NOT MEASUREMENT SENSITIVE

DOE G 420.1-1A
12-4-2012

NONREACTOR NUCLEAR SAFETY DESIGN GUIDE for use with DOE O 420.1C, *FACILITY SAFETY*

This Guide describes suggested non-mandatory approaches for meeting requirements. Guides are not requirements documents and are not to be construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual.

U.S. DEPARTMENT OF ENERGY
Office of Health, Safety and Security

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Office of Health, Safety and Security

FOREWORD

This Guide provides an acceptable approach for safety design of Department of Energy (DOE) hazard category 1, 2 and 3 nuclear facilities for satisfying the requirements of DOE Order 420.1C, *Facility Safety*, Attachment 2, Chapter I, *Nuclear Safety Design Criteria*.

DOE guides are part of the DOE Directives System and are issued to provide supplemental information regarding the Department's requirements as contained in rules, orders, notices, and technical standards. Guides also provide acceptable methods for implementing these requirements.

This Guide may be used by all DOE personnel and contractors, including personnel and contractors for the National Nuclear Security Administration (NNSA). Throughout this document, references to a contractor or a DOE contractor apply to a contractor for NNSA, as well.

This Guide does not establish or invoke any new requirements.

Beneficial comments (recommendations, additions, deletions, and any pertinent data) that may improve this document should be sent to:

HS-31/GTN
U.S. Department of Energy
Washington, D.C. 20585
Phone (301) 903-3331
Facsimile (301) 903-6172

Contents

1. OBJECTIVE

To provide an acceptable approach for safety design of Department of Energy (DOE) hazard category 1, 2 and 3 nuclear facilities satisfying the requirements of DOE Order (O) 420.1C, *Facility Safety*, Attachment 2, Chapter I, *Nuclear Safety Design Criteria*.

2. APPLICABILITY

This Guide (G) has the same applicability as Attachment 2, Chapter I of DOE O 420.1C, i.e.,

(1) new hazard category 1, 2, and 3 nuclear facilities as defined by 10 Code of Federal Regulations (C.F.R.) Part 830, *Nuclear Safety Management*; and,

(2) major modifications to hazard category 1, 2, and 3 nuclear facilities, as defined in 10 C.F.R. Part 830, that could substantially change the approved facility safety basis.

Design criteria related to natural phenomena hazard (NPH) mitigation, fire protection, and criticality safety can affect, or relate to, nuclear safety design criteria. These design requirements are contained in other parts of DOE O 420.1C and are not addressed in this Guide. For example, the use of non-nuclear building design requirements contained in International Building Code (IBC) or other government and non-government standards is not addressed in this Guide.

3. BACKGROUND AND OVERVIEW OF THIS GUIDE

3.1 Background

10 C.F.R. Part 830 establishes the Federal regulations that ensure the essential requirements for the protection of workers, the public, and the environment are systematically executed and maintained, including a requirement for the preparation and approval of a Preliminary Documented Safety Analysis for new nuclear projects. The regulations address requirements for nuclear safety design.

DOE O 420.1C establishes facility safety requirements in five major categories: (i) nuclear safety design criteria; (ii) fire protection; (iii) criticality safety; (iv) NPH mitigation; and, (v) the cognizant system engineer program (note: this topic is not addressed in this Guide). Each chapter in Attachment 2 of the Order provides fundamental and essential requirements, which provide the foundation for safety design. Additionally, Attachment 3 to DOE O 420.1C provides design criteria for safety structures, systems, and components (SSCs) and relevant design codes and standards.

Each chapter's requirements are further addressed in DOE technical standards (STDs) and guides, such as this Guide for nuclear safety design criteria, DOE-STD-1066-2012, *Fire Protection*, for fire protection requirements, and DOE-STD-1020-2012, *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities*, for NPH mitigation requirements.

The criteria for nuclear safety design are not limited to Chapter I in Attachment 2 of DOE O 420.1C. DOE O 420.1C has other requirements which are contained in Chapter II (fire protection), Chapter III, (nuclear criticality safety), and Chapter IV (NPH mitigation) that are applicable to the nuclear facility safety design. In addition, DOE O 420.1C and DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, dated 09-29-10, require implementation of DOE-STD-1189-2008, *Integration of Safety into the Design Process*, for the design of new hazard category 1, 2, and 3 nuclear facilities and major modifications of existing facilities. DOE O 413.3B requires a design code of record (COR) for nuclear facilities to be initiated during the conceptual design, placed under configuration control during preliminary design, and maintained throughout its remaining life-cycle. The COR will include the identification of guides and standards used for the design. It is the responsibility of the users to document the bases for their decisions in the selection and implementation of the guides and standards. It is DOE’s responsibility to review and approve the safety design bases that result from these decisions.

3.2 Organization

The following two sections of this Guide correspond with the two main requirements sections (3.a and 3.b) of Chapter I of Attachment 2 of DOE O 420.1C. Specifically:

- Section 4 provides guidance on integration of safety with design, and
- Section 5 provides guidance on nuclear facility design.

Appendices A through D of this Guide contain the Confinement Ventilation System Design and Performance Criteria, Definitions, Abbreviations and Acronyms, and References, respectively.

4. GUIDANCE FOR INTEGRATION OF SAFETY WITH DESIGN

Attachment 2, Chapter I of DOE O 420.1C requires integration of safety into the design early and throughout the design process consistent with DOE-STD-1189-2008. DOE-STD-1189-2008 provides detailed criteria and guidance on integrating safety into the design process. Appendices A through D of that standard contain requirements and guidance on the classification of safety functions and the SSCs selected to provide those functions.

10 C.F.R. 830, DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, and DOE-STD-1189-2008 provide criteria and guidance for the performance of a safety analysis to identify the major facility safety functions needed, and to identify safety-class (SC) and safety-significant (SS) SSCs needed to fulfill the safety functions. One of the objectives of the hazard and accident analyses is to identify the complete suite of safety SSCs for a facility and to designate them as SC or SS, as appropriate to their importance and role. Functional and design requirements specifically address the pertinent design parameters related to the safety function that is relied upon. These design requirements should also be included in SSC design documents. Chapter 7 of DOE-STD-1189-2008 provides guidance on important project interfaces relating to safety and design, including associated directives and requirements related to design.

5. GUIDANCE FOR NUCLEAR SAFETY DESIGN

5.1 Multiple Layers of Protection and Defense-in-Depth

Attachment 2, Chapter I of DOE O 420.1C requires that nuclear facility design includes multiple layers of protection (otherwise known as defense-in-depth) in the facility design to prevent or mitigate the unintended release of radioactive materials into the environment. The following is a general discussion followed by a more detailed discussion of each of the defense-in-depth elements.

5.1.1 General Discussion

Defense-in-depth is a fundamental strategy for nuclear facility safety. Defense-in-depth provides layers of defense against the release of hazardous materials so that no one layer by itself is completely relied upon. All safety activities, whether organizational, behavioral or equipment-related, are subject to layers of overlapping provisions, so that if a failure should occur it would be compensated for or corrected without causing harm to individuals or the public at large. When properly applied, the defense-in-depth strategy ensures that no single human or mechanical failure would lead to injury to individuals or to the public, or even combinations of failures that are only remotely possible would lead to little or no injury.

The strategy for defense-in-depth is twofold: first, to prevent accidents, and second, if prevention fails, to limit the potential consequences of accidents and to prevent their evolution to more serious conditions. Defense-in-depth is generally structured in five levels, as discussed below. Should one level fail, the next one comes into play.

Level 1 – Prevention of abnormal operation and failures. Accident prevention is the first priority. This is accomplished by conservative design and high quality in construction and operations and maintenance, including conservative site selection. This also includes design to minimize and control inventories of radioactive materials-at-risk. Provisions to prevent deviations of facility state from well-known operating conditions are generally more effective and more predictable than measures aimed at mitigation of such a departure.

Level 2 – Control of abnormal operation and detection of failures. This is accomplished by control, limiting and protection systems, as well as other surveillance features. Both safety systems and administrative controls are used. Multiple, diverse and independent means are provided to control and monitor facility processes.

Level 3 – Control of accidents within the design basis. This is accomplished by engineered safety features that are capable of leading the facility to a safe controlled state. A central component of defense-in-depth is the use of successive, multiple physical barriers for protection against release of radioactivity and hazardous materials. Multiple, diverse and independent means are provided to accomplish safety functions.

Level 4 – Control of severe facility conditions. This includes prevention of accident progression and mitigation of consequences of accidents.

Level 5 – Mitigation of radiological consequences. Significant adverse consequences from significant releases of radioactive materials are mitigated by emergency procedures and emergency response. As required for emergency response, means are provided to monitor accident releases.

At each level, a combination of design features and human aspects is evident. Human aspects of defense-in-depth are brought into play to protect the integrity of the barriers. These include quality assurance (QA), procedures, administrative controls, operating limits, safety reviews, personnel qualification and training, independent oversight, and safety culture. Design provisions (including both those for normal facility systems and those for engineered safety features) help to prevent: undue challenges to the integrity of physical barriers; failure of a barrier if it is jeopardized; and, consequential damage to multiple barriers in series.

The general objective of defense-in-depth is to ensure that a single failure (whether equipment failure or human failure) at one level of defense, or even combinations of failures at more than one level of defense, would not propagate to jeopardize defense-in-depth at subsequent levels. The independence of different levels of defense is a key element in meeting this objective. Special attention should be paid to hazards that could potentially impair several levels of defense, such as fire, earthquakes, and flooding.

5.1.2 Appropriate Site Selection

Attachment 2, Chapter I of DOE O 420.1C requires designers to choose an appropriate site location. The following factors should be considered in determining facility site suitability, as well as when establishing facility safety designs criteria:

- the site boundary and land-use characteristics of the site surroundings, including properties at risk from accidental exposures, public exclusion zones (access control), population-center distances, and population density;
- physical characteristics of the site, including topography, meteorology, and hydrology;
- geological and subsurface elements, such as the potential for fault rupture and the severity of vibratory ground motions from earthquakes, soil bearing design capacity, rock or other bearing stratum, ground settlement, and groundwater elevations;
- NPHs as discussed in Attachment 2, Chapter IV of DOE O 420.1C, including earthquakes, volcanic ejection, wind, flood, snow, hail, precipitation, and lightning;
- utility systems essential to support SC SSCs, such as electrical power supply and water supply;
- proximity of services, such as the fire department and emergency medical centers;
- emergency response considerations, including population sheltering or shielding parameters and evacuation delay times and rates for the public and co-located workers;

- potential human-induced hazards from nearby facilities or activities, such as industrial and military facilities (including other DOE facilities), aircraft impacts, pipelines, and transportation routes;

- proximity of nearby facilities and the hazards both to and from the proposed facility; and,

- site-related assumptions of the related environmental impact statement.

5.1.3 Minimization of Material-at-risk

The basic and most effective means of controlling the hazards inherent in the facility is the restriction of inventories and forms of radioactive and/or hazardous materials. Attachment 2, Chapter I of DOE O 420.1C requires emphasis to be placed on limiting the quantity and form of radioactive and/or hazardous materials in both process and storage areas consistent with mission needs. Materials may be rendered less hazardous by maintaining them in more stabilized and less dispersible forms.

5.1.4 Conservative Design Margins

The application of conservative design margins is required in Attachment 2, Chapter I of DOE O 420.1C. Conservative design provides a margin between the anticipated operating and accident conditions (covering normal operation as well as postulated incidents and accidents) and the failure conditions of the equipment. SSCs that provide a layer of protection are conservatively designed using established codes and standards that embody design margins. Appropriate conservative assumptions and safety margins are applied for SSC design, including design calculations, design analyses, and identification of design basis. The design of SSCs should incorporate suitably conservative criteria from applicable industry standards and design codes, and applicable DOE directives and technical standards. Where codes and standards are not complete, they should be supplemented with appropriate conservative design criteria. Where applications are unique or first-of-a-kind, additional efforts, such as testing or increased safety margins, should be taken to demonstrate conservatism of design. This should apply to all facets of the design including safety and non-safety SSCs.

Further, the facility design should accommodate means, such as monitors and automatic and manual controls, to restrict deviations from normal operations and to assist recovery during the early stages of an accident sequence.

5.1.5 Quality Assurance

The application of QA is required in Attachment 2, Chapter I of DOE O 420.1C. QA practices and requirements should be applied to the design and construction of SSCs at a level commensurate with the safety function of the SSC, including, but not limited to, the assurance of qualified design and construction personnel, the traceability of design decisions and procurements, and the documentation of changes in design and construction. Refer to section 7.1 of DOE-STD-1189-2008 for more specific guidance in implementing QA during the design process.

10 C.F.R. 830, Subpart A, *Quality Assurance Requirements*, requires designers to develop and implement a QA program that meets the requirements contained therein. These requirements are further refined in DOE O 414.1D, *Quality Assurance*, dated 04-25-11, which requires the use of American Society of Mechanical Engineers (ASME) NQA-1-2008 with the NQA-1a-2009 addenda (or a later edition*), Quality Assurance Requirements for Nuclear Facility Applications*, Part I and applicable requirements of Part II for select facilities. It is important to identify and implement the specific, applicable QA requirements and processes implemented early in the design process for nuclear facilities. Designers should work with their QA organizations to ensure these processes address and implement the applicable NQA-1 requirements.

The procurement of components will in most cases be ‘off-the-shelf’ and should follow the procurement process specified in the quality assurance program. For facilities that are required to meet the requirements of NQA-1, this should include the Commercial Grade Dedication (CGD) process requirements specified in NQA-1. A CGD process takes time to develop and implement; therefore, at the earliest possible stage, design personnel should establish a qualified CGD process if it will be used for the project.

Once the safety SSCs and their performance requirements are identified, a more detailed set of QA requirements can be specified. As part of the safety analysis, a list of all SC SSCs should be prepared and maintained for the life of the project through decommissioning. This listing should identify the safety functions, performance requirements, NPH design requirements, and QA requirements for each SC SSC. Many of the detailed component-specific requirements for safety SSCs are identified in applicable consensus codes and standards. A similar listing of all SS SSCs should also be prepared, including a discussion of any defense-in-depth role of the SS SSC. As the design progresses, more detailed safety analyses will be performed to develop the basis for safety SSCs performance requirements, and QA requirements can be refined as necessary. QA requirements should also be applied to non-safety SSCs commensurate with importance to facility operational requirements.

The design activity should implement a configuration management process consistent with the requirements of DOE O 420.1C and DOE O 413.3B where applicable, including design, change, document, and work control. Subsequent changes to project design and supporting documents should be made by means of a formal change control program in accordance with the requirements of NQA-1, where applicable, as well as the approved configuration management program.

5.1.6 Multiple Physical Barriers

Attachment 2, Chapter I of DOE O 420.1C requires the design to include multiple physical barriers to confine radioactive and other hazardous materials and, thereby, prevent uncontrolled releases. Physical barriers can include hazardous materials containers, gloveboxes, passive facility structural elements, and confinement ventilation systems (CVS). Confinement systems are discussed in more detail in Section 5.3 of this Guide.

5.1.7 Multiple Means to Achieve Safety Functions

Attachment 2, Chapter I of DOE O 420.1C requires that the design provide multiple means to ensure safety functions are met. These means consist of (1) controlling the process; (2) shutting down the process in a safe shutdown state, if the process control is challenged; (3) using preventive and mitigative safety features, if the safe shutdown is challenged; and, (4) monitoring the post-accident condition, if necessary.

5.1.7.1 Preventive Features

To prevent abnormal facility conditions from progressing to accidents, preventive features should be considered in the design. The objective of these features is to provide a return to normal operation or to a safe condition. These features may provide automatic system response to such events or may be monitors that alert operators to the necessity of taking manual action. Such responses to off-normal conditions should effectively halt and reverse the progression of events toward an accident. If these features are engineering controls (i.e., SSCs) they may need to be designated as SC or SS, as determined by the safety analysis.

5.1.7.2 Mitigating Features

Safety SSCs should be provided to mitigate consequences of accidents that may occur despite the application of the preceding conventions.

5.1.8 Equipment and Administrative Controls

Attachment 2, Chapter I of DOE O 420.1C requires the design to provide features to: control process variables to values within safe conditions; alert operating personnel of an approach toward conservative process limits; and, allow timely detection of failure or malfunction of critical equipment.

DOE-STD-1186-2004, *Specific Administrative Controls*, provides guidance on the selection and design of administrative controls. Where specific administrative controls are determined to be necessary, the design should provide adequate time for the operating personnel to take action.

5.1.9 Accident Release Monitoring

Attachment 2, Chapter I of DOE O 420.1C requires that provisions for monitoring during and after accident releases be included in the design as required for emergency response. DOE O 151.1C, *Comprehensive Emergency Management Systems*, dated 11-02-05, provides additional design feature for accident monitoring requirements.

5.1.10 Emergency Planning

Attachment 2, Chapter I of DOE O 420.1C requires that emergency plans be established for minimizing the effects of an accident. DOE O 151.1C provides detailed requirements for emergency planning. See Section 5.4.8 of this Guide and Section 7.12 of DOE-STD-1189-2008 for additional guidance.

5.2 Hierarchy of Controls

DOE-STD-1189-2008 provides a control selection strategy that addresses hazardous material release events, based on the following order of preference at all stages of design development:

- minimization of hazardous materials is the first priority;
- safety-SSCs are preferred over administrative controls;
- passive SSCs are preferred over active SSCs;
- preventive controls are preferred over mitigative controls;
- facility safety SSCs are preferred over personal protective equipment (PPE).

In addition, the following should be considered during design development:

- controls closest to the hazard are preferred since they may provide protection to the largest population of potential receptors, including workers and the public; and,
- controls that are effective for multiple hazards are preferred since they can be resource effective.

5.3 Radioactive Material Confinement

Attachment 2, Chapter I of DOE O 420.1C requires hazard category 1, 2, and 3 nuclear facilities with uncontained radioactive materials (as opposed to materials determined by safety analyses to be adequately contained within qualified drums, grout, or vitrified materials) to have the means to confine the uncontained radioactive materials to minimize their potential release in facility effluents during normal operations, as well as, during, and following accidents up to and including design basis accidents (DBAs).

Further, DOE O 420.1C requires confinement design to include the following:

- For a specific nuclear facility, the number, arrangement, and characteristics of confinement barriers, as determined on a case-by-case basis;
- The type, quantity, form, and conditions for dispersing the radioactive materials in the confinement system design; and,
- An active CVS as the preferred design approach for nuclear facilities with potential for radiological release.

CVSs are among the most important mitigating systems for protecting the public and co-located workers, and are generally relied upon as the final safety barrier to the release of hazardous materials.

Active confinement ventilation systems are the preferred alternative for nuclear facilities with potential for radiological release. They provide a positive means for ensuring the control of radioactive materials for operational and design basis events.

Alternate confinement approaches may be acceptable if a technical evaluation demonstrates that the alternate confinement approach results in very high assurance of confinement of the radioactive materials. The technical justification should address how the passive facility confinement design results in very high assurance of the confinement of radioactive materials when compared with active systems for all operational activities and DBAs. This technical justification should also include the consideration of conservative evaluations of accident conditions, including energy sources associated with the accident and post-accident recovery, building integrity, and building re-entry activities (see DNFSB/TECH 34, *Confinement of Radioactive Materials at Defense Nuclear Facilities*, for additional discussion). Furthermore, the evaluation should demonstrate how post-accident monitoring and off-site dose measurements will be performed to support potential worker and public evacuation.

When an active confinement ventilation strategy is selected as a means of confining radioactive materials, designers should use Appendix A, *Confinement Ventilation Systems Design and Performance Criteria,* of this Guide.

5.4 Other General Design Considerations and Practices

5.4.1 Design to Facilitate Deactivation, Decontamination, and Decommissioning

Attachment 2, Chapter I of DOE O 420.1C requires the design to include considerations related to deactivation, decontamination, and decommissioning requirements.

5.4.1.1 Deactivation

Deactivation is the process of removing hazardous materials and neutralizing hazardous conditions at the end of a facility’s life or mission prior to decontamination and decommissioning. A design to facilitate deactivation should incorporate facility features that aid in: the removal of surplus radioactive and chemical materials; storage tank cleanout and maintenance; stabilization of contamination and process materials; and, the removal of hazardous, mixed, and radioactive wastes. In general, these features should reduce the physical risks and hazards associated with facility decontamination and decommissioning and would also be called for when designing for ease of maintenance during operation.

5.4.1.2 Decontamination

The facility design should incorporate measures to simplify decontamination of areas that may become contaminated with radioactive or hazardous materials. Items such as service piping, conduits, and ductwork should be kept to a minimum in potential contamination areas and should be arranged to facilitate decontamination. Walls, ceilings, and floors in areas vulnerable to contamination should be finished with washable or strippable coverings. Metal liners should be used in areas that have the potential to become highly contaminated. Cracks, crevices, and joints should be filled and finished smooth to prevent accumulation of contaminated materials. The facility design should incorporate features that will facilitate decontamination to achieve facility decommissioning, to increase the potential for other uses, or both.

5.4.1.3 Decommissioning

Design features consistent with the requirements of DOE O 435.1, Chg 1, *Radioactive Waste Management*, dated 07-09-99, should be developed during the planning and design phases, based on decommissioning requirements or a conversion method leading to other facility uses. The following design principles should be considered:

- Use of localized liquid-transfer systems with emphasis on localized batch solidification of liquid waste to avoid long runs of buried contaminated piping. Special provisions should be included in the design to ensure the integrity of joints in buried pipelines;

- Location of exhaust filtration components of the ventilation systems at, or near, individual enclosures to minimize long runs of internally contaminated ductwork;

- Equipment, including effluent decontamination equipment that precludes, to the extent practicable, the accumulation of radioactive or other hazardous materials in relatively inaccessible areas, including curves and turns in piping and ductwork;

- Accessible, removable covers for inspection and cleanouts are encouraged;

- Use of modular radiation shielding in lieu of, or in addition to, monolithic shielding walls;

- Provisions for flushing and/or cleaning contaminated, or potentially contaminated, piping systems;

- Provisions for suitable clearances, where practical, to accommodate equipment removal and access for remote handling and safety surveillance equipment planned for use in future decontamination and decommissioning;

- Use of lifting lugs on large tanks and equipment; and,

- Piping systems that carry contaminated, or potentially contaminated, liquid should be free draining via gravity.

5.4.2 Design to Facilitate Inspection, Testing, and Maintenance

Attachment 2, Chapter I of DOE O 420.1C requires that facilities be designed to facilitate inspection, testing, maintenance, and repair and replacement of safety SSCs to ensure their continued function, readiness for operation, and accuracy. The facility design should include provisions for accessibility and maintainability that include, but are not limited to, the following:

- Surveillance equipment should be located and sufficient space provided for relative ease of routine testing and maintenance activities;

- Accessible inspection covers to allow for visual inspection should be provided and located such that necessary routine inspections can be conducted with minimum disruption to the facility or equipment operation, for example, flow test ports in ducting;

- The facility design should include features that provide for ease of routine maintenance without a subsequent mission reduction. Examples include providing sufficient clearance around equipment to accommodate the change out of large components and providing permanent ladder(s) and platform(s) to access lubrication and equipment areas;

- The facility design should consider the choice of manufacturer or software producer regarding future maintainability and availability of spare parts;

- The facility design should include provisions for integrated testing at the system level to verify safety functions; and,

- The facility design should use a reliability, maintainability and availability program to achieve operational needs for the design life of the desired end product, expected normal and worst-case operating conditions, and expected downtime for either corrective or preventive maintenance actions.

5.4.3 Design for Radiation Protection and Contamination Control

Attachment 2, Chapter I of DOE O 420.1C requires the design to include considerations related to radiation protection and contamination control requirements. 10 C.F.R. Part 835, *Occupational Radiation Protection,* also provides requirements for radiological protection.

The primary objective of radiological protection is to minimize external and internal personnel exposures to radioactive materials. This objective is accomplished through multiple features and measures, such as: providing adequate radiation posting, sampling, monitoring, and notification or alarm capabilities; applying as low as reasonably achievable (ALARA) principles; incorporating facility and system radiation protection features into the designs; and, through other measures. Typical radiation protection design features should include: shielding; remote handling; area and equipment layout to prevent radiation streaming; passive confinement structures and containers; active confinement ventilation negative pressure cascades; and, exhaust high-efficiency particulate air (HEPA) filtration, supplemented by cautionary systems. ALARA principles to minimize personnel exposures should be applied to all equipment and facility designs. The following are design considerations that support meeting these objectives:

- The type and level of hazards should be determined for each functional area, the attendant degree of risk identified, and the possibility of cross-contamination considered. Wherever possible, work areas with compatible contaminants should be located together to simplify design criteria related to air supply and exhaust, waste disposal, decontamination, and cross-contamination;

- Radioactive and other hazardous materials contamination control requirements should be considered together in the design to minimize the potential for contamination spread from either source;

- Office areas should be located in separate common-use facilities (e.g., data computation and processing, word processing, etc.) and away from process areas, if practicable, to minimize risks to workers from radioactive and/or hazardous materials;

- The building layout should provide protection from the hazards associated with handling, processing, and storing of radioactive and/or hazardous materials. In addition, the following items should be considered in the facility safety design:

    - Additional space should be provided for temporary or additional shielding in the event radiation levels are higher than anticipated;

    - The arrangement and location of hazardous process equipment and its maintenance provisions should provide appropriate protective and safety measures as applicable;

    - The building design should accommodate prompt return to a safe condition in emergencies, and should allow ready access for, and protection of, workers in areas where manual corrective actions are necessary, as well as in areas that contain radiation monitoring equipment readouts.

    - Facility layout should provide specific control and isolation, if possible, of quantities of flammable, toxic, and explosive gases, chemicals, and other hazardous materials admitted to the facility; and,

    - For some facilities, integration of security considerations with radiation protection considerations can be important in building layout and structural design.

Specific criteria for radiation monitoring and entry and exit control systems, posting and labeling of radioactive materials and spaces, nuclear accident dosimetry, and ALARA applications should be applied as required by 10 C.F.R. Part 835.

Physical layout and details of proven radiological equipment designs for plutonium facilities are contained in DOE-STD-1128-2008, *Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities.*

10 C.F.R. Part 835 requires that the projected dose rates are based on occupancy, duration, and frequency of exposure. If dose projections exceed values specified in 10 C.F.R. Part 835, shielding should be used for areas that need to be accessed normally or intermittently, such as

those for preventive maintenance, component changes, or adjustment of systems and equipment. The type of shielding should be determined by the characteristics of the radiation, structural requirements, fire protection requirements, and radiation damage potential. Shielding should also be installed to minimize non-penetrating external radiation exposures to the skin and lens of the eye, where necessary. In most cases, confinement barriers or process equipment provide this function. Where shielding is an integral part of the facility structure, it should be designed and installed to at least the same level of natural phenomenon qualification as the facility structure. Additional guidance is contained in American National Standards Institute/American Nuclear Society (ANSI/ANS) 6.4.2-2006, *Specification for Radiation Shielding Materials*.

Occupied operating areas for normal operating conditions should be designed not to exceed the airborne concentration limits of 10 C.F.R. Part 835. Respirators should not be needed under normal operating conditions except as a precautionary measure. Engineered controls and features should be designed with consideration of contaminant chemical forms to minimize potential inhalation of radioactive materials and to minimize potential chemical degradation of such engineered features.

Devices to monitor individual exposures to external radiation and to warn personnel of radioactive contamination are to be used in accordance with 10 C.F.R. Part 835. Air sampling equipment should be placed in strategic locations to detect and evaluate airborne contaminant conditions at work locations. Continuous air monitors with preset alarms should be provided to give early warning of significant releases of radioactive materials. Air monitoring and warning systems are to be used in compliance with the requirements of 10 C.F.R. Part 835.

Breathing-air supply systems, if needed, are to comply with the requirements of the Occupational Safety and Health Administration's (OSHA) 29 C.F.R. Part 1910, *Occupational Safety and Health Standards*, Section 134, *Respiratory Protection.*

DOE-STD-1098-2008, *Radiological Control,* provides details on radioactive material identification, storage, and transport. In addition, DOE-STD-1098-2008 provides descriptions and details of use-proven principles and designs and identifies considerations that affect configuration, hardware selection, installation, maintenance, and controls that can be used in developing a sound functional design.

- Shielding should be designed to limit the total external dose during normal operations to the annual exposure limit values as specified in 10 C.F.R. Part 835. Design of facilities and shields applicable to machines and sources is summarized as good practices in applicable National Council on Radiation Protection reports. Additional guidance is contained in ANSI N43.2, *Radiation Safety for X-ray Diffraction and Fluorescence Analysis Equipment*.

- Guidance on ventilation design is provided in the American Conference of Governmental Industrial Hygienists (ACGIH) 2096 *Industrial Ventilation: A Manual of Recommended Practice for Design, 27th Edition* and DOE Handbook (HDBK)-1169-2003, *Nuclear Air Cleaning Handbook.* Alarms for loss of ventilation or differential pressure should be provided on primary confinement systems (gloveboxes or hoods) and secondary confinement systems (rooms). ASME

AG-1, *Code on Nuclear Air and Gas Treatment*, contains requirements for the design of nuclear facility air cleaning systems and acceptance requirements for testing air cleaning systems.

- Change rooms for changing into and out of protective clothing should be designed to ensure that clean clothing (personal clothing) and contaminated clothing (protective clothing) are segregated. The design objective is to ensure that storage of contaminated protective clothing will control contamination so that it does not spread beyond the storage container. The change room exhaust air should be HEPA-filtered, as applicable, if dispersible radionuclides are handled in the process areas it serves.

- Personnel decontamination facilities should be located close to areas that are potential sources of contamination. Safety showers may be used if water collection from their use is controlled. Portable personnel decontamination equipment should be considered for facilities with no permanent structures.

- Respiratory protection should be provided to maintenance personnel in areas where the potential for significant exposures exist for maintenance operations and where design constraints preclude the ability to perform maintenance either remotely or in a glovebox. However, every reasonable effort should be made to allow routine maintenance activities to be conducted without the need for respiratory protection.

5.4.4 Design for Access Control

While not controlled by DOE O 420.1C requirements, the design should include considerations related to access control requirements.

The facility design should accommodate the requirements for: safeguards and security; access by emergency responders under normal and accident conditions; emergency egress; and, area access control for worker protection. Where these requirements conflict, life safety should take precedence. For example, safeguards and security requirements would minimize the number of entrances and exits, but for worker safety, the emergency-egress requirements would provide an adequate number of exits. Specific requirements for access control are to be implemented as specified by 10 C.F.R. Part 835 for radiological hazards, by the Resource Conservation and Recovery Act for hazardous waste treatment, storage, and disposal facilities, and by OSHA's 29 C.F.R. Part 1910, Occupational Safety and Health Standards and Part 1926, Safety and Health Regulations for Construction, for hazardous material locations within operating facilities and construction sites.

Whereas access control is provided for control rooms that contain SC and SS SSC controls and monitoring, the same level of qualification is to be considered for access control features. Access controls are to be designed and implemented so as not to prevent operator actions that would be necessary to achieve and maintain a facility in a safe condition.

5.4.5 Design for Non-Radioactive, Hazardous Material Protection

This section provides functional design guidance for hazardous material protection other than radioactive material protection. DOE-STD-1189-2008 (as invoked by DOE O 420.1C and DOE O 413.3B) requires that the hazard analysis identifies any potential for hazardous material release accidents that cause or exacerbate a nuclear accident. This potential is to be considered in the accident analysis and the selection of safety SSCs. In addition, Attachment 2, Chapter I of DOE O 420.1C requires that nuclear facilities be designed to protect against chemical hazards and toxicological hazards consistent with DOE-STD-1189-2008. Appendix B of DOE-STD-1189-2008 provides additional guidance for protection against chemical hazards and toxicological hazards.

Requirements for design of engineered controls for hazardous material protection are contained in the IBC, 10 C.F.R. Part 851, *Worker Safety and Health Program*, and 29 C.F.R. Part 1910, Subparts G, H, and Z.

Ventilation systems are engineering controls commonly used to prevent worker exposure to hazardous materials and may be used in combination with personal protective equipment and operational procedures. Where ventilation is used to control worker exposures, 29 C.F.R. Part1910, Subpart G 1910.94, *Ventilation*, requires that it is adequate to reduce the hazardous materials concentrations of air contaminants to the degree that the hazardous materials no longer poses a health risk to the worker (i.e., concentrations at, or below, the permissible exposure limits). Wherever engineering controls are not sufficient to reduce exposures to such levels, 29 C.F.R. Part 1910, Subpart Z, 1910.1000, *Air Contaminants*, requires that they be used to reduce exposures to the lowest practicable level and be supplemented by work practice controls. The design should ensure that respirators are not needed for normal operating conditions or routine maintenance activities except as a precautionary measure.

Ventilation systems for hazardous material protection should use exhaust hoods to control concentrations of hazardous materials from discrete sources, or should control the number of air changes per hour for an entire room or bay. Air flow and other design requirements for specific types of systems are required to comply with 29 C.F.R. Part 1910, Subparts G and H. 29 C.F.R. Part 1910, Subpart Z, provides requirements for monitoring and alarm systems for facilities that manage or use specific hazardous materials. Additional guidance on design of ventilation systems for hazardous material protection is provided in ANSI/American Industrial Hygiene Association (AIHA) Z9.2-2012, *Fundamentals Governing the Design and Operation of Local Exhaust Ventilation Systems* and the American Society of Heating, Refrigeration and Air Conditioning (ASHRAE) 62.1-2010, *Ventilation for Acceptable Indoor Air Quality*. Decontamination facilities, safety showers, and eyewashes to mitigate external exposures to hazardous materials are required where mandated by 29 C.F.R. Part 1910, Subparts H and Z. These systems should be designed in accordance with the requirements of ANSI Z358.1-2009, *American National Standard for Emergency Eyewash and Shower Equipment*.

Facilities with hazardous material exposure concerns should be designed to minimize personnel exposures, both external and internal, and to provide adequate monitoring and notification capabilities to inform workers of unsafe conditions. Hazardous material protection should be provided through facility design (e.g., remote handling, area and equipment layout, spill-control features, confinement, ventilation, specific code requirements for hazardous materials, etc.). Occupied spaces should be designed to preclude locations where low oxygen content or air displacement may occur or where reactive, combustible, flammable, or explosive gas, vapor, or liquid accumulation might occur.

Safety controls and features should be designed to consider contaminant chemical forms and minimize the potential for inhalation and contact under all conditions. Directed ventilation flow paths should be used to move contaminants away from worker breathing zones. The design should ensure that ventilation flow will cascade from clean areas to contaminated areas to preclude contamination spread. Uniform distribution of incoming air and/or air mixing equipment should be provided to ensure that no pockets of stagnant air exist in areas where workers are present. Air flow arrangements that are designed to ensure that air flow from the cleanest area to contaminated areas should be evaluated to ensure that the ventilation arrangement will not inhibit/compromise exiting under fire conditions.

DOE G 440.1-1B, *Worker Safety and Health Program for DOE (Including the National Nuclear Security Administration) Federal and Contractor Employees*, dated 10-20-2011, provides additional information on hazardous material protection vis-à-vis 10 C.F.R. Part 851 compliance.

5.4.6 Design for Effluent Monitoring and Control

This section applies to any DOE facility that produces airborne or liquid radioactive and/or hazardous material effluents, including contaminated storm water. Attachment 2, Chapter I of DOE O 420.1C provides high level requirements for managing uncontained radioactive materials. DOE O 435.1 and DOE Manual (M) 435.1-1, *Radioactive Waste Management Manual*, dated 07-09-99, provide requirements and guidance to ensure a radioactive release is managed in a manner that is protective of worker and public health and safety, and the environment.

Liquid process wastes containing radioactive and/or hazardous materials should be collected and monitored near the source of generation before a batch transfer via appropriate pipelines or portable tanks to a liquid-waste treatment facility. Waste storage tanks and transfer lines should be designed and constructed such that any leakage could be detected, contained, and collected for removal, before it reaches the environment. Double-walled transfer pipelines or multiple encasements should be used for high-level radioactive liquid wastes and other liquid wastes that have the potential to cause significant localized consequences, or significant exposures during the implementation of mitigating measures in the event of an accidental release. Provisions should be made for the collection, removal, and appropriate disposition of infiltration into the annulus of double-walled pipelines. Radioactive- and hazardous-waste collection, transfer, and storage systems should be designed to avoid the dilution of radioactive or hazardous waste due to waste of lower concentrations of radioactivity, toxicity, or other hazard. Airborne effluents from areas in which hazardous or radioactive materials are managed, are exhausted through a ventilation system designed to remove particulate materials, vapors, and gases. Such a system should comply with applicable release requirements (e.g. state or local limits) and should reduce releases of radioactive materials to ALARA levels. The design of airborne-effluent systems should preclude holdup of particulate materials in off-gas and ventilation ductwork and include provisions to continuously monitor the buildup of materials and material recovery. The design of systems should also preclude the accumulation of potentially flammable quantities of gases generated by radiolysis or chemical reactions within process equipment.

The design capacity for effluent monitoring and control systems should be consistent with the needs for handling process effluents during normal operations, anticipated operational occurrences, and DBA conditions. Alarms should be provided that will annunciate in the event concentrations of radioactive or hazardous materials above specified limits are detected in the effluent stream. Appropriate manual or automatic protective features should be provided to prevent an uncontrolled release of radioactive and/or hazardous materials into the environment or the workplace. Portions of effluent management systems and components that are necessary to control, or limit, the release of radioactive or hazardous materials into the environment, or for safe operation of the system, should be provided with redundancy where required by applicable Federal, state, and local environmental regulations and permits. Effluent monitoring and control systems are designed to allow periodic maintenance, inspection, and testing of components and to maintain ALARA occupational radiation doses during these operations. Appropriate nuclear criticality safety provisions should be applied to the design of airborne effluent systems. This includes a design that precludes the holdup or collection of materials capable of sustaining a chain reaction in portions of the system not geometrically favorable. This also includes a design to ease in-situ measurement and recovery of these materials.

Effluent monitoring and control SSCs are generally designed to operate in conjunction with physical barriers to form a confinement system to limit the release of radioactive or other hazardous materials into the environment and to prevent or minimize the spread of contamination within the facility.

Adequate instrumentation and controls (I&C) should be provided to assess system performance and to allow the necessary control of system operations. Equipment in safety systems is required to be appropriately qualified or protected to ensure reliable operation during normal operating conditions; during anticipated operational occurrences, and during and following DBAs, including a design basis earthquake. SC air filtration units, effluent transport systems, or effluent collection systems are to be designed to remain functional throughout DBAs and to retain collected radioactive and hazardous materials after the accident, as required by DOE O 420.1C.

5.4.7 Design for Waste Management

This section applies to any DOE facility that, under normal operating conditions produces wastes having constituents that are regulated as radioactive, hazardous, or mixed-waste. DOE O 435.1, and the Federal, state, and local requirements referenced therein, specify the criteria for the design of waste management systems. Waste management and storage systems, along with associated support systems, should be designed to remain functional following a DBA and should facilitate the maintenance of a safe shutdown condition and post-accident recovery activities. For high-level waste containment systems, at least one confinement barrier should be designed to withstand the effects of DBAs.

DOE M 435.1-1, *Radioactive Waste Management Manual*, dated 06-06-2011, addresses waste minimization.

5.4.8 Design for Emergency Preparedness and Emergency Communications

Attachment 2, Chapter I of DOE O 420.1C requires establishing emergency plans for minimizing the effects of an accident. Provisions for emergency preparedness are contained in the requirements of DOE O 151.1C, which address installation of an emergency operations center. Primary and backup means of communications with the emergency operations center, provisions for evacuation and accountability, as well as adequate equipment and supplies for emergency response personnel to carry out their respective duties and responsibilities related to nonreactor nuclear facility, are to be provided in the facility design in accordance with DOE O 151.1C requirements.

Emergency evacuation annunciation systems and general communication systems should be installed per the applicable National Fire Protection Association codes listed in DOE-STD-1066-2012. Installation requirements for transmission of alarm conditions to building occupants should be considered public mode systems and address topics such as: protection of circuits; minimum audibility requirements above background noise; voice intelligibility; and, visual signals, including minimum light intensities.

For facilities handling dispersible materials, meteorological data necessary to predict consequences from an emergency event should be obtained from the following sources in order of preference: (1) site specific information; (2) the nearest U.S. Geological Survey; (3) local (on-site) meteorological stations; (4) National Oceanic and Atmospheric Administration.

5.4.9 Human Factors Engineering

Appropriate human factors engineering principles and criteria should be integrated into the design, operation, and maintenance of DOE facilities. The human factor elements that should be considered include, but are not limited to, the following: equipment labeling; workplace environment (temperature and humidity, lighting, noise, vibration, and aesthetics); human dimensions; operating panels and controls; component arrangement; warning and annunciator systems; and, communication systems. The applicable criteria found in the following standards should be considered in the design of these elements: Nuclear Regulatory Guide (NUREG) 0700, *Human-System Interface Design Review Guidelines*; MIL-STD-1472F, *Department of Defense Design Criteria Standard: Human Engineering*; and Institute of Electrical and Electronics Engineers (IEEE) Std. 1023-2004, *IEEE Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations and other Nuclear Facilities*. DOE-STD-1195-2011, *Design of Safety Significant Safety Instrumented Systems Used at DOE Nonreactor Nuclear Facilities* also provides additional guidance for human factors engineering.

5.4.10 Design of Support Systems and System Interfaces

Safety SSCs often rely upon other SSCs to support their operation. Therefore, it is important to identify these supporting systems and the associated interfaces between safety and non-safety SSCs. The following subsections address the design considerations for these related systems.

5.4.10.1 Support Systems

In some cases, safety-SSCs rely upon supporting SSCs to perform their intended safety function. Attachment 3 of DOE O 420.1C requires that support SSCs be designed as SC or SS SSCs if their failures prevent safety-SSCs or specific administrative controls from performing their safety functions. For example, a SC designation may be appropriate for an I&C system that supports a tritium containment system if failure of the I&C support system could lead to either failure or reduced availability of the SC containment barrier. However, if the support system would not lead to immediate failure of the safety-SSC, such as for a heat tracer on a fire protection line, combined with a safety alarm, providing adequate time for restoration action, the support system may not need to be classified as a safety-SSC. The classification of the supporting SSCs would be at same level as the safety-SSCs or specific administrative controls that they could impact.

5.4.10.2 Interface Design

A nuclear safety design goal is to minimize interfaces between SC, SS, and non-safety SSCs. Interfaces, such as pressure retention boundaries, integrity of fluid systems, electrical equipment, I&C, and mechanical and support systems, exist between safety SSCs and non-safety SSCs. These interfaces should be evaluated to identify SSC failures that would prevent the safety SSCs from performing their intended safety function. For these SSC failures, isolation devices, interface barriers, or design class upgrades should be provided to ensure safety SSC protection and availability. In many cases, systems may consist of a group of subsystems, where each subsystem supports the operation of the whole system. For example, an auxiliary power diesel generator system may consist of lubricating oil, fuel oil, diesel engine, jacket cooling, and room ventilation subsystems. System interface evaluations should clearly define these boundaries. In all instances, a case-by-case evaluation should be performed.

5.4.10.3 System Interaction

DOE-STD-1020-2012 provides guidance and requirements on system interaction including potential interaction of non-safety SSCs and safety-SSCs.

5.4.11 Design of Mechanical Handling Equipment

Mechanical handling equipment (cranes, manipulators, etc.) should only be classified as SC or SS if their failure would create a hazardous material release exceeding the guidelines for either classification (see DOE-STD-1189-2008, Appendix C). The SS classification, as a defense-in-depth provision, will be the more common classification for remote material handling equipment.

Failure modes for mechanical handling equipment used to move radioactive materials should address mid-operational failures, and designs should include recovery methods.

Designs should accommodate periodic maintenance and inspection.

5.4.12 Design of Ventilation Systems

In general, the safety function of ventilation and off-gas systems is to provide confinement integrity and to filter exhaust, thereby preventing or mitigating uncontrolled releases of radioactive and/or hazardous materials into the environment. Ventilation and off-gas systems are included as a vital part of the primary and secondary confinement design. The need for redundancy should be determined by the safety analysis process and maintenance concerns for both active and passive components. Designs should provide for periodic maintenance, inspection, and testing of components. Adequate shielding should be included in the design of filters, absorbers, scrubbers, and other air treatment components to ensure that occupational exposure limits are not exceeded during maintenance and inspection activities.

SC and SS ventilation system designs should include adequate instrumentation to monitor and assess performance with necessary alarms for annunciation of abnormal or unacceptable operation. Manual or automatic protective control features should be provided to prevent or mitigate an uncontrolled release of radioactive and/or hazardous materials into the environment and to minimize the spread of contamination within the facility.

Vent streams potentially containing significant concentrations of radioactive and/or hazardous materials should be processed through an off-gas cleanup system before being exhausted into the environment. Cleanup systems are to remove particulates and noxious chemicals and control the release of gaseous radionuclides. The design of SC and SS off-gas systems should be commensurate with the sources and characteristics of the radioactive and chemical components of the off-gas air stream to prevent or mitigate the uncontrolled releases of radioactive and/or hazardous materials into the environment.

Appendix A of this Guide provides additional design and performance criteria for SC and SS ventilation systems[1].

5.4.13 Environmental Qualifications

Attachment 3 of DOE O 420.1C requires the design to use the IEEE STD 323-2003, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*, or other applicable standards, to ensure that safety-class SSCs can perform all safety functions, as determined by the safety analysis, with no failure mechanism that could lead to common cause failures under postulated service conditions (e.g., temperature, humidity, radiation). For equipment located in a mild environment, and which has no significant aging mechanisms, a qualified life is not required by IEEE STD 323.

For safety-significant SSCs that are located in a mild environment, the SSCs should be selected for application to the specific service conditions based on sound engineering practices and manufacturers' recommendations. Safety-significant SSCs located in a harsh environment,

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[1] Appendix A was derived from guidance developed by the Department for review of confinement ventilation systems as part of the Department's implementation plan in response to Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 2004-2, *Active Confinement Systems*.

however, should be evaluated for qualified life using manufacturers' recommendations or other appropriate methods.

System documentation should be maintained preserving the relationship between equipment application and service conditions.

5.4.14 Design of Electrical Systems

The safety function of an electrical power system is to provide power to systems and components that require electrical power in order to perform their safety functions, and such power systems should be classified as SC or SS accordingly. These systems consist of on-site AC/DC power supply systems and associated distribution systems and components (e.g., conduits, wiring, cable trays, etc.).

Attachment 3 of DOE O 420.1C requires that the single failure criterion, requirements, and design analysis identified in IEEE 379-2000, *IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Stations Safety Systems*, be applied to SC electrical systems and components. Redundancy requirements for electrical systems pertain to normal and alternative power sources and should be analyzed on a case-by-case basis. For SS systems, redundancy may not be needed if it can be shown that there is sufficient response time to provide a readily available and defined alternative source of electrical power.

For the commercial nuclear industry, a multitude of ANSI/IEEE standards define the requirements for the design, manufacturing, installation, and testing of reactor Safety Class 1E electrical systems and components. The Safety Class 1E requirements may not be directly applicable to the SC category defined for nonreactor nuclear facilities. These standards, however, contain useful and significant information that should be considered. Attachment 3 of DOE O 420.1C lists a set of national codes and standards to be used for SC and SS electrical systems, keeping in perspective the applicable use of ANSI/IEEE standards for Safety Class 1E components.

Environmental capability of SC and SS electrical equipment in harsh environments should be demonstrated using the guidance stated in Section 5.4.13 of this Guide.

5.4.15 Design of Instrumentation, Controls, and Alarm Systems

The safety functions of instrumentation, control, and alarm systems are to: provide information on out-of-tolerance conditions/abnormal conditions; ensure the capability for manual or automatic actuation of safety systems and components; ensure safety systems have the means to achieve and maintain a fail-safe shutdown condition on demand under normal or abnormal conditions; and/or, actuate alarms to reduce public or site-personnel risk (e.g., effluent monitoring components and systems).

Attachment 3 of DOE O 420.1C requires the design of SC I&C systems to incorporate sufficient independence, redundancy, diversity, and separation to ensure that all safety-related functions associated with such equipment can be performed as defined in the safety analysis. DOE O 420.1C also requires SS I&C components to be evaluated as to the need for redundancy on a case-by-case basis. DOE-STD-1195-2011 provides an acceptable method for achieving high reliability of SS safety instrumented systems.

DOE O 420.1C requires SC and SS instrumentation, controls, and alarms to be designed so that failure of non-safety equipment will not prevent the former from performing their safety functions.

DOE O 420.1C requires SC and SS instrumentation, control, and alarm-systems to be designed to ensure accessibility for inspection, maintenance, calibration, repair, or replacement.

SC and SS instrumentation, control, and alarm systems should provide the operators sufficient time, information, and control capabilities to perform the following safety functions:

- Readily determine the status of critical facility parameters to ensure compliance with the limits specified in the technical safety requirements;

- Initiate manual safety functions (e.g., take the necessary actions credited in the DSA); and,

- Determine the status of safety systems required to ensure proper mitigation of the consequences of postulated accident conditions and/or to safely shut down the facility.

ANSI/IEEE and ANSI/ISA standards contain design, installation, and testing requirements that should be considered for instrumentation, control, and alarm components without invoking all of the Safety Class 1E requirements.

5.4.16 Equivalencies for Codes and Standards

The facility design authority (as defined in DOE O 413.3B) is required to select and use an appropriate set of codes and standards to establish the COR and the design criteria, which provide assurance that the SSCs will reliably perform their intended functions. DOE technical standards and industry codes and standards are considered applicable when they provide relevant design requirements for the safety SSCs that are being designed. Applicable DOE technical standards and industry codes and standards contain requirements that are appropriate for the design materials, configuration, and service conditions; and provide design requirements that ensure that the desired SSC functions are achieved. In cases where the facility design uses alternative codes and standards to those identified in Attachment 3 of DOE O 420.1C, an approved equivalency is required by Attachment 1 of DOE O 420.1C. In such cases, the alternative codes and standards would be included in the COR.

Justification of equivalent codes and standards should demonstrate that the proposed design of the SSCs meets, or exceeds, the level of safety (e.g., meets, or exceeds, the level of protection) provided by the normally applied codes and standards. Evaluation of the level of safety should address:

- Critical safety attributes of the SSCs;
- Critical characteristics of the SSCs that are important to design, material, and performance of the SSCs;
- The reliability of safety SSCs; and,
- The margins of safety to failure of the SSCs (e.g., pressure, temperature, environmental conditions, and other design loads) provided by application of the code.

For individual components, equivalency should be demonstrated by defining and verifying that the substitute component meets or exceeds these characteristics. Equivalencies should be well documented with a technical basis and should receive peer review by a technically capable and experienced designer.

APPENDIX A: CONFINEMENT VENTILATION SYSTEMS DESIGN AND PERFORMANCE CRITERIA

The following table presents the design and performance criteria that should be used in the design and construction of new active confinement ventilation systems (CVSs) based on the safety classification of the system. Note: This table presents a summary of key design attributes; see DOE Handbook (HDBK) 1169-2003, *Nuclear Air Cleaning Handbook* for more complete design guidance.

Table A-1. Confinement Ventilation System Design and Performance Criteria

DESIGN/ PERFORMANCE	SAFETY CLASS	SAFETY SIGNIFICANT	DEFENSE-IN-DEPTH/OTHER	DISCUSSION	REFERENCE
Ventilation System – General Criteria					
Pressure differential should be maintained between zones and atmosphere	Applies	Applies	Applies	Number of zones as credited by accident analysis to control hazardous material release; demonstrate by use considering potential in-leakage	DOE-HDBK-1169 (2.2.9); ASHRAE Design Guide
Materials of construction should be appropriate for normal, abnormal and accident conditions	Applies	Applies	Applies		DOE-HDBK-1169 (2.2.5); ASME AG-1
Exhaust system should withstand anticipated normal, abnormal and accident system conditions and maintain confinement integrity	Applies	Applies	Applies	As required to prevent accident release	DOE-HDBK-1169-2003 (2.4); ASHRAE Design Guide
CVSs will have appropriate filtration to minimize release	Applies	Applies	Applies	Address: 1) type of filter (e.g., HEPA, sand, sintered metal); 2) filter sizing (flow capacity and pressure drop); 3) decontamination factor vs. accident analysis assumptions	DOE-HDBK-1169-2003 (2.2.1); ASME AG-1

Ventilation System – Instrumentation and Control					
Provide system status instrumentation and/or alarms	Applies	Applies	Applies	Address key information to ensure system operability (e.g., system delta-P, filter pressure drop)	DOE-HDBK-1169-2003; ASME AG-1: ASHRAE Design Guide (Section 4)
Interlock supply and exhaust fans to prevent positive pressure differential	Applies	Applies	Applies		DOE-HDBK-1169-2003; ASHRAE Design Guide (Section 4)
Post-accident indication of filter break-through	Applies	Applies	Does Not Apply	Instrumentation supports post-accident planning and response; should be considered critical instrumentation for SC	DNFSB/TECH-34
Reliability of control system to maintain confinement function under normal, abnormal and accident conditions	Applies	Applies	Applies	Address, for example, impacts of potential common mode failures from events that would require active confinement function	DOE-HDBK-1169-2003 (2.4)
Control components should fail safe	Applies	Applies	Applies		DOE-HDBK-1169-2003 (2.4)
Resistance to Internal Events – Fire					
CVSs should withstand credible fire events and be available to operate and maintain confinement	Applies	Applies	Does Not Apply	Required for new facilities; as required for existing facilities (discretionary). Address protection of filter media.	DOE-HDBK-1169-2003 (10.1); DOE-STD-1066-2012
CVSs should not propagate spread of fire	Applies	Applies	Applies	Required for new facilities; as required for existing facilities (discretionary). Address fire barriers, fire dampers arrangement	DOE-HDBK-1169-2003 (10.1); DOE-STD-1066-2012

Resistance to External Events - Natural Phenomena - Seismic					
CVSs should safely withstand earthquakes	Applies	Applies	Does Not Apply	If the active CVS system is not credited in a seismic accident condition there is no need to evaluate that performance and/or design attribute for the CVS (discretionary). Also, any seismic impact on the CVS performance will be based on the current functional requirements in the documented safety analysis (DSA). NOTE: Seismic requirements may apply to defense-in-depth items indirectly for the protection of safety SSCs.	DOE O 420.1C; DOE-HDBK-1169-2003 (9.2); ASME AG-1
Resistance to External Events - Natural Phenomena – Tornado/Wind					
CVS should safely withstand tornado depressurization	Applies	Applies	Does Not Apply	If the active CVS is not credited in a tornado condition there is no need to evaluate that performance and/or design attribute for the CVS (discretionary). Also, any tornado impact on the CVS performance will be based on the current functional requirements in the DSA.	DOE O 420.1C; DOE-HDBK-1169-2003 (9.2)
CVS should withstand design wind effects on system performance	Applies	Applies	Does Not Apply	If the active CVS is not credited in a wind condition there is no need to evaluate that performance and/or design attribute for the CVS (discretionary). Also, any wind impact on the CVS performance will be based on the current natural phenomena analysis in the DSA.	DOE O 420.1C; DOE-HDBK-1169-2003 (9.2)

Other Natural Phenomena Events (e.g., flooding, precipitation)					
CVS should withstand other natural phenomena events considered credible in the DSA where the CVS is credited	Applies	Applies	Does Not Apply	If the active CVS is not credited for this event there is no need to evaluate that performance and/or design attribute for the CVS (discretionary). Also, any wind impact on the CVS performance will be based on the current NP analysis in the DSA.	DOE O 420.1C; DOE-HDBK-1169-2003 (9.2)
Range Fires/Dust Storms					
Administrative controls should be established to protect CVSs from barrier threatening events	Applies	Applies	Does Not Apply	Ensure appropriately thought out response to external threat is defined (e.g., pre-fire plan)	DOE O 420.1C

Testability					
Design supports the periodic inspection & testing of filters and housing, and tests and inspections are conducted periodically	Applies	Applies	Applies	Ability to test for leakage per intent of N510	DOE-HDBK-1169-2003 (2.3.8); ASME AG-1; ASME N510
Instrumentation required to support system operability is calibrated	Applies	Applies	Applies	Credited instrumentation should have specified calibration/surveillance requirements. Non-safety instrumentation should be calibrated as necessary to support system functionality.	DOE-HDBK-1169-2003 (2.3.8)
Integrated system performance testing is specified and performed	Applies	Applies	Does Not Apply	Required responses assumed in the accident analysis are periodically confirmed including any time constraints	DOE-HDBK-1169-2003 (2.3.8)
Maintenance					
Filter service life program should be established	Applies	Applies	Applies	Filter life (shelf life, service life, total life) expectancy should be determined. Consider filter environment, maximum delta-P, radiological loading, age, and potential chemical exposure.	DOE-STD-1169-2003 (3.1 & APP C)

Single Failure					
Failure of one component (equipment or control) will not affect continuous operation	Applies	Does Not Apply	Does Not Apply	Address potential failures (example failures - fan, backup power supply, switchgear)	DOE O 420.1C, Attachment 2, Chapter I
Automatic backup electrical power will be provided to all critical instruments and equipment required to operate and monitor the CVS	Applies	Does Not Apply	Does Not Apply		DOE-HDBK-1169-2003 (2.2.7)
Backup electrical power will be provided to all critical instruments and equipment required to operate and monitor the CVS	Does Not Apply	Applies	Does Not Apply	NOTE: Safety class is addressed through previous line.	DOE-HDBK-1169-2003 (2.2.7)
Other Credited Functional Requirements					
Address any specific functional requirements for the CVS (beyond the scope of those above) credited in the DSA	Applies	Applies	Does Not Apply		10 C.F.R. 830, Subpart B

APPENDIX B: DEFINITIONS

NOTE: Origins of the definitions are indicated by references shown in brackets [ ] although in some cases the referenced orders are being replaced. If no reference is listed, the definition originates in this Guide and is unique to its application. Terms used within this Guide that are not defined in this Appendix carry their definition from the referenced documents.

Accident. An unplanned sequence of events that results in undesirable consequences. [DOE-STD-3009-94]

Accident Analysis. Accident analysis has historically consisted of the formal development of numerical estimates of the expected consequence and probability of potential accidents associated with a facility. Accident analysis is a follow-on effort to the hazard analysis, not a fundamentally new examination requiring extensive original work. As such, it requires documentation of the basis for assignment to a given likelihood of occurrence range in hazard analysis and performance of a formally documented consequence analysis. Consequences are compared with the Evaluation Guideline to identify safety-class structures, systems, and components. [DOE-STD-3009-94]

Confinement Barriers.

- Primary confinement. Provides confinement of hazardous material to the vicinity of its processing. This confinement is typically provided by piping, tanks, gloveboxes, encapsulating material, and the like, along with any off-gas systems that control effluent from within the primary confinement.

- Secondary confinement. Consists of a cell or enclosure surrounding the process material or equipment along with any associated ventilation exhaust systems from the enclosed area.

- Tertiary confinement. Typically provided by walls, floor, roof, and associated ventilation exhaust systems of the facility. It provides a final barrier against the release of hazardous materials into the environment.

Construction. Any combination of engineering, procurement, erection, installation, assembly, or fabrication activities involved in creating a new facility or altering, adding to, or rehabilitating an existing facility. It also includes the alteration and repair (including dredging, excavating, and painting) of buildings, structures, or other real property.

Decommissioning. Those actions taking place after deactivation of a nuclear facility to retire it from service and includes surveillance and maintenance, decontamination and/or dismantlement. [10 C.F.R. Part 830 Subpart B, Appendix A]

Decontamination. The removal or reduction of residual radioactive and hazardous materials by mechanical, chemical, or other techniques to achieve a stated objective or end condition. [10 C.F.R. Part 830 Subpart B, Appendix A]

Design Basis. Information that identifies the specific functions to be performed by a structure, system, or component of a facility, and the specific values or range of values chosen for controlling parameters as reference bounds of design. These values may be (1) restraints derived from generally accepted "state of the art" practices for achieving functional goals, or (2) requirements derived from analyses (based on calculations and/or experiments) of the effects of a postulated accident for which a structure, system, or component must meet its functional goals. [10 C.F.R. Part 50.2]

Effluent Monitoring. The collection and analysis of samples or measurements of liquid and gaseous effluents for the purpose of: characterizing and quantifying contaminants; assessing radiation exposures of members of the public; providing a means to control effluents at, or near, the point of discharge; and, demonstrating compliance with applicable standards and permit requirements.

Evaluation Guideline. Radiation dose value against which the safety analysis evaluates. Off-site evaluation guidelines are established for the purpose of identifying and evaluating safety-class structures, systems, and components.

Explosives Facility. A structure or defined area used for explosives storage or operations. Excluded are explosives presenting only localized, minimal hazards as determined by the Authority Having Jurisdiction. Examples of excluded items may include user quantities of small arms ammunition, commercial distress signals, or cartridges for cartridge actuated tools, etc. [DOE-STD-1212-2012]

Facility. For the purpose of this Guide, the definition most often refers to buildings and other structures, their functional systems and equipment, and other fixed systems and equipment installed therein to delineate a facility. However, specific operations and processes independent of buildings or other structures (e.g., waste retrieval and processing, waste burial, remediation, groundwater or soil decontamination, decommissioning) are also encompassed by this definition. The flexibility in the definition does not extend to subdivision of physically concurrent operations having potential energy sources that can seriously affect one another or which use common systems fundamental to the operation (e.g., a common glovebox ventilation exhaust header). [DOE-STD-3009-94]

Fail-Safe. A design characteristic by which a unit or system will become safe, and remain safe, if a system or component fails or loses its activation energy.

Hazard. A source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel or damage to a facility or to the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation). [10 C.F.R. Part 830.3]

Hazard Analysis. The determination of material, system, process, and plant characteristics that can produce undesirable consequences, followed by the assessment of hazardous situations associated with a process or activity. Largely qualitative techniques are used to pinpoint weaknesses in design or operation of the facility that could lead to accidents. The hazard analysis examines the complete spectrum of potential accidents that could expose members of the public, on-site workers, facility workers, and the environment to hazardous materials. [DOE-STD-3009-94]

Hazard Categorization. Evaluation of the consequences of unmitigated releases to classify facilities or operations into the following hazard categories: [10 C.F.R. Part 830, Subpart B, Appendix A]

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

DOE-STD-1027-92 provides guidance and radiological threshold values for determining the hazard category of a facility. DOE-STD-1027-92, Chg 1, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports,* interprets Hazard Category 1 facilities as Category A reactors and other facilities designated as such by the Program Secretarial Officer. [DOE-STD-3009-94]

Hazardous Material. Any solid, liquid, or gaseous material that is radioactive, toxic, explosive, flammable, corrosive, or otherwise physically or biologically threatening to health.

Major Modification. A modification to a DOE nuclear facility that substantially changes the existing safety basis for the facility. [10 C.F.R. Part 830.3]

Nonreactor Nuclear Facility. Those facilities, activities or operations that involve, or will involve, radioactive and/or fissionable materials in such form and quantity that a nuclear or a nuclear explosive hazard potentially exists to workers, the public, or the environment, but does not include accelerators and their operations and does not include activities involving only incidental use and generation of radioactive materials or radiation such as check and calibration sources, use of radioactive sources in research and experimental and analytical laboratory activities, electron microscopes, and x-ray machines. [10 C.F.R. Part 830.3]

Public. All individuals outside the DOE site boundary. [DOE-STD-3009-94]

Safety Analysis. A documented process: (1) to provide systematic identification of hazards within a given DOE operation; (2) to describe and analyze the adequacy of the measures taken to eliminate, control, or mitigate identified hazards; and, (3) to analyze and evaluate potential accidents and their associated risks. [DOE-STD-3009-94]

Safety Basis. The documented safety analysis and hazard controls that provide reasonable assurance that a DOE nuclear facility can be operated safely in a manner that adequately protects workers, the public, and the environment. [10 C.F.R. Part 830.3]

Safety-class SSCs. *Safety-class structures, systems, and components* means the structures, systems, or components, including portions of process systems, whose preventive or mitigative function is necessary to limit radioactive hazardous material exposure to the public, as determined from safety analyses. [10 C.F.R. Part 830.3]

Safety-significant SSCs. *Safety-significant structures, systems, and components* means the structures, systems, and components which are not designated as safety-class structures, systems, and components, but whose preventive or mitigative function is a major contributor to defense-in-depth and/or worker safety as determined from safety analyses. [10 C.F.R. Part 830.3]

Safety SSCs. Safety-class and safety-significant SSCs.

Single-failure Criterion. Safety-class systems are able to perform all required safety functions for a design basis accident (DBA) in the presence of the following:

- Any single detectable failure within the safety-class systems concurrent with all identifiable but undetectable failures.
- All failures caused by the single failure.
- All failures and spurious system actions that cause, or are caused by, the DBA requiring the safety-class system function.

The single failure could occur prior to, or at any time during, the DBA for which the safety system is required to function. [ANSI/IEEE Standard 379-2000]

Site Boundary. A well-marked boundary within which the owner and operator can exercise control without the aid of outside authorities. A public road or waterway traversing a DOE site is considered to be within the DOE site boundary if, when necessary DOE or the site contractor has the capability to control the road during accident or emergency conditions. [DOE-STD-3009-94].

APPENDIX C: ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ACI	American Concrete Institute
AGS	American Glovebox Society
AIHA	American Industrial Hygiene Association
AISC	American Institute of Steel Construction
ALARA	as low as reasonably achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
API	American Petroleum Institute
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
C.F.R.	Code of Federal Regulations
CGD	Commercial Grade Dedication
CMAA	Crane Manufacturers Association of America
COR	Code of Record
CVS	Confinement Ventilation System
DBA	design basis accident
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DSA	Documented Safety Analysis
G	Guide (DOE directive)
HEPA	high-efficiency particulate air (filter)
I&C	instrumentation and control
IBC	International Building Code
IEEE	Institute of Electrical and Electronics Engineers
ISA	International Society of Automation
M	Manual
NCRP	National Council on Radiation Protection
NFPA	National Fire Protection Association
NNSA	National Nuclear Security Administration
NPH	Natural Phenomena Hazard
NUREG	Nuclear Regulatory Guide
O	Order (DOE directive)
QA	quality assurance
RCRA	Resource Conservation and Recovery Act
SC	safety-class
SS	safety-significant
SSC	structures, systems, and components
STD	Standard (DOE directive)

APPENDIX D: REFERENCES

Note: The following is a list of references referenced in this Guide and/or DOE O 420.1C, *Facility Safety*.

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- 29 C.F.R. Part 1910, Subpart H, Section 1910.101, *Hazardous Materials.*
- 29 C.F.R. Part 1910, Subpart Z, Section 1910.100, *Toxic and Hazardous Substances.*
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