.1A, 3, 4, and 5. However, this guide takes precedence over the DOE standards cited above.

b) Discuss how hazard and accident analysis are used in design and evaluation of structures, systems, and components (SSCs).

Technical safety requirements (TSRs) and safety-significant SSCs that are major contributors to worker safety and defense in depth are identified in the hazard analysis.

The accident analysis designates safety-class SSCs and safety controls (i.e., TSRs) as a function of the evaluation guideline.

c) Discuss the classification implication of the following SSCs:

- **Safety class**
- **Safety significant**
- **Safety-related**

Safety Class
The safety-class designation pertains to structures, systems, or components, including primary environmental monitors and portions of process systems, whose preventive and mitigative function is necessary to limit radioactive hazardous material exposure to the public, as determined from the safety analyses.

Safety Significant
The safety-significant designation pertains to structures, systems, and components that are not designated as safety-class SSCs, but whose preventive or mitigative function is a major contributor to defense in depth and/or worker safety as determined from safety analyses.

Safety-Related
The safety-related SSC designation carries with it more stringent controls than the safety-significant SSC designation.

d) Discuss the graded approach methodology that is used by line management to determine an appropriate level of safety provided by civil/structural engineers for SSCs. Include factors that affect the level of safety.

The graded approach should be applied when identifying quality assurance requirements for SSCs; that is, the scope and breadth of the requirements contained within the quality assurance program should be adjusted to reflect the importance of the safety function of the SSCs.

The application of design criteria to safety SSCs entails the selection of appropriate and relevant criteria commensurate with the levels of safety. A purely prescriptive approach to the use of national codes and standards may fail to provide the appropriate level of safety. While national codes and standards will provide guidance and the basic design criteria for most systems, blanket application of such individual codes and standards, or collections thereof, is not necessary. It is necessary to tailor selections of codes and standards for each specific application based on the required safety function.

Note that the safety analysis conducted in accordance with DOE-STD-3009-94 that results in a particular safety classification is also the same analysis used to identify and define design criteria. Safety analyses identify the functions that must be performed, and the conditions under which these functions must perform. These analyses will then result in both the functional safety classification and the identification of the appropriate and relevant criteria to ensure that the prescribed safety functions can be performed.

Categorization and listing of design codes and standards as a portion of the design criteria process are performed to ensure that a correct and appropriate level of engineering design detail and attention is used for each safety classification. The intent is to specify the design codes and standards that will ensure that each safety SSC will perform its required safety function, including due consideration of the intangible areas of influence.

2. Civil/structural engineering personnel shall demonstrate an expert-level knowledge of the requirements of DOE-STD-1020-2002, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities.

a) Describe the purpose, scope, and application of the natural phenomena hazards evaluation and design requirements contained in the above standard.

This natural phenomena hazard (NPH) standard, developed from University of California Radiation Laboratory (UCRL) UCRL-15910, provides criteria for design of new SSCs and for evaluation, modification, or upgrade of existing SSCs so that DOE facilities safely withstand the effects of NPHs such as earthquakes, extreme winds, and flooding.

DOE-STD-1020 provides consistent criteria for all DOE sites across the United States. These criteria are provided as the means of implementing DOE O 420.1 and the associated guides, and Executive Orders 12699 and 12941 for earthquakes.

The design and evaluation criteria presented in this document provide relatively straightforward procedures to evaluate, modify, or upgrade existing facilities or to design new facilities for the effects of NPHs. The intent is to control the level of conservatism in the design/evaluation process such that (1) the hazards are treated consistently, and (2) the level of conservatism is appropriate for structure, system, and component characteristics related to safety, environmental protection, importance, and cost. The requirements for each hazard are presented in chapters of the guide. Terminology, guidelines, and commentary material are included in appendices which follow the requirement chapters.

Prior to applying these criteria, SSCs will have been placed in one of five performance categories (PCs) ranging from PC-0 to PC-4. No special considerations for NPH are needed for PC-0; therefore, no guidance is provided. Different criteria are provided for the remaining four performance categories, each with a specified performance goal. Design and evaluation criteria aimed at target probabilistic performance goals require probabilistic NPH assessments. NPH loads are developed from such assessments by specifying natural phenomena hazard mean annual probabilities of exceedance. Performance goals may then be achieved by using the resulting loads combined with deterministic design and evaluation procedures that provide a consistent and appropriate level of conservatism. Design/ evaluation procedures conform closely to industry practices using national consensus codes and standards so that the procedures will be easily understood by most engineers. Structures, systems, and components comprising a DOE facility are to be assigned to a performance category utilizing the approach described in DOE G 420.1-2 and the performance categorization standard. These design and evaluation criteria are the specific provisions to be followed such that the performance goal associated with the performance category of the SSC under consideration is achieved.

b) Discuss the relationship between the hazard exceedence probability, the target performance goal, and the risk reduction ratio. Describe how the risk reduction ratio is achieved.

Performance goals correspond to probabilities of structure or equipment damage due to NPHs; they do not extend to consequences beyond structure or equipment damage. The annual probability of exceedance of SSC damage as a result of natural phenomena hazards (i.e., performance goal) is a combined function of the annual probability of exceedance of the event, factors of safety introduced by the design/evaluation procedures, and other sources of conservatism. These criteria specify hazard annual probabilities of exceedance, response evaluation methods, and permissible behavior criteria for each NPH and for each performance category such that desired performance goals are achieved for either design or evaluation. The ratio of the hazard annual probability of exceedance and the performance goal annual probability of exceedance is called the risk reduction ratio (RR). This ratio establishes the level of conservatism to be employed in the design or evaluation process. For example, if the performance goal and hazard annual probabilities are the same (RR = 1), the design or evaluation approach should introduce no conservatism. However, if conservative design or evaluation approaches are employed, the hazard annual probability of exceedance can be larger (i.e., more frequent) than the performance goal annual probability (RR > 1). In the criteria, the hazard probability and the conservatism in the design/evaluation method are not the same for earthquake, wind, and flood hazards. However, the accumulated effect of each step in the design/evaluation process is to aim at the performance goal probability values that are applicable to each NPH separately.

c) Compare and contrast the procedures for the seismic design and evaluation of performance category 1 and 2 structures with the procedures used for performance category 3 and 4 structures.

Performance category 1 criteria include no extra conservatism against NPHs beyond that in model building codes that include earthquake, wind, and flood considerations. Performance category 2 criteria are intended to maintain the capacity to function and to keep the SSC operational in the event of NPHs. Model building codes would treat hospitals, fire and police stations, and other emergency-handling facilities in a similar manner as DOE-STD-1020 performance category 2 NPH design and evaluation criteria.

Performance category 3 and 4 SSCs handle significant amounts of hazardous materials or have significant programmatic impact. Damage to these SSCs could potentially endanger worker and public safety and the environment or interrupt a significant mission. As a result, it is very important for these SSCs to continue to function in the event of NPHs so that the hazardous materials may be controlled and confined. For these categories, there must be a very small likelihood of damage due to natural phenomena hazards. DOE-STD-1020 NPH criteria for performance category 3 and higher SSCs are more conservative than requirements found in model building codes, and are similar to Department of Defense (DOD) criteria for high-risk buildings and Nuclear Regulatory Commission (NRC) criteria for various applications as illustrated in table 1. Table 1 illustrates how DOE-STD-1020 criteria for the performance categories defined in DOE O 420.1 and the associated guides compare with NPH criteria from other sources.

Source	**SSC Categorization**			
DOE-STD-1020, DOE NPH Criteria	1	2	3	4
Uniform Building Code	General Facilities	Essential Facilities	--	--
DOD Tri-Service Manual for Seismic Design of Essential Buildings	--	--	High Risk Facilities	--
Nuclear Regulatory Commission	--	--	NRC Fuel Facilities	Evaluation of Existing Reactors

Table 1. Comparison of performance categories from various sources

For performance category 1 SSCs, the primary concern is preventing major structural damage or collapse that would endanger personnel. A performance goal annual probability of exceedance of about 10^{-3} of the onset of significant damage is appropriate for this category. This performance is considered to be consistent with model building codes, at least for earthquake and wind considerations. The primary concern of model building codes is preventing major structural failure and maintaining life safety under major or severe earthquakes or winds. Repair or replacement of the SSC or the ability of the SSC to continue to function after the occurrence of the hazard is not considered.

Performance category 2 SSCs are of greater importance due to mission-dependent considerations. In addition, failure of these SSCs may pose a greater danger to on-site personnel than performance category 1 SSCs because of operations or materials involved. The performance goal is to maintain capacity to function and occupant safety. Performance category 2 SSCs should allow relatively minor structural damage in the event of NPHs. This is damage that results in minimal interruption to operations and that can be easily and readily repaired following the event. A reasonable performance goal is judged to be an annual probability of exceedance of between 10^{-3} and 10^{-4} of structure or equipment damage, with the SSC being able to function with minimal interruption. This performance goal is slightly more severe than that corresponding to the design criteria for essential facilities (e.g., hospitals, fire and police stations, centers for emergency operations) in accordance with model building codes.

Performance category 3 and higher SSCs pose a potential hazard to workers, public safety, and the environment because radioactive or hazardous materials are present. Design considerations for these categories are to limit SSC damage so that hazardous materials can be controlled and confined, occupants are protected, and functioning of the SSC is not interrupted.

The performance goal for performance category 3 and higher SSCs is to limit damage such that DOE safety policy is achieved. For these categories, damage must typically be limited in confinement barriers (e.g., buildings, glove boxes, storage canisters, vaults), ventilation systems and filtering, and monitoring and control equipment in the event of an occurrence of severe earthquakes, winds, or floods. In addition, SSCs can be placed in performance categories 3 or 4 if improved performance is needed due to high-hazard material confinement, danger of criticality, and cost or mission requirements. For performance category 3 SSCs, an appropriate performance goal has been set at an annual probability of exceedance of about 10^{-4} of damage beyond which hazardous material confinement and safety-related functions are impaired.

For performance category 4 SSCs, a reasonable performance goal is an annual probability of exceedance of about 10^{-5} of damage beyond which hazardous material confinement and safety-related functions are impaired. These performance goals approach and approximate, at least for earthquake considerations, the performance goal for seismic-induced core damage associated with the design of commercial nuclear power plants. Annual frequencies of seismic core damage from published probabilistic risk assessments of recent commercial nuclear plants have been summarized in Evaluation of External Hazards to Nuclear Power Plants in the United States — Seismic Hazard, NUREG/CR-5042. This report indicates that mean seismic core damage frequencies ranged from $4x10^{-6}$/year to $1x10^{-4}$/year based on consideration of 12 plants. For 10 of the 12 plants, the annual seismic core damage frequency was greater than $1x10^{-5}$. Hence, the performance category 4 performance goals given in the NPH Guide for DOE O 420.1 are consistent with information contained in the Evaluation of External Hazards to Nuclear Power Plants in the United States.

d) Discuss the intent of the deterministic seismic evaluation and acceptance criteria in the above standard and the alternative evaluation and acceptance criteria.

The basic intention of the deterministic seismic evaluation and acceptance criteria defined in the standard is to achieve less than a 10 percent probability of unacceptable performance for an SSC subjected to a scaled design/evaluation basis earthquake (SDBE) defined by:

$$SDBE = 1.5(SF)(DBE)$$

where SF is the appropriate seismic scale factor.

The seismic evaluation and acceptance criteria presented in the standard have intentional and controlled conservatism such that the target performance goals are achieved. The amount of intentional conservatism has been evaluated such that there should be less than a 10 percent probability of unacceptable performance at input ground motion defined by 1.5SF times the DBE. The following equation is useful for developing alternative evaluation and acceptance criteria which are also based on the target performance goals such as inelastic seismic response analyses.

$$D_{SI} = SF \frac{D_S}{F_\mu}$$

where: $F\mu$ = Inelastic energy absorption factor for the appropriate structural system and elements having adequate ductile detailing

SF = Scale factor related to performance category
= 1.25 for PC-4
= 0.9 for PC-3

To evaluate items for which specific acceptance criteria are not yet developed, such as overturning or sliding of foundations, or some systems and components, this basic intention must be met. If a nonlinear inelastic response analysis that explicitly incorporates the hysteretic energy dissipation is performed, damping values that are no higher than response level 2 should be used to avoid the double counting of this hysteretic energy dissipation which would result from the use of response level 3 damping values.

e) Discuss the evaluation of existing facilities in relation to the design of new facilities for seismic, wind, and flood loads.

Existing facilities should be evaluated for ground motion in accordance with established guidelines. The process of evaluation of existing facilities differs from the design of new facilities in that the as-is condition of the existing facility must be assessed. This assessment includes reviewing drawings and making site visits to determine deviations from the drawings. In-place strength of the materials should also be determined, including the effects of erosion and corrosion as appropriate. The actual strength of materials is likely to be greater than the minimum specified values used for design, and this may be determined from tests of core specimens or sample coupons. On the other hand, erosive and corrosive action and other aging processes may have had deteriorating effects on the strength of the structure or equipment, and these effects should also be evaluated. The inelastic action of facilities prior to occurrence of unacceptable damage should be taken into account because the inelastic range of response is where facilities can dissipate a major portion of the input earthquake energy. The ductility available in the existing facility without loss of desired performance should be estimated based on as-is design detailing rather than using the inelastic energy absorption factors. An existing facility may not have seismic detailing to the desired level and upon which the inelastic energy absorption factors are based.

For new facilities, it is assumed that proper detailing will result in permissible levels of inelastic deformation at the specified force levels, without unacceptable damage. For existing facilities, the amount of inelastic behavior that can be allowed without unacceptable damage must be estimated from the as-is condition of the structure.

The key to the evaluation of existing SSCs is to identify potential failure modes and to calculate the wind speed to cause the postulated failure. A critical failure mechanism could be the failure of the main wind-force resisting system of a structure or a breach of the structure envelope that allows release of toxic materials to the environment or results in wind and water damage to the building contents. The structural system of many old facilities (25 to 40 years old) have considerable reserve strength because of conservatism used in the design, which may have included a design to resist abnormal effects. However, the facility could still fail to meet performance goals if breach of the building envelope is not acceptable.

The weakest link in the load path of an SSC generally determines the adequacy or inadequacy of the performance of the SSC under wind load. Thus, evaluation of existing SSCs normally should focus on the strengths of connections and anchorages and the ability of the wind loads to find a continuous path to the foundation or support system.

Existing SSCs may not be situated above the design basis flood (DBFL). In this case, an SSC should be reviewed to determine the level of flooding, if any, that can be sustained without exceeding the performance goal requirements. This is referred to as the critical flood elevation (CFE). If the CFE is higher than the DBFL, then the performance goals are satisfied.

This situation may not be unique for existing construction. For new construction, it may not be possible to situate all facilities above the DBFL, in which case other design strategies must be considered. For example, it may be possible to wet proof an SSC, thus allowing some level of flooding to occur.

For each SSC, there is a critical elevation, which if exceeded, causes damage or disruption such that the performance goal is not satisfied. The CFE may be located

- below grade because of the structural vulnerability of exterior walls or instability due to uplift pressures
- at the elevation of utilities that support SSCs
- at the actual base elevation of an SSC

Typically, the first-floor elevation or a below-grade elevation (i.e., foundation level) is assumed to be the critical elevation. However, based on a review of an SSC, it may be determined that greater flood depths must occur to cause damage (e.g., critical equipment or materials may be located above the first floor). If the CFE for an SSC exceeds the DBFL, then the performance goal is satisfied. If the CFE does not exceed the DBFL, options must be considered to harden the SSC, change the performance category, etc.

For performance categories 3 and 4, the performance goals require that little or no interruption of the facility operations should occur. This is an important consideration, since the assessment of the CFE must consider the impact of the flood on operations (i.e., uninterrupted access) as well as the damage to the physical systems.

f) Provide an overall description of the uniform approach used in the above standard for the wind load determination for straight, hurricane, and tornado winds.

This section of the standard presents a uniform approach to wind load determination that is applicable to the design of new and the evaluation of existing SSCs. A uniform treatment of wind loads is recommended to accommodate straight, hurricane, and tornado winds. SSCs are first assigned to appropriate performance categories by application of DOE-STD-1021. Criteria are recommended such that the target performance goal for each category can be achieved. Procedures according to the wind load provisions of the current version of American Society of Civil Engineers, ASCE-7, are recommended for determining wind loads produced by straight, hurricane, and tornado winds. The straight wind design basis is derived from the national wind map in figure 6-1 of ASCE-7, except in a few cases where hazard models for DOE sites published in Natural Phenomena Hazards Modeling Project: Extreme Wind/Tornado Hazard Models for Department of Energy Sites are used to establish site-specific criteria for these few DOE sites. For other sites, the wind/tornado hazard data shall be determined in accordance with DOE-STD-1023. The tornado hazard is based on recent studies conducted for various NNSA sites. Use of the same methodology is recommended for use by sites other than NNSA sites, and the tornado hazard curves should be developed for sites with a tornado hazard.

The performance goals established for performance categories 1 and 2 are met by model codes or national standards. These criteria do not account for the possibility of tornado winds because wind speeds associated with straight winds typically are greater than tornado winds at annual exceedance probabilities greater than approximately $1x10^{-4}$.

Since model codes specify winds at probabilities greater than or equal to $1x10^{-2}$, tornado design criteria are specified only for SSCs in performance categories 3 and higher, where hazard exceedance probabilities are less than $1x10^{-2}$.

In determining wind design criteria for performance categories 3 and higher, the first step is to determine if tornadoes should be included in the criteria. The decision can be made logically on the basis of geographical location using historical tornado occurrence records.

However, since site-specific hazard assessments are available for the DOE sites, a more quantitative approach can be taken. The annual exceedance probability at the intersection of the straight wind and tornado hazard curves is used to determine if tornadoes should be a part of the design criteria. If the exceedance probability at the intersection of the curves is greater than or equal to $2x10^{-5}$, then tornado design criteria are specified. By these criteria, tornado wind speeds are determined at $2x10^{-5}$ for PC-3 and $2x10^{-6}$ for PC-4. If the exceedance probability is greater than $2x10^{-5}$, only the effects of straight winds or hurricanes need be considered. For straight winds and hurricanes, wind speeds are determined at $1x10^{-3}$ for PC-3 and $1x10^{-4}$ for PC-4.

g) Describe the flood design criteria for performance categories 1–4 and the essential items to be included in the design procedure for floods.

The flood design criteria consider the design of SSCs for regional flood hazards (i.e., river flooding) and local precipitation that affect roof design and site drainage.

Table 2 provides the flood criteria for performance categories 1 through 4. The criteria are specified in terms of the flood hazard input, hazard annual probability, design requirements, and emergency operation plan requirements. The hazard annual probability levels in table 2 correspond to the mean hazard.

Item	**Performance Category**			
	1	**2**	**3**	**4**
Flood Hazard Input	Flood insurance studies or equivalent input	Site probabilistic hazard analysis	Site probabilistic hazard analysis	Site probabilistic hazard analysis
Mean Hazard Annual Probability	2×10^{-3}	5×10^{-4}	1×10^{-4}	1×10^{-5}
Design Requirements	Applicable criteria shall be used for building design for flood loads, roof design, and site drainage. The design of flood mitigation systems shall comply with applicable standards.			
Emergency Operations Plans	Required to evacuate on-site personnel if facility is impacted by the DBFL.	Required to evacuate on-site personnel and to secure vulnerable areas if site is impacted by the DBFL.	Required to evacuate on-site personnel not involved in essential operations, and to provide for an extended stay for personnel who remain. Procedures must be established to secure the facility during the flood such that operations may continue following the event.	

Table 2. Flood criteria summary (from DOE-STD-1020-2002)

Evaluation of the flood design basis for SSCs consists of the following:

- Determination of the DBFL for each flood hazard as defined by the hazard annual probability of exceedance and applicable combinations of flood hazards
- Evaluation of the site storm water management system (e.g., site runoff and drainage, roof drainage)
- Development of a flood design strategy for the DBFL that satisfies the criteria performance goals (e.g., build above the DBFL, harden the facility)
- Design of civil engineering systems (e.g., buildings, buried structures, site drainage, retaining walls, dike slopes) to the applicable DBFL and design requirements

h) Describe the essential items that should be included in the design documentation for all natural phenomena hazards considered.

It is the policy of DOE to design, construct, and operate DOE facilities so that workers, the general public, and the environment are protected from the impacts of natural phenomena hazards on DOE facilities. NPH safety requirements are briefly described in 10 CFR 830, Nuclear Safety Management, and DOE O 420.1B, Facility Safety. The associated guides (DOE G 420.1-2, Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-Nuclear Facilities; DOE G 420.1-1, Nonreactor Nuclear Safety Design Criteria and Explosive Safety Criteria Guide for use with DOE O 420.1 Facility Safety; and

DOE G 440.1-5, Fire Safety Program for use with DOE O 420.1 and DOE O 440.1) describe acceptable methods to meet these requirements in a consistent manner throughout DOE, which include (1) providing a safe work place, (2) protecting against property loss and damage, (3) maintaining operation of essential facilities, and (4) protecting against exposure to hazardous materials during and after occurrences of natural phenomena hazards. There is an established hierarchy in the set of documents that specify NPH requirements. In this hierarchy, 10 CFR 830 is the highest authority (for nuclear facilities only), followed by DOE O 420.1B. The next set of controlling documents consists of the associated guides followed by the set of NPH standards (DOE-STDS-1020 through 1023). The NPH requirements have been developed to provide the necessary information that assesses the NPH safety basis for DOE facilities, which is documented in documented safety analyses (DSAs) if available. Title 10 CFR 830 and the guidance provided in the associated standard, DOE-STD-3009, prescribe the use of a graded approach for the effort to be expended in safety analysis and the level of detail required to be presented in the associated documentation. DOE NPH mitigation requirements are also consistent with the National Earthquake Hazards Reduction Program (NEHRP) and Executive Orders 12699 and 12941.

The overall approach for NPH mitigation is consistent with the graded approach embodied in the facility DSA. The application of NPH design requirements to SSCs is based on the life-safety or the safety classifications for the SSCs as established by the safety analysis. The application of the most rigorous design requirements should be limited to those SSCs classified by safety analysis as safety-class or safety-significant consistent with DOE-STD-3009-94. Although DOE-STD-3009-94 is specifically applicable to non-reactor nuclear facilities, it is DOE's intention to apply DOE-STD-3009-94 definitions for "safety-class" and "safety-significant" to all nuclear non-reactor and other hazardous facilities. Mission importance and economic considerations should also be used to categorize SSCs that require NPH design.

Once the SSCs have been classified, DOE O 420.1B and the associated guides specify the NPH requirements to ensure that the SSCs are adequately designed to resist NPH. The NPH requirements use a graded approach to provide a reasonable level of NPH protection for the wide variety of DOE facilities. A graded approach is one in which various levels of NPH design, evaluation, and construction requirements of varying conservatism and rigor are established, ranging from common practice for conventional facilities to practices used for more hazardous critical facilities.

Four DOE standards (DOE-STDS-1020, 1021, 1022, and 1023) have been developed to provide specific acceptance criteria for various aspects of NPH to meet the requirements of DOE O 420.1B and the associated guides. These NPH standards should be used in conjunction with other pertinent documents which provide more detailed methods on specific NPH design and evaluation subjects, such as DOE guidance documents, consensus national standards, model building codes, and industry accepted codes and specifications.

DOE-STD-1020 was developed from UCRL-15910. The standard provides criteria for design of new SSCs and for evaluation, modification, or upgrade of existing SSCs so that DOE facilities safely withstand the effects of NPHs such as earthquakes, extreme winds, and flooding.

DOE-STD-1020 provides consistent criteria for all DOE sites across the United States. These criteria are provided as the means of implementing DOE O 420.1B and the associated guides, and Executive Orders 12699 and 12941 for earthquakes.

The design and evaluation criteria presented in the standard provide procedures to evaluate, modify, or upgrade existing facilities, or to design new facilities, for the effects of NPHs. The intent is to control the level of conservatism in the design/evaluation process such that (1) the hazards are treated consistently, and (2) the level of conservatism is appropriate for SSC characteristics related to safety, environmental protection, importance, and cost. The requirements for each hazard are presented in chapters of the standard. Terminology, guidelines, and commentary material are included in appendices that follow the requirement chapters.

Prior to applying the criteria, SSCs are placed in one of five performance categories ranging from PC-0 to PC-4. No special considerations for NPH are needed for PC-0; therefore, no guidance is provided. Different criteria are provided for the remaining four performance categories, each with a specified performance goal. Design and evaluation criteria aimed at target probabilistic performance goals require probabilistic NPH assessments. NPH loads are developed from such assessments by specifying the NPH mean annual probabilities of exceedance. Performance goals may then be achieved by using the resulting loads combined with deterministic design and evaluation procedures that provide a consistent and appropriate level of conservatism. Design/evaluation procedures conform closely to industry practices using national consensus codes and standards so that the procedures will be easily understood by most engineers. SSCs comprising a DOE facility are assigned to a performance category using the approach described in DOE G 420.1-2 and the performance categorization standard. These design and evaluation criteria are the specific provisions to be followed such that the performance goal associated with the performance category of the SSC under consideration is achieved. For each category, the criteria include the following steps:

1. NPH loads are determined at specified NPH probabilities as per DOE-STD-1023.
2. Design and evaluation procedures are used to evaluate SSC response to NPH loads.
3. Criteria are used to assess whether or not computed response in combination with other design loads is permissible.
4. Design detailing provisions are implemented so that the expected performance during a potential NPH occurrence will be achieved.
5. Quality assurance and peer review are applied using a graded approach.

For each performance category, target performance goals are provided in appendices B and C in terms of mean annual probability of exceedance of acceptable behavior limits. In item 1, the annual probability of exceedance of an NPH parameter such as ground acceleration, wind speed, or water elevation is specified. The level of conservatism in items 2, 3, 4, and 5, above, is controlled such that sufficient risk reduction from the specified NPH probability is achieved so that the target performance goal probability is met. DOE-STD-1020 provides an integrated approach combining definition of loading due to NPHs, response evaluation methods, acceptance criteria, and design detailing requirements.

Performance goals and NPH levels are expressed in probabilistic terms; design and evaluation procedures are presented deterministically. Design/evaluation procedures specified in the standard conform closely to common standard practices so that most engineers will readily understand them. The intended audience for these criteria is the civil/structural or mechanical engineer conducting the design or evaluation of facilities. These NPH design and evaluation criteria do not preclude the use of probabilistic or alternative design or evaluation approaches if these approaches meet the specified performance goals.

i) Demonstrate the ability to review structural analysis plans and approaches to ensure that methods and models are being properly defined.

j) Conduct a review of design/evaluation analysis and verify that methods used and calculation results are appropriate.

Elements "i" and "j" are performance-based competencies. The qualifying official will evaluate the completion of these competencies.

3. Civil/structural engineering personnel shall demonstrate a working-level knowledge of the civil/structural engineering related sections and/or requirements of the following DOE Standards:

- **DOE-STD-1021-93, Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components**
- **DOE-STD-1022-94, Natural Phenomena Hazards Characterization Criteria**
- **DOE-STD-1023-95, Natural Phenomena Hazards Assessment Criteria**

a) Describe the purpose, scope, and application of the requirements detailed in the listed standards.

DOE-STD-1021-93, Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Componenets
Purpose. This DOE standard gives design and evaluation criteria for NPH for selecting performance categories of SSCs in accordance with the requirements specified in DOE O 420.1B and the associated implementation guides. It also recommends procedures for consistent application of the determined performance category criteria so that the DOE review and approval process is simplified.

Scope. The criteria and recommendations presented in this standard shall apply to performance categorization of SSCs for the purpose of mitigating natural hazards phenomena in all DOE facilities covered by DOE O 420.1B.

Application. The provisions of this standard apply only to NPH evaluation of SSCs. Application of basic categorization guidelines presented in this standard will establish the preliminary performance category of SSCs. The procedural steps presented are general recommendations for NPH performance categorization only, and are not intended to provide procedures for performing facility safety reviews or accident analyses.

DOE-STD-1022-94, Natural Phenomena Hazards Characterization Criteria
Purpose. This DOE standard provides criteria for site characterization to provide site-specific information for implementing the requirements of DOE O 420.1B and the associated

implementation guides. Additionally, the purpose of this standard is to develop a site-wide database related to NPH that should be obtained to support individual DSAs. Appropriate approaches are outlined to ensure that the current state-of-the-art methodology is being used in the site characterization.

Scope. The criteria and recommendations in this standard shall apply to site characterization for the purpose of mitigating NPH in all DOE facilities covered by DOE O 420.1B. Criteria for site characterization not related to NPH are generally not included in this document unless they are deemed necessary for clarification. General and detailed site characterization requirements are provided in the areas of meteorology, hydrology, geology, seismology, and geotechnical studies.

Application. The criteria and recommendations in this standard shall apply to site characterization for the purpose of mitigating the effects of NPH in all DOE facilities covered by DOE O 420.1B.

DOE-STD-1023-95, Natural Phenomena Hazards Assessment Criteria
Purpose. The purpose of this standard is to provide criteria for natural phenomena hazard assessments to construct hazard curves. The mean hazard curve shall be used to determine the design basis NPH event for design and/or evaluation of DOE facilities. This standard provides specific criteria applicable to various natural phenomena hazards including seismic, wind and tornado, and flood hazards. This standard also provides criteria for determining ground motion parameters for the DBE, and criteria for determining the acceptable design response spectral shape.

Scope. Specific criteria applicable to seismic hazard assessment are provided in section 3.1 of this standard. Specific criteria applicable to wind hazard assessment are provided in section 3.2 of this standard. Specific criteria applicable to flood hazard assessment are provided in section 3.3 of this standard. Criteria for natural phenomena hazard assessments applicable to other natural phenomena hazards such as volcanic ash, lightning, and snow are not provided in this standard. Therefore, the minimum criteria necessary for these and other NPH assessments of DOE facilities should be derived from relevant consensus national codes and standards, or appropriate local codes wherever available. General guidelines for acceptable methods to meet the NPH assessment criteria can be found in appendix A.

Application. The criteria given in this standard should be used in conjunction with other DOE Orders, guides, and standards as listed in section 2 of this standard and with other pertinent national consensus codes and standards such as the model building codes.

DOE technical standards such as this technical standard do not establish requirements. However, all or part of the provisions in a technical standard can become requirements under the following circumstances:

- The provisions are explicitly stated to be requirements in a DOE requirements document.
- The organization makes a commitment to meet a standard in a contract or in a plan required by a DOE requirements document (such as in an implementation plan).

b) Explain the linkage between safety classification of SSCs and assignment of performance categories.

The concept of performance categories with corresponding target probabilistic performance goals has been developed to assist in applying the graded approach to NPH design and evaluation. Each SSC in a DOE facility is assigned to one of five performance categories depending on its safety importance.

Each performance category is assigned a target performance goal in terms of the probability of unacceptable damage due to natural phenomena. The unacceptable level of damage is related to the safety function of the SSCs during and after the occurrence of NPH. The target performance goals given in appendices B and C of DOE-STD-1020-94 have been prescribed to be substantially equivalent with the goals of model building code provisions for SSCs in PC-1 and PC-2 and the goals intended by commercial nuclear power plant seismic criteria for SSCs in PC 4. DOE-STD-1020-94 (appendices B and C) also provides details about the graded performance of SSCs in various performance categories, including the extent of expected damage, deformation, cracking, and yielding of SSCs in PC-1 to PC-4.

The relative probabilities and consequences of potential damage or failure of SSCs making up DOE facilities are accounted for by providing several sets of NPH design/evaluation provisions with increasing conservatism (i.e., producing a decrease in probability of damage or of failure to perform intended safety function). Mean annual exceedance probabilities for various PCs to accomplish these target performance goals for different NPHs are given in DOE-STD-1020-94.

This graded approach provides a different level of NPH provisions for each performance category, as described in the following paragraphs.

PC-0 SSCs are those for which no consideration of natural phenomena is necessary; that is, natural phenomena hazards are not an issue.

For PC-1 SSCs, the primary concern is preventing major structural damage, collapse, or other failure that would endanger personnel (life safety). Repair or replacement of the SSC or the ability of the SSC to continue to function after the hazard has occurred is not considered.

PC-2 SSCs are meant to ensure the operability of essential facilities (e.g., fire house, emergency response centers, hospitals) or to prevent physical injury to in-facility workers. When safety analyses determine that local and limited confinement of low-hazard materials is required for worker safety, PC-2 designation should be used for the SSCs involved. In these cases, PC-2 designation may apply to SSCs, such as drums, packaging, glove-boxes, local HEPA filters, air flow control systems (ventilation and dampers), room air monitors, alarms, corridors, stairways and doors, pager systems, and emergency lighting important to evacuation. Design of PC-2 SSCs should result in limited structural damage from design basis natural phenomena events to ensure minimal interruption to facility operation and repair following the event. PC-2 performance is analogous to the design criteria for an essential facility (e.g., hospitals, fire and police stations, centers for emergency operations) in the model building codes.

PC-3 SSCs are those for which failure to perform their safety function could pose a potential hazard to public health, safety, and the environment because radioactive or toxic materials are present and could be released from the facility as a result of that failure. PC-3 SSCs would prevent or mitigate criticality accidents, chemical explosions, and events with the potential to release hazardous materials outside the facility. Design considerations for these categories are to limit facility damage as a result of design basis natural phenomena events so that hazardous materials can be controlled and confined, occupants are protected, and the functioning of the facility is not interrupted. When safety analyses determine that local confinement of high-hazard materials is required for worker safety, PC-3 designation may be appropriate for the SSCs involved. PC-3 NPH provisions are consistent with those used for reevaluation of commercial plutonium facilities with conservatism in between that of model building code requirements for essential facilities and civilian nuclear power plant requirements.

PC-4 SSCs are also those for which failure to perform their safety function could pose a potential hazard to public health, safety, and the environment because radioactive or toxic materials are present in large quantities and could be released as a result of that failure. However, PC-4 SSCs are designated as reactor-like in that the quantity of hazardous materials and energetics present is similar to that of a large category A reactor (>200 MWt). These types of SSCs are associated with facilities having quantities and forms of hazardous materials and sufficient energy sources capable of producing significant off-site effects unless the SSCs withstand NPH effects. The DSA results provide an essential element in identifying specific SSCs for which a failure could result in a release as large as the potential release from a large reactor. Design considerations for this category are to limit facility damage from design basis natural phenomena events so that hazardous materials can be controlled and confined, occupants are protected, and essential functions of the facility are not interrupted. PC-4 seismic provisions are similar to those used for reevaluation or design of civilian nuclear power plants, where off-site release of hazardous material must be prevented.

c) Discuss system interaction effects and how they influence the assignment of performance categories to SSCs.

An SSC that has been placed in a preliminary performance category in accordance with the basic categorization guidelines of subsection 2.4 of DOE-STD-1021 shall have appropriate additional NPH mitigation requirements as provided in the paragraphs that follow if its behavior by itself, or the multiple common cause behavior of it with other SSCs, may adversely affect the performance of another SSC (designate it as target). These additional requirements will depend on the type of source behavior that causes adverse interaction with the target during or following an NPH event. System interaction may be between one SSC and another SSC or one facility as a whole with another facility, in which case similar consideration should be given for design of the facilities.

If the source behavior that causes adverse interaction is within the acceptable behavior limits of the source, i.e., if the adverse interaction occurs before source failure, adequate measures should be taken to preclude such interaction and to ensure that the performance goal for the target is preserved. For example, assume that the postulated seismic deflection of a PC-1 cabinet (source) is within its own acceptable behavior limits, but the cabinet can potentially impact and cause the failure of a PC-2 fire-suppression component (target). To prevent this adverse interaction, the cabinet support system or the cabinet itself can be stiffened/strengthened in such a way that the calculated deflection of the cabinet towards the target, when subjected to a seismic level corresponding to the performance category of the target, is less than the available clearance by a factor equal to the applicable design margin for the target. Alternatively, a barrier can be provided to preclude the adverse interaction and to protect the target. Such a barrier should be designed to withstand NPH effects combined with the interaction effects from the source (in this case the impact from the PC-1 cabinet). To ensure that the target performance goal is preserved, the barrier should be placed in the same performance category as the target (in this case PC-2).

If the adverse interaction is possible only after the source fails or exceeds its acceptable behavior limits, either of the following two requirements shall be met to preclude adverse interaction:

- The source shall have additional NPH requirements corresponding to the performance category of the target if the failure potential of the target, given the failure of the source, is assessed to be high. However, these additional requirements can be restricted to the source failure mode related to the adverse interaction effects. If the target failure potential is assessed to be low, no additional NPH mitigation requirements need to be applied.
- Adequate measures shall be taken to preclude adverse interaction and to ensure that the performance goal for the target is preserved. Examples of acceptable measures are stiffening/strengthening the source structure or support system, relocating the source and/or the target, installing barriers, installing new components, modifying existing components, or any combination of these measures.

If the behavior or failure of a source can adversely affect the performance of more than one target, the source shall have additional NPH requirements corresponding to the highest performance category that is determined by applying the rules provided DOE-STD-1021-93.

d) Discuss site characterization requirements for:

- **Meteorology**
- **Hydrology**
- **Geology and Seismicity**
- **Geotechnical Studies**

Meteorology

The sources of meteorological hazards include wind conditions, precipitation, and temperature changes. Meteorological data to be collected includes: wind speeds and direction, precipitation and rainfall records, and air temperature. The extent of meteorological data needed depends on the performance categories of facility SSCs.

For sites containing facilities with SSCs in PC-1 or PC-2, it is sufficient to use results of previous probabilistic wind hazard studies, if available, or to use information provided in model building codes or national consensus standards such as ANSI/ASCE 7. For sites containing facilities with SSCs in PC-3 or PC-4, and for which no up-to-date site-specific probabilistic wind hazard studies have been performed in accordance with specifications in DOE-STD-1023-95, site-specific characterization criteria are provided in the following paragraphs.

Regional climatology description and history. The general climate of the region should be described with respect topographic influences, general airflow patterns, temperature and humidity, precipitation, and relationships between regional atmospheric conditions and local meteorological conditions.

Regional extreme climatology history should be reported with dates, event descriptions, and related information on their effects.

Wind data collection. A distinction is made between three types of wind: straight winds, hurricane winds, and tornado winds. Site-specific characterization needs to be performed for each type of windstorm.

Straight winds. Straight winds are non-rotating winds such as those found in thunderstorms. This type of wind data should be collected for locations near the site. On-site data shall be collected, if available, and if they meet the following criteria:

- There should be at least 10 continuous years of annual extreme wind speed records with elevations at which they were obtained.
- The type of wind speed recorded over time shall be specified (fastest mile, peak, etc.).
- The recorded wind speeds should be obtained from anemometers located in flat, open terrain.
- The elevations at which wind speeds are recorded shall be 10 m (33 feet) above ground.

If the last two conditions are not met, the recorded wind speeds should be corrected using accepted wind boundary layer conversion methods. It is possible to use data from on-site stations for which less than 10 years of records exist if there are a sufficient number of historical records from nearby stations within the same topographic environment.

In absence or lack of sufficient on-site wind record data, it is possible to use data collected by federal agencies for stations close to the site (generally within 50 km) and located in a same wind environment (stations close to but separated by mountainous ranges from the site do not qualify). Such data have been collected at 129 weather stations within the continental U.S. and at coastal locations. In addition, wind speed records for more than 400 stations can be retrieved from the National Climatic Center.

Hurricane winds. Hurricane winds are rotating winds that can top 240 km/hr (150 mph). Hurricane-prone regions of the continental U.S. are located along the coastal areas. There are very few wind speed records from hurricanes at coastal locations. Therefore, for sites in hurricane-prone areas and for which no up-to-date site-specific probabilistic hurricane wind hazard analysis has been performed in accordance with DOE-STD-1023-95, the meteorological data of past historical hurricanes within 400 km (250 miles) from the site shall be collected, which include the following:

- Track locations (longitude and latitude) with landfall locations
- Intensity
- Reported minimal central pressure near the coast or at landfall points
- Reported maximum wind speeds near the coast or at landfall points
- Reported forward velocity and direction near the coast or at landfall points

Systematic sources of data on hurricanes are available from the National Hurricane Center of Miami and the National Severe Storm Center and the Meteorological Society of America.

Tornado winds. Tornado winds are violently rotating winds which can reach speeds in excess of 320 km/hr (200 mph). Midwestern states, especially Oklahoma and its neighboring states, have the greatest number of historically recorded tornadoes.

For sites containing facilities with SSCs in only PC-1 or PC-2, tornado data need not be considered. For sites containing facilities with SSCs in PC-3 or PC-4, and for which no up-to-date site-specific probabilistic tornado wind hazard analysis has been performed in accordance with DOE-STD-1023-95, the following data shall be collected for tornadoes striking within 500 km (310 miles) of the site:

- Tornado track (latitude and longitude)
- Intensity
- Length and width

Systematic sources of data on tornadoes are available from the National Severe Storms Forecast Center and the National Oceanographic and Atmospheric Administration.

Precipitation and snowfall data. For sites containing facilities with SSCs in only PC-1 or PC-2, it is sufficient to use model building codes or national consensus standards, or rainfall intensity frequency-duration curves from hydrometeorological reports from the National Weather Service.

For sites containing facilities with SSCs in PC-3 or PC-4, and for which no up-to-date site-specific probabilistic flood hazard analysis has been performed in accordance with DOE-STD-1023-95, the following data shall be collected:

- Monthly and annual summaries (including averages and extremes) of precipitation at or near the site
- Monthly and annual summaries (including averages and extremes) of snowfall and water contents at or near the site

Hydrology

The sources of hydrologic hazard include stream flooding, flood runoff, flood drainage, dam failure, levee or dike failure, storm surge, tsunami, seiche, wave action, volcano-induced hydrologic effects (e.g., rapid snow pack melting, mudflows that cause dam failure, and excessive siltation/sedimentation), and groundwater rise or decline. Collection of the characteristic data of these sources which could impact the site shall be performed. The impact of these hydrologic hazards shall be defined with respect to their proximity to the site and its elevation.

The extent of the data to characterize potential sources of flooding depends on the performance categories of the structures. For sites containing facilities with SSCs in PC-1 or PC-2, it is sufficient to use results of previous site-specific probabilistic flood hazard studies (e.g., McCann and Boissonnade, 1988a, 1988b, and 1991), if available, or to utilize information provided in the flood insurance studies by the Federal Emergency Management Agency (FEMA) and any other reliable hydrology resource.

For sites containing facilities with SSCs in PC-3 or PC-4, and for which no site-specific probabilistic flood hazard studies have been performed in accordance with specifications in DOE-STD-1023-95, site-specific characterization criteria are provided in the following paragraphs.

Hydrological data collection. The location, size, shape, and other hydrologic characteristics of streams, lakes, shore regions, and groundwater environments influencing the site should be described. Additionally, there should be a quantitative description of existing and planned water control structures that may influence the hydrologic conditions at the site.

The hydrologic events that are potential sources of flooding for the site should be determined. The hydrologic events considered should include those listed on the following table.

Hydrologic Event	Sources
River flooding	Precipitation, snow melt, debris jams, ice jams, rapid sedimentation (volcano)
Dam failure	Earthquake, flood, volcano, landslide, static failure
Levee or dike failure	Earthquake, flood, static failure, upstream dam failure, landslide, volcano
Flood runoff/drainage	Precipitation, ponding, drainage capacity
Tsunami	Earthquake
Seiche	Earthquake, wind
Storm surge	Hurricane
Wave	Wind, Tsunami
Groundwater	Precipitation, ponding, flooding, drought and over pumping
Mudflows	Volcano, earthquake
Subsidence-induced flooding	Fluid extraction

Table 3. Hydrologic events

The necessary hydrologic event data should be collected to determine the flood sources, and used to evaluate potential flood hazards at the site.

This data collection process is iterative. Initial data requirements focus on the need to identify potential sources of hydrologic hazards to the site. For each flood hazard, a summary of hazard characteristics shall be provided. Only the worst-case flood hazard should be summarized in detail. The summary should include the proximity of the potential source of flood hazard to the site and include applicable reasons why certain sources are unlikely or present negligible consequences for the site.

For hydrologic events that can pose a hazard, additional data shall be required to perform hazard assessment. Data sources should include, but not be limited to the following:

- Walkdown of site and vicinity
- Topographic maps (site-specific and regional)
- Aerial photographs
- Hydrologic data (i.e., stream gage data)
- Historical flood event reports

- FEMA flood insurance studies
- Dam break studies

The sources of available data include past site-specific hydrological studies by DOE and DOE-sponsored contractors, studies performed by other government agencies (e.g., U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, U.S. Geological Survey, Flood Insurance Administration, Department of Water Resources, Agricultural Department, National Weather Service), universities, and private organizations.

Geology and Seismicity

The seismic-related hazards include site earthquake ground shaking, tectonic site deformation (fault rupture and associated tectonic surface deformation), ground failure induced by ground shaking (including liquefaction), differential compaction and land sliding, and earthquake-induced flooding. Other geological hazards to be addressed include non-tectonic site deformation and volcanic hazards.

The extent of the investigation to characterize the seismic-related hazards depends on the performance categories of the structures, the geological and seismologic environment of the site region, and the local soil conditions at the site. Geologists, seismologists, geophysicists, and geotechnical engineers with the knowledge and experience for fulfilling the requirements stated in federal regulations and standards (e.g., 10 CFR 100, subparts A and B, NRC R.G. 1.165, NRC R.G. 1.132, DOE O 420.1B) for site characterization for DOE facilities should be consulted for defining the program of the investigation. Site experts who are knowledgeable about the geological, seismological, and geotechnical aspects of site characterizations should also be consulted.

For sites containing facilities with SSCs only in PC-1 or PC-2, it is sufficient to use results of previous site-specific probabilistic seismic hazard studies, if available, or to use information provided in the model building codes or national consensus standards (e.g., FEMA 368, IBC 2003). For sites containing facilities with SSCs in PC-3 or PC-4, and for which no site-specific probabilistic seismic hazard studies have been performed in accordance with DOE-STD-1023-95, site-specific characterization criteria are provided in the following paragraphs.

Seismic sources. Seismic sources define areas where future earthquakes are likely to occur. All seismic sources in the site region that could cause significant ground shaking at the site should be identified and characterized. Seismic sources may include seismogenic sources and capable tectonic sources. A seismogenic source is a portion of the earth that is considered to have uniform seismicity. A seismogenic source may be a well-defined tectonic structure or simply a large region of diffuse seismicity. A seismogenic source would not cause surface displacement. A capable tectonic source is a tectonic structure that can generate earthquakes and ground deformation. Geological, geophysical, and seismological investigations provide the information needed to identify and characterize source parameters, including the location, size, and geometry of the seismic sources, maximum earthquake, and frequency of occurrence of earthquakes of various magnitudes (earthquake recurrence).

The potential for fault rupture and associated tectonic surface deformation at the site (e.g., tilting or folding) should also be evaluated. The amount and style of deformation and the likelihood of future displacement should also be characterized for any Quaternary (approximately last 2 million years) faults in close proximity to the site (within about 8 km or 5 miles).

Seismic source identification data. All seismic sources that could contribute significantly (more than 5 percent to the total hazard) to a probabilistic ground motion assessment, as described in DOE-STD-1023-95, should be identified and characterized with respect to their location and geometry relative to the site. The following items shall be considered in collecting data for seismic source identification:

- Area of investigations. The boundaries of the region to be investigated for seismic hazards depend primarily on whether distant seismic sources could cause earthquakes large enough to govern or contribute significantly to the ground motion at the site, and on the performance category of facility SSCs within the site. The sizes of the regions to be investigated should be large enough to adequately characterize the hazards that can affect the site. The choice of an area and justification of that choice is the responsibility of the investigator. The results of a scoping hazard study may be used to aid in determining the area of investigation of the site. Additionally, the Senior Seismic Hazard Analysis Committee provides a methodology for characterizing seismic sources linked to completing a probabilistic seismic hazard analysis (see DOE-STD-1023-1995). If such a study clearly shows that the near site features dominate the hazard, more extensive site investigations should be made in the near field. For investigations of sites containing facilities with SSCs in PC-4 such as nuclear reactors, U.S. NRC R.G. 1.165 provides guidance for identification of the regions to be investigated:
  - Regional investigations using literature reviews and geological reconnaissance should generally be conducted for a radius of 320 km (200 miles) from the site.
  - Geological, seismological, and geophysical investigations should be carried out for a radius of 40 km (25 miles) from the site to identify and characterize the seismic and surface deformation potential of seismic sources, or to demonstrate that such structures are not present.
  - Detailed geological, geophysical, seismological, and geotechnical (GGSG) investigations should be conducted for a radius of 8 km (5 miles) from the site to determine the potential for surface tectonic and non-tectonic deformations in the site vicinity.
  - The area of detailed GGSG investigations may be larger than a 5-mile radius in regions of late Quaternary earth movements or historical seismic activities, or where a site is located near a fault zone or complex geology.
- Type of investigations. There are several acceptable types of investigations for identifying seismic sources. Different techniques are required depending on the geologic setting and tectonic environment. In most cases, more than one approach must be used, and the reliability of the results depends on the experience and competence of the investigators for synthesizing and interpreting various types of geological, seismological, and geophysical data. Types of investigations include the following:
  - Analysis of aerial photographs and other remote sensing imagery
  - Geologic (including stratigraphic and structural) reconnaissance and mapping
  - Geomorphic analysis (e.g., fault scarp morphology, terrace profiling, geodetic land surveys)
  - Analysis of local and regional geophysical data (e.g., seismic reflection, seismic refraction, aeromagnetics, gravity)

- Subsurface investigations of suspected fault traces (e.g., trenching, geophysical investigations, borings)
- Age dating techniques, including radiometric (e.g., carbon 14, thermoluminescence), chemical (e.g., pedogenic soils), biological (dendrochronology), and evolutionary (palynology) techniques
- Listing of all historically reported earthquakes (including instrumentally recorded data) that are associated with seismic sources, any part of which is within a radius of 320 km (200 miles) of the site, and seismicity analysis, including date of occurrence, earthquake sizes (intensity and/or magnitude), epicentral locations, focal depths, and focal mechanisms
- Correlation of seismicity with geologic structure
- Interpretation of stress orientation from focal mechanisms, geologic indicators, field experiments (e.g., hydrofracturing, borehole breakout investigations), and geodetic data

Seismic source characterization. The ranges of potential seismic sources and the uncertainties in seismicity parameters should be defined as required in DOE-STD-1023-95.

The characteristics of a seismic source may include the following:

- Source zone geometry (location and extent, both surface and subsurface)
- Description of Quaternary displacements (sense of slip on the fault, fault dimensions, age of displacement, estimated displacement per event, estimated magnitudes per offset, rupture length and area, and displacement history or uplift rates of seismogenic folds)
- Historical and instrumental seismicity associated with each source
- Paleoseismicity
- Relationship of the fault to other potential seismic sources in the region
- Maximum earthquake that the source would be capable of producing
- Recurrence model (frequency of earthquake occurrence versus magnitude)

Maximum earthquakes are usually assessed in two principal ways:

- Estimate the maximum dimensions of future ruptures and relate those dimensions to magnitude. This approach, which is geared toward characterizing the dimensions of faults, is commonly applied in the Western United States (WUS). The dimensions of ruptures and/or the amount of displacement that might be expected on a fault of interest are estimated from geologic investigations designed to assess what has occurred during past ruptures. As many of the rupture dimensions as possible should be used to lend stability to the magnitude estimates. Also, the uncertainties in the values of the rupture parameters should be incorporated.
- Consider the size of historical earthquakes associated with the source and with tectonically-analogous sources. This approach should only be applied after it has been shown that the approach commonly used in the WUS as described above is not applicable. Common acceptable approaches used in assessing maximum earthquakes in the Eastern United States (EUS) are (1) take the source zone’s maximum historical earthquake as the maximum, (2) take the maximum historical earthquake and add an arbitrary magnitude (or intensity) increment to it, or (3) draw an analogy to another source zone and use the maximum historical earthquake associated with that source.

The maximum earthquakes can also be evaluated based on the opinions provided by a panel of experts with knowledge of the site region.

Probabilistic seismic hazard analysis also requires the specification of the recurrence or frequency of occurrence of earthquakes of various magnitudes. Each seismic source requires its own recurrence relationship. For large area source zones, historical seismicity data are usually used to estimate earthquake recurrence rates. However, observed seismicity is usually insufficient to characterize adequately the recurrence curve for a given source throughout the range of magnitudes up to the maximum. It is important to correct the earthquake catalog for completeness of seismicity data to be used for probabilistic seismic hazard analysis. The following geological data shall be used to estimate the repeat times for large events:

- Geologic recurrence intervals. The geologic record captures the occurrence of earthquakes by recording: direct stratigraphic displacements within the fault zone; uplift, subsidence, or other tectonic deformation; or secondary effects related to seismic shaking, such as liquefaction and land sliding.
- Fault slip rate. Fault slip rates, derived from the amount of slip that has occurred over a geologically-defined interval, can be used to estimate average earthquake recurrence rates. Slip rates are determined by assessing the amount of fault displacement of a geologic unit having a known age.
- Temporal clustering. Earthquakes occurring on a seismic source may be clustered in time. The potential effects of temporal clustering on estimated recurrence rate should be considered.

Geotechnical Studies

Geotechnical studies may include investigations for: (1) defining site soil properties as may be required for hazard evaluations and engineering analyses and designs; (2) assessing local soil site effects on ground motions; (3) carrying out soil-structure interaction analyses; and (4) assessing the potential for soil failure or deformation induced by ground shaking (liquefaction, differential compaction, land sliding, etc.).

The extent of investigation to determine the geotechnical characteristics of a site depends on the performance categories of the facilities, the subsurface conditions, and the extent of available information. For facilities with SSCs in PC-4, the geotechnical studies shall include, at a minimum, the investigations specified in the following paragraphs. Reduced scope of investigation is allowed for sites containing facilities with SSCs in PC-3 or lower if the additional uncertainties resulting from the less extensive investigation are acceptable and justified based on analyses by the project team. By working with experienced geotechnical engineers and geologists, an appropriate scope of investigations can be developed for a particular facility.

Site investigations. Site investigations should be conducted for facilities if the site information is not available or is insufficient for NPH assessment and design/evaluation of the particular facilities. Soil/rock profiles (cross-sections) at the locations of the facilities should be provided based on the results of site investigations. The quantification of site soil/rock properties, such as classifications, strengths, compressibilities, densities, and wave velocities, is needed for engineering design and evaluations of soil amplification, soil-structure interaction, potential for liquefaction, differential compaction, and land sliding. The properties required are intimately linked to the designs and evaluations to be conducted.

For example, for analyses of soil response effects or soil-structure interaction, assessment of strain-dependent, soil dynamic modulus and damping characteristics are needed. An appropriate site investigation program should be developed in consultation with the geotechnical engineering representative of the project team.

Subsurface exploration. Subsurface conditions should be determined by means of borings, soundings, well logs, exploratory excavations, sampling, and geophysical methods (e.g., crosshole, downhole, and geophysical logging) that adequately disclose soil and groundwater conditions. Appropriate investigations should be made to determine the contribution of the subsurface soils and rocks to the loads imposed on the structures subjected to NPH.

The extent of subsurface investigations is dictated by the performance category of the facilities, by the foundation requirements, and by the complexity of the anticipated subsurface conditions. For sites containing facilities with SSCs in PC-3 and PC-4, the quality assurance requirements should be extended to retrieving, transportation, handling, and testing of soil samples. The locations and spacings of borings, soundings, and exploratory excavations shall be chosen to adequately define subsurface conditions. Subsurface explorations should be located to permit the construction of geological cross sections and soil profiles through foundations of safety-related structures and other important locations at the site. Sufficient geophysical and geotechnical data should be obtained to allow for reasonable assessments of representative soil profile and soil parameters and their variabilities across the site.

Laboratory tests. A laboratory testing program should be carried out to identify and classify the subsurface soils and rocks and to determine their physical and engineering properties. For evaluation and design of DOE facilities with SSCs in PC-3 or PC-4, laboratory tests for both static and dynamic properties (e.g., shear modulus, damping, liquefaction resistance) are generally required. The dynamic property tests may include cyclic triaxial tests, cyclic simple shear tests, cyclic torsional shear tests, and resonant column tests.

Both static and dynamic tests should be conducted as recommended in American Society for Testing and Materials (ASTM) standards or test procedures acceptable to the DOE. The ASTM specification numbers for static and dynamic laboratory tests can be found in the annual books of ASTM Standards, volume 04.08.

For coarse geological materials such as coarse gravels and sand-gravel mixtures, special testing equipment and a testing facility should be used (e.g., University of California Rockfill Testing Facility, Richmond, California). A larger sample size is required for laboratory testing of this type of material (e.g., samples with a 12-inch diameter were used in the Rockfill Testing Facility). It is generally difficult to obtain in-situ undisturbed samples of unconsolidated gravely soils for laboratory tests. If it is not feasible to collect test samples and, thus, no laboratory test results are available, the dynamic properties should be estimated from the published data of similar gravely soils.

Site response analysis. As part of the quantification of earthquake ground motions at a facility site, an analysis of soil response effects on ground motions may be needed. Note that a specific analysis is not required if the site is a hard rock site or if the subsurface soil conditions have already been adequately accounted for in the selection and use of strong motion data and attenuation relationships for subsurface conditions similar to those that exist at the site. For facilities with SSCs in PC-1 or PC-2, it is sufficient to comply with the criteria for ground motions specified in the model building codes, although sufficient site-specific information is needed to select the proper site category.

Site response analyses (often referred to as site amplification analyses) are relatively more important when the site surficial soil layer is a soft clay and/or when there is a high stiffness contrast (wave velocity contrast) between a shallow soil layer and underlying bedrock because a few ground motion recordings have been obtained for such conditions and have shown strong local soil effects on ground motion. Site response analyses are always important for those sites having predominant frequencies within the range of interest for the SSCs being evaluated. Thus, the stiffness of the soil and bedrock as well as the depth of soil deposit should be carefully evaluated.

In a site response analysis, the ground motions (usually acceleration time histories) that are defined at bedrock or outcrop are propagated through an analytical model of the site soils to determine the influence of the soils on the ground motions. The required soil parameters for the site response analysis include the depth, soil type, density, shear modulus and damping, and their variations with strain levels for each of the soil layers. Internal friction angle, cohesive strength, and over-consolidation ratio for clay are also needed for non-linear analyses. The results of the site response analysis shall show the input motion (rock response spectra), output motion (surface response spectra), and spectra amplification function. Criteria for developing the design response spectra are given in DOE-STD-1023-95.

The strain-dependent shear modulus and damping curves should be developed based on site-specific testing results, and should be supplemented as appropriate by published data for similar soils. Effects of sampling disturbance and machine characteristics must be carefully evaluated in developing these relationships. The effects of confining pressures (that reflect the depths of the soil) on these strain-dependent soil dynamic characteristics should be assessed and considered in site response analysis.

Soil-structure interaction analysis. Soil-structure interaction (SSI) analyses should be carried out when required to ascertain the influence of the interaction of the structure and the surrounding soil on the response of the structure to the defined site free-field ground motions. Soil-structure interaction effects are more significant for heavy and/or embedded structures.

The effect of soil-structure interaction should be considered for SSCs in PC-3 and should be performed for SSCs in PC-4. SSI analyses should use the design free-field ground motion as input. The same soil parameters specified in the previous paragraph should be obtained for SSI analyses. Due to the uncertainty in the input ground motion as well as soil parameters and structural properties used in the SSI analysis, a relatively wide range of soil shear moduli as required by DOE-STD-1020-2002 is recommended so that a conservative structure response calculation may be expected.

Dynamic soil properties can vary significantly depending on whether soil layers are saturated. For SSI analysis, unsaturated soil properties should be used for soil layers above the normal water table unless the site conditions indicate that additional soil saturation occurs frequently or for long durations.

Ground failure evaluations and seismic liquefaction of soils. Liquefaction is a soil behavior phenomenon in which cohesionless soils (sand, silt, or gravel) under saturated conditions lose a substantial amount of strength due to high pore water pressures generated in the soils by strong ground motions induced by NPH, such as earthquakes or wave actions. Potential effects of liquefaction include reduction in foundation bearing capacity, settlements, land sliding and lateral movements, flotation of lightweight structures (such as tanks) embedded in liquefied soil, and increased lateral pressures on walls retaining liquefied soil.

Investigations of liquefaction potential typically involve both geological and geotechnical engineering assessments. The parameters controlling liquefaction phenomena are the lithology of the soil at the site, the groundwater conditions, the behavior of the soil under dynamic loading, and the potential severity of the vibratory ground motion. The following site-specific data should be acquired and used along with state-of-the-art evaluation procedures:

- Soil grain size distribution, density, static and dynamic strength, stress history and geologic age of the sediments, and groundwater conditions
- Penetration resistance of the soil, e.g., standard penetration test (SPT) and cone penetration test (CPT)
- Shear wave velocity of the soil
- Evidence of past liquefaction
- Ground motion characteristics

A soil behavior phenomenon similar to liquefaction is strength reduction in sensitive clays. Although this behavior phenomenon is relatively rare in comparison to liquefaction, it should not be overlooked as a potential cause for land sliding and lateral movements. Therefore, the existence of sensitive clays at the site shall be identified.

Subsidence. Ground settlement during and after NPHs due to dynamic loads, change of groundwater conditions, soil expansion, soil collapse, erosion, and other causes shall be considered. Ground settlement due to the ground shaking induced by NPH can be caused by two factors: (1) compaction of dry sands due to ground shaking, and (2) settlement due to dissipation of dynamically induced pore water in saturated sands. Differential settlement would cause more damage to facilities than would uniform settlement. Differential compaction of cohesionless soils and resulting differential ground settlement can accompany liquefaction or may occur in the absence of liquefaction. The same types of geologic information and soil data used in liquefaction potential assessments, such as the SPT N-value, can also be used in assessing the potential for differential compaction. Ground subsidence has been observed at the surface above relatively shallow cavities formed by mining activities (particularly coal mines) and where large quantities of salt, oil, gas, or groundwater have been extracted. When these conditions exist near a site, consideration and investigation must be given to the possibility that surface subsidence will occur.

Slope instability. Stability of natural and man-made slopes should be evaluated when their failures would affect the safety and operation of DOE facilities during NPHs. In addition to land sliding facilitated by liquefaction-induced strength reduction, instability and deformation of hillside and embankment slopes can occur due to the ground shaking inertia forces causing a temporary exceedance of the strength of the soil or rock. When determining the potential for instability and deformations, the following should be considered: the slip surfaces of previous landslides; weak planes or seams of subsurface materials; mapping and dating of paleo slope failure events; loss of shear strength of the materials caused by natural phenomena hazards such as liquefaction, or reduction of strength due to wetting; hydrological conditions, including pore pressure and seepage; and loading conditions imposed by natural phenomena events. Various possible modes of failure should be considered. Static and dynamic analyses should be performed for the stability of the slopes.

The following information, at a minimum, should be collected for the evaluation of slope instability:

- Slope cross sections covering areas which would affect the slope stability
- Soil and rock profiles within the slope cross sections
- Static and dynamic soil and rock properties, including densities, strengths, and deformabilities
- Hydrological conditions and their variations
- Rock fall events

e) Describe the development of site-specific seismic hazard curves (SHC), including the development of a site-specific probabilistic seismic hazard study.

Two options are acceptable for the development of SHC. The first option is to use existing probabilistic seismic hazard assessment (PSHA) studies. The second option is to conduct a new site-specific PSHA. Any new site-specific seismic hazard assessment to generate seismic hazard curves should consider available site-specific geologic and seismic data in conformance with DOE-STD-1022-94.

Development of Seismic Hazard Curves Based on Existing PSHA
This option allows the use of existing PSHA studies similar to those conducted by the Electric Power Research Institute (EPRI, 1989a) for the commercial nuclear power industry and by the Lawrence Livermore National Laboratory (LLNL) (Bernreuter, et al., 1989) for the NRC, which can be used at particular DOE sites in the Eastern United States.

Experience has shown that application of the 1989 LLNL and EPRI methodologies can yield significantly different results. It is permissible to directly average the mean hazard curves from EPRI (1989a) and more recent hazard assessments from LLNL. The United States Geological Survey (USGS) has completed probabilistic seismic hazard estimates for the entire United States (USGS, 1996, USGS, 2001). While the USGS (1996) has stated that these curves do not consider the uncertainty in seismicity or fault parameters, the USGS (2001) seismic hazard curves should be compared to those available for the site. Differences in seismic hazard estimates should be evaluated after adjustments have been made to ensure these comparisons apply to similar site conditions. The technical basis for the differences must be understood and documented to validate the adequacy of the site-specific seismic hazard estimates.

This option is particularly suitable for DOE sites in the eastern United States, with the exception of sites located near active sources for large magnitude earthquakes, e.g., near New Madrid, Missouri, and Charleston, South Carolina. In these cases, it is required to either incorporate additional site-specific seismic sources, or to show that the regional seismic sources in the LLNL, EPRI, or USGS studies adequately model the tectonics in the vicinity of the site.

Development of Seismic Hazard Curves Based on New Site-Specific PSHA
Acceptable methodologies for conducting new PSHA for DOE sites should be consistent with the Senior Seismic Hazard Analysis Committee's (SSHAC) guidance for performing probabilistic seismic hazard analysis in SSHAC (1997), Recommendations for Probabilistic Seismic Hazard Analysis: Guidance of Uncertainty and Use of Experts (NUREG/CR-6372). As discussed in SSHAC (1997), an acceptable methodology for the development of DOE site-specific seismic hazard curves must accommodate uncertainties in the potential earthquake occurrence and ground motion attenuation processes affecting the site.

The description given here applies to facilities with SSCs in PC-4. For PC-3, the same methodology as for PC-4 is required, but simplifications are acceptable.

The following elements should be included in the methodology to conduct a new PSHA:

- The basic hazard model. The four steps required to determine the seismic hazard curve using the basic hazard model are shown in figure 1.
- Data used in the hazard modeling. The PSHA shall consider available data in conformance with DOE-STD-1022-94.

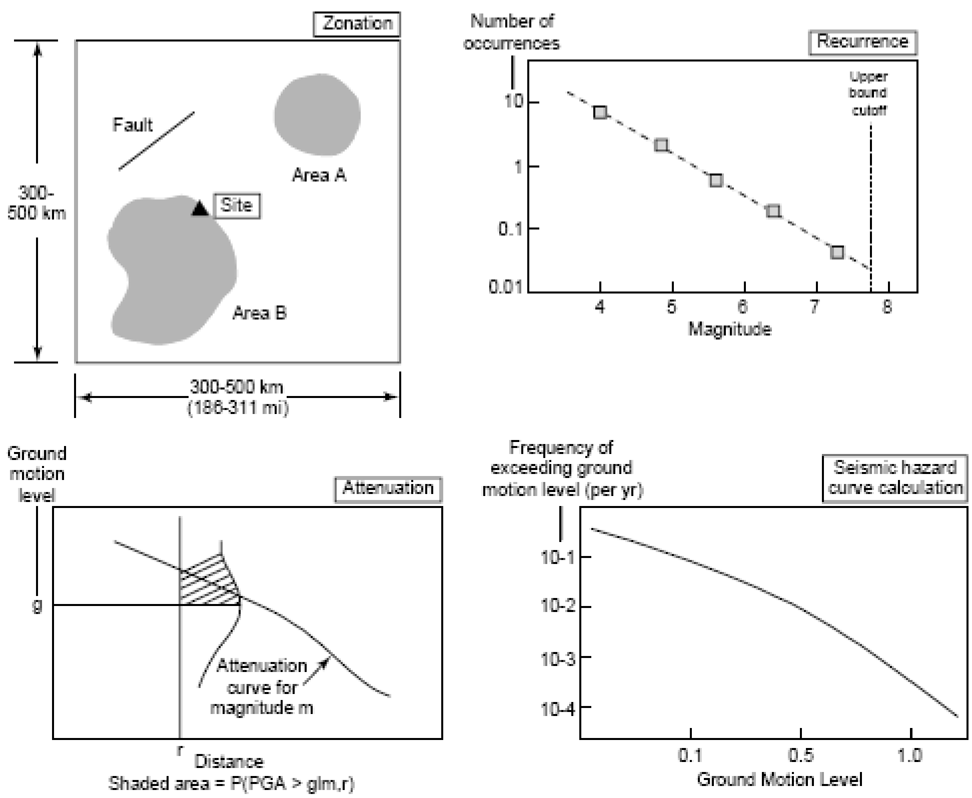


Figure 1. Four steps in probabilistic seismic hazard analysis

- Characterization of uncertainty in parameters of the hazard model. The PSHA should accommodate random variability in location, size, and ground motions associated with future earthquakes, as well as uncertainties related to the lack of knowledge of the models and parameters that characterize the hazard.

- Quantifying uncertainty. Two approaches are acceptable for characterizing and quantifying uncertainties in PSHA: (1) elicitation of multiple experts, and (2) peer review (the approaches can be used separately or together). Proper documentation of the technical basis for all assessments is an essential element.

f) Discuss the development of design basis earthquake (DBE) response spectra.

The target DBE response spectrum may be defined as the mean uniform hazard response spectrum (UHS) associated with the seismic hazard annual probability of exceedance over the entire frequency range of interest. The slope of the seismic hazard curve is also an important consideration when using the DBE for structural analysis (see DOE STD-1020-2002).

The target DBE response spectra should be reviewed to ensure its adequacy. Recommendations for spectral shapes as functions of magnitude, distance from the seismic source, and site conditions are presented in McGuire, et. al. (2001) and should be considered in this evaluation.

Earthquake vibratory ground motions to be used as input excitation for design and evaluation of DOE facilities, according to DOE-STD-1020-2002, is defined using an approach similar to that developed by the United States Nuclear Regulatory Commission (see Regulatory Guide 1.165, 1997). When site-specific response spectra are unavailable, a median standardized spectral shape may be used so long as such a spectrum shape is either reasonably consistent with or conservative for the site conditions. In these cases the median spectral shape should be scaled to the mean ground motion parameters based on the Uniform Hazard Spectrum to produce appropriate DBE spectra.

The final DBE ground motion at the site should be specified in terms of smooth and broad frequency content and horizontal and vertical response spectra that is defined at a specific control point. The control point is typically defined at the bedrock outcrop, at the top of ground, or at some intermediate surface. The selection of the appropriate control point depends on the details of the seismic response analysis that is performed for the facility. The method to transfer the DBE spectra from one depth of the site to another must adequately account for the effects of the primary contributors to the seismic hazard on all aspects of site response.

Acceptable methods for the development of site-specific response spectra are described in section 3.1.3.1 of DOE-STD-1023-95. Alternatively, methods commonly used for the development of standardized response spectra based on general site conditions instead of a site-specific geotechnical study are described in section 3.1.3.2 of DOE-STD-1023-95.

Site-specific DBE response spectra. The procedure for developing a median site-specific spectral shape is applicable for facilities with SSCs in PC-3 or PC-4. In accordance with the graded approach, the development of site-specific spectral shapes for facilities with SSCs in PC-3 may be relatively less rigorous than for those with SSCs in PC-4.

For those sites that choose to develop a site-specific spectral shape, information contained in the probabilistic seismic hazard analysis should be used to establish the appropriate magnitudes and distances for the controlling (or dominant) earthquakes. Controlling earthquakes are those potential earthquakes that could cause the greatest or governing ground motions at a site. There may be several controlling earthquakes for a site; e.g., a moderate nearby earthquake may control the high-frequency ground motions or the peak ground acceleration (PGA), and a large distant earthquake may control the low-frequency ground motions or the peak ground displacement (PGD).

For many cases of interest, the primary controlling earthquake is the postulated event that governs the spectral accelerations in the 5 to 10 Hz range. Thus, the primary seismic ground motion parameter is the average spectral acceleration of 5 and 10 Hz, $S_{A\ (5\text{-}10)}$. There may be some instances where the spectrum generated from this controlling earthquake may not be sufficiently broad-banded to capture the contributions from all sources. Therefore, if the controlling earthquake for the frequency range of 1 to 2.5 Hz is from a significantly different source, e.g., a large, distant event, its effect on the spectral shape should be included. In addition, for sites that have SSCs sensitive to low-frequency seismic response (e.g., below 1 Hz), it may be necessary to include the controlling earthquake based on seismic PGD. It should be noted that these primary frequency ranges of interest may be modified for cases of soft structures or for structures on soft soil sites.

g) Discuss the criteria for wind hazard assessment.

Design and evaluation criteria for DOE facilities against wind hazards are provided by DOE-STD-1020-2002. In accordance with DOE-STD-1020-2002, the following should be defined to carry out the design/evaluation process:

- The recommended basic wind speed for all PCs
- The atmospheric pressure change (APC) associated with a tornado for PC-3 or PC-4 SSCs
- Windborne missile criteria (size, weight, and speed) for PC-3 or PC-4 SSCs

Criteria for the atmospheric pressure change and recommended windborne missiles are contained in DOE-STD-1020-2002.

The recommended basic wind speed should be determined from a mean wind hazard curve developed for the site in accordance with the hazard annual probability specified in DOE-STD-1020-2002. The recommended basic wind speeds for 25 DOE sites have been modified from ASCE 7-98 requirements in DOE-STD-1020-2002. DOE O 420.1B requires that the need for updating the site wind hazard assessment be reviewed at least every 10 years. Therefore, for sites where existing wind hazard assessments are either unavailable or considered out of date, a new wind hazard assessment should be conducted.

The purpose of the criteria is to ensure that a consistent approach across DOE sites is achieved for design/evaluation of DOE facilities against wind hazards.

For sites containing facilities with SSCs in only PC-1 or PC-2, missile effects and atmospheric pressure change due to tornadoes need not be considered. Therefore, the only wind hazard design parameter to be established is the basic wind speed.

- For sites having no site-specific probabilistic wind hazard assessment, it is sufficient to use model building codes, or national consensus standards, such as ASCE (1998a), to define the basic wind speed.

- For sites that have a site-specific probabilistic wind hazard assessment, the SSCs in PC-1 or PC-2 should be evaluated for the greater of the site-specific values or the model code values unless lower site-specific values can be justified and approved by DOE.

For sites containing facilities with SSCs in PC-3 or PC-4, a site-specific probabilistic wind hazard assessment is conducted to establish the wind speed for design and/or evaluation of the facilities.

h) Discuss the criteria for flood hazard assessment.

Design and evaluation criteria for DOE facilities against flood hazards are provided by DOE-STD-1020-2002. In accordance with DOE-STD-1020-2002, a DBFL should be established to carry out the design/evaluation process. The DBFL is a flood level determined from the mean flood hazard curve and the hazard annual probability of exceedance specified in DOE-STD-1020-2002. A probabilistic flood hazard assessment is required to develop the flood hazard curve at the site.

For sites containing facilities with SSCs in PC-3 or PC-4, a site-specific probabilistic flood hazard assessment is required. A site-specific probabilistic flood hazard assessment at a site should involve the following two steps:

- Step 1: Perform a flood screening analysis to evaluate the magnitude of flood hazards that may impact the SSCs under consideration. Specific criteria for a flood screening analysis are provided in section 3.3.2 of DOE-STD-1023-95.
- Step 2: Perform a comprehensive flood hazard assessment, if needed, based on the results of the flood screening evaluation. Specific criteria for a comprehensive flood hazard assessment are provided in section 3.3.3 of DOE-STD-1023-95.

For sites containing facilities with SSCs in only PC-1 and PC-2 and having no existing site-specific probabilistic flood hazard assessment, it is sufficient to use flood insurance studies or equivalent to estimate the DBFL.

However, for sites containing facilities with SSCs in PC-2, a reduced-scope flood hazard assessment is generally required because most flood insurance studies available have not been conducted at a level that is compatible with the hazard annual probability of exceedance (5×10^{-4}) associated with PC-2 SSCs. A reduced-scope site-specific probabilistic flood assessment need contain only a flood screening analysis as specified in section 3.3.2 of DOE-STD-1023-95.

For sites that have site-specific flood hazard assessments, the SSCs in PC-1 and PC-2 should be evaluated or designed for the greater of the site-specific values, flood insurance studies, or equivalent unless lower site-specific values can be justified and are approved by DOE.

The flood hazard assessment should consider all the phenomena that can cause flooding (e.g., river flooding, storm surge, dam failure). Additionally, all sites must design a site drainage system to handle the runoff due to local precipitation.

If a site-specific flood hazard assessment is conducted, all effects of flooding, including submergence, waves and runups, debris, and hydrodynamic effects (e.g., peak flow velocity), should be considered for each identified source of potential flooding.

For determination of the DBFL, the flood hazard assessment should consider the possibility of simultaneous occurrence of flood events as specified in section 3.3.4 of DOE-STD-1023-95.

In completing a flood hazard assessment, it is extremely important that a site-specific database be available. DOE-STD-1022-94 provides criteria for the types of data that should be collected and compiled for such a database.

i) Demonstrate the ability to review site characterization and/or hazard analysis reports to ensure that methods used and calculation results are appropriate.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

4. Civil/structural engineering personnel shall demonstrate a working-level knowledge of the following National Consensus Codes and Standards:

- **American Concrete Institute (ACI) ACI 318-05, Building Code Requirements for Structural Concrete and Commentary (updated from ACI 318-02)**
- **ACI 349-01, Nuclear Safety-Related Concrete Structures and Commentary**
- **ACI 530-05, Building Code Requirements and Commentary for Masonry Structures and Specification for Masonry Structures and Related Commentaries, January 2005 *(* updated from ACI 530, Building Code Requirements for Masonry Structures, 1999)**
- **American Institute of Steel Construction (AISC), Manual of Steel Construction, Load and Resistance Factor Design (LRFD), 1998**
- **AISC, Manual of Steel Construction, Allowable Stress Design (ASD), 1989**
- **ANSI/AISC N690, Specifications for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities, 1994 and Supplement 1- 2002.**
- **ASCE 4-98, Seismic Analysis of Safety-Related Nuclear Structures and Commentary, 1998**
- **ASCE 7-02, Minimum Design Loads for Buildings and Other Structures, 2002**

a) Discuss the various design loads on structures, and explain how they are combined to achieve performance expectations.

Buildings and other structures should be designed using combined factored loads, or using strength of allowable stress designs. Either should be used exclusively for proportioning elements of a particular construction material throughout the structure.

Combination symbols and notations:
D = dead load
E = earthquake load
F = load due to fluids with well-defined pressures and maximum heights
F_a = flood load
H = load due to internal earth pressure, groundwater pressure, or pressure of bull materials
L = live load

L_r = roof live load
R = rain load
T = self-straining force
W = wind load

The load combinations and load factors provided below should only be used in those cases in which they are specifically authorized by the applicable material design standard.

Structures, components, and foundations should be designed so that their design strength equals or exceeds the effect of the factored loads in the following combinations:

1. 1.4(D+F)
2. 1.2(D+F+T) + 1.6(L+H) + 0.5(L_r or S or R)
3. 1.2(D + 1.6(L_r or S or R) + (0.5L or 08W)
4. 1.2D 1.6W + 0.5L + 0.5(L_r or S or R)
5. 1.2D + 1 0E – 0.5L + 0.25
6. 0.9D +1.6W + 1.6H
7. 0.9D + 1 0E + 1.6H

Each relevant strength limit state should be investigated. Effects of one or more loads not acting should be investigated. The most unfavorable effects from dead and earthquake loads should be investigated where appropriate, but they need not be considered to act simultaneously.

When a structure is located in a flood zone, the following load combinations should be considered:

- In V-zones or coastal A-zones, 1.6W in combinations 4 and 6 should be replaced by 1.6W +2.0F_a.
- In non-coastal A-zones, 1.6W combinations 4 and 6 should be replaced by 0.8W + 1 0F_a.

Loads using allowable stress design should be considered to act in the following combinations. The combination that produces the most unfavorable effect in the building foundation or structural member should be considered. Effects of one or more loads not acting should be considered.

1. D
2. D + L + F +H + T + (L_r or S or R)
3. D + (W or).7E) + L + (L_r or S or R)
4. 0.6D + W + H
5. 0.6D + 0 7E + H

The most unfavorable effect from wind and earthquake loads should be considered where appropriate, but they need not be assumed to act simultaneously.

For more information regarding load designs, refer to ASCE-07-02, Minimum Design Loads for Buildings and Other Structures.

b) Discuss similarities and differences between strength versus allowable design for concrete, steel, and masonry structures.

With allowable stress design, the working or service loads are combined for the various members of a particular structure to obtain the maximum loads. Then members are selected such that their computed elastic stresses (when the maximum loads are applied) do not exceed certain allowable values. In structural steel design, these stresses usually are given as being equal to some percentage of the yield stress.

Load resistance factor design is based on a limit states philosophy. The term limit state is used to describe a condition at which a structure or some part of that structure ceases to perform its intended function. There are actually two categories of limit states: strength and serviceability. Strength limit states are based on the safety or load carrying capacity of structures, and include plastic strengths, buckling, fracture, fatigue, overturning, and so on. Serviceability limit states refer to the performance of structures under normal service loads, and are concerned with the uses and/or occupancy of structures, including such items as excessive deflections, slipping, vibrations, cracking, and deterioration.

c) Discuss seismic ductile detailing as required by ACI and AISC.

The property of a material that describes its ability to withstand extensive deformation without failure under high tensile stresses is called ductility. When a mild or low-carbon steel member is being tested in tension, a considerable reduction in cross section and a large amount of elongation will occur at the point of failure before the actual fracture occurs. A material that does not have this property is generally unacceptable, is probably hard, and might break if subjected to sudden shock. Steel ductility is a function of the steel forming process.

In structural steel members under normal loads, high-stress concentrations develop at various points. The ductile nature of the usual structural steel members enables them to yield locally at these points, thus preventing premature failures. A further advantage of ductile structures is that, when overloaded, their large deflections give visible evidence of impending failure, jokingly referred to as “running time.”

Reinforced concrete ductility is more a function of design than material properties. Reinforced concrete works on a basic principle: the compressive strength of the concrete is used for the compressive zone in a member, and the tensile strength of steel is used in the tensile zone of the structure. The design of the beam can be handled in three ways:

1. Balanced section. The steel begins yielding just as the concrete reaches the point of crushing.
2. Over-reinforced section. Failure occurs by initial crushing of the concrete, as the steel is strong enough for the loads applied. This usually results in a violent failure situation.
3. Under-reinforced section. This is achieved by slightly under-designing the reinforcement in the tensile zone of the concrete. Because the steel begins yielding first, the ductile properties of steel may be taken advantage of during a slow failure.

d) Demonstrate knowledge to review and utilize various industry and proprietary computer codes.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

e) Discuss differences between requirements for nuclear safety-related and non-nuclear structures.

Nuclear facility design objectives must include multiple layers of protection to prevent or mitigate the unintended release of radioactive materials to the environment, otherwise known as defense in depth. These multiple layers must include multiple physical barriers unless the basis for not including multiple physical barriers is documented in the DSA and approved by DOE.

Defense in depth for nuclear structures must include

- choosing an appropriate site;
- minimizing the quantity of material at risk;
- applying conservative design margins and quality assurance;
- using successive physical barriers for protection against radioactive releases;
- using multiple means to ensure critical safety functions needed to control processes, maintain processes in safe status, and confine and mitigate the potential for accidents with radiological releases;
- using equipment and administrative controls that restrict deviation from normal operations, monitor facility conditions during and after an event, and provide for response to accidents to achieve a safe condition;
- providing the means to monitor accident releases as required for emergency response;
- establishing emergency plans for minimizing the effects of an accident.

Hazard category 1, 2, and 3 nuclear facilities must be sited, designed, and constructed in a manner that ensures adequate protection of the health and safety of the public, workers, and the environment from the effects of accidents involving radioactive materials release.

Hazard category 1, 2, and 3 nuclear facilities with uncontained radioactive material (as opposed to material determined by the safety analysis to be adequately contained within drums, grout, or vitrified materials) must have the means to confine the uncontained radioactive materials to minimize their potential release in facility effluents during normal operations and during and following accidents. Confinement design considerations must include

- for a specific nuclear facility, the number, arrangement, and characteristics of confinement barriers as determined on a case-by-case basis;
- consideration of the type, quantity, form, and conditions for dispersing the radioactive material in the confinement system design;
- use of engineering evaluations, tradeoffs, and experience to develop practical designs that achieve confinement system objectives;
- the adequacy of confinement systems to perform required functions as documented and accepted through the preliminary DSA (PDSA) and DSA.

Hazard category 1, 2, and 3 nuclear facilities must be designed to

- facilitate safe deactivation, decommissioning, and decontamination at the end of facility life, including incorporation of design considerations during the operational period that facilitate future decontamination and decommissioning;
- facilitate inspections, testing, maintenance, repair, and replacement of safety SSCs as part of a reliability, availability, and maintainability program with the objective that the facility is maintained in a safe state;
- keep occupational radiation exposures within statutory limits and as low as reasonably achievable (ALARA).

f) Describe minimum documentation requirements to demonstrate compliance with the listed consensus codes and standards.

System design basis documentation and supporting documents must be compiled and kept current using formal change control and work control processes or, when design basis information is not available, documentation must include the following:

- System requirements and performance criteria essential to performance of the system's safety functions
- The basis for system requirements
- A description of how the current system configuration satisfies the requirements and performance criteria

Key design documents must be identified and consolidated to support facility safety basis development and documentation.

g) Conduct a review of structural analysis to ensure that design loads are properly defined, structural member capacities are adequate, and that all applicable load combinations have been adequately considered.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

5. Civil/structural engineering personnel shall demonstrate a working-level knowledge of the industry and consensus codes, standards, and provisions related to civil/structural analysis and design requirements:

- **IBC 2000, International Building Code**

a) Discuss analysis/design requirements of building codes and their relationship to DOE Natural Phenomena Hazards standards.

Criteria are provided for each of the four performance categories as defined in DOE O 420.1B, the accompanying Guide, DOE G 420.1-2, and DOE-STD-1021-93. The criteria for PC-1 and PC-2 are similar to those from model building codes.

Executive Order 12699 establishes the minimum seismic requirements for new federal buildings. NEHRP updates the provisions required to meet these requirements every 3 years. The Interagency Committee on Seismic Safety in Construction (ICSSC) compares model building codes with the NEHRP provisions. Designers must consider the NEHRP provisions and ICSSC comparisons to ensure the use of the proper model building code in their design and evaluation. Currently the IBC 2000 and ASCE 7-98 meet the requirements of the NEHRP provisions. While using the IBC 2000 or successor documents, designers must consider the seismic use group and seismic design category.

The seismic provisions in the IBC 2000 have been specified for PC-1 and PC-2 because it is the only current model code meeting NEHRP provisions.

Seismic design or evaluation of PC-1 and PC-2 SSCs is based on model building code seismic provisions. In these criteria, the current version of the IBC should be followed. However, the other equivalent model building codes may be used. All of the IBC 2000 seismic provisions should be followed for PC-1 and PC-2 SSCs. Load combinations to be used for PC-1 and PC-2 will be based on the provisions in the IBC 2000. Use of site-specific data will be limited per provisions of IBC 2000.

Probability values specified for normal use SSCs are consistent with performance obtained through the use for model building code provisions for NPHs. Probability values specified for hazardous use SSCs approach performance obtained through the use of nuclear power plant NPH criteria. Acceptable behavior limits considered in the performance goals also depend on the SSC characteristics. For example, the acceptable behavior limits for normal use SSCs is major damage but limited in extent to below that at which occupants are endangered. However, the acceptable behavior limits for hazardous use SSCs is lesser damage such that the facility can perform its function.

Performance goal probability values apply to each NPH individually. Hence, the annual probability of exceedance of acceptable behavior limits for all NPH would be somewhat larger than the performance goal value if SSCs are designed exactly to the criteria.

The use of performance goal based criteria is becoming common practice as it is embedded in recent versions of the Uniform Building Code, IBC, and in the DOD seismic provisions for essential buildings. It has been used for DOE new production reactor NPH criteria, and it has been used in recent NRC applications, such as for the advanced light water reactor program and for revisions to commercial reactor geological siting criteria in 10 CFR 100, appendix A.

The primary concern of model building codes is preventing major structural failure and maintaining life safety under major or severe earthquakes or winds.

The performance goals for PC-1 SSCs are consistent with goals of model building codes for normal facilities. The performance goals for PC-2 SSCs are slightly more conservative than the goals of model building codes for important or essential facilities. For seismic design and evaluation, model building codes use equivalent static force methods except for very unusual or irregular facilities, for which a dynamic analysis method is employed.

Finally, the graded approach is common practice by model building codes such as the IBC 2000.

b) Discuss DOE and industry guidance for verifying adequacy of SSCs.

Seismic design or evaluation of PC-1 and PC-2 SSCs is based on model building code seismic provisions. In these criteria, the current version of the IBC should be followed. All of the IBC 2000 seismic provisions should be followed for PC-1 and PC-2 SSCs. Load combinations to be used for PC-1 and PC-2 will be based on the provisions in the IBC 2000. Use of site-specific data will be limited per provisions of IBC 2000. DOE-STD-1020-2002 provides additional guidance for the evaluation of SSCs.

6. Civil/structural engineering personnel shall demonstrate a working-level knowledge of the seismic principles, seismic analysis, seismic design of new facilities, and seismic evaluation of existing facilities.

- **NEHRP 2000, Recommended Provisions for Seismic Regulations for New Buildings and Other Structures-FEMA 368, 2001**

a) Discuss how the level of seismicity and site-specific geotechnical conditions influence the seismic design of facilities.

There are three levels of seismicity. They are as follows:

- Very high — areas where earthquakes could happen in the near future (e.g., the next 30 years)
- High — areas where damaging earthquakes could happen within the life of a typical building (e.g.,100 years)
- Moderate — Area where earthquakes could happen
- Low — Areas where earthquakes are not expected to happen at all

DOE O 420.1B requires that sites prepare upgrade plans for buildings that are deemed deficient in meeting NPH requirements. Some of these deficiencies may have been discovered during the facility safety reviews and or during implementation of Executive Order 12941. One of the prioritization schemes to upgrade such deficient buildings addresses seismicity, occupancy, and building condition. This scheme is provided in table 4, although sites may choose their own schemes.

The model building types listed in table 4 are defined in FEMA 178, NEHRP Handbook for the Seismic Evaluation of Existing Buildings. The model building types are defined as follows:

- Extremely poor: concrete moment frame, precast/tilt-up concrete walls with lightweight flexible diaphragms, precast concrete frames with concrete shear walls, unreinforced masonry buildings
- Very poor: steel braced frame, steel frame with infill shear walls, concrete shear walls, concrete frame with infill shear walls, reinforced masonry bearing walls with precast concrete diaphragms, other type, unknown type
- Poor: wood, light frame, wood, commercial and industrial, steel moment frame, steel light frame, steel frame with concrete shear walls, reinforced masonry bearing walls with wood or metal deck diaphragms
- Essential buildings: buildings that, in the judgment of the owning agency, require a level of seismic resistance higher than life safety to support earthquake response, critical functions, hazardous materials, or extremely valuable contents

Description	Priority Group	Function	Model Building Groups	Seismicity	Occupancy Groups
Buildings that pose the greatest risk to life or loss of essential function	1	All	Extremely poor buildings	Very high hazard	High occupancy
	2	All	Extremely poor buildings	Very high hazard	M/L occupancy
	3	All	Extremely poor buildings	High hazard	High occupancy
	4	All	Very poor buildings	High hazard	High occupancy
	5	All	Poor buildings	Very high hazard	High occupancy
	6	All	Poor buildings	High hazard	High occupancy
	7	Essential	Very poor buildings	Very high hazard	M/L occupancy
	8	Essential	Poor buildings	Very high hazard	M/L occupancy
	9	Essential	All buildings	Moderate hazard	High occupancy
	10	Non-essential	Extremely poor buildings	Moderate hazard	High occupancy
	11	Essential	All buildings	High hazard	M/L occupancy
	12	Non-essential	Extremely poor buildings	High hazard	M/L occupancy
	13	Non-essential	Very poor buildings	Moderate hazard	High occupancy
	14	Non-essential	Poor buildings	Moderate hazard	High occupancy
	15	Essential	All buildings	Moderate hazard	M/L occupancy
	16	Non-essential	Extremely poor buildings	Moderate hazard	M/L occupancy
	17	Non-essential	Very poor buildings	Very high hazard	M/L occupancy
	18	Non-essential	Very poor buildings	High hazard	M/L occupancy
	19	Non-essential	Poor buildings	Very high hazard	M/L occupancy
Buildings that pose the least risk to life or loss of essential function	20	Non-essential	Poor buildings	High hazard	M/L occupancy
	21	Non-essential	Very poor buildings	Moderate hazard	M/L occupancy
	22	Non-essential	Poor buildings	Moderate hazard	M/L occupancy

Table 4. Suggested prioritization scheme (Source: Draft FEMA Report to Congress on E.O.12941)

b) Describe importance of structural elements required in the seismic design of new facilities and the methods utilized in seismic strengthening of existing facilities.

When a structure or component is subjected to earthquake shaking, its foundation or support moves with the ground or with the structural element on which it rests. If the structure or equipment is rigid, it follows the motion of its foundation, and the dynamic forces acting on it are nearly equal to those associated with the base accelerations. However, if the structure is flexible, large relative movements can be induced between the structure and its base. Earthquake ground shaking consists of a short duration of time-varying motion that has significant energy content in the range of natural frequencies of many structures. Thus, for flexible structures, dynamic amplification is possible such that the motions of the structure may be significantly greater than the ground shaking motion. To survive these motions, the structural elements must be sufficiently strong, as well as sufficiently ductile, to resist the seismic-induced forces and deformations. The effects of earthquake shaking on structures and equipment depend not only on the earthquake motion to which they are subjected, but also on the properties of the structure or equipment. The ability to absorb energy (due to damping or inelastic behavior), the natural periods of vibration, and the strength or resistance of structures are among the more important structural properties.

c) Discuss methods for determining the magnitude of seismic forces and methods available for performing analysis of engineered structures.

A building riding an earthquake is like a cowboy riding a bull in a rodeo. As the ground moves in a complex and dynamic pattern of horizontal and vertical displacements, the building sways back and forth like an inverted pendulum. The horizontal components of this dynamic ground motion, combined with the inertial tendencies of the building, effectively subject the building structure to lateral forces that are proportional to its weight. In fact, the earliest seismic codes related these seismic forces, F, to building weight, W, with a single coefficient:

$$F = CW$$

where C was taken as 0.1.

What this simple equation does not consider are the effects of the building's geometry, stiffness, and ductility, as well as the characteristics of the soil, on the magnitude and distribution of these equivalent static forces. In particular, the building's fundamental period of vibration, related to its height and type of construction, is a critical factor. For example, the periods of short, stiff buildings tend to be similar to the periodic variation in ground acceleration characteristics of seismic motion, causing a dynamic amplification of the forces acting on those buildings. This is not the case with tall, slender buildings having periods of vibration substantially longer than those associated with the ground motion. For this reason, tall flexible buildings tend to perform well (structurally) in earthquakes, compared to short, squat, and stiff buildings.

But stiffness can also be beneficial since the large deformations associated with flexible buildings tend to cause substantial non-structural damage. The ideal earthquake-resistant structure must therefore balance the two contradictory imperatives of stiffness and flexibility.

In modern building codes, the force, F, has been replaced with a design base shear, V, equal to the total lateral seismic force assumed to act on the building. Additionally, the single coefficient relating this shear force to the building's weight (seismic dead load) has been replaced by a series of coefficients, each corresponding to a particular characteristic of the building or site that affects the building's response to ground motion. The 1994 U.S. Uniform Building Code (UBC), based on recommendations contained in the so-called Blue Book published by the Structural Engineers Association of California, relates base shear to weight with the following coefficients:

$$V = (Z\ I\ C\ /\ Rw)\ W$$

where V is the design base shear, and W is the seismic dead load (including permanent equipment, a percentage of storage and warehouse live loads, partition loads, and certain snow loads).

Z is the seismic zone factor, corresponding to the expected peak ground acceleration for a particular region during a given time span. The values for Z are as follows: 0 for zone 0 (where no earthquakes are expected to occur); 0.075 for zone 1; 0.15 for zone 2A; 0.20 for zone 2B; 0.30 for zone 3; and 0.40 for zone 4.

I is the seismic importance factor, equal to 1.0 for normal occupancies, and 1.25 for essential or hazardous facilities. Increasing the importance factor can be looked at as increasing the recurrence interval for which peak accelerations are computed, effectively increasing the seismic forces expected to act on the structure.

C is a coefficient that accounts for the effect of periodic modes of vibration, damping, and soil quality on a building's response to typical seismic ground motion. It is taken equal to $1.25\ S/T^{2/3}$, where S (for soil characteristics) ranges from 1.0 for the stiffest subsurface conditions to 2.0 for the poorest subsurface conditions (i.e., soft clay), and the fundamental period of vibration, $T^{2/3}$ (seconds), is taken as $Ct(h)^{3/4}$, based on a coefficient, Ct, related to building type (Ct = 0.085 for steel moment-resisting frames; 0.073 for reinforced concrete moment-resisting frames and eccentrically braced frames; and 0.049 for all other types), and building height, h, in meters.

Rw is a lateral-force-resisting system coefficient, relating the building's structural system (specifically, the part of the structural system that resists horizontal forces) to its performance under seismic loads. In particular, the structure's ability to absorb energy (ductility) is rewarded in assigning values to Rw. These values range from 12, for steel or concrete special moment-resisting frames, down to 4, for various bearing wall systems, including concrete and heavy timber braced frames resisting both gravity and lateral loads.

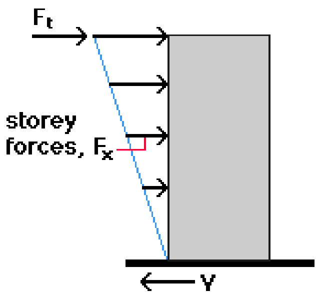
To approximate the structural effects that seismic ground motion produces at various story heights, seismic forces, Fx, are assigned to each level of the building structure in proportion to their weight times height above grade. An additional force, Ft (no greater than 0.25 V), is added to the top level of the structure whenever the period, T (defined in seismic data), is greater than 0.7 seconds, to account for more complex modal responses in tall, flexible buildings:

$$Ft = 0.07\ TV$$

The seismic forces, Fx, can then be calculated at each floor level by multiplying the base shear (minus the top-story force, Ft) by the ratio of "weight times height above the base" for the level being considered to the sum of "weight times height above the base" values computed for all levels; in other words:

$$F_x = (V - F_t)\, w_x h_x / (\sum w_i h_i)$$

A typical distribution of seismic forces resulting from the application of this equation is shown below.



Note that the calculation of Fx guarantees that these storey forces, together with the additional force Ft, are in equilibrium with the design base shear, V.

Building regulations and codes require that larger seismic forces be used for the design of individual building elements, and for the design of floor diaphragms. The rationale for the separate calculation of these forces is similar to the logic behind the calculation of larger component and cladding loads in wind design. Because the actual distribution of seismic forces is non-uniform, complex, and constantly changing, the average force expected to act on the entire lateral-force-resisting structural system is less than the maximum force expected to occur at any one level, or on any one building element.

Designers in seismically active regions should carefully consider the structural ramifications of their architectural design decisions, and provide for ductile and continuous load paths from roof to foundation. Following are some guidelines:

- Avoid irregularities in plan and section. In section, these irregularities include soft stories and weak stories that are significantly less stiff or less strong than the stories above, and geometric irregularities and discontinuities (offsets) within the structure. Plan irregularities include asymmetries, reentrant corners, discontinuities and offsets that can result in twisting of the structure (leading to additional torsional stresses), and other stress amplifications. Buildings articulated as multiple masses can be either literally separated (in which case the distance between building masses must be greater than the maximum anticipated lateral drift, or movement), or structurally integrated (in which case the plan and/or sectional irregularities must be taken into account).
- Provide tie-downs and anchors for all structural elements, even those that seem secured by the force of gravity. The vertical component of seismic ground acceleration can lift buildings off their foundations, roofs off of walls, and walls off of framing elements unless they are explicitly and continuously interconnected. Note that non-structural items such as suspended ceilings and mechanical and plumbing equipment must also be adequately secured to the structural frame.

- The explicit connection of all structural elements is also necessary for buildings subjected to high wind loads, since uplift and overturning moments due to wind loads can pull apart connections designed on the basis of gravity loads only. But unlike seismic forces, which are triggered by the inertial mass of all objects and elements within the building, wind pressures act primarily on the exposed surfaces of buildings so that the stability of interior non-structural elements is not as much of a concern.
- Avoid unreinforced masonry or other stiff and brittle structural systems. Ductile framing systems can deform inelastically, absorbing large quantities of energy without fracturing.

d) Discuss the seismic design of structures, structural elements, load transfer pathways, and material detailing requirements necessary to assure desired seismic performance.

The structure should include complete lateral- and vertical-force-resisting systems capable of providing adequate strength, stiffness, and energy dissipation capacity to withstand the design ground motions within the prescribed limits of deformation and strength demand. The design ground motions should be assumed to occur along any direction of the structure. The adequacy of the structural systems should be demonstrated through construction of a mathematical model and evaluation of this model for the effects of the design ground motions. Unless otherwise required, this evaluation should consist of a linear elastic analysis in which design seismic forces are distributed and applied throughout the height of the structure. The corresponding structural deformations and internal forces in all members of the structure should be determined and evaluated against acceptance criteria contained in NEHRP 2000. Approved alternative procedures based on general principles of engineering mechanics and dynamics are permitted to be used to establish the seismic forces and their distribution. If an alternative procedure is used, the corresponding internal forces and deformations in the members should be determined using a model consistent with the procedure adopted.

Individual members should be provided with adequate strength to resist the shears, axial forces, and moments determined in accordance with NEHRP 2000, and connections should develop the strength of the connected members or the forces indicated above. The deformation of the structure should not exceed the prescribed limits.

A continuous load path, or paths, with adequate strength and stiffness should be provided to transfer all forces from the point of application to the final point of resistance. The foundation should be designed to accommodate the forces developed or the movements imparted to the structure by the design ground motions. In the determination of the foundation design criteria, special recognition should be given to the dynamic nature of the forces, the expected ground motions, and the design basis for strength and energy dissipation capacity of the structure.

e) Discuss the differences in criteria for design of new facilities and evaluation of existing facilities.

NEHRP 2000 applies to the design and construction of structures, including additions, change of use, and alterations to resist the effects of earthquake motions. Every structure, and portion thereof, should be designed and constructed to resist the effects of earthquake motions as prescribed by NEHRP 2000.

Additions. Additions should be designed and constructed in accordance with NEHRP 2000.

An addition that is structurally independent from an existing structure should be designed and constructed as required for a new structure in accordance with NEHRP 2000.

An addition that is not structurally independent from an existing structure should be designed and constructed such that the entire structure conforms to the seismic-force-resistance requirements for new structures unless all of the following conditions are satisfied:

- The addition conforms to the requirements for new structures.
- The addition does not increase the seismic forces in any structural element of the existing structure by more than 5 percent, unless the capacity of the element subject to the increased forces is still in compliance with NEHRP 2000.
- The addition does not decrease the seismic resistance of any structural element of the existing structure to less than that required for a new structure.

Change of use. When a change of use results in a structure being reclassified to a higher seismic use group, the structure should conform to the requirements of section 1.2.1 of NEHRP 2000 for a new structure.

Exception: When a change of use results in a structure being reclassified from seismic use group I to seismic use group II, compliance with NEHRP 2000 is not required if the structure is located where S_{DS} is less than 0.3.

Alterations. Alterations are permitted to be made to any structure without requiring the structure to comply with NEHRP 2000 provided the alterations conform to the requirements for a new structure. Alterations that increase the seismic force in any existing structural element by more then 5 percent, or that decrease the design strength of any existing structural element to resist seismic forces by more than 5 percent, should not be permitted unless the entire seismic-force resisting system is determined to conform to the NEHRP 2000 requirements for a new structure. All alterations shall conform to NEHRP 2000 requirements for a new structure.

Exception: Alterations to existing structural elements or additions of new structural elements that are not required by NEHRP 2000 and are initiated to increase the strength or stiffness of the seismic-force-resisting system of an existing structure need not be designed for forces conforming to NEHRP 2000 provided that an engineering analysis is submitted indicating the following:

- The design strengths of existing structural elements required to resist seismic forces is not reduced.
- The seismic force on existing structural elements is not increased beyond their design strength.
- New structural elements are detailed and connected to the existing structural elements as required by NEHRP 2000.
- New or relocated nonstructural elements are detailed and connected to existing or new structural elements as required by NEHRP 2000.

7. Civil/structural engineering personnel shall demonstrate a working-level knowledge of the civil/structural engineering requirements of the applicable Federal Regulation 10 CFR 830, Nuclear Safety Management, safety-basis documents and processes, and associated standards and guides including:

- **DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports**
- **DOE-STD-3009-94, Chg 2, Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Documented Safety Analyses**
- **DOE-STD-1104-96, Review and Approval of Nuclear Facility Safety Basis Documents**
- **DOE G 421.1-2, Implementation Guide for use in Developing Documented Safety Analyses to Meet Subpart B, 10 CFR 830**
- **DOE G 423.1-1, Implementation Guide for use in Developing Technical Safety Requirements**
- **DOE G 424.1-1, Implementation Guide for use in Addressing Unreviewed Safety Question Requirements**

a) Explain the application of 10 CFR 830, subpart B, Safety Basis Requirements and the civil/structural engineering personnel's role in the oversight of safety authorization basis.

The safety management programmatic requirements identified in 10 CFR 830 form the boundaries within which the safety analysis is performed and represent the means of assuring safe operation of the facility. Hazard analysis and accident analysis are performed to identify specific controls and improvements that feed back into overall safety management. Consequence and likelihood estimates obtained from this process also form the bases for grading the level of detail and control needed in specific programs. The result is documentation of the safety basis that emphasizes the controls needed to maintain safe operation of a facility.

Civil/structural engineering personnel serve on the oversight team that reviews the safety basis documentation and perform the following functions:

- Determine if the contractor methodology used to prepare the DSA is appropriate
- Review and approve the nuclear safety design criteria to be used in preparing the PDSA
- Review and approve the PDSA for any new facilities or for major modifications to hazard category 1, 2, or 3 facilities
- Determine if the contractor may perform limited procurement and construction activities without approval of the PDSA for a new (or major modifications to a) hazard category 1, 2, or 3 facility
- Issue a safety evaluation report for any new (or major modification to) hazard category 1, 2, or 3 facility before operations or modification can begin
- Review and approve the contractor TSR(s) and any changes to the TSR(s)
- Review the safety basis for an existing hazard category 1, 2, or 3 facility and issue a safety evaluation report
- Review and approve the contractor's unreviewed safety question (USQ) procedure (initial deadline was April 10, 2001) and any revisions thereafter
- Review and approve (or take other action, as appropriate) USQs submitted by the contractor, including those for facility changes and discovery conditions

b) Discuss the contents of the listed safety authorization basis documents/processes and explain their relationship to each other:

- **Documented Safety Analysis (DSA)**
- **Technical Safety Requirements (TSR)**
- **USQ Process**
- **Safety Evaluation Report (SER)**

Documented Safety Analysis (DSA)
Development of a DSA or preliminary documented safety analysis (PDSA) is the process whereby facility hazards are identified, controls to prevent and mitigate potential accidents involving those hazards are proposed, and commitments are made for design, construction, operation, and disposition so as to ensure adequate safety at DOE nuclear facilities.

Technical Safety Requirements (TSR)
TSRs define the performance requirements of SSCs and identify the safety management programs used by personnel to ensure safety. TSRs are aimed at confirming the ability of the SSCs and personnel to perform their intended safety functions under normal, abnormal, and accident conditions. These requirements are identified through hazard analysis of the activities to be performed and identification of the potential sources of safety issues. Safety analyses to identify and analyze a set of bounding accidents that take into account all potential causes of releases of radioactivity also contribute to development of TSRs.

USQ Process
The purpose of the USQ process is to alert DOE of events, conditions, or actions that affect the DOE-approved safety basis of the facility or operation and ensure appropriate DOE line management action. If a change is proposed or a condition is discovered that could increase the risk of operating a facility beyond the risk established in the current safety basis, DOE line management, including, where applicable, the NNSA, must review and determine the acceptability of that risk through the process of approving a revised safety basis that would be developed and submitted by the contractor.

Safety Evaluation Report (SER)
The purpose of the SER is to allow DOE to review the safety basis developed by the contractor, and to approve operation of that facility to the standards set in the DSA and TSRs. The contents of a SER are as follows:

- Title page
- Signature page
- Executive summary
- Review process
- Base information
- Hazard and accident analysis
- Safety structures, systems, and components
- Derivation of technical safety requirements
- Safety management program characteristics
- Technical safety requirements
- Records

c) **Discuss the general approval process for the DSA, identifying the specific elements related to the civil/structural engineering review.**

DOE evaluates the DSA by considering the extent to which the DSA (1) adequately addresses the criteria set forth in 10 CFR 830.202 and 10 CFR 830.204, and (2) satisfies the provisions of the methodology used to prepare the DSA. DSA review and approval focuses on the adequacy of the following approval bases:

- Base information
- Hazard and accident analyses
- Safety structures, systems, and components
- Derivation of technical safety requirements
- Safety management program characteristics

Once technical justification exists to support conclusions that the DSA adequately describes how the facility is satisfactory with respect to the approval bases, the DSA may generally be considered adequate. These approval bases also form the foundation for documenting DSA approval in a SER.

Civil/structural engineering personnel's major contributions to the DSA approval process are to ensure that designated structural safety systems have been properly assessed, including a determination that they are performing intended safety functions, and to review the information provided in chapters 1, 2, and 4 of the DSA.

Chapter 1, Site Characteristics. This chapter provides a description of site characteristics necessary for understanding the facility environs important to the safety basis. Information is provided to support and clarify assumptions used in the hazard and accident analyses to identify and analyze potential external and natural event accident initiators and accident consequences external to the facility. Expected products of this chapter, as applicable based on the graded approach, include

- descriptions of the location of the site, the location of the facility within the site, its proximity to the public and to other facilities, and identification of the point where the evaluation guideline is applied;
- specification of population sheltering, population location and density, and other aspects of the surrounding area to the site that relate to assessment of the protection of the health and safety of the public;
- determination of the historical basis for site characteristics in meteorology, hydrology, geology, seismology, volcanology, and other natural events to the extent needed for hazard and accident analyses;
- identification of design basis natural events;
- identification of sources of external accidents, such as nearby airports, railroads, or utilities such as natural gas lines;
- identification of nearby facilities impacting, or impacted by, the facility under evaluation;
- validation of site characteristic assumptions common to safety analysis that were used in prior environmental analyses and impact statements, or of the need to revise and update such assumptions used in facility environmental impact statements.

Chapter 2, Facility Disposition. This chapter provides descriptions of the facility and processes to support assumptions used in the hazard and accident analyses. These descriptions focus on all major facility features necessary to understand the hazard analysis and accident analysis, rather than focusing only on safety SSCs. Expected products of this chapter, as applicable based on the graded approach, include

- an overview of the facility, its inputs and outputs, and its mission and history;
- a description of the facility structure and design basis;
- descriptions of the facility process systems and constituent components, instrumentation, controls, operating parameters, and relationships of SSCs;
- a description of confinement systems;
- a description of the facility safety support systems;
- a description of the facility utilities;
- a description of facility auxiliary systems and support systems.

Chapter 4, SSCs. This chapter provides details on those facility SSCs that are necessary for the facility to protect the public, provide defense in depth, or contribute to worker safety. Descriptions are provided of the attributes (i.e., functional requirements and performance criteria) required to support the safety functions identified in the hazard and accident analyses, and to support subsequent derivation of TSRs. Expected products of this chapter, as applicable based on the graded approach, include

- descriptions of safety SSCs, including safety functions;
- identification of support system safety SSCs depended upon to carry out safety functions;
- identification of the functional requirements necessary for the safety SSCs to perform their safety functions, and the general conditions caused by postulated accidents under which the safety SSCs must operate;
- identification of the performance criteria necessary to provide reasonable assurance that the functional requirements will be met;
- identification of assumptions needing TSR coverage.

d) Discuss the civil/structural engineering related conditions that can lead to determination of an inadequate safety analysis, and identify the required actions.

When a potential event is discovered that is not treated in the DSA, it should be considered as a possible new event or as an indicator of a potentially inadequate safety analysis issue.

e) Perform a review of safety basis documentation to ensure that designated structural safety systems have been properly assessed, including a determination that they are performing intended safety functions.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

8. Civil/structural engineering personnel shall demonstrate a familiarity-level knowledge of the relationships between the problems being addressed by safety analysis and building design and computer codes, the design requirements for the codes, and the components of the codes.

a) Identify how functional requirements and applicability of safety analysis and building design and computer codes are defined, documented, and controlled.

Functional requirements define what a software product must do to support the system owner's business functions and objectives. The functional requirements should answer the following questions:

- How are inputs transformed into outputs?
- Who initiates and receives specific information?
- What information must be available for each function to be performed?

Identify requirements for all functions, whether they are to be automated or manual. Describe the automated and manual inputs, processing, outputs, and conditions for all functions. Include a description of the standard data tables and data or records that will be shared with other applications. Identify the forms, reports, source documents, and inputs/outputs that the software product will process or produce to help define the functional requirements.

A functional model should be developed to depict each process that needs to be included. The goal of the functional model is to represent a complete top-down picture of the software product.

Flow diagrams should be used to provide a hierarchical and sequential view of the system owner's business functions and the flow of information through the processes.

Toolbox codes represent a small number of standard computer models or codes supporting DOE safety analysis. These codes have widespread use and are of appropriate qualification for use within DOE. The toolbox codes are acknowledged as part of DOE's Safety Software Central Registry. These codes are verified and validated, and constitute a "safe harbor" methodology. That is to say, the analysts using these codes do not need to present additional defense as to their qualification provided that the analysts are sufficiently qualified to use the codes and the input parameters are valid. These codes may also include commercial or proprietary design codes where DOE considers additional controls are appropriate for repetitive use in safety applications, and there is a benefit to maintain centralized control of the codes. The following six widely applied safety analysis computer codes have been designated as "toolbox" codes:

- ALOHA (chemical dispersion analysis)
- CFAST (fire analysis)
- EPI code (chemical dispersion analysis)
- GENII (radiological dispersion analysis)
- MACCS2 (radiological dispersion analysis)
- MELCOR (leak path factor analysis)

The current designated "toolbox" codes and any software recognized in the future as meeting the "toolbox" equivalency criteria are no different from other custom developed safety software. Consequently, software of this category should be developed or acquired, maintained, and controlled applying sound software practices.

In the future, new versions of software may be added to the Central Registry while the older versions are removed. Over time, some of the software may be retired and recommended not to be used in DOE safety analysis. Still other software may be added through the formal toolbox-equivalent process, having been recognized as meeting the equivalency criteria. Thus, the Central Registry collection of safety software applications will be expected to evolve as software life-cycle phases, usage, and application requirements change. Appendix B of DOE G 414.1-4 addresses the process for adding new software applications and versions to, and for removing retired software from, the Central Registry.

Information on additional toolbox procedures, the criteria and evaluation plan, evaluation of the software relative to current criteria (i.e., assessment of the margin of the deficiencies or "gap" analysis), user guidance documentation, a description of the toolbox-equivalent process, and code-specific information may be found in the Central Registry portion of the DOE Software Quality Assurance Knowledge Portal (http://www.eh.doe.gov/sqa/central_registry.htm).

b) Review a development project for safety analysis or design software.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

9. Civil/structural engineering personnel shall demonstrate the ability to independently conduct peer review of structural analysis and computations and to verify and assess field activities.

a) Discuss acceptable and unacceptable work performance and the increasing level of rigor required in reviewing performance categories (PCs) 1-4 SSCs.

The concept of PCs with corresponding target probabilistic performance goals has been developed to assist in applying the graded approach to NPH design and evaluation. Each SSC in a DOE facility is assigned to one of five performance categories depending upon its safety importance. Each performance category is assigned a target performance goal in terms of the probability of unacceptable damage due to natural phenomena. The unacceptable level of damage is related to the safety function of the SSCs during and after the occurrence of NPH. The target performance goals given in appendices B and C of DOE-STD-1020-94 have been prescribed to be substantially equivalent with (1) the goals of model building code provisions for SSCs in PC-1 and PC-2, and (2) the goals intended by commercial nuclear power plant seismic criteria for SSCs in PC-4. DOE-STD-1020-94 (appendices B and C) also provides details about the graded performance of SSCs in various performance categories, including the extent of expected damage, deformation, cracking, and yielding of SSCs in PC-1 to PC-4.

The relative probabilities and consequences of potential damage or failure of SSCs making up DOE facilities are accounted for by providing several sets of NPH design/evaluation provisions with increasing conservatism (i.e., producing a decrease in probability of damage or failure to perform intended safety function). Mean annual exceedance probabilities for various PCs to accomplish these target performance goals for different NPHs are given in DOE-STD-1020-94.

This graded approach provides a different level of NPH provisions for each performance category, as described below.

PC-0 SSCs are those for which no consideration of natural phenomena is necessary; that is, where natural phenomena hazards are not an issue.

For PC-1 SSCs, the primary concern is preventing major structural damage, collapse, or other failure that would endanger personnel (life safety). Repair or replacement of the SSC or the ability of the SSC to continue to function after the hazard has occurred is not considered.

PC-2 SSCs are meant to ensure the operability of essential facilities (e.g., fire house, emergency response centers, hospitals), or to prevent physical injury to in-facility workers. When safety analyses determine that local and limited confinement of low-hazard materials is required for worker safety, PC-2 designation should be used for the SSCs involved. In these cases, PC-2 designation may apply to SSCs, such as drums, packaging, gloveboxes, local HEPA filters, air flow control systems (ventilation and dampers), room air monitors, alarms, corridors, stairways and doors, pager systems, and emergency lighting important to evacuation. Design of PC-2 SSCs should result in limited structural damage from design basis natural phenomena events to ensure minimal interruption to facility operation and repair following the event. PC-2 performance is analogous to the design criteria for essential facilities (e.g., hospitals, fire and police stations, centers for emergency operations) in the model building codes.

PC-3 SSCs are those for which failure to perform their safety function could pose a potential hazard to public health, safety, and the environment because radioactive or toxic materials are present and could be released from the facility as a result of that failure. PC-3 SSCs would prevent or mitigate criticality accidents, chemical explosions, and events with the potential to release hazardous materials outside the facility. Design considerations for these categories are to limit facility damage as a result of design basis natural phenomena events so that hazardous materials can be controlled and confined, occupants are protected, and the functioning of the facility is not interrupted. When safety analyses determine that local confinement of high-hazard materials is required for worker safety, PC-3 designation may be appropriate for the SSCs involved. PC-3 NPH provisions are consistent with those used for reevaluation of commercial plutonium facilities with conservatism in between that of model building code requirements for essential facilities and civilian nuclear power plant requirements.

PC-4 SSCs are also those for which failure to perform their safety function could pose a potential hazard to public health, safety, and the environment because radioactive or toxic materials are present in large quantities and could be released as a result of that failure. However, PC-4 SSCs are designated as reactor-like in that the quantity of hazardous materials and energetics present is similar to that of a large category A reactor (>200 MWt). These types of SSCs are associated with facilities having quantities and forms of hazardous materials and sufficient energy sources capable of producing significant off-site effects unless the SSCs withstand NPH effects. The DSA results provide an essential element in identifying specific SSCs for which a failure could result in a release as large as the potential release from a large reactor. Design considerations for this category are to limit facility damage from design basis natural phenomena events so that hazardous materials can be controlled and confined, occupants are protected, and essential functions of the facility are not interrupted. PC-4 seismic provisions are similar to those used for reevaluation or design of civilian nuclear power plants, where off-site release of hazardous material must be prevented.

DOE-STD-1021-93, Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components, provides guidance to facility designers or safety evaluators to aid in determining which NPH performance category to assign to a specific system, structure, or component in a DOE facility. It addresses the concepts of facility hazard classification, SSC safety classification, and performance categorization. The standard does not attempt to define what constitutes a safety function in each type of facility, but refers the user to other DOE guidance on this subject. Engineers with knowledge of systems, safety requirements, and facility operations should select performance categories in a manner that ensures that DOE safety policies are met. Economic or programmatic considerations may require the use of more stringent goals for specific SSCs (i.e., they may be placed in a higher performance category). The performance categorization is to be derived from hazard analysis and the SSCs that are required to mitigate NPH hazards. For nuclear facilities, the DSA results provide an essential element in categorizing SSCs. For existing nonreactor nuclear facilities, DOE-STD-3009 should be used in conjunction with Standard 1021 and the DSA for performance categorization.

b) Perform a review of structural analysis for theory and assumptions and verify structural calculations and drawings for numerical accuracy.

c) Conduct a review of testing and inspection reports and periodically observe field compliance with plans and specifications.

d) Lead an assessment of construction and other field activities and develop a report based on findings.

e) Participate in formal meetings to discuss the results of Civil/Structural Engineering Assessments.

Elements “b” through “e” of this competency are performance-based competencies. The qualifying official will evaluate the completion of these competencies.

10. Civil/structural engineering personnel shall demonstrate a working-level knowledge of the DOE/facility contract provisions necessary to provide oversight and assessments of a contractor’s performance.

a) Describe the role of civil/structural engineering personnel in contractor oversight.

The role of civil/structural engineering personnel in the contractor performance evaluation process varies from site to site. The local qualifying official will evaluate the completion of this competency.

b) Describe the assessment requirements and limitations of civil/structural engineering personnel interfacing with contractor employees.

As assessment requirements and limitations associated with the interface of contractor employees vary from site to site, the local qualifying official will evaluate the completion of this competency.

c) Describe how planning, observing, interviewing, and document research are used during an assessment.

Effective assessments use a combination of tools and techniques to maximize the productivity of the assessment team and resources. Such assessment techniques include document reviews, interviews, and observation. In using these techniques, the assessor should not forget that the objective is to verify accomplishment of an organization's mission. To save time, the assessor should gather only data and information relevant to overall program performance and the achievement of program objectives.

It is generally not acceptable to identify suspicions about the adequacy or inadequacy of a program, system, or process. Investigations should be sufficiently thorough, and information should be gathered with sufficient diligence, that accurate, detailed conclusions and issues can be provided to assist the organizations that will receive the final report.

In using any of these techniques, assessors should maintain good records of the assessment results. These may include personal notes or other information to support the assessment, and may be included in the checklist information. These records are useful in writing the report and any associated findings and recommendations, and will become invaluable if questions arise during the report review process. All classified notes should be disposed of properly in accordance with established and agreed-upon procedures. A discussion of each of the techniques follows.

Document Review
Document review is used extensively during an assessment to substantiate the information obtained during interviews and observation. During the course of an assessment, questions may arise concerning what is heard and seen. The review of documents, including logs, procedures, work orders, and other data provides a method for answering these questions and validating the assessment results. The drawback of document review is that the accuracy of the records cannot be ascertained by review alone. This technique should be combined with interviews, observation, inspection, and/or performance testing to complete the picture of performance. Records and documents should be selected carefully to ensure they adequately characterize the program, system, or process being assessed.

Interviews
Interviews provide a means to verify the results of observation, document review, inspection, and performance testing. In addition, interviews allow the responsible person to explain and clarify those results. The interview helps to eliminate misunderstandings about program implementation, and provides a venue where apparent conflicts or recent changes can be discussed, and the organization and program expectations can be described. Tools developed during assessment planning are used to prepare for the interview. Assessors should also prepare questions in advance to keep the interview focused.

Observation
Observation, the viewing of actual work activities, is often considered the most effective technique for determining whether performance is adequate. Assessors should understand the effect their presence has on the person being observed and convey an attitude that is helpful, constructive, positive, and unbiased. The primary goal during observation is to

obtain the most complete picture possible of the performance, which should then be put into perspective relative to the overall program, system, or process.

Before drawing final conclusions, the assessor should verify the results through at least one other technique.

d) Explain the essential elements of an assessment, including the areas of investigation, fact-finding, and reporting.

Investigation
It is important to begin the investigation as soon as an assessment is called for to ensure that data is not lost. The information that should be collected consists of: conditions before, during, and after operation of the facility; personnel involvement; environmental factors; and other information having relevance to the operation of the facility.

Fact Finding
Once all the data has been collected, the data should be verified to ensure accuracy. The investigation may be enhanced if some physical evidence is retained. Establishing a quarantine area, or the tagging and segregation of pieces and material, should be performed for failed equipment or components. The basic need is to determine the direct, contributing, and root causes so that effective corrective actions can be taken that will prevent recurrence. Some areas to be considered when determining what information is needed include

- activities related to the operations of the facility
- initial or recurring problems
- hardware (equipment) or software (programmatic-type issues) associated with the facility
- recent administrative program or equipment changes
- physical environment or circumstances

Some methods of gathering information include conducting interviews and collecting statements. Interviews must be factual. Preparing questions before the interview is essential to ensure that all necessary information is obtained. Interviews should be conducted, preferably in person, with those people who are most familiar with the system. Individual statements could be obtained if time or the number of personnel involved makes interviewing impractical. Interviews can be documented using any format desired by the interviewer. Consider conducting a walk-through of the system or facility as part of the interview if time permits.

Reporting
Review of reports and documents helps develop the foundation for identifying weaknesses and areas that are of concern to an auditor.

Review relevant documents or portions of documents as necessary, and reference their use in support of facility operation. Record appropriate dates and times associated with the occurrence on the documents reviewed. Examples of documents include the following:

- Operating logs
- Correspondence
- Inspection/surveillance records

- Maintenance records
- Meeting minutes
- Computer process data
- Procedures and instructions
- Vendor manuals
- Drawings and specifications
- Functional retest specifications and results
- Equipment history records
- Design basis information
- Safety analysis report (SAR)/technical specifications
- Related quality control evaluation reports
- Operational safety requirements
- Safety performance measurement system/occurrence reporting and processing system (SPMS/ORPS) reports
- Radiological surveys
- Trend charts and graphs
- Facility parameter readings
- Sample analyses and results (chemistry, radiological, air, etc.)
- Work orders

e) Discuss the system engineering concept as it applies to oversight of safety systems, using the guidance in DOE-STD-1073-93, Configuration Management.

The contractor should identify and document the set of SSCs for an activity that will be managed through the configuration management process. This set will be referred to as the CM SSCs. The CM SSCs are compiled from several sets of SSCs. These sets may overlap.

The first set of SSCs that must be included in the CM SSCs for hazard category 1, 2, and 3 nuclear facilities is the set of safety SSCs identified in the DSA as required by 10 CFR 830.204(b)(1). Safety SSCs are defined as the combination of safety-class SSCs and safety-significant SSCs, and they include those SSCs whose preventive or mitigative functions are considered to be major contributors to defense in depth and worker safety. Defense in depth refers to the various layers of protection provided to ensure public safety, worker safety, and protection of the environment. The safety SSCs identified in the DSA constitute the baseline set of SSCs that must be included in the configuration management process.

In addition, contractors should include in the set of CM SSCs the SSCs whose functions are considered to be important to defense in depth or worker safety, but are not already included in the safety SSCs. The combination of the safety SSCs and the other defense in depth SSCs should encompass the vital safety systems. The vital safety systems include the safety significant systems, the safety class systems, and other systems that perform an important defense in depth safety function. Additional information on vital safety systems is available in documents responding to Defense Nuclear Facilities Board (DNFSB) Recommendation 2000-2 and at https://www.hss.doe.gov/deprep/vss.

The contractor should also review the activity to determine if it is appropriate to include other SSCs in the set of CM SSCs. Other categories of SSCs that should be considered include the following:

- Mission critical SSCs — SSCs whose failure could cause substantial interruption to the mission of the facility or activity
- Environmental protection SSCs — SSCs that could have a significant impact on the environment if they failed to perform their function
- Costly SSCs — SSCs that would be expensive to fix or replace or whose failure could result in problems that could be expensive to fix
- Critical software — Software whose proper performance is critical to the expected performance of a safety SSC, a defense in depth SSC, or the safety of the nuclear facility
- Master equipment list (MEL) SSCs — SSCs that are included in the maintenance program
- Adjacent SSCs — SSCs that are located adjacent to the safety or defense in depth SSCs such that changes to these SSCs could negatively impact the safety or mission of the activity

Identified systems must have defined system boundaries and component lists. Defined systems should contain those components necessary to accomplish the system's function and meet the system's design requirements. Applicable design codes and standards often define system boundaries. In addition, the following considerations may help to define system boundaries for some facilities or activities:

- Location of piping class breaks
- Location of isolation valves
- Location of seismic class breaks
- Location of test features

Some supporting features may be outside the system boundary, such as electrical power, instrument air, lubricating oil, and ventilation. In addition, some complete systems may cross multiple facility and activity boundaries, such as ventilation systems.

11. Civil/structural engineering personnel shall demonstrate the ability to represent DOE as subject matter experts for civil/structural engineering activities during the oversight and management of engineering programs.

a) Prepare program or technical data for communicating to external organizations and discuss any potential impacts on DOE programs.

b) Demonstrate skill in dealing with the public and other stakeholders.

Elements "a" and "b" of this competency are performance-based competencies. The qualifying official will evaluate the completion of these competencies.

c) State security precautions to be taken when dealing with the public and other stakeholders.

It is the policy of the DOE to make information publicly available to the fullest extent possible, except where this information is exempt from disclosure under the Freedom of Information Act (FOIA), 5 U.S.C. 552 (Public Law 90-23, as amended) or under other applicable statutes such as the Privacy Act of 1974. Officers and employees of the DOE may furnish to the public informally and without compliance with the procedures of this Order, information and records of types that are customarily furnished to the public in the regular performance of their duties. There is no obligation on the part of the DOE to compile or create a record solely for the purpose of satisfying a request for records.

Where a contract with the DOE stipulates that any documents relating to work under the contract shall be the property of the Government, such records shall be considered to be agency records and subject to disclosure under the FOIA. However, if a contract does not make such specific provisions, no DOE contractor records shall be considered to be agency records unless and until such time that the DOE acquires possession of the particular contractor documents.

For an FOIA request, records are to be promptly identified and reviewed by an authorizing official. The authorizing official will consult and obtain concurrence of the General Counsel prior to any determination to deny access to records.

Protection of classified information or of unclassified controlled nuclear information (UNCI) and restricted access to classified materials is required at many facilities. If there is any potential that information in the project documentation is classified, then classification guidance should be requested or documents reviewed by an authorized classifier. DOE O 470.4, Safeguards and Security Program, requires a security plan for projects considered to be a concern.

d) Discuss the applicability of reports/recommendations from external entities such as the Defense Nuclear Facilities Safety Board (DNFSB) or the Government Accounting Office (GAO) and any resulting implementation plans that affect the civil/structural engineering programs.

Reports/recommendations from the DNFSB of the GAO that are related to any of the following should be addressed by the civil/structural engineer:

- Building integrity
- Building size
- Designs
- Layouts
- Building materials
- Built environment
- Utility systems
- Building access
- Waste water
- Potable water
- Slope stability
- Soil properties
- Building codes
- Survey, grading, and drainage
- Weather and natural hazards
- Runoff

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