INL/EXT-11-24112

Causal Analysis of the Unanticipated Extremity Exposure at HFEF

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Level 1 Cause Analysis

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Executive Summary

The Hot Fuel Examination Facility (HFEF) is a Hazard Category 2 nuclear facility, located at the Materials and Fuels Complex (MFC) at the Idaho National Laboratory (INL), in which Post-Irradiation Examination (PIE) processes are conducted within a large, inert hot cell. One of the PIE processes involves dismantling irradiated fuel and placing portions of the structural material and/or fuel in metallurgical (Met) mounts in the Station 2M Containment Box. HFEF Operators cut and prepare the Met mounts according to procedure and a Process Work Sheets (PWS) submitted by a Principal Investigator (PI), which is reviewed by HFEF support personnel and approved by HFEF facility management. Approximately four hundred Met mount samples had been processed in HFEF so far this year.

The Fuel Conditioning Facility (FCF) Radiological Control (RadCon) Supervisor was contacted by the External Dosimetry Lead on October 5, 2011 to report that a Hot Fuel Examination Facility (HFEF) Operator's right hand [finger] extremity dosimetry had abnormally high results (i.e., 3.58 rem). The FCF RadCon Supervisor informed the HFEF RadCon Engineer and the Materials and Fuels Complex (MFC) RadCon Manager of the concerns with the extremity dose results. The HFEF RadCon Engineer notified the HFEF Management of the results and restricted the affected Operator from performing any radiological work.

A critique was held on October 6, 2011 and was continued and completed on October 10, 2011. The HFEF RadCon Engineer reviewed the affected Operator's external dosimetry results and other HFEF Operator's external dosimetry results and based his review on Radiological Work Permit (RWP) access and RWP entries for all HFEF activities requiring extremity dosimetry. No additional anomalies were identified.

A Causal Analysis Team was assigned to investigate the Unanticipated Exposure. The investigation focused on the affected Operator's August work assignments, primarily on the Operator's involvement with four Met mount samples that he manually handled on August 30, 2011. The Met mounts contained cross sections of irradiated Fast Flux Test Facility (FFTF) fuel prepared in the HFEF Station 2M Containment Box, located on the north side off the HFEF hot cell.

The metallurgical (Met) mounts associated with this Causal Analysis were transferred from the hot cell to the HFEF Hot Repair Area Glovewall on August 30, 2011. At the Glovewall, γ and β-γ readings were obtained on each of the samples at 30 cm and on contact. During the on contact survey of the third Met mount sample the RO20 meter indicated off-scale high (>50 rem/h β-γ). The acting HPT Supervisor was notified to discuss the situation and review the Glovewall RWP. It was determined that no RWP limiting conditions were exceeded since the RWP had no limit for β radiation. The acting HPT Supervisor made the decision to continue working with an identified unknown hazard. The samples where then placed into shielded transfer containers (1 sample per shielded container) for transfer to the MFC Electron Microscopy Laboratory.

The three Causal Factors for this event are listed below.

Causal Factor 1 - The procedures and RWPs covering post irradiated fuel Met mount sample handling work activities were less than adequate because they did not cover the hazards associated with the sample handling of post irradiated fuel Met mount samples.

Causal Factor 2 - Management direction created insufficient awareness of impact of actions on safety when an HPT Supervisor directed contact handled work to continue with an identified off-scale high meter indication (>50 rem/h β-γ). The HPT Supervisor's decision to proceed was repeated several times.

Causal Factor 3 - Inappropriate response to an off-scale high meter reading (pegged meter) by the acting HPT Supervisor, HPTs, and Operators directly resulted in the Operator at the next operation receiving an extremity dose of 3.58 rem.

CONTENTS

ACRONYMS

Admin	Administrative
ALARA	As Low As Reasonably Achievable
BEA	Battelle Energy Alliance
cβ	Corrected β
dpm	Decades per minute
EDMS	Electronic Document Management System
EML	Electron Microscopy Laboratory
FCF	Fuel Conditioning Facility
FFTF	Fast Flux Test Facility
HCA	High Contamination Area
HFEF	Hot Fuel Examination Facility
HPT	Health Physics Technician
HRA	Hot Repair Area
h	Hour
INL	Idaho National Laboratory
ISMS	Integrated Safety Management System
LH	Left Hand
LOW	Latent Organizational Weakness
LTA	Less Than Adequate
MFC	Materials and Fuels Complex
mrem	millirem
Met	Metallurgical
NS&T	Nuclear Science and Technology
Op	Operator
PI	Principal Investigator
PIE	Post-Irradiation Examination
PWS	Process Work Sheet
RadCon	Radiological Control
RBA	Radiological Buffer Area
rem	Roentgen Equivalent Man
RH	Right Hand
RWP	Radiological Work Permit
SS	Shift Supervisor
VSDS	Visual Survey Data System

DEFINITIONS

β	Beta
Corrected β	(Open window reading – Closed window reading) x 3 = corrected β $\left((\beta + \gamma) - \gamma\right) x\ 3 = Corrected\ \beta$
γ	Gamma
Pig	Shielded Cask

Causal Analysis of the Unanticipated Extremity Exposure at HFEF

1. BACKGROUND

The Hot Fuel Examination Facility (HFEF) is a Hazard Category 2 nuclear facility, located at the Materials and Fuels Complex (MFC) at the Idaho National Laboratory (INL), in which Post-Irradiation Examination (PIE) processes are conducted within a large, inert hot cell. One of the PIE processes involves dismantling irradiated fuel and placing portions of the structural material and/or fuel in metallurgical (Met) mounts in the Station 2M Containment Box. HFEF Operators cut and prepare the Met mounts according to a Process Work Sheets (PWS) submitted by a Principal Investigator (PI), which is reviewed by HFEF support personnel and approved by HFEF facility management. Approximately four hundred Met mount samples had been processed in HFEF so far this year.

On October 5, 2011, HFEF was informed that there was a higher than normal external dosimetry reading for an HFEF Operator. Subsequent investigation by the RadCon Engineer and RadCon Manager determined that the extremity exposure occurred while handling Met mount samples of FFTF fuel during the month of August, 2011. Further analysis shows that the exposure most likely occurred during Step 7 of the process described below, while in the process of transferring the samples out of the HFEF Hot Repair Area to place them in a small shielded cask, on August 30, 2011.

These Met mount samples were sized based on calculations and analysis to yield approximately 200 mrem/h γ on contact. These samples were prepared in stainless steel Met mounts, which have a very directional radiation field because the mount itself provides shielding on the bottom and sides of the fuel sample. The initial survey of the Met mount samples occurred in the HFEF Hot Repair Area.

1.1 Sample Handling Process in HFEF Hot Repair Area

The handling of the Met mount samples was scheduled on the HFEF Plan of the Week and briefed during the morning HFEF Plan of the Day meeting. Additionally, the lead Operator gave informal pre-job brief prior to performing work per the Briefings procedure (LWP-9201). Personnel participating in this process were at both briefs, but neither brief covered the fourth Basic Briefing Element, what could go wrong.

Basic Briefing Elements from LWP-9201

> *For all briefings performed in preparation for activities at the INL, the following questions, as a minimum, are answered to address the context of the activity hazards and associated mitigations:*
>
> 1. *Has this activity been previously performed?*
> 2. *What are the critical steps or phases of this activity?*
> 3. *How can we make a mistake at a critical step?*
> 4. *What could go wrong with the facility, the environment, the equipment, or personnel?*
> 5. *What barriers or defenses are needed or are in place?*

All Operators and HPTs discussed in this report are qualified INL Radiological Worker II, and all Operators had their MFC Basic Operator Qualification. Both the Glovewall Operator and the Stepout Room Operator were under the instruction of a qualified Operator during this sample handling process, since they had not yet completed HFEF General Area Operator, the facility specific qualification.

Figure 1 depicts the 8 step process that the samples followed in the HFEF Hot Repair Area concluding with samples being loaded in a small shielded cask (pig). The Crane Operator for these steps was located near the southwest corner of the Hot Repair Area and was in visual contact with the Glovewall Operator directly across the room at the Glovewall.

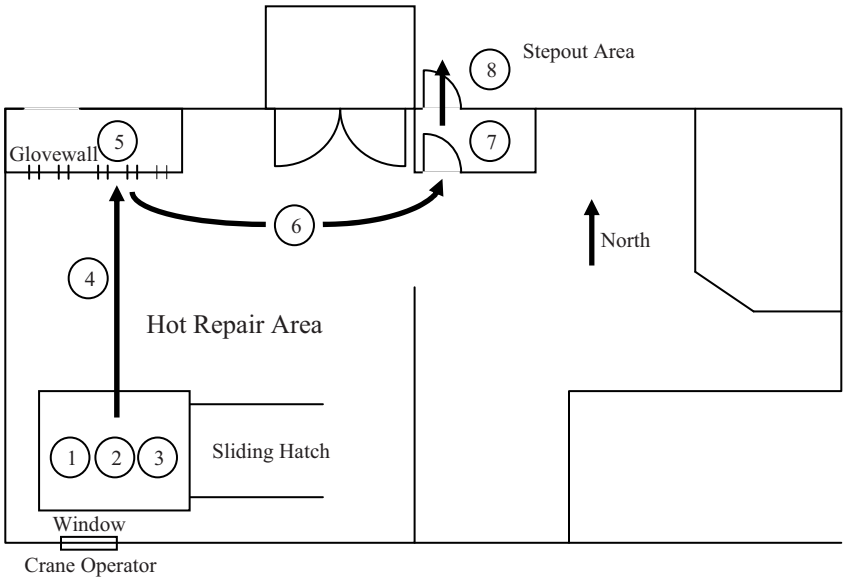

Figure 1. Hot repair area sample handling process flow diagram.

Figure 2. Transfer bag.

Step 1

The samples were transferred one at a time in a transfer bag (Figure 2) from the Decontamination Cell to the Hot Repair Area hatch remotely by crane for a remote radiation survey, per the Hot Repair Area 5-Ton Crane procedure (HFEF-OI-3341) and the Hot Repair Area Entry/Exit and Decontamination and Repair Operations procedure (HFEF-OI-3150). The Crane Operator worked with a Health Physics Technician (HPT) to survey for γ readings at 30 cm and on contact with an AMP100 meter. Surveys of Met mount samples 71T, 72T, and 74T were performed on 08/08/2011 and Met mount samples 73T, 75T, and 76T were performed on 08/09/2011. The readings were recorded on survey map number M-20110808-59.

Table 1. Survey Results at Hot Repair Area hatch, 8/08/2011 - 08/09/2011

Met Mount	On Contact, γ	30 cm, γ
71T	5.3 rem/h	
72T	11 rem/h	
73T	4.7 rem/h	
74T	2.7 rem/h	
75T	9 rem/h	
76T	1.2 rem/h	
71T, 72T, 73T, 74T, 75T, and 76T		9-70 mrem/h

Step 2

Radiation levels on the samples were >100 mrem/h above background. The samples were returned to the Decontamination Cell so the survey results obtained from Step 1 could be reviewed by the HPT Supervisor and HFEF Facility Manager.

HFEF-OI-3341 Section 2.2.6

> *If Radiation level is >100 mrem/h above background, then the item must be returned to the [Decontamination] Cell or approval from HPT Supervisor and Facility Manager is required to move the load into the [Hot Repair Area].*

The HPT Supervisor required an *additional wipe down at the Glovewall prior to bagout* for each sample on an In-Cell Smear Survey Data form (FRM-327). No additional controls were required by the HPT Supervisor or Facility Manager for the identified radiation levels.

Step 3

On 08/30/2011, twenty one days later, Met mount samples 71T, 72T, 74T, and 75T were returned to the Hot Repair Area hatch remotely with the crane, per HFEF-OI-3150 and HFEF-OI-3341.

Step 4

The samples were transferred from the Hot Repair Area hatch to the Glovewall remotely with the crane, per HFEF-OI-3341 and the Glovewall Operations procedure (HFEF-OI-3152). HPT1 monitored radiation levels with a RO20 meter at the Glovewall to ensure γ radiation levels did not exceed the Glovewall RWP (MFC2011129 Rev. 01) Evaluation Point of 100 mrem/h γ at 30 cm from the face of the Glovewall. This Evaluation Point was not met so Operator 1 (Op^1) then removed the transfer bag from the crane hook and placed it on the Glovewall work bench. Op^1 was under the instruction of Operator 2 (Op^2) and was working under HFEF-OI-3152 and the Performing general tasks under a General RWP section of the Skill of the Performer for HFEF Process and Facility Operators list (LST-482).

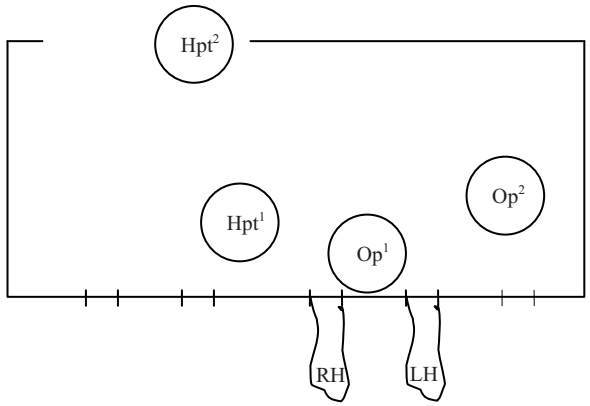

Figure 3. Step 5, Glovewall Room detail with personnel locations.

Figure 4. Met Mount in Bag[1].

Step 5

Op^1 performed a decontamination wipe as required per the FRM-327 on the outside of each sample bag. Then HPT1, with assistance from Op^1, surveyed for γ and β-γ on each of the samples at 30 cm and on contact, per HFEF-3152, LST-482, and the Radiological Surveys procedure (MCP-139). This was accomplished by pulling the sample into an inverted glove (see Appendix D, Figures 7 and 8) to allow for surveying in the Glovewall Room with a RO20 meter. This survey was the first survey of β radiation levels for these samples.

The Meter readings were called out by HPT1, using three way communications, and HPT2 recorded the readings on a piece of scratch paper. Readings for β are recorded as corrected β (cβ). Later the readings were entered into Visual Survey Data System (VSDS) to generate survey map number M-20110830-31. However, this survey map did not indicate or refer to any off-scale high meter indication. This survey map was later corrected on survey map number M-20111006-30 to reflect the >50 rem/h β-γ reading on Met mount sample 71T after the higher than anticipated extremity exposure was reported (see Table 2).

Table 2. Survey Results at Glovewall, 08/30/2011.

Met Mount	On Contact, γ	30 cm, γ	On Contact, cβ	30 cm, cβ
71T	5.3 rem/h	80 mrem/h	**>50 rem/h β-γ** (originally reported as 78.6 rem/h)	23.76 rem/h
72T	2.8 rem/h	110 mrem/h	72.6 rem/h	23.67 rem/h
74T	2.2 rem/h	100 mrem/h	14.4 rem/h	600 mrem/h
75T	1.0 rem/h	25 mrem/h	25.5 rem/h	225 mrem/h

Note 1: cβ = (Open window reading – Closed window reading) x 3
Note 2: 1000 mrem = 1rem

The RO20 meter indicated off-scale high (*pegged its highest scale,* >50 rem/h) during the survey of the third Met mount sample, 71T. The sample was placed back into the Hot Repair Area and the first two samples were resurveyed on both sides to ensure the survey was performed correctly, on the sample side of the Met mount. At this point HPT[1] instructed the Op[1] to step back from the Glovewall, and called the acting HPT Supervisor, who brought a copy of the Glovewall RWP up to the area. HPT[1], HPT[2], and the acting HPT Supervisor discussed the situation and reviewed the Glovewall RWP. It was stated that they *determined that no RWP requirements were exceeded, since the Glovewall RWP had no limit for β.* The decision was then made by the acting HPT Supervisor during this meeting to continue working in preparation to transfer the samples to the Electron Microscopy Laboratory (EML). They also decided that they would not survey the samples again at the Stepout Room to minimize exposure to personnel. The Stepout Room RWP (MFC2011130 Rev.03) was not referred to during this meeting. The survey of the fourth Met mount sample was completed after the conclusion of this meeting.

The Glovewall RWP did not contain the following evaluation point from the ALARA Review (HFEF-2011-007 rev. 1) covering this work, as required by the ALARA Review; however, this evaluation point was on the Stepout Room RWP (MFC2011130 Rev.03), which was not referred to.

Evaluation Point from HFEF-2011-007 Rev. 1:

> *Contact exposure rate of >5 rem/h β-γ, an HPT may install or direct installation of ALARA shielding, as many times as required. Contact Radiological Engineer to assess effectiveness of ALARA shielding.*

The ALARA Review covering this work had no additional β radiation Evaluation Points or Limiting Conditions for the Glovewall or Stepout Room.

Step 6

The Met mount samples, each still in its original unopened bag, were placed back into the transfer bag. The transfer bag was placed back on the crane hook by Op[1], and it was transferred to the personnel access door of the Stepout Room remotely with the crane, per HFEF-OI-3341.

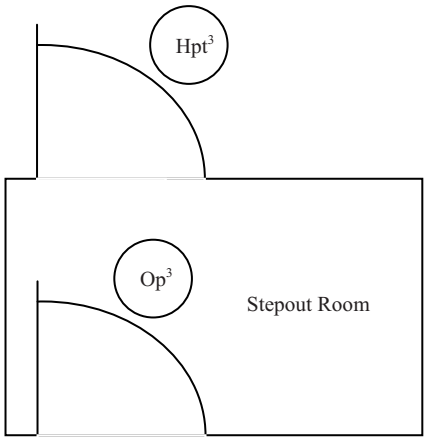

Figure 5. Step 7 and 8, Stepout Room detail with personnel locations.

Step 7

Operator 3 (Op^3) reaches into the Hot Repair Area and takes the transfer bag off of the crane hook and empties the transfer bag onto an uncontaminated bag staged on the floor of the Stepout Room. Op^3 then changes his gloves, since the Hot Repair Area is a High Contamination Area (HCA). Op^3 then rolls up bag^1 and places it into bag^2, which was held by HPT^3 located in the Radiological Buffer Area (RBA) outside of the Stepout Room. This series of bagging operations is shown in Appendix D, Figures 9, 10, 11, and 12. This step was performed per HFEF-OI-3152, LST-482, and the Performer Controlled Activity List for Laboratory and Hot Cells Services (LST-483).

It was determined by a RadCon Engineer and the MFC RadCon Manager that the extremity exposure most likely occurred at this step in the process while handling Met mount samples 71T, 72T, 74T, and 75T. This was based on a review of the following;

- The reported Op^3 extremity (finger ring) exposure data for the time period of 8/2/2011 through 8/31/2011
  - 3580 mrem (right hand)
- August exposure records for personnel that signed onto the same RWPs as Op^3
  - No additional personnel with abnormal exposure results
- Review of August survey maps and logs
  - This review identified that Met mount samples 71T, 72T, 74T, and 75T had significantly higher radiological survey results compared to any other work Op^3 handled during August
  - Met mount samples 71T, 72T, 74T, and 75T posed the only real possibility of receiving a dose of 3.58 rem
- August exposure records for personnel directly involved with all Met mount sample handling in HFEF
  - No additional personnel with abnormal exposure results
- Expanded review to include 06/01/2011 through 10/06/2011
  - No additional abnormal exposure results

Interviews and all evidence reviewed for this causal analysis supports this determination.

Step 8

HPT[3] rolls up bag[2] and places it into a small pig (a small shielded cask) (Appendix D, Figure 13). Steps 7 and 8 were repeated for each of the samples. The pigs were then surveyed and labeled, per MCP-139 and Radiological Control Posting and Labeling (MCP 187). Survey results were recorded and the readings were later entered into VSDS to create survey map number M-20110830-34.

Table 3. Survey Results of loaded pigs in RBA, 08/30/2011.

Loaded Pig	On Contact, γ	30 cm, γ	1 meter, γ	Wipe, β-γ
71T in #3 Pig	70 mrem/h	4 mrem/h	1 mrem/h	<1000 dpm/wipe
72T in #4 Pig	60 mrem/h	11 mrem/h	1.5 mrem/h	<1000 dpm/wipe
74T in #16 Pig	5 mrem/h	1 mrem/h	0.5 mrem/h	<1000 dpm/wipe
75T in #30 Pig	32 mrem/h	4 mrem/h	0.5 mrem/h	<1000 dpm/wipe

After Step 8, HPTs worked through lunch to prepare survey maps for Step 5 through Step 8 to support transferring the samples before 14:00 the same day. The loaded pigs were transferred to EML with the survey maps of the Met mount samples at Step 5 (M-20110830-31) and of the loaded pigs at Step 8 (M-20110830-34).

No survey maps indicated that there were any off-scale high meter readings when the samples were transferred to EML, and the HPT log entry covering Step 4 through Step 8 did not have any reference to any off-scale high meter readings and stated, “No problems noted during work activities.”

2. SCOPE OF THIS INVESTIGATION

This investigation is limited to the events preceding and during the activities associated with the unanticipated extremity exposure in HFEF, as reported on October 5, 2011. The intent of this investigation is to establish the facts and determine causes that contributed to the event. Corrective actions have been developed, and are included in this report, to address the causes of this event as well as other issues identified during the course of this investigation. This issue and its corrective actions will be tracked in ICAMS issue number IO-014862 under source document SD-005257.

3. FACTS

3.1 Chronology of Activities

Date	Action/Activity
11/03/2010	PI provided source term data to RadCon Engineer to determine the size of sample that would yield approximately 200 mrem/h γ on contact. These calculations were performed using MicroShield 7.02. Note MicroShield 7.02 can only calculate γ.
08/08/2011	Surveyed Met mount samples 71T, 72T, and 74T at roof hatch sliding door (Step 1)
	One at a time and then returned to Decontamination Cell (Step 2)
08/09/2011	Surveyed Met mount samples 73T, 75T, and 76T at roof hatch sliding door (Step 1)
	One at a time and then returned to Decontamination Cell (Step 2)
08/30/2011 Starting at 0900	Met mount samples 71T, 72T, 74T, and 75T were transferred into the Hot Repair Area and then to the Glovewall (Step 3,4) by crane
	A decontamination wipe was performed and radiological surveys were taken at the Glovewall (Step 5) • During the survey of the 3rd Met mount sample the RO20 meter indicated off-scale high on its highest scale (>50 rem/h β-γ) and HPT[1] directed Op[1] to place the Met mount sample back in to the Hot Repair Area • Resurveyed both sides of the first two Met mount samples to ensure readings were correct • Work was stopped with all samples in the Hot Repair Area • HPT[1] contacted acting HPT supervisor • HPT[1], HPT[2], and the acting HPT Supervisor to reviewed the Glovewall RWP and evaluated survey results • They determined that the limits of the Glovewall RWP were not exceeded and that work could be resumed (Stepout Room RWP was not referred to) • HPT Supervisor directed HPTs and Operators to finish surveying, surveyed 4th Met mount sample, and moved samples in preparation to be transferred out of the Hot Repair Area (Step 6) and directed not to survey the samples at the Stepout pad due to exposure concerns.
	Op[3] was informed by Op[2] that the samples were "hot" prior to handling samples
	Samples were transferred out of the Hot Repair Area through the Stepout Room by Op[3] (Step 7) • **The Unanticipated Exposure Event OCCURS AND ENDS at this step.**

Date	Action/Activity
	The timeline from this point forward is not causal to this event, but illustrates that the decisions which lead to this event were repeated by different personnel given similar information at different times.
	HPT[3] bagged samples individually by hand and placed each into separate pigs (small shielded cask) (Step 8)
	HPT[3] surveyed and labeled loaded pigs
	HPTs worked through lunch to complete the survey maps to support transfer to EML by 14:00 • No survey map reflected the off-scale high meter reading
	RadCon Engineer reviewed the EML Sample Request Form (FRM-1019), walked through the process with EML for Met mount sample 74T for radiation concerns, and then signed the FRM-1019. • FRM-1019 indicated that 74T was reading 120 rem/h cβ.
1400	Pigs were transferred to EML by Op[3]
1500	Pig containing Met mount sample 71T was opened in EML • Work was stopped because EML HPTs electronic dosimeter alarmed because of dose rate (set at 100 mrem/h γ). • EML HPT asked an HFEF HPT what HFEF had just sent because his *meter pegged*. • EML acting HPT Supervisor contacted RadCon Engineer and notified him that they had >50 rem/h open window and that the pig was closed – RadCon Engineer concurred. • Met mount sample 71T survey data at EML: 3 rem/h γ, >50 rem/h β-γ (open window) • EML Shift Supervisor (SS) notified of the high radiological reading. • EML HPT Supervisor and HFEF acting HPT Supervisor discussed issues with samples.
	EML personnel notified their HFEF counterparts on multiple levels that the sample was "hot" • HPT Supervisors, RadCon Engineers, Facility Managers, SS, HPT Supervisors, HPTs, and Operators.
09/01/2011	RadCon Engineer talks with RadCon Manager, discussion focused on differences between readings at HFEF and EML • RadCon Manager directed RadCon Engineer to discuss with the HPT Supervisors at each facility. • RadCon Manager assumed the samples were handled remotely at HFEF vice contact handled and was unaware that the survey map contained errors (no reference to off-

Date	Action/Activity
	scale meter reading (>50 rem/h β-γ open window)). • RadCon Manager was aware that the instrument read off-scale high in EML but was not aware that the instrument meter read off-scale high at HFEF.
	RadCon Engineer Met with EML HPT Supervisor and then EML HPT Supervisor discussed the process with HFEF HPT Supervisor.
09/12/2011	Survey of Met mount sample number 75T at EML: 2 rem/h γ, >50 Rem/h (open window).
09/13/2011	Met mount samples number 71T and 72T returned to HFEF by Op[3] for rework to reduce sample size in an attempt to decrease radiological levels to an acceptable level. • RadCon Engineer was not aware that the samples were transferred back to HFEF at this time • Samples 71T and 72T were returned to the main cell via the Hot Repair Area and contact handled by Op[4] at the Stepout Room • Samples were not surveyed prior to sending in cell due to exposure concerns, per HPT Supervisor direction • Briefing for this evolution did not include all personnel performing the work.
09/13/2011 through 09/26/2011	Samples reworked (grinding/polishing) in the main cell. The intent of the rework was to "reduce the radiation levels". It was not clear to Nuclear Science & Technology that the radiation levels of concern were β radiation. Statement from Process Engineer is that removal of material from the sample will decrease the γ radiation but could increase the β radiation based on the porosity of the fuel sample.
09/26/2011	Samples 71T and 72T surveyed at the hatch with AMP100 meter with hatch closed (Step 1). • Radiological readings were on both samples in the transfer bag at the same time 2.2 rem/h γ (on contact), 28 mrem/h γ at 30 cm • Samples moved to Glovewall (Step 4) • Op[3] performed a decontamination wipe prior to radiological readings being taken at Glovewall. • Op[3] works with HPT[4] to survey Met mount samples that are not individually bagged (see Appendix D) (Step 5) • HPT[4] started the survey with the RO20 meter on its lowest scale • RO20 meter *pegged* each scale until it indicated off-scale high (>50 rem/h) • HPT[4] directed Op[3] to put the sample back into the Hot Repair Area and back away. Work stopped. • HPT[5] (was recording survey results for HPT[4]) contacted HFEF HPT Supervisor • HPT Supervisor provided permission to survey second sample. There was no notification made to facility management.

Date	Action/Activity
	• Survey of second sample also indicated off-scale high on the RO20 meter. Work was stopped. Survey results: 71T (on contact): 500 mrem/h γ, >50 rem/h β-γ (open window) 72T (on contact): 550 mrem/h γ, >50 rem/h β-γ (open window) • HPT[5] contacts HFEF HPT Supervisor – decision was made to transfer samples to Stepout Room and into pigs. • Op[3]and Op[5] at Glovewall were aware that samples were >50 rem/h β-γ, but not Op[4] at the Stepout Room. • Samples are transferred to Stepout Room remotely via the crane • Op[4] transferred samples from the Hot Repair Area the same as the previous time (Step 7). • HPT placed the samples into individual pigs, then surveyed the pigs and labeled them (Step 8). • HPT transferred the pigs to the radiological storage area.
09/29/2011	Management meeting called to discuss hot samples going from HFEF to EML. • RadCon Manager, RadCon Engineers, HFEF Facility Manager, HFEF HPT Supervisor, EML SS, NS&T (Nuclear Science and Technology) manager, et al. ▪ Samples getting hotter and hotter ▪ Instruments – *pegged* readings ▪ Survey configuration between HFEF and EML ▪ Decision to pull extremity dosimetry for HFEF and EML workers
	Samples 71T and 72T surveyed with RO7 meter with a 200 rem/h detector. • Mounts were surveyed after being removed from pigs. • HPTs performed surveys and handled the samples. • Mount 71T Survey Results >200 rem/h contact β-γ open window 200 rem/h at 3” β-γ open window 5.5 rem/h at 30 cm β-γ open window 2.7 rem/h contact γ 200 mrem/h at 3” γ 100 mrem/h at 30 cm γ • Mount 72T Survey Results >200 rem/h contact β-γ open window 200 rem/h at 2” β-γ open window

Date	Action/Activity
	6.5 rem/h at 30 cm β-γ open window 2.3 rem/h contact γ 200 mrem/h at 2" γ 100 mrem/h at 30 cm γ
	The samples were returned to the pigs following radiological surveys
10/04/2011	External Dosimetry Lead received notice from Landauer (Subcontracted dosimetry services) of a higher than normal extremity dosimetry result • Finger ring data for the time period of 8/2/2011 to 8/31/2011 3580 mrem right hand 260 mrem left hand
10/05/2011	External Dosimetry Lead received notice from Landauer of the individual's results for the other hand
	External Dosimetry Lead called FCF HPT Supervisor to discus result
	FCF HPT Supervisor notified HFEF RadCon Engineer and MFC RadCon Manager
	HFEF RadCon Engineer notified HFEF SS, Sr. Staff Specialist, and NFM
	HFEF SS and HFEF HPT Supervisor restricted affected person (Op^3) from doing radiological work
	HFEF RadCon Engineer restricted affected personnel from being able to log onto RWP's in Sentinel
	HFEF HPT Supervisor put a hold on the Glovewall RWP
10/06/2011	Critique was held
10/10/2011	Critique was continued and completed

3.2 Analysis

3.2.1 ISMS Core Functions

The Why Tree, Barrier Table, and Behavior Analysis techniques were used in this investigation, and are attached as Appendix A, B, and C respectively. The results of this analysis are summarized within the context of the ISMS guiding principles below. Reviews of records, procedures, interviews with participants, and reviews of similar events were used to complete this analysis.

Core Function 1 – Define the Scope of Work

Missions are translated into work, expectations are set, tasks are identified and prioritized, and resources are allocated.

This core function was not fully met.

The procedures, RWPs, and the ALARA Review covering this work had a very broad scope covering all activities and were not properly bounded.

Core Function 2 – Analyze the Hazards

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

This core function was not met.

Recent past experience was the basis for the analysis of the hazards associated with work in the Hot Repair Area. Sample handling was perceived to be a low risk activity, so the ALARA Review covering this work did not contain limiting conditions for β, and the RWPs covering this work did not contain β values that would indicate a need for evaluation or stopping work. The hazards identification for the work scope of handling FFTF fuel samples was not adequate.

Core Function 3 – Develop and Implement Hazard Controls

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

This core function was not fully met.

Additional hazard controls were not developed and implemented for this work, because sample handling was perceived to be a low risk activity based on the previous year of sample handling. Sample handling was performed as a *Skill of the Performer Activity* because this was considered to be a low risk activity. No additional work control was considered necessary.

Procedures are administrative controls, but since this was a *Skill of the Performer Activity* there was no procedure with a clear link to the controls established in the RWP. RWPs are not intended to be used to control work activities and therefore must have their controls reflected in the procedure used to perform the activity.

The ALARA Review is an administrative control that failed to establish limiting conditions for β radiation, which is contrary to this core function.

An evaluation point for β radiation from the ALARA Review was not included in the Glovewall RWP, another administrative control. This was subsequently missed during the review of the RWP.

Core Function 4 – Perform Work within Controls

Readiness is confirmed and work is performed safely.

This core function was not fully met.

Personnel contact handled Met mount post-irradiated fuel samples to obtain survey data with an unknown β radiation hazard. This activity was performed as a *Skill of the Performer Activity* (LST-482), which is only intended for low hazard work. This work was performed with a radiation value that exceeded the maximum range of the radiation meter used. This was not identified as being outside the established work controls or hazard controls for a low hazard work. The unexpected exposure received by the worker following an identified off-scale high meter reading does not meet the requirements of performing work within controls.

Personnel paused and discussed the issue when the meter pegged the first time, but work continued following these discussions per the direction of the acting HPT Supervisor. When two of the samples were again surveyed at HFEF, a month later following a mass reduction in an attempt to reduce dose consequence, another pegged meter reading was received and again work was paused, discussed, and work again continued per the direction of the actual HPT Supervisor. Continuing to work following off-scale high meter indications again was not performing work within controls.

Radiological surveys on some samples were taken with the sample being directly held by the technician. Other surveys were performed by holding the corner of the bag the sample was in. The process of holding the bag during the radiation readings provided some distance between Op[1]'s hand and the sample. Continuing to perform work once the meter pegged placed the work outside of the controls established to perform the work.

Trained Personnel (HPTs and Operators) were qualified through training and experience to perform their assigned activities. They understood the requirements to follow established instructions and work control documents for the activity being undertaken. Personnel clearly understood that they had the right AND obligation to stop work at any time if they become aware that a potentially unsafe condition exists. Responding to an unknown risk hazard (pegged meter) by continuing work was not in accordance with this core function.

The radiological meter, RO20, was an engineered control to determine radiation levels in order to minimize exposure to personnel. Failure to take actions following an off-scale high reading at the Glovewall indicates that this core function was not understood and was not fully met. Following the off-scale meter reading, if the hazard was appropriately analyzed and hazard controls were developed and implemented, this event would not have occurred. Thinking the job could be performed quickly enough to minimize/prevent exposure from an identified unknown hazard was a conceptual error and a less than adequately implemented hazard control.

Personnel failed to consult the Stepout Room RWP following the off-scale meter reading and the subsequent decision to continue working.

Core Function 5 – Provide Feedback and Continuous Improvement

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

This core function was not fully met.

Feedback information is essential in ensuring adequate controls are in place and provide an opportunity of improvement. During May of 2011, samples were brought to the Glovewall for radiation survey which pegged the meter. The HPT instructed the samples to be placed back into the

Decontamination Cell and informed the supervisor of the situation. There was a review of the RWP by the HPT and the HPT Supervisor. It was noted at that time that there were not any β limits established and that the RWP needed to be revised. The feedback on the lack of β limits could not be found and the RWP was not changed.

Feedback following a high off-scale meter indication, >50 rem/h, at the Glovewall in HFEF, on August 30, 2011, was not communicated effectively at all levels in the facility and did not prevent the event from occurring at HFEF. Less than adequate communication of this issue at all levels of the organization at MFC resulted in the potential for exposing personnel at each of the following;

- Attempted to remove a sample from a pig at EML, 8/30/2011, meter pegged >50 rem/h
- Handled samples to transfer it back into HFEF, 9/13/2011
- Handled samples to survey them at the Glovewall, 9/26/2011, meter pegged >50 rem/h
- Handled samples to transfer to a pig, 9/26/2011

The opportunity to stop and revise the activity was lost several times.

Corrective actions as a part of the MFC Recovery Plan (PLN-3763) were performed to reduce errors in facility procedures and RWPs. LST-482 covered this work, but was intended for low risk activities and completely deferred to the RWP covering the work for hazard mitigation associated radiological hazards; additionally, errors and omissions were found in the Glovewall RWP, Stepout Room RWP, and associated ALARA Review. In these four cases corrective actions were less than adequate to prevent recurrence. The extent of the reviews that occurred per PLN-3763 resulted in an over confidence in the accuracy of the approved procedures and RWPs. Personnel were overly reliant on the approved procedures and RWPs as part of their decision process. In the case of the Glovewall RWP, this lead to the incorrect conclusion that they were not outside of the controls because there was no associated limit listed.

4. CONCLUSIONS

The causes that contributed to this event are described as Causal Factors and Contributing Factors. Causal Factors are the root causes that if corrected would prevent this event from recurring. Contributing Factors identified are issues that contributed to the event but if corrected may not prevent this type of event from recurring. Both sections are in order based on the level of significance. Cause codes listed are per Occurrence Reporting Causal Analysis Guide (DOE G 231.1-2).

4.1 Causal Factors

Causal Factor 1

A5B2C08, Written Communication LTA, Incomplete/Situation Not Covered

Work controls for Met mount sample handling at the HFEF Glovewall and Stepout Room were less than adequate to prevent this event. The procedures covered transferring the Met mount samples to the Glovewall workbench, but lacked sufficient detail to cover sample handling at the Glovewall.

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5.1.4 Perform required activities.

Because the procedure only stated to *perform required activities*, personnel performed this task as *Skill of the Craft* Performer Controlled activity, per LST-482, which is only supposed to be considered for low risk hazards per LWP-21220-2 (Analyze the Hazard). The initial surveying of post-irradiated fuel Met mount samples prior to knowing all of the radiological hazard levels was not a low risk activity based on the method that was used to perform the survey. To state it simply, an operator grasped the sample that was in the Hot Repair Area (Engineered Control) and pulled it through the shielded Glovewall (Engineered Control) in a Glovewall glove into the people space to take the survey. This Met mount sample handling evolution was estimated to have been performed in HFEF approximately 400 times this year prior to this extremity exposure event.

The Laboratory Requirements Document LRD-14005 (Activity Level Hazard Identification, Analysis, and Control) states that *the Performer Controlled Process may be considered when the knowledge, skills, and/or physical techniques acquired by the performer through education, experience, training (general or specific), or mentoring over time for a specific discipline or activity is* ***clearly sufficient for identifying and mitigating all hazards associated with the activity****.* Training and knowledge level of Operators and HPTs was less than adequate to successfully perform this activity as a Performer Controlled activity.

On August 30, 2011, a RO20 meter indicated off-scale high, >50 rem/h β-γ, during a survey of Met mount sample 71T at the Glovewall. Since this was a *Skill of the Craft* Performer Controlled activity ***identifying and mitigating all hazards associated with the activity*** was completely on the Operator and HPT performing the work. The HPT directed the Operator to stop, put work in a safe condition, and contacted the acting HPT Supervisor. The HPTs and HPT Supervisor reviewed the Glovewall RWP then decided the work could continue.

The RWP covering this work had no Evaluation Point or Limiting Condition for the identified β radiation hazard.

Causal Factor 2

A4B1C03, Management direction created insufficient awareness of impact of actions on safety/reliability

On August 30, 2011, although work initially stopped after receiving an off-scale high meter reading, the acting HPT Supervisor made a rule based decision to continue working with an identified unknown hazard. This decision created insufficient awareness of the impact of actions on personnel safety. This decision led to a condition where personnel continued to work with an unknown hazard. This situation

repeated on September 26, 2011, with all different Operators, HPTs, and the actual HFEF HPT Supervisor, and the result was the same.

Both HPT Supervisors based their decision on comparing the survey results with the Glovewall RWP, which had no Evaluation Point or Limiting Condition for the identified β radiation hazard, so in both cases the HPT Supervisor directed work to continue. Both HPT Supervisors also directed that surveys not be performed at the following operation to minimize potential exposure to personnel, but the RWP for the next step was not referred to either time. The Glovewall RWP did not contain the following Evaluation Point as required per the ALARA Review covering the work, but the Stepout Room RWP did.

Stepout Room RWP (MFC2011130 Rev.03)
Evaluation Point 1:

Contact exposure rate of >5 rem/h β-γ, an HPT may install or direct installation of ALARA shielding, as many times as required. Contact Radiological Engineer to assess effectiveness of ALARA shielding.

Evaluation Point 1 stated that "an HPT may," which implies a decision which may have prevented this event. This evaluation point did not state that notification to the HPT Supervisor or Facility Manager was required if this condition was met.

Stepout Room RWP (MFC2011130 Rev.03)
Evaluation Point 2:

Radiation levels >100 mrem/h @ 30 cm. Control the area and notify HPT Supervisor and Facility Management.

Evaluation Point 2 may have prevented this event if reviewed, but it is similar to the evaluation point from the Glovewall RWP that was reviewed and did not prevent this event. Note that this evaluation point is intended to be for γ based on a whole body dose consequence, but this is not stated in the RWP. This was another opportunity to inform Facility Management that was not performed, which may have prevented this event.

Conditions for both of the Evaluation Points on the Stepout Room RWP were exceeded. By not reviewing the Stepout Room RWP any opportunity of this document preventing this event was removed.

The ALARA Review and RWP's covering this work did not contain Limiting Conditions for β radiation. A Limiting Condition for β would have provided additional information that may have resulted in a different decision following the off-scale high meter reading and may have prevented this event.

Limiting Conditions for β are not always included in RWPs depending on the perceived radiological hazard, and β is often included as an Evaluation Point not a Limiting Condition.

Causal Factor 3

A3B1C03, Incorrect performance due to mental lapse
A4B1C03, Management direction created insufficient awareness of impact of actions on safety/reliability)

The inappropriate response to an off-scale high meter reading (pegged meter) at the HFEF Glovewall directly resulted in this event. The acting HPT Supervisor, HPTs, and Operators made a skill based error by not taking appropriate actions for an identified unknown hazard, which directly resulted in the operator at the following operation receiving an unanticipated extremity dose of 3.58 rem.

Personnel mistakenly believed time could reduce risk to an acceptable level for an unknown radiological hazard. Given an identified unknown radiological hazard, the belief that time could be used as an effective hazard mitigation to minimize exposure to an acceptable level is a conceptual error.

Met mount samples were transferred out of the Hot Repair Area via the Stepout Room with no additional hazard mitigation following an off-scale high, >50 rem/h β-γ, meter reading at the previous

operation. This resulted in an operator receiving an unanticipated extremity exposure of 3.8 rem during an evolution that involved between 15 to 30 seconds of contact handling per sample. This occurred on three separate occasions in the same manner, but only resulted in the one exposure event. It cannot be determined if this was due to luck or skill.

In all cases it is listed as a requirement for the Operators, HPTs, and HPT Supervisors to stop in the event that an unexpected hazard is identified and not continue until the issue is resolved and appropriate controls have been instituted.

Radiological Control Manual (LRD-15001) Chapter 3, Part 4, Radiological Work Controls Article 342, Work Conduct and Practices, Number 8

> *Upon identification of radiological concerns, such as inappropriate work controls or procedural deficiencies, workers should immediately report the concern to line supervision or the Radiological Control organization. If appropriate to control individual exposure to radiological hazards, the affected individuals should exit the radiological area* ***until these issues are resolved and appropriate controls have been instituted****.*

All individuals have stop work authority at the INL in accordance with established integrated safety management system procedures and detailed in LWP-14002.

4.2 Contributing Factors

Contributing Factor 1

A3B2C04 - Previous successes in use of rule reinforced continued use of rule

Operators and HPTs normally contact handled unshielded samples to transfer them into shielded pigs. Had the samples not been contact handled to transfer between two engineered controls that provide shielding, the Hot Repair Area and a shielded transfer cask, this event would not have occurred, but may still have occurred elsewhere. The practice of contact handling a radiological hazard as a normal part of this evolution is not in accordance with ALARA principles given the availability of other options.

Contributing Factor 2

A3B3C06 - Individual underestimated the problem by using past events as basis

The Operator was informed that the samples were hot. The small pig size required bags to be rolled up. The selected small pig resulted in additional handling time, and rolling up the bag by hand decreased distance to the hazard. Had a pig been selected with a larger interior that did not require rolling up the bag this event may have been prevented.

Contributing Factor 3

A5B2C03 – Data/computations wrong/incomplete

The samples were sized to get an estimated 200 mrem/h γ on contact based on calculations and analysis, but actual levels were much higher. Since there was no known method to calculate beta radiation levels this would still be an unknown hazard, which would require handling the samples as an unknown hazard until surveyed. Had the calculations been accurate the severity of this event would have been significantly reduced.

Contributing Factor 4

A4B1C01 - Management policy guidance / expectations not well-defined, understood or enforced
A5B4C06 - Suspected problems not communicated to supervision

Personnel failed to notify facility management of the following;

a. The γ reading of >100 mrem/h @ 30 cm per the Stepout Room RWP

b. The unexpected off scale high on contact meter reading.

Notifying facility management may have prevented this event.

Contributing Factor 5

A5B4C03 - Correct terminology not used

Communicated to the Stepout Room Operator that “the samples were hot” instead of informing the Operator of the >50 rem/h β-γ on contact off-scale high meter reading. Had the Stepout Room Operator been notified of the >50 rem/h β-γ on contact off-scale high meter reading the Operator may have prevented this event.

5. Corrective Actions

The following corrective actions have been developed to address the root causes (causal factors) that contributed to this event; additionally, the corrective actions to address the contributing factors are also included in this section.

1. Develop training for all MFC radiation workers on the following:
   a. Expected response to high radiation rates (with particular attention to β) (*A3B1C03/A4B1C03*)
   b. Expected response to off scale radiation readings (*A3B1C03/A4B1C03*)
   c. Expectations associated with time out and stop work (*A3B1C03/A4B1C03*)
   d. ALARA techniques and tools to minimize extremity dose (for example long reach tools) (*A3B1C03/A4B1C03*)
   e. Expectation that all radioactive materials will be surveyed prior to contact (*A6B1C03/A3B2C04*)
   b. Use of finger rings
   c. Expectations for formal, documented pre-job briefings on high hazard jobs like this (*A6B1C03/A3B2C04*)
   d. Specificity required when communicating radiation readings and conditions (*A5B4C03)*
   e. Expectations of when to involve higher levels of management when dealing with issues (*A4B1C01/A5B4C06)*
   f. Expectations for ownership for personal exposure (*A6B1C03/A3B2C04*).
   g. Conduct post training evaluation (including interviews) to ensure training was effective.

   Target Completion Date: 10/12/2011 (Completed)

   Actions Assigned to: Stephen Meldrum

   Objective Evidence: Copy of training documentation

2. Conduct training for all personnel targeted in (1) above

   Target Completion Date: 10/14/2011

   Actions Assigned to: Stephen Meldrum

   Objective Evidence: Documentation of training attendance for at least 80% of target audience.

3. Review all ALARA reviews and RWP's associated with extremity dose and revise as necessary to incorporate the following *(A4B1C03/A5B2C08)*:
   a. β limits
   b. Adequate radiation monitoring instruments and practices
   c. Requirements for safety glasses for high β jobs
   d. ALARA techniques and tools to minimize extremity dose (for example long reach tools)
   e. Ensure all requirements from ALARA reviews are incorporated
   f. Establish trigger points that require job specific RWPs and ALARA reviews.

   Target Completion Date: 10/17/2011

   Action Assigned to: Paul Nelson

   Objective Evidence: Evidence binder containing review documentation

4. Require dose tracking for all jobs requiring extremity monitoring *(A6B1C03/A3B2C04)*.

   Target Completion Date: 01/09/2012

   Action Assigned to: Paul Nelson

   Objective Evidence: Copy of LWP-15027 once updated and available on EDMS.

5. Develop a detailed procedure for sample handling, preparation, and transfer from HFEF *(A6B1C03/A3B2C04/A5B2C03)*.

   a. Incorporates; pre-handling characterization of the sample by process (utilizing NS&T or other knowledgeable personnel), analysis of actual remote readings prior to handling for packaging and transfer, RadCon Engineering evaluation and approval of actual versus expected dose rates versus controls, and pre-shipping acceptance by receiving facility management and principle investigator(s)
   b. Requires survey at the Stepout Room prior to samples being put in transfer device
   c. Incorporates required controls from the ALARA review and the RWP
   d. Specific conditions required to allow moving samples from the hatch to the Glovewall.

   Target Completion Date: 11/30/2011

   Action Assigned to: Rick Casler

   Objective Evidence: A copy of the approved procedure once available on EDMS.

6. Develop a focused field observation check list for high β radiation work *(A4B1C03/A5B2C08)*.

   Target Completion Date: 10/13/2011

   Action Assigned to: Tom Morgan

   Objective Evidence: Field observation cards.

7. Ensure first time use of all extremity monitoring RWPs is observed by NFM/FM or above using β checklist.

   Target Completion Date: 10/17/2011

   Action Assigned to: Phil Breidenbach

   Objective Evidence: Copy of Management Directive.

8. Conduct a Line Management Review to ensure we are ready to resume work requiring extremity dosimetry *(A6B1C03/A3B2C04)*.

   Target Completion Date: 10/17/2011

   Action Assigned to: Richard Cain

   Objective Evidence: Evidence binder showing all corrective actions required prior to resuming work are complete.

9. Modify the ALARA review process to require walk down of facility/job by the RadCon Engineer with workers during development of the RWP *(A6B1C03/A3B2C04)*.

   Target Completion Date: 01/31/2012

   Action Assigned to: Paul Nelson

   Objective Evidence: Copy of updated ALARA Review document.

10. Pull and analyze all finger rings of potentially affected personnel *(A6B1C03/A3B2C04)*.

    Target Completion Date: 10/13/2011

    Action Assigned to: Paul Nelson

    Objective Evidence: Copy of the results of finger ring readings.

11. Develop transfer/receipt procedures that focus attention on the radiological characteristics of the item being transferred versus "external radiation readings on transport container," for transfers of radioactive material from one MFC facility to another *(A6B1C03/A3B2C04)*.

    Target Completion Date: 01/31/2012

    Action Assigned to: Cory Brower

    Objective Evidence: Copy of revised SP-20.6.0 or equivalent once on EDMS.

12. Retrain HPTs on standards for completion of survey maps and logs *(A3B1C03/A4B1C03)*.

    Target Completion Date: 01/31/2012

    Action Assigned to: Stephen Meldrum

    Objective Evidence: Documentation of completion of training for at least 80% of target audience.

13. Perform a TEV that evaluates work performed at the HFEF Glovewall and recommends appropriate engineering controls to minimize extremity dose *(A6B1C03/A3B2C04)*.

    Target Completion Date: 01/31/2012

    Action Assigned to: Wayne Kanady.

    Objective Evidence: Completed Technical Evaluation.

14. Evaluate the availability of real-time extremity dose monitoring equipment *(A6B1C03/A3B2C04)*.

    Target Completion Date: 01/31/2012

    Action Assigned to: Paul Nelson

    Objective Evidence: Memo from Paul Nelson stating results of evaluation.

15. Develop training for personnel on proper use of extremity monitoring equipment.

    Target Completion Date: date 01/31/2012

    Action Assigned to Eric Horman

    Objective Evidence: Copy of training materials provided to INL Training.

16. Train personnel on the proper use of extremity monitoring equipment.

    Target Completion Date: 06/30/2012

    Action Assigned to: Loren Peterson

    Objective Evidence: Documentation of completion of training for at least 80% of target audience.

17. Have EML personnel tour HFEF and HFEF personnel tour EML with a specific focus on the flow of work related to samples and information sharing on how each group contact handles high radiation samples *(A6B1C03/A3B2C04)*.

    Target Completion Date: 10/31/2011

    Action Assigned to: Rick Casler

    Objective Evidence: Documentation from Casler stating completion of personnel tours.

18. Incorporate lessons learned from this event into Radworker I and Radworker II training.

    Target Completion Date: 03/31/2012

    Action Assigned to: Chere Morgan

    Objective Evidence: Copy of training materials provided to INL Training.

19. Conduct an effectiveness assessment of these corrective actions.

    Target Completion Date: 06/30/2012

    Action Assigned to: Scott Nelson

    Objective Evidence: Integrated Assessment Report provided to MFC Oversight and Assurance Group.