URS | URS Safety Management Solutions

Criticality Hazards Analysis

(Contingency Analysis)

Raymond Reed

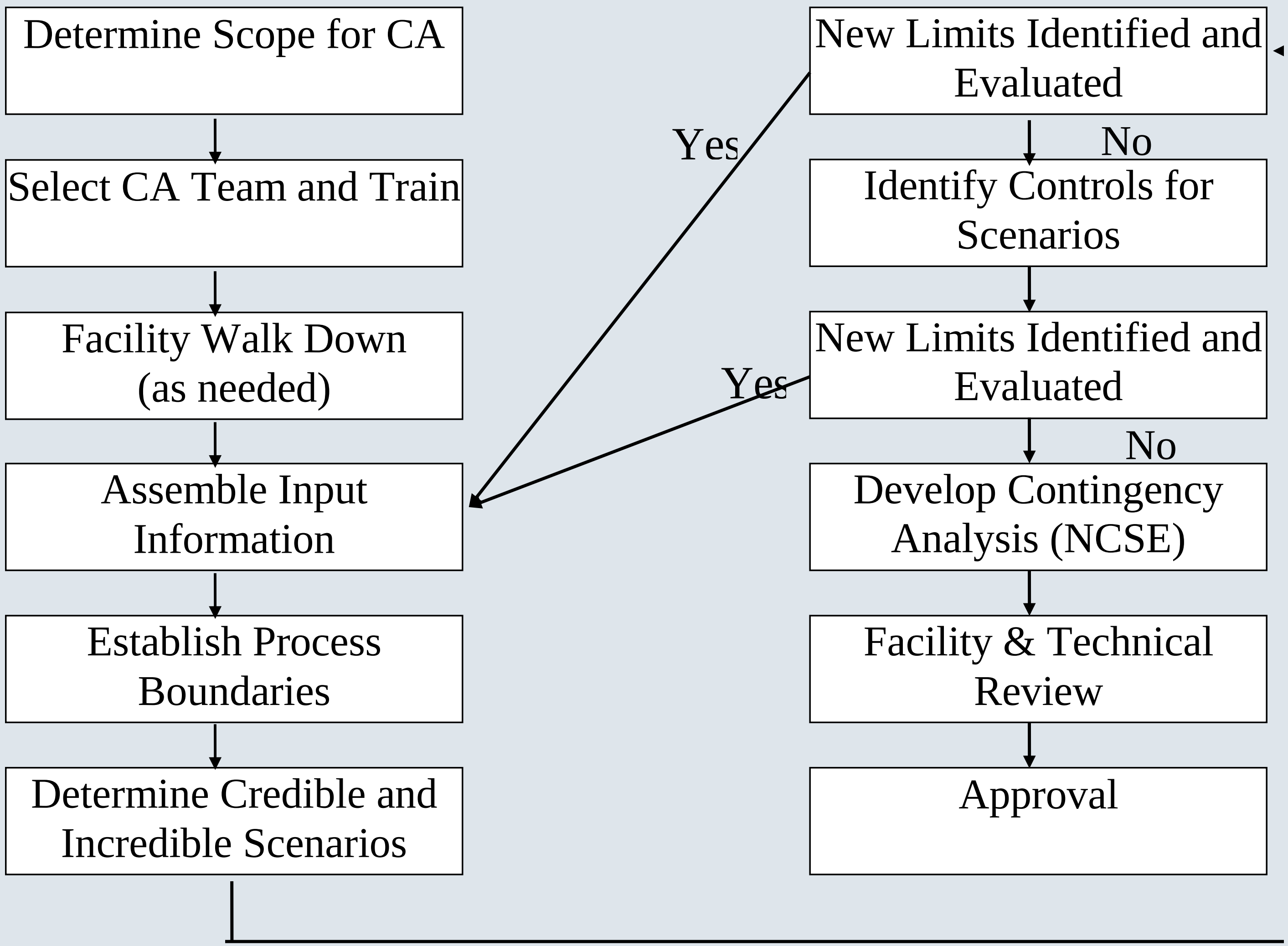
Contingency Analysis Objective

- Emphasis of this presentation is on contingency analysis
- Identify possible criticality scenarios (process upsets that could result in a critical configuration)
- For each scenario, identify set of barriers (e.g., controls and process features) that (help) prevent criticality
- For each scenario, demonstrate
  - Compliance with Double Contingency Principle (DCP),
  - Incredibility of criticality, or
  - Justify deviation (single parameter control) from DCP
- Document in Nuclear Criticality Safety Evaluation (NCSE)

Contingency Analysis Methodology

- **Can use various Hazard Analysis techniques**
  - ➢ **Checklist**
  - ➢ **What-if**
  - ➢ **Failure Mode and Effects**
  - ➢ **Hazards and Operability (HAZOP)**
  - ➢ **Event Tree and Fault Tree methodologies**
- **URS SMS uses Consolidated Hazard Analysis Process (CHAP)**
  - ➢ **Structured team-based approach**
  - ➢ **Uses multiple HA techniques**
  - ➢ **Detailed or simplified, as appropriate**

Contingency Analysis Process



Contingency Analysis Scope

- What portions/processes of the facility are within scope?
- What other processes may be running concurrently?
- What material will serve as feed to the process?
- Where will the feed material come from and how is it transported?
- What is the maximum anticipated material batch size?
- Where will the product go and how is it transported?
- What waste is expected and how will it be disposed of?
- Are there anticipated facility modifications that could impact criticality safety?
- What are management expectations for production rates?
- Are there any management restrictions on criticality safety controls (e.g., no funding for additional engineered controls)?
- Is it management's desire that calculational NCSEs be performed in those cases where the generation of new limits (e.g., subcritical limits, process limits) offers the potential of increased facility flexibility?

Contingency Analysis (CHAP) Team

- **Core team members knowledgeable about the process or facility under study**
  - **Nuclear Criticality Safety**
  - **Facility Operations**
  - **Facility Engineering**
  - **Nuclear Safety**
  - **NCSE Technical Review Lead**
  - **Scribe**
- **Core team members take part in each meeting to ensure continuity**
- **Core team members are supplemented by subject matter experts (SMEs)**

Contingency Analysis Aids

- **Guidance**
  - ➢ **URS SMS NCS Methods Manual**
    - ✓ **Contingency Analysis Chapter**
  - ➢ **CHAP Methodology Manual**

- **Electronic Tool for Records and Documentation of Hazard Analysis**
  - ➢ **Insight**

Process Description and Process Boundaries

- **Facility and Process Baseline Information**
  - **Facility and process description / sketches / as-built design information**
  - **Applicable Safety Basis (SB) documentation**
  - **Form and quantity of fissionable material, as well as reflectors, moderators and poisons**
  - **Applicable Criticality Safety Limits (CSLs)**
  - **Process features and controls**
  - **Facility and process assumptions and their justifications**
  - **Define process boundaries**
- **Utilize**
  - **Current DSAs, TSRs, NCSASRs, and NCSEs**
  - **Facility briefings**
  - **Walk down**

Identification of Criticality Scenarios

- **Review previous NCS analyses**
  - ➢ **Process and equipment changes**
  - ➢ **Additional information**
  - ➢ **Control reliability**
- **Screen each location within process or facility**
  - ➢ **Identify process location**
  - ➢ **Identify applicable NCS parameters**
  - ➢ **Identify applicable process changes that can affect an NCS parameter**
  - ➢ **Preliminary judgment whether process change in NCS parameter can result in critical configuration**

Parameters and Upset Mechanisms

Parameters	Upset Mechanisms
➢Geometry	➢Evaporation
➢Mass	➢Precipitation
➢Volume	➢Polymerization
➢Moderation	➢Solids Accumulation
➢Spacing (Interaction)	➢Mass Limit Exceeded
➢Concentration/Density	➢Geometry Altered
➢Enrichment	➢Interaction Increase
➢Reflection	➢Enrichment Increase
➢Absorption	➢Excess items in one location
➢Temperature	➢Other

Evaluation of Postulated Criticality Scenarios

- **Questions to ask for each postulated scenario**
  - ➢ **Can postulated upset result in a critical configuration?**
  - ➢ **How likely is the upset initiator?**
  - ➢ **If the upset happens, how bad could it get?**
    - ✓ **CSL exceeded, subcritical limit exceeded?**
  - ➢ **What else has to go wrong to attain criticality?**
  - ➢ **What are the barriers to criticality (controls, process features, nature of process, etc.)?**
  - ➢ **Would applying additional controls render scenario incredible?**

Is the scenario credible or incredible?

- **Criticality scenario is incredible if:**
  - **A sufficient set of robust controls, which will prevent criticality, is available**
  - **A critical configuration cannot be assembled, due to insufficient mass or less than optimal configurations for the fissile material involved in the process**

For Credible Scenarios

- Identified control set is robust and satisfies Double Contingency Principle (i.e., multi-parameter control)?
- Control set results in extremely unlikely scenario?
- If not, determine appropriate additional NCS parameter controls
  - Ensure multi-parameter control, if possible
  - Identify associated Criticality Safety Limits
  - Select controls in preference order of Passive engineered, Active engineered, and Administrative
  - Select controls that can be implemented
    - ✓ Cost constraints, physical constraints, accessibility constraints, etc.?

NCSE Documentation

- DOE-STD-3007-2007 compliant NCSE
- If all criticality scenarios in facility are incredible, document each scenario in the NCSE
- If only some criticality scenarios in facility are incredible, may document incredible scenarios in NCSE appendix
- All scenarios should be documented in Hazard Event tables (examples later), often included as an NCSE appendix

NCSE Documentation, Facility Criticality Incredible

- **Identify the initiating event (process upset) and postulated critical configuration**

- **Identify Critical Safety Limits that define the subcritical configuration**

- **Identify barriers (controls, process features, nature of process, etc.) that are credited with making criticality scenario not credible**

- **Provide logical reasoning demonstrating that the identified combination of barriers is sufficient to ensure that criticality as a result of the initiating event is not credible**

NCSE Documentation, Credible Scenario

- **Describe the initiating event (process upset) and criticality scenario**
- **Identify Critical Safety Limits that define the subcritical configuration**
- **Identify controls that are credited with making criticality scenario complaint with the DCP**
  - **Address and justify any single parameter control set as deviation from DCP**
- **Provide Double Contingency Control Table**
  - **Parameters, bounding assumptions, limits, and controls**
- **Discuss possible common mode failure of controls**
- **Discuss Defense-in-Depth controls**

NCSE Documentation, Credible Scenario Defense Table

Control Table			Safety Limits and Controls	
Parameter	**BA**	**CSL**	**Engineered**	**Administrative**
Geometry	Unrestricted			
Spacing (Interaction)	Unrestricted			
Neutron Absorber (Poison)		Min 72 g Fe : g Eq. ^{235}U or Min 14 g Mn : g Eq. ^{235}U or Min 1 g Gd : g Eq. ^{239}Pu		2
Concentration (Density)	Unrestricted			
Moderation and Reflection	Unrestricted			
Mass		Max 624 g Eq. ^{235}U		1
Enrichment	Unrestricted			
Temperature	Unrestricted			

CSL Reference:

- Overall Control Approach: Multiple Parameter
- The unmitigated frequency of the scenario is Unlikely; with the controls selected, the mitigated frequency is Extremely Unlikely.
- The unmitigated frequency of the scenario is Unlikely; with the controls selected, the mitigated frequency is Extremely Unlikely.

NCSE Documentation, Defense Table

Controls:

1. Prior to the transfer of solutions into the neutralization feed tank, ensure that the cumulative fissile mass in the neutralization feed tank and the neutralization tank will be less than the CSL. If a Head End cake is present, the fissile mass in the Head End cake shall be based on Ref. 34.

2. Prior to transfer of solution from the neutralization feed tank to the neutralization tank, ensure the poison:fissile mass ratio in the solution is greater than the CSL from a sample independent of Control 1.

Defense in Depth Controls:

None

CMF Discussion:

No CMF identified. Soluble poison is independent of maintaining a mass inventory. The sample results utilized in Control 1 and Control 2 are from independent samples. Note that for receipt of cakes from the Head End centrifuge, the mass of uranium in the cake is based on Reference 34 and samples upstream of the centrifuge.

Requirements Listing (Section 7 of NCSE)

- **Specify bounding assumptions that are credited in the calculational analysis or contingency analysis as part of the arguments demonstrating that criticality is prevented.**
- **Specify design features (engineered controls) that are credited to prevent criticality.**
- **Specify administrative criticality safety limits, administrative requirements, and administrative controls that are credited to prevent criticality (include applicable administrative programs).**
- **Identify process features, nature of process, etc. that are credited to (help) prevent criticality.**
- **Outline changes needed to facility and procedures (or DSA/TSR if appropriate) consistent with the operations changes/modifications analyzed in the NCSE.**

Note: For each item, identify each scenario for which the item is credited.

Example Hazard Event Table - Incredible Scenario

Description	Causes	Unmitigated System Effects	Unmitigated Consequences	Preventive Features Engineered	Mitigative Features Engineered	Credited SSCs and ACs Preventers	DSA Mitigated Consequences
Oxalic acid added to SRAT causes dissolution of poison in the SRAT	• 1. Addition of oxalic acid causes Fe and U to separate from the sludge • 2. Absence of agitation allows Pu solids to settle	None	Unmit Freq: NC Rad WG1 : N : NA WG2 : N : NA WG3 : N : NA MOI : N : NA	None	None	None	Mit Freq: NC Rad WG1 : N : NA WG2 : N : NA WG3 : N : NA MOI : N : NA
Locations		**Methods of Detection**		**Administrative**	**Administrative**	**Mitigators**	
• SRAT		None		• {IC} Prohibit Oxalic Acid (oxalic acid is prohibited in facility	None	None	
MAR							
• SWPF (based on PRFT overflow vol) + Case 1 Sludge = (9 kg Pu + 45 kg U) + (2.5 kg Pu + 3 kg U-235) • SWPF (based on PRFT overflow vol) + Case 2 Sludge = (9 kg Pu + 45 kg U) + (18 kg Pu + 3 kg U-235)							
Release Mechanisms							
None							
Assumptions							
None							

Notes	References	Reminders
• Event is not credible (NC) due to prohibition of oxalic acid.	None	None

Example Hazard Event Table - Credible Scenario

Hazard Evaluation Table - Event	
Description: Criticality results from precipitation of excess fissile material mass during neutralization	
Locations: Neutralization Tank	**MAR:** Fissile material
Release Mechanisms: nuclear criticality~~None~~	
Assumptions: None	
Causes: Mass inventory error Transfer of excess fissile material into neutralization vessel from mixer-settler upsets or cell/sump flushes	
Unmitigated System Effects: None	**Methods of Detection:** None
Unmitigated Frequency: U	**Mitigated Frequency:** EU

Example Hazard Event Table - Credible Scenario

Consequence / Risk Rank												
Receptor	Rad				Chem				Phy			
	Unmit.		PHR Mit.		Unmit.		PHR Mit.		Unmit.		PHR Mit.	
WG1	H	A1	H	A2	N	C	N	C	N	C	N	C
WG2	H	A1	H	A2	N	C	N	C	N	C	N	C
WG3	L	B	L	B	N	C	N	C	N	C	N	C
MOI	N	C	N	C	N	C	N	C	N	C	N	C
Preventive Features:												
Engineered	None											
Admin	Head tank for caustic drop is empty prior to receipt of solution or cakes into neutralization tank (GS) Prior to transfer to neutralization feed tank, ensure cumulative expected fissile mass in neutralization feed tank and neutralization tank less than single mass (Prevents criticality by ensuring less than a single mass is present in the neutralization tank) (SS-SAC) Prior to transfer to neutralization tank, verify from sample analysis poison to fissile ratio is greater than minimum (Prevents criticality by absorbing neutrons) Tank is empty prior to solution receipts Tanks are emptied to jet heel during transfers											
Mitigative Features:												
Engineered	None											
Admin	None											

Example Hazard Event Table - Credible Scenario

Credited SSCs and ACs				
	Class	Control	Attribute	Affected Receptors
Preventers	GS	Prior to transfer to neutralization feed tank, ensure cumulative expected fissile mass in neutralization feed tank and neutralization tank less than single mass	Prevents criticality by ensuring less than a single mass is present in the neutralization tank	All
		Safety Function:	Limits fissile mass	
	SS-SAC	Prior to transfer to neutralization tank, verify from sample analysis poison to fissile ratio is greater than minimum	Prevents criticality by absorbing neutrons	All
		Safety Function:	Addition of neutron poison to reduce k-eff	
Mitigators	None			
Notes:	Unmitigated frequency of "unlikely" selected because: (1) based on studies of Canyon tank mixing, the ability of fissile solids within the tank to form an unsafe configuration is improbable, and (2) undetected loss of a large mass of fissile material into the waste system is not likely. Per the CSPDD, these GS administrative controls are controlled by the SS Criticality Safety Program designated in the DSA and committed to in the TSR.			
References:	None			