

**Critical Drivers for Safety Culture:
Examining Department of Energy and U.S. Army Operational Experiences - 12382**

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ABSTRACT

Evaluating operational incidents can provide a window into the drivers most critical to establishing and maintaining a strong safety culture, thereby minimizing the potential project risk associated with safety incidents. By examining U.S. Department of Energy (DOE) versus U.S. Army drivers in terms of regulatory and contract requirements, programs implemented to address the requirements, and example case studies of operational events, a view of the elements most critical to making a positive influence on safety culture is presented. Four case studies are used in this evaluation; two from DOE and two from U.S. Army experiences. Although the standards guiding operations at these facilities are different, there are many similarities in the level of hazards, as well as the causes and the potential consequences of the events presented. Two of the incidents examined, one from a DOE operation and the other from a U.S. Army facility, resulted in workers receiving chemical burns. The remaining two incidents are similar in that significant conduct of operations failures occurred resulting in high-level radioactive waste (in the case of the DOE facility) or chemical agent (in the case of the Army facility) being transferred outside of engineering controls. A review of the investigation reports for all four events indicates the primary causes to be failures in work planning leading to ineffective hazard evaluation and control, lack of procedure adherence, and most importantly, lack of management oversight to effectively reinforce expectations for safe work planning and execution. DOE and Army safety programs are similar, and although there are some differences in contractual requirements, the expectations for safe performance are essentially the same. This analysis concludes that instilling a positive safety culture comes down to management leadership and engagement to (1) cultivate an environment that values a questioning attitude and (2) continually reinforce expectations for the appropriate level of rigor in work planning and procedure adherence.

INTRODUCTION

Based on experience in management positions within both DOE and U.S. Army environments it is clear that contractual standards and requirements can be different but expectations for safe performance are very consistent. A review of four case studies, one from the West Valley Demonstration Project (WVDP), a DOE high-level waste (HLW) management facility located in New York State; one from a groundwater treatment plant at a DOE Legacy Management facility located in Arizona; and two from the Tooele Chemical Agent Disposal Facility (TOCDF), a U.S. Army Chemical Demilitarization facility located in Utah, demonstrates significant commonalities in the primary causes of significant events. Conclusions can then be drawn for those elements most critical to safe performance in a high-hazard operational environment.

The four case studies examined in this analysis were chosen due to the impact they have had on the author, either from direct experience in terms of implementing post-event corrective actions, or in terms of involvement in the root cause analysis process, as well as the impact they had on overall project performance. Although having varying degrees of seriousness, all incidents resulted in consequences, and were defining moments for these facilities. Actions coming out of the incidents were important milestones in the facilities' continuous improvement processes. WVDP and TOCDF both demonstrated their commitment to such continuous improvement by later achieving STAR status in the Voluntary Protection Programs (VPP) administered by DOE and the Occupational Safety and Health Administration (OSHA), respectively. Likewise, the improvements implemented to address the Tuba City event have supported the Legacy Management Services (LMS) program in its recent pursuit of DOE VPP recognition.

METHOD

Experiences gained as a Federal project manager within the DOE Environmental Management program from the early 1990s through 2003, and as a senior manager within the Army's Chemical Demilitarization program contractor community from 2003 through 2010, have been used as the primary source to support this analysis. Four case studies are presented which span a period of fifteen years; each of these case studies presents an incident that resulted in serious consequence. It should be noted that the primary data sources for this examination are the investigation or root cause analysis reports, as well as the author's direct experience in working at or with these facilities either during or shortly after the incidents. In two cases the post-event investigations were independent investigations chartered by the government and these investigation reports were used to support the analysis; in the remaining two cases internal root cause analysis reports were used as the source documents. It is also important to note that each of the post-event investigations utilized a slightly different cause analysis method or technique. All investigations resulted in either one or multiple root causes, however, terminology varied with respect to contributing causes (e.g., terms utilized include "apparent cause", "direct cause", "indirect cause", "causal factors", "contributing causes", etc.) For the purposes of comparison, the term "key contributing causes" is used in the following discussion to present other primary factors, in addition to the root causes, that led to the events and that are important to consider as part of this analysis.

DISCUSSION

The following provides a summary of the four case studies used to examine safety culture influences within DOE and U.S. Army high-hazard operations. For each incident, a summary of the event, root cause(s), key contributing causes, and a discussion on corrective actions is presented. Note that as is the case with such operational events, the investigation reports are very detailed and quite complex. The discussions below are intended to summarize the events at a level sufficient for a

comparison of the primary performance failures, but do not attempt to provide a complete description of all aspects of each event.

Vitrification Facility HLW Backflow Event – DOE West Valley Demonstration Project, West Valley, New York

The WVDP began high-level waste (HLW) solidification (vitrification) operations in 1996. Operations included transfer of HLW from a tank farm to a shielded cell within the Vitrification Facility, where waste was mixed with chemicals to produce a “slurry” as part of the vitrification feed preparation process. The process required routine sampling of the slurry, which was performed remotely from a sampling station located within an operating aisle outside the shielded cell. On Saturday, November 16, 1996, during routine sampling operations, operators experienced lower-than-anticipated sample flow and problems in filling the sample bottles. In accordance with their procedure they contacted engineering support and per engineering instructions, a back flushing operation was attempted. Shortly following the back flushing attempt, various radiation monitors in the area went into alarm, personnel in the operating aisles exited, and response actions were taken. Although the event resulted in HLW being transferred outside of engineering controls, no personnel exposures resulted.

Initial investigation determined that diluted HLW “slurry” had exited the shielded cell through a demineralized water line and into piping in an operating aisle. The local DOE office commissioned an independent investigation into the root cause as well as an evaluation of the contractor’s corrective actions to verify that they would adequately prevent recurrence. Barrier analysis was used to support the accident investigation and analysis process, in accordance with the DOE “Root Cause Analysis Guidance Document” (DOE-NE-STD-1004-92). The DOE investigation determined that HLW slurry exited engineering controls due to failure or misalignment of a three-way valve (Valve HV-0213), which was the last of a number of barriers that could have prevented the event. The investigation report describes how the plugging problem experienced was not entirely uncommon and back flushing operations had been used in the past successfully, however no back flushing operation had been included in the operational procedure. When the problem was encountered that particular Saturday, the most knowledgeable system (“cognizant”) engineer was not available on site and the process for back flushing was established by a less knowledgeable on-site engineer with some guidance provided remotely by the cognizant engineer. No formal work control process was used that would have involved appropriate hazard analysis and reviews/approvals. The instructions developed, which were informally written on a system drawing, did not use the same back flushing process provided by the System Description, apparently due to the view on the part of the cognizant engineer that it was overly complex.

Guidance provided by the cognizant engineer to the on-site engineer provided a method to back flush by arranging the sample station valves and slurry pump such that demineralized water would flow backwards through the slurry sample station valves/piping and through the slurry pump up to Valve HV-0213, which would be positioned to flush back to the slurry waste tank inside the shielded cell. A

reconstruction of the event confirmed that with alignment of the valves to back flush through the sample station piping and slurry pump to the slurry waste tank via Valve HV-0213, HV-0213 malfunctioned and resulted in an incorrect position that allowed flush water to pass up through the demineralized water line and out of the shielded cell into the operating aisle. Figure 1 provides a summary of the failure sequence and barrier analysis.

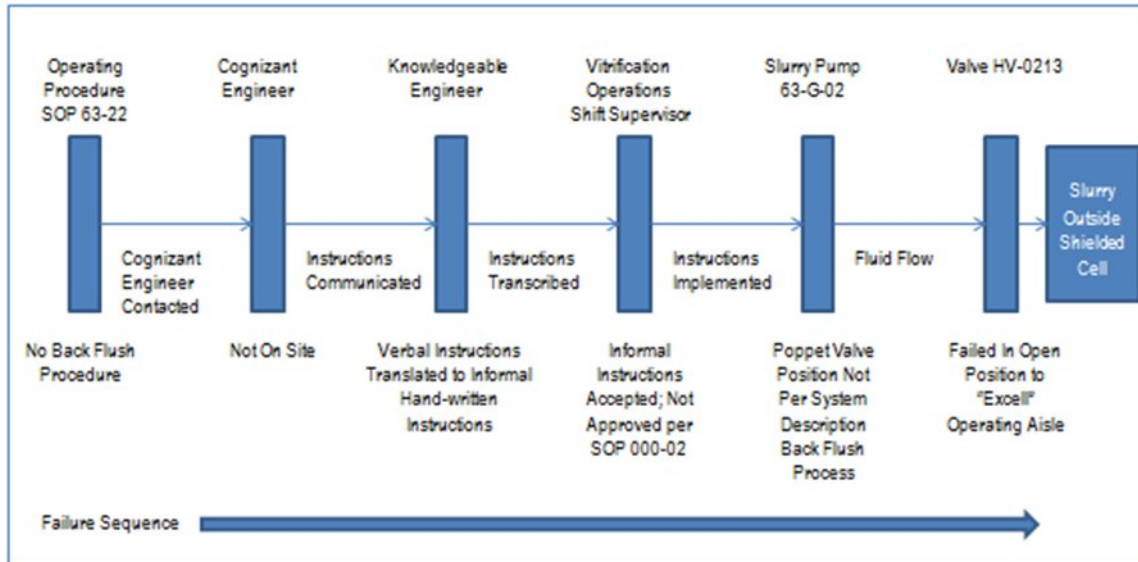


Fig. 1. 1996 WVDP Vitrification Backflow Event – Barrier Analysis.

The investigation identified the following as the root cause:

“An approved procedure was not used to perform the back flushing procedure. The informal instructions provided did not consider the risk of failure of Valve HV-0213 nor were they properly reviewed by appropriate technical disciplines.”

The following key contributing factors were identified:

- There was a perception of management pressure to complete the sampling operation.
- The engineer available on site for providing work instructions was not as familiar with the system as the cognizant engineer.
- A decision was made not to base the back flush instructions on a method described in the existing System Description.
- Uncontrolled drawings were used to verify valve line-up for the back flushing operation.
- The System Description did not reflect the current configuration of the sampling station.
- The location of Valve HV-0213 made verification of valve position very difficult.

The primary corrective action put in place following the event was the development of procedures for the sampling operation and other similar operations that included the

appropriate hazard analyses to ensure that the necessary defense-in-depth and controls were established.

Chemical Agent Exposure – U.S. Army Chemical Materials Agency Tooele Chemical Agent Disposal Facility, Tooele, Utah

TOCDF is a chemical agent munitions destruction facility that has processed both nerve and blister agents. The facility includes four incinerators for agent destruction – two liquid incinerators (LICs), a metal parts furnace (MPF) and a deactivation furnace (DFS). In short, the process involves draining the agent from the munitions bodies or items (e.g., ton containers, spray tanks, etc.), transferring the liquid agent to one of two LICs for incineration, processing energetics through the DFS, and processing the remaining metal parts/items through the MPF. This particular event occurred during what is referred to as a “changeover” period, when the facility is non-operational following completion of an agent campaign, and preparing for the next campaign. During this period, the facility equipment has been decontaminated to a specified level (determined by air monitoring) that allows work to be conducted within certain areas in a lower level of personal protective equipment (PPE). In July of 2002, TOCDF was in a changeover period following completion of the agent GB (the nerve agent also referred to as Sarin) campaign and making preparations for the future VX agent destruction campaign.

On July 15, 2002, two workers were conducting maintenance on one of the LICs (referred to as LIC 2). The maintenance involved installation of a modified air pressure regulator. TOCDF had performed a similar installation of a modified air pressure regulator on the other LIC (LIC 1) several months prior when the facility was still processing GB. The workers removed (using a wrench and by hand) a section of pipe containing the existing air pressure regulator and placed it on the floor. Immediately thereafter the air monitor being used to monitor GB during the maintenance work went into alarm. The workers exited the immediate area and changed their masks to those that offered a higher protection factor. During the change of masks, some of the contamination that was on the glove of the worker who handled the pipe contaminated that worker’s head area and resulted in agent exposure which was confirmed via medical evaluation. Note that there were also factors pertaining to the response and the length of time to decontaminate the worker that may have contributed to the exposure. For the purposes of this analysis, the focus is on the initiating event and the root and key contributing causes that led to it.

A Board of Investigation was established by the Army to determine the causes of the incident and recommend corrective actions to preclude future reoccurrence of this and similar incidents at TOCDF. The Board utilized an event and causal factor analysis process to investigate the incident in accordance with Department of Army (DA) Pamphlet 384-40, “Army Accident Investigation and Reporting.” The investigation determined that the prior air pressure regulator replacement work on LIC 1 had identified the failure of two check valves and a block valve that were intended to prevent backflow of agent into the air purge system associated with the incinerator feed system.

LIC 2 was configured with the same backflow isolation devices (Figure 2 provides a simplified schematic of the LIC Feed System). Since the maintenance work on LIC 1 was conducted during agent operations, there was more rigor in work planning and associated PPE selection; the LIC 1 pressure regulator replacement work was conducted in a fully encapsulated chemical protective suit with supplied air, referred to as a Demilitarization Protection Ensemble (DPE). Unfortunately, the lessons that could have been learned from the LIC 1 work did not get transferred to support the work planning for the similar maintenance on LIC 2. In addition, the work planning for the LIC 2 job was done primarily by the maintenance department and did not include sufficient involvement or review by the Engineering and Safety organizations. A bad assumption was made by those planning the work that TOCDF was in a decontaminated configuration; in fact, only external surfaces had been cleared and this particular maintenance evolution required breaking into the internal piping, with no steps for confirming the integrity of the internal air system. PPE specified for the job was a full face industrial respirator, overalls, and leather boots and gloves, which did not adequately account for the potential presence of agent.

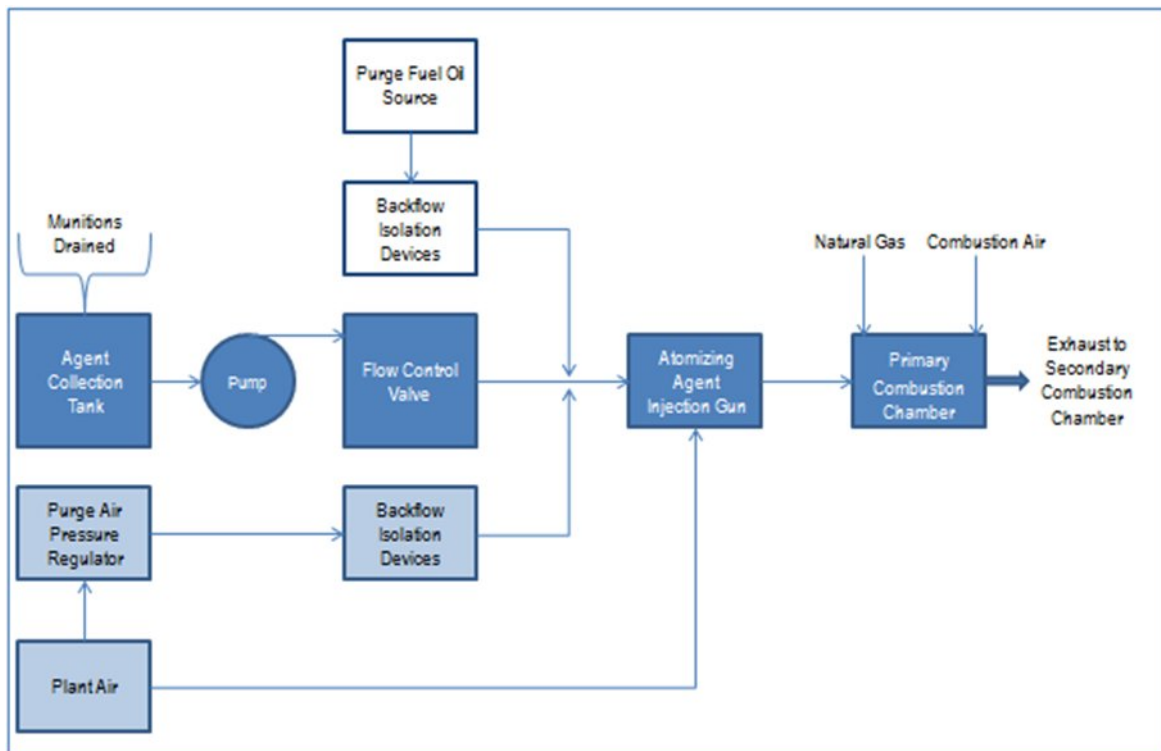


Fig. 2. Simplified schematic of the LIC Feed System.

The investigation revealed multiple shortcomings in the areas of: (1) worker safety, including work planning; (2) engineering, operations, and maintenance, including process safety and configuration management; (3) hazard communication and lessons learned; and (4) management involvement and oversight. The investigation concluded that the following root causes led to the incident:

- Failure to establish a TOCDF-specific lessons learned program that disseminated the information to the workforce.
- Poorly defined roles and responsibilities for the Safety and Engineering groups that did not require active participation and oversight of non-routine work.
- A lack of management involvement and oversight of non-routine activities during an outage involving many changes to TOCDF in preparation for a new agent campaign.

The following summarizes the key contributing factors (note that the investigation revealed many other contributors related to both the event and the response to the event; the below highlights the primary contributors to the initiating event):

- Inadequate non-routine work planning and pre-entry planning.
- Procedure non-compliance.
- Inadequate consideration of process safety basis in engineering change proposals.
- Failure to follow hierarchy of controls.
- Failure to recognize potential agent hazards during a changeover period.

The Board of Investigation concluded “When considering all of the findings and observations collectively, there appears to be a common theme involved in the issues discussed in this report; one can refer to it as ‘safety culture’. In the context of this report, the term ‘safety culture’ is used to describe a set of attitudes and attributes reflected in workers, Supervisors, and Managers that safety is the fundamental priority and prerequisite for doing work.” The report goes on to describe the attributes of a healthy safety culture, to include working in a structured, disciplined manner; observing the hierarchy of controls in work planning and execution; and providing an atmosphere that encourages the workforce to participate in near miss reporting, promotes technical inquisitiveness, and reinforces individual accountability for safety.

TOCDF was non-operational for an approximately nine month period following the chemical exposure event. Significant process improvements were put in place to include an entirely revised, team-based work planning process; revised engineering procedures for more robust configuration management; and a process for routine agent boundary verifications. In the spirit of continuous improvement, TOCDF continued to pursue many management initiatives that led to additional and significant performance improvement well after the event, to include more effective management engagement through a manager/supervisory leadership development program; new condition reporting, cause analysis, and corrective action processes; and the development of a key performance indicator program.

Caustic Burn During Toxic Entry – U.S. Army Chemical Materials Agency Tooele Chemical Agent Disposal Facility, Tooele, Utah

Approximately six years following the agent exposure event, and following a period of full implementation of the many process and management-related improvements that

were instituted in response, TOCDF experienced an event that reinforced the concept that once an organization believes it is approaching excellence, it is at risk of slipping backwards in performance. On May 7, 2008, two workers made an entry into an area within the TOCDF Munitions Demilitarization Building (MDB) to perform maintenance on a piece of demilitarization equipment, as well as several routine Preventative Maintenance items (PMs). The level of protection worn was DPE (a fully encapsulated chemical protective suit with supplied air). Work within the MDB can involve tight spaces and the potential for suit tears from contact with equipment. The entry procedure requires frequent “suit checks” by entrants, including prior to personal decontamination activities. During this entry one of the workers experienced a wet sensation in the shoulder area and asked the other worker to assist in a suit check, which resulted in the discovery of a small tear in the area of the wet sensation. As a result of the personal decontamination activities utilizing 18% sodium hydroxide solution that occurred just prior to the identification of the suit tear, the worker sustained a caustic burn to the left shoulder area.

An internal management-led root cause investigation was chartered, with participation from subject matter experts from the Umatilla Chemical Agent Disposal Facility (UMCDF) to provide an external perspective on entry control processes. An approach using event and causal factor analysis was taken to determine root, apparent, and contributing causes in accordance with the site-specific cause analysis procedure. DPE entries at TOCDF are videotaped and the tapes are maintained for a period of time, which was an invaluable tool for the investigation team. The videotape from the entry that resulted in the caustic burn was reviewed and revealed that entry procedures for performing suit checks were not followed and also revealed other procedure non-compliances. In addition to that videotape, those from other similar maintenance entries were reviewed. The entry videotape reviews, coupled with results of personnel interviews and document reviews, made it clear that the lack of procedure compliance that contributed to this event was not an isolated occurrence and that the lack of procedure adherence and poor work practices were known by supervision and not corrected.

The root cause of the event was determined to be:

“High hazard work has become routine and allowed complacency and poor work habits to develop; management has failed to identify and correct the issues due to a lack of oversight.”

Key contributing factors to the event included:

- A continuing overall lack of procedure compliance culture.
- Real or perceived pressure to complete DPE entry tasks.
- Ineffective work planning; particularly with respect to the use of generic safety plans, inconsistency in the level of detail provided within work packages, and inconsistent implementation of the team-based integrated work planning concept.

- Lack of demilitarization equipment reliability which has contributed to reactive, as opposed to proactive work planning.
- Lack of a clear and consistent entry control process.

Corrective actions implemented following this event substantially improved entry performance. Actions included:

- institutionalizing senior management expectations for management assessments of entries;
- a review and revision of PM instructions to ensure correct work steps and that hazards are analyzed and appropriate controls established;
- establishing clear accountability within the work control procedure;
- developing a revised entry control process that included increased resources to manage toxic entries;
- establishing a team led by Engineering to proactively manage demilitarization equipment maintenance and improve reliability; and
- establishing an employee-based team focused on cultivating a questioning attitude during toxic entries and improving entry performance.

Incidents and Adverse Trend Leading to Operational Shutdown of Water Treatment Plant – DOE Legacy Management Tuba City Site, Tuba City, Arizona

The Tuba City Disposal Site is located within the Navajo Nation, in the area of a former uranium mill that was remediated under the Uranium Mill Tailings Radiation Control Act. DOE completed site remediation in 1990; all mill tailings and remediation debris were consolidated within an on-site engineered disposal cell. Following site remediation, long-term surveillance and maintenance activities have been primarily associated with maintaining and monitoring the disposal cell, monitoring groundwater, and operating a Water Treatment Plant (WTP) to reduce levels of uranium and other constituents in the groundwater.

Over an approximately two-year period in 2009 and 2010 there were reoccurrences of operational issues at Tuba City related to water chemistry, clogging of the evaporator pond drain line, acid management, and poor condition of system equipment and components. The WTP was shut down in October 2010 following an acid tank overflow incident. Shortly thereafter two additional operational incidents occurred involving the acid tank system: (1) a minor acid burn to a worker's face and (2) an acid tank drain line flange leak. These incidents prompted the Legacy Management Support (LMS) contractor to charter a root cause analysis of the collective adverse trends and determine actions necessary prior to WTP restart.

An investigation approach using event and causal factor analysis, in accordance with LMS program-specific procedures, determined the following root causes:

- Management failed to recognize system design flaws, understand process chemistry, identify the lack of maintenance and inspection activities in

assessments, and recognize and control hazards associated with the design and with operational workarounds.

- There was a lack of accountability regarding corrective action response, identification and control of operational and maintenance issues, and analysis of incident trends. In addition, sufficient management mentoring and support were not provided for the Tuba City staff and operations.

The root cause analysis also prompted two additional reviews, to include an independent third-party engineering evaluation of system safety and operability, and a LMS program-wide conduct of operations assessment that included Tuba City and the other primary LMS operational facilities. A lessons learned report was generated that captured the collective results from all of the reviews and provides the following lessons from the Tuba City experience that also provide insight to the key contributing causes to the October 2010 WTP shutdown:

- Conduct of operations must be graded appropriately, to consider the wide range of facilities and operations within LMS; in the case of Tuba City there was a lack of understanding of the level of rigor required for operations and work planning considering hazards such as bulk storage and use of 93% sulfuric acid.
- LMS processes must maintain the appropriate level of engineering and software configuration management across its varied locations.
- Senior management must properly balance project management and line/operations management priorities.

Following the cause analysis, the safety and operability assessment, and the conduct of operations assessment, LMS determined the suite of corrective actions necessary to support restart which included: (1) an enhanced program for management oversight and support to include the establishment of new site operations manager and process engineer positions to provide the necessary on-site support to operators, (2) significant equipment modifications and repairs, (3) revision to the LMS work control process to increase rigor in corrective maintenance planning, (4) the development of a preventative maintenance program that had not previously existed, (5) the development of an operator training and qualification program that had not previously existed, and (6) significantly revised operational procedures that included step-by-step instructions as opposed to general descriptive language. The Tuba City WTP was non-operational for nearly a year while plant repairs and process-related corrective actions were implemented.

CONCLUSION

A review of the root causes and key contributing causes to the events indicate:

- Three of the four root cause analyses cite lack of management engagement (oversight, involvement, ability to recognize issues, etc.) as a root cause to the events.

- Two of the four root cause analyses cite work planning failures as a root cause to the events and all cause analyses reflect work planning failures as contributing factors to the events.
- All events with the exception of the Tuba City plant shutdown indicate procedure noncompliance as a key contributor; in the case of Tuba City the procedure issues were primarily related to a lack of procedures, or a lack of sufficiently detailed procedures.
- All events included discussion or suggestion of a lack of a questioning attitude, either on the part of management/supervision, work planners, or workers.

This analysis suggests that the most critical drivers to safety culture are:

- Management engagement,
- Effective work planning and procedures, and
- Procedure adherence with a questioning attitude to ensure procedural problems are identified and fixed.

In high-hazard operational environments the importance of robust work planning processes and procedure adherence cannot be overstated. However, having the processes by themselves is not enough. Management must actively engage in expectation setting and ensure work planning that meets expectations for hazard analysis and control, develop a culture that encourages incident reporting and a questioning attitude, and routinely observe work performance to reinforce expectations for adherence to procedures/work control documents.

In conclusion, the most critical driver to achieving a workforce culture that supports safe and effective project performance can be summarized as follows: “Management engagement to continually reinforce expectations for work planning processes and procedure adherence in an environment that cultivates a questioning attitude.”

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