

# Perspectives on Chemical Hazard Characterization and Analysis Process at DOE



## CHEMICAL Health & Safety

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## FEATURE

# Perspectives on chemical hazard characterization and analysis process at DOE

The United States (U.S.) Department of Energy (DOE) has a policy of Integrated Safety Management System (ISMS) that requires a hazard analysis and implementation of controls to protect the workers and public in an authorized hazard facility. The ISMS applies to all DOE facilities through DOE P 450.4, *Safety Management System Policy*, and DOE Acquisition Regulation (DEAR) clause 48 CFR 970.5223-1, *Integration of Environment, Safety, and Health into Work Planning and Execution*.

However, no DOE-order or standard currently exists that provides specific guidance for the development of safety basis (SB) documentation for non-nuclear facilities. Various DOE sites over the years have adopted individual site-specific chemical SB processes and documentation resulting in wide variations across the DOE complex. The CSTC Phase 1 report, *Current Chemical Hazard Characterization Practices in the DOE Complex* summarizes the variations in the DOE complex (CSTC 2003-C).<sup>1</sup>

In order to provide a common understanding of non-nuclear SB for chemical facilities, this report identifies various steps involved in developing a safety document that includes essential features of the five core steps of the ISMS. The SB development is an iterative process, but in general order of process completion, the listed steps for chemical, non-nuclear facility safety document are:

- Facility and work description;
- Hazard identification;
- Facility hazard classification – industry Process Safety Management (PSM) based versus DOE traditional based high/moderate/low classification;
- Hazard analysis – qualitative and/or semi quantitative;
- Identification of controls;
- Commitments to safety management programs (SMP);
- Document and approval process.

The non-nuclear SB process – (a) looks at different methodologies including hazard analysis from the chemical industry and DOE-STD-3009 nuclear facility-like approaches that can be used to implement each step, and (b) describes the advantages and disadvantages of various implementing methodologies that are either already in use or could be used by non-nuclear facilities.

To note, this report is *not* a proposed standard or guidance for chemical, non-nuclear safety document. This report outlines various steps and methodologies together with advantages and disadvantages associated with

**Abbreviations:** ACGIH, American Conference of Governmental Industrial Hygienists; AEGL, Acute Exposure Guidelines Level; AIChE, American Institute of Chemical Engineers; ALOHA, Areal Locations of Hazardous Atmospheres; ARCHIE, Automated Resource for Chemical Hazard Incident Evaluation; CBDPP, Chronic Beryllium Disease Prevention Program; CCPS, Center for Chemical Process Safety; CHC, Chemical Hazard Classification; ChSR, Chemical Safety Requirements; CSTC, Chemical Safety Topical Committee; DEAR, DOE Acquisition Regulations; DOE, Department of Energy; DSA, Documented Safety Analysis; EAL, Emergency Action Level; EG, Evaluation Guideline; EMP, Emergency Management Program; EPHA, Emergency Planning Hazards Assessment; EPA, Environmental Protection Agency; EPI (code), Emergency Prediction Information (Code); EPZ, Emergency Planning Zone; ERPG, Emergency Response Planning Guideline; ES&H, Environment; Safety and Health; ETA, Event Tree Analysis; FMEA, Failure Modes and Effects Analysis; FSP, Facility Safety Plan; FTA, Fault Tree Analysis; HAZOP, Hazard and Operability Study; HCP, Hazards Control Plan; HMIS, Hazardous Materials Identification System; IDLH, Immediately Dangerous to Life or Health; ISMS, Integrated Safety Management System; MACCS2, MELCOR Accident Consequence Code System; NIOSH, National Institute for Occupational Safety and Health; NNSA, National Nuclear Security Administration; OSHA, Occupational Safety and Health Administration; OSR, Operational Safety Requirements; PAC, Protective Action Criteria; PrHA, Process Hazard Analysis; PSM, Process Safety Management; RMP, Risk Management Program; RQ, Reportable Quantity; SAC, Specific Administrative Control; SAD, Safety Analysis Document; SB, Safety Basis; SC, Screening Criteria; SCAPA, Subcommittee on Consequence Assessment and Protective Actions; SER, Safety Evaluation Report; SMP, Safety Management Program; SSCs, Structures, Systems, and Components; TEDE, Total Effective Dose Equivalent; TEEL, Temporary Emergency Exposure Limit; TPQ, Threshold Planning Quantity; TQ, Threshold Quantity.

them. Each DOE/NNSA facility or site can determine the appropriate course of action based on the merits and demerits of each approach. Adoption of any step of the safety document is voluntary.

While intended for chemical, non-nuclear SB applications, the report may be useful in other related areas such as the emergency management program as required by DOE O 151.1B and explosive operations as required by 29 CFR 1910.109.

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## INTRODUCTION

Under the United States (U.S.) Department of Energy (DOE) Integrated Safety Management System (ISMS), DOE sites must ensure that hazards are identified and analyzed, engineering and administrative controls are implemented to protect the workers and public, and operations are properly authorized in an appropriately hazard classified facility. In essence, the ISMS provides the overarching authorization basis requirements to both nuclear and non-nuclear facilities as ISMS applies to all DOE facilities in accordance with DOE-P-450.4, *Safety Management System Policy*, and DOE Acquisition Regulations (DEAR) clause 48 CFR 970.5223-1, *Integration of Environment, Safety, and Health into Work Planning and Execution*. The DEAR clause requires contractors to apply the following guiding principles that relate to authorization basis:

- **Planning:** "Before work is performed, the associated hazards are evaluated and an agreed-upon set of ES&H standards and requirements are established which, if properly implemented, provide adequate assurance that employees, the public, and the environment are protected from adverse consequences".
- **Hazard Controls:** "Administrative and engineering controls to prevent and mitigate hazards are tailored to the work being performed and associated hazards". Emphasis should be on designing the work and/or controls to reduce or eliminate the hazards and to prevent accidents and unplanned releases and exposures.
- **Operations Authorization:** "The conditions and requirements to be satisfied for operations to be initiated and conducted are established and agreed upon". These

agreed-upon conditions by DOE and the contractor are requirements of the contract and binding by the contractor. The extent of documentation and level of authority for agreement shall be tailored to the complexity and hazards associated with the work and shall be established in a Safety Management System.

The operations authorization basis consists of safety basis (SB) requirements and environmental protection requirements. This report focuses only on the SB requirements or safety document that includes hazard identification, screening criteria, hazard analysis (qualitative and quantitative), selection of controls, and approval process.

Although, this report focuses on SB that is part of the ISMS, industrial hazards that are covered by Federal regulations and consensus standards also need to be addressed as part of the ISMS.

For nuclear facilities, 10 CFR 830, *Nuclear Safety Management*, Subpart B, adopted in January 2001, replaces earlier DOE Orders 5480.21, *Unreviewed Safety Questions*, 5480.22, *Technical Safety Requirement*, and 5480.23, *Nuclear Safety Analysis Report*.

For non-nuclear facilities, DOE Order 5481.1B, *Safety Analysis and Review System*, was cancelled in September 1995, and DOE-EM-STD-5502-94, *Hazard Baseline Documentation*, was cancelled in October 2001. As a result, there has been minimal guidance on SB for chemical, non-nuclear facilities. Various DOE sites over the years have adopted site-specific chemical SB processes and documentation that have resulted in wide variations across the DOE complex (Phase 1 report, CSTC 2003-C).<sup>1</sup>

**The purpose of this report is to identify those steps involved in the SB process or development of the**

safety document for chemical hazards at DOE non-nuclear facilities and to examine the different methodologies that may be used to implement each step. This report describes the *advantages and disadvantages* of various implementing methodologies that are either already in use or could be used by non-nuclear facilities to conduct an SB process for chemical hazards. While intended for SB applications, this report may be useful in other related areas that require hazards analyses.

For example, there are similarities between the Emergency Planning Hazards Assessment (EPHA), required by DOE-O-151.1B, and documented safety analyses that are compliant with 10 CFR 830, Subpart B. Hazards analysis data and results from Documented Safety Analyses (DSAs), or Process Hazard Analyses (PrHAs) in the case of a non-nuclear hazardous facility may be useful as a primary basis for conducting EPHAs. This includes the use of common baseline hazards information, equivalency of many accident initiators and similarity in consequence assessment models. This similarity also extends to some aspects of PrHA performed for hazardous non-nuclear operations subject to the OSHA Process Safety Management (PSM) and/or EPA Risk Management Program (RMP) requirements. This will help minimize the efforts needed to complete an EPHA. However, there are also additional features of the EPHA that go beyond the scope of DSAs and PrHAs.

In addition to the benefits that this report may provide to the emergency management program, some parts of the SB process may also benefit explosive facilities (29 CFR 1910.109) that are required to complete a process hazards analysis under the Occupational Safety and Health Administration (OSHA) PSM requirement (29 CFR 1910.119). "RELATED TOPICS" discusses these topics in more detail.

A non-nuclear facility referred to here may be a radiological facility, with below Hazard Category 3 quantities as defined in DOE-STD-1027; facilities that use or store explosives, accelerators, facilities that use or store hazardous chemicals, laboratories, bio-

logical research facilities, and general industrial type facilities.

#### APPLICABILITY

This report presents a proposed methodology that may be used for non-nuclear facilities or sites that have chemicals present that may represent a hazard to the worker, the environment, or the public. This report is not intended for facilities with only incidental or standard industrial usage of chemicals, such as the use of cleaning products in an office area.

**Note that this report is *not* a proposed standard or guidance for a Safety Basis (SB) process or safety document. This report simply outlines various SB steps and methodologies involved and their advantages and disadvantages associated with them, so that each site can decide on its own the merits and demerits of each approach. Adoption of any step of the SB process is voluntarily.**

#### RELEVANT GUIDANCE, REGULATIONS, AND DOE ORDERS

The United States (U.S.) Department of Energy (DOE) has an ISMS policy that requires hazard analyses and implementation of controls to protect the workers and public. The ISMS applies to all DOE facilities as required by DOE-P-450.4, *Safety Management System Policy*, and DEAR clause 48 CFR 970.5223-1, *Integration of Environment, Safety, and Health into Work Planning and Execution*. The DEAR clause requires DOE contractors to integrate environment, safety, and health into work planning and execution with guiding principles. The ISMS is further supported with additional relevant regulations and DOE orders.

Safety Basis for Hazard Category 1, 2, and 3 nuclear facilities is required by 10 CFR 830, Subpart B, *Safety Basis Requirements*. Previously, DOE required through DOE-O-5481.1B that non-nuclear facilities also develop SB documentation. Now, in essence, the ISMS DEAR clause provides the overarching safety basis requirements for non-nuclear facilities. There is not a

DOE order or standard that provides specific guidance for the development of SB documentation for non-nuclear facilities. Yet, there may be an expectation that non-nuclear facilities should also develop SB documentation for non-nuclear facilities. Various DOE sites over the years have adopted site-specific requirements for chemical SB processes and documentation resulting in wide variations across the DOE complex.

In addition to the ISMS, other DOE regulations, and Occupational Safety and Health Administration (OSHA), or U.S. Environmental Protection Agency (EPA) regulatory requirements may apply to non-nuclear facilities. Some sites take the position that hazards with existing Federal regulations and consensus standards are not unique hazards and already have sufficient controls identified and that the challenge is to consistently apply the controls. The following is a listing of requirements that have parts that can be related to the SB process or elements of the SB process. The list was adapted from DOE-HDBK-1163-2003, *Integration of Multiple Hazard Analysis Requirements and Activities* (Hazard Analysis Handbook).

- 10 CFR 830, *Subpart B, SB Requirements*
- 10 CFR 850, *Chronic Beryllium Disease Prevention Program*
- 29 CFR 1910 and 1926, *Various Hazard or Activity Specific OSHA regulations*
- 29 CFR 1910.109, *Explosives and Blasting Agents*
- 29 CFR 1910.119 and 29 CFR 1926.64, *Process Safety Management*
- 29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response*
- 40 CFR 302.4, *Designation, Reportable Quantities, and Notification*
- 40 CFR 355, *Emergency Planning and Notification*
- 40 CFR 372, *Toxic Chemical Release Reporting: Community Right to Know (This regulation is not directly related to SB, but is useful for reporting requirements)*
- 40 CFR 68, *Chemical Accident Prevention Provisions*

- 48 CFR 970.5204-2 (c)(2), *Laws, Regulations, and DOE Directives*
- DOE-G-151.1-1 V2, *Hazards Surveys and Hazards Assessments*
- DOE-G-420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-nuclear Facilities*
- DOE-M-440.1-1, *Explosives Safety Manual*
- DOE-O-151.1B, *Comprehensive Emergency Management System*
- DOE-O-420.1A, *Facility Safety*
- DOE-O-440.1A, *Worker Protection Management*
- DOE-P-450.4, *Safety Management System Policy*
- DOE-G-440.1, Locally enforced fire/building codes

This listing is not intended to imply that the requirements specifically drive the DOE-based SB process. Several of these regulations could be used as the basis for the SB process or development of safety document for non-nuclear facilities, such as *Chemical Accident Prevention Program (40 CFR 68) and Process Safety Management (29 CFR 1910.119)*. In addition, this list identifies multiple requirements for hazards analysis, and combining these multiple requirements into a single effort could minimize SB efforts as suggested by the *Hazards Analysis Handbook (DOE-HDBK-1163-2003, October 2003)*. Appendix A provides description of these CFR regulations and DOE orders.

#### A POSSIBLE SAFETY BASIS PROCESS

In compliance with the guiding principles of the DEAR clause and ISMS, there are some six main steps in developing SB documentation which include the essential features of the five core functions of the ISMS, as shown in Figure 1. The SB documentation development is an iterative process and can be developed using a graded approach. The key steps are as follows:

- **Facility and Work Description:** Describe the facility and define the work to be performed.



Figure 1. Five Core Steps of the ISMS (LANL, Laul 2001<sup>2</sup>; Cournoyer & Maestas 2004<sup>3</sup>).

- **Hazard Identification:** Identify hazards (e.g., chemical, physical, electrical, industrial) and potential initiators that could lead to an accident.
- **Facility Chemical Hazard Classification (CHC):** Performing a facility CHC is not required by the ISMS. However, it is an optional, useful step in the SB process. A facility CHC can be described in the facility and work description or hazard identification section or it can be a stand alone section.
- **Hazard Analysis (HA):** Perform hazard analysis that can be qualitative or quantitative depending on the nature of hazard and hazard facility (i.e., High, Moderate, and Low).
  - Qualitative HA is discussed using industry approach and DOE-STD-3009 nuclear facility-like approach, and various hazard analyses methodologies are discussed.
  - Quantitative HA (consequence/source term analysis) is discussed using various applicable chemical dispersion models.
- **Identification of Controls:** Develop hazard controls (e.g., engineered, administrative) to eliminate, limit, or mitigate identified hazards and to protect the workers and public. Define the process(es) for maintaining hazard controls.
- **Commitments to Safety Management Program:** Define commitments in terms of maintaining controls to perform work safely and ensure safe performance and operation of the facility.
- **Document and Approval Process:** Prepare SB documentation or safety document using the above steps. Approval is usually required or negotiated between the contractor and the field or site office of DOE/NNSA, depending on the level of the chemical hazard in the facility.

The details of each of the above steps are provided in the following sections.

#### FACILITY AND WORK DESCRIPTION

A thorough description of the facility, the chemical process system, and associated work activities being assessed are provided in this initial step. The description typically should include the site where the facility is located, the facility identification (e.g., building number and location), building configuration, and principal activities performed inside the facility. Site and facility description is provided to aid understanding of potential hazardous materials and operations.

These descriptions focus on facility features and work processes necessary to understand the hazard analysis and accident analysis, not just those structures, systems, and components (SSCs) important to safety. The descriptions may provide the following types of information.

- Overview of the facility, material inputs/outputs, mission, and history;
- Description of the facility structure and design basis;

- Description of the facility process systems and constituent components, instrumentation, controls, operating parameters, and relationships of SSCs;
- Description of bulk storage location and confinement systems;
- Description of the facility safety support systems;
- Description of the facility utilities, with schematic outline of the basic utility distribution systems;
- Description of individual processes within the facility.

The description of the individual process may include details on basic process parameters, summary of types and quantities of hazardous materials, process equipment, instrumentation and control systems and equipment, basic process flow diagrams, piping & instrumentation documents (P&IDs), and operational considerations associated with individual processes or the facility. Existing supporting documentation may be referenced. Summary of the referenced documentation may be provided for an understanding of how the referenced documentation furnishes information relevant to the SB documentation.

A summary description may be provided on compliance with local fire and building codes, as required by DOE O 440.1 on worker safety. The fire and building codes require that hazardous material present be properly controlled. If hazardous chemicals are present over specified limits in a given facility, descriptions may be provided on the special storage conditions, facility design, and controls available to mitigate these hazards.

Descriptions on meeting design requirements from DOE O 420.1A on facility safety, including descriptions of features to address fire protection and natural phenomena hazards (NPHs) (seismic, tornado, lightning, flooding) may be included in the discussion on code compliance. The discussion may include how DOE standards on NPH (DOE-STD-1020, -1021, -1022, -1023) are applied in addressing specific Performance Criteria (e.g., PC-1, PC-2, and PC-3) for various aspects of NPH to meet the requirements of DOE O 420.1A and associated DOE guides.

For a non-NPH event such as an aircraft crash, DOE-STD-3014 provides a guidance to evaluate if such an event is credible for a facility. If a credible event, this hazard analysis may need to be further evaluated. It should be noted, however, that chemical industry does not normally evaluate an aircraft crash in the PSM/RMP required process hazard analysis (PrHA).

Process operation descriptions, including identification of the organization responsible for the operation of the facility, may be provided to define the activities conducted in the facility. This step provides descriptions of the facility and processes to support assumptions used in the hazards analysis and, as required, accident analyses. Included are details on basic process parameters, including summary of location, types and quantities of hazardous materials, process equipment, instrumentation and control systems and equipment, basic process flow diagrams, and operational considerations associated with individual processes or the entire facility, including major interfaces and relationships between controls. The intent of these descriptions is to supply information to provide an understanding of the assessment of both normal and off-normal operations, the safety analysis and its conclusions, and insight into the types of operations for which safety management programs (SMPs) are developed.

Facility chemical hazard classifications (CHCs) may be described in the facility description. Currently, there is not a DOE driver or standard for facility hazards classification for non-nuclear facilities. DOE O 5481.1B and DOE-EM-STD-5502-94 provided guidance on facility CHC (e.g., High/Moderate/Low) but these have been cancelled.

Nonetheless, many DOE/NNSA sites still follow the same protocols based on their earlier practices or directives, which may vary. Typical examples are as follows.

- High-hazard facilities. Facilities with the potential for onsite and off-site impacts (consequences) to a large number of persons or for major impacts to the environment.
- Moderate-hazard facilities. Facilities with considerable potential for

onsite impacts to people or the environment, but, at most, only minor offsite impacts.

- Low-hazard facilities. Facilities with the potential for minor onsite and negligible offsite impacts to people or the environment.

However, the ISMS guide provides the following definitions on hazard classification that is also based on the consequences of unmitigated releases.

- Category 1: The hazard analysis shows the potential for significant off-site consequences.
- Category 2: The hazard analysis shows the potential for significant on-site consequences.
- Category 3: The hazard analysis shows the potential for significant localized consequences.

Typically, qualitative (and as appropriate, quantitative) assessments are provided to determine the impact of the release of hazardous materials and to provide a relative hazard classification such as High, Moderate, and Low or Category 1, 2, and 3, based on the unmitigated significance (consequences) of these releases. Thus, there seems to be a direct correlation between the two classification terminologies.

## HAZARD IDENTIFICATION

A hazards-based approach begins with a comprehensive identification of all types of hazards. This step identifies hazards in order to define the scope and structure of the safety document. Typically, general types of hazards (e.g., chemical, physical, electrical, kinetic energy) are first identified, and then process-specific and activity-specific hazards are identified for subsequent hazard analysis (HA).

Hazard identification may include the use of a check list, inventory, and a preliminary risk binning and other screening criteria to help determine the extent of the HA that should be performed. Standard industrial hazards, while not typically addressed in the HA, may be summarized in a table with a very brief description of the applicable industrial safety controls. The standard industrial hazards

can serve as initiators for accidents involving specific hazards present.

At a minimum, information adequate for proper hazard identification and categorization should be documented. The hazards of expected operations using the maximum planned quantities and types of hazardous material should be considered and listed. Non-specific hazards, including natural phenomenon hazard (NPH) driven, should be identified as potential initiators of events involving the specific hazards present.

Generally, the hazard identification processes involve the use of various tables that lists chemicals and their threshold planning quantities (TPQs), threshold quantities (TQs) or some other inventory-based indicator of the hazards associated with the chemicals present in the facility that is being evaluated. Many variations of hazard identification methodology are practiced, but the details vary depending on the complexity of their chemical safety analysis process. Typical hazards identification steps that may be used in a process are as follows:

- Identify chemicals and their hazards and processes that use them within the facility.
- Identify additional hazards such as chemical mixing hazards, chemical combustion hazards, and chemical incompatibility.
- Screen the chemical hazards against the regulatory criteria.
- Screen the chemical hazards against other criteria such as National Fire Protection Association (NFPA) or the Hazardous Materials Identification System (HMIS) ratings.
- Screen chemicals for common characteristics such as toxic, corrosive, reactive, unstable, shock-sensitive, time-sensitive, moisture-sensitive, light sensitive, or ignitable chemicals.

“Regulations with Lists” below discusses the regulations and orders that may be used for hazards identification. The type of facility and inventories of hazardous chemicals would dictate which of the following (typically more than one) would be best for the hazard identification portion of the process. There are three categories of regulation

and orders; those that have a specific list of chemicals of concern, those that are generic, and those that are specific to a single chemical. It should be noted that using the list-driven (inventory-driven) regulations out of context may introduce some inconsistencies when applied in SB hazard identification.

#### Regulations with Lists

There are many regulations that are used for inventory-based hazards screening and identifications. However, since each of these regulations was written with a specific purpose and objective in mind, using this list for hazards screening and identifications may lead to incomplete hazards identifications. Moreover, many inventory-based quantities were compromises between industry and the regulators and are not consistent with potential downwind impacts. However, these regulations provide an initial practical method to identify more generally recognized hazards. Readers may consult each enabling regulation for a better understanding for the purpose and objective.

#### **29 CFR 1910.119 and 29 CFR 1926.64, Process Safety Management**

This OSHA regulation currently lists 137 chemicals and their threshold quantities (TQs). It also includes and all flammable liquids and gases with a TQ of 10,000 lbs with a couple of exceptions for liquids. Typically these TQs are used to determine when industry is required to perform an in-depth analysis of the process (e.g., PrHA) to ensure the safety of the workers. Using these TQs to screen for chemicals that could be considered a hazard has advantages and disadvantages, which are as follows.

#### Advantages

- a. Using these TQs brings the DOE facility in line with requirements for private industry to perform special analyses when these limits are exceeded for a facility.
- b. Using these TQs is a simple and fast method for determining when hazardous quantities of specific chemicals that should be further analyzed are present.

- c. Using these TQs provides a list of chemicals that could be hazardous from many different perspectives (e.g., toxic, flammable, explosive, or corrosive).
- d. Processes and hazards for analyzing these chemicals are available from private industry to aid in any analysis.
- e. Using these TQs may enable a facility to impose limit on quantities of the chemical to below TQ levels and thus be exempt from this regulation (i.e., no need for a PrHA).

#### Disadvantages

- a. There are only 137 chemicals listed in this regulation, plus flammable liquids and gases with few exceptions for liquids. The vast majority of chemicals in DOE or private industry accidents are not listed on this list. For example sulfuric acid is only represented by oleum (fuming sulfuric acid).
- b. The list in this regulation does not correspond with lists obtained from other regulations. Therefore, a danger of improper overlap occurs when this regulation is used in conjunction with other regulations.
- c. Quantities of chemicals listed in this regulation could be much greater than that necessary to cause a severe accident. For example, the limit for ammonium perchlorate, which is either shock-sensitive or a Class 4 oxidizer depending on the particle size, is 7,500 pounds.
- d. Concentration thresholds are supplied for some chemicals. For example, for nitric acid at 94.5% and above the limit is 500 pounds. However, if the concentration of nitric is below 94.5% then this regulation does not apply.
- e. Reactive chemistry is not commonly addressed in PSM-listed chemicals and thus a PrHA should include chemical reactive hazards also, where possible.

#### **40 CFR 68, Chemical Accident Prevention Provisions**

This EPA regulation establishes a list of 140 regulated substances and their TQs for stationary sources concerning

the prevention of accidental releases to protect the public. It further establishes a list of toxic endpoints for offsite consequence analysis and sets the requirements for a Risk Management Plan (RMP) if TQs are exceeded. It is to note that only 40% of the RMP listed chemicals overlap with the PSM listed chemicals. The TQs for the RMP chemicals are usually higher than TQs for the PSM chemicals; because the RMP chemical process focuses towards protecting the public, while the PSM chemical process focuses towards protecting the worker.

#### **Advantages**

- Using these TQs is a simple and fast method for determining the presence of hazardous quantities of specific chemicals that should be further analyzed.
- Using TQ values puts in place requirements that are triggered by Federal requirements.
- Using these TQs may enable a facility to impose limit on quantities of the chemical to below TQ levels and thus be exempt from this regulation (i.e., no need for a PrHA).

#### **Disadvantages**

- Chemicals under this regulation are listed due to their health hazards or flammability. The list is limited to 77 toxic and 63 flammable substances, for a total of 140. The vast majority of chemicals in DOE or private industry accidents are not listed on this list. For example, HCN (hydrogen cyanide) is not on the list but is highly toxic.
- Chemicals listed are not consistent with chemicals listed in other enabling regulations. For example, ammonia in solution has a 29 CFR 1910.119 (PSM) threshold quantity (TQ) of 15,000 pounds (44% solution) and a 40 CFR 302 reportable quantity (RQ) of 100 pounds and a 40 CFR 355 threshold planning quantity (TPQ) of 500 pounds (10% solution) and a RMP TQ of 20,000 pounds (20% solution).
- Reactive chemistry is not commonly addressed in RMP listed chemicals and thus a PrHA should also

include chemical reactive hazards, where possible.

- There are many provisions in this regulation that could become confusing if used in a SB process, especially if this regulation is used in conjunction with other regulations. First, the three levels of reporting alluded to in this section are dependent upon both the product being present in quantities greater than a TQ and if an accident with the product had occurred within the previous five years. Second, this regulation is based upon a list of chemicals and their threshold quantities that would trigger the need to meet this regulation. This list of chemicals is of 140 items and does not coincide with other lists such as that found for the PSM standard (e.g., 40% overlap).
- One area where these lists do not coincide is in TQs. For example, the TQ for arsine in the PSM standard is 100 pounds while the TQ in this RMP standard is 1,000 pounds. There are other such examples (see table in "40 CFR 355, Emergency Planning and Notification").

#### **40 CFR 355, Emergency Planning And Notification**

This EPA regulation establishes the list of extremely hazardous substances, TPQ, and facility notification responsibilities necessary for the development and implementation of State and local emergency response plans. Chemicals are listed with an RQ and a TPQ value. Those chemicals not appearing on the list have an RQ and a TPQ of 10,000 pounds by default.

#### **Advantages**

- Using these RQs and TPQs is a simple and fast method for determining when hazardous quantities of specific chemicals that should be further analyzed are present.
- One can choose whether RQs or TPQs are used in the screening process.
- Using RQ and TPQ values puts in place requirements that are triggered by Federal requirements.

#### **Disadvantages**

- Chemicals listed in this regulation are listed due to their health hazards. Chemicals with other hazards (e.g., Na and K) are not listed, and are thus automatically defaulted to the 10,000-pound limit while a similar material with respect to reactivity, but not toxicity, phosphorous pentachloride (PCl<sub>5</sub>), has an RQ and TPQ of 500 pounds.
- Chemicals listed are not consistent with chemicals listed in other regulations. For example anhydrous ammonia gas has a 29 CFR 1910.119 (PSM) TQ of 10,000 pounds and 40 CFR 302 RQ of 100 pounds and a 40 CFR 355 TPQ of 500 pounds.
- Chemical RQ and TPQ values are not consistent with screening values from other regulations.
- RQ and TPQ values from this list vary from being the same to having a 500-fold difference, which can cause confusion.

#### **40 CFR 302.4, Designation, Reportable Quantities, and Notification**

This EPA regulation identifies RQs for a list of hazardous substances, and sets forth the notification requirements for releases of these substances. This regulation also establishes reportable quantities for hazardous substances designated in the Clean Water Act (CWA).

#### **Advantages**

- Provides a detailed list of substances with regulatory limits.
- A fast way of identifying the relative risk of a reportable release vs. the amount of a substance in a facility.

#### **Disadvantages**

- Inconsistent use of chemical nomenclature when compared to lists supplied in other regulations as shown below.
- Using this list and associated quantities in a process can become confusing. The list in this regulation does not coincide with lists from other regulations such as PSM or

40 CFR 68 (RMP). Items that are on this list may not be present on other lists. Hazardous materials such as arsine are listed on the PSM list and the list from 40 CFR 68 but are absent from this regulation.

- c. Likewise, hazardous materials on this list may not be found on any other list. Another difficulty is that RQs and TQs from the various lists do not coincide and there is no relationship between the RQ and TQ values from these lists.
- d. As with other regulations listed above, there could be difficulties if the list of extremely hazardous substances (EHSs), RQs TPQs, and TQs is used in the SB process. This difficulty stems from inconsistencies between those items listed in these various lists and differences between listed quantities. For examples, see the table below.

Chemical	29 CFR 1910.119 TQ (lbs)	40 CFR 68 TQ (lbs)	40 CFR 302 RQ (lbs)	40 CFR 355 TPQ (lbs)
Arsine	100	1,000	–	100
Fluorine	1,000	1,000	10	500
Methyl isocyanate	250	10,000	10	500
Hydrogen chloride	5,000	5,000	5,000	500

As can be seen in this table there is no relationship between these lists or the various quantities listed. In some cases (e.g., arsine, methyl isocyanate) values for 29 CFR 1910.119 are 10 to 40 times less than 40 CFR 68, while in other cases they are the same (hydrogen chloride, fluorine). Values from 40 CFR 302 range from being equal to 29 CFR 1910.119 and 40 CFR 68 (RMP) or much greater than 40 CFR 355 (hydrogen chloride) to being up to 50-fold less than 40 CFR 355 values and up to 1,000 times less than 40 CFR 68 (methyl isocyanate). This table shows how the use of these inventory-based regulations by themselves could lead to some confusion, and thus requires careful consideration and integration.

#### Generic DOE Orders

##### **DOE-O-420.1A, Facility Safety**

This DOE order establishes facility safety requirements related to nuclear safety

design, criticality safety, fire protection, and NPHs mitigation. Portions of this order apply to non-nuclear facilities.

#### Advantage

- Familiarity with nuclear safety documentation makes it relatively easy to develop a plan for non-nuclear facility. This order provides requirements and criteria for assessing fire and NPH.

#### Disadvantage

- For a non-nuclear facility, only two types of hazards are addressed (e.g., fire and NPH) and this order lacks guidance on a graded approach.

#### **DOE-O- 440.1A, Worker Protection Management**

This DOE order establishes the framework for an effective worker

protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE Federal and contractor workers with a safe and healthful workplace.

#### Advantages

- Provides a list of codes and standards to follow.
- Provides a detailed list of requirements beyond the code.

1910.1001 – Asbestos

1910.1003 – 13 carcinogens  
(4-nitrobiphenyl, etc.)

1910.1006 – Methyl chloromethyl ether

1910.1008 – bis-Chloromethyl ether

1910.1010 – Benzidine

1910.1012 – Ethyleneimine

#### Disadvantage

- Does very little to assist in identifying the hazard except to reference the codes and standards.

#### Single Chemical Regulations

##### **10 CFR 850, Chronic Beryllium Disease Prevention Program**

This health and safety regulation establishes a chronic beryllium disease prevention program (CBDPP) that supplements and is integrated into existing worker protection programs that are established for DOE employees and DOE contractor employees.

#### Advantages

- Hazard identification is simple, “Is beryllium present?”
- Not applicable, if beryllium is not present.

#### Disadvantage

- Some of the requirements are vague, leading to inconsistent implementation. For example, sampling for beryllium is required, however, the sampling technique, which can dramatically affect detection limits and results, is not specified. On the other hand, toxicity and dose/exposure are independent of detection limits.

##### **Chemical-specific OSHA Regulations as Found in 29 CFR 1910 and 29 CFR 1926**

There are many chemicals that have specific OSHA regulations as found in 29 CFR 1910 and 29 CFR 1926. The 1910 refers to facility operation and 1926 refers to construction. While many chemicals overlap between 1910 and 1926, only one regulation is cited for those chemicals. These are shown below.

1910.1002 – Coal tar pitch volatiles  
1910.1004 – Alpha-naphthylamine

1910.1007 – 3,3'-Dichlorobenzidine  
(and its salts)

1910.1009 – Beta-naphthylamine

1910.1011 – 4-Aminodiphenyl

1910.1013 – Beta-propiolactone

1910.1014 – 2-Acetylaminofluorene  
 1910.1016 – *N*-Nitrosodimethylamine  
 1910.1018 – Inorganic arsenic  
 1910.1027 – Cadmium  
 1910.1029 – Coke oven emissions  
 1910.1045 – Acrylonitrile  
 1910.1048 – Formaldehyde (formalin)  
 1910.1051 – 1,3-Butadiene  
 1926.62 – Lead  
 1926.1112 – Ethyleneimine  
 1926.1144 – 1,2-Dibromo-3-chloropropane

1910.1015 – 4-Dimethylaminoazobenzene  
 1910.1017 – Vinyl chloride  
 1910.1025 – Lead  
 1910.1028 – Benzene  
 1910.1044 – 1,2-Dibromo-3-chloropropane (DBCP)  
 1910.1047 – Ethylene oxide  
 1910.1050 – Methylenedianiline  
 1910.1052 – Methylene chloride  
 1926.1110 – Benzidine  
 1926.1113 – Beta-Propiolactone  
 1926.1148 – Formaldehyde

- RQ 40 CFR 302
- TPQ 40 CFR 355
- TQ 29 CFR 1910.119
- TQ 40 CFR 68

**The chemicals that do not screen out can be further evaluated for hazard and accident analysis, either qualitatively or quantitatively, and the selection of controls.**

All hazards below the screening criteria should be evaluated by the techniques listed in the ISM. Chemicals not appearing on the RQ list should be checked for the hazard characteristics in the TPQ and TQ, and chemical industry references such as Sax' "Dangerous Properties of Industrial Materials" or the National Institute for Occupational Safety and Health (NIOSH).

#### *Advantage*

- a. Using the proper RQ, TPQ and TQ values for screening, the facility can be classified accordingly and hazards can be further analyzed with graded approach and appropriate controls.

#### *Disadvantage*

- a. Some chemicals do not have a published RQ or TPQ or TQ values for screening, which may increase the difficulty in classifying the facility and hazards, even with graded approach.

#### *Physical Hazards*

There are other common facility or process hazards such as pressure, temperature, and voltage, that may be screened out. However, they can serve as initiators for accidents involving chemical hazards. Flammable materials, leaking of materials, and equipment failure are other examples of common hazards, which can serve as initiators for accidents. The following table provides some examples:

#### **Chemical of Concern**

Hazard	Screening Criteria
Asphyxiant	Oxygen <19.5%
Explosive	Class A, B, C in 49 CFR 173

#### *Advantages*

- a. Hazard identification is simple, is the chemical present?
- b. If you don't have it, the regulation is not applicable.

#### *Disadvantages*

- a. Some overlap between 1910 and 1926 regulations, which may cause confusion.
- b. 1910 speaks to facility operation, while 1926 speaks to construction therefore the implementation is different. Caution should be used to select the most appropriate standard on mission activities and apply consistently.

#### **Additional Hazard Evaluation (AHE)**

Many DOE sites use an additional hazard evaluation (AHE) due to the possibility of the mixing of chemicals or incompatible chemicals that could cause violent exothermic chemical reactions such as a detonation (explosion) or deflagration. An unplanned mixing of chemicals could be the result of mechanical failure or human error such as the introduction of an incorrect feedstock. For example, adding nitric acid to a process designed for sulfuric acid or adding 70% nitric acid where 25% nitric acid was required can result in off-normal conditions. The consequences of mixing could include a rapid temperature rise, toxic gas release, fire, deflagration or detonation.

A method for determining whether or not a chemical is incompatible

should be developed as a tool to assist in reducing the possibility of inadvertent mixing of incompatible chemicals.

#### *Advantages/Disadvantages*

- a. Identify chemicals that may have incompatibility for proper storage and handling. Process knowledge should be used for chemical mixing and associated hazard assessment for these chemicals. Savannah River Site (SRS) in its WSRC-IM-97-9 manual<sup>4</sup> cites a comprehensive listing of numerous incompatible chemicals.
- b. If process knowledge is not used in chemical mixing, inadvertent mixing of chemicals may result in:
  - Heat generation;
  - Fire;
  - Deflagration;
  - Detonation (Explosion);
  - Violent exothermic reaction;
  - Toxic fumes.

Non-chemical hazards such as mechanical equipment failure, wrong concentration of a material or leak in a system, etc., can trigger chemical hazards that should also be considered in an AHE.

#### **Common Hazards Screening Criteria**

##### *Screening criteria*

Common characteristic properties of hazardous chemicals are usually NFPA ratings; toxic, corrosive, reactive, ignitable, and incompatible chemicals. Thresholds that may be used for screening include

(Continued)

Hazard	Screening Criteria
Flammable Pressure	NFPA Class I or II >3,000 psig
Temperature	Can act as an initiator: Exceeds flash point, volatilize low vapor pressure chemical, increase pressure

### FACILITY CHEMICAL HAZARD CLASSIFICATION (CHC)

Cancelled DOE-O-5481.1B and DOE-EM-STD-5502-94 provided guidance on facility chemical hazard classification (CHC) (e.g., high/moderate/low), criteria for categorization (consequence, inventory), safety analysis details, and approval authority. Although many DOE/NNSA sites are still following the same protocols based on their earlier practices or these directives may be still in their contract terms, currently there is no DOE directive or guidance for the facility CHC, screening criteria, selection of controls, level of safety analysis, and approval authority. Each site is following its own protocol of chemical safety analysis practices negotiated with the local field or site office.

Two approaches are viable in the DOE/NNSA complex: 1) industry standard – OSHA (PSM) and EPA (RMP) regulations that do not require traditional facility hazard classification; and 2) traditional CHC that is based on inventory or consequence. Both approaches are discussed as follows.

#### Industry Standard (OSHA – PSM; EPA – RMP)

DOE/NNSA sites are required to follow the CFR regulations of OSHA and EPA and their use may be required through State Facility Agreement (agreement between State and DOE/NNSA). A site can select an approach suitable to its depth of analysis pertinent to meet the requirements of applicable regulations such as 40 CFR 68 (RMP) and 29 CFR 1910.119, TQ for process safety management (PSM), 40 CFR 355, TPQ for emergency planning and notification,

and 40 CFR 302, RQ for spill control for reportable quantities and notification and clean up.

Some DOE sites find that these three layers of control of chemicals addressing environmental, emergency response, and safety provide sufficient controls to identify chemical hazard and that the greater challenge is to consistently apply the controls. **These regulations do not require facility CHC**, which is an advantage with this approach. However, this approach should be in concurrence with the field or site office of DOE /NNSA.

The OSHA PSM is an industry standard for industrial hazards and focuses mainly towards workers (~100 m). However, it may also be used as part of the DOE's ISMS. The PSM has 14 elements that are geared towards safety management of facilities, operations, technologies, and personnel. These 14 elements are described as follows:

1. Employee participation
2. Process safety information
3. **Process hazard analysis (PrHA)**
4. Operating procedures
5. Training
6. Subcontractor safety
7. Pre-start up safety review
8. Mechanical integrity
9. Non-routine work authorization
10. Management of change
11. Incident investigation
12. Emergency planning and response
13. Compliance audit
14. Trade secrets.

The PSM rule is a performance-based regulation; it does not prescribe how each element is to be implemented. Two DOE handbooks (DOE-HDBK-1100-2004 and DOE-HDBK-1101-2004) have been developed to suggest approaches to effectively implement the 14 elements. This section focuses on the process hazard analysis (PrHA, Element #3). If a chemical inventory exceeds the 29 CFR 1910.119 (PSM) TQ, then it is a PSM facility and a PrHA can be performed using techniques such as

- What-If/Checklist or analysis
- Hazard and Operability (HAZOP) analysis
- Failure Mode and Effects Analysis (FMEA)

- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)

These techniques are discussed in "HAZARD ANALYSIS." The PrHA typically identifies hazards, assesses hazards of the process, examines causes and consequence of potential accidents, and identifies engineered and administrative controls. The selection of controls is usually based on risk (product of frequency and consequence) rather than on either likelihood of occurrence (frequency) or severity of consequence (DOE-HDBK-1100-2004, Section 3.2.8). The PrHA is *qualitative* (see Table 1, "HAZARD ANALYSIS"). The PSM focuses mainly on worker safety.

The PSM program evaluates and analyzes all process hazards and provides the needed set of controls to protect the worker. The requirements in terms of safety analysis are not extensive for a PSM facility. The format and content of a safety document and approval authority should be negotiated with the DOE/NNSA field or site office.

The 40 CFR 355 TPQ, *Emergency Planning and Notification*, and 40 CFR 302.4 RQ, *Designation, Reportable Quantities, and Notification*, when coupled with an institutional chemical management program, industrial hygiene program, worker safety program, and ES&H program with controls in place are adequate to meet the regulatory requirements to protect the public.

The 40 CFR 68 TQ, *Accidental Release Prevention Requirements: Risk Management Programs Under Clean Air Act*, requires the submittal of a single RMP that analyzes the worst case release scenario for regulated substances at site boundary (public) that exceed their TQs. The TQs in 40 CFR 68 are usually higher than TQs in PSM. The format and content of a safety document and approval authority should be negotiated with the DOE/NNSA field or site office.

**If a site adopts the PSM Rule, the PrHA is primarily qualitative and then qualitative or quantitative evaluations of frequency, consequence, and risk binning are not required. However, if a site adopts traditional**

**Table 1. An Example of a Hazard Evaluation Table (Qualitative HA)**

Event No.	Event Category	Hazard	Event Description/ Consequence	Causes	<i>Existing Controls</i>	
					Preventive (P)	Mitigative (M)
1	Fire	Flammable material; toxic release	Medium fire. In backpulse Chamber Areas results in release of toxic smoke or gases. Worker injury onsite-1, onsite-2, and offsite exposure.	Miscellaneous combustibles, hydrogen from uninterrupted power source battery, and ignition sources. Electrical short. Thermal energy from electrical equipment. Friction from belts.	Design: • Electrical equipment, P • NFPA standards, P • Fire detection. and suppression, M • Building ventilation, M  Administrative: • Combustible material control, P • Trained personnel, P, M • Standard operating procedure, P • Fire Dept. response, M • Emergency Operation Procedure, M	
2	Acid spill	Acid release	Nitric acid spills when a holding tank ruptures. Worker injury and floor damaged, and onsite release.	Human error. Equipment failure.	• Berm, P • Personal Protective Equipment, M • Trained personnel, P, M • Emergency Operating Procedures, M	
3	Explosion	Flammable gas	Flammable gas detonation in Lab area, while working with filtrate solution (50 gal) of toxic material, leading to an explosion. Onsite burns and worker injury and offsite exposure.	Explosive material: Oxygen diffuses into vapor space and mixes with flammable gas (e.g., benzene) and ignition sources. Electrical short. Thermal energy from electrical equipment. Friction from belts.	Design: • Hood design, P • Nitrogen supply, P • Fire detection & suppression, M • Building ventilation, M  Administrative: • Combustible material control, P • Trained personnel, P, M • Emergency Operating Procedures, M	

CHC based on inventory or consequence criteria, then qualitative or quantitative evaluations of frequency, consequence, and risk binning may be applicable depending on the type of facility (e.g., high/moderate).

#### *Advantages*

- PSM does not require CHC such as High/Moderate/Low.
- Does not require quantitative evaluation of frequency, consequence and risk.
- Controls are usually based on risk, and requirements focuses primarily towards worker.

d. Safety document requirement is short.

e. May not require DOE field office approval, however, this should be negotiated.

#### *Disadvantages*

- There is no hierarchy in hazard classification to better define a facility.
- PSM lists only 137 chemicals. There are many other chemicals in the DOE complex, for which there are no PSM thresholds available.
- PSM is focused primarily on workers, but potential consequences to

the public may be of concern for some sites that have a short site boundary distance (e.g., LLNL).

- In some cases, quantitative evaluation of consequence may be required as a bounding case for a short site boundary.

#### **Facility Chemical Hazard Category (Traditional Practice)**

For non-nuclear facilities, many DOE sites use facility CHC typically high, moderate, and low or high/low or moderate/low based on inventory or consequence criteria. There are wide variations in the facility CHC terminol-

ogy and the screening criteria (inventory or consequence) as noted in Table 4 of the Phase 1 report (CSTC 2003-C).<sup>1</sup> A typical example of each is as follows.

#### Inventory example:

<b>High (H)</b>	$\geq 29$ CFR 1910.119 TQ or $\geq 40$ CFR 68 TQ
<b>Moderate (M)</b>	$< 29$ CFR 1910.119 TQ - $\geq 40$ CFR 355, TPQ
<b>Low (L)</b>	$< 40$ CFR 355, TPQ - $\geq 40$ CFR 302, RQ

The use of 40 CFR 68 TQ, *Risk Management Program* is not common for CHC, because the thresholds (TQs) for chemicals in 40 CFR 68 are 4 to 10 times higher than in 29 CFR 1910.119 (PSM), which may increase the exposure for the worker and public.

The inventory criteria is suitable for sites where the site boundary distances are large (e.g., Hanford and SRS, where the site boundary exceeds 5 km), which provides an adequate safety for the public because the consequences are minimal at the site boundary.

#### Consequence example<sup>a</sup>:

<b>High (H)</b>	$\geq$ ERPG-3/TEEL-3 or $\geq$ ERPG-2/TEEL-2 @ site boundary (offsite)
<b>Moderate (M)</b>	$\geq$ ERPG-3/TEEL-3 or $\geq$ ERPG-2/TEEL-2 @ onsite (100 m)
<b>Low (L)</b>	$\geq$ ERPG-3/TEEL-3 or $\geq$ ERPG-2/TEEL-2 @ 10–30 m (local worker) <sup>b</sup>

<sup>a</sup> Definitions of ERPG-1,-2,-3 and TEEL-1,-2,-3 are provided in a later section on “Definition of Regulatory Limits and Guidelines”. If ERPG-2 or -3 values are not available, TEEL-2 or -3 values could be used (Craig and Lux, 1998).<sup>5</sup> Selection of ERPG/TEEL-3 or 2 criteria may be in concurrence with field or site office. Consequence estimate may not be reliable for  $< 100$  m; qualitative estimate may be used.

<sup>b</sup> TBD by local site. Worker distance of 10–30 m is flexible and can be determined by the local field or site office depending on the location and nature of the process involved.

ERPG-3/TEEL-3 or ERPG-2/TEEL-2 can be used for each hazard class, depending on the site boundary distance and the presence of public near the site boundary, and the nature of chemicals. If the site boundary is close to the public, ERPG-2/TEEL-2 is typically used (e.g., LLNL).

The consequence criteria is useful for sites where the site boundary distances are short (e.g., 200–600 m), and consequences to the public may be a concern. The ERPGs/TEELs values provide a gauge of some level of potential consequences for any concern for

the public, which is an advantage over the inventory or PSM criteria. “CONSEQUENCE/SOURCE TERM ANALYSIS” discusses the consequence analysis.

#### Hybrid criteria

Both inventory and consequence criteria may be used to determine CHC. For example, the initial CHC can be based on inventory criteria, while the final CHC can be based on consequence criteria (ERPG-3, -2, or -1).

The ERPG/TEEL guidelines are used at Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Oak Ridge-Y12, Pantex, Rocky Flats Environmental Technology Site (RFETS), and West Valley because of the short

and 60 min, 4 hr and 8 hr) and three severity levels (AEGL-1,-2,-3). It is anticipated that ERPGs values may be replaced by AEGL values. The specific AEGL to be used is the 60-minute AEGL; particular levels, such as AEGL-3 and AEGL-2 are the same as ERPG/TEEL-3 and -2. See <http://www.orau.gov/emi/scapa/teels.htm>.

#### Advantages

- There is a hierarchy in CHC to better define a facility based on inventory or consequence criteria.
- The level of controls can be better selected based on the CHC to protect the workers and public.
- Quantitative consequence exposure can be evaluated for the worker and public.

#### Disadvantages

- Safety document requirements for High and Moderate CHC may be more extensive than in PSM requirement by OSHA.
- Some DOE/NNSA sites require approval for all CHC.
- Quantitative Consequence for  $< 100$  m may not be reliable unless the ARCON96 code is used for dispersion calculations.
- ERPGs/TEELs address only toxicity and may not take into account other chemical and physical hazards (e.g., flammability, deflagration, detonation).

## HAZARD ANALYSIS

Hazard analysis (HA) provides a structured approach for evaluation of those process-related, NPH, and man-made hazards from non-nuclear facility activities that potentially could impact facility workers, collocated workers, and the public.

Hazard analysis systematically identifies facility hazards and accident potentials, providing these assessments through hazard identification and hazard evaluation techniques. The HA addresses the credible range of hazards and accidents anticipated for a facility. Typically, a qualitative approach is used in HA to support non-nuclear facilities SB development,

including specifically addressing the protection of workers and the public and providing for defense in depth.

There are different approaches to hazard analyses. A graded approach may be useful (see the ISMS guiding principles). It is important that all hazards are analyzed one way or another and the process is systematic and consistent. For hazards that are common in industry (often called standard industrial hazards), consensus standards such as OSHA and EPA standards dictate necessary hazard controls. DOE-unique hazards or common hazards resulting in the release of significant quantities of material or unique applications, or hazards that could initiate an event of significant consequence should be the primary focus of hazards analyses. A screening process may be useful to identify hazards needing detailed analysis.

Chemical hazards addressed in hazard analyses may include toxicological, flammability, explosive, reactive, and other hazardous aspects. Each identified hazard is evaluated to characterize relative risk (i.e., in terms of consequences and expected frequency) of unmitigated hazard scenarios. These analyses can also include a preliminary identification of control options that would prevent or mitigate a malfunction or an upset condition that leads to accident occurrences.

#### Comparison of Industry and DOE-STD-3009 Approaches

Section 2.5 of the Phase 1 report (CSTC 2003C)<sup>1</sup> shows that several methods are used across the DOE complex to perform hazard analyses. The methods used generally fall into one of two categories: a) a chemical industry approach and b) an approach based on DOE-STD-3009 for nuclear facilities. These approaches are discussed below:

##### Chemical Industry Approach

The primary references of the chemical industry for hazard evaluation are the PSM approach, and the Center for Chemical Process Safety (CCPS) book *Guidelines for Hazard Evaluation Procedures, Second Edition with Worked Examples* (AIChE, 1992).<sup>6</sup> The PSM

standard is often used by the chemical industry as good practice even for facilities that fall below the TQs of highly hazardous chemicals. The PSM standard lists six hazard evaluation techniques, although it allows other equivalent methodologies. The CCPS book describes in detail the six listed PSM methods, plus six additional methods are also described. It points out that some of the methods are "broad brush" techniques most useful early in the design process, others are good for detailed analysis, and still others are applicable to special situations. A number of the techniques focus on developing a list of recommendations for improvements to the process or facility. Several of the techniques suggest identifying "safeguards", which are engineered or administrative controls that prevent or mitigate the hazards.

##### Advantages

- a. This method provides consistency with the chemical industry approach, which may be easier to implement for contractors whose workforce has come largely from private industry.
- b. The analysis may be simpler and require fewer resources than using the DOE-STD-3009-like approach.

##### Disadvantages

- a. The analysis may not identify safeguards, and may not identify which are the most important controls. It will likely not analyze the ability of important controls to perform identified safety functions.
- b. There may be hazards that have not been recognized.

##### DOE-STD-3009-like Approach

This approach uses the basic methods for hazard evaluation as established in DOE-STD-3009, which starts the same as the chemical industry approach: by picking a hazard evaluation methodology from the chemical industry. Then accidents that can cause release of hazardous materials or energy are analyzed. This analysis includes a qualitative estimation of the frequency and consequences of each event and a list-

ing of engineered systems and administrative controls that would prevent or mitigate the scenario. Typically, the frequency and consequences are both estimated as *unmitigated*, which is before controls are applied. A best practice is to also estimate *mitigated* frequency and consequences, which is after controls are applied, to show the effectiveness of controls for potential accidents that affect both the worker and the public.

Engineered systems and administrative controls that significantly contribute to preventing an accident or reducing its consequences may be identified for special treatment to ensure they will perform their safety functions when needed. A further extension of this method used by some sites includes binning hazard scenarios by risk (considering both frequency and consequences) to identify scenarios that require more detailed analysis.

DOE-STD-3009 does not specify which hazard evaluation methodology to use. Instead, it refers the reader to the American Institute of Chemical Engineers, CCPS, *Guidelines for Hazard Evaluation Procedures, Second Edition with Worked Examples* (AIChE, 1992).<sup>6</sup> This reference is cited by DOE-STD-3009 Change Notice 2 as applicable to hazards analysis at non-reactor nuclear facilities and is considered appropriate for use at non-nuclear facilities. An appropriate hazard analysis technique can be chosen from several available standard methods that are widely used by government and industry, as described in the CCPS guidelines.

##### Advantages

- a. The analysis identifies safeguards, and supports identifying which are the most important ones. It also supports analyzing the ability of important controls to perform identified safety functions.
- b. The method has well defined binning of frequency, consequence, and risk rankings to establish with the level of rigor needed.
- c. The method is consistent with the SB approach for nuclear facilities, so contractors can use the same basic approach to perform hazard

analyses for nuclear and non-nuclear facilities.

### Disadvantages

- DOE-STD-3009-like analysis may be more structured and complex and require more resources than using the chemical industry approach.
- DOE-STD-3009-like approach uses other nuclear standard and nuclear terminology, which clouds the compliance issues.
- The airborne release fraction/release fraction (ARF/RF) values for chemicals and other hazardous compounds may not be available in DOE-HDBK-3010 (see "Atmospheric Transport and Dispersion Model").

### Hazard Analyses Methodologies

Hazard analysis is used to evaluate identified hazards within the context of the facility and authorized processes. References such as *Guidelines for Hazard Evaluation Procedures* provide the guidelines for selecting hazard evaluation techniques as well as general methodology for completing these techniques. An application of a graded approach in conducting hazards analysis is based on the guidance of DOE-STD-3009, as well as the judgment and experience of the analysts, resulting in the selection of an appropriate hazard analysis techni-

que. The graded approach, as presented in DOE-STD-3009, recommends using methods in proportion to the risk involved to evaluate hazards. A graded approach can use a binning matrix as an adjunct to the hazards evaluation method(s). The aim of the qualitative binning method is to select an appropriate bin in the matrix for a given accident scenario. Use of the bin qualitatively identifies the associated relative risk for a given scenario and then allows for the selection of higher risk scenarios for evaluation of preventive and mitigative controls. Some examples of risk binning matrix are shown in Table 8 of the Phase I report (CSTC 2003C).<sup>1</sup>

The chosen hazard evaluation method should help the analyst to further discriminate the importance of hazards, initiating events, and subsequent controls. Each of these methods will basically result in an initial listing of the hazard and associated consequences. To support the analysis of these hazards, a qualitative assessment of the frequency and likelihood of these consequences should be conducted. Under the chemical industry standard, risk assessment may be used to accomplish prioritization.

Some types of acceptable methods for HA, as provided by the 29 CFR 1910.119 OSHA PSM for process hazard evaluation and the CCPS *Guidelines for Hazard Evaluation Procedures*,<sup>6</sup> include:

- What If/Checklist, combination of What If and Checklist
- HAZOP (Hazard and Operability) Analysis
- FMEA (Failure Modes and Effects Analysis)
- FTA (Fault Tree Analysis)
- ETA (Event Tree Analysis)

Discussions on the application of these methods are provided in the PSM and CCPS references, as well as in the *System Safety Analysis Handbook* (published by the System Safety Society), and training course material (Course # 139, 2002)<sup>7</sup> from ABS Consulting Process Safety Institute. A summary of the above cited methodologies is presented below;

#### What-If/Checklist

This is one of the most popular methodologies used in hazard analysis. The typical nine steps in What-If/Checklist methodology are shown in Figure 2. Each methodology step is further discussed:

#### What-If Methodology

The purpose of the What-If Methodology is to identify hazards, hazardous situations, or specific accident events that could produce an undesirable consequence. The What-If technique is a loosely structured brainstorming approach in which a group of experienced individuals familiar with a process ask questions or voice concerns

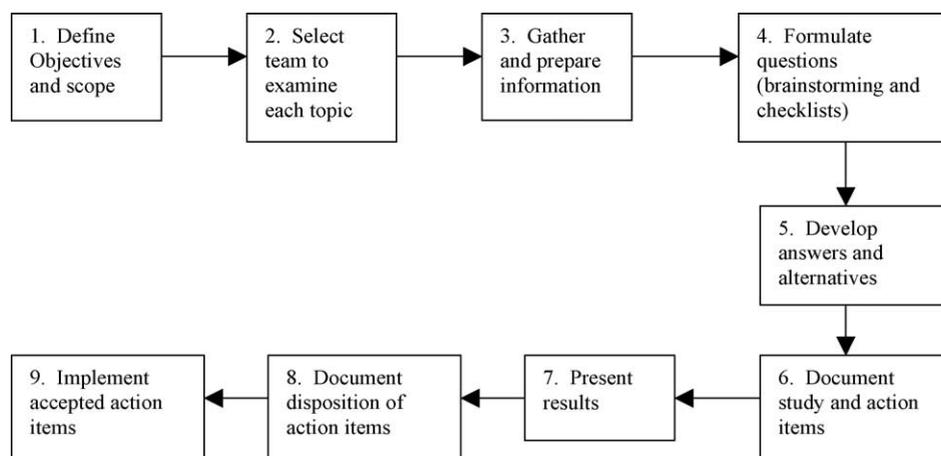


Figure 2. What-If/Checklist Methodology.

about possible undesired events in the process. It is inherently not as structured as some other techniques, such as the HAZOP or FMEA. Rather, it requires the analysts to adapt the basic concept to the specific application.

The "What-If" Analysis concept encourages an analysis team to think of questions that begin with "What If." Through this questioning process, an experienced group of individuals identify possible accident situations, their consequences, and existing safeguards, then suggest alternatives for risk reduction. The potential accidents identified are neither ranked nor given quantitative implications. The analysis team reviews the process from raw material to final product. At each step they ask "what if" questions dealing with procedural errors, hardware failures, and software errors.

The "What-If" Analysis technique may simply generate a list of questions and answers about the process. However, it usually results in a tabular listing of hazardous situations with "What-If", causes, their consequences, safeguards, and possible options for risk reduction for the workers and public.

#### Checklist Methodology

In a traditional Checklist Analysis, the analyst uses a list of specific items to identify known types of hazards, design deficiencies, and potential accident situations associated with common equipment and operations. The identified items are compared to appropriate standards. The Checklist Analysis technique can be used to evaluate materials, equipment, or procedures.

Checklists are most often used to evaluate a specific design with which a company or industry has a significant amount of experience, but they can also be used at earlier stages of development for entirely new systems or processes to identify and eliminate hazards that have been recognized through years of operation of similar systems. This can be done in a tabular form.

#### Advantages

- Universally applicable to process and non-process issues.
- Can be performed at any design stage.

- Can easily focus on specific concerns (e.g., spill, fire, deflagration, detonation).
- Easy to learn and apply.
- Efficient method.

#### Disadvantages

- Highly dependent on team experience and/or appropriateness of checklists (s).
- Has potential to miss some meaningful scenarios.
- Difficult to audit for thoroughness.
- Difficult to ensure regulatory compliance (if the what-if technique is used alone).

#### Hazard and Operability (HAZOP) Analysis

A HAZOP is a systematic examination of all possibilities to identify and assess the significance of the facility SSCs and processes that can malfunction or be improperly operated. Basically, HAZOP analyses are designed to identify potential process hazards resulting from system interactions or exceptional operating conditions.

The study is performed by a multidisciplinary team to identify hazards and operational problems that could result in accident scenarios. The HAZOP team, as identified in 29CFR 1910.119, consists of a team leader with HAZOP experience, a systems engineer with knowledge of facility systems, and a process engineer or operator with intimate knowledge of the process. The size of the HAZOP team will vary according to the scale and complexity of the process.

A HAZOP study relies greatly on design documentation such as piping and instrumentation diagrams (P&IDs), process flow diagrams (PFDs), system design documents, procedures, and equipment and material specifications. In order to perform a successful HAZOP study, it is imperative that the facility and process documentation is up to date and accurate.

The study uses a structured guide word approach to evaluate deviations from normal or design operating parameters such as temperatures, pressures, and flowrates. Guide words

such as *none*, *more*, and *less* are applied to the facility and process parameters. For example, applying the guide word *more* to the pressure variable of a facility vessel would result in the operating deviation of increased pressure. The HAZOP team would then determine the possible deviation, causes, consequences, controls, and any suggested actions to reduce or mitigate the risk; the results of which are recorded in a HAZOP table.

#### Advantages

- Offers a creative approach for identifying hazards, particularly those involving reactive chemicals.
- Thoroughly evaluates potential consequences of process upsets or failure to follow procedures.
- Systematically identifies engineering and administrative controls and consequences of their failures.
- Provides a good understanding of the system to team members.

#### Disadvantages

- Requires a well-defined system of engineering documentation and procedures.
- HAZOP is time consuming.
- Requires trained engineers or SMEs to conduct the study.
- HAZOP focuses on one-event causes of deviations or failures.

#### Failure Modes and Effects Analysis (FMEA)

An FMEA is a systematic method for examining the effects of component failures on system performance. Basically FMEA focuses on failures of systems and individual components and examines how those failures can impact facility and processes. FMEA is most effective when a system is well defined and includes the followings key steps:

- Listing of all system components;
- Identification of failure modes (and mechanisms) of these components;
- Description of the effects of each component failure mode;
- Identification of controls (i.e., safeguards, preventive and mitigative) to protect against the causes and/

or consequence of each component failure mode;

- e. If the risks are high or the single failure criterion is not met.

A FMEA table consists of the above five steps: (1) component description; (2) failure mode; (3) effects; (4) controls; and (5) any suggested action. FMEA explores single component/human failure. Multiple FMEAs may be needed to identify hazards in each system configuration (e.g., start up, operations), but Fault Tree Analysis is a better choice for multiple component failures.

At a minimum, the FMEA team should consist of a FMEA team leader with prior experience performing FMEAs and the system engineer responsible for the system that is being evaluated. More complex projects may require several additional personnel such as line managers, safety analysts, technical experts, and scribes. SMEs may be brought in by the team on an-as needed basis during the FMEA study.

#### Advantages

- Simple
- Efficient
- Cost effective
- Has quantitative applications

#### Disadvantages

- Limited capability to address operational interface and multiple failures
- Human error examination is limited
- Missing components are not examined
- Common-cause vulnerability may be missed

#### Fault Tree Analysis (FTA)

A fault tree is a detailed analysis using a deductive logic model (using Boolean algebra logic) in describing the combinations of failures that can produce a specific system failure or an undesirable event. An FTA can model the failure of a single event or multiple failures that lead to a single system failure. An FTA is often used to generate:

- Qualitative description of potential problems
- Quantitative estimates of failure frequencies/likelihoods and relative importance of various failure sequences/contributing events
- Suggested actions to reduce risks
- Quantitative evaluations of recommendation effectiveness

The FTA is a top-down analysis versus the bottom-up approach for the event tree analysis. The method identifies an undesirable event and the contributing elements (faults/conditions) that would initiate it.

The following basic steps are used to conduct a fault tree analysis:

1. Define the system of interest.
2. Define the top event/system failure of interest.
3. Define the physical and analytical boundaries.
4. Define the tree-top structure.
5. Develop the path of failures for each branch to the logical initiating failure.
6. Perform quantitative analysis (if necessary).
7. Use the results in decision making.

Once the fault tree has been developed to the desired degree of detail, the

various paths can be evaluated to arrive at a probability of occurrence. Cut sets are combinations of components failure causing system failure (i.e., causing the top event of the tree). Minimal cut sets are the smallest combinations causing system failure.

#### Advantages

- Allows an analyst to quantify risk associated with a failure
- Allows examination of multiple failures
- Provides easily understood graphical models

#### Disadvantages

- Requires a skilled analyst. It is an art and also a science
- Focuses only on one particular type of problem in a system, and multiple fault trees are required to address the multiple modes of failure
- Graphical model can get complex in multiple failures

#### Event Tree Analysis (ETA)

An ETA is an inductive analysis that graphically models, with the help of decision trees, the possible outcomes of an initiating event capable of producing a consequence. The procedure for an ETA is shown in Figure 3.

An analyst can develop the event tree by inductively reasoning chronologically forward from an initiating event through intermediate controls (safeguards) and conditions to the ultimate consequences. An ETA can identify a range of potential outcomes for a specific initiating event and allows an analyst to account for timing, dependence, and domino effects

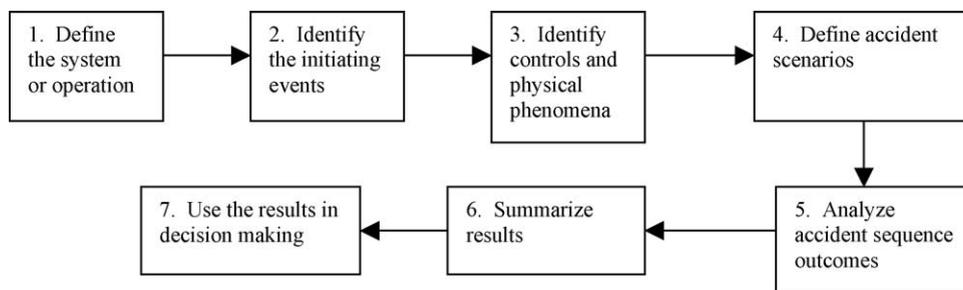


Figure 3. Procedure for Event Tree Analysis.

that are cumbersome to model in fault trees.

An ETA is applicable for almost any type of analysis application but most effectively is used to address possible outcomes of initiating events for which multiple controls (lines of assurance) are in place as protective features.

#### **Advantages**

- Accounts for timing of events
- Models domino effects that are cumbersome to model in fault trees analysis
- Events can be quantified in terms of consequences (success and failure)
- Initiating event, line of assurance, branch point, and accident sequence can be graphically traced

#### **Disadvantages**

- Limited to one initiating event
- Requires special treatment to account for system dependencies
- Quality of the evaluation depends on good documentations
- Requires a skilled and experienced analyst

The above techniques provide appropriate methods for performing analyses of a wide range of hazards during the design phase of the process and during routine operation. A combination of two or three methods (e.g., what-if/checklist and HAZOP) is more useful than individual methods as each method has some advantages and disadvantages. However, some of the more rigorous techniques such as FTA and ETA are reserved for special situations requiring detailed analysis of one or a few specific hazardous situations of concern.

#### **Risk Binning Evaluation**

Risk binning is a product of an accident frequency and consequences and is used to rank the risks involved with hazards and activities. Risk binning evaluates these hazard analysis parameters in keeping with the qualitative nature of these analyses. Quantitative measures are typically considered only in special cases.

For nuclear facilities, DOE-STD-3009 states that the purpose of risk binning is "to separate the lower risk

accidents that are adequately assessed by hazard evaluation from higher risk accidents that may warrant additional quantitative analysis". A similar approach may be used for non-nuclear facilities. For non-nuclear facilities, risk binning might also be used for grading controls (see "IDENTIFICATION OF CONTROLS") or to determine if appropriate controls are in place to ensure adequate safety.

Analysts may elect to define and analyze unmitigated releases as appropriate for the specification of controls based on ERPG/TEEL-3 or ERPG/TEEL-2 criteria.

#### **Receptors**

Immediate workers (10–30 m), collocated workers (typically 100 m), and the public (site boundary) are evaluated for each given scenario. Some scenarios may impact all receptors and some may only impact one receptor. Workers are defined as those within the localized operation or facility area(s) as well as collocated workers within 100 m of the hazard on DOE-controlled premises. The public is defined as people that are outside areas in the direct control of DOE/NSA. Various examples of immediate workers (onsite-1) and 100 m workers (onsite-2) and the public as adopted by various DOE sites are shown in Table 6 of the Phase 1 report. Some sites combine the immediate worker and the 100-m worker as just the worker.

#### **Consequence**

In general, all scenarios have the potential to impact the workers and public. For each scenario, the worst-case consequences are characterized qualitatively to each receptor, using a qualitative consequence matrix. A sliding scale for consequences is applied to the public, while a different scale applies to the localized and onsite worker receptors. A conservative difference typically exists between the consequences for the worker and for the public – e.g., catastrophic for the worker is loss of life, whereas catastrophic for the public is life-threatening injuries. There are different approaches to consequence ranking. Typically, high, moderate, low, and

negligible are used based on ERPG/TEEL-3, ERPG/TEEL-2, and ERPG/TEEL-1 criteria (See Table 7 of CSTC 2003-C report).<sup>1</sup>

#### **Frequency**

Four frequency ( $f$ ) levels from an example in DOE-STD-3009 are often used for hazard analysis. These are defined as: Anticipated (AN) – ( $10^{-1}/y \geq f \geq 10^{-2}/y$ ); Unlikely (UN) – ( $10^{-2}/y \geq f \geq 10^{-4}/y$ ); Extremely Unlikely (EU) – ( $10^{-4}/y \geq f \geq 10^{-6}/y$ ); and Beyond Extremely Unlikely (BEU) – ( $10^{-6}/y \geq f$ ). The nominal frequency is related to occurrence in the lifetime of the facility. Following the qualitative analysis principles, the nominal frequency should be used as a guide in assigning the relative likelihood for each scenario. A single likelihood ranking is then given for each scenario. The likelihood should be based on subject matter expert (SME) input and need not be based on empirical data. Various examples of frequency rankings are shown in Table 5 of the CSTC 2003-C report.<sup>1</sup>

#### **Examples of a Completed Hazard Evaluation Table**

The format of a hazard evaluation table usually reflects the results of the particular hazard evaluation process used, but generally these types of tables provide similar types of information. Hazard evaluation tables typically present a record of identified hazards, causes of events involved, potential consequences, hazard category, and preventive and mitigative control measures. These evaluation tables may be tailored to record a level of results that reflects the rigor provided in the particular hazard evaluation approach.

There may be two general types of hazard evaluation tables: qualitative and semi-quantitative. Examples of completed hazard evaluation tables are shown in Tables 1 and 2. See Table 1 in "Facility CHC" Section. In a qualitative hazard evaluation table, unmitigated and mitigated frequency/likelihood ranking, consequence ranking, and risk ranking are not included for the worker and public, whereas these parameters are included in a semi-quantitative/hazard evaluation table.

**Table 2. An Example of a Completed Hazard Evaluation Table (Semi Quantitative HA)**

Event No.	Event Category	Hazard	Event Description	Causes	Unmitigated			Controls Preventive (P) Mitigative (M)	Mitigated			
					Freq. Level	Conseq. Level	Risk Rank		Freq. Level	Conseq. Level	Risk Rank	
#1	Fire	Flammable material; Toxic release	Medium fire	Miscellaneous combustibles	AN	Onsite-1:	1	Design: • Electrical equipment, P • NFPA standards, P • Fire detec. & suppression, M • Building ventilation, M	UN	Onsite-1:	2	
			In backpulse Chamber Areas	Hydrogen from Uninterrupted Power Source battery		Onsite-2:	2			Onsite-2:	4	
			Release of toxic smoke or gases Worker injury onsite-1, onsite-2, and offsite exposure	Ignition sources Electrical short Thermal energy from electrical equipment, friction from belts		AND	Offsite:			3	Offsite:	4
#2	Acid spill	Acid release	Nitric acid spills when a holding tank ruptures.	Human error	AN	Onsite-1:	1	• Berm, P • PPE, M • Trained personnel, P, M • Emergency Op. Procedures, M	UN	Onsite-1:	2	
			Worker injury and floor damaged, and onsite release	Equipment failure		Onsite-2:	2			Onsite-2:	4	
						Offsite:	4			Offsite:	4	
#3	Explosion	Flammable gas	Flammable gas detonation in Lab area, while working with filtrate solution (50 gal) of toxic material, leading to an explosion.	Explosive material: Oxygen diffuses into vapor space & mixes with flammable gas (e.g., benzene)	UN	Onsite-1:	1	Design: • Hood design, P • Nitrogen supply, P • Fire detec. and suppression, M • Building ventilation, M	EU	Onsite-1:	2	
			Onsite burns and worker injury & offsite exposure	Ignition sources Electrical short Thermal energy from electrical equipment, friction from belts		AND	Onsite-2:			2	Onsite-2:	4
						Offsite:	4			Offsite:	4	

AN: Anticipated; UN: Unlikely; EU: Extremely Unlikely; Risk Ranking: 1 > 2 > 3 > 4; Mod.: Moderate; Neg.: Negligible.

These two types of hazard evaluation tables are essentially modified versions of a Preliminary Hazard Analysis (PrHA) summary worksheet format. The PrHA worksheet format is discussed in Section 6.4 of the AIChE handbook<sup>6</sup> and in MIL-STD-882.

In general, hazard evaluation tables can be tailored to provide those hazard evaluation results that are of interest to and useful for the facility. In addition to hazard evaluation results, some facilities add columns to these tables to denote assignment of follow-on responsibilities and associated schedules to address safety issues, as well as a column for tracking corrective actions implemented by the facility to address safety issues.

## CONSEQUENCE/SOURCE TERM ANALYSIS

### Introduction

As discussed previously, an HA can be qualitative, semi-quantitative or quantitative. A quantitative analysis may be necessary for higher hazard processes or facilities. A more quantitative analysis is sometimes termed consequence or accident analysis to denote an additional level of rigor than an HA. Accident analyses are also sometimes used to define a design basis event (DBE) for SB purposes. For a quantitative accident analysis, Gaussian dispersion model codes to simulate atmospheric transport and dispersion are commonly used. These models include:

- MACCS2 Model (uses historical meteorological onsite dataset to calculate  $\chi/Q$  value)
- Areal Locations of Hazardous Atmosphere (ALOHA)
- Emergency Prediction Information Code (EPIcode)

These models are approved models (codes) by the DOE-EH Central Toolbox Registry (Chung and O'Kula 2002)<sup>8</sup> for safety analysis and are also viable "approved" tool box codes recommended by Safety Analysis Working Group (SAWG)/Energy Facility Contractors Group (EFCOG). DOE-EH has provided computer code

application guidance for documented safety analysis for MACCS2, ALOHA, and EPIcode codes in DOE-EH-4.2.1.3, *Code Application Guidance*.

Other chemical consequence models are also used for specific purposes. These are DEGADIS, SLAB, HGSYSTEM, SCREEN3, ARCON96, and ARCHIE. For example, HGSYSTEM and DEGADIS can model heavy gases such as sulfur dioxide and chlorine, where SCREEN3 is not suitable for heavy gases. ARCON96 can calculate concentrations in the vicinity of buildings (short distances) and ARCHIE is used for fire modeling and explosion. The reader should refer to user manuals for these models for additional information. A discussion of 64 consequence assessment models is available from the Office of the Federal Coordinator of Meteorology (OFCM) in "Directory of Atmospheric Diffusion and Consequence Assessment Models". It can be accessed at [www.ofcm.gov](http://www.ofcm.gov).

### Atmospheric Transport and Dispersion Model

Atmospheric transport and dispersion models that are used for chemical consequence analyses are commonly based on a Gaussian dispersion equation from the *Workbook of Atmospheric Dispersion Estimates, An Introduction to Dispersion Modeling* (Turner 1994):<sup>9</sup>

$$\chi(x, y, z) = \left[ \frac{Q}{2\pi u \sigma_y \sigma_z} \right]^{[-y^2/2\sigma_y^2] \{[-(H-z)^2/2\sigma_z^2] - [(H+z)^2/2\sigma_z^2]\}} \quad (1)$$

where  $\chi$  is the air concentration, mg/m<sup>3</sup>;  $Q$ , continuous emission rate, mg/s (mass release/time);  $u$ , average wind speed, m/s;  $\sigma_y$ , standard deviation of concentration distribution in the crosswind direction ( $x$ ), m;  $\sigma_z$ , standard deviation of the concentration distribution (function  $x$ ) in the vertical direction, m;  $H$ , the effective release height of the centerline of the plume, m;  $x$ , downwind distance, m;  $y$ , crosswind distance, m;  $z$ : vertical height, m;  $\pi$ , 3.142.

For a ground-level release,  $y = 0$ ,  $z = 0$ , and  $H = 0$ . Equation (1) simplifies to

$$\chi(x) = Q(\pi u \sigma_y \sigma_z)^{-1} \quad (2)$$

$$\frac{\chi}{Q} = (\pi u \sigma_y \sigma_z)^{-1} \quad (3)$$

$\chi/Q$  (s/m<sup>3</sup>) is the relative atmospheric dispersion for a particular atmospheric condition; and exposure associated with the postulated release to a receptor. Atmospheric stability class (A-F) is a feature to estimate the atmospheric mechanical turbulence and buoyancy for the dispersion in the crosswind ( $y$ ) and vertical ( $z$ ) directions downwind ( $x$ ) from the source. The method may use the Pasquill stability class categories in combination with Pasquill-Gifford dispersion parameters or by dispersion parameters by Briggs (Turner, 1994).<sup>9</sup>

The chemical concentration is calculated by:

$$\text{Concentration (mg/m}^3\text{)} = \frac{\chi}{Q} \times \text{RR} \quad (4)$$

where RR is the release rate as mg/s, ST/T and ST, source term;  $T$ , release time.

$$\text{ST} = \text{MAR} \times \text{ARF} \times \text{RF} \times \text{DR} \times \text{LPF} \quad (5)$$

$$\text{Concentration (mg/m}^3\text{)} = \left[ \frac{\chi}{Q} \times \text{MAR} \times \text{ARF} \times \text{RF} \times \text{DR} \times \text{LPF} \right] \frac{1}{T} \quad (6)$$

where  $\chi/Q$  (s/m<sup>3</sup>): Relative atmospheric dispersion for a particular atmospheric condition; typically 50%

(median) and 95% meteorology is used. MAR (mg) is the material at risk available for release; ARF, airborne release fraction suspended in air as an aerosol and available for transport; RF, respirable fraction: the fraction of airborne particles that can be transported through air and inhaled into the human respiratory system; commonly assumed to include particles  $\leq 10 \mu$ ; Aerodynamic Equivalent Diameter (AED), RF = 1; DR, damage ratio of the total MAR that could be impacted by the accident generated conditions. For a conservative assumption, DR is 1. LPF, Leakpath factor: the fraction of airborne material transported from confinement deposition or filtration mechanism (e.g., fraction

of material passing through a HEPA filter); for breach confinement, LPF is 1. T (s): Release duration.

ARF and RF values are usually taken from DOE-HDBK-3010-94 or DOE-STD-1027-92. Release duration is typically 10 or 15 minutes, although a shorter duration (1–3 min) is possible for puff release or small MAR release (e.g., small gas cylinder whose contents are not under pressure). For releases of short duration, a time-weighted average (TWA) of 15 minutes is normally used.

A more detailed treatment of atmospheric transport and dispersion principles can be found in Chapter 9 of the DOE Accident Analysis Guidebook (DOE G 421.1-X) on DOE website – [www.directive.doe.gov](http://www.directive.doe.gov).

#### Gaussian Distribution ( $\chi/Q$ Method)

The  $\chi/Q$  value is a very important meteorological parameter that can vary significantly (1–3 orders of magnitude) depending on meteorological conditions (stability class A to F), thus its accurate determination is crucial. Two approaches to calculate  $\chi/Q$  values are:

- 1) 95th Percentile: DOE-STD-3009 Appendix A requires the use of Regulatory Guide 1.145 to generate the requisite meteorological data for computing the 95% distribution of concentration or dose to the MOI (maximum offsite individual) or public. This could be considered to be a “worst case” situation as being conservative. The consequence ( $\chi/Q$  value) is normally obtained through MACCS2 (MELCOR Accident Consequence Code System) by providing a historical meteorological onsite dataset of few years (e.g., 1–5 years of hourly data). If 5 years of data is available, it should be used.
- 2) Persistent Meteorology: For example, a single wind speed and stability class (A to F) is used as input for the duration of the release (e.g., ALOHA, EPIcode, simple hand calculations).

Many sites typically use an F stability class and 1–2 m/s wind speed for initial consequence calculations as being conservative. These codes calculate a centerline Gaussian dispersion

plume model as shown in Equation (2). Once a  $\chi/Q$  value is obtained, then using other parameters listed in Equation (6), chemical concentration (mg/m<sup>3</sup> or ppm) can be hand calculated (including a spreadsheet approach) at a receptor (worker or public) distance.

The  $\chi/Q$  value is usually not reliable below 100 meters, mainly because of the theoretical model and great uncertainty in the modeling. Therefore, a concentration value for short distance workers (~30 m) is viewed as a qualitative estimate. However, ARCON96 code can be used for short distances.

#### Aloha and EPIcode

ALOHA and EPIcode are well-developed computer models that can calculate  $\chi/Q$  values with the weather conditions input provided, such as stability class (A-F), temperature, wind direction, wind height and wind speed, and distance from release. These codes also use a centerline Gaussian dispersion plume model and are user-friendly. ALOHA can model heavy gas releases and has a much more robust evaporation submodel, and can calculate indoor concentrations using infiltration submodels.

With the other information provided as input – e.g., material at risk (MAR), release time, sampling time, receptor height, models calculate concentration (mg/m<sup>3</sup> or ppm) at a given distance (immediate worker, co-located worker, public). These values are then usually compared with ERPG-1, -2, and -3 values, which are based on up to 1-hour exposure. These models are used for gaseous and liquid releases.

A sampling (exposure) time of 15 min. TWA (time weighted average) is recommended to compare with the guideline, which is a conservative estimate for dose assessment to a receptor (Craig et al. 2000).<sup>10</sup> If ERPG-1, -2, and -3 values are not available for a chemical, TEEL-1, -2, and -3 values can be used.<sup>5</sup> Where available, AEGL-1, -2, and -3 values can also be used.

#### Advantages/Disadvantages

- a.  $\chi/Q$  values can be obtained by MACCS2 using historical meteoro-

logical onsite dataset of a few years, which is often more reliable method than from a single meteorological conditions at hand by ALOHA and EPIcode or input by hand calculations.

- b. EPIcode has a feature to print out  $\chi/Q$  value as a function of distance, where ALOHA does not. EPIcode can select the stability class that maximizes the ground level concentration for elevated release scenarios.
- c. ALOHA was originally written by NOAA (National Oceanic and Atmospheric Administration) for emergency responder and over the years has been modified to be used in other area. Thus, it has broader applications. ALOHA has a one-hour plume travel limit which truncates analyses at far-field receptors with light wind speeds.
- d. ALOHA can model heavy gas, whereas EPIcode does not model dense gas releases. ALOHA can model liquid releases from tanks, pipes, and pipelines, whereas EPIcode does not.
- e. EPIcode was originally written towards emergency preparedness application and now has been broadened towards safety analysis application. Its printout lists all the input parameters and output results, which is in a friendly readable form.
- f.  $\chi/Q$  method (MACCS2) and EPIcode have features for deposition velocity in their models, where ALOHA does not.
- g. In some cases, ALOHA and EPIcode yield reasonably good agreement. In some cases, the models do not; the differences can be attributed to different assumptions or equations in their models (e.g., liquid evaporation model).
- h. In general, Gaussian based dispersion models yield unreliable results within 100 meters. This may be due to plume meandering or dispersion coefficients that are not suitable for close-in distances. Models have not been validated for use at distances less than 100 m, with the exception of the empirically based ARCON96 code.
- i. Both ALOHA and EPIcode models are less reliable for conditions of

low wind speed or very stable atmospheric conditions.

- j. Both ALOHA and EPIcode models do not account for building wakes, where MACCS2 accounts for building wake effects.
- k. MACCS2 is commonly used for dispersion of particulates, although can be used for vapors and gases, whereas ALOHA and EPIcode are commonly used for vapors and gases.
- l. Both ALOHA and EPIcode can be used as an emergency response tool as a real time in the field, where MACCS2 can not be used as a real time in the field.

## IDENTIFICATION OF CONTROLS

The development, identification, and implementation of controls (i.e., engineered and administrative) is an essential step in any safety management process such as ISMS, PSM, or nuclear safety management. Controls are typically based on ERPG/TEEL values and will help to prevent or mitigate analyzed accidents if properly selected, implemented, and maintained. The controls should be based upon the hazard analysis using consequence or risk analysis (usually concurrence with the field or site office). The hazard analysis will identify the scenarios that may require controls. Each accident scenario may have one or more controls to prevent or mitigate the postulated accident. Obviously, accidents with more serious consequences should require more robust controls. The decisions regarding the adequacy of a control set for each accident are made by the hazard analysis team, operating staff, and potentially DOE.

For accidents with minor consequences, the HA team may recommend that safety management programs (SMPs) provide adequate controls. For more serious potential accidents, the team should consider having multiple controls, i.e., defense-in-depth. The team should also prefer engineered controls before considering administrative controls, and preference should be given to preventive over mitigative controls in accordance with applicable DOE gui-

dance and good engineering practice. The defense-in-depth concept also applies to using the safety management programs to increase the robustness of individual engineered controls through regular maintenance and surveillances, configuration management, and training. The identification of controls should include a discussion of the following elements:

- Consideration of any precedence for specific hazard control solutions;
- Identification of engineered controls integral to the design of a facility, equipment, or activity and serving one or more safety functions;
- Identification and description of the devices that measure or monitor a physical condition and notify operators to initiate other actions to shut down the operation, activate another control measure, and/or set off an alarm when a predetermined threshold has been exceeded;
- Identification of the administrative procedures involving personnel who are instructed or trained as appropriate to follow specified procedures;
- Identification of any other activities or measures taken for the purpose of preventing a hazardous situation from developing, or for the purpose of reducing the consequences of that situation, should it occur;
- Identification of safety management programs (SMPs) that provide defense-in-depth to specific administrative or engineered controls;
- Identification of controls to protect initial assumptions and conditions used in hazard and accident analysis.

### Grading of Controls

A possible step in the control identification process is the grading of the controls. There is no DOE order or other Federal regulations requiring the grading of controls for non-nuclear, chemically hazardous facilities or activities.

The grading of controls should be performed when justified as increasing safety commensurate with the costs. The process of control grading will rank controls based upon the their significance in reducing the conse-

quence or frequency of a postulated accident. Many different grading schemes can be developed. The benefits of implementing any control grading should be greater than the costs.

### Advantages

- a. The goal of control grading is to provide a more robust and reliable control that will perform its safety function upon demand. Some of the potential benefits of grading include increased emphasis on maintaining and managing the most important controls.
- b. A simple scheme could select the most important controls that protect workers and the public as safety-related. Another level of control grading could be added for controls that specifically protect the public.

### Disadvantages

- a. Instituting this system within a facility or DOE site may lead to increased costs to develop and maintain the controls and to develop and maintain the grading system. Many DOE sites have active nuclear facilities and the grading scheme could rely upon the nuclear system, minimizing the cost to develop and maintain a separate system.
- b. Some of the potential costs of grading controls are determining what each control grading level conveys in terms of possible design criteria, determination of control availability, defining safety functions, describing systems, evaluating systems to perform the functions, and selection of potential surveillance or testing requirements. Many of these same issues apply to administrative controls as well.
- c. There are no written criteria that establish evaluation guidelines, however, there are precedents and established practices within the DOE Complex and industry.

DOE-STD-1186-2004, *Specific Administrative Controls (SACs)*, provides additional guidance regarding the use of administrative controls, including SACs that are designated as the principal control for accidents that impact

the public or collocated workers. The DOE-STD-1186-2004 is written to address SACs for nuclear hazards; however, the concepts and recommendations can be applied to non-nuclear hazards as well.

### Evaluation Guidelines

Before one goes down the path of grading very far, the obvious question arises as to what are the evaluation guidelines for the selection of controls. There are no written criteria that establish evaluation guidelines. However, there are precedents and established practices within the DOE Complex and industry. As shown in Table 9 of the Phase I report (CSTC 2003-C), some sites have developed their own control selection criteria such as ERPG-1, -2, -3 or equivalents for evaluation guidelines. Most sites use ERPG-2 and occasionally ERPG-3 as an evaluation guideline to protect the public and ERPG-3 and occasionally ERPG-2 to protect the collocated worker (100 m). Table 3 lists typical consequence levels and effects.

ERPG-3 is often acceptable for protecting collocated workers due to their hazardous material training, emergency response training, and fitness for duty requirements. EPA's values in the Risk Management Plan (40 CFR 68.130) for protecting the public are based upon ERPG-2 or equivalents (61 FR 31667 et seq, 40 CFR 68, *Accidental Release Prevention Requirements: Risk Management Programs Under the Clean Air Act, Section 112(r)(7); List of Regulated Substances and Thresholds for Accidental Release Prevention, Stay of Effectiveness; and Accidental Release Prevention Requirements: Risk Management Programs Under Section 112(r)(7) of the Clean Air Act as Amended, Guidelines; Final Rules and Notice*, June

20, 1996). ERPG-2 or equivalent is also widely accepted as protective of the public within industry and the EPA has implemented it using the rulemaking process.

### DOE Complex Practices

As stated earlier, *DOE does not have any requirements to grade controls for chemically hazardous facilities*. However, many DOE sites do grade controls for these facilities. Often, the grading is similar to the practices in use at nuclear facilities and uses terms such as safety significant (SS) or safety features. Additional differentiation could also be added for controls that protect against high, moderate, or low consequences. Each site presently has its own practices.

### Chemical Industry Practices

OSHA and EPA do not have any requirements to grade controls for the chemical industry. The concept of control grading is commonly used in the nuclear industry and has not been widely used in the chemical industry. However, as a best practice, some companies in the chemical industry use graded controls (critical vs. non-critical controls) by applying frequency, consequence, and risk criteria. The chemical industry selects the appropriate controls and documents the controls in the required documentation. The regulators expect that the controls will be maintained and controlled appropriately and to take appropriate compensatory actions if the controls are not available. Ultimately, the regulators resort to the General Duty Clause, which obligates an owner to exercise his general duty to protect workers and the public from all types of circumstances, by the installation of additional controls.

Finally, the control identification process can result in the preparation of a safety requirements document. This safety requirements document can be called an operational safety requirements (OSR) document, chemical safety requirements (ChSR) document, or another site-defined term such as work control document (WCD). The safety requirements document will typically define the most important controls for the workers and public that must be maintained to provide a safe operating environment. Controls may be labeled as level 1 for public and level 2 for workers or similar terminology for distinction purpose between the public and workers.

The safety requirements document could list the important active engineered and administrative controls, including surveillance requirements that ensure control availability, other administrative controls including SMP, use and application, and a listing of passive engineered controls. The purpose of the safety requirements document is to provide a concise compilation of controls identified in the hazard analysis for operation of the facility (Table 4).

Preferred operational modes of controls are as follows:

- An engineered control is preferred over an AC.
- Hazard reduction/elimination is preferred over prevention and mitigation.
- A preventor control is preferred over mitigator control.
- A passive control is preferred over active control.
- A preventor control reduces the potential event's frequency (likelihood).
- A mitigator control reduces the potential event's consequence.

**Table 3. Typical Consequence Levels and Effects**

Consequences	Potential Effects
High	Exposures greater than ERPG-3 or 2 (TEEL-3 or 2) or equivalent offsite
Moderate	Exposures greater than ERPG-3 or 2 (TEEL-3 or 2) or equivalent to collocated workers at 100 m.
Low	Significant health effects to local workers (e.g., significant injuries to multiple workers or death)
Minor	Minor health effects to local workers

**Table 4. Sample Consequence Levels and Control Preferences**

Consequences	Control Preference
High	Engineered control with additional controls providing defense-in-depth. Passive engineered control preferred if feasible. Specific Administrative Controls (SACs) acceptable if DOE-STD-1186 <sup>a</sup> is met. SMPs required to protect controls, conditions, and assumptions.
Moderate	Engineered or administrative control with additional controls providing defense-in-depth. Engineered controls preferred if feasible. SACs acceptable if DOE-STD-1186 is met. SMPs required to protect controls, conditions, and assumptions.
Low	Engineered or administrative controls including SMPs. Defense-in-depth approach should be considered if feasible. SMPs required to protect controls, conditions, and assumptions.
Minor	SMPs

<sup>a</sup> DOE-STD-1186-2004 is guidance for developing SACs. It is a requirements document for nuclear facilities only. However, its principles can be applied for non-nuclear facilities.

### COMMITMENTS TO SAFETY MANAGEMENT PROGRAM

As noted in the DEAR clause of 48 CFR 970.5223-1 and ISMS, the agreed-upon conditions and requirements for safe operation of a facility are requirements of the contract and binding upon the contractor. Development of safety requirements in SB documentation is the process whereby these commitments are established to ensure facility hazards are identified and that controls to prevent and mitigate potential accidents involving those hazards are proposed, approved, and implemented. The safety requirements developed by the contractor and approved by the DOE form a set of commitments to a safety management program (SMP) that are in essence binding for safe operation of a facility.

Commitments can be both engineered safety features and administrative controls. In some cases, more of the safety controls set commitments may be in the form of administrative controls, as opposed to facility engineered design features. As such, an approach may be taken to implement SMP and potentially to use specific administrative controls (SACs) or a similar approach to provide key aspects of the SB for these facilities. In describing these administrative control aspects, it may be important to clearly state those elements and attributes of SMP that are credited in the safety document.

As a minimum, commitments for worker safety and defense in depth identified in the safety document should be covered within relevant SMP (e.g., occupational safety, industrial safety,

maintenance, configuration management, quality assurance), as credited in the safety document.

The SMP and related administrative controls could also address other institutional aspects of the safety document, including organization and management, procedures, recordkeeping, assessment, and reporting necessary to ensure safe operation of a facility consistent with the safety requirements committed to by the operating contractor. In general, the administrative controls address:

- Requirements associated with administrative controls, (including those requirements for dispositioning and reporting violations of safety requirement);
- Staffing requirements for facility positions important to safe conduct of the facility;
- Commitments to the SMP identified in the safety document analysis for the facility.

As noted in "IDENTIFICATION OF CONTROLS", controls may be labeled as Level 1 for public and Level 2 for workers or any other terminology for distinction purpose. However, such controls noted as barriers or preventive or mitigative features in the hazard and accident analyses could be addressed in the safety requirements document (e.g., OSR, ChSR).

Requirements for safety function and availability of these engineered features may be addressed through operating limits/surveillance requirements, SACs, or programmatic safety program commitments. The selection

of the particular control approach could be made commensurate with the level of rigor needed to ensure that SB-credited safety functions for these engineered features are met.

The role of programmatic safety commitments could be explicitly stated. The safety document, however, includes only an overview of the program elements and attributes, not the details of the program or its implementing documents. The details of programmatic coverage are not developed in or as part of the safety document. Discrepancies in the implementation of a program credited in the safety document would not constitute violation unless the discrepancies were so notable as to not provide the elements and attributes of the program that are credited in the safety document.

One overall commitment that could be made in the safety document is that the contractor should not change the facility configuration underlying the documented SB without implementing and completing a review of the change to ensure that new hazards are not introduced, or previously analyzed conditions are not altered. If there is a change or alteration to these set of conditions or parameters, then an unreviewed safety question (USQ)-like process is applicable. The USQ-like process and approval should follow the same protocol as the facility hazard category SB process and approval protocol.

For facilities using PSM/RMP approach, those regulations identify some SMP that may need to be addressed. These are for example, operating procedures, training, man-

agement of change, emergency planning and response (see "Industry Standard (OSHA – PSM; EPA – RMP)").

## DOCUMENTS AND APPROVAL PROCESS

As noted in DEAR clause of 48 CFR 970.5223-1 and ISMS, the extent of documentation and level of authority for agreement shall be tailored to the complexity and hazards associated with the work and shall be established in a Safety Management System.

The safety document contains the results and discussion of the various steps of the process(es) outlined in various sections such as the SB methodologies, hazards identification, CHC, PrHA, and establishment of appropriate safety controls to protect the workers, public, and the environment.

The level of rigor in the safety documents depends largely on the hazard classification of the chemical facility (e.g., high, moderate, and low; PSM/RMP). The safety document can take various forms using a graded approach such as an auditable safety analysis (ASA), facility use agreement (FUA), hazard control plan (HCP), hazard evaluation report (HER), or other safety document. The document requirement can be negotiated with the local field or site office. Usually, the safety documents are flexible in format but the content should be well defined to address the important steps as outlined above. These practices vary significantly from site to site as noted in Table 24 of the CSTC 2003-C report.

### Chemical Hazard Classification (CHC)

Approval of SB documents is provided by the appropriate approval authority. In cases, where DOE sites uses CHC practices (e.g., High, Moderate, Low), typically contractor approval is adequate for a Low hazard facility. For moderate or high hazard facilities, DOE approval of the SB documents may be required, depending on the DOE site specific approval requirements established between the local DOE office and the contractor. The same protocol applies to the USQ-like process for the corresponding High/Moderate/Low type hazard facility.

### OSHA and EPA Regulations

If a site selects to follow OSHA 29 CFR 1910.119 and EPA 40 CFR 68 regulations to perform PSM and RMP approaches, the CHC is not required and the PrHA is qualitative (see "FACILITY CHEMICAL HAZARD CLASSIFICATION (CHC)" and "HAZARD ANALYSIS"). The approval and requirements of a document in terms of format, content, depth of analysis, and selection of controls can be short and negotiated with the local field or site office for facilities that are above or below the PSM or RMP.

### Approval Process and SER

The review and approval of a SB document are typically negotiated and established on a site-specific basis. Typically, DOE/NNSA approval is required for High and Moderate or PSM/RMP facility. The DOE/NNSA, in its review and approval role, may require modification or addition to the SB commitments made by the contractor.

For a formal DOE/NNSA review of a safety assessment, the bases for DOE/NNSA approval are typically documented in a Safety Evaluation Report (SER). This SER may include Conditions of Approval (CoA) that need to be met either prior to implementation of the safety assessment or prior to the next scheduled update of the safety assessment. The SB developers resolve approval issues prior to implementation of the SB or before its next submission, as applicable. The final SER serves as an acceptance of the risk of the operations as described and evaluated in the safety documents by DOE/NNSA.

### Advantages/Disadvantages

- PSM/RMP does not require a hazard classification (HC), whereas CHC requires High, Moderate, or Low.
- Safety document requirement can be short for PSM/RMP, where the safety document can be written with a graded approach from High/Moderate/Low.
- PSM process hazard analysis is qualitative, where CHC can be quantitative in some cases as a bounding scenario for High and Moderate HC in the selection of safety controls.

- The approval authority (contractor vs. DOE/NNSA) can be negotiated with the local field or site office for facilities above or below PSM/RMP or depending on the level of CHC - High/Moderate/Low.

## RELATED TOPICS

This section discusses two related topics of interest in the development of a chemical, non-nuclear safety document. An EPHA for EMP, which is required by DOE Order 151.1, and explosive and blasting agents required by 29 CFR 1910.109 under the purview of 29 CFR 1910.119 are discussed. Some part of the safety document such as HA and controls are applicable to EPHA and explosive areas.

### EMERGENCY PLANNING HAZARDS ASSESSMENT (EPHA)

DOE O 151.1B establishes the policy and describes roles and responsibilities for the DOE *Comprehensive Emergency Management System*. The Order requires that the release of or loss of control of hazardous materials be quantitatively analyzed, in an EPHA. If chemicals are present above the thresholds specified in the Order, an EPHA must be prepared. Chemicals that have no published thresholds, or chemicals where small quantities may produce significant consequences outside the facility must be analyzed or the facility should establish its own thresholds, lower than those specified in DOE O 151.1B. The DOE O 151.1B is currently under revision and text shown here may change with the new revision.

Chemical thresholds specified in DOE-O-151.1B are:

- OSHA TQ (Threshold Quantities under 29 CFR 1910.119)
- EPA TQ (Threshold Quantities under 40 CFR 68)
- EPA TPQ (Threshold Planning Quantities under 40 CFR 355)

If a chemical is present in quantities exceeding either a TQ or TPQ, it must be included in the hazards assessment for quantitative analysis (i.e., source term and consequence assessment).

[Note that the Office of Assessment (OA-30) has been issuing findings against sites that use only the CFR thresholds.]

Radiological thresholds specified in DOE-O-151.1B are:

- 10 CFR 30.72 screening quantities.

If the sum of the ratios  $< 1$ , inventory screens. [Note that the latest draft of DOE-O-151.1 recommends use of DOE-STD-1027 Category 3 thresholds instead of CFR thresholds.]

Segmentation of hazardous material inventories is allowed. If the inventory is segregated such that a release could not be caused by a common initiator, each segment may be treated independently. Sealed sources and material packaged in Department of Transportation type B containers is typically excluded from inventory.

If material is in a physical form that makes airborne dispersion unlikely (e.g., particle size  $>10 \mu\text{m}$ , or vapor pressure  $<10 \text{ mmHg}$ ), it may be excluded. If the material is in the same form, quantity, and concentration as a product packaged for use by the general public, it may be excluded. If the material does not exceed Laboratory Scale (as defined in 29 CFR 1910.1450), it may be excluded. [Note that the latest draft of DOE-O-151.1 allows material with an NFPA 704 Health Hazard Rating  $<3$  to be excluded.]

The EPHA uses barrier analysis and normally does not consider frequency. That is, an event should not be dismissed just because it is incredible (beyond extremely unlikely). The analysis may or may not consider barriers (e.g., tank wall) or mitigators (e.g., dike, filter, stack) without regard to functional classification (e.g., SSC, OSR, ChSR).

The spectrum of events requiring consideration in the EPHA is typically greater than that in safety document. For example, minor events that would normally not be considered in a DSA because they are bounded by another event may require analysis in an EPHA because it may lead to a classifiable accident (e.g., Alert, Site Area Emergency). The EPHA must consider mal-evolent acts as well (although release mechanisms may be the same or similar to events already considered and

analyzed). Overall, approaches outlined in this report are applicable here (e.g., "HAZARD IDENTIFICATION", "HAZARD ANALYSIS", "CONSEQUENCE/SOURCE TERM ANALYSIS", "IDENTIFICATION OF CONTROL", COMMITMENT TO SMP, and "DOCUMENTS AND APPROVAL PROCESS").

A realistic worst-case source term is determined. This typically is done for particulates and non-volatile liquids using the DOE Handbook (DOE-HDBK-3010). For evaporative chemical releases, a model such as ALOHA or EPIcode is often used for both source term and consequence assessment for chemical hazards. HOTSPOT is commonly used for radiological hazards. Consequence assessments are typically performed using 95% adverse, or worst case meteorology (see "CONSEQUENCE/SOURCE TERM ANALYSIS").

Consequences are calculated at specified receptors (30 m, facility boundary, and site boundary) and compared to specified Protective Action Criteria (PAC). For radiological releases, the PAC is 1 rem TEDE (Total Effective Dose Equivalent; 5 rem CEDE thyroid). For chemical release, the PAC is either 60-minute AEGL-2 or ERPG-2 (or equivalent, normally TEEL-2).

EPA is currently developing Acute Exposure Guidelines Levels (AEGL-1, -2, -3), which are based on five emergency exposure periods (10, 30 and 60 min., 4 hr and 8 hr) and three severity levels. It is anticipated that ERPGs values may be replaced by AEGL values. The specific AEGL to be used is the 60-minute AEGL; particular levels, such as AEGL-3 and AEGL-2 are the same as ERPG/TEEL-3 and ERPG/TEEL-2. See <http://www.orau.gov/emi/scapa/teels.htm>.

The following emergency classes are defined:

**Alert:** PAC exceeded at 30 m; or Small fraction of the PAC exceeded at the facility boundary. [Note: the revision to DOE-O-151.1B defines "small fraction" as 10% and lists this as the preferred criterion.]

**Site Area Emergency (SAE):** PAC exceeded at the facility boundary

**General Emergency (GE):** PAC exceeded at the site boundary

Based upon results of the EPHA, Emergency Action Level (EAL) procedures are written to identify conditions that indicate when an emergency classification threshold may have been crossed. In addition, the EPHA documents the technical basis for the Emergency Planning Zone (EPZ). The EPZ must be at least large enough to encompass a circle defined by the distance to the Threshold to Early Lethality (TEL). The TEL is defined by a radiological dose of 100 rem TEDE or a chemical concentration equal to ERPG-3 (or equivalent).

#### *Advantages/Disadvantages*

- Integrates requirements by other agencies in order to eliminate duplication of efforts.
- Non-mandatory implementation guidance for this order is published separately in DOE G 151-series Emergency Management Guides.
- Guidance provides a methodology to examine the potential consequences at distance and develop specific plans and procedures to tailor to the specific hazards present.
- Protective Action Criteria are well defined for Alert, SAE, GE, and EPZ.

#### **29 CFR 1910, 109 EXPLOSIVES AND BLASTING AGENTS**

29 CFR 1910.109, *Explosives and Blasting Agents*, establishes in the Scope section (section (k)(2) of the CFR) that "The manufacture of explosives as defined in paragraph (a)(3) of this section shall also meet the requirements contained in Sec. 1910.119.

#### **Discussion of a Possible Safety Basis Approach**

Analysis and control of the hazards associated with the manufacture of explosives must be conducted in accordance with the regulations associated with PSM as defined in 29 CFR 1910.119. The methodologies described in this report for development of hazards analysis would also be applicable for the development of hazards analysis for explosives operations.

For operations other than those associated with manufacturing of explosives, 29 CFR 1910.109 does

not specifically prescribe SB requirements. However, other drivers (such as ISM and Emergency Planning) may require analysis of these activities as previously discussed in this report.

#### **Clarification of Definition of Manufacture of Explosives**

In order to provide clarification to the confusion associated with the definition of the scope of "Manufacture of Explosive," OSHA issued various interpretation letters in response to specific questions from industry. The following summarizes clarifications to the definition of manufacture of explosives are provided based on various OSHA interpretation letters.

#### **Testing, Research Formulation, Evaluation and Analysis**

OSHA Interpretation Letter to Mr. F. A. White,<sup>11</sup> Organization Resources Counselors, Inc., states "Activities OSHA considers outside the scope of the explosives manufacturing process if conducted in a separate, non-production research or test area or facility; and do not have the potential to cause or contribute to a release or interfere with mitigating the consequences of a catastrophic release from the explosive manufacturing process include:

- Product testing and analysis which is not part of any in-production sampling and testing of the explosive manufacturing process;
- chemical and physical property analysis of explosive and propellants and pyrotechnic formulations;
- Scale-up research chemical formulations to develop production quantity formulations;
- Analysis of age tests conducted on finished products;
- Failure analysis of tests conducted on pre-manufactured or finished products;
- X-raying;
- Quality assurance testing (not including the extraction of samples from an active explosives manufacturing [production] process);
- Evaluating environmental effects, such as hot, cold, jolt, jumble, drop, vibration, high altitude, salt, and for; and

- Assembly of engineering research and development models.

These operations are covered under the general explosives handling requirements of 29 CFR 1910.109, however, they may require hazards analysis under a separate driver to ensure worker safety. The remainder of the operations involved with the manufacture of explosives is considered to be covered under the scope of PSM.

#### **Nuclear Explosives-Like Assemblies (NELAs) (JTAs/Test Beds/Trainer Assemblies)**

OSHA Interpretation Letter to Mr. G. Rountree<sup>12</sup> Aerospace Industries Associated of America, Inc., states "OSHA did not intend that the PSM standard apply to the installation of explosive devices, such as, explosive bolts, detonating cords, explosive actuators, squibs, heating pellets, thermal batteries, ejection seat rocket motors and similar small explosive devices . . . into larger finished products or devices that are not intended to explode. The preceding installation is considered a handling activity covered by 1910.109." Based on this interpretation, only those NELAs that are intended to explode or have the potential to cause or contribute to a release or interfere with mitigating the consequences of a catastrophic release (i.e., contain main charge explosives) are covered under the PSM process. This includes all NELAs that contain main charge high explosives. All other NELA-related operations are covered under the general explosives handling requirements of 29 CFR 1910.109, however, they may require an HA under a separate driver to ensure worker safety.

#### **Packaging**

OSHA Interpretation Letter to Mr. D. H. Delsemme,<sup>15</sup> August 18, 1994, states "The re-packaging you describe is considered to be storage and handling activities which are not covered by the PSM standard."

Based on this interpretation letter, packaging operations which are not performed as a part of the explosives manufacturing process (i.e., packaging a finished component after completion of a manufacturing related

activity) are not covered under the scope of PSM. These operations are under the scope of the general handling requirements of 29 CFR 1910.109, however, they may require HA under a separate driver to ensure worker safety.

#### **Advantages/Disadvantages**

- a. Provides a list of specific chemicals and some general categories.
- b. Establishes very specific criteria for manufacturer, storage, transportation and use of explosives and blasting agents.
- c. Speaks only to those chemicals classifiable as explosives or blasting agents.
- d. Would require implementation in conjunction with PSM or RMP for mixed-use facilities.

#### **Other Drivers Associated with Explosives**

In addition to the requirements discussed in "29 CFR 1910 109 Explosives and Blasting Agents" above, there are various drivers exist that relate to development of hazards analysis for explosives operations. The Contractors Requirements Document (Attachment 2, items 9 and 10) from DOE O 440.1A, *Worker Protection Management*, requires the contractor to implement a hazard prevention/abatement program to identify, analyze and control hazards in the work place. These hazards would include those associated with explosives operations, and assumes the application of a graded approach for their evaluation and control.

As incorporated by DOE O 440.1A, the DOE M 440.1-1, *DOE Explosives Safety Manual* requires an explosives hazards analysis for those facilities where explosives are used, stored or manufactured. This manual specifically references the use of the OSHA defined Process hazard analysis (PrHA) found in 29 CFR 1910.119, *Process Safety Management*, for any activity involving the manufacturing, formulation, synthesis, testing or disposal of explosives covered by this manual. However, the specific operations for which this requirement applies are not clearly identified, and as such, requires some sight level evaluation, interpretation,

and decision to determine which operations are covered.

## CONCLUSION

This report presents the methods, together with the advantages and disadvantages, for developing a safety document for chemical, non-nuclear facilities. The outline of a non-nuclear hazards analysis document is provided in various steps.

- Facility and Work Description
- Hazard Identification
- Facility Hazard Classification; Industry- PSM/RMP vs. traditional-high/moderate/low
- Hazard Analysis; Qualitative and/or semi-quantitative
- Identification of Controls
- Commitments to Safety Management Program (SMP)
- Document and Approval Process

The outline follows the essential steps of the ISMS as well as incorporates those ideas from DOE nuclear facilities safety document and industry based analyses.

The facilities should discuss the concepts, methods, and strategies with the respective DOE field or site offices to develop the necessary process(es) that ensure protection of the worker, public, and environment from hazardous material releases from high/moderate hazard facilities.

A standard industry approach following the OSHA and EPA (PSM, RMP) requirements and/or an approach similar to the DOE/NNSA nuclear facility SB process (DOE-STD-3009 like) are viable options.

**This report is *not* a proposed standard nor is it guidance for the SB process. This report outlines various safety analysis steps and methodologies with the advantages and disadvantages associated with them, so that each DOE/NNSA site can decide on its own the merits and demerits of each approach. Adoption of any step of the safety document process is voluntarily.**

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<sup>a</sup> Own view.

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13. Letter from J. B. Miles, Jr., Directorate of Compliance Programs, OSHA, Department of Labor to Mr. D. H. Delsemme. Subject: "Explosives and Blasting Agents." August 18, 1994.

## FURTHER READING

### NFPA

NFPA-704, *Standard System for the Identification of the Hazardous Material for Emergency Response*.

### DOE DIRECTIVES

- DOE-G-151.1-1V2, *Hazards Survey and Hazards Assessment*, August 21, 1997.
- DOE-O-151.1B, *Comprehensive Emergency Management System*, October 29, 2003.
- DOE-G-420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear and Non-Nuclear Facilities*, October 24, 2001.
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- DOE-STD-1021-93 (Reaffirmed), *Natural Phenomena Hazard Performance Categorization Guidelines for Structures, Systems, and Components*, April 2002.
- DOE-STD-1022-94 (Reaffirmed), *Natural Phenomena Hazards Site Characterization Criteria*, April 2002.
- DOE-STD-1023-95 (Reaffirmed), *Natural Phenomena Hazards Site Characterization Criteria*, April 2002.
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- DOE-STD-1186-2004, *Specific Administrative Controls*, August 2004.
- DOE-STD-3009-2002, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, Change Notice 2, April 2002.
- DOE-STD-3014, *Accident Analysis for Aircraft Crash Into Hazardous Facilities*, October 1996.
- DOE-EM-STD-5502-94 (Cancelled), *Hazard Baseline Documentation*, U.S. Department of Energy, Washington, DC, August 1994.

### DOE HANDBOOKS

- DOE-EH-4.2.1.3, *Computer Code Application Guidance for Documented Safety Analysis for MACCS, ALOHA, and EPI-code codes*, June 2004.
- DOE-HDBK-1100-2004, Rev.1, *Chemical Process Hazard Analysis*, August 2004.
- DOE-HDBK-1101-2004, Rev.1, *Process Safety Management for Highly Hazardous Chemical*, August 2004.
- DOE-HDBK-1163-2003, *Integration of Multiple Hazard Analysis Requirements and Activities* (Hazard Analysis Handbook), October 2003.
- DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, Change Notice 1, March 2000.

### CODE OF FEDERAL REGULATIONS (CFR)

10 CFR 830, *Nuclear Safety Management*, Vol. 66, No. 7, pp. 1810-1827, January 2001. 10 CFR 830, Subpart B, *SB Requirements*.

- 10 CFR 850, *Chronic Beryllium Disease Prevention Program*, January 4, 2001.
- 29 CFR 1910.109, *Explosives and Blasting Agents*, Revised July 1, 2004.
- 29 CFR 1910.119, *Process Safety Management of Highly Hazardous Chemicals*, Revised July 1, 2004.
- 29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response*, Revised July 1, 2004.
- 29 CFR 1910 and 1926, *Various Hazard or Activity Specific OSHA regulations*, Revised July 1, 2004.
- 40 CFR 68, *Accident Prevention Provisions*, March 1995.
- 40 CFR 302.4, *Designation, Reportable Quantities, and Notification*, July 1992.
- 40 CFR 355, *Emergency Planning and Notification*, Revised July 1992.
- 40 CFR 372, *Toxic Chemical Release Reporting: Community Right-to-Know*, July 2004.
- 48 CFR 970.5204-2 (c)(2), *Laws, Regulations, and DOE Directives*.
- 48 CFR 970.5223-1, *Integration of Environment, Safety, and Health into Work Planning and Execution*, December 2000.

### DEFINITIONS OF REGULATORY LIMITS AND GUIDELINES

#### Acute Exposure Guideline Level (AEGL):

AEGLs for hazardous substances are being developed by the National Advisory Committee on AEGLs. The AEGLs are based on five emergency exposure periods (10 and 30 min., 1 hr, 4 hr, and 8 hr) and three severity levels as defined below.

**AEGL-1:** Airborne concentration of a substance above which is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, effects are not disabling and are transient and reversible upon cessation of exposure.

**AEGL-2:** Airborne concentration of a substance above which is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

**AEGL-3:** Airborne concentration of a substance above which is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or deaths.

**Emergency Response Planning Guidelines (ERPG)** provides values intended as estimates of concentration ranges where one might reasonably anticipate observing adverse effects as a consequence of exposure to a specific substance. Three ERPG values are given in each guide:

**ERPG-1:** The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.

**ERPG-2:** The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective actions.

**ERPG-3:** The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

**Immediately Dangerous to Life and Health (IDLH):** The atmosphere of a work environment that poses an immediate hazard to life or poses an immediate irreversible debilitating effect on health. This term is defined within Occupational Safety and Health Administration (OSHA) regulation Title 29 of the Code of Federal Regulations (CFR) 1910.120, *Hazardous Waste Operations and Emergency Response*.

**Permissible Exposure Limit (PEL):** Are established by OSHA to protect workers

against the health effects of exposure to hazardous substances. PELs are regulatory limits on the amount or concentration of a substance in the air. Some substances may also contain a skin designation. PELs are enforceable and are based on an 8-hour time weighted average exposure.

**Temporary Emergency Exposure Limits 1, 2, and 3 (TEEL-1, 2, and 3):** Where ERPG - 1, 2, and 3 values are not available, TEEL values can be used. TEEL limits are listed for over 2,520 chemicals. These are alternate guideline limits based on comparisons between toxicity parameters and ERPGs.

**Threshold Limit Value (TLV):** Guidelines prepared by the ACGIH designed for use in making determinations on the safe levels of exposure to various chemical substances and physical agents found in the workplace. These exposure limits are considered guidelines and are prepared by the ACGIH as best practices in preventing disease or injury.

**Integrated Safety Management Systems (ISMS):** A Safety Management System to systematically integrate safety into management and work practices at all levels of activity as required by Department of Energy P 450.4, Safety Management System Policy. An ISMS consists of five core functions, which are defined as: 1. Define

work, 2. Identify and analyze hazards, 3. Develop and implement controls, 4. Perform work safely, and 5. Ensure performance and continuous improvement.

**Occupational Safety and Health Administration (OSHA):** Provides regulatory control on exposure limits to chemicals within the work environment quantified as a Permissible Exposure Limit. Regulates the type and quantity of certain listed chemicals to prevent or minimize the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals. These releases may result in toxic, fire, or explosion hazards and are documented in Title 29 of the Code of Federal Regulations Part 1910, subpart 119, Process Safety Management of highly hazardous chemicals and also addressed in Title 29 of the Code of Federal Regulations 1910.120. **U.S. Environmental Protection Agency (EPA):** Provides for the protection of human health and safeguarding the natural environment. Regulations applicable to the release of hazardous chemicals is covered in Title 40 of the Code of Federal Regulations subpart 68, Chemical accident prevention provisions; 40 CFR 302, Designation, reportable quantities, and notification; and 40 CFR 355, Emergency planning and notification.

## Appendix A: Description of Relevant DOE Orders and CFR Regulations

#	Reference	Title	Description
1	DOE-O-420.1A	Facility Safety	DOE-O-420.1A, <i>Facility Safety</i> , establishes facility safety requirements for DOE and NNSA for nuclear safety design, criticality safety, fire protection, natural phenomena hazards mitigation, and a system engineer program. The Order is split applicability for nonnuclear and nuclear facilities as well as explosive facilities. The Order requires that a fire hazards analysis (FHA) be developed for all DOE facilities, nonnuclear and nuclear facilities. The FHA is a comprehensive evaluation of fire hazards in a facility and includes the postulation of fire accident scenarios and estimates of their potential consequences (i.e., maximum credible fire loss). For non-nuclear and nuclear facilities, the Order also requires a Natural Phenomena Hazard (NPH) Assessment.
2	DOE-G 420.1-2	Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-nuclear Facilities	DOE-G-420.1-2 provides guidance for implementing the natural phenomena hazards (NPH) mitigation requirements of DOE O 420.1, Facility Safety. The guide addresses radiological and nonradiological hazards and life-safety issues, including protection of workers from exposure to hazardous materials that is caused by the failure of structures, systems, and components (SSCs). A contractor or operator responsible for a DOE nuclear or nonnuclear facility must design, construct, and operate the facility so that the public, workers, and environment are protected from the adverse impacts of the listed NPHs. The four DOE Standards (DOE STD 1020, 1021, 1022, and 1023) have been developed to provide specific acceptance criteria for various aspects of NPH to meet the requirements of DOE O 420.1, <i>Facility Safety</i> and DOE G 420.1-2.

## Appendix A: (Continued)

#	Reference	Title	Description
			<ul style="list-style-type: none"> <li>• DOE-STD-1020, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities"</li> <li>• DOE-STD-1021, "Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components"</li> <li>• DOE-STD-1022, "Natural Phenomena Hazards Site Characterization Criteria"</li> <li>• DOE STD-1023, "Natural Phenomena Hazards Assessment Criteria"</li> </ul>
3	DOE-O-151.1B	Comprehensive Emergency Management System	DOE Order 151.1B, <i>Comprehensive Emergency Management System</i> , requires that each DOE site/facility perform a Hazards Survey. The Hazards Survey must identify potential emergencies (e.g., fires, natural phenomena) and describe potential health, safety, and environmental impacts. Based upon results of the hazardous material screening performed within the Hazards Survey, an Emergency Planning Hazards Assessment (EPHA) may be required. The EPHA is the technical basis for the Emergency Planning Zone and many Emergency Plan implementing procedures.
4	DOE-G 151.1-1 V2	Hazards Surveys and Hazards Assessments	DOE-G 151.1-1 V2, <i>Hazards Surveys and Hazards Assessments</i> , acknowledges similarities between the EPHA and safety analyses that are compliant with 10 CFR 830, Subpart B, SB Requirements. This includes the use of common baseline hazards information, equivalency of many accident initiators and similarity in consequence assessment models.
5	DOE-O-440.1A	Worker Protection Management	The Contractors Requirements Document (Attachment 2, items 9 and 10) from DOE-O- 440.1A, <i>Worker Protection Management</i> , requires the contractor to implement a hazard prevention/abatement program to identify, analyze and control hazards in the work place, but does not provide specific guidance on how this program should be accomplished. This order does not specify whether the hazard prevention/abatement program should be applied at the work/process level, facility level, or both. This order also requires the DOE contractors follow regulatory and consensus standards such as OSHA (29CFR1910), National Fire Protection Association (NFPA) standards, etc.
6	DOE-M 440.1	Explosives Safety Manual	As incorporated by DOE-O- 440.1A, the DOE M 440.1, <i>DOE Explosives Safety Manual</i> requires an explosives hazards analysis for those facilities where explosives are used, stored or manufactured. This manual specifically references the use of the OSHA defined Process hazard analysis found in 29CFR1910.119, <i>Process Safety Management</i> , for any activity involving the manufacturing, formulation, synthesis, testing or disposal of explosives covered by this manual.
7	DOE-P 450.4	Safety Management System Policy	An ISMS provides the overarching SB requirements for non-nuclear facilities. ISMS applies to all DOE facilities through DOE-P- 450.4, <i>Safety Management System Policy</i> , and Department of Energy Acquisition Regulations (DEAR) clause 48 CFR 970.5223-1 <i>Integration of environment, safety, and health into work planning and execution</i> . The DEAR clause requires DOE contractors to integrate environment, safety, and health into work planning and execution. Specifically, it requires contractors to apply the following guiding principles that relate to SB for both nuclear and non-nuclear facilities.  <b>Planning:</b> Before work is performed, hazards associated with the work to be performed are evaluated and an agreed-upon set of ES&H standards and requirements established which, if properly implemented, provide adequate assurance that employees, the public, and the environment are protected from adverse consequences.

## Appendix A: (Continued)

#	Reference	Title	Description
			<p><b>Hazard Controls:</b> Administrative and engineering controls to prevent or mitigate hazards are developed for the work being performed. Emphasis should be on designing the work and/or controls to reduce or eliminate hazards and to prevent accidents and unplanned release exposure.</p> <p><b>Operations Authorization:</b> The conditions and requirements to be satisfied for operations to be initiated and conducted are established and agreed- upon by DOE and the contractor. These agreed-upon conditions and requirements are requirements of the contract and binding upon the contractor. The extent of documentation and level of authority for agreement shall be tailored to the complexity and hazards associated with the work and shall be established in a Safety Management System.</p> <p>See DOE G 450.4 “Integrated Safety Management System Guide” for additional guidance.</p>
8	10 CFR 830, Subpart B	SB Requirements	<p>Subpart B establishes SB requirements for hazard category 1, 2, and 3 DOE nuclear facilities and is not applicable to non-nuclear facilities. The contractor must obtain approval from DOE for the methodology used to prepare the documented safety analysis for the facility unless the contractor uses a methodology set forth in Table 2 of Appendix A to this Part. The documented safety analysis for a hazard category 1, 2, or 3 DOE nuclear facility must, as appropriate for the complexities and hazards associated with the facility as follows:</p> <ul style="list-style-type: none"> <li>• Describe the facility (including the design of safety structures, systems and components) and the work to be performed.</li> <li>• Provide a systematic identification of both natural and man-made hazards associated with the facility.</li> <li>• Evaluate normal, abnormal, and accident conditions, including consideration of natural and man-made external events, identification of energy sources or processes that might contribute to the generation or uncontrolled release of radioactive and other hazardous materials.</li> <li>• Derive the hazard controls necessary to ensure adequate protection of workers, the public, and the environment, demonstrate the adequacy of these controls to eliminate, limit, or mitigate identified hazards, and define the process for maintaining the hazard controls.</li> </ul> <p>See DOE-G-421.1-2, “Implementation Guide for Use in Developing Documented Safety Analyses to Meet Subpart B of 10 CFR 830” for additional guidance.</p>
9	10 CFR 850	Chronic Beryllium Disease Prevention Program	<p>10 CFR 850<sub>2</sub> Chronic Beryllium Disease Prevention Program, establishes a chronic beryllium disease prevention program (CBDPP). A baseline inventory is required to identify those areas that contain beryllium and the responsible employer must evaluate potential exposures by performing a beryllium hazard assessment. These assessments should include analyses of existing conditions, exposure data, medical surveillance trends, and the exposure potential of planned activities.</p>
10	29 CFR 1910.109	Explosives and Blasting Agents	<p>For facilities that manufacture explosives, 29 CFR 1910.109, <i>Explosives and Blasting Agents</i>, invokes the requirements of PSM (29CFR1910.119), including the completion of a hazards analysis. Two issues should be noted. First, the requirement to use PSM applies to all facilities (including laboratories) that manufacture any amount of explosive. There is no de minimus quantity. Second, the requirement to use PSM does not apply to facilities that store explosives even though 29CFR1910.109 has numerous regulations concerning the storage of explosives in bunkers or other specialized facilities and the structure of these facilities. The PSM standard does not address explosives.</p>

## Appendix A: (Continued)

#	Reference	Title	Description				
11	29 CFR 1910.119 and 1926.64	Process Safety Management	<p>29CFR1910.119 and 1926.64, Process Safety Management (PSM), has many requirements for the management of industrial chemicals that are listed in these standards. One of these requirements is a chemical process hazard analysis (PrHA) for facilities having listed chemicals present in quantities that exceed threshold quantities for approximately 140 chemicals.</p> <p>The PrHA by PSM shares some similarity to the documented safety analysis (DSA) that is required by 10 CFR 830, Subpart B for DOE nuclear facilities. The PrHA and the DSA serve as the primary analysis of facility level hazards, and both involve the following processes:</p> <ul style="list-style-type: none"> <li>• Identification of hazardous material or radionuclide inventories;</li> <li>• Implementation of formal hazard analysis techniques that are commensurate with facility complexity;</li> <li>• Identification of systems and equipment vital to safety;</li> <li>• Formal documentation of findings; and</li> <li>• Periodic updates of hazard analysis information.</li> </ul> <p>Both OSHA PSM and DOE DSA references require the use of established, standard hazard evaluation methodologies. The OSHA PSM requires qualitative PrHA that include What-If/Checklist, Hazard and Operability Study (HAZOP), Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA), and other acceptable methods.</p>				
12	29 CFR 1910.120	Hazardous Waste Operations and Emergency Response	<p>OSHA (29 CFR 1910.120) requires that a health and safety plan (HASP) be prepared for hazardous waste cleanup operations. The HASP must involve a hazard/risk assessment of planned activities to identify any conditions that pose significant hazards to workers. A thorough hazard characterization provides the primary basis for the hazard/risk assessment and typically includes a facility walk down, visual inspections, air monitoring and sampling, and a review of facility records. This regulation applies only to clean up at hazardous waste sites; operations at treatment, storage and disposal facilities; or where emergency response operations are anticipated.</p>				
13	29 CFR 1910 and 1926	Various Hazard or Activity Specific OSHA regulations	<p>A number of regulations have hazard analysis requirements that are specific to certain activities, hazardous conditions, or specific substances. These rules include substance or operation specific hazards such as lead, asbestos, beryllium, confined spaces, laboratory operations, and blasting operations. The hazard analysis requirements of this type are an integral part of work planning that feeds into the preparation of hazardous and radiation work permits, Health and Safety Plans, Industrial Hygiene Plans and overall work packages and documentation. These activities have a different emphasis than facility-level hazard analysis, because these are primarily focused on worker protection. As such, activity-level hazard analysis addresses the hazards associated with individual job functions and tasks.</p> <p>For the below listing, these regulations do not specifically provide for hazard analyses or screening quantities, but do detail many requirements for those areas where these chemicals are stored or used. Requirements for regulated work areas, signage, training, etc., should be reflected in the appropriate SB documentation. Many chemicals overlap between 1910 and 1926. Only one regulation is cited for that chemical. These are shown below.</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">1910.1001 – Asbestos</td> <td style="width: 50%;">1910.1002 – Coal tar pitch volatiles</td> </tr> <tr> <td>1910.1003 – 13 carcinogens (4-nitrobiphenyl, etc.)</td> <td>1910.1004 – Alpha-naphthylamine</td> </tr> </table>	1910.1001 – Asbestos	1910.1002 – Coal tar pitch volatiles	1910.1003 – 13 carcinogens (4-nitrobiphenyl, etc.)	1910.1004 – Alpha-naphthylamine
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1910.1003 – 13 carcinogens (4-nitrobiphenyl, etc.)	1910.1004 – Alpha-naphthylamine						

## Appendix A: (Continued)

#	Reference	Title	Description
			1910.1006 – Methyl chloromethyl ether
			1910.1007 – 3,3'-Dichlorobenzidine (and its salts)
			1910.1008 – bis-Chloromethyl ether
			1910.1009 – Beta-naphthylamine
			1910.1010 – Benzidine
			1910.1011 – 4-Aminodiphenyl
			1910.1012 – Ethyleneimine
			1910.1013 – Beta-propiolactone
			1910.1014 – 2-Acetylaminofluorene
			1910.1015 – 4-Dimethylaminoazobenzene
			1910.1016 – N-Nitrosodimethylamine
			1910.1017 – Vinyl chloride
			1910.1018 – Inorganic arsenic
			1910.1025 – Lead
			1910.1027 – Cadmium
			1910.1028 – Benzene
			1910.1029 – Coke oven emissions
			1910.1044 – 1,2-Dibromo-3-chloropropane (DBCP)
			1910.1045 – Acrylonitrile
			1910.1047 – Ethylene oxide
			1910.1048 – Formaldehyde (formalin)
			1910.1050 – Methylenedianiline
			1910.1051 – 1,3-Butadiene
			1910.1052 – Methylene chloride
			1926.62 – Lead
			1926.1110 – Benzidine
			1926.1112 – Ethyleneimine
			1926.1113 – Beta-Propiolactone
			1926.1144 – 1,2-Dibromo-3-chloropropane
			1926.1148 – Formaldehyde
14	40 CFR 68	Chemical Accident Prevention Provisions	<p>The Chemical Accident Prevention regulation requires facilities to meet the planning and analysis requirements of the applicable level of a three level program that increases in stringency. For all three levels, facilities exceeding established thresholds for a limited set of chemicals are required to submit a risk management plan (RMP). The RMP requires analysis of the worst-case release scenario for the facility process(es) to ensure that the nearest public receptor is beyond the distance to a toxic, explosion, radiant heat, or flammable endpoint.</p> <p>In addition, a five-year accident history for the processes must be evaluated. For the next two levels of stringency, the RMP must also include documentation that the facilities have implemented a RMP, conducted a hazard assessment, implemented an emergency response program, and developed an accident prevention program. The hazard assessment requires a review of the hazards associated with the regulated substances, process, and procedures. The hazards review identifies the hazards associated with the process and regulated substances; opportunities for equipment malfunctions or human errors that could cause an accidental release; the safeguards used or needed to control the hazards or prevent equipment malfunction or human error; and any steps used or needed to detect or monitor releases.</p>
15	40 CFR 302.4	Designation, Reportable Quantities, and Notification	<p>This regulation designates under section 102(a) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (“the Act”) those substances in the statutes referred to in section 101(14) of the Act, identifies reportable quantities for these substances, and sets forth the notification requirements for releases of these substances. This regulation also sets forth reportable quantities for hazardous substances designated under section 311(b)(2)(A) of the Clean Water Act. 40 CFR 302.4, Designation, Reportable Quantities, and Notification, provides a list of hazardous substances and their reportable quantities (RQs). These reportable quantities are those that if exceeded in a release require the notification to the National Response Center and possibly the state in which the release occurred.</p>

## Appendix A: (Continued)

#	Reference	Title	Description
16	40 CFR 355	Emergency Planning and Notification	This regulation establishes the list of extremely hazardous substances (EHS), threshold planning quantities (TPQs), and facility notification responsibilities necessary for the development and implementation of State and local emergency response plans. The requirements of this section apply to any facility at which there is present an amount of any extremely hazardous substance equal to or in excess of its threshold planning quantity.
17	48 CFR 970.5204-2 (c)(2)	Laws, Regulations, and DOE Directives	Environmental, safety, and health (ES&H) requirements appropriate for work conducted under DOE contracts may be determined by a DOE approved process to evaluate the work and the associated hazards and identify an appropriately tailored set of standards, practices, and controls, such as a tailoring process included in a DOE approved Safety Management System implemented under the clause entitled "Integration of Environment, Safety, and Health into Work Planning and Execution."
18	48 CFR 970.5223-1	Integration of Environment, Safety, and Health into Work Planning and Execution	For Department of Energy facilities, the primary hazard analysis requirement is found in the DOE Acquisition Regulations (DEAR, ES&H Clause), which requires the identification and evaluation of hazards associated with work as part of an overall documented safety management system (i.e., ISM). The purpose of the ISM is to identify and analyze potential dangers to workers, public or environment to ensure that effective controls can be established to minimize or prevent adverse impacts. For additional guidance see DOE G 450.4-1B, "Integrated Safety Management System Guide", March 1, 2001.
19	DOE-G 440.1-2	Locally Enforced Fire/Building Codes	This guide requires that DOE facilities follow numerous codes and regulations including the locally enforced building and fire codes. Every building/fire code used in the United States contains provisions for hazardous materials (e.g., Article 80 of the Uniform Fire Code, Chapter 22 of the Southern Building Code, Chapter 27 of the International Fire Code) These codes require every hazardous material present in the facility to be evaluated to determine all hazards associated with them. Hazards classifications are present in each fire/building code and are similar from code to code.  Examples of hazards are toxic; highly toxic; class 1, 2, 3 or 4 oxidizer; class I, II, III, IV or V organic peroxide; class 1, 2, 3, or 4 unstable reactive, pyrophoric, etc. If any chemical hazard is present over specified limits in a given facility, then special storage conditions, facility design, and controls to mitigate the hazards may need to be implemented.