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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management
Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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Hanford
Safety Analysis
and
Risk Assessment
Handbook

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Fluor Hanford
Richland, Washington

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Acronyms

AED - aerodynamic equivalent diameter

AR - Accident (Source Term) Ratio

ARF - airborne release fraction

ARR - airborne release rate

BR - breathing rate

CSER - criticality safety evaluation report

CW - co-located worker

DBA - design basis accident

DCF - dose conversion factor

DE-Ci - Dose Equivalent Curies

DFA - Driver Fuel Assembly

DOE - U.S. Department of Energy

DR - damage ratio

DSA - Documented Safety Analysis

EG - Evaluation Guideline

EM - Environmental Management

EPA - U.S. Environmental Protection Agency

ERPG - emergency response planning guideline

FHA - fire hazard analysis

FMEA - Failure Modes and Effects Analysis

FMECA - Failure Modes and Effects Criticality Analysis

FTA - Fault Tree Analysis

HAZOP - Hazards and Operability Analysis

HC-"N" - Hazard Category "N" ("N" = 1, 2, or 3)

HEPA – High-Efficiency Particulate Air (filter)

ICRP - International Commission on Radiological Protection

IWS - Inactive Waste Sites

JCO - justification for continued operation

LPF - leak path factor.

MAR - material at risk

MOI - maximally exposed offsite individual

NFSP - DOE Office of Nuclear and Facility Safety Policy

NPH - natural phenomena hazard

NSTP - Nuclear Safety Technical Position

OSHA - Occupational Safety and Health Standards

PC - Performance Category

PF - Package Factor

PHA - preliminary hazard analysis

PMMA - polymethylmethacrylate

POCs - Pipe Overpack Containers

PR - Package (Source Term) Ratio

RF - respirable fraction

RIMS - RL Integrated Management System

RL - DOE Richland Operations Office

RQs - Reportable Quantities

RST - respirable source term

S&M - surveillance and maintenance

SARAH - Hanford Safety Analysis and Risk Assessment Handbook

SC - safety class

SER - Safety Evaluation Report

SSC - structure, system, or component

TEDE - total effective dose equivalent

TEDE - total effective dose equivalent

TEEL - temporary emergency exposure limit

TRU - transuranic

TSR - Technical Safety Requirement

USQ - unreviewed safety question

WSD - Waste Stabilization and Disposition Project

χ/Q' - atmospheric dispersion coefficient

1.0 INTRODUCTION

1.1 PURPOSE OF THIS HANDBOOK

The purpose of the Hanford Safety Analysis and Risk Assessment Handbook (SARAH) is to support the development of safety basis documentation for Hazard Category 2 and 3 (HC-2 and 3) U.S. Department of Energy (DOE) nuclear facilities to meet the requirements of 10 CFR 830, *Nuclear Safety Management*, Subpart B, "Safety Basis Requirements."

Consistent with DOE-STD-3009-94, Change Notice 2, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses* (STD-3009), and DOE-STD-3011-2002, *Guidance for Preparation of Basis for Interim Operation (BIO) Documents* (STD-3011), the Hanford SARAH describes methodology for performing a safety analysis leading to development of a Documented Safety Analysis (DSA) and derivation of Technical Safety Requirements (TSR), and provides the information necessary to ensure a consistently rigorous approach that meets DOE expectations. The DSA and TSR documents, together with the DOE-issued Safety Evaluation Report (SER), are the basic components of facility safety basis documentation.

For HC-2 or 3 nuclear facilities in long-term surveillance and maintenance (S&M), for decommissioning activities, where source term has been eliminated to the point that only low-level, residual fixed contamination is present, or for environmental remediation activities outside of a facility structure, DOE-STD-1120-98, *Integration of Environment, Safety, and Health into Facility Disposition Activities* (STD-1120), may serve as the basis for the DSA.

HC-2 and 3 environmental remediation sites also are subject to the hazard analysis methodologies of this standard.

1.2 SAFETY BASIS REQUIREMENTS AND EXPECTATIONS

The requirements for the planning, development, review, and approval of safety basis documentation are provided by DOE regulations and orders. These are supplemented by DOE technical standards, guides, supplementary guidance, and letters of direction for specific applications. They form the basis for the content of the Hanford SARAH.

The regulatory requirements are promulgated in 10 CFR 830, Subpart B. The applicability of Subpart B is dictated by 1) the definition of a facility as provided by §830.3, and 2) the categorization of the facility as HC-2 or 3 as determined by DOE-STD-1027-92, Change Notice 1, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports* (STD-1027). Hanford has no HC-1 facilities. Once the applicability of 10 CFR 830, Subpart B is established, the facility is required to develop a DSA and TSR document that, together with the DOE-issued SER, establishes its safety basis.

DSA development follows a graded approach and uses one of several "safe harbor" DOE Technical Standards for its methodology. Hanford facilities use STD-3009, STD-3011, and STD-1120 as follows:

- STD-3009 is generally applicable and can be used for any HC-2 or 3 facilities

- STD-3011 applies to HC-2 or 3 facilities 1) with a limited operational life, 2) in deactivation, or 3) in transition surveillance and maintenance (S&M).
- STD-1120 applies to HC-2 or 3 facilities in decommissioning, long-term S&M, or where only low-level residual fixed contamination is present.

The following implementation guides supplement safety basis documentation requirements for all HC-2 or 3 facilities:

- DOE G 421.1-2, *Implementation Guide for Use in Developing Documented Safety Analyses to Meet Subpart B of 10 CFR 830*
- DOE G 423.1-1, *Implementation Guide for Use in Developing Technical Safety Requirements*

DOE O 420.1A, *Facility Safety,* and its associated guides apply provisions of facility safety for nuclear design criteria, nuclear criticality safety, fire protection, explosive safety, and natural phenomena hazards.

Supplementary direction from the DOE Office of Environmental Management (EM) and the DOE Richland Operations Office (RL) applies to safety basis development at Hanford and is reflected in the Hanford SARAH:

- Letter, K. A. Klein, RL, to R. G. Gallagher, FH, "Approval of the Hanford Safety Analysis and Risk Assessment Handbook (SARAH), Draft 1C," 05-SED-0007, dated October 20, 2004, provides direction for revision of the Hanford SARAH, Revision 1, prior to publication.
- Letter, K. A. Klein, RL, and R. J. Schepens, ORP, to E. K. Thomson, FH, and E. S. Aromi, CH2M HILL, "Replacement of Previous Guidance Provided by RL and ORP," 03-ABD-0047, dated February 4, 2003, revises previous supplemental direction for implementing 10 CFR 830, Subpart B.
- Letter, K. A. Klein, RL, to E. K. Thomson, FH, "Approval of Hazard Categorization Procedure for Inactive Waste Sites (IWS)," 03-ABD-0025, dated December 13, 2002, approved hazard categorization process for inactive waste sites and transmitted the DOE technical position for re-categorizing a facility to below HC-3.
- Letter, K. A. Klein, RL, to E. K. Thomson, FH, "Hanford Safety Analysis and Risk Assessment Handbook (SARAH)," 02-ABD-0145, dated August 27, 2002, provided direction for updating and supplementing the Hanford SARAH.
- Letter, K. A. Klein, RL, to E. K. Thomson, FH, "Transmittal of Memorandum 'Supplementary Environmental Management (EM) Guidance for Implementing 10 CFR 830, Subpart B, Safety Basis Requirements,'" 02-ABD-0109, dated June 26, 2002, transmitted EM supplemental direction for facility hazard categorization.
- Letter, K. A. Klein, RL, to E. K. Thomson, FH, "FHI Nuclear Safety Expectations for Nuclear Facilities in Surveillance and Maintenance," 02-ABD-0091, dated May 9, 2002 provided direction for developing DOE-STD-1120-98 DSAs for facilities in long-term S&M.

Additionally, the RL Integrated Management System (RIMS), Authorization Basis Document Review Planning, Guidance, and Suggested Review Times, September 2003, provides expectations to RL for management of the planning and review of safety basis documentation, and is an interface point affecting the planning, development, review, approval, and implementation of the facility safety basis documentation.

1.3 SAFETY ANALYSIS PROCESS

"Safety analysis" is defined in STD-3009 as "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."

The main elements of the safety analysis are:

- Facility description, a description of the facility and the work to be performed
- Hazard identification, the part of hazard analysis concerned with identifying hazards and potential hazardous conditions associated with the facility and the work to be performed
- Hazard evaluation, the part of hazard analysis concerned with evaluating, binning, and ranking the hazards and potential hazardous conditions identified
- Hazard categorization, the part of hazard analysis concerned with categorizing the nuclear facility as HC-1, 2, or 3 consistent with STD-1027
- Accident analysis, for HC-1 or 2 facilities, a formal analysis of potential accidents and their consequences to the public, workers, and the environment
- Control selection, derivation of technical safety requirements and other hazard controls from the hazard analysis and, as applicable, the accident analysis
- Definition of characteristics of safety management programs

The safety analysis process also includes planning the performance of the safety analysis, its documentation, review, approval, and implementation. The Hanford SARAH considers the planning and review of the safety analysis, but focuses primarily on hazard analysis, accident analysis, and control selection. Applicable Site procedures are:

- HNF-RD-8316, *Safety Basis Requirements*
- HNF-PRO-700, *Safety Basis Development*
- HNF-PRO-8317, *Safety Basis Implementation and Maintenance*
- HNF-PRO-8366, *Facility Hazard Categorization*

1.3.1 Planning and Review

The initial planning for developing safety basis documentation (prior to the development of draft documentation) should establish a common understanding between the contractor and DOE of specific expectations and objectives. The safety basis expectations and objectives may include:

- Defining the safety basis scope and applicability, e.g.:
  - coverage of specific mission elements, operations, activities, and structures

  - inclusion of fire hazard analysis (FHA) or criticality safety evaluation report (CSER) updates
  - treatment of any existing justification for continued operation (JCO) or outstanding unreviewed safety question (USQ)
  - defining interfaces with facilities, activities, or processes, including those covered by other safety basis documentation
- Determining the appropriate "safe harbor" methodology and graded approach
- Consideration of control selection strategies (see Section 1.3.2 below)
- Establishing acceptance criteria for the safety basis documentation, e.g.:
  - applicability of review standards or guides
  - use of document review checklists
- Assumptions for the analysis, e.g.:
  - qualitative vs. quantitative evaluations
  - deviations from SARAH parameters
  - anticipation of need for formal accident analysis
- Use of particular analytical tools or models
- In addition to the expectations for the safety basis documentation itself, planning should include the conduct and type of review (in-process review is the preferred model), the general schedule, and any interim milestones. Consult the RIMS at http://rims.rl.gov/navigate/frameset/ms14/supsets/15/set_1.htm for in-process review expectations and additional considerations.

1.3.2 Influence of Facility Mission and Status

1.3.2.1 Facilities with a Long-Term Operational Mission

For facilities with a long-term operational mission, the methodology of STD-3009 applies to the development of DSAs. Analysis of bounding, representative, or unique accidents to establish the suite of hazard controls is acceptable, as long as an "unmitigated" hazard or accident analysis is the basis for classifying the structures, systems, or components (SSC) relied on as safety class or safety significant.

For these facilities, the analysis groups hazardous conditions and accidents into bins sharing attributes that support control selection. TSRs that control the bounding, representative, and unique accidents also control the hazards and accidents within their group as well. A qualitative review should be performed to verify the control suite effectively manages these smaller events.

Where practical, elements of the DSA strategy for life-cycle transition (such as step-out controls) should be incorporated into the hazard controls for operational facilities as well.

1.3.2.2 Facilities in Life-Cycle Transition

For facilities in life-cycle transition, the methodology of STD-3011 or STD-3009 applies to the development of DSAs. The DSA should support application of hazard controls to each applicable life-cycle stage and provide for "stepping out" of controls that are no longer applicable as the transition proceeds. This process involves the following:

- Populating each hazard analysis frequency bin with an analysis for each family of accidents that establishes bounding/representative accidents and associated controls for that bin (e.g., small, medium, and large fires of the same family).
- As an operational facility is deactivated and decommissioned, hazardous materials are removed or stabilized, and the potential for high-consequence accidents is reduced, the controls for such accidents may be deleted as the hazard is eliminated, leaving controls for less severe accidents in place.
- Other controls for hazards (typically initiators) associated with the decommissioning activities become applicable as they are introduced.
- Exceptions to populating all frequency bins include those accident/event categories that do not have a higher frequency (e.g., natural phenomena hazards or external events), instances where bounding consequences are low, and other cases where there is no advantage to the planned transition.

When the analysis and controls are constructed to anticipate near-term mission changes (such as facility transition), the need for new safety analysis is minimized and the number of required DOE review cycles to support transition activities is greatly reduced. Establishment of step-out criteria defined by applicability statements or modes facilitates planning and ensures the appropriate controls are in place for the hazard/activity at any point in time.

1.3.2.3 Facilities in Long-Term Surveillance and Maintenance (S&M) / Decommissioning or with Removed Source Term

For facilities in long-term S&M, for decommissioning activities, where the source term has been reduced to the point that only low-level, residual fixed contamination is present, or for environmental remediation activities outside of a facility structure; the methodology of STD-1120 or STD-3009 applies to the development of DSAs. This methodology also supports decommissioning activities that may proceed while long-term S&M is the primary mission, or when using a "master" DSA approach for multiple facilities in S&M.

The emphasis for S&M is the hazard analysis; if accident analysis is necessary (consequences of identified hazardous conditions are "Moderate" or "High" per Chapter 3 of this document), it is limited to bounding analysis demonstrating that the offsite Evaluation Guideline is not challenged. Hazard controls are primarily programmatic in nature, supporting S&M activities such as radiological and hazardous material control, monitoring, work control, and programs that support decommissioning such as medical surveillance.

1.3.3 Graded Approach

The development of a DSA follows a "graded approach" as defined by 10 CFR 830, §830.3. The graded approach, as applied by STD-3009, is based on the magnitude of the hazards, the complexity of the facility, and the life-cycle stage of the facility. Other relevant factors, such as programmatic mission, are also specified by §830.3. The graded approach used in a DSA is reflected by the methodology used in the performance of the safety analysis (see Table 2 of 10 CFR 830, Subpart B) and the rigor and detail in the evaluation of hazards and potential accidents for a safety analysis. This means that a complex HC-2 facility with a relatively long mission life will require a rigorous and detailed DSA, while the DSA for a simple HC-3 facility with a more limited mission life may be generally short and qualitative.

The magnitude of facility hazard is characterized by its hazard categorization. In accordance with 10 CFR 830, DOE nuclear facilities are categorized "consistent with" STD-1027, as one of the following:

- Hazard Category 1 – has the potential for significant offsite consequences
- Hazard Category 2 – has the potential for significant onsite consequences beyond localized consequences
- Hazard Category 3 – has the potential for only local significant consequences
- Below Category 3 – has the potential for only consequences less than those that provide a basis for categorization as a Hazard Category 1, 2, or 3 nuclear facility.

Hanford has no HC-1 facilities. The consequence potential for hazard categorization considers only nuclear or radiological hazards; however, the DSA addresses all facility hazards and the controls necessary to provide adequate protection of the public, workers, and the environment.

1.3.4 Hazard Analysis and Risk Binning

The hazard analysis process includes hazard identification, hazard evaluation, and hazard categorization. The resulting hazardous conditions are then binned by frequency and consequence (risk binning) as a means of ordering the hazardous conditions by severity and establishing a basis for selection of hazard controls and/or accidents to be analyzed. Standard industrial hazards that are adequately controlled by one or more safety management programs do not require further hazard evaluation consideration.

Chapter 2 of SARAH describes the hazard analysis process for Hanford facilities.

1.3.5 Accident Analysis

For HC-2 facilities, hazardous conditions generally result in the potential for significant onsite consequences. In this case, potential hazardous conditions are evaluated for selection as unique, representative, or bounding accidents in the development of formal accident analysis.

Chapter 3 of the Hanford SARAH contains the accident analysis process and parameters for Hanford facilities.

1.3.6 Control Selection

Based on the results of the hazard analysis and/or accident analysis, hazard controls are selected for each hazard, hazardous condition, or accident. Hazard controls for significant hazards may be established in the TSR document and safety significant SSC designated. Where a formal accident analysis results in consequences challenging the EG, safety class SSC may be required.

Chapter 4 of SARAH details the control selection process and criteria.

2.0 HAZARD ANALYSIS

2.1 OVERVIEW

The hazard analysis includes hazard identification, hazard evaluation, and hazard categorization. In developing potential hazard controls, the hazard analysis considers the hazardous material quantity, form, location, dispersability, and interaction with available energy sources (which themselves are potential hazards).

The hazard analysis:

- Includes reasonably bounding assumptions regarding initial facility conditions (e.g., presence of transient combustibles) without consideration of active or administrative controls (e.g., fire suppression, combustible control program). Passive safety design features may be considered in the evaluation of the hazard; however, no credit may be taken for a leakpath reduction in source term.
- Does not consider the effect of existing or planned active safety features or controls that act to mitigate the frequency or consequence of the hazardous conditions.
- Qualitatively assesses and documents the consequence and event frequency associated with hazardous conditions to the public, onsite or collocated worker, facility worker, and/or environment.

Once the frequency and consequence of the hazardous condition is evaluated for application of hazard controls and/or performance of a formal accident analysis, the effect of active and/or administrative controls should be considered. When the credited features are determined, the hazard analysis reflects the preventive or mitigative effect those features produce.

The hazards identification task results in a list of "hazardous conditions," which describes the potential interaction of hazardous material with energy sources associated with a particular activity, event, or condition. The hazard evaluation results in a qualitative assessment of the frequency associated with each hazardous condition; and the consequences to the receptors of interest, i.e., facility worker, collocated worker, and offsite public. The term "preliminary hazard analysis" (PHA) is used generically in this handbook to describe the process of systematically identifying and evaluating hazards.

Prioritizing hazards and hazardous conditions into risk bins facilitates the selection of candidate accidents for formal accident analysis (when necessary). Where accident analysis is necessary, accidents should be organized as bounding and/or representative accidents for various families of common accidents, plus other accidents that are more specific or "unique" to the facility or activity being analyzed.

Hazard analyses that directly support the facility safety analysis should be integrated with the development of the DSA, and treated as described by the following guidance provided for the fire hazards analysis (FHA) and criticality safety evaluation report (CSER).

2.1.1 Fire Hazards Analysis (FHA)

The FHA and DSA should be developed on the same schedule and use consistent analyses to identify and evaluate fire hazards. Specifically, the analysis of fire and fire-related hazards should use expertise from fire protection and safety analysis disciplines and be integrated within both documents. In general, a single set of unmitigated and mitigated analyses, using reasonably conservative assumptions (versus absolute bounding conditions) should be developed to support each fire scenario considered in the DSA, from which an assessment of fire loss can be made in the FHA. The DSA and FHA should consistently consider the effectiveness of preventive or mitigative controls identified and relied on to control the fire hazards. If a new or revised analysis is being developed for an existing DSA or FHA, the corresponding FHA or DSA should also be evaluated for revision to ensure integration of the two documents.

2.1.2 Criticality Safety Evaluation Report (CSER)

Criticality safety evaluations should be integrated with the safety basis. This is accomplished in a manner similar to that discussed for the FHA. Specific criticality control derivation occurs in the CSER, where the engineer preparing the CSER identifies major, significant engineered features relied upon to prevent a criticality. The engineering judgment of the criticality safety engineer and the safety analyst determines which engineered safety features are safety significant, described in the DSA, and included in the TSRs. Because criticality accidents do not generally lead to major releases of radioactive material, the analysis of criticality accidents as beyond-design-basis accidents is not necessary.

For minor changes, e.g., changes to a sample container size, or the number of containers permitted in a glovebox, the CSER may provide the analysis of the hazard in lieu of a new hazard analysis document. However, any new information must be integrated into the hazard analysis. Administrative controls implementing the CSER are developed as needed in the CSER and implemented in operating procedures and postings. They should normally *not* be listed in the DSA or TSRs as additional controls in addition to the Fluor Hanford Criticality Safety Program (which is identified as a TSR-level safety management program).

2.2 HAZARD IDENTIFICATION

This step of the process identifies hazards associated with internal, external, natural phenomena, and common cause events with the potential to adversely affect the public, workers, or the environment. Table 2-1 shows an example of a Hazard Identification Checklist and Energy Designator checklist. In addition to initially understood energy sources and hazardous material generation, hazard identification continues throughout the hazard evaluation process.

The hazards identification process consists of three discrete steps: facility walkdowns/data collection, boundary identification, and defining activities to be evaluated as shown in Figure 2-1.

A multi-disciplinary team of individuals, including safety analysts, facility personnel (operations and support groups), and subject matter experts such as criticality safety, health physics, fire protection, and industrial safety/hygiene, conduct the PHA. Collectively, the team completes the following preparatory activities:

- Data collection that encompasses review of existing documentation (e.g., existing TSRs, compliance and limiting condition of operation tracking, design basis documentation, occurrence reports, FHAs, health and safety plans, operational procedures, outstanding USQs, JCOs), and facility walkdowns, including interviews with building personnel and completion of hazardous materials and energy source checklists

- Defining facility boundaries and "nodes" to facilitate the analysis
- Defining current and projected activities to be evaluated

While identifying and evaluating the hazards, the hazard analysis team considers the complete spectrum of hazards and accidents, including standard industrial hazards, other facility worker hazards, and accidents that could initiate a release of radioactive or other hazardous materials or worsen the consequences of potential releases.

2.2.1 Screening of Standard Industrial Hazards

Hazard identification involves identifying all hazards, including those considered to be standard industrial hazards. If hazards are identified in separate documents, such as those developed under DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*, ensure they are integrated such that all hazards are identified and appropriately dispositioned.

As described by STD-3009, the DSA covers worker safety issues related to hazards in processes and associated activities. It is not the intention of the DSA to cover safety as it relates to the common industrial hazards that make up a large portion of basic regulatory compliance of 29 CFR 1910, *Occupational Safety and Health Standards* (OSHA), or to expend DSA resources on those hazards for which institutional safety management programs already define and regulate appropriate practices without the need for special analysis. These types of standard industrial hazards should be screened from further consideration in the hazard analysis. Industrial hazards that could affect radiological or large chemical inventories or cause facility wide effects are included in the facility safety basis, but are primarily controlled through application of TSR Administrative Controls.

As part of the hazard identification process, present the basis that was used in the hazards screening to remove standard industrial hazards or insignificant hazards from further consideration by citing the applicable safety management programs as identified in the DSA programmatic controls chapter and HNF-11724, *Fluor Hanford Safety Management Programs.* For these cases, the hazards analysis process interfaces with other programs such as specific topics of OSHA compliance or general industrial safety or fire protection.

Table 2-1. Hazard Identification Checklist and Energy Designators. (5 sheets)

LOTE Low Thermal Energy	AE Acoustic Energy	BIO Biological
☐ 1 Cryogenic Systems	☐ 1 Equipment/Platform Vibration	☐ 1 Animal/Insect Hazard
☐ 1.1 Freeze Seal Equipment	☐ 2 Equipment Rooms	☐ 1.1 Dead Animals
☐ 1.2 Liquid N_2 in Dewars	☐ 2.1 Motor Rooms	☐ 1.2 Animal Droppings
☐ 1.3 Liquid N_2 in Tanks	☐ 2.2 Pump Rooms	☐ 1.3 Animal Bites
☐ 1.4 Liquid N_2 Production	☐ 2.3 Fan Rooms	☐ 1.4 Insect Bites
☐ 1.5 Other Cryogenic Systems	☐ 2.4 Compressor Rooms	☐ 1.5 Insect Stings
☐ 2 Low Ambient Temperatures	☐ 2.5 Other Equipment Rooms	☐ 2 Plant Hazards
☐ 2.1 Loss of HVAC [system impacts]	☐ 3 Decontamination & Size Reduction Tools	☐ 2.1 Allergens
☐ 2.2 Loss of HVAC [worker impacts]	☐ 3.1 Cutting Devices	☐ 2.2 Toxins
☐ 2.3 Freezers/Chillers	☐ 3.2 Decontamination Devices	☐ 3 Disease Related Hazards
☐ 2.4 Other Low Temperatures	☐ 3.3 Abrading Devices	☐ 3.1 Bacteria
☐ 3 Other LOTE Hazards	☐ 3.4 Other AE Tools	☐ 3.2 Viruses
	☐ 4 Other AE Hazards	☐ 3.3 Sewage
		☐ 3.4 Blood/Body Fluids
		☐ 3.5 Medical Waste
		☐ 4 Other BIO Hazards

NPH Natural Phenomena	OTH Other	KE Kinetic Energy
☐ 1 Earthquakes	☐ 1 Inert/Low O_2 Atmosphere	☐ 1 Vehicle/Transport Devices in Motion
☐ 2 Natural Radiation	☐ 1.1 Dust [breathing]	☐ 1.1 Rail Cars/Trains
☐ 3 Lightning	☐ 1.2 N_2/He Atmosphere	☐ 1.2 Excavators/Backhoes
☐ 4 Solar/Heat Wave	☐ 1.3 Confined Spaces	☐ 1.3 Cranes/Crane Loads
☐ 5 Range Fire	☐ 1.3.1 Tanks	☐ 1.4 Trucks/Cars
☐ 6 Dust/Sand	☐ 1.3.2 Basins	☐ 1.5 Forklifts/Loaders
☐ 7 Fog	☐ 1.3.3 Manholes	☐ 1.6 Conveyors
☐ 8 Heavy Rain	☐ 1.3.4 Pits	☐ 1.7 Man-Powered Devices in Motion
☐ 8.1 Flooding [from rain]	☐ 1.4 Trench/Excavation Collapse	☐ 1.7.1 Hoists
☐ 8.2 Sediment Transport	☐ 1.5 Water in Confined Space	☐ 1.7.2 Carts/Dollies
☐ 9 Hail	☐ 1.6 Other Low O_2 Atmospheres	☐ 1.8 Other Device in Motion
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☐ 11 Freeze	☐ 2.1 Respirator Fogging	☐ 2.1 Crane Loads [loaded]
☐ 12 Heavy Snow	☐ 2.2 Dust [visibility]	☐ 2.2 Trucks [loaded]
☐ 13 High Winds	☐ 2.3 Glare	☐ 2.3 Forklifts [loaded]
☐ 14 Tornadoes	☐ 2.4 Other Impaired Visibility	☐ 2.4 Conveyors [loaded]
☐ 15 Volcanoes	☐ 3 External/Offsite Event	☐ 2.5 Loaded Man-Powered Transports in Motion
☐ 16 Volcanic Ash	☐ 3.1 Aircraft Crash	☐ 2.5.1 Hoists [loaded]
☐ 17 Other NPH	☐ 3.2 Offsite Transportation Accident	☐ 2.5.2 Pallet Jacks [loaded]
	☐ 3.3 Offsite Explosion	☐ 2.5.3 Carts/Dollies [loaded]
	☐ 3.4 Major Fire	☐ 2.6 Other Transport in Motion
	☐ 3.5 Reservoir Failure	☐ 3 Decontamination & Size Reduction Tools
	☐ 3.6 Other External Event	☐ 3.1 Impact Tools
	☐ 4 Unknown Material	☐ 3.2 Projectile Tools
	☐ 5 Unknown Configuration	☐ 3.3 Other KE Tools
	☐ 6 Other OTH Hazards	☐ 4 Relief Valve Blow-down
		☐ 5 Other KE Hazards

Table 2-1. Hazard Identification Checklist and Energy Designators. (5 sheets)

LOEE Loss of Electrical Energy	CM Chemical Materials	CE Chemical Energy
☐ 1 Loss of Powered Equipment	☐ 1 Toxins	☐ 1 Oxidizers
☐ 1.1 Motor Stoppage	☐ 1.1 Hepatotoxins [Carbon Tetrachloride]	☐ 1.1 Organic Peroxides
☐ 1.2 Pump Stoppage	☐ 1.2 Nephrotoxins [Chloroform]	☐ 1.2 Corrosives/Acids/Reagents/ Bleaches [in use]
☐ 1.3 Fan Stoppage in Areas with Differential Pressure	☐ 1.3 Neurotoxins [Mercury]	☐ 1.3 Residual Corrosives/Acids
☐ 1.3.1 Flow Reversal	☐ 1.4 Reproductive Toxins [Lead]	☐ 1.4 Battery Banks
☐ 1.3.2 Supply Fan Pressurization	☐ 1.5 Toxic Agents [Strychnine]	☐ 1.5 Other Oxidizers
☐ 1.3.3 Static Air Situation	☐ 1.6 Agents that Attack the Lungs [Asbestos]	☐ 2 Reactives
☐ 1.4 Fan Stoppage in Ventilated Areas	☐ 1.6.1 Ceiling Tiles/Insulation	☐ 2.1 Water Reactives [Sodium]
☐ 1.4.1 Accumulation of Hazardous Vapors	☐ 1.7 Agents that Attack the Skin [Acetone]	☐ 2.2 Shock Sensitive Chemicals [Nitrates]
☐ 1.4.2 Accumulation of Asphyxiants	☐ 1.8 Agents that Attack the Eyes [Organic Solvents]	☐ 2.3 Peroxides/ Superoxides/Ethers
☐ 1.4.3 Accumulation of Flammable Gases	☐ 1.9 Agents that Attack the Mucous Membranes [Ammonia]	☐ 2.4 Explosive Substances
☐ 1.5 Compressor Stoppage	☐ 1.10 Agents that Attack the Blood [Carbon Monoxide/ Cyanides]	☐ 2.4.1 Electric Squibs
☐ 1.5.1 Loss of Air [dry-pipe]	☐ 1.11 Carcinogens [Carbon Tetrachloride, PCBs]	☐ 2.4.2 Dynamites/Caps/ Primer Cord
☐ 1.5.2 Loss of Air [no inert]	☐ 1.12 Sensitizers [Beryllium/Epoxy Resins]	☐ 2.4.3 Dusts [explosive]
☐ 1.5.3 Reduced PPE Pressure	☐ 1.13 Irritants [Calcium Chloride]	☐ 2.5 Other Reactives
☐ 1.6 Loss of Heaters	☐ 1.14 Pesticides/Insecticides	☐ 3 Other Chemical Energy Hazards
☐ 1.6.1 System Freeze Impacts	☐ 1.15 Herbicides	☐ 3.1 Corrosion/Oxidation [rust]
☐ 1.6.2 Worker Freeze Impacts	☐ 1.16 Other Toxins	☐ 3.2 Bonding Agents
☐ 1.7 Loss of Coolers/Chillers	☐ 2 Asphyxiants	☐ 3.2.1 Sealants/Fixatives
☐ 1.7.1 System Overheat Impacts	☐ 3 Miscellaneous Chemicals/Groups	☐ 3.2.2 Epoxies/Adhesives
☐ 1.7.2 Worker Overheat Impacts	☐ 3.1 Hazardous Wastes [RCRA, TSCA]	☐ 3.3 Refrigerants/Coolants [Propylene Glycol]
☐ 1.8 Misdirected Flow due to Loss of Valves/Dampers	☐ 3.2 Creosote	☐ 3.4 Water Treatment Products
☐ 1.9 Loss Instrumentation	☐ 3.3 Other Miscellaneous Chemicals	☐ 3.5 Decontamination Chemicals
☐ 1.10 Other Equipment Loss	☐ 4 Other CM Hazards	☐ 3.6 Miscellaneous Laboratory Chemicals
☐ 2 Inadequate Light/Illumination		☐ 3.7 Soil/Air/Water Reactions [Buried Materials]
☐ 2.1 Operations Impacts		☐ 4 Incompatible Wastes
☐ 2.2 Worker Impacts		☐ 5 High Temperature Wastes
☐ 3 Loss of Batteries/Direct Current Systems		☐ 6 Other CE Hazards
☐ 4 Other LOEE Hazards		

Table 2-1. Hazard Identification Checklist and Energy Designators. (5 sheets)

ME Mechanical Energy	TP Thermal Potential Energy	EE Electrical Energy
☐ 1 Transverse [single direction] Motion Devices	☐ 1 Flammable Gases	☐ 1 High Voltage Equipment
☐ 1.1 Forklift Tines [puncture]	☐ 1.1 Natural Gas/Propane	☐ 1.1 Power Transmission Equipment
☐ 1.2 Piston Compressors [crush]	☐ 1.2 Welding/Cutting Gases	☐ 1.1.1 Wiring [high voltage]
☐ 1.3 Presses [crush]	☐ 1.3 Laboratory/Calibration Gases	☐ 1.1.2 Overhead Transmission Lines
☐ 1.4 Pinch Points [pinch]	☐ 1.3.1 Methane/Butane	☐ 1.1.3 Transformers [high voltage]
☐ 1.5 Sharp Edges/Objects [cut]	☐ 1.3.2 H_2 [lab]	☐ 1.1.4 Switchgear [high voltage]
☐ 1.6 Drills [puncture]	☐ 1.4 Process/Reaction Off-Gases	☐ 1.2 Capacitor Banks
☐ 1.7 Sanders/Brushes [wear]	☐ 1.4.1 H_2 [containers]	☐ 1.3 Lightning Grids
☐ 1.8 Shears/Pipe Cutters [shear]	☐ 1.4.2 H_2 [process]	☐ 1.4 Other High Voltage Hazards
☐ 1.9 Grinders [crush/pinch/shear]	☐ 1.4.3 Sewer Gas	________
☐ 1.10 Other Transverse Motion	☐ 1.4.4 Carbon Monoxide	☐ 2 Low Voltage Equipment
________	☐ 1.5 Other Flammable Gases	☐ 2.1 480/240/120 Volt Equipment
☐ 2 Reciprocating [back and forth] Motion Devices	________	☐ 2.1.1 Wiring [low voltage]
☐ 2.1 Vibration [wear]	☐ 2 Flammable/Combustible Liquids	☐ 2.1.2 Cable Runs
☐ 2.2 Saws [cut]	☐ 2.1 HEPA Test Aerosol Fluid	☐ 2.1.3 Overhead Wiring
☐ 2.3 Other Reciprocating Motion	☐ 2.2 Petroleum Based Products	☐ 2.1.4 Underground Wiring
________	☐ 2.2.1 Gasoline	☐ 2.1.5 Transformers [low voltage]
☐ 3 Circular Motion Devices	☐ 2.2.2 Diesel Fuel	☐ 2.1.6 Switchgear [low voltage]
☐ 3.1 Belts/Hoist Cables [pull/wrap]	☐ 2.2.3 Oils [lube, coolant]	☐ 2.1.7 Service Outlets
☐ 3.2 Bearings/Shafts [wrap]	☐ 2.2.4 Grease	☐ 2.1.8 Other Electrical Equipment
☐ 3.3 Gears/Couplings [pull]	☐ 2.3 Vehicle/Equipment Fuel Tanks	________
☐ 3.4 Diesel Generators/ Turbines [wrap]	☐ 2.3.1 Gasoline [tank]	☐ 2.2 Temporary Power Equipment
☐ 3.5 Pumps [wrap]	☐ 2.3.2 Diesel Fuel [tank]	☐ 2.2.1 Diesel Units
☐ 3.6 Fans [wrap]	☐ 2.4 Paint/Cleaning/ Decontamination Solvents	☐ 2.2.2 Battery Banks
☐ 3.7 Rotary Compressors [wrap]	☐ 2.5 Paints/Epoxies/Resins	☐ 2.2.3 12-32 V DC Systems
☐ 3.8 Centrifuges [wrap]	☐ 2.6 Other Flammable Liquids	☐ 2.2.4 Other Temporary Electrical
☐ 3.9 Drills/Rotary Sanders [wrap]	________	________
☐ 3.10 Grinders [wrap]	☐ 3 Combustible Solids	☐ 2.3 Electrical Equipment [low voltage]
☐ 3.11 Other Circular Motion	☐ 3.1 Paper/Wood Products	☐ 2.3.1 Motors
________	☐ 3.2 Cloth/Rags	☐ 2.3.2 Pumps
☐ 4 Other ME Hazards	☐ 3.3 Rubber	☐ 2.3.3 Fans
________	☐ 3.4 Plastic Materials	☐ 2.3.4 Compressors
	☐ 3.4.1 Size Reduction Tents/ Permacons	☐ 2.3.5 Heaters
	☐ 3.4.2 Benelex/Lexan/HDPE	☐ 2.3.6 Valves/Dampers
	☐ 3.4.3 Rigid Liners/Poly-Liners/ Bagging Materials	☐ 2.3.7 Power Tools
	☐ 3.5 Other Combustible Solids	☐ 2.3.8 Instrumentation
	________	☐ 2.3.9 Other Electrical Use Equipment
		________
		☐ 2.4 Grounding Grids
		☐ 2.5 Static Charge
		☐ 2.6 Other Low Voltage Hazards
		________

Table 2-1. Hazard Identification Checklist and Energy Designators. (5 sheets)

RE Radiant Energy

- ☐ 1 Direct Radiation Sources
- ☐ 1.1 Calibration Sources
- ☐ 1.2 Other Radioactive Material
- ☐ 1.2.1 Fissile Material Storage/ Holdup
- ☐ 1.2.2 Actinide Solutions
- ☐ 1.2.3 Waste Containers
- ☐ 1.2.4 Contamination
- ☐ 1.3 Other Direct Radiation Hazards
- ______
- ☐ 2 Ionizing Radiation Devices
- ☐ 2.1 Radiography Equipment
- ☐ 2.2 X-Ray Machines
- ☐ 2.3 Electron Beams
- ☐ 2.4 Ultra-Intense Lasers
- ☐ 2.5 Accelerators
- ☐ 2.6 Other Ionizing Hazards
- ______
- ☐ 3 Non-Ionizing Radiation Sources
- ☐ 3.1 Electromagnetic Sources
- ☐ 3.1.1 Electromagnetic Communication Waves
- ☐ 3.1.2 Radio-Frequency Generators
- ☐ 3.1.3 Microwave Frequencies
- ☐ 3.1.4 Electromagnetic Fields
- ☐ 3.1.5 Electric Furnaces
- ☐ 3.1.6 Computers
- ☐ 3.2 Welding/Cutting Devices
- ☐ 3.2.1 Plasma Arc Magnetic Field
- ☐ 3.2.2 Plasma Arc Infrared/Ultraviolet Light
- ☐ 3.2.3 Welding
- ☐ 3.3 Low Power Lasers
- ☐ 3.4 Other Non-Ionizing Hazards
- ______
- ☐ 4 Potential RE Sources
- ☐ 4.1 Critical Masses
- ☐ 4.1.1 Solid Fissile Material
- ☐ 4.1.2 Liquid Fissile Material
- ☐ 4.1.3 Containerized Fissile Material
- ☐ 4.2 Irradiated Equipment
- ☐ 4.3 Other Potential RE Hazards
- ______
- ☐ 5 Other RE Hazards
- ______

RM Radioactive Material

- ☐ 1 Fissile Material [Metals/Oxides/Residues]
- ☐ 1.1 Bag
- ☐ 1.2 Glovebox [exposed]
- ☐ 1.3 Can
- ☐ 1.4 Welded Can
- ☐ 1.5 Drum
- ☐ 1.6 Overpack
- ☐ 1.7 Type B Shipping Container
- ☐ 1.8 Ducting [exposed]
- ☐ 1.9 Plenum [exposed]
- ☐ 1.10 Filter [exposed]
- ☐ 1.11 Cooler
- ☐ 1.12 Hood [exposed]
- ☐ 1.13 Other Solid Fissile Material
- ______
- ☐ 2 Actinide Solution
- ☐ 2.1 Bottle
- ☐ 2.2 Drum
- ☐ 2.3 Piping
- ☐ 2.4 Tank
- ☐ 2.5 Other Liquid Fissile Material
- ______
- ☐ 3 Waste [LLW, LLM, TRU, TRM]
- ☐ 3.1 Bag
- ☐ 3.2 Glovebox [exposed]
- ☐ 3.3 Drum
- ☐ 3.4 Metal Crate
- ☐ 3.5 Pipe Overpack Container
- ☐ 3.6 Overpack
- ☐ 3.7 Shipping Cask
- ☐ 3.8 Ducting [exposed]
- ☐ 3.9 Plenum [exposed]
- ☐ 3.10 Filter [exposed]
- ☐ 3.11 Hood [exposed]
- ☐ 3.12 Wooden Crate
- ☐ 3.13 Cargo Container
- ☐ 3.14 Other Waste Material
- ______
- ☐ 4 General Contamination
- ☐ 4.1 Contaminated Soils
- ☐ 4.2 Contaminated Water
- ☐ 4.3 Contaminated Oil/Antifreeze
- ☐ 4.4 Other Contamination
- ______
- ☐ 5 Burial Grounds
- ☐ 6 Other RM Hazards
- ______

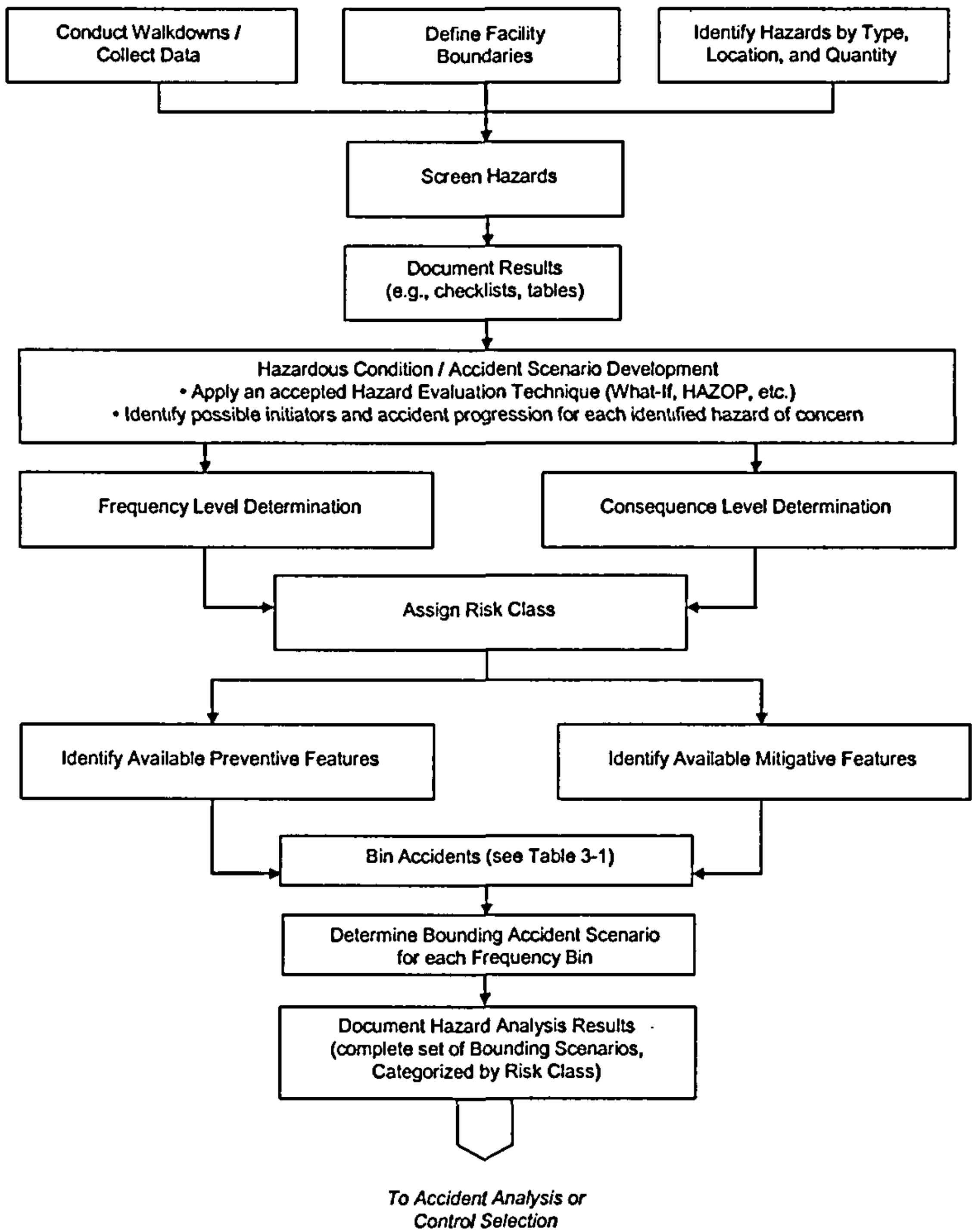
TE Thermal Energy

- ☐ 1 Chemical Reactions
- ☐ 2 Pyrophoric Material
- ☐ 2.1 Plutonium/Uranium Metal
- ☐ 2.2 Pyrophoric Chemicals
- ☐ 2.3 Other Pyrophoric Material
- ______
- ☐ 3 Spontaneous Combustion Material
- ☐ 3.1 Petroleum Based Products
- ☐ 3.2 Reactive Chemicals
- ☐ 3.3 Nitric Acids/Organics
- ☐ 3.4 Paint/Cleaning/ Decontamination Solvents
- ☐ 4 Open Flame Sources
- ☐ 4.1 Cutting Torches
- ☐ 4.2 Welding Torches
- ☐ 4.3 Laboratory Burners
- ☐ 4.4 Other Open Flames
- ______
- ☐ 5 Heating Devices/Systems
- ☐ 5.1 Furnaces
- ☐ 5.2 Boilers
- ☐ 5.3 Heaters
- ☐ 5.4 Hot Plates
- ☐ 5.5 RTGs
- ☐ 5.6 Other Heating Equipment
- ______
- ☐ 6 Radioactive Decay
- ☐ 7 High Temperature Items
- ☐ 7.1 Lasers
- ☐ 7.2 Incinerators/Fire Boxes
- ☐ 7.3 Engine Exhaust Surfaces
- ☐ 7.4 Steam Lines
- ☐ 7.5 Electrical Equipment
- ☐ 7.5.1 Electrical Wiring
- ☐ 7.5.2 Portable Lamps/Lighting
- ☐ 7.6 Welding/Cutting/Grinding Surfaces
- ☐ 7.6.1 Plasma Arc Surfaces
- ☐ 7.6.2 Welding Surfaces
- ☐ 7.6.3 Grinder/Saw Surfaces
- ☐ 7.7 Friction Heated Surfaces
- ☐ 7.7.1 Belts [friction]
- ☐ 7.7.2 Bearings [friction]
- ☐ 7.7.3 Gears [friction]
- ☐ 7.7.4 Power Tools [friction]
- ☐ 7.7.5 Motors/Fans [friction]
- ☐ 7.8 Other High Temperature Items
- ______
- ☐ 8 High Ambient Temperature Areas
- ☐ 8.1 Loss of Ventilation
- ☐ 8.2 Areas Around Furnaces/Boilers
- ☐ 8.3 Multiple Layers PPE
- ☐ 9 Other TE Hazards
- ______

Table 2-1. Hazard Identification Checklist and Energy Designators. (5 sheets)

PE Potential Energy	PE Potential Energy (cont'd)	PE Potential Energy (cont'd)
☐ 1 Pressure-Related PE Hazards	☐ 2 Gravity-Related PE Hazards	☐ 3 Momentum-Related PE Hazards
☐ 1.1 Compressed Gases	☐ 2.1 Elevated Equipment/Structures	☐ 3.1 Moving Vehicle/Transport Devices
☐ 1.1.1 Breathing Air/Compressed Air/O_2	☐ 2.1.1 Cranes/Hoists	☐ 3.1.1 Rail Cars/Trains [in motion]
☐ 1.1.2 He/Argon/Specialty Gases	☐ 2.1.2 Ducting/Lights/Piping	☐ 3.1.2 Cranes [in motion]
☐ 1.1.3 Refrigerants/CO_2 Bottles	☐ 2.1.3 Rollup Doors	☐ 3.1.3 Trucks [in motion]
☐ 1.1.4 Other Bottled Gases	☐ 2.1.4 Elevators	☐ 3.1.4 Forklifts/Loaders [in motion]
☐ 1.1.5 Gas/Air Receivers/ Compressors	☐ 2.1.5 Roofs/Plenums	☐ 3.1.5 Other Moving Materials
☐ 1.1.6 Other Compressed Gas	☐ 2.1.6 Upper Floor Components	
	☐ 2.1.7 Tanks/Solutions in Elevated Equipment	☐ 3.2 Rotating Equipment
☐ 1.2 High Pressure Gas Systems	☐ 2.1.8 Steam/Natural Gas Lines	☐ 3.2.1 Bearings/Rollers/Shafts
☐ 1.2.1 Pressure Vessels	☐ 2.1.9 Power Lines/ Transformers	☐ 3.2.2 Gears/Couplings/Pivot Joints
☐ 1.2.2 Instrument/Plant Air	☐ 2.1.10 Other Elevated Equipment	☐ 3.2.3 Diesel Generators/Turbines
☐ 1.2.3 Chemical Reaction Vessels/ Autoclaves		☐ 3.2.4 Pumps
☐ 1.2.4 Furnaces/Boilers	☐ 2.2 Elevated Hazardous Materials	☐ 3.2.5 Fans/Air Movers
☐ 1.2.5 Steam Header/Lines	☐ 2.2.1 Crane Loads	☐ 3.2.6 Rotary Compressors
☐ 1.2.6 Pneumatic Lines	☐ 2.2.2 Truck Loads	☐ 3.2.7 Centrifuges
☐ 1.2.7 Impact Tools	☐ 2.2.3 Forklift/Other Lifts Loads	☐ 3.2.8 Other Rotating Equipment
☐ 1.2.8 Sand/CO_2 Blasting Equipment	☐ 2.2.4 Conveyor Loads	
☐ 1.2.9 Other Pressurized Gas	☐ 2.2.5 Hoist Loads	☐ 3.3 Other Momentum PE Hazards
	☐ 2.2.6 Cart Loads	
☐ 1.3 High Pressure Liquid Systems	☐ 2.2.7 Hand Carried Loads	☐ 4 Other PE Hazards
☐ 1.3.1 Water Heaters	☐ 2.2.8 Stacked Hazardous Materials	
☐ 1.3.2 Excavators/Backhoes [hydraulics]	☐ 2.2.9 Other Elevated Materials	
☐ 1.3.3 Cranes [hydraulics]		
☐ 1.3.4 Trucks/Cars [hydraulics]	☐ 2.3 Pits/Trenches/ Excavations	
☐ 1.3.5 Forklifts [hydraulics]	☐ 2.4 Elevated Work Surfaces	
☐ 1.3.6 Conveyors [hydraulics]	☐ 2.4.1 Roofs/Elevated Doors/Loading Docks	
☐ 1.3.7 Hydrolazing Equipment	☐ 2.4.2 Stairs/Elevators	
☐ 1.3.8 Tool Hydraulic Lines	☐ 2.4.3 Ladders/Fixed Ladders	
☐ 1.3.9 Solution Transfer Systems	☐ 2.4.4 Cherry-Pickers/Hysters	
☐ 1.3.10 Other Pressurized Liquids	☐ 2.4.5 Scaffolding/Scissor Jack Scaffolds	
	☐ 2.4.6 Other Elevated Surfaces	
☐ 1.4 Pressurized Systems/ Components		
☐ 1.4.1 Coiled Springs	☐ 2.5 Other Gravity PE Hazards	
☐ 1.4.2 Stressed Members		
☐ 1.4.3 Torqued Bolts		
☐ 1.4.4 Gaskets/Seals/O'Rings		
☐ 1.4.5 Fire Suppression Systems		
☐ 1.4.6 Other Pressurized Systems		
☐ 1.5 Vacuum Systems		
☐ 1.6 Other Pressure PE Hazards		

Figure 2-1. Preliminary Hazard Analysis Methodology Simplified Flow Diagram



2.2.2 Hazards Analysis for Chemicals

Chemical hazards that may be considered standard industrial hazards do not warrant further analysis beyond the verification that a safety management program adequately controls the hazard, as described in section 2.2.1 above. Risks posed by these chemical hazards are more appropriately controlled through a chemical management program than with a uniquely developed TSR. DOE-HDBK-1139, *Chemical Management*, provides useful guidance on chemical management in general and hazards analysis specifically.

To determine when a chemical hazard warrants further analysis, use the following approach:

- During hazard identification, develop a comprehensive listing of chemicals present and their quantities.
- Where chemical inventory exceeds the Threshold Quantities (TQs) in 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals," or 40 CFR 68, "Risk Management Plans" (or 40 CFR 355, *Emergency Planning and Notification*, if not listed in 29 CFR 1910.119), perform a quantitative or qualitative analysis to evaluate potential chemical exposures. Implement the elements of Process Safety Management as applicable. SSC designation or Specific Administrative Controls (SAC) based on worker safety for chemical hazards are limited to those whose failure is estimated to result in prompt worker fatality, serious injuries to workers, or significant chemical exposures.
- Where chemical inventory exceeds the Reportable Quantities (RQs) in 40 CFR 302, *Designation, Reportable Quantities, and Notification*, evaluate the adequacy of the chemical management program and other safety management programs to control the hazard. Additional hazard analysis is warranted if these controls are potentially inadequate. SSC designation or Specific Administrative Controls based on worker safety for chemical hazards are limited to those whose failure is estimated to result in prompt worker fatality, serious injuries to workers, or significant chemical exposures.
- Where chemical inventory does not exceed the RQs of 40 CFR 302, further hazard analysis is not necessary. Confirm the adequacy of hazard controls provided by safety management programs or other implemented controls.

2.2.3 Facility Worker Hazards

The following guidance for evaluating hazards to facility workers is provided by 05-SED-0007:

> "During the performance of hazards analysis, the hazards analysis team should consider the impacts of evaluated hazards on the Facility Worker (FW). For each hazardous condition evaluated for the public and collocated worker (CW) in the hazards analysis, a qualitative evaluation of unmitigated consequence to the FW and identification of candidate preventive and mitigative controls should be included. The provided information is for the determination of FW safety-significant SSCs or Specific Administrative Control (i.e., meets the STD-3009 'significant' criteria of prompt death, serious injury, or significant radiological or chemical exposure criteria).

"Examples of conditions where a significant consequence to the FW should be considered for controls include:

- Energetic releases of high concentrations of radiological or toxic chemical materials where the FW would normally be immediately present and therefore unable to take self-protective actions.
- Deflagrations or explosions within process equipment or confinement / containment structures or vessels where grievous injury or death to a FW may result from the fragmentation of the process equipment failing or the confinement (or containment) with the FW close by.
- Chemical or thermal burns to a FW that could reasonably cover a significant portion of the FW body where self-protective actions are not reasonably available due to the speed of the event or where there may be no reasonable warning to the FW of the hazardous condition.
- Exposures to radiological or toxic materials of sufficient magnitude that death or ongoing large-scale medical intervention may reasonably be expected to result.
- Leaks from process systems where asphyxiation of a FW normally present may result.

"These and other unique conditions that may be 'significant' for a specific process should be discussed by the hazard analysis team prior to initiating the hazards analysis process so that all members of the team may participate in the assessment of FW hazards. Lesser FW hazards may be evaluated and any results identified in the comments section for the hazardous condition. These lesser FW hazards are considered to be 'standard industrial hazards' and are normally controlled through application of existing safety management programs."

2.3 HAZARD EVALUATION

The term "preliminary hazard analysis" (PHA) is used in a generic sense to indicate the hazard identification and evaluation process, as hazard identification is frequently completed with the hazard evaluation. Consideration is given to the potential for accidents associated with facility activities, external events, or natural phenomena.

Hazards evaluation is the primary focal point of the facility PHA and the starting point for the accident analysis and control set selection (see Figure 2-1). Through the PHA process, the hazards and a comprehensive set of postulated unique, representative, and bounding accidents associated with the facility activities are systematically and qualitatively or semi-quantitatively evaluated, using one or more of the hazard evaluation techniques described in Section 2.3.1.

The evaluation should begin with a comprehensive study of the identified hazards by facility personnel and the PHA Team with the objective of identifying hazardous conditions and potential accidents:

- Identify and evaluate hazards associated with authorized activities, external events, or natural phenomena to develop a comprehensive list of postulated accident scenarios. Review hazardous materials and energy sources to determine possible interactions that could lead to accident conditions.

- Identify and evaluate factors such as hardware, process materials, and mission activities that could affect the initiation and progression of the accident conditions.
- Review applicable safety documentation, process history, occurrence reports, and other information sources to identify hazardous conditions or potential accidents associated with the facility.

Following this study, the hazards evaluation process is completed with the documentation of hazardous conditions and potential accidents identified, followed by the estimation of the associated frequencies and consequences based on potential interactions between hazardous materials and energy sources. These results are Risk Ranked by frequency and consequence in accordance with Section 2.3.2. Table 2-2 provides a suggested correlation of the hazardous energy sources to typical accident types or categories.

Table 2-2. Correlation of Hazardous Energy and Material Sources to Accident Types/Categories

Accident Category*	Hazard Energy and Material Source Groups
E-1: Fire	Electrical Thermal Friction Pyrophoric Material Spontaneous Combustion Open Flame Flammables Combustibles Chemical Reaction
E-2: Explosion	Potential (Pressure) Explosive Materials Chemical Reactions
E-3: Loss of Containment or Confinement	Radiological Material Hazardous Material
E-4: Direct Radiological Exposure	Ionizing Radiation Sources
E-5: Nuclear Criticality	Fissile Material
E-6: External Hazards	Non-Facility Events (e.g., aircraft crashes) Vehicles in Motion Cranes
E-7: Natural Phenomena	Natural Phenomena- Seismic Event, Wind, Flood, etc.

*The E-number assigned to the accident categories is for ease of data management.

Based on the information developed by the PHA Team, further evaluation of specific hazards may be necessary. In addition to hazards screened as standard industrial hazards, no further evaluation is generally performed on those hazards that have limited impact on postulated accident initiation frequency, accident mitigation, and accident consequences.

During the hazard evaluation, the PHA Team identifies a comprehensive set of passive barriers, available operational controls, and other physical and administrative features that can prevent the hazardous condition or accident from occurring, or mitigate the consequences of an uncontrolled release of hazardous material. The hazards evaluation results, in combination with the Risk Ranking, are used to determine whether any engineered features should be designated as safety SSCs or hazard controls should be captured in the TSRs.

When shown to be necessary by the Consequence Level determination of Section 2.3.2, the last step of the hazards evaluation is accident selection in preparation of formal accident analysis. The selection of accidents for accident analysis is addressed in Chapter 3.0.

2.3.1 Hazard Evaluation Techniques

Hazard evaluation techniques identify hazardous conditions and potential accidents and qualitatively assess their frequency of occurrence and severity of consequence. The frequency and consequence estimates are used to rank, or bin, the events in a risk matrix. Ranking the events in this manner facilitates identification of those hazardous conditions that are of greatest concern (i.e., highest risk) and provides a basis for selection of the accidents that require more detailed quantitative analyses.

Several hazard evaluation techniques have been shown to produce acceptable results. The technique used depends on the system being analyzed and the details available. *Guidelines for Hazard Evaluation Procedures* (by the American Institute of Chemical Engineers) gives a detailed description of the various techniques, which are summarized as follows:

1. What-if Analysis

   The what-if analysis is used to analyze external events, natural phenomena, and potential common-cause failures. The what-if analysis is a brainstorming approach in which a group of experienced people familiar with the subject process asks questions or voices concerns about possible undesired events. The what-if analysis is not as inherently structured as other techniques (e.g., HAZOP analysis). Instead, it requires the analyst to adapt the basic concept to the specific application.

   Because what-if analysis is so flexible, it can be performed at any stage of the process, using whatever process information and knowledge are available. For each area of the process, two or three people may be assigned to perform the analysis; however, a larger team may be preferred. It is better to use a large group for a complex process, dividing the process into smaller pieces, than to use a small group on the whole process.

2. Hazards and Operability (HAZOP) Analysis

   The HAZOP study was developed to identify and evaluate safety hazards in systems, equipment, and processes and to identify operability problems, which, although not necessarily hazardous, could compromise the productivity goals the plant was designed to achieve. Although used primarily to anticipate hazards and operability problems for technology with which organizations have little experience, the HAZOP study has been found to be very effective for use with existing operations. However, completion of a HAZOP study is time consuming and can be resource-intensive, depending on the complexity of the failure being investigated. Use of the HAZOP study requires a detailed source of information concerning the design and operation of a process.

3. Fault Tree Analysis (FTA)

   FTA is a graphic technique that allows an analyst to systematically examine combinations of failures that are required to achieve a particular event as defined as the "top event" (the event specified at the "top" of the fault tree). An FTA provides all the combinations of conditions required to achieve the top event. FTAs are effective for complex systems in which multiple failures can be significant.

   An FTA can be used to perform qualitative and quantitative evaluations. Once a fault tree is constructed, it can be quantified by providing failure rates for the basic events. The actual computation of probabilities can be quite complex for a large fault tree, and is usually done with software such as Computer Assisted Fault Tree Analysis (see *CAFTA [Computer Assisted Fault Tree Analysis] Users Manual)*.

4. Event Tree Analysis

   Event trees provide a systematic framework to identify and qualitatively or quantitatively evaluate accident sequences. Event trees are particularly useful for quantifying the frequencies of accidents where many events can affect the potential outcome of the accident. The usefulness of event trees is dependent on the analyst's ability to identify important events that define the course of the accident.

5. Failure Modes and Effects Analysis (FMEA) and Failure Modes and Effects Criticality Analysis (FMECA)

   FMEA and FMECA are techniques used to identify equipment failure or improper equipment operation. The analyst examines single failures of each hardware component of the system. The analysis does not include multiple failures and events. Other events such as FTA should be used for systems in which multiple failures are believed to be significant.

   The FMEA is documented in a tabular format. The actual format may be adjusted to match the needs of the user. Typical headings include the component description, the failure mode, the failure effect, failure detection, and failure mitigation features. The FMECA adds a mission or project criticality measure, which is a qualitative level of the impact of the failure in terms of dose, equipment down time, or other relevant parameter.

2.3.2 Risk Ranking

Risk ranking organizes the hazardous conditions and potential accidents identified by the hazard evaluation into frequency and consequence level bins and an associated Risk Class. Risk ranking provides a basis for evaluating the need for safety SSCs, TSR-level hazard controls, and determines the need for formal accident analysis.

Table 2-3 identifies Consequence Levels for the offsite public and collocated worker, including the Evaluation Guideline (EG) for the maximally exposed offsite individual. Table 2-4 identifies the Qualitative Risk Ranking Bins (Risk Class) by frequency and consequence level.

In general, formal accident analysis is required for HC-2 facilities unless the bounding consequences are Low. Consequences to the MOI or collocated worker that are Moderate or High indicate the potential need for safety SSCs and TSR controls. Significant chemical exposure can also indicate the need for accident analysis and possible designation of safety significant SSC and TSRs (non-radiological hazards, such as chemical exposure, does not result in the designation of safety class SSCs).

Table 2-3. Consequence Levels and Risk Evaluation Guidelines

Consequence Level	Offsite Public (MOI)	Collocated Worker
High	Considerable offsite impacts on people or the environs. >25 rem TEDE or >ERPG-2/TEEL-2	Considerable onsite impacts on people or the environs. >100 rem TEDE or > ERPG-3/TEEL-3
Moderate	Minor offsite impacts on people or the environs. ≥1 rem TEDE or >ERPG-1/TEEL-1	Considerable onsite impacts on people or the environs. ≥25 rem TEDE or >ERPG-2/TEEL-2
Low	Negligible offsite impact on people or the environs. <1 rem TEDE or <ERPG-1/TEEL-1	Minor onsite impacts on people or the environs. <25 rem TEDE or <ERPG-2/TEEL-2

Notes:

1. MOI location is the shortest distance to the Hanford Site boundary in the direction of release.
2. Collocated worker location not less than 100 m from the point of release or at facility boundary. For elevated releases, use the point of highest dose.
3. See Section 2.2.3 for guidance on evaluating facility worker hazards.

ERPG = emergency response planning guideline	TEDE = total effective dose equivalent
MOI = maximally exposed offsite individual	TEEL = temporary emergency exposure limit

Table 2-4. Qualitative Risk Ranking Bins

Consequence	Beyond Extremely Unlikely (Below 10^{-6}/yr)	Extremely Unlikely (10^{-6} – 10^{-4}/yr)	Unlikely (10^{-4} – 10^{-2}/yr)	Anticipated (Above 10^{-2}/yr)
High	III	II	I	I
Moderate	IV	III	II	I
Low	IV	IV	III	III

Note: External events determined to be "Beyond Extremely Unlikely" are not considered further for control set development. "Beyond Design Basis Accidents" for natural phenomena events are evaluated in accordance with STD-3009.

2.4 FACILITY HAZARD CATEGORIZATION

Facility hazard categorization methodology is given in STD-1027 and HNF-PRO-8366. Initial hazard categorization considers the total inventory of radioactive materials in the facility or that the facility safety basis proposes to be authorized for the facility. Final hazard categorization is based on the hazards analysis (or accident analysis where applicable) and can adjust the initial categorization results based on airborne release fraction, segmentation, and qualified container exclusion to arrive at the "material at risk" (*MAR*) in hazardous conditions or postulated accidents. See HNF-PRO-8366 for required hazard categorization documentation and submittal to RL.

2.4.1 Initial Hazard Categorization

Initial hazard categorization is based on the total inventory of radioactive material either present in the facility or being authorized for the facility, based on the following process:

1. Calculate the quantity of each radioactive isotope as a fraction of its associated HC-2 threshold value as presented in Table A.1 of STD-1027.
2. Sum the isotopic fractions.
3. If the sum of fractions equals or exceeds unity, the facility is categorized as HC-2 and the initial categorization process is completed.
4. If the sum of fractions is less than unity, calculate the quantity of each radioactive isotope as a fraction of the associated HC-3 threshold values presented in Table A.1 of STD-1027.
5. Sum the isotopic fractions.
6. If the sum of fractions equals or exceeds unity, the facility is categorized as HC-3 and the initial categorization process is completed.
7. If the sum is less than unity, the facility is categorized as less than HC-3.

Facilities initially categorized as HC-2 or 3 are subject to the requirements of 10 CFR 830, Subpart B. In general, HC-3 facilities do not require a formal accident analysis; final hazard categorization and hazard controls are derived from the hazards analysis. HC-2 facilities may require an accident analysis; final hazard categorization and hazard controls are derived from the hazard or accident analysis. For facilities that are less than HC-3, final hazard categorization is not necessary and the safety basis requirements of 10 CFR 830, Subpart B do not apply.

2.4.2 Final Hazard Categorization

Final hazard categorization applies to facilities initially categorized as HC-2 or HC-3. Final categorization is based on the results of the hazard or accident analysis and may be changed from initial hazard categorization by particular considerations detailed in STD-1027. These are as follows:

- Airborne release fraction adjustment (HC-2 facilities only). The threshold values of Table A.1 are based on airborne release fractions specified by the Standard. If a lower airborne release fraction is technically justified, the hazard category threshold value(s) can be adjusted upward by the ratio of the release fraction specified in the Standard to that justified for the analysis.

Note: In rare cases, a higher release fraction is applicable, and the corresponding threshold value is then adjusted downward.

- Sealed source and Type B container exclusion. Sealed radioactive sources that meet applicable sealed source standards, and material contained in qualified U.S. Department of Transportation, Type B shipping containers may be excluded from material inventory for the purpose of hazard categorization (unless not justifiable by the accident analysis).
- Segmentation. Facilities are "segmented" when postulated accidents occurring in one portion of the facility do not affect radioactive inventory in a different portion of the facility. Facility segments are generally separated by substantial passive barriers or other physical means that can justify such segmentation.

  Typically, a facility is associated with its highest segment categorization (i.e., if a facility has a HC-2 segment, it is typically considered as a HC-2 facility), but the development of safety analysis and management of hazards in a particular segment should be consistent with its specific final categorization. This may be relevant for distributed facilities (e.g., tank farms) or facilities undergoing decommissioning activities, where hazardous material and energy sources are reduced to the point where controls may be relaxed.

An additional consideration applies to the reduction of categorization from HC-3 to below HC-3 as provided by the DOE Office of Nuclear and Facility Safety Policy (NFSP). In their Nuclear Safety Technical Position (NSTP) 2002-2, *Methodology for Final Hazard Categorization for Nuclear Facilities from Category 3 to Radiological,* the NFSP cites the U.S. Environmental Protection Agency (EPA) Technical Background Document (locally published in WHC-SD-GN-HC-20002, *Category 3 Threshold Quantities for Hazard Categorization of Nonreactor Facilities*) which provides the basis for the HC-3 threshold values published in STD-1027. The HC-3 threshold quantities are based on the most limiting dose pathway of inhalation, direct radiation, food ingestion, and water ingestion. Of these, inhalation and food ingestion depend on an airborne release fraction for dose to the receptor. For these pathways, NSTP 2002-2 permits the following adjustment:

> "The HC-3 threshold values for radionuclides for which the food pathway or the inhalation pathway are limiting may be revised if, based on the physical and chemical form and available dispersive energy sources for the facility and its hazardous materials, the credible release fractions (airborne release fractions) can be shown to be significantly different than the values used in the EPA Technical Background Document [see WHC-SD-GN-HC-20002 for comparison]. All potential accident scenarios must be considered under unmitigated conditions. All the pathways must be considered and the most limiting pathway must be used. All data and assumptions used to modify the STD-1027 Table A.1 HC-3 values must be supported in the hazard analysis."

Previous memos from NFSP and other DOE offices relative to justifying hazard categorization as below HC-3 (e.g., "10-rem at 30-m" criterion) were written before the publication of 10 CFR 830, Subpart B, and have no standing under the regulation.

Facilities that have an approved final hazard categorization of below HC-3 are excluded from the requirements of 10 CFR 830, Subpart B, apart from maintaining the hazard categorization documentation in accordance with HNF-PRO-8366.

2.4.3 Hazard Categorization of Environmental Remediation Activities and Inactive Waste Sites (IWS)

Environmental remediation activities can involve large inventories of radioactive materials that are not readily dispersed (e.g., large volumes of contaminated soil or residual contamination within deactivated process equipment). Typically, these activities also involve relatively minor energy sources. Given these circumstances, the hazard analysis for an environmental remediation activity may conclude that there is no possibility of significant consequences to the workers or the public from the activity.

In some cases, such as surveillance and maintenance of IWS, the hazard analysis may conclude that there is no identifiable mechanism for releasing the radioactive material. The very small risk of accidental release posed by IWS allows these sites to be categorized as below HC-3 provided the IWS criteria are maintained in accordance with Attachment 1 of 03-ABD-0025.

See HNF-PRO-8366 for IWS criteria and details.

2.5 HAZARD ANALYSIS RESULTS

The hazard analysis is generally captured in a formal report that documents the analysis and provides a tabular summary of the results (see STD-3009, Table 3-1 for an example). For each hazard, hazardous condition, or potential accident identified and evaluated, the hazard analysis results identify possible initiators; physical and administrative features that can serve to prevent or reduce likelihood or mitigate consequences to the worker, public, and environment; and the frequency, consequence, and risk class bins to which the hazard, hazardous condition, or potential accident is assigned.

Chapter 3 provides the process for formal accident analysis. Accident analysis is required when hazards, hazardous conditions, or potential accidents present the potential for High or Moderate consequences to the maximally exposed offsite individual (MOI) or co-located worker (CW). If accident analysis is not required, Chapter 4 provides the process to determine the hazard controls that are documented in the facility DSA and TSRs.

3.0 ACCIDENT ANALYSIS AND STANDARDIZED PARAMETERS

3.1 INTRODUCTION

Accident analysis entails the formal quantification of a limited subset of accidents, termed "design basis accidents" (DBAs) by STD-3009. The identification of DBAs results from the hazard evaluation ranking of the complete spectrum of facility accidents. These accidents represent a complete set of bounding conditions. In general, formal accident analysis is performed for HC-2 facilities. A simplified process for performing an accident analysis is shown in Figure 3-1. The basic components of accident analysis are accident selection, accident scenario development, source term analysis, and consequence analysis. The actual process is highly iterative within itself and with control selection to ensure accident scenarios are adequately developed and bounding, the suite of controls are comprehensive and tailored to reflect accident conditions, and all identified facility hazards are understood and controlled.

This chapter defines standardized methods and assumptions for performing accident analysis of Hanford facilities. The chapter discusses selection of potential accidents and accident types from which to develop DBAs, provides source term analysis (material at risk, damage ratio, airborne release fraction, respirable fraction), atmospheric dispersion coefficients, radiological consequence assessment, and standardized assumptions and generic scenario descriptions.

3.2 ACCIDENT SELECTION

The accident selection activity identifies the process and criteria used to select the bounding, representative, and unique DBAs to be included in accident analysis. Its purpose is to analyze the minimum number of accidents from which to identify safety SSC and develop a comprehensive suite of hazard controls. Representative accidents bound a number of similar accidents of lesser consequence (e.g., the worst fire for a number of similar fires). Unique accidents are those that are not representative of other accidents or similar hazardous conditions but severe enough to warrant individual examination (e.g., a single fire whose consequences challenge the EG).

At least one bounding accident from each of the major types determined from the hazard analysis (e.g., fire, explosion, spill, etc.) should be selected except where the bounding Consequence Level is "Low" (see Table 2-3). Accidents are identified and listed by accident category (operational, external, natural phenomena), type (e.g., fire, explosion, spill, etc.), and size (e.g., small, medium, or large fires). Other means of grouping accidents are used as well, especially for complex facilities that may require a broad suite of hazard controls. Table 3-1 presents a list of general candidate accidents grouped by type and size. It also provides a description of the characteristics of these accident types. This list is not a complete spectrum of accidents as it doesn't necessarily reflect all facility-specific hazards or process history.

Table 3-1. General Candidate Scenarios. (9 sheets)

Scenario	Issues	Description	Remarks
Large fires (pool)	• Fast/high-heat burning combustibles that can lead to metal drum lid failures and expulsion of some or all of the drum contents. • Non-waste combustible liquid inventories.	Fire involving combustible liquids (confined material fire release + unconfined material fire release)	• Size of fire dependent on largest inventory of non-waste combustible liquids. • Examples of combustible liquid sources include vehicle fuel tanks, fuel tankers, hydraulic sources, solvent containers, sump collection tanks that potentially collect fuels, and oil storage/accumulation. • Pool footprint and container storage arrangement defines number of containers impacted. • Pool fires can cause drum lid loss and expulsion of some or all of the container contents leading to unconfined combustible material releases; not all containers are necessarily ruptured leading to confined material releases for some containers. • Fire mitigation may lead to the spread of the fire into a larger pool due to the potential addition of water. • Can lead to requirements for liquid confinements (dikes, berms, etc.), restrictions on fuel inventories, prohibiting fossil-fueled vehicles, and fire protection systems.
Large fires (high-heat propagating)	• Containers of high heat release combustibles that can lead to propagation of the fire from one metal container to the next. • Waste combustible liquid/metal inventories.	Fire involving combustible liquids/metals (volatile liquid fire release)	• Size of fire dependent on largest inventory of waste combustible liquids/metals. • Examples of combustible liquid/metal sources include flammable liquid storage and alkali metal storage. • Facility inventory and container storage arrangement defines number of containers impacted. • Generally, the entire contents of volatile liquid content containers involved in fire; may involve other containers in a facility as confined material releases if fire is large enough to extend beyond containers with combustible liquids and metals. • Fire mitigation may lead to a larger fire due to the potential addition of water to alkali metals. • Can lead to inventory limits, segregation of these types of containers from other containers, and fire protection systems requirements.
Large fires (lower-heat propagating)	• Combustible containers that can lead to propagation of the fire from one container to the next. • Combustible container inventories.	Fire involving combustible containers (confined material fire release)	• Size of fire dependent on maximum inventory of combustible containers in a facility or area. • Examples of combustible containers include wooden crates and plastic overpacks. • Facility inventory and container storage arrangement defines number of containers impacted for combustible containers inside facility; inventory of combustible containers defines number of containers impacted if outside or segregated. • Generally, fires of this type do not involve metal container lid loss and are modeled as confined material releases. • Can lead to inventory limits, segregation of these types of containers from other containers, and fire protection systems requirements.

Table 3-1. General Candidate Scenarios. (9 sheets)

Scenario	Issues	Description	Remarks
Large fires (normal combustibles)	• Normal combustible materials that can lead to fires impacting containers in a facility. • Facility combustible loading.	Fire involving normal combustibles (confined material fire release)	• Size of fire defined by the Fire Hazards Analysis Maximum Possible Fire Loss based on facility combustible loading. • Examples of normal combustibles include wooden pallets, packaging materials, construction materials, and office equipment. • Facility inventory and container storage arrangement may define number of containers impacted. • Generally, fires of this type do not involve metal container lid loss and are modeled as confined material releases. • Can lead to combustible material control program and fire protection system requirements.
Small fires (normal combustibles)	• Fuel packages that can lead to fires that are not large enough to actuate fire suppression systems but can impact containers in a facility. • Unmitigatible fire.	Fire involving normal combustibles (confined material fire release)	• Size of fire defined by maximum fuel package that will not activate the wet-pipe sprinkler systems in a facility. • Relevant issues include height of facility ceilings, set-point of sprinklers, and fuel package. • Combustible load associated with that fire and container storage arrangement defines number of containers impacted. • Generally, fires of this type do not involve metal container lid loss and are modeled as confined material releases. • Can lead to combustible material control program.
Small fires (pyrophorics)	• Pyrophoric radioactive material fire. • In container or glovebox.	Fire involving pyrophoric radioactive materials (metal/chip fire release)	• Size of fire defined by amount of pyrophoric material in container or glovebox. • Examples of pyrophoric radioactive materials include plutonium/uranium metals, chips, and fines. • Generally, only single container or glovebox impacted unless fire propagates to medium fire due to other combustibles. • Fires of this type are modeled as metal or chip fire releases. • Can lead to limitations or restrictions on pyrophoric materials and glovebox inerting.

Table 3-1. General Candidate Scenarios. (9 sheets)

Scenario	Issues	Description	Remarks
Medium fires (facility)	• Standard combustible material package that can lead to fires impacting containers in a facility. • Combustible fuel package.	Fire with maximum expected fuel package (confined material fire release + unconfined material fire release)	• Size of fire defined by largest expected combustible fuel package based on facility operations. • Examples of fuel packages include a specific number of wooden pallets, drum liners, and transuranic package transporter slip sheets. • Combustible load associated with that fire and container storage arrangement defines number of containers impacted. • Fires of this size could involve normal combustibles or fast burning combustibles like plastics and can cause drum lid loss and expulsion of container contents leading to unconfined combustible material releases; not all containers are necessarily ruptured or fuel package may only involve normal combustibles leading to confined material releases. • Fire propagation in waste container stacks using wooden pallets should be considered. • Can lead to combustible material controls on fuel package size and separation from containers and on fire protection system requirements.
Medium fires (glovebox)	• Combustible materials that can be located in a glovebox line that can lead to fires impacting the glovebox line. • Glovebox combustible loading.	Fire involving glovebox line combustibles (unconfined material fire release + volatile liquid fire release)	• Size of fire defined by largest expected combustible fuel loading in a glovebox line based on facility operations. • Glovebox line inventory may define impact. • Generally, fires of this type do not burn the materials inside of the container and are modeled as unconfined combustible material releases and volatile liquid releases. • Can lead to combustible material controls on glovebox and fire protection system requirements.
Vehicle fires (pool)	• Vehicle fuel tank fires that can lead to metal drum lid failures and expulsion of drum contents. • Vehicle fuel tank inventories.	Fire involving combustible liquids (confined material fire release + unconfined material fire release)	• Size of fire dependent on largest inventory of combustible liquids associated with vehicle fuel tanks. • Pool footprint, vehicle inventory and container storage arrangement defines number of containers impacted. • Pool fires can cause drum lid loss and expulsion of some or all of the container contents leading to unconfined combustible material releases; not all containers are necessarily ruptured leading to confined material releases for some containers. • Can lead to requirements for restrictions on fuel inventories in transport vehicles or prohibiting fossil-fueled vehicles.

Table 3-1. General Candidate Scenarios. (9 sheets)

Scenario	Issues	Description	Remarks
Range fires	• Exterior combustible materials that can lead to fires impacting containers in a facility or in an area. • Combustible materials in close proximity to storage areas.	Fire involving normal combustibles (confined material fire release)	• Size of fire defined by the combustible loading in close proximity to a facility or a waste storage area. • Facility/area inventory and container storage arrangement may define number of containers impacted. • Generally, fires of this type do not involve metal container lid loss and are modeled as confined material releases. • Can lead to combustible material control program associated with zones of limited combustibles around facilities or storage areas.
Large spills/fires (aircraft crash, vehicle crash)	• Aircraft or vehicle crashes can lead to ruptured containers and subsequent fires involving uncontained materials. • High energy vehicles.	Aircraft/vehicle crash leading to spill and fire (confined material fire release + unconfined material fire release + confined material spill release)	• Size of spill dependent on energy associated with the crash. • Size of fire dependent on amount of fuel in analyzed aircraft or transport vehicle. • Pool footprint and container storage arrangement defines number of containers impacted, some containers breached by impact energy of the plane. • Pool fires can cause drum lid loss and expulsion of some or all of the container contents leading to unconfined combustible material releases although assuming that all breached containers burn their contents as unconfined materials is generally conservative; assuming that the non-breached containers in the fuel pool are confined material releases may be assumed.
Spills (liquids)	• Containers with contaminated liquids can be breached leading to spills. • Container liquid inventories.	Spill involving liquids (liquid spill release + powder resuspension release)	• Size of spill dependent on the largest inventory container/component with liquids. • Examples include tanks, tankers, piping systems, and storage containers (liquids can include sludges). • Entire contents of container/component involved in spill. • Depending on potential for discovery of the spill, spill may go undetected leading to dry out of liquid and potential resuspension of the radioactive material contents. • Can lead to inventory limits on containers/components with liquids.
Spills (containerized solids)	• Containers with contaminated solids can be breached leading to spills. • Container inventories.	Spill involving containerized solids (confined material spill release)	• Size of spill dependent on the largest inventory container(s) with wastes that are handled as a unit. • Examples include drum(s), box(es), pallet(s) of drums, transuranic package transporter assembly, cargo container, and specialty container. • Entire contents of container(s) involved in spill. • Generally modeled as confined material spills. • Can lead to inventory limits on containers/components or on limits to number of containers involved in a lift. • Need to determine if the container is breached by the impact from the spill.

Table 3-1. General Candidate Scenarios. (9 sheets)

Scenario	Issues	Description	Remarks
Spills (un-containerized solids)	• Uncontained contaminated solids in glovebox lines can be dropped leading to spills. • Glovebox inventories.	Spill involving un-containerized solids (unconfined material spill release)	• Size of spill dependent on the largest inventory of material in a glovebox line. • Examples include sorted radioactive materials, unpackaged wastes, and hazardous materials. • Generally modeled as unconfined material spills. • Can lead to inventory limits on glovebox lines.
Large spills (containerized solids)	• Containers with contaminated solids can be breached due to loads being dropped upon them leading to spills. • Elevated loads.	Spill involving containerized solids (confined material spill release)	• Size of spill dependent on the size of loads being lifted above waste container storage/staging areas. • *Inventory of lift as well as footprint containers are included in the spill.* • Entire contents of container(s) involved in spill. • Generally modeled as confined material spills unless the container is breached. • Can lead to limits on the number of containers involved in a lift or on the path taken by lifted materials.
Vehicle spills (containerized solids)	• Transport vehicle loads with containers of contaminated solids can be breached due to vehicle accidents leading to spills. • Transport vehicles.	Spill involving containerized solids (confined material spill release)	• Size of spill dependent on the amount of containers on a vehicle load. • Inventory of transport vehicle defines the number of containers impacted.. • Entire contents of container(s) involved in spill. • *Generally modeled as confined material spills unless the container is breached* • Can lead to limits on the number of containers or inventory on a transport vehicle.
Punctures (containerized solids)	• Containers with contaminated solids can be punctured leading to spills. • Forklift operations. • Gas cylinder missiles.	Spill involving containerized solids (unconfined material spill release)	• Size of spill dependent on the largest inventory container(s) with wastes that can be impacted by forklift tines. • Generally, a fraction of the contents of container(s) punctured involved in the spill, depending on the type of materials in the containers; powder-like wastes can have full involvement; contaminated solid wastes do not "flow" out the puncture hole as readily and only a fraction of the material actually spills. • Generally modeled as unconfined material spills. • Can lead to inventory limits on containers and restrictions on forklifts.

Table 3-1. General Candidate Scenarios. (9 sheets)

Scenario	Issues	Description	Remarks
Explosions or Over-pressurization (containers)	• Containers with flammable gas generation can have contents ignited leading to container explosion. • Container flammable gas generation.	Internal container explosion (overpressure/ explosion release)	• Size of release dependent on the largest inventory container with materials that can generate flammable gases and where the container is vulnerable to internal explosions or overpressurizations • Generally, a fraction of the contents of the container involved in the release since material at bottom of container is impacted less than that at the top. • Generally modeled as explosive release on surface contaminated materials. • Can lead to container venting requirements.
Explosions (glovebox)	• Glovebox that accumulates flammable gas can have gas ignited leading to glovebox explosion. • Glovebox flammable gas accumulation.	External explosion in glovebox line (glovebox overpressure/ explosion release)	• Size of release dependent on the largest inventory glovebox with materials that can generate flammable gases or where flammable gas can accumulate. • Examples of gas sources include furnace operations with organics, chemical reactions, propane or natural gas lines, air intakes located near sources of gas, and opening of containers with internal flammable gas. • Entire contents of the glovebox can be involved in the release since material may be exposed to the overpressure/blast effects of the explosion. • May be modeled as explosive release on powders and surface contaminated materials. • Can lead to furnace controls, glovebox ventilation requirements, rupture disks, glovebox inventory limitations, or glovebox material restrictions.
Explosions (facility)	• Flammable gas accumulation or inventories can have gas ignited leading to explosion. • Flammable gas accumulation or storage.	External explosion in facility (confined material spill release)	• Size of explosion based on largest source of flammable gas used in the facility. • Examples of gas sources include propane-fueled vehicles, acetylene gas cylinders, propane or natural gas lines, and air intakes located near sources of gas. • Room or area top-tier inventory defines number of containers impacted. • Some containers potentially impacted by blast wave leading to stack toppling or container breach and confined material spills; top-tier containers potentially impacted by falling debris from the facility ceiling leading to container punctures and confined material spills. • Can lead to flammable gas inventory limitations/restrictions, facility ventilation requirements, or hot work permitting process.

Table 3-1. General Candidate Scenarios. (9 sheets)

Scenario	Issues	Description	Remarks
BLEVE Explosions/ Spills/Fires (facility or area)	• Flammable gas container involved in a fire can result in container overpressure and BLEVE. • Flammable gas containers.	BLEVE in facility or exterior area (confined material spill release + unconfined material fire release)	• Size of boiling liquid expanding vapor explosion based on largest flammable gas container in the facility or area. • Examples of gas sources include propane fuel tanks on vehicles, propane storage tanks, propane delivery tankers. • Facility or area inventory and container stacking arrangement defines number of containers impacted. • Some containers potentially impacted by blast wave leading to stack toppling or container breach due to missiles and confined material spills; breached container contents ignited by fireball leading to unconfined combustible material releases. • Can lead to flammable gas inventory limitations/restrictions, routing controls on flammable gas deliveries, or siting criteria for flammable gas tanks.
Explosions/ Fires (glovebox)	• Glovebox accumulates flammable gas. Gas ignited leading to glovebox explosion and fire. • Glovebox flammable gas accumulation.	Explosion and fire in glovebox line (glovebox overpressure / explosion release + unconfined material fire release)	• Size of release dependent on the largest inventory glovebox with materials that can generate flammable gases or where flammable gas can accumulate. • Examples of gas sources include chemical reactions, propane or natural gas lines, air intakes located near sources of gas, and opening of containers with internal flammable gas. • Entire contents of the glovebox involved in the release since material may be exposed to the overpressure/blast effects of the explosion and the subsequent fire. • May be modeled as explosive release on powders and surface contaminated materials along with unconfined combustible material fire releases. • Can lead to glovebox ventilation requirements, rupture disks, glovebox inventory limitations, or glovebox material restrictions.
Explosions/ Fires (facility)	• Flammable gas accumulation or inventories can have gas ignited leading to explosion and fire. • Flammable gas accumulation or storage.	External explosion and fire in facility (confined material spill release + unconfined material fire release)	• Size of explosion and fire based on largest source of flammable gas used in the facility. • Examples of gas sources include propane-fueled vehicles, acetylene gas cylinders, propane or natural gas lines, and air intakes located near sources of gas. • Room or area top-tier inventory defines number of containers impacted. • Some containers potentially impacted by blast wave leading to stack toppling or container breach and confined material spills along with unconfined combustible material fire releases; top-tier containers potentially impacted by falling debris from the facility ceiling leading to container punctures and confined material spills (these materials would not be subsequently ignited since punctures occur at top of containers). • Can lead to flammable gas inventory limitations/restrictions, facility ventilation requirements, or hot work permitting process.

Table 3-1. General Candidate Scenarios. (9 sheets)

Scenario	Issues	Description	Remarks
Criticality (container)	• Fissile material in containers arranged and moderated in a manner to cause a criticality • Containerized fissile material	Criticality (criticality release + container overpressure release)	• Size of criticality based on minimum container configuration leading to criticality. • Examples include overmass container stacking, container collapse and breach due to application of loads to containers, and supercompactor crushing with accumulation of densely packed waste. • Configuration defines number of containers involved. • Criticality releases noble gases and volatile fission products; some containers may over pressurize leading to particulate material releases from the containers from the overpressure and container failure. • No mechanism for stopping the criticality other than disruption of the material by mechanical means. • Can lead to container inventory limits and criticality safety program.
Criticality (liquid)	• Liquid fissile material collects in sumps, tanks or glovebox in a manner to cause a criticality • Liquid fissile material	Criticality (criticality release + liquid boiling/ explosive release)	• Size of criticality based on amount of fissile material in liquids. • Examples include glovebox liquid spills and sump collection tanks. • Criticality releases noble gases and volatile fission products; liquid will be violently dispersed due to energy from the criticality leading to boiling or explosive liquid release. • Criticality pulse will disrupt liquid leading to shutdown of the reaction. • Can lead to fissile liquid inventory limits and criticality safety program. • Criticalities involving metals or powders may also need to be evaluated.
NPH Spills (seismic)	• Seismic event results in container toppling and facility collapse leading to spill. • Seismic potential	Spill involving radioactive materials (confined material spill release + liquid spill release + unconfined material spill release)	• Stacks of containers can topple leading to confined material spill releases • Facility structures can collapse leading to debris impacting containers and confined material spill releases. • Tanks of radioactive liquids can breach leading to liquid spill releases. • Glovebox, ducting, and filter plenum inventories can be impacted leading to unconfined material and filter spill releases. • Containers in trenches can be breached from trench collapse leading to confined material spill releases that are mitigated, to some extent, by the earth causing the container failures.
NPH Spills (heavy snow or volcanic ash loading)	• Heavy snow or volcanic ash results in facility collapse leading to spill. • Facility roof strength	Spill involving radioactive materials (confined material spill release + liquid spill release + unconfined material spill release)	• Facility structures can collapse leading to debris impacting containers and confined material spill releases. • Tanks of radioactive liquids can breach due to facility structure impacts leading to liquid spill releases. • Glovebox, ducting, and filter plenum inventories can be impacted by collapsing facility leading to unconfined material and filter spill releases.

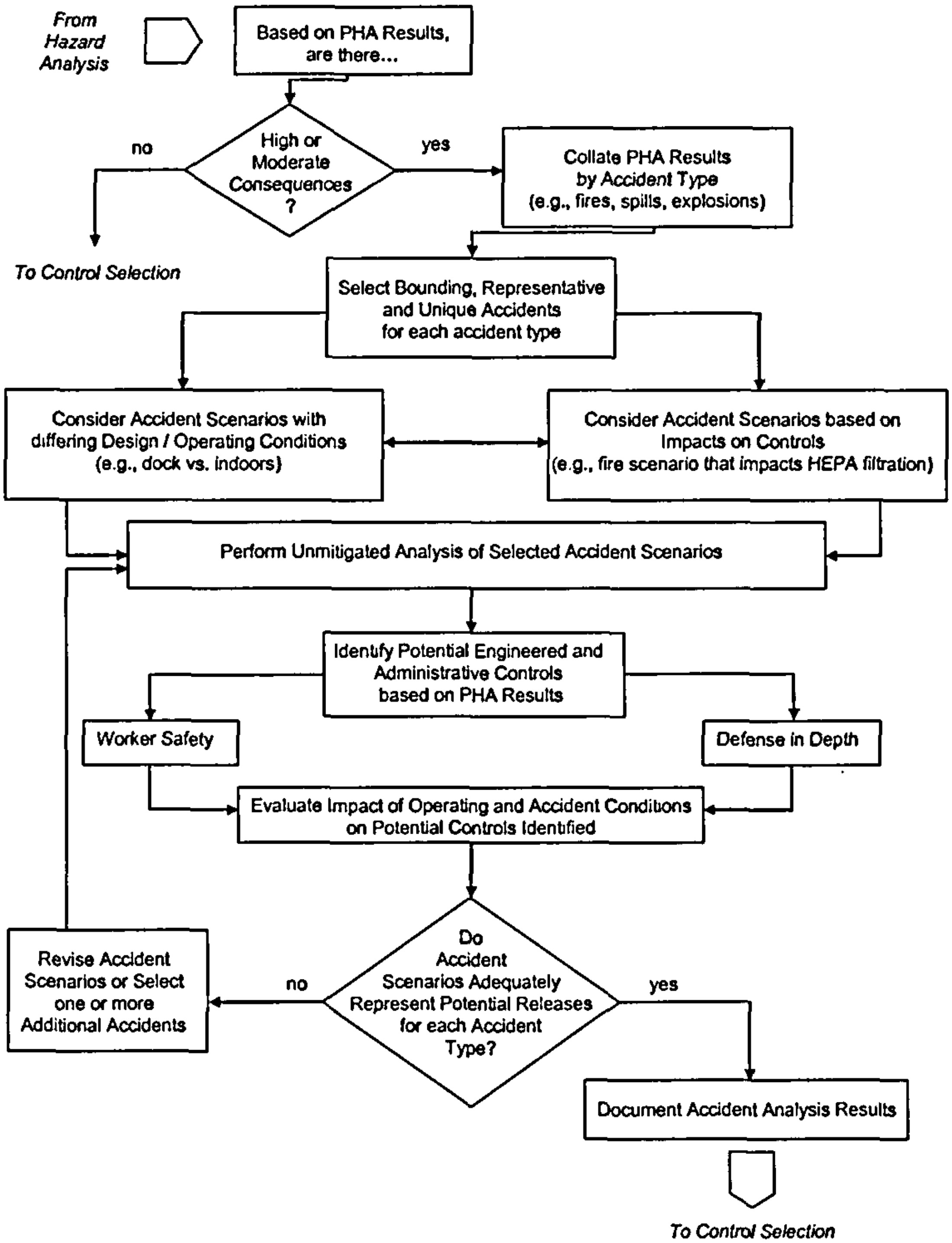
Table 3-1. General Candidate Scenarios. (9 sheets)

Scenario	Issues	Description	Remarks
NPH Spills (high winds)	• High winds result in facility collapse and wind-borne missiles leading to spill. • Facility wind resistance • High winds affect contained and uncontained material outside of a facility	Spill involving radioactive materials (confined material spill release + liquid spill release + unconfined material spill release)	• Facility structures can collapse leading to debris impacting containers and confined material spill releases. • Exposed containers can be impacted by wind-borne missiles leading to confined material spill releases. • Tanks of radioactive liquids can breach due to facility structure impacts leading to liquid spill releases. • Glovebox, ducting, and filter plenum inventories can be impacted by collapsing facility leading to unconfined material and filter spill releases. • High wind greatly increases radioactive material dispersion and significantly lessens release consequences
NPH Spills/Fires/ Explosion (seismic)	• Seismic event results in container toppling and facility collapse leading to spill and subsequent fires. • *Seismic potential*	Spill and fire involving radioactive materials (confined material spill release + liquid spill release + unconfined material spill release + confined material fire release + unconfined material fire release)	• Stacks of containers can topple leading to confined material spill releases • Facility structures can collapse leading to debris impacting containers and confined material spill releases. • Tanks of radioactive liquids can breach leading to liquid spill releases. • Glovebox, ducting, and filter plenum inventories can be impacted leading to unconfined material and filter spill releases. • Flammable/combustible liquid or flammable gas containers may be breached, become ignited by damaged electrical equipment, leading to fire. • Fire can impact containerized materials leading to confined material fire releases; fire can impact *breached containers and glovebox materials leading to unconfined combustible material fire* releases. • Fire can pressurize sealed containers, possibly resulting in a release.

NOTES:

1. All scenarios that apply should be qualitatively analyzed or dispositioned (i.e., some may not be applicable) during the Hazards Analysis.
2. "Large fires" includes "major fires" that could cause collapse of unprotected steel buildings or plugging of HEPA filters resulting in bypass or blow-through.
3. Fire Hazards Analysis should help develop sizes of fires for maximum expected fuel loadings and plausible failure of combustible control scenarios.
4. Combustible control program can include controls on ignition sources (e.g., hot work, no smoking, etc.).
5. Fire protection system requirements can include fire detection, fire suppression, or fire barriers.
6. HEPA filtration requirements may be derived from any scenario that challenges Evaluation Guidelines or is unmitigated Risk Class 1 or 2.
7. NPH events can also initiate explosions or criticalities, similar to the NPH Spills/Fires discussion, that may need to be evaluated.
8. This list is not necessarily a complete spectrum of accidents due to unique facility or processing hazards.

Figure 3-1. Accident Analysis Methodology Simplified Flow Diagram.



The selection and development process undergoes several iterations during document preparation and review to ensure the selection of a complete spectrum of accidents suitable for defining facility-level controls. The selection process includes the following key elements:

- Completeness. Beginning with the PHA and continuing through the preparation and review process, the analyst should consider hazards or candidate scenarios that may have been overlooked. These are examined, and the analyzed scenarios are updated, when appropriate, to ensure that a broad spectrum of events is represented in the accident analysis.
- Simplification. Variations on the same scenario (e.g., small fires in different locations from various activities) are combined into generalized scenarios as long as selected controls address particular circumstances. The resulting analyses are more compact and avoid the incorporation of distinctions that are insignificant to safe facility management.
- Control Orientation. Variations on the same scenario are included when they have clear implications for facility-level controls (e.g., fires with and without suppression or ventilation, HEPA filtration coverage). Such implications affect the adequacy of the control set and the communication of significant considerations for safety management programs. Where frequency bins are populated to support facility transition, control orientation for selection of accidents is most applicable.

3.3 UNMITIGATED ANALYSIS

The concept of an "unmitigated" accident analysis was developed to conservatively estimate the potential severity of candidate accidents for the purpose of establishing the importance of hazard controls selected to mitigate their frequency or consequence. Therefore, accidents are initially analyzed without consideration of engineered or administrative features that act to mitigate the frequency or consequence of the accident.

3.3.1 Initial Conditions

In establishing the initial conditions for the unmitigated accident scenario, the following general guidance is provided:

- The *MAR* may be chosen to be the same mass as that allowed in the criticality limits or allowed by design (for *MAR* that is non-transuranic). Values smaller than that allowed by design may need a TSR-level control. For scenarios involving small energy releases, or small amount of damage, use of criticality limits is a good choice for *MAR*. For larger accidents, design or flowsheet conditions are more appropriate. For cases in which the inventory could be very small or very large, a combination of judgment and inventory controls is needed. For some scenarios (e.g., seismic collapse of a facility), the limiting value may be established such that the results are not sensitive to normal variation in the facility inventory and thus, a material limit would not be necessary.

- The conditions that limit the involvement of hazardous material or energy sources in a particular accident scenario should be carefully examined to determine if those conditions could be exceeded. If so, a larger "bounding case" should be considered. This may occur for conditions intended to provide facility segmentation, for normal operating conditions intended to preclude introduction or addition of energy sources (e.g., combustible materials), or by violation of an administrative control.

3.3.2 Unmitigated Accident Scenario

The unmitigated accident scenario is intended to represent a reasonably conservative bounding analysis of potential consequences and their likelihood in the absence of functional hazard controls. Based on recent implementation experience at Hanford, the potential for "inherently credited controls" to define the scenario and frequency considerations, and the guidance of STD-3009, Appendix A, "Evaluation Guideline," the following general features of an unmitigated analysis are recommended:

1. Consider material quantity, form, location, dispersability, and interaction with available energy sources. The unmitigated release calculation represents a theoretical limit to scenario consequences assuming that all safety features have failed, so that the physical release potential of a given process or operation is conservatively estimated. The unmitigated release should characterize the energies driving the release, and the release fractions in accordance with the physical realities of the accident phenomena at a given facility or process.
    a. The analysis should address reasonably conservative bounding estimates of materials and hazards that could be present to support full mission needs as authorized by the analysis being performed.
    b. The analysis should consider transient hazards due to support or maintenance needs, e.g., introduction of additional combustibles and ignition sources.
    c. For transient fire hazards, the unmitigated accident analysis and the FHA maximum possible fire loss candidate scenarios should evaluate the same hazards, accounting for maintenance, support, or rare operational practices. For example, for a waste drum storage area with very low or no fixed combustible loadings, agreement on the amount of transient combustibles or the extent of failure of combustible control programs should be established (e.g., amount of trash, pallets, flammable liquids) for the unmitigated analysis, and this scenario would be the same used to determine the maximum possible fire loss for that fire area. If a small quantity of flammable liquids is considered a plausible failure of the combustible control program that could potentially result in an exposure fire with direct flame impingement or generate sufficient heat to cause releases from a drum storage array, the unmitigated analysis need not address a flammable liquid pool fire engulfing the drums (with the potential to eject contents) if there is no operational or maintenance need for such materials. To maintain this assumption, the facility combustible control program must strictly limit flammable liquid quantities within the facility or outside of flammable liquid storage cabinets

and the spill would be assumed to occur in major traffic aisleways and not in smaller inspection aisles between rows of drums.

2. The analysis should take no credit for active safety features such as ventilation, filtration systems, and process controls.
3. The analysis should take no credit for passive safety features producing a leakpath reduction in source term, such as a building, a hot cell, drum, or glovebox.
4. The analysis may credit building wake only in the calculation of MOI dose consequence in accordance with STD-3009, Appendix A. For CW dose, building wake correction may be included to provide additional context of the analysis, but it is not appropriate for the purpose of risk class binning or in determining the need for hazard controls.
5. The analysis should assume the availability of passive safety features that are assessed to survive accident conditions or that are not affected by the accident scenario. For instance, in the case of a process vessel rupture, it should be assumed that other vessels not affected by the accident are not ruptured. Another example is crediting a rated fire barrier that is credited in the FHA to evaluate candidate maximum possible fire loss scenarios based on the normally present and transient fire hazards. However, it is important to note that such defining assumptions likely will warrant some level of safety SSC designation or other hazard control to ensure that the assumptions remain valid in the future.
6. The analysis may take credit for passive safety features where the capability is necessary to define a physically meaningful scenario. As stated by Appendix A, Section A.3.1 of STD-3009:

   "...For example, in the case of a container drop where the impact of the drop does not challenge container integrity, it should not be assumed that the contents have dropped in an uncontained manner. Similarly, if the presence of permanently installed resilient flooring prevents an undesired consequence given a drop, an assessment of the drop against some other non-resilient surface is not meaningful. However, it is important to note that such defining assumptions may warrant some level of safety SSC designation to assure that the assumptions remain valid in the future."

7. The effect of acknowledging passive features in the unmitigated analysis to define a meaningful accident scenario means that the unmitigated analysis is not necessarily a "parking lot release" expectation. Some examples include the following:

   a. The container design strength could be credited to withstand a short drop from a glovebox or workbench by also crediting permanent rubber flooring.

   b. Many flammable gas releases, e.g., a hydrogen deflagration, require confinement, which will influence the damage assessment depending on the facility or container design. Another example is that credit needs to be taken for the presence of a glovebox or furnace for scenarios involving a flammable gas explosion. Without the glovebox or furnace, the gas may never exist in a flammable concentration.

c. A spray release scenario is meaningless absent pressure based on the failed confinement vessel.

d. Credit may be taken for designed storage racks and fixed aisle spacing.

e. External confinement barriers and structures that survive a design basis natural phenomena event should be credited for the design basis accident unmitigated analysis. In general, this means that nonreactor nuclear facilities should be evaluated for the Site's Performance Category (PC) 3 design basis accidents as defined by DOE-STD-1020-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*. In lieu of a natural phenomena hazard engineering evaluation for an existing facility, it is generally assumed that the facility would not survive the PC-3 event and suffer major damage and/or collapse. For existing, lower-hazards facilities that would only require PC-1 or 2 design criteria, the structure should be assumed to sustain major damage and/or collapse for an unspecified level of natural phenomena hazard less than the PC-3 event, unless engineering analysis demonstrates that an existing structure could survive the PC-3 loads.

8. Care should be taken to recognize that the presence of some design features could result in greater releases. As an example, if a facility interior contains heavy objects (equipment, concrete floors) on floors above the ground floor, the unmitigated seismic accident may have greater releases if this equipment falls onto the ground floor rather than assume that no facility exists. This also applies to the difference between a postulated collapse of a concrete facility compared to much less damage for collapse of a lightweight metal-type facility. Another example is the double-welded cans for storage of plutonium that are designed in accordance with DOE-STD-3013-2000, *Stabilization, Packaging, and Storage of Plutonium-Bearing Materials*. In the event of a significant fire or direct flame impingement, the cans will burst at a much higher pressure than previous storage containers such as food pack cans, resulting in a much higher release due to the increase in the *ARF/RF* (see Section 3.4.4).

9. In general, credit should not be taken for administrative controls, e.g., combustible controls, or restrictions. Based on implementation experience within the DOE complex, exceptions include the following:

   a. Application of a *MAR* control to preserve a HC-3 designation (e.g., for low-level waste storage) or an imposed HC-2 facility inventory.

      Note: The potential for inadvertently exceeding the *MAR* control should be evaluated where it exists.

   b. Not evaluating an externally initiated fire in a special nuclear material storage vault (i.e., robust noncombustible construction meeting safeguards physical and access requirements, and no fixed or transient combustibles that could propagate a fire).

   c. Administrative aisle spacing or waste storage arrangements as required by state or federal regulations (e.g., *Resource Conservation and Recovery Act of 1976* permits) and enforced through required periodic inspections.

d. Not evaluating prohibited hazards such as specified flammable gases or wooden waste crates that would never be introduced into the facility for operational, support, or maintenance needs.

10. The following guidance on assessing accident frequency is based on recent implementation experience:

    a. The frequency of the unmitigated event is normally the frequency of the initiating event and any necessary enabling events that could cause a radiological release if preventive controls are not credited. The frequency of the initiating event should be based on the assumption that there are no TSR controls or "best management practices" (other than minimum regulatory requirements such as those from the Occupational Safety and Health Administration/U.S. Environmental Protection Agency, but not well-implemented safety management programs), and that standard industrial design practices for low-impact equipment and structures are used. If multiple initiating events are identified, they must all be considered to provide a meaningful event frequency. This generally means that if the initiating event normally is expected to occur in the life of a facility or mission activity, it would have a qualitative unmitigated frequency assignment of Anticipated (i.e., greater than 10^{-2}/yr).

    b. If the failure is caused by human error, a failure probability of 0.1 to 0.01 per control failure or opportunity should be assumed, and the unmitigated annual frequency of occurrence normally should be assumed to be "Anticipated."

    c. If the failure is by component failure, the failure rate (per year) or failure probability of the component could be used. If the accident is caused by catastrophic failure of a major piece of equipment, a fault tree may be appropriate to determine the frequency of occurrence because failure may require a series of individual component or human failures, a low-probability system failure, or natural phenomena occurrence. However, care should be exercised that inherent controls (e.g., preventive maintenance to increase component reliability, administrative checks and balances) are not being credited for the unmitigated analysis.

    d. A conservative failure probability or rate obtained through judgment is also acceptable in cases where the failure is such that conservative judgment can be justified.

    e. Natural phenomena and external events generally have a lower initiating event frequency, e.g., Unlikely (earthquakes) or Extremely Unlikely (aircraft crashes) as recommended in applicable DOE Standards (e.g., DOE-STD-1021-93, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components* and DOE-STD-3014-96, *Accident Analysis for Aircraft Crash into Hazardous Facilities*).

    f. Efforts should be made to base frequency assessment on plant experience, DOE complex, or industry experience, and use of failure rate databases, while ensuring that the role of humans as a cause of the failure is properly considered.

g. The frequency of performing particular activities that lead to initiating events should be considered in determining accident frequencies. For example, in a waste storage facility, the frequency of an unmitigated fire that could involve more than a few drums (i.e., greater than a "small" fire) may be "Unlikely" because storage and handling activities may not introduce combustibles or ignition sources, and maintenance-induced fires would be less likely due to the relatively low frequency of hot work activities. Similarly, the unmitigated frequency for a gas cylinder missile hazard may be "Unlikely" due to its relatively infrequent presence. Such considerations are not necessarily associated with an administrative control, but all assumptions and their bases should be explicitly identified.

h. Quantitative frequency evaluations are not required; qualitative frequency bins span two orders of magnitude (see Table 2-2) that should facilitate agreement on what the unmitigated frequency is for a particular accident scenario.

i. STD-3009 and STD-3011 caution that a frequency cutoff such as less than 10^{-6}/yr ("Beyond Extremely Unlikely") should not be used as an absolute criterion for operational accidents. The caution is related to ensuring that the physical possibility of the initiator or physical possibility of the phenomenon be evaluated for the unmitigated analysis. Therefore, operational accidents should not be screened out as "Beyond Extremely Unlikely" in the unmitigated hazards analysis without qualitatively evaluating potential consequences so that they can be appropriately considered in the spectrum of representative and unique accidents that require further evaluation in the accident analysis.

j. For deactivated facilities in a surveillance and maintenance mode, where no ignition sources are present and energy source limited to electrical power for lighting, an "Unlikely" unmitigated frequency is appropriate if supported by the FHA conclusion that normally present combustibles would not propagate a fire to involve radioactive material holdup. However, reliance on combustible control program restrictions (e.g., quantities, spacing) cannot provide the basis for an unmitigated frequency assessment.

3.4 RADIOLOGICAL SOURCE TERM

3.4.1 Introduction

Radiological doses arise from 1) uptake of radioactive material into the body through inhalation or ingestion, and 2) exposure to direct radiation (e.g., from a criticality or shine from a pool of radioactive liquid).

For the transuranic radionuclides that make up the primary source term in DOE facilities, chronic dose (50-yr committed dose) is more limiting than acute dose. The total effective dose equivalent from inhalation is typically dominant over ingestion, resuspension, or shine (i.e., direct shine, groundshine, skyshine), and calculation of the chronic dose from inhalation is usually adequate for evaluating radiological consequences.

The exceptions to this rule are criticality accidents, in which the direct radiation exposure to the worker is the dominant concern unless there is significant shielding between the worker and the source. Also, shine may be a significant contributor where fission products or other gamma emitters are stored or could be released to the environment (e.g., Waste Encapsulation and Storage Facility, with a very large inventory of Cs-137).

Inhalation dose depends, among other things, on the amount of respirable material inhaled during plume passage. The amount of respirable material released during an accident is called the *respirable source term*, Q (generally in units of activity, Bq). It is given by

$$Q = MAR \times DR \times ARF\ (or\ ARR \times T) \times RF \times LPF$$

where

MAR = material at risk

DR = damage ratio

ARF = airborne release fraction

ARR = airborne release rate (for continuous releases)

T = release duration

RF = respirable fraction

LPF = leak path factor.

(Frequently, Q is replaced with Q_i to account for different isotopes involved in an accident. In this case, each i^{th} isotope is carried forward to consequence calculation as shown in Section 3.5.)

3.4.2 Material at Risk (*MAR*) and Damage Ratio (*DR*)

The *MAR* is defined by DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, as the amount of hazardous material available to be acted on by a given physical stress. The *DR* is the fraction of the *MAR* that actually is impacted by the accident. There is an obvious interdependence in the definitions of *MAR* and *DR*. Material not affected by the accident forces could be excluded from the *MAR*, or could be included and accounted for using the *DR*. The product of the *MAR* and *DR*, called the "effective *MAR*," is the quantity of the material that is subjected to the stresses of the accident.

3.4.2.1 Waste Container *MAR* for Waste Stabilization and Disposition (WSD) Facilities

Conservative upper bound material inventories have been established for waste drums and other types of containers as shown in Table 3-2. The *MAR* is given in terms of "equivalent" grams of TRU material. The equivalency is necessary because inventory in the Solid Waste Operations Complex is maintained using Dose Equivalent Curies (DE-Ci) to account for the wide range of isotopic distribution in the waste. The default conversion for DE-Ci to grams TRU is 0.165 DE-Ci/g based on the assumption that all of the TRU material is plutonium containing 12 percent nominal ^{240}Pu with ^{241}Am included, based on 20-year aging.

Quantities of TRU material present in containers involved in postulated accidents within WSD facilities are given in Table 3-2 and generally follow the pattern that the involvement of a single container assumes the presence of the single maximum loaded drum, while multiple drum involvement assumes the presence of the maximum loaded drum or a significant fraction of other highly loaded containers in some combination with 95 percentile loaded drums and drums containing the average or mean quantity of TRU from the population of the drums.

In some cases there is a small possibility that waste containers that exceed the inventory algorithm of Table 3-2 might be found. However, because of the small possibility of this situation, the accident analysis is adequately conservative, and no additional analysis or specifications of additional controls are required. HNF-14741, *Waste Management Project (WMP) Master Documented Safety Analysis (MDSA) for the Solid Waste Operations Complex (SWOC)*, Appendix 3B, provides the technical basis for identifying waste container "equivalent" inventory values based on their associated "package factors." Appendix 3D provides a discussion of the hazardous material constituents of the TRU waste containers.

For all numbers of containers it is assumed that the *MAR* comprises 65 percent combustible materials (34 percent cellulose and 31 percent plastics) and 35 percent noncombustible waste, as discussed in Appendix 3B, Section 3B.2.3.1, of HNF-14741.

Table 3-2. Material at Risk for Waste Management Accidents

Number of containers involved in the accident	Inventory of those containers, grams of equivalent plutonium (12% ^{240}Pu, ^{241}Am based on 20-year aging)
1	500 g
2	One container at 500 g, one at 200 g
3	One container at 500 g, one at 200 g, one at 75 g
4	Four containers at 200 g each
>4	Four containers at 200 g each, 25% of all additional containers at 75 g each*; remainder at 14 g each.

* Normal rounding protocols apply. The total number of containers at 75 g each is not to exceed 400 containers.

In addition to this algorithm, two unique waste container configurations are not subject to Table 3-2, specifically:

- LDCs that contain the spent fuel sludge from the K-Basins are assumed to contain 1610 DE-Ci

- Shippingport pressurized water reactor fuel casks containing spent fuel are assumed to contain 2100 DE-Ci

Section 3.4.5 provides a methodology for establishing a Package Factor (PF) that allows taking credit for container packaging being more robust than a standard 208-L drum or having a different material form. In addition to casks and other special containers, this accounts for standard waste containers such as pipe overpack containers and standard waste boxes.

3.4.2.2 FFTF Fuel Assembly Storage

The *MAR* associated with FFTF Fuel Assembly Storage is detailed in HNF-20337, *Preliminary Hazard and Accident Analysis FFTF Fuel Assembly Interim Storage and Disposition.* Estimated releases during the accidents analyzed are calculated in terms of the standard Driver Fuel Assemblies (DFAs).

The total mass of mixed oxide per fuel pin is calculated based on fuel column dimensions (36 in. long by 0.2 in diameter) with a maximum assumed oxide density of $10 g/cm^3$. Each DFA contains 217 fuel pins for a mass of 40.22 kg mixed oxide per DFA.

3.4.2.3 Damage Ratio (*DR*)

Typically, the effective *MAR* is used in lieu of reporting an explicit value for *DR*. However, Table 3-3 provides acceptable *DR* values for the following circumstances:

1. Bagless Transfer Cans in a Fire: HNF-7616, *Justification for Continued Operation for the 2736ZB Building at the PFP*, provides calculations that show that bagless transfer cans do not fail unless they experience flame impingement. Not all of the bagless transfer cans will be impacted by the flame if they are in a close packed array, a shield sleeve, or an overpack.

2. Mechanical Release from Drum: The values provided are derived from drop tests involving drums. In these tests, a drum weighing 318 kg containing waste in 90-mil liners was dropped from varying heights. Unless the drum was dropped from at least 13 m, no drum contents were ejected.

3. Fraction of Waste Ejected from a Drum due to Deflagration: The value of *DR*, 0.05, is based on HNF-19492, *Revised Hydrogen Deflagration Analysis,* which modifies the previous SARAH values for this parameter.

4. Fraction of Ejected Waste that Burns Outside of a Drum following a Deflagration: The value of *DR*, 0.18, is based on HNF-19492.

5. Fraction of Waste that Burns in a Drum Fire that does not Eject Contents (i.e., lid seal failure only): The value of DR, 0.06 is based on HNF-14741.

6. Fraction of Sludge Transported in the LDC subject to Fire: The value of *DR*, 0.03, is based on SNF-10272, *Accident Analysis and Control Options in Support of the Sludge Water System Safety Analysis,* Rev 2.

7. Fraction of Mixed Oxide in a Driver Fuel Assembly due to Impact: The values of *DR*, 1×10^{-3} and 1×10^{-4}, are based on HNF-20337.

Table 3-3. Damage Ratio (*DR*) Values

Bagless transfer cans in a fire	*DR* = 1.0 (for an individual can or cans that are unshielded and exposed to direct flame impingement) *DR* = 0.1 (for cans in a metal sleeve [i.e., shielded], in overpacks, or in an array of close packed cans with no direct flame impingement)
Mechanical release from a drum (HNF-SD-W026-SAR-002,[a] HNF-SD-WM-SARR-028, Addendum 1)[b]	*DR* = 0.001 (for drums containing closed pipes or welded containers AND drop <13 m or low vehicle speed [less than ~35 mph]) *DR* = 0.01 (for seismic event forces, drums vibrate and fall over, or for drums impacted by sheets of metal walls or roof [butler building collapse]) *DR* = 0.1 (for a drop of <13 m) *DR* = 0.1 (for vehicle impact at low- or high-speed into multiple drums [tens of drums or more], or drums that are impacted by large I-beams in a butler building collapse) *DR* = 1.0 (for drop of a corroded drum) *DR* = 1.0 (for high-speed impact [greater than ~35 mph], sufficient to damage a drum) *DR* = 1.0 (for beyond design basis seismic event, or when large pieces of concrete floor or roof fall onto waste drums)
Fraction of waste ejected from drum due to deflagration inside (HNF-19492)[c]	*DR* = 0.05
Fraction of ejected waste that burns outside of a drum following a deflagration. (HNF-19492)[c]	*DR* = 0.18
Fraction of sludge transported in the LDC subject to fire. (SNF-10272, Section 3.4.8)[d]	*DR* = 0.03
Bagged waste (no drum)	*DR* = 1.0 (impact or explosion)
Drum fires	*DR* = 1.0
Drum fire, no ejected contents (lid seal failure only)	*DR* = 0.06
Dropped FFTF Driver Fuel Assemblies	*DR* = 1×10^{-3} or 1×10^{-4} (higher *DR* value for horizontal DFA impacted by dropped DFA; lower *DR* value for vertically dropped DFAs)

Table 3-3. Damage Ratio (*DR*) Values

[a]HNF-SD-W026-SAR-002, 2001, *WRAP Final Safety Analysis Report*, Rev. 2, Fluor Hanford, Richland, Washington. [b]HNF-SD-WM-SARR-028, 2002, *Solid Waste Burial Grounds Interim Safety Analysis*, Rev. 3E, Waste Management Federal Services, Inc., Richland, Washington. [c] HNF-19492, *Revised Hydrogen Deflagration Analysis*, Rev. 0A, Fluor Hanford, Richland, Washington. [d] SNF-10272, *Accident Analysis and Control Options in Support of the Sludge Water System Safety Analysis*, Rev. 2, Fluor Hanford, Richland, Washington.

3.4.3 Leakpath Factor (*LPF*)

The *LPF* is the fraction of airborne particles that escape the facility into the atmosphere. For unmitigated analysis, the *LPF* is unity. For mitigated analysis, *LPF* is dependent on the physical characteristics and configuration of the facility as it is estimated to exist under the accident conditions postulated.

For example, if a release passes through filtration before reaching the atmosphere, the *LPF* would be that of the filter as it performs under the postulated accident conditions. A single stage of HEPA filtration is generally assumed to have an *LPF* of 5×10^{-4} under normal operating conditions, however, the filter may be breached by flame impingement which will open up the leak path to near unity, or it may be located remote from flame but be plugged by soot, which could either drive the *LPF* to near zero through the filter and drive the release to other openings or if exhaust fans continue to run, the plugged filter could be breached by excessive differential pressure.

Similarly, if the release passes through long passageways, cracks, or torturous routes before exiting to the atmosphere, fall-out and plate-out should be considered in determining *LPF*. Because of this strong dependency on the facility and phenomena together, the Hanford SARAH does not contain default *LPF* values.

3.4.4 Airborne Release Fraction (*ARF*) and Respirable Fraction (*RF*)

The *ARF* is the fraction of the effective *MAR* that becomes airborne. "Airborne" particles are those small enough to remain in the air for a considerable time, generally considered to be particles with an aerodynamic equivalent diameter (AED) smaller than about 100 μm in still air. In the case of moving air (wind or turbulence) that lofts particles from a pool or contaminated surface, the *ARF* is replaced by $ARR\times T$. The *ARR* is the rate at which "airborne sized" particulates are released from the surface and *T* is the duration of this release, or the exposure time of the receptor, whichever is less.

The *RF* is that portion of the airborne particles small enough to pass into the deepest parts of the lungs when inhaled. These are generally considered smaller than 10 μm AED. The *RF* for gases is taken to be unity.

The acceptable values for *ARF* and *RF* are provided in Table 3-4. The material types described (e.g., packaged waste) are defined in Table 3-5.

Table 3-4. Airborne Release Fraction (*ARF*) and Respirable Fraction (*RF*) Values

Material	Fire *ARF, RF*	Impact, Explosion, or Overpressure *ARF, RF*	Spills *ARF, RF*	Resuspension *ARF, RF*
Packaged waste	5×10^{-4}, 1.0 HDBK-3010, Section 5.2.1.1	10^{-3}, 1.0 internal explosion or overpressure HDBK-3010, Section 5.2.2.2. *ARF* and *RF* apply to the fraction ejected. See Note 1. 10^{-3}, 0.1 external impact HDBK-3010, Section 5.2.3.2	See "Impact, Explosion, or Overpressure"	Not used
Uncontained, combustible, contaminated material	10^{-2}, 1.0 cellulosic material only; HDBK-3010, Section 5.2.1.2	See "Packaged waste"	See "Packaged waste"	Not used
Noncombustible contaminated solids	6×10^{-3}, 0.01 HDBK-3010, Section 4.4.1.1. See Note 2.	See "Packaged waste"	For drums, see "Packaged waste" For powders, see "Plutonium oxide and other powders"	Not used

Table 3-4. Airborne Release Fraction (*ARF*) and Respirable Fraction (*RF*) Values

Material	**Fire** ***ARF, RF***	**Impact, Explosion, or Overpressure** ***ARF, RF***	**Spills** ***ARF, RF***	**Resuspension** ***ARF, RF***
Uncontained, contaminated organic solids	5×10^{-2}, 1.0 HDBK-3010, Section 5.2.1.4. See Note 3. 10^{-2}, 1.0 for polystyrene HDBK-3010, Section 5.2.1.4	See "Packaged waste"	See "Packaged waste"	Not used
High-efficiency particulate air (HEPA) filters	10^{-4}, 1.0 HDBK-3010, Section 5.4.1	10^{-2}, 1.0 HDBK-3010, Section 5.4.2.2. See Note 4.	See "Impact, Explosion, or Overpressure"	See "Plutonium oxide and other powders"
Plutonium metal	5×10^{-4}, 0.5 HDBK-3010, p. 4-2, first bullet. Value valid for bulk metal, large pieces, and chips.	10^{-3}, 1.0 for oxide coating (energy insufficient to fracture metal) *HDBK-3010*, Sections 4.2.2.2 and 4.2.2.3 for a deflagration near metal (refers to Section 5.3.3.2.2). See Note 5.	Not used	Not used

Table 3-4. Airborne Release Fraction (*ARF*) and Respirable Fraction (*RF*) Values

Material	Fire *ARF, RF*	Impact, Explosion, or Overpressure *ARF, RF*	Spills *ARF, RF*	Resuspension *ARF, RF*
Plutonium oxide and other powders	6×10^{-3}, 0.1, for oxide having a large respirable fraction 6×10^{-3}, 0.01 for oxide having a small respirable fraction HDBK-3010, Sections 4.4.1.1 and 4.4.1.2, and RFP-5098, *Safety Analysis and Risk Assessment Handbook*. See Note 6.	2×10^{-3}, 1.0 muffle furnace (for deflagrations in furnaces having a small internal free volume) HDBK-3010, Table 4-12. See Note 7. 5×10^{-3}, 0.4 food pack cans 0.18, 0.1 bagless transfer can HDBK-3010, Section 4.4.2.3.2 and HNF-17926, 2736-Z *Complex Documented Safety Analysis*.	From 1 m 8×10^{-5}, 0.5 (TRU) HDBK-3010, Table 4-13 for UO_2. 5×10^{-4}, 0.5 (non-TRU) HDBK-3010, Table 4-13 for 1000 g TiO_2. Glovebox topple, oxide 1 m above floor initially: *ARF* x *RF* = 1.4×10^{-4} for plutonium oxide, 3.5×10^{-4} for non-transuranic oxides See Note 8.	4×10^{-5}/h, 1.0 (nominal facility ventilation flow) HDBK-3010, Section 4.4.4.1 4×10^{-6}/h, 1.0 (nearly static conditions or shielded by debris) HDBK-3010, Section 4.4.4.1 10^{-3}, 0.1 for oxide beds due to seismic vibration (glovebox qualified) HDBK-3010, Section 4.4.3.3.1

Table 3-4. Airborne Release Fraction (*ARF*) and Respirable Fraction (*RF*) Values

Material	**Fire** ***ARF, RF***	**Impact, Explosion, or Overpressure** ***ARF, RF***	**Spills** ***ARF, RF***	**Resuspension** ***ARF, RF***
Aqueous waste or plutonium solutions	2×10^{-3}, 1.0 (boiling) 2×10^{-4}, 1.0 (simmering) HDBK-3010, Sections 3.2.1.2 and 3.2.1.3. (Does not apply to solutions having a significant fraction volatile or flammable component.)	Not used	From 1 m 3×10^{-5}, 0.5 HDBK-3010, Tables 3-6 and 3-7 Glovebox topple, 3.5×10^{-5}, 1.0 liquids 1 m above floor initially See Note 9.	4×10^{-7}/h, 1.0 (nominal facility ventilation flow) HDBK-3010, Section 3.2.4.5 4×10^{-8}/h, 1.0 (nearly static conditions or shielded by debris) HDBK-3010, Section 3.2.4.5 SPRAY code with pump discharge pressure, 30 µm droplets as respirable, code run to find largest respirable release. See Note 10.

Table 3-4. Airborne Release Fraction (*ARF*) and Respirable Fraction (*RF*) Values

Material	Fire *ARF, RF*	Impact, Explosion, or Overpressure *ARF, RF*	Spills *ARF, RF*	Resuspension *ARF, RF*
K Basin sludge	3×10^{-5}, 1.0 (sludge boiling) HDBK-3010, Table 3-1, entry of "100 C, 0.5 m/s air velocity over pool." 3.33×10^{-4}, 1.0 (rapid oxidation) SNF-4267, *Consequence Analysis of IWTS Metal-Water Reactions*	1.61×10^{-3}, 1.0 Spray release; 5.5E-6 L/s respirable release rate. See Note 10. 5×10^{-3}, 0.3 HDBK-3010, Section 4.4.2.2.2 for Large-Diameter Container Overpressurization	5×10^{-5}, 0.25 North Loadout Pit sludge splash and splatter based on "typical values for slurries in a splash and splatter scenario" from HDBK-3010.	Not used
FFTF Fuel Storage	N/A	3.58E-4, Respirable Release Fraction (*ARF* x *RF*) based on calculation of the empirical correlation of HDBK-3010, Section 4.3.3 (the correlation must be recalculated for each case).	N/A	N/A

Table 3-4 Notes:

Note 1. For deflagration involving hydrogen, the waste left in the drum and ejected waste will burn. The *ARF* and *RF* for fire are needed to determine the respirable releases due to an explosion caused fire. The *ARF* and *RF* for the combustible fraction of the uncontained waste that burns must be the value for "uncontained, contaminated organic solids" unless data exist to show the fraction of combustible waste that is cellulosic and the fraction that is organic solids. The respirable release is the sum of the explosion release and fire release.

Note 2. This is the bounding value for plutonium oxide, classified as a nonreactive material. This value applies to all noncombustible contaminated waste.

Note 3. This applies to polymethylmethacrylate (also known as PMMA), polychloroprene, and all other plastics, resins, and elastomers with the exception of polystyrene.

Note 4. The value chosen was specified for "blast effects." A much smaller value was specified for detonation; however, the justification for the smaller value is not easily defendable for all detonation conditions. A detonation should release more than a blast, not 10^4 times less. In addition, a detonation is a very rare phenomenon where blast effects are, by comparison, more likely. As a result, the "blast effect" data should be used for all explosion-like phenomena.

Note 5. Values apply to oxide coating only; energy insufficient to fracture metal.

Note 6. The value of *ARF* chosen was that for the conditions listed in Table 4.10 of the reference. The value was based on tests with oxide having a small *RF*. For oxide having a large *RF*, the *RF* is increased to 0.1. The value for *RF* came from RFP-5098, *Safety Analysis and Risk Assessment Handbook.*

Note 7. Interpolated for 35 psig (0.24 MPa, gauge) based on a small free volume (e.g., 6 L). The pressure is the pressure achieved during the deflagration (this assumes that the door cannot withstand the forces caused by the deflagration).

Note 8. Values based on 1-m spill value plus 1×10^{-4} (*ARF* of 10^{-3}, *RF* of 0.1, from HDBK-3010, Section 4.4.3.3.1) to account for shock and vibration release when glovebox impacts floor. *ARF* x *RF* (TRU) = $(8 \times 10^{-5})(0.5) + 10^{-4} = 1.4 \times 10^{-4}$; *ARF* x *RF* (non-TRU) = $(5 \times 10^{-4})(0.5) + (1 \times 10^{-4}) = 3.5 \times 10^{-4}$.

Note 9. Value based on 1-m spill value plus 2×10^{-5} (*ARF* of 2×10^{-5}, *RF* of 1.0, a value equal to that for the 1-m oxide spill [*ARF* of 3×10^{-5}, *RF* of 0.5] rounded up to the nearest whole number) to account for shock and vibration release when glovebox impacts floor.

Note 10: WHC-SD-GN-SWD-20007, *A Model for Predicting Respirable Release from Pressurized Leaks*, the SPRAY code should be used with the pressure at the leak equal to the pump discharge pressure and respirable droplet being 30 µm. The droplet can evaporate to a 10 µm respirable particle if evaporation leaves behind a salt that made up 4 percent of the initial droplet. Smaller diameters can be used if it is demonstrated that the salt content is great enough (see Equation 5 of the reference). The code should be used to find the leak size that results in the largest respirable release unless sound engineering judgment is used to justify a more realistic leak size. Fractional losses through relatively thick walls can be considered (see Section 3.3 of the reference). The respirable quantity should not be less than that in Section 3.2.2.3.1 of HDBK-3010. The SPRAY code model validation is provided in Section 2.5 of WHC-SD-GN-SWD-20007 and verification cases are documented in Section 3.0 and Appendix A of that document. Future applications of the SPRAY code must meet current software quality assurance requirements.

Table 3-5. Definition of Material Types

Packaged waste – Per HDBK-3010, Section 5.2.1.1, packaged waste is generally combustible waste that is contained in plastic bags or similar (or more robust) confinement. The bounding *ARF* of 5×10^{-4} for packaged waste applies even to waste in taped plastic bags or in pails. Waste does not contain volatile chemicals or cans capable of pressurizing. The concern is that these two components could result in waste being ejected from the barrier due to a fire or pressurization event within the barrier due to heating by an external fire or other initiator. This category is intended to cover contaminated waste in bags, drums, and waste boxes. It does not cover casks, "3013 cans," and other very strong containers.
Uncontained, combustible, contaminated material – Waste that is cellulosic in nature. Material that is ejected from the barrier as discussed in packaged waste also falls either in this category or in one of the next two, depending on the type of waste it is.
Noncombustible contaminated solids – Applies to contamination on all noncombustible waste, contained or not.
Uncontained, contaminated organic solids – Applies to all uncontained, contaminated plastics, elastomers, and resins. Note that the airborne release fraction and respirable fraction for fire differs for polystyrene over that for all other materials in this category.
High-efficiency particulate air – Applies to filters.
Plutonium metal – Applies to bulk uranium and plutonium metal as well as large pieces and chips. Does not apply to fines. Based on processing history no concentration of fines is expected at Hanford.
Plutonium oxide and other powders – Applies to all inorganic powders.
Aqueous waste or plutonium solutions – Applies to all aqueous waste. Does not apply to solutions that have more than a very small fraction of organic or volatile components. That is, solutions having more than 1 percent organic or volatile components.
Fast Flux Test Facility fuel – Applies to whole or pieces of clad fuel pins and declad pellets. Also applies to reactor fuel assemblies.
K Basin sludge – Self-explanatory.

3.4.5 Package Factors

Different types of storage containers respond differently to the same accident phenomena. The form, distribution, and packaging can affect the *DR, ARF,* and *RF* used in calculating the respirable source term (RST):

$$RST_{container} = MAR * DR * ARF * RF * LPF$$

In facilities with multiple types of storage containers it may be useful to develop a "Package Factor." This allows comparison of container, zone, and facility inventory limits, by adjusting the total inventory to an effective inventory based on the container type and material form or distribution (the "package") using the existing bounding accident analysis. It is expected that the application of a Package Factor is limited to cases where the parameters important to supporting a reduced effective release fraction are known, including waste form, design and qualification of the package, and sound condition of the package. Development of this Package Factor is discussed below (for a full discussion of its use and application, refer to HNF-14741, Appendix 3B).

1. An Accident (Source Term) Ratio (AR) is determined for each bounding container accident:

   $AR_{accident\ type} = RST_{reference\ typical\ container}$ / Total *MAR* in the bounding container accident

2. For each type of storage container, a Package (Source Term) Ratio (PR) is determined for the appropriate accident type (e.g., fire, spill):

   $PR_{accident\ type} = RST_{specific\ container}$ / Total *MAR* in the bounding container accident

3. The Package Factor can then be calculated for each type of accident (e.g., spill, fire) using:

   $$PF_{accident\ type} = PR_{accident\ type} / AR_{accident\ type}$$

   (e.g., $PF_{spill} = PR_{spill} / AR_{spill}$)

4. Once package factors are determined they can be used to find a "package effective *MAR*":

   Package Effective *MAR* = *MAR* of the container * Package Factor

   or

   $$MAR_{PE} = MAR * PF$$

   then

   Total Effective *MAR* = MAR_{PE} * number of containers

5. The values for MAR_{PE} are additive for various package types for the same accident. The most limiting Total Effective *MAR* of the applicable bounding accidents can be used for comparison with the facility inventory limit.

A practical application example would be as follows:

Determine PF_{spill} for Pipe Overpack Containers (POCs) in Facility A

Facility A has calculated a bounding single drum spill. The drum contains 82.5 DE-Ci *MAR* (500 g Pu * 0.165 DE-Ci/g = 82.5 DE-Ci). Accident variables are assumed as follows: *DR* = 1.00, *ARF* = 1.00E-3, *RF* = 0.10, *LPF* = 1.00.

$$
\begin{aligned}
RST_{drum} &= MAR_{drum} * DR_{drum} * ARF_{drum} * RF_{drum} * LPF_{drum} \\
&= 82.5 \text{ DE-Ci} * 1.00 * 1.00\text{E-3} * 0.10 * 1.00 \\
&= 8.25\text{E-3 DE-Ci}
\end{aligned}
$$

$$
\begin{aligned}
AR_{spill} &= RST_{drum} / MAR_{drum} \\
&= 8.25\text{E-3DE-Ci} / 82.5 \text{ DE-Ci} \\
&= 1.00\text{E-4}
\end{aligned}
$$

A spill is calculated at Facility A involving POCs. The POCs contain 33 DE-Ci *MAR* (200 g Pu * 0.165 DE-Ci/g). Accident variables are assumed as follows: *DR* = 0.001, *ARF* = 2.00E-2, *RF* = 0.30, *LPF* = 1.0.

$$
\begin{aligned}
RST_{POC} &= MAR_{POC} * DR_{POC} * ARF_{POC} * RF_{POC} * LPF_{POC} \\
&= 33 \text{ DE-Ci} * 0.001 * 2.00\text{E-2} * 0.30 * 1.0 = 1.98\text{E-4 DE-Ci}
\end{aligned}
$$

$$
\begin{aligned}
PR_{spill} &= RST_{POC} / MAR_{POC} \\
&= 1.98\text{E-4 DE-Ci} / 33 \text{ DE-Ci} = 6.00\text{E-6}
\end{aligned}
$$

Therefore a PF can be calculated for the POC as follows:

$$
\begin{aligned}
PF_{spill} &= PR_{spill} / AR_{spill} \\
&= 6.00\text{E-6} / 1.00\text{E-4} = 6.00\text{E-2}
\end{aligned}
$$

3.5 RADIOLOGICAL CONSEQUENCE ASSESSMENT

This section provides guidance for evaluating radiological dose consequences from accidents. Accident scenarios typically postulate a release of radioactive material that is the carried by the wind to the collocated worker and public receptors.

Appendix A, Section A.3, of STD-3009 states:

> "...The dose estimate is that received during a 2-hour... exposure to [the] plume, as discussed in section A.3.3, considering inhalation, direct shine, and ground shine. Other slow developing release pathways, such as ingestion of contaminated food, water supply contamination, or resuspension are not included. However, quick release accidents involving other pathways, such as a major tank rupture, which could release large

amounts of radioactivity in liquid form to water pathways, should be considered. In this case, real potential uptake locations should be the evaluation points."

The dose from inhalation is given by:

$$Dose\ (inhalation) = Q_i * \chi/Q' * BR * DCF_i$$

where:

Q_i	=	respirable source term of isotope *i* (Bq)
χ/Q'	=	atmospheric dispersion coefficient (s/m^3)
BR	=	breathing rate (m^3/s).
DCF_i	=	dose conversion factor for isotope *i* (Sv/Bq)

The approved dose calculation tool is DOE/RL-2002-50, *RADIDOSE for Hanford.* The respirable source term calculation is described in Section 3.4.1; other input parameters are discussed below.

3.5.1 Atmospheric Dispersion and Receptors

3.5.1.1 Introduction

This section provides an overview of atmospheric dispersion, basic information for atmospheric dispersion calculations, and guidance concerning the use of dispersion factors.

The atmospheric dispersion factor, χ/Q', accounts for the effects of atmospheric dispersion of material released under postulated accident conditions at a specified receptor location. It is defined as the concentration in air per unit release rate of the material from an upwind source at a particular receptor location. The value of χ/Q' is a function of the type of release (elevated, buoyant, ground level, etc.), release duration, wind speed, atmospheric stability class, and distance from the source (only centerline or under-centerline, ground-level values are considered). The duration of the release is assumed to conclude within two hours or proceed for up to 8 hours for more slowly developing accidents, based on accident phenomenology.

When evaluating consequences of exposure to hazardous materials, radiological and chemical consequences are evaluated differently. For radiological consequences, the analysis evaluates dose (time-integrated exposure) in units of total effective dose equivalent (TEDE) because health effects are dose-driven. Consequences from hazardous chemicals are generally based on the concentration of the material to which an individual is exposed, rather than a time-integrated dose. This document does not cover evaluation of chemical exposure.

3.5.1.2 Receptors and their Location

The receptor locations are conservatively selected to maximize the dose received by hypothetical receptors that represent populations of interest. The receptors of primary interest in evaluations involving atmospheric dispersion are:

- Offsite Public – The offsite public is represented by the MOI, a hypothetical receptor located at or beyond the Site boundary at the distance and in the direction from the point of release at which the maximum dose occurs.

- Onsite Public – The onsite public is characterized by a hypothetical receptor within the Site boundary at locations bounded by (1) the near bank of the Columbia River, (2) Highway 240 traversing the Site, and (3) Horn Rapids Road on the southern boundary of the Site at the distance and in the direction from the point of release at which the maximum dose occurs. Consequences to this receptor are used for informational reporting purposes only.
- Collocated Worker – The collocated worker is represented by a hypothetical onsite receptor located at the distance (not less than 100 m or at the boundary of the facility) from the point of release at which the maximum dose occurs. If the release is elevated, the onsite receptor is assumed to be at the location of greatest dose, which is typically where the plume touches down.

3.5.1.3 Calculation of χ/Q'

In the calculation of the atmospheric dispersion factor, χ/Q', the units of material may be expressed as mass (e.g., mg), activity (e.g., Ci), or volume (e.g., liters). For example, if a quantity of material expressed in terms of Ci, the χ/Q' has units of Ci/m^3 per Ci/s. This is condensed to s/m^3 as the units associated with the material cancel and, therefore, are arbitrary. For radiological exposures, the dose is cumulative, being proportional to the time integrated air concentration. If the release rate of the material and the atmospheric dispersion are assumed constant, a time-integrated dispersion coefficient is $(\chi T)/(Q'T)$, where T is the release duration (assuming this equals the exposure duration). Since the time factor T cancels, the time-integrated dispersion coefficient is equal to the χ/Q' if the release rate of the material and the atmospheric dispersion are constant. If the release rate varies over time, the release can be numerically divided into a number of segments which are then summed to calculate dose.

The values of χ/Q' used for consequence analysis are generated using the computer code GXQ, Version 4.0F (WHC-SD-GN-SWD-30002, *GXQ Program Users' Guide* and WHC-SD-GN-SWD-30003, *GXQ Program Validation and Verification*). GXQ reproduces the statistical treatment of the Hanford Site joint frequency meteorology specified in U.S. Nuclear Regulatory Commission Guide 1.145 (RG 1.145), *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants.* These values are based on nine-year averaged data (1983-1991) taken at the Hanford Meteorology Station.

RG 1.145 indicates that the larger of the "99.5 percent sector" and "95 percent overall" χ/Q' values should be used. Appendix A of STD-3009 indicates the 95 percent value should be used, and new analyses follow this guidance. The 99.5 percent sector value is usually slightly larger than the 95 percent overall value and is generally conservative for existing analyses that use it.[1]

For release durations up to one hour, the bounding integrated χ/Q' values used are the 95th percentile values overall. For release durations of between one and two hours, the integrated χ/Q' with plume meander (called the 2-hr χ/Q') are used. Plume meander accounts for enhanced horizontal spreading of the plume due to random changes in wind direction during light wind and

[1] GXQ can also produce a 95 percent normalized χ/Q' using the methods described in the GENII code. The numbers are similar to other χ/Q' but are not entirely consistent with Regulatory Guide 1.145; therefore, use of this option is not recommended.

relatively stable atmospheric conditions. Plume meander corrections are made according to the empirical model given in RG 1.145.

For accident conditions that leave a structurally-intact building, building wake χ/Q' values may be used. Building wake is the effect that a large structure has on the dispersion characteristics of the plume. RADIDOSE version 2.0 models building wake differently than recommended by RG 1.145. To correct the dose consequence results of RADIDOSE when applying building wake, it is necessary to multiply the calculated dose consequence by the ratio of the RG 1.145 building wake χ/Q' (from HNF-13007, *The 95th Percentile χ/Q' values for the Hanford Site*) to the RADIDOSE value.

> Note 1: This method for correcting consequence calculations is recommended because 1) it requires the user to run RADIDOSE and select the building wake option, ensuring this is documented in the output, and 2) GXQ is used for both values in the ratio, capturing any perturbations in the meteorological data.
>
> Note 2: Use of building wake for unmitigated analysis is limited to calculating MOI dose consequences. See Section 3.3.2.

Plume rise models may be used for fires that are outdoors or venting though a large breach in the facility. Note that the χ/Q' for a small fire is greater than that for a large fire. Therefore, it is necessary to perform parametric analyses or a sensitivity calculation to determine the bounding case.

As recommended in RG 1.145 for release durations greater than two hours, a logarithmic interpolation is made between the acute bounding χ/Q' with plume meander (i.e., the 2-hr χ/Q' values) and the chronic annual average χ/Q' values. The equations for logarithmic interpolation are:

$$\left(\chi/Q'\right)_T = \left(\chi/Q'\right)_{2hr}\left(\frac{T}{2\,hr}\right)^{slope}$$

where

T = release duration, and

$$slope = \frac{\log\left[\dfrac{(\chi/Q')_{1yr}}{(\chi/Q')_{2hr}}\right]}{\log\left[\dfrac{8760\,hr}{2\,hr}\right]}$$

For example, a receptor at 100 m with a ground release, the slope is

$$\text{Slope} = \log\left(4.03\times10^{-4}/9.40\times10^{-3}\right) / \log\left(8760/2\right) = -0.3756$$

The interpolation for eight hours is

$$\chi/Q' = 9.40\times10^{-3}\ (8hr/2hr)^{-0.3756} = 5.58\times10^{-3}\ s/m^3$$

Corrections may be appropriate for several mechanisms depending on the details of the accident scenario. In addition to plume meander, these mechanisms include plume depletion, momentum/buoyancy rise, building wake, and area source effects.

3.5.2 Breathing Rate

The default breathing rate value is $3.3 \times 10^{-4}\ m^3/s$, corresponding to the light activity breathing rate for adults.

3.5.3 Dose Conversion Factors

Federal Guidance Report Number 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,* established dose conversion factors (DCFs) based on the International Commission on Radiological Protection (ICRP) publications ICRP 26, *1977 Recommendations of the International Commission on Radiological Protection,* and ICRP 30, *Limits for Intakes of Radionuclides by Workers.* The ICRP modified its internal dose conversion model in 1990, which resulted in the generation of different DCFs, provided in ICRP 60, *1990 Recommendations of the International Commission on Radiological Protection,* and ICRP 61, *Annual Limits on Intake of Radionuclides by Workers Based on the 1990 Recommendations.*

ICRP 60 and 61 were subsequently updated by ICRP 68, *Dose Coefficients for Intakes of Radionuclides by Workers,* ICRP 71, *Age Dependent Doses to Members of the Public from Intake of Radionuclides, Part 4, Inhalation Dose Coefficients,* and ICRP 72, *Age Dependent Doses to Members of the Public from Intake of Radionuclides, Part 5, Compilation of Ingestion and Inhalation Dose Coefficients.* ICRP 68, 71, and 72 provide the DCFs that are used for most current Hanford DSAs and preferred by RL. ICRP 26 and 30 DCFs are still found in some analyses; however, their application in new analyses requires approval by RL on a case basis.

3.6 CONFIRM ACCIDENT SCENARIO ADEQUACY AND DOCUMENT RESULTS

Once the bounding, representative, and unique accident scenarios are developed and analyzed, it is necessary to review the remaining accidents and hazardous conditions not analyzed to determine whether all potential abnormal and accident conditions to which the facility could be subjected:

1. Are appropriately represented by one or more of the analyzed accidents
2. Are bounded by one or more of the analyzed accidents
3. Identify atypical characteristics or parameters that indicate the need for analyzing the condition as a unique accident

If the accidents analyzed are comprehensive and adequate, the accident analysis results should be documented both as the unmitigated case and with a preliminary assessment of the preventive or mitigative effect of candidate hazard controls. Final mitigated accident results should be developed only after formal control selection.

3.7 IDENTIFICATION OF POTENTIAL HAZARD CONTROLS

The results of the hazard evaluation and/or subsequent accident analysis indicate potential hazard controls whose function is mitigative (reduces the consequence of analyzed accidents) or preventive (reduces the frequency of analyzed accidents). Postulated accident scenarios can clarify the abnormal or accident conditions in which selected controls must function. The hazards evaluation and/or accident analysis indicates the safety significance of the preventive or mitigative features identified. Taken together, these factors help to refine the set of candidate hazard controls that the safety basis credits to perform a safety function.

Chapter 4 provides the process used to determine the hazard controls that are documented in the facility documented safety analysis and technical safety requirements.

4.0 CONTROL SET DEVELOPMENT

4.1 INTRODUCTION

This chapter provides the process for identification, selection, and development of hazard controls for HC-2 or 3 nuclear facilities, operations, and activities (including environmental restoration activities) based on the results of the hazard and/or accident analysis. The definition of hazard control by 10 CFR 830 is as follows:

> *"Hazard controls means measures to eliminate, limit, or mitigate hazards to workers, the public, or the environment including (1) physical, design, structural, and engineering features; (2) safety structures, systems, and components; (3) safety management programs; (4) technical safety requirements; and (5) other controls necessary to provide adequate protection from hazards."*

In this chapter, "controls" refers to those hazard controls that are derived from a facility hazard or accident analysis.

Safety SSCs should be designed, qualified, procured, installed, and maintained so that they will perform their safety function when called upon to do so during normal, abnormal, or accident conditions. DOE O 420.1A and its associated Guides provide requirements and guidance in these respects for new facilities and major modifications of existing facilities. For existing facilities, the design of designated safety SSC do not necessarily reflect new design codes and standards. In this case, compensatory measures, such as enhanced surveillance and maintenance or supplementary controls may be necessary to ensure that the required safety function can be performed or maintained under accident conditions.

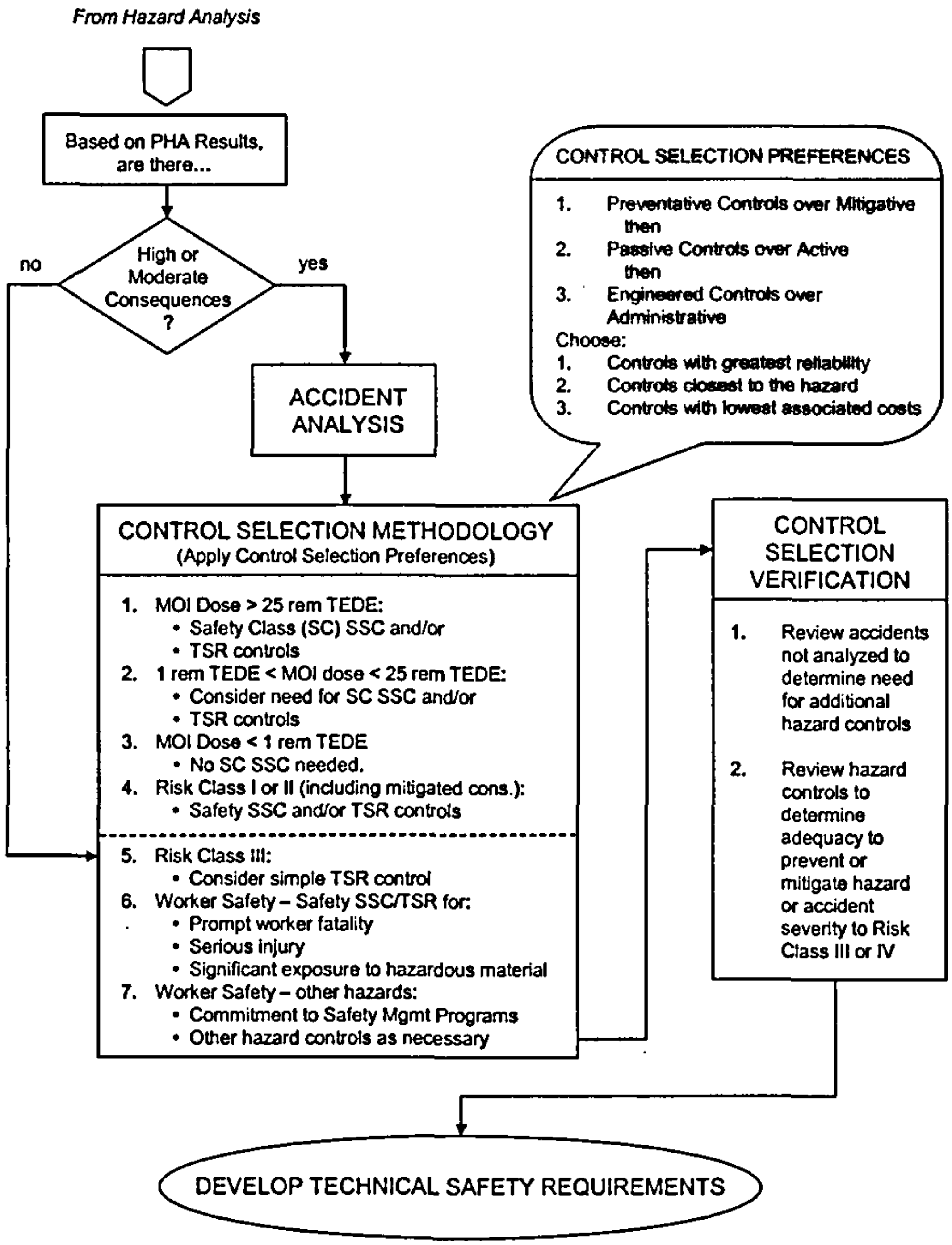
A quantitative criterion, the Evaluation Guideline of STD-3009, Appendix A, is used for designating safety class SSC for protection of the offsite public (i.e., the MOI). Safety significant SSC are those of particular importance to defense-in-depth and worker safety from other than standard industrial hazards, as determined in the hazard and accident analyses. While a quantitative criterion such as the Evaluation Guideline, is appropriate for designating safety class SSCs, safety significant SSC address risk for all individuals within the site and facility boundary and are based on more qualitative criteria. Establishing a quantitative dose/exposure guideline at any one point within the facility or site boundary creates an artificial distinction that distorts the process of systematically evaluating an SSC for the function performed and its relative importance to safety. While the use of such guidelines provides an additional perspective to be factored into the selection of controls, they serve only as a starting point for establishing a complete set of hazard controls for defense in depth and worker safety.

4.2 CONTROL SELECTION

The control selection process and control selection preferences are illustrated in Figure 4-1. The hazards analysis identifies physical and administrative features that can prevent or mitigate a hazardous condition or potential accident. These features are the starting point for selecting the set of controls relied upon by the facility to protect the public, workers, and the environment.

Step 4.2.1.A below applies when formal accident analysis is performed. Otherwise, control selection may proceed from Step 4.2.1.B.

Figure 4-1. Control Selection Process



4.2.1 Methodology

A. Where an accident analysis is performed, the following control selection methodology applies to each analyzed accident to determine safety significance of SSCs and the need for TSR-level controls:

1. MOI dose exceeds the Evaluation Guideline (EG) of 25 rem TEDE:
   - Designate safety class (SC) SSC, and/or
   - TSR-level control to preclude the accident or mitigate dose to below the EG.
2. MOI dose "challenges" the EG, i.e., is between 1 rem TEDE and 25 rem TEDE:
   - Consider need for TSR control and SC SSC. Provide basis for determination.
   - If TSR control and Safety Class equipment needed, specify as in B.1 above.
3. MOI dose is less than 1 rem TEDE:
   - No SC SSC designation needed.
4. Risk Class I or II frequency / consequences for the CW:
   - Designate safety significant SSC and/or
   - TSR controls to reduce accident severity to Risk Class to III or IV under mitigated conditions.

   Note: It is expected that all Risk Class I events are controlled with safety SSC and TSR-level controls. In those cases where it may not be practical to reduce accident severity to below Risk Class II, it is necessary to advise RL and determine a path forward.

B. The following control selection methodology applies to the results of the hazard or accident analysis to determine safety significance of SSCs and the need for TSR-level controls:

1. Risk Class III frequency / consequences:
   - Consider simple TSR-level or defense-in-depth controls when hazards are not controlled by safety management programs.
2. Worker Safety – Designate safety significant SSC and/or TSR controls where consequences to facility workers (exclusive of standard industrial hazards) include:
   - Prompt worker fatality
   - Serious injury (i.e., requires medical treatment for immediate life-threatening or permanently disabling injuries)
   - Significant radiological or chemical exposure

   Note: The control selection methodology for worker safety "represents a lower threshold of concern for which safety-significant SSC designation may be warranted. Estimates of worker consequences for the purpose of safety-significant SSC designation are not intended to require detailed analytical modeling. Considerations should be based on engineering judgment of possible effects and the potential added value of safety-significant SSC designation." [STD-3009, page xxvii]

3. Worker Safety – Hazards are less severe than in B.2 above:
   - Safety significant SSCs and/or specific TSR controls are not required
   - Evaluate need for non-TSR hazard controls to supplement HNF-11724

C. Where initial conditions rely on particular design features or administrative controls (see Section 3.3.2), determine whether these assumptions should be protected in the TSRs as Design Features or Administrative Controls.

4.2.2 Control Selection Preferences

Control selection preferences are as follows:

1. Preventative Controls over Mitigative Controls, then
2. Passive Controls over Active Controls, then
3. Engineered Controls over Administrative Controls.

Choose: The Controls with the greatest reliability, the Control closest to the hazard, and the Control with the lowest implementation and maintenance cost.

These control selection preferences are not required, but deviations should have a sound basis.

4.3 CONTROL SELECTION VERIFICATION

Once the final set of hazard controls are selected, it is necessary to review them as a set to verify their adequacy as follows:

1. Review accidents not formally analyzed to determine whether additional hazard controls are necessary.
2. Review the hazard controls to determine their adequacy to prevent or mitigate the severity of hazardous conditions or accidents to Risk Class III or IV.

4.4 TSR DEVELOPMENT

The following instructions apply to the derivation and content of TSR controls necessary to protect the health and safety of the public and to minimize risk to workers from the uncontrolled release of radioactive or other hazardous materials and from radiation exposure due to a nuclear criticality accident. This is provided by 10 CFR 830, §830.205 and Appendix B:

1. Base the TSRs on the facility DSA, according to the control selection methodology described in Section 4.2 above.
2. Prepare TSR controls that define the operating limits and surveillance requirements, the bases thereof, safety boundaries, and management or administrative controls.
3. Use the TSR content expectations of Table 4-1 and the guidance of DOE G 423.1-1 to prepare the TSR document. Variance from this guidance requires prior approval by RL.

In addition, DOE-STD-1186-2004, *Specific Administrative Controls,* provides guidance on the selection and development of SAC.

4.5 CONTROL REVISION

For facilities in life-cycle transition, specific criteria apply to the development of TSRs that establish "step-out" criteria to facilitate revision of controls as defined by applicability statements or modes. The step-out criteria define the point where the safety function is no longer required and the TSR is no longer applicable. This typically occurs when a facility or portion of a facility is "operationally clean" and the hazard no longer warrants controls over and above those provided by safety management programs.

For transition facilities, the following criteria apply:

- Limited conditions for operations will be clear, concise, and formatted so that applicability requirements, conditions, associated actions, and surveillance requirements are presented together.
- The TSR will include acceptance criteria for surveillances.

Limited conditions for operations should describe, as precisely as practical, the lowest functional capability or performance level of equipment, including needed redundancy, required for the safe operation of the facility. Applicability statements will transition from specific equipment requirements to functional specification as a facility moves through transition.

Table 4-1. TSR Content Expectations from 10 CFR 830, Appendix A.

As appropriate for a particular DOE nuclear facility, the section of the technical safety requirements on * * *	Will provide information on * * *
(1) Safety limits	The limits on process variables associated with those safety class physical barriers, generally passive, that are necessary for the intended facility function and that are required to guard against the uncontrolled release of radioactive materials. The safety limit section describes, as precisely as possible, the parameters being limited, states the limit in measurable units (pressure, temperature, flow, etc.), and indicates the applicability of the limit. The safety limit section also describes the actions to be taken in the event that the safety limit is exceeded. These actions should first place the facility in the safe, stable condition attainable, including total shutdown (except where such action might reduce the margin of safety) or should verify that the facility already is safe and stable and will remain so. The technical safety requirement should state that the contractor must obtain DOE authorization to restart the nuclear facility following a violation of a safety limit. The safety limit section also establishes the steps and time limits to correct the out-of-specification condition.
(2) Operating limits	Those limits which are required to ensure the safe operation of a nuclear facility. The operating limits section may include subsections on limiting control settings and limiting conditions for operation.
(3) Limiting control settings	The settings on safety systems that control process variables to prevent exceeding a safety limit. The limited control settings section normally contains the settings for automatic alarms and for the automatic or nonautomatic initiation of protective actions related to those variables associated with the function of safety class SSCs if the safety analysis shows that they are relied upon to mitigate or prevent an accident. The limited control settings section also identifies the protective actions to be taken at the specific settings chosen in order to correct a situation automatically or manually such that the related safety limit is not exceeded. Protective actions may include maintaining the variables within the requirements and repairing the automatic device promptly or shutting down the affected part of the process and, if required, the entire facility.
(4) Limiting conditions for operations	The limits that represent the lowest functional capability or performance level of safety structures, systems, and components required to perform an activity safely. The limiting conditions for operation section describes, as precisely as possible, the lowest functional capability or performance level of equipment required for continued safe operation of the facility. The limiting condition for operation section also states the action to be taken to address a condition not meeting the limiting conditions for operation section. Normally this simply provides for the adverse condition being corrected in a certain time frame and for further action if this is impossible.

Table 4-1. TSR Content Expectations from 10 CFR 830, Appendix A.

As appropriate for a particular DOE nuclear facility, the section of the technical safety requirements on * * *	Will provide information on * * *
(5) Surveillance requirements	Requirements relating to test, calibration, or inspection to assure that the necessary operability and quality of safety structures, systems, and components is maintained; that facility operation is within safety limits; and that limiting control settings and limiting conditions for operation are met. *If a required surveillance is not successfully completed,* the contractor is expected to assume the systems or components involved are inoperable and take the actions defined by the technical safety requirement until the systems or components can be shown to be operable. If, however, a required surveillance is not performed within its required frequency, the contractor is allowed to perform the surveillance within 24 hours or the original frequency, whichever is smaller, and confirm operability.
(6) Administrative controls	Organization and management, procedures, recordkeeping, assessment, and reporting necessary to ensure safe operation of a facility consistent with the technical safety requirement. In general, the administrative controls section addresses (1) the requirements associated with *administrative controls, (including those for reporting violations of the* technical safety requirement); (2) the staffing requirements for facility positions important to safe conduct of the facility; and (3) the commitments to the safety management programs identified in the documented safety analysis as necessary components of the safety basis for the facility.
(7) Use and application provisions	The basic instructions for applying the safety restrictions contained in a technical safety requirement. The use and application section includes definitions of terms, operating modes, logical connectors, completion times, and frequency notations.
(8) Design features	Design features of the facility that, if altered or modified, would have a significant effect on safe operation.
(9) Bases appendix	The reasons for the safety limits, operating limits, and associated surveillance requirements in the technical safety requirements. The statement for each limit or requirement shows how the numeric value, the condition, or the surveillance fulfills the purpose derived from the safety documentation. The primary purpose for describing the basis of each limit or requirement is to ensure that any future changes to the limit or requirement is done with full knowledge of the original intent or purpose of the limit or requirement.

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