



Part 1 (Open)



# Integrated Safety Analysis

## ISA Methods Overview

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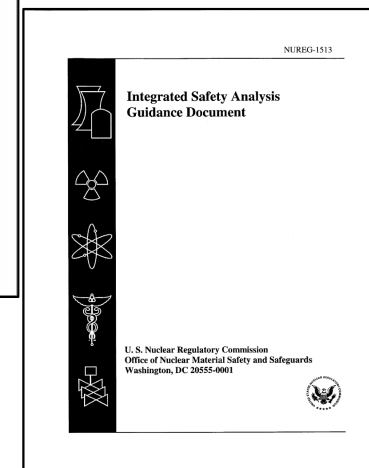
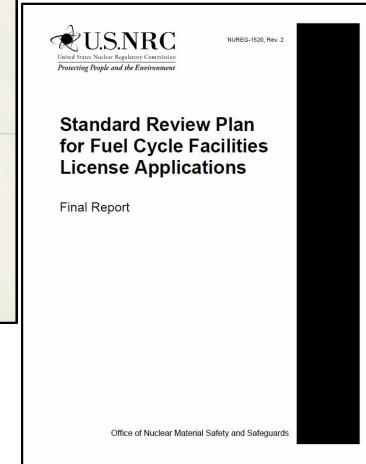
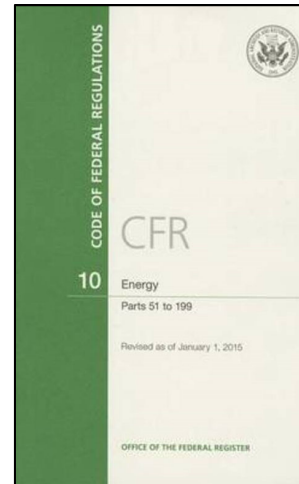
Regulatory Affairs, Fuel Production

11 September 2019



# ISA Regulations and Guidance

- 10 CFR 70 Subpart H, *Additional Requirements for Certain Licensees Authorized to Possess a Critical Mass of Special Nuclear Material (SNM)*
- NUREG-1520, *Standard Review Plan for Fuel Cycle Facilities License Applications*
- NUREG-1513, *Integrated Safety Analysis Guidance Document*



# Additional Guidance

- DOE-STD-1189-2016, *DOE Standard, Integration of Safety into the Design Process*
- DOE-HDBK-1100-2004, *DOE Handbook, Chemical Process Hazards Analysis*
- DOE-HDBK-1163-2003, *DOE Handbook, Integration of Multiple Hazard Analysis Requirements and Activities*
- Crowl, D. A., et al., *Chemical Process Safety Fundamentals with Applications*, Fourth Edition
- Center for Chemical Process Safety of the American Institute of Chemical Engineers, *Inherently Safer Chemical Processes, A Life Cycle Approach*, Second Edition

# Additional Guidance

- Center for Chemical Process Safety of the American Institute of Chemical Engineers, *Guidelines for Engineering Design for Process Safety*, Second Edition
- Center for Chemical Process Safety of the American Institute of Chemical Engineers, *Guidelines for Risk Based Process Safety*

# ISA Applicability

10 CFR 70.4  
10 CFR 70.62(c)

Integrated means joint consideration of, and protection from, all relevant hazards directly associated with NRC licensed radioactive material, including:

- Nuclear Criticality
- Radiological Exposure
- Chemical Exposure

# ISA Applicability

10 CFR 70.4  
10 CFR 70.62(c)

## Chemical Exposure

- From chemicals comingled with SNM or were produced from reactions with SNM
- From concurrent release that results in comingling of chemicals and licensed materials (seismic, fire, explosion, etc.)
- Worker impairment due to a chemical exposure from chemicals, even if not comingled with licensed materials, is evaluated to ensure there is not an intermediate or high consequence due to a single failure of an administrative action (shutdown equipment, mishandle container, etc.)

# TRISO-X Fuel Fabrication Facility Process Areas

SNM Receipt,  
Storage,  
Package, Ship

Dissolution

Sol-Gel  
Process

Conversion

Coating

Overcoating

Pebbles

Cylindrical  
Compacts

Quality Lab +  
Buffer Storage

Recovery

Waste Ops

Facility-wide +  
Utilities

# Requirements for New Facilities

10 CFR 70.64

- Baseline Design Criteria as listed in 70.64(a)(1-10) must be addressed in the design of new facilities
- Facility and system design and facility layout must be based on defense-in-depth practices per 70.64(b)

Using these design practices results in a facility design that includes successive levels of protection

- the net effect is a conservatively designed facility and system



# Baseline Design Criteria

10 CFR 70.64(a)(1)

- Quality standards and records
  - Industry recognized codes and standards are being used from the beginning of the design activity to ensure good engineering practices and safety margin are applied to the design of the facility and its safety features
    - ANSI, ASCE, ASME, ASTM, IBC, NEC, NFPA, OSHA, and others
  - Design of the facility, equipment, and IROFS is being prepared under a quality program
  - Design details are thoroughly documented and the records are controlled

# Inherently Safe Design Concepts

Strategies being considered during Preliminary Design

- Limit quantities of hazardous materials available for release
  - Bulk storage outside
  - Smaller storage vessels inside building
  - Metering columns with siphon breaks
- Substitute less hazardous chemicals where possible
- Secondary containment to further reduce exposures
- Keyed connections for portable containers to prevent wrong material inputs

# Baseline Design Criteria

10 CFR 70.64(a)(5)

- Chemical protection
  - Relevant codes and standards and good engineering practices for the expected hazards are being used to ensure chemical process safety is provided
  - Design considers materials of construction, equipment sizing, and system fabrication techniques to prevent chemical accidents from occurring
  - Inherently safe design concepts (minimize, substitute, moderate, simplify)
  - Physical barriers / secondary containment (dikes, vent hoods, gloveboxes, splash shields)
  - Siphon breaks, overflows, chemical traps / filters
  - Leak detection, hazardous source isolation, pressure relief devices

# Baseline Design Criteria

10 CFR 70.64(a)(3-4)

- Fire Protection
  - Relevant codes and standards for the expected hazards are being used to ensure protection is provided against fires and explosions
  - Noncombustible materials of construction, fire detection, fire suppression
  - Inspection, testing, and maintenance programs for fire protection systems
- Environmental and dynamic effects
  - Design accounts for normal operations, maintenance, testing, and events that could lead to loss of safety functions
  - Design considers expected operating conditions (vibration, temperature, pressure, corrosion, weather conditions, impact, etc.)

# Natural Phenomena

10 CFR 70.62(c)(iv)  
10 CFR 70.64(a)(2)

**Design Basis Natural Phenomena Event** – An earthquake, high wind, tornado, or flood event that has been determined to be Highly Unlikely using appropriate consideration of the most severe documented historical events for the site

- (1) Design Basis Earthquake – American Society of Engineers (ASCE) 7-16, *Minimum Design Loads for Buildings and Other Structures*
- (2) Design Basis High Wind – American Society of Engineers (ASCE) 7-16, *Minimum Design Loads for Buildings and Other Structures*
- (3) Design Basis Tornado – NUREG/CR-4461, Revision 2, *Tornado Climatology of the Contiguous United States*
- (4) Design Basis Flood – Federal Emergency Management Agency, *Flood Insurance Rate Maps*

Not expecting hurricane to be a concern due to inland site locations being considered; snow / local site runoff will be addressed to the degree necessary through design

# Baseline Design Criteria

10 CFR 70.64(a)(6)

- Emergency capability – Relevant codes and standards and good engineering practices are used to ensure the design provides
  - Methods to prevent or mitigate releases during an emergency
  - Means to detect criticality, radiological and chemical releases, and fires
  - Unobstructed routes to enable
    - Timely evacuation of onsite personnel
    - Safe and timely response to emergencies
    - Transport of injured personnel to onsite and offsite medical facilities
  - A means to notify and coordinate with both onsite and offsite emergency response personnel

# Baseline Design Criteria

10 CFR 70.64(a)(7-10)

- Utility services
  - Facility is being designed so that loss of utilities causes control devices to fail in a safe state or continued operation of essential utility services will be provided
- Inspection, testing, and maintenance
  - Design of IROFS allows for periodic inspection, testing, and maintenance
- Criticality Safety
  - Design includes adherence to the double contingency principle
- Instrumentation and controls
  - Design includes the goal of having supervisory systems to monitor and provide status of IROFS so that appropriate actions can be taken

# Defense-in-Depth

10 CFR 70.64(b)

- A design philosophy, applied from the outset and through completion of the design, that is based on providing successive levels of protection such that health and safety will not be wholly dependent upon any single element of the design, construction, maintenance, or operation of the facility
- The net effect is a conservatively designed facility and system that will exhibit greater tolerance to failures and external challenges
- Risk insights gained through performance of the ISA can then be used to supplement the final design by focusing attention on the prevention and mitigation of the higher-risk potential accidents



# Defense-in-Depth

10 CFR 70.64(b)

- The design must incorporate, to the extent practicable:
  - Preference for the selection of engineered controls over administrative controls to increase overall system reliability
  - Features that enhance safety by reducing challenges to IROFS

# PHA Method/Process

Primary Guidance Documents

Assemble ISA Team

Determine Process Hazard Analysis (PHA)  
Scope

Assemble Process Safety Information

Identify Hazards

Conduct PHA

Consequence Analysis

# Primary Guidance Documents – PHA

- NUREG-1513, *Integrated Safety Analysis Guidance Document*
- Center for Chemical Process Safety of the American Institute of Chemical Engineers, *Guidelines for Hazard Evaluation Procedures*, Third Edition
- Center for Chemical Process Safety of the American Institute of Chemical Engineers, *Guidelines for Process Safety Documentation*

# Assemble ISA Team

10 CFR 70.62(c)(2)

- Manager provides overall direction for the ISA process
- ISA Team Leader
  - Trained and knowledgeable in the PHA methods chosen
  - Adequate understanding of all process operations and hazards
  - Not the responsible, cognizant engineer or expert for the evaluated process
- ISA Team
  - At least one member knowledgeable in the type of process design under evaluation
  - Includes one or more members familiar with the safety disciplines relevant to hazards that could credibly be present in the process

# Determine PHA Scope

- Consequences of concern – radiological, nuclear criticality, and certain chemical accidents that can affect workers or the public
- Physical scope – site characteristics, structures on the site, equipment and materials in use, process operations, and personnel operating the facility
  - Credible external meteorological and seismic events that can cause accidents at the facility
  - Events from fires external to the facility, transportation accidents, and accidents at nearby industrial facilities
- Initial conditions and bounding assumptions

# Process Safety Information

10 CFR 70.62(b)

- Information pertaining to the hazards of the materials used and produced in the process
  - Chemical and physical forms of SNM in process areas, including properties such as information on Safety Data Sheets
  - Maximum amounts of SNM in process areas
  - Amounts and discharge points of waste streams and effluents
- Information regarding the technology of the process
  - Block or flow diagrams
  - Outline of process chemistry
  - Safe upper and lower limits for controlled parameters (temperature, pressure, etc.)

# Process Safety Information

10 CFR 70.62(b)

- Information pertaining to the equipment used in the process
  - Materials of construction
  - Piping and instrumentation diagrams
  - Building and equipment layouts
  - Ventilation
  - Design codes and standards
  - Material and energy balances
  - Electrical Classification
  - Design basis

# Conduct PHA

10 CFR 70.62(c)(i-iv)

- Identify all credible accident sequences from a single upset event
- Unmitigated consequences
- Choice of method
  - Based on guidelines in NUREG-1513
  - Depends on complexity of the process being analyzed, severity of the hazards, and perceived risk of the process
  - Typical methods used are “What-If/Checklist” and “Hazard and Operability Analysis (HAZOP)”



# Nuclear Criticality Safety Evaluation

10 CFR 70.61(b)  
10 CFR 70.61(d)

- Credible accident sequences with the potential of resulting in a criticality are assumed to be “High” consequence events
- Double contingency evaluation ensures that no single credible upset can result in a possible criticality
- Risk Assessment provides basis for preventive controls designated as IROFS

# Accident Consequence Evaluation (ACE)

- Evaluation of unmitigated radiological and chemical accident sequences to determine consequence level (low, intermediate, or high) for
  - Workers
  - Any individual located offsite
  - Offsite releases to the environment greater than 5000 times the effluent limits
- Airborne and liquid releases

# Accident Consequence Evaluation (ACE)

- Stresses are physical forces that cause material to be released
- Types of stresses
  - Mechanical
  - Fires
  - Explosions

# ACE Exposure Pathways

- Inhalation is the dominant exposure mechanism for airborne releases
  - Powder spills
  - Liquid spills
  - Gas releases
- Ingestion is the dominant exposure mechanism for liquid releases offsite

# ACE Consequence Levels

10 CFR 70.61

10 CFR 70.61 Radiological and Chemical Consequence Exposure Levels				
Consequence Level	Radiological		Chemical	
	Worker	Public/Environment	Worker	Public/Environment
High	TEDE $\geq$ 100 rem	TEDE $\geq$ 25 rem	$\geq$ CHEM3 $\geq$ 400 mg soluble U *	$\geq$ CHEM2 $\geq$ 30 mg soluble U
Intermediate	100 rem > TEDE $\geq$ 25 rem	25 rem > TEDE $\geq$ 5 rem  5000 x 10 CFR 20, Table 2, App. B limits averaged over 24-hour period	$\geq$ CHEM2 < CHEM3  $\geq$ 150 mg * and < 400 mg soluble U	$\geq$ CHEM1 < CHEM2  $\geq$ 10 mg ** and < 30 mg soluble U
Low	TEDE < 25 rem	< Intermediate Levels	< Intermediate Levels	< Intermediate Levels

\* ISG-14, Revision 0

\*\* NUREG-1391 and DOE-STD-1136-2017

**CHEM = AEGL, ERPG, or TEEL**



# Chemical Exposure Limits

- Acute Exposure Guidelines Levels (AEGL) Used if Available
- Emergency Response Planning Guidelines (ERPG) if no AEGL
- Temporary Emergency Exposure Level (TEEL) if no ERPG
- Soluble Uranium Intake Limits are based ISG-14, NUREG-1391, DOE-STD-1136-2017, and 10 CFR 70.61 rather than AEGL/ERPG/TEELs
- Sources:
  - EPA Website, Access Acute Exposure Guideline Levels (AEGs) Values, <https://www.epa.gov/aegl/access-acute-exposure-guideline-levels-aegls-values#chemicals>
  - Protective Action Criteria PAC Database, <https://sp.eota.energy.gov/pac/>