NUREG-1601

Chemical Process Safety at Fuel Cycle Facilities

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

D. A. Ayres

DF02

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ABSTRACT

This NUREG provides broad guidance on chemical safety issues relevant to fuel cycle facilities. It describes an approach acceptable to the NRC staff, with examples that are not exhaustive, for addressing chemical process safety in the safe storage, handling, and processing of licensed nuclear material. It expounds to license holders and applicants a general philosophy of the role of chemical process safety with respect to NRC-licensed materials; sets forth the basic information needed to properly evaluate chemical process safety; and describes plausible methods of identifying and evaluating chemical hazards and assessing the adequacy of the chemical safety of the proposed equipment and facilities. Examples of equipment and methods commonly used to prevent and/or mitigate the consequences of chemical incidents are discussed in this document.

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PREFACE

NUREG-1601 is being issued to provide broad guidance on chemical safety. It describes an approach acceptable to NRC staff, although the examples offered are not exhaustive. NUREG-1601 is not a substitute for the regulations, and compliance is not a requirement. This guidance document describes a general philosophy of the role of chemical process safety with respect to NRC-licensed material.

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1. INTRODUCTION

The issuance and continuance of specific licenses for activities involving source and special nuclear materials require that the applicant's proposed procedures, equipment, and facilities be adequate to protect health and minimize danger to life or property in accordance with 10 CFR 40.32(c) and 70.23(a)(3) and (4). To protect health and minimize danger, the applicant should address all hazards of nuclear material, including chemical hazards posed by radioactive materials, chemicals, and plant conditions which may directly or indirectly affect the licensed nuclear material in an adverse manner. According to the October 21, 1988, Memorandum of Understanding (MOU) between NRC and the Occupational Safety and Health Administration (OSHA), the regulation of these hazards is the responsibility of NRC. Also, 10 CFR 76.87 requires gaseous diffusion enrichment plants to establish procedures and/or equipment to address chemical safety.

Performing an adequate analysis of chemical safety in processing licensed material at fuel cycle facilities decreases the potential for radiological and nonradiological exposures to workers and the public and minimizes releases to the environment. This report highlights the importance of chemical process safety at facilities where licensees handle, process, and store nuclear materials. It provides broad guidance on chemical process safety issues at such facilities and discusses methods of preventing or mitigating the consequences of chemical incidents.

2. DISCUSSION

Most NRC fuel cycle licensees possess materials that are chemically hazardous and/or pose some sort of nonradiological risk. Chemical and radiological risks have been known to compound one another, and in many cases, radioactive materials are also chemically hazardous. A chemical explosion in a fuel cycle facility could disperse radioactive material, just as the radiation environment could make it more difficult to respond to a hazardous chemical spill. Thus, chemical process safety plays a major role in the proper operation of nuclear fuel cycle facilities. Virtually all processes of source and special nuclear materials use chemicals which can be considered hazardous or potentially hazardous under certain conditions.

For the purpose of this document, hazardous chemicals are substances which are toxic, explosive, flammable, corrosive, or reactive to the extent that they can cause significant damage to property or endanger life if not adequately controlled. Some of the more common hazardous chemicals used in nuclear fuel cycle facilities are uranium hexafluoride (UF_6), strong acids, ammonia, and hydrogen. Additionally, systems containing substances which are not normally considered hazardous under ambient conditions may, under extreme conditions or in combination with other chemicals, produce hazardous situations. These substances include hot water, steam and cryogenic or compressed gases such as air, nitrogen, and carbon dioxide.

Many hazardous chemicals are also regulated by other agencies, but mainly in the prevention of catastrophic events or major releases to the environment. This regulation of hazardous chemicals is based on threshold limits. The NRC's concern is not only with the effect of the chemicals on public and worker safety, but also with their effect on safe operations, regardless of the total amount of the chemicals onsite. The MOU between NRC and OSHA on chemical safety issues makes provision for the NRC to assume responsibility for the control of risks which may affect radioactive materials. Paragraph 3 of the MOU states:

> There are four kinds of hazards that may be associated with NRC-licensed nuclear facilities.
>
> a. Radiation risk produced by radioactive materials;
>
> b. Chemical risk produced by radioactive material;
>
> c. Plant conditions which affect the safety of radioactive materials and thus present an increased radiation risk to workers. For example, these might produce a fire or an explosion, and thereby cause a release of radioactive materials or an unsafe reactor condition; and
>
> d. Plant conditions which result in an occupational risk, but do not affect the safety of licensed radioactive materials. For example, there might be exposure to toxic nonradioactive materials and other industrial hazards in the workplace.

Generally, NRC deals with the first three hazards listed in paragraph 3 (a, b, and c), and OSHA deals with the fourth hazard (d). The risks covered by NRC include those posed directly by radioactive chemicals, such as with UF_6, and any other condition which may directly or indirectly affect radiation risk to workers or the environment. Thus the NRC does not regulate chemicals per se; rather, the NRC verifies that the interactions of chemicals with NRC-licensed nuclear materials and/or with equipment which processes, transports, or stores these licensed materials have been considered in the design of the equipment and facilities and in the operating and maintenance procedures. Such interactions may cause degradation of equipment, loss of confinement, and misdirection of licensed materials, resulting in potential danger to workers, the public, and the environment.

2.1 Chemical Process Information

Safety of chemical processing of nuclear materials depends largely on the information available about the process and about the chemicals used in the process (including chemical intermediates, process parameter limits, etc.). The following information should be documented and made available to persons responsible for verifying and maintaining chemical process safety throughout the facility.

2.1.1 Process Description

A description of the proposed chemical and mechanical process steps for the licensed material aids the reviewer in understanding the design basis. A complete description of the processes should contain the following elements.

2.1.1.1 Purpose

The process description should state the purpose or objective of each process step, including the operation(s) to be performed, the equipment to be used, and destinations of outputs and effluents.

2.1.1.2 Material Form

The process description should include the chemical and physical form(s) of the licensed material at each process step. It should include inputs, outputs, and any intermediary transformations occurring at each step.

2.1.1.3 Process Chemicals

The process description should include a list of all chemicals input to each process step, specifying which ones are to be in contact with the licensed materials and which chemicals could potentially contact licensed materials in case of leaks or human error.

2.1.1.4 Process Variables

The process description should include the approximate ranges of temperatures, pressures, and mass flow rates for each of the process chemicals and the licensed materials. These ranges should be included for inputs, outputs, and materials and chemicals in process.

2.1.1.5 Process Control

The process description should generally cover the process equipment and engineering design features used for process control in each process step, including setpoint ranges for safety controls. Any special administrative or procedural controls should also be described.

2.1.1.6 Materials of Construction

The process description should provide a list or description of the materials of construction used in the processing, storage, and in-process transport of licensed material when that information is necessary for understanding the potential degradation, or the effect of radiation on the strength and properties, of the construction material.

2.1.1.7 Safety Features

The process description should include the structures, systems, equipment, components, engineered design controls, and human actions and administrative controls relied on for chemical process safety. Such features may include not only the engineered design controls and materials of construction mentioned above, but also items such as chemical confinement, barriers, leak suppression equipment, emergency shutdown or response procedures, and passive engineered controls such as rupture disks. Where special nuclear material (SNM) might accumulate, as in dikes or bags to contain leaks, criticality-safe geometries may need to be considered.

2.1.2 Auxiliary Systems

The process safety information should include a description of other systems (including safety features) in the licensed-material process areas, transport areas, or storage areas, such as plant utilities, bulk chemical systems, and ventilation. These systems are not necessarily part of the licensed-material processing system but, under off-normal[1] conditions, could affect licensed material processing.

2.1.2.1 Bulk Chemicals

Attention should be given to systems which contain toxic and hazardous substances under NRC jurisdiction as defined by the MOU between OSHA and NRC. These include hazardous substances identified in 29 CFR Part 1910, Subparts H and Z, regardless of quantity.

2.1.2.2 Utilities

A description of utilities near licensed-material processing should be part of or referenced by the process safety information. Steam, water, vacuum systems, compressed gases, and electrical power supplies could, if interrupted or uncontrolled cause a hazardous condition to develop with the licensed materials.

2.1.2.3 Ventilation

The operation of the ventilation system may be the single most important protection against radiological exposure. Design information of the ventilation system ducting, scrubbers, filters, and controls should be included or referenced in the process safety information.

2.1.2.4 Chemical Traps and Filters

These systems may be considered a subset of the other process or auxiliary systems, but are important enough to be mentioned separately. The design of chemical traps and filters should be part of the process safety information. Trap design, filter media, operating temperatures and pressures, cleanout or filter change procedures, and automated controls should be described.

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[1]Off-normal conditions refers to conditions that are in some respect outside of the range for routine operations but have not resulted in an accident.

2.1.2.5 Emergency Systems

Systems which provide mitigative services (e.g., fire suppression equipment) or backup for main systems (e.g., emergency power supply) should be included or referenced in the process safety information. Descriptions of their locations, operations, and testing methods may be important with regard to chemical process safety.

2.1.3 Specialty Chemical Data

The process safety information should provide the general information included on the Material Safety Data Sheets[2] for any specialty chemical used in the licensed-material process areas, transport areas, or storage areas.

2.2 Hazard Audit

In order to minimize the probability of accidents[3] and their impact on the licensed material, potential chemical process safety hazards should be identified through a hazard audit.

2.2.1 System Review

The first step is to thoroughly review the facility to identify potential chemical hazards[4] of radioactive materials and radiation hazards caused by chemicals. The system review should include the following elements.

2.2.1.1 Process Chemistry

Observe the chemical components added to each process step. Identify all chemical process hazards where chemical reactions could produce hazardous materials which were not previously present (e.g., the evolution of hydrogen when metals are dissolved in acids).

2.2.1.2 Effects of Variable Chemical Additions

At each process step, analyze the effect that adding variable amounts of chemicals has on generating hazardous materials and on the chemical and physical forms of the licensed material. Evaluate the possibility and effects of adding the wrong chemicals to a process step or adding them in the wrong sequence. Also evaluate the potentially unwanted dissolution or precipitation of the licensed material, especially if the licensed material could thereby be released into a waste stream.

2.2.1.3 Energy Sources

Evaluate the potential energy sources of the process components, such as source elevated temperatures and pressures, electrostatic forces, exothermic reactions, erosion caused by abrasive materials, and flammable and explosive materials. The potential effects of these sources of energy on equipment and personnel should be considered as part of any hazard audit.

2.2.1.4 Materials of Construction

Determine whether the materials of construction and the process equipment have been chosen in such a manner that a catastrophic failure resulting in a release of

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[2]Pursuant to 29 CFR 1910.1200g, OSHA requires Material Safety Data Sheets to be supplied by U.S. chemical manufacturers and importers.

[3]An accident is an unplanned event or sequence of events that results in undesirable consequences; or an incident with specific safety consequences or impacts.

[4]A hazard is an inherent physical, radiological, or chemical characteristic that has the potential for causing harm to humans or to the environment.

hazardous materials is unlikely. A catastrophic failure could be caused by chemical incompatibility, thermal cycling, or excessive heat and pressure.

2.2.1.5 Process Control and Safety Devices

Determine whether adequate safety devices or systems are in place to minimize potential hazards from process chemicals or chemical reactions; for example whether ventilation, pressure relief valves, combustible gas detectors, double-walled pipe, etc., are available to prevent, mitigate, or warn of a hazardous condition. Determine whether process controls are adequate to prevent avoidable chemical hazards (e.g., controls for temperature, pressure, level, interface, pH, conductivity).

2.2.1.6 Other Chemical Systems in the Licensed-Material Process Areas

Chemical systems which are not directly involved in the processing of licensed materials but are in the same general area can interact with the licensed materials and/or associated equipment. Therefore, review the controls that are in place to prevent these systems from leaking into and onto equipment containing licensed material. A review of whether potential releases from other chemical systems could affect the access to or operability of equipment containing licensed materials should also be considered.

2.2.1.7 Management Controls

The administrative controls placed on chemical systems and the requirements placed on workers can have an overriding effect on the operation of the facility. The management control systems needed to maintain chemical process safety (Section 2.6) should be reviewed during each iteration of the hazard audit.

2.2.1.8 Human Factors

Potential human errors in the operation and maintenance of the process should be guarded against. The review of chemical systems should consider ergonomics and worker fatigue as a potential cause of hazards. The design and location of the equipment, the layout of the process, and the clarity and sequence of instructions in procedures should all be reviewed with human factors in mind.

2.3 Identification of the Hazards

2.3.1 Potential Accident Scenarios

If the system review reveals, potential chemical hazards of radioactive materials and radiation hazards caused by chemicals, the hazards should be identified, documented, and analyzed to determine their effects. Whenever possible, a licensee's own experience should be used to supplement the identification of potential chemical hazards. Chemical accidents that have occurred in the past show the more common hazards, but reliance on past experiences alone may cause many hazards to be overlooked. The lack of chemical accident occurrences in a particular area does not mean that chemical hazards do not exist there.

There are many different methods of identifying potential chemical hazards. Some of the more common methods involve developing interaction matrices or using specific hazard evaluation techniques. However, any method which sufficiently identifies potential interactions of the process area chemicals with the licensed material and its associated confinement, process equipment, and workers would be acceptable. Regardless of the method chosen for identifying hazards, the consequences to people and the environment must be considered in determining which conditions are hazards.

2.3.1.1 Effects on Public and Workers

The most commonly faced situation at fuel cycle facilities is the exposure of workers to chemicals containing the licensed material. Such situations could adversely affect the health of workers and/or members of the general public and should be identified as potential chemical hazards. Chemicals which do not contain licensed materials should also be identified as potential chemical hazards because, even in the absence of workers, release of such chemicals may affect the process by releasing the licensed material or may affect the confinement of the licensed material in a favorable geometry.

2.3.1.2 Effects on the Environment

Chemicals which can cause a release of licensed material to the environment above NRC-prescribed limits should be identified as potential chemical hazards. Such releases include onsite and offsite contamination of air, water, and soil.

2.3.1.3 Effects on the Facility

The impact of chemicals on facility systems, structures, equipment, and components (i.e., process equipment) is an integral part of any chemical hazard analysis. Chemical effects causing degradation of process safety equipment (equipment for preventing, mitigating, and annunciating a process hazard), process control equipment, and confinement vessels and structures should be identified as chemical hazards if the degradation could affect the licensed material and potentially have a human or environmental impact.

2.3.2 Instruments and Control Functions

Instrumentation and control systems, as identified by the integrated safety analysis[5] (ISA), should be provided to monitor variables and operating systems important to safety during normal and off-normal operations, accidents, and shutdown conditions. In addition, the overall confinement system, the confinement barriers, and the other systems which affect plant safety should be monitored. Controls should maintain variables within prescribed operating ranges under all normal conditions, and control systems should be designed to fail to a safe state. Protection systems whose primary functions are to prevent releases, facilitate process shutdowns, or protect worker and public health and safety should be designed to:

a. initiate actions to ensure that design limits are not exceeded,

b. sense potentially hazardous conditions,

c. have reliability and testability,

d. maintain function with loss of a single active component,

e. maintain function with removal from service of any component[6], and

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[5] Integrated safety analysis means an analysis to identify hazards and their potential for initiating event sequences, the potential event sequences and their consequences, and the site, structures, systems, equipment, components, and activities of personnel, that are relied on for safety as stated in the Draft NUREG-1513.

[6] e.g. Use of acceptable compensatory measures or backup equipment to assure availability and reliability of items relied on for safety or remove hazard from system.

f. fail to a safe state in loss of power.

Thus, the identification of hazards should consider accident scenarios where instrumentation and control systems can fail in the performance of one or more of these safety functions.

2.4 Design Basis

Assurance of chemical safety within a facility begins with a good design basis. Adequately designed chemical systems, including the controls used to prevent accidents, will have few safety problems through most of their operating life. Properly specified features such as materials of construction, equipment sizing, and system fabrication techniques will prevent many chemical accidents from occurring. The system's engineered-design process control schemes enhance these features to provide an even higher margin for safety. When the risk involving the licensed material is high, additional measures should be taken to ensure the chemical safety of the process.

2.4.1 Physical Barriers

The establishment of physical barriers is an effective method to prevent releases of licensed materials to unwanted locations. Physical barriers can be used to prevent auxiliary systems which do not contain licensed material from interacting with the licensed-material systems. Commonly used physical barriers are described below.

2.4.1.1 Double-Walled Piping and Tanks

These physical barriers capture liquid leaks and (when properly installed) alert personnel to the occurrence. They should normally be used on piping and storage vessels containing highly corrosive materials (such as hydrogen fluoride) in areas where a leak could easily affect the licensed material or its confinement. They are not normally recommended for SNM-bearing solutions unless adequate provisions are made in the criticality control calculations.

2.4.1.2 Liquid Confinement Dikes

These barriers are widely used in bulk chemical storage areas for confinement of large spills. Dikes should also be used to contain smaller amounts of spilled corrosives to prevent potential interaction with licensed-material process equipment. Dikes used to contain SNM-bearing solutions should not exceed criticality design constraints on volume, concentration, and enrichment.

2.4.1.3 Glove Boxes

In licensed-material handling areas where chemicals are present, glove boxes should be used to contain the licensed material and protect it from undesired chemical interactions. If other barriers are not in place, glove boxes should be constructed from materials that are resistant to the chemicals in the area.

2.4.1.4 Splash Shields

Splash shields can be used to direct spills of hazardous liquids away from licensed material storage and process areas and should also be used to protect workers from potential spills of solutions containing licensed material. Splash shields should be transparent when possible so that a dripping solution can be identified and corrected quickly.

2.4.1.5 Fire Walls

Fire walls can be used to protect licensed-material storage and process systems from potential fires and explosions. They should be used as a barrier between licensed material and large quantities of flammable or explosive chemicals which, when ignited, could disrupt the integrity of confinement systems. Fire walls should also be used as a barrier for high-pressure systems located near licensed materials.

2.4.1.6 Protective Cages

These barriers are used to protect chemical and licensed-material systems from impacts with moving objects. They are particularly useful in protecting polymer or glass components of chemical piping systems. Protective cages should be utilized where such components are exposed to major traffic areas.

2.4.1.7 Backflow Preventers and Siphon Breaks

These devices can be used in piping systems to prevent chemicals or licensed material solutions from flowing into undesirable locations and creating hazardous conditions. They should only be necessary where the process design requires interconnection of two or more potentially incompatible systems. Good process design practices should be used to minimize such connections.

2.4.1.8 Overflow Vessels

There should be an overflow strategy for each process vessel containing licensed materials and/or hazardous chemicals associated with it. In most instances, a separate vessel can be provided to accommodate possible overflow of the primary vessel. Such an overflow vessel should contain an alarm system so that the overflow condition can be recognized. Automatic cutoff systems on the process vessel feed lines can also be used. Multiple process vessels can be piped into the same overflow vessel if all of the associated solutions are chemically compatible with each other and with the overflow vessel construction materials.

2.4.1.9 Chemical Traps and Filters

These are typically used for collecting vapors, aerosols, and particulates from air and gas streams. Chemical traps capture vapors and aerosols by absorption or adsorption onto a collection medium. An example is the use of alumina to collect small quantities of UF_6 vapors from an air stream. Filters are widely used to remove radioactive particulates from air flows, but can be used in other situations.

2.4.2 Mitigative Features

Mitigative features help reduce the impact of chemical accidents. Chemical systems which tend to have an associated high risk level should include mitigative features in the equipment design. Multiple mitigative features may need to be combined to truly minimize the hazard. Some of the more common mitigative features in fuel cycle facilities are described below.

2.4.2.1 Driving Force Controls

These controls help stop the driving force of the hazard. They are typically devices which cut power to heating elements or other electrically driven equipment. They also include cutoffs for air-driven equipment, pressure relief devices, and emergency cooling systems. These controls should be in place on any system which contains licensed materials or hazardous substances at elevated temperatures or pressures.

2.4.2.2 Solenoid and Control Valves

These valves help stop the flow of hazardous substances from their confinements in cases of pipe breakage or downstream equipment failure. To be effective, they should be used in conjunction with inline pressure- or flow-monitoring equipment. They should be used on any system containing highly hazardous chemicals or explosive gases which does not have a secondary confinement system (e.g., double-walled piping). For fuel cycle facilities, highly hazardous chemicals[7] would typically include ammonia and ammonia solutions (>44wt%), fluorine, hydrogen chloride and concentrated hydrochloric acid, hydrogen fluoride and concentrated hydrofluoric acid, hydrogen peroxide (>52wt%), concentrated nitric acid (>94.5wt%), and uranium hexafluoride.

2.4.2.3 Spray Systems

Spray systems can be used to lessen the effects of a chemical accident by scrubbing chemicals from the air, diluting chemicals on the ground, or providing a quick cooling mechanism. The most common spray medium is water, but spray media can include dilute solutions which react with the hazardous chemical and render it nonhazardous. Carbon dioxide is a typical cooling medium. Equipment containing licensed material should use spray systems only after thorough consideration of their effect on criticality control.

2.4.2.4 Auxiliary Ventilation

Auxiliary ventilation systems can be located in high-risk areas to reduce the effects of a chemical release. These systems can be run continuously or on demand when a release occurs. Since these systems typically have a limited capacity, they should be used in conjunction with other mitigative features. They are particularly useful in areas where spray systems are not feasible.

[7]Highly hazardous chemicals as listed in 29 CFR 1910.119, Appendix A.

2.4.2.5 Alarm systems

Alarm systems can be used as a mitigative feature by alerting workers to the situation and enabling them to act quickly to reduce the effects of a chemical release. These actions could include measures to stop the release and/or evacuate the area. Alarm systems should be used in all high-risk chemical process areas.

2.5 Hazard Evaluation

The potential chemical hazards, once identified, should be evaluated for their impact on humans and the environment. The evaluation of chemical hazards should be performed as part of an integrated effort, along with other safety and safeguards measures, including fire protection, radiation safety, criticality safety, and physical security measures. Electrical and industrial safety concerns may also be part of the integrated safety analysis if their effects on workers can have a subsequent effect on the confinement of the licensed material.

2.5.1 Methods

The methods used for performing the hazard evaluation can vary from a simple qualitative checklist to a complex quantitative risk assessment. The Integrated Safety Analysis Guidance Document (Draft NUREG-1513) and other documents referenced therein describes most of the techniques used by the chemical industry for hazards evaluation. The method chosen should be consistent with the apparent risk associated with the facility, the level of detail desired from the results, the amount of process safety information available, and the current stage of the process life cycle.

2.5.2 Results

The results of the hazard evaluation should undergo internal peer review for reasonableness by personnel not involved in the original evaluation. The peer review team must be knowledgeable of the process facility operations. Management should then scrutinize the results and decide how to address each potential chemical hazard. It is important to update and revalidate the evaluation periodically and when a significant change to the process is made. Radiological and chemical accidents which already have adequate preventive and mitigative controls and those involving very low risks (low probability and low consequence) may not require any further action. Other chemical hazards may need to be addressed by establishing additional engineered-design controls; by installing protective barriers; and by implementing administrative controls (e.g., revised procedures, a preventive maintenance schedule, or an inspection- and/or test-based predictive maintenance system). A risk matrix can be used to provide guidelines for accepting or not accepting the analyzed frequency and consequence of the potential chemical hazard.

2.6 Continuing Assurance of Chemical Safety

Effective implementation of chemical safety demands management involvement and control. The inherent uncertainties associated with the input parameters for the hazard analysis can affect the accuracy of the results. Therefore, the elements discussed below may affect chemical processes at the facility and should be considered in the analysis. These elements should be reviewed iteratively with subsequent hazards analyses as new knowledge is gained. This periodic review should reduce the uncertainties and provide assurance of chemical safety at the facility.

2.6.1 Management Structure and Concepts

The management structure at a fuel cycle facility can vary widely according to the licensee's mission and capabilities. The important aspects of management structure and functions have been assembled in NUREG/CR-6287, "Management Concepts and Safety Applications for Nuclear Fuel Facilities." It is recommended that each licensee and license applicant designate one person to have overall responsibility and authority for chemical process safety in each facility, as is done for other disciplines such as criticality and radiological safety.

2.6.2 Procedures

Clear and comprehensive procedures are necessary to assure the safe operation of a fuel cycle facility. Without such procedures, measures taken to assure chemical safety would quickly lose their usefulness. Chemical safety issues identified by the hazard evaluation as having potentially significant impacts[8] on people or the environment should be addressed within the licensee's procedures. Procedures for fuel cycle facilities are generally of two types,

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[8] Impacts are considered significant if they could involve violations of Federal statutes.

operating procedures and management control procedures.

2.6.2.1 Operating Procedures

Operating procedures directly control process operations and should include instructions on handling chemical safety concerns during normal and off-normal conditions. These procedures should provide specific direction regarding administrative controls to ensure process chemical safety. Procedures for process operations which can affect chemical safety should include process operating limits and controls and the required actions for normal and off-normal conditions of operation. Off-normal conditions are conditions created by human failure or failure of any system, structure, or component.

2.6.2.2 Management Control Procedures

Management control procedures should be used to manage activities such as configuration management, maintenance, plant-wide safe work practices, training, audits, and incident investigations. There should be an overall chemical safety element describing the methods, activities, and implementation of the overall safety program.

2.6.3 Training

Effective chemical safety training helps employees understand the nature and causes of problems that could arise from process operations and increases awareness of the particular hazards of a process. The training programs described in a licensee's safety program description should include provisions for chemical safety training of all personnel who routinely access licensed-material areas, including contractor personnel, and visitors who are allowed unescorted access to those areas. More intensive chemical safety training should be provided to qualify personnel as chemical process operators.

2.6.4 Maintenance

Effective maintenance and surveillance of facility equipment ensure that equipment used to process, store, or handle hazardous materials is constructed, installed, and maintained to minimize the risk of accidental releases because of equipment failure. The mechanical integrity of all structures, systems, components, and detection and monitoring equipment important for ensuring chemical safety should be included in the maintenance activities. These activities should include corrective maintenance, scheduled preventive maintenance, instrumentation calibration and testing, and scheduled surveillance and inspections for verifying the integrity of the chemical safety of the facility. Maintenance and surveillance activities on chemical safety systems should include:

a. pre-maintenance reviews of the work to be performed;

b. confirmed notification to pertinent operators and supervisors of the maintenance to be performed and its potential effects of maintenance on ongoing operations, and notification of the completion of the planned maintenance and the restoration of the affected equipment;

c. comprehensive procedures which address qualification of personnel authorized to perform the maintenance or surveillance, controls on and specification of any replacement components or materials to be used, post-maintenance testing to verify operability of the equipment, and documentation of the results of the maintenance or surveillance activity.

2.6.5 Configuration Management

Configuration management (CM) ensures oversight and control of all design bases and modifications (both temporary and permanent) to equipment, procedures, and processing conditions important to chemical safety. Configuration management is one of the measures that should be integrated into a single safety program that incorporates chemical safety systems. A Configuration Management system should include the following elements.

2.6.5.1 Implementation Plan

The implementation of a CM system should determine the scope of the safety elements to be considered, a description of each CM activity and its objectives, and prescribe the functional interfaces with quality assurance, maintenance, and training. All chemical safety hazards identified as significant should be considered. The CM system should also have formalized configuration management procedures and provide a method for initiating immediate corrective actions to problems found with the CM system.

2.6.5.2 Design Requirements

Design requirements and associated design bases should be established and maintained by an appropriate organizational unit. These design requirements should be kept current and suitable hazard analysis methods should be used to evaluate chemical safety aspects of proposed changes to the process. The design basis should be a set of facts about the chemical safety elements covered by the CM system and should be reviewed and approved by an appropriate authority within the organization. A specific group should be assigned the responsibility for maintaining the design and licensing bases and the design requirements.

2.6.5.3 Document Control

The control of documents within the CM system should be established to include cataloging the document data base and maintaining and distributing the documents. Such documents should include items from the process safety information (design requirements, chemical hazards analysis, as-built drawings, specifications, operating and non-operating procedures pertinent to chemical safety, etc.), emergency response plans, system modification documents, assessment reports, and any other documents deemed necessary. Original or master copies of documents should be stored under quality assurance (QA) requirements.

2.6.5.4 Change Control

The CM system should maintain strict consistency among the design requirements, the physical configuration, and the facility documentation. Methods should be developed for identifying changes in the configurations relied on for chemical safety, ensuring technical and managerial review of proposed changes, and tracking and implementing those changes by placing documentation in a document control center and disseminating information to the training, engineering, operations, maintenance, and QA functions.

2.6.5.5 Assessments

Assessments of the CM system should be conducted to determine its effectiveness and to correct deficiencies. Periodic physical assessments (walkdowns) of the chemical safety systems should be performed to confirm the program's accuracy and adequacy.

2.6.6 Emergency Planning

The emergency plan, prescribes a comprehensive response to chemical-related accidents and plant emergencies to protect the public, the workers, and the environment. The portion of the emergency plan relating to chemical process safety concerns should describe the significant chemical hazards identified in the hazard evaluation process and methods to be used to detect and mitigate the corresponding chemical accidents.

2.6.7 Incident Investigations and Corrective Actions

Incident investigation activities identify the root causes of and responses to chemical safety incidents that affect the licensed material and that have or could have significant health and safety implications. Such investigations should identify corrective actions to be taken to minimize the incident or prevent it from recurring. A system should be developed with an organizational structure and procedures for establishing investigation teams, determining root causes, tracking and completing corrective actions, and documenting and applying the "lessons learned" to other operations.

2.6.8 Safety Program Audits

Audits and assessments provide assurance that the safety program is functioning as intended and should be used to determine the effectiveness of chemical process safety controls. Audits and assessments should be conducted according to written procedures and checklists that ensure the documentation of findings, the distribution of reports, and the assignment of follow up responsibilities. The audits and assessments should be conducted by qualified personnel who are not responsible for chemical safety controls, and the results should be reviewed and acted upon by the licensee's management.

2.6.9 Quality Assurance

Quality assurance (QA) provides confidence that the structures, systems, equipment, components, and human actions relied on for chemical safety are of acceptable quality. Items relied on for chemical safety should be subject to the quality assurance criteria described below.

2.6.9.1 Design Control

Systems, structures, and components relied upon for chemical safety should be designed with well-defined objectives and functions. The design should be controlled to adhere to its defined function and should be verified by knowledgeable personnel not directly involved in the original design.

2.6.9.2 Procurement Document Control

Applicable design bases and other requirements necessary to ensure adequate quality should be included or referenced in documents for procurement of items or services related to chemical safety. If possible, suppliers should have a QA program consistent with the quality level of the item to be procured.

2.6.9.3 Control of Purchased Material, Equipment, and Services

Purchased material, equipment, and services should be controlled to ensure conformance with specified requirements. Materials should be inspected upon receipt for accuracy and quality, and critical measurements should be verified.

Equipment should be tested for operational acceptance before being relied upon for chemical safety. Purchased services which are relied upon for chemical safety should be monitored frequently for assurance of adequacy and completeness.

2.6.9.4 Identification and Control of Unacceptable Materials, Parts, and Components

Provisions should be made to identify and control those items which were to have been relied on for chemical safety and are discovered to have incorrect or defective materials, parts, and components. Unacceptable items should be physically segregated from acceptable or untested items when possible, and clearly marked or tagged as unacceptable so that they cannot be mistaken for acceptable items.

2.6.9.5 Measurement and Test Controls

Provisions should be made to ensure that tools, gauges, instruments, and other measuring and testing devices used on items relied upon for chemical safety are properly identified, controlled, calibrated, and adjusted at specified intervals. Testing requirements for chemical safety systems should be specified in written procedures.

2.6.9.6 Corrective Actions, Record keeping, and Audits

Provisions should be made to ensure that conditions adverse to the quality of chemical safety systems are promptly identified and corrected and measures taken to preclude repetition. Provisions should also be made for the identification, retention, retrieval, and maintenance of records that furnish evidence of the control of quality for activities important to chemical safety. Audits should be performed to verify compliance with all aspects of the QA program and to determine its effectiveness.

2.6.10 Human Factors

Human factors are a potential cause of accidents involving hazardous chemicals and should be evaluated when humans interface with structures, systems, components, or functions that are considered important to chemical safety. Such human actions should be supported by information such as data, alarms, directions or management policies, training programs, and control displays so that they can be performed properly. A human factors program should contribute to reducing the probability of significant chemical-safety-related human errors, provide for the detection and correction of the human errors that do occur, and integrate with other programs to provide reasonable assurance that system performance will degrade in a safe manner, despite failures to prevent, detect, or correct human errors.

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11. ABSTRACT *(200 words or less)*

This NUREG provides broad guidance on chemical safety issues relevant to fuel cycle facilities. It describes an approach acceptable to the NRC staff, with examples that are not exhaustive, for addressing chemical process safety in the safe storage, handling, and processing of licensed nuclear material. It expounds to license holders and applicants a general philosophy of the role of chemical process safety with respect to NRC-licensed materials; sets forth the basic information needed to properly evaluate chemical process safety; and describes plausible methods of identifying and evaluating chemical hazards and assessing the adequacy of the chemical safety of the proposed equipment and facilities. Examples of equipment and methods commonly used to prevent and/or mitigate the consequences of chemical incidents are discussed in this document.

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