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DOE STANDARD

HAZARD CATEGORIZATION AND ACCIDENT ANALYSIS TECHNIQUES FOR COMPLIANCE WITH DOE ORDER 5480.23, NUCLEAR SAFETY ANALYSIS REPORTS

U.S. Department of Energy
Washington, D.C. 20585

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Order No. DE98001283

Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports

Page/Section	Change
p. 1 / third paragraph	The following sentence was deleted. "In addition, Environmental Restoration and Waste Management (EM) is preparing a limited standard to provide additional and more specific guidance for EM facilities and activities."
p. 2 / fourth paragraph	The following phrase was deleted. ". . . Division Systems Analysis and Standards Division (NE-74). . ." and "(EH-31)" was added at the end of the paragraph.
p. 2 / Section 1.0 / first paragraph	The third sentence was added.
p. 2 / Section 1.0 / second paragraph	The second sentence was added.
p. 2 / Section 1.0 / second paragraph	The following sentence was deleted. "Hazardous chemicals in facilities are governed by DOE Orders 5480.4, 5480.10, 5481.1B and 5483.1A, and accelerators are covered by DOE Order 5480.25."
p. 2 / Section 1.0 / second paragraph	The last sentence was updated.
p. 4 / Section 2.1	The last sentence was modified.
p. 4 / Section 3.0	The first sentence was modified.
p. 5 / Section 3.1.2 / second paragraph	The sixth sentence was modified.
p. 5 / Section 3.1.2 / second paragraph	The following phrase was deleted from the last sentence. ". . . which places the 'burden of proof' on the Management and Operating Contractor . . ."
p. 5 / Section 3.2 / second paragraph	The last sentence was deleted. "OSH requirements and referenced standards for nonradiological hazards can be found in DOE Orders 3791.1A (Federal Employee Occupational Safety and Health Program), 5483.1A (Occupational Safety and Health Program for DOE Contractor Employees), and 5480.10 (Contractor Industrial Hygiene Program)."

Page/Section	Change
p. 5 / Section 3.2	The following paragraph was deleted. "Other requirements and guidance concerning a spectrum of chemical safety issues, including hazard categorization of nonradiological hazards, are being developed by EH to augment existing OSH standards and provide implementing guidance to 5481.1B (Safety Analysis and Review System) for nonnuclear facilities. Once developed, certain of these requirements and guidance will be applicable to the nonradiological hazards of nuclear facilities as well."
p. A-2 / Treatment of Sealed Sources section / third paragraph	The first sentence was modified.
p. A-2 / Treatment of Sealed Sources section	The fourth paragraph was added.
p. A-2 / Summation of Radionuclide section	The "Part Time Inventory" paragraph was added.
p. A-2 / Hazard Category 1 / Considerations	The following phrase was deleted from the sentence, ". . . as defined in DOE Order 5480.6."
p. A-3 / Hazard Category 2 / Radiological Criteria / second paragraph	The reference in the first sentence, ". . . ANSI 16.1 - 'Standard for Nuclear Criticality Safety in Operations with Fissionable Material Outside Reactors'. . ." was replaced with ". . . ANSI/ANS-8.1–1983, R88 'Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors . . ."
p. A-4 / Hazard Category 3 / Considerations / second paragraph	The following paragraph was deleted. "Specific groundrules for Category 3 hazard categorization are as follows: 1. The one exception to the use of modified Reportable Quantities (RQs) values for radionuclides is tritium. The DOE Tritium Task Force has recommended a value of 1000 curies."
p. A-4 / Discussion / Hazard Category 1	The following phrase was deleted. ". . . as defined by DOE Order 5480.6."
p. A-5 / Hazard Category 3	The following two sentences were deleted. "The one exception to this is tritium. The tritium threshold was lowered from its calculated value to 1000 curies based on a recommendation from the Tritium Task force."
p. A-9 / Release Fractions / Calculation of Category 3 Radiological Thresholds / second paragraph	The following phrase was deleted from the last sentence. ". . . in order to account for the slow movement of radionuclides in ground water."

Page/Section	Change
p. A-9 / Release Fractions / Calculation of Category 3 Radiological Thresholds / third paragraph	This paragraph was added.
p. A-10 / Table A.1	Isotope H-3, Category 3 Curies entry changed to 1.6E+04* from 1.0E+03*. Threshold Grams (column 4) entry changed to 1.6E+00* from 1.0E−01*.
p. A-10 / Table A.1	Isotope P-32, Category 2 Curies entry changed to 4.4E+03 from 4.4E+01.
p. A-10 / Table A.1	Isotope P-32, acid**, Category 2 Curies entry changed to 2.2E+06 from 2.2E+04.
p. A-10 / Table A.1	Isotope Mn-52, Category 2 Curies entry changed to 4.0E+06 from 1.8E+07. Threshold Grams (column 2) entry changed to 8.8E+00 from 3.9E+01.
p. A-10 / Table A.1	Isotope Se-75, Category 2 Curies entry changed to 3.4E+05 from 3.4E+06. Threshold Grams (column 2) entry changed to 2.4E+01 from 2.4E+02.
p. A-11 / Table A.1	Isotope Sb-126, Threshold Grams (column 2) entry changed to 3.0E+01 from 3.0E+00. Threshold Grams (column 4) changed to 3.4E−03 from 3.4E−04.
p. A-11 / Table A.1	Isotope Te-127m, Threshold Grams (column 2) entry changed to 1.6E+01 from 1.6E−01. Threshold Grams (column 4) entry changed to 4.2E−02 from 4.2E−04.
p. A-11 / Table A.1	Isotope Pm-147, Threshold Grams (column 2) entry changed to 9.0E+02 from 8.0E+02.
p. A-11 / Table A.1	Isotope Hg-203, Threshold Grams (column 2) entry changed to 3.1E+01 from 3.1E+00. Threshold Grams (column 4) entry changed to 2.6E−02 from 2.6E−03.
p. A-11 / Table A.1	Isotope Bi-207, Category 2 Curies entry changed to 2.2E+06 from 1.9E+06. Threshold Grams entry (column 2) changed to 4.3E+04 from 3.8E+04. Threshold Grams (column 4) entry changed to 1.1E+01 from 9.7E+00.
p. A-12 / Table A.1	Isotope Cf-252, Category 2 Curies entry changed to 2.2E+02 from 3.0E+02. Threshold Grams (column 2) entry changed to 4.1E−01 from 7.0E−01. Threshold Grams (column 4) entry changed to 5.9E−03 from 2.2E−04.
p. A-12 / Table A.1, footnote 1	New information added.

Page/Section	Change
p. A-12 / Table A.1, footnote 2	New information added.
p. A-12 / Table A.1, single asterisk	New information added.
Concluding Material	Preparing Activity updated.

FOREWORD

The purpose of this DOE Standard is to establish guidance for facility managers and Program Secretarial Officers (PSOs) and thereby help them to comply consistently and more efficiently with the requirements of DOE Order 5480.23, Nuclear Safety Analysis Reports. To this end, this guidance provides the following practical information:

1) The threshold quantities of radiological material inventory below which compliance with DOE Order 5480.23 is not required.

2) The level of effort to develop the program plan and schedule required in Section 9.b.(2) of the Order, and information for making a preliminary assessment of facility hazards.

3) A uniform methodology for hazard categorization under the Order.

4) Insight into the “graded approach” for SAR development, especially in hazard assessment and accident analysis techniques.

Individual PSOs may develop additional guidance addressing safety requirements for facilities which fall below the threshold quantities specified in this document.

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Purpose

The purpose of this DOE Standard is to establish guidance for the preparation and review of hazard categorization and accident analyses techniques as required in DOE Order 5480.23, Nuclear Safety Analysis Reports. This new Order requires further guidance to ensure consistency across all nuclear facilities within the DOE complex. This DOE Standard imposes no new requirements on nuclear facilities. Instead, it focuses on (1) the definition of the standard identifying nuclear facilities required to have SARs in order to comply with the Order, (2) the SAR implementation plan and schedule, (3) the hazard categorization methodology to be applied to all facilities, and (4) the accident analysis techniques appropriate for the graded approach addressed in the Order. DOE Order 5480.23 and its attached guidance document provide some direction on the use of the graded approach. This report is intended not to supersede that direction, but to supplement and clarify it. Methods other than those suggested in this guide may be considered for applying the graded approach, but they must be justified whenever grading is applied.

Applicability/Scope

This DOE Standard is to be used with DOE Order 5480.23 and may not be applicable to other DOE Orders. Regarding the applicability of other nuclear safety Orders to those facilities which fall below category 3 criteria, as defined by this standard, the PSOs shall provide guidance, as appropriate.

Developed by a working group with contributions from all Secretarial and oversight organizations having nuclear safety responsibilities, with input from several field and contractor organizations, and with clarifying direction from the Senior Nuclear Managers meeting of October 26, 1992, this standard applies to DOE nuclear facilities as defined in the Order and is suitable for DOE nuclear facilities.

Background and Format

The Department of Energy (DOE) has the responsibility to establish rules, regulations, and Orders as necessary to protect health or to minimize danger to life or property. In carrying out this responsibility, DOE has issued Order 5480.23, Nuclear Safety Analysis Reports. This Order specifies requirements for safety analyses involving DOE nuclear facilities, and for submittal, review, and approval of contractor plans and programs to meet these requirements.

This document provides specific guidance on several of the requirements contained in this Order. Section 1 establishes the threshold quantities of hazardous materials which, if exceeded, would mandate the development of a SAR under this Order. Section 2 discusses the SAR upgrade plan and schedule which must to be submitted to each PSO. Section 3 provides a uniform methodology for hazard categorization. Finally, Section 4 gives additional specific guidance on the use of the graded approach and accident/hazard analysis techniques for compliance with this Order.

Figure 1 portrays the relationships between the Order and the topics covered in this guidance document.

Questions regarding this standard should be addressed to the Director, Office of Nuclear Safety Policy & Standards (EH-31).

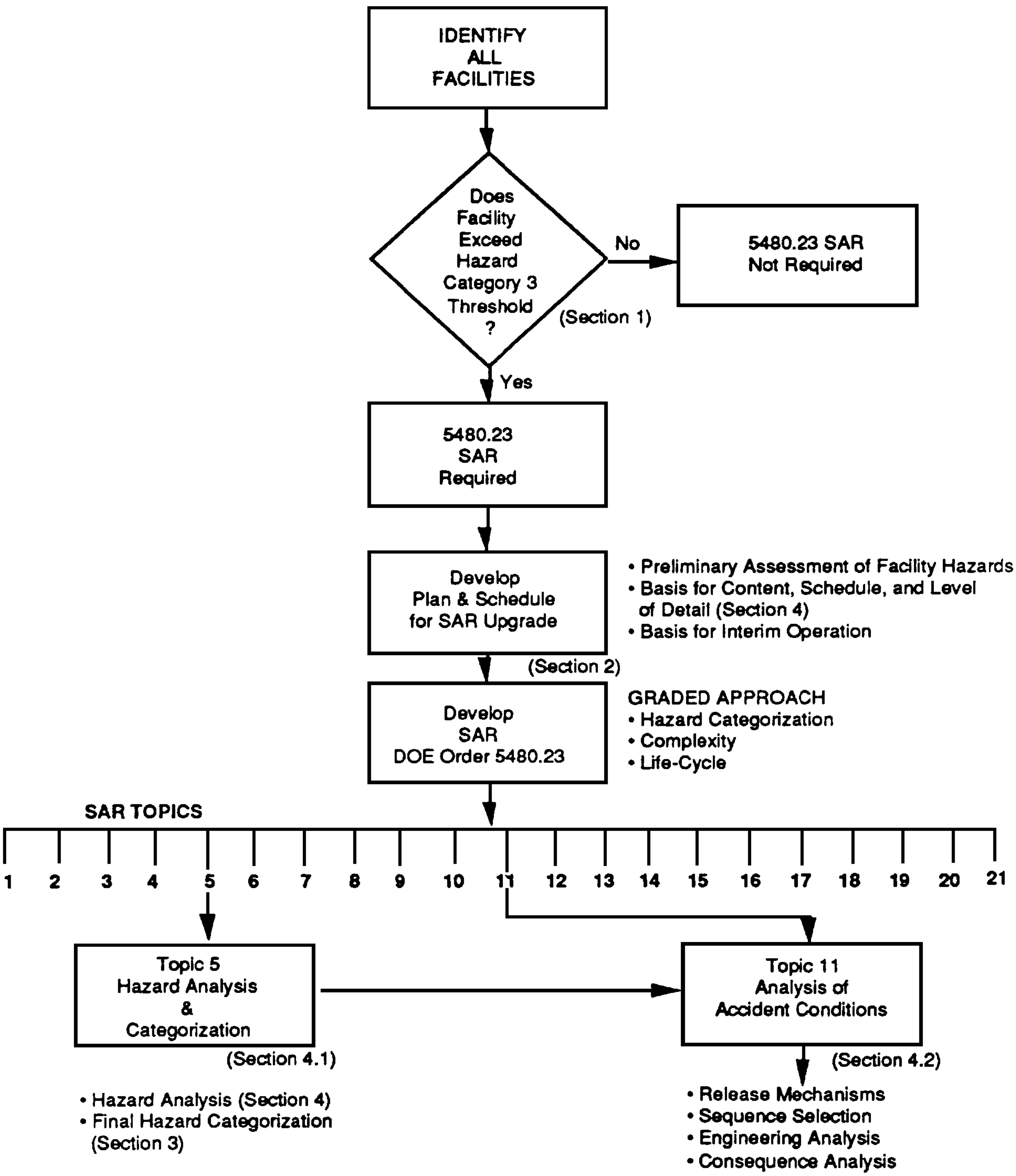
Guidance

1.0 SAR NUCLEAR FACILITY GUIDANCE FOR DOE ORDER 5480.23

Order 5480.23 defines the “level of concern” within the framework of Hazard Categorization, which requires the preparation of a SAR for DOE nuclear facilities. Section 3 and Attachment 1 of this Standard provide consistent guidance on facility categorization. All facilities classified as at least Category 3 in accordance with this guidance are required to comply with DOE Order 5480.23. Additional guidance regarding some environmental restoration activities is provided in an Interpretation Memo dated June 9, 1997, Black to Psaras. Facilities that do not meet or exceed Category 3 threshold criteria but still possess some amount of radioactive material may be considered Radiological Facilities.

Radiological Facilities are exempt from this Order, but they are not exempt from other safety requirements. 10 CFR 835 applies for all facilities including those that are exempt from DOE Order 5480.23. Exemption from the requirements of 5480.23 does not excuse contractors from doing analysis, where applicable, to evaluate potential significant radiation exposures to workers. For example, EM has prepared a limited standard to provide additional and more specific guidance regarding measures necessary to ensure safety for EM facilities and activities below category 3 criteria (DOE-EM-STD-5502-94).

Figure 1. SAR Guidance Topics and General Flow



2.0 SAR UPGRADE PLAN AND SCHEDULE

Order 5480.23 requires that a plan and schedule for SAR upgrades be submitted to each PSO. The requirement includes the following elements, for which guidance is provided.

2.1 Preliminary Assessment of Facility Hazard

The preliminary assessment of hazards at a DOE nuclear facility requires only a minimal effort to identify the inventory of hazardous material in order to perform an initial hazard categorization as directed by paragraph 4.f.(10).(d) of the attachment to DOE Order 5480.23 and discussed in Section 3 and Attachment 1 of this Standard. Reviewing basic facility information on intended facility operations and using estimates of material quantities should lead to an acceptable assessment. Whenever questions concerning appropriate facility categorization arise, provide for a margin of error by selecting the higher hazard category. This step results in the preliminary categorization of a DOE nuclear facility in a Hazard Category 1, 2, or 3 or below Category 3, (Radiological Facility).

2.2 Basis for Content, Schedule, and Level of Detail Proposed

This Standard gives additional information on the accident analysis techniques and the level of detail needed as allowed in the graded approach. Section 4 describes a reasonable graded approach for the analysis techniques and level of detail which should be included in the SAR.

3.0 HAZARD CATEGORIZATION

This section contains a uniform methodology to develop the initial Hazard Categorization specified in the preliminary assessment of facility hazards in paragraph 9.b.(2) (BIO, Implementation Plan) of Order 5480.23 and the final Hazard Categorization specified in paragraph 8.b.(3)(e) (SAR). The method should enable facility managers and PSOs to determine quickly the likely facility categorization called for in paragraph 8.c. An overview of this facility hazard categorization is presented in Table 3.1 and Figure 3.1, with detailed information about facility categorization in Attachment 1. As discussed in the Order, Hazard Categorization is used as only one consideration in the graded approach concept (see Section 4).

3.1 Radiological Hazards

Attachment 1 classifies a facility as either Hazard Category 1, 2, or 3, depending only on the quantities of radioactive material in the facility, and gives the threshold quantities as well as the appropriate groundrules for evaluating the facility. Only facilities which fall below the Category 3 threshold are exempt from the requirements of DOE Order 5480.23. However, these facilities should have administrative controls in place to ensure minimum values are not exceeded through introduction of new material.

3.1.1 Initial Radiological Hazards Screening

The radiological hazards screening enables facility managers to determine quickly the likely facility categorization required in paragraph 8.c. This process is to provide an initial screening of the potential hazards represented by a facility. It should be used for preliminary assessment of facility hazards in “plans and schedules” for proposed upgrades to SARs when a Hazards Analysis (see Section 4) has not been performed. An overview of the radiological hazards screening is provided in Table 3.1 and Figure 3.1.

3.1.2 Final Hazard Categorization

Once a Hazards Analysis has been performed as defined in Section 4, the hazard categorization can be finalized. The final categorization is based on an “unmitigated release” of available hazardous material. For the purposes of hazard categorization, “unmitigated” is meant to consider material quantity, form, location, dispersibility and interaction with available energy sources, but not to consider safety features (e.g., ventilation system, fire suppression, etc.) which will prevent or mitigate a release.

The Hazards Analysis (or other existing safety analyses) provides an understanding of the material which can physically be released from the facility. This inventory should be compared against the Threshold Quantities (TQs) identified in Attachment 1. The airborne release fractions used in generating the TQ values for Category 2 in Table A.1 are provided on Page A-9 of Attachment 1. As discussed in the attachment, these are intended to be generally conservative for a broad range of possible situations. Therefore, the inventory values of Table A.1 may be used directly for determination as to whether a facility exceeds Category 2. Alternatively, for final Categorization, for facilities initially classified as Hazard Category 2, if the credible release fractions can be shown to be significantly different than these values based on physical and chemical form and available dispersive energy sources, the threshold inventory values for Category 2 in Table A.1 may be divided by the ratio of the maximum potential release fraction to that found on Page A-9. All assumptions which are used to reduce the inventory at risk should be supported in the Hazards Analysis. This also applies to ground rules identified in Attachment 1, to demonstrate that the ground rule conditions exist.

3.2 Occupational and Nonradiological Hazards

DOE Order 5480.23 places new emphasis on already existing requirements concerning the protection of workers, the public, and the environment against all hazards. The order not only requires the analysis of radiological hazards, but also requires that the analysis and safety basis of occupational and nonradiological hazards be documented in the SAR.

Occupational hazards, including common industrial hazards, that are identified in the hazards analysis and that are clearly regulated by DOE-prescribed occupational safety and health (OSH) standards should be segregated from non-routine hazards. No specific SAR analyses will be required for these hazards; however, analyses required by the OSH standards should be referenced, and all applicable OSH standards listed in the SAR.

The balance of the hazards that are not covered by OSH regulations and that present significant, non-routine concerns to workers, the public, or the environment should undergo the hazard and accident analysis as summarized in Section 4.1.

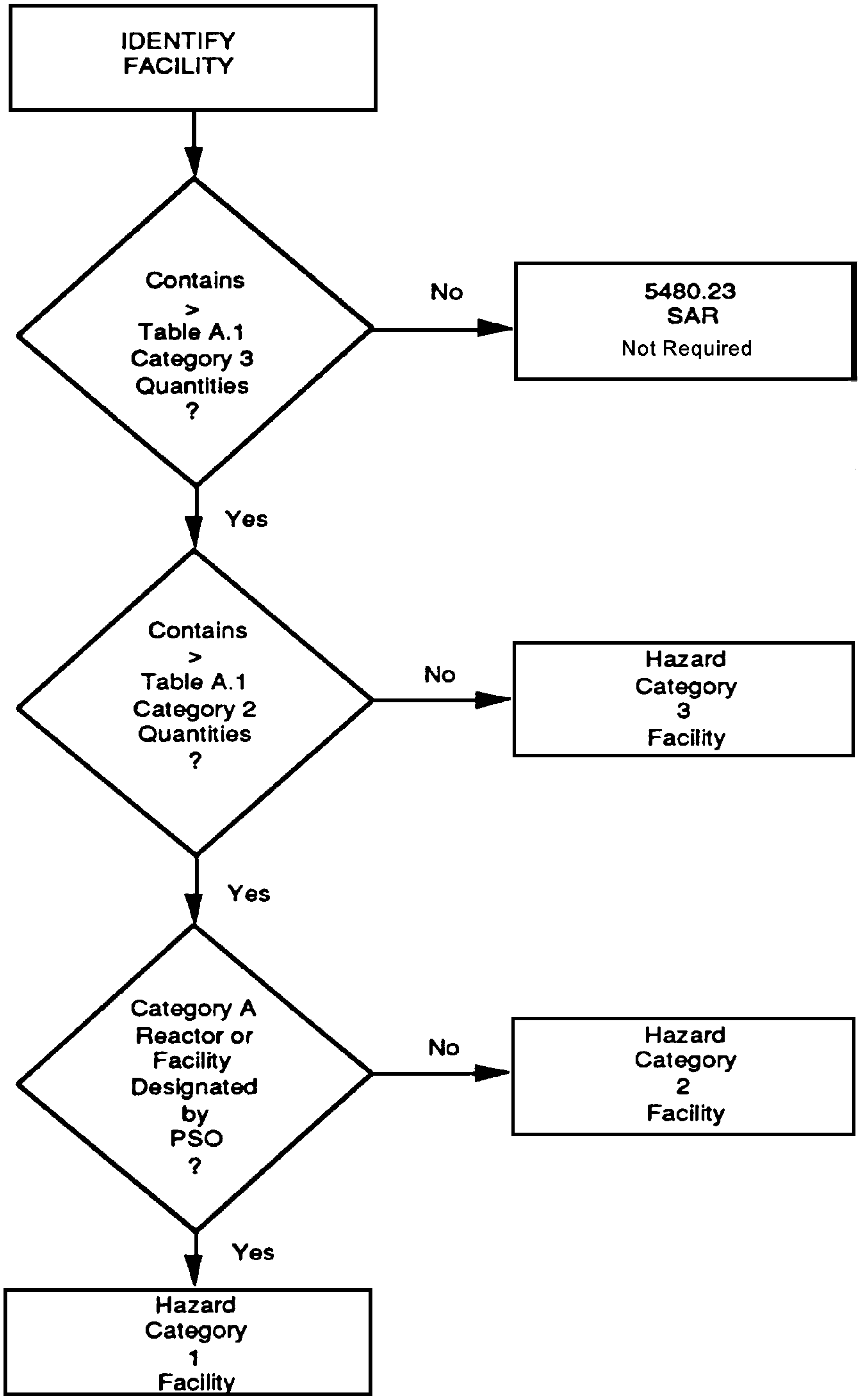
For chemical hazards covered by 29 CFR 1910.119 (Process Safety Management (PSM) Rule), the SAR should reference all analyses and summarize their significant findings. When analyses of chemical hazards show the potential for significant off-site consequences, then the requirements of 29 CFR 1910.119 may apply regardless of the type or quantity of chemical involved. The Office of Environment, Safety, and Health (EH) has developed implementing guidance and training to assure adequate compliance with the PSM rule.

Any nonradiological hazard that acts to initiate, or increase the consequences of, a radiological scenario should be fully analyzed as part of that scenario.

Table 3.1 NUCLEAR HAZARD CATEGORIZATION SUMMARY

CATEGORY	
3	DEFINITION *Hazard Analysis shows the potential for only significant localized consequences.* INTERPRETATION Facilities with quantities of hazardous radioactive materials which meet or exceed Table A.1 values (see Attachment 1).
2	DEFINITION *Hazard Analysis shows the potential for significant on-site consequences.* INTERPRETATION Facilities with the potential for nuclear criticality events or with sufficient quantities of hazardous material and energy, which would require on-site emergency planning activities (see Attachment 1).
1	DEFINITION *Hazard Analysis shows the potential for significant off-site consequences.* INTERPRETATION Category A reactors and facilities designated by PSO.
Other	Exempt from SAR Order 5480.23

Figure 3.1 HAZARD CLASSIFICATION DECISION PROCESS (Section 3)



4.0 GRADED APPROACH - ANALYSIS TECHNIQUES

Order 5480.23 states that a graded approach is to be used in the preparation of SARs for nuclear facilities.

Graded Approach Objective

The objective of a graded approach is to proportion SAR requirements for analysis, evaluation, and documentation to the potential hazards associated with operating DOE nuclear facilities. The level of understanding and control of hazards to workers, the public, and the environment will be comparable for all facilities. For relatively simple facilities, an acceptable level of understanding and control of hazards can be achieved with less sophisticated techniques and less detailed knowledge of facility characteristics than those required for more complex facilities.

The anticipated effect of applying the graded approach is that competing resources will be used more efficiently and produce maximum benefit. As a result, SARs for complex, higher-hazard facilities would be expected to use more resources in meeting the requirements than SARs for simple, lower-hazard facilities. The expectation of the greater expenditure of resources for SARs for complicated, higher-hazard facilities is not meant to imply that a lower level of safety or attentiveness is acceptable for simple, lower-hazard facilities. Regardless of hazard and complexity of a facility, adequate safety analysis, evaluation, and supporting documentation must be provided.

The graded approach should be used to eliminate unproductive or unnecessary features or activities which add to the costs of implementation, narrow the envelope of permissible operation, or make the facility management unnecessarily ponderous or burdensome. It does not relieve the contractor or the responsible manager or PSO from the obligation to maintain and operate the facility safely and efficiently. Requirements which conflict with this responsibility should be brought to the attention of the appropriate DOE management.

This document provides the guidelines for a graded approach to development of the analysis techniques which should be used in the SAR. This is the first step to the graded approach for safety analysis of DOE facilities. The analysis techniques described below are useful in the Hazard Analysis Section and the Accident Analysis Section of the SAR. These sections discuss the analysis expected for various types of facilities.

The primary objective of the graded approach to the accident analysis is to select and apply a rigorous analysis technique which provides sufficient detail to assess each postulated accident or failure, the resulting consequences, and all means of prevention or mitigation. The choice of the technique should be defensible and produce meaningful results.

In general, a graded approach dictates a more rigorous and more thoroughly documented analysis and evaluation of higher-hazard facilities than lower-hazard facilities, given the potential for more widespread and severe consequences if a higher-hazard facility fails to meet its safety basis requirements. In all cases, however, the SAR must provide adequate safety analysis, evaluation, and supporting documentation. The Order provides direction on how the graded approach is to be applied to the SAR. The level of effort, sophistication of analysis, and the thoroughness of documentation are to be graded or proportioned commensurate with the considerations listed below:

(1) The magnitude of the hazards being addressed

(2) The complexity of both the facility and/or the safety systems relied on to maintain an acceptable level of risk

(3) The stage or stages of the facility life cycle

<u>Magnitude of the hazards</u>

The Order states that contractors shall be required to perform a Hazard Analysis of their nuclear activities and to classify their processes, operations, or activities. On the basis of that analysis, they shall evaluate and classify the consequences of unmitigated releases of hazardous radioactive and chemical material in the following categories:

<u>Category 1 Hazard</u>: The Hazard Analysis shows the potential for significant off-site consequences.

<u>Category 2 Hazard</u>: The Hazard Analysis shows the potential for significant on-site consequences.

<u>Category 3 Hazard</u>: The Hazard Analysis shows the potential for only significant localized consequences.

The hazard categorization process provides a method for assessing potential hazards and does not consider potential risk. Section 3 and Attachment 1 provide detailed guidance on a consistent methodology which should be used for hazard categorization.

<u>Complexity of the Facility and/or its Safety Systems</u>

The graded approach directs that the effort should be proportional to the complexity of the facility and the safety systems relied on to maintain an acceptable level of risk. Simple facilities would require less sophisticated analysis. Consequently, the sophistication of the information to be provided in the SAR would be proportioned accordingly. In many cases, the complexity of a facility may have a greater impact on the grading of effort than the hazard categorization.

In evaluating complexity, the SAR should consider the complexity of the person-machine interface as well as the design and hardware of a facility. The preferred approach is to provide for safety through engineered safeguards and not to rely on administrative controls for safety. However, if the safety of the facility depends more heavily on personnel to initiate, control, or perform safety functions than on the use of automated safety devices, then the procedures and training of operators warrant more detailed discussion in the SAR.

The remainder of this Standard provides additional guidance on the relationship between complexity and the analysis techniques which are to be used in the SAR.

<u>Facility's Stage in its Life-Cycle</u>

The third consideration is the stage or stages of the facility life cycle for which SAR approval is sought. For a new facility, the SAR covers the commitments for facility design and construction. For a facility which merely seeks authorization to continue operations, the SAR need not elaborate on completed phases of the project. Information about safety decisions previously made, such as site selection, should be developed only to support current and anticipated safety decisions. A SAR for a facility near the end of its operating life and unlikely to be modified before retirement need not develop safety engineering bases with the thoroughness expected of a SAR for a facility which may be modified or extended in the future. When modifications are performed or the facility mission is extended or changed, additional detail to support the justification for the design adequacy will be required. For a facility which is partly shut down and is used for only limited functions, the SAR should develop the basis for confidence in the safety of the inactive portions of the facility and the safety basis for the intended operations. The inactive portion of a facility should be evaluated to ensure that the risks from the residual hazards (e.g., contamination, hazardous material inventory) are evaluated and controlled.

All SARs should furnish information about subsequent stages of the facility life cycle beyond that stage for which approval is sought, including end-of-life decontamination and decommissioning. However, SARs need to develop this information only enough to demonstrate that adequate attention is being given to anticipated future safety problems. For facilities which are approaching decommissioning, the emphasis should be on these remaining activities. Documentation provided on the operations being phased out should be the minimum necessary to demonstrate the safety of the facility during its remaining operating life, and future decontamination and decommissioning activities.

4.1 Hazard and Accident Analysis

The Hazard Analysis process consists of the identification of the relative and absolute hazards of the materials in a facility. The objective is to focus the safety assessment effort on those hazards which have the potential to present significant, non-routine concerns to the worker, the public, and the environment.

4.1.1 Hazard Analysis

Hazard Analysis is the initial step in the process of identifying and evaluating potential accidents in a facility. It is used to identify the hazardous chemical or radioactive material in a process or facility and the energy sources and initiating events which could lead to the potential consequences of an accident.

The objectives of Hazard Analysis are to (1) identify the hazards contained in a facility, (2) perform final hazard categorization in accordance with Section 3 and Attachment 1, based on hazardous material quantity identified in 4.1.1.a and energy sources and initiating events identified in 4.1.1.b (preventive and mitigative features are not to be considered in hazard categorization), (3) provide an overall assessment of the importance of the various hazards, (4) identify occupational hazards and related DOE prescribed standards, and (5) characterize and analyze the remaining non-routine hazards that are unique and representative hazards to be analyzed in the SAR. To accomplish these objectives, each facility preparing a SAR must perform a Hazard Analysis as a means of fulfilling the requirement of DOE Order 5480.23, Section 8.c.

Hazard Analysis consists of collecting and integrating four interrelated sets of information:

- Hazardous Material Quantity, Form, and Location
- Energy Sources and Potential Initiating Events
- Preventive Features
- Mitigative Features.

4.1.1.a <u>Hazardous Materials Quantity, Form, and Location</u>

Hazard Analysis identifies the hazardous chemical and radiological materials at risk in the facility. The quantity of material is assumed to be the maximum inventory permitted to be processed or present in specific locations in the facility. This quantity is generally determined from either process flow information or existing facility operating experience. Examples of material form would include powder, metal (large pieces or shavings), sludge, gas, solid waste, or liquid. Location indicates the part of the building, glovebox, or process line in which the hazardous material is present. Occupational hazards, including common industrial hazards, should be identified, and the applicable DOE-prescribed OSH regulations, standards, and analyses should be referenced in the SAR.

4.1.1.b <u>Energy Sources and Potential Initiating Events</u>

Hazard Analysis then identifies potential energy sources and potential initiating events which could affect the hazardous material and lead to a release of material or other occurrence. Such events include internally initiated events (e.g., explosions and fires), process-initiated events (e.g., spills or improper material transfers), and externally initiated events (e.g., floods or earthquakes). Inherent energies within the process (e.g., reactivity, temperatures, and pressures) should also be described.

Those accident initiators inappropriate for the facility or process under consideration should be eliminated, and the Hazard Analysis should include the rationale for doing so. For example, if the process does not include any liquid material and the potential for spill does not exist, this potential initiator should be eliminated at the Hazard Analysis level, with a brief discussion of the reasons for the elimination.

4.1.1.c <u>Preventive Features</u>

Hazard Analysis identifies any structure, system, or component that serves to prevent the release of hazardous material in an accident scenario. Preventive features may include passive barriers such as piping, material containers, material cladding, gloveboxes, or facility structures as well as systems or components such as pressure relief valves, monitoring systems for material concentrations with automatic actions to stop or isolate the process, or dilution systems to control explosive or flammable mixtures. The discussion should begin with the preventive feature closest to the hazardous material or mixture, end with the preventive feature farthest from the hazardous material or mixture, and include all preventive features which may contribute to preventing the release of the hazardous chemical or radioactive material.

4.1.1.d <u>Mitigative Features</u>

Hazard Analysis identifies any structure, system, or component that serves to mitigate the consequences of a release of hazardous materials in an accident scenario. Mitigative features may include passive barriers such as dikes, confinement systems, or containment systems; or active systems or components such as air cleanup systems, sump systems, dilution systems, and liquid cleanup system. The discussion should begin with the mitigative feature closest to the point of uncontrolled release, end with the mitigative feature farthest from the hazardous material or mixture, and include all mitigative features which may contribute to reducing the consequences of a release of the hazardous chemical or radioactive material to affected on-site and off-site populations.

4.1.2 Accident Analysis

The effort expended in performing an accident analysis in the SAR is a function of the hazard and the complexity of a particular process, and will build upon the Hazard Analysis already performed. There are a wide variety of techniques available. A primary objective of the graded approach to accident analysis is to select and apply a rigorous analysis technique which provides sufficient detail to assess each postulated accident or failure, the resulting consequences, and all means of prevention or mitigation.

Accident analysis consists of the four distinct elements highlighted in Figure 4.1: (1) Release Mechanism Analysis, (2) Sequence Selection, (3) Engineering Analysis, and (4) Consequence Analysis. Figure 4.1 displays the relationships between the analysis techniques available to evaluate accident consequences, and the hazard and complexity parameters associated with the graded approach. The decision criteria blocks shown immediately after each of the distinct elements provide for immediate consideration of the information learned in that step of the analysis. For example, if the Release Mechanism Analysis identifies information concerning an obvious flaw in the design or operation of a facility, immediate action should be taken to correct the flaw, and the release mechanism analysis would be appropriately modified. This same iterative consideration to correct problems identified in the analysis would occur throughout the accident analysis process.

Thus, accident analysis is used not only to provide insight into the vulnerabilities in the system, but also to improve the systems and reduce the consequences of accidents. The following discussion highlights the four key elements of the accident analysis.

<u>Release Mechanism</u>

This element provides the analysis for determining the vulnerabilities in the structures, systems, and components to create conditions for or cause releases of hazardous material. There are several Hazard Analysis techniques used to identify these vulnerabilities. They range from simple techniques such as checklists to complex techniques such as Hazard and Operability (HAZOP) Studies or integrated fault trees and event trees. The analysis technique should be selected on the basis of the significance of the potential hazards in the facility and the complexity of the processes which could affect the hazard. A summary of the levels for the preferred analysis technique as a function of the hazard and complexity of the facility is shown in Figure 4.1. The objective of the identification of release mechanisms is to provide an evaluation sufficiently detailed to identify potential releases which could adversely affect the worker, the public, or the environment. The results of the release mechanism step are a comprehensive set of potential accident sequences which provide the basis for the next element, sequence selection.

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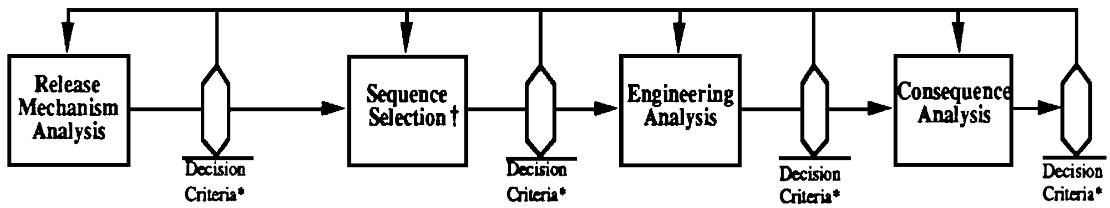
Figure 4.1: Simplified Overview of Accident Analysis Techniques and the Graded Approach



Hazard Category				
Category 3	• Hazards Analysis **	• Checklist • Walkthrough	• Minimal	• Qualitative
Category 2	• Simple Facilities - Hazards Analysis ** • Electro-Mechanical - FMEA • Simple Processes/Barriers - Event Trees (ETs) • Large Complex Systems - Fault Trees (FTs) • Complex Fluid Processes - HAZOP • Complex Interdependencies - Integrated FTs/ETs	• Unique & Representative - Operational Events (e.g., Fires, Explosions - Design Basis Natural Phenomena - External Events	• Systems, structures and components important to safety	• Source Term • Dose Assessment
Category 1	• Use Appropriate Category 2 Analysis Techniques above	• Above	• Above	• Above

† Selection based on facility hazard class, facility/process complexity and life cycle stage (i.e., information available and relevant to the facility)

* Interactively consider modifying the facility design or operation based on information developed during the accident analysis process

** Hazards Analysis is described in Section 4.1

Sequence Selection

The process for selecting postulated accident sequences used in the remainder of the accident analysis process is critical to the SAR and must receive sufficient attention in it. Accidents presented in an accident analysis section of a SAR include design-basis accidents and discussions of beyond-design-basis events.

This element provides a means to reduce the information generated in the previous element to a manageable set of sequences to be used for the remainder of the accident analysis. The objective of the sequence selection element is to choose (1) the unique sequences which could have major effect on workers or the public, and (2) the typical sequences which would encompass all of the principal release mechanisms. Sequence selection is discussed in more detail in relation to each of the hazard categories.

Engineering Analysis

Engineering analysis identifies the physical relationships among the systems, structures, and components, and the release mechanisms for the selected sequences. It is a critical part of the analysis because it connects the facility, the hazardous material, and the physical conditions during the postulated accident. This step is critical to the development of the Technical Safety Requirements for the facility.

Consequence Analysis

The final element in the accident analysis is consequence analysis. This step evaluates the effect of the postulated accident on the workers, the public, and the environment. It includes source term evaluation and dose calculations. For some facilities, consequence analysis may also include health effects assessment, accident frequency estimates, or safety goal comparisons.

4.1.2.a Nuclear Hazard Category 3 Facilities

DEFINITION
Hazard Analysis shows the potential for only significant localized consequences.

INTERPRETATION
Facilities with quantities of hazardous material which meet or exceed Table A.1 values (see Attachment 1).

This category of facilities and hazards by definition cannot release the quantities of materials which could threaten workers at adjacent facilities, the public, or the environment. Thus, as DOE Order 5480.23 states in paragraph 4.f.(1).(c) of the attachment, “For facilities of little hazard, or hazards in Category 3 level, the SAR may be simple and short. In such cases all of the topics for the SAR listed in paragraph 8b(3) of this Order will not be necessary and, with proper technical bases, some topics may be omitted or reduced in the detail that would otherwise be required of Hazards Category 1 or 2 facilities."

The four elements of accident analysis as related to Category 3 facilities are discussed below:

Release Mechanisms

The Hazard Analysis alone should be sufficient to identify important release mechanisms for the level of hazard present in a Class 3 facility. The focus of the analysis is to identify unique or non-routine scenarios which could have significant adverse effect on the workers in the facility and to demonstrate that there are sufficient preventive or mitigative features to protect them. If complexity were considered to warrant a higher-order technique, selection would follow the same line of reasoning presented for Category 2 facilities.

Sequence Selection

A checklist should be used to ensure that a comprehensive set of the potential accident conditions is qualitatively considered. An example list of the potential accident sequences is included in Table 4.1.

Table 4.1 Example Category 3 Accident Sequences

No.	Accident Sequences
1	Equipment Fire
2	Room Fire
3	Room Fire Involving Radioactive or Toxic Materials
4	Uncontrolled Chemical Reaction
5	Chemical Exposure
6	Inhalation, Ingestion, or Dermal Exposure to Toxic, Radioactive or Carcinogenic Materials
7	Compressed Gas Explosion
8	Gas Explosion (Oxygen, Acetylene, LP Gas)
9	High-intensity Laser-Light Exposure
10	Ionizing Radiation Exposure Due to ICF Target Implosions
11	Ionizing Radiation Exposure Due to Contaminated Components
12	Nonionizing Radiation Exposure

Engineering Analysis

Limited engineering analysis is needed to determine the preventive and mitigative features relied upon for the specific accident sequences identified to determine the effectiveness for worker protection.

Consequence Analysis

A qualitative determination of consequences from the identified accidents is required. An example of a qualitative analysis is given in the Table 4.2.

Table 4.2 Example Category 3 Qualitative Consequence Analysis

Uncontrolled Chemical Reaction

Causes:	Mixing of incompatible chemicals due to personnel error, container leakage, or improper maintenance of equipment
Preventive Features	
Design:	Ventilated storage cabinets and/or storage areas provided with sumps for spill containment
Administrative:	Segregation of non-compatible chemicals, regular inspection of containers and storage areas, instruction of personnel in proper handling techniques
Method of Detection:	Smoke and ionization detectors for fire conditions, personnel observation, appropriate alarms
Mitigation Features	
Design:	Fire suppression equipment (sprinklers, portable fire extinguishers), laboratory fume hoods, ventilation design
Administrative:	Employee training, safety procedures, automatic fire department response, emergency medical technicians available on site
Potential Impact:	Physical damage to affected area, potential water damage, potential injury to personnel from burns, explosions, or inhalation of toxic materials, partial shutdown of operations
Risk Determination:	
Probability Level:	**Low**
Consequence Level:	**Medium**
Risk Level:	**Low**

4.1.2.b Nuclear Hazard Category 2 Facilities

DEFINITION
Hazard Analysis shows the potential for significant on-site consequences.

INTERPRETATION
Facilities with the potential for nuclear criticality events or with sufficient quantities of hazardous material and energy which would require on-site emergency planning activities (see Attachment 1).

This category of facilities contains Category B reactors and the most significant nonreactor nuclear facilities within the DOE complex. While these facilities are different in design, construction, and operation, the non-reactor facilities are similar in character to chemical industrial facilities. Extensive work has been performed in the development of analysis techniques for such facilities. Many of these techniques are documented in several American Institute of Chemical Engineers (AIChE)-sponsored reports and are described in the Occupational Safety and Health Administration (OSSA) Regulation, 29 CFR 1910.119, Process Safety Management. Because these techniques are driven by the overall complexity of the facility operations, judgment is needed on the type and level of analysis required to obtain sufficient information on the safety of the facility in order to judge its overall acceptability.

The facilities in this category represent a level of hazard for which significant management attention is warranted and thus require on-site emergency planning.

<u>Release Mechanisms</u>

There are many analytical techniques available for evaluating the safety of the wide spectrum of chemical and nuclear DOE facilities of varying complexity. These techniques are commonly applied in the design and operation of various types of processes in many industries. A good reference for applying these techniques is "Selecting Hazard Evaluation Techniques of Guidelines for Hazard Evaluation Procedures," Second Edition with Worked Examples (Center for Chemical Process Safety, 1992). A list of target levels of analysis sophistication for types of operations in order of increasing complexity is presented below:

1) <u>Low-Complexity Operations</u>

<u>Use Hazard Analysis</u>

Low-complexity operations include those in which very little or no processing of materials takes place. Waste storage, vaults, tanks, cylinders, canisters, or even very simple batch laboratories are examples of such facilities. Release mechanisms are largely intuitive or straightforward and can generally be identified by simple checklists. Hazard Analysis that has already been performed (see Section 4.1.1) is considered sufficient for identifying release mechanisms.

2) Single-Failure Electro-Mechanical Systems

Use Failure Modes and Effects Analysis (FMEA)

These systems include relatively simple electrical and mechanical devices in which a single-failure mechanism causes a release of materials. Simple one-step processes, single glove box operations, and small furnaces are example of such devices. FMEA is a bottom-up approach that looks at the failure of each element of a system or process and identifies the consequence of each failure. FMEA is most appropriate for analysis of small segments of a system or process when it is determined that failure of single components in this segment could lead to system or process failure or release of material.

FMEA has some limitations which must be recognized to ensure its appropriate use. First, FMEA is not very efficient for large-scale systems analysis because, by virtue of its bottom-up approach, it examines and documents the effects of component failures having little, if any, relevance to system failure or potential release. Second, FMEA considers only one failure at a time and has no logical process for considering multiple or combined failures. Third, FMEA is strictly equipment-oriented. It looks at failure of equipment in different nodes and assesses their consequences but does not look at failures of a process, which, by its very nature, may have complexities and instabilities far beyond those which can be assessed only by examining the failure of individual components.

3) Systems with Redundant Barriers or Requiring Multiple Failures

Use Event Tree Analysis (ET)

ET analysis is a simple approach to delineating sequences of events which could lead to an undesired event. An undesired event could be uncontrolled release of hazardous material from a facility or core damage in a reactor. In the ET analysis, for each initiating event, various systems or barriers designed to prevent the occurrence of the undesired event or to mitigate the progress of the accident are identified. At each node, the success or failure of these systems or barriers, known as event tree headings, is graphically shown. The result is a pictorial representation of various combinations of systems or barriers which succeed or fail to prevent the occurrence of the undesired event or to achieve a final safe condition. ET analysis is most helpful for delineation of sequences of events leading to release of material when there are multiple or redundant barriers for mitigation of the progression of the accident. Examples of such sequences include fire scenarios or seismic events. In such cases, the combination of various barrier successes and failures is best represented by using ET analysis.

4) Large, Moderately Complex Processes

Use Fault Tree Analysis (FT)

Large, moderately complex processes include solid handling (e.g., machining and assembly) activities which include rather simple movement of materials from one discrete step to another. Both ET analysis and FT analysis techniques are appropriate for such facilities. FT analysis is a top-down approach for systematic assessment of various ways by which an undesirable event can occur. It begins with the undesirable event and proceeds to identify the event or sequence of events leading to that event. The fault tree can be developed to any desired level of detail. If quantification is desired, the fault tree is usually developed to the lowest level where data for these basic events are available, be it the subsystem, component, or component piece or part level.

Since FT analysis starts from the undesirable event and logically identifies basic fault conditions which can contribute to its occurrence, only those faults contributing to the occurrence of undesired event are modeled. This process is much more efficient than bottom-up approaches such as FMEA and is the main reason for its wide spread use. FT analysis is most suitable for analysis of large, moderately complex systems or processes where multiple component failures including human errors can contribute to the failure of the system or process.

5) Complex Fluid Processes

Use Hazard and Operability Studies (HAZOP)

Complex fluid processes involve arrays of piping, tanks, and instrumentation and control systems. Examples of these processes include PUREX, chemical separations, isotope separations (e.g., uranium enrichment), and petrochemical processing. HAZOP is a standard and widespread technique used for the analysis of chemical flow processes. The main elements of HAZOP include determining (1) the hazards which exist in a unit or are associated with a process, (2) the effects associated with the hazard (e.g., safety, environmental, economic), (3) the occurrence of accidents, and (4) the measures to prevent a hazard from occurring or to mitigate the effects of an accident or failure.

HAZOP entails the investigation of deviations from design intent for a process by a team of individuals with expertise in different areas such as engineering, chemistry, safety, operations, and maintenance. The approach is to review the process in a series of meetings during which the multidisciplinary team "brainstorms" the plant design methodically by following a sequence based on prescribed guide words and the team leader's experience. The guide words are used to ensure that the design is explored in every conceivable way. The HAZOP is based on the principle that several experts with different backgrounds can interact and better identify problems when working together than when working separately and combining their results.

Generally, HAZOP should be used for identifying accident scenarios associated with continuous processing which involves the control of a significant number of parameters in order to maintain the process in steady-state conditions and within safe limits. Such processes generally have systems intended to monitor key parameters. Such monitoring systems may interface with automatic control and protection systems which act to maintain the process in a safe condition or may only trigger alarms to alert the operator that a parameter change requires a response. Thus, such a process can be either one that is automatically controlled and generally expected to operate without or with a minimum of supervision, or one requiring intense operator involvement for control. For this reason, detailed design information (e.g., Piping & Instrumentation Diagrams) is required for the analysis.

Fault trees may be used to complement to the HAZOP process. However, the use of fault trees in this context does not imply that the trees should be quantified probabilistically since the purpose is only the identification of scenarios for release.

6) <u>High Complexity Facilities</u>

<u>Use Integrated Event Tree and Fault Tree Techniques (ETs/FTs)</u>

Facilities with a large number of interdependent components or systems and fluid flow processes are highly complex. Highly interdependent systems and components should not be taken to include basic buildings systems such as Heating, Ventilation, and Air Conditioning (HVAC) and electrical power distribution systems unless these systems have significant effect on the progress of the accident sequence. Highly complex facilities include multi-component transfer and control systems for which extensive instrumentation and control systems are needed. Extensive redundancy at the component, system, and safety level are also inherent in highly complex facilities. Such processes generally cannot be completely controlled through manual actions because the interactions between systems are too intricate for an operator to interpret in the time required for action. Thus, these processes are generally characterized by large-scale monitoring and automatic control systems. Further, such facilities generally vary greatly in the design of the plant systems, especially safety systems. Large power reactors and very large chemical processing or petroleum refineries are representative of this class of facilities.

For such facilities, the extensive use of event trees and fault trees is needed to understand the potential release mechanisms. The specification of the use of these techniques is due to the complex system interdependencies found in such facilities. ET/FT is capable of clarifying these interdependencies. The ET/FT technique involves defining initiating events leading to process disturbance and constructing detailed ET and FT models to represent plant response to various accident conditions resulting from those disturbances. These techniques have been proven to be especially useful in evaluating processes involving very complex systems with high levels of integration and interdependency.

Connecting of the initiating event and ET and FT models in a structured fashion is a proven technique capable of handling, in an efficient and comprehensive fashion, the very complex nature of the system designs, interactions, and dependencies prevalent in these processes. A large part of the reason for selecting this technique is that the nature of the hazard is straightforward, but its possible causes are numerous. For example, insufficient cooling to the reactor core leads to the release of large quantities of radionuclides from the core, but the causes of loss of coolant are many and intricate. Thus, the emphasis on systems is a key benefit for evaluating these processes; other techniques structured to consider the hazards themselves (such as HAZOP) are not required.

Further, because the integrated nature of the processes results in a large number of intricate combinations of failures which can lead to a release, the probabilistic approach used is essential in determining which of these combinations is necessary to consider in addressing consequences, for the sheer number of them makes the use of engineering judgment more complicated and less reliable.

<u>Sequence Selection</u>

As general guidance for Category 2 facilities, it is necessary to include a range of accident conditions to adequately characterize the safety basis for the facility. Accident sequences should be selected to provide insight into the hazards associated with the facility. Because these accidents are used in establishing the Technical Safety Requirements for the facility, their selection is very important. The selection process should be based on the implementation of the analysis techniques discussed in the previous section. The search should include higher-probability unique events which pose hazards only to workers as well as unusual, lower-probability events which include a reasonable maximum release from the facility. Design basis natural phenomena should also be included in the range of undesired events. The following section discusses the range of events in somewhat more detail.

1) Operational Accidents - Operational accidents are those that result from processes and activities involved in operating the facility and generally cover many diverse routine or non-routine events with potentially adverse consequences to the workers or the public. Fires, explosions, spills, process disturbances, and criticality events are included as operational events. A reasonable set of operational events should be selected which represents the accident release mechanisms identified. Explicit consideration should be given to non-routine or unique events which present significant risks to facility workers. These events should include process explosions or criticalities which have the potential for serious worker injury or death but would not necessarily cause significant releases outside of the facility.

2) Design Basis Natural Phenomena Events - As currently defined by DOE, design basis natural phenomena events include earthquakes, high winds, tornados, floods, etc. for which the facility has been (or should have been) designed. Explicit consideration should be given to such sequences and a representative set of accidents described.

3) External Events - The effect of facility- or site-specific events such as airplane crashes, transportation accidents, or collocated facility accidents on the Category 2 facility should also be addressed.

Sequence Engineering Analysis

Engineering analysis concentrates on those structures, systems, and components relevant to the accident scenarios developed. Although listed before actual consequence determination, it will normally be conducted in an integrated fashion with accident quantification. Engineering analysis is needed to determine the amount of material which would be released in the scenario. For example, if an accident scenario assumes that the High Efficiency Particulate Air (HEPA) filters will work as designed, then an engineering analysis is needed to ensure that the accident conditions experienced by the filters is within the filter design envelope. However, for an event such as the explosion of an ion exchange column, where there is sufficient energy to lift the charging lid on a dissolver, an elaborate analysis of the structural strength of the vessel and its lid would be unwarranted if the consequences are insignificant.

It should be noted that the detailed engineering analysis could be part of the design documentation for the facility. Also, the engineering analysis will become a significant part of the designation of safety class systems, structures, and components and drive the Technical Safety Requirements for the facility.

Consequence Analysis

Consequence analysis is the final step in the accident analysis section of the SAR. For Category 2 facilities, the following analyses must be provided.

1) Source Term Analysis - Provide a reasonably conservative analysis by using defensible realistic values of the characteristics of the release from the building. This analysis includes the amount and form of material, the timing of the release, energy, particle size distribution, etc.

2) Dose Assessment - Perform dose calculations by using conservative analysis techniques for workers and site boundary distances.

4.1.2.c Nuclear Hazard Category 1 Facilities

DEFINITION
Hazard Analysis shows the potential for significant off-site consequences.

INTERPRETATION
Category A reactors and facilities designated by the PSO.

Release Mechanisms

Refer to the discussion in Category 2 for release mechanism analysis techniques. It should be noted that large reactors would probably be considered highly complex facilities and utilize fully, integrated, quantitative ET and FT techniques.

Sequence Selection

For highly complex facilities, an extensive set of accident sequences need to be categorized so that a reasonable spectrum of sequences is analyzed.

Engineering Analysis

Extensive engineering analysis is required for Category 1 facilities.

Consequence Analysis

The requirements are the same as the ones given for Category 2 facilities.

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HAZARD CATEGORIZATION OF DOE FACILITIES

The hazard categorization approach and criteria outlined below can be consistently applied to all DOE nuclear facilities. It is based on a simple approach which is intended to meet DOE Order 5480.23 requirements for a preliminary assessment and hazard categorization. This approach is also intended to supplement the graded approach as discussed in Section 4 of the guidance document. An interpretation of the Hazard Categories discussed in the Order with detailed groundrules for each category, is given below.

General Groundrules

Facility Segmentation

In facility categorization, flexibility must be allowed in the definition of facility segments. Many DOE facilities conduct a wide variety of activities in one facility, ranging from simple assay or lab experiments to complex fluid flow separations. It is necessary to avoid placing excessive requirements on simple or even trivial co-located operations. The concept of independent facility segments should be applied where facility features preclude bringing material together or causing harmful interaction from a common severe phenomenon.

It should be noted that DOE 5480.23 states that an analysis and categorization is to be performed on “processes, operations, or activities” and not necessarily whole facilities. For the purposes of hazard categorization and estimating hazardous material inventory, the objective is to understand the available hazards that could interact and cause harm to individuals or the environment. It is not desirable to estimate the potential consequences from an inventory of hazardous materials when facility features would preclude bringing this material together. Therefore, the standard permits the concept of facility segmentation provided the hazardous material in one segment could not interact with hazardous materials in other segments. For example, independence of HVAC and piping must exist in order to demonstrate independence for facility segmentation purposes. This independence must be demonstrated and places the “burden of proof” on the analyst.

Treatment of Sealed Sources, Commercially Available Products and DOT Shipping Containers

Sealed radioactive sources that are engineered to pass the special form testing specified by the Department of Transportation (DOT) in 49 CFR 173.469 or testing specified by ANSI N43.6 “Sealed Radioactive Sources, Categorization,” may be excluded from summation of a facility’s radioactive inventory. The facility must have documentation that the source or prototypes of the source have been tested and passed the tests specified by DOT or ANSI. Facilities must also have in place a source control policy that complies with DOE Notice 5400.9, “Sealed Source Control Policy” and the source control policy specified in Article 431 of the DOE RadCon Manual. Should a sealed radioactive source fail, as indicated by an increase in the removable activity, the source shall be removed from service and handled in accordance with the source control policy established for the facility.

Hazardous materials used in exempted, commercially available products, should not be considered part of a facility's inventory. These materials are described in 10 CFR 30 Parts 30.11–30.19 and include timepieces, illumination devices, thermostats, electron tubes, microwave receiver tubes, etc.

Additionally, material contained in DOT Type B shipping containers (with or without overpack) may also be excluded from summation of a facility's radioactive inventory if the Certificates of Compliance are kept current and the materials stored are authorized by the Certificate. However, Type B containers without overpack should have heat protection provided by the facility's fire suppression system.

These exclusions do not apply to fissile material in the determination of Hazard Category 2 status relative to criticality.

Summation of Radionuclide Threshold Ratios

Facilities or facility segments where there are combinations of radioactive materials should be designated as Category 2 or 3 if the sum of the ratios of the quantity of each material to the Category 2 or 3 thresholds exceeds one (e.g., [inventory of isotope A/threshold of isotope A] + [inventory of isotope B/threshold of isotope B] + [inventory of isotope n/threshold of isotope n] >1).

<u>Part Time Inventory</u>

A facility that is involved with an inventory of hazardous materials that varies with time must be categorized on the basis of its maximum inventory of hazardous materials.

<u>Hazard Categories</u>

Hazard Category 1

DEFINITION: *Hazard Analysis shows the potential for significant off-site consequences.*

INTERPRETATION: Category A reactors and facilities designated by PSO.

CONSIDERATIONS: Category A reactors are those that have a steady-state power level greater than 20 MWt.

Hazard Category 2

DEFINITION: *Hazard Analysis shows the potential for significant on-site consequences.*

INTERPRETATION: Facilities with the potential for nuclear criticality events or with sufficient quantities of hazardous material and energy, which would require on-site emergency planning activities.

RADIOLOGICAL CRITERIA: The criterion is that given in 10 CFR 30, with rebaselined calculation. This criterion is essentially possession of quantities of material whose unmitigated release could produce total doses of 1 rem in the range of 100 meters from the facility.

In addition, any facility containing fissile material in quantities greater than the theoretical minimum mass limits for criticality emergencies as specified in ANSI/ANS-8.1-1983, R88 "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors" should be included. For aqueous solutions of U_{233}, U_{235}, and $Pu_{239,}$ these values are 500, 700, and 450 grams, respectively. Credit may be taken if segmentation or nature of process precludes potential for criticality.

CONSIDERATIONS: The intent of this threshold is to capture those quantities of material whose unmitigated release would require an emergency plan for on-site evacuation. The NRC has specified certain values in 10 CFR 30 with a defined threshold of a 1 rem dose at 100 meters. DOE has evaluated these numbers and made certain modifications to release fractions which are explicitly allowed in the regulation. DOE has also modified the meteorology used in the threshold calculation.

Specific groundrules for Category 2 hazard categorization are as follows:

1. In general, it is necessary to consult the individual threshold values only if an individual isotope is being isolated and collected for some purpose. For example, if a facility processes weapons grade plutonium, it can simply be classified on the aggregate amount of Pu_{239} present without specifying quantities of trace isotopes (i.e., Pu_{238}, Pu_{240}, Am_{241}, etc.) carried along in the mixture. Likewise, if a fuel reprocessing plant has more than 1000 curies of mixed fission products, it is a Category 2 facility with no need to consider individual radionuclide make-up.

2. Facilities are considered Category 2 if the potential for criticality exists in the storage arrays and processing means used.

Hazard Category 3

DEFINITION: *Hazard Analysis shows the potential for significant but localized consequences.*

INTERPRETATION: Facilities with quantities of hazardous radioactive materials, which meet or exceed the Table A.1 values.

RADIOLOGICAL CRITERIA: Quantities of radioactive materials as specified in Table A.1.

CONSIDERATIONS: The definition of the Category 3 threshold is designed to exclude those facilities which cannot have a significant radiological impact outside the facility.

DISCUSSION

Hazard Category 1

DOE Order 5480.23 states that Category 1 hazards have the potential for "significant off-site consequences." Based on total curie content, potential material forms, and maximum energy for dispersion available, one class of facilities which possess this hazard potential is the Class A nuclear reactors. In addition, the PSO may designate other facilities as Category 1 if he feels there exists the potential for significant off-site consequences.

Hazard Category 2

The approach for designating Category 2 hazards was constructed from existing regulations which define minimum thresholds for many radionuclides and hazardous chemicals on the basis of consequences from these hazards in the immediate vicinity of a facility. Table A.1 provides the resulting TQs for radioactive materials which define a Category 2 facility. Such an approach is consistent with the intent of DOE Order 5480.23 to categorize at level 2 those facilities with the potential for "significant on-site consequences."

For radioactive materials, 10 CFR 30 derived quantities above which byproduct material licensees must provide emergency plans for responding to a release because such a release could give a dose of 1 rem at 100 meters under very conservative meteorological conditions (stable air with intermittent breezes, i.e., F at 1 m/sec). Table A.1 includes thresholds for byproduct material on the basis of this regulatory premise. Differences between the NRC calculation and the DOE calculation are explained in the Calculations and Assumptions Section of this Attachment.

The threshold value for fissile material as specified in Table A.1 is the minimum theoretical mass necessary for a nuclear criticality to occur with moderation and reflection. These values for aqueous solutions are approximately 450 grams for Pu_{239}, 500 grams for U_{233}, and 700 grams for U_{235}. This stipulation is necessary because the on-site effects of a criticality are potentially severe within the immediate vicinity of a facility. Category B nuclear reactors should therefore be classified as Category 2 since critical quantities of fissile materials are present in these facilities but not in sufficient quantities to represent a significant off-site impact.

Hazard Category 3

Category 3 is designed to capture facilities which largely include lab operations, low level waste handling facilities, and research machines which possess less than the Category 2 quantities of material and are considered to represent a low hazard. DOE Order 5480.23 states that facilities should be classified as Level 3 if there is only the potential for "significant localized consequences." Essentially all industrial facilities have a potential for significant localized consequences because the potential to injure workers from typical industrial accidents is always present. However, Category 3 facilities pose additional hazards due to the presence of radionuclides. To establish a system based on inventories, DOE has modified the EPA definitions of RQs for radionuclides contained in 40 CFR 302.4, Appendix B. The values for radionuclides represent levels of material which, if released, would produce less than 10 rem doses at 30 meters based on 24 hour exposure. Table A.1 provides the Category 3 thresholds for radionuclides.

Results

Categorization of most nuclear hazards present in facilities or facility segments should be possible from the thresholds listed in Table A.1. Further discussion on the origin of some thresholds is provided in the following section on “Calculations and Assumptions.”

CALCULATIONS AND ASSUMPTIONS

Calculation of Category 2 Radiological Thresholds

The NRC derived 10 CFR 30, Schedule C threshold quantities which could result in a dose of 1 rem at 100 meters by using standard air dispersion/dose calculations. The basic calculation stated is as follows:

$$Q = (1\ \text{rem})/(RF^*(H_I + H_G + H_{CS}))$$

where

Q = Quantity of material used as threshold (grams)

RF = Release fraction for material of concern (unitless)

H_I = Effective dose equivalent from inhalation (rem/gm)

H_G = Effective dose equivalent from ground contamination (rem/gm)

H_{CS} = Effective dose equivalent from cloud shine (rem/gm)

The NRC then stated that "for all materials of greatest interest for fuel cycle and other radioactive material licensees, the dose from the inhalation pathway H_I will dominate the dose" and dismissed the other contributors. Simplifying assumptions for Gaussian dispersion and particle deposition were then used to calculate inhalation doses.

In modifying the NRC results, DOE has restated the equation above as

Q = (1 rem)/(RF*SA*X/Q*(CEDE*RR + CSDE))

where

Q = Quantity of material used as threshold (grams)

RF = Airborne release fraction of material averaged over an entire facility (unitless)

SA= Specific activity of radionuclide released (Ci/gm)

X/Q= Expression accounting for dilution of release at a point under given meteorological conditions (sec/m^3)

CEDE= Committed effective dose equivalent for a given radionuclide (rem/Ci)

RR= Respiration rate, which is assumed equal to the standard value used for an active man (3.5 E-4 m^3/sec)

CSDE= Cloud shine dose equivalent (rem*m^3/Ci*sec)

Specific modifications to forms of the equation are discussed in distinct sections below.

Exposure Pathways

As can be seen from the modified equation, DOE concurred with the NRC's dismissal of the ground contamination exposure pathway. In general, DOE concurred with the dismissal of cloudshine exposure as well because this path accounted for, on average, slightly less than 2% of dose for all radionuclides but the noble gases. Although, for the types of material that DOE handles, it is expected that the values for noble gases will be included in the mixed fission product threshold, DOE decided to retain this exposure pathway in the calculation for completeness.

Meteorological Conditions

DOE chose to modify the NRC meteorological assumptions used for hazard categorization purposes. NRC used F stability at 1 m/sec meteorological conditions whereas DOE used D stability at 4.5 m/sec for the following reasons:

1. The NRC use of a conservative value at 100 meters was based on the fact that most of the commercial radionuclide handling facilities for which emergency planning was being considered have boundaries with populated areas at or less than 100 meters. The majority of DOE Category 2 facilities have site boundary distances much greater than 100 meters.

2. The calculation of values at 100 meters achieves a less accurate result from dispersion models since building wake effects are still a predominant effect at this distance.

3. The use of F at 1 m/sec was considered to be overly conservative, particularly in light of the difference in application between the DOE and NRC in the resulting calculated quantities. DOE consequently decided to use a Pasquill stability class D at 4.5 m/sec windspeed, a value used for comparison by NRC, as the assumed meteorological conditions for the dispersion calculations. Using a no-buoyancy model, which will by itself be conservative for many releases, a nominal distance for the 1 rem evaluation would be slightly less than 300 meters. These conditions correspond to a X/Q of approximately 1 E-4 sec/m^3, which is considered adequate for a calculation which does not account for mitigation or size distribution of particles.

Release Fractions

The final set of assumptions modified by DOE were the set of release fractions used by the NRC in NUREG-1140. NRC proposed the following set of release fractions based upon experimental data and historical observations:

1.	Noble Gases	1.0
2.	Highly Volatile/Combustible	0.5
3.	Carbon	1 E-2
4.	Semi-volatile	1 E-2
5.	Unknown form	1 E-2
6.	Nonvolatile powder	1 E-3
7.	U and Pu Metal	1 E-3
8.	Nonvolatile solids	1 E-4
9.	Nonvolatiles in flammable liquid	5 E-3
10.	Nonvolatiles in non-flammable liquid	1 E-3

DOE desired to simplify this list because some components could be combined, some of the categories were not used by the NRC, and the regulatory framework for the list clearly allowed lowering release fractions for regulatory calculations.

Therefore, DOE first changed the noble gas category to simply gases and moved specific gases such as tritium from the highly volatile/combustible category into the gas category, where the release fraction of 1.0 was retained. DOE then chose to keep the highly volatile/combustible category as defined by NRC, with the addition of sodium to the group. The release fraction of 0.5 is somewhat higher than is usually estimated for these compounds, but DOE chose to retain the conservative value. At the same time, DOE also noted that use of such a release fraction would not be appropriate if a flammable substance such as phosphorus had been turned into a phosphoric acid solution, the normal form for research activities. At that point, it would be a material best represented by the general powder/liquid/solid category described below.

DOE did not consider carbon-14 thresholds to be a major issue on the basis of typical quantities used. As a result, carbon was grouped as a semi-volatile with the same release fraction of 1 E-2. The DOE then decided to abandon the use of the unknown form category as an unnecessary complication. NRC used this value for a number of the isotope thresholds, largely relating to materials unlikely to be found outside of fission product mixtures or sources. The use of a curie threshold for fission product mixtures would capture such material in most DOE applications. Additionally, there was no compelling reason to believe these materials would react to physical energy stresses differently from most powders, liquids, or solids.

NRC did not use the nonvolatile in flammable liquid, nonvolatile in non-flammable liquid, or nonvolatile solid categories in final calculations. DOE concurred with this approach and dropped these categories because applying average release fractions over an entire building makes such detailed subdivision of questionable value. DOE believes that the 1 E-3 value is a reasonably conservative approximation because it will be applied to an entire building without scenario-specific considerations. DOE recognizes that some accidents, particularly those involving powders and liquids, can produce much higher values, whereas metal incidents would normally produce slightly smaller release fractions. However, it is unlikely that any event will affect all material in a building, and high release phenomena such as ion exchange explosions, powder pressurization, etc., will affect only a localized fraction of the material. Therefore, the value is believed an adequate average for hazard categorization purposes.

The final release fraction values for Hazard Category 2 were produced by DOE as listed below:

1.	Gases (such as tritium, krypton, xenon, argon, radon, chlorine, etc.)	1.0
2.	Highly volatile/combustible (phosphorus, sulfur, potassium, iodine, sodium, bromine)	0.5
3.	Semi-volatile (selenium, mercury, cesium, polonium, tellurium, ruthenium, carbon)	1 E-2

4.	Solid/Powder/Liquid (All materials not listed above)	1 E-3

Calculation of Category 3 Radiological Thresholds

In the Senior Nuclear Managers' meeting of October 26, 1992, DOE determined that it is reasonable to set the limit based upon the value that is accepted by the EPA for protection of workers for planned reentry into a facility after an incident (EPA in Manual of Protective Action Guides and Protective Actions for Nuclear Incidents, EPA 400-R-92-001) and cited in Appendix 2A of the RadCon Manual, which is 10 rem.

DOE has chosen to use an EPA model* to calculate the threshold quantities for Category 3. The model assumes that: the distance from the point of release to the point of exposure is 30 meters; the dose-equivalent limit is 10 rem effective whole body dose; and there is no radioactive decay (for the sake of conservatism and simplicity). For the period of exposure, the models used assume that persons are exposed for one day for inhalation and direct exposure, but that persons are exposed for longer periods through the ingestion pathway.

See Section 3.0 of this Standard for guidance on the proper use of this Table.

* 40 CFR 302.4 Appendix B, calculations described in User's Manual for the Radionuclides Database Version 1.02

Table A.1 Thresholds for Radionuclides

Isotope	Category 2 [1] Curies	Threshold Grams	Category 3 [2] Curies	Threshold Grams
H-3	3.0E+05	3.0E+01	1.6E+04*	1.6E+00*
C-14	1.4E+06	3.1E+05	4.2E+02	9.4E+01
Na-22	6.3E+03	1.0E+00	2.4E+02	3.8E-02
P-32	4.4E+03	1.5E-04	1.2E+01	4.2E-05
P-33	3.0E+04	1.9E-01	9.4E+01	6.0E-04
P-32, acid**	2.2E+06	7.7E-02	1.2E+01	4.2E-05
P-33, acid**	1.5E+07	9.6E+01	9.4E+01	6.0E-04
S-35	2.5E+04	5.8E-01	7.8E+01	1.8E-03
Cl-36	1.4E+03	4.3E+04	3.4E+02	1.0E+04
K-40	4.7E+03	6.8E+08	1.7E+02	2.4E+07
Ca-45	4.7E+06	2.6E+02	1.1E+03	6.2E-02
Ca-47	4.8E+06	7.8E+00	7.0E+02	1.1E-03
Sc-46	1.4E+06	4.0E+01	3.6E+02	1.1E-02
Ti-44	3.2E+04	1.9E+02	6.2E+01	3.6E-01
V-48	3.0E+06	1.8E+01	6.4E+02	3.8E-03
Cr-51	1.0E+08	1.1E+03	2.2E+04	2.4E-01
Mn-52	4.0E+06	8.8E+00	3.4E+02	7.6E-04
Fe-55	1.1E+07	4.6E+03	5.4E+03	2.2E+00
Fe-59	1.8E+06	3.7E+01	6.0E+02	1.2E+02
Co-60	1.9E+05	1.7E+02	2.8E+02	2.5E-01
Ni-63	4.5E+06	8.0E+04	5.4E+03	9.5E+01
Zn-65	1.6E+06	1.9E+02	2.4E+02	2.9E-02
Ge-68	5.8E+05	8.8E+01	1.0E+03	1.5E-01
Se-75	3.4E+05	2.4E+01	3.2E+02	2.2E-02
Kr-85	2.8E+07	7.2E+04	2.0E+04	5.1E+01
Sr-89	7.7E+05	2.7E+01	3.4E+02	1.2E-02
Sr-90	2.2E+04	1.6E+02	1.6E+01	1.2E-01
Y-91	6.5E+05	2.7E+01	3.6E+02	1.5E-02
Zr-93	8.9E+04	3.6E+07	6.2E+01	2.5E+04
Zr-95	1.5E+06	6.9E+01	7.0E+02	3.3E-02
Nb-94	8.6E+04	4.6E+05	2.0E+02	1.1E+03
Mo-99	7.8E+06	1.6E+01	3.4E+03	7.1E-03
Tc-99	3.8E+06	2.3E+08	1.7E+03	1.0E+05
Ru-106	6.5E+03	1.9E+00	1.0E+02	3.0E-02
Ag-110m	5.3E+05	1.1E+02	2.6E+02	5.5E-02
Cd-109	2.9E+05	1.1E+02	1.8E+02	7.0E-02
Cd-113	1.8E+04	5.3E+16	1.1E+01	3.2E+13
In-114m	3.7E+05	1.6E+01	2.2E+02	9.5E-03
Sn-113	3.2E+06	3.2E+02	1.3E+03	1.3E-01

Isotope	Category 2 Curies	Threshold Grams	Category 3 Curies	Threshold Grams
Sn-123	9.5E+05	1.2E+02	3.2E+02	3.9E-02
Sn-126	3.3E+05	1.2E+07	1.7E+02	6.0E+03
Sb-124	1.3E+06	7.5E+01	3.6E+02	2.1E-02
Sb-126	2.5E+06	3.0E+01	2.8E+02	3.4E-03
Te-127m	1.5E+05	1.6E+01	4.0E+02	4.2E-02
Te-129m	1.4E+05	4.7E+00	4.0E+02	1.3E-02
I-125	2.4E+03	1.4E-01	5.6E-01	3.2E-05
I-131	1.8E+03	1.4E-02	9.2E-01	7.4E-06
Xe-133	1.8E+06	9.6E+00	2.0E+04	1.1E-01
Cs-134	6.0E+04	4.6E+01	4.2E+01	3.3E-02
Cs-137	8.9E+04	1.0E+03	6.0E+01	6.9E-01
Ba-133	4.0E+06	1.6E+04	1.1E+03	4.3E+00
Ba-140	7.8E+06	1.1E+02	6.0E+02	8.2E-03
Ce-141	3.3E+06	1.2E+02	1.0E+03	3.5E-02
Ce-144	8.2E+04	2.6E+01	1.0E+02	3.1E-02
Pm-145	1.1E+06	7.6E+03	2.0E+03	1.4E+01
Pm-147	8.4E+05	9.0E+02	1.0E+03	9.5E-01
Sm-151	9.9E+05	3.7E+04	1.0E+03	3.8E+01
Eu-152	1.3E+05	7.5E+02	2.0E+02	1.2E+00
Eu-154	1.1E+05	4.2E+02	2.0E+02	7.6E-01
Eu-155	7.3E+05	1.6E+03	9.4E+02	2.0E+00
Gd-153	1.4E+06	3.9E+02	1.0E+03	2.8E-01
Tb-160	1.3E+06	1.1E+02	5.6E+02	5.0E-02
Ho-166m	4.0E+04	2.2E+04	7.2E+01	4.0E+01
Tm-170	1.2E+06	2.1E+02	5.2E+02	8.7E-02
Hf-181	2.2E+06	1.3E+02	7.6E+02	4.5E-02
Ir-192	1.2E+06	1.3E+02	9.4E+02	1.0E-01
Au-198	9.3E+06	3.8E+01	2.0E+03	8.2E-03
Hg-203	4.3E+05	3.1E+01	3.6E+02	2.6E-02
Pb-210	2.2E+03	2.9E+01	3.6E-01	4.7E-03
Bi-207	2.2E+06	4.3E+04	5.0E+02	1.1E+01
Bi-210	1.5E+05	1.2E+00	3.2E+02	2.6E-03
Po-210	3.5E+02	7.8E-02	1.9E+00	4.2E-04
Rn-222	1.6E+08	1.1E+03	1.0E+01	6.5E-05
Ra-223	3.8E+03	7.4E-02	6.2E+01	1.2E-03
Ra-224	9.9E+03	6.1E-02	2.0E+02	1.2E-03
Ra-225	3.8E+03	9.6E-02	7.2E+01	1.8E-03
Ac-225	2.9E+03	4.9E-02	3.2E+01	5.5E-04
Ac-227	4.3E+00	5.9E-02	4.2E-02	5.8E-04
Th-228	9.2E+01	1.1E-01	1.0E+00	1.2E-03
Th-230	8.9E+01	4.4E+03	6.2E-01	3.1E+01
Th-232	1.8E+01	1.6E+08	1.0E-01	9.1E+05

Isotope	Category 2 Curies	Threshold Grams	Category 3 Curies	Threshold Grams
U-233	2.2E+02***	2.3E+04***	4.2E+00	4.4E+02
U-234	2.2E+02	3.5E+04	4.2E+00	6.7E+02
U-235	2.4E+02***	1.1E+08***	4.2E+00	1.9E+06
U-238	2.4E+02	7.1E+08	4.2E+00	1.3E+07
Np-237	5.8E+01	8.3E+04	4.2E-01	6.0E+02
Np-238	9.1E+05	3.5E+00	1.3E+03	5.0E-03
Pu-238	6.2E+01	3.6E+00	6.2E-01	3.6E-02
Pu-239	5.6E+01***	9.0E+02***	5.2E-01	8.4E+00
Pu-241	2.9E+03	2.8E+01	3.2E+01	3.1E-01
Am-241	5.5E+01	1.6E+01	5.2E-01	1.5E-01
Am-242m	5.6E+01	5.8E+00	5.2E-01	5.3E-02
Am-243	5.5E+01	2.8E+02	5.2E-01	2.6E+00
Cm-242	1.7E+03	5.1E-01	3.2E+01	9.7E-03
Cm-245	5.3E+01	3.1E+02	5.2E-01	3.0E+00
Cf-252	2.2E+02	4.1E-01	3.2E+00	5.9E-03

1 For isotopes not listed below, users may refer to LA-12846-MS, Specific Activities and DOE-STD-1027-92 Hazard Category 2 Thresholds, LANL Fact Sheet or to 10 CFR 30.72, Schedule C and adjust the values consistent with the X/Q value described in Attachment 1 of this Standard. (Note that although LA-12846-MS misstates the Category 2 threshold criterion, its use of the proper X/Q negates any effect of the misstatement. See "Radiological Criteria, p A-3 and Meteorological Conditions, p A-7 for clarification)

Any other beta-gamma emitter - 4.3E+05 Ci
Mixed fission products - 1.0E+03 Ci
Any other alpha emitter - 5.5E+01 Ci

2 For isotopes not listed below, users may refer to LA-12981-MS, Table of DOE-STD-1027-92 Hazard Category 3 Threshold Quantities for the ICRP-30 List of 757 Radionuclides, LANL Fact Sheet for threshold quantities of any isotopes of interest.

* At the recommendation of the Tritium Focus Group, the Category 3 tritium threshold value has been increased from 1.0E+03 Ci and 1.0E-01 grams to 1.6E+04 Ci and 1.6E+00 grams, consistent with the methodology of EPA used for the other nuclides.

** Provided as an example to indicate that when a substance such as P_{32} is used in a solution (i.e., phosphoric acid) for experimentation, medical treatment, etc., it should no longer be considered as highly volatile/combustible.

*** To be used only if segmentation or nature of process precludes potential for criticality. Otherwise, use the criticality lists for U_{233}, U_{235} and Pu_{239} of 500, 700, and 450 grams, respectively.

CONCLUDING MATERIAL

Review Activities:

DOE
DP
EH
EM
ER
NE
NP
NS
RW

Preparing Activity:

EH-31

Project Number:

SAFT-0004