Formal Cause Analysis for the ARP V (WMF-1617) Drum Event at the RWMC

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Idaho Cleanup Project Core
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ABSTRACT

This report documents a formal cause analysis conducted of a thermal event and subsequent energetic release of radioactive material from four 55-gal drums that occurred in the Accelerated Retrieval Project V facility (WMF-1617) on April 11, 2018. No workers were in the facility at the time of the event, and no release to the environment was detected. The ARP V facility is part of the Radioactive Waste Management Complex at the Idaho National Laboratory Site.

EXECUTIVE SUMMARY

At approximately 2235 Mountain Daylight Time (MDT) on April 11, 2018, there was an incident in the Accelerated Retrieval Project (ARP) V facility, WMF-1617, at the Radioactive Waste Management Complex (RWMC) at Idaho National Laboratory (INL) Site. This incident resulted in a thermal event and subsequent energetic release of radioactive material from four 55-gal drums to a work area normally accessible to facility workers. There were no workers in the facility at the time. There was no detected release to the environment. The retrieval enclosures in ARP V (WMF-1617) are large tension membrane buildings erected over specified exhumation areas to limit the spread of contamination and provide protection from the weather. They are actively ventilated with high efficiency particulate air (HEPA) filtration systems.

The INL Fire Department responded to the site following receipt of fire alarms and initially entered the facility through the vestibule in turnout gear. Upon entry, the first firefighter smelled smoke, backed out of the facility, and had the entry team don self-contained breathing apparatuses. The firefighters then re-entered the facility into the airlock area where drums that had been repackaged that afternoon were staged to be removed the next day. On initial entry, one drum was observed with a lid off; no flames were observed, but smoke was emanating from the top of the drum. The external temperature of the drum was measured to be 190 degrees Fahrenheit and increasing, using a thermal imaging camera. The firefighters attempted unsuccessfully to extinguish the hot spots in the affected drum, moved the drum away from the array of staged drums, and exited the facility at 0005 on April 12, 2018.

A loud noise was heard at 0024, indicative of additional drum breaching. Personnel in the area later stated there was so much dust and debris in the air that they could not see through the window. At this time, personnel were evacuated to 100m per emergency response guidelines.

All three firefighters were taken to the Central Facilities Area (CFA) for decontamination at the Site decontamination facility where they were successfully decontaminated and transported to the Radiological and Environmental Sciences Laboratory (RESL) in town for precautionary lung counts.

Another loud noise was reported at 0328 by personnel in the vicinity of ARP V indicative of an escalating event. During initial reentry on April 19, 2018, it was discovered that a total of four drums had undergone exothermic reactions with their lids and contents being ejected.

On April 16, 2018, Fred Hughes, Fluor Idaho Project Manager, directed the establishment of an event investigation team led by Gene Balsmeier. Mr. Balsmeier established teams to address causal analysis, technical investigation, and reentry/facility recovery planning and execution. The letter from Mr. Hughes directed development of a comprehensive corrective action plan following the investigation and cause analysis of the event to address root, direct, and contributing causes to prevent recurrence. The Root Cause Team was also chartered to provide recommendations for a corrective action plan addressing the identified root causes.

PROBLEM STATEMENT

At approximately 2235 on April 11, 2018, the Accelerated Retrieval Project (ARP) V facility, WMF-1617, experienced an overpressure event on a repackaged sludge drum. Additionally, three other drums experienced similar over pressurizations during the night.

This causal analysis report is supported by available results from the Technical Team's analysis of samples taken from the event drums, selected unreacted drums and locations, and sampling of expelled material in the airlock area.

Data gained from the sample results will be used in the technical analysis to confirm that drum containing depleted uranium was processed which was ultimately packaged into four daughter drums that exothermically reacted approximately 8 hours later. When all sample results have been obtained and analyzed, the Technical Team will prepare an addendum to this final report that will provide a detailed analysis of the materials, chemicals, and mechanics of the exothermic event. At that time, the Root Cause Team will revise the Cause Analysis if necessary, based on the additional information.

The most recent data from indicates that two previously unidentified mechanisms possibly led to the event:

1. Oxidation of a nonroaster oxide depleted uranium metal over a period of approximately eight hours (heat source that initiated secondary reactions)
2. Generation of methane from secondary chemical reactions from beryllium carbide with a smaller possible contribution from uranium carbide reactions

Neither of these mechanisms was captured in existing Acceptable Knowledge documents and neither was anticipated. A literature review of uranium oxidation experiments indicate that uranium oxidation could occur over an extended period of time. A review of previous methane issues revealed that, in 2015, a population of drums was identified that contained high methane levels that precluded shipment to WIPP. A team was brought in from LANL to identify the source of methane but was unsuccessful (LA-UR-15-26657). These drums have been isolated and remain onsite. The Technical Team is conducting tests to verify this hypothesis and to confirm the mechanisms listed above.

The Root Cause Team was chartered to determine the cause of the drum excursion, identify organizational and process weaknesses, analyze potential gaps in hazard controls, and develop recommendations regarding correcting the identified causes. The Root Cause Team performed a detailed analysis of the drum over pressurization event.

The Root Cause Team used the information and approaches described in DOE O 225.1B "Accident Investigations"; MCP-190, "Event Investigation and Occurrence Reporting"; and MCP-598, "Corrective Action System." The analysis was performed in a manner consistent with the requirements of STD-1113, "Cause Analysis and Corrective Action Development."

A comprehensive event and causal factor (E&CF) chart was developed that presents the time sequence for the series of tasks and/or actions that were taken surrounding conditions leading to the project event. The results are displayed in a format that graphically relates event conditions and behaviors to the subsequent causal factors. Summaries are presented in Appendixes N and O. Additionally, the Root Cause Team performed barrier analysis (Appendix D), developed a comparative timeline/change analysis (Appendix C), and performed a safety culture evaluation of the inappropriate actions identified by the Root Cause Team during their analysis of the event timeline which started in 2009 and ended April 12, 2018.

The analysis covers a timespan up to the actual event on April 11, 2018 that includes receipt of waste from Rocky Flats, burial, retrieval, storage, and development of the process used to treat the waste. Multiple prime contractors were involved and many of the decisions and actions predate the current contractor. The E&CF chart delineates transition to Fluor Idaho on June 1, 2016.

Discussion of Direct, Root, and Contributing Causes

Overall, the Root Cause Team identified two root causes and eight contributing causes. The Root Cause Team also provided recommended actions to address the root causes and contributing causes.

Direct Cause (DC)—the immediate events or conditions that caused the accident.

Based on available sample results, the Root Cause Team identified the direct cause of this event.

DC—Based on available sample results, the Root Cause Team identified the direct cause of this event as the breach of four transuranic (TRU) waste containers in the ARP V building resulting from the mixing of waste containing reactive uranium from Container #10595963 with additional parent drum material in the repackaging process. The uranium initiated an exothermic reaction that ultimately led to an over pressurization and subsequent expulsion of material from four containers. The initiating mechanism (heat source), based on sample results, was oxidation of the uranium metal which then supported secondary chemical reactions. The breaches resulted in airborne radioactivity escaping to a filtered, uncontaminated area normally occupied by workers. The direct cause will be revised as necessary when additional sample results are available and upon analysis by the Technical Team.

Root Causes (RC)—causal factors that, if corrected, would prevent recurrence of the same or similar accidents.

The Root Cause Team Identified Two Root Causes for this Event.

The root causes will be reviewed and revised (if necessary) when additional input is provided by the Technical Team.

RC-1: Management failed to fully understand, characterize, establish and implement adequate process controls for treating waste which lacked documented origin or process information.

Prior to initiating the processing of the specific item description code (IDC) involved in the event (SD-176) in March 2016, communication between AMWTF and RWMC personnel failed to identify SD-176 as a composite collection of homogeneous solids containers from more than one waste generator and various waste generating processes. Previous SRP waste sludges that had been processed at ARP V included IDCs from a single known generator and specific waste form or process. Information used to base acceptance of the waste at SRP did not adequately describe the attributes of the waste including some known prohibited items and the potential for pyrophoric and reactive material. Additionally, an adequate chemical compatibility evaluation was not performed. This led to a failure to ensure that effective controls were in place, personnel were trained on the waste, required management oversight for processing a new waste was established, and that upper-tier requirements documents received a thorough analysis.

RC-2: **Management failed to continue to develop the safety culture over a number of years.**

This cause is attributed to exhibited behaviors identified by the analysis of the inappropriate actions throughout the investigation that were not consistent with the tenets of a strong nuclear safety culture. The overall project approach was not conservatively based, lacked documentation and procedures for key safety requirements, and was focused on processing waste to meet milestone requirements rather than compliance with requirements. Some personnel in the approval process for the event drum stated they did not feel comfortable identifying issues that were not consistent with management direction, would delay mission-related objectives, or would otherwise impact cost or schedule.

Schedule pressure was felt by contractor personnel over the entire period evaluated. Management interviews indicated that meeting the Idaho Settlement Agreement drove contract performance and fee, which translated down to personnel as the primary driver for some decisions, leading to reluctance to raise issues that could affect schedule performance. This schedule pressure was reinforced by multiple occasions of accommodations/agreements to waive or delay meeting requirements to not impact schedule.

Contributing Causes (CC)—Events or conditions that collectively, with other causes, increased the likelihood or severity of an event, but that individually did not cause the event.

CC-1: A change-management process was not implemented to identify, evaluate, and disposition the existing vulnerabilities for processing SD-176.

CC-2: A documented plan or path to disposal was not established as required by DOE O 435.1, "Radioactive Waste Management," prior to processing SD-176.

CC-3: Management did not effectively analyze extent of condition following the December 2017 box line fire event and apply lessons learned to relevant ongoing activities outside of AMWTP, which could have identified the presence of pyrophoric and reactive material other than roaster oxides in containerized waste.

CC-4: Oversight of the Sludge Repackaging Project was ineffective in identifying process failures that caused and/or contributed to the ARP V event.

CC-5: An effective integrated human performance improvement program has not been implemented.

CC-6: **Action in applying lessons learned from the 2014 WIPP event was not effective in strengthening processes such that major contributors to the drum event were able to be identified and mitigated.**

CC-7: The project failed to provide an adequate number of trained acceptable knowledge (AK) personnel to support the daily activities along with providing effective program oversight.

CC-8: The Tenant Use Agreement was inappropriately used when initiating the Sludge Repackaging Project (SRP).

These direct and contributing causes are compiled in Table ES-1, along with conclusions from the barrier analysis (see CON 12) and extent of cause analysis (see CON 13) and the resulting judgments of need.

<u>Evaluation of Issues that Did Not Elevate to Root or Contributing Cause Status.</u>

For the purposes of the review, the Root Cause Team has chosen to identify issues from the event day, response to the event, and recovery using the terminology from the Fluor Idaho Quality program.

Significant Conditions Adverse to Quality (SCAQ)—Conditions which, if uncorrected, could have serious effect on the worker, public, and the environment.

Significant conditions adverse to quality identified during the event day, response to the event, and event recovery include the following:

SCAQ-1: Contrary to the requirements of MCP-2726, "Respiratory Protection," during the drum event, an AMWTP radiological control technician (RCT) entered the ARP V facility without wearing the proper respiratory protection for entering a potential immediately dangerous to life or health (IDLH) situation.

Conditions Adverse to Quality (CAQ)—Conditions that include failures, malfunctions, deficiencies, deviations, defective material and equipment, and state of noncompliance with Quality Assurance (QA) program requirements.

Conditions adverse to quality that were identified:

CAQ-1: The Ever-bridge communication system was not working/out-of-service and caused delays in providing notifications of the drum event.

CAQ-2: Following the Fluor Idaho transition, management did not effectively train and manage available resources to ensure AMWTP personnel could effectively respond to an event at the ARP complexes.

CAQ-3: The emergency, abnormal operating, and alarm response procedure (EAR) -246, "RWMC—Respond to Fire," does not include some procedure steps that are identified in the hazard controls of the procedure hazard analysis.

CAQ-4: The INL Fire department responded to the fire alarm condition in WMF-1617 and based initial response actions without an awareness of airborne contamination conditions in the normally clean side of the building.

CAQ-5: Continuous air monitors (CAMs) did not indicate airborne contamination in the airlock and alert the entry team of the condition.

In the absence of fire alarm activation, facility personnel would have been vulnerable to airlock entry the following normal operating period with no indication of airborne contamination.

CAQ-6: The INL Fire Department response actions were not effectively coordinated with facility operations to function in unified command because of the lack of a knowledgeable operations representative at the scene.

CAQ-7: Conduct of operations weaknesses were noted in communicating the need for urgent RCT responses, and then not documenting some required actions during the emergency response.

CAQ-8: The AMWTP RCT inappropriately directed the INL Fire Department firefighters to doff their anti-contamination clothing and equipment in a potentially high risk area in which a lid had already been ejected off a drum, and minutes after the Fire Department exited a lid was ejected off another drum.

CAQ-9: Fire department personnel disturbed the heated product in the drum and moved the drum contrary to facility expectations.

Stirring of contents is not consistent with Fire Department training. Movement of the drum is standard Fire Department protocol to isolate and minimize exposure to adjacent hazards. Alternate actions must be coordinated by an effective unified command, which was not in place.

CAQ-10: Contrary to the requirements of DOE O 422.1,Chg 2,"Conduct of Operations," which states that procedures should be clearly written, MCP-3003, Performing Pre-Job Briefings and Documenting Feedback," does not clearly define management roles and responsibilities for determining that a post job brief is conducted.

CAQ-11: Affected Nondestructive assay (NDA) personnel were not included in the procedure revision process when additional requirements were included in MCP-4226, "TRU Programs Site Project Office Process."

CAQ-12: PLN-4669, "Implementation Plan for PER-109, Book 3, HWMA Storage and Treatment Permit for the Idaho Nuclear Technology and Engineering Center and the Radioactive Waste Management Complex—ARP on the INL," does not adequately roll down Permit Condition VI.C.1 of the RWMC HWMA/RCRA permit: "The Permittee shall not perform treatment of waste containing pyrophoric/reactive radionuclides at the RMWC." As written, PLN-4669 identifies TPR-7867, "SRP RA V Waste Processing"; TPR-7988, "Debris Waste Processing"; and TPR-7990, "Debris DPS Waste Packaging"; and as the procedures that implement Permit Condition VI.C.1.

Although these Operations technical procedures describe the process of processing SRP wastes, they are not sufficient to ensure the wastes selected and shipped to ARP V for SRP processing do not contain pyrophoric radionuclides.

CAQ-13: RCTs were not familiar with Fire Department donning and doffing protocols which compromised the timeliness and effectiveness of doffing contamination control measures.

CAQ-14: Fire Department quick access plans (QAPs) and pre-incident plans (PIPs) do not identify comprehensive radiological hazard conditions, most notably, the potential for airborne alpha contamination in ARP V.

Conclusions and Judgements of Need

Based on analysis of this event, the Root Cause Team concluded that the significance of this event with regard to implications for worker health and safety, public health and safety, and environmental contamination is captured in the following Conclusions (CONs). The conclusions are derived from analytical results (Event and Causal Factor Chart Analysis, Comparative Timeline Analysis, and Barrier Analysis) performed during this event investigation. Also listed are Judgements of Need (JONs) determined by the Team as managerial controls and safety measures necessary to prevent or minimize the probability or severity of a recurrence of this type of event.

It should be note that the fortunate timing of the drum lid ejections played a substantial role in limiting personnel injuries, radiological exposure and environmental contamination. No personnel were in the vicinity of the drum when the reactions occurred and the drums were in a HEPA filtered area.

Table ES-1 summarizes the conclusions (CONs) and judgements of need (JONs) determined by the Root Cause Team.

Table ES-2 captures issues identified during the event day, event response, and recovery that, while they did not cause the event, need to be addressed through the Fluor Idaho Quality Management program.

These tables do not include evaluation of DOE actions/contributions leading to the event. Areas where DOE impacted or contributed to the event can be seen in the event and causal factor chart. DOE may want to consider further evaluation of the identified areas from the event and causal factor chart and develop additional Judgements of Need.

Table ES-1. Conclusions and judgments of need.

Conclusion (CON)	Judgments of Need (JON)
CON 1: Based on available sample results, the Root Cause Team identified the direct cause of this event as the breach of four transuranic (TRU) waste containers in the ARP V building resulting from the mixing of waste containing reactive uranium from Container #10595963 with additional parent drum material in the repackaging process. The uranium initiated an exothermic reaction that ultimately led to an over pressurization and subsequent expulsion of material from four containers. The initiating mechanism (heat source) based on sample results was oxidation of the uranium metal which then supported secondary chemical reactions. The breaches resulted in airborne radioactivity escaping to a filtered, uncontaminated area normally occupied by workers. The direct cause will be revised as necessary when additional sample results are available and upon analysis by the Technical Team.	**JON 1:** Fluor Idaho needs to complete review and analysis of sample results to make an absolute determination as to the mechanism of the reaction and subsequent breaches. **JON 2:** Following analysis, the Event Technical Team needs to analyze the results from sampling and issue an addendum to this final report. This addendum should also identify and address: • Confirmation of methane generation sources • Process safety actions required associated with methane including fire department response • Evaluation of existing historical drum population including adequacy of current drum vents **JON 3:** Following issuance of the Technical Team's final report, the Root Cause Team needs to evaluate the data provided to: • Determine any related conditions and causal factors changes • Determine the need for further causal evaluation • Reach conclusions • Confirm judgements of need • Identify additional judgements of need.

Table ES-1. (continued).

Conclusion (CON)	Judgments of Need (JON)
CON 2: Management failed to fully understand, characterize, establish and implement adequate process controls for treating waste which lacked documented origin or process information. Prior to initiating the processing of the specific item description code (IDC) involved in the event (SD-176) in March 2016, communication between AMWTF and RWMC personnel failed to identify SD-176 as a composite collection of homogeneous solids containers from more than one waste generator and various waste generating processes. Previous SRP waste sludges that had been processed at ARP V included IDCs from a single known generator and specific waste form or process. Information used to base acceptance of the waste at SRP did not adequately describe the attributes of the waste including prohibited items and the potential for pyrophoric and reactive material nor was an adequate chemical compatibility evaluation performed. This led to a failure to ensure that (1) effective controls were in place, (2) personnel were trained on the waste, (3) required management oversight for processing a new waste was established, and (4) upper-tier requirements documents received a thorough analysis.	**JON 4:** Fluor Idaho needs to evaluate the existing process (in place since November 2012) and revise the process for treating waste that is from unknown generators to reflect the lessons learned from the event. **JON 5:** Fluor Idaho needs to review and revise the contents of documents used for AK supporting processing of SD-176 waste to address chemical compatibility, pyrophoric and reactive issues including potential nonroaster oxide waste, identification of all prohibited items reflected in AK source documents, and conclusions from this event. Chemical compatibility requirements need to be established and met. Procedures for identification of potentially pyrophoric and reactive materials need to reflect this effort and provide specific criteria and guidance, including defining of pyrophoric and reactive materials. **JON 6:** Fluor Idaho needs to provide training to personnel regarding pyrophoric materials, controls, and procedure compliance. **JON 7**: Fluor Idaho needs to review the existing RWMC Hazardous Waste Management Act (HWMA)/Resource Conservation and Recovery Act (RCRA) Permit and AMWTP HWMA/RCRA permits for requirement implementation and flow-down of those requirements.

Table ES-1. (continued).

Conclusion (CON)	Judgments of Need (JON)
CON 3: Management failed to continue to develop the safety culture over a number of years. This cause is attributed to exhibited behaviors identified by the analysis of the inappropriate actions throughout the investigation that were not consistent with the tenets of a strong nuclear safety culture. The overall project approach was not conservatively based, lacked documentation and procedures for key safety requirements, and was focused on processing waste to meet milestone requirements rather than compliance with requirements. Some personnel in the approval process for the event drum stated they did not feel comfortable identifying issues that were not consistent with management direction, would delay mission-related objectives, or would otherwise impact cost or schedule. Schedule pressure was felt by contractor personnel over the entire period evaluated. Management interviews indicated that meeting the Idaho Settlement Agreement drove contract performance and fee, which translated down to personnel as the primary driver for some decisions, leading to reluctance to raise issues that could affect schedule performance. This schedule pressure was reinforced by multiple occasions of accommodations/ agreements to waive or delay meeting requirements to not impact schedule.	**JON 8:** Fluor Idaho, in consultation with the U.S. Department of Energy Idaho Operations Office (DOE-ID), needs to commission an independent nuclear safety culture assessment for its scope of work. **JON 9:** Fluor Idaho needs to develop immediate corrective actions to ensure personnel feel free to report all issues without fear of consequences or retaliation.

Table ES-1. (continued).

Conclusion (CON)	Judgments of Need (JON)
CON 4: A change-management process was not implemented to identify, evaluate, and disposition the existing vulnerabilities for processing SD-176. Management failed to ensure that a change-management process was implemented to identify, consider, and disposition the existing vulnerabilities for processing SD-176 Implementation of a change management process would have allowed the project team to analyze the risk associated for processing a composite collection of containers from various generators versus an IDC from a single known generator. Currently, Fluor Idaho has certain programs and processes that require a formal change management process (for example, implementation of changes to DSA/TSR, critical safety controls, RCRA permit changes, contract modification). For this event, processing of SD-176 was not recognized as a significant change due to the waste form (sludge) and a "unique" IDC. No change process was applied to the initiation of the campaign.	**JON 10:** Fluor Idaho needs to improve execution of change management processes at the project level so that formal evaluations include identification of hazards, development of controls, review, and approval when existing process parameters or inputs are changed.
CON 5: A documented plan or path to disposal was not established as required by DOE O 435.1, "Radioactive Waste Management," prior to processing SD-176. Management failed to ensure a documented plan or path to disposal, as required by DOE O 435.1, "Radioactive Waste Management," was established prior to processing SD-176. Decisions to process SD-176 were made without recognition that the facility was transitioning from processing a well characterized, relatively homogeneous generator specific and process specific IDC waste stream to an IDC waste that was not well characterized and originated from various generators and processes, and did not have a comprehensive chemical compatibility evaluation (CCE). Undefined characterization activities and Waste Isolation Pilot Plant (WIPP) approval still remain to be completed.	**JON 11:** Fluor Idaho needs to update project procedures and environmental safety, health, and quality (ESH&Q) documents to appropriately analyze the hazards, define quantities allowed, and revise RCRA permits to reflect project activities. **JON 12:** Fluor Idaho needs to develop a technically based process to treat remaining drums that identifies and evaluates the presence of pyrophoric and reactive material, and potentially incompatible chemicals. This process needs to be validated using data from the final technical report. **JON 13:** Fluor Idaho needs to develop and execute training for personnel following completion of JONs 10,11, and 12

Table ES-1. (continued).

Conclusion (CON)	Judgments of Need (JON)
CON 6: Management did not effectively analyze extent of condition following the December 2017 box line fire event and apply lessons learned to relevant ongoing activities outside of AMWTP, which could have identified the presence of pyrophoric and reactive material other than roaster oxides in containerized waste. Management did not effectively determine the extent of condition and communicate corrective actions taken at AMWTP after the December 2017 box line fire that could have identified the existence of a previously unknown waste form containing pyrophoric uranium other than roaster oxides. While the material processed at AMWTP was not sludge or roaster oxide, an extent-of-condition review should have required an evaluation of other potential pyrophoric and reactive materials and waste forms. During the extent of condition review, the event drum 10595963 had been identified as a potential problem drum on the basis of a U-238 mass of greater than 5 kg. However, drum 10595963 was not considered any further in the Box line event extent of condition because it was "Not TF (Treatment Facility) Feed, Not on RPT-TRUW-83."	**JON 14:** Fluor Idaho needs to review the Fluor Idaho lessons-learned program against the requirements from DOE O 210., DOE Corporate Operations Experience Program," and DOE O 226.1B, "Implementation of Department of Energy Oversight Policy," and implement changes such that feedback and improvement changes are visible aspects of the event investigation and causal analysis processes. **JON 15:** Fluor Idaho needs to incorporate the lessons from this event into the complex wide program.
CON 7: Oversight of the Sludge Repackaging Project was ineffective in identifying process failures that caused and/or contributed to the ARP V event. Oversight was not effective in identifying or questioning that SD-176 was being processed in the same manner as previous IDCs that were well evaluated with respect to generating process and source. Oversight did not verify that specific process requirements were appropriately documented through procedural sign-offs, particularly when performed by different organizations. Management did not ensure that all the tools they have to provide oversight were being effectively implemented to prevent this event.	**JON 16:** Fluor Idaho needs to strengthen its oversight program to provide management and U.S. Department of Energy (DOE) confidence that work is being performed compliantly, risks are identified, and controls are effectively implemented.

Table ES-1. (continued).

Conclusion (CON)	Judgments of Need (JON)
CON 8: An effective integrated human performance improvement program. The root cause team identified numerous human performance weaknesses during the team's analysis. Attachment F describes the human performance issues along with the error modes.	**JON 17:** Fluor Idaho needs to reconsider the use of e-mails as a basis for decisions, and revise MCP-3930, "Repackage Project Waste Transfers Between RWMC-AMWTP and RWMC-ARP," to reflect management expectations regarding the use and control of e-mail in procedures. **JON 18:** Flour Idaho needs to implement a human performance program that integrates the program and projects, including trending of corrective action program information for improvement. **JON 19:** Discuss lessons learned with appropriate individuals to address human performance identified issues from Attachment F. Include knowledge based corrective actions such as Training on fundamentals; Increase problem solving skills; Work specialization; Train on work processes; Reinforce knowledge based performance error reduction tools (Watch out – Stop) and Rule based corrective actions such as Train/Reinforce/Clarify; Work specialization; Reinforce rule based performance error reduction tools (QV&V)
CON 9: Lessons learned from the 2014 WIPP event was not effective in strengthening processes such that major contributors to the drum event were able to be identified and mitigated. Lessons learned from the 2014 WIPP event were not effectively evaluated or acted upon by RWMC and AMWTP to preclude some of the major contributors to the drum event. For example, evaluations and subsequent corrective actions taken in 2015 did not effectively identify safety culture and change control issues. Similarly, the actions taken to address the WIPP fire event did not expand to evaluate other potential pyrophoric and reactive materials and waste forms.	**JON 20:** Fluor Idaho needs to re-evaluate the WIPP CONs and JONS in context with Fluor Idaho processes and take necessary corrective actions to address each CON/JON.
CON 10: The project failed to provide an adequate number of trained acceptable knowledge (AK) personnel to support the daily activities along with providing effective program oversight.	**JON 21:** Fluor Idaho needs to continue to evaluate and hire the necessary number of AK personnel needed to provide daily AK activities and effective oversight of the program. **JON 22:** Fluor Idaho needs to provide training for the AK personnel based on upgrades to the AK documentation.

Table ES-1. (continued).

Conclusion (CON)	Judgments of Need (JON)
CON 11: The Tenant Use Agreement was inappropriately used when initiating the Sludge Repackaging Project (SRP). Management inappropriately applied the Tenant Use Agreement process when initiating the SRP. Since two contractors were involved in the start of the SRP process, DOE directed the contractors to use an interface agreement (IAG) rather than establishing a prime contractor to subcontractor relationship. The IAG that was developed contained steps and requirements that should have been in a technical procedure. It also was the vehicle to authorize specific IDCs to be processed. When IAG-592 was modified to include SD-176, it did not receive a USQ evaluation against the safety basis since interface agreements are categorically excluded from the USQ process.	**JON 23:** Fluor Idaho needs to evaluate where any other interface agreements could potentially affect compliance with the facilities' safety basis. This evaluation needs to include a review of the categorical exclusion process. **JON 24:** Fluor Idaho needs to discuss the lessons learned for inappropriate use of the IAG process when IAG-592 was first developed.
CON 12: Numerous barriers were identified that were failed, weak, missing or compromised. Attachment D identifies the issues with recommended actions.	**JON 25:** Fluor Idaho needs to review and address the issues identified from the Root Cause Team's barrier analysis.
CON 13: The Extent of Cause identified that similar management behaviors could be actively impacting the success at other Fluor Idaho facilities.	**JON 26:** Fluor Idaho needs to review and address where similar management behaviors are affecting other Fluor Idaho facilities.

Additionally, the Root Cause Team evaluated the issues from the event day, response to the event, and event recovery. It is the recommendation of the Root Cause Team that these issues be addressed through the Fluor Idaho Quality Program. Table ES-2 contains a summary of these issues and recommended corrective actions.

Table ES-2. Conditions adverse to quality and recommended corrective actions.

Significant Conditions Adverse to Quality	Recommended Corrective Actions
SCAQ-1: Contrary to the requirements of MCP-2726, "Respiratory Protection," during the drum event, an AMWTP radiological control technician (RCT) entered the ARP V facility without wearing the proper respiratory protection for entering a potential immediately dangerous to life or health (IDLH) situation.	Conduct training for all AMWTP RCTs to ensure understanding of the difference between using a powered air purifying respirator (PAPR) and self-contained breathing apparatus (SCBA) for entering an area where there is a fire. Discuss lessons learned with Flour Idaho personnel on the ramifications of wearing the required respiratory protection.

Table ES-2. (continuous).

Conditions Adverse to Quality	Recommended Corrective Actions
CAQ-1: The Ever-bridge communication system was not working/out-of-service and caused delays in providing notifications of the drum event.	Initiate a work order to troubleshoot the Ever-bridge communications system and correct identified deficiencies.
CAQ-2: Following the Fluor Idaho transition, management did not effectively train and manage available resources to ensure AMWTP personnel could effectively respond to an event at the ARP complexes.	Fluor Idaho needs to provide training for AMWTP personnel to respond to RWMC events, especially on the off hours. Develop or revise a change management guidance document to include these types of process changes. Conduct training and implement the document.
CAQ-3: The emergency, abnormal operating, and alarm response procedure (EAR) -246, "RWMC—Respond to Fire," does not include some procedure steps that are identified in the hazard controls of the procedure hazard analysis.	Revise EAR-246 to include lessons learned from this event and to address the specific steps from the hazard analysis section of the EAR to be included in the body of the procedure.
CAQ-4: The INL Fire department responded to the fire alarm condition in WMF-1617 and based initial response actions without an awareness of airborne contamination conditions in the normally clean side of the building.	Evaluate requirements, establish expectations, incorporate into procedure, conduct training and implement changes.
CAQ-5: Continuous air monitors (CAMs) did not indicate airborne contamination in the airlock and alert the entry team of the condition.	Revise Fire Department procedures to address lessons learned from this event. Conduct training on the entry and exit from radiological facilities. Evaluate placement of CAMS to allow the Fire Department to use CAM data for entry into facilities.
CAQ-6: The INL Fire Department response actions were not effectively coordinated with facility operations to function in unified command because of the lack of a knowledgeable operations representative at the scene.	Evaluate backshift response training, qualification, turnover process, and expectations for emergency response. Conduct training on changes identified from the above evaluation. Additionally, include training on effective communication of urgent support needs during an emergency.
CAQ-7: Conduct of operations weaknesses were noted in communicating the need for urgent RCT responses, and then not documenting some required actions during the emergency response.	Evaluate requirements, establish expectations, incorporate into procedure, conduct training and implement changes

Table ES-2. (continuous).

Conditions Adverse to Quality	Recommended Corrective Actions
CAQ-8: The AMWTP RCT inappropriately directed the INL Fire Department firefighters to doff their anti-contamination clothing and equipment in a potentially high risk area in which a lid had already been ejected off a drum, and minutes after the Fire Department exited a lid was ejected off another drum.	Provide training to AMWTP RCTs regarding doffing locations when there is a potentially high risk area that requires immediate exiting.
CAQ-9: Fire department personnel disturbed the heated product in the drum and moved the drum contrary to facility expectations. **Stirring of contents is not consistent with Fire Department training. Movement of the drum is standard Fire Department protocol to isolate and minimize exposure to adjacent hazards. Alternate actions must be coordinated by an effective unified command, which was not in place.**	Ensure all firefighters are aware of the Fire Department expectations provided in Training.
CAQ-10: Contrary to the requirements of DOE O 422.1,Chg 2,"Conduct of Operations," which states that procedures should be clearly written, MCP-3003, Performing Pre-Job Briefings and Documenting Feedback," does not clearly define management roles and responsibilities for determining that a post job brief is conducted.	Revise MCP-3003 to better define requirement for post job brief and management roles and responsibilities for ensuring an effective post job brief is conducted.
CAQ-11: Affected Nondestructive assay (NDA) personnel were not included in the procedure revision process when additional requirements were included in MCP-4226, "TRU Programs Site Project Office Process."	Strengthen the MCP-135, "Document Management," process to require the review and approval of affected personnel. Ensure that steps are implementable and provide documentation of completion of key requirements. Develop criteria for identifying or evaluating for potential pyrophorics and train NDA personnel regarding their responsibilities of MCP-4226.

Table ES-2. (continuous).

Conditions Adverse to Quality	Recommended Corrective Actions
CAQ-12: PLN-4669, "Implementation Plan for PER-109, Book 3, HWMA Storage and Treatment Permit for the Idaho Nuclear Technology and Engineering Center and the Radioactive Waste Management Complex—ARP on the INL," does not adequately roll down Permit Condition VI.C.1 of the RWMC HWMA/RCRA permit: "The Permittee shall not perform treatment of waste containing pyrophoric/reactive radionuclides at the RMWC." As written, PLN-4669 identifies TPR-7867, "SRP RA V Waste Processing"; TPR-7988, "Debris Waste Processing"; and TPR-7990, "Debris DPS Waste Packaging"; and as the procedures that implement Permit Condition VI.C.1.	Revise Plan-4669 and incorporate technical procedures (TPRs) that will meet the RCRA permit requirement.
CAQ-13: RCTs were not familiar with Fire Department donning and doffing protocols which compromised the timeliness and effectiveness of doffing contamination control measures.	Train RCTs on the Fire Department doffing process. Conduct Fire Department and RCTs drills as a team to ensure training is effective.
CAQ-14: Fire Department quick access plans (QAPs) and pre-incident plans (PIPs) do not identify comprehensive radiological hazard conditions, most notably, the potential for airborne alpha contamination in ARP V.	Revise QAPs and PIPs to provide comprehensive radiological hazard conditions that specifically address the potential for air borne alpha contamination.

CONTENTS

FIGURES

TABLES

ACRONYMS

AEC	Atomic Energy Commission
AK	acceptable knowledge
AL	airlock
AMWTF	Advanced Mixed Waste Treatment Facility
AMWTP	Advanced Mixed Waste Treatment Project
ARP	Accelerated Retrieval Project
BEA	Battelle Energy Alliance, LLC
BoK	basis of knowledge
CAM	continuous air monitor
CAQ	condition adverse to quality
CAR	corrective action report
CBFO	Carlsbad Field Office
CC	contributing cause
CCE	chemical compatibility evaluation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CFR	Code of Federal Regulations
CON	Conclusion
CP	command post
CWI	CH2M-WG Idaho, LLC
D&D	decommissioning and demolition
DAC	derived air concentration
DC	Direct Cause
DEQ	Department of Environmental Quality
DOE	Department of Energy
DOE-HQ	Department of Energy Headquarters
DOE-ID	Department of Energy Idaho Operations Office
DPS	drum packaging station
DRP	Debris Repackaging Project
DSA	documented safety analysis (document type)
DU	depleted uranium
EAL	emergency action level
EAM	emergency action manager
EAR	emergency, abnormal operating, and alarm response procedure (document type)
EC	emergency coordinator

E&CF	event and causal factor (chart)
ECC	emergency control center
ECS	emergency communications system
ED	emergency director
EDE	effective dose equivalent
EDMS	Electronic Document Management System
EHA	Emergency Hazard Assessment
EHS	Emergency Hazard Survey
EMT	emergency medical technician
ENS	emergency notification system
EOC	emergency operations center
EOC	extent of condition
EPA	Environmental Protection Agency
EPHA	Emergency Planning Hazards Assessment
EPHS	Emergency Planning Hazards Survey
EPI	Emergency Plan Implementing (procedures)
EPOC	emergency point of contact
EPZ	emergency planning zone
ERAP	emergency readiness assurance plan
ERP	emergency response plan
ERO	emergency response organization
EROB	Engineering Research Office Building
ERPG	Emergency Response Planning Guideline
ESH&Q	Environment, Safety, Health and Quality (organization)
EWR	Early Waste Retrieval Project
FAC	fire alarm center
FAS	fire alarm system
FD	INL Fire Department
GE	general emergency
HAD	hazards assessment document (document type)
HASP	health and safety plan
HAZMAT	hazardous material
HEPA	high-efficiency particulate air
HIC	high-integrity container
HPI	human performance improvement
HWN	Hazardous Waste Number
IAG	interface agreement (document type)

IC	incident commander
ICDF	Idaho CERCLA Disposal Facility
ICP	Idaho Cleanup Project Core
ICS	incident command system
IDC	item description code
IDLH	immediately dangerous to life or health
IFFD	Idaho Falls Fire Department
INL	Idaho National Laboratory
IS/IH	Industrial Safety/Industrial Hygiene
ITG	Idaho Treatment Group, LLC
IWTS	Integrated Waste Tracking System
JIC	joint information center
JON	Judgement of Need
MCP	management control procedure (document type)
MDO	management duty officer
MOA	memorandum of agreement
MOU	memorandum of understanding
MSCF	Materials Storage and Consolidation Facility
MWV	management workplace visit
NDA	nondestructive assay
NFM	nuclear facility manager
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NWP	Nuclear Waste Partnership
OE	operational emergency
OM	Operations manager
OSC	On-scene communicator
OSHA	Occupational Safety and Health Administration
OWL	Observe, Watch, and Learn
PA	protective action
PAC	protective action criteria
PAD	protective action decision
PAGs	protective action guides
PAL	personnel accountability leader
PAPR	powered air purifying respirator
PAR	protective action recommendation
PCB	polychlorinated biphenyl

PDD	program description document (document type)
PEW	Process Equipment Waste
PIP	pre-incident plan
PISA	potentially inadequate safety analysis
PSM	plant shift manager
QA	quality assurance
QAP	quick access plan
R2A2	roles, responsibilities, accountabilities, and authorities
RadCon	Radiological Control
RC	root cause
RCA	recommended corrective action
RCM	Radiological Control manager
RCRA	Resource Conservation and Recovery Act
RCT	radiological control technician
RFP	request for proposal
RFP	Rocky Flats Plant
RH	remote-handled
RMWSF	Radioactive Mixed Waste Storage Facility
RTR	real-time radiography
RWMC	Radioactive Waste Management Complex
RWP	radiological work permit
SAE	site area emergency
SCAQ	Significant Condition Adverse to Quality
SCBA	self-contained breathing apparatus
SDA	subsurface disposal area
SMOP	six-drum metal overpack
SMT	site monitoring team
SOM	shift operations manager
SOP	standard operating procedure
SRP	Sludge Repackaging Project
SS	shift supervisor
SSA	Staging and Storage Annex
SSF	Sawtelle Street Facility
TBD	to be determined
TIC	thermal imaging camera
TPR	technical procedure (document type)
TRU	transuranic (waste)

TSA	Transuranic Storage Area
TSC	technical support center
USQ	unreviewed safety question
VE	visual examiner
WAC	waste acceptance criteria
WDDF	waste determination and disposition form
WIPP	Waste Isolation Pilot Plant
WO	Waste Operations
WTS	Waste Tracking System

DEFINITIONS

Alert—A condition in which an actual or potential substantial degradation in the level of control over hazardous materials exists.

Barrier analysis—Review the hazards, the targets (people or objects) of the hazards, and the controls or barriers that management systems put in place to separate the hazards from the targets. Barriers may be physical or administrative. Types of barriers include physical, equipment design, warning devices, procedures and work processes, knowledge and skills, and supervision. Barriers may be control barriers, safety barriers, or act as both.

Causal factor—An event or condition in the event sequence that contributes to the unwanted result. There are three types of causal factors: direct cause(s), which is the immediate event(s) or condition(s) that caused the event; root causes(s), which is the causal factor that, if corrected, would prevent recurrence of the event; and the contributing causal factors, which are the causal factors that collectively with the other causes increase the likelihood of an event, but which did not cause the event.

Comparative timeline/change analysis—A systematic approach that examines planned or unplanned changes in a system that caused the undesirable results related to the event. The comparative timeline summarizes the occurrences and omissions that most significantly affected the outcome of the drum event.

Conditions adverse to quality—Conditions that include failures; malfunctions; deficiencies; deviations; defective material and equipment; and state of noncompliance with Quality Assurance program requirements.

Contributing causes—Events or conditions that collectively with other causes increased the likelihood or severity of an event but that individually did not cause the event. Contributing causes may be longstanding conditions or a series of prior events that, alone, were not sufficient to cause the event, but were necessary for it to occur. Contributing causes are the events and conditions that "set the stage" for the event and, if allowed to persist or recur, increase the probability of future events.

Direct cause—Immediate causes(s) or condition(s) that caused the event.

Event and causal factors analysis—Charting that depicts the logical sequence of events and conditions (causal factors that allowed the event to occur), and the use of deductive reasoning to determine the causes or conditions that contributed to the event.

Item Description Code—An alpha numeric designator typically used to describe or represent the contents of a waste container. An IDC may range from a specific waste type from a single generator to describing a general waste category. An IDC may be used to represent a container only.

Operational Emergency—A major unplanned or abnormal incident or condition that involves or affects DOE facilities and activities by causing or having the potential to cause serious health and safety or environmental impacts and requires additional resources to supplement the planned initial response off-Site (DOE O 151.1D, "Comprehensive Emergency Management System").

Pyrophoric—Multiple definitions

Fluor Plan, PLN-5198, “AMWTP CH TRU Waste Certification Plan”

> Materials that may ignite spontaneously in air or that emit sparks when scratched or struck, especially with materials such as steel. A flammable solid that, under transport conditions, might cause fires through friction or retained heat or that can be ignited readily and, when ignited, burns vigorously and persistently so as to create a serious transportation hazard. Included in the pyrophoric definition are spontaneously combustible materials, water reactive materials, and oxidizers. Examples of nonradioactive pyrophorics are organic peroxides, sodium metal, and chlorates.

WIPP WAC definition:

> Materials that may ignite spontaneously in air or that emit sparks when scratched or struck, especially with materials such as steel. A flammable solid that, under transport conditions, might cause fires through friction or retained heat or that can be ignited readily and, when ignited, burns vigorously and persistently so as to create a serious transportation hazard. Included in the pyrophoric definition are spontaneously combustible materials, water reactive materials, and oxidizers. Examples of nonradioactive pyrophorics are organic peroxides, sodium metal, and chlorates.

DOE Handbook DOE-HDBK-1081-94, December 1994, Primer on Spontaneous Heating and Pyrophoricity:

> Pyrophoric Material:
>
> > Pyrophoric substances ignite instantly upon exposure to air (atmospheric oxygen). A pyrophoric substance may be a solid, liquid, or gas. Most materials are not pyrophoric unless they are in a very finely divided state.

US EPA SW-846 Test Method 1050, for substances likely to spontaneously combust:

> Wastes (including mixtures and solutions, liquid or solid) which, even in small quantities, ignite within five minutes of coming in contact with air. These wastes are the most likely to spontaneously combust and are considered to have pyrophoric properties.

OSHA Hazard Communication Standard 29 CFR 9110.1200:

> “Pyrophoric” means a chemical that will ignite spontaneously in air at a temperature of 130 deg. F (54.4 deg. C) or below, but in the same table, a pyrophoric solid means a solid that, even in small quantities, is liable of igniting within 5 minutes after coming into contact with air. Substances and mixtures of this hazard class are assigned to a single hazard category on the basis of the outcome of the test: The solid ignites within 5 minutes of coming into contact with air.

US DOT, 49 CFR 173.124, definitions:

> A pyrophoric material is a liquid or solid that, even in small quantities and without an external ignition source, can ignite within 5 minutes after coming in contact with air when tested according to UN Manual of Tests and Criteria (GHS).
>
> Globally Harmonized System (GHS), as of 2006
>
> A pyrophoric solid is a solid which, even in small quantities, is liable to ignite within 5 minutes after coming into contact with air. Substances and mixtures of this hazard class are assigned to a single hazard category on the basis of the outcome of the UN Test N.2 (UN Manual of Tests and Criteria).

Reactive Uranium—Oxidation of uranium metal that does not meet the definition of pyrophoric uranium.

Root causes—The causal factors that, if corrected, would prevent recurrence of the occurrence. It is the most basic cause that explains why the event happened, that can reasonably be identified, that senior management has the control to fix, and for which effective recommendations for corrective actions to remedy the problem, prevent specific recurrence of the problem, and preclude occurrence of similar problems can be generated, if necessary. (DOE-STD-1197-2011, "Occurrence Reporting Causal Analysis," definition)

Significant conditions adverse to quality—Conditions that, if uncorrected, could have serious effect on workers, the public, and the environment.

Unknown waste—Composite collection of containers from various generators and from waste generating processes lacking documentation and markings

Formal Cause Analysis for ARP V Drum Event

1. INTRODUCTION

This report documents a formal cause analysis performed of a thermal event and subsequent energetic release of radioactive material from a 55-gal drum that occurred on April 11, 2018, in the Accelerated Retrieval Project (ARP) V facility (WMF 1617). Although the work area normally is accessible to facility workers, no workers were in the facility at the time of the event. No release to the environment was detected. The ARP V facility is part of the Radioactive Waste Management Complex (RWMC) at the Idaho National Laboratory (INL) Site.

This section provides an overview of the pertinent history, facilities, processes, and operations associated with the breaching of four drums of transuranic (TRU) waste during the April 11, 2018, event at the ARP V facility.

At approximately 2235 on April 11, 2018, a repackaged drum experienced an exothermic reaction that resulted in an over pressurization that ejected the lid off the drum and littered the WMF-1617 (ARP V) airlock with contaminated waste. Over the next few hours three additional drums experienced similar over pressurizations, resulting in lid ejections.

1.1 Facility Overview and History

The INL was established in 1949 in southeast Idaho to support national nuclear energy research. The Radioactive Waste Management Complex (RWMC) was established in 1952 for disposal of radioactive waste. RWMC is located in the southwestern quadrant of INL and encompasses approximately 177 acres.

RWMC consists of three areas: the Subsurface Disposal Area (SDA), the Transuranic Storage Area (TSA), and the Administration and Operations Area. The approximate size of each area is 97 acres, 58 acres, and 22 acres, respectively. The SDA contains waste in unlined pits, trenches, and soil vaults within surface sediments and on Pad A, which is an above grade disposal area within the SDA. Waste in the landfill is contaminated with radionuclides and hazardous chemicals.[1] The SDA disposed of both INL Site-generated and off-Site-generated waste, primarily Rocky Flats Plant (RFP), near Golden, Colorado. The first shipment of waste from the RFP was authorized in March 1954 and received at RWMC on April 22, 1954. The SDA is currently the site of several remedial action efforts including retrieval of targeted waste forms at ARP. The TSA was established in 1970 to address the Atomic Energy Commission Immediate Action Directive (IAD) No. 0511-21, "Policy Statement Regarding Solid Waste Burial," requiring segregation of waste contaminated with long-lived TRU nuclides.[2] Disposal of TRU waste in the SDA ceased and aboveground storage of TRU wastes was implemented. The TSA provides for aboveground TRU waste storage, treatment of waste at AMWTP, and preparation of waste for shipment to the Waste Isolation Pilot Plant (WIPP). The Administration and Operations Area provides for equipment maintenance, material storage, and office space for workers.

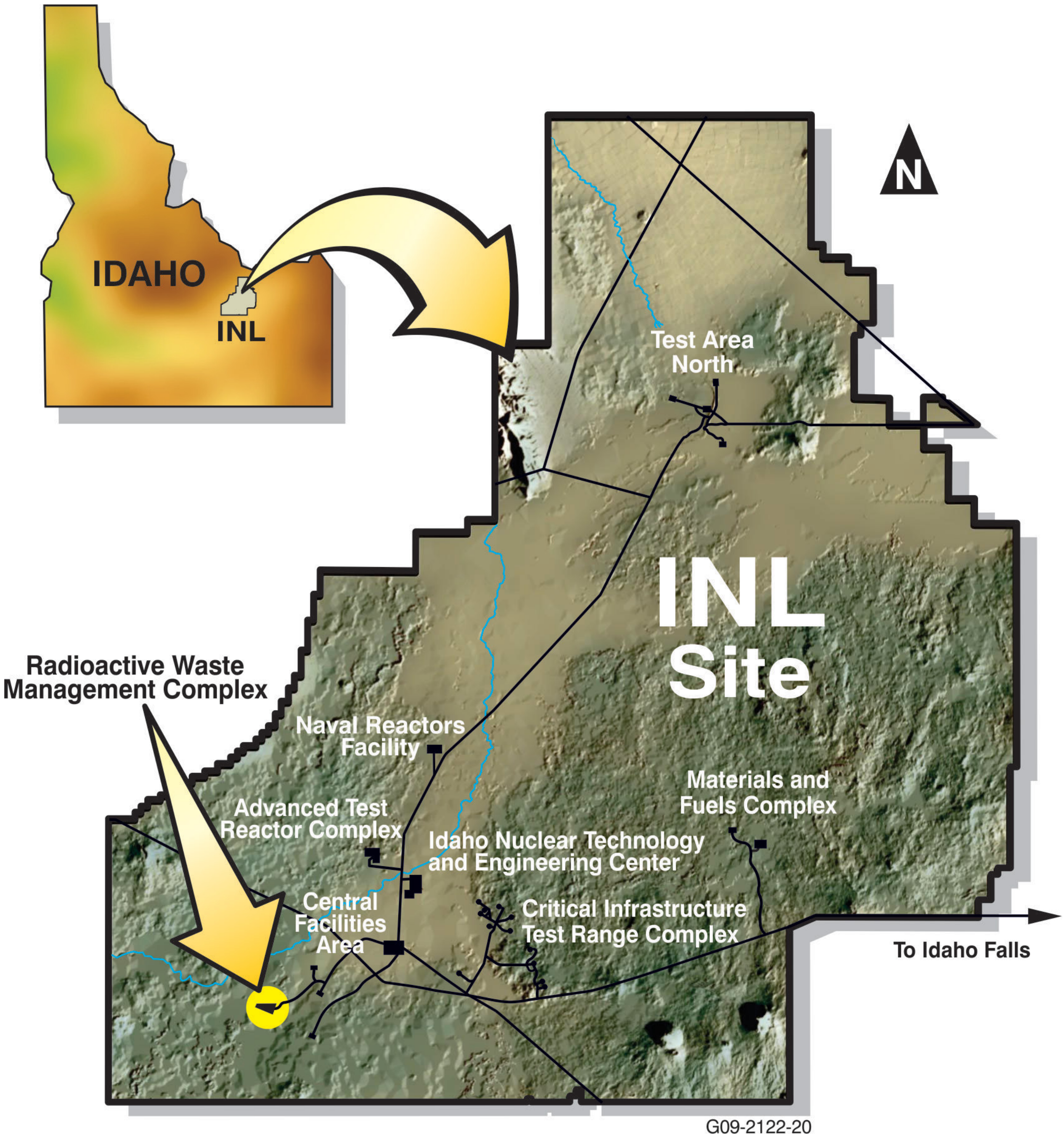


Figure 1. Location of the Radioactive Waste Management Complex at the Idaho National Laboratory Site in Idaho.

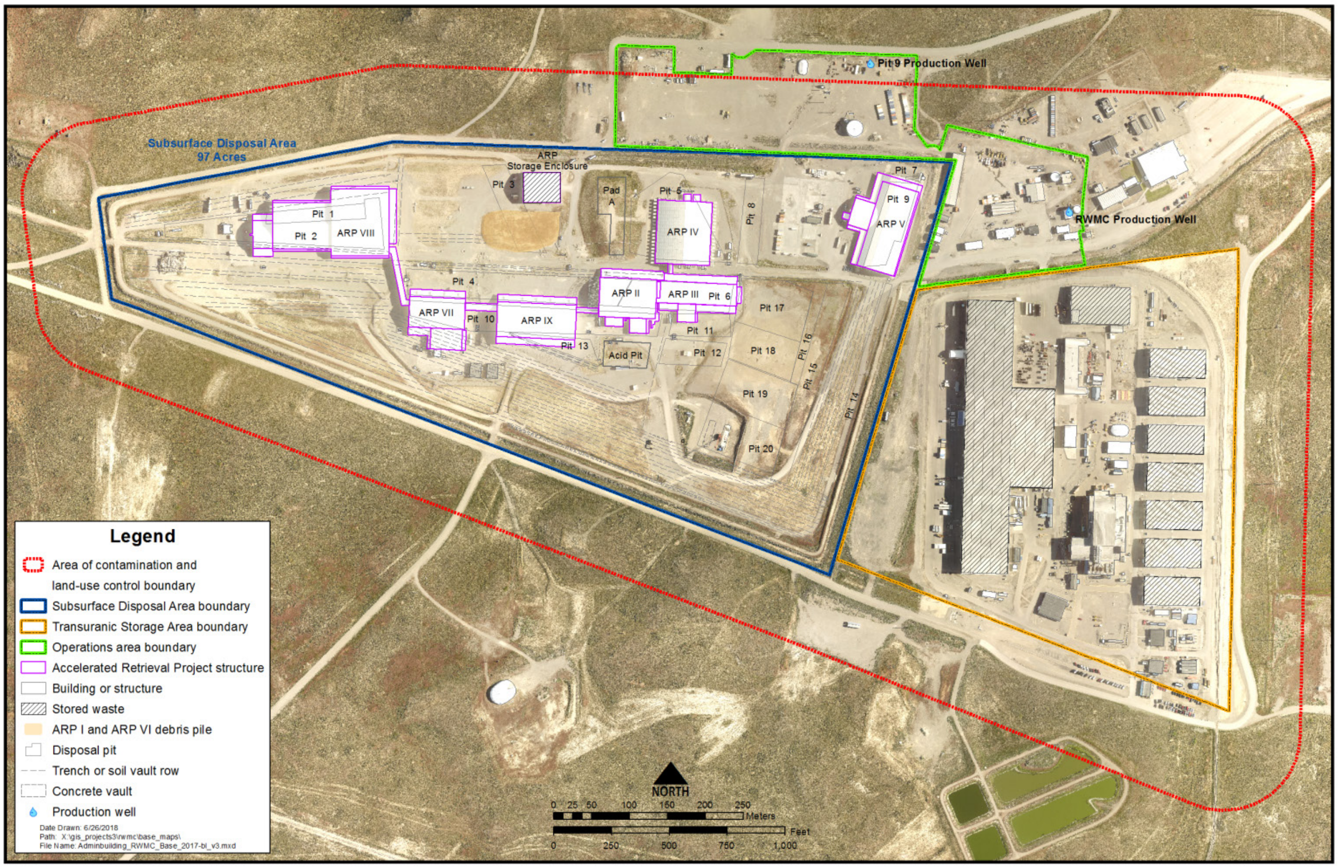


Figure 2. Radioactive Waste Management Complex facilities and disposal/storage areas.

1.2 Retrieval Projects

Between 1969 and 2004, five waste retrieval projects have been completed to date in the RWMC SDA to evaluate the condition of disposed waste containers and evaluate methods for retrieving waste. Two of the retrieval projects, the Initial Drum Retrieval (IDR) project and the Early Waste Retrieval (EWR) project, are important to this investigation.

The retrieved IDR and EWR waste was placed in retrievable storage at the TSA and subsequently became the "Pre-1980 SDA exhumed waste" inventory from which the April 11, 2018, event drum originated.

1.2.1 Initial Drum Retrieval Project

The IDR project, conducted between 1974 and 1978, was designed to demonstrate the safe retrieval, packaging, and placement of drums identified as containing TRU-contaminated waste buried between 1968 and 1970 into interim storage at the TSA. These wastes were buried in Pits 11 and 12. The disposal operation period for each pit was:

- Pit 11: Opened on April 14, 1970, and closed on October 16, 1970
- Pit 12: Opened on July 2, 1970 and closed on September 12, 1972.[2]

During the IDR project, retrieved drums were repackaged and transferred to TSA Pad R (those containing TRU waste) or Pad A (those containing Series-745 salt) at the SDA.[3] No cardboard or wood boxes were retrieved due to poor condition determined during an earlier retrieval project in 1971. Each retrieved drum was evaluated for integrity. If a drum was breached, had external contamination, or was leaking free liquids, the drum was wrapped in plastic (after all liquid had been drained from the drum, if necessary) and placed into an M-III bin. All other TRU drums were placed into 83-gal over pack drums at the beginning of the project or cargo containers later in the project. Prior to over pack into 83-gal drums, retrieved 55-gal drums were triple-bagged in plastic, taped, and placed into the over pack drum, with approximately 50 lb. of absorbent material between the second and third bags and absorbent material between the outer bag and over pack drum.[3]

A total of approximately 20,262 drums were retrieved of which approximately 18,029 drums were placed in aboveground storage at the TSA.[4,6] Some retrieved drums were over packed into new 83-gal drums for storage, and others were placed into M-III bins or into cargo containers. Some waste was packaged into DOT 19A boxes. It was reported that 91.5% of the drums had good integrity and were intact.

Figure 3. Initial Drum Retrieval Project.

1.2.2 Early Waste Retrieval Project

The EWR project, beginning in May 1976 and ending September 1978, investigated methods, risks, and hazards associated with retrieval of TRU-contaminated waste buried in the SDA.[5] The EWR project retrieved waste from the following pit and trench locations and operational timeframes[2]:

- Pit 1: Opened on November 1, 1957, and closed on October 1, 1959
- Pit 2: Opened on October 1, 1959, and closed on July 1, 1963
- Trench 1: Opened on July 8, 1952, and closed October 01, 1954
- Trench 5: Opened on November 4, 1955, and closed on March 29, 1956
- Trench 7: Opened on August 14, 1956, and closed on December 20, 1956
- Trench 8: Opened on December 13, 1956, and closed on May 7, 1957
- Trench 9: Opened on January 17, 1957, and closed on September 6, 1957
- Trench 10: Opened on July 19, 1957, and closed on February 7, 1958.

Figure 4. EWR retrieval activities.

A total of 170.6 m^3 of retrieved waste drums, loose waste, contaminated soil, and self-generated waste from the retrieval operations was packaged and placed in storage. Retrieved drums were placed into plastic bags and taped shut. Breached 55-gal drums were over packed into 83-gal drums; all loose waste and newly-generated waste was placed into plastic bags and taped shut, mechanically compacted, and placed into 55-gal drums; contaminated soil was also placed into plastic bags, taped shut, and placed into 55-gal drums. A Tri-Wall cardboard box was used to contain waste drums with poor integrity and contaminated soil. A total of 306 drums were retrieved, with 205 being severely breached. Retrieval included loose waste and contaminated soil. None of the drums retrieved were specifically identified (for example, drum barcode or container number), but the project targeted the oldest of the buried waste, so drums and any labels present were in poor condition. Most waste was repackaged into new drums. All drums and/or Tri-Wall containers were placed in DOT-7A M-III metal bins and then transferred to the TSA-retrieved pad for storage.[2,5]

1.3 Waste Generation and Description

The Rocky Flats Plant (RFP) is the primary source of waste contained in the pre-1980 SDA exhumed waste inventory, originating from the IDR and EWR projects, which are the subject of this investigation. Smaller amounts of waste were generated from on-Site INL facilities, off-Site waste facilities shipping directly to the SDA for disposal, and other generators that transshipped their waste through RFP for disposal at the SDA. A brief synopsis is provided for these generators. More detail can be found in the referenced reports.

1.3.1 Rocky Flats Plant

The RFP was located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver. The 6,550-acre government-owned and contractor-operated facility was part of the nationwide nuclear weapons production complex. Groundbreaking for the first permanent buildings for the plant began in 1951. By 1954, approximately 700,000 square feet of building space had been completed. As the plant operations expanded, as much as 1.6 million square feet were occupied by manufacturing, chemical processing, plutonium recovery, and waste treatment operations. The plant had two primary missions during the period of operations from 1952 through 1990: the production of triggers for nuclear weapons and the processing of retired weapons for plutonium recovery. Weapons parts were manufactured from plutonium, uranium, beryllium, stainless steel, and various other metals. In general, the plant's primary mission changed little from 1952 until 1990, when plutonium operations were suspended.[7]

Waste materials contaminated with TRU radionuclides were generated during the fabrication, assembly, and processing of nuclear weapons components in the DOE weapons production complex. TRU wastes generated at RFP were primarily associated with operations that manufactured, recovered, and treated plutonium metal, plutonium-containing materials, and other radioactive and nonradioactive weapons components. Materials used included plutonium, uranium, beryllium, aluminum, and stainless steel. Other metals such as cadmium, vanadium, silver, and gold were also used. In addition, TRU waste was generated during activities that supported plutonium production, including maintenance, laboratory, and R&D operations. Nonroutine events, including renovations, spills, fires, and decommissioning, also generated TRU waste. Although plutonium-related operations generated the majority of radioactive waste shipped to the SDA, other nonplutonium operations (such as fabrication of depleted uranium, beryllium, and enriched uranium weapon components) were conducted. These operations accounted for approximately 22% of the total RFP containers sent to the SDA for disposal.[3,7]

A variety of wastes were generated by plutonium and nonplutonium operations and disposed in the SDA. These wastes were typically categorized by RFP as follows[3]:

- Type I—Combustibles for example, paper, rags, and wood), also defined as housekeeping wastes in some documents
- Type II—Filter paper, including fiber/fibrous pads (containing asbestos), and non-HEPA filters
- Type III—Filters and filter media, defined as including Chemical Warfare Service (CWS) and HEPA filters from gloveboxes and building ventilation systems. "CWS filters" refers to the brand Chemical Warfare Service filters that were used in building ventilation systems

- Type IV—Inorganic sludges, primarily the series of sludges produced by the Liquid Waste Treatment Plant (Building 774)
- Type V—Noncombustibles, such as glass, scrap metal, firebrick, spent equipment, wire, electric motors, piping, sheet metal, glovebox material, and tantalum molds
- Type VI—Contaminated organics (55-gal oil drums)
- Type VII—A code established by INL[3] to identify beryllium-contaminated debris based on review of shipping records from RFP.

In summary, the generation location of RFP waste containers disposed in the SDA was:

- 25%—Building 774 inorganic and organic sludge, and special setups (cemented waste form)
- 53%—from plutonium Areas
- 22%—from nonplutonium areas
- More detail concerning the RFP waste can be found in References 3, 4, and 7.

1.3.2 Off-Site Waste Transshipped by RFP

In June 1957, the RFP was granted permission by the Rocky Flats Atomic Energy Commission office, now the Department of Energy, to accept waste from off-Site generators and then ship this waste to INL for disposal in the SDA. From 1957 through 1970, the following off-Site waste was included in RFP waste:

- Bureau of Reclamation
- Coors Porcelain Company
- University of Colorado Medical Center
- U.S. Department of the Interior
- Dow Construction
- Denver Research Institute
- GE Sandia
- Lowry Air Force Base
- Lawrence Radiation Lab
- Martin Aircraft
- Colorado School of Mines
- Sundstrand Manufacturing
- The Oil Shale Corporation
- U.S. Food and Drug Administration
- US Geological Survey
- Veterans Administration Hospital.

These generators provided a small contribution to the overall RFP waste disposed in the SDA. More detailed information is contained in References 3 and 4.

1.3.3 Non-INL Off-Site Generated Waste

During the period of 1960 through 1963, the Atomic Energy Commission (AEC) authorized disposal of waste generated by non-INL off-Site generators at the SDA. Two additional shipments were received in 1967 and 1969. Over 40 non-INL generators sent waste to the SDA. The largest non-INL generators, accounting for approximately 90% of the total non-INL volume, were:

- Lawrence Radiation Laboratory
- Rockwell International-Atomics International Division
- Nuclear Regulatory Commission-Region V
- General Atomic Company.

The non-INL off-Site waste received during 1960 through1963 was intermixed with INL Site and RFP waste in Pits 2, 3, and 4. The EWR project retrieved waste from Pit 2. More detailed information concerning the non-INL off-Site generators is available in several reference reports.[4,8]

1.3.4 INL-Generated Waste

Primary generators of INL-generated waste disposed at the SDA include:

- Idaho Chemical Processing Plant (ICPP), now the Idaho Nuclear Technology and Engineering Center (INTEC)
- Naval Reactors Facility (NRF)
- Test Area North (TAN) and now the Advanced Test Reactor Complex
- Test Reactor Area (TRA)
- Argonne National Laboratory-West (ANL-W) and now the Materials and Fuels Complex (MFC).

These generators are estimated to have generated about 90% of the volume of INL generated waste disposed in the SDA. About 10% of the total INL-generated volume came from:

- INL decontamination and decommissioning projects
- Auxiliary Reactor Area
- Central Facilities Area
- Power Burst Facility
- RWMC.

More detailed information concerning the INL generators is available in several referenced reports.[4,8] For EWR, there is no information available regarding the presence of INL-generated waste in the retrieved waste due to the degraded condition of the containers. For the IDR project, a very limited amount of INL-generated waste was disposed in Pits 11 and 12. The INL-generated waste contribution is approximately 19 55-gal drums and one dumpster load. Generating facilities included the ICPP, NRF, TRA, and CFA (determined to actually be RFP fire waste) based on information in the WILD database.[9]

1.4 Management of Pre-1980 SDA Exhumed Waste

Wastes generated from the IDR and EWR projects, excluding RFP evaporator salts sent to the SDA disposal location, were placed in aboveground storage at the TSA on asphalt pads. Storage locations included the TSA-1 pad, TSA-2 pad, and TSA-Retrieved pad. Storage was initially uncovered, but as the individual storage cell on the pads filled, they were covered with wood, plastic, geofabric, and soil. The TSA-R was eventually covered with a geofabric material. The TSA-Retrieval Enclosure (TSA-RE) was constructed in the 1990's. The TSA-RE effectively enclosed the earthen covered storage cells on Pads 1 and 2, and waste containers that had not been covered on TSA-2, and the TSA-R pad.

In 2003, retrieval operations in TSA-RE began. Operations were limited to removing the soil overburden, and unstacking drums and covered boxes. In 2009, recovery of IDR and EWR containers from the storage cargo containers and bins was initiated. The process for recovery and unpacking IDR and EWR waste containers from cargo containers and bins included:

- Open over pack box in controlled conditions
- Remove one drum at a time
- Assign a container ID
- Record historical information, if available, in the Waste Tracking System (WTS)
- Overpack degraded containers as necessary
- Send the drum for venting, nondestructive assay (NDA) and real time radiography (RTR)
- Store in an enclosed building pending validation of characterization data and remediation or disposal.

The assignment of IDCs to the pre-1980 SDA exhumed waste inventory has evolved over the years. When historic information was available, this information was linked with the container ID in WTS and the unpacked container would be associated with a generator, generation process, generator assigned waste form, etc. This information was used to assign an item description code (IDC) to the container linking the waste to its historic lineage, and the waste form was then confirmed during characterization.

However, if historical information was not available, the containers unpacked from cargos and bins would be temporarily assigned an IDC of SD-179 (Pre-1980 INL-Exhumed SDA Waste Retrieval Containers). This IDC allowed the container to be tracked to storage and tracked through the characterization process. During characterization, the waste form would be determined and an IDC of SD-176 (Pre-1980 INL-Exhumed SDA Homogeneous Solids), SD-177 (Pre-1980 INL-Exhumed SDA Heterogeneous Debris), or SD-178 (Pre-1980 INL-Exhumed SDA Soil) would then be assigned with AK concurrence.

It is important to note that assignment of SD-176 was not intended to meet WIPP characterization requirements for generator process and chemical compatibility. These items were planned to be addressed at some point in the future. The delineation of waste streams is identified in RPT-TRUW-12, "AMWTP Waste Stream Designations."[10,14]

Following IDC assignment, containers of SD-176 homogeneous solids identified for potential Sludge Repackaging Project (SRP) processing undergo review and screening. Processing SD-176 at SRP was not initiated until March 2016. Prior to assignment, SRP processed only IDCs from previously characterized and accepted by WIPP as an approved waste stream. Subsequent campaigns were approved for known IDCs using historical knowledge of the waste forms and generating processes through the acceptable knowledge process. AK review is performed for appropriate IDC assignment and review of historical information, if available. NDA SME review is performed for potential pyrophoric (roaster oxide or high U-238), nitrate salt, and fissile gram equivalent (FGE) assignment. RTR information, including recordings if necessary, is reviewed. Site project manager (SPM) review of Nonconformance Reports (NCRs) and other information (RTR SME review, weights, inner container information, etc.) are performed.

Acceptance of SRP SD-176 homogeneous solids for processing at SRP is controlled by several key documents including:

- Resource Conservation and Recovery ACT (RCRA) permits:
  - AMWTP HWMA/RCRA Permit: Section C (Waste Characteristics) of the AMWTP Final Partial Permit describes the overall waste characteristics of the mixed waste (MW) stored at AMWTP. EPA Hazardous Waste Numbers (HWNs) have been assigned based on RPT-TRUW-12, "Advanced Mixed Waste Treatment Project Waste Stream Designations." RPT-TRUW-12, Appendix A, summarizes available acceptable knowledge (AK) associated with hazardous waste constituents for transuranic (TRU) item description codes (IDCs)
  - ARP V activities included in HWMA Storage and Treatment Permit for the Idaho Nuclear Technology and Engineering Center and the Radioactive Waste Management Complex: Section C (Waste Characteristics) of the RWMC/HWMA/RCRA Partial Permit describes the overall waste characteristics of the MW stored and treated at the WMF-1617 (ARP V) facility. The waste to be accepted from AMWTP has been previously characterized in RPT-TRUW-05, "Waste Matrix Code Reference Manual," and RPT-TRUW-12. Only MW with HWNs listed in RWMC/HWMA/RCRA Permit is accepted for storage and treatment at WMF-1617 (ARP V).
- Safety analysis report for the Radioactive Waste Management Complex-Accelerated Retrieval Project (SAR-4): this document addresses the SRP project at ARP V (WMF-1617).
- Technical procedure TPR-7601, "RWMC Waste Handling and Overpacking": this procedure contains waste acceptance criteria for SRP waste received from AMWTP. Key criteria include:
  - Container configuration
  - Venting requirements
  - Prohibited item restrictions including "potential pyrophorics" or waste containing suspect depleted uranium roaster oxides"
  - RCRA code restrictions
  - List of approved IDCs.

Following these reviews, containers requiring SRP remediation that are deemed acceptable are approved for this processing. Containers that are unacceptable for SRP processing are rejected. Rejected containers may undergo additional review, may require IDC change, may require additional processing, etc.

Containers approved for SRP processing are then sent over for remediation on approved shipments or loads. Each campaign is limited to waste of the same IDC, with the exception of waste having IDCs RF-001, RF-002, RF-741, RF-742, RF-003, and RF743. SRP limits requires processing to one unique IDC, with the exception of those listed above, and processing of these can be mixed together. Prior to processing a new IDC, all waste from the previous IDC is removed from the sorting table and trays to minimize cross contamination between IDCs.[10] SD-176 was considered a one unique IDC. Once an SRP SD-176 container is processed at ARP V, IDC CW-216 (Sludge Repack Project PCB Contaminated Inorganic Sludge) is assigned to the new drum.

1.5 SRP Processing at ARP V

The Accelerated Retrieval Project (ARP) was established to support environmental restoration of the RWMC under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Specifically, targeted waste retrievals are performed as selected as one of the remedial actions performed for RWMC Operable Unit 7-13/14. Targeted waste retrievals are focused on removal of specific waste forms that are highly contaminated with solvents, transuranics, and uranium. These waste forms generated by RFP are inorganic sludge (Series 741, Series 742), organic sludge (Series 743), graphite, filters, and roaster oxides. Removal of other mutually agreed-to wastes can be agreed upon between regulatory agencies. A total of eight ARP retrieval facilities have been completed with remediation activities completed in seven of the retrieval facilities. Reuse of two ARP facilities has been implemented to support treatment of TRU waste from AMWTP.

The ARP V facility was associated with retrieval of RFP targeted waste forms from Pit 9. ARP V consists of the Retrieval Enclosure (RE), which is a tension membrane building erected over a specified exhumation area. The RE provides for contamination control and weather protection. ARP V includes an air lock that contains both the drum packaging stations (DPSs) and equipment service facilities. Equipment including an excavator and telehandlers are used to excavate, vent drums, open drums, and remove waste from drums. The telehandler is used to move waste from the retrieval zone or sorting table to the DPS.[11] The DPS provides a work area to examine the waste, remediate prohibited items, and repackage the waste into new drums. Retrieval of targeted waste from ARP V was completed in late 2011**.**

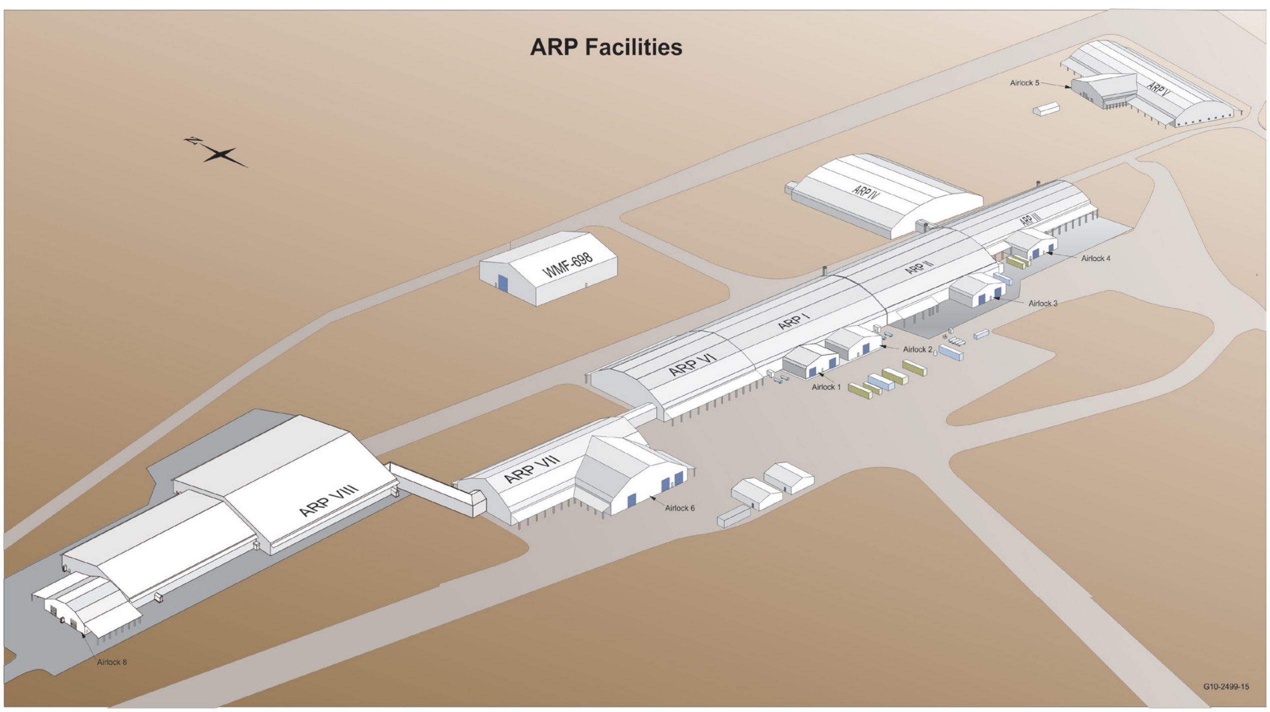


Figure 5. Accelerated Retrieval Projects I through VIII retrieval structures.

Figure 6. Drum packaging station.

In 2012, the ARP V facility was RCRA permitted for an additional mission to process RCRA waste stored above ground from the Advanced Mixed Waste Treatment Facility.

The processing of SRP containers at ARP V includes unloading containers from the transport and staging for entry into the airlock. From the airlock, containers are taken into the retrieval enclosure and opened by the excavator. The waste is emptied onto a sorting table. SRP is limited to processing two drums within the same IDC campaign on the sorting table at a time. It is important to understand that one parent input container of waste can be in several waste trays and eventual daughter containers based on the mixing of parent containers on the sorting table. There is no cleanout on the sorting table between each drum, only between IDC campaigns. There is no RCRA cradle-to-grave traceability documentation of which parent container(s) went into which daughter output containers; however, there is communication of cleanouts between campaigns via verbal, e-mail, and/or written notification on FRM-1421, “RCRA Waste Verification.” Activities performed at the sorting table to remediate a noncompliant container include segregation/sorting of WIPP-prohibited items (such as free liquids, inner containers with or without liquid, and unvented aerosol cans) or other packaging issues (such as high FGE). When free liquids are present, Oil-Dri Premium Absorbent is added as needed, and mixed into the waste on the sorting table to absorb any free liquids. Inner containers with or without liquid are opened using the excavator bucket. If liquids are present, Oil-Dri Premium Absorbent is used to absorb the liquid. Only one inner container of liquid is processed at a time on the sorting table and only one processed inner container of absorbed liquid per waste tray. Unvented aerosol cans are removed from the waste and transported back to AMWTP for future disposition. High FGE containers are divided among multiple waste trays to ensure a shippable container. During processing, the waste in the sorting table is monitored using a thermal imaging camera. The waste is not removed from the sorting table if the temperature exceeds 125°F following liquid absorption or container venting. Once processing is complete, the waste is scraped into a lined waste tray for transfer to a DPS. RCRA empty containers are compacted to facilitate off-Site waste disposition of the secondary waste.[10,13]

Figure 7. DPS visual examination.

The DPS units are Lexan-covered glovebox-like units used for contamination control to support waste examination. The DPS units are open to the ARP V retrieval enclosure on one end. A waste tray from the sorting table is placed on a trolley at this open end and moved into position for examination. DPS operations personnel access the waste through glovebox ports and rake through the waste verifying no WIPP-prohibited items (such as liquids) are present and no prohibited items or noncompliant conditions exist with the waste. Inner containers with liquids are not opened or deliberately mixed in the DPS. If an inner container with liquid is encountered in the DPS units, the waste tray is returned to the sorting table for mitigation. Free liquids identified in the waste are absorbed with Oil-Dri Premium Absorbent. Prohibited items that cannot be treated (for example, nonvented aerosol cans) but are identified in the waste are segregated from the waste stream and returned to AMWTP. Visual examination personnel oversee DPS activities. The visual examination technique in TPR-7997, "Visual Examination Activities at RWMC," is used to confirm the waste stream description absence of WIPP-prohibited items, and estimate waste material parameter weights. The visual examination events are recorded in WTS and are assigned to the new drum container ID. Once processing is complete, the DPS operators load the waste into a new 55-gal drum. Secondary waste that has come in contact with the waste material (for example, small quantities of sludge contaminated debris such as the tray liners, plastic sheeting, rubber bands, glovebox gloves, HEPA filters, and metal tools from repackaging operations) may also be added to the waste stream. The vented bag lining the waste drum is sealed, and the vented drum lid installed. Following visual examination, the drums are moved to WMF-610 to undergo NDA and are then staged for future processing or disposal.[10,11,12,13]

Since October 2015, the SRP daughter output containers are assigned a temporary IDC of CW-216 and the location of the CW-216 containers is tracked in IWTS (when located at ARP) and WTS (when transferred to AMWTP). No IDC CW-216 drums have been certified to ship to WIPP. IDC CW-216 waste will be evaluated in the future to determine whether sufficient information is available to prepare a WIPP waste stream to meet the WIPP waste acceptance criteria (WAC) and WIPP Waste Analysis Plan (WAP); otherwise, additional investigations will be conducted.

2. CAUSE ANALYSIS TEAM

The Root Cause Team was made up of a "core team" (highlighted in blue) and numerous individuals who supported the analysis (not highlighted).

Area	Team Member	Organization/Company
Responsible manager/team leader	Gene Balsmeier/Joe Giebel	Fluor Idaho
Assistant team lead	Pat Perry	Fluor Idaho
Reentry/facility recovery	Jason Chapple	Fluor Idaho
WIPP/extent of condition Lead	John McCoy	Fluor Idaho
Nuclear Safety	Scott Perry	Fluor Idaho
Technical support team lead	Joe Giebel/Bill Reed	Fluor Idaho
Root cause analysis core team member	Lee Fife	Fluor Idaho
Root cause team training support	Cindy McCormick	Fluor Idaho
Root cause analyst core team lead	Steve Crowe	TFE Inc.
Root cause analysis core team member	Mike Fecht	TFE Inc.
Root cause team / root cause specialist	Richard Swanson	PMI-Inc.
Nuclear safety culture expert	Mike Coyle	TFE Inc.
Root cause analysis core team RCRA specialist	Ron Guymon	Northwind
Root cause analysis core team TRUW specialist	Tom Clements	JFoster & Associates

3. CAUSE ANALYSIS

The number of programmatic issues resulting from the April 11, 2018, drum event indicated to the Root Cause Team that the event and causal factor charting methodology along with barrier and change/comparative timeline analysis, consistent with the requirements of DOE O 225. 1B, “Accident Investigations,” would be appropriate. Therefore, the Root Cause Team conducted an analysis of the events and developed a detailed event and casual factor (E&CF) chart and timeline to document and analyze the conditions and behaviors. Techniques similar to those described in DOE Guide 231.1-2, “Occurrence Reporting Causal Analysis Guide,” were used to organize and analyze the data so that conclusions could be drawn regarding overarching program problems.

3.1 Methodology

The assigned Root Cause Team focused on determining the factors resulting in the current drum event, by examining documents, interviewing individuals, identifying key evidence elements, and understanding how those elements resulted in the event. The Root Cause Team has a multi-disciplinary Fluor Idaho team, including several outside consultants with extensive root cause experience. A detailed plan is included in Appendix M.

3.2 Problem Statement

At approximately 2235 on April 11, 2018, the ARP V facility, WMF-1617, experienced an over-pressure event on a repackaged sludge drum. Additionally, three other drums experienced similar over pressurizations during the night.

3.3 Lines of Inquiry

The Root Cause Team reviewed available documentation describing the current state of the project, including assessments, surveillances, external reports, and corrective action reports (CARs). The Root Cause Team then used this ‘organized evidence’ to develop potential lines of inquiry to investigate.

The Root Cause Team considered many lines of inquiry at the start of the analysis and carefully selected a set to pursue through the investigation. The lines of inquiry pursued included, but were not restricted to:

- Missed opportunities to have prevented or mitigated the situation
- Failed, missing, and ineffective barriers that could have protected against threats
- Earlier indications of emerging issues
- Application of corrective action programs (self-identification, reporting, and resolution of issues)
- Causal factors
- Roles and responsibilities
- Training
- Conditions that shaped behaviors.

3.4 Comparative Timeline/Change Analysis

The comparative timeline is an enhanced variation of the usual timeline chronology frequently used in significant event analysis. The comparative timeline included: what happened, what should have happened, significance, failed or ineffective barriers, why the barriers failed, and recommended corrective actions to restore barriers. This tool organized the event information and provided a collective source of information to identify differences between what happened and what should have happened, and to determine the significance to the organization of these differences to the organization.

The Comparative Timeline catalogues the behaviors and condition that shaped the event, and organizes the information for use by other tools to determine what made the project fail. The Comparative Timeline is an evolved form of a change analysis tool.

The Comparative TimeLine documented the major deviations from expected conditions and behaviors, including those shown in Appendix C, Comparative Timeline.

3.5 Event and Causal Factor Chart

The event and causal factor (E&CF) chart was used to identify the time sequence for the series of tasks and/or actions that were taken surrounding conditions leading to the project events. The results are displayed in a graphic format that provides a picture of the relationships of the conditions and behaviors, and the subsequent causal factors. A detailed E&CF chart was developed for this investigation. The chart is approximately 36 ft printed on 40-in. paper, and is available as two supporting documents on the Electronic Document Management System (EDMS) document page for this report at https://edms.inl.gov/pls/edms/toto.dmx_3?f_doc=6734674 for the time period from 2012 through April 10, 2016, and at https://edms.inl.gov/pls/edms/toto.dmx_3?f_doc=6734673 for the April 11, 2018, event day and additional key subsequent events through April 25, 2018. The Event and Causal Factors (EC&F) Summary Chart Prior to Event Day is shown in Appendix N and the EC&F Summary Chart on Event Day is shown in Appendix O.

3.5.1 Event Chronology Summary

A detailed event chronology is addressed in the Comparative Timeline and is discussed in Appendix C. The major areas that are discussed in that appendix include:

- SD-176 Preparations
- Sludge Repacking Project Begins – Pre-SD-176
- SD-176 Processing
- Processing the Six Event Parent Drums/Event Day
- Event Night.

Table 1 presents a summary chronology of the analyzed events leading up to the event and event response.

Table 1. A summary chronology of the analyzed events leading up to the event and event response.

When	SD-176 Processing Preparations
2012	DOE/ITG/CWI decide to use ARP V as the treatment facility for waste sludge
8/15/2012	IAG-592, "Roles and Responsibilities for Sludge Repackage Project Waste Transfers between ITG and CWI," Rev. 0, issued. Contained procedure like steps for compliance. Listed approved IDCs.
	IAG-592 states what IDCs can be processed from AMWTP to RWMC. Did not include SD-176 until Rev. 10.
10/18/2012	RWMC HWMA/RCRA Permit approved for treatment at WMF-1617 (ARP V).
10/18/2012	ARP V changes from a CERCLA facility to a Resource Conservation Recovery Act (RCRA) facility.
10/29/2012	TPR-7867 SRP V Waste Processing Rev 0 approved.
11/13/2012	IAS13557 Contractor Readiness Assessment for SRP conducted

When	SRP Non SD-176 Processing
11/20/2012	CWI receives authorization from DOE to begin the SRP.
11/2012	The SRP begins with RF-003/743 organic sludge.
12/2013	The SRP IDC campaign of RF-002/742 inorganic sludge begins and continues through March 2018.
02/05/2014	RPT-TRUW-91, Rev. 2, *Acceptable Knowledge Document for Pre-1980 INL Exhumed SDA Waste*, is approved.
4/2014	SRP Operations begin IDC campaigns RF-001/741, RF-002/742, RF-003/743, and RF-800.
Spring 2014	Draft request for proposal (RFP) for recompete for the Prime Contract issued RFP/RFP process involved substantial scrutiny and comments regarding schedule performance against Idaho Settlement Agreement milestones.
9/2/2014	RPT-TRUW-12, Rev. 24, *AMWTP Waste Stream Designations*, is issued to define waste streams, hazardous waste numbers (HWNs), and assignment of IDCs to WIPP-approved waste streams. Hazardous and numerous chemical constituents for SD-176 were included.
12/08/2014	RPT-TRUW-05, Rev. 37, *Waste Matrix Code Reference Manual*, includes SD-176. The SD-176 Reference Table, Special Notes, did not reflect prohibited items identified in Section 3.5.8. Section 3.5.8 references RPT-TRUW-91 but does not contain the same level of detail concerning prohibited items nor the reactive concerns identified in Section 6.5.1.3.
02/2015	DOE directs CWI to repackage an additional inventory of sludge drums. Contractor shall also prepare the ARP V sludge repackaging facility for processing IDC-002/742 (inorganic) sludge waste.

Table 1. (continued).

When	SRP Non SD-176 Processing
05/2015	ARP management requested an independent assessment of SRP because WMF-1617 had not been used for 8 months following completion of initial drum repackaging in June 2014.
6/10/2015	CWI responds to DOE and identified actions to address WIPP Phase 2 report. CWI identifies 3 "Gaps" with additional actions needed.
6/18/2015	ITG responds to DOE and identified actions to address the WIPP Phase 2 report. ITG information identified 14 actions "in progress."
9/29/2015	Contract DE-EM0001467 is issued to ITG, which includes: • Contractor shall treat waste to the most current WIPP WAC • Complete characterization for ~2,500 "unknown" containers that are currently in storage.
10/2015	DOE-EM-1 directs RCRA self-assessment to validate operating procedures that generate, package, or treat TRU waste and comply with the RCRA permits.
10/19/2015	CWI notifies DOE that the initial SRP scope is complete.
11/05/2015	DOE acknowledges SRP scope completion.
11/2015	RPT-ESH-014, Rev. 9, *Chemical Compatibility Evaluation Wastes for the Advanced Mixed Waste Treatment Project*, is issued. No chemical compatibility evaluation (CCE) is reflected for SD-176
11/05/2015	CWI RCRA self-assessment is performed.
12/02/2015	Meeting is conducted with ITG/CWI/DOE ID/CCP on chemical compatibility.
12/02/2015	A letter from ITG to DOE notifies DOE of a break in feed to SRP. (C-2015-0353).
12/10/2015	DOE directs ITG to not allow a break in feed to SRP. (AS-CMD-AMWTP/ITG-16-014)
12/17/2015	ITG responds to DOE addressing the December 10, 2015, direction. (C-2015-0385) ITG stated that ITG will continue to prioritize aboveground inventory. Secondly, ITG evaluated new IDCs to ensure IDCs can be processed beginning in January 2016.
12/21/2015	DOE responds to ITG addressing the December 17, 2015, letter. (AS-CMD-AMWTP/ITG-16-018)
12/21/2015	DOE directs ITG to issue RPT-TRUW-94, *Acceptable Knowledge Summary for AMWTP Combined Homogeneous Solids Repackage Project (BN650),* with the additional IDCs to perform visual examinations.
12/21/2015	DOE letter states that RPT-TRUW-94 cannot be used for waste certification until the Carlsbad Field Office (CBFO) provides concurrence.
12/21/2015	DOE approves that repackaging operations continue the practice of absorbing liquids.
12/21/2015	DOE acknowledges that some mixing of contents between waste containers will occur.

Table 1. (continued).

When	SRP Non SD-176 Processing
12/21/2015	DOE directs ITG to campaign waste by individual IDCs, not by groups of compatible IDCs.
12/21/2015	DOE directed that only one IDC is to be processed at a time to maintain chemical compatibility. (DOE letter AS-CMD-AMWTP/ITG-16-0 18)
12/21/2015	DOE directed that the trays and sorting table are cleaned to a deminimus level (nothing visible) between IDCs. (DOE letter AS-CMD-AMWTP/ITG-16-0 18)
01/18/2016	ITG responds to DOE addressing the December 10, 2015, direction. (C-2015-0385) ITG stated that ITG will continue to prioritize aboveground inventory. Secondly, ITG evaluated new IDCs to ensure IDCs can be processed beginning in January 2016.
01/26/2016	DOE responds to ITG addressing the December 17, 2015, letter. (AS-CMD-AMWTP/ITG-16-018)
02/02/2016	DOE directs ITG to issue RPT-TRUW-94, *Acceptable Knowledge Summary for AMWTP Combined Homogeneous Solids Repackage Project (BN650),* with the additional IDCs to perform visual examinations.
02/03/2016	DOE letter states that RPT-TRUW-94 cannot be used for waste certification until the Carlsbad Field Office (CBFO) provides concurrence.
02/9/2016	DOE approves that repackaging operations continue the practice of absorbing liquids.
02/12/2016	ITG responds to DOE addressing the December 10, 2015, direction. (C-2015-0385) ITG stated that ITG will continue to prioritize aboveground inventory. Secondly, ITG evaluated new IDCs to ensure IDCs can be processed beginning in January 2016.
03/01/2016	DOE responds to ITG addressing the December 17, 2015, letter. (AS-CMD-AMWTP/ITG-16-018)
03/01/2016	DOE directs ITG to issue RPT-TRUW-94, *Acceptable Knowledge Summary for AMWTP Combined Homogeneous Solids Repackage Project (BN650),* with the additional IDCs to perform visual examinations.

When	SRP Operations Processing SD-176
3/10/2016	The first SD-176 drum is processed in ARP V.
06/01/16	CWI and ITG transition to Fluor Idaho.
08/19/2016	The RWMC HWMA/RCRA Permit is revised to ensure the HWNs for the SRP and Debris Repackaging Project (DRP) are consistent. The following permit language was added: “Some of the waste streams have the potential to contain liquids that exhibit the characteristic of corrosivity (D002). If found, the liquids will be absorbed, and the corrosivity characteristic removed to ensure compliance with the WIPP acceptance criteria.”

Table 1. (continued).

When	SRP Operations Processing SD-176
10/18/2016	The CBFO Recertification Audit for AMWTP is performed.
12/2016	CBFO Recertification Audit for AMWTP performed.
12/1/2016	IAG-592, Rev. 10, is canceled after the Fluor Idaho transition.
01/2017	A Generator Site Technical Review (GSTR) assessment is conducted by DOE-CBFO and Nuclear Waste Partnership (NWP).
5/4/2017	TPR-8151, "TRU Programs Site Project Office Process," Rev. 0, is created to supersede AMWTP INST-TRUW-8.13.1 and implement new section for SRP container review. Section 4.11.1.5 includes the NDA expert technical reviewer (ETR) requirement to "determine nitrate salts, potential pyrophorics, or roaster oxides are NOT present."
6/8/2017	The RWMC HWMA/RCRA Permit is modified to state "waste to be accepted from AMWTP has been previously characterized in RPT-TRUW-05 and RPT-TRUW-12." The RWMC HWMA/RCRA Permit was also modified to add HWNs to be consistent with AMWTP HWMA/RCRA Permit, with the exception of D001 (ignitability).
7/2017	DOE-EM-4.21-01, *U.S. Department of Energy Implementation of Chemical Evaluation Requirements for Transuranic Waste Disposal at the Waste Isolation Pilot Plant*, is issued by LANL: • New requirements include chemical compatibility • Evaluating oxidizing chemicals in conjunction with the AK procedures • Evaluation must begin with a list of all chemicals used in the waste stream based on the AK summary report • AK assessment of container by container to determine whether waste is consistent with documentation • Basis of knowledge (BoK) evaluation provides criteria for evaluating oxidizing chemicals in TRU waste.
12/11/2017	TPR-7601, RWMC Waste Handling and Overpacking," Rev. 85, adds new note in Step 4.4.1 for WGS. Note 2 states, "Incoming SRP waste has been evaluated in accordance with the 'Chemical Compatibility Evaluation of Wastes for the Advanced Mixed Waste Treatment Project' (RPT-ESH-014)."
12/21/2017	Waste being processed through AMWTP causes a fire. High-kilogram uranium in a nonroaster oxide package experienced a pyrophoric reaction when exposed to air while being processed in the WMF-676 treatment facility north boxline.
12/21/2017	SD-176 training is approved and given at a tailgate meeting. Training was presented on a list of possible chemicals contained in the waste but no implementable actions were identified.
1/2018	Extent of condition (EOC) evaluation was completed on North Box Line Fire Event. The WTS query against all active drums onsite reported 693 with >5 kg U-238. One of those drums was the "event" drum of April 11, 2018. Because this drum was sludge, it had an IDC of SD-176 (not one of the IDCs listed in RPT-TRUW-83), it was screened out, and no further action was taken to address this problem drum.

Table 1. (continued).

When	SRP Operations Processing SD-176
1/11/2018	Contract direction is requested by Fluor Idaho for not yet implementing BoK into current processes.
3/10/2018	Contract direction is received from DOE. DOE concurs with Fluor Idaho to continue to process Idaho Settlement Agreement waste to current processes. DOE response acknowledges that Fluor Idaho has not implemented any changes to the waste procedures related to BoK. DOE acknowledges this joint decision minimizes the impacts to Idaho Settlement Agreement milestones. Fluor Idaho shall continue to process, package, characterize, and certify waste and not implement BoK pending further direction.
03/2018	The Pyrophoric Event in North Box Line report is issued.
4/2/2018	Email communications on Drum 10595963: AKE points to finely divided material (floor sweepings); generated from Building 444 (known to fabricate depleted uranium (DU), Be and other weapon parts); and NDA is indeterminate (but assay indicates 11.9 kg of DU). NDA states sludge-like; depleted uranium and not a roaster oxide.
4/3/2018	Emails reflect continued discussion about receiving Drum 10595963. Ultimately, ARP management decides to bring the drum over and ensure it comes out a sludge.
4/3/2018	Email communications are used for basis of approval to process ARP V Drum 10595963.
Event Day	
0830 04/11/2018	The prejob brief is conducted. The day's activities are addressed using MCP-3003, "Performing Pre-Job Briefings and Documenting Feedback," and Form 434.14, "Pre-Job Briefing Checklist," as guidance.
04/11/2018	IDC waste is processed including as existing backlog of trays in the morning. Operators stated they had a 32-tray backlog.
04/11/2018	Morning shift thought they saw what appeared to be salt and stopped. Called visual examiner to evaluate.
04/11/2018	Sorting table and tray handling practices as described by the operators met procedures, the hazard assessment document, and management requirements.
1355 04/11/2018	In close proximity to ARP V activities, a forklift operator drops a drum being moved from a flatbed truck. (CAR 119250)
	Management initiates a projectwide step back and evacuated the area where drum drop event occurred. The step back delayed processing drums and removing them from the ARP V facility.
Afternoon Event Day 04/11/2018	Six parent drums are processed: - 10595963 - 10293740 -10630243 - 10314818 -10630238 - 10295807

Table 1. (continued).

When	SRP Operations Processing SD-176
Event Day	
04/11/2018	Parent Drum 10595963 direct filled two daughter drums: SRP34398 SRP34402
04/11/2018	Parent Drum 10630243 direct filled two daughter drums: SRP 34384 SRP34405
04/11/2018	Parent Drum 10630238 direct filled one daughter drum and one tray: SRP 34415 Tray 299
04/11/2018	Parent Drum 10293740 direct filled two daughter drums and one tray: SRP 34418 SRP34403 Tray 268
04/11/2018	Parent Drum 10295807 direct filled three daughter drums: SRP 34417 SRP 34401 SRP 34404
04/11/2018	Parent Drum 10314818 direct filled two trays: Tray 255 Tray 280
04/11/2018	An operator identifies a liter bottle 1/3 filled with 1/3 an unknown dark liquid; in the bottle and uses waste on the sorting table to absorbs the liquid in waste on sorting table in accordance with approved operating procedures. This bottle of liquid was processed well after the event drum and did not contribute to the event. Drum 10621441
04/11/2018	Received 2 CAM alerts in Ops Room – RCT turned the CAM off.
04/11/2018	RCTs take dose reading on the trays and on the packaged waste drums. A few of the trays registered higher than normal dose rates. RCT did not have a concern because the readings were within the requirement for dose rates at the window. The RCTs did not report the dose readings to management.
Evening Event Day	
04/11/2018	After the end of day shift, ARP V is not manned and AMWTP takes over responsibility for backshift event response for ARP V.
04/11/2018	AMWTP personnel were not aware of ARP conditions, including status of repackaged drums in ARP V. AMWTP personnel did not discuss ARP status during backshift shift briefing. In interviews, AMWTP personnel stated that they are not generally aware of ARP conditions and rarely, if ever, discuss ARP status during backshift shift briefings, including on the day/night of the event.
2235 04/11/2018	CAM readings for ARP V increasing.

Table 1. (continued).

When	SRP Operations Processing SD-176
2235 04/11/2018	Fire Alarm ARP V (WMF-1617).
2235 04/11/2018	The RWMC-AMWTP plant shift manager is notified by the dispatcher that the INL Fire Department is responding to ARP.
2240 04/11/2018	Fire Department dispatches engine and ambulance.
2240 04/11/2018	Second alarm. Fire Department dispatches additional units. Indication of not entering just to investigate/expect smoke recognized by Fire Department.
2243 04/11/2018	Plant shift manager (PSM) notifies NFM of the situation.
2245 04/11/2018	Fire Department engine arrives; parks upwind; RWMC Shift Supervisor is called while on route; no additional information is available.
2247 04/11/2018	Fire Department Battalion Chief arrives and completes a 360-degree external check.
04/11/2018	The Quick Access Plan does not provide sufficient radiological data for ARP V (for example, the location of CAMs, normal derived air concentration (DAC), or the location of radiological work permit (RWP) information).
04/11/2018	The Fire Plan does not contain sufficient radiological data (for example, radiological material that could go airborne, normal DAC, or expectation to mask up).
2251 04/11/2018	The Fire Department team enters the ARP V vestibule using Procedure SOP-2.4B.1. "Structural Engine Company Operations"; smelled smoke; described as like a heavy metallic fire. The vestibule is part of ARP V and is considered a radiological area.
2252 04/11/2018	The Fire Department team reports seeing smoke through the ARP V vestibule window, reports masking up, and entering ARP V.
04/11/2018	Orders are given to hook up water to the engine to relocate rescue, hazmat, and ladder trucks to south side.
04/11/2018	The Fire Department identifies fire in a radiologically marked drum and smoke in ARP V and did not exit.
04/11/2018	The current Fire Department radiological procedure is confusing for Fire Department responsibilities.
04/11/2018	Management expectations for entering a radiological building and Fire Department procedures are not consistent when responding to a fire situation.
04/11/2018	INL Fire Department personnel stated they did not understand how the ARP V CAMs operate.
04/11/2018	The plant shift manager (PSM)/emergency action manager (EAM) arrives onsite then leaves to establish Emergency Control Center (ECC) and assume EAM responsibilities. The Fire Department is left with no Operations representative at the scene.

Table 1. (continued).

When	SRP Operations Processing SD-176
04/11/2018	The Fire Department uses a dry chemical extinguisher with no effect.
2257 04/11/2018	The entry team reports a ruptured drum; 190°F reading on the thermal imaging camera (TIC) ~one-fourth of the drum had material remaining; the white liner was still in drum; is described as “caving in.” Material is reported as looking like “boiling sand” in interview. Charcoal-looking white pockets are identified with rest of material as gray.
2300 04/11/2018	The entry team reports the temperature is increasing; applying Met-L-X to the drum.
04/11/2018	The Fire Department has some problems with the Met-L-X discharge of the extinguisher.
04/11/2018	Met-L-X is ineffective at extinguishing fire.
04/11/2018	The FD captain orders firefighters to get something to stir the material in the drum to allow Met-L-X to get to the hot spots.
04/11/2018	Attempted to pull back other material with shovel so Met-L-X could be applied on hots spots. Really fine material dust/particles pushed up obscuring vision.
04/11/2018	The Fire Department records information from stickers on the involved drum 1 mrem/h drum; 15 mrem/h on the adjacent drum; writes down numbers.
2301 04/11/2018	The Incident Commander HAZMAT Team is requested via radio.
2303 04/11/2018	The EAM requests RCT support to support the Fire Department with egress and decontamination: urgency of request was not conveyed.
2304 04/11/2018	The entry team reports Met-L-X is applied (second application).
2308 04/11/2018	The AMWTP RCT notified the Radiological Control manager (RCM) they were responding to WMF-1617.
2313 04/11/2018	The entry team reports Met-L-X is ineffective; backing out.
2314 04/11/2018	The event drum reported to be 215°F.
2315 04/11/2018	The entry team is ordered out by the forward operating officer.
04/11/2018	Smoke is reported in vestibule (not heavy).
04/11/2018	No RCT support is available at the scene, so the Fire Department prepares to survey the team out.
2316 04/11/2018	The decision to exit through airlock doors vice rollup doors is communicated.

Table 1. (continued).

When	SRP Operations Processing SD-176
2317 04/11/2018	The Fire Department moves the event drum (of radioactive material) away from the other ARP V drums. The Fire Department personnel were not prohibited by procedure from moving a radioactive material. RCT personnel were not at scene to advise Fire Department personnel.
2317 04/11/2018	Event drum temperature readings from the thermal imaging camera (TIC): • TIC 284°F prior to moving. • TIC 298°F after moving. • Particulates being discharged upward from the drum going close to the ceiling.
2318 04/11/2018	Radio discussion (firefighters) is held regarding hot spot on the bottom of the drum.
2319 04/11/2018	Communication is reported that radiological contamination and Be contamination are expected.
2320 04/11/2018	The ECC and Emergency Operations Center (EOC) are activated as a conservative measure.
2322 04/11/2018	AMWTP RCTs report they were a couple of minutes out. The incident commander (IC) decides to wait for the AMWTP RCT to survey Fire Department personnel out of the ARP V vestibule.
2323 04/11/2018	Two firefighters walk into vestibule in full gear to attempt to pass drum information along.
2323 04/11/2018	Communications are difficult so a gas meter is used as a probe to get attention of people outside ARP V. Outside could not see information being held up to the window because of reflection, so a hand opened the door and extended into the vestibule.
2328 04/11/2018	The entry team communicates the drum is still venting; Metal-X did not work.
2330 04/11/2018	The entry team look at radiation instrument; reported no alpha, 61 beta.
2331 04/11/2018	Firefighter electronic dosimeter reading is reported as 0.2 mR.
2333 04/11/2018	Ventilation stated as confirmed over radio.
2336 04/11/2018	Firefighters silence fire alarm; no other alarms are sounding.
2346 04/11/2018	The Radiological Control (RadCon) team arrives on scene 43 minutes after the EAM request.
04/11/2018	An RCT enters in a powered air-purifying respirator (PAPR).

Table 1. (continued).

When	SRP Operations Processing SD-176
04/11/2018	The RCT stated in an interview that there was some smoke in the vestibule.
2347 04/11/2018	The self-contained breathing apparatus (SCBA) vibration alerts from low air in the bottle; made communications difficult. Low pressure in SCBA tanks; increased urgency to exit. The RCT directed firefighters to exit.
2347 04/11/2018	Firefighter bunker gear is doffed excluding SCBAs near the inner vestibule door inside airlock.
2347 04/11/2018	Firefighter personnel anti-contamination clothes are doffed inside vestibule.
2355 04/11/2018	First firefighter exits; contamination surveying is in progress.
0000 4/12/2018	Second firefighter exits; contamination survey is in progress.
0005 4/12/2018	Third firefighter exits; contamination survey is in progress.
0005 04/12/2018	All firefighters are out 48 minutes after being directed to back out.
0024 04/12/2018	The second drum breaches; EOC is notified via radio by IC.
0024 04/12/2018	On scene personnel are ordered to leave; “worry about contamination later.”
0025 04/12/2018	The IC orders personnel to evacuate the area to a distance of 100 m per ERG Guide 111.
0026 04/12/2018	The IC evaluates the ARP V structure finding no exterior problems.
04/12/2018	The potential for interior damage to ARP could not be assessed by the exterior evaluation.
0028 04/12/2018	The entry team members are surveyed by RCTs, are found to be contaminated, and loaded up for transport.
0030 04/12/2018	The RWMC-ARP shift operations manager (SOM) and ARP RCT supervisor arrive onsite.
02110 4/12/2018	The ARS arrives at EOC for 100-m planning/air samples.
0245 04/12/2018	The ARS goes to Trailer 23 and EAM declares ERO operational. The EAM did not formally declare “Alert.”
0320 04/12/2018	Personnel in the area of ARP V hear another loud bang.
0503 04/12/2018	No contamination found in the 100-m area.

Table 1. (continued).

When	SRP Operations Processing SD-176
0857 04/12/2018	The RCT identifies that no radiological or volatile organics are around the exterior of the building.
1001 4/12/2018	The Fire Department releases the facility back to Operations.
1035 4/12/2018	The scene is preserved and the ECC is secured.
4/25/2018	A potentially inadequate safety analysis (PISA) is declared positive.

3.6 Causal Factor Discussion/Prior to the Event Day Results (2012 to April 10, 2018)

3.6.1 Discussion of Direct Cause (DC)

DC: Based on available sample results, the Root Cause Team identified the direct cause of this event as the breach of four transuranic (TRU) waste containers in the ARP V building resulting from the mixing of waste containing reactive uranium from Container #10595963 with additional parent drum material in the repackaging process. The uranium initiated an exothermic reaction that ultimately led to an over pressurization and subsequent expulsion of material from four containers. The initiating mechanism (heat source) based on sample results was oxidation of the uranium metal which then supported secondary chemical reactions. The breaches resulted in airborne radioactivity escaping to a filtered, uncontaminated area normally occupied by workers. The direct cause will be revised as necessary when additional sample results are available and upon analysis by the Technical Team.

3.6.2 Discussion of Root Causes (RCs)

RC-1: Management failed to fully understand, characterize, establish and implement adequate process controls for treating waste which lacked documented origin or process information.

During the investigation, the Root Cause Team identified that RWMC did not have an overall plan or process developed that would provide an approved path to disposal, as described in DOE O 435.1 for SD-176 drums. Drums were to be brought into ARP V, processed on the sorting table, placed into trays which were taken to the DPS for visual examination and then packaged into drums compliant with WIPP requirements. The process that was identified for controlling IDCs to be introduced to ARP V was the Tenant Use Agreement process. This process led to the development of IAG-592, which was originally developed to include roles and responsibilities for both ITG and CWI ARP V personnel. The IAG described the processes for what and how waste would be transferred between AMWTP and ARP V, including specific requirements. The investigation identified that the IAG process was not the appropriate location for these operational controls at a Hazard Category II nuclear facility (see CC-8). Use of the IAG as the governing document resulting in the USQ process not being appropriately applied when the IAG was revised to include SD-176 since IAG are categorically excluded from review by the USQ process. No new hazards were identified and the existing SRP operational and safety procedures were not evaluated or revised.

As the investigation progressed, the Root Cause Team identified weaknesses in knowledge of the waste being processed. Specifically, there were managers and personnel who did not know that SD-176 was different than other IDCs that had been processed through the SRP. They did not know that SD-176 was a waste that had included a composite collection of containers from various generators. When the SRP changed to processing SD-176, the change was made without recognition that the facility was transitioning from processing well characterized, relatively homogeneous IDCs to a less well characterized waste from undocumented generators and processes with a variety of potential chemicals. The previous success that the project had with safely processing ~ 9,000 drums led to a belief that any issues would be seen immediately as the waste was mixed on the sorting table. Additionally, previous experience with SRP sludge repackaging of waste containing uranium had been successfully completed with no pyrophoric or reactive issues.

Neither ITG nor CWI management identified the need to implement a change-management process that would have helped to identify concerns with implementing the RCRA requirements, protect personnel from the potential of additional hazards, potential DSA/SAR compliance issues, and to help both ITG and CWI personnel fully understand the difference in the waste that was to be processed. A chemical compatibility analysis was not performed and the need for it was dispositioned by processing only one IDC at a time. SD-176 was treated as single IDC which allowed mixing of multiple drums on the sorting table.

The event investigation team evaluated what risks had been taken into account for processing an unknown waste. The Root Cause Team found that, at the inception of SD-176 and having two independent contractors being involved, there was a lack of communication regarding the attributes of the waste. At the fact finding for this drum event, ARP V management and Nuclear Safety personnel were "surprised" when the TRUW programs stated that SD-176 was being processed as an unknown waste. The assumption by operations personnel was that once assigned an IDC, all waste with that IDC would be compatible. The ARP V operations group expressed in interviews their belief that when they were done treating SD-176, those drums would be ready to be shipped to WIPP. When the Root Cause Team interviewed the TRUW program about shipping to WIPP, they stated that the drums would be processed at ARP V and then returned to AMWTP for further characterization. Communication between organizations and established processes were not effectively developed or implemented to ensure both organizations understood the basis of processing SD-176.

Almost all individuals did not understand the existence of potentially pyrophoric material in waste. When asked, what are pyrophoric/ materials they immediately stated "roaster oxides." They had no knowledge of any other pyrophoric material. When pyrophoric material was discussed, personnel only acknowledged "roaster oxides" as potentially pyrophoric material. During an interview with one NDA person, the individual did not know his procedure required him to evaluate waste by looking for salts, roaster oxides, and other pyrophoric material. He had not been looking for other pyrophoric material. He stated he needed "criteria" to look for pyrophoric material. One individual from AMWTP stated that if the waste had an IDC it could not have pyrophoric material in the waste. While evidence of other than roaster oxide pyrophoric uranium bearing waste was contained in source reference documents, no description of any source of these materials was included in the acceptable knowledge (AK) document, RPT-TRUW-94 (DRAFT) that formed the basis for this project, which contributed to this lack of knowledge.

The Team evaluated requirements for prohibiting pyrophoric radionuclides in ARP V. Besides procedural requirements, the RWMC HWMA/RCRA Permit was evaluated.

The RWMC HWMA/RCRA Permit specifically includes the following Permit Condition VI.C.1:

> *"The Permittee shall not perform treatment of waste containing pyrophoric radionuclides at the RWMC."*

The Team determined the direct cause of this event as the breach of four transuranic (TRU) waste containers in the ARP V building resulted from the mixing of waste containing reactive uranium from container #10595963 with additional parent drum material in the repackaging process. The uranium initiated an exothermic reaction that ultimately led to an over pressurization and subsequent expulsion of material from four containers. The initiating mechanism (heat source), based on sample results, was oxidation of the uranium metal which then supported secondary chemical reactions.

The RWMC HWMA/RCRA Permit also requires incompatible waste or materials that are incompatible shall not be placed in the same treatment container (Permit Condition VI.D.1). The RWMC HWMA/RCRA Permit also establishes requirements for ignitable, reactive, and incompatible wastes (Section F-5a), as follows:

> *"The waste streams to be stored and treated within WMF-698, WMF-1617 and WMF-1619 have completed characterization as detailed in the characterization reports in Attachment 2. The waste streams to be stored and treated were also evaluated in accordance with the "Chemical Compatibility Evaluation of Wastes for the Advanced Mixed Waste Treatment Project (RPT-ESH-014). No issues of ignitability or reactivity have been identified."*

The Root Cause Team determined that a chemical compatibility evaluation had not been documented for SD-176 in RPT-ESH-014.

The Team also reviewed various definitions for pyrophoric material. The DOE WIPP WAC identified pyrophoric material as "Materials that may ignite spontaneously in air or that emit sparks when scratched or struck, especially with materials such as steel. A flammable solid that, under transport conditions, might cause fires through friction or retained heat or that can be ignited readily and, when ignited, burns vigorously and persistently so as to create a serious transportation hazard. Included in the pyrophoric definition are spontaneously combustible materials, water reactive materials, and oxidizers. Examples of nonradioactive pyrophoric are organic peroxides, sodium metal, and chlorates." The Team evaluated existing procedures and reports for a definition of Pyrophoric. PLN-5198, *AMWTP CH TRU Waste Certification Plan* states the same definition as the WIPP WAC. The Team could not find any other definitions of pyrophoric in project procedures or reports.

The Team was provided a definition from the Technical Team used in the evaluation of the event. Each of the various definitions is included in the definition section of this event. The Team also reviewed the information that was assembled for the "sparking" event that occurred during the cleanup. During the initial cleanup operations, personnel noticed that large particles produced sparks when moved across the floor. Assuming that the sparking was caused by uranium, the project collected a sample of the debris on the ARP V floor and assayed via gram estimation. Follow-on analysis by the Technical Team discounts the material as pyrophoric and will be confirmed in their report.

The Root Cause Team identified that Management was focused on production and milestone completion at the expense of procedural adherence and ensuring a questioning attitude. The team identified two separate examples where contractors asked for and received relief from requirements to minimize impacts on project milestones (specifically, the contract and Idaho Settlement Agreement). The examples included:

1. In December 2015, in order to keep feed going to ARP V, the contractor asked DOE for accommodations to keep feed going to ARP V. ITG stated they had insufficient time to resolve CBFO comments on AK RPT-TRUW-94 prior to SRP feed running out (CBFO would not approve this document as written). They needed the AK document to process. They received the relief with the condition that they could only use the draft document for VE not for certification. The second accommodation was that repackaging must continue current practices; adsorbing liquids as found, and to continue to allow mixing contents. This relief was also granted.

2. In January of 2018, Fluor asked for contract direction to not complete implementation of remaining Basis of Knowledge (BoK) requirements into current processes. Fluor stated that the project needed to continue to process and package waste with current processes, or come into alignment with WIPP WAC Rev 8 and fully implement BoK. DOE concurred with Fluor continuing to process the ISA waste to current processes and stated that Fluor should continue to process, package, characterize and certify waste and not implement BoK to minimize impacts to project milestones.

During interviews with TRU Waste Program personnel familiar with the challenges associated with SD-176 waste, the Root Cause Team identified that there was pressure placed on the previous AMWTP contractor (ITG) to find additional waste drums that were eligible for treatment at ARP V (WMF-1617). This pressure led to a re-evaluation of waste IDC (for example, RF-751) that were specifically excluded from treatment at the AMWTP Treatment Facility (WMF-676) and ARP V (WMF-1617). A re-evaluation of IDC RF-751 waste drums resulted in the re-categorization of a number of these drums. RF-751 was a holding IDC for potentially pyrophoric drums or drums without documentation were placed in the waste tracking system pending RTR and NDA. One of these re-categorized waste drums (10317249) contributed to a pyrophoric event in the AMWTP Treatment Facility (WMF-676) North Box Line (NBL) during waste processing activities on December 21, 2017. Approximately 4 months later, another re-categorized waste drum (10595963) was involved in a reactive event, which is the subject of this Root Cause Analysis.

Prior to initiating the processing of the specific item description code (IDC) involved in the event (SD-176) in March 2016, communication between Idaho Treatment Group, LLC, (ITG) and CH2M-WG Idaho, LLC, (CWI) failed to identify SD-176 as a composite collection of homogeneous solids containers from more than one waste generator and various waste generating processes versus an IDC from a single known generator and specific waste form or process. Information used to base acceptance of the waste at SRP was lacking in adequately describing the attributes of the waste including prohibited items and the potential for reactive material. Review of this information prior to acceptance of the SD-176 waste for processing did not identify discrepancies. This led to a failure to ensure that effective controls were in place, personnel were trained on the waste, required management oversight for processing a new waste was established, and that upper-tier requirements documents received a thorough analysis.

Safety Culture Issues

RC-2: **Management failed to continue to develop the safety culture over a number of years.**

This cause is attributed to exhibited behaviors identified by the analysis of the inappropriate actions throughout the investigation that were not consistent with the tenets of a strong nuclear safety culture. The overall project approach was not conservatively based, lacked documentation and procedures for key safety requirements, and was focused on processing waste to meet milestone requirements rather than compliance with requirements. Some personnel in the approval process for the event drum stated they did not feel comfortable identifying issues that were not consistent with management direction, would delay mission-related objectives, or would otherwise impact cost or schedule.

Schedule pressure was felt by contractor personnel over the entire period evaluated. Management interviews indicated that meeting the Idaho Settlement Agreement drove contract performance and fee, which translated down to personnel as the primary driver for some decisions, leading to reluctance to raise issues that could affect schedule performance. This schedule pressure was reinforced by multiple occasions of accommodations/agreements to waive or delay meeting requirements to not impact schedule.

During the investigation, the Root Cause Team identified several weaknesses in the implementation of a healthy safety culture. This root cause analysis evaluated safety culture from a performance-based approach that analyzed inappropriate actions from the E&CF chart against DOE G 450.4-1C, "Integrated Safety Management System Guide," Attachment 10, Safety Culture Focus Areas and Associated Attributes.

The Root Cause Team evaluated other Fluor recent events to identify if any trends could be observed that would indicate a declining trend in performance as it relates to safety culture. Fluor Idaho does not have a safety culture causal factor so no trending was being performed. The Root Cause Team did identify a recent event at AMWTP, glove box puncture event, where weaknesses were identified in the implementation of a Healthy Safety Culture. As in the glove box event, this Root Cause Team's evaluation focused on actual performance to answer the question, did management and personnel exhibit behaviors leading up to the drum event that would support a healthy safety culture.

The Root Cause Team evaluated the drum event using performance based attributes (how well did the project perform) by analyzing behaviors related to a healthy safety culture. The Root Cause Team then evaluated each inappropriate action and causal factors that would lead to identifying safety culture weaknesses. Of the 19 inappropriate actions evaluated, all 19 involved management causal factors. The Root Cause Team then evaluated each management behavior weakness and compared these behaviors to the DOE G 450.4-1C focus areas and attributes. Taken together, these behaviors pointed to numerous deficiencies in the safety culture.

DOE G 450.4-1C discusses three safety culture focus areas and several attributes associated with each focus area. The attachment states that implementation of these focus areas and attributes offered the greatest potential for achieving excellence in both safety and production performance.

DOE G 450.4-1C, Attachment 10, includes:

Leadership

- Demonstrated safety leadership
- Risk-informed, conservative decision making
- Management engagement and time in field
- Staff recruitment, selection, retention, and development
- Open communication and fostering an environment free from retribution
- Clear expectations and accountability

Employee/Worker Engagement

- Personal commitment to everyone's safety
- Teamwork and mutual respect
- Participation in work planning and improvement
- Mindful of hazards and controls

Organizational Learning

- Credibility, trust, and reporting errors and problems
- Effective resolution of reported problems
- Performance monitoring through multiple means

- Use of operational experience
- Questioning attitude.

The Root Cause Team evaluated the DOE safety culture focus areas and attributes to each inappropriate action identified on the E&CF chart that describes the analysis of the drum event. Listed below is the evaluation of each ISMS safety culture focus area and the inappropriate behaviors that were exhibited during the ARP V Drum Event.

Leadership

Numerous Management and Human Performance weaknesses were observed during the root cause analysis which indicated that Management and individuals did not continuously challenge existing conditions and activities in order to identify discrepancies that might result in errors or inappropriate actions.

Some personnel interviewed stated that they did not feel comfortable in raising concerns and if they did, they did not feel like management listened. Differing professional opinions were not encouraged. One significant example noted was in the approval of event drum #10595963 (the drum with reactive uranium), where one individual knew the drum should not be processed yet felt like he could not stop the process and report this to management. Additionally, this same individual raised a concern with event drum #10595963that it could have potential pyrophoric uranium and was from building 444. This questioning was during the re-categorization of this drum from RF-751 to SD-176 on 10/18/2016. Again, here was a chance for leadership to stop the event drum from being included in SD-176.

There appeared to be a strong culture of using historical practices for processing waste from AMWTP to ARP V. The process worked well with processing known waste; however, it was not reevaluated when the project began processing a composite collection of containers from various generators and waste generating processes versus an IDC from a specific waste process or specific waste generated by a single known generator in March of 2016. Leadership did not effectively identify and communicate the differences with processingSD-176.

The Root Cause Team identified various examples of procedure noncompliance associated with the development of background documentation, evaluation of waste, and the acceptance of waste at ARP V. Leadership allowed personnel to use e-mails to make decisions and authorize transferring and receiving waste drums. Since procedural sign-offs were not required, responsibilities were not known in some instances for key activities, such as verification of no pyrophorics.

Effective management oversight did not occur to identify issues in the development of the process or when processing new waste IDCs. Management oversight tools were ineffective in identifying weakness in processing SD-176. OWLS, management workplace visits (MWVs), self--assessments, and independent audits/assessments did not thoroughly evaluate requirements using performance based attributes of the AMWTP and ARP V processes.

ITG significantly reduced AK staff and AK field personnel from approximately 30 people to about two staff in late 2011/early 2012, based on interviews with personnel familiar with this action. This reduction impacted the ability to ensure day-to-day oversight of field activities; address waste issues; maintain existing AK documents and perform revisions; submit Waste Stream Profile Forms for WIPP acceptance; and perform programmatic development of new AK documents for all remaining and difficult AMWTP waste streams. The AK staff shortage was recognized by Fluor Idaho during transition. After Fluor Idaho takeover the contract on June 1, 2016, efforts to hire additional staff were immediately initiated. The loss of AK staff under ITG continues to be a significant issue in finding qualified AK personnel to develop for addressing AMWTP waste issues and preparing AK documents addressing remaining waste streams.

Leaders should use a systematic process for evaluating and implementing change. When making decisions related to major changes like processing SD-176, leaders did not use a systematic process for planning, coordinating, and evaluating the safety impact and potential negative effects,

Employee/Worker Engagement

Personnel involved in the development of the process to treat SD-176 drums did not recognize the potential for the hazardous conditions that facility workers would encounter when handling SD-176. Personnel did not complete a chemical compatibility evaluation for SD-176. The major focus was production oriented and did not ensure all processes used to protect personnel from hazards were employed (CCE, USQD, etc.).

Prejob reviews of event day activities were minimal, while compliant with procedures. Postjob briefs were not conducted. As a result, issues identified during the fact finding from the event and personal statement observations would have never been captured without the event happening.

Some workers indicated that they felt like they could not report some issues that impacted schedule. During the investigation, many comments from workers involved blaming others instead of taking ownership and correcting what happened. These are indications that an effective, self-critical team has not been established.

During the development of SD-176 there were many opportunities for personnel to identify that SD-176 was not a normal sludge that had been processed in the past. The recognition that this waste was a composite collection of containers from various generators versus an IDC from a single known generator and could potentially have incompatible materials was not effectively communicated.

During the investigation, the Root Cause Team observed that the RWMC organizations were operating like they were still separate companies with what the Root Cause Team called the “Silo” effect. The Silo effect is a label to describe stove pipe communications and organizational priorities that are not aligned. Training for the AMWTP personnel to effectively respond to ARP back shift events had not been provided. Several interviews indicated that AMWTP and ARP continue to operate to different priorities. AMWTP and ARP procedures are not integrated and approved by both facilities which impacted the processing of different IDCs. AMWTP and ARP had not effectively coordinated with the INL Fire Department to ensure that expectations were communicated and procedures were adequate to respond to fire events at the RWMC facility.

Worker engagement in identifying potential pyrophoric material from AMWTP prior to processing was not effectively implemented. Individuals tasked by the procedure to verify that drums did not contain salts, roaster oxides, and pyrophoric materials were not aware of the requirement or of the existence of nonroaster oxide pyrophoric uranium.

Additionally, for the attribute of mindful of hazards and controls, individuals did not understand and proactively identify hazards and controls before beginning work activities. Examples included during the development of the SD-176 process, personnel approved processing an unknown waste without any additional hazardous control evaluations. While most of these attributes are a carryover from previous contractors, the Root Cause Team considers that improvements are needed with the nuclear safety culture in the area of employee/worker engagement and associated attributes.

Organizational Learning

Management workplace visits (MWVs) conducted by facility management did not identify issues associated with the processing of SD-176. There were numerous MWVs identified at the ARP facility with limited MWVs conducted by AMWTP personnel. The MWVs that were reviewed indicated a lack of intrusive observations. Most did not identify problems. The major contributor of not identifying issues was the culture of relying on past successes. Other off-Site assessments did not identify any issues with processing unknown waste or that additional controls should have been in place when processing unknown waste. Requirements were not effectively reviewed to validate compliance (specifically, the RCRA permit).

Independent assessments were conducted in 2012 and again in 2015 by the contractor. However, they were narrowly focused and would not have been expected to identify the SD-176 issues. A lack of oversight of human performance issues (see the write up on CC #6) contributed to the overall event. Neither QA trending nor the HPI programs are integrated into the project to improve overall human performance. The attribute of having a questioning attitude established to support a healthy nuclear safety culture was a significant weakness throughout the development of the SRP.

Additionally, other weaknesses have been identified with a lack of trust; poor oversight, not learning from past events and a lack of self-critical assessments which led the Root Cause Team to conclude that improvements are needed with the nuclear safety culture in the area of organizational learning.

Since assumption of the contract, Fluor Idaho has continued the "Safety Culture Sustainment Plan" that had previously been implemented by previous contractors and was transitioned to Fluor Idaho. It states, "The strength of an organization's dedication to safe operation can be seen in its safety culture." It also states that prior contractors had been working on improving their safety culture. The drum event highlights the fact that previous efforts were not successful in developing a healthy safety culture. Based on the Root Cause Team's investigation into this event and each inappropriate action identified during the cause analysis, the Root Cause Team determined that a second root cause of this event was that management failed to continue to develop the safety culture over a number of years.

This is attributed to exhibited behaviors identified by the Root Cause Team throughout the investigation that were not consistent with the tenets of a strong nuclear safety culture. The overall project approach was not conservatively based, lacked documentation and procedures for key safety requirements, and was focused on processing waste to meet milestone requirements rather than compliance with requirements. Some personnel in the approval process for the event drum did not feel comfortable identifying issues that were not consistent with management direction, would delay mission-related objectives, or would otherwise impact cost or schedule.

Schedule pressure was felt by contractor personnel over the entire period evaluated. Management interviews indicated that meeting the Idaho Settlement Agreement drove contract performance and fee which translated down to personnel as the primary driver for some decisions which led to reluctance to raise issues that could affect schedule performance. This was reinforced by multiple occasions of accommodations/agreements to waive or delay meeting of requirements in order to not impact schedule.

This conclusion was based on several management behaviors identified throughout this investigation that do not support a strong safety culture. The Root Cause Team utilized DOE G 450.4-1C for the safety culture review of the drum event behaviors.

3.6.3 Discussion of Contributing Causes

CC 1: A change-management process was not implemented to identify, evaluate, and disposition the existing vulnerabilities for processing SD-176.

Management failed to ensure that a change-management process was implemented to identify, consider, and disposition the existing vulnerabilities for processing SD-176 Implementation of a change management process would have allowed the project team to analyze the risk associated for processing a composite collection of containers from various generators versus an IDC from a single known generator.

Currently, Fluor Idaho has certain programs and processes that require a formal change management process (for example, implementation of changes to DSA/TSR, critical safety controls, RCRA permit changes, contract modification). For this event, processing of SD-176 was not recognized as a significant change due to the waste form (sludge) and a "unique" IDC. No change process was applied to the initiation of the campaign.

During the investigation, several points during the evolution of SRP were identified when the use of a change-management program should have been implemented. During contract changes, MCP-1414, "Change Control" (used for procurement changes), was not implemented to evaluate change for health, safety, environmental, disposal, training, remediation, and other project impacts.

One example when change control should have been implemented was when the decision was made to change from processing a waste from a single known generator to processing a composite collection of containers from various generators. Major safety management processes were not reviewed that should have indicated that the unknown waste had not been properly evaluated for processing in ARP V. The DSA/SAR, RCRA permits, training, procedures, and site health and safety plans (HASPs) should have been evaluated and revised to address potential new hazards.

Another example of not effectively implementing change control was in 2015 when ITG and CWI received contract modifications ITG-MOD 056 DE-EM0001467 and CWI-MOD 284 DE-AC07-05ID14516, MCP-1414, "Change Control," was not effectively implemented. The MCP states to review changes for health, safety, environmental, disposal, training, remediation, and other project impacts. What the Root Cause Team found in 2018 was that these areas identified in MCP-1414 were not effectively implemented. No change plan was identified. Additionally, a thorough review of the change from known waste to unknown waste processing was not conducted prior to the contract transition.

During this investigation, the team identified was change management had been identified in various cause analyses reports but has not resulted in correcting the change management issues. An observation included when cause analysis is performed, numerous times the cause analyst identifies "Change Management" as a cause code. The Root Cause Team could not identify any corrective actions that were taken in cause reports with change management as a cause and corrective actions taken.

CC 2: A documented plan or path to disposal was not established as required by DOE O 435.1, "Radioactive Waste Management," prior to processing SD-176.

During the development of the SRP in 2012 and up to the present event, the Root Cause Team noted several missed opportunities to ensure that a documented plan or path to disposal was in place and to implement processes that would have effectively evaluated the shipping of pyrophoric material to the ARP V project. Management failed to ensure that a documented plan or path to disposal for – SD-176. This path forward would have identified and communicated to both AMWTP and ARP V what type of waste SD-176 was and the intentions of where it would go after processing in ARP V.

The presence of potential pyrophoric and reactive material in nonroaster oxide depleted uranium waste forms was not specifically addressed in AMWTP AK document RPT-TRUW-94 (DRAFT) that formed the basis of accepting SD-176 at SRP. RPT-TRUW-94 did not identify all potential prohibited items nor address the potential for pyrophoric and reactive uranium in the SD-176 waste. Historical AK source documents, including some used as references in AMWTP RPT-TRUW-94 (DRAFT) provide indication of presence of pyrophoric and reactive material depleted uranium in waste other than roaster oxide. For example, AMWTP RPT-TRUW-91, Revision 2 (February 2014) provides a broad statement concerning the possibility of adverse reaction on a case-by-case basis for the SD-176 homogeneous solid waste. Examples of cited potential reactive materials included "uranium/"roaster oxide". The AMWTP RPT-TRUW-91 references other historical source documents such as ICP/EXT-04-00248 (March 2005). The ICP/EXT-04-0028 report addresses a June 1, 1970 drum fire at RWMC. This drum fire involved a depleted uranium waste drum from Building 444 that contained nonroaster oxide material (copper, cadmium plated copper, plastics, paper etc.). This event apparently was not investigated more thoroughly during development of AMWTP AK documents to further understand post fire investigation results.

Additionally, some prohibited items of concern identified in the ICP/EXT-04-00248 report were not addressed in AWTMP AK documents. Examples include revolvers and ammunition; radioactive sources; mercury in bottles; and containerized chemicals. Missing or incomplete information concerning the attributes of waste intended for processing, including all potential prohibited items, does not allow development of adequate evaluation criteria or identification of controls into other programmatic documents, operating procedures, or into training for staff.

RPT-TRUW-05 Waste Matrix Code Reference Manual (July 2016) does not reflect any prohibited items in the reference manual table (section 4.0) for IDC SD-176. RPT-TRUW-05 is a reference manual that provides waste generation information, waste packaging configurations, and physical waste form descriptions for use by RTR/VE operators and validators. Section 3.0 provides guidance for use of the reference tables. Pertinent information, such as potential prohibited items, is to be included in the Special Notes for each IDC reference table. Section 3.5 also states that prohibited items, as described in AK source documents or detected during RTR or visual examination, are to be identified in the Description or Special Notes section of the IDC reference tables. For SD-176, prohibited items, such as those identified in section 3.5.8 of the report or identified in RPT-TRUW-91, have not been included in the reference manual table for SD-176. Inclusion of potential prohibited items in the RPT-TRUW-05 reference tables would improve operator knowledge, support development of evaluation criteria and controls, and ensure staffs do not need to review multiple AK documents to obtain an understanding of a particular waste population.

RPT-ESH-014, "Chemical Compatibility Evaluation Wastes for AMWTP," Revision 9, was issued in late 2015. This document identified IDCs 176, 177, 178, and identifies the chemical compatibility as TBD and the reactivity group numbers as N/A. The Root Cause Team also identified that this report has other IDCs, including some SDA IDCs for chemical compatibility that were marked as N/A. This report also did not use the most current hazardous constituent information (it referenced the wrong revision). It appears none of the reviews during the acceptance process of SD-176 at ARP evaluated RPT-ESH-014. A thorough review should have identified that SD-176 had not been evaluated, and possibly identified this as a composite or unknown waste.

In early 2016, the RWMC RCRA permit was revised that included a RPT-TRUW-94 (DRAFT), which was never approved. In the RCRA permit, the report is referenced and indicated as draft. The RCRA permit was revised two more times with this report continuing to be referenced as a draft report. The processes being implemented by AMWTP to ship waste to ARP V were not adequate to support safe handling by the ARP V operators. Interviews indicated that ~50% of the drums being requested to be shipped to ARP V were being rejected by the ARP V management team. On March 10, 2016, the first SD-176 drum was processed at ARP V.

The Root Cause Team also evaluated whether any changes were made to site HASPs to accommodate the handling of SD-176 radiological and hazardous waste. The Root Cause Team did not identify any changes for personnel protection for individuals handling SD-176.

Decisions to process SD-176 were made without recognition that the facility was transitioning from processing a well characterized, relatively homogeneous generator specific and process specific IDC waste stream to an IDC waste that was not well characterized and originated from various generators and processes, and did not have a comprehensive chemical compatibility evaluation (CCE). Undefined characterization activities and Waste Isolation Pilot Plant (WIPP) approval still remain to be completed.

CC-3: Management did not effectively analyze extent of condition following the December 2017 box line fire event and apply lessons learned to relevant ongoing activities outside of AMWTP, which could have identified the presence of pyrophoric and reactive material other than roaster oxides in containerized waste.

The event investigation team evaluated a recent event for the possibilities for its impact on the ARP V drum event. On December 21, 2017, a fire occurred in the WMF-676 treatment facility (TF) north box line east trough during waste processing operations. Although originally designated a fire, during the emergency response it was determined to be a pyrophoric reaction. Operators were processing the fifth drum from a six drum metal over pack pallet (SMOP). An operator opened the 83-gal over pack drum using the BROKK (remote operated manipulator) and removed the 55-gal inner drum. The 55-gal drum was then opened using the BROKK and a bag of material was removed from the drum. As soon as the inner bag was breached, the operator observed a flash and saw a fire start in the waste.

The pyrophoric event in WMF-676 treatment facility north box line occurred on 12/21/2017, approximately 4 months before the reactive uranium event in ARP V. Corrective actions from the north box line event (CAR 116640) were completed 4/25/2018, just two weeks after the ARP V event. Neither the extent of condition (EOC) review nor the completed corrective actions from CAR 116640 considered waste to be processed at RWMC/ARP V. In both cases, drums previously categorized as RF-751 were recategorized to nonpyrophoric codes (RF-750 and SD-176) to allow them to be processed rather than to be held in storage. In both cases, the U-238 mass was significant (46.7 kg and 11.9 kg).

The EOC evaluation was completed on north box line fire event in January 2018. The WTS query against all active drums onsite reported 693 drums with >5 kg U-238. One of those drums was the "event" drum of 4/11/2018. Since this drum had an IDC of SD-176 (not one of the IDCs listed in RPT-TRUW-83), it was screened out and no further action was taken to address this problem drum. The corrective actions taken for this event resulted in the development of a new IDC (SD-761). At this time, more than 70 drums containing similar characteristics have been assigned this new IDC.

Parent drum #10595963 (event drum) had been identified as a potential problem drum since it had a U-238 mass of greater than 5 kg. However, it was not considered in the extent of condition because it was "Not TF Feed, not on RPT-TRUW-83." Had this drum been flagged, it would have been identified as a problem drum prior to the SRP management review process, completed on 4/3/2018.

CC-4: Oversight of the Sludge Repackaging Project was ineffective in identifying process failures that caused and/or contributed to the ARP V event.

Oversight was not effective in identifying or questioning that SD-176 was being processed in the same manner as previous IDCs that were well evaluated with respect to generating process and source. Oversight did not verify that specific process requirements were appropriately documented through procedural sign-offs, particularly when performed by different organizations.

Management did not ensure that all the tools they have to provide oversight were being effectively implemented to prevent this event.

The event investigation team evaluated what oversight was performed that could have identified potential issues that could have prevented the ARP V drum event. The Root Cause Team evaluated the current Fluor Idaho corrective action program and also the corrective action programs that were being implemented by ITG and CWI leading up to and during the initial SRP project. There were no issues identified that would have led management to take additional actions.

The Root Because Team then reviewed Quality Assurance oversight activities and observed that there were no activities/issues identified that would have indicated problems with the implementation of the SRP. There were no indications of QA oversight for effective implementation of RCRA permit requirements.

Hundreds of MWVs were reviewed to determine if management had identified any issues that would have indicated that additional actions should have been taken to address the SRP. MWVs did not identify issues that would have indicated potential problem areas.

The Root Cause Team also evaluated if there were any trends from the Performance Assurance group that would have identified any issues with the SRP process. Performance Assurance did not identify the lack of thorough/intrusive MWVs, and determined there was no trending of HPI issues

CC-5: The project has not implemented an effective integrated human performance improvement program.

The root cause team identified numerous human performance weaknesses during the team's analysis. Attachment F describes the human performance issues along with the error modes.

The Root Cause Team evaluated the contributing factors of each inappropriate action and identified actions that had a human performance factor affecting the action. A summary of the Human Performance related issues identified by the Root Cause Team included:

- Personnel did not effectively use change management practices when changing to SD-176
- Personnel using email to make decisions for shipping and approving receipt of the event drum.
- Personnel did not effectively implement MCP-135 when revising MCP-4226 and include NDA personnel as required reviewers
- Personnel did not ensure that DOE conditions provided in a 2015 DOE memo, AS-CMD-AMWTP/ITG-16-0 18, were fully implemented. One of the two conditions did not get implemented
- Personnel were using unapproved documents/emails to make decisions.
- Personnel did not ensure that the information in the approved RCRA permit was accurate (specifically, referenced a DRAFT document)
- Personnel allowed drum #10595963 to be shipped to ARPV and did not meet procedural requirements.
- Personnel miss-applied an IAG as a procedure instead of just identifying roles and responsibilities
- Personnel did not recognize noncompatible hazards with SD-176.

Eighty percent of the causal factors involving human performance were evaluated as knowledge based errors. There were a few inappropriate actions assigned to other error codes (such as skill based errors, check of work was less than adequate, and rule based errors such that previous success in use of a rule reinforced continued use of the rule). Using the error-type analysis as a method to analyze each inappropriate action provides a tool to ensure that the corrective actions are appropriate (Appendix G describes corrective actions for each applicable error type).

The Root Cause Team evaluated the current actions Fluor Idaho has taken to address human performance improvement (HPI). The investigation identified that currently there is no ongoing trending of Human Performance causes. Additionally, the Root Cause Team spoke to the HPI Program Lead/SME and this individual stated that HPI has not been integrated into the projects. It was also identified that any HPI information from the corrective action program was not being used by the HPI Program. The corrective action program, does not track HPI issues, and the Human Performance Program established to review OWLs has not been effective in preventing and reducing the number of HPI issues.

See Appendix F for further human performance discussions.

CC-6: Action in applying lessons learned from the 2014 WIPP event was not effective in strengthening processes such that major contributors to the drum event were able to be identified and mitigated.

Lessons learned from the 2014 WIPP event were not effectively evaluated or acted upon by RWMC and AMWTP to preclude some of the major contributors to the drum event. For example, evaluations and subsequent corrective actions taken in 2015 did not effectively identify safety culture and change control issues. Similarly, the actions taken to address the WIPP fire event did not expand to evaluate other potential pyrophoric and reactive materials and waste forms.

The Root Cause Team reviewed several previous similar events and evaluated their applicability and corrective actions. The Root Cause Team evaluated these similar events to identify if any of their corrective actions would have prevented or mitigated the drum event. One internal event reviewed for applicability of its corrective actions is addressed in CC-4: the AMWTP box line fire. This previous event was determined to be applicable to the drum event.

One other event that did have applicability to the drum event was the WIPP radiological event in 2014. Each conclusion (CON) was evaluated along with the judgement of needs (JONs) to see which CONs could have been applicable to the drum event. The Root Cause Team identified eight CONs where the contractor's corrective actions were not effective when reviewed against the circumstances of the drum event. For example, evaluations and subsequent corrective actions taken in 2015 did not effectively address safety culture (CON 13) and management oversight (CON 21) issues that were identified in the WIPP report and are now identified as issues during the drum event. Other CONs included CON-5 (CAMs), CON-6 (Change Control), CON-7 (IAGs not receiving USQs), CON-12 (Emergency Management DOE O 151.1D), and CON-15 (Conduct of Operations/Procedures).

CC-7: The project failed to provide an adequate number of trained acceptable knowledge (AK) personnel to support the daily activities along with providing effective program oversight.

The Root Cause Team reviewed the AK process and current staffing to determine if they were adequate to support ongoing activities. Both AMWTP and ARP V do not appear to have adequate resources to provide sufficient support to daily activities and provide effective oversight of the requirements and implementation of the AK process at each site.

ITG significantly reduced AK staff and AK field personnel from approximately 30 people to about two staff in late 2011/early 2012, based on interviews with personnel familiar with this action. This reduction impacted the ability to ensure day-to-day oversight of field activities; address waste issues; maintain existing AK documents and perform revisions; submit Waste Stream Profile Forms for WIPP acceptance; and perform programmatic development of new AK documents for all remaining and difficult AMWTP waste streams. The AK staff shortage was recognized by Fluor Idaho during transition. After Fluor Idaho takeover the contract on June 1, 2016, efforts to hire additional staff were immediately initiated. The loss of AK staff under ITG continues to be a significant issue in finding qualified AK personnel to develop for addressing AMWTP waste issues and preparing AK documents addressing remaining waste streams.

ARP V does not have the AK technical expertise to effectively evaluate waste shipments from AMWTP and to ensure the shipments are meeting requirements. AMWTP has “loaned” an AK individual to ARP V to aid in their day-to-day activities. Effective oversight of the AK process and its impact on ARP V is not being achieved.

CC-8: The Tenant Use Agreement was inappropriately used when initiating the Sludge Repackaging Project (SRP).

Management inappropriately applied the Tenant Use Agreement process when initiating the SRP. Since two contractors were involved in the start of the SRP process, DOE directed the contractors to use an interface agreement (IAG) rather than establishing a prime contractor to subcontractor relationship.

The IAG that was developed and included both steps and requirements that should have been in a technical procedure. It also was the vehicle to authorize specific IDCs to be processed. When IAG-592 was modified to include SD-176, it did not receive a USQ evaluation against the safety basis since interface agreements are categorically excluded from the USQ process. The Root Cause Team evaluated the processes that were implemented to transfer waste to and from AMWTP and ARP V. This included the timeframe from when the SRP was originally developed. One “process” identified that was being inappropriately implemented was the Inter-group Agreement, IAG-592. This was the process that was originally identified to control what work was going to be shared between the two contractors, ITG and CWI. The original IAG-592 was approved on 8/15/2012. Contract Mod 224 directed the contractors to use the IAG process. MCP-9141, “Tenant Use Agreements,” and TEM-8, “Template for Interface Agreements,” control the use of IAGs.

Additionally, the Root Cause Team identified that the IAG described the processes for what and how waste would transferred between AMWTP and ARP V, including specific requirements such as which IDC to process. Using the IAG bypassed the USQ evaluation process because the IAG is categorically excluded from performing a USQ. The investigation identified that the IAG process was not appropriate for these type controls at a Hazard Category II nuclear facility.

Issue Discussions from Event Day and Evening

Listed below is a summary of the issues the event investigation team identified during the event day and evening. The issues below were evaluated as not impacting the direct, root, or contributing causes and will be included in the Fluor Idaho corrective action program. The Root Cause Team performed an analysis of the inappropriate actions that were observed for the event day and evening, and determined that one issue that met the criteria of a significant condition adverse to quality, as defined in the Fluor Idaho corrective action program.

3.6.4 Discussion of the Significant Conditions Adverse to Quality

Definition of a Significant Conditions Adverse to Quality (SCAQ) - Conditions which, if uncorrected, could have a serious effect on the worker, public, and the environment.

SCAQ-1: Contrary to the requirements of MCP-2726, "Respiratory Protection," during the drum event, an AMWTP radiological control technician (RCT) entered the ARP V facility without wearing the proper respiratory protection for entering a potential immediately dangerous to life or health (IDLH) situation.

During the investigation and during interviews, the Root Cause Team identified that one of the RCTs from AMWTP responding to the fire at ARP V on the evening of 4/11/2018 and entered the ARP V building airlock where the drum was reacting to support the INL Fire Department in a powered air purifying respirator (PAPR). PAPRs do not generate oxygen and are inappropriate for entering an area filled with smoke/toxic fumes. Discussions with the individual indicated that he did not recognize that he should not have entered without an SCBA; however, when questioned, he stated that he was not trained for a SCBA. Further follow-up indicated that the RCTs in AMWTP are not qualified for SCBAs.

Based on the Root Cause Team's evaluation of this issue and how a SCAQ is defined, RCTs not knowing that PAPRs were not appropriate for entering an enclosure that has a potential IDLH atmosphere could have a serious effect on the workers. The Root Cause Team determined this inappropriate action was SCAQ-1: Contrary to the requirements of MCP-2726, "Respiratory Protection," during the drum event, an AMWTP RCT entered the ARP V facility without wearing the proper respiratory protection for entering a potential immediately dangerous to life or health (IDLH) situation.

Discussion of the Conditions Adverse to Quality

Definition of Conditions Adverse to Quality (CAQ) - Conditions that include failures, malfunctions, deficiencies, deviations, defective material and equipment, and state of noncompliance with Quality Assurance program requirements.

The investigation determined that there were fourteen conditions that should be addressed with identified corrective actions. These do not meet the level of a SCAQ, but should be entered into the corrective action programs as CAQ. They include the following:

CAQ-1: The Ever-bridge communication system was not working/out-of-service and caused delays in providing notifications of the drum event.

Throughout the event, personnel stated that because of the Ever-bridge communication tool was not effectively working and communication activities were challenged throughout the initial response to the drum event. The investigation concluded that this issue was a condition adverse to quality.

CAQ-2: Following the Fluor Idaho transition, management did not effectively train and manage available resources to ensure AMWTP personnel could effectively respond to an event at the ARP complexes.

One of the major contributors to the event response (such as RCTs responding to ARP V who did not know what was in the facility and then used a PAPR in a fire environment) was based on the fact that, when Fluor Idaho took over from ITG and CWI, Fluor Idaho did not implement a change plan to address all the changes for AMWTP personnel assuming the responsibility for ARP facilities emergency response on the back shift was not developed or implemented.

CAQ-3: The emergency, abnormal operating, and alarm response procedure (EAR) -246, "RWMC—Respond to Fire," does not include some procedure steps that are identified in the hazard controls of the procedure hazard analysis.

During the review of emergency procedures, the investigation identified that EAR-246, "RWMC-Respond to Fire," which is for fire response, had critical steps in the hazard analysis that were not included in the actual procedure. The hazard analysis states for personnel to follow the requirements of the RWP, but there is no mention of that in the EAR procedure steps. Similarly the hazard analysis calls for a fire watch and requires information to be provided to the battalion chief on the types of material in the fire. Both of these are critical steps for responding to a fire.

CAQ-4: The INL Fire department responded to the fire alarm condition in WMF-1617 and based initial response actions without an awareness of airborne contamination conditions in the normally clean side of the building.

The investigation determined that the INL Fire Department (FD) used their normal fire investigation procedure for the immediate entry into ARP V. Based on interview information; the FD personnel stated that complacency contributed to their initial response to the drum fire. They had responded to the ARP facilities numerous times when there were false alarms. Additionally, one firefighter explained that, since he did not hear an audible CAM alarm, he assumed that it was another false alarm. He communicated that if there had been a CAM alarm, response would have been different. Based on interviews and reviews of the CAM status, CAMs ceased to function about the same time as the fire alarm.

Also during the drum event, the INL Fire Department (FD) did not exit the ARP V enclosure in a timely manner after self-identifying the need to leave given the existing conditions. This resulted in the FD narrowly missing being in the immediate vicinity of another drum breach. Also during the day shift, operators were handling the potentially volatile repackaged drums that were involved in the event that evening.

CAQ-5: Continuous air monitors (CAMs) did not indicate airborne contamination in the airlock and alert the entry team of the condition.

In the absence of fire alarm activation, facility personnel would have been vulnerable to airlock entry the following normal operating period with no indication of airborne contamination.

During the evaluation of some of the actions taken by the INL Fire Department, the Root Cause Team determined that the INL Fire Department depends heavily on the use of CAMs within a facility. What the FD did not know that as soon as the drum expelled its contents and the fire alarm initiated, the CAMs stopped working. There was too must dust/debris for the CAMs to continue to work. A review of CAM operability should be made involving the FD for their future awareness.

CAQ-6: The INL Fire Department response actions were not effectively coordinated with facility operations to function in unified command because of the lack of a knowledgeable operations representative at the scene.

The Plant Shift Manager was the initial operations responder to the ARP V event. He had to come from AMWTP and was not familiar with the ARP V process. After initial discussions with the onsite FD Commander, he left and went to the ECC. No other operations personnel were sent to coordinate with the FD. Response actions between the FD and operations were not effectively coordinated from the FD, PSM, and the ECC.

CAQ-7: Conduct of operations weaknesses were noted in communicating the need for urgent RCT responses, and then not documenting some required actions during the emergency response.

The Plant Shift Manager (PSM) communicated to them that "something happened at ARP V and could they go over and see." There was no urgency in the request to respond to help the firefighters. Additionally, actions from EAR-246, "RWMC—Respond to Fire," and EAR-278, "Hazardous Substance and Waste Spill Control," were not documented as being completed.

CAQ-8: The AMWTP RCT inappropriately directed the INL Fire Department firefighters to doff their anti-contamination clothing and equipment in a potentially high risk area in which a lid had already been ejected off a drum, and minutes after the Fire Department exited a lid was ejected off another drum.

The AMWTP RCT inappropriately directed the FD to doff their clothing and equipment in a high airborne area. During interviews with the RCTs, the RCT that was in ARP V with the firefighters said he told the firefighters to doff at the inner door. When asked if he would change anything from that night, he stated he wished he had them doff in the vestibule. He was very self-critical and showed ownership for his decision.

CAQ-9: Fire department personnel disturbed the heated product in the drum and moved the drum contrary to facility expectations.

Stirring of contents is not consistent with FD training. Movement of the drum is standard FD protocol to isolate and minimize exposure to adjacent hazards. Alternate actions must be coordinated by an effective unified command which was not in place.

CAQ-10: Contrary to the requirements of DOE O 422.1,Chg 2,"Conduct of Operations," which states that procedures should be clearly written, MCP-3003, Performing Pre-Job Briefings and Documenting Feedback," does not clearly define management roles and responsibilities for determining that a post job brief is conducted.

Contrary to the requirements of DOE O 422.1, "Conduct of Operations," which states that procedures should be clearly written, MCP-3003, Performing Pre-Job Briefings and Documenting Feedback," does not clearly define management roles and responsibilities for determining that a post job brief is conducted. The Root Cause Team also reviewed the criteria for a post job brief. When asked of Operations to see the post job briefing form, we were informed that they did not have to have a post job brief. MCP-3003, Performing Pre-Job Briefings and Documenting Feedback," leaves the post job "feedback" to the workers.

CAQ-11: Affected Nondestructive assay (NDA) personnel were not included in the procedure revision process when additional requirements were included in MCP-4226, "TRU Programs Site Project Office Process."

Affected personnel were not included in the procedure revision process when additional requirements were included in MCP-4226, "TRU Programs Site Project Office Process During a review of procedure MCP-4226, "TRU Programs Site Project Office Process," requirements with NDA personnel, they were unaware of the requirement for them to review for potentially pyrophoric waste. Additionally, they do not have criterion to evaluate against. The NDA personnel did not review MCP-4226 prior to the requirement being incorporated. Based on NDA personnel not knowing they were required to review for potential pyrophoric material, the Root Cause Team identifies this as an issue.

CAQ-12: PLN-4669, "Implementation Plan for PER-109, Book 3, HWMA Storage and Treatment Permit for the Idaho Nuclear Technology and Engineering Center and the Radioactive Waste Management Complex—ARP on the INL," does not adequately roll down Permit Condition VI.C.1 of the RWMC HWMA/RCRA permit: "The Permittee shall not perform treatment of waste containing pyrophoric/reactive radionuclides at the RMWC." As written, PLN-4669 identifies TPR-7867, "SRP RA V Waste Processing"; TPR-7988, "Debris Waste Processing"; and TPR-7990, "Debris DPS Waste Packaging"; and as the procedures that implement Permit Condition VI.C.1.

During a review of the RCRA permit for ARP V, PLN-4669, Rev 2, Implementation Plan for PER-109, Book 3, HWMA Storage and Treatment Permit for RWMC on the INL was reviewed. The three TPRs that are listed as implementing the RCRA permit inappropriately identifies TPR-7867, TPR-7990, and TPR-7988 as the procedures that implement the following RCRA permit requirement, VI.C.1 states "The Permittee shall not perform treatment of waste containing pyrophoric radionuclides at the RMWC." TPRs 7867 and 7990 state that radioactive pyrophorics in concentrations greater than 1 percent by weight and all nonradioactive pyrophorics shall be reacted (or oxidized) and/or otherwise rendered nonreactive prior to placement in the payload container. Neither of these TPRs meets the PLN-4669 requirement. Additionally, TPR-7988 does not mention radioactive or nonradioactive pyrophorics in the TPR.

Although these Operations technical procedures describe the process of processing SRP wastes, they are not sufficient to ensure the wastes selected and shipped to ARP V for SRP processing do not contain pyrophoric radionuclides.

CAQ-13: RCTs were not familiar with Fire Department donning and doffing protocols which compromised the timeliness and effectiveness of doffing contamination control measures.

During interviews with AMWTP RCTs that responded to the ARP V drum event they indicated that they were not familiar with the FD doffing process. Interviews with the fire fighters also indicated a weakness with the RCTs and the FD doffing process. One fire fighter responded that the RCT took off his mask and he was surprised. He indicated that each fire fighter takes off their mask when doffing.

CAQ-14: Fire Department quick access plans (QAPs) and pre-incident plans (PIPs) do not identify comprehensive radiological hazard conditions, most notably, the potential for airborne alpha contamination in ARP V.

During the root cause team's review of the FD QAPs and PIPs, the team identified weaknesses in the level of detail provided in the procedure for providing detailed information on how the FD would respond to an event like the drum event. Weaknesses such as entering a building and in a potential air borne area were not provided.

3.6.5 Discussion of Emergency Response Recommendations

The emergency action response was also evaluated by the event investigation team. Interviews indicated that EAM response did not enter the EALs based on the ventilation system running. In the review of the EALs, the Root Cause Team identified several entry points that could have been entered. The Root Cause Team evaluated the actions that were taken by the Fluor Idaho team responding to an escalating event. Actions taken were thorough and involved manning the ECC and EOC, including notifying DOE and the State of Idaho. The Root Cause Team did not identify any issues with the actions taken however, the team evaluated should the EAM have entered EALs with an escalating event.

The Root Cause Team identified a lack of a conservative approach for not entering EPI-13, Operational Emergency Categorization/Classification and Protective Actions for RWMC, to the escalating event. The Root Cause Team's evaluation included the following:

- Conservative actions taken by the facility the night of the event indicated that the EAM took actions but did not declare that any of the EALs were entered. Conservative actions were not taken for entering into the EALs.
- The entry steps in EPI-13, "Operational Emergency Categorization/Classification and Protective Actions for RWMC," indicated to the Root Cause Team that EALs could have been entered up to an alert.
- During an event where there were multiple fire alarms and one drum that expelled its hazardous contents and continued to heat up (as indicated by the INL Fire Department), the INL Fire Department attempted to extinguish and lower the temperature of the contents and could not. The Hazmat team was summoned by the INL Fire Department and, after the 0024 breach, evacuated out to a 100m boundary.
- An event with one drum breach at 2235, another drum breach at 0024, and another drum breach at 0328 indicated an escalating event, and ventilation still had not been verified per Emergency Preparedness comments.
- Known container damage and contents. Radiological and hazardous material expelled into a filtered environment. With the breach at 0024, an RCT interview noted he could not see into the ARP V structure because of so much debris.
- It could not be confirmed that the ventilation system was operable or capable of performing its intended function until 0350 the next morning, based on a picture of the structure (emergency procedures state that the ventilation system is running).
- Consideration of potential breaches of other SD-176 drums that had been processed and were outside the ARP V structure on a flatbed trailer.
- The potential consideration of the ventilation system filters being plugged.

Based on the above information, the preliminary Root Cause Team's conclusion was that the project took the required actions for specific EALs, with the exception of declaring an operational emergency or an alert. Based on the information above, the Root Cause Team is making the following three recommendations to capture their analysis of the emergency response:

REC-1: Review the DOE guidance to ensure the EALs meet the guidance provided.

REC-2: Evaluate the EALs for inadequacies and ensure entrance events are clearly defined so that, if another escalating event occurs, there would be no question on whether EALs should be entered.

REC-3: Validate the event issues above and ensure that not entering the EALs meets management expectations.

3.7 Comparative Timeline and Change Analysis

The comparative timeline organized the event information and provided a collective source of information to identify differences between what happened and what should have happened, and to determine the significance to the organization of these differences. The Comparative Timeline catalogues the behaviors and condition that shaped the event, and organizes the information for use by other tools to determine what made the project fail. The Comparative Timeline is an evolved form of a change analysis tool. Change is anything that disturbs the “balance” of a system from operating as planned. Change is often the source of deviations in system operations. Change can be planned, anticipated, and desired, or it can be unintentional and unwanted. Change analysis examines planned or unplanned changes that caused in desired outcomes. In an event investigation, this technique is used to examine an event by analyzing the difference between what has occurred before or was expected, and the actual sequence of actions. The cause analyst identified specific differences between the event-free or “ideal” situation, and the event scenario. These differences are evaluated to determine whether the differences caused or contributed to the event. The results of the change analysis are used to support the development of causal factors. In light of the inherent similarities between comparative timeline and change analysis, the Root Cause Team elected to integrate these methods.

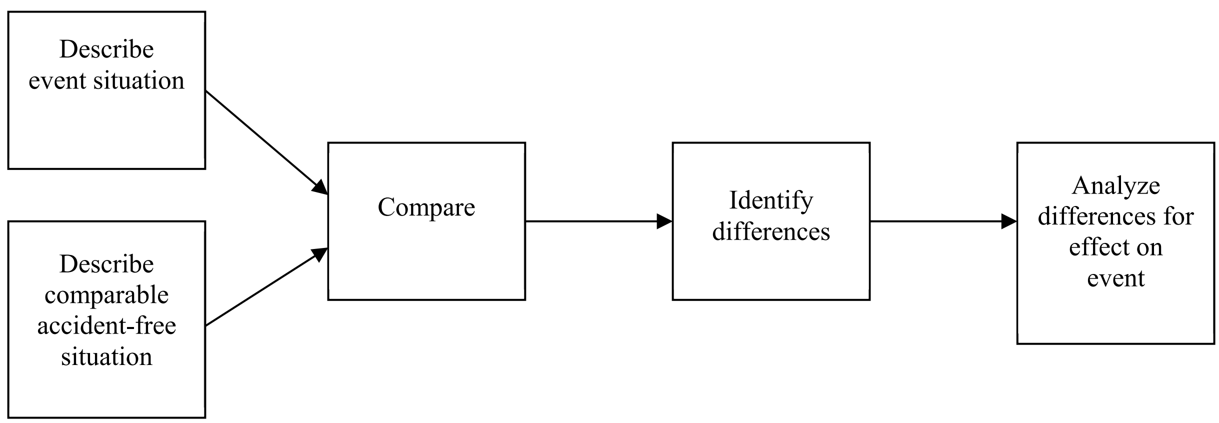


Figure8. Change analysis process.

The Root Cause Team identified and evaluated numerous “departures from normal” on the E&CF chart. These were evaluated on a comparative timeline/change analysis as “what happened” (or didn’t happen). Next, the Root Cause Team evaluated “what should have happened,” followed by significance. As a result of this analysis, the Root Cause Team identified numerous setup factors, missed opportunities, and failed or missing barriers. The most significant of these deviations from the ideal were related to the change from processing generator specific IDCs to ARP V to processing a composite collection of containers from various generators and processes. The SD-176 represents a composite of generators versus from a single known generator. This change was made without recognition that the facility was transitioning from processing a relatively homogeneous well characterized IDC to an IDC that was not well characterized, originated from various generators and processes, and did not have a comprehensive CCE.

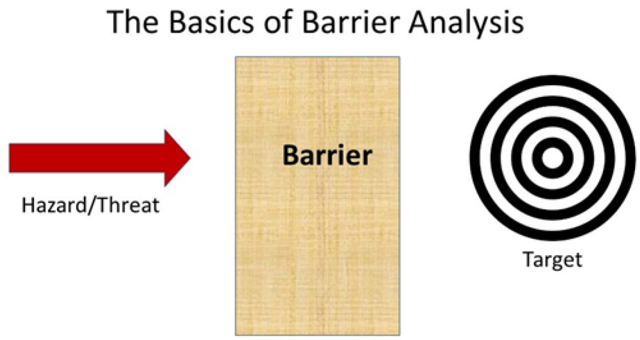
As a result of the failure to recognize this significant change, an effective analysis of the potential hazards associated with SD-176 was not performed. These unrecognized and unanalyzed hazards included the potential presence of pyrophoric metals within the SD-176 waste.

An additional significant deviation from the ideal occurred in conjunction with consolidating the Idaho Cleanup Project Core AMWTP and RWMC organizations. AMWTP operators and RCTs were given the responsibility to cover the balance of the RWMC facility during the backshift, when RWMC was essentially unmanned, without being provided the requisite orientation regarding RWMC processes and associated hazards. This contributed to a less than optimal response to the drum overpressure events.

The integrated comparative timeline and change analysis is included in Appendix C.

3.8 Barrier Analysis

3.8.1 Barrier Analysis Discussion



Barrier: A measure or device that has the effect of [or is intended to] reducing the probability and/or consequences of the effect of a threat on a target.

A “barrier” is a measure or a device that has the effect of reducing the probability or consequences of a “threat” to a “target.” A “threat” is any phenomenon that can adversely affect a target. A “target” is any entity that needs to be protected. A “barrier” is any physical structure, any device, any configuration, or any measure that can delay the effect of a threat on a target, or can reduce its likelihood or severity. A barrier is anything that tends to protect a target from a threat by making the consequences less adverse, reducing the probability or delaying the impact to a more favorable time.

Types of barriers include physical, equipment design, warning devices, procedures and work processes, knowledge and skills, and supervision. Barriers may be control barriers, safety barriers, or act as both. The Root Cause Team relied heavily on the inappropriate actions identified in the event and causal factors (E&CF) chart to identify the barriers most likely to have contributed to this event. In this manner, the Root Cause Team was afforded the opportunity to look at failed barriers at different times and from different vantage points.

At each inappropriate action, the Root Cause Team:

- Identified the hazards and their associated targets
- For each barrier identified, evaluated the barrier’s performance.

For each barrier, the Root Cause Team:

- Determined which barriers were in place, but failed
- Determined which barriers were not used
- Identified missing barriers that were not in place
- Identified barriers which, if strengthened, would prevent recurrence
- Evaluated the probable reasons for barrier failure
- Evaluated the consequence of the barrier failure and how the failure affected the event.

The Root Cause Team evaluated barrier performance at each inappropriate action identified on the E&CF chart. The barrier analysis identified that human performance was the most frequently failed barrier followed by essentially equal failures in management policy/expectations, management oversight/assessment performance, independent performance and process/procedures, with only slightly fewer failures of the organizational roles, responsibilities, accountabilities, and authorities (R2A2) barriers. This analysis indicated that the most fundamental barriers that failed in this project were related to personnel failing to follow required procedures; management not effectively communicating, monitoring, or enforcing expectations; and independent QA oversight was insufficient (specifically, only one surveillance) to identify inappropriate issues and ensure line management effectively resolved underlying causes. The recommended corrective actions for barriers are identified in Appendix C, Comparative Timeline.

3.9 Previous Similar Event Review

The Root Cause Team evaluated numerous similar events to identify the potential of past corrective actions taken for previous events that may not be totally effective. Many of the events reviewed were screened out because the corrective actions taken did not affect the drum event or would have not been expected to prevent the drum event.

Three events that required further evaluation included:

WIPP Radiological Event in 2014 – The Root Cause Team reviewed and evaluated Event Investigation Report Phase 2 Radiological Release Event at the Waste Isolation Pilot Plant, February 14, 2014, report date, April 2015. The review consisted of the report's CONs and JONs for any applicability to the ARP V drum event. Contributing Cause 7 provides the analysis of the WIPP event.

The WIPP radiological event occurred in 2014 and a subsequent DOE report was issued. The DOE report identified a release of radioactive material from a transuranic (TRU) waste container (55 gallon drum) that had been placed in Panel 7 Room 7 of the DOE WIPP facility. The direct cause of the WIPP event was an exothermic reaction of incompatible materials in a waste drum. Based on the similarity of this event and its causes, the event root cause team reviewed the CONs and JONs for applicability to the ARP V drum event. Each conclusion (CON) was evaluated along with the judgement of needs (JONs) to identify which CONs could have been applicable to the drum event. The Root Cause Team identified eight CONs where the contractor's corrective actions were not effective when reviewed against the circumstances of the drum event. For example, evaluations and subsequent corrective actions taken in 2015 did not effectively address safety culture (CON 13) and management oversight (CON 21) issues that were identified in the WIPP report and are now identified as issues during the drum event. Other CONs included CON-5 (CAMs), CON-6 (Change Control), CON-7 (IAGs not receiving USQs), CON-12 (Emergency Management DOE O 151.1D), and CON-15 (Conduct of Operations/Procedures).

December 21, 2017 2017 AMWTP box line fire – The Root Cause Team evaluated the box line event for any lessons learned. The box line fire was a drum that was re-categorized from RF-751 (potential roaster oxides) to RF-750 (no roaster oxides) and processed. When opened, the drum experienced a pyrophoric chemical reaction and immediately started a fire. This event is discussed in contributing cause 3.

The similarity of the boxline fire to the ARP V drum event was that a drum that had been re-categorized from RF-751to RF 750 to be processed at AMWTP had unexpected pyrophoric waste present. Event drum #10595963 was also re-categorized from RF-751 to SD-176 at the same time the boxline drum event was. During the extent of condition review, the ARP V event drum 10595963 had been identified as a potential problem drum on the basis of a U-238 mass of greater than 5 kg. However, drum 10595963 was not considered any further in the Box line event extent of condition because it was "Not TF Feed".

Management did not effectively determine the extent of condition and communicate corrective actions taken at AMWTP after the December 2017 box line fire that could have identified the existence of a previously unknown waste form containing pyrophoric uranium other than roaster oxides. While the material processed at AMWTP was not sludge or roaster oxide, an extent-of-condition review should have required an evaluation of other potential pyrophoric and reactive materials.

June 1970 RWMC Fire Summary - Interviews conducted by the CA Team indicate a wide-held perception exists that pyrophoric and reactive uranium would only exist in roaster oxide waste. Review of historical AK source documents was performed to identify historical source documents that discussed concerns with waste generated at Rocky Flats building 444, where depleted uranium, beryllium, and other metal fabrication took place, and with nonroaster oxide waste containing potential pyrophoric and reactive uranium. Report ICP/EXT-04-00248, Historical Background Report for Rocky Flats Plant Waste Shipped to the INEEL and Buried in the SDA from 1954 to 1971, Revision 1 (March 2005) is a key AK source document that addresses the buried TRU waste including wastes retrieved as part of the IDR/EWR projects that make up the SD waste inventory. This report is referenced in AMWTP AK reports such as RPT-TRUW-91. Report ICP/EXT-04-00248 includes details concerning building 444 operations, roaster operations in building 447, and identifies prohibited items of concern.

The ICP/EXT-04-00248 report discusses a June 1, 1970 fire at RWMC that involved a Rocky Flats Plant waste drum originating at Building 444. The report states that analytical data from drum samples indicated the "presence of copper (plated on both sides with cadmium), copper cadmium alloys, plastics such as polystyrene and nylon in the form of rods and diced pieces loaded with uranium oxide, and high-fired uranium oxide. The sample of prime interest appears to be melted slag with uranium oxide present". The ICP/EXT-04-00248 report references this information as coming from an October 23, 1970 Rocky Flats letter that provides preliminary analysis of the samples and determination that the drum originated from Building 444. The contents of the drum appeared to contain other than roaster oxide waste.

The CA team performed additional research for information pertaining to the June 1, 1970 drum fire at RWMC. This investigation yielded information from EDMS, historical records recovered from the INL Site Records Center, and an internet search. A summary of the 1970 drum fire event is provided as follows.

On June 1, 1970, a smoldering drum was discovered at the RWMC by the security patrol. The drum was on the top tier of a stack of waste in a temporary aboveground storage area established to store incoming Rocky Flats Plant waste while decisions on transitioning from subsurface disposal of waste to aboveground storage of transuranic waste were pending. Initial attempts to extinguish the fire failed. The drum was removed from the stack, isolated, placed in a hole and covered with soil to extinguish the fire. The drum was determined to have been shipped to RWMC in February 1970. The drum did not have any remaining paper identification tags or labels, and did not have a metal identification tag.

On June 3, 1970, the fire drum was uncovered, overpacked and then transported to the INL Auxiliary Reactor Area II (ARA II) Hot Cell No. 1 further examination. The drum lid was removed and an "extremely fine black powder was present" and "all observable contents were extremely black". A representative from Rocky Flats was present to inspect the drum prior to transfer and participate in the examination of the drum. On June 4, 1970, the examination was performed at the ARA II hot cell.

The fire drum contained a 30-gallon drum inside a 55-gallon drum. It appeared the annular space between the drums was filled with sand. The materials removed from the inner drum included broken glass (jars), dirt, rocks, paper, plastic, plastic rods, insulation, and several other metal components. Much of the paper consisted of ice cream cartons lined with plastic, some of which contained turnings. At about the mid-point of the inner drum, a "large solid object" was encountered in the drum that instantaneously burst into flame. The object was removed from the drum and extinguished. Subsequent examination indicated the material to be a "porous brown plastic type material plus a shiny substance which appeared to be melted metal". Another description states the material that burned was on a bundle of plastic rods. The bottom portion of the inner drum contained numerous jars and bottles, some capped and some broken. Metal shavings were encountered and one jar was labeled as LiO2.

Samples were taken of the contents of the drum including the object that burned in the hot cell. A sample from the burned item in the hot cell was analyzed at the Chemical Processing Plant indicated mostly natural uranium and a trace of beryllium but no lithium. These samples, the drum, and drum contents were returned to Rocky Flats for further evaluation and analysis. The drum was received at Rocky Flats, September 25, 1970.

The October 23, 1970 Rocky Flats letter provided the preliminary analysis from 24 different samples (as stated above), identifies the drum as originating in Building 444 and buried in November 1955 in a trench area north of the Rocky Flats 903 area. In the fall of 1968, the barrel was accidently uncovered and the lid removed during grading operations. A new lid was installed and the drum placed in above ground storage. In October 1969, the barrel was moved to Building 663 and subsequently shipped to RWMC in February 1970.

The October 23, 1970 Rocky Flats letter indicated a final report would be available in December 1970. This limited investigation by the CA Team did not recover any final report concerning the Rocky Flats analysis and interpretation of the results.

In summary, based on the recovery of additional information from the June 1, 1970 drum fire at RWMC, nonroaster oxide waste materials from Building 444 can be pyrophoric or reactive which is addressed in RC-1.

The Root Cause Team's evaluation of the three previous similar events indicated that some actions taken from each of these events were not fully effective. If a more thorough review would have been conducted of these events' corrective actions, mitigation or prevention of the ARP V drum event would have been achieved. The WIPP 2014 radiological event is described in Contributing Cause 7, the 2017 box line fire is described in Contributing Cause 3 and the June 1970 RWMC fire is addressed in RC-1 as a missed opportunity for including the 1970 fire in AK documentation.

3.10 Extent of Condition

3.10.1 Purpose

The "extent of condition" evaluation utilizes up-front information that is known about the problem and the context in which it occurred, including what failed and the consequences and locations that might be vulnerable to similar issues.

This evaluation determines if the same (or similar) condition involved in this consequential event may exist elsewhere within the Fluor Idaho enterprise. The extent of condition evaluation is conducted early in the investigation and establishes the bounds of the investigation.

3.10.2 Extent of Condition Evaluation Approach

The evaluation starts with a statement of the condition to be evaluated for extent. In this event, the condition statement is:

> *Four containers of solidified radioactive and hazardous wastes breached in the ARP V building on the evening of 04/11/2018.*

The evaluation considers a defined "object" that has a defined "defect." In this event, the object and defect are defined as follows:

Object: Containers of repackaged solidified radioactive and chemical wastes ("daughter" containers)

Defect: The presence of uranium-238

The analysis starts by considering the object and defect in the location at which the event occurred, and proceeds through consideration of other locations at which the same object could be present with the same defect ("same-same").

The analysis then identifies:

- "Similar" objects that might pose a similar risk (for example, containers of radioactive and chemical waste that have not been repackaged)
- "Similar" defects that might pose a similar risk (for example, the presence of other materials with pyrophoric properties, or combinations of materials that are chemically incompatible).

The analysis then considers locations where:

- A "similar" object with the "same" defect might be present ("similar-same")
- A "same" object with a "similar" defect might be present ("same-similar")
- A "similar" object with a "similar" defect might be presented ("similar-similar").

This evaluation was initially conducted based on "best available" information early in the investigation, and later refined using information provided by the RH/CH TRU Program manager in mid-August.[a]

3.10.3 Extent of Condition Evaluation Summary

The scope of the evaluation included all waste containers in SD-176, -177, -178, -179, and CW-216, and related secondary waste containers.

"Similar Objects" considered include:

- "Parent" containers of radioactive and chemical wastes
- Material on process trays
- Containers of "secondary wastes" (specifically, wastes produced in the course of processing SD-176 through SD-179).

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a. E-mail, J. McCoy to M. Fecht, S. Crowe, G. Sprenger, and R. Swanson dtd 08/10/2018, subj: "Re: ARP V EOC Information – Drum Data"

“Similar Defects” considered include:

- Other pyrophoric material
- Combinations of materials that are chemically incompatible.

The potential for similar events from other pyrophoric material and/or combinations of materials that are chemically incompatible was monitored by Fluor Idaho, for several months following the event, through temperature monitoring of all waste containers from the evaluated population. As of the conclusion of this recommended corrective action (RCA), temperature monitoring has been discontinued on the basis that none of the monitored waste containers exhibited a temperature rise over the months they were monitored. Risks imposed by the potential for other pyrophoric materials, and/or for incompatible chemicals, will be managed by revisions to handling and processing procedures.

The Extent of Condition evaluation table is found in Appendix E: Extent of Condition.

3.11 ISMS Core Function Analysis

A review of the ISMS core functions was completed. The ISMS core functions, as shown in PDD-1004, “Integrated Safety Management System,” are presented in BOLD in the following list.

3.11.1 Define the Work Scope

Missions are translated into work, workers are involved in work planning to improve hazard analysis, work boundaries are established, expectations are set, tasks are identified and prioritized, and resources are allocated.

Investigation into the ARP V drum event identified that, although work was generally identified in TPRs and MCPs, when applied to SD-176 through SD-179 the defined work scope did not adequately describe the work to be performed.

This weakness is addressed by JONs 4, 9 11 and Recommended corrective action (RCA) for CAQs 4 and 9.

3.11.2 Analyze the Hazards

Hazards associated with the work are identified, analyzed, and categorized.

Investigation into the ARP V drum event identified that numerous potential hazards have not been identified or analyzed. Specific examples include the presence of nonroaster oxide pyrophoric and the potential chemical incompatibilities within SD-176.

This weakness is addressed by JONs 1, 2, 3, 4, 5, 9, 10, 11, 13 and 16.

3.11.3 Develop and Implement Hazard Controls

Applicable standards and requirements are identified and agreed upon, controls to prevent/mitigate hazards are identified, the safety envelope is established, and controls are implemented.

Investigation into the ARP V drum event identified that, although controls were developed to address known hazards within fully characterized waste streams, controls were not developed and implemented to address potential hazards related to SD-176 and SD-179.

This weakness is addressed by JONs 4, 6, 9, 10, 11, 12, 13, 16, and RCAs for SCAQ-2, CAQ-3, CAQ-8.

3.11.4 Perform Work within Controls

Readiness is confirmed and work is performed safely.

Investigation into the ARP V drum event identified several areas where work was not performed within existing controls while preparing to process SD-176, while executing the processes of shipping waste to ARP V, and in responding to the event.

This weakness is addressed by JONs 16, 17, and RCAs for SCAQ-1, SCAQ-2, CAQ-8.

3.11.5 Provide Feedback and Improvement

Feedback information on the adequacy of controls is gathered, opportunities for improving the definition and planning of work are identified and implemented, line and independent oversight is conducted, and, if necessary, regulatory enforcement actions occur.

Investigation into the ARP V event identified weaknesses in the area of feedback and improvement. Post-job reviews were rarely conducted. Some workers were not comfortable in bringing forward concerns due to a reluctance to adversely affect production.

This weakness is addressed by JONs 7, 8, 14, 15, 16, 19 and RCAs for SCAQ-1, SCAQ-2, CAQ-2, CAQ-9.

3.12 Extent of Cause

The ARP V drum event was a significant event. When a significant event occurs and pervasive weaknesses are identified with how core processes are managed (RC-1), the potential extent of cause includes each related facility. In this case, each Fluor Idaho facility falls within the potential extent of cause for RC-1.

Safety culture is by DOE definition:

> *Safety culture is an organization's values and behaviors modeled by its leaders and internalized by its members, which serve to make safe performance of work the overriding priority to protect the workers, public, and the environment.*

Organizational cultures, by their very nature, pervade the organization. When safety culture is causal, the extent of cause is the entire organization, plus related organizations that share commonalities. As was the case for RC-1, each Fluor Idaho facility falls within the potential extent of cause for RC-2.

CON 13 and JON 25 will address the corrective actions for the Extent of Cause.

The Extent of Cause evaluation implications for the Technical Teams results will be conducted after the Technical Team report is done, reviewed, digested, and evaluated for impact on this RCA report. And then, after receiving the Technical Team report, an Extent of Cause evaluation will be performed.

3.13 Interim Recommended Corrective Actions

The Root Cause Team recommended the following interim corrective actions to be taken and added to CAR 119255.

The section below presents the Root Cause Team's recommended corrective actions provided to Fluor Idaho on June 25, 2018.

1. Recommended Interim Corrective Actions (CAR119255)
    a. Root Cause Team recommends the following Interim corrective action be taken and added to CAR 119255.
2. Revise Technical Procedures to ensure that personnel hazards are effectively implemented.
    a. TRUW documents should be revised to include detailed information for the activities to be conducted in ARP VIII.
    b. AK data
    c. Chemical compatibility
    d. Recognition of potentially pyrophoric U
    e. Independent reviews to evaluate recognition of noncompatible hazards
3. Discuss with personnel
    a. Follow procedures
    b. Schedule pressure will not circumvent implementing requirements
    c. Use only approved documents
    d. Understand what type of waste you are handling
4. Develop a change management plan to address implementation of actions above and contained in ESS to include:
    a. Evaluate previous lessons learned and implement corrective actions to prevent ARP VIII events
    b. Assign appropriate management oversight (SSW) of the process
    c. Validate that TPRs include necessary requirements for the work being performed
    d. Provide detailed Training to personnel implementing the TPRs
    e. Conduct a Pre and Post job brief with management oversight to ensure expectations are being met
5. Assign managers for AMWTP/ARP/Fire Department to discuss lessons learned from the drum event on the following:
    a. Daily activities that were performed at ARP
    b. Provide RCTs training on the ARP projects
    c. Provide ARP/AMWTP and the Fire Department on lessons learned from the drum event concerning their response to the drum event

6. Run an emergency drill at ARP on the backshift to include the FD

7. Revise EAR 246 to include lessons learned from the drum event

8. Validate the Fire Department understands their lessons learned
   a. Do not enter a radiological building without implementing their Radiological procedure
   b. Do not enter a radiological building without Operations present
   c. Do not stir a radiological drum
   d. When the order for backing out of a location is given, that order should be implemented immediately

9. Direct Operations to effectively communicate the urgency of supporting the fire department.

10. Direct Operations to maintain logs of actions being taken

11. Discuss with all AMWTP RCTs understand the difference e between using a PAPR and SCBA for entering an area where there is a fire

12. Discuss with all AMWTP RCTs proper doffing locations when there is an airborne concern

13. Discuss with Emergency Management personnel the importance for making conservative decisions while implement the EALs

4. COMPLEX PICTURES

Figure 9. Drum area.

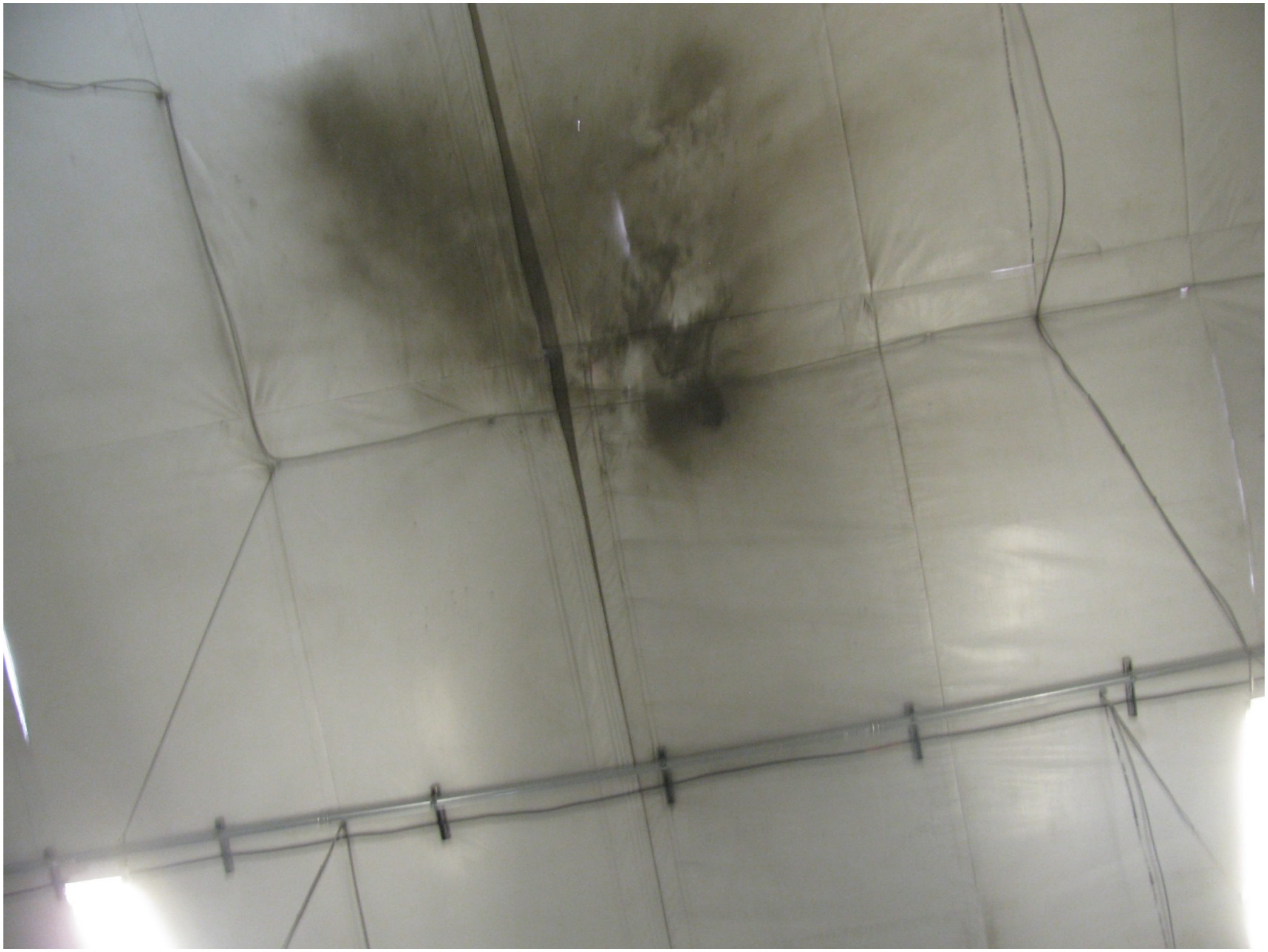

Figure 10. ARP V ceiling.

Figure 11. Drum pictures.

Figure 12. Drum event.

Figure 13. Drum pictures.

Figure 14. Drum pictures.

Figure 15. Drum lid.

Figure 16. ARP V airlock.

Figure 17. Ventilation pre-filters.

Figure 18. Tray 299.

Figure 19. Tray 268.

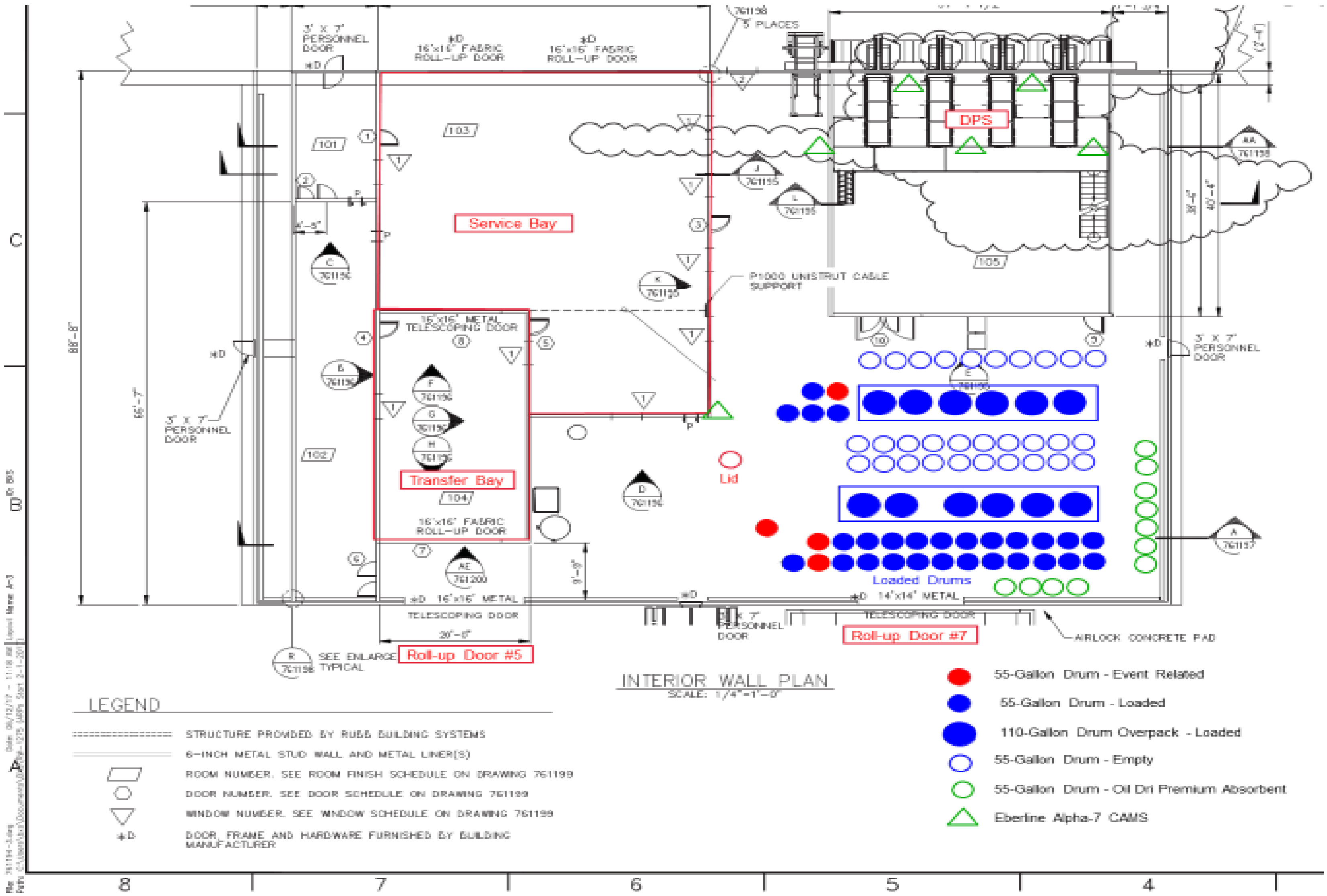

Figure 20. Post-drum layout.

Figure 21. ARP V facility pictures.

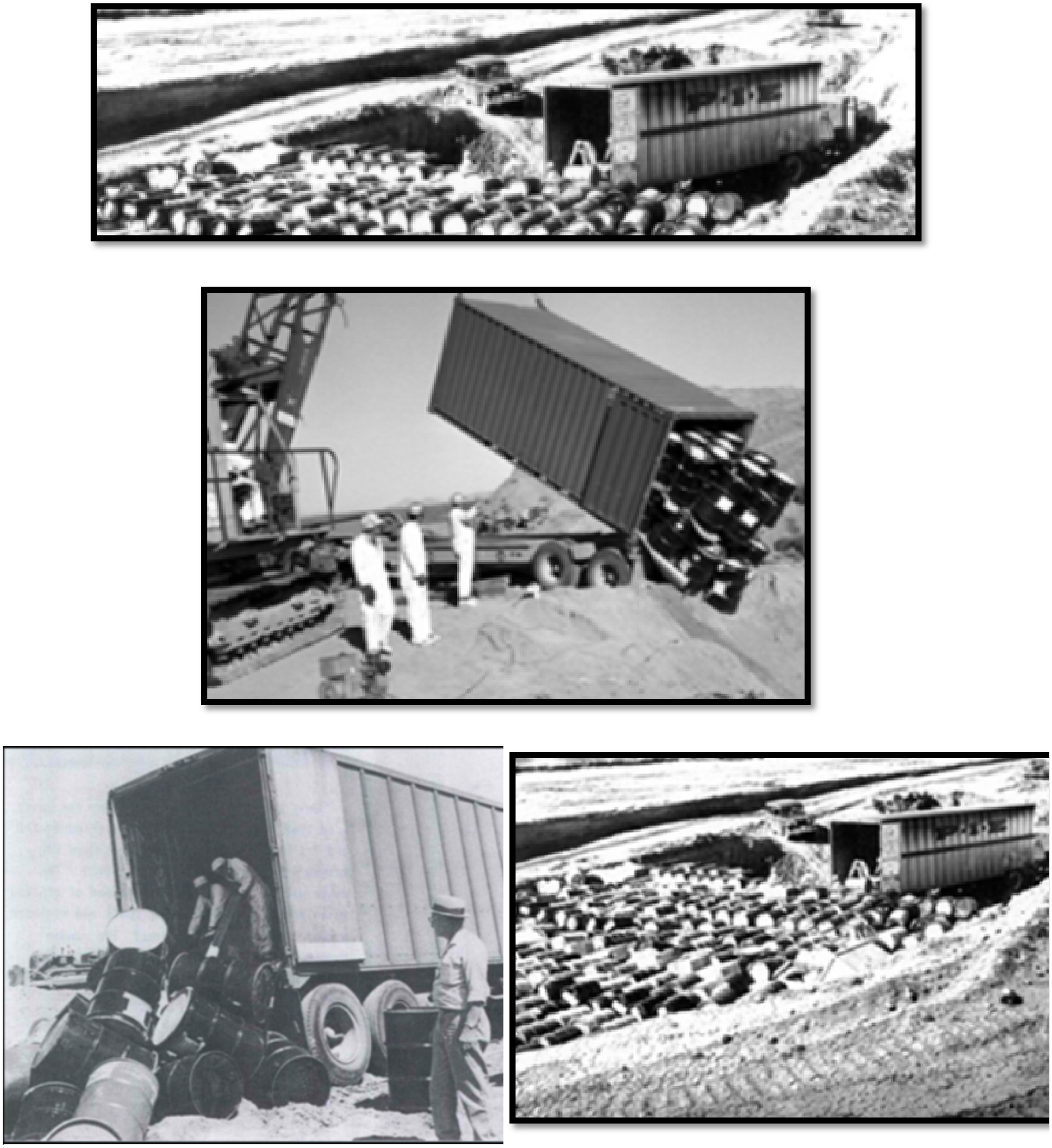

Figure 22. Historical pictures.

5. REFERENCES

1. Phase 1 Remedial Design/Remedial Action Work Plan for Operable Unit 7/13/14, DOE/ID-11389, Revision 2, June 2013.

2. A History of the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory, WM-F1-81-003, Revision 2, July 1984.

3. Historical Background Report for Rocky Flats Plant Waste Shipped to the INEEL and Buried in the SDA from 1954 to 1971, ICP/EXT-04-00248, Revision 1, March 2005.

4. Acceptable Knowledge Document for Pre-1980 INL-Exhumed SDA Waste, RPT-TRUW-91, Revision 2, February 2014.

5. Early Waste Retrieval Final Report, TREE-1321, August 1979.

6. Initial Drum Retrieval Final Report, TREE-1286, August 1978.

7. Acceptable Knowledge Document for INL Stored Transuranic Waste-Rocky Flats Plant, RPT-TRUW-56, November 2014.

8. Central Characterization Program Acceptable Knowledge Summary Report for Waste Retrieved from Designated Areas within the Subsurface Disposal Area at the Idaho National Laboratory, CCP-AK-INL-001, Revision 12, August 2013.

9. Kirk M. Green email to Timothy E. Venneman, Pits 11 & 12, October 20, 2009.

10. History of the SD-176 Waste at the INL RWMC, 4/26/18, Revision 1, author not identified.

11. TPR-7997, "Visual Examination Activities at RWMC," Revision 3, 01/19/18.

12. Chapter 2-Safety Analysis Report for the Radioactive Waste Management Complex-Accelerated Retrieval project, SAR-4, Revision 27.

13. HWMA Storage and Treatment Permit for the Idaho Nuclear Technology and Engineering Center, and the Radioactive Waste Management Complex on the Idaho National Laboratory, Volume 18. PER-109, Book 3.

14. Steve Carpenter draft section 2.4 review comments, July 19, 2018.

Appendix A

List of Personnel Contacted

Appendix A

List of Personnel Contacted

The Cause Analysis Team contacted or interviewed or contacted the following personnel during this causal analysis:

- RWMC/ARP RadCon Supervisor
- Technical Investigation Team
- RWMC/ARP Administrative Assistant
- Director Performance Assurance
- BEA Operations Manager
- RCT
- RWMC/ARP Senior Project Manager
- RH CH TRU Manager
- AKE Manager
- Vice President/Project Director Fluor Corp
- RWMC/ARP Project Manager
- RCT
- Chemist/Technical Expert
- IWTU Engineer
- Quality Assurance
- RH TRU Programs
- RH CH TRU Chief Engineer
- SRS Closure Program Manager
- Battalion Fire Chief
- WGS Waste Control Specialist
- Senior RCT
- Subcontracts Manager
- RWMC/ARP IH IS Manager
- AMWTP Operator
- AMWTP operator
- Battalion Fire Chief
- Battalion Fire Chief
- RadCon Engineer
- AMWTP Operations Manager

- RWMC/ARP RadCon Manager
- DOE
- RH/CH TRU Executive Manager
- RWMC/ARP Engineering Manager
- Waste Packaging and Transportation Manager
- Environmental WGS Sampling lead
- Director Process Engineering
- Nuclear Safety
- RWMC/ARP Operations Manager
- Nuclear Safety/Criticality Safety Department Manager
- Engineering and Design Manager
- RCT
- Packaging and Transportation manager
- Director, Supply Chain Management
- RWMC/ARP Operations
- AMWTP Engineering
- RWMC/ARP RadCon Engineer
- Engineering Programs
- BEA Firefighter (5)
- Waste Management Manager
- RWMC Project Environmental Lead
- RCRA Permitting Project Environmental Lead
- Environmental Compliance Manager
- Environmental Programs Manager
- Nondestructive Assay Expert Technical Reviewer
- Previous DOE Managers
- Former ITG Program Manager

Appendix B

List of Documents Reviewed

Appendix B

List of Documents Reviewed –

Document Number	Document Title	Document Revision
119250 CAR	Corrective Action Report/ Conduct of Operations	NA
119255 CAR	Corrective Action Report/Crit Safety	NA
DE-EM-0001467	AMWTP Statement of work	NA
DOE-EM-4.21-01	Chemical evaluation for trans waste at WIPP	NA
DOE-G-4501-4-1-C	Safety Culture Focus/Common Language	NA
DOE-HDBK-1081-94	DOE Handbook	NA
DOE-O-225.1B	Accident Investigations	NA
DOE-O-435.1	Radioactive Waste Management	NA
DOE-M-435.1-1	Radioactive Waste Management Manual	NA
DOE-5820.1	Management Transuranic Contaminated Material	NA
DOE/WIPP-02-3122	Transuranic Waste Acceptance Criteria for The Waste Isolation Pilot Plant	REV 8
EAR—246	RWMC Respond to Fire	Rev 19
EAR-278	Hazardous Substance and Waste Spill Control	Rev 7
EDF-0822	RWMC Criticality Safety Requirement documents involving SRP	Rev 6
EDF-5307	Chemical compatibility and inventory Evaluation for ARP	Rev 1&2
EDF-6750	RWMC accident analysis info based on AK	Rev 5
EDF-8723	Allowable Nitrate salt concentration in ARP waste	Rev 2
EDF-9908	ARP Evaluation of roaster oxides	Rev 0
EHA-30	Emergency Management Hazards Assessment	Rev 8
EPI-13	Operational Emergency Categorization/Classification and Protective Actions for RWMC	Rev 16
ESS-167	Evaluation of the Safety Situation for the drum event	Rev 0
GDE-318	SDA Targeted and Non targeted waste guide	Rev 8
GDE-630	ICP HPI	Rev 0
HAD-453	*Combination Fire Hazards Analysis & Fire Safety Assessment for WMF-1617.*	Rev 9
IAG-592	Roles and responsibilities for SRP for transfers from ITG and CWI	Rev 0-10
IAS-1555	Resumption of sludge drum repackaging at WMF-1617	NA
IAS-13557	Contractor readiness assessment for startup of SRP at WMF-1617	NA
IAS-13567	Review of safety culture assessment results	NA

Document Number	Document Title	Document Revision
IAS-16677	WIPP –WAC Compliance	NA
ICP/EXT-04-00248	Historical background for RF waste shipped to the INL, Buried in SDA from 1954-1971	Rev 1
ICP-1547	Safety Analysis refresher training	Rev 0
ID-C101	RA Chemical Evaluation and RCRA hazard analysis	Rev 2
IDC-176	Waste at INL	Rev 1
INST-OI-114	Liquid remediation of inorganic sludge	Rev 3
ITGEST-2414-002	Cost estimate support data summary	NA
LA-UR-15-28116	Thermal analysis of WIPP and LANL waste drum	NA
MCP-135	Document Management	Rev 43
MCP-1414	Change control	Rev 16
MCP-1405	Overall Management of Projects for ICP	Rev 15
MCP-1519	Project requirement change implementation	Rev 14
MCP-2374	Formal Analysis and calculations	Rev 27
MCP-2726	Respiratory protection	Rev 23
MCP-3003	Performing pre job briefings and documenting feedback	Rev 22
MCP-3562	Hazard Identification Analysis and control of operational activities	Rev 16
MCP-3930	Repackage Project Waste transfers between AMWTP and ARP	Rev 10
MCP-4004	TRU Waste Certification	Rev 3
MCP-4010	Collection Review and Management AK documentation	Rev 2
MCP-4015	Preparation of chemical compatibility	Rev 2
MCP-4225	TRU program AK Container Evaluation process	Rev 0
MCP-4226	TRU Programs site project office process	Rev 0
MCP-9141	Tenant use agreements	Rev 5
POL-143	Change management for ICP	Rev 2
PLN-260	ICP radiation protection program	Rev 14
PLN-720	Environmental surveillance plan	Rev 15
PLN-4308	Waste management plan for SRP at WMF-1617	Rev 3
PLN-4669	Implementation Plan for PER-109, Book 3, HWMA Storage and Treatment Permit for the Idaho Nuclear Technology and Engineering Center and the Radioactive Waste Management Complex on the INL	Rev 2
PLN-5198	Certification Plan for INL transuranic waste	Rev 1
RF-P559	Chemicals	NA
RF Report-1599	Hazardous radiological characterization of Sludge	NA

Document Number	Document Title	Document Revision
RFP-4873	Potential of Uranium	NA
RPT-1154	Health and safety plan SRP at WMF-1617 and DRP at WMF-1619	Rev 2
RPT-1552	RWMC WMF-636 Drum corrosion history	NA
RPT-ESH-014	Chemical compatibility Evaluation of waste for AMWTP	Rev 9
RPT-TRUW-05	Waste Matrix code reference manual AMWTP	Rev 30
RPT-TRUW-05	Waste matrix code reference manual AMWTP	Rev 41
MP-TRUW-8.1	Certification plan for INL transuranic waste AMWTP	Rev 27
RPT-TRUW-12	Waste stream designations for AMWTP	Rev 24
RPT-TRUW-91	AK document for pre 1980 INL exhumed SDA waste for AMWTP	Rev 2
RPT-TRUW-94	AK summary for AMWTP combined repackaged project	Rev 0
RPT-TRUW-97	AK Document for INL SRP combined sludge waste	Rev 0
RPT-190	Independent Investigation report for drum fire at INL 2005	NA
RPT-1639	Formal cause analysis report for event in WMF-676	NA
RPT-1648	ALPHA 7 CAM data for ARP V Drum breach	Rev 0
SAR-4	RWMC Nuclear Safety basis	Rev 27
SOP 2.4B.1	Structural Engine Company Operations	
SOP 2.5E.8	Radiological Response	
SOW-514	Revision of chemical compatibility for ICP	Rev 4
TEM -8	Template for inter face agreements	Rev 6
TEM -176	Self-assessment of SRP RCRA	Rev 1
TPR-7420	ARP waste retrieval	Rev 60
TPR-7601	RWMC Waste Handling and Over packing	Rev 67.68.89
TPR-7866	SRP DPS waste packaging	Rev 18
TPR-7867	SRP RA V Waste processing	Rev 9.16
TPR-7988	Debris Waste Processing	REV 7
TPR-7990	Debris DPS Waste Packaging	REV 5
TPR-7997	VE at RWMC	Rev 3
TPR-8103	Non Facility VE	Rev 2
TRS-008	RWMC ARP V event	
TRS-4	Safety requirements for RWMC ARP	Rev 19
TREE-1321	Early waste retrieval report	
WM-F1-81-003	ITR for RWMC	Rev 2
NA-AK	Acceptable Knowledge Documents	Rev 12

Document Number	Document Title	Document Revision
NA-AK Info	Acceptable Knowledge MISC reports	
NA- Assessment	Assessment of RW radioactive waste	
NA-Cause analysis	Cause analysis, matrix and documentation	
NA-DCR	Document change requests	
NA-DRF	Document revision forms	
NA-DOE	DOE Information	
NA-Email communications	Communications via email	
NA-Engineering	Engineering Path forward	
NA-Event reports	Timelines, fact findings, Pre job briefs	
NA-Explosion at NTS	Accident report of explosion at NTS	
NA-FD	INL Fire Department notes from interviews, reports	
NA-Hanford Explosion	Occurrence report from Hanford explosion	
NA-INPO	Preform test or evolutions	
NA-Inspection	Surveillance report	
NA- CBFO	Interview notes	
NA-MWV’s	Management work place visits	
NA-PDE	Paducah Drum Explosion	
NA-PCF	Proposed change forms	
NA-Radiological	RWP	
NA-RCRA permit	Permits	
NA-Training	RWMC access training	
NA- Self assessment	2016 AMWTP Performance assessment report	
NA-SRP	SRP containers	
NA-VE	VE data sheets	
NA-WDDF	Waste determination and disposition forms	
NA-WIPP	WIPP Training	
LA-UR-15-26657	Over Pressurized Drums – Their Causes and Mitigation - LLNL-JRNL-419445	R0
DOE/EH-0697	Gas Buildup in Drums	NA

Appendix C

Comparative Timeline/Change Analysis

Appendix C

Comparative Timeline/Change Analysis

The Comparative Timeline is an enhanced variation of the usual timeline chronology frequently used in significant event analysis. The Comparative Timeline included: what happened, what should have happened, significance, failed or ineffective barriers, why the barriers failed, and recommended corrective actions to restore barriers. This tool organized the event information and provided a collective source of information to identify differences between what happened and what should have happened, and to determine the significance to the organization of these differences. The Comparative Timeline catalogues the behaviors and condition that shaped the event, and organizes the information for use by other tools to determine what made the project fail. The Comparative Timeline is an evolved form of a change analysis tool.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
5/2009	RPT-TRUW-05 Rev 21 discusses initial information on IW-179, 176, 177,and 178.	OK	None. IW was the first identifier used for RWMC waste from the early projects.	
~2010	BBWI initial process was to run sludge in the south box line and debris in the north box line.	OK		
2012	BBWI turns project control over to ITG.	OK	Responsibility for project control was reassigned.	
2012	ITG reduces AK staff and AK field personnel from approximately 30 people to approximately 2 people.	Maintaining AK staffing level would ensure day-to-day oversight of field activities; ability to address waste issues; and perform programmatic development of AK for all remaining AMWTP waste streams.	Lack of resources insufficient to ensure all needed AK activities are addressed.	Insufficient AK staff to perform needed activities. Fluor identified and initiated hiring AK staff at contract transition June 1, 2016.
2012	DOE/ITG/CWI decides to use ARP V as the treatment facility for waste sludge.	OK	HEPA filter facility re-purposed to meet need.	

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
8/15/2012	IAG-592, Rev 0 Roles and Responsibilities for SRP between ITG issued. Contained procedure like steps for compliance. Listed approved IDCs.	Use of a TPR or other technical procedure should have been used for implementing SD-176.	First result of using an IAG as a procedure. No USQ performed. DOE recommended an IAG instead of using the procurement process.	**Set-up Factor:** Created stovepipe communication process Use of the IAG did not allow a USQ to be performed.
	IAG-592 states what IDCs can be processed from AMWTP to RWMC. Did not include SD-176 until rev. 10.	OK		
	IAG-592 mis-applied as a TPR type procedure. DOE/ITG/CWI uses the IAG process instead of a TPR. A comprehensive TPR for the process was not developed This resulted in a condition where: The hazards associated with the varied constituents of the composite SD-176 waste were not fully evaluated, understood and mitigated (SD-176 was not included in the IAG.	A comprehensive TPR procedure/process should have been developed in which: Hazards associated with the varied constituents of the composite waste (SD-176) are evaluated, understood and mitigated.	A comprehensive TPR procedure/process is not in place. Hazards are not fully understood and mitigated	**Set-up Factor:** Hazards are not fully understood and mitigated. Workers exposed to unknown hazards while performing work.
08/2012	AMWTP RCRA permit narrowly focused on Roaster Oxides and does not address details in ICP/EXT-04-00248.	Existence of potentially pyrophoric material should have been known.		**Missed opportunity** to have identified potential pyrophoric controls.
10/18/12	RWMC HWMA/RCRA permit approved for treatment at WMF-1617 (ARP V).	OK	Authorized SRP to commence operation as a RCRA facility.	

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
10/18/12	ARP V changes from a CERCLA facility to a Resource Conservation Recovery Act (RCRA) facility.	OK		
10/18/12	RWMC HWMA/RCRA permit Allows contents of up to 3 drums may be processed on the sorting table at one time.	OK	Established limit of 3 drums on the sorting table.	**Set-up Factor:** Allowed mixing of parent drum content, contributed to the number of over-pressurized daughter drums on 04/11/2018.
10/18/12	RWMC HWMA/RCRA permit Does not address repackaging of UNKNOWN waste.	Repackaging of UNKNOWN waste should have been discussed or expressly prohibited.	No immediate impact.	**Set-up Factor:** repacking requirements for SD-176 through -179 remained undefined. **Missed Opportunity** to have defined requirements, limitations, and performance criteria for processing SD-176 through -179 undefined.
10/18/12	RWMC HWMA/RCRA permit allows liquid containers to be opened/crushed with the excavator to allow absorption to take place.	OK		
10/18/12	RWMC HWMA/RCRA permits contain requirements regarding ignitable, reactive, or incompatible waste.	OK		
10/18/12	RWMC HWMA/RCRA permit states "no issues of ignitability or reactivity have been identified in waste streams to be treated". RWMC HWMA/RCRA permit also states "Containers that have	Should have addressed "potential pyrophoric" in addition to "roaster oxides."		**Set-up Factor:** The possibility that pyrophoric could be in a form other than roaster oxides were not addressed.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	identified aerosol cans and roaster oxides waste will not be accepted for treatment."			
10/18/12	RWMC HWMA/RCRA permit relies upon waste characterization provided in Summary Report for Rocky Flats Immobilized Organic Liquids Stored at the Idaho National Laboratory, CCP-AK-INL-005, Revision 4, and other specific AK summary reports (Appendix C-3 and C-4) for the sludge waste streams to be received, stored, and treated at the RWMC.	OK		
10/18/12	No IDC waste streams in RPT-TRUW-12 are identified as reactive (D003).	Inclusion of potential other issues, such as reactive potential or other prohibited items of concern, would have made this information available to document users.	Personnel not fully informed of other issues beyond assignment of HWNs to IDCs.	**Missed opportunity** to build in controls and defenses into processing approach and procedures.
10/18/12	A few IDCs in RPT-TRUW-12 are identified as ignitable (D001) due to presence of nitrate salts or cyclohexane.	OK		
10/18/12	Waste streams were evaluated in accordance with RPT-ESH-014 for potential incompatibilities for inclusion in the RWMC HWMA/RCRA permit.	RPT-ESH-014 indicates TBD for hazardous constituents and N/A for Reactivity Group Numbers for SD-176.	No evaluation of SD-176 was performed.	**Missed opportunity:** Recognition that a chemical compatibility evaluation had not been completed may have triggered more detailed review and recognition that this was composite waste.
10/29/12	TPR 7867 SRP V Waste Processing Rev. 0 approved.	OK		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
11/13/12	IAS13557 Contractor Readiness Assessment for SRP conducted.	OK		
	CRA does not review the basis for the types (IDCs) of waste that was going to be processed.	CRA should have included a review of IDCs and verified compatibility with the SRP process as implemented.	SD-176 was not an approved IDC for SRP processing at this time.	**Missed opportunity:** Scope should have covered other waste that would be processed.
11/20/12	CWI received authorization from DOE to begin SRP.	OK	Waste processing at ARP V was authorized.	
11/2012	SRP begins with RF-003/743 organic sludge and continues through 03/2018.	OK	WIPP Approved waste stream	
	WIPP had approved waste stream RF-002/743 after verifying documentation, AK, and process requirements implementation as satisfactory.	OK		
12/2013	SRP IDC campaign of RF-002/743 inorganic sludge begins and continues through 03/2018.	OK	WIPP Approved waste stream.	
02/05/14	RPT-TRUW-91-Rev 2 AK document for PRE-1980 Exhumed SDA Waste approved.	OK	Established the approach for managing the SDA Exhumed Waste including the basis for HWN determination and addressed ignitability, corrosivity, and reactivity aspects.	**Set-up Factor:** Established a perception that waste was characterized adequately for processing in ARP V. Historically identified reactivity concerns were not recognized and communicated adequately.
02/05/14	RPT TRUW-91 Rev 2 lacks info on waste and refers reader to referenced documents.	RPT TRUW-91 Rev 2 should have contained more specific description of pyrophoric and reactive uranium from referenced reports and identified the risk of	No impact on known waste streams	**Set-up Factor:** Set the stage for processing unknown waste using IDC-179. **Missed Opportunity** to have identified potentially pyrophoric and reactive

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
		pyrophoric and reactive uranium in unknown waste streams; it did point to the reactive concerns- "uranium/roaster oxide".		uranium and chemical incompatibilities. Historical information on hazards has not fully been carried forward over time with creation of new documents.
	RPT-TRUW-91 Rev 2 issued. All potential prohibited items reflected in referenced AK source documents not included. Potential for adverse reactions on a case-by-case basis identified as concern for homogeneous solids. Potential reactive waste includes: "uranium/roaster oxide". Report references historical AK source document ICP/EXT-04-00248 which discusses June 1, 1970 RWMC drum fire. References point to nonroaster oxide materials in fire drum.	RPT-TRUW-91 Rev 2 should have included all potential prohibited items reflected in AK source documents. Report should have further evaluated June 1, 1970 fire which indicates nonroaster oxide waste from Building 444 potential to be pyrophoric and reactive uranium. These details should be reflected in RPT-TRUW-91.	All potential prohibited items are not identified in RPT-TRUW-91 Rev 2. Details from referenced documents are not included. Presence of non roaster pyrophoric material not identified/reported. Information not available for use in other AK documents or program/operations procedures.	**Missed opportunity** to evaluate and address prohibited items and potential for pyrophoric and reactive uranium in nonroaster oxide waste. Contributed to a lack of awareness of potential materials in the SD-176 waste **Set-up Factor:** Contributed to a lack of awareness of the presence and pyrophoric and reactive potential of depleted uranium and other materials from materials from RF-444 details nor complete list of all potential prohibited items.
2/14/2014	WIPP experienced a breach of a TRU waste container in the underground storage location which resulted in airborne radioactivity escaping to the environment.	Drum should not have breached.	Shutdown of waste shipments to WIPP.	Delays of meeting the Idaho Settlement Agreement.
4/2014	SRP Operations begins IDC campaigns RF-001/741, RF-002/742, RF-003/743, RF-800. Campaigns continue through 02/2016	OK	First time processing sludges that still required WIPP approval prior to shipping.	

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
4/22/2014	WIPP Phase 1 Accident Investigation Report Issued: Root cause of Phase 1 of the investigation of the release of radioactive material from underground to the environment was NWP's and CBFO's management failure to fully understand, characterize, and control the radiological hazard. The cumulative effect of inadequacies in ventilation system design and operability compounded by degradation of key safety management programs and safety culture resulted in the release of radioactive material from the underground to the environment, and the delayed/ineffective recognition and response to the release.	OK	ARP immediate actions: Project reviewed CON/JONs CWI expanded to all CWI scope later No record of ITG response.	ITG lack of response indicates a weakness in Safety Culture.
Spring 2014	Draft RFP for re-compete for the Prime Contract issued RFP/RFP process involved substantial scrutiny and comments regarding schedule performance against ISA milestones.	OK	Communicated that DOE considered schedule performance to be an important performance measure.	**Set-up Factor:** contributed to perception of schedule pressure that culminated in a cultural emphasis of schedule performance at the expense of safety and compliance.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	RPT-TRUW-05 Waste Matrix Code Reference Manual does not identify prohibited items in SD-176 Reference Table Special Notes. Prohibited items are identified in section 3.5.8 and section 6.5.1.3 of RPT-TRUW-91 but not reflected in the Reference Table.	Information for RTR/VE operators and validators should have included prohibited items and case-by-case evaluation for reactive material.	Pyrophoric and reactive potential of SD-176 waste steam not highlighted.	**Set-up Factor:** Potential for a pyrophoric and reactive event while processing SD-176 not recognized or addressed. **Missed opportunity:** to evaluate/revise comingling of waste during ARP V processing.
12/08/2014	RPT-TRUW-05, Rev 37, Waste Matrix Code Reference Manual, includes SD-176. The SD-176 Reference Table, Special Notes, does not reflect prohibited items identified in section 3.5.8. Section 3.5.8 references RPT-TRUW-91 but does not contain the same level of detail concerning prohibited items nor the reactive concerns identified in RPT-TRUW-91 section 6.5.1.3.	The reference table for SD-176 in the Special Notes section should have included information known about reactive waste concerns and prohibited items.	Personnel using or referring to the SD-176 Reference Table were not provided all pertinent information about prohibited items.	**Missed Opportunity:** Information known in AK documents was not fully carried forward and not include in the SD-176 Reference Table. Opportunity to inform personnel was lost. The ability to further evaluate and put in place mitigating actions or procedural controls was lost.
02/2015	DOE directed CWI to repackage an additional inventory of sludge drums (SD-176 not included in inventory). Contractor shall also prepare the ARP V sludge repackaging facility for processing IDC-002/742 (inorganic) sludge waste.	OK		
05/2015	ARP Mgt requested an independent assessment of SRP because WF-1617 had not been used for 8 months following	Independent assessment could have addressed the attributes of the future waste to be processed at SRP and	More robust controls may have been identified especially if the attributes of the waste were not well-defined.	Missed opportunity to recognize that the well characterized inventory of waste would be depleted and

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	completion of initial drum repackaging in June 2014. Scope of Independent assessment was to evaluate project "state of operability."	adequacy of criteria for acceptance.		less well characterized waste would need improved controls.
05/2015	Independent assessment scope does not consider what type of waste was going to be processed.	OK		
6/10/2015	CWI responds to DOE and identified actions to address WIPP Phase 2 report. CWI identifies 3 "Gaps" with additional actions needed.	CWI identified three GAPs with corrective actions: 1. Evaluate and implement as appropriate, more formal documentation of CWI review/approval of CCP CH TRU documents. 2. CWI will evaluate and modify as appropriate. Applicable procedures to address procedure weaknesses of prohibiting addition of secondary waste or materials. 3. Revise refresher training to include a discussion of lessons learned for Nuclear Safety personnel.	First opportunity to take thorough corrective actions to mitigate WIPP CONs.	**Missed Opportunity:** A lack of a thorough review and subsequent corrective actions identified in some CONs not being effectively addressed.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
6/18/2015	ITG responds to DOE and identified actions to address WIPP Phase 2 report. ITG information identifies 14 actions "in progress" (Trackwise issues validated to be closed during his investigation).	ITG identified 14 actions they needed to take. Actions such as participating in CBFO audits; ITG evaluate controls for secondary waste; Develop a requirements flow-down matrix; Evaluate document revision process to include a SME; and evaluation of the procedures to ensure critical process steps are documented in a quality manner appear to not be applicable to the WIPP CONs.	First opportunity to take thorough corrective actions to mitigate WIPP CONs.	**Missed Opportunity:** A lack of a thorough review and subsequent corrective actions identified in numerous CONs not being effectively addressed.
9/29/15	Contract DE-EM0001467 issued to ITG included: • Contractor shall treat waste to the most current WIPP WAC. • Complete characterization for ~2500 "unknown" containers that are currently in storage.	OK	Continued effort to support ISA milestone completion	**Set-up Factor:** Acknowledged "unknown waste quantity remaining on ISA milestone
	CWI did not implement MCP-1414, the procurement change control process for contract change.	The change control process should have been implemented.	Change control not implemented.	**Set-up Factor:** As related to ARP V processing of waste, health, safety, environmental, disposal, training, remediation and other project Impacts were not adequately reviewed.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
10/2015	DOE-EM-1 directed RCRA self-assessment to validate operating procedures that generate, package, or treat TRU waste and complied with the RCRA permits. Purpose of self-assessment was to ensure unauthorized hazardous waste streams would not be introduced into WIPP.	A critical self-assessment performed.	No findings were identified.	**Missing Barrier:** Not a self-critical assessment.
10/19/15	CWI notifies DOE that initial SRP Scope is complete.	OK		
11/05/15	DOE acknowledges SRP Scope Completion.	OK		
11/2015	RPT-ESH-014 Rev 9 provides chemical compatibility evaluation of AMWTP waste. Identifies IDCs SD-176, 177, 178, & shows the chemical compatibility as TBD and the Reactivity Group Numbers as N/A.	RPT-ESH-014 Rev 9 should have addressed chemical compatibility and reactivity for SD-176.	None until processing of SD-176 drums started.	**Failed Barrier:** Report did not contain essential information. **Missed Opportunity:** Completion of the report to include evaluation of SD-176 may have raised concerns that it was a composite waste stream and addressed potential items of concern. **Set-up Factor:** Established process that allowed SD-176 drums to be treated as unique IDC that was not generator and process specific.
11/2015	RPT-ESH-014 published in 11/2015, referenced the wrong revision of RPT-TRUW-12 Rev 13 instead of Rev 24.	RPT-TRUW-12 Revision 24 provided the HWNs identified for SD-176 and should have been used to perform the chemical compatibility in RPT-ESH-014.	Waste processing was planned without the benefit of a chemical compatibility evaluation being performed.	**Failed Barrier:** Report did not contain essential information. **Missed Opportunity:** Completion of the report to include evaluation of SD-176

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
			Evaluation of SD-176 may have raised concerns that it was a composite waste stream and addressed potential items of concern.	may have raised concerns that it was a composite waste stream and addressed potential items of concern. **Set-up Factor:** Established process that allowed SD-176 drums to be treated as unique IDC.
11/05/15	CWI RCRA self-assessment did not identify any findings. Specifically, self-assessment failed to identify potential for generating repackaged waste containing pyrophoric and reactive uranium.	CWI RCRA self-assessment should have identified implicit assumption that campaign 3 waste streams were same as those from earlier campaigns, when in fact the unknown origins created a potential for the waste stream to contain unidentified pyrophoric materials, including depleted uranium.	Potential for pyrophoric and reactive uranium in campaign 3 waste stream(s) remained unrecognized and unaddressed.	**Missed Opportunity** to have identified potential for pyrophoric and reactive uranium in campaign 3 waste stream. **Set-up Factor:** Potential for pyrophoric and reactive uranium remained unidentified.
11/05/15	On the basis of the self-assessment, ITG concluded that repackaging activities have sufficient controls to identify; handle, treat, and control mixed waste, when, in fact, the potential for pyrophoric and reactive uranium in campaign 3 waste stream(s) remained unrecognized and unaddressed.	OK	Potential for pyrophoric and reactive uranium in campaign 3 waste stream(s) remained unrecognized and unaddressed.	**Missed Opportunity** to have identified potential for pyrophoric and reactive uranium in campaign 3 waste stream(s).
12/02/15	Meeting with ITG/CWI/DOE ID/CCP on Chemical Compatibility.	OK		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
12/02/15 (same meeting continued)	ITG (AMWTP) proposed approach was to combine Pre-1980 SDA exhumed waste into "mega" waste streams RPT-TRUW-94 was effort to authorize processing of combined waste streams. WIPP disapproved mixed IDC (combined sludge waste stream) processing. In response, DOE Idaho decided to proceed with single IDC processing.	SD-176 should have been identified as a composite waste stream requiring additional evaluation and approval.	ITG proceeded with single IDC processing, as directed by DOE.	**Missed Opportunity:** Evaluation of SD-176 may have raised concerns that it was a composite waste stream and addressed potential items of concern.
12/02/2015	Letter from ITG notified to DOE by letter notifying DOE of a break in feed to SRP (C-2015-0353).	OK		
12/10/2015	DOE directed ITG to not allow a break in feed to SRP (AS-CMD-AMWTP/ITG-16-014).	OK	Continued effort to support ISA milestone completion	12/10/2015
	DOE directs ITG to fully evaluate and take action to ensure continued SRP feed. DOE states that there may be up to 910 untreated containers in AMWTP. These 910 containers would qualify for SRP processing with no AK changes needed. This was allowed W/O the full resolution of the chemical compatibility concerns on the AK.	OK		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
12/17/2015	ITG responds to DOE addressing the 12/10 direction. (C-2015-0385) ITG stated that ITG will continue to prioritize above ground inventory. Secondly, ITG evaluated new IDCs to ensure IDCs can be processed beginning 01/2016.	OK		
12/17/2015	ITG states that in order to keep SRP operating in the near term (specifically, to avoid a break in feed), ITG needs DOE Idaho approval of two accommodations.	Contractor asks for relief from requirements.	The contractor gets relief.	**Broken Barrier:** Safety Culture perception established that it is more important to keep processing than meeting requirements.
12/17/2015	Accommodation #1 to avoid break in feed: ITG will issue the revised AK with all additional IDCs W/O processing the AK thru the new CBFO review process. There is insufficient time to resolve CBFO comments prior to SRP feed running out. We cannot perform VE W/O an associated AK report.	Contractor asks for relief from requirements.	The contractor gets relief.	**Broken Barrier:** Safety Culture perception established that it is more important to keep processing than meeting requirements.
12/17/2015	Accommodation #2 to avoid break in feed: Repackaging operations must (1) continue to use current practice of absorbing liquids as found; (2) continue to allow some mixing of contents	Contractor asks for relief from requirements.	The contractor gets relief.	**Broken Barrier:** Safety Culture perception established that it is more important to keep processing than meeting requirements.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	between waste containers; and based on the way waste is processed through the mixing trough, the remains of one container may be mixed with another.			
12/21/2015	DOE response to ITG addressing the 12/17 letter (AS-CMD-AMWTP/ITG-16-018).	Contractor asks for relief from requirements.	The contractor gets relief.	**Broken Barrier:** Safety Culture perception established that it is more important to keep processing than meeting requirements.
12/21/2015	DOE allows ITG to issue AK RPT-TRUW-94 with the additional IDCs to perform VEs.	Should not have been used since CBFO rejected process.	Contractor continues processes at risk.	**Broken Barrier:** Safety Culture perception established to continue production.
12/21/2015	DOE letter directs that RPT-TRUW-94 cannot be used for waste certification until CBFO provides concurrence.	OK		
12/21/2015	DOE concurred with ITG approach represented in C-2015-0385 and acknowledges that repackaging operations will continue the practice of absorbing liquids as found.	DOE provides relief from requirements	The contractor gets relief.	**Broken Barrier:** Safety Culture perception established that it is more important to keep processing than meeting requirements.
12/21/2015	DOE acknowledges that some mixing of contents between waste containers will occur.	DOE provides relief from requirements	The contractor gets relief.	**Broken Barrier:** Safety Culture perception established that it is more important to keep processing than meeting requirements.
12/21/2015	DOE directs ITG to campaign waste by individual IDCs, not by groups of compatible IDCs.	OK		
12/21/2015	DOE directed that only one IDC is to be processed at a time to preclude any possible blending	OK		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	of waste between IDCs and will minimize risk while chemical compatibility issues are being resolved.			
01/18/2016	Draft Chemical Compatibility assessment, prepared by ITG, was performed on waste inventory for SRP. This assessment does not identify SD-176 as being evaluated as an issue. ITG viewed as "Not as relevant now because of campaigning IDCs". IDC-176 not included. RPT-TRUW-94 not issued.	Should have recognized that chemical compatibility assessment remained relevant when dealing with waste streams from unknown sources.	Information used in decision making process on waste was not complete.	**Broken Barrier:** Allowed the acceptance of waste for which there was not an adequate chemical compatibility performed.
01/18/2016	Process was not developed to treat unknown waste in ARP V.	A thorough analysis of the hazards associated with the potential unknown waste constituents should have been performed. The results of the hazard analysis should have been used in developing a process to treat the unknown waste.	Allowed waste to be treated in ARP V without sufficient controls in place to mitigate existing hazards.	**Set-up Factor:** Created the situation where depleted uranium and as other potential unidentified hazards are present in ARP V and in resulting treated drums. **Missing Barrier:** In addition to creating the conditions necessary for this event, this also presented a potential unidentified threat to ARP V workers. **Missing Barrier:** Process was not developed to treat unknown waste in ARP V. **Missed Opportunity** to have prevented or mitigated the event.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
01/18/2016	1 of the 2 conditions from the 12/21/2015 DOE memo was not Implemented. Condition #1 - contractor will issue the revised AK with all additional IDCs W/O processing the AK thru the new CBFO review process. There is insufficient time to resolve CBFO comments prior to SRP feed running out. We cannot perform VE W/O an associated AK report.	Condition 1 from the 12/21/2015 DOE memo should have been implemented.	A revised AK with all (including IDC-176) was not issued.	**Set-up Factor:** Allowed for processing of IDC-176 waste without an issued AK which included SD-176.
01/26/2016	ITG informs CWI that RPT-TRUW-94 will not be issued and ITG will not be sending any waste not addressed in draft RPT-TRUW-94. Draft contains the applicable HWNs for CWI use.	RPT-TRUW-94 should have been issued as directed by DOE.	CWI uses a draft report RWMC RCRA Permit uses RPT-TRUW-94 (Draft) as a reference for three revisions.	**Set-up Factor**: Contributing to the culture of not using approved processes. Inaccurate RWMC RCRA Permit.
02/02/2016	ITG approves WDDF RWMC 15005 Section I, Process Knowledge Evaluation. Potential prohibited items not complete and potential for reactive waste not reflected in WDDF.	A complete list of prohibited items should have been implemented.	Incomplete documents used.	**Set-up Factor**: Reactive waste not identified**.**
02/03/2016	CWI approved WDDF RWMC 15005 to allow movement of SD-176 waste from AMWTP to ARP V. Detailed review of SD-176 was not performed due to RPT-ESH-014 marking N/A for SD-176 chemical compatibility.	SD-176 should have been reviewed for chemical compatibility.		**Broken barrier:** Form was approved based on flawed procedure (RPT-ESH-014).

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
02/04/2016	CWI requests ITG to address chemical compatibility questions and double check IDCs not listed.	ITG processes should have identified the issues being raised by ARP V.	Conditions for accepting SD-176 and compliance with IAG-592 criteria not met. CWI rejects the waste based on not meeting the criteria.	**Broken Barrier:** Lack of communications allowed for acceptance of waste for which there was not an adequate understanding of the attributes of the waste or potential hazards.
02/9/2016	CWI notifies ITG that approved RPT-ESH-014 will be used for "non-mixed IDCs."	RPT-ESH-014 should have been evaluated to confirm all intended IDCs for transfer to SRP had been addressed.	SD-176 was not addressed or evaluated in RPT-ESH-014.	**Bypassed Barrier:** Allowed for acceptance of waste for which there was not an adequate understanding of the attributes of the waste or potential hazards.
	Decisions were made and tasks were performed based on unapproved documents and e-mails rather than approved procedure(s).	Decisions should be made based on approved documents and tasks would be performed to an approved procedure.	Work performed based on unapproved documents.	**Set-up Factor:** Unapproved RPT-TRUW-94 was used as basis for ARP to allow processing: Management did not recognize document was a CBFO rejected draft. This led to ARP continuing to use the process used for fully characterized waste while processing the not fully characterized waste contained in SD-176.
02/12/16	RCRA permit revised that referenced AK Report RPT-TRUW-94 (draft) which described CWI's intent to repackage 'Combined Homogeneous Solids Repackage Project' at ARP V. SD-176 was to be included in this 'Combined Homogeneous Solids Repackage Project'.)	A thorough review performed that would have not included a DRAFT report reference.	ARP V began processing SD-176 waste on 3/10/2016 based upon the draft AK document RPT-TRUW-94. Processing SD-176 without a comprehensive CCE, without recognition of the potential for pyrophoric and reactive uranium in nonroaster waste; and without a clear defined	**Missed Opportunity** to question missing information.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
			path to disposal created a daughter waste stream with potential safety, compliance and acceptability issues.	
	RCRA permit was prepared using inadequate information and referenced a Draft report.	RCRA permit should have been prepared using approved/verified information.	RCRA permit based on inaccurate/incomplete information.	**Set-Up Factor:** RCRA permit did not include necessary information for chemical compatibility.
03/01/16	IAG-592 Rev 10 Roles and Responsibilities for SRP/ITG and CWI revised to add SD-176.	Recognition of processing an unknown waste was different than what had previously been approved and the process revised.	Processing unknown waste the same as known waste would allow potential pyrophoric and reactive metals and incompatible chemicals to be shipped to ARP V.	**Set-up Factor:** Allowed entry of SD-176 into facility to be processed. **Missed opportunity:** Last opportunity to review and question IDC.
	Communications and processes did not emphasize the composite nature of IDC-SD-176 not being generator-specific and process-specific.	SD-176 should not have been included in the new population of SRP feedstock.	Composite nature of IDC-SD-176 was not emphasized.	**Set-up Factor:** Contributed to the assumption that SD-176 was "just another IDC."
03/01/2016	Step 4.4 of IAG 592 states that potential pyrophorics will not be transferred to CWI.	OK		
03/01/2016	IAG-592 screened by USQ process but was marked as "Categorically Excluded".	Due to specific steps/requirements contained within the IAG, it should have been a procedure and entered into the USQD process for evaluation.	Allowed SD-176 to be authorized without a USQ evaluation.	**Missed Opportunity:** A full USQ evaluation could have identified the lack of hazard information
	Workers and AK personnel did not recognize the presence of incompatible hazards associated with SD-176 drum.	Workers and AK personnel should have recognized the presence of incompatible hazards associated with SD-176.	Workers and AK personnel were unaware of the incompatible hazards associated with SD-176.	**Set-up Factor:** Allowed for continued comingling of waste from drum to drum within a specific IDC while processing SD-176 which had a potential for incompatible waste.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	USQ for the IAG did not address SD-176 as was a composite of waste from multiple generators and processes, and would be co-mingled during processing at SRP; did not have a comprehensive CCE; and did not recognize the waste could contain potentially pyrophoric and reactive uranium.	IAG should have stressed the fact that SD-176 contained multiple unknown waste generators.	There was no emphasis/recognition of the potential for unknown waste contents and potential incompatibility of waste within SD-176.	**Set-Up Factor:** Allowed for continued comingling of waste from drum to drum within a specific IDC while processing SD-176 which had a potential for incompatible waste since it is a composite waste stream with multiple generators and processes. Contributed to the assumption that SD-176 was "just another IDC."
	SD-176 was processed without recognition that the waste was a composite of waste from multiple generators and processes, and would be co-mingled during processing at SRP. Processing occurred without a comprehensive chemical compatibility evaluation and without recognition of the potential for pyrophoric and reactive uranium that was not in the form of a roaster oxide was present.	SD-176 should not have been processed without recognition of the actual attributes of the waste and a chemical compatibility evaluation.	SD-176 was processed without recognition of the actual attributes of the waste.	**Set-Up Factor:** Led to SD-176 waste being processed without understanding its potential pyrophoric and reactive hazards
	Change control for handling SD-176-178 not effectively implemented.	Change control for handling SD-176 should have been effectively implemented.	SAR not updated for different IDC with unknown waste. Incomplete compatibility evaluation resulted in processing waste that was not known to be compatible. Processing SD-176 did not preclude mixing unidentified liquids.	**Root Causal Factor:** Failure to effectively implement change control for handling SD-176 – 178.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
			Cautions in SAR not implemented. HASP was not revised to address the potential for fire in a drum or include additional controls to protect workers processing unknown waste. Additional controls to address composite waste from multiple generators were not implemented in the RWMC HWMA/RCRA permit. Controls for comingling of composite waste were not included evaluated/revised in accordance with the unknown nature of SD-176.Controls for comingling of unknown waste were not included evaluated/revised in accordance with the unknown nature of IDCs SD-176	
			Procedures not updated for processing SD-176. Training not updated for SD-176 processing of composite waste.	
	Personnel did not recognize that pyrophoric metals included material other than roaster oxides.	All Personnel should have understood/recognized that roaster oxides are just one of many potential pyrophoric and reactive metals.	Non roaster pyrophoric and reactive not recognized.	**Set-up Factor:** ARP personnel did not understand/recognize depleted uranium as a potential pyrophoric/reactive. **Failed Barrier:** Training did not address pyrophoric and reactive metals other than roaster oxides.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
3/10/16	First SD-176 drum processed in ARP V.	OK	Waste stream SD-176 processing started; the event has started.	Once SD-176 drums began to be processed in APR-V under the contemporaneous procedures and processing requirements, the event was inevitable.
03/10/2016	TPR-7867 Rev 9 was not revised for SD-176. TPR-7866 Rev 13 was not revised for SD-176.	TPR-7876 Rev 9 and TPR-7866 Rev 13 should have been revised to accommodate SD-176.	SD-176 was processed with no change to existing process or procedures.	**Missed Opportunity** to identify composite waste stream requiring modification to the process.
03/10/2016	TPR 7601, Revision 68 Appendix C does not allow "potential pyrophorics or waste containing suspect depleted uranium roaster oxides" to be transferred to SRP. TPR-8151 directs containers to meet TPR-7601 App. C requirements.	These procedures contained the review requirements that prohibit salts, roaster oxides, and pyrophoric and reactive materials.	SD-176 was processed with no change to existing process or procedures.	**Missed opportunity** to identify additional training on pyrophoric and reactive and procedure requirements not allowing pyrophoric/reactive.
06/01/16	CWI, ITG, Transition to Fluor Idaho.			
06/01/2016	No issues were identified in SRP operations during transition. Information turned over to Fluor Idaho concerning ARP V Work and ITG. Personnel transferred. Procedures "blue sheeted." Personnel stated that the IAG requirements were incorporated into site procedures.	OK – normal turnover when new prime contractor takes over.	No changes were identified.	**Missed opportunity** to possibly question the operation.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
06/01/2016	RPT-ESH-014 Chemical Compatibility Evaluation of Wastes for AMWTP was not rolled-down into Fluor Idaho procedures.	At Contract transition, RPT-ESH-014 should have been formally handed over to the new Fluor Idaho document owner and the significance of its maintenance communicated. The requirements of RPT-ESH-014 should have been rolled down to Fluor Idaho implementing procedures.	ARP implementing documents did not reference the correct document for chemical compatibility evaluations.	**Missed opportunity** to have discovered problem.
08/19/2016	RWMC HWMA/RCRA Permit was modified to ensure the HWNs for SRP and DRP were the same. Permit language added: "Some of the waste streams have the potential to contain liquids that exhibit the characteristic of corrosivity (D002). If found, the liquids will be absorbed, and the corrosivity characteristic removed to ensure compliance with the WIPP acceptance criteria."	OK		
10/18/2016	Decision process taken from AKE spreadsheet. "The remaining waste (10595963) appears to be floor sweepings. AK does not concur with the recommended IDC UN-00B for container 10595963 because per AK personnel, this is not debris and RF-751 should be retained.	OK. Expert based process but indicates a lack of formality in recordkeeping.	Drum 10595963 becomes a candidate for SRP.	Broken barrier: AK knew that this was not roaster oxide material. RTR review indicated it was not debris so SD-176 was the option.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	Instead, AK recommends an IDC of RF-751. CHD 10/18/16. Rework to update IDC per AK's recommendation comment. 10/19/16. Rework Corrected IDC Per AK ERW 10-20-2016. AK concurs with the recommended IDC, SD-176, for container 10595963. No AKR or NCR is necessary. 10/20/16. Rework corrected waste item by weight, corrected PCBs present/ comment, PCB Mass, corrected impenetrable dense objects/comment ERW 10-26-2016".			
12/2016	CBFO Recertification Audit for AMWTP.	OK		
12/2016	Recertification Interim Audit report reflects 6 areas of concern. The AK process was indeterminate due to implementation of enhanced AK requirements; lack of CBFO Basis of Knowledge document; and Generator Site Technical Review was not completed. Overall-implementing procedures are adequate and technical activities satisfactorily implemented and effective.	Narrow scope audit that only looked at CBFO process. Audit scope addresses the CBFO certification program requirements, program, waste certification procedures and processes.	Did not identify SD-176 as a potential future waste to be shipped to WIPP.	**Missed Opportunity** – Future waste stream discussion may have resulted in questions concerning SD-176.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
01/2017	Generator Site Technical Review (GSTR) assessment conducted by DOE-CBFO and NWP.	Scope of GSTR is focused on non-WIPP certified processes such as repackaging waste.	Planned processing of a new IDC waste (SD-176) was not evaluated as a potential to be shipped to WIPP.	**Missed Opportunity** – Discussion on upcoming processing campaigns may have resulted in questions on approach to treating SD-176.
01/2017	GSTR stated: "high confidence that waste repackaged will be acceptable for waste certification program" "Processes reviewed demonstrated competence needed to prevent a similar WIPP event" GSTR does discuss RCRA Compliance and incompatible chemicals within the waste. GSTR did not discuss new requirements for chemical compatibility evaluations.	GSTR should have questioned upcoming waste treatment campaigns and waste attributes relative to future WIPP disposal. This discussion may have led to questions on the SD-176 treatment approach for a composite waste stream.		**Missed Opportunity** to recognize the vulnerability of processing a composite waste from multiple generators and waste generating processes and co-mingling the waste during SRP treatment without a CCE.
5/3/2017	TPR-7601, Rev. 79 changes specified responsibility for pyrophoric determinations to TRU Programs per TPR-8151.	OK	Defined responsibility.	
5/4/2017	TPR-8151 Rev 0 created to supersede AMWTP INST-TRUW-8.13.1 and implement new section for SRP container review. Section 4.11.1.5 includes NDA ETR requirement to "determine nitrate salts, potential pyrophorics, or roaster oxides are NOT present".	DRF does not reflect NDA group review of SRP requirements.	No knowledge of requirement communicated to NDA group and no criteria established for "potential pyrophoric"	**Broken barrier:** Roll down of requirement not effectively implemented NDA-ETR did not evaluate ARP V event parent drum for "potential pyrophoric."

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
6/8/2017	RWMC HWMA/RCRA Permit was modified to state "waste to be accepted from AMWTP has been previous characterized in RPT-TRUW-05 and RPT-TRUW-12.	The RWMC HWMA/RCRA Permit should be revised to recognize that AK documentation is found in more than just RPT-TRUW-05 and RPT-TRUW-12.	None	None
7/6/17	Six of eight GSTR identified issues closed. Remaining two required to be closed prior to shipping new waste to WIPP.	OK	Not required until ready to ship to WIPP.	
7/2017	DOE-EM-4.21-01 Implementation of Chemical Evaluation Requirements for TRU Waste report issued by LANL: New Requirements include Chemical Compatibility Evaluating oxidizing chemicals in conjunction with the AK procedures Evaluation begins list of all chemicals used in the waste stream based on the AK summary report AK Assessment of container by container to determine if waste is consistent with documentation BOK evaluation provides criteria for evaluating oxidizing chemicals in TRU waste.	Ok		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
12/11/2017	TPR-7601 revision adds new note in step 4.4.1 for WGS. Note 2 states: "Incoming SRP waste has been evaluated in accordance with the "Chemical Compatibility Evaluation of Wastes for the Advanced Mixed Waste Treatment Project (RPT-ESH-014)".	Evaluation of RPT-ESH-014 for SD-176 should have identified there was no chemical compatibility performed.	Opportunity to stop and perform further evaluation on acceptance of SD-176 lost.	**Bypassed Barrier:** Allowed for acceptance of waste for which there was not an adequate understanding of the attributes of the waste stream or potential hazards.
12/21/17	Unknown Waste being processed through AMWTP causes a fire. High kg U in a nonroaster oxide package experienced a pyrophoric reaction when exposed to air while being processed in a glovebox.	Fire occurred in the proper location.		**Missed opportunity** to stop and evaluate existence of pyrophoric and reactive materials other than roaster oxides.
1/2018	Extent of Condition (EOC) evaluation was completed on North Box Line Fire Event. The WTS query against all active drums onsite reported 693 with >5 kg U-238. One of those drums was the "event" drum of 4/11/2018. Since this drum had an IDC of SD-176 (not one of the IDCs listed in RPT-TRUW-83), it was screened out and no further action was taken to address this problem drum.	Action should have been taken to evaluate drum 10595963 for impacts during SRP processing at ARP V.	No action was taken and drum 10595963 containing reactive uranium was involved in an event similar to the North Box Line fire event on 4/11/2018.	**Missed opportunity** to stop and evaluate existence of potential reactive materials in drum 10595963.
January 2018	SD-176 Training approved and given at a tailgate meeting as a corrective action from the GSTR report. Training was presented on a list of possible	Training should have included prohibited items listed in RPT-TRUW-91 including adverse reactions.	Personnel were not fully informed of potential prohibited items present.	**Missed opportunity** to question process and compliance; address criteria to evaluate the waste to ensure compliance with TPR-7601

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	chemicals contained in the waste but no implementable actions were identified. Prohibited items appear to be limited to those reflected in RPT-TRUW-94 instead of broader list contained in RPT-TRUW-91.			Appendix C requirements.
1/11/18	Contract direction requested by Fluor Idaho for not yet implementing BOK into current processes.	OK		
1/11/18	Continue to process ISA to current procedures without implementing BoK into process. Based on direction from DOE reinforced in numerous IPT meeting. Decision was arrived jointly to minimize impacts to project milestones. Either continues to process and package waste with current procedures or come into alignment with WIPP WAC Rev 8 and fully implement BoK.	OK	Request submitted to get formal DOE approval of path forward.	
1/18/18	MCP-4226, Rev 0, revised to add two new steps requiring greater than 5 Kg U-238 to be rejected for MLLW direct feed consideration and rejected for direct feed consideration.	SRP should have been included in evaluation of more restrictive requirement.	Limitation of 5 Kg would not have allowed the event drum to be sent to SRP.	**Missed Opportunity**: Rejection of event drum would have prevented the ARP V incident.
3/1/18	Contract direction received from DOE.	OK		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
3/1/18	DOE concurs with Fluor Idaho to continue to process ISA waste to current processes.	Not rely on past successes and evaluate process.	Fluor Idaho continued to process ISA using existing processes.	**Missed opportunity** to have possibly identified chemical compatibility issues, DOE provides direction to continue processing understanding that Fluor Idaho has not implemented any changes SRP waste processing approach.
3/10/18	DOE understands that Fluor Idaho has not implemented any changes to the waste procedures related to BoK. DOE understands this joint decision minimizes the impacts to ISA milestones. DOE directs Fluor Idaho to continue processing, package, characterize, and certify waste and not implement BoK pending further direction.	Not rely on past successes and evaluate process.	Fluor Idaho continued to process, package, characterize, and certify waste without having implemented BoK changes. The direction given defers completion of the AK Summary Report; Chemical Compatibility Evaluation, and development of approach for addressing the oxidizing potential of SD-176.	**Missed opportunity** to have possibly identified chemical compatibility issues.
	Schedule pressure and requirement relief to meet Contract and ISA milestones.	Schedules should have been based on time and resources needed to complete milestones in compliance with established requirements.	Schedule pressure applied and requirement relief granted.	**Failed Barrier:** Contractors request relief and DOE allows contractors requirement relief to continue processing waste using current processes based on schedule/milestones.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	Project is processing SD-176 at risk. AK briefing for SD-176 did not contain all potential prohibited items and concerns reflected in RPT-TRUW-91.AK briefing for unknowns did not contain all potential prohibited items and concerns reflected in RPT-TRUW-91. Up to two drums may be processed on the sorting table at the same time, and daughter drums may be mixed together.	Processing of SD-176 should have been performed in accordance with fully evaluated and approved procedure and in compliance with all applicable requirements.	SD-176 was processed without fully evaluated and approved procedures and not in compliance with all applicable requirements.	
03/07/2018	The Pyrophoric Event in North Box Line report issued. MCP-4226 revised to add two steps requiring greater than 5 Kg U-238 to be rejected for MLLW direct feed consideration and rejected for direct feed consideration.	SRP should have been included in evaluation of more restrictive requirement.	Limitation of 5 Kg would not have allowed the event drum to be sent to SRP.	**Missed Opportunity**: Rejection of event drum would have prevented the incident.
03/07/2018	Information from event was not shared with other Fluor Idaho sites Generic applicability to other facilities is not addressed in corrective action program. No DOE order or standard requirement exists to perform generic applicability.		Generic applicability of causal factors and conditions at other waste processing facilities was not evaluated.	**Missing Barrier:** a generic applicability requirement could have resulted in additional analysis of pyrophoric U-238 in other than roaster oxide forms.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
03/07/2018	Pyrophoric event involved processing nonroaster form of Uranium waste material. Corrective Actions: Add new IDC for potential nonroaster oxide pyrophoric material Revised AMWTP procedures to limit U-238 to < 5 kg Continue to process > 5 kg at SRP No documented basis for implementing < 5 kg.	Corrective actions should have been reviewed for application across the Site. A basis for limiting U-238 at AMWTP should have been established and evaluated Site-wide.	ARP V personnel reviewed event and video. No similar waste had been processed.	**Missed opportunity:** Viewing the existence of a different pyrophoric waste form could have led to questioning SD-176 and to reevaluating AK reports for pyrophoric and reactive information.
03/07/2018	IDC changed to new IDC-RF-761.	OK	Addressed AMWTP issue.	**Missed opportunity** to identify potential existence of similar issues.
03/07/2018	Evaluation of the Box line fire did not effectively analyze ARP V applicability.	Corrective actions should have reviewed for application across the Site. A basis for limiting U-238 at AMWTP should have been established and evaluated Site-wide.	AMWTP did not share applicable corrective actions that were taken for processing unknown waste that could impact ARP V (The potential pyrophoric and reactive reaction from for nonroaster Uranium). ARP continued to operate without regard to an allowable quantity of depleted uranium.	**Missed opportunity:** to identify potential existence of similar issues.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	Personnel did not recognize ARP V drum #10595963 contained reactive uranium Material. TRU Waste personnel identified the subject drum #10595963 was from RFP Building 444 - Be and Uranium operations at RFP, but did not recognize this presented a potential for reactive uranium material. Some personnel did not feel like they could raise an issue to not ship drum #.	Personnel should have recognized that Drum #10595963 contained reactive uranium and would not have been sent to ARP V for processing. Operators should have recognized this presented a potential for reactive uranium material. Personnel should have felt comfortable raising concern regarding shipping ship drum #10595963 to ARP.	Reactive material was processed at ARP V. Operators processed drum #10595963 from RFP Building 444 at ARP.	**Set-up Factor:** Drum containing reactive uranium was sent to ARP V for processing thus setting the stage for the event to occur. **Failed Barrier:** Significance Concerns regarding shipping drum to ARP were not recognized or voiced.
	Project became complacent with processing a composite waste from multiple generators and processes.	Composite waste should not have been processed at ARP V.	Workers were exposed to unknown hazards without understanding the associated risks.	**Set-up Factor:** Drum containing reactive material was sent to ARP V for processing thus setting the stage for the event to occur. **Failed Barrier:** Significance Concerns regarding shipping drum to ARP were not recognized or voiced.
4/2/2018	Email communications on drum #10595963: AKE points to finely divided material (floor sweepings); generated from Building 444 (known to fabricate DU, Be and other weapon parts); and NDA is indeterminate (but assay indicates 11.9 Kg of DU). NDA states sludge-like; depleted uranium and not a roaster oxide.	The generation location of the drum from building 444; finely divided material; and presence of 11.9 Kg of depleted uranium should have been warning flags of potential pyrophoric and reactive. NDA did not address required criteria of potential pyrophoric/reactive. This knowledge should have resulted in reassignment of a different IDC.	Allowed a drum that should have been rejected to move forward in the approval process.	Four daughter drums reacted after repackaging at ARP V and ejected waste contents resulting in contamination and shutdown of ARP V operations.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
4/3/2018	Emails reflect continued discussion about receiving drum #10595963. Ultimately ARP management decides to bring drum over and ensure it comes out a sludge.	TPR-7601 Appendix C criteria concerning "potential pyrophoric/reactive or waste containing suspect depleted uranium roaster oxides will not be transferred to SRP" should have been implemented based on the results of the reviews and kept #10595963 out of ARP V.	Drum accepted and transferred to SRP.	Parent drum #10595963 processed on 4/11/2018. Four daughter drums produced that react and eject contents resulting in contamination and shutdown of ARP V operations.
4/3/18	Email communications used for basis of approval to process ARP V Drum #10595963.	Process should require signatures for key verifications.	Review for identification of pyrophoric and reactive /reactive material not documented/ completed.	**Broken barrier:** Pyrophoric and reactive /reactive review not completed.
	Shipped waste to ARP and did not meet requirements.	Waste shipped to ARP should have been characterized sufficiently to meet the requirements of TPR-7601.	Nonconforming waste was shipped to ARP. Waste containing reactive material was shipped to ARP	**Set-up Factor:** Waste containing reactive material was shipped to ARP set stage for event.
	AMWTP and ARP project oversight by Fluor Idaho and DOE not effective.	AMWTP and ARP project oversight should have been effective.	MWVs, QA, Contractor Assurance oversight were not sufficient to identify weakness in processing of composite wastes. DOE oversight was unaware that SD-176 was a composite waste from multiple generators and processes Organizational ITG/CWI/Fluor Idaho did not recognize the hazards in processing composite waste.	**Missed Opportunity**: Oversight could have identified the weaknesses and reduced the likelihood of the event.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
Event Day				
0830 04/11/2018	Pre-Job Brief conducted Addressed the day's activities using MCP-3003 and 434.14 as guidance.	OK		
	Documentation of the Pre-Job Briefing does not demonstrate that the briefing documentation did not include all discussion topics.	Documentation of the Pre-Job Briefing should have demonstrated that the briefing included the following critical items.	Pre-Job documentation LTA.	No effect on event.
	Discussions for protecting personnel while handling pyrophoric and chemical waste not documented.	Discussions for protecting personnel while handling pyrophoric and reactive and chemical waste should have been documented.		No effect on event
	Pre-Job did not discuss three potential personnel safety steps for handling drums with pyrophoric material included in TPR-7867 • Personnel handling drums at sorting table • Personnel handling trays and drums in DPS • Personnel handling drums after treatment.	Pre-Job should have discussed the three potential personnel safety steps for handling drums with pyrophoric and reactive uranium included in TPR-7867.		No effect on event
	Pre-Job Brief documentation did not demonstrate that the following items were discussed: • Waste expectations/RTR data/Assay data/any potential dose rates to be observed	Pre-Job Brief documentation should have demonstrated these items were discussed:		No effect on event

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	• Reactions of potentially pyrophoric and chemical waste • Locations of fire extinguishers and their use • Mitigations if any reactions occur.			
04/11/2018	IDC Waste processed existing backlog of trays in the morning. Operators stated they had a 32 tray backlog.	OK		
04/11/2018	Morning shift thought they saw what appeared to be salt and stopped. Called VE to evaluate.	OK		Evidence that personnel do not appear reluctant to call the VEs.
Comment: Interviews and records show personnel do not appear to hesitate to call the VEs to evaluate anything that looks different than expected				
04/11/2018	Sorting table and tray handling practices as described by the operators met procedures, Hazard Assessment Document and management requirements.	OK		
1355 04/ 11/2018	In close proximity to ARP V activities, fork lift operator drops a drum being moved from a flatbed truck (CAR 119250).	Fork lift operator should not have dropped a drum.	Initiated a project-wide "step back" and evacuation of the area adjacent to the drop.	Resulted in a delay in processing event parent drum until after lunch.
	Management initiated a project wide step back and evacuated area where drum drop event occurred. The step back delayed processing drums and removing them from the ARP V facility.	OK	Event drums from DPS were left in the HEPA filtered WMF-1617 instead of outside on a flatbed truck.	**Mitigating Factor:** as a result of the "step back," the four event daughter drums were inside ARP V (rather than outside the facility) when they over-pressurized and dispersed their contents. In the absence of the step back, the daughter drums would likely have been

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
				outside the facility on a trailer when the reactions occurred.
	Historical reports were not used to develop procedures that would identify potential problem drums.	Historical reports should have been used to develop procedures that identify potential problem drums and Process should have been reevaluated/revised because SD-176 does not consist of one compatible waste stream like other IDCs.	Comingling of waste was allowed while processing SD-176 even though it does not consist of one compatible waste stream like other IDCs.	**Missed opportunity:** Had historical reports been used, procedures would have been more likely to address the potential for nonroaster pyrophoric and reactive uranium and would not have allowed comingling drums, trays & daughter drums of SD-176.
Afternoon event Day 04/11/2018	Processed six parent drums -10595963 - 10293740 -10630243 - 10314818 -10630238 - 10295807	OK		
04/11/2018	Parent Drum 10595963 direct filled two Daughter drums: SRP34398 SRP34402	OK		
04/11/2018	Parent Drum 10630243 direct filled two Daughter drums: SRP 34384 SRP34405	OK		
04/11/2018	Parent Drum 10630238 direct filled one Daughter drum and one tray: SRP 34415 Tray 299	OK		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
04/11/2018	Parent Drum 10293740 direct filled two Daughter drums and one tray: SRP 34418 SRP34403 Tray 268	OK		
04/11/2018	Parent Drum 10295807 direct filled three Daughter drums: SRP 34417 SRP 34401 SRP 34404	OK		
04/11/2018	Parent Drum 10314818 direct filled two trays: Tray 255 Tray 280	OK		
Comment: During the day shift personnel implemented step-backs when something looked different than expected. Operators stated in interviews that they called on the VEs when anything that looks different than expected. VEs validated the operators' statements.				
04/11/2018	In the waste stream, an Operator identifies a liter bottle 1/3 filled with 1/3 an unknown dark liquid; in the bottle and uses waste on the sorting table to absorbs the liquid in waste on sorting table in accordance with approved operating procedures. Drum 10621441	OK Information is from operator interviews. This action was not documented as required by procedure. Review of RTR records identified the parent drum which contained the bottle. It was processed later in the day after the event drum had been processed. This did not play into this event.	No impact	No impact
Comment: The 1/3 full liter bottle was processed in accordance with approved procedures and did not play a role in this event.				
04/11/2018	Received 2 CAM alerts in Ops Room – RCT turned the CAM off.	RF issue. Other CAMs provided coverage.	No impact	No impact

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
04/11/2018	RCTs take dose reading on the trays and on the packaged waste drums. During interviews one RCT reported that a few of the trays registered higher than normal dose rates. RCT did not have a concern because the readings were within the requirement for dose rates at the window. The RCTs did not report the dose readings to management.	RCTs should have reported "higher than normal" significant reading dose rates to management for evaluation.	Presence of U not identified. A questioning attitude of self-reporting and management follow-up did not occur.	**Missed opportunity** to identify problem.
	No Post Job brief or Feedback provided MCP-3003, Performing Pre-Job Briefings and Documenting Feedback does not require post job briefs and states "if needed.	OK	Management did not get the opportunity to hear about the higher dose rates until after the event.	No Impact
Evening Event Day				
04/11/2018	After the end of day shift, ARP V is not manned and AMWTP takes over responsibility for backshift event response for ARP V.	OK		
	Change for AWMTP personnel to address backshift responses to ARP not effective.	Change for AWMTP personnel to address backshift responses to ARP should have been effective.	AMWTP personnel not trained to effectively address ARP emergency situations. INL Fire Department and Response personnel did not drill together.	**Missing Barrier**: AMWTP Operations and RCT personnel were not adequately prepared to respond to the event. RCTs were not familiar with ARP waste material AMWTP response personnel were not aware of how to operate/read alpha CAMS.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
				INL Fire Department was not familiar with ARP V hazards.
04/11/2018	Management did not establish expectations regarding turnover protocol and information to be exchanged between ARP V and AMWTP.	Management should have established formal protocol and expectations with regard to end-of-shift turnover of responsibilities between ARP V and AMWTP.	The specific information regarding ARP V conditions and status that was exchanged was left to the discretion of ARP V and AMWTP workers.	**Set-up Factor:** Lack of information and training led issues during the emergency response. **Missing Barrier:** Operational turnover of ARP V responsibilities were not controlled.
04/11/2018	AMWTP personnel were not aware of ARP conditions; including status of repackaged drums in ARP V. AMWTP personnel do not discuss ARP status during backshift shift briefing. In interviews, AMWTP personnel stated that they are not generally aware of ARP conditions and rarely, if ever, discuss ARP status during backshift shift briefings, including on the day/night of the event.	AMWTP personnel should have been aware of ARP conditions, particularly the status of repackaged drums in ARP V, since they were responsible for responding to ARP emergencies.	AMWTP personnel were not aware of status of repackaged drums in ARP V.	**Set-up Factor**: Personnel were not aware of conditions.
2235 04/11/2018	CAM readings for ARP V increasing.	OK	Occurred at same time as first fire alarm.	
2235 04/11/2018	Fire Alarm ARP V (WMF-1617).	OK, given that a fire was in progress.	INL Fire Department responded to the alarm.	
2235 04/11/2018	RWMC-AMWTP plant shift manager notified by dispatcher that fire protection was responding to ARP.	OK		
	EAR 246 does not include instructions for informing the INL Fire Department of the	EAR 246 does not include instructions for informing the INL Fire Department of the	Firefighters were not informed regarding radiological concerns associated with entry.	**Set-up Factor**: Contributed to firefighters

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	radiological concerns associated with entry, but hands off to the associated RWP.	radiological concerns associated with entry.		entering ARP V without suitable protection from radiological contamination.
	EAR 246 Hazard analysis states to provide information to battalion chief on type of materials Involved.	OK		
2240 04/11/2018	FD dispatched Engine and Ambulance.	OK		
2240 04/11/2018	2nd Alarm FD dispatched additional units. Indication of not entering just to investigate/expect smoke recognized by FD.	OK		
2243 04/11/2018	PSM notified NFM of the situation	OK		
2245 04/11/2018	FD engine arrives; parks upwind; RWMC Shift Supervisor called while on route; no additional info available.	OK		
2247 04/11/2018	FD Battalion Chief arrives and completes a 360 degree external check.	OK		
04/11/2018	Quick Access Plan does not provide sufficient radiological data for ARP V (for example, location of CAMs, normal DAC, location of RWP info, etc.).	Quick Access Plan should contain additional radiological data		
04/11/2018	Fire Plan does not contain sufficient radiological data (for example, rad material that could go airborne, normal DAC,	Fire plan should have provided necessary data and expectations regarding fighting a drum fire in a		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	expectation to mask up, etc.).	radiological facility.		
2251 04/11/2018	FD team enters ARP V vestibule using procedure SOP-2.4B.1 (non rad facility investigation); smelled smoke; described as like a heavy metallic fire. Vestibule is part of ARP V and considered a radiological area.	FD team should not have used nonrad facility procedure to enter vestibule.	Entry into a radiological facility without RCT support.	
2252 04/11/2018	FD team reports seeing smoke thru ARP V vestibule window, reports masking up, and entering ARP V.	Should have exited SOP-2.4B.1 and followed SOP 2.5E.8 which addressed Radiological issues.		
04/11/2018	Orders given to hook up water to Engine to relocate rescue, hazmat, and ladder trucks to south side.	OK		
04/11/2018	FD identifies fire in a radiologically marked drum and smoke in ARP V and did not exit.	FD team should have exited ARP V upon discovery of radiologically marked drum.		**Set-up Factor:** failure to exit contributed to team receiving radiological uptakes.
04/11/2018	Current FD radiological procedure is confusing for FD responsibilities.	FD radiological procedure should be clear and meet the needs of the procedure user.	FD did not treat fire as radiological issue.	
04/11/2018	Management expectations for the FD to enter a radiological building and procedures are not consistent.	Management expectations and governing procedures for FD rad building entry should be defined and consistent.		**Set-up Factor:** made it more difficult for FD personnel to identify and implement appropriate actions in radiological environment.
04/11/2018	INL Fire Department personnel stated they did not understand how the ARP V CAMS operate.	INL Fire Department personnel should understand how ARP V CAMS operation.	FD personnel were expecting a CAM alarm to indicate high airborne activity levels.	**Set-up Factor:** FD personnel were relaying on nonfunctioning CAMs for personnel protective action decisions

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
04/11/2018	PSM/EAM arrives onsite then leaves to establish ECC and assume EAM responsibilities. FD is left with no Operations representative at the scene.	PSM should have coordinated actions from scene until a relief was arranged.	FD personnel were left without radiological support.	**Aggravating Factor:** absence of on-scene radiological support hindered firefighter response.
04/11/2018	FD uses a dry chemical extinguisher with no affect.	OK		
2257 04/11/2018	Entry Team reports ruptured drum; 190 degree Fahrenheit reading on Thermal Imaging Camera (TIC) ~¼ of drum had material remaining; white liner still in drum; describes as “caving in” Material reported as looking like “boiling sand” in interview Charcoal looking white pockets identified with rest of material was gray	OK	Visual evidence that a drum over-pressure event occurred.	
2300 04/11/2018	Entry team reports temp. increasing; applying Met-L-X to drum.	OK		
04/11/2018	FD had some problems with the Met-L-X discharge of the extinguisher.	Nozzle sprays issue. Removed nozzle and discharged extinguisher.		
04/11/2018	Met-L-X was ineffective at extinguishing fire.	OK	Confirmed to be correct agent.	
04/11/2018	FD Captain orders FF to get something to stir the material in the Drum to allow Met-L-X to get to the hot spots.	FD Captain should not have ordered FFs to stir the drum.		**Missed barrier:** Training on radiological drum fire and expectations are not established.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
04/11/2018	Attempted to pull back other material with shovel so Met-L-X could be applied on hots spots Really fine material dust/particles pushed up obscuring vision.	Should not have stirred the drum.	Increased temperature of drum contents.	
04/11/2018	Procedures do not provide clear direction on FD actions for handling of radiological waste when on fire.	Procedures [specific #s and names] should provide clear, unambiguous direction regarding firefighting actions.		**Set-up Factor:** Firefighters were not fully prepared/trained to fight fires involving radiological waste.
04/11/2018	FD recorded info from stickers on involved drum 1/mr/hr drum; 15mr/hr on adjacent drum; wrote down numbers.	OK		
2301 04/11/2018	Incident Commander HAZMAT Team requested via radio.	OK		
2303 04/11/2018	EAM requests RCT support to support FD with egress and decon: urgency of request was not conveyed.	Urgency of request for RCT support of FD should have been clearly communicated.	RCT support was slow to arrive.	**Aggravating Factor:** failure to convey urgency of RCT support request is likely to have delayed arrival of RCT support.
	Urgent RCT support was not requested to support INL Fire Department due to poor communication to relay urgency to support FD.	Communication should have conveyed the requisite urgency to RCTs.	RCT support did not arrive onsite in a timely manner.	**Set-up Factor**: Delayed RCT response and contributed to response errors.
	RCTs did not have experience or knowledge to respond to an ARP event.	Training and coordinated drills should have provided RCTs with sufficient knowledge and experience.	RCTs were not prepared to respond to conditions encountered.	Contributed to response errors.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
2304 04/11/2018	Entry Team reports Met-L-X applied (2nd application).	OK		
	ConOps weaknesses for documenting and communicating actions: No evidence of the following actions taken during initial entry into the EARs EAR 246, "RWMC—Respond to Fire" 1.1 STOP all work activities 1.2. WARN others in the immediate area 1.4 EVACUATE the affected area to designated assembly area 1.5 SS: MAKE an ENS and radio announcement 1.7 ENSURE accountability has been conducted 1.10 Provide radiological conditions to the Battalion Chief, as requested. EAR 278 Hazardous Substance and Waste Spill Control 1.1 STOP all work activities and WARN personnel in the vicinity 1.2. NOTIFY RCT, IH, SS, and SOM of the event 1.4 EVACUATE and shelter as directed by RadCon and or supervision	EAR required actions would have been completed and documented.	Contributed to nonconservative decisions and increased radiological exposure to workers.	Contributed to nonconservative decisions and increased radiological exposure to workers.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	1.5 SS: MAKE and REPEAT an announcement requiring personnel within the event area to take shelter or evacuate to approx. 100 m ENS and radio announcement 1.8 ENSURE accountability has been conducted.			
2308 04/11/2018	AMWTP RCT notified RCM they were responding to WF-1617.	OK		
2313 04/11/2018	Entry Team reports Met-L-X ineffective; backing out.	OK		
2314 04/11/2018	Event drum reported @ 215 degrees Fahrenheit.	OK	Temperature continues to rise following Met-L-X application.	
2315 04/11/2018	Entry team ordered out by forward operating officer.	OK		**Mitigating Factor**: entry team was out of the room when the second, third, and fourth drums over-pressurized.
Comment: The entry team took 48 minutes to egress ARP V following the order to do so. (See CTL entry at approximately 0005 04/12/2018.)				
04/11/2018	Smoke reported in vestibule (not heavy)	Ventilation system may not be working.	Indication to EOC and ECC that ventilation may not be effective even though being on.	**Failed Barrier:** Entry into EALs is poorly written as to meaning of ventilation on.
04/11/2018	No RCT support available at scene; so Fire Dept. prepares to survey team out.	RCT support to fire personnel should have been at the scene.	HAZMAT Team prepares to perform surveys.	**Set-up Factor:** Delay in getting RCT support resulted in a delay in FF exiting
2316 04/11/2018	Decision communicated to exit through airlock doors vice roll up doors.	OK		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
2317 04/11/2018	FD moved the event drum (of radioactive material) away from the other ARP V drums. FD personnel were not prohibited by procedure from moving a radioactive material. RCT personnel were not at scene to advise FD personnel.	OK since FF were already there.		**Missing Barrier:** RCT personnel were not at the scene to advise FD personnel. **Missing Barrier**: Governing procedures for FD personnel do not prohibit moving radioactive material, or specific conditions under which it shall not be moved.
04/11/2018	Event drum temperature readings from the thermal imaging camera (TIC): TIC 284 degrees prior to moving TIC 298 degrees after moving Particulates being discharged upward from the drum going close to the ceiling.	FF should have evacuated.		**Aggravating Factor:** Failure of the FF to exit resulted in a near miss event if any of the other event drums had over-pressurized while they were nearby.
2318 04/11/2018	Radio discussion (FF) regarding hot spot on bottom of drum.	OK		
2319 04/11/2018	Communication reported expected rad contamination and Be contamination.	OK	Discussion was in preparation for FF exiting facility.	
2320 04/11/2018	ECC and EOC were activated as a conservative measure.	OK		**Mitigating Factor:** increased support available to respond to the event.
2320 04/11/2018	The EAM did not enter the emergency response process.	EAM should have formally declared an “Operational Emergency”.		**Bypassed Barrier:** event conditions met criteria for a formal declaration that was not made.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
2322 04/11/2018	AMWTP RCTs reported they were a couple of minutes out. The IC decided to wait for AMWTP RCT to survey FD out of the ARP V vestibule.	OK		
2323 04/11/2018	2 FFs walked into vestibule in full gear to attempt to pass drum info along.	FF's should have remained in vestibule from this time on.		
04/11/2018	Comms were difficult so gas meter used as a probe to get attention of people outside ARP V. Outside could not see information being held up to window because of reflection, so a hand opened the door and extended into the vestibule.	Outside personnel should not have reached into tent.		**Aggravating Factor:** difficult communications between personnel inside ARP V and support personnel outside ARP V.
2328 04/11/2018	Entry Team communicated drum still venting; Metal-X did not work.	OK	Contamination continues to be spread within ARP V from the first event drum.	
2330 04/11/2018	Entry Team looked at rad instrument; reported no alpha, 61 beta.	OK		
2331 04/11/2018	FF Electronic dosimeter reading reported as .2 mr.	OK	Evidence that the event involved contamination and low dose rates.	
2333 04/11/2018	Ventilation stated as confirmed over radio.	Should not have been confirmed.		**Failed Barrier:** Communication should have indicated fans running and current conditions.
2333 04/11/2018	Ventilation is running, however could not determine operability by D/P.	Should have been confirmed without D/P readings.		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	RCT and FD interviews indicated airflow was stagnate in airlock area.	OK		
2336 04/11/2018	FFs silenced fire alarm; no other alarms sounding.	OK		
2346 04/11/2018	RadCon team arrived on scene 43 min. after EAM request.	OK	Firefighters now have support from radiologically trained personnel.	**Mitigating Factor:** firefighters now have radiological support available to manage radiological safety, contamination control, and personnel decontamination.
04/11/2018	RCT entered in PAPR.	RCT should not have entered into area without SCBA.		**Failed Barrier:** Training
04/11/2018	RCT stated upon entry there was minor contamination that looked like foot prints in the vestibule.	OK		
04/11/2018	RCT stated in an interview that there was some smoke in the vestibule.	OK	Should have reported that to IC.	
04/11/2018	AMWTP RCT personnel do not understand operation of the ARP V CAMs (different).	AMWTP RCT personnel should understand operation of the ARP V CAMs.		**Aggravating Factor:** Further evidence that AMWTP RCT personnel were not prepared for backshift responsibility for ARP V emergencies.
04/11/2018	RCT not qualified to wear SCBA.	RCT should be qualified to wear SCBA.		**Aggravating Factor:** Further evidence that AMWTP RCT personnel were not prepared for backshift responsibility for APR-V emergencies.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
2347 04/11/2018	SCBA vibration alerts from low air in bottle; made comms difficult.	OK	Time to exit.	
2347 04/11/2018	Low pressure in SCBA tanks; increased urgency to exit. RCT directed FF to exit.	OK		**Mitigating Factor:** increased urgency to exit contributed to FFs being outside when 2nd drum over-pressurized.
2347 04/11/2018	FF bunker gear was doffed excluding SCBAs near inner vestibule door inside airlock.	Doffing should have started in the vestibule with the airlock door closed.	Increased likelihood of potential for uptake and spread of contamination.	**Aggravating Factor:** contributed to likelihood of uptake and spread of contamination.
2347 04/11/2018	Firefighter personnel clothes doffed inside vestibule.	OK		
04/11/2018	RCT removes FF mask which is different than FD procedures.	Procedures should be consistent or determined which takes precedence.		**Set-up Factor:** unresolved differences in RCT and FD requirements were left to field personnel to resolve under emergency conditions.
2355 04/11/2018	1st firefighter exits; contamination surveying progress.	OK		
4/12/2018 0000	2st firefighter exits; contamination survey in progress.	OK		
4/12/2018 0000	FF reported that he saw another drum lid starting to bulge as he was exiting.	OK	Evidence that the event extends to more than one drum and remains in progress.	The event involves more than one drum over pressurization.
4/12/2018 0005	3st firefighter exits; contamination survey in progress.	OK	All firefighters are on the external side of the ARP V airlock.	**Mitigating Factor:** no personnel were in the interior of ARP V when the second drum over-pressurized 19 minutes later.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
04/12/2018 0005	All firefighters out 48 minutes after being directed to back out.	Firefighters should have exited expeditiously once inability to extinguish a radiological drum fire was identified.	Untimely backing out created a significant "Near Miss" of being inside the building when the second drum breached.	**Aggravating Factor:** delayed egress increased likelihood that firefighters would have been in close proximity to a second drum over-pressure event.
	Near miss issue for not effectively protecting personnel.	Personnel should have been adequately protected personnel.	Near misses occurred.	**Near-Miss Event:** for not effectively protecting personnel • DSP Operations sorting through the potential pyrophoric and reactive waste • Operations personnel handling the drums with Potential pyrophoric and reactive waste.
0012 04/12/2018	EOC declared Operational; EAM did not formally declare "Operational Emergency."	EAM should have formally declared "Operational Emergency".	"Operational Emergency" was not declared.	**Missed Opportunity:** to formally declare "Operational Emergency" Bypassed Barrier: event conditions met criteria for a formal declaration that was not made.
0024 04/12/2018	2nd drum breaches; EOC notified via radio by IC.		The magnitude of the event continues to increase with over pressurization and breach of the second drum.	**Near-Miss Event:** firefighters had been adjacent to the second drum to breach until approximately 19 minutes prior to the breach.
0024 04/12/2018	On scene personnel ordered to leave; "worry about contamination later".	OK		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
0024 04/12/2018	The event met criteria for escalating emergency (specifically an "Alert"); EAM did not declare "Alert".	EAM should have declared an "Alert" and entered the emergency response procedures.	"Alert" was not declared.	**Missed Opportunity:** to formally declare "Alert" **Bypassed Barrier:** event conditions met criteria for a formal declaration that was not made.
Comment: the Project took appropriate actions to address an emergency at the "Alert" level, but did not formally declare an Emergency Level. Conditions included: fire that could not be extinguished in a radiological facility; known 1 drum on fire with a secondary explosion at time 0024. Actions included: evacuated area, requested HAZMAT team				
0025 04/12/2018	RCT in vestibule stated there was so much dust and debris within the building he could not see through the window.	OK	Visual evidence of second drum over-pressure event and subsequent spread of contamination within ARP V.	
0025 04/12/2018	IC Ordered personnel to evacuate the area to a distance of 100m per ERG Guide 111.	OK		
04/12/2018	Operations could identify that the ventilation system was running, but could not verify that it was operable.	Conservative decision making would have been to take actions for an inoperable system.		
0026 04/12/2018	IC evaluated the ARP V structure finding no exterior problems.	OK		
04/12/2018	The potential for interior damage to ARP could not be assessed by the exterior evaluation.	OK		
0028 04/12/2018	Entry team surveyed by RCTs, found to be contaminated, and loaded up for transport.	OK		
04/12/2018	Initial nose smears were lost.	Should not have lost initial nasal smears.		

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
0030 04/12/2018	RWMC-ARP SOM and ARP RCT supervisor arrived onsite.	OK		
02110 4/12/2018	ARS arrives at EOC for 100 m planning/air samples.	OK		
0245 04/12/2018	ARS goes to trailer 23 and EAM declares ERO operational EAM did not formally declare "Alert."	EAM should have formally declared an "Alert."	"Alert" was not declared.	**Missed Opportunity:** to formally declare "Alert" **Bypassed Barrier:** event conditions met criteria for a formal declaration that was not made.
0320 04/12/2018	Personnel in the area of ARP V heard another loud bang.	OK	Indication of another drum over pressurization.	**Missed Opportunity**: The magnitude of the event continues to increase with over pressurization and breach of the third drum.
0503 04/12/2018	No contamination found in the 100 m area.	OK		
0857 04/12/2018	RCT identified that no radiological or volatile organics around the exterior of the bld.	OK		
1001 4/12/2018	FD released the facility back to Operations.	OK		
1035 4/12/2018	The scene was preserved and the ECC was secured.	OK		
4/25/2018	Potentially Inadequate Safety Analysis declared positive.	OK		
	Corrective Actions taken by contractors to address WIPP CONs not fully effective: • Lessons learned were not reviewed for applicability to a first time processing of composite waste from	Corrective actions taken by contractors should have been comprehensive in addressing Lessons Learned and CONs from WIPP reports.	Weaknesses continued to exist.	**Missed Opportunity:** Hazards associated with processing an unknown waste were not fully identified and mitigated Potentially incompatible waste being comingled at ARP V reactive waste being sent to

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	multiple generators and processes • CON 5 Implementation requirements of the QA plan and AK process did not prevent shipment of ignitable or reactive waste to ARP • CON 6 implementation of AK not effective in identifying potential impact of adding incompatible secondary waste streams • CON 8 Placed incompatible wastes and materials in the same container and did not impose special precautions. • CON 12 identifies procedural weaknesses. “No Gap” was identified however the Drum event indicates different • CON 14 identifies actions to review the SAR and DSA. “No Gap” was identified however the Drum event indicates different • CON 15 identifies USQ issues. Action taken, however not fully effective • CON 16 identifies weaknesses with RCRA program implementation and Contractor Assurance program and change control. “No GAP” was identified.			and processed ARP V.

Comparative Timeline/Change Analysis				
When	What Did Happen	What Should Have Happened	Immediate Result (consequence)	Significance (impact on final consequences)
	• CON 23 identifies Safety Culture weaknesses and "No GAP" was identified.			
	Corrective Actions taken to address Change Control issues not effective.	Actions should have been identified and implemented to effectively manage change at ICP.		**Missed Opportunity:** Changes associated with processing SD-176, and unknown waste stream were not effectively managed which directly led to this event.

Appendix D

Barrier Analysis

Appendix D

Barrier Analysis

Number	Barrier Categories
1.	Permits
2.	Procedures that Implement Permit Requirements
3.	Chemical Compatibility
4.	Waste Examination and Evaluation
5.	Safety and Oversight Processes
6.	Reports Upon Which Decisions Are Based
7.	Physical Barriers
8.	Safety Culture
9.	Management
10.	Human Performance

A 'barrier' is a device that has the effect of reducing the probability or consequences of a 'hazard' to a 'target.' Devices that could have or are intended to have the same effect are also called 'barriers.' Barriers that did work can be retained and reinforced. Barriers that did not exist can be deployed. Barriers that existed, but did not work, can be strengthened. The most significant barriers identified are summarized in the tables below

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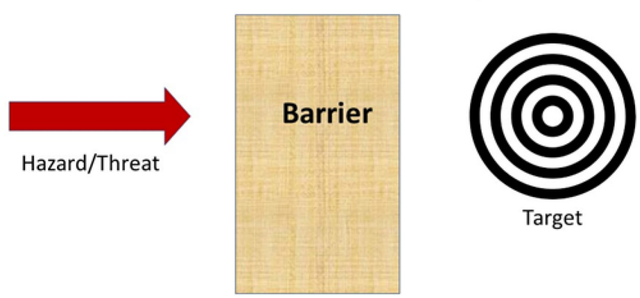
The Basics of Barrier Analysis



Barrier: A measure or device that has the effect of [or is intended to] reducing the probability and/or consequences of the effect of a threat on a target.

Table D-1. Barrier Analysis: Permits				
Barrier	Target Protected	Hazard	Effectiveness in This Case Why Did Barrier Fail?	Significance and Recommended Corrective Actions
B-1-01 AMWTP HWMA/RCRA Permit Permit Condition II.C – Waste Analysis Plan Attachment 2 – Waste Characteristics This permit recognized that pyrophoric radionuclides could be present in AMWTP wastes, but relied on implementing procedures and "Acceptable Knowledge" to prevent them from being processed by or sent to facilities that are not authorized to deal with them.	(1) Compliance with federal law and state regulations related to RCRA; (2) Implementing procedures that comply with requirements of RCRA.	(1) Noncompliance with requirements of RCRA. (2) Implementing procedures that do not address all applicable requirements of RCRA.	Ineffective: The AMWTP RCRA permit adequately describes the requirements for accurately characterizing radioactive mixed wastes managed at AMWTP. However, the implementing procedures (or their implementation) failed to identify the presence of pyrophoric radionuclides in the "event drum."	Compromised barrier: Had AMWTP fully complied with the AMWTP RCRA permit, the event would not have happened. The AMWTP RCRA permit correctly established the requirements for properly identifying the waste characteristics of parent drum 10595963. However, AMWTP implementing procedures established a requirement that prohibited "potential pyrophorics" from being transferred to ARP V but did not specify criteria for meeting that requirement. Revise RCRA implementing procedures to ensure potential pyrophoric and reactive uranium is effectively addressed.

Table D-1. Barrier Analysis: Permits				
Barrier	Target Protected	Hazard	Effectiveness in This Case Why Did Barrier Fail?	Significance and Recommended Corrective Actions
B-1-02 RWMC HWMA/RCRA Permit Section C – Waste Analysis Plan For wastes to be accepted from the AMWTP, the RWMC HWMA/RCRA Permit relies upon the waste characterization performed under the AMWTP permit to accurately describe the waste received at ARP V and to ensure that no prohibited items are included in wastes accepted for processing at ARP V. Previously characterized AMWTP wastes are documented in RPT-TRUW-05 and RPT-TRUW-12.	(1) Compliance with federal law and state regulations related to RCRA; (2) Implementing procedures that comply with requirements of RCRA.	(1) Noncompliance with requirements of RCRA. (2) Implementing procedures that do not address all applicable requirements of RCRA.	Ineffective: The RWMC HWMA/RCRA Permit correctly prohibited treatment of waste containing pyrophoric radionuclides at the RWMC. However, the items prohibited to be accepted for treatment were limited to aerosol cans and roaster oxides. The RWMC HWMA/RCRA Permit was silent with respect to the *acceptance* of "potential pyrophorics. " The RWMC HWMA/RCRA Permit reflected the content of the permit modification request (PMR). The PMR should have proposed a prohibition with regard to accepting and potential pyrophoric and reactive uranium.	Compromised Barrier: The RWMC HWMA/RCRA Permit prohibited the treatment of pyrophoric radionuclides but did not recognize that pyrophoric and reactive radionuclides may be present in waste containers not containing roaster oxides. The RWMC HWMA/RCRA PMR should have proposed a prohibition with regard to accepting potential pyrophoric and reactive uranium. Revise RWMC HWMA/RCRA permit to include other than roaster oxide pyrophoric waste.

Table D-1. Barrier Analysis: Permits				
			Effectiveness in This Case	Significance and Recommended Corrective Actions
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	
B-1-03 RWMC HWMA/RCRA Permit Condition F-5 Prevention of Reaction of Ignitable, Reactive, and Incompatible Wastes This barrier (Condition F-5) relates to "Ignitable, Reactive, and Incompatible Wastes" only; other provisions of the RWMC HWMA/RCRA Permit (for example, those that deal with waste characterization and acceptance criteria) are considered as a separate barrier.	(1) Compliance with federal law and state regulations related to RCRA regarding chemical compatibility and ignitable or reactive wastes; (2) Implementing procedures that comply with requirements of RCRA regarding chemical compatibility and ignitable or reactive wastes.	(1) Presence of incompatible chemicals, and ignitable or reactive wastes. (2) Implementing procedures that do not prevent the presence of incompatible chemicals and ignitable or reactive wastes.	Ineffective: The RWMC HWMA/RCRA Permit states the waste streams to be stored and treated have been evaluated in accordance with RPT-ESH-014 and "no issues of ignitability or reactivity have been identified." However, RPT-ESH-014, Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) had incomplete and outdated Reactivity Group Numbers (RGNs) for SD-176 waste.	Compromised Barrier: Permit Condition F-5 established requirements for evaluating incompatible wastes; however, the report that was the basis for implementing F-5 requirements was incomplete and out of date. RPT-ESH-014, Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) had incomplete and outdated Reactivity Group Numbers (RGNs) for SD-176 waste. Had ITG and CWI personnel reviewed RPT-ESH-014 to evaluate chemical compatibility of SD-176, they would have realized that RGNs were not provided in Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) for SD-176. A thorough evaluation of SD-176 for chemical compatibility may have identified the potential for pyrophoric and reactive materials being present in SD-176 and/or raised awareness that SD-176 waste was not similar to previously processed IDCs and consisted of a composite of waste from multiple generators and processes. As a result, this event may have been prevented. Revise RPT-ESH-014 to include complete and accurate information.

Table D-2. Barrier Analysis: Procedures That Implement Permit Requirements

Barrier	Target Protected	Hazard	Effectiveness in the Case Why Did Barrier Fail?	Significance
B-2-01 MCP-1390, Waste Generator Services Waste Management (MCP-1390 was used company-wide (throughout Fluor Idaho) for container tracking, records management, container storage, and container transfer of TRU wastes; however, the specific transfers between AMWTP and ARP for the SRP are implemented by a more detailed process (MCP-3930).)	Waste accepted and processed by Fluor Idaho projects meets acceptance criteria and complies with federal law, state regulations, and related permits.	Waste accepted and processed by Fluor Idaho that does not meet the requirements of acceptance criteria, federal law, state regulations, and/or related permits.	Ineffective: This barrier performed as expected to characterize SD-176. It was not intended to characterize the waste on a container-by-container basis. Container-by-container characterization (which failed) was governed by MCP-3930 and MCP-4226.	Compromised barrier: MCP-1390 performed as intended. The barrier was intended to characterize SD-176 rather than on a container-by-container basis. Parent drum 10595963 did not meet ARP V acceptance criteria when received at ARP V. The procedures that evaluated the waste on a container-by-container basis were TPR-7601, MCP-3930, and MCP-4226. The barrier was further compromised through the use of an unapproved document (RPT-TRUW-94) as the basis for acceptance at ARP V. Revise MCP-3930 and MCP-4226 to update container-by-container characterization.
B-2-02 MCP-3930, "Repackage Project Waste Transfers Between RWMC-AMWTP and RWMC-ARP" (This is an SRP procedure that implements requirements in MCP-1390 for waste transfers between AMWTP and ARP-V.)	Waste accepted at ARP-V meets acceptance criteria.	Waste accepted at ARP-V that does not meet ARP-V waste acceptance criteria.	Ineffective: During a container-by-container review of parent drum 10595963, SRP personnel did not identify the presence of "potential pyrophoric"," during the container by container review required by MCP-3930.	Compromised barrier: MCP-3930 required a container-by-container evaluation without establishing acceptance criteria. Evaluation criteria were implemented by MCP-4226; however, MCP-4226 similarly established a requirement that prohibited pyrophoric material without specifying criteria for meeting that requirement. Revise MCP-3930 and MCP-4226 to update container-by-container characterization.

Table D-2. Barrier Analysis: Procedures That Implement Permit Requirements				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-2-03 TPR-7601, RWMC Waste Handling and Overpacking, Section 4.4 (Shipping/ Receiving Waste at RWMC), and Appendix C, (Waste Acceptance Criteria for SRP Container Transfers) TPR-7601 prohibits acceptance of pyrophoric material; implementation of acceptance criteria is through MCP-4226. (RWMC now includes ARP-V and AMWTP; until June 2016, AMWTP and ARP-V were managed by separate companies.) MCP-3930 and MCP-4226 are subordinate to TPR-7601.	Waste accepted at ARP-V meets acceptance criteria.	Waste accepted at ARP-V that does not meet ARP-V waste acceptance criteria.	Ineffective: During its container-by-container review of parent drum 10595963, SRP personnel did not identify the presence of "potential pyrophorics" which were specifically prohibited by TPR-7601. Additionally, Note 2 in Section 4.4.1 states that incoming SRP waste has been evaluated in accordance with RPT-ESH-014. Any review would have identified that SD-176 had not been evaluated in RPT-ESH-014.	Compromised barrier: The TPR-7601 requirement to prohibit pyrophoric material was not met, due to weaknesses in procedures as well as weaknesses in implementation of procedures. Procedures that compromised this barrier were MCP-4226 and MC-3930. Definition of potential pyrophoric and reactive was not defined. Had Waste Generator Services (WGS) personnel reviewed RPT-ESH-014, it would have been clear a Chemical Compatibility Evaluation (CCE) had not been completed for SD-176 waste and this event may have been prevented. Revise TPR-7601 to include the definition potential pyrophoric and include other than roaster oxide uranium waste.

Table D-2. Barrier Analysis: Procedures That Implement Permit Requirements				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-2-04 INST-TRUW-8.13.3, TRU Program Acceptable Knowledge Container Evaluation Process, Rev. 4 09/02/2014 Section 4.1 (Evaluation, Reporting, and Queue Management for Recommended IDC Changes (On 02/13/2017, INST-TRUW-8.13.3 was replaced by TPR-8165, Program Acceptable Knowledge Container Evaluation Process) (On 4/5/2018, TPR-8165 was replaced by MCP-4225, Program Acceptable Knowledge Container Evaluation Process) Required when changing IDC designations. The “event drum” was re-designated from RF-751 (pit 11 and 12 roaster oxides) to SD-176 on 10/20/2016.	Re-categorized waste containers meet criteria of new designation.	Drums approved for processing at ARP-V that do not satisfy ARP-V waste acceptance criteria.	Ineffective: The AK Expert (AKE) was required at that time to evaluate assay data (U-238) for indications of pyrophoric waste. INST-TRUW-8.13.3, Rev. 4, required the AK Expert to consult with an NDA Expert Technical Reviewer and/or RTR SME to evaluate the Assay/RTR/VE data, if a determination was inconclusive. A U-238 mass of depleted uranium, particularly when the mass was known to be 11.9 kg, should have prompted further evaluation.	Weak barrier: INST-TRUW-8.13.3 established a requirement to identify the presence of pyrophoric material without identifying implementable criteria for meeting the requirement. INST-TRUW-8.13.3 was replaced by MCP-4225 so no recommendation for the replaced document. Revise MCP-4225 to include the definition potential pyrophoric and include other than roaster oxide uranium waste.
B-2-05 – Not used				

Table D-2. Barrier Analysis: Procedures That Implement Permit Requirements				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-2-06 MCP-4226, TRU Programs Site Project Office Process This AMWTP procedure governs the process by which waste is approved for shipment to ARP-V on a container-by-container basis using Acceptable Knowledge, RTR, and nondestructive assay.	Waste shipped to ARP-V from AMWTP meets ARP-V acceptance criteria.	Waste shipped to ARP-V from AMWTP that does not meet ARP-V acceptance criteria.	Ineffective: The procedure establishes a requirement to prohibit the shipment to ARP-V of “potential pyrophorics” but fails to identify implementable criteria by which this requirement can be met. During a container-by-container review of parent drum 10595963, personnel did not identify the presence of “pyrophoric radionuclides,” which was specifically prohibited in the RWMC HWMA/RCRA Permit.	Weak barrier: MCP-4226 established a requirement to identify the presence of pyrophoric material without identifying implementable criteria for meeting the requirement. Revise MCP-4225 to include the definition potential pyrophoric and include other than roaster oxide uranium waste including guidance/implementable criteria.

Table D-2. Barrier Analysis: Procedures That Implement Permit Requirements				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-2-07 Implementation of MCP-4226, TRU Programs Site Project Office Process	Waste shipped to ARP-V from AMWTP meets ARP-V acceptance criteria.	Waste shipped to ARP V from AMWTP that does not meet ARP V acceptance criteria.	Ineffective. AMWTP personnel did not correctly identify the presence of reactive uranium in parent drum 10595963. The Non Destructive Assay (NDA) Expert Technical Reviewer (ETR) verified that containers did not contain nitrate salts or roaster oxides; however, the reviewer believed "potential pyrophoric" to be synonymous with "roaster oxides" and failed to identify the presence of pyrophoric and reactive material.	Failed barrier. Implementation of this procedure failed to meet the requirement to identify "potential pyrophoric." Note: Instead of evaluating the presence of "potential pyrophoric," the absence of roaster oxides was accepted as equivalent to the absence of pyrophoric material (based on interviews). Identify personnel responsible for implementing MCP-4226; conduct training (and verify training effectiveness) for personnel assigned responsibility to identify "potential pyrophorics."

Table D-3. Barrier Analysis: Chemical Compatibility

Barrier	Target Protected	Hazard	Effectiveness in the Case Why Did Barrier Fail?	Significance
B-3-01 RPT-ESH-014, Chemical Compatibility Evaluation of Wastes for the Advanced Mixed Waste Treatment Project. This report implements part of the AMWTP RCRA permit, and is one of three documents referenced by the RWMC HWMA/RCRA permit as required to be maintained up to date to maintain permit compliance. The document focus as it relates to this event is to prevent mixing waste streams containing incompatible chemicals.	Processed waste streams with contents that are compatible and free of ignitable or reactive wastes.	Presence of incompatible chemicals, and ignitable or reactive wastes in processed waste streams.	Ineffective: RPT-ESH-014, Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) had incomplete and outdated Reactivity Group Numbers (RGNs) for SD-176 waste, suggesting that a chemical compatibility evaluation had not been performed. Had the evaluation of SD-176 been complete, Attachment 1 constituent and reference columns would have contained entries, rather than “N/A” or “TBD.” Personnel did not ensure a CCE was performed for SD-176	Failed Barrier: RPT-ESH-014, Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) had incomplete and outdated Reactivity Group Numbers (RGNs) for SD-176 waste suggesting that a chemical compatibility evaluation had not been performed. Had ITG and CWI personnel reviewed RPT-ESH-014 to evaluate chemical compatibility of SD-176, they would have realized that RGNs were not provided in Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) for SD-176. A thorough evaluation of SD-176 for chemical compatibility may have identified the potential for pyrophoric and reactive materials being present in SD-176 and this event may have been prevented. Revise RPT-ESH-014 Attachment 1: Update with current RGNs for SD-176 waste; verify information in Attachment 1 is complete.

Table D-3. Barrier Analysis: Chemical Compatibility				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-3-02 Implementation of RPT-ESH-014, Chemical Compatibility Evaluation of Wastes for the Advanced Mixed Waste Treatment Project. This report implements part of the AMWTP RCRA permit, and is one of three documents referenced by the RWMC HWMA/RCRA permit as required to be maintained up to date to maintain permit compliance.	Processed IDCs with contents that are compatible and free of ignitable or reactive wastes.	Presence of incompatible chemicals, and ignitable or reactive wastes in processed IDCs.	Ineffective: RPT-ESH-014, Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) had incomplete and outdated Reactivity Group Numbers (RGNs) for SD-176 waste. Had the evaluation of SD-176 been complete, Attachment 1 constituent and reference columns would have contained entries, rather than "N/A" or "TBD."	Failed Barrier: Personnel using RPT-ESH-014, Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) should have identified that the report had incomplete and outdated Reactivity Group Numbers (RGNs) for SD-176 waste. A thorough evaluation of SD-176 for chemical compatibility may have identified the potential for pyrophoric and reactive materials being present in SD-176 and this event may have been prevented. After updating/revising RPT-ESH-014, identify personnel responsible for using it; conduct training (and verify training effectiveness) for affected personnel.

Table D-4. Barrier Analysis: Waste Examination and Evaluation				
Barrier	Target Protected	Hazard	Effectiveness in the Case Why Did Barrier Fail?	Significance
B-4-01 Understanding by ITG and CWI personnel of the limitations of Acceptable Knowledge available for SD-176.	Accurate and rigorous characterization of SD-176 wastes.	Prohibited items (for example, pyrophoric and reactive) in SD-176 released for processing and/or shipping.	Ineffective: Neither ITG nor CWI personnel recognized that SD-176 waste had the potential to contain pyrophoric and reactive materials. AMWTP procedures (for example, MCP-4225 and MCP-4226) established a requirement to identify the presence of pyrophoric material without identifying implementable criteria for meeting the requirement.	Failed barrier: During the treatment of parent drum #10595963, unidentified prohibited material (reactive uranium) was present, contrary to criteria for processing at ARP V. Upon reaction with oxygen, an exothermic reaction occurred. Had the potential for pyrophoric and reactive materials being present in SD-176 been recognized, it is highly likely that more robust waste characterization, inspection, and evaluation processes would have been established, and the event prevented. Identify personnel responsible for producing, maintaining, understanding and/or using AK for SD-176; conduct training and verify training effectiveness for affected personnel.
B-4-01 – Not used				

Table D-4. Barrier Analysis: Waste Examination and Evaluation				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-4-03 Implementation of IAG-592, Rev 10 (03/01/2016) Roles and Responsibilities for Sludge Repackage Project Waste Transfers Between ITG and CWI. [This document is no longer active.] This document served the same purpose as would a contract between ITG and CWI. (At the time this IAG was established, ITG and CWI were two different companies.) This revision established the overall requirements to be met by SD-176 for processing by SRP.	Process and criteria by which SD-176 was approved and processed at SRP.	Inappropriate approval of waste IDCs for processing at SRP.	Ineffective: ITG personnel did not provide a Chemical Compatibility determination for SD-176, as required by IAG-592, Section 4.2. Contrary to IAG-592, Section 4.2, CWI personnel did not require a Chemical Compatibility determination for SD-176. Upon interview, CWI personnel did not believe a Chemical Compatibility determination was required since comingling of IDCs would not be performed for SD-176.	Failed Barrier: ITG/CWI personnel did not implement IAG-592 requirements to provide a chemical compatibility determination for SD-176 as required by Section 4.2. Had ITG and CWI personnel reviewed RPT-ESH-014 to evaluate chemical compatibility of SD-176, they would have realized that Reactivity Group Numbers (RGNs) were not provided in Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) for SD-176. A thorough evaluation of SD-176 for chemical compatibility may have identified the potential for pyrophoric and reactive materials being present in SD-176 and this event may have been prevented. No action required based on IAG-592 was deleted.

Table D-4. Barrier Analysis: Waste Examination and Evaluation

Barrier	Target Protected	Hazard	Effectiveness in the Case Why Did Barrier Fail?	Significance
B-4-04 MCP-48, Training Analysis, Design, Development, and Release	A staff that is trained and capable of properly characterizing the SD-176.	Personnel that lack sufficient knowledge and training characterize and process SD-176 wastes.	Ineffective. SRP personnel did not recognize that SD-176 wastes may contain prohibited (for example, pyrophoric and reactive) materials. SRP personnel responsible for characterizing candidate SRP wastes were aware of the hazards of roaster oxides but were generally unaware that SD-176 waste may contain prohibited (pyrophoric and reactive materials even though roaster oxides are absent Training was not evaluated to determine whether changes were necessary for this new waste IDC.	Broken Barrier: SRP personnel did not recognize that SD-176 wastes may contain prohibited (for example, pyrophoric and reactive) materials. Training requirements and content were not evaluated to determine whether changes were necessary when this new waste IDC began to be processed. Re-train personnel on the lessons learned from this event.

Table D-4. Barrier Analysis: Waste Examination and Evaluation

Barrier	Target Protected	Hazard	Effectiveness in the Case Why Did Barrier Fail?	Significance
B-4-05 TPR-7997, “Visual Examination Activities at RWMC” Section 4.2 Visual Examination Appendix B (List of TRU Prohibited Items) This document replaced INST-TRUW-8.13.4 This document defines the process used by trained and qualified Visual Examiners (VEs) to examine a waste container in order to verify that the physical form of the waste matches the waste stream description as determined by Acceptable Knowledge.	Accurate identification of TRU prohibited items before they are packaged for shipment.	TRU prohibited items are not identified and are processed in violation of waste acceptance criteria.	Ineffective. The Visual Examiners (VEs) were not placed in the process where they needed to be in order to accurately perform this assigned function. Parent drums are emptied in the ARP V Retrieval Enclosure (RE) onto a sorting table, where untrained ARP Equipment Operators (not trained as VEs) examine the drum contents for WIPP prohibited items (for example, radioactive pyrophoric) in accordance with TPR-7867. Instead, the VEs were stationed at the DPS where daughter drums were being loaded. By the time the contents of the “event drum” had been mixed with the contents other parent drums, the ability of the VEs to accurately identify finely divided pyrophoric and reactive materials was compromised.	Broken barrier: Had a trained VE watched the event drum (10595963) as it was emptied on the sorting table, the VE may have observed the visual characteristics of this drum were not recognizable as typical SD-176 waste and called a “step-back” to evaluate the situation prior to proceeding with waste processing. As a result, the drum contents may have been rejected and additional controls implemented to manage this unknown waste material. Revise TPR-7997 and review role (s) of VEs in process flow and have them inspect locations appropriately.

Table D-4. Barrier Analysis: Waste Examination and Evaluation				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-4-06 Training on Pyrophoric and reactive Metals	A staff that is trained and capable of properly identifying the presence of pyrophoric and reactive materials in waste containers or during waste repackaging activities.	Personnel that lack sufficient knowledge and training to identify the presence of pyrophoric and reactive materials.	Ineffective: Training was ineffective for TRU Waste Program personnel regarding the ability to determine whether pyrophoric and reactive materials (or other prohibited items not addressed in AK documentation) may be present in a given container prior to authorizing shipment to ARP V for waste processing.	Missing Barrier: Training covered roster oxides but did not effectively address other indications that pyrophoric and reactive waste (or other prohibited items not addressed in AK documentation) may be present. Conduct training regarding definition of, identification criteria, roles and responsibilities, and procedural requirements for identifying pyrophoric materials; evaluate training effectiveness.

Table D-5. Barrier Analysis: Safety and Oversight Processes

Barrier	Target Protected	Hazard	Effectiveness in the Case	Significance
			Why Did Barrier Fail?	
B-5-01 SAR-4, Safety Analysis Report for the Radioactive Waste Management Complex	A documented, current, rigorous, and complete Safety Basis for operations related to radioactive waste management and processing.	Changes are made to a nuclear facility that are not appropriately and accurately reflected in the Safety Basis and that reduce the margin of safety.	Ineffective: The results of the annual review of SAR-4/TSR-4 did not identify that an update to SAR-4/TSR-4 was required to accommodate the increased risks associated with processing SD-176 wastes.	Broken Barrier: SAR-4/TSR-4 did not reflect new risks associated with processing SD-176 waste. Revise SAR-4/TSR-4 and update to reflect new risks associated with processing SD-176, -177, and -178 wastes.
B-5-02 MCP-2449, Nuclear Safety Analysis Section 4.4 (DSA and TSR Maintenance, including annual update)	Integrity of DSA and TSR and their fidelity to physical plant and way in which it is operated.	Changes made to a nuclear facility that is not appropriately and accurately reflected in the Safety Basis, configuration documents, and operating procedures.	Ineffective: Individuals that conducted the annual review of SAR-4/TSR-4 did not recognize that SAR-4/TSR-4 required updating to accommodate the increased risks associated with treating SD-176 wastes.	Failed Barrier: The integrity and fidelity of the DSA and TSR to the nuclear facility were not maintained. Review and evaluate underlying factors that caused the annual review to miss the increased risk associated with processing SD-176; revise implementing procedures as appropriate; train affected personnel; and evaluate training effectiveness.

Table D-5. Barrier Analysis: Safety and Oversight Processes				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-5-03 MCP-123, Unreviewed Safety Questions Section 4.2 (Execution of the USQ Process for Proposed Changes) Section 4.3 (Execution of the USQ Process for New Information or Discoveries)	Integrity of DSA and TSR and their fidelity to physical plant and way in which it is operated.	Changes made to a nuclear facility that is not appropriately and accurately reflected in the Safety Basis, configuration documents, and operating procedures.	Ineffective: During the review process for revising IAG-592, Rev. 10, and a determination was made that a USQ determination was not required because the change was categorically excluded, based upon the document (IAG) not affecting nuclear operations. It was not recognized that a change to Appendix A (Approved IDCs) had a direct impact on the safety basis (SAR-4/TSR-4) for ARP V.	Failed Barrier: The integrity and fidelity of the DSA and TSR to the nuclear facility were not maintained. Bypassed Barrier: IAG-592 rev 10 (which authorized SD-176) was not reviewed for USQs, because IAGs are categorically excluded from USQ review. Revisit the assumption that IAGs do not require review for USQs and revise MCP-123 accordingly.
B-5-04 ICP/EXT-04-00209, Health and Safety Plan for the Accelerated Retrieval Project, Rev. 15	Worker safety and health at ARP facilities.	Threats to worker health and safety introduced through ARP operations.	Ineffective: The HASP does not consider the increased risks associated with treating SD-176 wastes at ARP V (for example, the potential presence of pyrophoric and reactive materials).	Broken/Missing Barrier: The health and safety plan (HASP) for the Accelerated Retrieval Project (ARP) has not been updated since July 2010 and does not address processing SD-176 wastes at ARP V. Update ICP/EXT-04-00209; establish and enforce expectations for periodic review and update.
B-5-05 MCP-2985, Technical Procedures	Compliance with company Conduct of Operations requirements.	Procedures that do not meet company Conduct of Operations requirements.	Ineffective: MCP-3930 was issued which did not meet the requirements of MCP-2985, in that it does not require formal documentation of decisions, conclusions, and actions that are material to processing of waste IDCs (including SD-176).	Compromised barrier: The barrier was ineffective because MCP-3930 was not written to ensure that process decisions, conclusions, and actions that are material to waste processing are formally documented. The failure of this barrier did not have a direct, measurable effect on compliance with DOE or RCRA requirements.

Table D-5. Barrier Analysis: Safety and Oversight Processes				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
				Conduct "extent of condition" evaluation of failure of procedures to comply with MCP-2985 requirements regarding Conduct of Operations; revise procedures as necessary.
B-5-06 Change Management Process	The integrity of policies, processes, and procedures (PPP) impacted by the identified change(s).	Failure to fully accommodate identified change(s) through appropriate changes to how business is done.	Ineffective. On 3/10/2016, the first drum of waste was repackaged from the SD-176. SRP management did not recognize (and did not follow a formal process to identify) that this new IDC was significantly different than waste streams successfully processed at ARP V in the past. A "change control" procedure existed since 2005 (MCP-1414); however this procedure was narrowly focused on managing the Performance Management Baseline and associated funding assignments. (See Barrier B-5-11)	Missing Barrier: SRP did not have a formal Change Management process that required rigorous evaluation of the impact of scope changes on policies, processes, and procedures related to waste handling. There is no contractual requirement to have a Change Management Program. Establish and implement a formal Change Management Process. Coordinate with actions to address Barrier B-5-11 (MCP-1414, Change Control).

Table D-5. Barrier Analysis: Safety and Oversight Processes				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-5-07 SRP Management oversight and questioning of waste processing criteria, policies, procedures, and practices.	Safe and compliant treatment and storage of mixed TRU waste.	Improperly handled, categorized, or stored mixed TRU waste.	Ineffective: Complacency led to a management belief that previous success would translate into future success so long as the process remained the same. There was apparently no thought to change the process at the beginning of SD-176 processing campaign, even though there were differences noted between distinct Rocky Flats Sludges IDCs (RF-001/741, 002/742, 003/743) and SD-176 (Pre-1980 INL-Exhumed SDA Homogeneous Solids) that was a composite of waste from multiple generators and processes.	Weak Barrier. Lack of questioning attitude with regard to waste processing criteria, policies, procedures, and practices. Belief that processing SD-176 waste was not substantially different than processing waste in previous successful campaigns. Discussion: this is a symptom of a wide-spread cultural issue that will require substantial time and effort to address. Identify compensatory measures involving additional 'devil's advocate' in-line process reviews for key decisions until such time as the company has a basis upon which to demonstrate that this problem has been addressed.

Table D-5. Barrier Analysis: Safety and Oversight Processes				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-5-08 MCP-3930, "Repackage Project Waste Transfers Between RWMC-AMWTP and RWMC-ARP," Rev. 10 (Management Review Process) Section 4.2, Container Review and Approval (to verify that each waste container is acceptable for transfer to ARP V)	Containers transferred to ARP V meet waste acceptance criteria.	Accepting waste containers at ARP V that do not meet acceptance criteria (for example, that include pyrophoric and reactive materials).	Ineffective. The SRP Management Review Process, described in MCP-3930, was ineffective in detecting the presence of pyrophoric and reactive materials in the waste drum 10595963.	Failed Barrier. In the case of the "event drum" (10595963), the SRP Management Review Process was ineffective in detecting the presence of pyrophoric and reactive materials in the waste. However, if the EOC review, conducted as part of CAR 116640, EM-ID--FID-AMWTF-2018-0001, Pyrophoric Event In WMF-676 Treatment Facility North Box Line, had alerted SRP management that a similar, high U-238 content drum was susceptible to pyrophoric reaction, the 4/11/2018 event may have been avoided. See corrective action for Barrier B-5-07 above.
B-5-09 – Not used				
B-5-10 CAR 116640, EM-ID--FID-AMWTF-2018-0001, Pyrophoric Event In WMF-676 Treatment Facility North Box Line	Controls to prevent similar event from occurring, involving pyrophoric and reactive uranium.	Failure to identify and/or take actions to prevent future events involving pyrophoric and reactive uranium.	Ineffective. The reactive uranium event in WMF-676 Treatment Facility North Box Line occurred on 12/21/2017, approximately 4 months before the reactive uranium event in ARP V. Corrective actions from the North Box Line event (CAR 116640) were completed 4/25/2018, just two weeks after the ARP V event. Neither the EOC review nor the completed corrective actions from CAR 116640	Weak Barrier. The barrier, if strengthened, might have prevented the ARP V event. As a result of CAR 116640, an Extent of Conditions review was performed for drums containing >5 kg of U-238 in the configuration of concern (predominant presence of items such as machine turnings, tailings, machining waste or waste items resembling machining waste, or metal filings). The parent drum 10595963 had been identified as a potential problem drum on the basis of a U-238 mass of greater than 5 kg.

Table D-5. Barrier Analysis: Safety and Oversight Processes				
Barrier	Target Protected	Hazard	Effectiveness in the Case Why Did Barrier Fail?	Significance
			addressed the ARP V SD-176 waste processing operations. In both cases, drums previously categorized as RF-751 were re-categorized to nonpyrophoric and reactive codes (RF-750 and SD-176) to allow them to be processed rather than to be held in storage. In both cases, the U-238 mass was significant (46.7 kg and 11.9 kg.	However, it was not considered any further the Box line event extent of condition because it was "Not TF Feed, Not on RPT-TRUW-83." Had this drum been flagged, it would have been identified as a problem drum prior to the SRP Management Review Process (including drum 10595963) that was described in MCP-3930 and completed on 4/3/2018. Establish enhanced management expectations for quality, thoroughness, and attention paid to "extent of condition" reviews; enforce the expectations. In particular, train all causal analysts, CAR evaluators, and anyone else who may conduct EOC evaluations how to do them, increase the rigor and depth of management review of EOC evaluations.
B-5-11 MCP-1414, "Change Control" This procedure has been in place and used since September 2005 to manage the Performance Measurement Baseline (PMB) and associated funding assignments. The change control process, described in MCP-1414, is an integral part of the monthly reconciliation of the contract to the baseline.	Changes to work scope are identified, prioritized, and resources allocated and funded so that the work is accomplished safely and in compliance with DOE contractual requirements.	Changes to existing work scope are not properly identified and resources are not allocated and funded such that the work is not accomplished safely and in compliance with DOE contractual requirements.	Ineffective MCP-1414 was intended for use in managing the contract rather than managing waste handling or related processes. (See also B-5-06)	Weak Barrier The scope and applicability of MCP-1414 are narrowly limited to processing directed and proposed changes to the Fluor Idaho PMB and associated funding assignment. MCP-1414 is not directly applicable to evaluating and managing the impact of changes on production policies, processes, or procedures. What was missing from MCP-1414 includes a complete and robust identification of new work scope, new hazards that potentially impact health, safety, environmental, disposal,

Table D-5. Barrier Analysis: Safety and Oversight Processes				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
It is focused on managing the contract, and not on managing work processes.				training, remediation, and other aspects of the project. Revise MCP-1414 to incorporate requirements for complete and robust identification of new work scope and new hazards that potentially impact health, safety, etc. Coordinate with actions to address Barrier B-5-06 (Change Management Process).

Table D-6. Barrier Analysis: Reports Upon Which Decisions Are Based

Barrier	Target Protected	Hazard	Effectiveness in the Case Why Did Barrier Fail?	Significance
B-6-01 RPT-TRUW-05, Waste Matrix Code Reference Manual. This report implements part of the AMWTP RCRA permit, and is one of three documents referenced by the RWMC HWMA/RCRA permit as required to be maintained up to date to maintain permit compliance. Nothing in RPT-TRUW-05 identifies the potential for SD-176 to contain pyrophoric materials.	Correct and complete characterization of SD-176 waste.	Incorrect or incomplete characterization of SD-176 waste.	Ineffective The RWMC HWMA/RCRA Permit references this document and relies upon it to correctly characterize the waste associated with all IDCs listed, including SD-176. RPT-TRUW-05 section 4.0 reference table for IDC SD-176 did not identify potential prohibited items including possibility that pyrophoric and reactive materials may be in a form other that roaster oxides and may require additional analysis rather than RTR alone to detect potential pyrophoric and reactive materials. The Special Notes section did not make any mention of prohibited items.	Failed barrier: RPT-TRUW-05 did not adequately identify the potential for SD-176 reference table to contain prohibited reactive wastes. Such wastes were later determined to be present in the “event drum (10595963)”. Revise RPT-TRUW-05 SD-176 reference table to reflect potential prohibited items including reactive uranium. Other reference table IDCs should be evaluated as well.
B-6-02 – Not used				

Table D-6. Barrier Analysis: Reports Upon Which Decisions Are Based				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-6-03 RPT-TRUW-91,Acceptable Knowledge Document for Pre-1980 INL-Exhumed SDA Waste, Rev. 2, (This document describes the origin of SD-176, and is referred to by Acceptable Knowledge experts.) Draft RPT-TRUW-94 was provided for SD-176. This report was never completed or issued. Information about the potential for pyrophoric materials contained in RPT-TRUW-91 was not replicated in RPT-TRUW-94. RPT-TRUW-94 used to complete the WDDF for acceptance at SRP.	Correct and complete characterization of waste on the basis of accurate and approved "Acceptable Knowledge" documents.	Inaccurate characterization of waste and subsequent noncompliance with ARP V waste acceptance criteria.	Ineffective: The basis for characterization of the "event drum" (10595963) as documented in WDDF RWMC-15005 came from the unapproved, draft RPT-TRUW-94. The approved AK document (RPT-TRUW-91) was not used as the basis. RPT-TRUW-91 did give a broad statement on case-by-case concerns but did not identify any criteria for evaluation. RPT-TRUW-91 did not identify all potential prohibited items and did not assess the June 1970 drum fire or evaluate all historical AK source documents to identify potential pyrophoric and reactive could exist in non-RO waste.	Bypassed barrier: The approved AK document, RPT-TRUW-91, was not used as the basis for characterizing waste in the "event drum" (10595963); rather, an unapproved, draft document (RPT-TRUW-94) was used as the basis. Weak barrier: RPT-TRUW-91 did give a broad statement on case-by-case concerns but did not identify any criteria for evaluation. RPT-TRUW-91 did not identify all potential prohibited items and did not assess the June 1970 drum fire or evaluate all historical AK source documents to identify potential pyrophoric and reactive could exist in non-RO waste. Revise RPT-TRUW-91 to include all prohibited items and include pyrophoric other than roaster oxides. Re-communicate management expectations that using DRAFT material to make decisions at a CAT 2 facility is unacceptable.

Table D-6. Barrier Analysis: Reports Upon Which Decisions Are Based				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-6-04 RPT-TRUW-94, Acceptable Knowledge Summary for AMWTP Combined Homogeneous Solids Repackage Project (DRAFT) RPT-TRUW-94 was provided to support processing of SD-176. Information about the potential for pyrophoric materials contained in TRUW-91 was not replicated in TRUW-94. Draft RPT-TRUW-94 was used as the basis for characterization of SD-176 waste.	Correct and complete characterization of waste on the basis of accurate and approved "Acceptable Knowledge" documents.	Inaccurate characterization of waste and subsequent noncompliance with ARP V waste acceptance criteria.	Ineffective: The basis for characterization of the "event drum" (10595963) as documented in WDDF RWMC-15005 came from the unapproved, draft RPT-TRUW-94. The approved AK document (RPT-TRUW-91) was not used as the basis. RPT-TRUW-94 did not replicate information from RPT-TRUW-91 regarding the case-by-case potential for pyrophoric and reactive waste being present in SD-176.	Missing barrier: RPT-TRUW-94, Acceptable Knowledge Summary for AMWTP Combined Homogeneous Solids Repackage Project, was never issued to support WIPP approval of SD-176, but was used in draft form as the basis for characterizing SD-176. Information from the predecessor document (RPT-TRUW-91) regarding the potential for pyrophoric and reactive materials was not replicated in draft RPT-TRUW-94. Revise RPT-TRUW-91 to include all prohibited items and include pyrophoric other than roaster oxides. Re-communicate management expectations that using DRAFT material to make decisions at a CAT 2 facility is unacceptable.

Table D-6. Barrier Analysis: Reports Upon Which Decisions Are Based				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-6-05 Implementation of DRAFT RPT-TRUW-94, Acceptable Knowledge Summary for AMWTP Combined Homogeneous Solids Repackage Project	Correct and complete characterization of waste (including SD-176) on the basis of accurate and approved "Acceptable Knowledge" documents.	Inaccurate characterization of waste and subsequent noncompliance with ARP V waste acceptance criteria (including with regard to SD-176).	Ineffective. DOE directed the use of DRAFT RPT-TRUW-94 for processing SD-176 waste to be held locally, pending future shipment off-Site after meeting currently unidentified criteria.	Broken Barrier. Mixed radiological/chemical waste was processed using unapproved "Acceptable Knowledge" documentation. Use of unapproved basis documents that bypassed the review and approval processes is an inappropriate practice. Even if RPT-TRUW-94 had been approved, as written, the document did not adequately describe the waste characteristics of SD-176 because it did not replicate information contained in the predecessor document (RPT-TRUW-91) regarding the potential for pyrophoric and reactive materials in SD-176. Re-communicate management expectations that using DRAFT material to make decisions at a CAT 2 facility is unacceptable.

Table D-7. Barrier Analysis: Physical Barriers				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-7-01 55-gal daughter drums (4): • 10647931 • 10648033 • 10648030 • 10647918 These four drums of TRU mixed waste were generated during SRP repackaging of parent drums 10595963 (event drum), 10630243, and 10630238.	Radioactive mixed waste is completely contained within the drum.	Radioactive mixed waste is not contained within the drum and presents environmental hazards and/or hazards to personnel and public safety.	Ineffective. Reactive uranium, present in the event drum (10595963), when mixed with the contents of two other parent drums, initiated heating resulting in secondary reactions (volatile pressurization). In four daughter drums (10647931, 10648033, 10648030, 10647918) the reactive metal heating of the waste matrix resulted in exceeding the burst pressure of the drum lid.	Compromised Barrier: The sealed drums were subjected to internal pressures and exceeded design pressure and were subsequently breached. A release of radioactive material occurred from each of the four daughter drums. Radioactive contamination was confined within Airlock 5 (AL5) in WMF-1617. ARP workers were not in the building at the time of each drum rupture. No injuries were reported and no release to the environment occurred. Corrective actions to address the root and contributing causes will address this barrier.
B-7-02 WMF-1617, Airlock 5 (AL5)	Radioactive mixed waste and associated contamination is completely contained within WMF-1617.	Radioactive mixed waste and/or contamination is not contained within WMF-1617 and presents environmental hazards and/or hazards to personnel and public safety.	Effective. Radioactive contamination was confined within Airlock 5 (AL5) in WMF-1617. WMF-1617 is designed to contain any contamination inside the building. No release to the environment occurred.	Successful Barrier: Radioactive contamination was confined within Airlock 5 (AL5) and the interior of the workspace it served in WMF-1617. No release to the environment occurred.

Table D-7. Barrier Analysis: Physical Barriers				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-7-03 WMF-1617, Retrieval Enclosure	Radioactive mixed waste and associated contamination are completely contained within MWF-1617.	Radioactive mixed waste and/or contamination is not contained within WMF-1617 and presents environmental hazards and/or hazards to personnel and public safety.	Effective. WMF-1617 is designed to contain any contamination inside the building.	Successful Barrier: Radioactive contamination was confined within Airlock 5 (AL5) and the interior of the workspace it served in WMF-1617. No release to the environment occurred.
B-7-04 WMF-1617, Drum Packaging Stations	Radioactive mixed waste and associated contamination are completely contained within the Drum Packaging Stations during drum packaging evolutions.	Radioactive mixed waste and/or contamination is not contained within the Drum Packaging Stations and presents environmental hazards and/or hazards to personnel and public safety.	Effective. WMF-1617 is designed to contain any contamination inside the building.	Successful Barrier: Radioactive contamination was confined within Airlock 5 (AL5) and the interior of the workspace it served in WMF-1617. No release to the environment occurred.
B-7-05 WMF-698	Radioactive mixed waste and associated contamination are completely contained within WMF-698.	Radioactive mixed waste and/or contamination is not contained within WMF-698 and presents environmental hazards and/or hazards to personnel and public safety.	Unchallenged. The four daughter drums were not located in WMF-698 at the time of the event. WMF-698 is not designed to contain any contamination inside the building	Unchallenged

Table D-8. Barrier Analysis: Safety Culture

Barrier	Target Protected	Hazard	Effectiveness in the Case Why Did Barrier Fail?	Significance
B-8-01 Weaknesses in Nuclear Safety Culture: • Inhibited problem identification at times; • Allowed instances of nonconservative decision-making; • Led to situations where compliance to requirements was subordinated to schedule performance, and • Cases where key safety requirements were not well supported with documentation and/or rigorous procedures.	Organizational adherence and performance to a set of core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment.	One or more competing goals become organizationally more important than safety, directly increasing the risk of adverse consequences to public and worker health and safety, the environment, and compliance with federal and state requirements.	Less than fully effective. The Root Cause Team identified safety culture weaknesses in the focus areas of: • Leadership • Employee/Worker Engagement, and • Organizational Learning The impact of these weaknesses was spread throughout the organization, as is generally the case with cultural weaknesses. [See Root Cause 2 and supporting discussion.]	Degraded Barrier Less than fully effective safety culture: • Reduces the likelihood that an organization will find and fix its own problems before they become major events; • Reduces the effectiveness of people and processes; • Increases the frequency of undetected/ uncorrected human error; and • Increases the risk of a consequential event happening. Perform an independent Safety Culture assessment and implement the recommendations from that assessment. Discuss lessons learned with all Fluor Idaho personnel to ensure they understand how their actions can impact the overall Safety Culture at their facility.

Table D-9. Management				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-9-01 Management Integrated Safety Management	Project objectives are properly planned, with work tasks properly identified, prioritized, and resources allocated and funded so that the work is accomplished safely.	Changes experienced during the performance of contract objectives are not properly evaluated resulting in an increased risk of performing work in an unsafe manner.	Ineffective: Management failed to fully understand, characterize, and establish adequate process controls for treating composite waste from multiple generators and processes. Weaknesses in proper characterization of drum contents when adding additional drum populations that included containers of unknown origin were not conservatively managed and resulted in issues in effectively meeting the RCRA permit, hazard recognition, controls development, and procedure compliance.	Failed Barrier: Management did not recognize that SD-176 waste was different from waste streams that had been successfully processed in the past. Consequently, the risks/consequences associated with this change were not adequately reviewed/assessed. Had Management been successful in identifying the risks involved in processing SD-176 waste, this event may have been avoided. Revise the existing process to ensure that lessons learned from this event are incorporated into existing procedures. Train personnel on those changes.

Table D-9. Management				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-9-02 Management (ITG, CWI) Successful Contract Performance	Work is performed in compliance with the requirements DOE O 435.1, Radioactive Waste Management	Work is not performed in compliance with the requirements DOE O 435.1, Radioactive Waste Management.	Ineffective: Management failed to ensure a documented plan or path to disposal as required by DOE O 435.1, Radioactive Waste Management, was established prior to processing SD-176. The change to process SD-176 was made without recognition that the facility was transitioning from processing a well characterized, relatively homogeneous IDC waste stream, to an IDC waste that was not well characterized and originated from various generators and processes and which did not have a comprehensive CCE. Undefined characterization activities and WIPP approval still remain to be completed.	Failed Barrier: The repackaging of SD-176 waste drums was performed at risk. There is a potential that these drums will require additional characterization activities and possibly require repackaging in order to meet off-Site waste disposal requirements (for example, WIPP). Perform effective due diligence evaluations prior to taking on new responsibilities or work scope.
B-9-03 Management (ITG, CWI) Successful Contract Performance	Contractor performance decisions are based upon incentives provided in the contract.	The more difficult contract deliverables are not performed or are delayed based upon management discretion.	Partially effective: The tendency of prior AMWTP management to set aside difficult waste issues has contributed to the recent issue in that all waste processing is being done with waste that is difficult to process, has incomplete data, or the facilities lack the processes or equipment to deal with it.	Weak Barrier: The degree of difficulty in properly characterizing and processing SD-176 waste has resulted in increased risks to personnel and public safety, and an increased risk of radiological releases to the environment. Perform effective due diligence evaluations prior to taking on new responsibilities or work scope.

Table D-9. Management				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-9-04 Management (ITG) Acceptable Knowledge (AK) Program Personnel	A sufficient number of trained and qualified Acceptable Knowledge (AK) personnel are available to effectively and compliantly perform waste characterization activities in support of DOE goals and objectives.	A sufficient number of trained and qualified Acceptable Knowledge (AK) personnel are not available to effectively and compliantly perform waste characterization activities in support of DOE goals and objectives.	Ineffective: A lack of trained and qualified AK personnel that could support the daily activities along with providing effective program oversight was not turned over to Fluor at transition and has not been corrected. ITG released approximately 30 AK personnel on the project. ITG laid all of them off, except 2, shortly after contract turnover in late 2011/early 2012.	Compromised Barrier: The lack of trained and qualified AK personnel has compromised the ability of current ICP contractors to effectively and compliantly perform waste characterization activities in support of DOE goals and objectives. Perform effective due diligence evaluations prior to taking on new responsibilities or work scope.
B-9-05 Fluor Idaho Management Acceptable Knowledge (AK) Program Personnel	A sufficient number of trained and qualified Acceptable Knowledge (AK) personnel are available to effectively and compliantly perform waste characterization activities in support of DOE goals and objectives.	A sufficient number of trained and qualified Acceptable Knowledge (AK) personnel are not available to effectively and compliantly perform waste characterization activities in support of DOE goals and objectives.	Ineffective: A lack of trained AK personnel that could support the daily activities along with providing effective program oversight was not turned over to Fluor at transition and has not been corrected. Fluor has recognized this lack of expertise and has reversed this trend. Negotiations with DOE-ID are continuing to increase funding for sufficient staffing.	Compromised Barrier: The lack of trained and qualified AK personnel has compromised the ability of past and current ICP contractors to effectively and compliantly perform waste characterization activities in support of DOE goals and objectives. Increase staffing to allow for more qualified AK personnel.

Table D-9. Management				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-9-06 Fluor Idaho Management Oversight Program - MWVs, Management Assessments, Independent Assessments	Management conducts oversight activities through management assessment processes at the SRP to monitor performance and to ensure safe and compliant execution of work.	Management does not conduct sufficient oversight activities through management assessment processes at the SRP and consequently does not ensure safe and compliant execution of work.	Ineffective: Hundreds of MWVs were reviewed to identify if management had identified any issues that would have indicated additional actions should have been taken to address SRP. MWVs did not identify issues that would have indicated potential problem areas. The Team also evaluated if there were any trends from the Performance Assurance group that would have identified any issues with the SRP process. Management oversight was not effective in identifying or questioning that an unknown waste IDC was being processed in the same manner as an IDC for a specific known waste stream. Oversight did not verify that specific process requirements were appropriately documented through procedural sign-offs, particularly when performed by different organizations.	Failed Barrier: Had Fluor Idaho Management been successful in identifying the risks involved in processing SD-176 waste, this event may have been avoided. Perform an independent assessment of the Fluor self-assessment process to identify their oversight weaknesses for the drum event. Perform an independent assessment of the Quality Assurance organization to identify their oversight weaknesses for the drum event. Review the corrective actions from the direction received from DOE concerning the lack of effectiveness of the Performance Assurance Program. Identify weak or ineffective corrective actions and take required actions.

Table D-9. Management				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-9-07 Fluor Idaho Management Integrated Safety Management System (ISMS) Voluntary Protection Program (VPP)	Work is performed safely and in compliance with regulatory requirements. Schedule pressures do not impact contractors' ability to perform work safely and in compliance with regulatory requirements.	Schedule pressures negatively impact contractors' ability to perform work safely and in compliance with regulatory requirements.	Ineffective: Management interviews indicated that meeting the Idaho Settlement Agreement drove contract performance and fee which translated down to personnel as the primary driver for some decisions which led to reluctance to raise issues which could affect schedule performance. This was reinforced by multiple occasions of accommodations/agreements to waive or delay meetings of requirements in order to not impact schedule	Weak Barrier: Schedule pressure was felt by contractor personnel over the entire period evaluated. This schedule pressure may have contributed to persons evaluating the event drum (10595963) for satisfying ARP V waste acceptance criteria. If this barrier been successful, this event may have been avoided. Corrective actions to address the Safety Culture root cause will address this barrier.

Table D-9. Management				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-9-08 MCP-135, Document Management MCP-135 establishes the requirements for revising existing company-wide documents, including the identification of personnel necessary to perform technical reviews.	Personnel who perform specific functions of a procedure are involved in the document creation and revision process and as a result, are aware of their assigned functions and responsibilities.	Personnel who perform specific functions of a procedure are not involved in the document creation and revision process and as a result, are not aware of their assigned functions and responsibilities and do not perform their assigned duties in accordance with established requirements.	Ineffective: MCP-135 requires the Document Owner to identify designated (Review Response Required) reviewers to review proposed changes to an existing procedure. In December 2017, when TPR-8151 was converted to MCP-4226, Rev. 0, the NDA Expert Technical Reviewer (ETR) was not designated as a RRR reviewer, although that function had specific functions and responsibilities. As a result, the NDA/ETR was unaware of the revisions made to TPR-8151.	Broken Barrier: The NDA ETR, who performed a review of the event drum #10595963 prior to transfer to ARP V, did not perform the procedure, as written. As a result, the NDA ETR did not specifically verify "potential pyrophorics" were not present. The absence of roaster oxides was accepted as equivalent to the absence of pyrophoric material (based on interviews). Had the NDA ETR been given the opportunity to review the revision to TPR-8151, the subtle change to the procedure may not have occurred or at a minimum, the NDA ETR would have been aware of the revised requirement. Review MCP-135 requirements and strengthen the requirement that leaves the review of a revised document solely up to the owner of the document.

Table D-10. Human Performance				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-10-01 Fluor Idaho Management - Human Performance Improvement (HPI) Program	An HPI Program is in place that effectively evaluates human performance data and identifies appropriate corrective actions, resulting in improved human performance attributes.	An HPI Program is not in place or is ineffective in evaluating human performance data such that human performance does not improve.	Ineffective: Fluor Idaho Management has not implemented an effective HPI program. Numerous human performance weaknesses were identified during the root cause team's analysis. The Team determined that the Fluor Idaho HPI program is not sufficiently mature and is not integrated into existing programs and projects to be effective.	Weak Barrier: Had a robust and effective HPI Program been in place within Fluor Idaho, this event may not have occurred. HPI metrics may have identified trends (for example, schedule pressure, complacency) resulting in management actions to address known human performance issues. Appoint a sponsor to HPI. Start trending HPI issues. Develop HPI performance metrics that will indicate actual performance.
B-10-02 Human Performance Trending Analysis	An HPI Program is in place that effectively evaluates human performance data and identifies appropriate corrective actions, resulting in improved human performance attributes.	An HPI Program is not in place or is ineffective in evaluating human performance data such that human performance does not improve.	Ineffective: The Team evaluated the contributing factors of each inappropriate action and identified actions that had a human performance attribute affecting the action. The Team concluded use of an error type analysis (Skill-, Rule-, and Knowledge-Based) as a method to analyze each inappropriate action may have provided a tool to ensure that corrective actions were appropriate and effective.	Missing Barrier: Had an HPI trending tool been in place and effective, this event may have been avoided. HPI metrics may have identified trends (for example, schedule pressure, complacency) resulting in management actions to address known human performance issues. Appoint a sponsor to HPI. Start trending HPI issues. Develop HPI performance metrics that will indicate actual performance.

Table D-10. Human Performance				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-10-03 Human Performance Weaknesses	An HPI Program is in place that effectively evaluates human performance data and identifies appropriate corrective actions, resulting in improved human performance attributes.	An HPI Program is not in place or is ineffective in evaluating human performance data such that human performance does not improve.	Ineffective: SRP successes in repackaging thousands of containers for disposal at WIPP and other disposal sites led to a strong belief within management and staff that application of the EPA binary chemical approach combined with Acceptable Knowledge of waste characterization would lessen any possible adverse reaction. That strong belief coupled with additional controls (for example, no mixing of chemicals during treatment and mixing of waste on the sorting table while looking for prohibited items) led to a mindset that the SRP process would effectively rule out all adverse reactions or that they would be identified immediately in the process. This mindset led to complacency and SRP management underestimated the problem by using past events as the basis.	Missing Barrier: Had a HPI Program been in place and effective in evaluating human performance data (for example, schedule pressure, complacency), this event may have been avoided. Appoint a sponsor to HPI. Start trending HPI issues. Develop HPI performance metrics that will indicate actual performance.

Table D-10. Human Performance				
			Effectiveness in the Case	
Barrier	Target Protected	Hazard	Why Did Barrier Fail?	Significance
B-10-04 Human Performance Weaknesses	An HPI Program is in place that effectively evaluates human performance data and identifies appropriate corrective actions, resulting in improved human performance attributes.	An HPI Program is not in place or is ineffective in evaluating human performance data such that human performance does not improve.	Ineffective: Schedule pressure was felt by contractor personnel over the entire period evaluated. Management interviews indicated that meeting Idaho Settlement Agreement (ISA) milestones drove contract performance and fee which translated down to personnel as the primary driver for some decisions. This schedule pressure led to reluctance to raise issues which could affect schedule performance. For example, during an interview with the AK Expert (AKE) reviewing documentation associated with the "event drum" (10595963) prior to its transfer to ARP V, he stated he felt schedule pressure when he called out drum 10595963 as "NDA indeterminate." During a subsequent management review of drum 10595963, signs to stop were ignored and the procedural step accepting this container was performed incorrectly.	Missing Barrier: Had a HPI Program been in place and effective in evaluating human performance data (for example, schedule pressure, complacency), this event may have been avoided. Appoint a sponsor to HPI. Start trending HPI issues. Develop HPI performance metrics that will indicate actual performance.

Table D-11. Key for Cross-Walk for Barrier Analysis to Event and Causal Factor Chart Barrier Categories Table Number	
Number	Barrier Analysis to Barrier Categories on the Event and Causal Factor Chart Cross-Walk
1.	Management /Policy/Expectation
2.	Organization/R2A2/Latent Organizational Weakness
3.	Programmatic/Written Procedure/Report
4.	Individual Barriers/Personnel Performance/Human Performance
5.	Oversight/Management/QA/DOE
6.	Training
7.	Safety Culture

Table D-11. Barrier Analysis and Event and Causal Factor Chart Cross-Walk:			
Number	Inappropriate Action (E&CF)	Barrier (Barrier Analysis)	Barrier Category (E&CF Chart)
1.	IAG process was mis-applied as a TPR type procedure (IAGs do not receive USQ reviews)	B-5-03 (MCP-123, USQ review) – Bypassed B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-10-03 (Human Performance Weaknesses) - Missing	1. Management /Policy/Expectation 4. Individual Barriers/Personnel Performance/ Human Performance 7. Nuclear Safety Culture
2.	RPT-TRUW-91 Rev 2, does not address all prohibited items of concern	B-6-03 (RPT-TRUW-91) – Bypassed; replaced by DRAFT RPT-TRUW-94) B-6-04 (DRAFT RPT-TRUW-94) – Missing B-6-05 (Implementation of DRAFT RPT-TRUW-94) – Broken B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-04 (Management) – Compromised B-10-03 (Human Performance Weaknesses) - Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/ Human Performance 7. Nuclear Safety Culture
3.	RPT-TRUW-5 reference table for SD-176 did not list prohibited items or potential for pyrophoric/reactive materials in waste failed to identify ignitability /reactivity wastes	B-6-01 (RPT-TRUW-05) – Failed B-9-01 (Management) – Failed B-9-04 (Management) – Compromised B-10-03 (Human Performance Weaknesses) - Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture
4.	CWI and ITG did not effectively evaluate how the contract change would impact project	B-5-06 (Change Management Process) – Missing B-5-11 (MCP-1414, “Change Control”) – Weak B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-10-03 (Human Performance Weaknesses) - Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture

Table D-11. Barrier Analysis and Event and Causal Factor Chart Cross-Walk:			
Number	Inappropriate Action (E&CF)	Barrier (Barrier Analysis)	Barrier Category (E&CF Chart)
5.	Chemical compatibility evaluation not completed for SD-176	B-3-01 (RPT-ESH-014) – Failed B-3-02 (Implementation of RPT-ESH-014) – Failed B-4-03 (Implementation of IAG-592) – Failed B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-03 (Management) – Compromised B-9-06 (Fluor Idaho Management) - Failed B-10-03 (Human Performance Weaknesses) - Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture
6.	1 of 2 DOE assigned conditions from the 12/21/2015 DOE memo did not get implemented (RPT-TRUW-94 was not approved)	B-6-04 (RPT-TRUW-94) – Missing B-6-05 (Implementation of RPT-TRUW-94) – Broken B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-03 (Management) – Compromised B-10-03 (Human Performance Weaknesses) – Missing B-10-04 (Human Performance Weaknesses) - Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture
7.	Using unapproved documents/emails to make decisions rather than perform tasks	B-6-04 (DRAFT RPT-TRUW-94) – Missing B-6-05 (Implementation of DRAFT RPT-TRUW-94) – Broken B-8-01 (Safety Culture) –Degraded B-9-06 (Fluor Idaho Management) - Failed B-9-07 (Fluor Idaho Management) - Weak	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 7. Nuclear Safety Culture

Table D-11. Barrier Analysis and Event and Causal Factor Chart Cross-Walk:			
Number	Inappropriate Action (E&CF)	Barrier (Barrier Analysis)	Barrier Category (E&CF Chart)
8.	Information provided to support the RCRA permit was not adequate	B-1-01 (AMWTP RCRA permit) – compromised B-2-01 (MCP-1390) – Compromised B-2-02 (MCP-3930) – Compromised B-2-03 (TPR-7601) – Compromised B-2-06 (MCP-4226) – Weak B-2-07 (Implementation of MCP-4226) – Failed B-4-01 (Understanding limitations of AK) – Failed B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-02 (Management) – Failed B-9-04 (Management) – Compromised B-9-06 (Fluor Idaho Management) – Failed B-10-03 (Human Performance Weaknesses) – Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture
9.	Weakness in Communications and processes to identify IDC-SD-176 as an unknown waste	B-1-01 (AMWTP RCRA permit) – compromised B-1-02 (RWMC RCRA permit) – compromised B-2-01 (MCP-1390) – Compromised B-2-02 (MCP-3930) – Compromised B-2-03 (TPR-7601) – Compromised B-2-04 (INST-TRUW-8.13.3) – Weak B-2-06 (MCP-4226) – Weak B-2-07 (Implementation of MCP-4226) – Failed B-4-01 (Understanding by ITG and CWI personnel of the limitations of	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture

Table D-11. Barrier Analysis and Event and Causal Factor Chart Cross-Walk:			
Number	Inappropriate Action (E&CF)	Barrier (Barrier Analysis)	Barrier Category (E&CF Chart)
		Acceptable Knowledge available for SD-176) – Failed B-4-03 (Implementation of IAG-592, Rev 10) – Failed B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-04 (Management) – Compromised	
10.	Lack of recognition of noncompatible hazards associated with SD-176 drum	B-1-03 (RWMC RCRA permit) – Compromised B-4-04 (MCP-48; training analysis) – Broken B-4-05 (TPR-7997, VE) – Broken B-4-06 (Training on Pyrophoric and reactive Materials) – Missing B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-02 (Management) – Failed B-9-03 (Management) – Compromised B-9-04 (Management) – Compromised B-9-06 (Fluor Idaho Management) – Failed B-10-03 (Human Performance Weaknesses) – Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture

Table D-11. Barrier Analysis and Event and Causal Factor Chart Cross-Walk:			
Number	Inappropriate Action (E&CF)	Barrier (Barrier Analysis)	Barrier Category (E&CF Chart)
11.	USQ IAG does not address SD-176 as potentially multiple unknown waste	B-4-03 (Implementation of IAG-592) – Failed B-5-01 (SAR-4) – Broken B-5-02 (MCP-2449, Nuclear Safety Analysis) – Failed B-5-03 (MCP-123, USQs) – Failed B-9-01 (Management) – Failed B-9-02 (Management) – Failed B-9-04 (Management) – Compromised B-10-03 (Human Performance Weaknesses) – Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance
12.	Change control for handling SD-176 not effectively implemented	B-4-04 (MCP-48, Training Analysis) – Broken B-5-06 (Change Management Process) – Missing Barrier B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-02 (Management) – Failed B-9-06 (Fluor Idaho Management) – Failed B-10-03 (Human Performance Weaknesses) – Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 6. Training 7. Nuclear Safety Culture

Table D-11. Barrier Analysis and Event and Causal Factor Chart Cross-Walk:			
Number	Inappropriate Action (E&CF)	Barrier (Barrier Analysis)	Barrier Category (E&CF Chart)
13.	Personnel did not understand pyrophoric and reactive metals	B-4-04 (MCP-48; training analysis) – Broken B-4-06 (Training on Pyrophoric and reactive Materials) – Missing B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-02 (Management) – Failed B-9-03 (Management) – Compromised B-10-03 (Human Performance Weaknesses) – Missing	1. Management /Policy/Expectation 4. Individual Barriers/Personnel Performance/Human Performance 6. Training 7. Nuclear Safety Culture
14.	Inappropriate schedule pressure to meet Contract and ISA milestones	B-8-01 (Safety Culture) –Degraded B-9-07 (Fluor Idaho Management) - Weak	1. Management /Policy/Expectation 7. Nuclear Safety Culture
15.	Project is processing IDC-SD-176 at business risk	B-8-01 (Safety Culture) –Degraded B-9-02 (Management) – Failed B-9-07 (Fluor Idaho Management) – Weak B-10-04 (Human Performance Weaknesses) - Missing	1. Management /Policy/Expectation 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture
16.	Evaluation of the Box line fire did not effectively analyze ARP V applicability	B-5-10 (CAR 116640) – Weak B-8-01 (Safety Culture) –Degraded B-9-08 (Fluor Idaho Management) - Failed	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 7. Nuclear Safety Culture

Table D-11. Barrier Analysis and Event and Causal Factor Chart Cross-Walk:			
Number	Inappropriate Action (E&CF)	Barrier (Barrier Analysis)	Barrier Category (E&CF Chart)
17.	Personnel did not recognize ARP V drum #10595963 had pyrophoric and reactive material	B-2-06 (MCP-4226) – Weak B-2-07 (Implementation of MCP-4226) – Failed B-4-01 (Understanding of limitations of AK available for SD-176 – Failed B-4-02 (IAG-592) – Ineffective B-4-04 (MCP-48; training analysis) – Broken B-4-05 (TPR-7997, VE) – Broken B-4-06 (Training on Pyrophoric and reactive Materials) – Missing B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-02 (Management) – Failed B-9-03 (Management) – Compromised B-9-04 (Management) – Compromised B-9-05 (Fluor Idaho Management) – Compromised B-9-06 (Fluor Idaho Management) - Failed B-10-03 (Human Performance Weaknesses) – Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture

Table D-11. Barrier Analysis and Event and Causal Factor Chart Cross-Walk:			
Number	Inappropriate Action (E&CF)	Barrier (Barrier Analysis)	Barrier Category (E&CF Chart)
18.	Shipped waste to ARP and did not meet requirements	B-2-01 (MCP-1390) – Compromised B-2-02 (MCP-3930) – Compromised B-2-03 (TPR-7601) – Compromised B-2-04 (INST-TRUW-8.13.3) – Weak B-2-06 (MCP-4226) – Weak B-2-07 (Implementation of MCP-4226) – Failed B-4-01 (Understanding of AK limits) – Failed B-4-04 (MCP-48, Training Analysis) – Broken B-5-08 (MCP-3930) – Failed B-6-04 (RPT-TRUW-94) – Missing B-9-01 (Management) – Failed B-9-02 (Management) – Failed B-9-03 (Management) – Compromised B-9-04 (Management) – Compromised B-9-05 (Fluor Idaho Management) – Compromised	1. Management /Policy/Expectation3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance
19.	AMWTP and ARP project oversight by Fluor Idaho and DOE not effective	B-5-07 (SRP Management oversight) – Weak B-5-04 (HASP) – Broken/Missing B-8-01 (Safety Culture) –Degraded B-9-01 (Management) – Failed B-9-02 (Management) – Failed B-9-06 (Fluor Idaho Management) – Failed	1. Management /Policy/Expectation 7. Nuclear Safety Culture

Table D-11. Barrier Analysis and Event and Causal Factor Chart Cross-Walk:			
Number	Inappropriate Action (E&CF)	Barrier (Barrier Analysis)	Barrier Category (E&CF Chart)
20.	NDA personnel were unaware of MCP-4226 requirements for reviewing for potential pyrophoric and reactive waste	B-2-01 (MCP-1390) – Compromised B-2-03 (TPR-7601) – Compromised B-2-06 (MCP-4226) – Weak B-2-07 (Implementation of MCP-4226) – Failed B-4-01 (Limits of AK) – Failed B-8-01 (Safety Culture) –Degraded B-9-05 (Fluor Idaho Management) – Compromised B-9-07 (Fluor Idaho Management) – Weak B-10-03 (Human Performance Weaknesses) – Missing B-10-04 (Human Performance Weaknesses) - Missing	1. Management /Policy/Expectation 3. Programmatic/Written Procedure/Report 4. Individual Barriers/Personnel Performance/Human Performance 7. Nuclear Safety Culture

Appendix E

Extent of Condition

Purpose

The "Extent of Condition" evaluation utilizes up-front information that is known about the problem and the context in which it occurred, including what failed the consequences and locations that might be vulnerable to similar issues. This evaluation determines if the same (or similar) condition involved in this consequential event may exist elsewhere within the Fluor Idaho enterprise. The extent of condition evaluation is conducted early in the investigation and establishes the bounds of the investigation.

The evaluation starts with a statement of the condition to be evaluated for extent. In this event, the Condition Statement is:

> *Four containers of solidified radioactive and hazardous wastes breached in the ARP-V building on the evening on 04/11/2018.*

The evaluation considers a defined "object" that has a defined "defect." In this event, the object and defect are defined as follows:

> ***Object:*** Containers of repackaged solidified radioactive and chemical wastes ("daughter" containers)
>
> ***Defect:*** The presence of uranium-238

The analysis starts by considering the object and defect in the location at which the event occurred, and proceeds through consideration of other locations at which the same object could be present with the same defect ("Same-Same").

The analysis then identifies:

- "Similar" objects that might pose a similar risk (for example, containers of radioactive and chemical waste that have *not* been repackaged)
- "Similar" defects that might pose a similar risk (for example, the presence of other materials with pyrophoric and reactive properties, or combinations of materials that are chemically incompatible).

The analysis then considers locations where:

- A "similar" object with the "same" defect might be present ("Similar-Same");
- A "same" object with a "similar" defect might be present ("Same-Similar");
- A "similar" object with a "similar" defect might be present ("Similar-Similar").

"Similar Objects" considered include:

- "Parent" containers of radioactive and chemical wastes;
- Material on Process Trays;
- Containers of "Secondary Wastes" (specifically, wastes produced in the course of processing SD-176 through -179)

"Similar Defects" considered included:

- Other pyrophoric and reactive material;
- Combinations of materials that is chemically incompatible.

This evaluation was initially conducted based on "best available" information early in the investigation, and confirmed by information provided by the RH/CH TRU Program Manager in mid-August.[b]

The results of the "Extent of Condition" evaluation are summarized in the table below.

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b. Email, J. McCoy to M. Fecht, S. Crowe, G. Sprenger, and R. Swanson dtd 08/10/2018, subj: "Re: ARP V EOC Information – Drum Data"

Extent of Condition Table			
Condition Statement:	4 containers of solidified radioactive and hazardous wastes breached in the ARP-V building on the evening of 04/11/2018.		
Object: Containers of repackaged solidified radioactive & chemical wastes		**Defect:** Presence of uranium-238	
Tier	**Object**	**Defect**	**Comments** **Risk**
Same-Same (Object-Defect)	4 daughter containers of repackaged solidified rad & chemical wastes [CW-216; SRP #s 34398, 34402, 34405, 34415]	Uranium-238 present (confirmed)	Presence of uranium-238 led to over-pressurized drums and ejected contents sometime after oxygen was added during repackaging. **High risk**; Actually happened with 4 daughter containers. Hazardous radioactive and chemical materials contaminated personnel fighting the fire as well as the ARP V structure
Same-Same (Object-Defect)	Daughter container CW-216; SRP # 34384 (unbreached) created from parent container 10630243, a parent container that was involved in breaches of two other daughter containers.	Uranium-238 present (potential)	Assay not yet performed; uranium-238 content unknown Immediately after 4/11 event: **high risk**. Compensatory actions included monitoring for temperature rise. Currently located in ARP-V airlock.
Same-Same (Object-Defect)	Other CW-216 daughter containers of repackaged solidified rad & chemical wastes from same parent containers and/or same process trays [SRP #s 34401, 34403, 34404, 34417, 34418]	Uranium-238 present (potential)	Assay not yet performed; uranium-238 content unknown Immediately after 4/11 event: **high risk**. Compensatory actions included monitoring for temperature rise. Currently located in ARP-V airlock.
Same-Same (Object-Defect)	Other CW-216 daughter containers of repackaged solidified rad & chemical wastes with confirmed uranium-238 from other parent containers [718 containers located at WMF-628, -629, -631, -636]	Uranium-238 present (confirmed by assay results)	Assay results confirmed presence of uranium-238. Immediately after 4/11 event: **high risk.** Compensatory actions included monitoring for temperature rise.

EXTENT OF CONDITION TABLE

Condition Statement:	4 containers of solidified radioactive and hazardous wastes breached in the ARP-V building on the evening of 04/11/2018.
Object: Containers of repackaged solidified radioactive & chemical wastes	**Defect:** Presence of uranium-238

Tier	Object	Defect	Comments Risk
Same-Same (Object-Defect)	Other CW-216 daughter containers of repackaged solidified rad & chemical wastes from other parent containers with unknown uranium-238 content [36 containers located at WMF-628; -629; -631; -636; ARP-V]	Uranium-238 present (potential)	Assay not yet performed; uranium-238 content unknown Immediately after 4/11 event: **high risk**. Compensatory actions included monitoring for temperature rise.
Same-Same (Object-Defect	Other CW-216 daughter containers of repackaged solidified rad & chemical wastes from other parent containers with <MDL uranium-238 content [1,008 containers located at WMF-628; -629; -630; -631; -636)	Uranium present (refuted by assay results)	Uranium-238 content determined to be <MDL. Immediately after 4/11 event: **low risk**. Compensatory actions included monitoring for temperature rise.
Similar-Same (Object-Defect)	SD-176 parent containers of solidified rad & chemical wastes with >MDL uranium-238. [9 containers located at WMF-628, -631, -1617 (ARP-V)]	Uranium present (confirmed by assay results)	Assay results confirmed presence of uranium-238. Immediately after 4/11 event: **high risk.** Compensatory actions included monitoring for temperature rise.
Similar-Same (Object-Defect)	SD-176 parent containers of solidified rad & chemical wastes with >MDL uranium-238 located off-Site. [120 containers located at Energy Solutions, LLC (Clive, UT)].	Uranium present (confirmed by assay results)	Assay results confirmed presence of uranium-238. Immediately after 4/11 event: **high risk.** Compensatory actions included monitoring for temperature rise.
Similar-Same (Object-Defect)	SD-176 parent containers of solidified rad & chemical wastes with <MDL uranium-238. [48 containers located at WMF-628, -629, -630, -631, -633, -1617 (ARP-V)]	Uranium present (refuted by assay results)	Uranium-238 content determined to be <MDL. Immediately after 4/11 event: **low risk**. Compensatory actions included monitoring for temperature rise.

Extent of Condition Table			
Condition Statement:	4 containers of solidified radioactive and hazardous wastes breached in the ARP-V building on the evening of 04/11/2018.		
<u>Object:</u> Containers of repackaged solidified radioactive & chemical wastes		**<u>Defect:</u>** Presence of uranium-238	
Tier	**Object**	**Defect**	**Comments Risk**
Similar-Same (Object-Defect)	SD-176 parent containers of solidified rad & chemical wastes with <MDL uranium-238 located off-Site. [158 containers located at Energy Solutions, LLC (Clive, UT)].	Uranium present (refuted by assay results)	Uranium-238 content determined to be <MDL. Immediately after 4/11 event: **<u>low risk</u>**. Compensatory actions included monitoring for temperature rise.
Similar-Same (Object-Defect)	SD-176 parent containers of solidified rad & chemical wastes from other parent containers with unknown uranium-238 content. [95 containers located at WMF-628, -633, -1617 (ARP-V)]	Uranium present (potential)	Assay not yet performed; uranium-238 content unknown Immediately after 4/11 event: **<u>high risk</u>**. Compensatory actions included monitoring for temperature rise.
Similar-Same (Object-Defect)	SD-177 parent containers of solidified rad & chemical wastes with >MDL uranium-238. [85 containers located at WMF-629; -630; -631; -633, -634, -635]	Uranium present (confirmed by assay results)	Assay results confirmed presence of uranium-238. Immediately after 4/11 event: **<u>moderate risk.</u>** Compensatory actions included monitoring for temperature rise; no SD-177 containers were processed.
Similar-Same (Object-Defect)	SD-177 parent containers of solidified rad & chemical wastes with <MDL uranium-238. [429 containers located at WMF-628, -629, -630, -631, -632, -633, -634, -635, -636, -676]	Uranium present (refuted by assay results)	Uranium-238 content determined to be <MDL. Immediately after 4/11 event: **<u>low risk</u>**. Compensatory actions included monitoring for temperature rise; no SD-177 containers were processed.

EXTENT OF CONDITION TABLE			
Condition Statement:	4 containers of solidified radioactive and hazardous wastes breached in the ARP-V building on the evening of 04/11/2018.		
Object: Containers of repackaged solidified radioactive & chemical wastes		**Defect:** Presence of uranium-238	
Tier	**Object**	**Defect**	**Comments** **Risk**
Similar-Same (Object-Defect)	SD-177 parent containers of solidified rad & chemical wastes from other parent containers with unknown uranium-238 content. [47 containers located at WMF-629, -631, -632, -633, -636]	Uranium present (potential)	Assay not yet performed; uranium-238 content unknown Immediately after 4/11 event: **moderate risk**. Compensatory actions included monitoring for temperature rise; no SD-177 containers were processed.
Similar-Same (Object-Defect)	SD-178 parent containers of solidified rad & chemical wastes with >MDL uranium-238. [11 containers located at WMF-628, -629, -631, -636]	Uranium present (confirmed by assay results)	Assay results confirmed presence of uranium-238. Immediately after 4/11 event: **moderate risk.** Compensatory actions included monitoring for temperature rise; no SD-178 containers were processed.
Similar-Same (Object-Defect)	SD-178 parent containers of solidified rad & chemical wastes with <MDL uranium-238. [52 containers located at WMF-628, -629, -631, -636]	Uranium present (refuted by assay results)	Uranium-238 content determined to be <MDL. Immediately after 4/11 event: **low risk**. Compensatory actions included monitoring for temperature rise; no SD-178 containers were processed.
Similar-Same (Object-Defect)	SD-178 parent containers of solidified rad & chemical wastes with unknown uranium-238 content. [7 containers located at WMF-632, -633]	Uranium present (potential)	Assay not yet performed; uranium-238 content unknown Immediately after 4/11 event: **moderate risk**. Compensatory actions included monitoring for temperature rise; no SD-178 containers were processed.

EXTENT OF CONDITION TABLE			
Condition Statement:	4 containers of solidified radioactive and hazardous wastes breached in the ARP-V building on the evening of 04/11/2018.		
Object: Containers of repackaged solidified radioactive & chemical wastes		**Defect:** Presence of uranium-238	
Tier	**Object**	**Defect**	**Comments** **Risk**
Similar-Same (Object-Defect)	Secondary waste (90 ft^3 boxes with "drum pucks") created from processing SD-176 containers; no SD-177, -178 containers had been processed when the event occurred. [45 containers located in CPP-1617, WMF-1617TSA, and NNSS disposal]	Uranium present (potential)	Assay not yet performed; uranium-238 content unknown. Immediately after 4/11 event: **low risk.** The container was comprised of secondary waste that was in contact with the contents of SD-176 parent containers.
Similar-Same (Object-Defect)	Secondary waste (90 ft^3 boxes with used filters and drum lids) created from processing SD-176, -177, and -178 parent containers. [53 containers located in CPP-1617, -2725; WMF-1617BN, -1617TSA; WMF-698]	Uranium present (potential)	Assay not yet performed; uranium-238 content unknown. Immediately after 4/11 event: **low risk.** The container was comprised of secondary waste that was in contact with the contents of SD-176 parent containers.
Similar-Similar (Object-Defect)	Waste containers in CW-216; SD-176, -177, and -178; and SD-179.	Other pyrophoric and reactive materials present.	**Unknown level of risk**; compensatory measures in place address the potential risk from containers in their current configurations. Risk going forward will include treating all DU containers as being pyrophoric and reactive until the possibility can be ruled out by waste form. Those that cannot be ruled out as pyrophoric and reactive will be subject to further mitigating actions prior to and during processing.
Similar-Similar (Object-Defect)	Waste containers in CW-216; SD-176, -177, and -178; and SD-179.	Individual waste containers loaded with chemically incompatible waste.	**Unknown level of risk:** compensatory measures in place address the potential risk from containers in their current configurations.

Appendix F

Human Performance Analysis

Appendix F

Human Performance Analysis

Human Performance Discussion

Human performance was a key contributor to this event. The basic understanding of processing composite waste to ARP V was identified. This weakness indicated a lack of knowledge of requirements, focusing on the wrong area, following procedures, and attention to detail. Multiple instances of failures in which personnel did not display a questioning attitude when they encountered issues and/or process problems were identified.

Human Performance Summary

The Root Cause Team evaluated each inappropriate action for any human performance behaviors that contributed to the specific action. The team also looked for any human factors, discrepancies in procedural steps, lack of training that would have contributed to the inappropriate actions. Using personnel statements, interview results, procedure reviews, and performance results, the team identified 14 inappropriate actions that related to human performance deficiencies. The list of 14 inappropriate actions is included in Table F-1. Error Mode Analysis – Inappropriate Actions and is in this Appendix.

The primary benefit of determining the error type is to ensure the corrective actions are appropriate for each error mode. Included in this appendix are recommended corrective actions for the error mode that is identified. For example, on a Rule Based Error, you do not want to assign a Skill Based Error corrective action such as, “simplify the task”. Since most of the error modes were knowledge based errors some of the corrective actions that should be taken are, training on fundamentals; increase problem solving skills; train on work processes; and reinforce knowledge based performance error reduction tools (Watch out – Stop)

Human Performance Initiatives

Based on the number of human performance issues, the team evaluated the Fluor ongoing actions to address human performance weaknesses. The Root Cause Team concluded that management has not integrated human performance improvement into project activities. As a result, little action had been taken to drive improvements in human performance at either an organizational or individual level as indicated in the identified human performance weaknesses identified in this root cause analysis. Also, lacking clearly defined management expectations and supporting performance feedback mechanisms such as the Corrective Action Program, MWVs, Quality Assurance oversight and Performance Metrics, human performance greatly impacted the drum event.

The goal of human performance improvement (HPI) is to facilitate the development of a facility structure that recognizes human attributes and develops defenses that proactively manage human error and optimize the performance of individuals, leaders, and the organization. DOE-HDBK-1028-2009, “Human Performance Improvement Handbook,” Volumes 1 and 2, describe the HPI tools available for use at DOE sites. The Root Cause Team evaluated both the HPI program implementation and actual performance during the drum event. Human error is not a cause of failure alone, but rather the effect or symptom of deeper trouble in the system. A review of Human Performance is a review of an individual’s abilities, tasks, and operating environment to determine if the organization supports them for success.

The Anatomy of an Event Model (Figure F-1) illustrates the elements that exist before an event occurs and is a very useful model to guide the analysis of an event from an HPI perspective. The elements analyzed are the flawed defenses that allowed the event to occur or did not mitigate the consequences of the event; the error precursors that existed; the latent organizational conditions that allowed those to be in existence; and finally the vision, beliefs and values of management and workers.

Human performance issues are those events or conditions caused by inadequate human performance. The events or conditions result from an error (or noncompliance by an individual where the act was under control of an individual such as; not following procedure steps; not wearing the proper breathing protection; communication errors; and inappropriate actions.

Human Performance Mode

Human Performance analysis describes three modes in which errors occur. The performance mode in which an error occurs is based on the individual's familiarity with the task being performed. The three modes, progressing from most familiar to the task to the least familiar to the task are: skill based, rules based, and knowledge based. Errors will most likely occur in the knowledge based performance mode.

1.8.1.1 Knowledge Based Errors

The knowledge based errors were predominately attributed to attention given to the wrong issues; schedule and client satisfaction over quality and requirements. The second area of concern was that personnel underestimated the problems based on their experience. Engineering emphasis was based on professional output; not on meeting process requirements and regulations. The combination of a lack of NQA-1 experience, ineffective training and a lack of commitment to following procedures exacerbated these knowledge based errors.

1.8.1.2 Rule Based Errors

Rule based errors were predominately attributed to errors where previous success reinforced continued practices. Other rule based errors were evenly divided between errors where signs to stop were ignored and errors where too much activity was occurring and errors were made in problem solving.

Past project successes and the lack of management expectations led personnel (to have the mindset) to incorrectly assume that past ways of doing business were sufficient for this project. Personnel did not recognize warning signals that indicated the need to stop and look closely at the situation. From interviews and record review, schedule pressure was evident throughout the project. Interviewees stated there was pressure from DOE to meet the Idaho settlement agreement and also from internal management to meet contractual requirements.

These errors were distributed among several different groups, so no direct correlation to any specific group was made. Additionally, procedures were sometimes identified as ambiguous or unclear, so procedure problems played a role in these human errors since a key attribute in reducing this type of error is following procedures.

1.8.1.3 Skill Based Errors

The skill based errors were predominately attributed to inattention to detail with less than adequate checking of work. These errors were cross-cutting throughout the project timeline. The numerous issues identified were the issues were also not detected by management oversight.

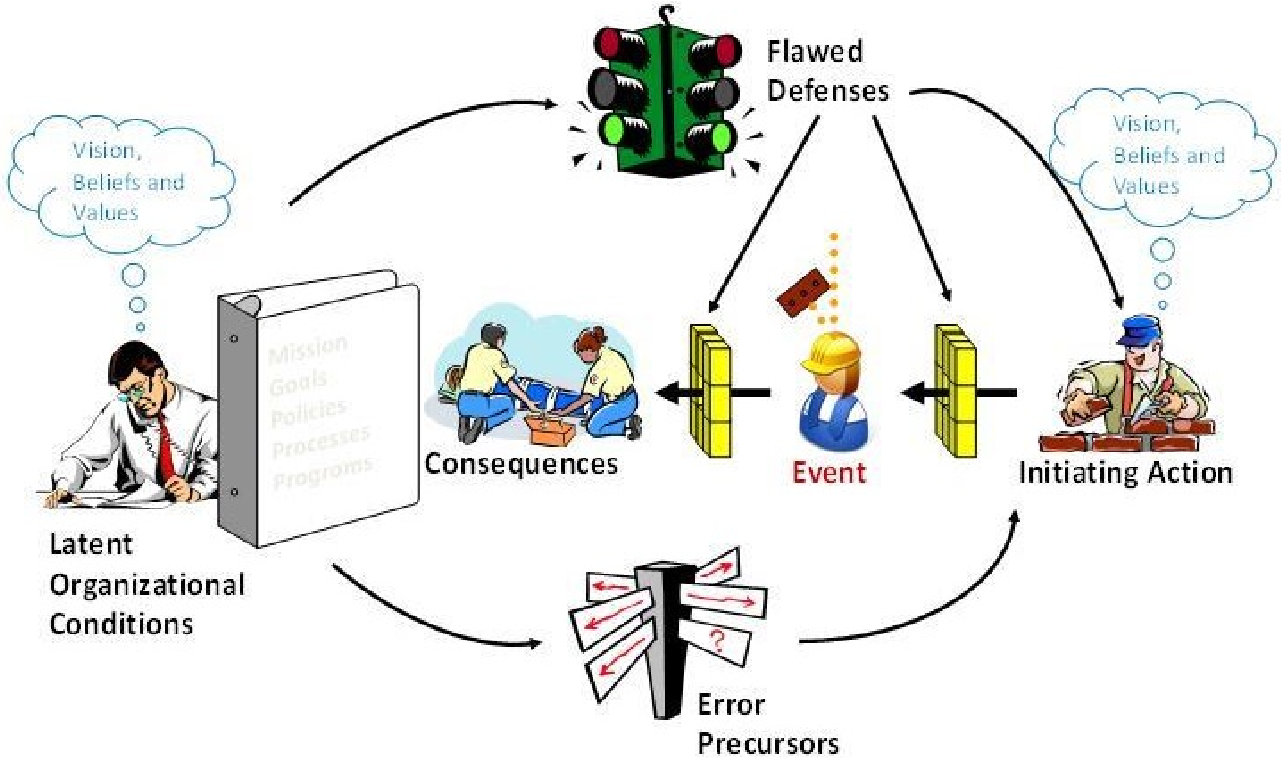


Figure F-1. Anatomy of an event model.

Error Modeling Summary

The model presents an integrated picture of the error mechanisms operating at all three levels of performance.

Skill-Based - Human performance driven by learned behaviors/actions; characterized by routine tasks performed in a familiar environment.

Rule-Based - Human performance driven (decision made) by stored rules accumulated through life experience, training, and written policies; characterized by "if/then" statements.

Knowledge-Based - Human performance driven (decision made by analytical thinking and fundamental knowledge) - no learned skills or rules exist to determine correct course of action; characterized by problem solving and decision making.

The primary benefit of determining the error type is to ensure the corrective actions are appropriate. Figure F-2, Proven Corrective Actions Specified Human Error Modes provides guidance for applying the correct corrective actions to the applicable error mode.

Number	Error Mode	Corrective Action
1	Skill Based Error	• Simplify task • Reduce time pressure • Reduce distractions • Provide awareness aids • Increase experience • Increase mental alertness • Reinforce skill based performance error reduction tools (STAR)
2	Rule Based Error	• Train/Reinforce/Clarify • Work specialization • Reinforce rule based performance error reduction tools (QV&V)
3	Knowledge	• Training on fundamentals • Increase problem solving skills • Work specialization • Train on work processes • Reinforce knowledge based performance error reduction tools (Watch out – Stop)

Figure F-2. Proven Corrective Actions for Specified Human Error Modes.

The Root Cause Team evaluated the inappropriate actions as identified on the E&CF chart, Appendix 16, and determined that there were numerous human performance related issues. Based on interviews and analysis, the Root Cause Team identified the error modes for each identified human performance related error. Of the 16 inappropriate actions evaluated and the 18 cause codes applied to those actions, approximately 80 percent of the error modes were knowledge based error with the attention was given to the wrong issue. Corrective actions identified in CC-7 including the identified JONs for CON 8, for developing a human performance program will address the human performance issues in Table F-1. The human performance issues are summarized in Table F-1.

Table F-1. Error Mode Analysis – Inappropriate Actions.

Number	Inappropriate Action/Behavior	Error Mode
1.	Mis-use of an IAG instead of using a Technical procedure (E&CF) • DOE provided direction to use the IAG process • A TPR was not developed • Management did not ensure that a technical document and process was used at a CAT 2 facility • Management did not enhance work activities, procedures and processes with safety practices and processes that a technical procedure would have provided	**Knowledge Based** – Attention was given to the wrong issue.
2.	Report does not address prohibited items (E&CF) • RPT-TRUW-91-Rev 2 does not address details found in referenced documents • Reference documentation identified the presence of pyrophoric material found in RF building 444 not addressed • Reference documentation identified RF wastes of depleted uranium not addressed • Reference documentation identified that incomplete oxidation, pyrophoric, D38 and plutonium wastes material	**Knowledge Based** – Attention was given to the wrong issue. **Knowledge Based** – Individual justified action by focusing on biased evidence
3.	Report failed to identify ignitable /reactivity wastes (E&CF) • RPT-TRUW-5 identified that there were no issues of ignitability or reactivity identified. • SDA and AMWTP RCRA permits require establishing requirements regarding ignitability, reactive, or incompatible waste • Reports were not sufficiently thorough to identify pyrophoric and reactive wastes • Comingling was allowed without compatibility evaluation	**Knowledge Based** – Attention was given to the wrong issue. **Knowledge Based** – Individual justified action by focusing on biased evidence

Number	Inappropriate Action/Behavior	Error Mode
4.	Contractors did not effectively evaluate how the contract change would impact project (E&CF) • ITG and CWI did not effectively implement MCP- 1414 Change Control when Contract MODs which added ARPV SRP to their contracts • Did not identify safety, training, and other project changes • Personnel did not recognize SD-176 additions changed work scope • Personnel did not recognize the significant change when the contract change stated to "complete characterization for ~2500 "unknown" containers that are currently in storage".	**Knowledge Based** – Attention was given to the wrong issue.
5.	Chemical compatibility not performed (E&CF) • AMWTP did not perform a chemical compatibility evaluation for SD-176. • RPT-ESH-14 Rev 9, Chemical Compatibility Evaluation Wastes for AMWTP did not use the most current hazardous constituent information (referenced the wrong number) • RPT-ESH-14 Rev 9, Chemical Compatibility Evaluation Wastes for AMWTP was issued and identified SD-176, 177, 178 as "TBD". • Also identifies the Reactivity Group Numbers as N/A	**Knowledge Based** – LTA conclusion based on the sequencing of facts
6.	One of two DOE actions not implemented (E&CF) • ITG asked for relief from requirements and DOE stated they could if the two conditions were met: • (1) The AK RPT-TRUW-94 with the additional IDCs may be issued and used to perform VE. However, it cannot be used for certification of the waste until CBFO provides concurrence. (Report 94 was never issued and continued to be used by AMWTP as a DRAFT). • (2) DOE acknowledges that repackaging operations will continue the practice of absorbing liquids as found: and that some mixing of contents between waste containers will occur, However, ITG is directed to campaign waste by individual IDCs, not by groups of compatible IDCs. This will preclude possible blending of waste between IDCs and minimize risk of chemical compatibility issues are being resolve. (process was implemented)	**Knowledge Based** – Attention was given to the wrong issue. **Knowledge Based** – LTA conclusion based on the sequencing of facts

Number	Inappropriate Action/Behavior	Error Mode
7.	Using unapproved documents/emails to make decisions to perform tasks (E&CF) • MCP-3930 allows using emails • ITG emails to use HWNs from a draft report • ARP V response stated they would use the most current draft of RPT-TRU-94 • Management allowed this practice	**Knowledge Based** – Attention was given to the wrong issue. **Knowledge Based** – LTA conclusion based on the sequencing of facts
8.	Information for RCRA permit was incorrect (E&CF) • RCRA permit referenced RPT-TRU-94 (Draft) • RCRA permit revised two more times and continued to identify RPT-TRU-94 as Draft. • RPT-ESH-014 did not address SD-176 • RPT-ESH-014 not maintained per RCRA permit requirements	**Knowledge Based** – Attention was given to the wrong issue.
9.	Weakness in communication to identify SD-176 as an unknown waste (E&CF) • Nuclear Safety Personnel did not know that SD-176 was unknown waste • ARP V Operations personnel did not know SD-176 was unknown waste • Individuals did not communicate across the organizations (different companies) • No EDF/formal analysis prepared for SRP project for introduction of SD-176 into ARP.	**Rule Based Error** – Previous successes in use of rule continued use of rule
10.	Lack of recognition of noncompatible hazards (E&CF) • RPT-ESH-014 states that spontaneous combustion uranium many be present and should be managed as potential pyrophoric radionuclide • MCP-4226 was not effectively implemented to address RPT-ESH-014 • ARP V personnel did not effectively implement cautions from RPT-ESH-014 for pyrophoric material other than roaster oxides.	**Knowledge Based** – Attention was given to the wrong issue.

Number	Inappropriate Action/Behavior	Error Mode
11.	Change control not effectively implemented (E&CF) • SAR not updated for IDC with unknown waste • HASP was not updated • Additional controls for HWMA RCRA permit were not taken • AK did not include potential chemical interactions • Management did not recognize change • Procedures were not update for SD-176 • No additional Training was provided	**Knowledge Based** – Attention was given to the wrong issue.
12.	NDA personnel were unaware of a MCP-4226 change that impacted them. (E&CF Chart) • Personnel did not follow MCP-135 for revising a procedure. They did not request personnel that were affected by a change to review prior to issuing.	**Rule Based Error** – Strong rule incorrectly chosen over other rules
13.	Processing waste at business risk (E&CF) • WIPP WAC not fully implemented • AK briefing for unknowns was an unusable document for operations • Inappropriate management schedule pressure • Safety of personnel not addressed • Chemical compatibility not addressed for SD-176 • 2015 both DOE and CBFO believe that risk would remain low	**Rule Based Error** – Previous successes in use of rule continued use of rule
14.	Personnel did not recognize pyrophoric and reactive waste (E&CF) • Personnel relied on an email exchanges to approve the event drum • NDA personnel did not know they were or be looking for potential pyrophoric waste • Some personnel did not feel comfortable raising an issue • TRU Waste personnel identified the event drum as coming from RF-444 which processed BE and DU • TRU Waste identified that there was a presence of fines and might involve uranium • Emails instead of procedures were used to accomplish this review and information exchange	**Knowledge Based** – Attention was given to the wrong issue. **Skill Based** – Check of work LTA

Number	Inappropriate Action/Behavior	Error Mode
15.	Shipped waste to ARP V and did not meet procedure requirements (E&CF) • RCRA Permit states that the owner must take precautions to prevent accidental ignition and ARP V had an accidental ignition • TPR-7601 and MCP-4226 do not allow pyrophoric material in ARP V and it was shipped and processed. • Having not performed a CCE for SD-176, did not meet the RCRA Permit • TPR-7601 references ESH-14 which does not address chemical compatibility for SD-176-SD-176 (TBD and NA) • TPR-8151 Rev 86 identifies incoming waste has been evaluated for CCE. CCE for SD-176 not completed	**Knowledge Based** – Attention was given to the wrong issue. **Rule Based Error** – Previous successes in use of rule continued use of rule

Appendix G

Causal Factors and Related Conditions

Appendix G

Causal Factors and Related Conditions

Number	Causal Factor	Related Conditions
DC -1	Based on available sample results, the Root Cause Team identified the direct cause of this event as the breach of four transuranic (TRU) waste containers in the ARP V building resulting from the mixing of waste containing reactive uranium from Container #10595963 with additional parent drum material in the repackaging process. The uranium initiated an exothermic reaction that ultimately led to an over pressurization and subsequent expulsion of material from four containers. The initiating mechanism (heat source) based on sample results was oxidation of the uranium metal which then supported secondary chemical reactions. The breaches resulted in airborne radioactivity escaping to a filtered, uncontaminated area normally occupied by workers. The direct cause will be revised as necessary when additional sample results are available and upon analysis by the Technical Team.	Management didn't understand the risk of processing unknown waste with potential pyrophoric and reactive material. Management did not recognize the need for additional controls for processing of unknown waste, such as chemical or pyrophoric and reactive reactions. Management did not implement a change management process that would have provided additional reviews of requirements and procedures that needed revision when changing from processing a known waste to an unknown waste. Personnel did not understand that other materials besides roasters were pyrophoric and reactive (for example, Depleted Uranium. Procedures and training did not specify appropriate tools and provide adequate guidance for personnel to handle drums containing pyrophoric and reactive material. Comingled drums with potential pyrophoric and reactive material that can spread material from one parent drum to several daughter drums.

Number	Causal Factor	Related Conditions
RC-1	**RC-1: Management failed to fully understand, characterize, establish and implement adequate process controls for treating waste which lacked documented origin or process information.** Prior to initiating the processing of the specific item description code (IDC) involved in the event (SD- 176) in March 2016, communication between AMWTF and RWMC personnel failed to identify SD-176 as a composite collection of homogeneous solids containers from more than one waste generator and various waste generating processes. Previous SRP waste sludges that had been processed at ARP V included IDCs from a single known generator and specific waste form or process. Information used to base acceptance of the waste at SRP did not adequately describe the attributes of the waste including prohibited items and the potential for pyrophoric and reactive material nor was an adequate chemical compatibility evaluation performed. This led to a failure to ensure that (1) effective controls were in place, (2) personnel were trained on the waste, (3) required management oversight for processing a new waste was established, and (4) upper-tier requirements documents received a thorough analysis.	Management didn't understand the risk of processing unknown waste with potential pyrophoric/reactive material. Management did not ensure that nuclear safety was the overriding priority. The Project did not properly manage the transition from processing waste streams from known generators to processing waste streams from unknown generators. Areas of weakness included hazard recognition, controls development, and procedure compliance. Reliance on previous successes in the handling of pyrophoric and reactive uranium encouraged complacency and a failure to question the adequacy and application of the existing, unmodified process designed for known waste streams when they were used to process waste streams from unknown sources. Risks to personnel were not effectively evaluated and managed before processing waste from unknown sources. For SD-176, MCP-4226 TRU Programs Site Project Office Process was not implemented effectively when reactive material was sent to ARP V. Chemical compatibility was not performed for SD-176 and in RPT-ESH-014 even though the hazardous constituent information was available. Processes did not ensure waste characterization methods and AK prevented ignitable, reactive waste to be packaged prior to being sent to ARP. Personnel did not understand the nature, identity, and presence of pyrophoric and reactive metals while processing waste. A robust procedure including appropriate approvals that would have ensured that pyrophoric and reactive material was not sent to ARP V.

Number	Causal Factor	Related Conditions
RC-2	**RC-2: Management failed to continue to develop the safety culture over a number of years.** This cause is attributed to exhibited behaviors identified by the analysis of the inappropriate actions throughout the investigation that were not consistent with the tenets of a strong nuclear safety culture. The overall project approach was not conservatively based, lacked documentation and procedures for key safety requirements, and was focused on processing waste to meet milestone requirements rather than compliance with requirements. Some personnel in the approval process for the event drum stated they did not feel comfortable identifying issues that were not consistent with management direction, would delay mission-related objectives, or would otherwise impact cost or schedule. Schedule pressure was felt by contractor personnel over the entire period evaluated. Management interviews indicated that meeting the Idaho Settlement Agreement drove contract performance and fee, which translated down to personnel as the primary driver for some decisions, leading to reluctance to raise issues that could affect schedule performance. This schedule pressure was reinforced by multiple occasions of accommodations/agreements to waive or delay meeting requirements to not impact schedule.	Safety Culture was not continually improving over a number of years as evidenced by the workers feedback to the Root Cause Team that they do not feel comfortable identifying issues that may adversely affect management direction, delay mission related objectives, or otherwise affects cost or schedule. Management allowed a work environment to be in place where some personnel felt they could not safely identify and report process weaknesses. Management did not ensure that deviations from standards and expectations were corrected (for example following procedures). Management didn't understand the risk of processing unknown waste with potential pyrophoric and reactive material. Management did not ensure that nuclear safety was the overriding priority. Management follow-up activities were not identified and personnel responsibilities were not defined. Management did not consistently exhibit behaviors that set the appropriate standard for safety. Management did not consistently ensure that the bases for operational decisions were communicated to affected organizations. Management inappropriately emphasized meeting Contract and ISA milestones at the expense of safety. Management did not consistently provide workers with an environment that encouraged individuals to voice concerns. Management permitted a culture to exist that permitted personnel to work outside the process and approve waste transfers by email rather than having a detailed process that accomplished receiving the proper approvals. Interviews identified that some personnel did not believe that they could raise a concern about shipping drum #10595963. Project became complacent with processing unknown waste "at risk". The first two SRP campaigns were DOE approved. The others were processed at risk. Management decisions were not always consistent with fostering and maintaining a positive safety culture.

Number	Causal Factor	Related Conditions
CC-1	**CC-1: A change-management process was implemented to identify, evaluate, and disposition the existing vulnerabilities for processing SD-176.** Management failed to ensure that a change-management process was implemented to identify, consider, and disposition the existing vulnerabilities for processing SD-176 Implementation of a change management process would have allowed the project team to analyze the risk associated for processing a composite collection of containers from various generators versus an IDC from a single known generator. Currently, Fluor Idaho has certain programs and processes that require a formal change management process, for example, implementation of changes to DSA/TSR, Critical Safety controls, RCRA permit changes, contract modification, etc. For this event, processing of SD-176 was not recognized as a significant change due to waste form (sludge) and a "unique" IDC. No change process was applied to the initiation of the campaign	Management did not recognize change from processing known waste to unknown waste and take effective action. Management did not consistently ensure that the bases for operational decisions were communicated to affected organizations. Management does not have a change management process to implement. No additional QA oversight was implemented prior to the change. Nuclear Safety Personnel had no knowledge that IDC-176 was unknown. ARP V personnel not informed on processing unknown waste. Management did not recognize the significance of the change from processing known to unknown waste. Poor communication between Operations and TRUW that processing unknown waste would require additional Diligence. Fluor Idaho does not have a company Change Management Program. DOE does not provide guidance for a Change Management Program nor require one.

Number	Causal Factor	Related Conditions
CC -2	**CC 2: A documented plan or path to disposal was not established as required by DOE O 435.1, "Radioactive Waste Management," prior to processing SD-176.** Management failed to ensure a documented plan or path to disposal, as required by DOE O 435.1, "Radioactive Waste Management," was established prior to processing SD-176. Decisions to process SD-176 were made without recognition that the facility was transitioning from processing a well characterized, relatively homogeneous generator specific and process specific IDC waste stream to an IDC waste that was not well characterized and originated from various generators and processes, and did not have a comprehensive chemical compatibility evaluation (CCE). Undefined characterization activities and Waste Isolation Pilot Plant (WIPP) approval still remain to be completed.	Management did not ensure that personnel and procedures were adequate to support nuclear safety. CCE not completed for SD-176 TPRs did not include the precautions for include precautions for potential for pyrophoric and reactive uranium Comingling was performed without compatibility evaluation. RPT-TRUW-94 did not identify prohibited items and potential for pyrophoric and reactive materials reflected in historical AK source documents and other AMWTP AK reports. pyrophoric and reactive Comingling was performed without compatibility evaluation. Reports were not thorough to identify pyrophoric and reactive. Management didn't understand the risk of processing unknown waste with potential pyrophoric and reactive material. RPT-ESH-014 did not use the most current hazardous constituent information (referenced the wrong revision). Using unapproved documents/emails to make decisions rather than perform tasks. Hydrofluoric acid was identified on the AK Brief and report with no specific evaluation identified. Hydrochloric acid was identified on the AK Brief and report with no specific evaluation identified. Procedures and process not updated for SD-176-179 processing. ITG did not have a process to address what was going to happen with the composite waste when it came back to them after ARP treatment. Training not updated for SD-176 processing of composite waste from multiple generators and waste generating processes. Did not include unknown wastes and depended on previous U roaster experience. Processing was based on past practices and not protection of workers. AK training was inadequate as all prohibited items and potential for pyrophoric/reactive metals in nonoxide roaster waste. Personnel did not understand what pyrophoric and reactive metals were. Most stated that they were roasters.

Number	Causal Factor	Related Conditions
CC-3	**CC-3: Management did not effectively analyze extent of condition following the December 2017 box line fire event and apply lessons learned to relevant ongoing activities outside of AMWTP, which could have identified the presence of pyrophoric and reactive material other than roaster oxides in containerized waste.** Management did not effectively determine the extent of condition and communicate corrective actions taken at AMWTP after the December 2017 box line fire that could have identified the existence of a previously unknown waste form containing pyrophoric uranium other than roaster oxides. While the material processed at AMWTP was not sludge or roaster oxide, an extent of condition review should have required an evaluation of other potential pyrophoric materials and waste forms. During the extent of condition review, the event drum 10595963 had been identified as a potential problem drum on the basis of a U-238 mass of greater than 5 kg. However, it was not considered any further the Box line event extent of condition because it was "Not TF Feed, Not on RPT-TRUW-83."	Management did not ensure that some problems were thoroughly evaluated to ensure resolutions address causes and extent of conditions. AMWTP did not share applicable corrective actions that were taken for processing unknown waste that could impact ARP V. Corrective Actions to add new IDC for potential non roaster oxide pyrophoric material not incorporated in other projects. Personnel did not recognize ARP V drum #10595963 had reactive Material. Management did not ensure that personnel and procedures were adequate to support nuclear safety. Risks were not effectively evaluated and managed before proceeding. HASP was not revised to include additional controls to protect workers processing unknown waste. Personnel did not perform a chemical compatibility evaluation for IDC-176. ITG did not issue RPT-TRU-94 and did not get CBFO concurrence MCP-3562 Hazard Identification, Analysis and Control of Operational Activities not implemented for new hazards. HASP does not address a fire in a drum. Additional controls to address composite waste were not implemented in the SDA HWMA/RCRA permit. Allowed mixing unknown liquids into unknown waste controls. Sampling not required. Controls for comingling of composite waste not included. Previous AK, ARP chemical compatibility study did not identify drum hazard (unoxidized U outside of roaster oxide process). Procedures and process not updated for SD-176-179 processing. Processing was based on past practices and not protection of workers. Personnel experience was with roaster oxides and did not consider other pyrophoric and reactive. One person felt that if it had an IDC, the waste could not have pyrophoric and reactive.

Number	Causal Factor	Related Conditions
CC-4	**CC-4: Oversight of the Sludge Repackaging Project was ineffective in identifying process failures that caused and/or contributed to the ARP V event.** Oversight was not effective in identifying or questioning that SD-176 was being processed in the same manner as previous IDCs that were well evaluated with respect to generating process and source. Oversight did not verify that specific process requirements were appropriately documented through procedural sign-offs, particularly when performed by different organizations. Management did not ensure that all the tools they have to provide effective oversight were being effectively implemented to prevent this event.	Management did not ensure that nuclear safety was constantly scrutinized through a variety of monitoring techniques. Personnel safety evaluations were not adequate for processing composite waste Personnel did not identify "composite waste" since it had an IDC number. Neither DOE nor ITG/CWI evaluates the implementation of assigned DOE conditions. Neither DOE nor ITG identify the campaign of IDC 176 as composite waste. No additional QA or management oversight was implemented prior to the change. Risk not recognized/No Management Oversight Plan. DOE oversight did not recognize that SD-176 was composite and require additional controls. Quality Assurance and Contractor Assurance did not conduct effective oversight of the AMWTP and ARP V processes. MWVs and Management self-assessment were not thorough to capture processing of composite wastes from multiple generators and waste generating processes.
CC-5	**CC 5: An effective integrated human performance improvement program has not been implemented.** The root cause team identified numerous human performance weaknesses during the team's analysis. Attachment F describes the human performance issues along with the error modes.	Management did not ensure that some problems were thoroughly evaluated to ensure resolutions address causes and extent of conditions.

Number	Causal Factor	Related Conditions
CC-6	**CC-6: Action in applying lessons learned from the 2014 WIPP event was not effective in strengthening processes such that major contributors to the drum event were able to be identified and mitigated.** Lessons learned from the 2014 WIPP event were not effectively evaluated or acted upon by RWMC and AMWTP to preclude some of the major contributors to the drum event. For example, evaluations and subsequent corrective actions taken in 2015 did not effectively identify safety culture and change control issues. Similarly, the actions taken to address the WIPP fire event did not expand to evaluate other potential pyrophoric and reactive materials and waste forms.	Several previous similar events were reviewed and evaluated their applicability and corrective actions. The Root Cause Team evaluated these similar events to identify if any of their corrective actions would have prevented or mitigated the drum event. One internal event reviewed is addressed in **CC-,** the AMWTP box line fire. The other event that did have applicability to the drum event was the WIPP radiological event in 2014. Each CON was evaluated along with the JONs to see which CONs could have been applicable to the drum event. The Root Cause Team identified eight CONs where the contractor's corrective actions were not effective when reviewed them against the circumstances of the drum event. For example, evaluations and subsequent corrective actions taken in 2015 did not effectively address Safety Culture (CON 23) and Change Management (CON 16) issues that were identified in the WIPP report and now identified as issues during the drum event. Other CONs included 5, 6, 8, 12, 14, and 15

Number	Causal Factor	Related Conditions
CC-7	**CC-7: The project failed to provide an adequate number of trained acceptable knowledge (AK) personnel to support the daily activities along with providing effective program oversight.** The Root Cause Team reviewed the AK process and current staffing to determine if they were adequate to support ongoing activities. Both AMWTP and ARP V do not appear to have adequate resources to provide sufficient support to daily activities and provide effective oversight of the requirements and implementation of the AK process at each site. ITG significantly reduced AK staff and AK field personnel from approximately 30 people to about two staff in late 2011/early 2012, based on interviews with personnel familiar with this action. This reduction impacted the ability to ensure day-to-day oversight of field activities; address waste issues; maintain existing AK documents and perform revisions; submit Waste Stream Profile Forms for WIPP acceptance; and perform programmatic development of new AK documents for all remaining and difficult AMWTP waste streams. The AK staff shortage was recognized by Fluor Idaho during transition. After Fluor Idaho takeover the contract on June 1, 2016, efforts to hire additional staff were immediately initiated. The loss of AK staff under ITG continues to be a significant issue in finding qualified AK personnel to develop for addressing AMWTP waste issues and preparing AK documents addressing remaining waste streams.	Interviews indicated that there were not a sufficient number of trained AK personnel. Weaknesses in the oversight of the AK program were observed. Weaknesses in updating AK information were observed. AK personnel were loaned to ARP V to aid in providing management oversight of incoming drum data.

Number	Causal Factor	Related Conditions
CC-8	**CC-8: The Tenant Use Agreement was inappropriately used when initiating the Sludge Repackaging Project (SRP).** Management inappropriately applied the Tenant Use Agreement process when initiating the SRP. Since two contractors were involved in the start of the SRP process, DOE directed the contractors to use an interface agreement (IAG) rather than establishing a prime contractor to subcontractor relationship. The IAG that was developed and included both steps and requirements that should have been in a technical procedure. It also was the vehicle to authorize specific IDCs to be processed. When IAG-592 was modified to include SD-176, it did not receive a USQ evaluation against the safety basis since interface agreements are categorically excluded from the USQ process Additionally, the Root Cause Team identified that the IAG described the processes for what and how waste would transferred between AMWTP and ARP V, including specific requirements such as which IDC to process. Using the IAG bypassed the USQ evaluation process because the IAG is categorically excluded from performing a USQ. The investigation identified that the IAG process was not appropriate for these type controls at a Hazard Category II nuclear facility. When IAG-592 was modified to include SD-176, it did not receive a USQ evaluation against the safety basis since interface agreements are categorically excluded from the process.	DOE Contract Modification 224 directed ITG and CWI to use the IAG process. ITG and CWI mis-applied the IAG process and used it to define specific processes instead of roles and responsibilities. Authorized IDCs to be processed IAG was revised to include SD-176 and did not receive a USQ.

Appendix H

Technical Team Report

Appendix H

Technical Team Report

The Technical Team (TT) is one of three teams formed to investigate and recover from the lid ejections experienced at ARP V. This report summarizes the current status of its findings and conclusions. The investigation is ongoing. The analytical data is in the validation process and marked preliminary, however, the TT believes the conclusion to date can be used to support the cause team recommendations.

Objective

The TT objective was to determine the reactive components and associated reaction mechanism that resulted in over-pressurization of the drums and subsequent ejection of the lids/drum contents at ARP V.

This information will be used to support future processing, characterization, and waste disposition decisions with the goal of preventing similar incidents in the future.

Technical Team

The TT consisted of a team of subject matter experts as follows:

- Dr. Rod E. Arbon (Nuclear and Analytical Chemistry) Fluor Idaho
  - Dr. Arbon has over 25 years of experience in radiolysis, TRU waste characterization, and analytical/laboratory techniques.
- Dr. Tim Burns (Chemical Engineering) Los Alamos National Laboratory
  - Dr. Burns has over 25 years of experience in organometallic chemistry, TRU program implementation and participated in the recent drum event at the Waste Isolation Pilot Plant.
- Dr. H.B Eldredge (Chemical Engineering) Eldredge Consulting
  - Dr. Eldredge has over 30 years of experience in resolving complex chemical engineering problems.
- Dr. Gary S Groenewold (Physical and Analytical Chemistry) Idaho National Laboratory
  - Dr. Groenewold has over 20 years of experience in determining both physical and chemical mechanism.
- Mr. Arnold R. Smith (Chemical Engineering) Fluor Corporate
  - Mr. Smith has over 40 years of experience in R&D and industrial processing, with a focus on scale-up and first of a kind technologies
- Dr. William Onstot (Chemical Engineering) Fluor Corporate
  - Dr. Onstot has over 30 years of experience in complex industry chemical engineering challenges.

In addition to the core membership of the TT, numerous Fluor Idaho personnel have made significant contributions to the investigation effort.

Analytical Testing and Investigation

Based upon the description of the event and operational experience, the TT developed the following working hypothesis:

> *Metal oxidation/heating resulted in secondary reactions (volatile pressurization) leading to lid ejection and partially expelled drum contents.*

Analytical objectives were developed to evaluate this working hypothesis.

Bounding Analyte Selection

Given the wide range of chemicals used at both Rocky Flats Plant (RFP) and the Idaho National Lab (INL) the potential list of reactants is large (thousands of chemicals). To support the fingerprinting and determine the reactive constituents, a comprehensive list of analytes was determined. The list was expected to bound the most likely reactive components involved in the ARP V drum lid ejection events and the most likely generator processes at RFP and INL. The following techniques were utilized to characterize the sample material.

- Gamma Spectroscopy
- Alpha Spectroscopy
- Metals, Totals and Tentatively Identified Compounds (TICs)
- Anions
- Volatile Organic Compounds and TICs
- Semi- Volatile Organic Compounds and TICs
- Dioxins and Furans
- Polychlorinated Biphenyls
- Ignitability
- Thermogravimetric Analysis
- Scanning Electron Microscopy
- X-Ray Powder Diffraction

SPR-252, *Sampling and Analysis Protocol for Investigation of the ARP V Drum Incident* contains a comprehensive list of the target analytes. Two independent laboratories, Savannah River National Laboratory (SRNL) and Southwest Research Institute (SwRI) were utilized in the analysis.

Sampling Events

Guided by the TT, a series of sampling activities were completed. These efforts gathered a variety of materials from sources evolved with, and related to, the event and were designed to provide the data to meet the objectives of the TT. An overall sampling plan, SPR-252, *Sampling and Analysis Protocol for Investigation of the ARP V Drum Incident*, was developed and implemented in phases as the investigation proceeded. This phased approach was required due to the evolving nature of the investigation, specifically, lines of investigation are developed as analytical and testing results are received and reviewed. The various sampling events are described below.

- Ejected Material – Ejected material samples were collected from specific areas in the airlock. The figure below shows the locations from which directed samples of the ejected material were collected. A sampling plan was prepared and documented in EPF-MISC-1386, *ARP-V Drum*

Incident Bulk Sampling, Transportation and Analysis Plan. Twenty five directed samples were collected. Sub-samples were sent to both of the analytical laboratories, SwRI and SRNL. An archive sample was retained.

- Reacted Drum Contents - Material from the four event drums was collected. Further, the figure above shows the locations from which directed samples of the ejected material were collected. A sampling plan was prepared and documented in EPF-MISC-1387, ARP-V Drum Incident Bulk Sampling, Transportation and Analysis Plan. Twelve directed samples were collected. Sub-samples were sent to both of the analytical laboratories, SwRI and SRNL. An archive sample was retained.
- Large Particle Clean-up Samples - During the initial cleanup operations, personnel noticed that large particles produced sparks when moved across the floor. Assuming that the sparking was caused by uranium, this collected and assayed via gram estimation. Sub-samples of the material were sent to SwRI for testing. Archive samples were retained.
- Unreacted Drums – The sampling activities discussed above all involve analysis of the reacted material, making it difficult to understand the initial conditions in the drums before the event occurred. To close this information gap, the TT identified one daughter drum, Drum 106474909, from the repackaging operation that is closely related to the event drums. This daughter had the same parents and therefore, should have similar composition. Head-space gas samples (HSGS) was drawn before opening the drum. Samples of the solid contents were then obtained. This activity is described in SPR-252. The HSGS and the solid sub-samples were shipped to SwRI for analysis. Archive samples were retained.
- Table and Tray – Similarly, the sorting table and Tray-299 used in the repackaging operation contained unreacted material from the operations that preceded the event. These materials could provide insight to the composition and distribution (cross-contamination) of the pre-event material. Solid samples were recovered from these locations and shipped to SwRI for analysis. This sampling activity is described in SPR-252. Archive samples were retained.
- High Methane Drums – In the 2016 timeframe, several drums were discovered at Advanced Mixed Waste Treatment Project (AMWTP) that produced signification quantities of methane, well beyond the allowable limit for shipment and disposal at the Waste Isolation Pilot Plant (WIPP). Through visual examination, these drums were described to be similar in appearance as the ARP-V event materials. Since gas generation is believed to have caused the lid displacement in the ARP-V event, these drums could provide information to support the investigation. Thus, the AMWTP high methane producing drums were sampled. Head-space gas samples (HSGS) were drawn before opening the drum. Samples of the solid contents were then obtained. This activity is described in SPR-252. The HSGS and the solid sub-samples were shipped to SwRI for analysis. Archive samples were retained.

Analytical Results (Highlights)

Compositional analysis and experimental testing of the ejected material and the contents of the event drums are summarized below.

- Radiological Data - All samples of the ejected material contained depleted Uranium at concentrations ranging from 0.6 to 3.0% by mass. Cross contamination at these levels could not have occurred as a result of material ejection and dispersion during the breach event. This information indicates that DU from the single parent drums was distributed to the daughter drums during the repackaging operation. Further, weapons grade isotopes were also measured in the sampled materials.

- Metals - Numerous potentially reactive metals identified in each of the event drums, for example:
  - Beryllium - 1.2 to 12% by mass
  - Uranium - 0.65 to 9.7 % by mass
  - Zirconium - 0.27 to 1.07 by mass

  Each of these metals were evaluated for possible participation in the event.
- Volatiles Organic Compounds - A number of flammable and nonflammable compounds have been measured (low ppm to high ppb), for example, acetone and trichloroethene. In each case, the drum concentration was significantly lower than the ejected sample.
- Semi-volatile Organic Compounds - A number of semi-volatile compounds have been detected in the low ppm range, for example, phenol and phthalates.
- Polychlorinated biphenyls - Aroclors 1254 and 1260 were detected. This is consistent with IDC 003.
- Samples of the large particles contained up to 10% uranium.
- Drums containing high quantities of beryllium (3 to 30%) generate significant amounts of methane in the drum's head-space (2 to 3%).

Several preliminary inferences can be drawn from the analytical data. Specifically,

- The source material from the parent drums were mixed as a result of the repackaging operation and not during ejection and dispersion of the material during the event.
- Metals with the potential to exothermically oxidize were present in the daughter drums. Uranium, in specific forms, can oxidize and release heat at ambient conditions.
- Organic compounds were available to generate over-pressurization in the drums through volatilization or secondary reaction.
- Due to the lower organic concentrations in the burnt drum, it achieved a much higher temperature during the event than the nonstirred drums.

In addition to the compositional analysis, additional tests and studies to aid in determining the reaction mechanism have been performed. Of particular significance, has been the temperature and pressure curves generated on waste material. In this test, a sub-sample of the involved material was placed in a sealed reaction vessel and heated with an external source. The samples evolved significant volumes of gas (for example, methane, carbon dioxide, hydrogen, and carbon monoxide) at a very rapid rate, when the temperature reached between 150 and 200^{o}C. Pressures of up to 350 psi were observed.

To determine the importance of oxygen in the response, the tests were conducted in two different atmospheres, the first in air (containing oxygen) and the second in argon (void of oxygen). Both atmospheres exhibited similar results. Oxygen is not required for gas evolution. The product gas after from the reaction of was sampled. Analysis indicated that hydrogen, methane, carbon monoxide, and carbon dioxide were in the resulting gas.

As noted above, the high methane producing drums contained significant amounts of beryllium. To examine the influence of beryllium versus uranium on the generation of methane, a gravity separation was performed on sub-samples of the event material and the fractions were subjected to the temperature – pressure test. The light fraction containing the beryllium continued to produce methane, while the heavy fraction containing the uranium did not. Further, the event material produced methane upon addition of either acid or base. This response is indicative of a carbide hydrolysis reaction. Since beryllium has been correlated to high methane production in unreacted drums, beryllium carbide appears to be the source of the methane generation.

These tests indicate that the resulting pressure in a closed container (repackage drum) is sufficient to dislodge the lid and eject the contents of the drums.

Chemical Compatibility Evaluation

The TT completed a comprehensive chemical compatibility evaluation specific to the drums involved to aid in understanding the interactions and to provide guidance to future repackaging operations.

This evaluation reviewed the metal, organic, and inorganic constituents measured in the compositional analysis discussed above. Metals with concentrations below 0.1% were not considered to be significant contributors to the event and were not included in the evaluation. However, because the original organic chemical concentration in the waste matrix is unknown, all measured analytes were considered in the evaluation.

After evaluating the data, the following chemical compatibility conclusions can be drawn.

- The first conclusion is that water reactive substances were not a concern in the waste because the visual examination of the waste before packaging indicated no free liquids, or breached containerized liquids. All probable parent containers were reported as containing light, fluffy, flowing material, not clumpy or damp sludge. The absence of liquid precludes aqueous fluid from being a source of an incompatible reaction. Minor amounts of moisture in the atmosphere or in the interstitial spaces of the waste matrix could not have caused the reaction because the moisture would be unable to migrate (diffuse) within the mass to maintain a chemical reaction. The exception to this conclusion is uranium which is hypothesized to exist in the waste in the metallic form. When metallic uranium is exposed to the ambient atmosphere, its surface will immediately oxidize to form a thin layer of UO_2. Over the course of time, in the sealed parent drum, uranium will continue to slowly oxidize, forming hypervalent oxide UO_{2+x} depleting O_2. This makes the uranium significantly more susceptible to H_2O oxidation when subsequently exposed to the ambient atmosphere with a relative humidity > 2%. Reaction of H_2O with oxygen anions at the surface of the UO_{2+x} lattice are hypothesized to form OH^- which is capable of diffusing through the oxide layer to the underlying uranium metal, where it exothermically reacts to form UO_2 and H_2, the latter subsequently reacting with additional metal to form UH_3. If the heat generated by these reactions cannot be dissipated, the temperature will increase, which will further speed the diffusion of OH^- (and the slower $O^=$ diffusion) through the oxide layer to the metal surface, and increase the rate of the oxidation reaction, releasing more heat, and further increasing the temperature. The humidity, estimated to be 50 % or greater to which the waste was exposed when the parent drum was opened, spread out, and repackaged, is sufficient to support this reaction sequence, and is consistent with the latency period.
- Most metals listed in the analysis could not have participated in an incompatible reaction. Either the metals were previously reacted, would not have survived storage, or were not in the proper configuration (fines). The metals that could have participated in an oxidation reaction are plutonium and uranium. Plutonium is dismissed because its concentration was low, below an amount that is reactive. Uranium, especially depleted uranium (DU) did end up as a waste product. The behavior of the heating is consistent with DU.
- Alkali and alkaline earth metals (RGN 21) are not a concern in the waste because they would have been consumed in their intended reactions, or were never present as an unreacted metal. For example, potassium metal was not used in the processes that produced the waste, but was present as potassium hydroxide.

- The metals that could have participated in an oxidation reaction are plutonium and uranium. Plutonium is dismissed because it was recovered up to the economic discard limit. This prevents the plutonium from being in the waste in an amount that is reactive. Uranium, especially depleted uranium (DU) did end up as a waste product. Uranium metal does not have to be in the form of fines to ignite, and the larger particle sizes (coarse fines) may remain in the waste until conditions change and the oxidative nature of uranium becomes favorable.
- Most volatile and semi-volatile compounds do not have a concentration great enough to participate in an incompatible reaction. The exception is methane. Heating the residue from the WMF-1617 (ARP-5) drum incident may have liberated large quantities of methane. Methane could cause pressurization, fire, and an explosion. Along with the methane, carbon dioxide was also liberated. Carbon dioxide may not pose the same potential chemical risks as methane, but it could contribute to a pressurization event.

Most metals listed in the analysis could not have participated in an incompatible reaction. Either the metals were previously reacted, would not have survived storage, or were not in the proper configuration (fines). All of the metal categories (RGNs 21, 22, 23, and 24) have potential incompatibilities with explosives (RGN 102). The only explosive, according to the EPA method, from the elemental list is calcium. The processes that employed calcium metal used it as a reducing agent for plutonium salts. This process would consume the calcium, so there should be no unreacted calcium metal in the final waste form. If any survived the process, the slag was leached to reclaim any plutonium. The leaching process would then consume the any remaining calcium. Analysis of the waste indicates the calcium came from the compound calcium fluoride. Calcium fluoride would be unable to participate in further chemical reactions in the waste.

From the analysis results, the reducing agents (RGN 105) are represented by sodium and phosphorus. Sodium metal was not used as a reagent because of the difficulty of storage and use. Also, the storage requirements for sodium would prevent it from persisting in the waste. The source of sodium in the waste is from other reagents that contain the sodium ion. In this instance, the situation with phosphorus is very similar. Elemental phosphorus was not used in the processes that generated the waste. The phosphorus contribution to the waste is due to reagents that contained the phosphorus. Sodium and phosphorus will not be available for further chemical reactions in the waste form.

Preliminary Conclusions

The initiating mechanism (heat source) of lid ejections, based on sample results, was oxidation of the uranium metal which supported secondary chemical reactions. The secondary reactions created an over-pressurization in the drums ejecting the lids and dispersing a portion of the drum contents.

Uranium, a potentially oxidative metal, was found in the ejected material, the event drum contents, and the larger particles. Uranium content in the event drums was measured to be between 0.6 and 9.7%, while the sparking particles contained up to 10%. The gas evolution tests indicated that when the event material reaches a temperature of approximately 150^{o}C, a significant volume of gas is evolved very rapidly. Beryllium carbide has been identified in the event materials and can generate significant amounts of methane when heated in the presence of acid, base, or water. The resulting pressure in a closed container (repackage drum) is sufficient to dislodge the lid and eject the contents of the drums.

Supplemental Information: Pyrophoricity versus Metal Oxidation

An emergent question arising from the ARP-V Drum Venting Event is whether or not the depleted uranium which initiated the lid expulsion was pyrophoric. There are multiple definitions of pyrophoric material, which include the following:

1. **DOE Handbook DOE-HDBK-1081-94, December 1994, Primer on Spontaneous Heating and Pyrophoricity**
   a. Pyrophoric Material: Pyrophoric substances ignite instantly upon exposure to air (atmospheric oxygen). A pyrophoric substance may be a solid, liquid, or gas. Most materials are not pyrophoric unless they are in a very finely divided state.

2. **US EPA SW-846 Test Method 1050, for substances likely to spontaneously combust**
   a. (https://www.epa.gov/hw-sw846/sw-846-test-method-1050-test-methods-determine-substances-likely-spontaneously-combust)
   b. Definition: Wastes (including mixtures and solutions, liquid or solid) which, even in small quantities, ignite within five minutes of coming in contact with air. These wastes are the most likely to spontaneously combust and are considered to have pyrophoric properties.
   c. Test Method A for pyrophoric solids: a sample is dropped from a height of 1 meter onto a noncombustible surface. If ignition is not observed, as indicated by any smoke, flame or incandescence, then it is not pyrophoric
   d. Test Method C, for self-heating wastes. A 100 mm stainless steel cube containing the wastes is heated for 140°C for 24 H. If the temperature rises to 200°C within 24 hours, then it is classified as a self-heating waste per DOT.

3. **OSHA Hazard Communication Standard 29 CFR 9110.1200**
   a. The definition here is "Pyrophoric" means a chemical that will ignite spontaneously in air at a temperature of 130 deg. F (54.4 deg. C) or below, but in the same table, a pyrophoric solid means a solid which, even in small quantities, is liable of igniting within five minutes after coming into contact with air. Substances and mixtures of this hazard class are assigned to a single hazard category on the basis of the outcome of the test: The solid ignites within 5 minutes of coming into contact with air.
   b. (https://www.osha.gov/dsg/hazcom/ghd053107.html)

4. **US DOT @ 49 CFR 173.124, definitions**
   a. (https://www.gpo.gov/fdsys/granule/CFR-2011-title49-vol2/CFR-2011-title49-vol2-sec173-124)
   b. Under Division 4.2, Spontaneously Combustible Material, which means
      i. A pyrophoric material. A pyrophoric material is a liquid or solid that, even in small quantities and without an external ignition source, can ignite within five (5) minutes after coming in contact with air when tested according to UN Manual of Tests and Criteria (GHS).

5. Globally Harmonized System (GHS), as of 2006

a. (https://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf). Note that the GHS system was adopted by the US, and implemented by OSHA in the 2012 – 2015 timeframe, about the time we went to the SDSs (from MSDSs).

b. 3.1.10, Pyrophoric solids

   i. A pyrophoric solid is a solid which, even in small quantities, is liable to ignite within five minutes after coming into contact with air. Substances and mixtures of this hazard class are assigned to a single hazard category on the basis of the outcome of the UN Test N.2 (UN Manual of Tests and Criteria).

Within each definition of a pyrophoric substance there is an expectation that ignition occurs immediately or within five minutes of coming into contact with air after dropping from a height of 1 meter.

This was not the case for the waste resulting in lid ejections. The waste contents were dropped/dumped into a processing tray and physically mixed looking for prohibited items. The visual examination experts present were trained to look for sparking. No sparking/ignition were observed. The process to perform a visual examination typically exceeds 5 minutes. The contents in the tray are then loaded into a drum. Again, no sparking/ignition were observed.

The event drum experienced a temperature rise due to oxidation of depleted uranium subsequent to repackaging, which led to a pressure build-up and subsequent lid ejection. The process of opening the parent drum and performing the visual examination exposed the contents to ambient atmosphere, which initiated the oxidation reaction. The long delay time – 7+ hours – that occurred between the repackaging of the contents and the drum over pressurization is not consistent with the waste as pyrophoric.

During the clean-up, two instances of particle sparking was observed during the recovery of particles on the floor. This occurred about 7 days after the repackaging and lid ejection. The circumstances were favorable to the sparking of depleted uranium. The individuals performing the clean-up were using the vacuum to consolidate lager particles into a pile. The particles were too large for the vacuum head and were being scrapped along the floor with a constant atmospheric gas stream enveloping the particle. The combination of scrapping, a physical insult, and the oxygen stream lead to two sparks being observed. This is more aggressive than the sparking as a result of a 1 meter drop and sparking within 5 minutes.

Based upon the physical observations of the waste during processing the depleted uranium did not meet the definition of a pyrophoric. It did, however, begin an oxidation reaction generating heat which led to secondary reactions ultimately ejecting the drum lids.

Appendix I

Fire Department Audio Transcript

Appendix I

Fire Department Audio Transcript

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
1	Engine 1, ambulance 4, batallion1; respond to WMF-1617 to a fire alarm.	4-11	22_36_46
2	Engine 1 copies, WMF-1617 gives us check count.	4-11	22_37_58
3	Dispatch, engine 1 is back	4-11	22_39_14
4	Go ahead engine 1	4-11	22_39_19
5	N/A	4-11	22_39_25
6	N/A	4-11	22_39_32
7	N/A	4-11	22_39_37
8	Dispatch battalion 1 is in route.	4-11	22_39_40
9	N/A	4-11	22_39_44
10	Dispatch copy Battalion 1	4-11	22_39_51
11	Battalion 1, dispatch	4-11	22_40_16
12	Go ahead Dispatch	4-11	22_40_23
13	Battalion 1 be advised we have also received 2 other camera alarms coming from this building do you want me to upgrade the dispatch?	4-11	22_40_26
14	That is an affirmative	4-11	22_40_35
15	N/A	4-11	22_40_43
16	Ladder 1, Medic 1, Rescue 1, respond to WMF-1617 to multiple fire alarms. All responding units, Command 3.	4-11	22_40_57
17	Ladder copy WMF-1617	4-11	22_42_44
18	Ladder in route.	4-11	22_43_24
19	Dispatch copies,	4-11	22_43_28
20	Medic 1 is in traffic.	4-11	22_43_41
21	Dispatch copies ladder or medic 1	4-11	22_43_46
22	Is on command 3	4-11	22_44_00
23	N/A	4-11	22_44_20
24	Dispatch rescues in rad 1 , plan 3	4-11	22_44_23
25	Be advised all responding units. N/A	4-11	22_44_35
26	Dispatch battalion 1 has arrived at RWMC area.	4-11	22_45_42
27	Dispatch copies dt 1area	4-11	22_45_53
28	Dispatch battalion 1 has arrived on a singular story megastructure, industrial occupancy at this time we have nothing showing, battalion 1 will be located on alpha side in investigative mode, and battalion 1 will be 1617 command, completed the 360 of the building.	4-11	22_47_26
29	Dispatch copies, battalion 1 showed up on a mega sized building 1 story commercial nothing showing, alpha side, 360 completed and 1617 command.	4-11	22_47_55

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
30	Dispatch engine 1 is on scene.	4-11	22_48_20
31	Dispatch copies engine 1 on scene.	4-11	22_48_28
32	N/A	4-11	22_49_06
33	Dispatch Captain Undhjem	4-11	22_51_22
34	Go Ahead Captain Undhjem	4-11	22_51_27
35	Myself and 2 firefighters are going to make entry.	4-11	22_51_33
36	Dispatch copies, Captain Udjhjem and 2 firefighters are making entry.	4-11	22_51_41
37	Dispatch Ladder 1 in RWMC area, break incident command Ladder 1	4-11	22_51_59
38	Go for 1617 command	4-11	22_52_10
39	Yea do you have an assignment for us?	4-11	22_52_15
40	Just level 1 stage ladder 1	4-11	22_52_24
41	Copy	4-11	22_52_29
42	N/A	4-11	22_52_32
43	1617 command	4-11	22_52_33
44	Go for 1617 Command	4-11	22_52_38
45	We got smoke inside of the facility; we are going to go on air. Stand by for update.	4-11	22_52_44
46	1617 Command copies, you do have smoke in the building, break, ladder 1 (fix) the hydrant and stretch the line to engine 1	4-11	22_52_50
47	Copy	4-11	22_53_05
48	Ladder 1 from Battalion 1	4-11	22_54_46
49	Ladder 1 from Battalion 1	4-11	22_54_59
50	N/A	4-11	22_55_06
51	Go for Ladder 1	4-11	22_55_11
52	Ladder 1, I am going to have you relocate, move to the north side of the building since they caught a hydrant, we will have them break there line and come across.	4-11	22_55_14
53	Want me to get out	4-11	22_55_49
54	N/A	4-11	22_56_34
55	Entry team from 1617 command	4-11	22_56_49
56	1617 command Undhjem	4-11	22_57_38
57	Go for command	4-11	22_57_44
58	We made entry inside of the facility, we have a drum that is ruptured and is currently gassing off into the building, temperatures of 190 we are going to need RadCon to terminate us out of here.	4-11	22_57_50
59	N/A	4-11	22_58_12
60	N/A	4-11	22_58_13

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
61	Command copies, you've had a drum that has ruptured and will be exiting the building, we will be getting ahold of RadCon to survey you out, break, at this time is that drum going to cause any other problems at the moment.	4-11	22_58_17
62	I do not believe so, we can put an extinguishing method on it, to keep the vapors or fumes off of it, and it's currently only 190 degrees and continuing to set off the smoke alarms.	4-11	22_58_38
63	1617 command copies	4-11	22_59_00
64	1617 command it is Undhjem	4-11	23_00_01
65	Go for 1617 command	4-11	23_00_05
66	Our drum is getting warmer we are going to apply an extinguishing method on it.	4-11	23_00_12
67	I copy there should be 2 class D metal ex portal fire extinguishers with penetrating nozzles that are in that room. We have hydrogen gas that may be present in the sealed drum. Just folks we need to plan for the event.	4-11	23_00_26
68	Dispatch from battalion 1	4-11	23_00_53
69	Go ahead battalion 1	4-11	23_00_59
70	Can I get you to dispatch our hazmat team	4-11	23_01_06
71	Dispatch copies, dispatch hazmat team	4-11	23_01_17
72	Command, Ladder 1	4-11	23_01_24
73	Go for command	4-11	23_01_31
74	N/A	4-11	23_01_34
75	Do you want to go back and get hazmat	4-11	23_01_36
76	That is an affirmative, break, ladder 1 also set up rec team	4-11	23_01_46
77	Hazmat team respond to WMF-1617 to command	4-11	23_01_47
78	Dispatch this is Captain Voyles who did you call for	4-11	23_02_14
79	Captain Voyles I requested the hazmat team to respond to 1617	4-11	23_02_26
80	Copy that, I will be sending myself and 2 other guys from station 3	4-11	23_02_37
81	Dispatch copies	4-11	23_02_45
82	Station 2 will be sending Captain Okopny and Wes Moore	4-11	23_02_48
83	Dispatch copies	4-11	23_02_54
84	Entry team for 1617 command	4-11	23_03_23
85	Go ahead	4-11	23_03_27
86	What are your air levels at	4-11	23_03_32
87	7500	4-11	23_03_50
88	1617 command	4-11	23_04_17
89	Go for 1617 command	4-11	23_04_21
90	We are applying the metal x extinguishers in the barrel	4-11	23_04_28
91	I copy, what time of readings are you getting on your gas monitor	4-11	23_04_34
92	Dispatch ambulance 4 on dispatch	4-11	23_05_01

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
93	Lost the alarm	4-11	23_05_05
94	Go ahead ambulance 4	4-11	23_05_08
95	I am responding back to the station to retrieve hazmat van	4-11	23_05_12
96	Dispatch copies ambulance 4	4-11	23_05_19
97	Can you repeat that Captain Undhjem	4-11	23_05_27
98	All that is showing is a O2 alarm	4-11	23_05_33
99	N/A	4-11	23_06_35
100	N/A	4-11	23_06_44
101	Medic 1 from1617 command	4-11	23_06_48
102	Go for Medic 1	4-11	23_06_58
103	Medic 1 when you get back to the station, when you grab the hazmat will you stop by my cubicle and grab my phone	4-11	23_07_02
104	Ambulance 4 did you copy that	4-11	23_07_15
105	That is a affirmative, ambulance 4 copies	4-11	23_07_19
106	Dispatch, pick up 3 is responding with 3 personnel	4-11	23_09_44
107	N/A	4-11	23_09_50
108	Dispatch do you copy, BR-402 is in response	4-11	23_09_50
109	Dispatch copies, pickup 3 and BR-402	4-11	23_09_59
110	BR-402 clear to MFC gate	4-11	23_11_01
111	Dispatch copies, clear to MFC gate	4-11	23_11_09
112	Entry team from 1617 command	4-11	23_11_56
113	Go ahead	4-11	23_12_01
114	Stand by 1 entry team	4-11	23_12_12
115	Entry team from Battalion 2 can you give me a status update	4-11	23_12_37
116	Continuing to apply the metal x, having difficulty getting it to cool down, air is at 3000	4-11	23_12_48
117	I am unable to copy due to the alarm in the background can you repeat that	4-11	23_13_02
118	Applying the metal x extinguisher, air is at 3000	4-11	23_13_14
119	I copy your still copying metal x, your air is at 3000 do you have any needs	4-11	23_13_26
120	No needs	4-11	23_13_38
121	I copy, are you able to stay out of the plume and out of the product while you are doing that	4-11	23_13_41
122	That is a negative, there is product all over the floor	4-11	23_13_50
123	Ok if that doesn’t look like that is doing any good I want you to come on back on out.	4-11	23_13_58
124	I copy, can we have RadCon at the door for our exit	4-11	23_14_22
125	We got RadCon coming there are not here right now, but we have our guys out ready to survey you to see if you got anything	4-11	23_14_29

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
126	1617 copy our barrel is at 215 degrees that is the lowest we are able to get it	4-11	23_14_45
127	I copy that I don’t want you to stay there any longer than you have to if you not doing good with that extinguisher	4-11	23_14_56
128	We are going to exit	4-11	23_15_13
129	Can you repeat that last transmission Captain Undhjem	4-11	23_15_22
130	We are going to go ahead and exit the facility we will have to decon outside the door	4-11	23_15_31
131	I copy is the area outside of the airlock to the exit door clear	4-11	23_15_41
132	We’d have to roll up the roll up door in the airlock	4-11	23_15_55
133	Dispatch, hazmat in route	4-11	23_15_58
134	I’m sorry with that alarm you are hard to understand can you repeat that again	4-11	23_16_03
135	Dispatch, copies that	4-11	23_16_03
136	The airlock has a roll up door we would have to roll up to get out otherwise we have a foyer through a man door	4-11	23_16_10
137	I copy is that area clear or does it have smoke in it as well	4-11	23_16_19
138	It has smoke from our entry but not heavy	4-11	23_16_27
139	I copy whenever you get to this exit door, I need you to hold tight our guys are just about ready to survey you as you come out the door	4-11	23_16_36
140	I copy we’ll hold tight inside of the foyer	4-11	23_16_51
141	Captain Undhjem was there anything else around that drum or was it isolated on its own	4-11	23_17_34
142	It is next to other drums sitting on the floor	4-11	23_17_45
143	I copy is the leak close enough to where it is exposing heat to others or was there just constant 200 degree temperature around the whole drum	4-11	23_17_51
144	We have placed the barrel away from the others and it is in one isolated lower portion of the barrel	4-11	23_18_06
145	I am unable to copy that would you please repeat one more time	4-11	23_18_18
146	We isolated the barrel from the others, one hot spot on the lower portion of the barrel	4-11	23_18_26
147	I copy you isolated from the other barrels there is a hot spot on the bottom of the barrel, thank you, we’ll have our guys give you further direction at the exit door.	4-11	23_18_35
148	1617 command, entry team	4-11	23_19_28
149	Go for 1617 command	4-11	23_19_32
150	Be advise, we have air borne contaminate, beryllium, and that we are possibly exposed to on our bunker gear so when we doff our hazmat’s will have to be accommodated for us	4-11	23_19_43
151	N/A	4-11	23_19_45
152	N/A	4-11	23_19_49

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
153	1617 command copies, that possibly airborne contamination with beryllium.	4-11	23_20_01
154	Entry team from 1617 command	4-11	23_21_46
155	Go ahead	4-11	23_21_52
156	What is your air	4-11	23_21_54
157	2500	4-11	23_22_04
158	Ok RWMC has there RadCon team should be here in just a few minutes just wait inside until they arrive	4-11	23_22_09
159	Command survey team is ready	4-11	23_22_22
160	Entry team copies, standing by	4-11	23_22_28
161	RWMC shift supervisor from INL fire department give you a update, one of the drums has vented, there is 2 other drums next to it they have been moved away a little bit, the temperature on the one drum is rising	4-11	23_22_43
162	Go for INL fire department	4-11	23_23_03
163	Battalion 1 be advised you are on command 3	4-11	23_23_06
164	1617 command, entry team	4-11	23_23_18
165	Go for command entry team	4-11	23_23_23
166	We have information off the barrel that we can hand off, do you want that	4-11	23_23_31
167	That is an affirmative	4-11	23_23_39
168	Hazmat club 1	4-11	23_23_53
169	Entry team from 1617 command go ahead with that information	4-11	23_24_02
170	Hazmat, ambulance 4	4-11	23_24_48
171	Go to channel 4	4-11	23_24_58
172	Hazmat from battalion 2	4-11	23_25_13
173	1617 command	4-11	23_27_29
174	Entry team, Undhjem	4-11	23_27_53
175	Entry team from command	4-11	23_27_59
176	N/A	4-11	23_28_07
177	Stand by, are extinguishing attempts were unsuccessful, were continuing to vent off.	4-11	23_28_14
178	1617 command copies, the extinguishing attempts didn't work it is still venting	4-11	23_28_24
179	1617 command be advised the whole building inside here is contaminated it has particles all over	4-11	23_28_37
180	Entry team	4-11	23_28_51
181	Entry team do you have your radio on	4-11	23_28_56
182	Yeah go ahead	4-11	23_29_00
183	Do you have any air monitors alarm	4-11	23_29_07
184	Beta monitor is showing 61 on the meter	4-11	23_29_43

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
185	Can you repeat	4-11	23-29_53
186	Alpha beta monitor in the facility showing Beta 61 , no Alpha	4-11	23_30_00
187	You're going to have to repeat that one more time	4-11	23_30_17
188	Entry team from Battalion 2 confirming you said you getting beta readings from 61 inside	4-11	23_30_36
189	That is correct, no Alpha, 2 cams are not alarming	4-11	23_30_44
190	Can you repeat what is alarming	4-11	23_30_54
191	No reading on our DPM	4-11	23_31_00
192	Ok what is your reading DMC saying	4-11	23_31_07
193	22 mili rem	4-11	23_31_20
194	22 mili rem	4-11	23_31_23
195	Please repeat	4-11	23_31_28
196	22 mili rem	4-11	23_31_34
197	Confirming 22 mili rem	4-11	23_31_39
198	Negative .2	4-11	23_31_44
199	Copy much better .2	4-11	23_31_48
200	Entry team from 1617 command	4-11	23_32_21
201	Go ahead	4-11	23_32_31
202	Was there any ventilation going on in the building could you tell	4-11	23_32_34
203	Stand by	4-11	23_32_50
204	That is affirmative	4-11	23_33_02
205	Command Pick up 3	4-11	23_34_07
206	N/A	4-11	23_34_14
207	Go ahead	4-11	23_34_17
208	Pick up 3 is in CFA, do you need us to pick up anything up or just come right to the scene.	4-11	23_34_20
209	Pick up 3 from 1617 command, hold at CFA for just a minute.	4-11	23_34_51
210	Copy that we'll level 2 at CFA	4-11	23_34_59
211	N/A	4-11	23_35_26
212	Entry team from Battalion 2	4-11	23_35_30
213	Go ahead	4-11	23_35_33
214	Do you have any other types of alarms going off in there	4-11	23_35_36
215	Stand by	4-11	23_35_53
216	Command entry team	4-11	23_36_29
217	Go for command	4-11	23_36_35
218	We just silenced the fire alarm no other alarms are alarming	4-11	23_36_40
219	I copy, you've silenced the fire alarms, you got no other alarms, have you been able to determine if the ventilation has been shut down or do you have anything to tell you that	4-11	23_36_46

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
220	The monitor is showing the ventilation is still operating	4-11	23_37_06
221	Is there, standby	4-11	23_37_11
222	I copy that, how is your air supply and how are you doing in general	4-11	23_37_36
223	Air at 2000, doing good	4-11	23_37_45
224	I copy, are your readings on your DMC going up at all	4-11	23_37_50
225	Readings are the same	4-11	23_38_12
226	I copy your readings are the same thing, they just a couple minutes out, they are getting some respiratory protection so RadCon can work you on your way out.	4-11	23_38_15
227	Engine 2 copies	4-11	23_38_28
228	Command, entry team	4-11	23_40_49
229	Go for command entry team	4-11	23_41_00
230	Give you a heads up, the accumulation start date on the barrel is today	4-11	23_41_11
231	The accumulation what started today	4-11	23_41_20
232	The accumulation start date for the barrel was today	4-11	23_41_27
233	I copy the accumulation start date was today, were going to get you guys out of here pretty quick and then we're going to have you give us a rundown of what's going on, then were going to be relocating.	4-11	23_41_31
234	Engine 2 copy	4-11	23_41_43
235	Command BR-402 level 1 to personnel	4-11	23_41_49
236	Command from Battalion 2	4-11	23_42_20
237	Entry team from Battalion 2, I have a guy getting suited up in a PAPR right now he's going to be the one survey you as you come out it'll just be another minute or two	4-11	23_42_45
238	Entry team copies	4-11	23_42_58
239	Command BR-402 level 1 to personnel	4-11	23_43_18
240	Command from Battalion 2	4-11	23_45_28
241	1617 command, entry team	4-11	23_47_01
242	Go for command	4-11	23_47_07
243	Be advised we are down to the vibe alert	4-11	23_47_14
244	1617 command copies you are down to your vibe alert you are being surveyed right now correct	4-11	23_47_22
245	That is a negative we're too contaminated for him	4-11	23_47_37
246	Captain Undhjem from battalion 2	4-11	23_49_55
247	Go ahead	4-11	23_50_22
248	Is everybody comfortable with the doffing procedure or are you going to need help with that	4-11	23_50_25
249	We're going to doff, (N/A)	4-11	23_50_35
250	Have you got anybody in there that doesn't have a vibe alert going off I can't hear you through it	4-11	23_50_46

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
251	Negative just went off	4-11	23_50_54
252	Br-402 is on scene	4-11	23_51_11
253	Dispatch copies, Br-402 is on scene	4-11	23_51_25
254	Command from Battalion 2	4-11	23_54_34
255	Command from Battalion 2	4-11	23_54_57
256	Battalion 2 from 1617 command	4-11	23_55_11
257	Your first firefighters made exit they are surveying his body	4-11	23_55_16
258	Captain Christensen, from Battalion 2	4-11	23_55_56
259	Go ahead	4-11	23_56_01
260	Make sure they as soon as they get out they are cleared and send them to the ambulance for eval	4-11	23_56_03
261	Copy can we move in a little closer	4-11	23_56_09
262	That's affirmative I will work on getting you one by up the hazmat van	4-11	23_56_18
263	Kevin's grabbing it	4-11	23_56_23
264	I copy	4-11	23_56_26
265	Command from Battalion 2	4-11	23_59_55
266	Go ahead Battalion 2	4-12	00_00_00
267	Firefighter number 2 is on the outside of the building they will be surveying his person	4-12	00_00_03
268	Command copies, second individual is out and they will be surveying that person	4-12	00_00_09
269	Command from Battalion 2	4-12	00_05_18
270	Go for command	4-12	00_05_22
271	Third firefighter is on the outside of the building there surveying his person	4-12	00_05_26
272	Command copies, third person is out being surveyed	4-12	00_05_32
273	Command, dispatch	4-12	00_08_55
274	N/A	4-12	00_09_16
275	1617 command, dispatch	4-12	00_09_25
276	Dispatch this is Battalion 2 you can go for command	4-12	00_09_33
277	Command be advised I spoke with Dallas and Barry Ferguson, they do not have any camera use in the airlock, according to them the retrieval area cameras are at normal condition.	4-12	00_09_37
278	I copy you've made contact and they do not have any views from the camera, they are in normal condition	4-12	00_09_53
279	N/A	4-12	00_12_15
280	Command from Battalion 2	4-12	00_13_06
281	Go ahead Battalion 2	4-12	00_13_22

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
282	I got Captain Okopny assigned to get us some blankets out here from station 1 these guys might be here a little while getting surveyed, just trying to keep them a little warmer	4-12	00_13_25
283	Command copies	4-12	00_13_40
284	Station 1, Captain Okopny	4-12	00_14_00
285	Go ahead Captain Okopny	4-12	00_14_07
286	Yeah can you get me about 10 blankets and meet up with BR-402 who will be in route to CFA and transfer blankets	4-12	00_14_17
287	Command from Battalion 2	4-12	00_14_31
288	N/A	4-12	00_14_33
289	That is affirmative we will get you 10 blankets and rendezvous with you	4-12	00_14_37
290	He will meet your personnel at the turnout by the highway	4-12	00_15_03
291	N/A	4-12	00_15_12
292	Copy that, we'll meet him at the, we'll meet him were just going into the station now to get the blankets now we'll meet him	4-12	00_15_15
293	Copy	4-12	00_15_23
294	N/A	4-12	00_17_47
295	To pick up 3	4-12	00_22_26
296	We just had another barrel blow up	4-12	00_24_22
297	Yup everybody get out of there we will worry about contamination later	4-12	00_24_26
298	N/A	4-12	00_24_51
299	Go ahead and turn around Wes we will walk you	4-12	00_24_59
300	All INL apparatus get your rig put back in service and get away from the building back away at least 100 m	4-12	00_25_00
301	Command to Pick up 3	4-12	00_25_47
302	Pick up 3 go command	4-12	00_25_55
303	Do you still want us to return to station 3 or hold up	4-12	00_25_58
304	Where are you at	4-12	00_26_03
305	Where just dropped off blankets off to wild land 2	4-12	00_26_06
306	Turn off at EBR-1	4-12	00_26_14
307	Command Christensen from Battalion 2	4-12	00_28_10
308	Go ahead Battalion 2	4-12	00_28_18
309	I am going to leave it to you to button up those people up down there and get them out of there as soon as you can and let me know when they are clear	4-12	00_28_21
310	We're loaded up	4-12	00_28_27
311	N/A	4-12	00_28_36
312	Battalion 2 we're loaded up and headed out	4-12	00_28_40
313	All INL fire apparatus please relocate up to RWMC parking lot from 1617 command	4-12	00_31_15

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
314	Ladder 1 copies	4-12	00_31_28
315	Hazmat copies	4-12	00_31_31
316	N/A	4-12	00_31_33
317	Rescue copies	4-12	00_31_37
318	Engine 101 copies	4-12	00_31_40
319	Medic 4 copies	4-12	00_31_45
320	Battalion 1 copies	4-12	00_31_54
321	Go for command	4-12	00_31-58
322	We're make sure everybody's out	4-12	00_32_02
323	Battalion 1 you guys are going to be the only ones left	4-12	00_32_49
324	I copy that Captain Okopny I'll go ahead	4-12	00_32_58
325	N/A	4-12	00_34_52
326	Medic 1 to Captain Christensen	4-12	00_34_56
327	Go ahead	4-12	00_35_03
328	N/A	4-12	00_35_05
329	Do you the have firemen in your ambulance	4-12	00_35_08
330	That is affirmative I have the firemen and RadCon personnel and firefighter Crystal in Medic 4	4-12	00_35_12
331	Copy	4-12	00_35_23
332	We need to take these guys somewhere to be deconned and have their hands washed are we ok to go into AMWTP or CFA medical	4-12	00_35_26
333	Battalion 2, Captain Christensen	4-12	00_35_41
334	Captain Christensen that is an affirmative let's go ahead and get our guys to CFA medical to get cleaned up	4-12	00_35_56
335	Just makes sure RadCon stays with them and we got Captain Okopny, Captain Van Orden and myself in the hazmat	4-12	00_36_06
336	I copy that is affirmative keep RadCon with them and we need to have Captain Undhjem give BC Kelly a land line asap	4-12	00_36_13
337	He is in medic 1	4-12	00_36_23
338	N/A	4-12	00_36_29
339	Medic 1 from 1617 command	4-12	00_36_32
340	This is medic 1 go ahead command	4-12	00_36_38
341	Can you have Captain Undhjem land line my phone number is 821-4127	4-12	00_36_44
342	Copy we're land lining you now his hands are contaminated so you are just on speaker phone	4-12	00_36_56
343	Dispatch, Medic 4	4-12	00_38_10
344	Go ahead Medic 4	4-12	00_38_13
345	Medic 4 is in route with 4 firefighters headed to CFA dispensary please notify them and let them know were coming to get there decon facility ready	4-12	00_38_16

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
346	Dispatch copies, ambulance 4 is in route to CFA medical request notification to CFA medical	4-12	00_38_30
347	Okopny Br-402 is stationed in the parking lot	4-12	00_38_57
348	Command to Okopny	4-12	00_39_22
349	Command to Okopny	4-12	00_39_43
350	Command Captain Okopny	4-12	00_39_43
351	BC to Okopny	4-12	00_40_18
352	Go ahead Captain Okopny	4-12	00_40_27
353	We have an all-clear personnel	4-12	00_40_31
354	I copy just make sure everyone gets to where we told them to go I appreciate your help	4-12	00_40_35
355	Copy at this time we are doing the same, survey out here in the parking lot of all personnel	4-12	00_40_45
356	I copy sounds good	4-12	00_40_52
357	N/A	4-12	00_42_07
358	Station 1 to Medic 1	4-12	00_45_07
359	N/A	4-12	00_45_26
360	Station 1 to Medic 1	4-12	00_45_30
361	Pick up 3 go ahead	4-12	00_45_36
362	N/A	4-12	00_45_41
363	Medic 1 be advised there is nobody in the station	4-12	00_45_56
364	Captain Barrow, Station 1, Medic 1	4-12	00_45_57
365	Go ahead Medic 1	4-12	00_46_02
366	Yea were just about 3 minutes out from the dispensary can you go over and help us decon these firefighters	4-12	00_46_05
367	We'll have to turn around we got released we are just about to gate 4 if you need us to turn around we'll do that	4-12	00_46_16
368	Go ahead, disregard you can continue in route	4-12	00_46_29
369	Copy that I asked them if they wanted us to hold on they never did get back to us so	4-12	00_46_39
370	Dispatch, Medic 1	4-12	00_48_15
371	Go ahead Medic 1	4-12	00_48_17
372	Medic 1 has arrived at CFA medical dispensary for decon	4-12	00_48_21
373	Dispatch copy, Medic 1 at CFA medical for decon	4-12	00_48_29
374	Medic 1 from Battalion 2	4-12	00_48_21
375	Go ahead Battalion 2 from Medic 1	4-12	00_48_47
376	Confirming that you still have Captain Undhjem with you	4-12	00_48_51
377	Correct we have all firefighters personnel and 1 RadCon tech	4-12	00_48_56
378	I copy as soon as he's able I need him to land line the chief will you let me know as soon as he is ready for the number	4-12	00_49_02

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
379	Copy stand by	4-12	00_49_12
380	Battalion 2 this is Medic 1 go ahead with the number	4-12	00_49_21
381	Copy number is 521- (N/A)	4-12	00_49_25
382	Medic 1 copies	4-12	00_49_40
383	Battalion 2, Captain Christensen	4-12	00_49_44
384	Correction on that number it is 520-4927, 520-4927	4-12	00_49_48
385	Copy 520-4927	4-12	00_50_02
386	Go ahead Captain Christensen	4-12	00_50_07
387	This time RadCon is checking with management there thinking they might have to survey all of the trucks before they release us to go any where	4-12	00_50_10
388	I copy let's go ahead and let them do their job let them get all the readings they need too we'll keep in touch with you	4-12	00_50_19
389	I just got confirmation, they want us, there management will be here in 20 minutes they want us to stay here unit they get those survey's	4-12	00_50_30
390	I copy that, about 20 minutes your still in the RWMC parking lot still	4-12	00_50_39
391	That is an affirmative	4-12	00_50_45
392	I copy that should be a good place	4-12	00_50_48
393	Dispatch, Medic 1	4-12	00_50_54
394	Go ahead Medic 1	4-12	00_50_57
395	Can you notify CFA medical and have them open their decon bay, everything's locked over here	4-12	00_51_00
396	Dispatch copy	4-12	00_51_07
397	Medic 1 I know you know this but don't drive into the bay	4-12	00_51_23
398	N/A	4-12	00_51_45
399	N/A	4-12	00_52_21
400	Dispatch, Pick up 3	4-12	00_52_48
401	Go ahead Pick up 3	4-12	00_52_55
402	Pick up 3 has arrived back at station 3 we are going to go back up on dispatch	4-12	00_52_59
403	Dispatch copies	4-12	00_53_05
404	Captain Christensen, Battalion 2	4-12	00_54_47
405	Go for Captain Christensen	4-12	00_54_52
406	Do you guys still have that piece of paper that had identifiers written on it, or did that go with or do we know where that is at	4-12	00_54_55
407	BC-Okopny they said the guy in the ambulance should have that information if not we do have a picture on the camera	4-12	00_55_21
408	I copy you've got a picture of the piece of paper or the drum on the camera	4-12	00_55_33

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
409	We took a picture of the piece of paper but the RadCon in the ambulance has all the information according to the RadCon here	4-12	00_55_41
410	Ok is that on the personal cell phone that one of the guys can text to BC Kelly	4-12	00_55_51
411	Battalion 2 this is Medic 1	4-12	00_55_59
412	Go ahead Medic 1	4-12	00_56_04
413	RadCon tech here has the information (N/A)	4-12	00_56_06
414	I copy have I got somebody who can relay that information to me so we can write it down on this end	4-12	00_56_16
415	Battalion 2 this is Medic 1 what information do you need the bar code number	4-12	00_57_00
416	If you have the bar code number that is affirmative	4-12	00_57_08
417	The bar code number is 10648033 I repeat bar code number 10648033	4-12	00_57_27
418	I copy number bar code number 10648033	4-12	00_57_52
419	Copy, they also said there is another number on that that S in Sam, R in Romeo, P as in Paul, 34402 again that is S in Sam, R in Romeo, P as in Paul 34402	4-12	00_58_00
420	I copy number Sam, Romeo, Paul 34402, thank you	4-12	00_58_21
421	That is correct	4-12	00_58_30
422	All INL fire department resources from 1617 command	4-12	01_02_22
423	Captain Christensen from 1617 command	4-12	01_02_42
424	Go ahead for Captain Christensen I am almost to him	4-12	01_03_01
425	Go ahead	4-12	01_03_06
426	Captain Christensen from 1617 command, at this time until we get better plans together I want all resources from the fire department to return to station 1 once they are cleared by RadCon survey	4-12	00_03_09
427	Affirmative we will wait till cleared we've got engine 101 in service just in case we get a response	4-12	01_03_25
428	1617 copy	4-12	01_03_34
429	Captain Okopny from 1617 command	4-12	01_04_25
430	Go for Okopny	4-12	01_04_31
431	Once you get surveyed out and cleared I will have you return to station 2	4-12	01_04_35
432	I copy talking to rad techs here they are waiting for their personnel to get out here to approve us to leave the area to survey our vehicles	4-12	01_04_43
433	That is an affirmative once they get you clear however long takes just let us know and return to station 2	4-12	01_04_57
434	Will do I came with Wes Moore do you want him to go as well	4-12	04_05_06
435	That is a negative I believe I got a firefighter already out there covering, called back	4-12	01_05_12
436	N/A	4-12	01_05_19
437	N/A	4-12	01_05_24

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
438	I copy	4-12	01_05_27
439	Command 3, Captain Christensen	4-12	01_21_12
440	N/A	4-12	01_21_18
441	Go ahead	4-12	01_21_21
442	Are you still in the area	4-12	01_21_24
443	N/A	4-12	01_21_27
444	Not right now no	4-12	01_21_28
445	Randy had his mask and regulator on your truck somewhere I didn't know where you was at	4-12	01_21_32
446	I copy I will leave it at the station for him	4-12	01_21_40
447	Copy and they've cleared the wild land so he's going to head back and get that and go to station 2	4-12	01_21_44
448	I copy thanks	4-12	01_21_53
449	Dispatch, BR-402 departing RWMC heading to CFA	4-12	01_25_19
450	Dispatch copies BR-402	4-12	01_25_30
451	Command 3, Captain Christensen	4-12	01_29_59
452	Go ahead	4-12	01_30_04
453	Rescue has been released you have Wes Moore and you have Bart Nelson returning to station 1	4-12	01_30_07
454	I copy rescue has been released Nelson and Moore heading to station 1	4-12	01_30_15
455	Correct	4-12	01_30_21
456	Dispatch, rescue is back to station 1 going back to dispatch	4-12	01_42_42
457	Dispatch copies rescue	4-12	01_42_50
458	N/A	4-12	02_01_48
459	Captain Christensen, Battalion 2	4-12	02_19_03
460	Go ahead	4-12	02_19_12
461	Do we have a status on your apparatus	4-12	02_19_16
462	They have taken swaps on the ladder truck it is clear but they haven't got confirmation to let it go	4-12	02_19_21
463	I copy, were going to need your engine to stay put we may need to get some equipment off of it for a while, everything else looks clear	4-12	02_19_29
464	Affirmative we've only got 2 people on it	4-12	02_19_42
465	That is fine that is all we need right now	4-12	02_19_48
466	Ok	4-12	02_19_51
467	Battalion Chief Kofoed ladder 1 has been cleared returning to station	4-12	02_22_30
468	I copy ladder 1 has been cleared it is returning to station	4-12	02_22_37
469	Battalion Chief Kofoed this engine 101	4-12	02_30_56
470	Go ahead 101	4-12	02_31_03

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
471	They've cleared engine101 and hazmat do you want engine 101 to stay here and hazmat to respond back to station	4-12	02_31_07
472	That is affirmative the only apparatus I need on scene right now is 101	4-12	02_31_16
473	Copy	4-12	02_31_23
474	Also confirming you are going to have 2 personnel with that truck you and your driver is that correct	4-12	02_31_27
475	Correct engineer Larsen and myself	4-12	02_31_35
476	I copy	4-12	02_31_40
477	Captain Christensen, Crystal on command 3	4-12	02_36_16
478	Go ahead	4-12	02_36_23
479	LaGrand and I have been surveyed and are clear and are back at the station do you have an assignment for us	4-12	02_36_26
480	Just check in with the BC's	4-12	02_36_33
481	I copy, break, Battalion 1 or Battalion 2 station 1	4-12	02_36_37
482	Go ahead station 1	4-12	02_36_45
483	Information only LaGrand and myself have been cleared by RadCon we're back at station 1 with 2 firefighters do you have an assignment for us	4-12	02_36_49
484	That is an affirmative we are going to have one of the two of you bring ambulance 5 up here to the AMWTP ECC which is the building just outside the gate as you approach from the south	4-12	02_37_00
485	That's good copy, ambulance 5 to the AMWTP main gate	4-12	02_37_18
486	When you get here just stage in the parking somewhere kind of out of the way there'll have people coming and going all night	4-12	02_37_25
487	Ok good copy	4-12	02_37_33
488	Also Crystal could you confirm and check if they got any addition staffing in place at station 1	4-12	02_37_40
489	That is affirmative I will check and advise	4-12	02_37_50
490	I copy thanks	4-12	02_37_55
491	Battalion 1, Station 1	4-12	02_38_33
492	Go for Battalion 1	4-12	02_38_37
493	Hey we got Wes Moore, Bart Nelson, LA Grand Thompson, and Travis Crystal at Station 1	4-12	02_38_41
494	I copy, do you know how far behind you Captain Undhjem and the others were	4-12	02_38_51
495	There just finishing up there whole body frisk and then there going to get the ambulance deconned and then come back over	4-12	02_38_59
496	I copy thanks	4-12	02_39_08
497	How many do you want to come out in ambulance 5	4-12	02_39_11
498	I just want 1 Medic could you repeat the names back of who I have at the station right now minus the one Medic	4-12	02_39_19

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
499	Ok in the station right now you have LA Grand Thompson, Bart Nelson, Wes Moore, and I'll be coming out there in ambulance 5	4-12	02_39_28
500	I copy thanks	4-12	02_39_40
501	BC, Cooed, Ben Meyers should be there in a few minutes	4-12	02_39_46
502	I copy you had Meyers on one of the apparatus who was driving the others	4-12	02_39_51
503	You had Ben Meyers on ladder 1 and Kevin Van Oren on hazmat	4-12	02_39_58
504	Copy thanks	4-12	02_40_04
505	N/A	4-12	02_40_17
506	Dispatch, ladder 1 back in station in service	4-12	02_40_28
507	Dispatch copies ladder 1 back at station 1	4-12	02_40_38
508	N/A	4-12	02_50_20
509	Dispatch ambulance 5 is out at RWMC staging	4-12	02_50_20
510	Dispatch copies ambulance 5 is at RWMC staging	4-12	02_50_26
511	BC to dispatch	4-12	02_50_47
512	Go ahead dispatch	4-12	02_51_51
513	Just giving you a update Okopny gave me a call station 2 is fully staffed	4-12	02_50_53
514	I copy station 2 is fully staffed thanks dispatch	4-12	02_51_01
515	Ambulance 5 to Battalion 2	4-12	02_51_11
516	Go for ambulance 5	4-12	02_51_18
517	Is he there with you	4-12	02_51_22
518	That is affirmative	4-12	02_51_24
519	Ok your truck has been cleared by RadCon as well	4-12	02_51_28
520	That is correct	4-12	02_51_33
521	I copy we'll just keep you both down there for now	4-12	02_51_36
522	Copy	4-12	02_51_44
523	Dispatch Hazmat back in quarters in service	4-12	02_53_07
524	Dispatch copies Hazmat back in station 1	4-12	02_53_16
525	BC-2 to dispatch	4-12	03_12_54
526	Go ahead dispatch	4-12	03_12_58
527	BC-2 be advised I just received an another camera there at 1617 that has a fire alarm	4-12	03_13_00
528	I copy do you have a identifier on that camera	4-12	03_13_10
529	That's a zone 41	4-12	03_13_18
530	I copy zone 41	4-12	03_13_22
531	Captain Christensen, Battalion 2	4-12	03_34_22
532	Go ahead	4-12	03_34_29

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
533	I am going to have you and your ambulance deploy over here to the ECC which is the command center that is right outside of the AMWTP gate, so just pull around the back side like we normally come into AMWTP and stage your apparatus out of the way somewhere near the parking lot or short of the building	4-12	03_34_32
534	Copy	4-12	03_34_56
535	When you get here you guys just stay in your apparatus and we'll give you a briefing whenever were ready to do that	4-12	03_34_59
536	Copy	4-12	03_35_08
537	Captain Christensen to Cooed	4-12	03_35_18
538	Go ahead	4-12	03_35_23
539	Are you still in the RWMC parking lot	4-12	03_35_25
540	That is correct	4-12	03_35_30
541	I'm just about a minute and half out from your location I got to grab a couple things off that engine	4-12	03_35_34
542	Ok	4-12	03_35_43
543	Battalion 2 also copies that traffic	4-12	03_35_49
544	Battalion Chief Cooed do you want Wes to stay with us or go back to the station	4-12	03_40_14
545	Wes is to report back to station 1	4-12	03_40_21
546	Alright we're moving our rig now	4-12	03_40_35
547	I copy	4-12	03_40_42
548	BC Cooed, Engine 101	4-12	03_44_24
549	Go ahead	4-12	03_44_29
550	Did you want us to go out RWMC gate or did you want us on the other side	4-12	03_44_32
551	I want you at the AMWTP gate	4-12	03_44_38
552	Copy	4-12	03_44_43
553	It would be building 685 that is where we're at	4-12	03_44_46
554	Ok	4-12	03_44_51
555	101 from AB-5 just follow me down here and you can turn around	4-12	03_54_13
556	101 copies thanks	4-12	03_54_26
557	Command from Battalion 2	4-12	03_55_37
558	Can you repeat Battalion 2	4-12	03_55_51
559	Disregard	4-12	03_55_56
560	Command from Battalion 2	4-12	03_59_01
561	Go ahead Battalion 2	4-12	03_59_14
562	The crew has been briefed, they are not in their gear they will notify command post whenever they are ready to deploy	4-12	03_59_23
563	Command copies, can you have them set up on INL arc	4-12	03_59_36

Number	INL Fire Department Communication April 11 & 12, 2018	Date	Time
564	That is affirmative they said there communications are established	4-12	03_59_44
565	Thank you Battalion 2	4-12	03_59_50
566	I am in route back to your location	4-12	03_59_58
567	N/A	4-12	04_09_19
568	Hello	4-12	04_09_42
569	N/A	4-12	04_09_45
570	Engine 101	4-12	05_01_21
571	Go ahead	4-12	05_01_28
572	After you return to CFA	4-12	05_01_32
573	Copy you want us to return to base	4-12	05_01_48
574	N/A	4-12	05_13_39
575	Dispatch, engine 101 is back in quarters going back into dispatch	4-12	05_21_40
576	Dispatch copies engine 101 back in quarters	4-12	05_21_49
577	N/A	4-12	05_24_06

N/A – Not Audible

Appendix J

Root Cause Analysis Core Team Member Biography

Appendix J

Root Cause Analysis Core Team Member Biography

Steve Crowe

- 40 years nuclear experience, Navy/SRP reactor supervisor, TVA HPES coordinator, Nuclear Safety Review Board Manager, ESH&Q Director RFETS Closure Projects, multiple ORR/RAs, performed root cause analyzes at both commercial nuclear and DOE
- Trained in MORT, Kepner-Tragoe, INPO Human Performance Evaluation/Root Cause Methodology, Phoenix Methodology, and TapRooT

Mike Fecht

- 45 years nuclear experience, Commercial Senior Reactor Operator, Lessons Learned Manager (TVA), Nuclear Assurance and Licensing Manager (Sequoyah Nuclear Plant), TVA Corporate QA Director, Senior Advisor to the Yucca Mountain DOE Quality Assurance Director, multiple ORR/RAs, performed root cause analyzes at both commercial nuclear and DOE sites.
- Commercial Nuclear Power Plant Emergency Action Manager at a Nuclear Power Plant, TVA Corporate Emergency Management Operations Support Lead, and TVA Corporate Emergency Management Command Center Director.
- Trained in MORT, Kepner-Tragoe, PII, and INPO Human Performance Evaluation/Root Cause Methodology. Established initial HPES root cause training for TVA. Conducted Corrective Action Program Workshops at TVA, DOE personnel at Yucca Mountain, and WIPP**.**

Jim Gregory

- 49 years nuclear experience , US Navy, (Engineering Officer of the Watch, Engineer), Naval Reactors Project Officer, Independent Assessment Manager, Radiological Controls Manager (ATR), multiple Independent Assessments US Navy and DOE nuclear facilities and programs, US Navy Accident Investigations, and multiple ORR/RAs, performed root cause analyzes at Navy nuclear and DOE facilities
- Trained in MORT, INPO Safety Conscious Work Environment Assessment Methodology, and TapRoot

Richard N. Swanson, P.E. (Industry Expert peer review)

- 46 years nuclear experience, QA Director, Nuclear Safety Assessment Manager, Engineering General Manager, Regulatory Affairs Director, Director of Project Management, and Construction Manager at commercial nuclear sites Over 25 years formal causal analysis and investigative experience. Formally trained in Phoenix, SOURCE, and PII methodologies and has worked with MORT and TapRooT. Contracted by the NRC to train inspectors how to evaluate licensee Root Cause Assessments conducted by licensees, was one of the course developers, has taught this course since 2006, and is a member of the team that was recently awarded a contract to teach the course for a third consecutive five-year period (through 2022) Conducted multiple Root Cause Assessment workshops for HPRCT and ANS conferences. Performed many causal analyzes and assessments for clients in the commercial nuclear, DOE, and other high hazard industries.

Lee Fife

- 35 years nuclear experience, Naval Reactors Facility, Nuclear Plant Engineer Trained at NRF, Maintenance Engineer at A1W , Experiments Engineer Test Reactor Area, Maintenance Engineer at RWMC, Price Anderson Coordinator, Idaho Clean-up Project Cause Analysis SME
- Trained in Kepner-Tragoe, and INPO Human Performance Evaluation/Root Cause Methodology, Multiple other Root Cause Analysis training techniques including Phoenix Methodology and Operational Safety/Accident Analyst (DOE National Training Center SAF-231).

Ron Guymon

- 35 years experience in Environment, Safety, and Health (ES&H) programs, including 30 years at the following DOE sites: Hanford; Waste Isolation Pilot Plant (WIPP); Nevada Test Site (NTS); Paducah Gaseous Diffusion Plant; and the Idaho National Laboratory (INL).12 years' experience in independent oversight of ES&H programs. Primary assessment disciplines included: environmental compliance; environmental management systems; integrated safety management; waste management; industrial hygiene; and industrial safety.
- 35 years' experience with the requirements of the Resource Conservation and Recovery Act (RCRA), including waste characterization and RCRA permitting.
- Trained in DOE Causal Analysis

Tom Clements

- 39 years nuclear experience, TRU Waste Program Manager; TRU National Program Corporate Board Member; Radioactive Waste Management Complex Director; TRU Waste Technology Manager; TRU/LLW Technology Manager; supported National TRU Program efforts (RH Working Group, EPA Tier 1 Improvement Process) and conducted early characterization studies on INL TRU waste
- Trained in MORT and Kepner-Tregoe

Appendix K

Root Cause Team Plan

Appendix K

Root Cause Team Plan

Overview

Gene Balsmeier has been assigned the responsible manager in accordance with MCP-190, Event Investigation and Occurrence Reporting and MCP-598, Corrective Action System for CAR 119255. Mr. Balsmeier will be responsible for the performance of a root cause analysis addressing the ARP V WMF-1617 Drum Over pressurization Event. This plan will also serve as the charter for the Root Cause Team executing the analysis.

Problem Statement

At approximately 2235 on April 11, 2018, the Accelerated Retrieval Project (ARP) V facility, WMF-1617 experienced an overpressure event on a repackaged sludge drum. Additionally, three other drums experienced similar over pressurizations during the night.

Scope

The independent team was chartered to determine the cause of the drum excursion, identify organizational and process weaknesses, analyze potential gaps in hazard controls, and develop recommendations regarding correcting the identified cause (s). The Root Cause Team will perform a detailed analysis of the Drum Over- Pressurization Event.

Plan and Report Overview

This plan utilizes the information and approaches provided in DOE O 225.1B *Accident Investigations*, MCP-190, *Event Investigation and Occurrence Reporting*, and MCP-598, *Corrective Action System*. The analysis will be performed in accordance with STD-1113 *Cause Analysis and Corrective Action Development.* The Root Cause Team shall deliver a report documenting the analysis. The analysis will be performed in an expeditious manner with a target date of May 31, 2018. A final report shall be prepared with a completion date of June 29, 2018. The conduct of the analysis shall be given the highest priority by the Root Cause Team members and all personnel from whom the Root Cause Team needs support.

Root Cause Analysis Team

Area	Team Member	Organization/Company
Responsible Manager/Team Leader	Gene Balsmeier	Fluor Idaho
Assistant Team Lead	Pat Perry	Fluor Idaho
Reentry/Facility Recovery	Jason Chapple	Fluor Idaho
WIPP/Extent of Condition Lead	John McCoy	Fluor Idaho
Nuclear Safety	Scott Perry	Fluor Idaho
Technical Support Team Lead	Joe Giebel/Bill Reed	Fluor Idaho
Fluor Idaho Cause Analyst Lead	Lee Fife	Fluor Idaho
Senior Advisor/Root Cause Team Lead	Steve Crowe	TFE Inc.
Cause Analyst Team Lead	Mike Fecht	TFE Inc.
Root Cause Team Oversight	Richard Swanson	PMI-Inc.
Cause Analysist/Tru Program	Tom Clements	JFoster
Cause Analysist/RCRA Permit	Ron Guyman	Northwind
Analysist	Mike Coyle	TFE Inc.

Analysis Methodology

The assigned Root Cause Team will be focused on determining the factors resulting in the current drum event, by examining documents, interviewing individuals, identifying key evidence elements, and understanding how those elements resulted in the event. The Root Cause Team has a multi-disciplinary Fluor Idaho Root Cause Team including two outside consultants with extensive root cause experience.

The methodology will be as follows:

Gather Facts

1. Attend Fact Finding Meeting
2. Review Project logs associated with the event and potential precursor events will be reviewed for information and compliance with requirements
3. Obtain/review fact-finding, critiques, and ORPS records
4. Obtain/review witness records
5. Review work documents
6. Key documents associated with ARP activities will be reviewed for adequacy, content, and compliance
7. Controls contained within the documents will be assessed for adequacy and applicability to this event
8. Review safety basis (SB)
    a. The SB will be specifically reviewed to ensure operations conducted and actions taken in this event were in compliance with the existing safety basis
    b. The SB analysis and controls related to this event will be assessed
    c. The USQD/change controls process as related to the safety basis governing this activity will be reviewed to ensure appropriate evaluations and approvals were obtained
    d. Review/obtain compliance records to verify safety basis requirements were in place at the time of the event
9. Review Acceptable Knowledge/Historical Information
    a. AK/Historical Information will be reviewed to determine potential fire/explosion initiators and fuels that could have contributed to this event
10. Interview personnel directly associated with the event.
11. Examine the accident scene. The accident scene examination is to be recorded and will focus on identification and location marking of potential debris from the event
12. Identify tests/sampling necessary to support investigation based on evaluation of the above steps. Ensure samples can confirm or disprove potential fire/explosion scenarios
13. Review policies, standards, and requirements applicable to the event to be included in the evaluation of safety management systems. This review includes an evaluation of the event response actions taken by the facility
14. Examine previous similar events and evaluate for corrective action effectiveness
15. Develop DRAFT event and causal factor (E&CF) chart per MCP-598, *Corrective Action System*
16. Ensure evidence is properly segmented and stored for any future data analysis.
17. Review results of sample and other technical data when received
18. Request additional data analysis as required

19. Revise E&CF based on physical results
20. Identify follow-on sampling needs if required
21. Evaluate effectiveness of safety management systems once E&CF is finalized. Identify any areas of concern or weaknesses. Conduct additional reviews and interviews as necessary to ensure adequate information is obtained to make a team conclusion.
22. Evaluate effectiveness of line management oversight as related to event. Identify areas where management oversight could have prevented or mitigated this event. Identify weaknesses and strengths.

<u>Develop Root Cause Report</u>

1. Develop Draft Investigation Report
2. Identify Corrective Actions to prevent Recurrence to address the root cause(s); Judgments of Need which are defined as "managerial controls and safety measures necessary to prevent or minimize the probability or severity of a recurrence of an accident." These actions shall be based on objective analysis of facts, root and contributing causes, and management systems that could have prevented the accident. Identify Areas for Improvement and Recommendations.
3. Conduct Factual Accuracy Review of Draft by Line Management
4. Conduct Technical Accuracy Review
5. Perform an independent "Red Team" evaluation of the Root Cause Report
6. Issue Root Cause Report

______________________________________ ____________________
Independent Root Cause Analysist Lead Date

______________________________________ ____________________
Senior Advisor/Independent Root Cause Team Lead Date

Appendix L

Corrective Action Summary

Appendix L

Corrective Action Summary

Table L-1. Summary of Report Actions.

<table>
<tr><th>Number</th><th>CONs</th><th>JONs</th></tr>
<tr><td>1.</td><td>CON 1: Based on available sample results, the Root Cause Team identified the direct cause of this event as the breach of four transuranic (TRU) waste containers in the ARP V building resulting from the mixing of waste containing reactive uranium from Container #10595963 with additional parent drum material in the repackaging process. The uranium initiated an exothermic reaction that ultimately led to an over pressurization and subsequent expulsion of material from four containers. The initiating mechanism (heat source) based on sample results was oxidation of the uranium metal which then supported secondary chemical reactions. The breaches resulted in airborne radioactivity escaping to a filtered, uncontaminated area normally occupied by workers. The direct cause will be revised as necessary when additional sample results are available and upon analysis by the Technical Team.</td><td>JON 1: Fluor Idaho needs to complete planned sampling and analysis of waste to make an absolute determination as to the mechanism of the reaction and subsequent breaches.

JON 2: Following analysis, the Event Technical Team needs to analyze the results from sampling and issue an addendum to this final report. This addendum should also identify and address:
Confirmation of methane generation sources
Process safety actions required associated with methane including fire department response
Evaluation of existing historical drum population including adequacy of current drum vents
JON 3: Following issuance of the Technical Team’s final report, the Root Cause Team needs to evaluate the data provided to:
Determine any related conditions and causal factors changes
Determine the need for further causal evaluation
Reach conclusions
Confirm judgements of need
Identify additional judgements of need.</td></tr>
</table>

Number	CONs	JONs
2.	**CON 2: Management failed to fully understand, characterize, establish and implement adequate process controls for treating waste which lacked documented origin or process information.** Prior to initiating the processing of the specific item description code (IDC) involved in the event (SD-176) in March 2016, communication between AMWTF and RWMC personnel failed to identify SD-176 as a composite collection of homogeneous solids containers from more than one waste generator and various waste generating processes. Previous SRP waste sludges that had been processed at ARP V included IDCs from a single known generator and specific waste form or process. Information used to base acceptance of the waste at SRP did not adequately describe the attributes of the waste including prohibited items and the potential for pyrophoric and reactive material nor was an adequate chemical compatibility evaluation performed. This led to a failure to ensure that (1) effective controls were in place, (2) personnel were trained on the waste, (3) required management oversight for processing a new waste was established, and (4) upper-tier requirements documents received a thorough analysis.	**JON 4:** Fluor Idaho needs to evaluate the existing process (in place since November 2012) and revise the process for treating waste that is from unknown generators in order to reflect the lessons learned from the event. **JON 5:** Fluor Idaho needs to review and revise the contents of documents used for acceptable knowledge supporting processing of SD-176 waste to address chemical compatibility, pyrophoric and reactive issues including potential nonroaster oxide waste, identification of all prohibited items reflected in AK source documents, and conclusions from this event. Chemical compatibility requirements need to be established and met. Procedures for identification of potentially pyrophoric and reactive materials need to reflect this effort and provide specific criteria and guidance, including the definition of pyrophoric and reactive metals. **JON 6:** Fluor Idaho needs to provide training to personnel regarding pyrophoric materials, controls, and procedure compliance. **JON 7**: Fluor Idaho needs to review the existing RWMC HWMA/RCRA Permit and AMWTP HWMA/RCRA permits for requirement implementation and flow-down of those requirements.

Number	CONs	JONs
3.	**CON 3: Management failed to continue to develop the safety culture over a number of years.** This cause is attributed to exhibited behaviors identified by the analysis of the inappropriate actions throughout the investigation that were not consistent with the tenets of a strong nuclear safety culture. The overall project approach was not conservatively based, lacked documentation and procedures for key safety requirements, and was focused on processing waste to meet milestone requirements rather than compliance with requirements. Some personnel in the approval process for the event drum stated they did not feel comfortable identifying issues that were not consistent with management direction, would delay mission-related objectives, or would otherwise impact cost or schedule. Schedule pressure was felt by contractor personnel over the entire period evaluated. Management interviews indicated that meeting the Idaho Settlement Agreement drove contract performance and fee, which translated down to personnel as the primary driver for some decisions, leading to reluctance to raise issues that could affect schedule performance. This schedule pressure was reinforced by multiple occasions of accommodations/ agreements to waive or delay meeting requirements to not impact schedule.	**JON 8:** Fluor Idaho, in consultation with DOE-ID, needs to commission an independent nuclear safety culture assessment for their scope of work. **JON 9:** Fluor Idaho needs to develop immediate corrective actions to ensure personnel feel free to report all issues without fear of consequences or retaliation.

Number	CONs	JONs
4.	**CON 4: A change-management process was implemented to identify, evaluate, and disposition the existing vulnerabilities for processing SD-176.** Management failed to ensure that a change-management process was implemented to identify, consider, and disposition the existing vulnerabilities for processing SD-176 Implementation of a change management process would have allowed the project team to analyze the risk associated for processing a composite collection of containers from various generators versus an IDC from a single known generator. Currently, Fluor Idaho has certain programs and processes that require a formal change management process (for example, implementation of changes to DSA/TSR, critical safety controls, RCRA permit changes, contract modification). For this event, processing of SD-176 was not recognized as a significant change due to the waste form (sludge) and a "unique" IDC. No change process was applied to the initiation of the campaign.	**JON 10:** Fluor Idaho needs to improve execution of change management processes at the project level such that formal evaluations include identification of hazards, development of controls, review, and approval when existing process parameters or inputs are changed.
5.	**CON 5: A documented plan or path to disposal was not established as required by DOE O 435.1, "Radioactive Waste Management," prior to processing SD-176.** During the development of the SRP in 2012 and up to the present event, the Root Cause Team noted several missed opportunities to ensure that a documented plan or path to disposal was in place and to implement processes that would have effectively evaluated the shipping of pyrophoric material to the ARP V project. Management failed to ensure that a documented plan or path to disposal for –SD-176. This path forward would have identified and communicated to both AMWTP and ARP V what type of waste SD-176 was and the intentions of where it would go after processing in ARP V Decisions to process SD-176 were made without recognition that the facility was transitioning from processing a well characterized, relatively homogeneous generator specific and process specific IDC waste stream to an IDC waste that was not well characterized and originated from various generators and processes, and did not have a comprehensive chemical compatibility evaluation (CCE). Undefined characterization activities and Waste Isolation Pilot Plant (WIPP) approval still remain to be completed.	**JON 11:** Fluor Idaho needs to update project procedures and ESH&Q documents to appropriately analyze the hazards, define quantities allowed, and revise RCRA permits to reflect project activities. **JON 12:** Fluor Idaho needs to develop a technically based process to treat remaining drums that identifies and evaluates the presence of pyrophoric and reactive material, and potentially incompatible chemicals. This process needs to be validated using data from the final technical report. **JON 13:** Fluor Idaho needs to develop and execute training for personnel following completion of JONs 10,11, and 12

Number	CONs	JONs
6.	**CON 6: Management did not effectively analyze extent of condition following the December 2017 box line fire event and apply lessons learned to relevant ongoing activities outside of AMWTP, which could have identified the presence of pyrophoric and reactive material other than roaster oxides in containerized waste.** Management did not effectively determine the extent of condition and communicate corrective actions taken at AMWTP after the December 2017 box line fire that could have identified the existence of a previously unknown waste form containing pyrophoric and reactive uranium other than roaster oxides. While the material processed at AMWTP was not sludge or roaster oxide, an extent-of-condition review should have required an evaluation of other potential pyrophoric and reactive materials and waste forms. During the extent of condition review, the event drum 10595963 had been identified as a potential problem drum on the basis of a U-238 mass of greater than 5 kg. However, drum 10595963 was not considered any further in the Box line event extent of condition because it was "Not TF Feed, Not on RPT-TRUW-83."	**JON 14:** Fluor Idaho needs to review the Fluor Idaho lessons-learned program against the requirements from DOE Order 210.2A and DOE Order 226.1B, and implement changes such that feedback and improvement changes are visible aspects of the event investigation and causal analysis processes. **JON 15:** Fluor Idaho needs to incorporate the lessons from this event into the complex wide program.
7.	**CON 7: Oversight of the Sludge Repackaging Project was ineffective in identifying process failures that caused and/or contributed to the ARP V event**. Oversight was not effective in identifying or questioning that SD-176 was being processed in the same manner as previous IDCs that were well evaluated with respect to generating process and source. Oversight did not verify that specific process requirements were appropriately documented through procedural sign-offs, particularly when performed by different organizations. Management did not ensure that all the tools they have to provide effective oversight were being effectively implemented to prevent this event.	**JON 16:** Fluor Idaho needs to strengthen its oversight program to provide management and DOE confidence that work is being performed compliantly, risks are identified, and controls are effectively implemented. **JON 17:** Fluor Idaho needs to reconsider the use of e-mails as a basis for decisions, and revise MCP-3930, "Repackage Project Waste Transfers Between RWMC-AMWTP and RWMC-ARP," to reflect management expectations regarding the use and control of e-mail in procedures.

Number	CONs	JONs
8.	**CON 8: An effective integrated human performance improvement program has not been implemented.** The root cause team identified numerous human performance weaknesses during the team's analysis. Attachment F describes the human performance issues along with the error modes.	**JON 17:** Fluor Idaho needs to reconsider the use of e-mails as a basis for decisions, and revise MCP-3930, "Repackage Project Waste Transfers Between RWMC-AMWTP and RWMC-ARP," to reflect management expectations regarding the use and control of e-mail in procedures. **JON 18:** Flour Idaho needs to implement a human performance program that integrates the program and projects, including trending of corrective action program information for improvement. **JON 19:** Discuss lessons learned with appropriate individuals to address human performance identified issues from Attachment F. Include knowledge based corrective actions such as Training on fundamentals; Increase problem solving skills; Work specialization; Train on work processes; Reinforce knowledge based performance error reduction tools (Watch out – Stop) and Rule based corrective actions such as Train/Reinforce/Clarify; Work specialization; Reinforce rule based performance error reduction tools (QV&V)
9.	**CON 9: Action in applying lessons learned from the 2014 WIPP event was not effective in strengthening processes such that major contributors to the drum event were able to be identified and mitigated.** Lessons learned from the 2014 WIPP event were not effectively evaluated or acted upon by RWMC and AMWTP to preclude some of the major contributors to the drum event. For example, evaluations and subsequent corrective actions taken in 2015 did not effectively identify safety culture and change control issues. Similarly, the actions taken to address the WIPP fire event did not expand to evaluate other potential pyrophoric and reactive materials and waste forms.	**JON 20:** Fluor Idaho needs to re-evaluate the WIPP CONs and JONS in context with Fluor Idaho processes and take necessary corrective actions to address each CON/JON.

Number	CONs	JONs
10.	**CON 10: The project failed to provide an adequate number of trained acceptable knowledge (AK) personnel to support the daily activities along with providing effective program oversight.** The Root Cause Team reviewed the AK process and current staffing to determine if they were adequate to support ongoing activities. Both AMWTP and ARP V do not appear to have adequate resources to provide sufficient support to daily activities and provide effective oversight of the requirements and implementation of the AK process at each site. ITG significantly reduced AK staff and AK field personnel from approximately 30 people to about two staff in late 2011/early 2012, based on interviews with personnel familiar with this action. This reduction impacted the ability to ensure day-to-day oversight of field activities; address waste issues; maintain existing AK documents and perform revisions; submit Waste Stream Profile Forms for WIPP acceptance; and perform programmatic development of new AK documents for all remaining and difficult AMWTP waste streams. The AK staff shortage was recognized by Fluor Idaho during transition. After Fluor Idaho takeover the contract on June 1, 2016, efforts to hire additional staff were immediately initiated. The loss of AK staff under ITG continues to be a significant issue in finding qualified AK personnel to develop for addressing AMWTP waste issues and preparing AK documents addressing remaining waste streams. ARP V does not have the AK technical expertise to effectively evaluate waste shipments from AMWTP and to ensure the shipments are meeting requirements. AMWTP has "loaned" an AK individual to ARP V to aid in their day-to-day activities. Effective oversight of the AK process and its impact on ARP V is not being achieved.	**JON 21:** Fluor Idaho needs to continue to evaluate and hire the necessary number of AK personnel needed to provide daily AK activities and effective oversight of the program. **JON 22:** Fluor Idaho needs to provide training for the AK personnel based on upgrades to the AK documentation.

Number	CONs	JONs
11.	**CON 11: The Tenant Use Agreement was inappropriately used when initiating the Sludge Repackaging Project (SRP).** Management inappropriately applied the Tenant Use Agreement process when initiating the SRP. Since two contractors were involved in the start of the SRP process, DOE directed the contractors to use an interface agreement (IAG) rather than establishing a prime contractor to subcontractor relationship. The IAG that was developed and included both steps and requirements that should have been in a technical procedure. It also was the vehicle to authorize specific IDCs to be processed. When IAG-592 was modified to include SD-176, it did not receive a USQ evaluation against the safety basis since interface agreements are categorically excluded from the USQ process. Additionally, the Root Cause Team identified that the IAG described the processes for what and how waste would transferred between AMWTP and ARP V, including specific requirements such as which IDC to process. Using the IAG bypassed the USQ evaluation process because the IAG is categorically excluded from performing a USQ. The investigation identified that the IAG process was not appropriate for these type controls at a Hazard Category II nuclear facility. When IAG-592 was modified to include SD-176, it did not receive a USQ evaluation against the safety basis since interface agreements are categorically excluded from the process. Management inappropriately applied the interface agreement (IAG) process when initiating the SRP. Since two contractors were involved in the start of the SRP process, DOE directed the contractors to use an interface agreement (IAG) rather than establishing a prime contractor to subcontractor relationship. The IAG that was developed contained steps and requirements that should have been in a technical procedure. It also was the vehicle to authorize specific IDCs to be processed. When IAG-592 was modified to include SD-176, it did not receive a USQ evaluation against the safety basis since interface agreements are categorically excluded from the USQ process.	**JON 23:** Fluor Idaho needs to evaluate if any other interface agreements could potentially affect compliance with the facilities' safety basis. This evaluation needs to include a review of the categorical exclusion process. **JON 24:** Fluor Idaho needs to discuss the lessons learned for inappropriate use of the IAG process when IAG-592 was first developed.
12.	**CON 12: Numerous barriers were identified that were failed, weak, missing or compromised.** **Attachment D identifies the issues with recommended actions.**	**JON 25:** Fluor Idaho needs to review and address the issues identified from the Root Cause Team's barrier analysis.

Number	CONs	JONs
13.	**CON 13: The Extent of Cause identified that similar management behaviors could be actively impacting the success at other Fluor Idaho facilities.**	**JON 26:** Fluor Idaho needs to review and address if similar management behaviors are affecting other Fluor Idaho facilities.

	SCAQ/CAQ	Recommendations
14.	**SCAQ-1: Contrary to the requirements of MCP-2726, "Respiratory Protection," during the drum event, an AMWTP radiological control technician (RCT) entered the ARP V facility without wearing the proper respiratory protection for entering a potential immediately dangerous to life or health (IDLH) situation.**	Conduct training for all AMWTP RCTs to ensure understanding of the difference between using a powered air purifying respirator (PAPR) and self-contained breathing apparatus (SCBA) for entering an area where there is a fire. Discuss lessons learned with Flour Idaho personnel on the ramifications of wearing the required respiratory protection.
15.	**CAQ-1: The Ever-bridge communication system was not working/out-of-service and caused delays in providing notifications of the drum event.**	Initiate a work order to troubleshoot the Ever-bridge communications system and correct identified deficiencies.
16.	**CAQ-2: Following the Fluor Idaho transition, management did not effectively train and manage available resources to ensure AMWTP personnel could effectively respond to an event at the ARP complexes.**	Fluor Idaho **needs** to provide training for AMWTP personnel to respond to RWMC events, especially on the off hours. Develop or revise a change management guidance document to include these types of process changes. Conduct training and implement the document.
17.	**CAQ-3: The emergency, abnormal operating, and alarm response procedure (EAR) -246, "RWMC—Respond to Fire," does not include some procedure steps that are identified in the hazard controls of the procedure hazard analysis.**	Revise EAR-246 to include lessons learned from this event and to address the specific steps from the hazard analysis section of the EAR to be included in the body of the procedure.
18.	**CAQ-4: The INL Fire department responded to the fire alarm condition in WMF-1617 and based initial response actions without an awareness of airborne contamination conditions in the normally clean side of the building.**	Evaluate requirements, establish expectations, incorporate into procedure, conduct training and implement changes.
19.	**CAQ-5: Continuous air monitors (CAMs) did not indicate airborne contamination in the airlock and alert the entry team of the condition.** In the absence of fire alarm activation, facility personnel would have been vulnerable to airlock entry the following normal operating period with no indication of airborne contamination.	Revise FD procedures to address lessons learned from this event. Conduct training on entry and exit from radiological facilities. Evaluate placement of CAMS to allow the FD to utilize CAM data for entry into facilities.

	SCAQ/CAQ	Recommendations
20.	**CAQ-6: The INL Fire Department response actions were not effectively coordinated with facility operations to function in unified command because of the lack of a knowledgeable operations representative at the scene.**	Evaluate backshift response training, qualification, turnover process, and expectations for emergency response. Conduct training on changes identified from the above evaluation. Additionally, include training on effective communication of urgent support needs during an emergency.
21.	**CAQ-7: Conduct of operations weaknesses were noted in communicating the need for urgent RCT responses, and then not documenting some required actions during the emergency response.**	Evaluate requirements, establish expectations, incorporate into procedure, conduct training and implement changes
22.	**CAQ-8: The AMWTP RCT inappropriately directed the INL Fire Department firefighters to doff their anti-contamination clothing and equipment in a potentially high risk area in which a lid had already been ejected off a drum, and minutes after the Fire Department exited a lid was ejected off another drum.**	Provide training to AMWTP RCTs regarding doffing locations when there is a potentially high risk area that requires immediate exiting.
23.	**CAQ-9: Fire department personnel disturbed the heated product in the drum and moved the drum contrary to facility expectations.** Stirring of contents is not consistent with FD training. Movement of the drum is standard FD protocol to isolate and minimize exposure to adjacent hazards. Alternate actions must be coordinated by an effective unified command which was not in place.	Ensure all fire fighters are aware of the FD expectations provided in Training.
24.	**CAQ-10: Contrary to the requirements of DOE O 422.1,Chg 2,"Conduct of Operations," which states that procedures should be clearly written, MCP-3003, Performing Pre-Job Briefings and Documenting Feedback," does not clearly define management roles and responsibilities for determining that a post job brief is conducted.**	Revise MCP-3003 to better define requirement for post job brief and management roles and responsibilities for ensuring an effective post job brief is conducted.
25.	**CAQ-11: Affected Nondestructive assay (NDA) personnel were not included in the procedure revision process when additional requirements were included in MCP-4226, "TRU Programs Site Project Office Process."** NDA personnel did not know that they were required to review for potential pyrophoric and reactive material.	Strengthen MCP-135 process to require the review and approval of affected personnel. Ensure that steps are implementable and provide documentation of completion of key requirements. Develop criteria for identifying or evaluating for potential pyrophorics and train NDA personnel regarding their responsibilities of MCP-4226.

	SCAQ/CAQ	Recommendations
26.	**CAQ-12: PLN-4669, "Implementation Plan for PER-109, Book 3, HWMA Storage and Treatment Permit for the Idaho Nuclear Technology and Engineering Center and the Radioactive Waste Management Complex—ARP on the INL," does not adequately roll down Permit Condition VI.C.1 of the RWMC HWMA/RCRA permit: "The Permittee shall not perform treatment of waste containing pyrophoric/reactive radionuclides at the RMWC." As written, PLN-4669 identifies TPR-7867, "SRP RA V Waste Processing"; TPR-7988, "Debris Waste Processing"; and TPR-7990, "Debris DPS Waste Packaging"; and as the procedures that implement Permit Condition VI.C.1.** Although these Operations technical procedures describe the process of processing SRP wastes, they are not sufficient to ensure the wastes selected and shipped to ARP V for SRP processing do not contain pyrophoric and reactive radionuclides.	Revise Plan-4669 and incorporate TPRs that will meet the RCRA permit requirement.
27.	**CAQ-13: RCTs were not familiar with Fire Department donning and doffing protocols which compromised the timeliness and effectiveness of doffing contamination control measures.**	Train RCTs on the doffing process that the FD utilizes. FD and RCTs drill as a team to ensure training is effective.
28.	**CAQ-14: Fire Department quick access plans (QAPs) and pre-incident plans (PIPs) do not identify comprehensive radiological hazard conditions, most notably, the potential for airborne alpha contamination in ARP V.**	Revise QAPs and PIPs to provide comprehensive radiological hazard conditions that specifically address the potential for air borne alpha contamination.

	Barrier Analysis	Recommendations
29.	The AMWTP RCRA permit correctly established the requirements for properly identifying the waste characteristics of parent drum 10595963. However, AMWTP implementing procedures established a requirement that prohibited "potential pyrophorics" from being transferred to ARP V but did not specify criteria for meeting that requirement.	Revise RCRA implementing procedures to ensure potential pyrophoric and reactive waste is effectively addressed.
30.	The RWMC HWMA/RCRA Permit correctly prohibited treatment of waste containing pyrophoric radionuclides at the RWMC. However, the items prohibited to be accepted for treatment were limited to aerosol cans and roaster oxides.	Revise RWMC HWMA/RCRA permit to include other than roaster oxide pyrophoric waste.
31.	RPT-ESH-014, Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) had incomplete and outdated Reactivity Group Numbers (RGNs) for SD-176'	Revise RPT-ESH-014 to include complete and accurate information.

	Barrier Analysis	Recommendations
32.	Parent drum 10595963 did not meet ARP V acceptance criteria when received at ARP V. The procedures that evaluated the waste on a container-by-container basis were TPR-7601, MCP-3930, and MCP-4226.	Revise MCP-3930 and MCP-4226 to update container-by-container characterization.
33.	During a container-by-container review of parent drum 10595963, SRP personnel did not identify the presence of "potential pyrophoric," during the container by container review required by MCP-3930.	Revise MCP-3930 and MCP-4226 to update container-by-container characterization.
34.	During its container-by-container review of parent drum 10595963, SRP personnel did not identify the presence of "potential pyrophoric and reactive," which were specifically prohibited by TPR-7601.	Revise TPR-7601 to include the definition potential pyrophoric and include other than roaster oxide uranium waste.
35.	INST-TRUW-8.13.3 was replaced by MCP-4225 so no recommendation for the replaced document.	Revise MCP-4225 to include the definition potential pyrophoric and include other than roaster oxide uranium waste.
36.	MCP-4226 established a requirement to identify the presence of pyrophoric and reactive material without identifying implementable criteria for meeting the requirement.	Revise MCP-4225 to include the definition potential pyrophoric and include other than roaster oxide uranium waste including guidance/implementable criteria.
37.	AMWTP personnel did not correctly identify the presence of "potential pyrophoric and reactive" in parent drum 10595963.	Identify personnel responsible for implementing MCP-4226; conduct training (and verify training effectiveness) for personnel assigned responsibility to identify "potential pyrophorics."
38.	RPT-ESH-014, Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) had incomplete and outdated Reactivity Group Numbers (RGNs) for SD-176 waste suggesting that a chemical compatibility evaluation had not been performed.	Revise RPT-ESH-014 Attachment 1: Update with current RGNs for SD-176 waste; verify information in Attachment 1 is complete.
39.	RPT-ESH-014, Attachment 1 (AMWTP Hazardous Waste RGN Compatibility Determination for Storage/Treatment) had incomplete and outdated Reactivity Group Numbers (RGNs) for SD-176 waste suggesting that a chemical compatibility evaluation had not been performed.	After updating/revising RPT-ESH-014, identify personnel responsible for using it; conduct training (and verify training effectiveness) for affected personnel.
40.	Neither ITG nor CWI personnel recognized that SD-176 waste had the potential to contain pyrophoric materials.	Identify personnel responsible for producing, maintaining, understanding and/or using AK for SD-176; conduct training and verify training effectiveness for affected personnel.
41.	SRP personnel did not recognize that SD-176 wastes may contain prohibited (for example, pyrophoric and reactive) materials.	Re-train personnel on the lessons learned from this event.

	Barrier Analysis	Recommendations
42.	Had a trained VE watched the event drum (10595963) as it was emptied on the sorting table, the VE may have observed the visual characteristics of this drum were not recognizable as typical SD-176 waste and called a "step-back" to evaluate the situation prior to proceeding with waste processing. As a result, the drum contents may have been rejected and additional controls implemented to manage this unknown waste material.	Revise TPR-7997 and review role (s) of VEs in process flow and have them inspect locations appropriately.
43.	Training covered roster oxides but did not effectively address other indications that pyrophoric and reactive waste (or other prohibited items not addressed in AK documentation) may be present.	Conduct training regarding definition of, identification criteria, roles and responsibilities, and procedural requirements for identifying pyrophoric materials; evaluate training effectiveness.
44.	SAR-4/TSR-4 did not reflect new risks associated with processing IDC SD-176 waste.	Revise SAR-4/TSR-4 and update to reflect new risks associated with processing SD-176, -177, and -178 waste.
45.	The integrity and fidelity of the DSA and TSR to the nuclear facility were not maintained.	Review and evaluate underlying factors that caused the annual review to miss the increased risk associated with processing SD-176; revise implementing procedures as appropriate; train affected personnel; and evaluate training effectiveness.
46.	During the review process for revising IAG-592, Rev. 10, and a determination was made that a USQ determination was not required because the change was categorically excluded, based upon the document (IAG) not affecting nuclear operations. It was not recognized that a change to Appendix A (Approved IDCs) had a direct impact on the safety basis (SAR-4/TSR-4) for ARP V.	Revisit the assumption that IAGs do not require review for USQs and revise MCP-123 accordingly.
47.	The health and safety plan (HASP) for the Accelerated Retrieval Project (ARP) has not been updated since July 2010 and does not address processing SD-176 wastes at ARP V.	Update ICP/EXT-04-00209; establish and enforce expectations for periodic review and update.
48.	The barrier was ineffective because MCP-3930 was not written to ensure that process decisions, conclusions, and actions that are material to waste processing are formally documented	Conduct "extent of condition" evaluation of failure of procedures to comply with MCP-2985 requirements regarding Conduct of Operations; revise procedures as necessary.
49.	SRP did not have a formal Change Management process that required rigorous evaluation of the impact of scope changes on policies, processes, and procedures related to waste handling.	Establish and implement a formal Change Management Process. Coordinate with actions to address Barrier B-5-11 (MCP-1414, Change Control).

	Barrier Analysis	Recommendations
50.	Lack of questioning attitude with regard to waste processing criteria, policies, procedures, and practices. Belief that processing SD-176 waste was not substantially different than processing waste in previous successful campaigns. Discussion: this is a symptom of a wide-spread cultural issue that will require substantial time and effort to address.	Identify compensatory measures involving additional 'devil's advocate' in-line process reviews for key decisions until such time as the company has a basis upon which to demonstrate that this problem has been addressed.
51.	The SRP Management Review Process, described in MCP-3930, was ineffective in detecting the presence of reactive materials in the waste drum 10595963.	Identify compensatory measures involving additional 'devil's advocate' in-line process reviews for key decisions until such time as the company has a basis upon which to demonstrate that this problem has been addressed.
52.	The Pyrophoric Event in WMF-676 Treatment Facility North Box Line occurred on 12/21/2017, approximately 4 months before the reactive event in ARP V. Corrective actions from the North Box Line event (CAR 116640) were completed 4/25/2018, just two weeks after the ARP V event. Neither the EOC review nor the completed corrective actions from CAR 116640 addressed the ARP V SD-176 waste processing operations. In both cases, drums previously categorized as RF 751 were re-categorized to nonpyrophoric and reactive codes (RF 750 and SD-176) to allow them to be processed rather than to be held in storage. In both cases, the U 238 mass was significant (46.7 kg and 11.9 kg.	Establish enhanced management expectations for quality, thoroughness, and attention paid to "extent of condition" reviews; enforce the expectations. In particular, train all causal analysts, CAR evaluators, and anyone else who may conduct EOC evaluations how to do them, increase
53.	MCP-1414 was intended for use in managing the contract rather than managing waste handling or related processes.	Revise MCP-1414 to incorporate requirements for complete and robust identification of new work scope and new hazards that potentially impact health, safety, etc. Coordinate with actions to address Barrier B-5-06 (Change Management Process).
54.	RPT-TRUW-05 did not adequately identify the potential for SD-176 to contain prohibited pyrophoric/reactive wastes. Such wastes were later determined to be present in the "event drum (10595963)".	Revise RPT-TRUW-05 and reflect the potential for SD-176 waste to contain prohibited pyrophoric wastes, and that additional analysis beyond RTR may be required.
55.	The approved AK document, RPT TRUW-91, was not used as the basis for characterizing waste in the "event drum" (10595963); rather, an unapproved, draft document (RPT TRUW-94) was used as the basis.	Re-communicate management expectations that using DRAFT material to make decisions at a CAT 2 facility is unacceptable.

	Barrier Analysis	Recommendations
56.	RPT-TRUW-94, Acceptable Knowledge Summary for AMWTP Combined Homogeneous Solids Repackage Project, was never issued to support WIPP approval of IDC SD-176, but was used in draft form as the basis for characterizing IDC SD-176. Information from the predecessor document (RPT-TRUW-91) regarding the potential for pyrophoric and reactive materials was not replicated in draft RPT TRUW-94.	Revise RPT-TRUW-91 to include all prohibited items and include pyrophoric other than roaster oxides. Re-communicate management expectations that using DRAFT material to make decisions at a CAT 2 facility is unacceptable.
57.	Mixed radiological/chemical waste was processed using unapproved "Acceptable Knowledge" documentation.	Re-communicate management expectations that using DRAFT material to make decisions at a CAT 2 facility is unacceptable.
58.	The sealed drums were subjected to internal pressures and exceeded design pressure and were subsequently breached. A release of radioactive material occurred from each of the four daughter drums. Radioactive contamination was confined within Airlock 5 (AL5) in WMF-1617. ARP workers were not in the building at the time of each drum rupture. No injuries were reported and no release to the environment occurred.	Corrective actions to address the root and contributing causes will address this barrier.
59.	Less than fully effective safety culture: • Reduces the likelihood that an organization will find and fix its own problems before they become major events; • Reduces the effectiveness of people and processes; • Increases the frequency of undetected/ uncorrected human error; and • Increases the risk of a consequential event happening. Perform an independent Safety Culture assessment and implement the recommendations from that assessment.	Discuss lessons learned with all Fluor Idaho personnel to ensure they understand how their actions can impact the overall Safety Culture at their facility.
60.	Management did not recognize that SD-176 waste was different from waste streams that had been successfully processed in the past. Consequently, the risks/consequences associated with this change were not adequately reviewed/assessed. Had Management been successful in identifying the risks involved in processing SD-176 waste, this event may have been avoided.	Revise the existing process to ensure that lessons learned from this event are incorporated into existing procedures. Train personnel on those changes.

	Barrier Analysis	Recommendations
61.	The repackaging of SD-176 waste drums was performed at risk. There is a potential that these drums will require additional characterization activities and possibly require repackaging in order to meet off-Site waste disposal requirements (for example, WIPP).	Perform effective due diligence evaluations prior to taking on new responsibilities or work scope.
62.	The degree of difficulty in properly characterizing and processing IDC SD-176 waste has resulted in increased risks to personnel and public safety, and an increased risk of radiological releases to the environment.	Perform effective due diligence evaluations prior to taking on new responsibilities or work scope.
63.	The lack of trained and qualified AK personnel has compromised the ability of current ICP contractors to effectively and compliantly perform waste characterization activities in support of DOE goals and objectives.	Perform effective due diligence evaluations prior to taking on new responsibilities or work scope.
64.	The lack of trained and qualified AK personnel has compromised the ability of past and current ICP contractors to effectively and compliantly perform waste characterization activities in support of DOE goals and objectives.	Increase staffing to allow for more qualified AK personnel.

	Opportunity for Improvement	Recommendations
65.	Fluor is not trending Human Performance Issues.	REC-1: Trend Human Performance Issues and include OWLs, MWVs, and CARs in the trend review.
66.	Fluor is not identifying or trending Safety Culture weaknesses	REC-2: Include Safety Culture on the causal analysis tree and start trending Safety Culture
67.	During the event analysis, the root cause team identified some weaknesses with Emergency Management not making some conservative decisions on entering the EALs.	REC-3: Review the DOE guidance to ensure the EALs meet the guidance provided. REC-4: Evaluate the EALs for inadequacies and ensure entrance events are clearly defined so that, if another escalating event occurs, there would be no question on whether EALs should be entered. REC-5: Validate the event issues above and ensure that not entering the EALs meets management expectations.
68.	Numerous causal analysis report identify Change Management as a causal factor yet no effective actions have been taken to address this causal factor.	Perform a trend analysis on “Change Management” and take actions on those that identified Change Management as a causal factor.

	Opportunity for Improvement	Recommendations
69.	Causal Reports reviewers are not ensuring effective corrective actions are being taken for identified causal factors.	Causal report reviewers should ensure that when Change Management (or any other causal factor is provided), a corrective action is aligned with that causal factor.
70.	Documentation while conducting pre-job briefs needs improvement	Reinforce management expectations on the conduct of prejob briefs to include documenting what was specifically covered.

Appendix M

GDE-Q&SI-01 Rev.—Causal Analysis Tree

Appendix M

GDE-Q&SI-01 Rev.—Causal Analysis Tree

AMWTP Advanced Mixed Waste Treatment Project	CAUSAL ANALYSIS TREE	GDE-Q&SI-01 Rev. 1 Effective: 02/26/13 Page 1 of 1

Start Here

A1 Design/Engineering Problem

B1 DESIGN INPUT LTA
- C01 Design input cannot be met
- C02 Design input obsolete
- C03 Design input not correct
- C04 Necessary design input not available

B2 DESIGN OUTPUT LTA
- C01 Design output scope LTA
- C02 Design output not clear
- C03 Design output not correct
- C04 Inconsistent design output
- C05 Design input not addressed in design output
- C06 Drawing, specification, or data error
- C07 Error in equipment or material selection
- C08 Errors not detectable
- C09 Errors not recoverable

B3 DESIGN / DOCUMENTATION LTA
- C01 Design / documentation not complete /LTA
- C02 Design / documentation not up-to-date
- C03 Design / documentation not controlled

B4 DESIGN / INSTALLATION VERIFICATION LTA
- C01 Independent review of design / documentation LTA
- C02 Testing of design / installation LTA
- C03 Independent inspection of design / installation LTA
- C04 Acceptance of design / installation LTA

B5 OPERABILITYOF DESIGN / ENVIRONMENT LTA
- C01 Ergonomics LTA
- C02 Physical environment LTA
- C03 Natural environment LTA

A2 Equipment/Material Problem

B1 CALIBRATION FOR INSTRUMENTS LTA
- C01 Calibration LTA
- C02 Equipment found outside acceptance criteria

B2 PERIODIC / CORRECTIVE MAINTENANCE LTA
- C01 Preventive maintenance for equipment LTA
- C02 Predictive maintenance LTA
- C03 Corrective maintenance LTA
- C04 Equipment history LTA

B3 INSPECTION / TESTING LTA
- C01 Start-up testing LTA
- C02 Inspection / testing LTA
- C03 Post-maintenance / Post-modification testing LTA

B4 MATERIAL CONTROL LTA
- C01 Material handling LTA
- C02 Material storage LTA
- C03 Material packaging LTA
- C04 Material shipping LTA
- C05 Shelf life exceeded
- C06 Unauthorized material substitution
- C07 Marking / labeling LTA

B5 PROCUREMENT CONTROL LTA
- C01 Control of changes to procurement specifications / purchase order LTA
- C02 Fabricated item did not meet requirement
- C03 Incorrect item received
- C04 Product acceptance requirements LTA

B6 DEFECTIVE, FAILED OR CONTAMINATED
- C01 Defective or failed part
- C02 Defective or failed material
- C03 Defective weld, braze or soldering joint
- C04 End of life failure
- C05 Electrical or instrument noise
- C06 Contaminant

A3 Human Performance LTA

B1 SKILL BASED ERROR
- C01 Check of work was LTA
- C02 Step was omitted due to distraction
- C03 Incorrect performance due to mental lapse
- C04 Infrequently performed steps were performed incorrectly
- C05 Delay in time caused LTA actions
- C06 Wrong action selected based on similarity with other actions
- C07 Omission / repeating of steps due to assumptions for completion

B2 RULE BASED ERROR
- C01 Strong rule incorrectly chosen over other rules
- C02 Signs to stop were ignored and step performed incorrectly
- C03 Too much activity was occurring and error made in problem solving
- C04 Previous success in use of rule reinforced continued use of rule
- C05 Situation incorrectly identified or represented resulting in wrong rule used

B3 KNOWLEDGE BASED ERROR
- C01 Attention was given to wrong issue
- C02 LTA conclusion based on sequencing of facts
- C03 Individual justified action by focusing on biased evidence
- C04 LTA review based on assumption that process will not change
- C05 Incorrect assumption that a correlation existed between two or more facts
- C06 Individual underestimated the problem by using past event as basis

B4 WORK PRACTICES LTA
- C01 Individuals capability to perform work LTA [Examples include: Sensory / perceptual capabilities LTA, Motor / physical capabilities LTA, and Attitude / psychological profile LTA.
- C02 Deliberate violation

A4 Management Problem

B1 MANAGEMENT METHODS LTA
- C01 Management policy guidance/ expectations not well defined, understood or enforced
- C02 Job performance standards not adequately defined
- C03 Management direction created insufficient awareness of impact of actions on safety/reliability
- C04 Management follow-up or monitoring of activities did not identify problems
- C05 Management assessment did not determine causes of previous event or known problem
- C06 Previous industry or in-house experience was not effectively used to prevent recurrence
- C07 Responsibility of personnel not well defined or personnel not held accountable
- C08 Corrective action responses to a known or repetitive problem was untimely
- C09 Corrective action for previously identified problem or event was not adequate to prevent recurrence

B2 RESOURCE MANAGEMENT LTA
- C01 Too many administrative duties assigned to immediate supervisor
- C02 Insufficient supervisory resources to provide necessary supervision
- C03 Insufficient manpower to support identified goal/objective
- C04 Resources not provided to assure adequate training was provided/ maintained
- C05 Needed resource changes not approved/funded
- C06 Means not provided to assure procedure/documents/records were of adequate quality and up to-date
- C07 Means not provided for assuring adequate availability of appropriate materials/tools
- C08 Means not provided for assuring adequate equipment quality, reliability, or operability
- C09 Personnel selection did not assure match of worker motivations/ job descriptions
- C10 Means/methods not provided for assuring adequate quality of contract services

B3 WORK ORGANIZATION & PLANNING LTA
- C01 Insufficient time for worker to prepare task
- C02 Insufficient time allotted for task
- C03 Duties not well distributed among personnel
- C04 Too few workers assigned to task
- C05 Insufficient number of trained or experienced workers assigned to task
- C06 Planning not coordinated with inputs from walk-downs/task analysis
- C07 Job scoping did not identify potential task interruptions and/or environmental stress
- C08 Job scoping did not identify special circumstances and/or conditions
- C09 Work planning not coordinated with all departments involved in task
- C10 Problem performing repetitive tasks and/or subtasks
- C11 Inadequate work package preparation

B4 SUPERVISORY METHODS LTA
- C01 Tasks and individual accountability not made clear to worker
- C02 Progress/status of task not adequately tracked
- C03 Appropriate level of in-task supervision not determined prior to task
- C04 Direct supervisory involvement in task interfered with overview role
- C05 Emphasis on schedule exceeded emphasis on methods/doing a good job
- C06 Job performance and self-checking standards not properly communicated
- C07 Too many concurrent tasks assigned to worker
- C08 Frequent job or task "shuffling"
- C09 Assignment did not consider worker's need to use higher-order skills
- C10 Assignment did not consider worker's previous task
- C11 Assignment did not consider worker's ingrained work patterns
- C12 Contact with personnel too infrequent to detect work habit/attitude changes
- C13 Provided feedback on negative performance but not on positive performance

B5 CHANGE MANAGEMENT LTA
- C01 Problem identification did not identify need for change
- C02 Change not implemented in timely manner
- C03 Inadequate vendor support of change
- C04 Risks/consequences associated with change not adequately reviewed/assessed
- C05 System interactions not considered
- C06 Personnel/department interactions not considered
- C07 Effects of change on schedules not adequately addressed
- C08 Change-related training/retraining not performed or not adequate
- C09 Change-related documents not developed or revised
- C10 Change-related equipment not developed or revised
- C11 Changes not adequately communicated
- C12 Change not identifiable during task
- C13 Accuracy/effectiveness of change not verified or not validated

A5 Communications LTA

B1 WRITTEN COMMUNICATIONS METHODS OF PRESENTATION LTA
- C01 Format deficiencies
- C02 Improper referencing or branching
- C03 Checklist LTA
- C04 Deficiencies in user aids (charts, etc.)
- C05 Recent changes not made apparent to user
- C06 Instruction step/information in wrong sequence
- C07 Unclear/complex wording or grammar

B2 WRITTEN COMMUNICATION CONTENT LTA
- C01 Limit inaccuracies
- C02 Difficult to implement
- C03 Data/computations wrong/ incomplete
- C04 Equipment identification LTA
- C05 Ambiguous instructions/ requirements
- C06 Typographical error
- C07 Facts wrong/requirements not correct
- C08 Incomplete/situation not covered
- C09 Wrong revision used

B3 WRITTEN COMMUNICATION NOT USED
- C01 Lack of written communication
- C02 Not available or inconvenient for use

B4 VERBAL COMMUNICATION LTA
- C01 Communication between work groups LTA
- C02 Shift communications LTA
- C03 Correct terminology not used
- C04 Verification/repeat back not used
- C05 Information sent but not understood
- C06 Suspected problems not communicated to supervision
- C07 No communication method available

A6 Training Deficiency

B1 NO TRAINING PROVIDED
- C01 Decision not to train
- C02 Training requirements not identified
- C03 Work incorrectly considered "skill of the craft"

B2 TRAINING METHODS LTA
- C01 Practice or hands-on experience LTA
- C02 Testing LTA
- C03 Refresher training LTA
- C04 Inadequate presentation

B3 TRAINING MATERIAL LTA
- C01 Training objectives LTA
- C02 Inadequate content
- C03 Training on new work methods LTA
- C04 Performance standards LTA

A7 Other Problem

B1 EXTERNAL PHENOMENA
- C01 Weather or ambient conditions LTA
- C02 Power failure or transient
- C03 External fire or explosion
- C04 Other Natural Phenomena LTA

B2 RADIOLOGICAL/HAZARDOUS MATERIAL PROBLEM
- C01 Legacy contamination
- C02 Source unknown

B3 LEGACY
- C01 Legacy issues that are not related to radiological or hazardous material

B4 NO CAUSE IS APPLICABLE
- C01 No cause know for this event

USED ONLY FOR ORPS CODING

Level A nodes are underlined
Level B nodes are in ALLCAPS
Level C nodes are "sentence case."
LTA = Less than adequate

NOTE: *For optimum readability, printer settings must be set so that both print size and paper size are Ledger (11x17) and page scaling is 'Fit to Printer Margins.'*

Appendix N

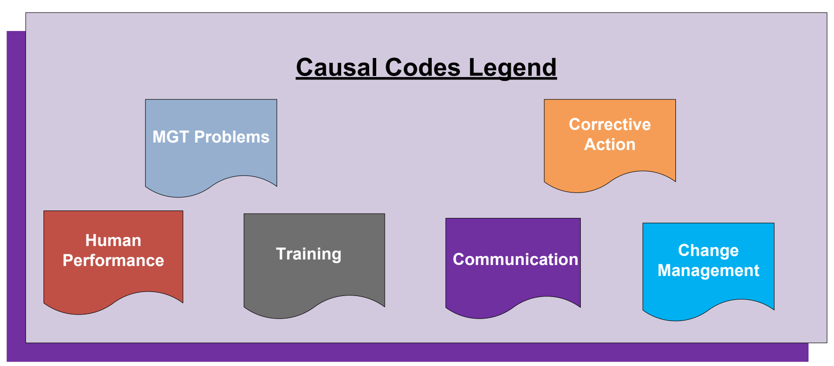
Event and Causal Factors Summary Chart
Prior to Event Day

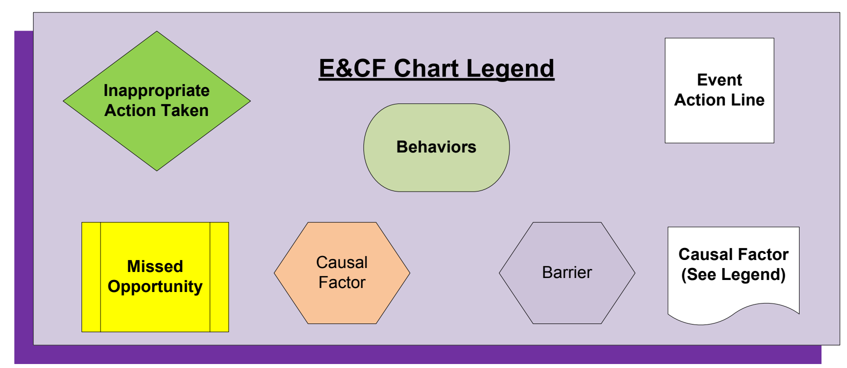
Appendix N

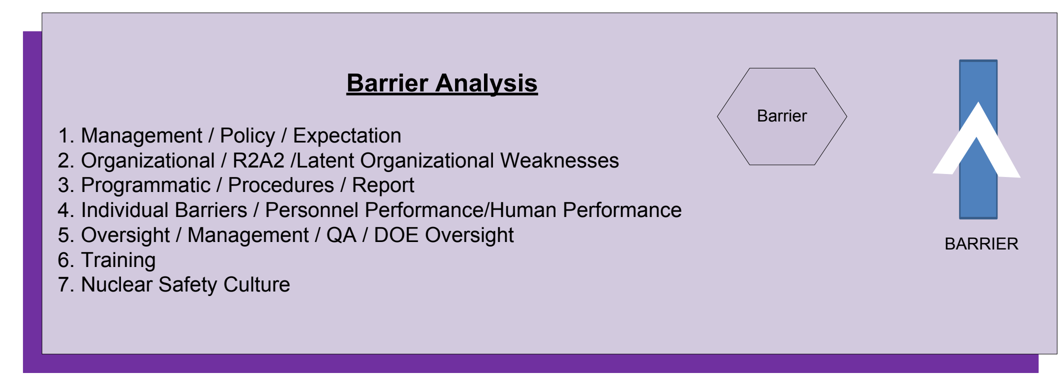
Event and Causal Factors Summary Chart Prior to Event Day

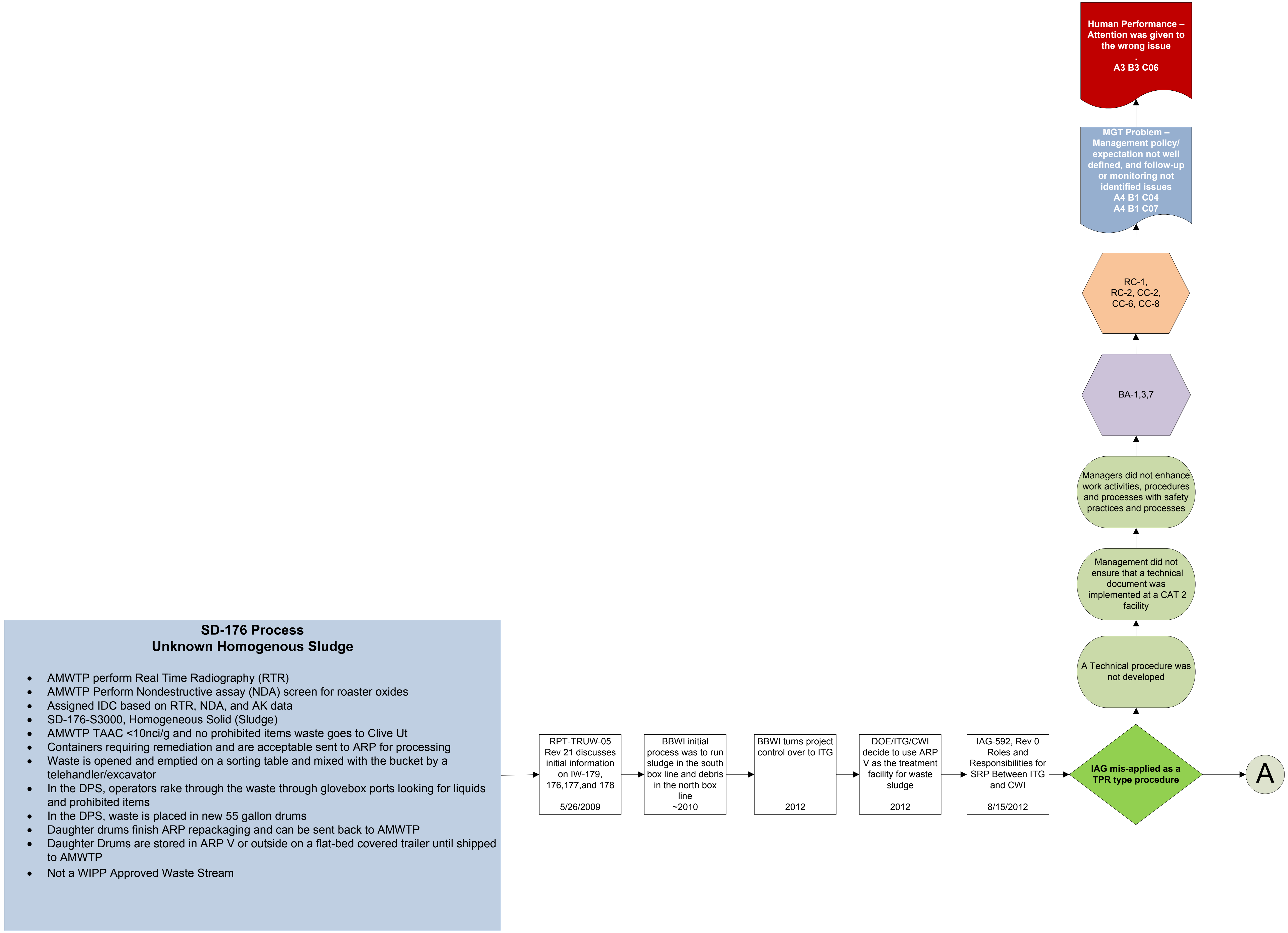
In accordance with STD-1113 Revision 7 an events and Causal Factor Chart was developed. Events and causal factors charting is useful in identifying the multiple causes and graphically depicting the triggering conditions and events necessary and sufficient for an event to occur. Events and causal factor charting is a graphical display of the events chronology and is used for compiling and organizing evidence to portray the sequence of the event.

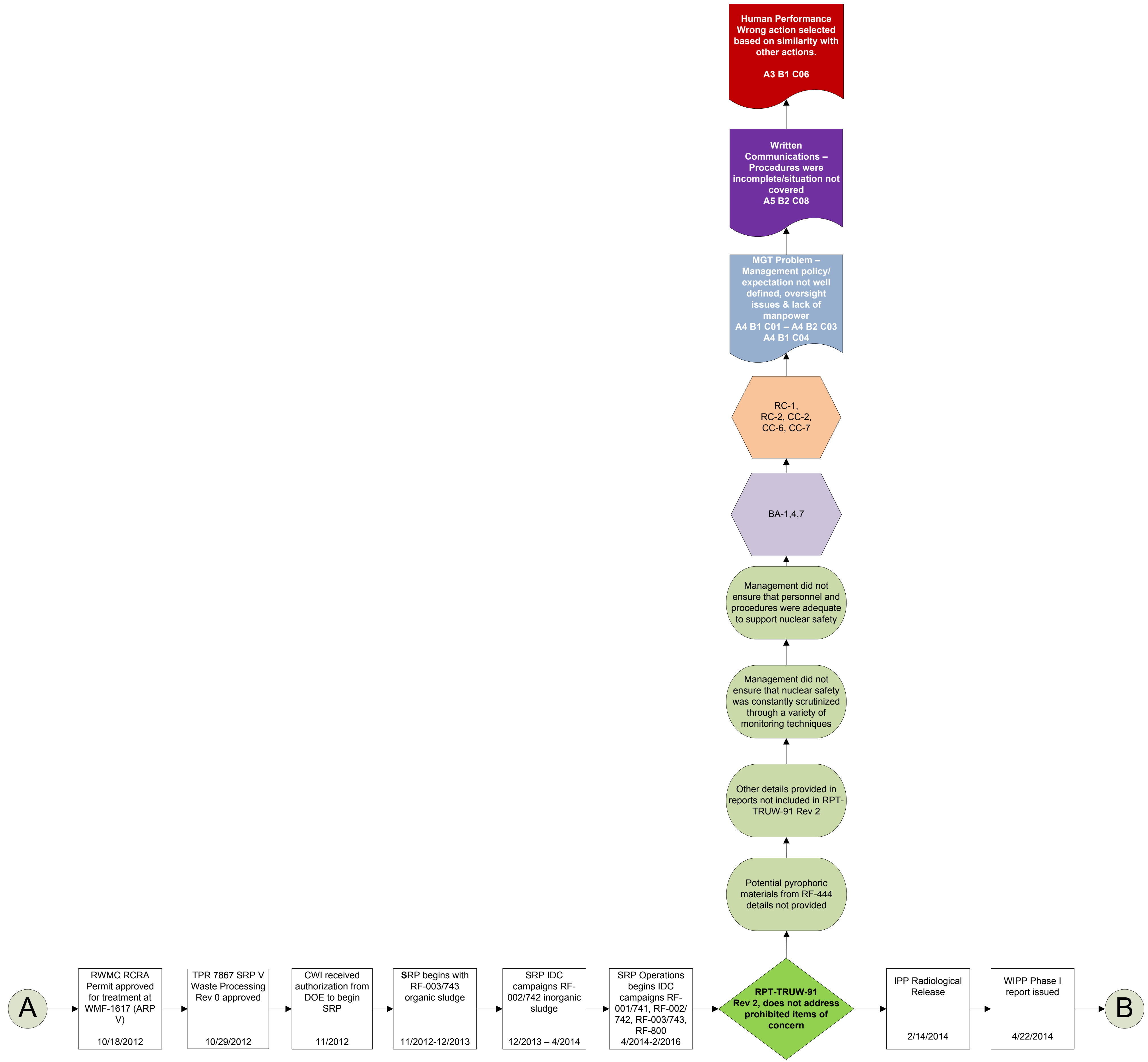
The following legends were developed to identify the different boxes that make up the E&CF chart. The causal factors are identified in Attachment I.

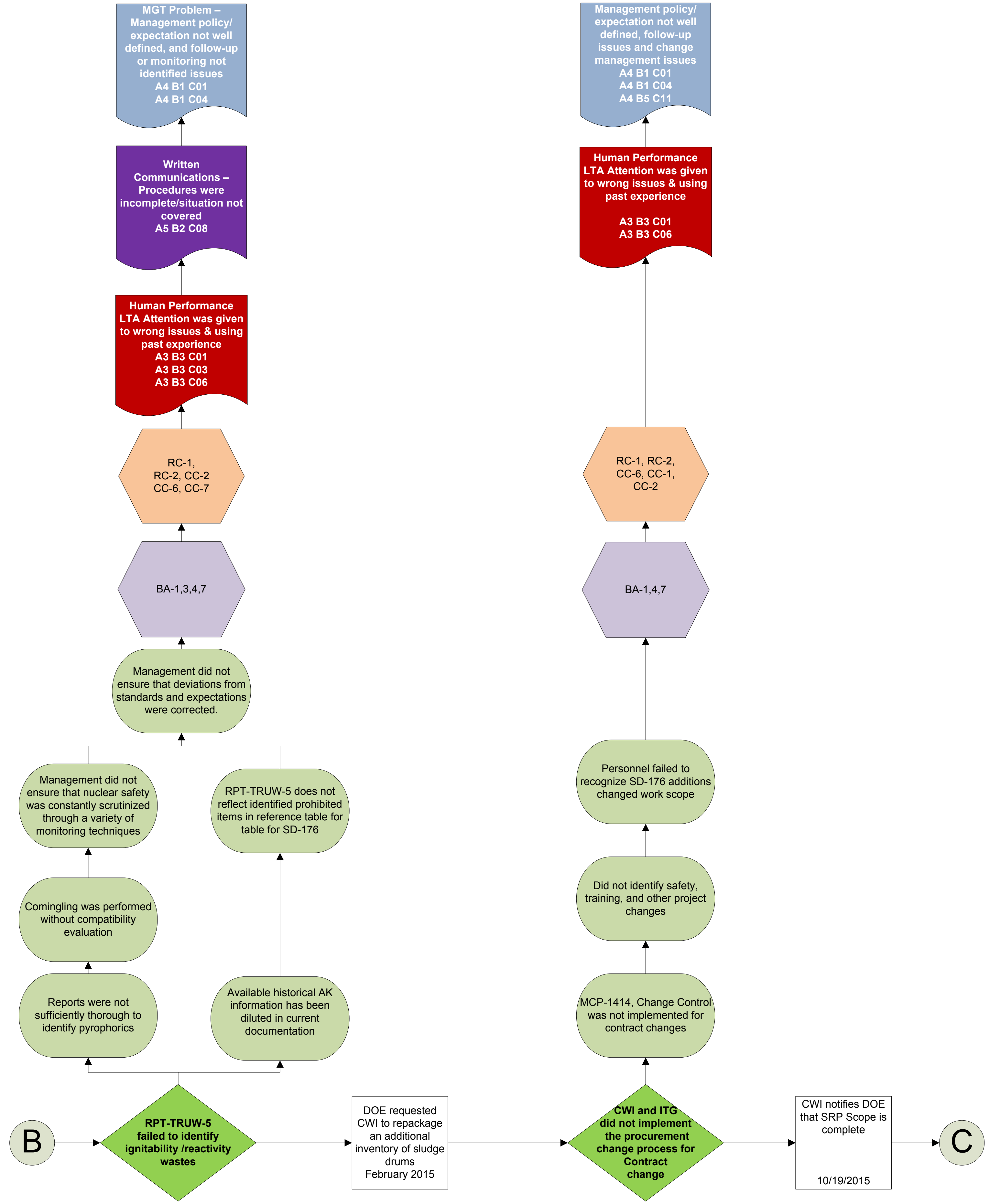


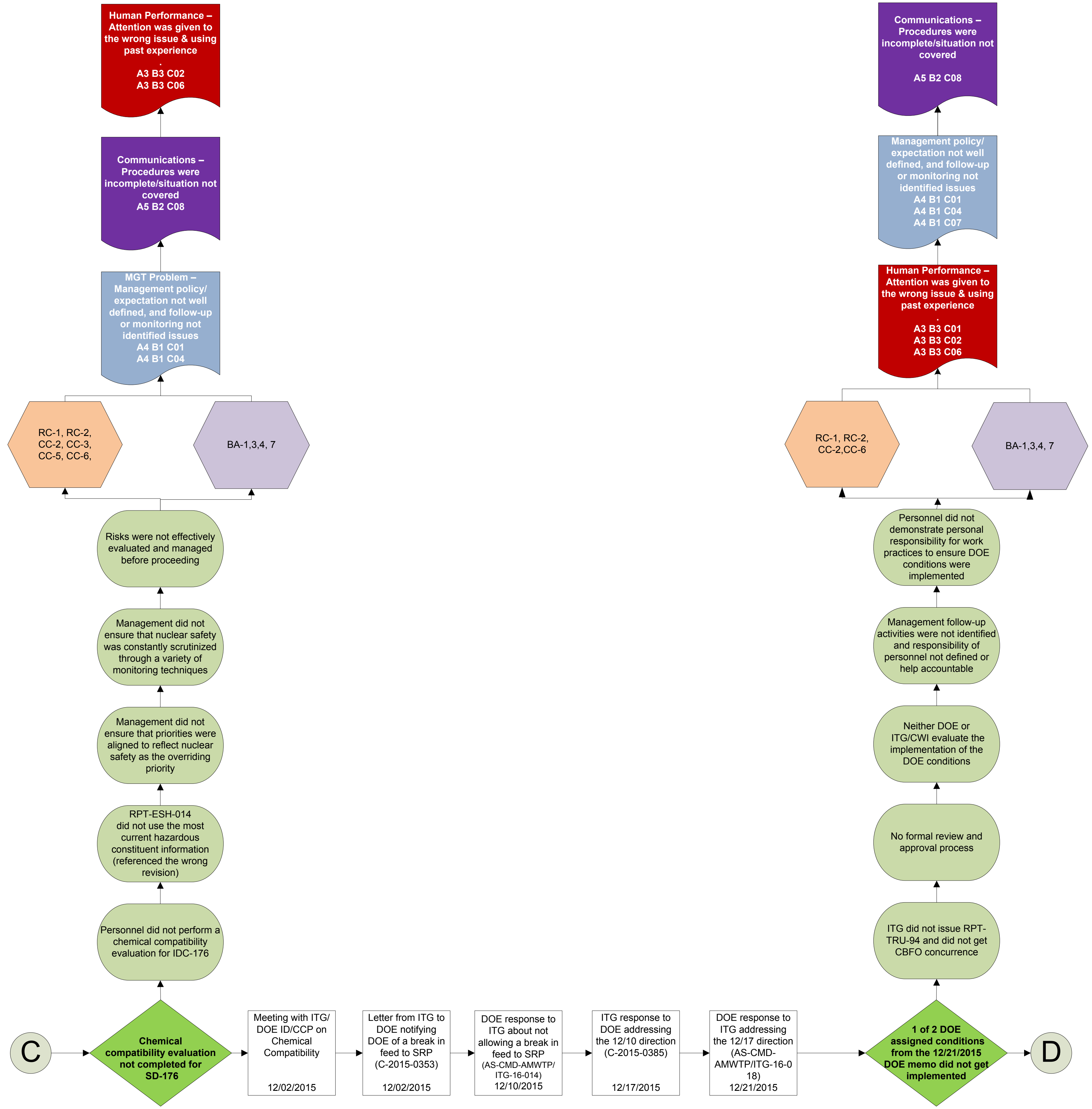


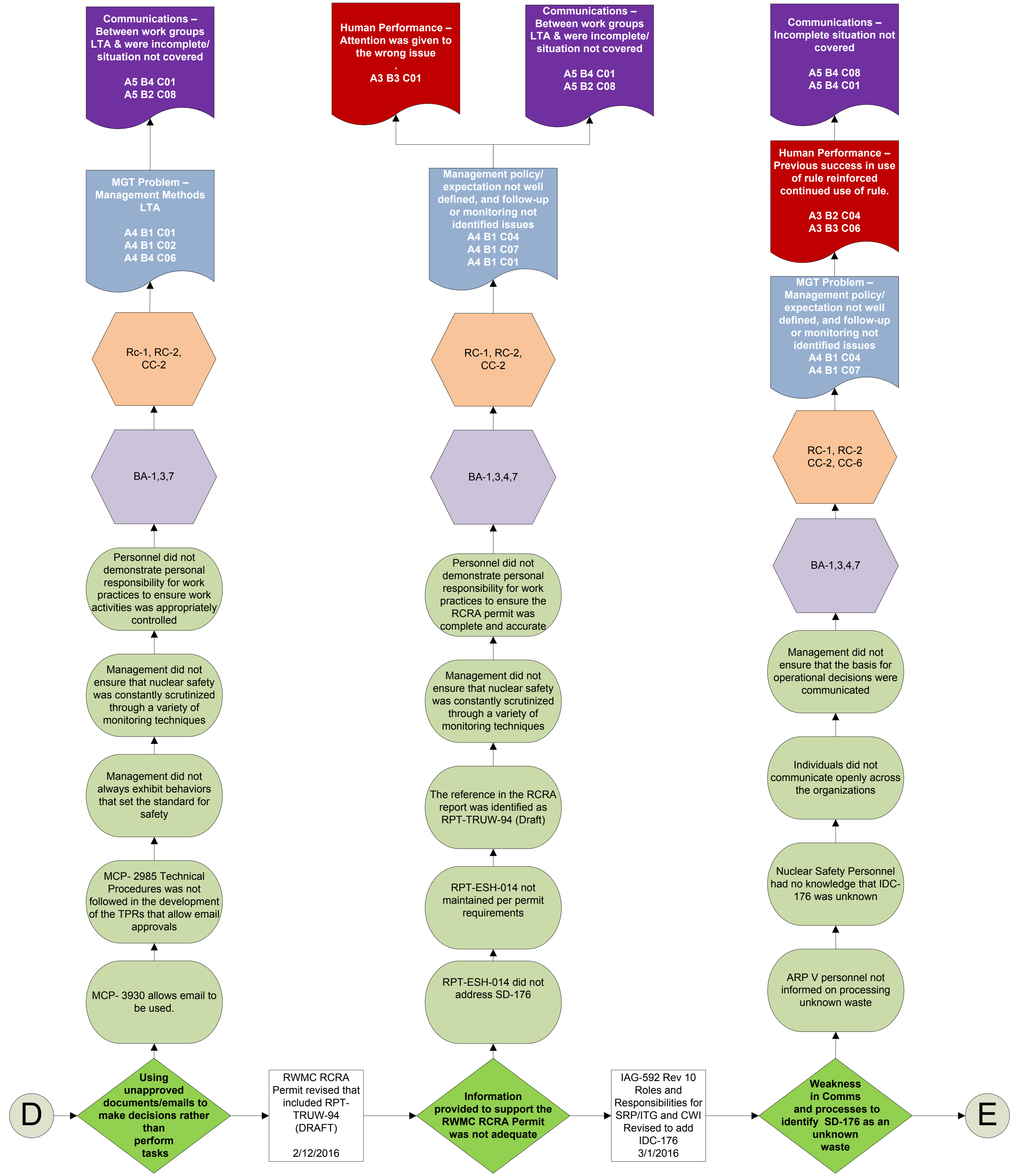


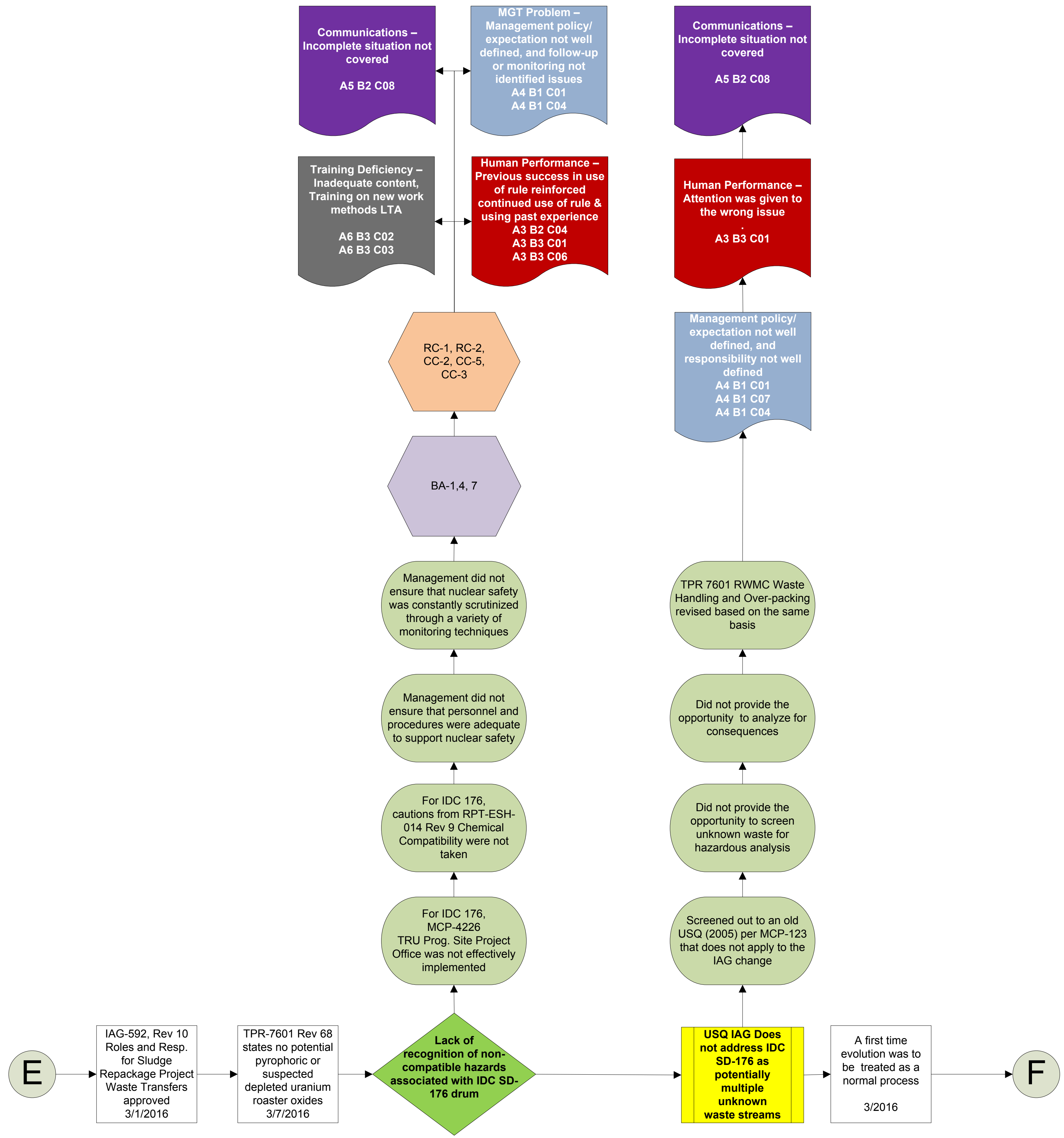

Human Performance – Attention was given to the wrong issue
A3 B3 C06
MGT Problem – Management policy/ expectation not well defined, and follow-up or monitoring not identified issues
A4 B1 C04
A4 B1 C07
RC-1, RC-2, CC-2, CC-6, CC-8
BA-1,3,7
Managers did not enhance work activities, procedures and processes with safety practices and processes
Management did not ensure that a technical document was implemented at a CAT 2 facility
A Technical procedure was not developed
SD-176 Process
Unknown Homogenous Sludge
AMWTP perform Real Time Radiography (RTR)
AMWTP Perform Nondestructive assay (NDA) screen for roaster oxides
Assigned IDC based on RTR, NDA, and AK data
SD-176-S3000, Homogeneous Solid (Sludge)
AMWTP TAAC <10nci/g and no prohibited items waste goes to Clive Ut
Containers requiring remediation and are acceptable sent to ARP for processing
Waste is opened and emptied on a sorting table and mixed with the bucket by a telehandler/excavator
In the DPS, operators rake through the waste through glovebox ports looking for liquids and prohibited items
In the DPS, waste is placed in new 55 gallon drums
Daughter drums finish ARP repackaging and can be sent back to AMWTP
Daughter Drums are stored in ARP V or outside on a flat-bed covered trailer until shipped to AMWTP
Not a WIPP Approved Waste Stream
RPT-TRUW-05 Rev 21 discusses initial information on IW-179, 176,177,and 178
5/26/2009
BBWI initial process was to run sludge in the south box line and debris in the north box line
~2010
BBWI turns project control over to ITG
2012
DOE/ITG/CWI decide to use ARP V as the treatment facility for waste sludge
2012
IAG-592, Rev 0 Roles and Responsibilities for SRP Between ITG and CWI
8/15/2012
IAG mis-applied as a TPR type procedure
A


Human Performance Wrong action selected based on similarity with other actions.
A3 B1 C06
Written Communications – Procedures were incomplete/situation not covered
A5 B2 C08
MGT Problem – Management policy/ expectation not well defined, oversight issues & lack of manpower
A4 B1 C01 – A4 B2 C03
A4 B1 C04
RC-1, RC-2, CC-2, CC-6, CC-7
BA-1,4,7
Management did not ensure that personnel and procedures were adequate to support nuclear safety
Management did not ensure that nuclear safety was constantly scrutinized through a variety of monitoring techniques
Other details provided in reports not included in RPT-TRUW-91 Rev 2
Potential pyrophoric materials from RF-444 details not provided
A
RWMC RCRA Permit approved for treatment at WMF-1617 (ARP V)
10/18/2012
TPR 7867 SRP V Waste Processing Rev 0 approved
10/29/2012
CWI received authorization from DOE to begin SRP
11/2012
SRP begins with RF-003/743 organic sludge
11/2012-12/2013
SRP IDC campaigns RF-002/742 inorganic sludge
12/2013 – 4/2014
SRP Operations begins IDC campaigns RF-001/741, RF-002/ 742, RF-003/743, RF-800
4/2014-2/2016
RPT-TRUW-91 Rev 2, does not address prohibited items of concern
IPP Radiological Release
2/14/2014
WIPP Phase I report issued
4/22/2014
B

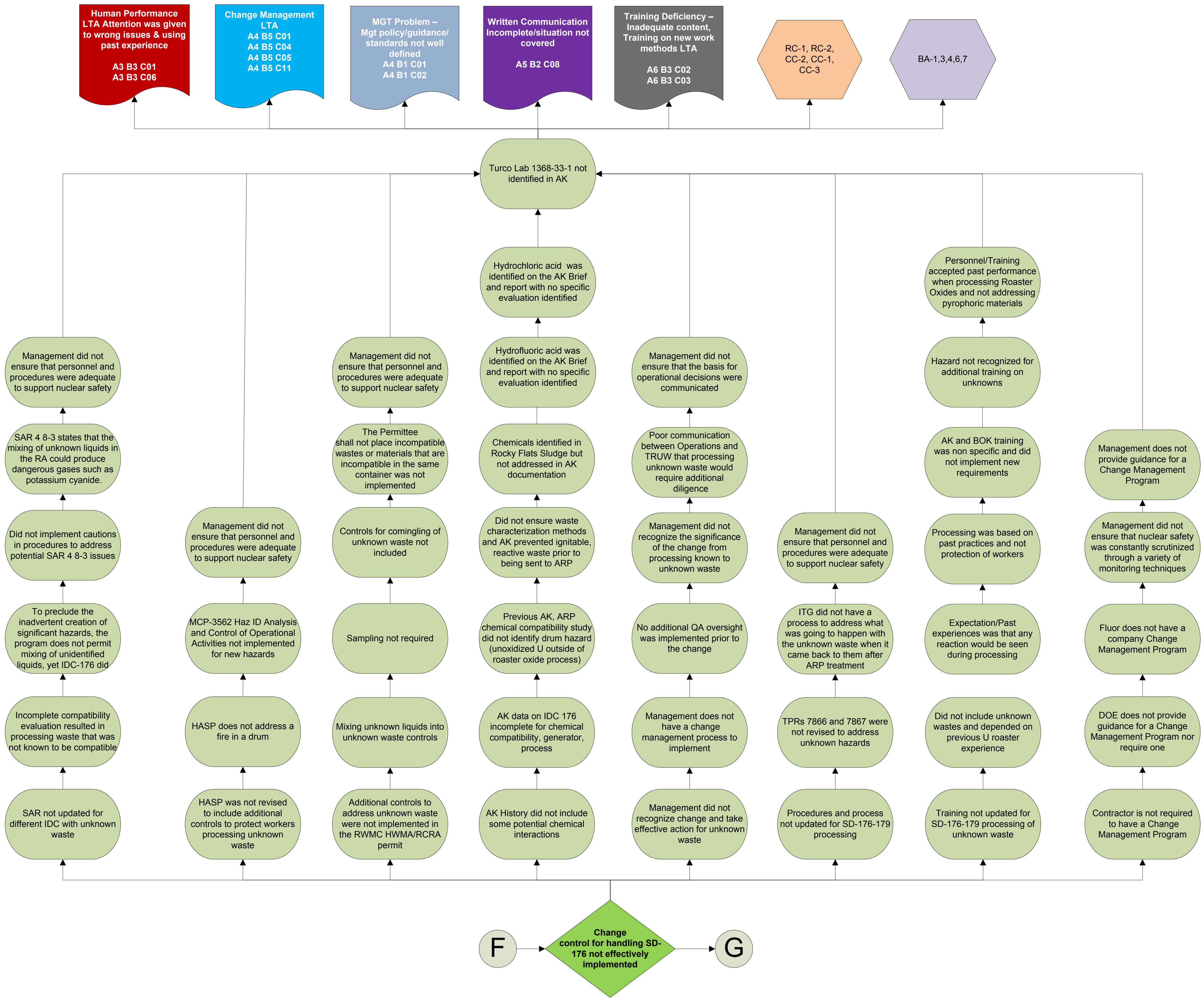

MGT Problem – Management policy/ expectation not well defined, and follow-up or monitoring not identified issues A4 B1 C01 A4 B1 C04
Written Communications – Procedures were incomplete/situation not covered A5 B2 C08
Human Performance LTA Attention was given to wrong issues & using past experience A3 B3 C01 A3 B3 C03 A3 B3 C06
RC-1, RC-2, CC-2 CC-6, CC-7
BA-1,3,4,7
Management did not ensure that deviations from standards and expectations were corrected.
Management did not ensure that nuclear safety was constantly scrutinized through a variety of monitoring techniques
RPT-TRUW-5 does not reflect identified prohibited items in reference table for table for SD-176
Comingling was performed without compatibility evaluation
Reports were not sufficiently thorough to identify pyrophorics
Available historical AK information has been diluted in current documentation
B
RPT-TRUW-5 failed to identify ignitability /reactivity wastes
DOE requested CWI to repackage an additional inventory of sludge drums February 2015
Management policy/ expectation not well defined, follow-up issues and change management issues A4 B1 C01 A4 B1 C04 A4 B5 C11
Human Performance LTA Attention was given to wrong issues & using past experience A3 B3 C01 A3 B3 C06
RC-1, RC-2, CC-6, CC-1, CC-2
BA-1,4,7
Personnel failed to recognize SD-176 additions changed work scope
Did not identify safety, training, and other project changes
MCP-1414, Change Control was not implemented for contract changes
CWI and ITG did not implement the procurement change process for Contract change
CWI notifies DOE that SRP Scope is complete 10/19/2015
C

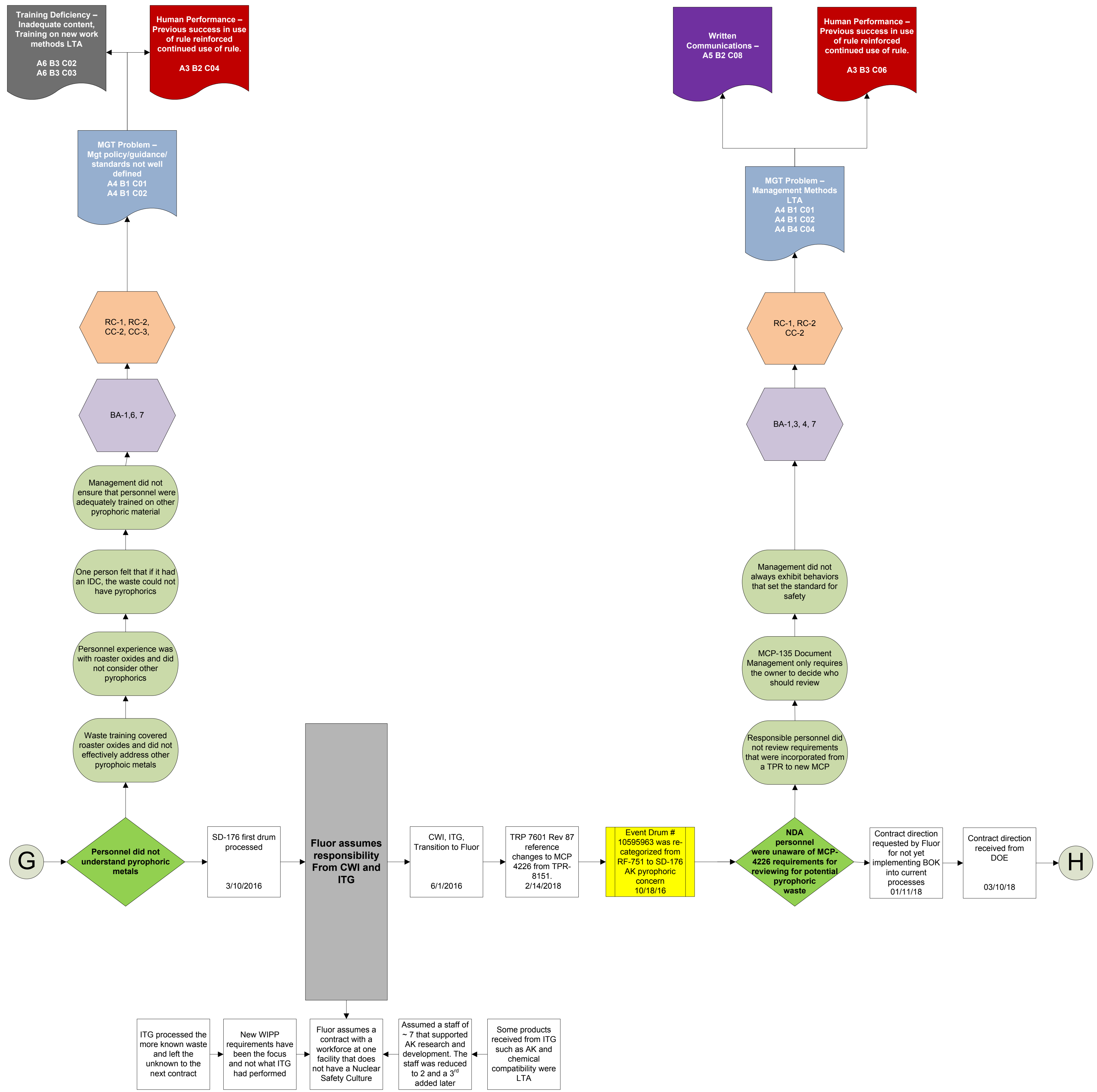

Human Performance – Attention was given to the wrong issue & using past experience
A3 B3 C02
A3 B3 C06
Communications – Procedures were incomplete/situation not covered
A5 B2 C08
MGT Problem – Management policy/ expectation not well defined, and follow-up or monitoring not identified issues
A4 B1 C01
A4 B1 C04
RC-1, RC-2, CC-2, CC-3, CC-5, CC-6,
BA-1,3,4, 7
Risks were not effectively evaluated and managed before proceeding
Management did not ensure that nuclear safety was constantly scrutinized through a variety of monitoring techniques
Management did not ensure that priorities were aligned to reflect nuclear safety as the overriding priority
RPT-ESH-014 did not use the most current hazardous constituent information (referenced the wrong revision)
Personnel did not perform a chemical compatibility evaluation for IDC-176
C
Chemical compatibility evaluation not completed for SD-176
Meeting with ITG/ DOE ID/CCP on Chemical Compatibility 12/02/2015
Letter from ITG to DOE notifying DOE of a break in feed to SRP (C-2015-0353) 12/02/2015
DOE response to ITG about not allowing a break in feed to SRP (AS-CMD-AMWTP/ ITG-16-014) 12/10/2015
ITG response to DOE addressing the 12/10 direction (C-2015-0385) 12/17/2015
DOE response to ITG addressing the 12/17 direction (AS-CMD-AMWTP/ITG-16-0 18) 12/21/2015
1 of 2 DOE assigned conditions from the 12/21/2015 DOE memo did not get implemented
D
ITG did not issue RPT-TRU-94 and did not get CBFO concurrence
No formal review and approval process
Neither DOE or ITG/CWI evaluate the implementation of the DOE conditions
Management follow-up activities were not identified and responsibility of personnel not defined or help accountable
Personnel did not demonstrate personal responsibility for work practices to ensure DOE conditions were implemented
RC-1, RC-2, CC-2,CC-6
BA-1,3,4, 7
Human Performance – Attention was given to the wrong issue & using past experience
A3 B3 C01
A3 B3 C02
A3 B3 C06
Management policy/ expectation not well defined, and follow-up or monitoring not identified issues
A4 B1 C01
A4 B1 C04
A4 B1 C07
Communications – Procedures were incomplete/situation not covered
A5 B2 C08

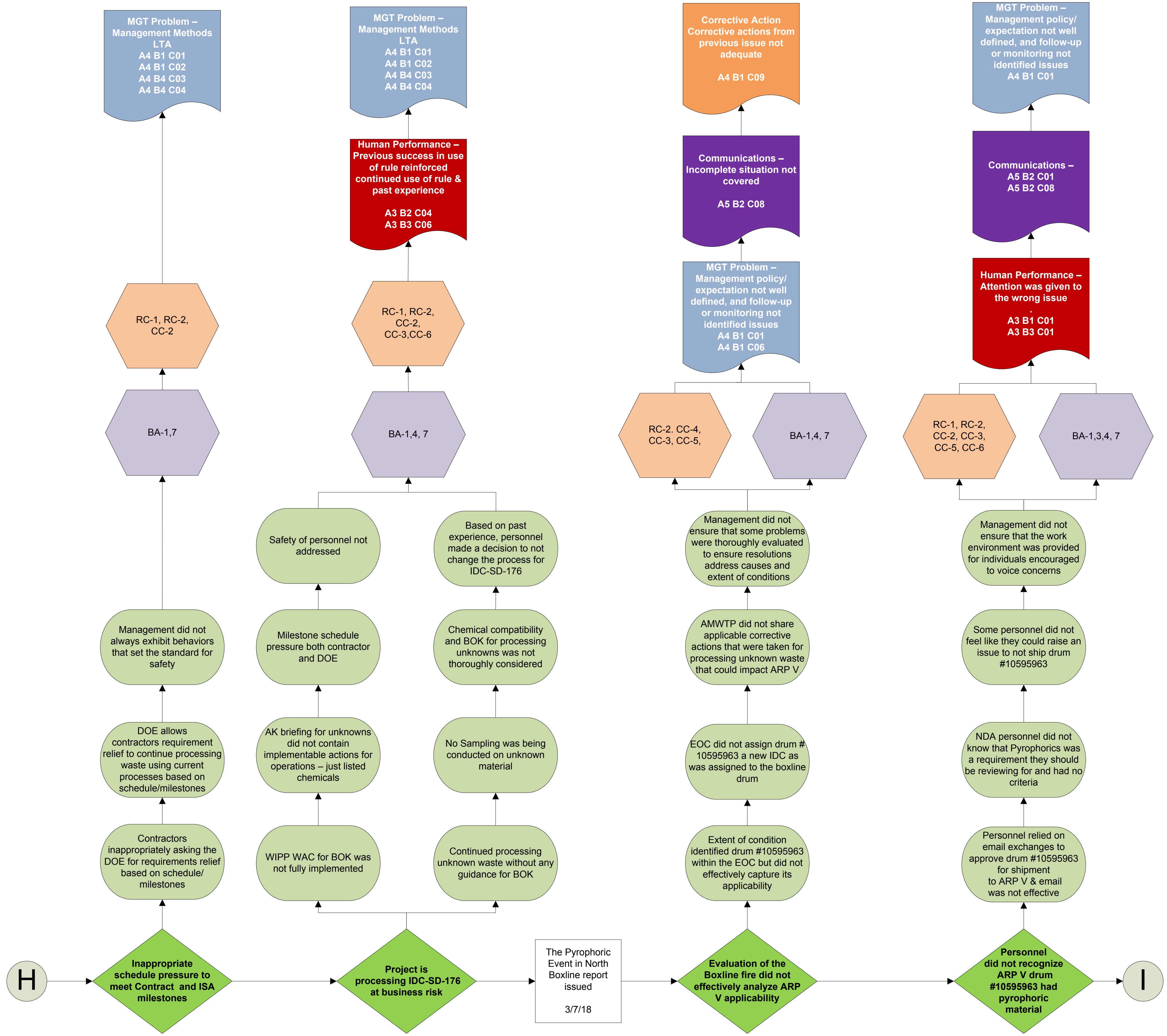

D
Using unapproved documents/emails to make decisions rather than perform tasks
MCP- 3930 allows email to be used.
MCP- 2985 Technical Procedures was not followed in the development of the TPRs that allow email approvals
Management did not always exhibit behaviors that set the standard for safety
Management did not ensure that nuclear safety was constantly scrutinized through a variety of monitoring techniques
Personnel did not demonstrate personal responsibility for work practices to ensure work activities was appropriately controlled
BA-1,3,7
Rc-1, RC-2, CC-2
MGT Problem – Management Methods LTA
A4 B1 C01
A4 B1 C02
A4 B4 C06
Communications – Between work groups LTA & were incomplete/ situation not covered
A5 B4 C01
A5 B2 C08
RWMC RCRA Permit revised that included RPT-TRUW-94 (DRAFT)
2/12/2016
Information provided to support the RWMC RCRA Permit was not adequate
RPT-ESH-014 did not address SD-176
RPT-ESH-014 not maintained per permit requirements
The reference in the RCRA report was identified as RPT-TRUW-94 (Draft)
Management did not ensure that nuclear safety was constantly scrutinized through a variety of monitoring techniques
Personnel did not demonstrate personal responsibility for work practices to ensure the RCRA permit was complete and accurate
BA-1,3,4,7
RC-1, RC-2, CC-2
Management policy/ expectation not well defined, and follow-up or monitoring not identified issues
A4 B1 C04
A4 B1 C07
A4 B1 C01
Human Performance – Attention was given to the wrong issue
A3 B3 C01
Communications – Between work groups LTA & were incomplete/ situation not covered
A5 B4 C01
A5 B2 C08
IAG-592 Rev 10 Roles and Responsibilities for SRP/ITG and CWI Revised to add IDC-176
3/1/2016
Weakness in Comms and processes to identify SD-176 as an unknown waste
ARP V personnel not informed on processing unknown waste
Nuclear Safety Personnel had no knowledge that IDC-176 was unknown
Individuals did not communicate openly across the organizations
Management did not ensure that the basis for operational decisions were communicated
BA-1,3,4,7
RC-1, RC-2
CC-2, CC-6
MGT Problem – Management policy/ expectation not well defined, and follow-up or monitoring not identified issues
A4 B1 C04
A4 B1 C07
Human Performance – Previous success in use of rule reinforced continued use of rule.
A3 B2 C04
A3 B3 C06
Communications – Incomplete situation not covered
A5 B4 C08
A5 B4 C01
E



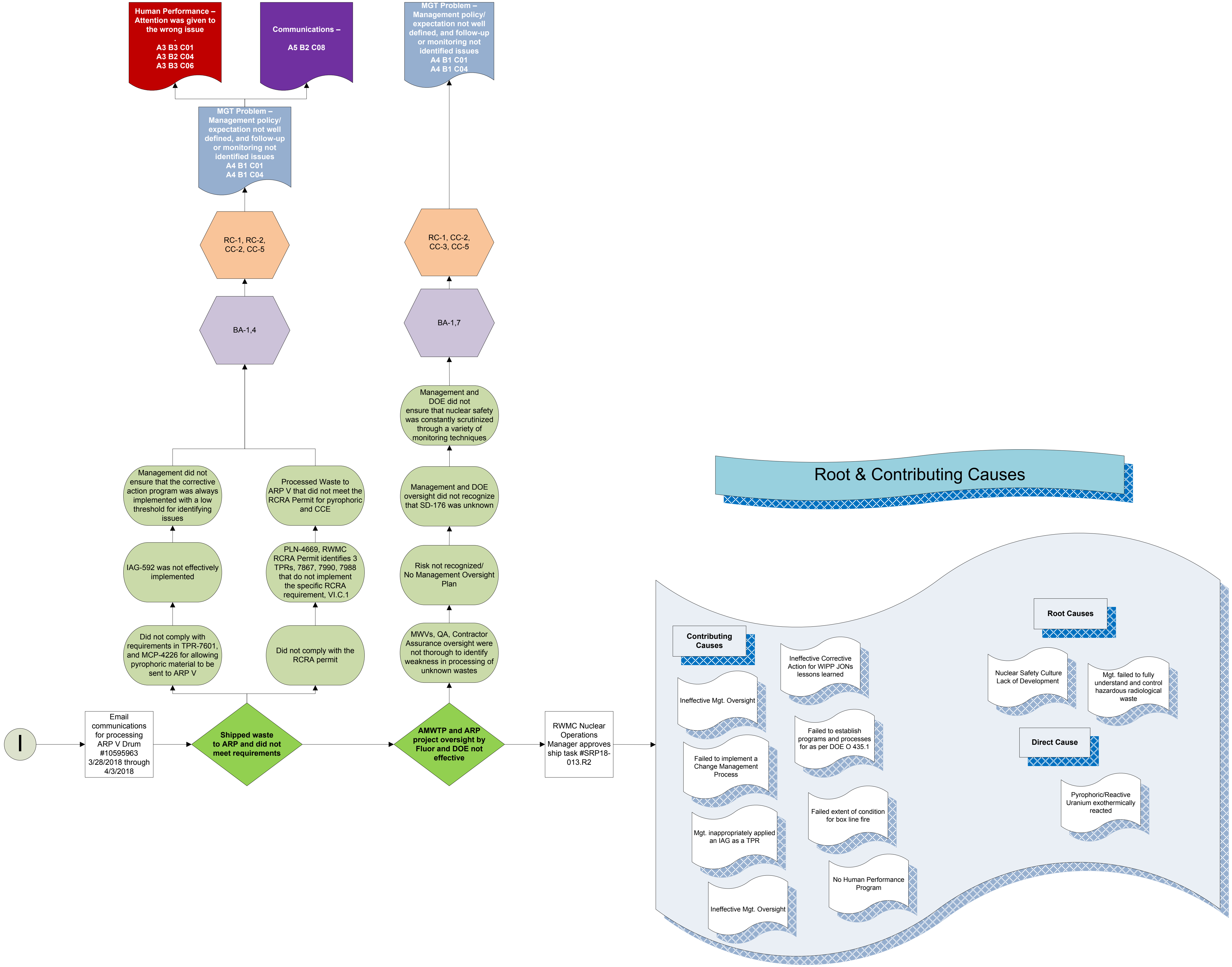
Communications – Incomplete situation not covered A5 B2 C08
MGT Problem – Management policy/ expectation not well defined, and follow-up or monitoring not identified issues A4 B1 C01 A4 B1 C04
Communications – Incomplete situation not covered A5 B2 C08
Training Deficiency – Inadequate content, Training on new work methods LTA A6 B3 C02 A6 B3 C03
Human Performance – Previous success in use of rule reinforced continued use of rule & using past experience A3 B2 C04 A3 B3 C01 A3 B3 C06
Human Performance – Attention was given to the wrong issue A3 B3 C01
RC-1, RC-2, CC-2, CC-5, CC-3
Management policy/ expectation not well defined, and responsibility not well defined A4 B1 C01 A4 B1 C07 A4 B1 C04
BA-1,4, 7
Management did not ensure that nuclear safety was constantly scrutinized through a variety of monitoring techniques
TPR 7601 RWMC Waste Handling and Over-packing revised based on the same basis
Management did not ensure that personnel and procedures were adequate to support nuclear safety
Did not provide the opportunity to analyze for consequences
For IDC 176, cautions from RPT-ESH-014 Rev 9 Chemical Compatibility were not taken
Did not provide the opportunity to screen unknown waste for hazardous analysis
For IDC 176, MCP-4226 TRU Prog. Site Project Office was not effectively implemented
Screened out to an old USQ (2005) per MCP-123 that does not apply to the IAG change
E
IAG-592, Rev 10 Roles and Resp. for Sludge Repackage Project Waste Transfers approved 3/1/2016
TPR-7601 Rev 68 states no potential pyrophoric or suspected depleted uranium roaster oxides 3/7/2016
Lack of recognition of non-compatible hazards associated with IDC SD-176 drum
USQ IAG Does not address IDC SD-176 as potentially multiple unknown waste streams
A first time evolution was to be treated as a normal process 3/2016
F


Human Performance LTA Attention was given to wrong issues & using past experience
A3 B3 C01
A3 B3 C06
Change Management LTA
A4 B5 C01
A4 B5 C04
A4 B5 C05
A4 B5 C11
MGT Problem – Mgt policy/guidance/ standards not well defined
A4 B1 C01
A4 B1 C02
Written Communication Incomplete/situation not covered
A5 B2 C08
Training Deficiency – Inadequate content, Training on new work methods LTA
A6 B3 C02
A6 B3 C03
RC-1, RC-2, CC-2, CC-1, CC-3
BA-1,3,4,6,7
Turco Lab 1368-33-1 not identified in AK
Hydrochloric acid was identified on the AK Brief and report with no specific evaluation identified
Personnel/Training accepted past performance when processing Roaster Oxides and not addressing pyrophoric materials
Management did not ensure that personnel and procedures were adequate to support nuclear safety
Management did not ensure that personnel and procedures were adequate to support nuclear safety
Hydrofluoric acid was identified on the AK Brief and report with no specific evaluation identified
Management did not ensure that the basis for operational decisions were communicated
Hazard not recognized for additional training on unknowns
SAR 4 8-3 states that the mixing of unknown liquids in the RA could produce dangerous gases such as potassium cyanide.
The Permittee shall not place incompatible wastes or materials that are incompatible in the same container was not implemented
Chemicals identified in Rocky Flats Sludge but not addressed in AK documentation
Poor communication between Operations and TRUW that processing unknown waste would require additional diligence
AK and BOK training was non specific and did not implement new requirements
Management does not provide guidance for a Change Management Program
Did not implement cautions in procedures to address potential SAR 4 8-3 issues
Management did not ensure that personnel and procedures were adequate to support nuclear safety
Controls for comingling of unknown waste not included
Did not ensure waste characterization methods and AK prevented ignitable, reactive waste prior to being sent to ARP
Management did not recognize the significance of the change from processing known to unknown waste
Management did not ensure that personnel and procedures were adequate to support nuclear safety
Processing was based on past practices and not protection of workers
Management did not ensure that nuclear safety was constantly scrutinized through a variety of monitoring techniques
To preclude the inadvertent creation of significant hazards, the program does not permit mixing of unidentified liquids, yet IDC-176 did
MCP-3562 Haz ID Analysis and Control of Operational Activities not implemented for new hazards
Sampling not required
Previous AK, ARP chemical compatibility study did not identify drum hazard (unoxidized U outside of roaster oxide process)
No additional QA oversight was implemented prior to the change
ITG did not have a process to address what was going to happen with the unknown waste when it came back to them after ARP treatment
Expectation/Past experiences was that any reaction would be seen during processing
Fluor does not have a company Change Management Program
Incomplete compatibility evaluation resulted in processing waste that was not known to be compatible
HASP does not address a fire in a drum
Mixing unknown liquids into unknown waste controls
AK data on IDC 176 incomplete for chemical compatibility, generator, process
Management does not have a change management process to implement
TPRs 7866 and 7867 were not revised to address unknown hazards
Did not include unknown wastes and depended on previous U roaster experience
DOE does not provide guidance for a Change Management Program nor require one
SAR not updated for different IDC with unknown waste
HASP was not revised to include additional controls to protect workers processing unknown waste
Additional controls to address unknown waste were not implemented in the RWMC HWMA/RCRA permit
AK History did not include some potential chemical interactions
Management did not recognize change and take effective action for unknown waste
Procedures and process not updated for SD-176-179 processing
Training not updated for SD-176-179 processing of unknown waste
Contractor is not required to have a Change Management Program
F
Change control for handling SD-176 not effectively implemented
G


Training Deficiency – Inadequate content, Training on new work methods LTA
A6 B3 C02
A6 B3 C03
Human Performance – Previous success in use of rule reinforced continued use of rule.
A3 B2 C04
MGT Problem – Mgt policy/guidance/ standards not well defined
A4 B1 C01
A4 B1 C02
RC-1, RC-2, CC-2, CC-3,
BA-1,6, 7
Management did not ensure that personnel were adequately trained on other pyrophoric material
One person felt that if it had an IDC, the waste could not have pyrophorics
Personnel experience was with roaster oxides and did not consider other pyrophorics
Waste training covered roaster oxides and did not effectively address other pyrophoic metals
G
Personnel did not understand pyrophoric metals
SD-176 first drum processed
3/10/2016
Fluor assumes responsibility From CWI and ITG
CWI, ITG, Transition to Fluor
6/1/2016
TRP 7601 Rev 87 reference changes to MCP 4226 from TPR-8151.
2/14/2018
Event Drum # 10595963 was re-categorized from RF-751 to SD-176 AK pyrophoric concern
10/18/16
NDA personnel were unaware of MCP-4226 requirements for reviewing for potential pyrophoric waste
Contract direction requested by Fluor for not yet implementing BOK into current processes
01/11/18
Contract direction received from DOE
03/10/18
H
ITG processed the more known waste and left the unknown to the next contract
New WIPP requirements have been the focus and not what ITG had performed
Fluor assumes a contract with a workforce at one facility that does not have a Nuclear Safety Culture
Assumed a staff of ~ 7 that supported AK research and development. The staff was reduced to 2 and a 3rd added later
Some products received from ITG such as AK and chemical compatibility were LTA
Written Communications – A5 B2 C08
Human Performance – Previous success in use of rule reinforced continued use of rule.
A3 B3 C06
MGT Problem – Management Methods LTA
A4 B1 C01
A4 B1 C02
A4 B4 C04
RC-1, RC-2 CC-2
BA-1,3, 4, 7
Management did not always exhibit behaviors that set the standard for safety
MCP-135 Document Management only requires the owner to decide who should review
Responsible personnel did not review requirements that were incorporated from a TPR to new MCP



MGT Problem – Management Methods LTA A4 B1 C01 A4 B1 C02 A4 B4 C03 A4 B4 C04
RC-1, RC-2, CC-2
BA-1,7
Management did not always exhibit behaviors that set the standard for safety
DOE allows contractors requirement relief to continue processing waste using current processes based on schedule/milestones
Contractors inappropriately asking the DOE for requirements relief based on schedule/ milestones
Inappropriate schedule pressure to meet Contract and ISA milestones
MGT Problem – Management Methods LTA A4 B1 C01 A4 B1 C02 A4 B4 C03 A4 B4 C04
Human Performance – Previous success in use of rule reinforced continued use of rule & past experience A3 B2 C04 A3 B3 C06
RC-1, RC-2, CC-2, CC-3,CC-6
BA-1,4, 7
Safety of personnel not addressed
Milestone schedule pressure both contractor and DOE
AK briefing for unknowns did not contain implementable actions for operations – just listed chemicals
WIPP WAC for BOK was not fully implemented
Based on past experience, personnel made a decision to not change the process for IDC-SD-176
Chemical compatibility and BOK for processing unknowns was not thoroughly considered
No Sampling was being conducted on unknown material
Continued processing unknown waste without any guidance for BOK
Project is processing IDC-SD-176 at business risk
The Pyrophoric Event in North Boxline report issued 3/7/18
Corrective Action Corrective actions from previous issue not adequate A4 B1 C09
Communications – Incomplete situation not covered A5 B2 C08
MGT Problem – Management policy/ expectation not well defined, and follow-up or monitoring not identified issues A4 B1 C01 A4 B1 C06
RC-2. CC-4, CC-3, CC-5,
BA-1,4, 7
Management did not ensure that some problems were thoroughly evaluated to ensure resolutions address causes and extent of conditions
AMWTP did not share applicable corrective actions that were taken for processing unknown waste that could impact ARP V
EOC did not assign drum # 10595963 a new IDC as was assigned to the boxline drum
Extent of condition identified drum #10595963 within the EOC but did not effectively capture its applicability
Evaluation of the Boxline fire did not effectively analyze ARP V applicability
MGT Problem – Management policy/ expectation not well defined, and follow-up or monitoring not identified issues A4 B1 C01
Communications – A5 B2 C01 A5 B2 C08
Human Performance – Attention was given to the wrong issue A3 B1 C01 A3 B3 C01
RC-1, RC-2, CC-2, CC-3, CC-5, CC-6
BA-1,3,4, 7
Management did not ensure that the work environment was provided for individuals encouraged to voice concerns
Some personnel did not feel like they could raise an issue to not ship drum #10595963
NDA personnel did not know that Pyrophorics was a requirement they should be reviewing for and had no criteria
Personnel relied on email exchanges to approve drum #10595963 for shipment to ARP V & email was not effective
Personnel did not recognize ARP V drum #10595963 had pyrophoric material
H
I

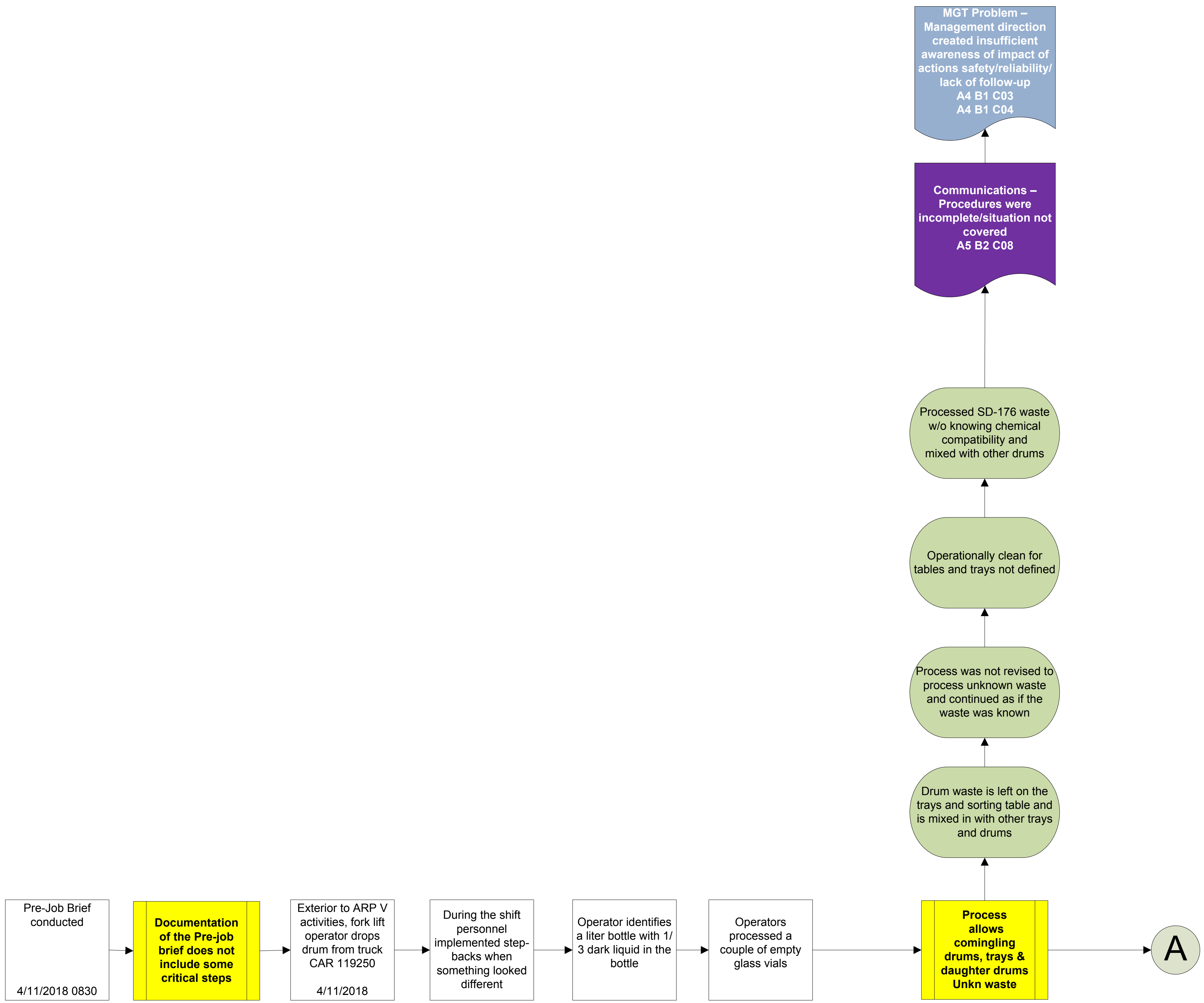

Human Performance – Attention was given to the wrong issue
A3 B3 C01
A3 B2 C04
A3 B3 C06
Communications –
A5 B2 C08
MGT Problem – Management policy/ expectation not well defined, and follow-up or monitoring not identified issues
A4 B1 C01
A4 B1 C04
MGT Problem – Management policy/ expectation not well defined, and follow-up or monitoring not identified issues
A4 B1 C01
A4 B1 C04
RC-1, RC-2, CC-2, CC-5
RC-1, CC-2, CC-3, CC-5
BA-1,4
BA-1,7
Management and DOE did not ensure that nuclear safety was constantly scrutinized through a variety of monitoring techniques
Management did not ensure that the corrective action program was always implemented with a low threshold for identifying issues
Processed Waste to ARP V that did not meet the RCRA Permit for pyrophoric and CCE
Management and DOE oversight did not recognize that SD-176 was unknown
IAG-592 was not effectively implemented
PLN-4669, RWMC RCRA Permit identifies 3 TPRs, 7867, 7990, 7988 that do not implement the specific RCRA requirement, VI.C.1
Risk not recognized/ No Management Oversight Plan
Did not comply with requirements in TPR-7601, and MCP-4226 for allowing pyrophoric material to be sent to ARP V
Did not comply with the RCRA permit
MWVs, QA, Contractor Assurance oversight were not thorough to identify weakness in processing of unknown wastes
I
Email communications for processing ARP V Drum #10595963 3/28/2018 through 4/3/2018
Shipped waste to ARP and did not meet requirements
AMWTP and ARP project oversight by Fluor and DOE not effective
RWMC Nuclear Operations Manager approves ship task #SRP18-013.R2
Root & Contributing Causes
Contributing Causes
Ineffective Mgt. Oversight
Failed to implement a Change Management Process
Mgt. inappropriately applied an IAG as a TPR
Ineffective Mgt. Oversight
Ineffective Corrective Action for WIPP JONs lessons learned
Failed to establish programs and processes for as per DOE O 435.1
Failed extent of condition for box line fire
No Human Performance Program
Root Causes
Nuclear Safety Culture Lack of Development
Mgt. failed to fully understand and control hazardous radiological waste
Direct Cause
Pyrophoric/Reactive Uranium exothermically reacted

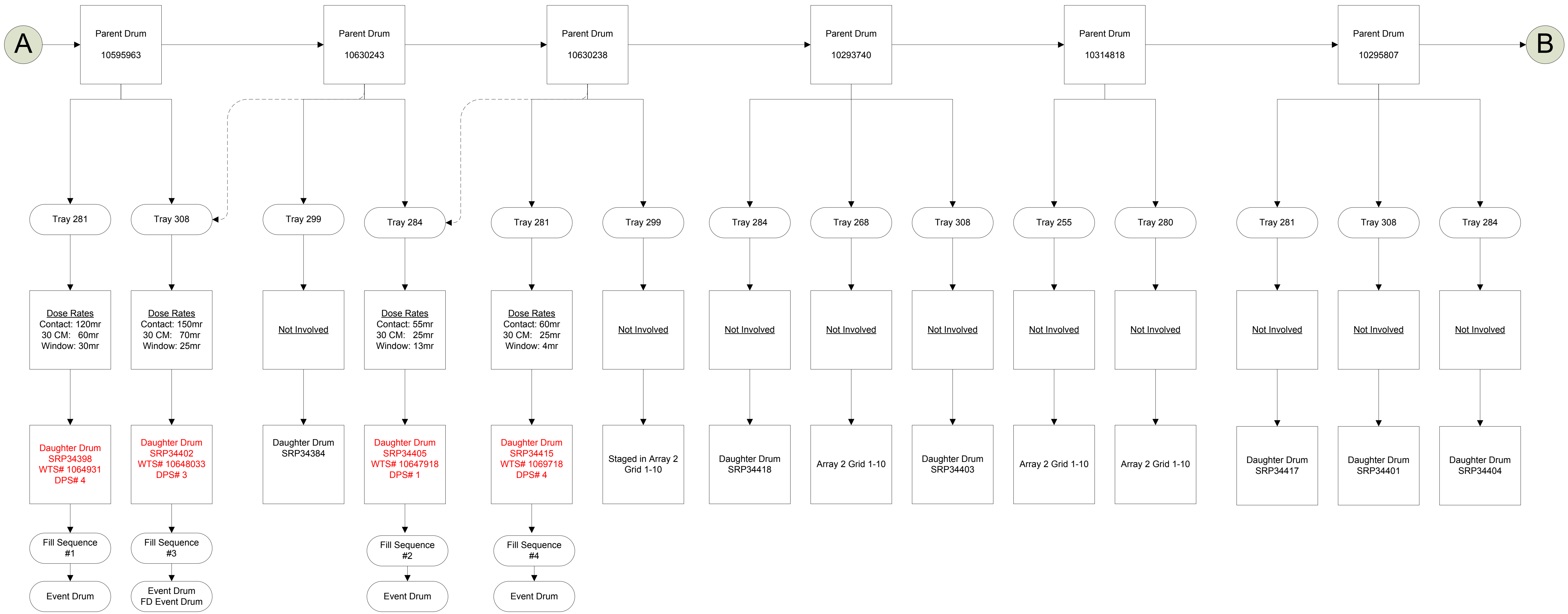
Appendix O

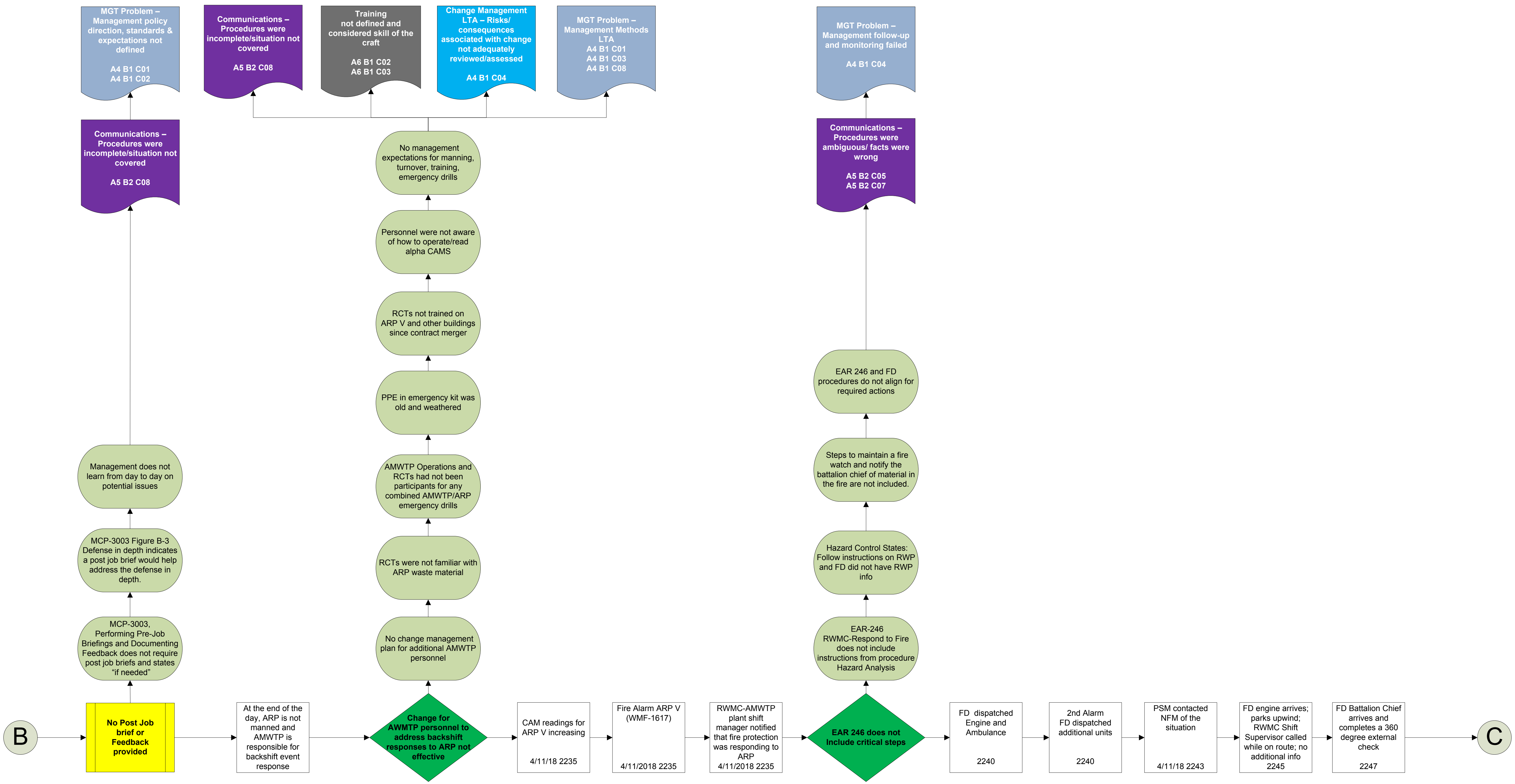
Event and Causal Factors Summary Chart for Event Day

Appendix O

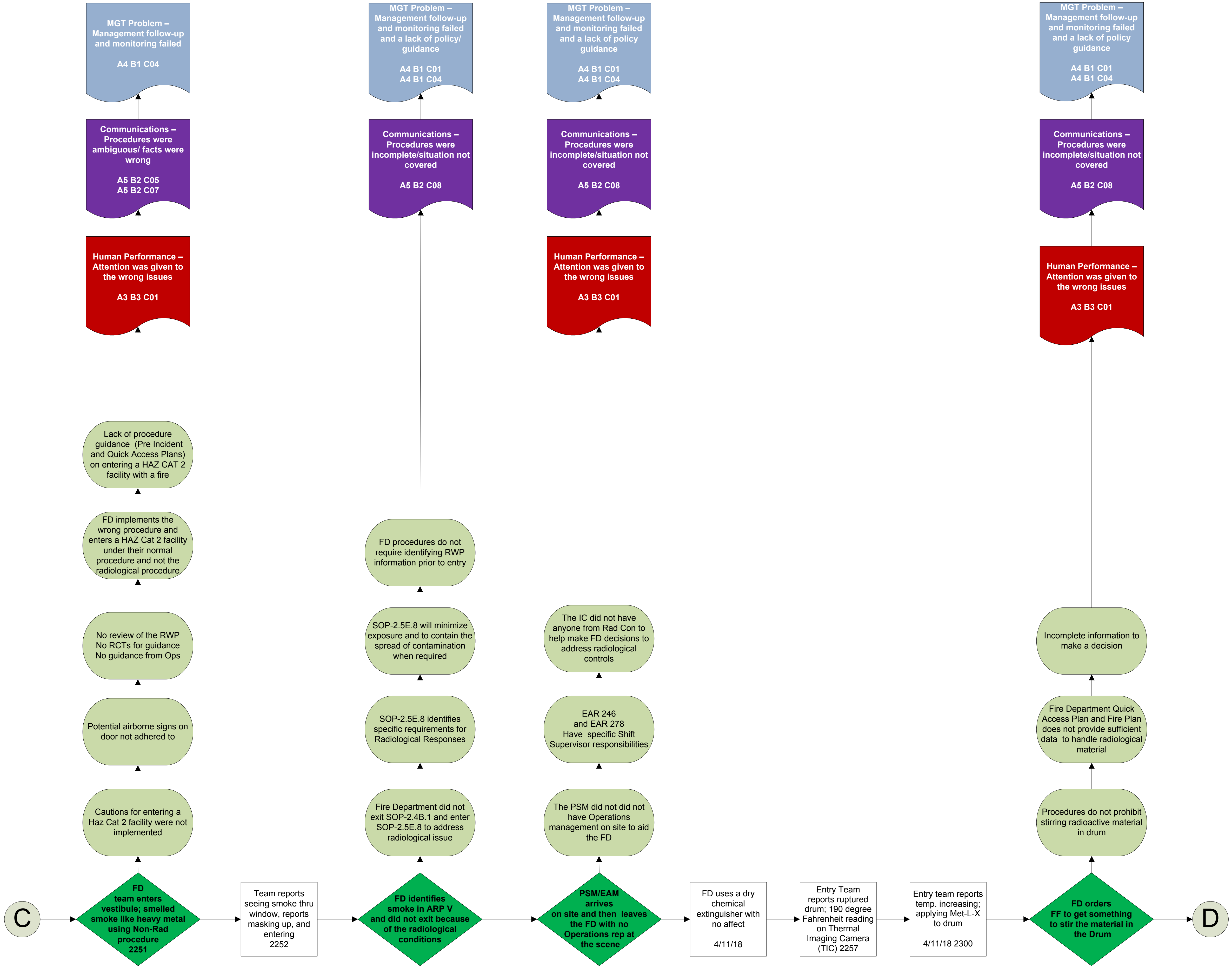
Event and Causal Factors Chart for Event Day



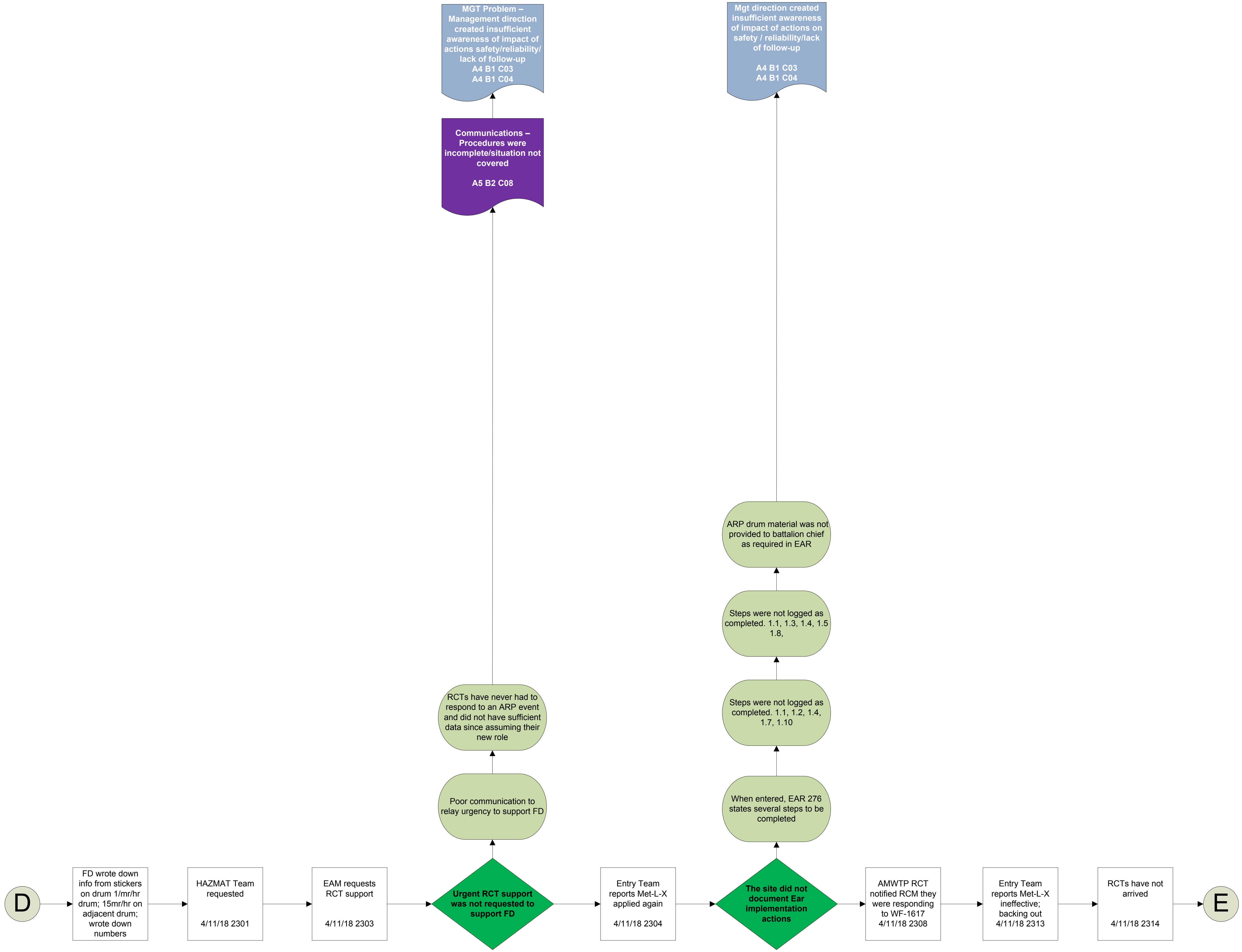

A
Parent Drum
10595963
Parent Drum
10630243
Parent Drum
10630238
Parent Drum
10293740
Parent Drum
10314818
Parent Drum
10295807
B
Tray 281
Tray 308
Tray 299
Tray 284
Tray 281
Tray 299
Tray 284
Tray 268
Tray 308
Tray 255
Tray 280
Tray 281
Tray 308
Tray 284
Dose Rates
Contact: 120mr
30 CM: 60mr
Window: 30mr
Dose Rates
Contact: 150mr
30 CM: 70mr
Window: 25mr
Not Involved
Dose Rates
Contact: 55mr
30 CM: 25mr
Window: 13mr
Dose Rates
Contact: 60mr
30 CM: 25mr
Window: 4mr
Not Involved
Not Involved
Not Involved
Not Involved
Not Involved
Not Involved
Not Involved
Not Involved
Not Involved
Daughter Drum
SRP34398
WTS# 1064931
DPS# 4
Daughter Drum
SRP34402
WTS# 10648033
DPS# 3
Daughter Drum
SRP34384
Daughter Drum
SRP34405
WTS# 10647918
DPS# 1
Daughter Drum
SRP34415
WTS# 1069718
DPS# 4
Staged in Array 2
Grid 1-10
Daughter Drum
SRP34418
Array 2 Grid 1-10
Daughter Drum
SRP34403
Array 2 Grid 1-10
Array 2 Grid 1-10
Daughter Drum
SRP34417
Daughter Drum
SRP34401
Daughter Drum
SRP34404
Fill Sequence
#1
Fill Sequence
#3
Fill Sequence
#2
Fill Sequence
#4
Event Drum
Event Drum
FD Event Drum
Event Drum
Event Drum

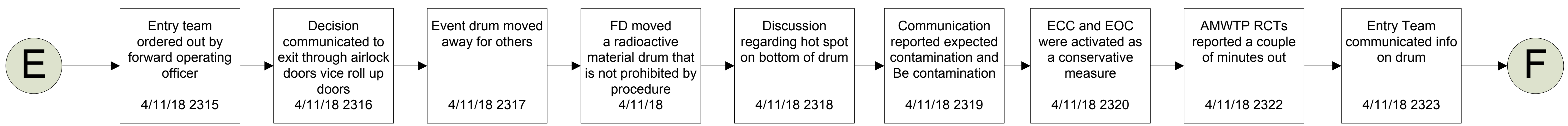


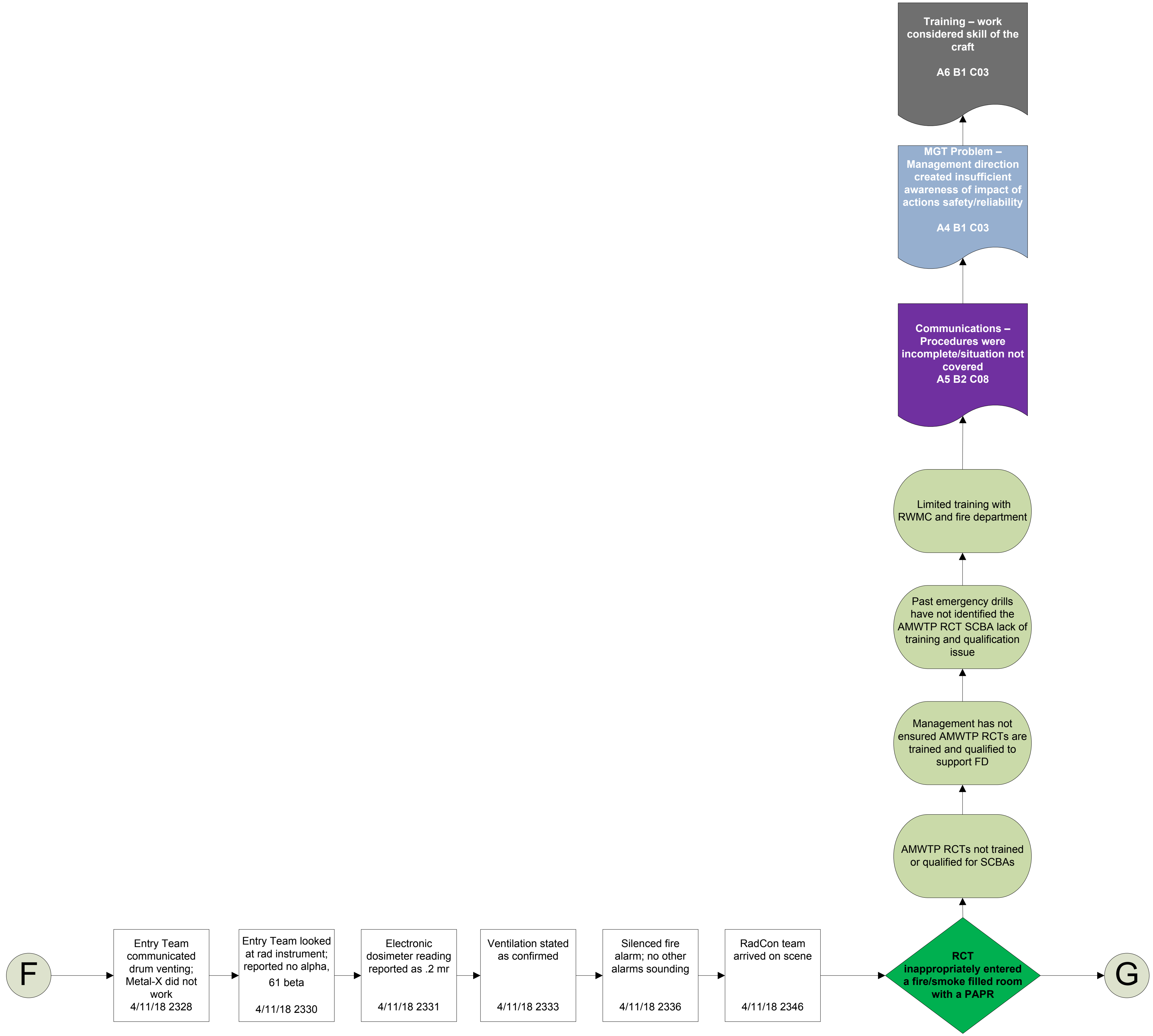
MGT Problem – Management policy direction, standards & expectations not defined
A4 B1 C01
A4 B1 C02
Communications – Procedures were incomplete/situation not covered
A5 B2 C08
Training not defined and considered skill of the craft
A6 B1 C02
A6 B1 C03
Change Management LTA – Risks/ consequences associated with change not adequately reviewed/assessed
A4 B1 C04
MGT Problem – Management Methods LTA
A4 B1 C01
A4 B1 C03
A4 B1 C08
MGT Problem – Management follow-up and monitoring failed
A4 B1 C04
Communications – Procedures were incomplete/situation not covered
A5 B2 C08
Communications – Procedures were ambiguous/ facts were wrong
A5 B2 C05
A5 B2 C07
No management expectations for manning, turnover, training, emergency drills
Personnel were not aware of how to operate/read alpha CAMS
RCTs not trained on ARP V and other buildings since contract merger
PPE in emergency kit was old and weathered
AMWTP Operations and RCTs had not been participants for any combined AMWTP/ARP emergency drills
RCTs were not familiar with ARP waste material
No change management plan for additional AMWTP personnel
EAR 246 and FD procedures do not align for required actions
Steps to maintain a fire watch and notify the battalion chief of material in the fire are not included.
Hazard Control States: Follow instructions on RWP and FD did not have RWP info
EAR-246 RWMC-Respond to Fire does not include instructions from procedure Hazard Analysis
Management does not learn from day to day on potential issues
MCP-3003 Figure B-3 Defense in depth indicates a post job brief would help address the defense in depth.
MCP-3003, Performing Pre-Job Briefings and Documenting Feedback does not require post job briefs and states "if needed"
B
No Post Job brief or Feedback provided
At the end of the day, ARP is not manned and AMWTP is responsible for backshift event response
Change for AMWTP personnel to address backshift responses to ARP not effective
CAM readings for ARP V increasing
4/11/18 2235
Fire Alarm ARP V (WMF-1617)
4/11/2018 2235
RWMC-AMWTP plant shift manager notified that fire protection was responding to ARP
4/11/2018 2235
EAR 246 does not include critical steps
FD dispatched Engine and Ambulance
2240
2nd Alarm FD dispatched additional units
2240
PSM contacted NFM of the situation
4/11/18 2243
FD engine arrives; parks upwind; RWMC Shift Supervisor called while on route; no additional info
2245
FD Battalion Chief arrives and completes a 360 degree external check
2247
C

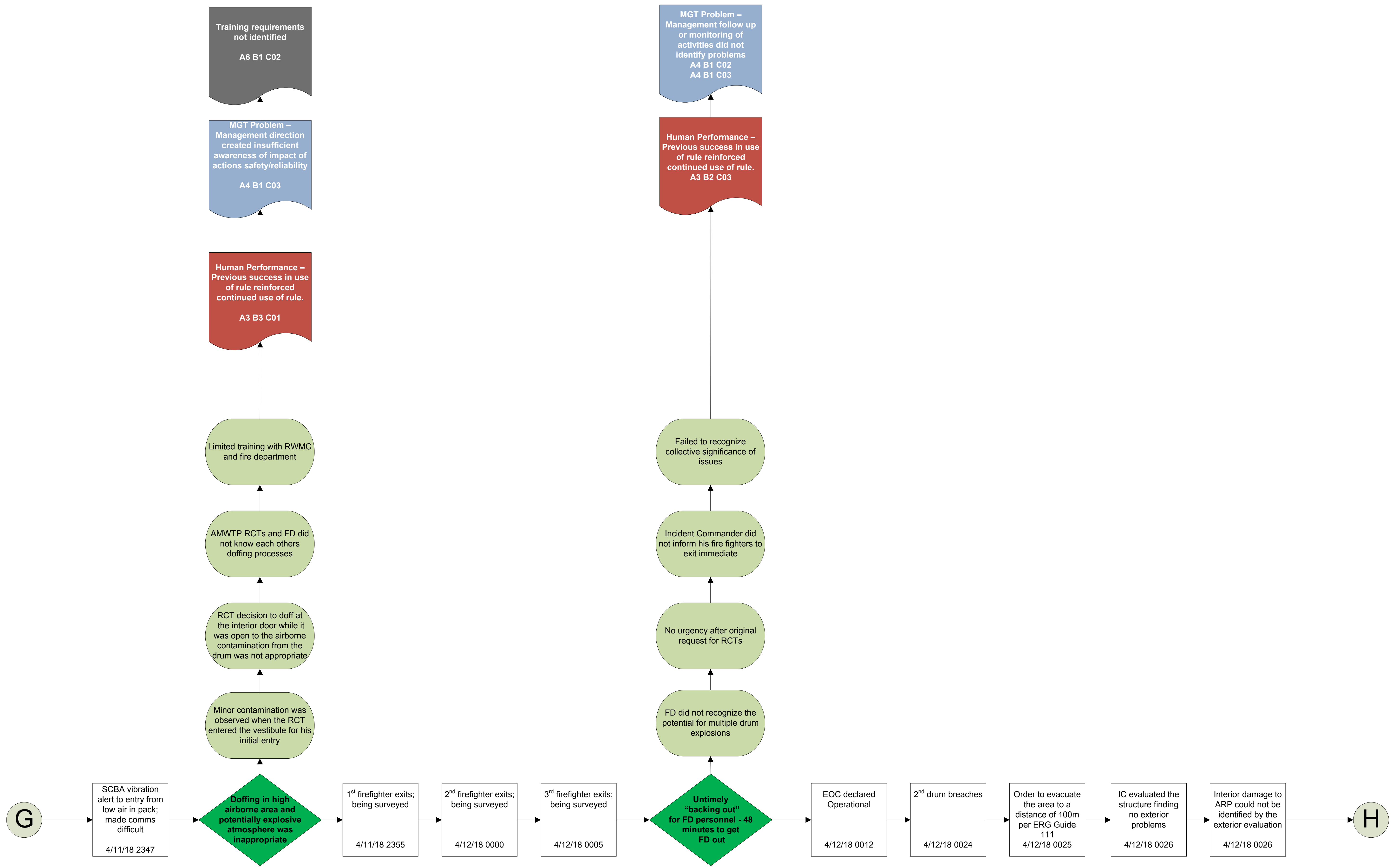


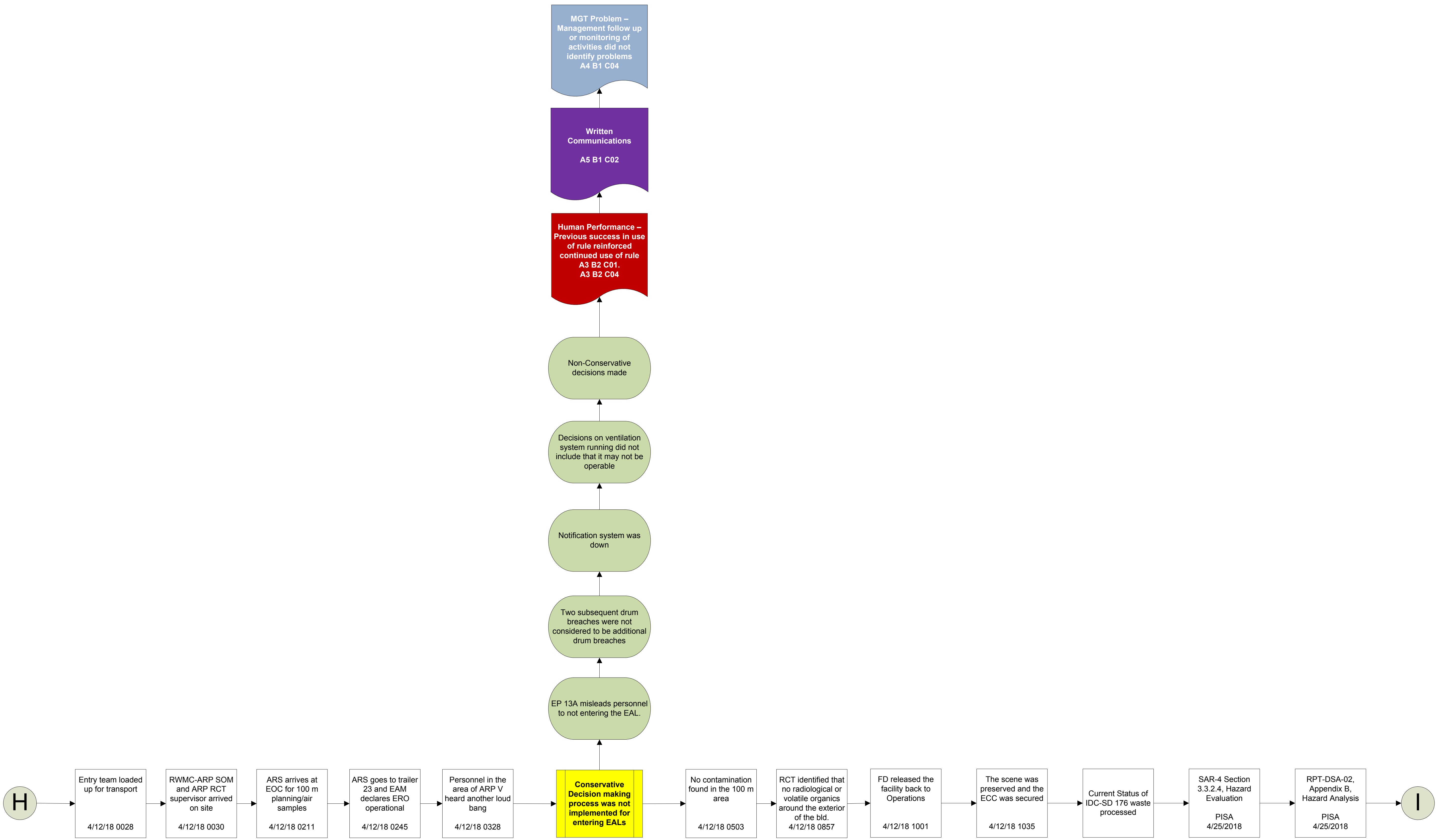
C
FD team enters vestibule; smelled smoke like heavy metal using Non-Rad procedure 2251
Cautions for entering a Haz Cat 2 facility were not implemented
Potential airborne signs on door not adhered to
No review of the RWP No RCTs for guidance No guidance from Ops
FD implements the wrong procedure and enters a HAZ Cat 2 facility under their normal procedure and not the radiological procedure
Lack of procedure guidance (Pre Incident and Quick Access Plans) on entering a HAZ CAT 2 facility with a fire
Human Performance – Attention was given to the wrong issues A3 B3 C01
Communications – Procedures were ambiguous/ facts were wrong A5 B2 C05 A5 B2 C07
MGT Problem – Management follow-up and monitoring failed A4 B1 C04
Team reports seeing smoke thru window, reports masking up, and entering 2252
FD identifies smoke in ARP V and did not exit because of the radiological conditions
Fire Department did not exit SOP-2.4B.1 and enter SOP-2.5E.8 to address radiological issue
SOP-2.5E.8 identifies specific requirements for Radiological Responses
SOP-2.5E.8 will minimize exposure and to contain the spread of contamination when required
FD procedures do not require identifying RWP information prior to entry
Communications – Procedures were incomplete/situation not covered A5 B2 C08
MGT Problem – Management follow-up and monitoring failed and a lack of policy/ guidance A4 B1 C01 A4 B1 C04
PSM/EAM arrives on site and then leaves the FD with no Operations rep at the scene
The PSM did not did not have Operations management on site to aid the FD
EAR 246 and EAR 278 Have specific Shift Supervisor responsibilities
The IC did not have anyone from Rad Con to help make FD decisions to address radiological controls
Human Performance – Attention was given to the wrong issues A3 B3 C01
Communications – Procedures were incomplete/situation not covered A5 B2 C08
MGT Problem – Management follow-up and monitoring failed and a lack of policy guidance A4 B1 C01 A4 B1 C04
FD uses a dry chemical extinguisher with no affect 4/11/18
Entry Team reports ruptured drum; 190 degree Fahrenheit reading on Thermal Imaging Camera (TIC) 2257
Entry team reports temp. increasing; applying Met-L-X to drum 4/11/18 2300
FD orders FF to get something to stir the material in the Drum
Procedures do not prohibit stirring radioactive material in drum
Fire Department Quick Access Plan and Fire Plan does not provide sufficient data to handle radiological material
Incomplete information to make a decision
Human Performance – Attention was given to the wrong issues A3 B3 C01
Communications – Procedures were incomplete/situation not covered A5 B2 C08
MGT Problem – Management follow-up and monitoring failed and a lack of policy guidance A4 B1 C01 A4 B1 C04
D

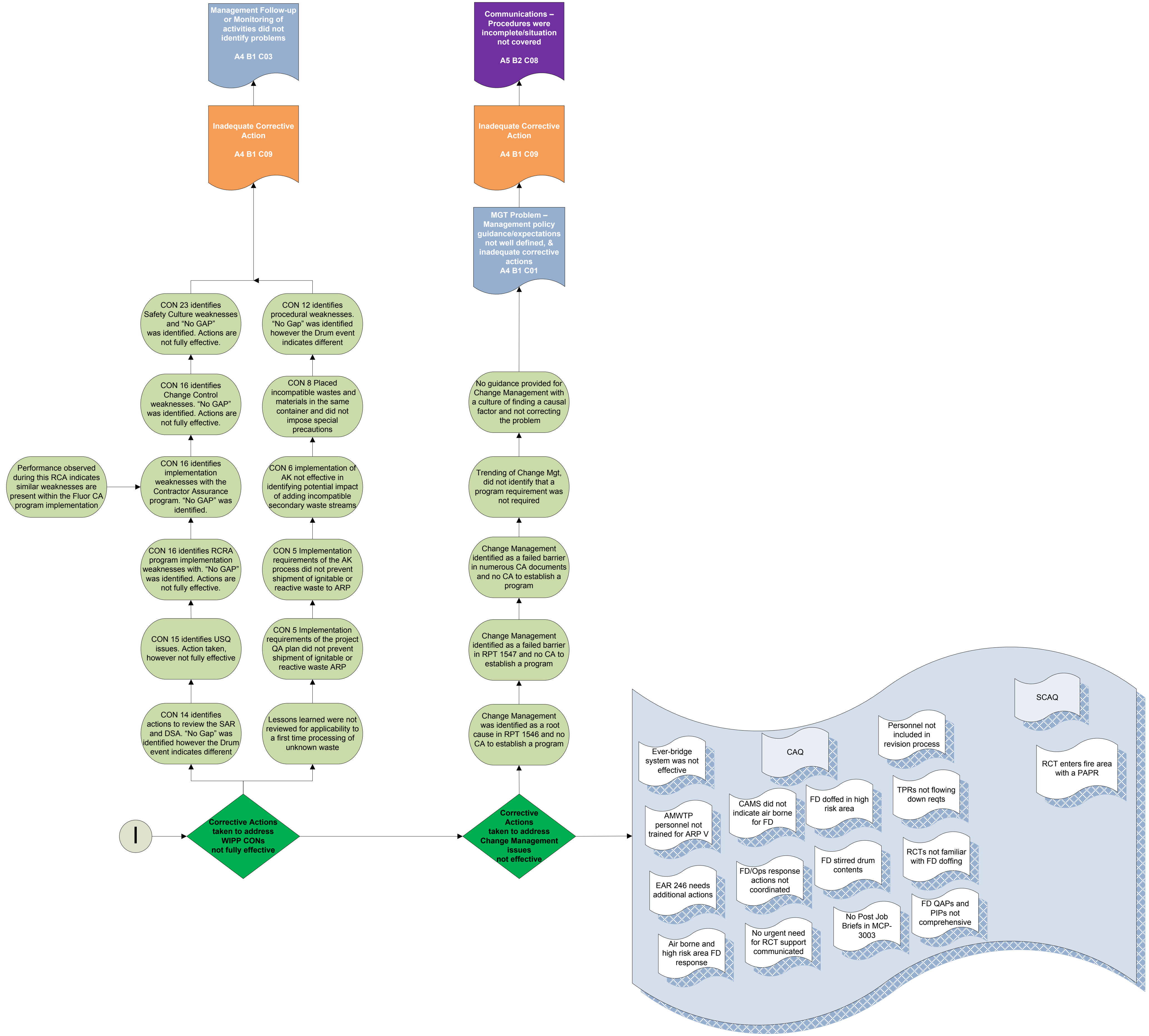

MGT Problem – Management direction created insufficient awareness of impact of actions safety/reliability/ lack of follow-up A4 B1 C03 A4 B1 C04
Mgt direction created insufficient awareness of impact of actions on safety / reliability/lack of follow-up A4 B1 C03 A4 B1 C04
Communications – Procedures were incomplete/situation not covered A5 B2 C08
ARP drum material was not provided to battalion chief as required in EAR
Steps were not logged as completed. 1.1, 1.3, 1.4, 1.5 1.8,
Steps were not logged as completed. 1.1, 1.2, 1.4, 1.7, 1.10
RCTs have never had to respond to an ARP event and did not have sufficient data since assuming their new role
Poor communication to relay urgency to support FD
When entered, EAR 276 states several steps to be completed
D
FD wrote down info from stickers on drum 1/mr/hr drum; 15mr/hr on adjacent drum; wrote down numbers
HAZMAT Team requested 4/11/18 2301
EAM requests RCT support 4/11/18 2303
Urgent RCT support was not requested to support FD
Entry Team reports Met-L-X applied again 4/11/18 2304
The site did not document Ear implementation actions
AMWTP RCT notified RCM they were responding to WF-1617 4/11/18 2308
Entry Team reports Met-L-X ineffective; backing out 4/11/18 2313
RCTs have not arrived 4/11/18 2314
E


E
Entry team ordered out by forward operating officer 4/11/18 2315
Decision communicated to exit through airlock doors vice roll up doors 4/11/18 2316
Event drum moved away for others 4/11/18 2317
FD moved a radioactive material drum that is not prohibited by procedure 4/11/18
Discussion regarding hot spot on bottom of drum 4/11/18 2318
Communication reported expected contamination and Be contamination 4/11/18 2319
ECC and EOC were activated as a conservative measure 4/11/18 2320
AMWTP RCTs reported a couple of minutes out 4/11/18 2322
Entry Team communicated info on drum 4/11/18 2323
F


Training – work considered skill of the craft
A6 B1 C03
MGT Problem – Management direction created insufficient awareness of impact of actions safety/reliability
A4 B1 C03
Communications – Procedures were incomplete/situation not covered
A5 B2 C08
Limited training with RWMC and fire department
Past emergency drills have not identified the AMWTP RCT SCBA lack of training and qualification issue
Management has not ensured AMWTP RCTs are trained and qualified to support FD
AMWTP RCTs not trained or qualified for SCBAs
F
Entry Team communicated drum venting; Metal-X did not work
4/11/18 2328
Entry Team looked at rad instrument; reported no alpha, 61 beta
4/11/18 2330
Electronic dosimeter reading reported as .2 mr
4/11/18 2331
Ventilation stated as confirmed
4/11/18 2333
Silenced fire alarm; no other alarms sounding
4/11/18 2336
RadCon team arrived on scene
4/11/18 2346
RCT inappropriately entered a fire/smoke filled room with a PAPR
G


Training requirements not identified
A6 B1 C02
MGT Problem – Management direction created insufficient awareness of impact of actions safety/reliability
A4 B1 C03
Human Performance – Previous success in use of rule reinforced continued use of rule.
A3 B3 C01
Limited training with RWMC and fire department
AMWTP RCTs and FD did not know each others doffing processes
RCT decision to doff at the interior door while it was open to the airborne contamination from the drum was not appropriate
Minor contamination was observed when the RCT entered the vestibule for his initial entry
MGT Problem – Management follow up or monitoring of activities did not identify problems
A4 B1 C02
A4 B1 C03
Human Performance – Previous success in use of rule reinforced continued use of rule.
A3 B2 C03
Failed to recognize collective significance of issues
Incident Commander did not inform his fire fighters to exit immediate
No urgency after original request for RCTs
FD did not recognize the potential for multiple drum explosions
G
SCBA vibration alert to entry from low air in pack; made comms difficult
4/11/18 2347
Doffing in high airborne area and potentially explosive atmosphere was inappropriate
1st firefighter exits; being surveyed
4/11/18 2355
2nd firefighter exits; being surveyed
4/12/18 0000
3rd firefighter exits; being surveyed
4/12/18 0005
Untimely “backing out” for FD personnel - 48 minutes to get FD out
EOC declared Operational
4/12/18 0012
2nd drum breaches
4/12/18 0024
Order to evacuate the area to a distance of 100m per ERG Guide 111
4/12/18 0025
IC evaluated the structure finding no exterior problems
4/12/18 0026
Interior damage to ARP could not be identified by the exterior evaluation
4/12/18 0026
H


MGT Problem – Management follow up or monitoring of activities did not identify problems A4 B1 C04
Written Communications A5 B1 C02
Human Performance – Previous success in use of rule reinforced continued use of rule A3 B2 C01. A3 B2 C04
Non-Conservative decisions made
Decisions on ventilation system running did not include that it may not be operable
Notification system was down
Two subsequent drum breaches were not considered to be additional drum breaches
EP 13A misleads personnel to not entering the EAL.
H
Entry team loaded up for transport 4/12/18 0028
RWMC-ARP SOM and ARP RCT supervisor arrived on site 4/12/18 0030
ARS arrives at EOC for 100 m planning/air samples 4/12/18 0211
ARS goes to trailer 23 and EAM declares ERO operational 4/12/18 0245
Personnel in the area of ARP V heard another loud bang 4/12/18 0328
Conservative Decision making process was not implemented for entering EALs
No contamination found in the 100 m area 4/12/18 0503
RCT identified that no radiological or volatile organics around the exterior of the bld. 4/12/18 0857
FD released the facility back to Operations 4/12/18 1001
The scene was preserved and the ECC was secured 4/12/18 1035
Current Status of IDC-SD 176 waste processed
SAR-4 Section 3.3.2.4, Hazard Evaluation PISA 4/25/2018
RPT-DSA-02, Appendix B, Hazard Analysis PISA 4/25/2018
I


Management Follow-up or Monitoring of activities did not identify problems
A4 B1 C03
Communications – Procedures were incomplete/situation not covered
A5 B2 C08
Inadequate Corrective Action
A4 B1 C09
Inadequate Corrective Action
A4 B1 C09
MGT Problem – Management policy guidance/expectations not well defined, & inadequate corrective actions
A4 B1 C01
CON 23 identifies Safety Culture weaknesses and "No GAP" was identified. Actions are not fully effective.
CON 12 identifies procedural weaknesses. "No Gap" was identified however the Drum event indicates different
CON 16 identifies Change Control weaknesses. "No GAP" was identified. Actions are not fully effective.
CON 8 Placed incompatible wastes and materials in the same container and did not impose special precautions
No guidance provided for Change Management with a culture of finding a causal factor and not correcting the problem
Performance observed during this RCA indicates similar weaknesses are present within the Fluor CA program implementation
CON 16 identifies implementation weaknesses with the Contractor Assurance program. "No GAP" was identified.
CON 6 implementation of AK not effective in identifying potential impact of adding incompatible secondary waste streams
Trending of Change Mgt, did not identify that a program requirement was not required
CON 16 identifies RCRA program implementation weaknesses with. "No GAP" was identified. Actions are not fully effective.
CON 5 Implementation requirements of the AK process did not prevent shipment of ignitable or reactive waste to ARP
Change Management identified as a failed barrier in numerous CA documents and no CA to establish a program
CON 15 identifies USQ issues. Action taken, however not fully effective
CON 5 Implementation requirements of the project QA plan did not prevent shipment of ignitable or reactive waste ARP
Change Management identified as a failed barrier in RPT 1547 and no CA to establish a program
CON 14 identifies actions to review the SAR and DSA. "No Gap" was identified however the Drum event indicates different
Lessons learned were not reviewed for applicability to a first time processing of unknown waste
Change Management was identified as a root cause in RPT 1546 and no CA to establish a program
I
Corrective Actions taken to address WIPP CONs not fully effective
Corrective Actions taken to address Change Management issues not effective
SCAQ
Personnel not included in revision process
CAQ
Ever-bridge system was not effective
RCT enters fire area with a PAPR
TPRs not flowing down reqts
FD doffed in high risk area
CAMS did not indicate air borne for FD
AMWTP personnel not trained for ARP V
RCTs not familiar with FD doffing
FD stirred drum contents
FD/Ops response actions not coordinated
EAR 246 needs additional actions
FD QAPs and PIPs not comprehensive
No Post Job Briefs in MCP-3003
No urgent need for RCT support communicated
Air borne and high risk area FD response