NNSA Production Office

DNFSB REACTIVE MATERIALS BRIEFING

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This document has been reviewed by a CNS Dual Authority DC/RO and confirmed to be UNCLASSIFIED.
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Overview

NNSA and CNS appreciate the Board's efforts to research and evaluate the adequacy of Y-12's control strategies to ensure that facility worker hazards related to uranium and reactive materials are being addressed.

Actions being taken to improve how these hazards are evaluated and controlled include the following:

Controls for Pyrophoric Events

- Developing and implementing enhanced hazard analysis methods to improve documentation of plausibility of sudden energy release events in the hazard analysis
- Taking additional preventive and mitigative actions to minimize occurrence of pyrophoric events
- Conducting basic and process specific training and drills on operators' response to pyrophoric events

Evaluation of Process Changes

- Improved monitoring of process change through Statistical Process Control and more rigorous Change Control
- Expanded use of Material Form Codes

NNSA and CNS agree that there are opportunities to improve upon the corrective actions initially taken in response to events cited in the report enclosed with the Board's letter

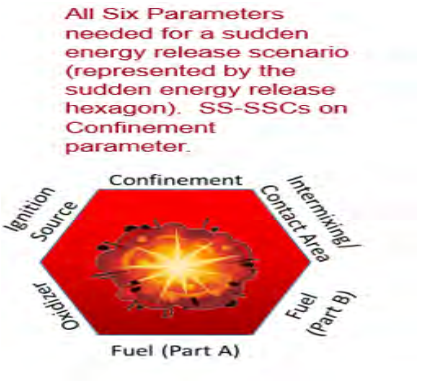
Analysis of Uranium Pyrophoric Events

Completed a comprehensive review of current Y-12 hazard analysis documentation to ensure all plausible scenarios related to uranium pyrophoric hazards are documented and preventive and mitigative controls have been identified, as warranted

- Utilized DOE-STD-3009-2014 and DOE-HDBK-1224-2018, *Hazard and Analysis Handbook*, as a framework for evaluating the existing hazards analysis
  - *An operational event is not considered plausible if it is either … a process deviation that consists of a sequence of many unlikely human actions or errors for which there is no reason or motive … [or] there is a convincing argument, given physical laws, that they are not possible.*
  - *SS controls shall be selected for cases where a fatality, serious injury, or significant radiological or chemical exposure to a facility worker may occur.*
- Reviewed the plausibility and consequence evaluation for each hazard scenario related to uranium pyrophoric reactions
- Confirmed that safety-significant controls are identified for plausible uranium pyrophoric energetic events with the potential to have significant consequences to facility workers
- For uranium pyrophoric events that would result in only minor consequences to facility workers, Safety Management Programs are implemented to prevent or mitigate the events

Controls to Prevent and Mitigate Pyrophoric Events

Reduction – Example of a plausible hazard scenario that could result in significant consequences and safety-significant controls are identified



Parameters needed for a "Sudden Energy Release" are present, so several safety-significant SSCs were identified

Recent Pyrophoric Event

9212 Briquette Fire February 22, 2023

Briquette

Fire

Progression to Sudden Energy Release For This Scenario Not Plausible

No Confinement; No Intermixing/Contact Area

Similar to 15 events that occurred at Y-12 between 2016 and 2021 Event Progression towards a Sudden Energy Release for this scenario deemed Not Plausible

Examples of Completed Comprehensive Review of Current Y-12 Hazard Analysis

Verified documentation to ensure all plausible scenarios are documented and safety-significant controls have been identified, as warranted.

ªFOR INFORMATION ONLYª Summary of Selected Energetic Events in Y-12 Safety Basis and Supporting Documentation ªFOR INFORMATION ONLYª 6/16/2022

Facility	Description of Event	Unmitigated Likelihood	Unmitigated Facility Worker Consequence	HES Document Number	HES Event #	SS/SC SSCs or SACs (Y/N)	List of SS/SC SSCs or SACs	List of DID Controls, SMPs, or SBS Compensatory Measures For Event
9204-2E	An explosion occurs during Oven Operations involving temperature-sensitive material in a non-approved oven	Credible	Potential Fatality, Serious Injury, or Significant Exposure	DAC-FS-32042E-A001 HER 9204-2E-F-0001	N/A (See Appendix D) D.9	Y	**SAC:** Hazardous Material Heating Control SAC	**SMPs:** Fire Protection Program Emergency Management Program Conduct of Operations Program Hazardous Material Protection Program Procedures and Training Program
	Machining Dust Energetic Reaction	Not Credible	Minor Consequences Only Due to Limited MAR	DAC-FS-32042E-A021	1.53	N	N/A	(Event consequences are very minor due to low quantity of dust)
9212	Red oil reaction or fume-off explosion in intermediate evaporator	Credible	Potential Fatality, Serious Injury, or Significant Exposure	RP 9212-F-0184, Rev. 0	IE 6.7	Y	**SSCs:** Phase separators Vents Flow limiting equipment **SAC:** Density Verificaiton SAC	**SMPs:** Nuclear Criticality Safety Program Procedures and Training Program Emergency Management Program Configuration Management Program
	The oxidation of enriched uranium briquettes in contact with air (e.g., during storage in a container) could result in a heat load, potentially causing a fire	Briquette oxidation is considered to be anticipated based on operational history. However, a fire with significant consequences is considered to be unlikely based on calculations in DAC J9212-STOR-0001.	Minor Consequences Only	RP 9212-F-0178, Rev. 2	10.209	N/A	N/A	**SSCs:** Portable Fire Extinguisher Coke **SMPs** Radiation Protection Program Conduct of Operations Fire Protection Program
9215	EU chip fire occurs in M Wing	Credible	Minor Consequences Only Due to Limited MAR	DAC-FS-921500-A005	3.1.13	N	N/A	**SMPs:** Fire Protection Program Emergency Management Program Configuration Management Program Conduct of Operations Program Procedures and Training Program

The following reports have been issued to document the basis for and results of the extent-of-condition review:

- RP 000Y12-F-0055 000 00, *Analysis of Energetic Events in Hazard Evaluation Studies*
- RP 000Y12-F-0057 000 00, *Comprehensive HES Review for Worker Hazard - Energetic Events*

Enhanced Hazards Analysis Methods

Improving hazards analysis methods with a focus on complex phenomena involved in pyrophoric events (i.e., focus on parameters).

CNS is updating Y-12's hazards analysis processes to include additional guidance for evaluating pyrophoric material hazards, consistent with the approaches and principles of DOE Handbook 1224-2018, *Hazard and Accident Analysis Handbook.*

The new expectations include the following:

a) Documenting whether it is plausible for a given scenario to result in a sudden energy release event

b) For implausible scenarios, this will include identifying operational parameters that make the scenario implausible and elements of Safety Management Programs being relied upon to prevent or mitigate these events

c) If the scenario could plausibly result in a sudden energy release event, identifying safety-significant controls for preventing or mitigating the given scenario

The following command media will be revised by the end of FY2023:

- Y74-48-018, *Hazard and Accident Analysis*
- RP YAREA-F-0788, *Hazard Analysis Handbook*
- RP YAREA-F-1094, *Accident Analysis Handbook*

Enhanced Hazards Analysis Methods (Plausible)

"Plausible" Scenario with Safety-Significant SSC Documented in HES (Future state – Reduction vessel explosion example)

Process: 9212 Reduction Operations		Operation: Uranium Metal Production via UF4 Reduction
Event No: RO-005	**Event Type:** Explosion/Deflagration/Overpressure	**Event:** What if reaction pressure/temperature exceeds the maximum allowable working pressure and a release occurs?
MAR Description:	Hazard: Enriched Uranium (feed as UF_4, product as metal, contaminants: UO_2 and UC_x). Calcium (metal as feed, product as CaF_2 with excess Ca). MAR: 5 kg U Sudden Energy Release Hexagon: ALL PARAMETERS PLAUSIBLY PRESENT Notes: Calcium is present as Fuel B/Other, Feed is blended to maximize intermixing/contact area, confinement is robust, Ignition is intentional part of process, Water may be Oxidizer, Uranium is present	
Event Causes:	Sequence of Operator Errors; Passive equipment failure; water in feed	
Event Outcome:	A release of EU (airborne or molten) to the furnace could result in significant consequences for the facility worker. A hydrogen deflagration in the furnace vent piping is conservatively assumed to significantly injure the operator/facility worker.	

Controls				Unmitigated Risk Analysis					
				Frequency	Type:	FW	CW	P	Risk Bin
				A	Radiological:	N/A	L	L	I
Type	Controls	Comments	P/M/B		Non-Radiological:	H	L	L	
PE	ASME B&PV Code-Stamped Reduction Reactor Vessel and Rupture Disk	Haynes 230 Alloy reactor vessel and rupture disk prevents the release of airborne EU to the furnace.	P			SS			
PE	MgO Liner/Sand	Provides primary confinement of the molten reaction products, including EU.	P			SS			
PE	Pressure Relief Header and Collection Vessel	Release of hydrogen from the reactor vessel through the rupture disk to the furnace could result in a hydrogen deflagration in the	M			SS			
SMP	Configuration Management Program		P						
SMP	Emergency Management Program		M						
SMP	Training Program		B						
SMP	Industrial Safety/Industrial Hygiene Program		B						
SMP	Radiological Control Program		B						
SMP	Hazardous Material Management Program		B						
SMP	Procedures Program		B						
SMP	Conduct of Operations Program		B						
Type - AE - Active Engineered; PE - Passive Engineered; SMP - Safety Management Program; SAC - Specific Administrative Control			Mitigated Analysis	N/A	Radiological:	N/A	L	L	IV
P/M/B - P - Preventive; M - Mitigative; B - Both					Non-Radiological:	N/A	L	L	
Freq. - A-Anticipated; U-Unlikely; EU-Extremely Unlikely; BEU-Beyond EU		Conseq. N/A-Not Applicable; L-Low; M-Moderate; H-High		Risk - N/A-Not Applicable; I-Major; II-Concern; III-Minor; IV-Minimal					

Enhanced Hazards Analysis Methods (Not Plausible)

"Not Plausible" Scenario Documented in HES (Future state – Briquette explosion example)

Process: Briquette Storage and Handling		Operation: Briquette Loading/Unloading Station
Event No: BRIQ-005	**Event Type:** Explosion/Deflagration/Overpressure	**Event:** What if there is a sudden energy release from briquettes initiated by a uranium pyrophoric event?

MAR Description: Hazard: Enriched uranium materials (Cralloy) are limited based on NCS Program requirements and allowable storage and work areas. Up to two 2-Cylinder Chip Dollies may be located in the area, which would limit the amount of chips/briquettes to ≤ 20 kg. The maximum amount of solid enriched uranium for all work areas, in-process storage arrays and caged storage is used for the general area. Inert gases (i.e., argon and nitrogen) utility piping may be routed through the area, but are not used for any process activity.
MAR: 20 kg Chips/Turnings/Fines/Briquettes.
Sudden Energy Release Hexagon: At least 2 parameters not plausibly present
Notes: not intermixed, minimal contact area, no presence of fuel B/other

Event Causes: Uranium pyrophoric events

Event Outcome: NSCI – The sudden energy release from 2-Cylinder Chip Dollies/Briquettes is not plausible because at least two of the six parameters needed for a sudden energy release are not credibly present.

Controls				Unmitigated Risk Analysis					
				Frequency	Type:	FW	CW	P	Risk Bin
				Not Plausible	Radiological:	N/A	L	L	IV
Type	Controls	Comments	P/M/B		Non-Radiological:	N/A	L	L	
SMP	Training Program		B						
SMP	Industrial Safety/Industrial Hygiene Program		B						
SMP	Radiological Control Program		B						
SMP	Hazardous Material Management Program		B						
SMP	Procedures Program		B						
SMP	Conduct of Operations Program		B						
SMP	Nuclear Criticality Safety Program		B						
Type - AE - Active Engineered; PE - Passive Engineered; SMP - Safety Management Program; SAC - Specific Administrative Control			Mitigated Analysis	Not Plausible	Radiological:	N/A	N/A	N/A	N/A
P/M/B - P - Preventive; M - Mitigative; B - Both					Non-Radiological:	N/A	N/A	N/A	
Freq. - A-Anticipated; U-Unlikely; EU-Extremely Unlikely; BEU-Beyond EU		Conseq. N/A-Not Applicable; L-Low; M-Moderate; H-High		Risk - N/A-Not Applicable; I-Major; II-Concern; III-Minor; IV-Minimal					

Implementation of Enhanced Hazards Analysis Methods

Commitment to Improving hazard analysis documentation for ongoing projects involving new technologies

Below is our schedule for updating the hazard analysis of potential pyrophoric events for projects involving new technologies:

- **Uranium Processing Facility: 1st Qtr FY24**
- **Electrorefining: 4th Qtr FY23**
- **Calciner: 3rd Qtr FY23**
- **Direct Chip Melt: 3rd Qtr FY23 (Front Loading Furnace)**

Actions Taken to Minimize Recurrence of Pyrophoric Events

- 9212 – Briquette exothermic events
  - As of July 2022, we eliminated the backlog of briquettes
  - Instituted increased monitoring to minimize briquette storage time (target is less than a month) and improved argon inerting of briquette containers
- 9204-2E – Chip fire during transfer from hospital can to chip dolly
  - SME review led to procedure change to wet specific chips to minimize fire concern
  - Larger funnel was installed for use in 9204-2E and was evaluated for use in other areas with similar operations
- 9212 – Glowing red buttons in Alligator shear enclosure
  - Updated procedure to address low-quality parts, oxidized parts, and/or parts lacking complete oil coverage
- 9202 – Sparking of DU metal cut by band saw
  - Added more streams of coolant to band saw cutting surface and to chip catch pan and increased the frequency of chip cleanout from the catch pan
- 9212 – Fire after Chips Pressed into Briquette
  - Evaluating actions to increase monitoring to minimize storage time of chips similar to briquette actions being taken

Actions Taken to Mitigate Pyrophoric Events

Enhanced training and procedures for how workers should respond to pyrophoric events

- Training developed and implemented based on lessons learned from recent pyrophoric events:
  - Operator basic training on factors that cause different material forms of uranium to be pyrophoric
  - Operator training tailored to specific operations and material forms, with a focus on lessons learned from application of coke, use of process chemicals, and self-extinguishment
- Drills tailored to specific operation to reinforce training being conducted

Target Month	Completed Date	Organization	Description
Dec-22	1/16/2023	EUO	9212: OCF dock HF leak in the enclosure, roof leak caused reschedule
Jan-23	1/5/2023	SMO	9204-2: Rubber shop injury, stairs blocked, FD involved (Emily Korson and Tyler Brooks)
Jan-23	1/12/2023	SMO	9204-2: Hydrogen concentration above LEL at HRV, FD involved (Joe Hough)
Jan-23	1/17/2023	SMO	9204-2: Machine shope - Loss of chuck vacuum
Mar-23		EUO	9212: R&A
Mar-23		FAB	9215: turnings/chip fire in M-wing (machinist, supervisor, material cleark, 9215 supervisor
Mar-23		ADO	9204-2E: event causing shelter in place
Mar-23		SNMO	
Mar-23		Quality	
Apr-23		EUO	9212: turnings/chip/powder fire
May-23		EUO	9212: turnings/chip fire
May-23		FAB	9215: EU chip fire
May-23		SNMO	
Jun-23		Quality	
Jul-23		FAB	9201-5N/W: DU chip fire
Jul-23		ADO	9204-2E: chip fire in area
Aug-23		SNMO	
Sep-23		FAB	9201-1

Training improvements integrated into operator qualification and drill program

Actions to Mitigate Pyrophoric Events (cont.)

Enhanced training and procedures for how workers should respond to pyrophoric events.

Examples of recent events and operator response:

9215 Material Sparking in Part Marking Hood – February 14th

- Material Movement personnel were transferring legacy samples at Part Marking Hood from glass jars into a Chip Can.
- As the 5th jar was being unloaded, the material already in the pan began to glow.
- Coke was applied and the employees contacted their supervisor who made the additional notifications.

9212 Material Sparking in Hood 84 – February 20th

- Chemical Operators were opening a container of Clinkers and Screenings and putting material into a transfer container to begin splitting process.
- Upon scooping material to take bulk density samples, material briefly sparked, turned red hot, and smoked.
- Operators entered into sparking material procedure, allowed the material to self extinguish, and contacted their supervisor, who in turn contacted the shift manager, NMC&A, and NCS.

9212 Briquette Fire – February 22nd

- Operators were weighing a newly pressed briquette of compressed enriched uranium chips in an open-faced hood when the briquette began to smolder and glow red.
- Operators attempted to extinguish fire per abnormal operating procedure by pouring coke on briquette. Due to placement of briquette on scale coke did not extinguish reaction.
- Operators evacuated area. No contamination of workers or CAM alarms.

Evaluation of Process Changes

Y-12's evaluation of process changes does not adequately identify uranium chemical reactivity hazards.

To improve consideration of potential reactive material concerns associated with proposed changes to operations or operational practices drifting over time, including unintended consequences for downstream processes, the following improvements are being implemented:

- Enhanced Change Control: Identifying Chemical Reactivity Hazards
- Enhanced Monitoring: Utilizing statistical process monitoring
- Enhanced Tracking: Improved Material Form Code Training

Evaluation of Process Changes (cont.)

Enhanced Change Control: Identifying Chemical Reactivity Hazards

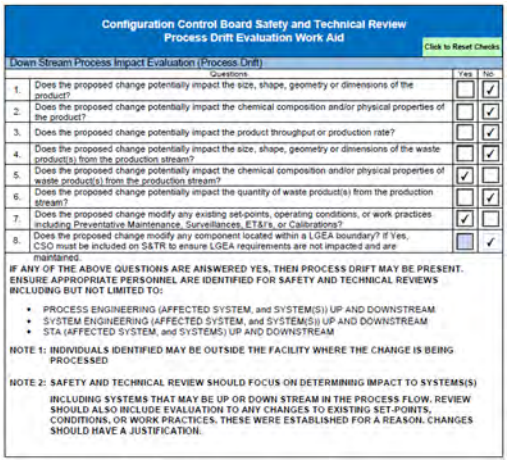
- Y15-187 dictates the use of form UCN-22542 in change control.
- UCN-22542 was revised to include a Process Drift Evaluation Work Aid to initiate the required review by Process Engineering, System Engineering, and/or Shift Technical Advisor when any of the questions are checked "Yes."
- Change Control Board (CCB) reviews the Process Drift Evaluation Work Aid section of UCN-22542 during the CCB and encourages all attendees to provide insight into the drift evaluation.
- In August 2021, CNS began conducting courses with a focus on Y-12 Engineering and Production Operations for recognizing process drift. More than 300 Y-12 personnel taught in the first year of the training being offered.

Evaluation of Process Changes (cont.)

Enhanced Change Control: Identifying Chemical Reactivity Hazards

Change control for fuel elements repackaging and preparation for shipment

- Completion of UCN-22542 identified two areas of potential process drift
- Fuel elements contained Uranium compounds not normally processed in Special Processing area
- Initiated additional review into area limits and controls for the work activity
- Additional controls implemented to mitigate hazards in handling, storage and packaging



Configuration Control Board Safety and Technical Review
Process Drift Evaluation Work Aid

Click to Reset Checks

Down Stream Process Impact Evaluation (Process Drift)

	Questions	Yes	No
1.	Does the proposed change potentially impact the size, shape, geometry or dimensions of the product?	☐	☑
2.	Does the proposed change potentially impact the chemical composition and/or physical properties of the product?	☐	☑
3.	Does the proposed change potentially impact the product throughput or production rate?	☐	☑
4.	Does the proposed change potentially impact the size, shape, geometry or dimensions of the waste product(s) from the production stream?	☐	☑
5.	Does the proposed change potentially impact the chemical composition and/or physical properties of waste product(s) from the production stream?	☑	☐
6.	Does the proposed change potentially impact the quantity of waste product(s) from the production stream?	☐	☑
7.	Does the proposed change modify any existing set-points, operating conditions, or work practices including Preventative Maintenance, Surveillances, ETA's, or Calibrations?	☑	☐
8.	Does the proposed change modify any component located within a LGEA boundary? If Yes, CSO must be included on S&TR to ensure LGEA requirements are not impacted and are maintained.	☐	✓

IF ANY OF THE ABOVE QUESTIONS ARE ANSWERED YES, THEN PROCESS DRIFT MAY BE PRESENT. ENSURE APPROPRIATE PERSONNEL ARE IDENTIFIED FOR SAFETY AND TECHNICAL REVIEWS INCLUDING BUT NOT LIMITED TO:

- PROCESS ENGINEERING (AFFECTED SYSTEM, and SYSTEM(S)) UP AND DOWNSTREAM
- SYSTEM ENGINEERING (AFFECTED SYSTEM, and SYSTEM(S)) UP AND DOWNSTREAM
- STA (AFFECTED SYSTEM, and SYSTEMS) UP AND DOWNSTREAM

NOTE 1: INDIVIDUALS IDENTIFIED MAY BE OUTSIDE THE FACILITY WHERE THE CHANGE IS BEING PROCESSED

NOTE 2: SAFETY AND TECHNICAL REVIEW SHOULD FOCUS ON DETERMINING IMPACT TO SYSTEMS(S) INCLUDING SYSTEMS THAT MAY BE UP OR DOWN STREAM IN THE PROCESS FLOW. REVIEW SHOULD ALSO INCLUDE EVALUATION TO ANY CHANGES TO EXISTING SET-POINTS, CONDITIONS, OR WORK PRACTICES. THESE WERE ESTABLISHED FOR A REASON. CHANGES SHOULD HAVE A JUSTIFICATION.

Evaluation of Process Changes (cont.)

Enhanced Monitoring: Utilizing Statistical Process Control

Y-12 implements continuous quality improvement through Y60-015, Integrated Quality Manual, and is working to enhance the execution of Statistical Process Control (SPC) through the following:

- Strengthening requirements flow down from Y60-015 into lower level manufacturing planning documents
- Continuing deployment of SPC on existing production operations
- Institutionalization of SPC through development of an SPC course and including it in the Process Engineering Training and Qualification requirements
- Development of additional process-specific SPC training modules

Evaluation of Process Changes (cont.)

Enhanced Tracking: Material Form Code Improvements

- Improvements have been made to how material form codes are utilized and implemented to ensure assumptions related to material form in process safety analyses remain bounding and that only those material forms of uranium that have been previously evaluated for the process are introduced.
- These improvements have been incorporated into material form code training for operators and supervisors.

- Material Form Codes w/ Potential Pyrophoric Hazards
  - 1A Saw Fines
  - 1B Briquettes
  - 1C Chips/Turnings
  - 1E Machine/Mill Fines
  - 1G Reduction Metal Salvage
- Electrorefining Material Form Codes
  - 3B ER Dendrites
  - 3C ER U Crystals
  - 3D ER Cell Sludge
  - 3E ER UCF by Products
  - 3F ER Salt Eutectic
- Calciner Material Form Codes (pending)
  - 9A Sodium Diuranate (SDU)
  - 9B Calciner Product

To ensure assumptions related to material form in process safety analyses remain bounding … improvements have been made to how material form codes are utilized and implemented

Conclusion

- NNSA and CNS are committed to continuous improvement and appreciate the Board's oversight and feedback.
- The Board's feedback enables NNSA and CNS to take additional actions to improve the safety posture of Y-12.
- NNSA and CNS look forward to continuing to work with the Board's staff to ensure the improvement actions we are taking are effective at minimizing the risk to our workforce to the lowest practical level.