United States Department of Energy

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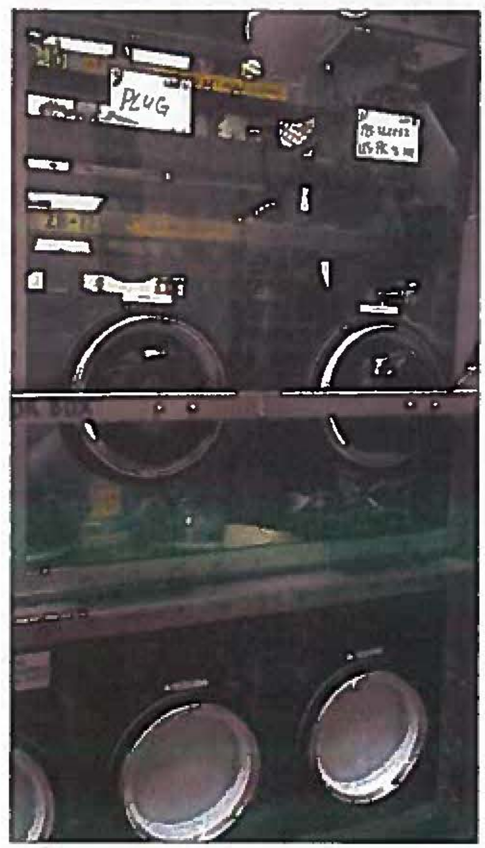
Savannah River Site

SRNS Independent Investigation Team Report: Tritium Unloading Puncture Event (U)



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February 26, 2015

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DATE: 8/26/2025

SIGNATURE

On behalf of the SRNS Independent Investigation Team, the Team Lead respectfully submits the Tritium Unloading Puncture Event Report.

26 FEB 15

Jack Goldenberg
Team Lead

Date

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LIST OF ACRONYMS AND ABBREVIATIONS

AHA	Assisted Hazards Analysis
BBS	Behavior-based safety
CA/MP	Causal Analysis/Mistake Proofing
CARB	Corrective Action Review Board
CIP	Continuous Improvement Process
ConOps	Conduct of Operations
CY	Calendar year
EMS	Emergency medical services
EMT	Emergency medical technician
FLM	First-line manager
FM	Facility manager
GCO	Generator Certification Official
HANM	H-Area New Manufacturing Facility
HPI	Human Performance Improvement
IPC	Immediate Procedure Change
ISMS	Integrated safety management system
MFO	Management Field Observations
OFI	Only for information
OTO	One time only
PPE	Personal protective equipment
R2A2	Roles and Responsibilities, Accountability and Authorities
RBA	Radiological Buffer Area
RMA	Radioactive Material Area
RPD	Radiological Protection Department
RWP	Radiation Work Permit
SAFER	Summarize, Anticipate, Foresee, Evaluate, Review
SAR	Safety Analysis Report
SME	Subject-matter expert
SOM	Site Occupational Medicine
SRP	Standard Revision Process
SRS	Savannah River Site
SRTE	Savannah River Tritium Enterprise
SSW	Senior Supervisory Watch
STAR	Site Tracking, Analysis, and Reporting system
TBL	Technical Baseline List
TRNP	Total Rewrite New Procedure
TWD	Technical Work Document

I. EXECUTIVE SUMMARY

This report documents the results of the independent review of the puncture injury event in the Tritium Facilities at the Savannah River Site on January 27, 2015.[1] The review was conducted by a team of Savannah River Nuclear Solutions personnel not associated with the event who are expert in appropriate disciplines, including facility management, conduct of operations, radiological controls, industrial safety, and engineering; the investigation team also included corporate and company management and a support team.

The investigation team's principal investigative activities were document reviews and personnel interviews. Documents reviewed included pertinent facility plans, reports, procedures/procedure revisions, work permits, work logs, engineering drawings, and training materials.[2] The investigation team interviewed the personnel directly involved in the event as well as other Tritium personnel in pertinent disciplines, such as operations, radiological protection, first-line management, and line management.[3] Comparison of the results of the document reviews and personnel interviews allowed the investigation team to identify discrepancies between policy and practice. The investigation team recognized that safely and efficiently operating non-reactor nuclear facilities demands an emphasis on *how* work is performed above *what* work is completed. If there is excellence in *how* it is done, then *what* is done becomes a natural output. Mitigating the risks inherent in this operational environment requires technical knowledge, inquisitiveness, and discipline.

The January 27 event resulted in minor physical injury; however, evaluation of the event led the investigation team to conclusions regarding latent organizational weaknesses, flawed controls, error precursors, and initiating actions with application to safety and operations in the Tritium Facilities beyond the single event.[4] Major causal factors of the event identified by the investigation team are:

1. Lack of a tool control/sharps program
2. Incomplete execution of the Assisted Hazards Analysis (AHA) Program
3. Non-compliant disciplined operations, specifically in the areas of procedure compliance, pre-job briefing, complacent reliance upon Skill of the Craft, and execution of the Immediate Procedure Change (IPC) process
4. Causal Analysis Process rigor insufficient to capture latent organization weaknesses
5. Facility Operations, Engineering, Safety, and Radiological Protection management lacking in effective engagement, enabling the "drift and accumulation" noted.

Based upon its comprehensive review of the January 27 puncture injury event, the investigation team recommends that facility management take these actions to prevent another such event and to improve safety and operational practices within the Tritium Facilities[5]:

1. Establish a tool control/sharps program.
2. Develop and conduct AHA training focusing on event-related AHA deficiencies.
3. Continue emphasis on Conduct of Operations (ConOps) Improvement, focusing on why a high standard of ConOps is important and correction of non-compliant issues identified during this review. Particular attention should be on proper use of the IPC process and validation of procedures, thorough understanding and compliance with procedures; and adequate pre-job briefings.
4. Strengthen the Causal Analysis/Mistake Proofing and Review Board execution processes with a focus on finding systemic issues.
5. Execute a management plan to strengthen field engagement. Sustainability in this action is paramount.
6. Brief facility personnel on the findings of this investigation team.

[1] See Section IV, "Event Description."
[2] See Section X, "Documents Reviewed."
[3] See Section Y, "Personnel Contacted by Area."
[4] See Section III, "Pre-Work Activities."
[5] See Section VIII, "Recommendations," for expanded explanations and supporting recommendations regarding these over-arching recommendations

II. INTRODUCTION

FACILITY DESCRIPTION

The design of the H-Area New Manufacturing Facility (HANM) facility, which was built in 1994, included space for potential future needs. In 2004, a project was completed that consolidated most of the remaining functions from the old (1955) Tritium Manufacturing Facility, allowing the old facility to be deactivated and placed in a cost-effective, long-term surveillance and maintenance mode. The HANM facility is currently used to remove gases from returned reservoirs using a laser that is mounted on a mobile base and housed in its own secure enclosure. Operators use an alignment laser in back of the cutting laser, in conjunction with a video monitor, to ensure the cutting beam's alignment. The cutting laser beam is directed through a prism, and then passes through a series of containment windows before striking the stem of the reservoir. A series of pinpoint firings cut a hole in the stem of the reservoir, allowing gas to expand into the receiving tank.

SUMMARY OF PUNCTURE INJURY EVENT

On January 27, 2015, two Tritium operators were troubleshooting leaks in an unloading glovebox. One employee was removing an o-ring from an adapter plate. He held a removal tool (Figure A) in his right hand and the adapter plate (Figure B) in his left. During the removal, the employee's right hand slipped, and the removal tool punctured the glovebox glove, nitrile glove, and cotton liner on his left hand, pricking the palm of his left hand and drawing a small amount of blood. The operators notified Radiological Control Operations and Shift Operations Management. Work was halted in the glovebox, and a medical emergency procedure was initiated. An ambulance was requested and responded. The unloading area was barricaded. A baseline bioassay sample was obtained, and a 90-minute bioassay was obtained and sent to B-Area for analysis. A fact-finding meeting was held immediately thereafter to investigate the incident.[6]

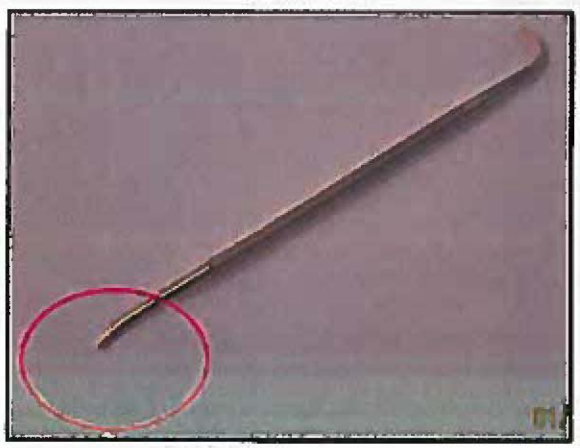

Figure A. O-ring extraction tool designed with shepherd's hook at one end and straight tip at the other end

Figure B. Adapter plate in glovebox

[6] See Appendix A for the full event timeline.

III. PRE-WORK ACTIVITES

The investigation team examined the pre-work activities and planning pertinent to the event through document reviews and interviews of involved personnel from various disciplines (i.e., operations, radiological controls, safety, and engineering). Included in the pre-work activities review were shift turnover activities, the pre-job briefing, the unloading procedure "Fixturing Operations in Unloading", SOP 233-57000 (Rev 42), Assisted Hazards Analysis (AHA) TRI-13433 R2, and Radiation Work Permits (RWP) (15-TRI-003 for the work and 15-TRI-009 for insertion of tools into the glovebox). The following is a summary of what the investigation team learned about the pre-work activities.

During the last half of calendar year 2014 (CY14) the facility had undergone several months of Senior Supervisory Watch (SSW) along with dedicated Conduct of Operations (ConOps) coaches assigned to each shift. The facility operations group has a program that requires managers down to first-line manager (FLM) to perform regular Management Field Observations (MFO). These MFOs provide an opportunity to give coaching and feedback as well as find issues with procedures or work packages. A review of the MFOs done over the last 5 years found no documented MFO on this particular work activity.

After closer examination, the investigation team discovered that procedure SOP 233-57000 (Revision 41) introduced a new section, 4.4, "Special Tools, Measuring and Test Equipment, Parts, and Supplies", which did not include the o-ring extraction kit. The tool listed for o-ring extraction was a pair of needle nose pliers (Figure C).

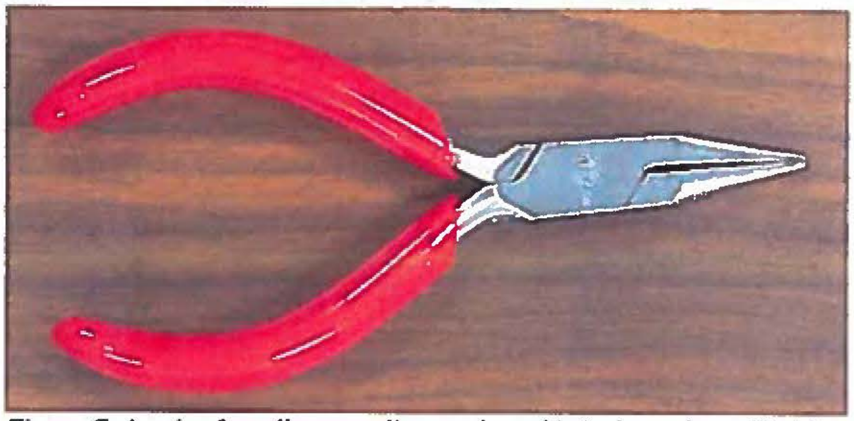

Figure C. A pair of needle-nose pliers such as this is the tool specified for o-ring extraction.

Additionally, a new section 4.5, "Employee Safety", was added that required over gloves be worn over glovebox gloves when exposed to potential sharps. Another new section, 5.7, "Troubleshoot a Position Leak", was introduced. This section included general flow of troubleshooting. Section 5.7.2.c provided the only o-ring related guidance: "Replace O-ring(s) if necessary." All of these changes were introduced utilizing the Immediate Procedure Change (IPC) process and approved on 8/19/14.

The procedure used during the event was revision 42 approved on 9/21/14. As part of the procedure change process, a training review was conducted and stipulated that no training was required.

AHA TRI-13433 R2 was initiated to assess the hazards introduced by IPC # 1 of SOP 233-57000 Revision 42. The Team AHA was performed per 8Q, 122, Revision 9 and Hazard Tree Version 3.05. The Team AHA participants were the Operations Procedure Preparer, Engineering, and Safety Engineer but not anyone who had performed or observed the adapter o-ring replacement task. Consequently, the Team AHA failed to identify a hazard, specifically that a sharp tool was being used to remove o-rings. In addition, the Team AHA participants did not include an operator or Rad Protection. (A review of the last 15 AHAs performed on HANM procedure revisions found that an operator was included only 3 times in Team AHAs.) Neither did the Team AHA participants perform a walkdown of the job, which may have identified that tools other than needle nose pliers were being used to extract the adapter o-ring. Because the use of the o-ring extraction tool was not known to the System Engineer, a technical review was not performed to determine the suitability of the tool in the process environment inside a contaminated glovebox. The AHA was inadequate in that it did not stipulate that puncture resistant gloves were required when replacing adapter o-rings because of sharps. This resulted in the procedure not identifying to the operator that sharps were involved in the task and that over gloves were required for protection. Neither the operators nor the FLM identified the hazards involved in removing the o-ring using needle nose pliers or the o-ring extraction tools.

On January 27, troubleshooting continued to correct process leaks that had been ongoing for several days and turned over from shift to shift. This operation was being conducted in accordance with SOP 233-57000, "Fixturing Operations in Unloading", Section 5.7 Troubleshooting. During turnover, the previous shift identified o–ring replacement for positions 5 and 8 as the next steps to be performed in the troubleshooting section. Previous troubleshooting steps were not documented in the troubleshooting comments section of the procedure as required by step 5.7.4. One of the off-going shift operators stated in an interview that he noticed the o-ring extractor tools were not included in the section 4.4 special tools list but did not turn over that observation to the oncoming operator. Two operators stated that they performed a task analysis but admittedly did not review the "Prerequisite Actions" section. They reviewed only the steps of section 5.7 that they intended to perform that shift. The FLM did not verify that the operators performed an adequate task analysis. The pre-job brief was not accomplished in accordance with the requirements of TRIT-1304 or the 2S manual because an informal pre-job briefing card was used in lieu of a documented brief. Additionally, all items on the pre-job briefing card were not adequately covered. The FLM provided a set of o-ring extraction kit tools to the operators for o-ring removal, indicating that they were the best tools for the job based on past experience. The kit consisted of two brass tools. One tool is designed with a straight tip similar to the tip of a ballpoint pen at one end and a shepherd's hook at the other end (at bottom in Figure D). The second tool is designed with a forked end and a blunt end (in the middle in Figure D).

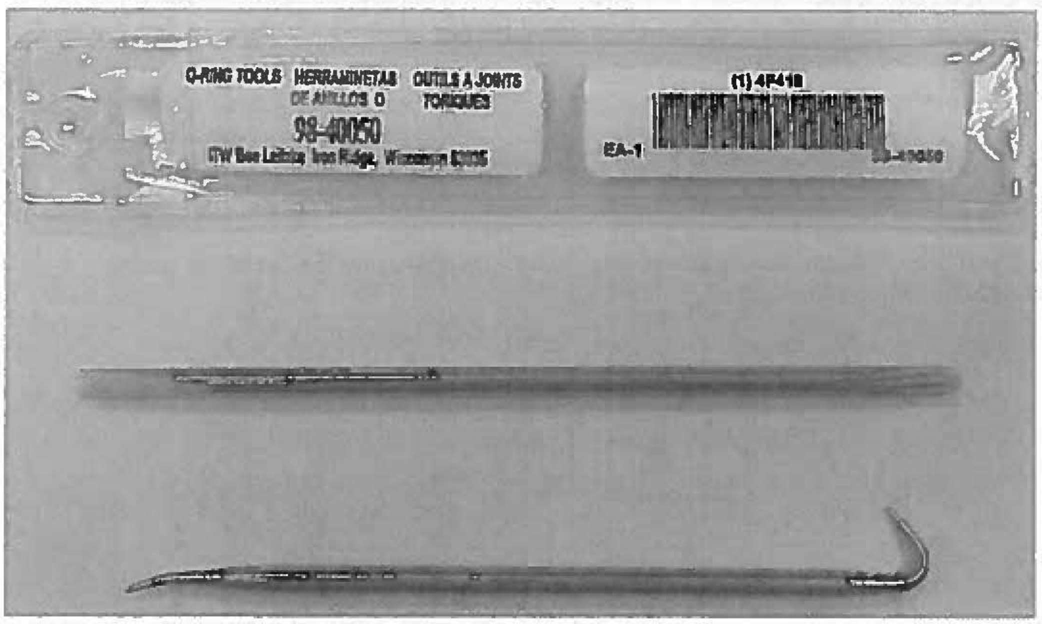

Figure D. The two tools in the o-ring extraction kit

The FLM did not verify that the tools were on the section 4.4 special tools list. He indicated that he did not check that they were on the list since he had always used these tools for this task. Interviews determined that various operators had used these two tools for this task since the mid-1990s. No hazards were identified on the shift turnover or task preview. During the pre-job brief, the FLM discussed pinch points but not sharps. The FLM made a general statement during pre-job brief to wear the appropriate personal protective equipment (PPE) but did not specify what the appropriate PPE for the job should be.

Contributing factors in not identifying the hazards were:

- The procedure at step 5.7 did not identify that the task involved using sharps nor did it require wearing over gloves. Other sections of the procedure provide a note to remind the operator to use the over gloves.
- There were no specific instructions or training on how to use the tools to minimize injury potential.
- The procedure did not require inspection of the over glove before donning.
- The FLM did not warn the operators about sharps in the pre-job meeting when he gave them the o-ring removal kit.
- The operators did not identify the tools used as sharps.
- The FLM and operators did not identify that the o-ring removal kit tools were not approved by the procedure.
- One of the operators interviewed did not know that over gloves were for puncture protection.

While Tritium has done extensive work with SRNL to identify the best glove for puncture resistance, neither operator was wearing the gloves during o-ring removal: One indicated that there was no such warning in this section of the procedure, and the other said that he did not think his tool was a sharp. It should also be noted that the combination of radiological gloves (nitrile and glove liners) with the glove-port gloves and over gloves significantly reduce dexterity and fatigue the hands. While it is not certain that the puncture resistant over glove would have prevented the puncture, it would have reduced the potential.

The Radiological Protection staff was unaware that operators would be conducting these activities in the unloading gloveboxes. However, the activities were considered routine and were within the scope of the two associated Radiological Work Permits:

1. The specific troubleshooting work of removing o-rings is conducted in a RBA/RMA and permitted by Radiological Work Permit (RWP) 15-TRI-003, which states this in the "Job Description" section: "*Routine glovebox work in RBAs and RMAs with glovebox activity ≥ 0.1μCi/cc tritium.*"
2. During fact finding and interviews, it was determined that "tools" were introduced into the glovebox. This action is permitted by RWP-TRI-009, which states this in the "Job Description" section: "*General access or work in CAs (and HCAs posted for tritium only). Activities allowed by this RWP include, but are not limited to, decontamination, **insertion of materials into airlocks through sash hoods**, [emphasis added] RPD duties, housekeeping and job site preparations.*"

When analyzing the pre-work activities utilizing the Anatomy of an Event model (Figure E), the investigation team noted inadequacies that contributed to this event.

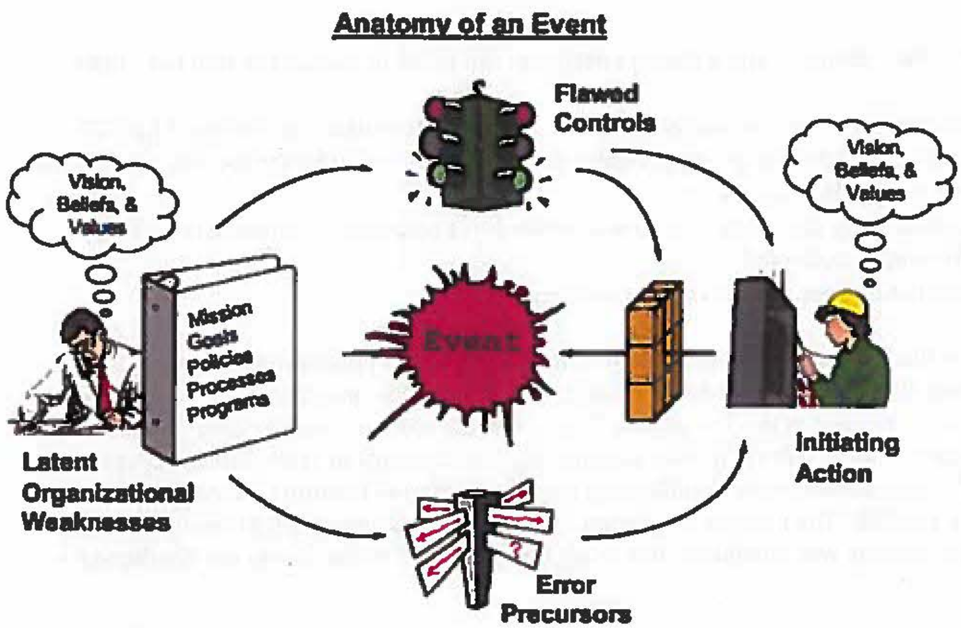

Figure E. Anatomy of an event model

Inadequacies identified by the investigation team are listed below.

Latent Organizational Weaknesses:
- Absence of a formal sharps/puncture/laceration hazard control program.
- Absence of a formal tool control program.
- Inadequate AHA and procedure development (Team AHA did not involve all pertinent disciplines.)
- Improper utilization of the IPC process.
- Inadequate Job Task Analysis with respect to Skill of the Craft tasks and resulting training requirements.
- There was no record that o-ring removal had been observed (i.e., MFO).

Flawed Controls/Defenses:
- Pre-Job Brief was less than adequate in scope, hazards, and controls.
- Inadequate procedure steps for addressing sharps.
- Task Preview was inadequately performed.
- Mindset that use of the tool, based on Skill of the Craft, became accepted practice for twenty-two years preventing a formal hazards analysis process.

Error Precursors
The investigation team identified these precursors to the puncture injury:
- Lack of or unclear standards with respects to sharps and tool control
- Unfamiliarity with task/first time (adapter o-ring – recognized as most difficult and least frequent troubleshooting step)
- Interpretation Requirements – operator interviewed believed over glove was for rad vice sharp protection
- Assumptions – tool was authorized for use
- Inaccurate risk perception – didn't view tool as a sharp

Initiating Actions

- Procedure preparation was less than adequate since the tool used was not listed in the special tool list of the procedure.
- Neither the FLM nor operators showed a questioning attitude about why the tool that they had used for >20 years was not present in the glovebox, why the wrong pre-job brief form was used, why the tool was not on the tool list, or why there had been no training on tool use.
- First time adapter o-ring replacement by the operator who was injured, yet no behavior-based safety (BBS) observation, MFO, or FLM oversight conducted.
- The opportunities to call a time out and get issues resolved were missed.

Facility Management did review the issue of sharps and puncture hazards after the puncture wound in a site transuranic (TRU) facility in June 2010 and determined that the level of rigor of the puncture prevention program required in the TRU facility was not needed in the Tritium Facilities. Tritium workers were briefed on the TRU event, causes, and corrective actions. Some risk mitigation actions, such as warnings in procedures, were taken. The evaluation of the Tritium Facilities determined that the only glovebox with the potential for punctures from sharps was the unloading box in HANM. The investigation team's review of the January 2015 event pre-work activities indicated that while an analysis was conducted following the June 2010 event, it was not conducted at an adequate depth of detail.

IV. EVENT DESCRIPTION[7]

In addition to reviewing the pre-work and planning activities pertinent to the puncture injury event, the investigation team reviewed the physical event itself.

As described in the pre-work activities section of this report, on the morning of January 27, the off-going shift turned over the continuation of troubleshooting, in accordance with SOP 233-57000, section 5.7, on two positions. The on-shift FLM conducted a general pre-job briefing for two operators, handed them an o-ring extraction kit, and the operators departed for the worksite. The FLM was not present at the worksite while the work was being performed.

Operator A (injured operator) dressed out, entered the contamination area (CA), opened the glovebox airlock sash hood, and passed in new o-rings and the 2 o-ring extraction tools contained in the o-ring extraction kit. Operator B retrieved the o-rings and one of the tools and proceeded to work on an o-ring at position 8 while Operator A was exiting the CA. Operator B did not wear over gloves during the evolution because he did not consider the tool he was working with to be a sharp. The particular o-ring extraction tool he was using for work was blunt on one end. Operator B was able to remove the o-rings at his station using the second tool with blunt and forked ends. Operator A proceeded to enter position 5 and evaluated o-rings at this position. Operator A determined that the o-ring on the adapter plate was degraded and needed replacement. He proceeded to remove the o-ring from the underside of the adapter plate with the pointed end of the second tool while holding the adapter plate in his left hand and the tool in his right hand. After some difficulty and multiple pushing motions, the tool slipped and penetrated through the 30 mil butyl glove-port glove (Figure F), the nitrile glove (Figure G), and the cotton liner (Figure H) with a glancing blow, breaking the skin on his left palm near the thumb (Figure I).

Figure F. 30 mil. butyl glove-port glove

Figure G. Nitrile glove

Figure H. Cotton liner

Figure I. The puncture wound to the left palm of Operator A

[7] See Appendix A, "Full SRTE Puncture Injury Timeline," for additional details.

He also was not wearing over gloves (Figure J). In an interview, Operator A stated that he believed the over gloves were for contamination control. In Part 2 of the fact finding, Operator A said he recognized that over gloves should be used when dealing with sharps and he now recognized that he was using a sharp, but stated that the over gloves were not present in the glovebox nor did the procedure flag him to use them. Additionally, he recognized that he used the tool in an unsafe way by applying a significant amount of pressure with the sharp pointed towards his unprotected hand that resulted in the puncture wound to his left hand.

Figure J. 20 mil. over glove

During the performance of the work, the System Engineer was not present, but was notified of the injury the same morning. The System Engineer initially thought the needle nose pliers listed in the procedure was used improperly or that a different tool, such as a screwdriver, had caused the injury. The System Engineer was surprised that an o-ring extraction tool had caused the event.

The event became a radiological event when the glove-port glove as well as the PPE were compromised and the individual's hand came in direct contact with a tritium-contaminated item. The puncture of the skin with potential deposition of radioactive material into the individual's body added directly to the complexity of the event recovery. Specifics related to radiological control actions at this point are covered in the Event Response Actions section of this report.

A Phase 1 Fact Finding Session was convened at 1500.

This event and its radiological impacts can be directly tied to the absence of a co-located hazard control, cut/puncture resistant gloves, in the presence of sharps. Flawed industrial safety and ConOps defenses removed barriers to the engineered control of the glovebox gloves. The Assisted Hazard Analysis (AHA) process should have been the mechanism to identify collocated hazards and to provide controls sufficient to mitigate the risks. However, the absence of direct radiological protection and operator subject matter expertise in the AHA review and discussion process, in addition to the failure to walk down the job, contributed to the failure to ensure that controls were clearly identified and prescribed for this work. Because the Team AHA participants did not include anyone who had performed or observed the adapter o-ring replacement task, the Team AHA failed to identify a hazard, specifically that a sharp (extraction tool) was being used to remove o-rings. The execution of the AHA process was not adequate in that an operator was not part of the Team AHA.

V. EVENT RESPONSE

The investigation team's review of the actions taken by the affected operators, the radiological protection staff, the operations staff, the emergency response staff, and the medical staff indicates a high level of performance. All parties acted decisively and correctly.

Once the puncture occurred, Operator A removed his arms from the glovebox, while Operator B notified radiation protection, the control room, and the FLM. Operator B then tied off the punctured glove to prevent oxygen in-leakage.

EMTs were notified that an employee had received an injury in HANM. When EMS arrived at HANM, the injured employee had just completed decon and the Tritium First Responders had wrapped the hand in gauze. The EMTs transported the injured person and an RP person by ambulance after determining that the wound was possibly contaminated and the injured person had elevated blood pressure.

From an Integrated Safety Management System (ISMS) perspective, the response to this emergency (potentially contaminated injury) was well executed by all involved.

There are two Human Performance Improvement (HPI) items that may be opportunities for improvement:

1. The medical response to a contaminated injury is focused on transuranic or fission/activation products. The assumptions and unfamiliarity of the task of dealing with Tritium contamination were new to the medical staff. However, the execution of the response procedure was an excellent exercise in that this was a real event with very low radiological risk. A review including both the medical personnel and radiological protection staff may identify additional improvements to the recently revised medical procedure. Medical evaluated and treated the injured employee using Manual Q3.1, Procedures 2401, "Chelation" and 2402, "Treating Injuries Involving Radioactive Contamination".
2. A latent organizational weakness may be that there has never been an analysis of a tritium puncture wound and the differences in response to a more significant TRU or beta-gamma contaminant. Specifically, the ability to assess the potential dose consequence and estimate a bounding dose is very rapid for tritium. However, the administrative restriction process is the same whether the preliminary dose estimate is rapid (i.e. within 30 minutes) or requires up to a week.

Again, overall the response to this event was excellent.

VI. ANALYSIS

ANALYSIS FROM A FACILITY MANAGEMENT PERSPECTIVE

Based on interviews with managers from the director down to the FLM level and two production operators this particular work activity was not considered to have a high potential for a puncture injury. Everyone interviewed could see after the fact that the tool being used in the manner it was used was a hazard but did not see it prior to or during the work evolution. The manner in which the procedure was revised to add the tool list did not involve the proper level of operations participation nor did it require any level of training. It was evident that the normal AHA and procedure development process used would not have ensured that tools being proposed for introduction into the work space would be properly evaluated for need and proper usage. A formal tool/puncture/laceration hazard control program (such as 235-F and H-Area) would drive the proper tool controls, procedure reviews by the appropriate subject matter experts, and training on proper use of tools.

When asked about how hazards are managed in the facility or how management helps keep workers protected from hazards no one mentioned the BBS program. Even though the operators were relatively inexperienced and this was the first time Operator A was replacing the adapter o-ring, recognized as the most difficult to replace, no BBS observation or MFO was conducted. A review of the BBS statistics for Tritium shows a decreasing trend in the number of active and participating observers. Since the event was the direct result of at risk behavior (not using the over gloves and tool used in an unsafe manner), the downward trend of observations could be viewed as an error precursor to this event.

With the preceding issue in mind, the FLM was not present at the job site while the work was being performed. Interviews conducted indicate that FLMs can have up to 7 operators under them at any time, and have a significant administrative burden placed on them which prevents them from observing a lot of work in the field. Since observation of field work is arguably the most important job of an FLM, Facility Management should have known of this condition and taken appropriate measures to improve this situation.

Staffing issues and organizational structure were mentioned in several of the interviews. Like everywhere else on the Site, Tritium is dealing with attrition from both the experienced workers retiring and the newer workers leaving after only a couple years. The two operators involved in this event had less than 5 years of total experience and were doing an activity that is only performed once or twice a year. One experienced operator stated he had not performed that specific activity in the last 2 years. While o-ring removal is performed every few months, a review of MFOs performed over the last 5 years found no MFOs were performed on o-ring removal. Additionally, the MFOs reviewed provided few opportunities for improvement, nor did they point out program or technique deficiencies/improvements.

The Fact Finding was not critical enough. Responses in the Fact Finding were written in a manner to defend performance. The actions recommended by the Causal Analysis/Mistake Proofing (CA/MP) did not go beyond issues directly related to the natural team. It did not discuss systemic issues with the procedure revision, worker involvement in Technical Work Document (TWD) development, tool and sharp control, or lack of management oversight. See Appendix C for additional information about the Tritium Facilities Fact Finding and CA/MP related to the puncture injury event.

ANALYSIS FROM A CONDUCT OF OPERATIONS PERSPECTIVE

This event exhibited multiple operational deficiencies including inadequate procedure administration, log keeping, task analysis, pre-job brief, procedural compliance, and improper use of tools. The following items were gathered from interviews and review of data supplied by facility.

An Immediate Procedure Change (IPC) was used to insert the new troubleshooting section into the procedure as well as a new tool list. The reason given for the IPC was "procedural enhancements". Per 2S, IPCs are limited to those changes required to continue work in progress, to support temporary modifications, or for critical activities as identified by the procedure owner. This procedure change did not fall within the defined scope of an IPC. Additionally, the procedure owner both prepared and validated the IPC, which is not the intent of the 2S manual. Per 2S, the procedure owner determines if a validation is required. The intent is that if a validation is required, an end user should validate. Interviews with management personnel indicated that the practice of procedure preparers validating their own procedures was very common prior to issuance of the recent Standing Order prohibiting it. The IPC request form indicated that no training and no AHA were required. The reason the procedure owner gave for not requiring an AHA is that he did not consider the tool he approved for o-ring removal (needle nose pliers) to be a sharp. He was unaware that some operators preferred to use the o-ring extractor tools because he only received input from one operator. The IPC form was concurred to by Engineering, GCO, and RPD.

The process by which this particular IPC (which added new sections including tools) was approved indicated that that there may be a more widespread issue of IPCs being utilized in a fashion inconsistent with the 2S manual. The investigation team requested the numbers of all types of procedure revisions performed in the last 6 months at the Tritium facility. There were 697 IPCs, 68 Standard Revision Processes (SRPs), and 64 Total Rewrite New Procedures (TRNPs). Interviews to determine why the IPC process was being utilized so often revealed that those interviewed believed that the SRP/TRNP process was too cumbersome to support production goals. It is estimated that an SRP revision takes approximately 3-4 weeks to process and the TRNP process takes approximately 6 weeks to complete, whereas an IPC can be approved within one hour.

A sample of 50 IPCs was reviewed to evaluate their scope and how they were being processed. It was found that 21 of the 50 had scopes that exceeded the approved bounds of an IPC per the 2S manual. The Tritium IPC form (OSR-49-005) was also reviewed for consistency with the 2S manual. This form has an option for training required which was unexpected since an IPC is typically only used for minor editorial changes. None of the 50 sampled IPC request forms indicated that training was required. Additionally the training group said that they never see training request from IPCs. However, our review indicated that at least 12 of the 50 sample ICPs should have had required training because procedure changes were being affected which were beyond the bounds of what is allowed for IPCs per the 2S manual. Also, the IPC form does not give the preparer an option to opt out of the validation process per the 2S, therefore someone must sign the validated by block. Of the 50 IPCs samples, 47 were validated by someone other than an end-user (operator). Another issue with the IPC form is that there is no approval block for the SOM to review/concur with the IPC in accordance with 2S section 5.4.3.

When the troubleshooting procedure was turned over to a new shift, the off-going shift verbally described where they were in the procedure, but no troubleshooting comments were documented as required by step 5.7.4 of the procedure. The investigation team was informed that troubleshooting had been going on for 3 days. The lack of documentation recording troubleshooting actions taken was not challenged by any shift. This indicates a lack of questioning attitude by the oncoming operators as well as procedural non-compliance by the off-going operators. The senior operator in the off-going crew stated in an interview that he noticed that the o-ring extractor tool that they normally used was not on the new tool list, but he did not bring it up since he personally did not have to remove the o-ring. This indicates a lack of watch team back-up.

The operators stated that they performed a task preview but admittedly did not review the sections for special tools (4.4) or Employee Safety (4.5). The FLM did not verify that an adequate task preview was performed. Additionally the incorrect type of pre-job briefing was selected for this evolution.

TRIT-1304 makes the following distinction between the different types of pre-job briefings that are to be used:

- *Safety Pre-Job Checklist with Attendance Roster* is the most formal and detailed, and is to be used for first time, non-routine, or infrequent jobs identified as high risk activities…or when the person in charge/manager determines that extra detail and formality is required.

- *Pre-Job Briefing with Attendance Roster* is a "short form" version to be used for routine work activities (such as line breaks inside a glovebox) that are well defined by the controls included within the package/procedure.
- *Safer Pre-Job Briefing Card* is used to perform a pre-job brief prior to initiating very routine work such as equipment calibrations, surveillances...etc.

The least formal type of brief, the SAFER pre-job briefing card, was selected to brief this evolution even though the job involved infrequent troubleshooting actions in a high activity glovebox. Additionally, not all sections of the pre-job briefing card were adequately covered. Nearly all management personnel interviewed indicated that they believed that the card brief was an adequate method of briefing this particular evolution. This led the investigation team to believe that the facility was frequently utilizing the SAFER pre-job briefing card in cases where a more formal documented pre-job brief is required by both TRIT-1304 and the 2S manual. A review of all documented pre-job briefs from the last 6 months was performed. Only 34 were on file and 11 of those were the short form variety. This number seems low considering the number of jobs that are worked at the facility.

A tool provided by the FLM and used by the operators was not included on the procedure approved tools list due to an inadequate procedure review by all involved. Additionally, for various reasons indicated in the above sections, the appropriate PPE was not worn while this sharp tool was used, and the sharp was used in an inappropriate manner by putting the operator's hand in the line of fire. Management interviews indicated that specific training on use of over gloves and tools for o-ring removal had not been given to the operations staff. This resulted in a deficient level of knowledge of safety requirements by the operators and FLM.

From the Conduct of Operations review, it appears that the execution and effectiveness of the Self-Assessment and MFO programs are less than adequate. More evaluation needs to be given to how those programs are executed. In addition, a stricter standard should be established to ensure that issues are recognized by those programs.

ANALYSIS FROM A RADIOLOGICAL CONTROLS PERSPECTIVE

The failure to identify and understand the collocated hazards (radiological contamination and the presence of sharps) led to the failure to properly analyze these hazards and to identify and implement synergistic and complimentary controls. Once these controls are identified and specified in the controlling work documents, i.e., the process procedure, communication of the hazards and the associated controls is critical for the individual worker to execute the work in a safe manner.

ANALYSIS FROM A SAFETY PERSPECTIVE

The Team AHA TRI-13433 R2 failed to identify the hazards involved in replacing o-rings. This resulted in Procedure SOP 233-57000 not identifying that

- The tools normally used to perform the job were not on the approved tool list
- The tools used were sharps
- There was no warning at that step in the procedure requiring wearing over gloves and keeping hand out of the line of fire when handling sharps.

ANALYSIS FROM AN ENGINEERING PERSPECTIVE

The relevant facts pertaining to the puncture wound event were determined from walk downs and interviews of engineering personnel, safety basis authority, and operators. The engineering evaluation included a detailed review of documents pertaining to the design of the unloading fixture for possible latent design characteristics that could pose a significant contribution to the event. The evaluation also included a review of the tools used, the tool selection criteria, and the suitability of the tools in the application. The evaluation also identified the most likely causes, the error precursors, and flawed defenses from an engineering perspective. Finally, the evaluation included the extent of condition of related cultural issues and safety culture from the lessons learned and the corrective actions recommended from the previous puncture wound event.

Unloading Fixture
The fixture was designed by Savannah River National Laboratory (SRNL) during the 1988-1992 timeframe, and has been used since startup operations commenced in 1992. The fixture is shown on SRS drawing W822533 (Revision 13). The unloading fixture is comprised of an adapter plate, an insert, and multiple o-rings that provide a seal between the adapter and receiver pipe, between the adapter and insert and between the insert and the reservoir. Only one adapter plate design is available (with a few exceptions). The adapter plate is fabricated of stainless steel and incorporates a dovetail (i.e. trapezoidal) o-ring groove on the bottom as shown on SRS drawing D816886.

Multiple insert designs are used in the unloading line. A list of insert designs is shown on SRS drawing W822538. The insert sits on top of the adapter plate. The insert is fabricated of aluminum/brass alloy and designed with one o-ring groove on top and one on the bottom. The bottom groove also employs a dovetail design. The top groove employs the more common square shape.

The dovetail groove design on the underside of the adapter plate and inserts provides a more secure seating of the o-ring to facilitate assembly of the fixture components without dislodging the o-rings due to gravity. The o-ring has been installed unlubricated since 2010. To the best recollection of the 1992 startup engineer, the fixture design was performed without consideration for "maintainability". The design did not include a feature (or features) to facilitate removal of lubricated o-rings from the more difficult dovetail groove configuration while working in a glovebox with multiple layers of gloves.

O-ring Removal Tool
The design of the fixture did not include or suggest an o-ring removal tool in the design drawings. Per the 1992 startup engineer, the tool of choice was an o-ring extractor tool similar to the tool used in the 2015 event. The tool was utilized to remove all the o-rings in the fixture without reported issues. Per the best recollection of the startup engineer, needle nose pliers also were used as another general industry tool. However, the use of needle nose pliers can be difficult when the user is clad in multiple gloves and can lead to pain due to fatigue cramping.

The tool used in the recent puncture event came from an o-ring extraction kit that is supplied with two tools in a vinyl case. The length of each tool is approximately 5.5" and fabricated of brass. The first tool is designed with a shepherd's hook at one end and a straight point at the other end similar to the tip of a ball point pen. The second tool has a blunt "scraper type" end, and a forked or "V" shape at the other end that can be used for scooping and scraping to remove o-ring and tightly adhering gasket material. The width of the second tool is approximately 0.125". The brass extraction kit can be used without concern for scratching the sealing surface of the steel grooves that may pose potential leak paths.

Most Likely Engineering Related Causes for this Event
Based on interviews and documents reviewed, the three most likely causes from an engineering perspective were less than adequate A) communications, B) system ownership, and C) design features.

A. Communications
The communication between Operations and Engineering is a major causal factor to this event. The engineers were unaware that Operations was using the o-ring extraction tool to remove o-rings in the unloading line at the HANM facility since 1992. This is a validation of the lack of a strong engineering field presence for this activity. The error precursors associated with this area were:

- Complacency

It is recognized that o-rings become brittle and wear over time and must be replaced. Per interviews with the engineer responsible for startup activities in 1992-93, there was no formal tool selection criteria employed. The choice of the o-ring removal tool was based on tools commonly available throughout the industry. The tool of choice was an o-ring extraction tool similar to the tool used in the puncture wound. The tool selection process was never formally documented. In addition, the startup engineer does not recall who, or which organization(s), selected the o-ring tool during the early 1990s. Since unloading is an Operations function, the engineers speculated that Operations selected the tool. The work was performed by operators numerous times using Skill of the Craft since 1992.

- <u>Inaccurate Assumption</u>

The use of the needle nose pliers was added to procedure SOP 233-57000 (R41) in August 2014 as approved by Engineering, Safety and Operations per AHA TRI 13433 (R2), and is the only tool known to the System Engineers for o-ring removal in the Unloading line. The four engineers responsible over the past twelve years had the misconception that a needle nose plier was being used, even before it was added to the procedure as an approved tool in August 2014. The inaccurate assumption that a needle nose plier was the only tool used in a contaminated glovebox went unquestioned.

As a result, a technical review by the System Engineer to address the suitability of the extraction tools did not occur. The evaluation would typically address metallic compatibility, system impact, space envelope, and the consequence of dropping the tool in the glovebox that could "impact" other equipment, as well as the ability to retrieve the tool.

B. <u>System Ownership</u>

Manual 1-01/Policy 5.38 "Site Engineering Policy" defines engineering leadership, philosophy, expectations, and roles and responsibilities. This policy requires the engineer to challenge old methods of performing work and to strive to make effective changes through innovative solutions and the Continuous Improvement Process (CIP).

Conduct of Engineering Manual E7/Procedure 1.10 defines the Roles and Responsibilities, Accountability and Authorities (R2A2) of the system engineer. These responsibilities include monitoring and tracking of assigned systems and performing informal walk downs on a periodic basis to observe general conditions, such as degrading material, improper configurations, and abnormal equipment performance. This procedure invokes Manual E7/Procedure 3.04 "Performance Monitoring" that requires the engineer to maintain overall cognizance of the assigned systems, to perform trending, and to remain cognizant of system-specific maintenance and operation history. This procedure does not exclude non-safety system that could have an adverse impact on safety systems, operations, missions, and most importantly, that may have the potential to compromise personnel safety.

The responsibilities of the engineer includes not only reviewing calculations, creating designs, and updating drawings, but also to be actively involved in the field, conducting walkdowns and observing field work. Essentially, these procedures and policy, coupled with the System Engineer Handbook, require a high level of engineering rigor and system ownership in all aspects of facility operations. The need for improvement in system ownership and rigor is evident from the engineers interviewed.

As part of the engineering qualifications, the System Engineer is required to receive initial training by witnessing a typical fixturing/unloading operation in the field. However, none of the engineers interviewed had witnessed an o-ring removal. After the initial field training, it was not a practice for System Engineers to witness subsequent fixturing/unloading operations that would include o-ring removal.

The error precursors associated with this area can be attributed to:

- <u>Complacency</u>

None of the engineers interviewed had any knowledge the tool was being used. The engineers during the past twelve years never witnessed the removal of o-rings in the field or in trial runs. Although considered routine, one engineer proactively witnessed the unloading task again after training, but not the o-ring removal effort. The startup engineer responsible in 1992-93 witnessed o-ring removal, but was not the System Engineer during full operations. In addition, the engineers had not attended a pre-job briefing because the task was considered routine.

The responses received from engineering showed the need for improvement in engineering oversight, system ownership, and technical inquisitiveness.

- Engineering Turnover

Per information gathered from the interviews, approximately eight engineers were assigned to the Unloading system from 1998 to the present. This represents an average of about two years' tenure per engineer. This turnover rate could lead to unfavorable continuity in system oversight and knowledge transfer, as the system is turned over to multiple subsequent engineers after short periods of ownership. The turnover rate could also contribute to a drift in engineering formality and a drift into error precursors from technical inquisitiveness. One engineer stated that an engineer could be system qualified but inexperienced due to the short tenure. Another engineer commented that the Unloading System was a stepping stone to other more significant and more desired systems.

C. Design Features

The underside of the adapter plate contains a dovetail groove for one o-ring about 6.75" inside diameter and a cross-section of 1/8". The adapter plate is removed about once per month to change a window; but its o-ring is replaced every 6-12 months to resolve leakage problems. Per the operators interviewed, an adapter plate o-ring with 6-12 month service life is very difficult to remove. An o-ring with less than six month service is relatively easier to remove. The o-ring with longer service life is badly dry-rotted, is very hard and stiff, and with a near-flat appearance. Aside from alignment issues, the degraded condition of the 6-12 month adapter o-ring is one of the causes for the leakage problems.

Under ordinary situations in a clean area, removal of an o-ring from a dovetail groove requires a little more effort while wearing leather gloves. This effort but can be quite challenging in a contaminated glovebox while wearing multiple protective gloves.

The o-ring replacement effort on the adapter plate takes up to 30 minutes to remove and up to 20 minutes to install for a total of up to one hour depending on o-ring condition and operator experience. The use of multiple gloves made o-ring replacement cumbersome and time consuming. The operators stated that many pushing motions with the tool is needed while dressed in multiple gloves inside a glovebox. A strong engineering presence in the field could have identified the need for operator training on tool use to prevent the use of excessive force. By contrast, the inserts are removed more frequently about once per month, and its o-rings are easier to replace.

During the o-ring removal effort, the adapter plate is held in one hand and the tool in the other. As the operator is pushing the sharp end of the tool with one hand, the other hand is in the line-of-fire and susceptible to a puncture wound should the tool slip away from the adapter groove. A strong engineering presence in the field could have identified the difficulties and the excessive force employed to remove o-rings, and possible improper tool use.

Vacuum grease (a non-petroleum product) was used prior to 2010, as specified on the design drawings, which made for a better seal, kept o-rings supple and afforded protection against embrittlement from the glovebox environment. Vacuum grease was discontinued in 2010 due to Tritium retention in the grease and the permeation of the greater quantity of absorbed Tritium in the grease via the butyl rubber glovebox glove. In qualitative terms, past experience has shown that the discontinuance of vacuum grease in 2010 increased the difficulty of the o-ring removal effort because the o-ring tends to harden more rapidly in the glovebox atmosphere in the absence of the protective film of vacuum grease.

Per interviews with the engineers, the startup engineer, and the operators who struggle with o-ring removal, the fixture design did not consider the following:

- The anticipated numerous o-ring replacements in the process
- The difficulty of removing o-rings from a dovetail groove in multiple gloves
- A suggested best tool for a hard to remove groove configuration

- A small slot in the adapter plate to insert a tool to grab and pull the o-ring
- Radiological contamination issues with vacuum grease
- O-ring service life in the application, with and without vacuum grease
- A fixture or vise to hold the adapter plate stationary (rather than the hand) to avoid puncture wounds from line-of-fire hazards, recognizing that gloves are not puncture proof.
- Increased o-ring embrittlement from the glovebox atmosphere after the discontinuance of vacuum grease in 2010. Design review did not identify a sustainable technical solution. Essentially, the problem was transferred from a RadCon issue to an Operations issue.

VII. CONCLUSIONS

In this section the investigation team presents their conclusions based on each area's interviews and document review.

FACILITY MANAGEMENT AREA CONCLUSIONS

The lack of a formal puncture/laceration hazard control program in combination with insufficient implementation of the AHA process and procedure change management were direct contributors to the event. The protection of the worker from an injury caused by a sharp in the glovebox depended on both his perception of the risk and proper controls being in place in the procedure.

Through attendance at the Phase Two Fact Finding, review of the CA/MP, and review of the Corrective Action process, these management tools were judged to be less than adequate.

The current CA/MP process in SRTE does not have a proper feedback system to ensure results of the CA/MP are deep enough and consistent between CA/MP directors.

Corrective Action Review Board (CARB) issues identified centered on the depth of analysis. The CARB only directed corrective actions for the listed Apparent Causes:

- Formality of Operations
- Procedure Noncompliance
- Inadequate Pre-Job Brief
- Sharps / Tool Control
- Training
- Procedure Revision Process
- Inaccurate Risk Perception.

Broader Issues/Causes were not discussed:

- Did not discuss procedure compliance issues related to the Pre-job briefing performance by the FLM.
- Did not discuss the development of the AHA without input by workers
- Did not discuss engineering roles in the design for maintenance of the adaptor
- Did not discuss the earlier procedure compliance issue with multiple shifts not properly filling out the procedure troubleshooting table
- Did not specifically discuss a corrective action that requires procedure validation by the workforce.

The discussion of inaccurate risk perception focused only on the workforce, and did not focus on management oversight.

CONDUCT OF OPERATIONS AREA CONCLUSIONS

Many of the building blocks of disciplined operations such as procedural compliance, questioning attitude, ownership, level of knowledge, watch team backup, and formality were less than adequate during performance of this evolution, which the investigation team believes directly contributed to the puncture accident. Interviews and review of prior IEB and Defense Nuclear Facilities Safety Board (DNFSB) assessment data indicates that these ConOps deficiencies are not isolated to this specific incident. Multiple areas of improper procedure administration were also identified during this investigation, the most significant being inappropriate use of the IPC process, which appears to be well known and tolerated. The investigation team believes this to be true because the normal revision process is seen by the facility as cumbersome.

As a result of the puncture wound in F area, the Facility Evaluation Board (FEB) in 2010 identified lack of Sharps control for several Tritium procedures including the procedure for unloading reservoirs. The closure statement indicated a SICAM review would be completed on the procedures noted to institute the proper controls. From a review of this accident it appears that this corrective action was not effective. Several instances were noted where STAR items were closed based on future actions or incomplete corrective actions. These findings indicate a problem verifying completion and effectiveness of corrective actions, not only for the short term but for future operations.

There were approximately 300 individual issues (Findings, Observations, and OFIs) recorded in STAR and identified for Tritium from January 2011 through 2014. Issues in selected categories are summarized below: Procedure Compliance - 38 issues, PPE – 25 issues, Ladders/Scaffold/Elevated Work – 25 issues, Lock-Out/Tag-Out – 14 issues, AHA controls not in TWD – 14 issues, Pre Job Brief – 11 issues. Some of the items that are directly related and are potential precursors are listed below:

- Observed an informal pre-job briefing (PJB) for WO# 1204742-02, Adjust Vibration Switch Per Vendor Instruction or Engineering. The PJB did not cover the SAFER Task Preview, as required by 2S, Procedure 2.1, section H.5.c
- Pre-job to cover T/S of alarm on ZR.288L and to replace T/S thermocouple in HANM did not cover the minimum items require per 18Q procedure 2, for electrical work.
- The IPC request form (OSR 49-005, Revision 21) used and controlled by the facility allows for One Time Only (OTO) IPCs to be exempt from validation. Since OTO-IPCs can be performed on technical procedures and Manual 2S, Proc.1.1, Step 5.4.2.6 states that the Procedure Owner must determine if the change warrants a validation; therefore the OTO-IPC should not get an automatic exemption.
- Changes to operating procedures were made using the IPC process that did not meet the criteria of Manual 2S, Proc. 1.1, Step 5.4.1.1 for IPCs. SOP 234-H-311, Revision 0 changed the purpose and scope of the procedure with IPC-1, SOP 233-54039, Revision 16 was changed to add a new bottle type to the procedure "until separate procedure is written" (i.e. using an IPC to create a new procedure). There were also IPCs that made changes on 10 or more pages of the procedure and did not appear to be necessary for continuing work in progress.
- For TPBAR cutting, the datasheet (DS-6-RS-001) was observed being used instead of the Use Every Time (UET) procedure (SOP 264-H-5223). Even though the facility inserted a statement in the procedure to allow this practice, the failure to use the steps in the UET procedure 5233 as written to perform the evolution did not comply with Manual 2S, Procedure 1.3 requirements "Whenever technical [Use Every Time (UET)] and/or response procedures are performed, verbatim compliance with the procedure is mandatory (i.e., the procedure shall be present and in use with each step performed as written)." Management's decision to allow a deviation which was not in accordance with Manual 2S, Procedure 6.1, Alternate Implementation Approval, and Manual 1-01, Procedure 4.20, Conduct of Operations.

A fundamental tool in our safety and ConOps arsenal is procedure compliance. If a procedure is not understood, or is incorrect, then the workers are expected to call a time out, another HPI tool. Meaningful pre-job briefs with all workers associated with the evolution are needed to heighten awareness, understand scope, hazards, and engage the workers before they take an active role in their assigned tasks. Not following procedures as-written is unacceptable.

RADIOLOGICAL CONTROLS AREA CONCLUSIONS

Improvements in observing and understanding details of work activities in high contamination areas and environments are warranted. RP subject matter experts should participate in process procedure walk-downs and validation to assure an understanding of task sequence and exposure to hazards (both radiological and industrial). Following this insight and understanding, participation in the hazard analysis process is based on informed understanding rather than assumptions or correlation to perceived similar work and environment.

The Assisted Hazard Analysis (AHA) for this specific procedure was not recognized by the RP staff as containing collocated hazards of radioactive contamination and the use of a tool that was a sharp. The principal Error Precursors that led to this are:

- Task Demands – A combination of error precursors may have contributed to the absence of RP in this specific Team AHA review. Recent staff attrition has caused increased responsibilities and duties to the remaining managers. This has resulted in an increased sense of Time Pressure to accomplish more in the same amount of time, causing the need to prioritize activities and attention. Another aspect of this could be characterized as High Workload and/or being required to do Simultaneous, Multiple Tasks or Role Responsibilities.
- Individual Capabilities – There is no indication that RP staff had ever observed the removal of the difficult o-rings. This Lack of Knowledge may have led to a faulty mental model of "routine or low hazard" work being performed.
- Work Environment – The absence of a sharps control program and a tool control program are flawed defenses which could prevent Unexpected Equipment Conditions and Changes/Departures from Routine actions by the operators.
- Human Nature – there is a distinct difference in the dose implications of an intake of tritium versus a transuranic radionuclide. This can be illustrated in the activity associated with an Annual Limit of Intake (ALI) which would result in a Committed Effective Dose of 5 rem. For Tritium, this value is eighty milliCuries (80 mCi) [inhalation]. For Pu-238, the ALI is 7E-6 mCi [inhalation], or a factor of ~5.7 million. This magnitude may contribute to Complacency or Overconfidence. An Inaccurate Risk Perception may be based only on the health impacts of introducing tritium to one's body as opposed to the perceived life-time impact of a Pu-238 uptake. The individual health consequence, while important, is not the only risk that must be considered. Disregard for contamination control and risking intakes of radioactive material cannot be tolerated regardless of nuclide. A culture of assuring the appropriate controls are in place and maintained is fundamental and essential to performing disciplined nuclear operations.

SAFETY AREA CONCLUSIONS

Execution of the AHA was inadequate. The Team AHA did not involve all required participants (did not have anyone who had performed or seen the job performed before) and did not include a walkdown of the job; therefore the AHA did not properly identify all of the hazards.

The inadequate execution of the AHA resulted in the procedure not:

- Identifying the sharps present in replacing the o-ring
- Warning the operator that an over glove was required for puncture protection and that removal of an o-ring using the o-ring extraction kit was a potential puncture situation
- Instructing as to the appropriate method for o-ring removal (i.e., keep the hand not holding the tool out of the line of fire)
- Specifying the specific type of over glove to be worn
- Requiring inspection of the glove before use.

ENGINEERING AREA CONCLUSIONS

SRS continually emphasizes a safety culture for the protection of its workforce. The HPI tools and the principles of ISMS available to us are not complicated and provide us with the defenses to protect ourselves and our workers from workplace hazards. Our Human Performance Improvement (HPI) error reduction tools and the principles of Integrated Safety Management System (ISMS) are the vanguard of the SRS safety culture. These tools are not passive elements but active hallmarks to be ingrained into our mindset in every facet of our daily duties at SRS.

Complacency, inaccurate risk perception, and faulty assumptions were the error precursors that resulted in the use of a tool that prevented a formal hazards analysis and technical review from being conducted. Less than adequate communication among organizations and individual workers, as well as less than adequate system ownership, were two other apparent error precursors that led to this event, which could have been avoided by a questioning attitude. Hidden system responses during the design and engineering phase of the fixture can be identified through increased technical rigor, as well as frequently exercising the CIP to identify issues to achieve better, safer and more efficient methods throughout mission implementation.

VIII. OTHER ISSUES IDENTIFIED

During this investigation a number of issues were identified that required additional action/follow-up/consideration but were not causal factors in this event. So as not to lose these items, they are provided in this section and are arranged by functional areas used during the investigation.

Facility Management Area Other Issues Identified
The organizational structure currently in place in Tritium appears to put an inordinate amount of responsibility on a few key managers - in particular the HANM Facility Manager and the Gas Operations Manager. Although it does not appear to have been a contributor to this particular event it could become a precursor to future events.

Safety Area Other Issues Identified
IPC changes do not require subject matter expert engagement.

AHA Tree Question 110H does not require the Safety subject-matter expert (SME) to approve the compensatory measures. The Site Safety Manual 8Q Procedure 122 needs to include Sharps as part of Attachment 8.1 Prescreen Criteria, item 4.A.

Tritium does not require inspection of the over glove before use. Per the manufacturer, the glove only has a 3 year shelf life. The "new" glove obtained from Tritium was manufactured in 2007.

Engineering Area Other Issues Identified
Manual E7/Procedure 1.05 requires each facility to maintain a Technical Baseline List (TBL). Tritium maintains their TBL in SmartPlant. The use of vacuum grease was discontinued in 2010. Yet, a technical review revealed that two drawings (re: W822538 and W822533) still require the use of grease on the o-rings. None of the four open amendments against these drawings in DCR is related to grease. The drawings represent the governing documents that form the technical basis for the unloading operations. Procedure SOP 233-57000 removed the use of grease about 4-1/2 years ago that is still required by the governing drawings. One drawing is listed as TBL/GEN and the other is listed as NTB (Non-Technical baseline). This appears to be a discrepancy in Configuration Management, regardless of functional class.

The engineers stated that management provided Lessons Learned from the prior puncture wound events in group meetings. Workplace emphasis was placed on the use of over gloves for puncture protection for the sharp tools known to be used in the Tritium Area; but no formal documentation. Walk downs and "environment scans" were performed for sharps. Engineers did not specifically recall required reading, training, etc. Engineers stated that actions taken did not result in a sustainable long term effect.

IX. RECOMMENDATIONS

In this section the investigation team presents recommendations based on the conclusions stated in the previous section. These recommendations also consider other technical issues presented throughout the report.

FACILITY MANAGEMENT AREA RECOMMENDATIONS

- Develop and implement a program to address puncture and laceration hazards in all radiologically contaminated areas of the Tritium facilities. This program should be modeled after existing programs such as 235-F or H-Area. The program should address tool design, worker training on proper use of tools, review and approval of AHAs and associated procedures or work packages. Selection of controls should involve appropriate subject matter experts.
- The MFO program should be enhanced to ensure that any activity not routinely performed or one being done by a worker for the first time has a MFO performed.
- The value of the BBS program as a means to identify hazards and at risk behaviors to the workers should be reemphasized.
- Improved Fact Finding and Causal Analysis (CA/MP) will provide better input to the CARB, which will drive better corrective actions. Fact Finding and CA/MP results should be reviewed and approved by a predefined Single Point of Contact (SPOC). The SPOC would be charged with ensuring the Fact Finding and CA/MP results are consistent and contain the following attributes:
  - Were the proper disciplines represented?
  - Was the Fact Finding and CA/MP self-critical?
  - Were all the causes identified and can the causal chain be followed?
  - Did the Fact Finding and CA/MP cover deeper systemic issues?
  - Are the Corrective Actions complete (specific, preventive, with defined due dates?)
  - Did the CA/MP identify potential Mistake Proofing opportunities?
  - Were any Systemic issues dealt with?

CONDUCT OF OPERATIONS AREA RECOMMENDATIONS

As a result of the facility going into deliberate operations and stationing Senior Supervisory Watches last summer, a Tritium Facility Performance Improvement Plan (PIP) was established. This plan covers three main areas: Training, Procedures, and Efficiency. While it covers many of the deficiencies identified in this report, the actions to date either have not been implemented or have not been effective. Management should take the following additional actions as well as add these steps to the PIP.

Facility/operations management should:

- Establish a set of ConOps principles for the facility that all training, drills, boards, fact findings, MFOs, etc. are tied to.
- Retrain all shifts on pre-job briefing requirements/expectations. This training should be administered by Facility Managers (FMs).
- Clarify Pre-Job Briefing expectations, including what type steps need to be included and type of briefing to be used.
- Assign a permanent (or long-term) ConOps coach on backshift.
- Add an action step to the pre-job briefing card to decide when a more formal brief is required.
  - Simplify the SAFER task preview/ pre-job briefing card.
  - Set expectations/requirements for operator validation of procedure changes and involvement in AHAs to encourage ownership and engagement.
  - Schedule CARB review of all targeted MFOs.
  - Schedule MFOs across shifts to target high risk work.
  - Require all FMs to attend state of the plant sessions for other facilities (cross training).
  - Complete a facility level 12Q, PA-1 Assessment.

- Institute additional management training for FLMs to set expectations for ownership and responsibility.
- Alleviate administrative burdens from FLMs to allow more time supervising.
- Schedule daily field observations of at least one hour for all managers (no documentation required).
- Evaluate organizational structure to see if the most efficient structure is being used to allow supervision of operators.
- Evaluate need for all FMs to have deputies to spread the workload and allow more time supervising shifts.

Training management should:

- Conduct training on the proper use of procedure revisions, to include when ICPs are allowed, and what the approval/validation process should entail.
- Incorporate ConOps training into the Integrated Operations Seminars.
- Send trainers to shift coverage to ensure ConOps principles are being correctly taught to new employees.
- Implement operator training explaining when and why specific PPE is required for certain hazards.
- Implement operator training on safe use of hand tools.
- Institute significantly more ConOps training to new employees before they report to shift. This should include acting out scenarios and hands-on activities to the maximum extent possible.
- Require the training department to perform frequent periodic evaluations/audits of on-shift operations. Report the results to the Facility Managers.

Procedure management organization should:

- Review the current IPC Request form against the requirements of the 2S and make changes as necessary.
- Reword section 2.1.2 of TRIT-1304 to more clearly define when different types of briefings are required.
- Until the above recommendations are evaluated/implemented, it is recommended that the following compensatory actions be taken:
  - Place ConOps coaches on all shifts. They should attend task previews, pre-job briefings, and observe field activities to set the standard and teach a ConOps mindset. ConOps Coaches should be in place for two to three months prior to initiating Senior Supervisory Watch (SSW).
  - Targeted Senior Supervisory Watches stationed for high hazard/high risk activities and operations slowed so that adequate management attention (Shift Mangers and above) is given to <u>all</u> tasks. (This is different from the SSW noted in the preceding bullet, which is the longer term, "testing" SSW.)
  - Train management on SSW expectations with respect to attitudes, behaviors, and beliefs.
  - All high hazard/high risk procedures/tasks are reviewed using the SICAM process prior to issuance.
  - SOM to approve and log the type of pre-job brief selected for each work evolution in accordance with the requirements of SOP TRIT-1304.
  - SOM to approve the use of the IPC process in accordance with the requirements of 2S 1.1 as well as approve the final approved IPC for incorporation into the procedure.
  - Institute a review of all facility procedures modified by IPCs to ensure:
    - IPC changes did not exceed the scope of what is allowed by 2S 1.1
    - All IPCs received the appropriate reviews and approvals
    - All IPCs received the appropriate validation if required

RADIOLOGICAL CONTROLS AREA RECOMMENDATIONS

While the Radiological Controls support provided during this event was satisfactory, the following opportunities for improvement are provided:

- Review RP management (FLM and Facility Manager) work load against established or expected R2A2 to confirm appropriate level of work load and schedule.
- Identify processes or tasks that take place in higher hazard work environments, i.e. highly contaminated gloveboxes, schedule participation in pre-job walk downs, pre-job briefings, and observe work by various work functions, i.e. Operations, Maintenance, etc. Document observations through Management Field

Observation (MFO) process and identify implications of work activities, techniques, and tools to the associated radiological controls, in particular Radiological Work Permits.

- Provide new RP Inspectors with opportunity to develop contamination monitoring and control skills in facilities which have alpha and beta-gamma emitting radionuclides. This experience will provide direct feedback on radiation survey techniques and reaction to detection which will provide an appropriate paradigm for conduct of surface contamination and dose rate surveys in Tritium. This will also promote understanding and proficiency required for advancement as a Radiological Protection Inspector including job performance measures and oral board examinations. (Contamination control techniques and respect for contamination potential may also be appropriate for reinforcement of other Tritium work groups expected to operate in a disciplined manner in radiological areas.)
- Provide training to RPD personnel addressing this event emphasizing where they could have helped to prevent its occurrence. ConOps fundamentals should be used to address expected culture.

SAFETY AREA RECOMMENDATIONS

- Operators need to be included on Team AHAs.
- RP needs to directly participate in any Team AHA involving intrusive work into a radiologically contaminated containment, work in a high contamination area, or other planned work activities where existing engineered or administrative controls are reduced in order to confirm the appropriate level of controls relative to the known or expected hazards.
- When possible, the Team AHA participants should walk down the task being reviewed.
- Procedure SOP 233-57000 should be revised to specify the specific type of over glove to be worn when handling sharps.
- Procedure SOP 233-57000 should be revised to warn the operator at each step where they may be exposed to sharps and the procedure should include a reminder to wear the over gloves at those steps.
- AHA Tree Question 110H should be revised to require the Safety SME to approve the compensatory measures that the Team AHA specifies.
- The Prescreen Criteria in Attachment 8.1 of 8Q, 122 should be revised to require a Team AHA if the task involves handling of sharps where there is exposure to significant hazards.
- Tritium should develop an inspection for the over gloves which includes replacing the gloves as specified by manufacturer or determine that a longer useful life is allowed based on the application that the glove is used.
- Tritium should conduct an extent of condition review to identify and eliminate where possible sharps and line of fire opportunities.

ENGINEERING AREA RECOMMENDATIONS

Communication between Operations and Engineering was a causal factor to this event. Because engineers are the "technical conscience" for the facility, they must question every piece of information, including routine activities. Continuous communications is a cornerstone of the roles and responsibilities of an engineer.

The following actions are recommended

- The training department and engineering management to administer training on the roles and responsibilities of the engineer. (re: Management Policy Manual 1-01/Policy 5.38 and Conduct of Engineering Manual E7/Procedure 1.10).
- The engineering manager to administer periodic training on Human Performance Tools.

There were a number of system ownership issues identified. The Conduct of Engineering manual defines the Roles and Responsibilities, Accountabilities and Authorities (R2A2) of the system engineer. These responsibilities coupled with the System Engineer Handbook require the engineer to provide oversight, conduct walkdowns, observe field work, perform trending, maintain overall cognizance of the assigned systems, and remain cognizant of system-specific maintenance and operation history. Essentially, the management policy and procedures require a high level of engineering rigor and system ownership in all aspects of facility operations. System ownership and rigor was not at the level expected as evidenced by the engineers interviewed.

As a result of the lack of system ownership, the following actions are recommended:

- The training department and engineering management to administer periodic training to emphasize Manual 1-01 Management Policies and Manual E7 Conduct of Engineering to emphasize the principles of disciplined Conduct of Engineering, system ownership, engineering oversight, teamwork within and across functional boundaries, and continuous improvement to make the activities safer, better, and more efficient.
- The system engineer to revise drawings W822538 and W822533 that still require the use of grease on o-ring, and to evaluate the need to re-designate W822533 as a technical baseline drawing instead of "NTB" in SmartPlant.

The technical issues associated with tool maintainability and the consequences of discontinuance of vacuum grease were not thoroughly evaluated to achieve a sustainable and safe and technical solution.

The following actions are recommended:

- Mock-ups with Operations in full PPE prior to using the tool selected for use in the unloading line.
- A different o-ring removal tool(s).
- A fixture or vise to hold the adapter plate stationary (rather than hand-held) to ensure the worker's hand is outside the line-of-fire.
- A small slot in the adapter plate to enable insertion of a tool to grab and pull the o-ring
- An acceptable grease to achieve a good seal without the embrittlement and radiological permeation issues
- A periodic preventive maintenance (or procedure change) to replace adapter o-rings more frequently, possibly with each window replacement to facilitate removal of less degraded o-rings.

X. DOCUMENTS REVIEWED

Facility Management

NA—SRSO-SRNS-TRIT-2015-0001, (U) Unloading Glovebox Puncture Wound
Slides from Facility's Phase II Fact Finding
SRNS NNSA Programs (SRTE) Organization Chart, 11/12/2014
SRNS-RP-2009-01039, Rev 4, SRTE Operational Excellence Plan
Current Tritium Shift Orders as of 2/3/15
Redacted Version of SOP 233-57000, (U) Fixturing Operations in Unloading
Causal Analysis and Mistake Proofing (CAMP) for "Unloading Glovebox Hand Wound at HANM (CA/MP—Five Why Process Answer Flow Sheet)"
Slides from Facility's Correction Action Review Board *Apparent Causes and Corrective Actions, Hand Injury in HANM Glovebox*
Management Field Observations (MFO)/Self-Assessments (SA):

2009-SA-006867
2010-SA-004925
2010-SA-007610
2011-SA-000970
2011-SA-003819
2012-SA-002112
2012-SA-011999
2012-SA-019312
2014-MFO-000578
2014-MFO-000655
2014-MFO-001151
2014-MFO-001476
2014-MFO-005870
2014-MFO-009730
2015-MFO-000170
2015-MFO-000291
2015-MFO-000487
2015-MFO-000669

Conduct of Operations

SOP 233-57000-DV2 Rev 42 IPC-1
SOP 233-57000-DV Rev 41
SOP TRIT-1304 Rev 21
2S Manual
SRNS-T0000-2014-00220 Track #10667 (Tritium Facility Performance Improvement Plan), 10/23/14
Prejob Briefing Card revisions 1-7
NNSA Operations and Programs Organizational Chart, 11/12/14
IPC Request Forms:

SOP 233-58006 Rev 4 IPC1
SURV 233-59025 Rev11 IPC2
SOP 233-64024 Rev48 IPC2
SOP 233-64057 Rev12 IPC3
SOP 233-64044 Rev16 IPC1
SURV 233-59023 Rev12 IPC2
SURV 233-59023 Rev12 IPC3
SURV 233-59023 Rev 13 IPC1
SURV 233-59025 Rev11 IPC1
SURV 233-59025 Rev11 IPC3
SURV 233-59121 Rev17 IPC1
SURV 233-59121 Rev17 IPC2
SURV 233-59121 Rev18 IPC1
SOP 233-64019 Rev16 IPC1
SOP 233-64024 Rev46 IPC4
SOP 233-64031 Rev11 IPC1
SOP 233-64031 Rev11 IPC2
SOP 233-29007 Rev11 IPC2
SOP 233-20048 Rev8 IPC1
SOP 233-20038 Rev 12 IPC1
SOP 233-20024 Rev21 IPC1
SOP 233-20005 Rev24 IPC1
SOP 233-20032 Rev19 IPC1
SOP 233-64024 Rev48 IPC1
SURV 233-59022 Rev32 IPC1
SURV 233-59022 Rev32 IPC 2
SURV 233-59023 Rev12 IPC1
SOP 233-64031 Rev11 IPC3
SOP 233-64024 Rev46 IPC2
SOP 233-64024 Rev46 IPC1
SOP 233-64019 Rev16 IPC2
SURV 233-59116 Rev41 IPC1

PP 233-59083 Rev5 IPC1
SOP 233-64057 Rev12 IPC1
SOP 233-64057 Rev12 IPC-2
SOP 233-20010 Rev22 IPC1
SOP 233-20023 Rev30 IPC3
SOP 233-20012 Rev24 IPC1
SURV 233-59116 Rev41 IPC2
SOP 233-64054 Rev7 IPC1
SOP 233-64024 Rev47 IPC1
SOP 233-64024 Rev45 IPC2
SOP 233-64007 Rev5 IPC1
SOP 233-64000 Rev13 IPC1
SOP 233-62003 Rev4 IPC1
SOP 233-57009 Rev0 IPC3
SOP 233-64055 Rev9 IPC1
SOP 233-70012 Rev1 IPC1
SOP 233-57000 Rev40 IPC7
SOP 233-20064 Rev23 Temp IPC1
SOP 233-20003 Rev16 Temp IPC3

Radiological Controls
SOP 233 – 57000, Revision 41, (08/19/14), "Fixturing Operations in Unloading" [Deleted Version]
AHA ID: TRI-13433 R2 (08/19/14)
AHA ID: TRI-13433 R2 (08/19/14) Hazard Tree
AHA ID: TRI-13433 R1 (undated) Hazard Tree
"Injured Person 233-H Rad. Summary" (e-mail Bates to Quillin, et al.) (01-29-15)
"Radiological Protection Department Turnover Checklist for HANM", Shift M2, (01-27-15)
Visual Survey Data System (VSDS) Survey TRI-M-20150127-3, "233-H Survey of 233-H Injury Incident"
Radiological Work Permit 15-TRI-003, "Routine glovebox work in RBAs and RMAs with glovebox activity ≥ 0.1 μCi/cc tritium"
Radiological Work Permit 14-TRI-003, "Routine glovebox work in RBAs and RMAs with glovebox activity > 0.1 μCi/cc tritium"
Radiological Work Permit 15-TRI-009, "General Access or Work in CAs (and HCAs posted for tritium only)."
Radiological Work Permit 15-TRI-010, "General Access or Work in CAs" (no hand-on work)
Causal Analysis and Mistake Proofing (CAMP) for "Unloading Glovebox Hand Wound at HANM (CA/MP-Five Why Process Answer Flow Sheet)"

Safety

8Q, 122	Task Level Hazards Analysis
SRNL-STI-2012-00068	Puncture Test Characterization of Glovebox Gloves
SRNL-STI-2012-00030	Thermogravimetric Characterization of Glovebox Gloves
SRNL-STI-2012-00069	Characterization of Tensile Strength of Glovebox Gloves
SRNL-STI-2012-00028	Evaluation of Glovebox Gloves for effective Permeation Control
Work Release Form	AHA ID: TRI-13433 R2
TRI-13433 R2	AHA for the Main Task: Fixturing Operations in Unloading
SOP 233-57000-DV, Rev 41	Deleted Version of Fixturing Operations in Unloading
SOP 233-57000-DV2, Rev 42	Deleted Version of Fixturing Operations in Unloading
Piercan Technical Sheet	Gant Pour Isolateur En CSM/Polyurethane/CSM (Tritium Glove) SC-COM-22
Piercan Technical Sheet	Gant Pour Isolateur En CSM/Polyurethane/CSM (now manufactured) SC-COM-12
Q3.1, 2401	Chelation
Q3.1, 2402	Treating Injuries Involving Radioactive Contamination

AHAs Reviewed:
TRI-30172 R0
TRI-30188 R0
TRI-30386 R0
TRI-30407 R0
TRI-30520 R0
TRI-30633 R0
TRI-30642 R0
TRI-30704 R0
TRI-30705 R0
TRI-30878 R0
TRI-13688 R1
TRI-29505 R0

TRI-29565 R0
TRI-29721 R0
TRI-29746 R0
TRI-13433 R1
TRI-13433 R2

Engineering
Tritium Safety Basis Documents
CHA, WSRC-TR-2004-00163, Revision 6
SAR, WSRC-SA-1-2 Revision 18
TSR, WSRC-TS-96-17, Revision 23
WSRC-TR-2003-00573, Revision 6 (TSR Methodology)

Fixture Design Drawings
M-M5-H-7765 (R5), GEN, 2 Open Amends.
W817341 (R33), No Cat., 0 Open Amends.
W822538 (R0), GEN, 3 Open Amends. (Still shows use of grease)
D816889 (R30), No Cat., 1 Open Amends.
W822533 (R13), No Cat., 1 Open Amend. (Still shows use of grease)
D816886 (R14), SUP, 2 Open Amends.

Material IDs for O-Rings
67-19329.23 (O-ring for Adapter Plate)
67-19329.24 (O-ring at Bottom of Insert)
67-19329.27 (O-ring at top of Insert), Procedure SOP 233-57000 (R41) with AHAID: TRI-13433 (R2)

APPENDIX A. FULL SRTE PUNCTURE INJURY TIMELINE

Since Facility startup, operators used an o-ring extractor kit while removing o-rings in unloading glovebox.

Date	Time	Occurrence
02/10/10		Initiated use of Hex Armor gloves in unloading gloveboxes for radiological reasons.
03/03/10		Initiated Unloading Glovebox Contamination Study related to RA and RB Glovebox gloves.
03/09/12		SRNL completed glovebox glove characterization summary (SRNL-STI-2012-00147) to include evaluation of permeation, thermogravimetric analysis, puncture resistance, tensile properties, and dynamic mechanical analysis.
Date not determined		Started using 20 mil Polyurethane Hypalon puncture resistant over gloves in unloading gloveboxes.
August - October 2014		Conducted extended Senior Supervisory Watch (SSW) activities.
08/19/14		Revised Procedure 233-57000 *Fixturing Operations in Unloading* to include a list of tools to be used in unloading operations (included needle nose pliers for o-ring removal but not o-ring extractor kit). An operator was not used to validate the procedure change.
09/21/14		Revised Procedure 233-57000 *Fixturing Operations in Unloading* to incorporate multiple Immediate Procedure Changes (IPCs) including the IPC to include a new section for troubleshooting leaks (did not include warning in 5.7 to use over gloves). An operator was not used to validate the procedure change.
01/25/15		Troubleshooting for leaks on Unloading Glovebox B started and continued for multiple shifts. Documentation of troubleshooting was not performed as required in procedure 233-57000, Section 5.7, Step 4.
01/27/15		Shift N2 begins troubleshooting leaks in Unloading B using procedure 233-57000.
	0700	Task Preview was performed by operators. Tool section was not reviewed.
	0730	Simple Pre-job brief was conducted with 3 operators by First Line Manager (FLM). FLM gave the operators the o-ring extractor kit. FLM did not cover specific PPE for the tasks directed.
01/27/15	0800	Three operators began executing procedure 233-57000, section 5.7 to perform troubleshooting in unloading which included removal of o-rings.
	0900	Process Operator A punctured glovebox glove with o-ring removal tool
		Process Operator A removed hands from glovebox glove and realized that there has been contact with skin, possible puncture.
		Process Operator B was made aware of situation and was requested to contact RadCon.
	0901	Process Operator B contacted RadCon and informed them that an injury had occurred in an RBA (Unloading Glove Box Room)
	0902	Three RP Inspectors arrived at the incident scene. Operator A was assisted in doffing PPE (gloves, glove liner, and lab coat). Operator B tied off punctured glove.
	0903	Injured Operator was taken to Decontamination Room and instructed to wash hands with warm water and soap for at least 10 minutes. Injury was confirmed to be minor and not life threatening.

Date	Time	Occurrence
	0904	RP First Line Manager (FLM) was paged.
		Tritium Operations First Responders arrived at decon room and confirmed stability of Operator A
	0908	RP FLM arrived at decon room and confirmed that Operator A was being appropriately supported. Tritium Safety Engineer also arrived
	0909	RP FLM notified RP Facility Manager of event and status. Discussion involved actions and items of concern.
	0910	Emergency Response Personnel (Engine 1) dispatched by SRSOC to HANM
	0910	ER personnel were in route
01/27/15	0913	Facility First Responders evaluated injury and wrapped the wound with gauze in preparation for transport. Absence of contamination could not be confirmed so wound was assumed to be contaminated.
	0914	ER Personnel arrived on-scene. Two dispatched to lower level of HANM and one remained at ground level to facilitate radio communications.
	~0916	Emergency Medical Technicians (EMTs) assessed Operator A and confirmed injury not life-threatening. Vital signs revealed elevated blood pressure, with potential contamination, it was determined to transport via ambulance. Operator A provided baseline bioassay sample.
	~0920	Tritium Health and Safety Manager notified of injury
	0927	Health and Safety, Site Occupational Medicine Director (SOMD), and RP Director notified of injury
	0937	Operator A was placed in ambulance (M4) with EMTs and RP Inspector were in route to 719-5N
	0946	M4 arrived at Site Medical (719-5N)
	1000	Medical staff received patient (due to understanding that injury was minor, contamination control was primary concern so area was covered with paper to minimize contamination. Patient waited in ambulance until a doctor and nurse were present and treatment room was available.)
	1015	Medical examination and treatment were completed. There was no spread of contamination including ambulance. Ambulance was released and returned to service.
	1020	Ambulance returned to fire station, available for service.
	1030	Equilibrium bioassay (90 minute) sample submitted and employee returned to work, no medical restrictions.
	~1300	Bioassay results indicate positive bioassay. Operator A was placed on administrative Rad Hold in ProRad.
02/18/15		Final dose of 4.0 mrem Committed Effective Dose (CED) was assigned to the Operator A.

APPENDIX B. PERSONNEL CONTACTED BY AREA

Facility Management
Director, Integrated Supply Chain
Facility Operations Manager
HAOM Facility/Reservoir Operations Manager
Gas Processing Operations Manager
FLM
Conduction of Operations
Operator A (injured)
Operator B
FLM
Reservoir Operations
Gas Processing Operation Manger
HAOM Facility Manager
Facility Operations Manager
Director, Tritium Integrated Supply Chain
Procedures Manager
Operations Training Manager
Radiological Controls
Radiological Protection First Line Manager (FLM)
Radiological Protection Facility Manager
Safety Engineer
Process Operator A
Registered Nurse
Emergency Medical Technicians
EMTs (6)
Safety Programs
SRNS Tritium Safety Engineer
SRNS Tritium Safety Engineer
Operator A
SRNS Tritium Procedures
SRNS Physician
SRNS Nurse
SRNS Fire Department
SRNS Fire Department
SRNS Fire Department
SRNS Tritium Engineering
Tritium Operations
Engineering
Systems Engineers
From April 2013 to Present
From 2012 to Feb 2013
From Jan 2008 to April 2010
From 2002 to 2004
From 1992 to 1994

SBRA & N&CSE Interviewed
Tritium SBRA (2)
Operators
Operator A
Operator B

APPENDIX C. TRITIUM FACILITIES PUNCTURE EVENT FACT FINDING AND CA/MP

FACT FINDING

The Fact Finding was not critical enough. Responses in the Fact Finding were written in a manner to defend performance.

Additional Fact Finding issues include:

- The Fact Finding did not discuss how the FLM was able to procure his own set of o-ring removal tools to be distributed to the operators.
- The Fact Finding did not discuss SAFER Program Critical Action Steps or the use of the Savannah River Tritium Enterprise (SRTE) "Bomb Stamp" on those identified steps.
- In the Fact Finding meeting, on at least two occasions, the Fact Finding Director interrupted the response by a member of the actual work crew ("natural team") to interject information, directing the response.

As an example, the final Fact Finding Report answers the following ISMS questions:

Were we outside of the job-scope when the event occurred? ***No, Section and step were reviewed in the pre-job brief.***
This is incorrect. The tool offered by the FLM was not on the list of approved tools in the procedure. The use of the o-ring removal tool was outside the scope of the procedure as written.

Were the Hazards Analyzed? ***Yes, the hazards had been analyzed in the Assisted Hazard Analysis (AHA) process.***
This is incorrect. The tool offered by the FLM was not on the list of approved tools in the procedure, and was not analyzed using the AHA Process.

Was there a hazard directly related to this event that we did not identify before going to work? ***No, the hazard of sharps was known, and the hazard of these sharp tools was discussed in the Pre-Job Brief.***
This is incorrect. The tool offered by the FLM was not described as a sharp in the pre-job briefing and one operator interviewed admitted to not considering the tool a sharp.

Was a Control Developed? ***Yes, 20 mil Polyurethane Hypalon puncture resistant over gloves over 30 mil Butyl Rubber glovebox gloves.***
This is incorrect. The sharp was not analyzed in the AHA, and the procedure did not list warnings in the troubleshooting section that the over gloves should be worn during o-ring removal.

Was a Control Implemented? ***Yes, in that the gloves were designated, made available, and normally used when handling sharps in this glovebox.***
This is incorrect. The FLM did not describe the tool he offered to the operators as a sharp and did not describe specific PPE. The over glove was not being used by either operator while removing o-rings.

CAUSAL ANALYSIS/MISTAKE PROOFING (CA/MP)

The actions recommended by the Causal Analysis/Mistake Proofing (CA/MP) did not go beyond issues directly related to the natural team. The CA/MP natural team consisted of 2 operators involved in the event, 1 very experienced operator in doing this work who was not involved in the event, the First Line Manager involved, and the Safety Engineer. It did not discuss systemic issues with the procedure revision, worker involvement in Technical Work Document (TWD) development, tool and sharp control, or lack of management oversight.

The actions recommended by the CA/MP included only:

- Determine the appropriate (best) tools that should be used to remove o-rings.
- Establish tool control program for any jobs where sharps may be used.
- Evaluate the continued use of the o-ring extraction kit.
- Add whatever tools are selected to the 233-57000 Procedure, and provide direction in the procedure for their use.
- Add warnings to the 5.7 section of the procedure like the other sections if needed.
- Identify use of a "hold down" device for the Adapter and Insert when o-ring removal may be difficult. This would take the other hand out of the line of fire.
- Provide training for the use of sharp tools including applied force, work angle, proper use of specific tools, etc.)
- Make sure that appropriate gloves are always in the correct place for use before beginning work.
- Proceduralize these directions.