FINAL REPORT **OCTOBER 2002**

TYPE B ACCIDENT INVESTIGATION BOARD REPORT OF THE JUNE 2002 HIGH RADIATION DOSE TO EXTREMITIES IN BUILDING 151 LAWRENCE LIVERMORE NATIONAL LABORATORY, LIVERMORE, CALIFORNIA

OAKLAND OPERATIONS OFFICE
DOE/OAK—505

DOE/OAK–505

This report is an independent product of the Type B Accident Investigation Board appointed by Camille Yuan-Soo Hoo, Manager of the U.S. Department of Energy, Oakland Operations Office.

The Board was appointed to perform a Type B Investigation of this accident and to prepare an investigation report in accordance with the DOE Order 225.1A, *Accident Investigations*.

The discussion of the facts, as determined by the Board, and the views expressed in the report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents, or subcontractors at any tier, or any other party. This report neither determines nor implies liability.

On July 26, 2002, I established a Type B Accident Investigation Board to investigate the June 2002 High Radiation Dose To Extremities of a researcher in Building 151, at Lawrence Livermore National Laboratory, Livermore, California. The Board's responsibilities have been completed with respect to this investigation. The analysis, identification of root and contributing causes, and judgments of need reached during the investigation were performed in accordance with DOE Order 225.1A, *Accident Investigations.*

I accept the findings of the Board and authorize the release of this report for general distribution.

Camille Yuan-Soo Hoo,
Manager
Oakland Operations Office

Date: 10-21-02

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ACRONYMS & ABBREVIATIONS

AD	Associate Director
AI	Authorizing Individual
ALARA	As Low As Reasonably Achievable
ANCD	Analytical and Nuclear Chemistry Division
AM	Assurance Manager
AMNS	Assistant Manager for National Security
Board	Accident Investigation Board
CAM	Continuous Air Monitor
Cf - 249	californium 249
Cm	centimeter
Cm - 245	curium 245
Cs - 137	cesium 137
CMS	Chemistry and Materials Science Directorate
DAP	Health Physics Discipline Action Plan
DOE	U. S. Department of Energy
DOELAP	DOE Laboratory Accreditation Program
DOE/OAK	U. S. Department of Energy, Oakland Operations Office
DP	Office of Defense Programs
ES&H	Environment, Safety and Health
FM	Facility Manager
FPOC	Facility Point of Contact
FR	Facility Representative
FSP	Facility Safety Plan
HA	Hazard Assessment
HAR	Hazard Analysis Report
HC	Hazards Control Department
HCl	Hydrochloric Acid
HEPA	High Efficiency Particulate Air
HNO_3	Nitric Acid
HP	Health Physicist

ACRONYMS & ABBREVIATIONS

hr	hour
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
IWS	Integration Work Sheet
JON	Judgments of Need
LANL	Los Alamos National Laboratory
LDRD	Laboratory Directed Research and Development
LLNL	Lawrence Livermore National Laboratory
LSO	Livermore Site Office
LSOD	Livermore Safety Oversight Division
LTRAIN	Livermore Training Records and Information Network
mCi	millicurie
mg	milligram
ml	milliliter
mR	milliroentgen
mrem	millirem
NNSA	National Nuclear Security Administration
OA	Office of Independent Oversight and Performance Assurance
OAK	Oakland Operations Office
ORNL	Oak Ridge National Laboratory
ORPS	Occurrence Reporting and Processing System
OSP	Operational Safety Plan
PPE	Personnel Protection Equipment
QA	Quality Assurance
RATS	Radioactivity Allowance Tracking System
SME	Subject Matter Expert
TLD	Thermoluminescent Dosimeter
TM	Training Manager

Authorizing Individual: The individual responsible for authorizing work after controls are implemented, procedures, IWS and OSP are approved. (Reference: LLNL *ES&H Manual* Document 3.4)

Barrier: Any means used to control, prevent, or impede the hazard from reaching the target. Barriers may be physical or administrative barriers or both.

Barrier Analysis: An analytical technique used to identify energy sources and the failed or deficient barriers and controls that contributed to an accident.

Causal Factors: All events or conditions in the accident sequence necessary and sufficient to produce or contribute to the unwanted result. Some types of causal factors are:

- *Direct cause:* The immediate events or conditions that caused the accident.
- *Contributing causes:* Events or conditions which increase the likelihood of an accident but which individually did not cause the accident.
- *Root causes:* Conditions or events which if eliminated or modified, will prevent recurrence of an accident or similar events.

Discipline Action Plan: An ES&H team plan used by health physicists and ES&H technicians for monitoring individuals and areas, demonstrate compliance with DOE radiological conditions, and verify adequacy of engineering controls.

Eberline E-120 Survey Meter: A Geiger-Mueller radiation detection and measurement device.

Eberline R02 Survey Meter: An ionization chamber type radiation detection and measurement device.

ES&H Technician: A member of ES&H Team 5 tasked with providing multi-discipline ES&H support to CMS.

Facility Manager: The Facility Manager has overall responsibility for safe facility operations; tasks includes the review of documents such as FSPs, OSPs, and IWSs. (Reference: LLNL *ES&H Manual* Document 2.1)

Facility Representative: The Facility Representative (FR) is the OAK representative who has principal ES&H and QA oversight responsibility for their assigned facility(ies), in accordance with DOE STD 1063-2000. The FR functions as the OAK day-to-day interface with contractor management and OAK management. (Reference: AMLSO-SOP-00062-02.0 Facility Representative Program)

Facility Safety Plan: A facility or complex specific document that provides a framework for ISM; and that addresses ES&H parameters, the responsibilities of building personnel for ensuring safe operations, hazards and controls, and requirements for training, maintenance, and QA.

Fume Hood: A work place designed with ventilation pulling air away from the room and into an exhaust stack. The purpose is to protect the operator from coming into contact with contamination.

Glovebox: An enclosed workplace designed to protect the environment, public and workers from exposure to radioactive material. A glovebox is constructed with gloves attached to the gloveports, and allows the operator to manipulate material without coming in contact with it.

Hazard Analysis Report: A document that provides systematic identification of the hazards associated with a particular facility or complex of facilities.

Hazard Assessment: This is a review performed by the Health and Safety Professionals in conjunction with line management and the workers and the subsequent establishment of controls to protect the workers from the hazards.

Hazards Control ES&H Teams: LLNL Environment, Safety and Health support teams organized through the Hazards Control Department. Each team, consists of ES&H specialists and technicians, provides support to one or more of LLNL's program areas (directorates). Team 5 provides ES&H support to CMS.

$HN0_3$: Nitric Acid

Judgments of Need: Managerial controls and safety measures determined by the Board to be necessary to prevent or minimize the probability or severity of a recurrence of an accident.

Lead Pig: A storage container used to store radioactive materials, for the purpose of minimizing radiation exposure from the material(s).

Micro(μ): One millionth (10^{-6})

Milli (m): One Thousandth (10^{-3})

Occurrence Reporting and Processing System (ORPS): The reporting system established and maintained for reporting occurrences related to the operation of DOE facilities.

Operational Awareness: Generally consists of surveillances, observations, walk-throughs, and attendance at contractor meetings. Operational awareness activities are documented in the Functional Information on Safety, Health, and the Environment (FISHE) database. (Reference: AMNS-SOP-000228-02.0 Facility Operational Awareness Program)

Operational Safety Plan (OSP): A safety document that delineates controls specific to an activity, including safety responsibilities and specific operational controls necessary to ensure a low-risk work environment.

rem: Unit of dose equivalent.

Transuranic Waste: Per DOE M 435.1-1, Transuranic waste is radioactive waste containing more than 100 nanocuries (3700 becquerels) of alpha – emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for: high-level radioactive waste, waste that does not need the degree of isolation required by the 40 CFR Part 191 disposal regulations, or, waste approved for disposal in accordance with 10 CFR Part 61.

Type B Accident: In this case, a radiation exposure in which the dose equivalent to the worker's extremity is greater than 100 rem. (Reference: DOE Order 225.1A, *Accident Investigations*)

EXECUTIVE SUMMARY

INTRODUCTION

On July 22, 2002, the June finger ring thermoluminescent dosimeters worn by a Lawrence Livermore National Laboratory (LLNL) employee (referred to as the Researcher) were determined to have exceeded the annual dose limit. The annual occupational dose, per 10 CFR 835. 202, to any extremity is limited to 50 rem. The ring dosimeters (Nos. 92783 and 92758) were initially determined to have received 120 and 54 rem dose respectively. Following recalibration of the dosimeters with cesium 137 to doses approximating the actual doses, the doses were revised to 111 and 62 rem, respectively. These doses represent 2.2 and 1.2 times the annual extremity dose limit.

The Researcher was authorized to purify several milligrams (mg) of californium 249 from which about 11 mg were to be sent out for collaborative research overseas. The purification work was conducted in Room "B" of Building 151 from June 10 through June 21, 2002.

In the judgment of the Accident Investigation Board (the Board), the high doses to the Researcher's ring dosimeters resulted from the californium 249 purification work activity. This judgment is based on the facts gathered and analysis conducted during the investigation. The Board inspected the accident site, reviewed the events surrounding the accident, conducted extensive interviews, and reviewed pertinent documents to identify the factors that led to the accident, including any management system deficiencies. The Board used a variety of analytical techniques, including events and causal factors charting and analysis, barrier analysis, and root cause analysis to identify the causal factors that led to the accident. Relevant management systems and factors that could have contributed to the accident were evaluated using the components of the Department's Integrated Safety Management System (ISMS), as described in DOE Policy 450.4.

CAUSAL FACTORS

The **direct cause** of the overexposure was that the Researcher physically handled the radioactive materials for an extended period of time.

Contributing causes (causes that increased the likelihood of the overexposure without individually causing the overexposure and that are important enough to warrant corrective action) are as follows:

1. The Researcher did not follow administrative requirements, such as the Integration Work Sheet (IWS) and the referenced Operational Safety Plans (OSP). He did not request and therefore did not receive Hazards Control/Environment, Safety and Health (ES&H) team support at the beginning of the job. This resulted in insufficient engineering and administrative controls being put in place before the work began.

2. The Researcher's radiation survey results that met the radiation area criteria (>5 mR/hr at 30 cm) were not communicated to the ES&H team so that the area/room could be posted appropriately and the HP notified (per IWS and OSP requirements).

3. The lack of full integration of the ES&H team into CMS line management activities prevented the implementation of safety controls.

Root causes of the overexposure (the fundamental cause that, if eliminated or modified, would prevent recurrence of this and similar overexposures) were:

1. The failure to implement ISM principles, including following documented procedures and work authorization requirements.
2. The failure to implement ALARA principles, including the use of adequate shielding and exposure time considerations.

CONCLUSIONS AND JUDGMENTS OF NEED

Conclusions are a synopsis of the facts and analytical results that the Board considers especially significant. Judgments of Need are managerial controls and safety measures believed necessary to prevent or mitigate the probability or severity of a recurrence. The Judgments of Need are generated from the conclusions and causal factors, and are directed at guiding managers in developing follow-up actions. The table below summarizes the conclusions of the Board and Judgments of Need.

Conclusions	*Judgments of Need*
The Researcher did not follow procedures: • Researcher did not become familiar with the IWS requirements. • Researcher did not practice CONOPS.	CMS to ensure that individuals read, understand, and follow procedures.
The Researcher did not implement the knowledge acquired in training: • Researcher did not practice ALARA. • Researcher did not practice ISM as it is related to job planning and hazard analysis. • Researcher did not wear ring dosimeters while handling radioactive materials in Room "A".	CMS to hold individuals accountable for implementing ALARA, ISM and CONOPS. CMS to ensure that individuals wear their dosimeters when handling radioactive materials or radiation generating devices, or entering areas where dosimeters are required.
CMS failed to fully integrate the ES&H functions into line management: • Line management does not adequately interact with the ES&H team thus the ES&H team is not always aware of operations and activities in the facilities. • Line management failed to request the ES&H team assistance for the implementation of the OSP radiological control requirements.	CMS to develop and implement a systematic approach to inform the ES&H team of activities and operations to improve the integration of the ES&H program.
ES&H team displayed lack of "attention to detail" in their service to ANCD: • Package surveys were not performed as required by OSP. • Dose rates in Room "A" were not updated as required by OSP. • The discrepancy between RATS curie content and materials transfer tag curie information was not questioned.	HC Management to ensure that the ES&H Team is aware of applicable requirements and complies with them and conducts their ES&H support with attention to detail. CMS to foster an environment that encourages the ES&H team members to be proactive and exercise more initiative when providing ES&H coverage.

Conclusions	*Judgments of Need*
ANCD failed to ensure the existence of adequate procedures to perform the work safely: • DAP does not require surveys of incoming radioactive packages. • OSPs and DAP contain conflicting survey requirements. DAP requires dose rates to be obtained at contact with glovebox window; OSP requires the survey at 30 cm from glovebox window. • OSPs do not contain adequate frequency requirements for direct and contamination surveys; do not contain ALARA requirements.	CMS to ensure that safety documents are in place and updated with respect to frequency, methodology, and quality of the surveys. ALARA requirements need to be spelled out for all potentially high dose work activities. CMS to ensure that safety procedures (i.e., OSP and DAP) do not contain conflicting requirements. CMS to ensure that ES&H team responsibilities that are listed in safety documents (e.g., OSP, IWS) are clearly communicated to the ES&H team.

TYPE B ACCIDENT INVESTIGATION BOARD REPORT OF THE JUNE 2002 HIGH RADIATION DOSE TO EXTREMITIES IN BUILDING 151, LAWRENCE LIVERMORE NATIONAL LABORATORY, LIVERMORE, CALIFORNIA

14 INTRODUCTION

14.1 Background

The Researcher had been approved under an existing Integration Work Sheet (IWS) No. 2284 to purify about 13.2 milligrams (mg) of californium 249 (Cf-249) from which about 11 mg were to be sent out for collaborative research overseas. The purification work was conducted in Room "B" of Building 151 (B151) from June 10 through June 21, 2002.

On July 22, 2002, the ring dosimeters of an employee (referred to as the Researcher) at the Lawrence Livermore National Laboratory (LLNL) were read and determined to exceed the annual radiation dose limit of 50 rem to any extremity/hand. The ring dosimeters were submitted for readings the first week in July and were read on July 22, 2002. The initial readings were 120 rem for dosimeter # 92783 and 54 rem for dosimeter # 92758. After recalibrating the dosimeters with cesium 137 (Cs-137) to doses in the range of the actual exposures, the initial dose estimates were revised to 111 rem and 62 rem, respectively. The Researcher and the Chemistry and Materials Science (CMS) Directorate were notified of the results and thereafter, the Researcher was notified to abstain from further radiological work activities until further notice. These doses represent 2.2 and 1.2 times the annual extremity dose limit.

On July 26, 2002, Camille Yuan-Soo Hoo, Manager of the National Nuclear Security Administration (NNSA) Oakland Operations Office (OAK), appointed a Type B Accident Investigation Board (the Board) to investigate the accident in accordance with DOE Order 225.1A, *Accident Investigations*. The Board commenced its investigation on July 26, 2002.

1.2 Facility Description

LLNL is a DOE facility under the cognizance of NNSA/OAK. LLNL is managed and operated by the Regents of the University of California for NNSA. The facility in which this accident occurred is under the programmatic direction of the NNSA.

Building 151 (B151) is one of several research facilities at LLNL under the direction of the CMS Directorate. B151 is a radiological, low hazard facility that provides office, laboratory, and electronics shop facilities for laboratory operations for a broad range of chemical, radiochemical, and bioanalytical research. Primary activities include research in radiochemical and chemical analysis, transport of radionuclides in geological materials, preparation of radionuclides, analysis of environmental and waste samples, biological analysis, and clean room activities.

Figure 1 is a schematic of Room “B” in B151. Room “B” is a research room used for high level radiochemistry and Authorization Level 4 operations. Level 4 is work that is not commonly performed by the public and necessitates the preparation of an IWS and Safety Plans (e.g., Operational Safety Plan). The research room houses several HEPA-filtered gloveboxes, two Continuous Air Monitors, and a hand and foot counter. Room “A” is mainly used for counting and storage of radioactive materials and wastes.

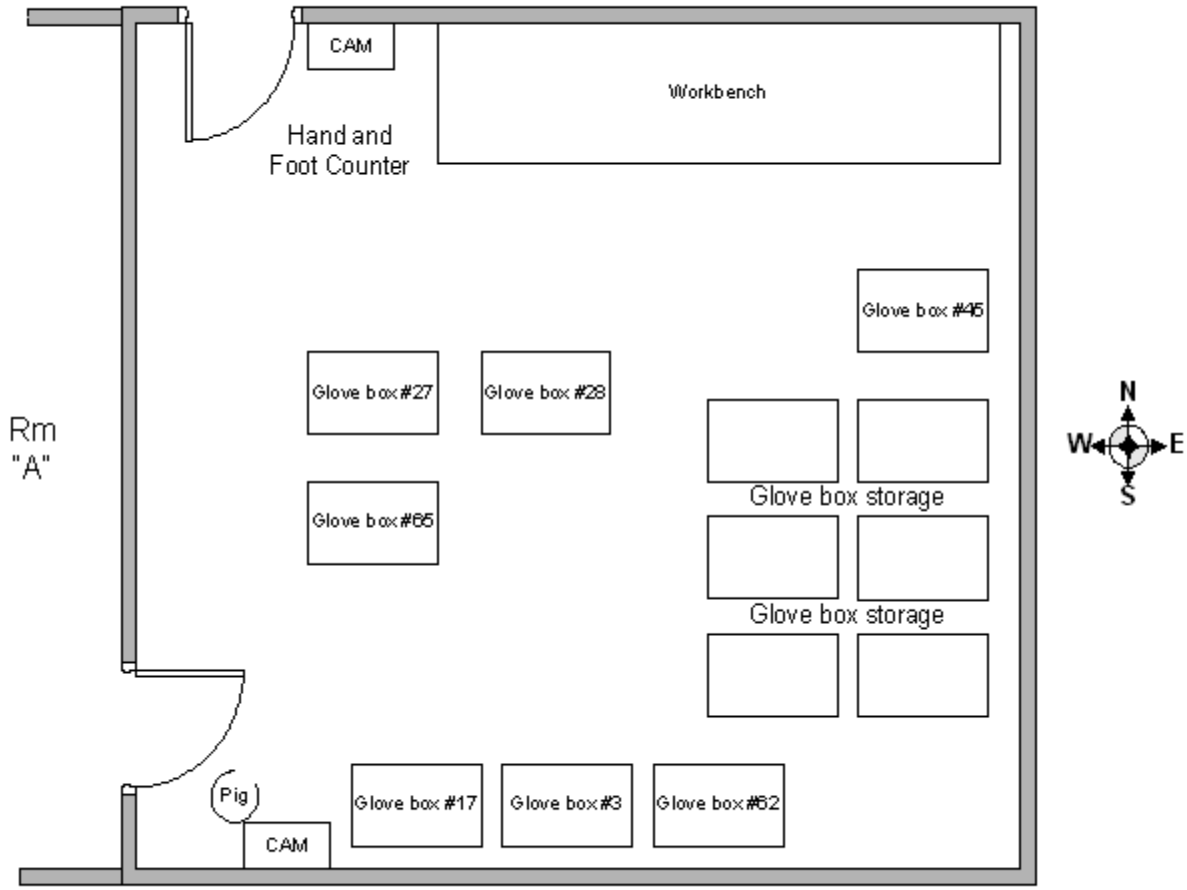


Figure 2. Room “B” Layout.

1.3 Scope, Conduct, and Methodology

The scope of the Board's investigation was to investigate the causal factors of the accident in accordance with DOE O 225.1A, *Accident Investigations*. The Board also evaluated the adequacy of the DOE and contractor's safety management system and work control practices. Based on the investigation, the Board identified Judgments of Need for corrective actions to prevent the recurrence of similar events.

The objectives of the investigation were to: 1) determine the cause of the accident, including deficiencies, if any, in safety management systems; 2) assist NNSA in identifying and understanding lessons learned to promote safety improvement; and 3) reduce the potential for similar accidents. The Board conducted its investigation, focusing on management systems, using the following methodology:

- The Board inspected the accident site.
- The Board conducted extensive interviews with key personnel and reviewed pertinent documentation and policies.
- Event and causal factors charting, along with a barrier analysis and root cause analysis were used to provide supportive correlation and identification of the accident's causes.

2 FACTS AND ANALYSES

2.1 Accident Description, Chronology, and Dose Evaluation

2.1.1 Background

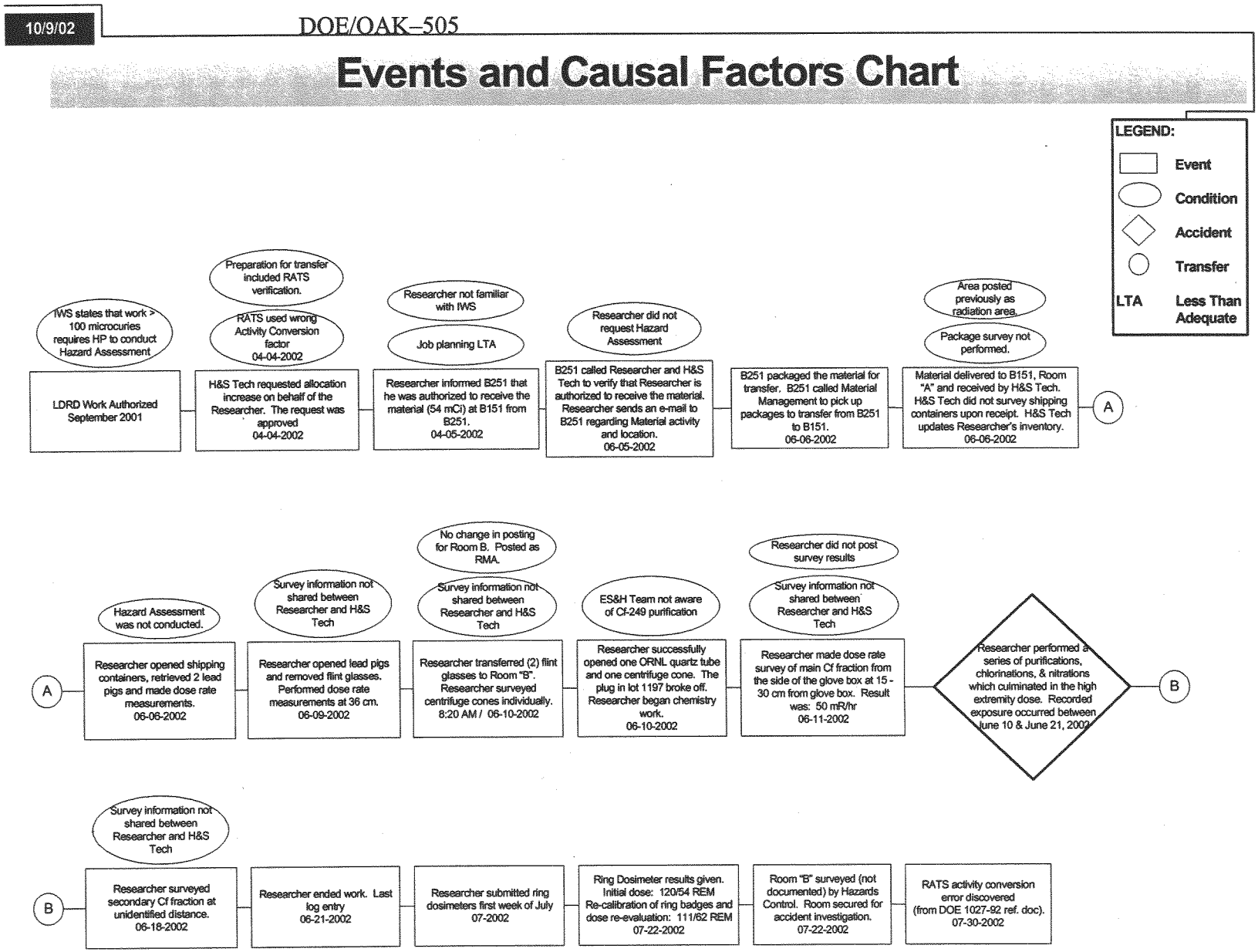
In April, 2002, the Researcher requested the transfer of about 13.2 milligrams (mg) of Cf-249 materials from Building 251 (B251) to B151 to purify the materials and subsequently ship about 11 mg to overseas collaborators. The Researcher indicated that the intended recipients had insisted on receiving only pure Cf-249. On June 6, 2002, two shipping packages containing the materials were delivered to B151, Room "A".

Beginning on June 10, 2002 through the next several days, the Researcher proceeded to purify the materials in Room "B", performing the work under the IWS No. 2284. He completed the work on June 21, 2002.

In early July, 2002, the Researcher submitted his ring dosimeters for the end-of-the-month reading. On July 22, 2002, he was informed that the readout of the dosimeters had indicated an overexposure of the extremities, and he was verbally told to stop all radiological work activities. On July 25, 2002, he was formally informed to stop working with any radioactive materials or radiation producing devices that would expose him to additional radiation.

Figure 2 is a time-line of key events entitled "Events and Causal Factors Chart." Section 2.1.2 provides the chronology of events based on the Researcher's notes and interviews with the Researcher and other personnel associated with the work activity.

Figure 2. Events and Causal Factors Chart.



Note: Health & Safety (H&S) technician is the same as ES&H technician.

2.1.2 Chronology of Events

June 6, 2002—At the request of the Researcher, two radioactive packages from B251 were transferred to B151 Room "A". The transfer was conducted in accordance with LLNL operating procedures. One package, with a "Controlled Material ID Tag No. 299911", contained two ORNL quartz tubes with an estimated quantity of 5 milligrams (20.4 millicuries) of Cf-249. The second package, with ID Tag No. 299912, contained 8.2 milligrams (33.5 millicuries) of Cf-249 in a single 40-ml centrifuge cone (Lot 5). The ORNL quartz tubes, Lots 1197 & 1244, were packed in a Flint-glass bottle, and then over packed respectively in a lead pig, a juice can, a Pit storage container, and finally in a shipping container. The 40-ml centrifuge cone (Lot 5) was similarly over packed (Figure 3 Packing Diagram).

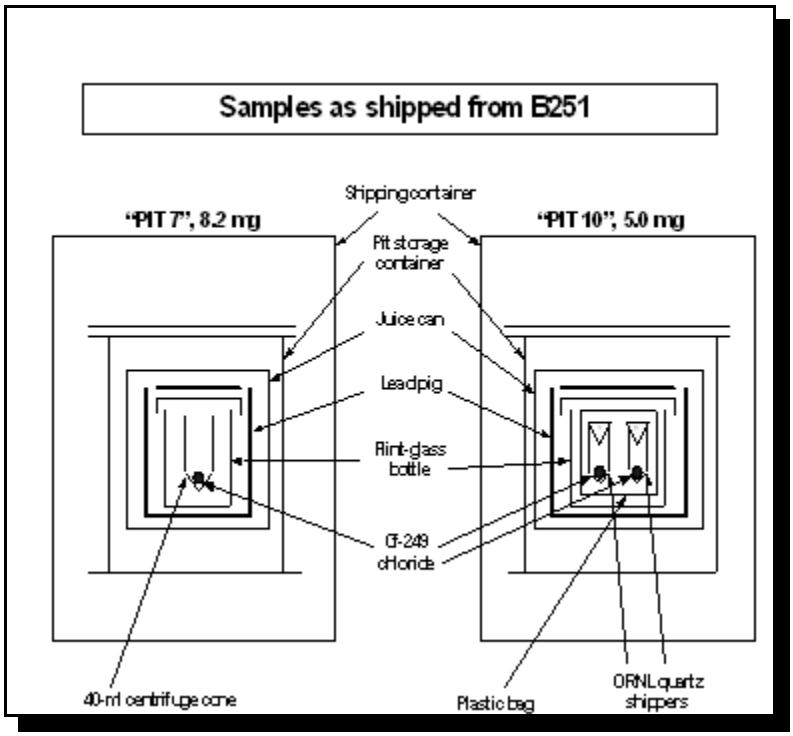


Figure 4. Packing Diagram.

Upon arrival on June 6, 2002, the ES&H technician placed the two packages in front of the fumehood in Room "A" and updated the Researcher's (and the Facility's) inventory of radioactive materials. The same day, the Researcher opened the two packages in the fumehood and took dose rate measurements of the lead pigs, using an Eberline E-120 survey meter with a HP 177 probe. The dose rate at approximately 30 cm from the lead pig containing Lots (L) 1197 & 1244 was 5 mR/hr. At the same distance, L5 (in its lead pig) gave a dose rate of 9 mR/hr. The Researcher was not wearing his ring dosimeters during these surveys.

June 9, 2002—While the packages were still in the fumehood, the Researcher took the Flint-glass bottles out of the pigs to survey them for contamination (without wearing his ring dosimeters). Finding no contamination, he then took a dose rate measurement of each bottle at a distance of approximately 36 cm. He obtained a dose rate of 34 mR/hr from the L1197/1244 Flint bottle and 44 mR/hr from the L5 bottle.

June 10, 2002—Prior to 0800 hours, the Researcher moved the two Flint-glass bottles into Glovebox 65 in Room "B" (see Figure 4). It was during this time that the Researcher put on his ring dosimeters. His ring dosimeters are normally stored on the workbench in the room, away from the radioactive materials or storage areas. He took the ORNL quartz bottles (L1197 and 1244) out of the Flint bottle and surveyed each tube individually, placing each tube one at a time, as close to the inside edge of the glovebox (box) as possible and taking a box-contact reading from outside of the box. The dose rate from L1197 was 13.5 mR/hr while L1244 was 44 mR/hr. The dose rate for the 40-ml centrifuge cone (L5) was not indicated.

Glovebox 65

Figure 5. Glovebox 65 in Room "B".

The Researcher proceeded to remove the glass stopper (lid) from L1197 but the stopper broke off. Additional efforts to pull out the stuck or bottom portion of the stopper were unsuccessful. The Researcher set L1197 aside and turned to the L1244 stopper, which was successfully removed.

At 0820 hrs, the Researcher added 1 ml of hydrochloric acid (HCl) to L1244 and let it stand for about 2 hours. He then transferred more than half of the solution to the L5 cone, bringing L5 to about 12 mg of Cf-249.

By 1115 hours, the Researcher loaded the 12-mg Cf-249 onto a Dowex 50 × 4 cation-exchange column and began elution. Between 1130 and 1230 hours, the Researcher rinsed (4 times) the original L5 cone with incremental volumes (1 to 3 ml) and molarity (1 to 3 molar in later washes) of HCl with the objective of extracting most of the Cf-249. Each rinse solution was pipetted back into the column.

All of the B251 shipments were in the Glovebox 65 during this stage of the chemistry work. L5 was in the column, the remainder of L1244 was being dried while L1197 might have been inside a Flint-glass bottle.

By 1325 hours, the Cf-249 band had only migrated some 30% through the column and the Researcher decided to accelerate the migration by adding a series (seven) of 1 ml, 2 molar HCl to the column. With each addition, he moved the pre-fraction collection cone to the side of the box and surveyed it for the presence of radioactivity. After he started detecting radioactivity in the pre-fraction cone at around 1425 hours, he changed cones and began to collect Cf-249 in a new 40-ml centrifuge cone. To accelerate the process even further, he increased the volume and molarity of the HCl being added, completing the last HCl addition at 1610 hours.

June 11, 2002—By 0530 hours, the Researcher began drying the main Cf-249 fraction in Glovebox 65. The drying time was estimated to be about 1 hour. While the main Cf fraction was on the evaporator, the Researcher began to re-elute the previous day's 50 × 4 cation column to recover curium 245 (Cm-245), the decay product of Cf-249. The Cm-245 (which the Researcher described as very valuable) was recovered in a separate 12 ml centrifuge cone. This process achieved two goals—recovering a valuable resource and minimizing transuranic waste generation.

After the main Cf-249 was dried, the Researcher moved the cone to the inside edge of the box and obtained a dose rate of greater than 50 mR/hr with the survey probe at an estimated distance of 15 to 30 cm from the side of the glovebox. The Researcher also estimated a box-contact dose rate of approximately 500 mR/hr. The Researcher made similar measurements (but with the probe in contact with the box) for the Cm-245 and pre-fraction cones and obtained 6 and 0.5 mR/hr, respectively. These survey results were noted in the Researcher's notebook. None of the survey results was posted as required by the OSP.

To nitrate the californium and curium, the Researcher began a series of additions of 8 molar HNO_3 to both the californium and curium fractions. He would, for example, add three drops of HNO_3, evaporate, and then repeat the process several times, according to his notes.

By 1625 hours, the Researcher had secured all fractions (main Cf-249, Cm-245, and pre-fraction/waste) in Glovebox 65. Sometime during the day, the ES&H technician performed a quarterly radiation survey of Room "B" using an Eberline 120/HP 177 probe. The ES&H technician obtained the maximum reading of 2.4 mR/hr (according to the Discipline Action Plan [DAP] requirements: in physical contact with the glovebox window).

June 12, 2002—The Researcher loaded the Cf-249 fraction onto an AGMP-1 anion-exchange column and again began a series of washes (with 90/10 methanol/HNO_3 and later with 40% methanol/5 molar HNO_3) of the now empty Cf-249 cone to extract everything from the bottle as he had done previously.

By 1025 hours, the pure Cf-249 band had been collected and the Researcher switched cones to collect any Cm-245 that still remained in the previous day's main Cf-249 fraction. Meanwhile, the new Cf-249 nitrate fraction was simultaneously being evaporated in the box. After evaporation, the Researcher added 10 ml of dilute HNO_3 to the Cf-249 fraction and set it aside after withdrawing some 15 microliters for a quantitative analysis.

The Researcher then began to evaporate the pre-fraction/waste and curium fractions. Work for the day ended at around 1300 hours with a californium nitrate fraction, a curium nitrate fraction, and one and possibly two pre-fraction/waste components in Glovebox 65.

June 13, 2002—The Researcher took two additional samples from the main Cf-249 fraction and evaporated them to dryness. He then performed radiation surveys of all fractions and obtained the following results:

dry main Cf-249 fraction	45 mR/hr at an unspecified distance[1]
Cm-245 fraction	3.5 mR/hr at the same unspecified distance 23 mR/hr at half of the unspecified distance
pre-fraction/waste fraction	0.5 mR/hr at half of the unspecified distance

June 14, 2002—The Researcher placed the main Cf-249 cone into a Flint-glass bottle and set it aside. While his notes did not indicate further action, the Researcher said in an interview that he moved the Cf-249 cone out of Glovebox 65 and into another glovebox (3) directly across from Glovebox 65.

June 17, 2002—The Researcher further purified the Cm-245 fraction because it still appeared to contain trace quantities of Cf-249. Around 0815 hours, he added 10 drops of the 90/10 methanol/HNO_3 solution to the curium fraction and loaded it back onto the anion-exchange column. The Researcher rinsed the empty curium cone with 10 drops of 90/10 solution, repeated with 15 drops, and then switched twice to 5 drops of 40% methanol rinse, emptying the rinse solution into the column each time. Finally, he added 1 ml of 40% methanol to the anion column.

Between 1035 and 1200 hours and as the extraction began, the Researcher made radiation survey measurements every 5-10 minutes as he followed the migration of the residual Cf-249 into the centrifuge cone that was seated in the lead pig. By 1200 hrs, he had finished collecting the residual Cf-249 fraction and switched cones to collect the pure Cm-245.

For the rest of the day, the Researcher continued to evaporate the three fractions (residual Cf-249, pure Cm-245, and pre-fraction/waste).

June 18, 2002—The Researcher evaporated all fractions to dryness, and obtained the assay results of the aliquots previously taken from the main Cf-249 fraction (11.3 mg).

June 21, 2002—The Researcher performed radiation surveys of all fractions at an unspecified distance and obtained the following results:

Residual Cf-249 fraction	>50 mR/hr at an unspecified distance; 22 mR/hr at twice the unspecified distance; and 88 mR/hr (estimated) on contact with the box

[1] *Based on the dose rates the unspecified distance was estimated to be the same as that used on June 11, 2002; i.e., 15 to 30 cm from side wall of the box).*

Cm-245 fraction	3.3 mR/hr at the same unspecified distance
Waste fraction	0.1 mR/hr at the same unspecified distance

The Researcher made final assays and calculations of radioactivity for the different fractions. His final entries indicate that the chemistry work yielded:

main Cf-249 fraction	11 to 11.3 mg for shipment overseas
residual Cf-249 fraction	1 to 2 mg (which may also include the curium component). This quantity was identified during an interview with the Researcher.

From the interview with the Researcher, the following should also exist:

2 to 3 mg of Cf-249 as a remnant of Lot # 1244
1 to 2 mg of Cf-249 of unused Lot # 1197

First Week in July—The Researcher's ring dosimeters were submitted to the Laboratory's dosimetry office in early July.

July 22, 2002—The ring dosimeters were read. The ring dosimeter with the red strap (Dosimeter #92783) gave a dose of 120 rem while the dosimeter with black strap (Dosimeter #97258) showed a dose of 54 rem. (The red strapped dosimeter is normally worn on the right hand; the black strap is worn on the left hand.) Following the discovery of the high doses, the Researcher was verbally informed by the HP not to perform further radiological work.

The dosimeters, normally calibrated to 500 mrem, were recalibrated on July 23, 2002, using Cs-137 to doses in the range of the actual measurements (98 and 49 rem). Based on the recalibration, the extremity doses were revised to 111 rem and 62 rem, respectively. The Researcher was notified, Hazards Control (HC) notified CMS, and LLNL filed an Unusual Occurrence Report to report the overexposure.

July 25, 2002—Based on the high extremity doses, the Researcher was formally notified to abstain from any more work involving the use of radioactive materials or radiation producing devices until further notice.

July 30, 2002—It was discovered that RATS had used the wrong activity conversion factors. The conversion factor (mg to mCi) derived from DOE-STD-1027-92 reference document (LANL-12846-MS), which provides specific activities for calculating activity thresholds for unidentified isotopes, was off by a factor of 10.

July 31, 2002—LLNL established a dose reconstruction committee of technical experts.

2.1.3 Post Accident Information and Analysis

After CMS was notified of the overexposure, Room "B" was surveyed by HC personnel to determine if there were unknown sources of radiation that could have produced the doses. They also needed to verify that the dose rates in the area where the Researcher's ring dosimeters were stored was at background

radiation levels. After they determined that the room was safe for further entry, it was secured for an accident investigation. Based on the level of the extremity doses, the Manager of the Oakland Operations Office established a Type B Accident Investigation Board. The Board arrived on site on July 26, 2002, to begin the investigation. After establishing the necessary logistics and administrative infrastructure, the Board received a briefing from the CMS Directorate and HC Department.

The Board began its investigation on July 26, 2002, by first visiting Room "B" where the accident occurred. The Board spent the next two to three weeks interviewing all pertinent individuals and departments connected with the work activity. The individuals that were interviewed included the Researcher, personnel from B251 where the Cf-249 had originated, and the management and operational staff of B151. Others included personnel from HC, the ES&H Team 5 and the Dosimetry Office.

2.1.4 Dose Reconstruction and Assessment

2.1.4.1 Cf-249 Characteristics

Cf-249, with a 351 year half life, emits alpha (100%), spontaneous fission neutron (5E-7%), and photons. Its photon energy spectrum ranges from 15 keV to 1 MeV. In a 2 millimeter Pyrex glass or centrifuge cone, photons below 10 keV will be highly attenuated so that most of the exposure to the extremities and wholebody will be due to the 0.1 MeV to 0.8 MeV photons. The Microshield version 5.03 calculated the exposure rate as 2.71 R/hr/mCi at 1 cm (approximately 11 R/hr/mg based on a specific activity of 4.1 mCi/mg). The exposure rate at 30 cm is 2.97 mR/hr/mCi. Cf-249 mostly decays into Cm-245. Cm-245 is also an alpha, neutron, and photon emitter. Its half life is 18.1 years and it has an exposure rate of 2.39 R/hr/mCi at 1 cm. Its specific activity is 0.172 Ci/gm.

2.1.4.2 Dose Reconstruction

On July 31, 2002, LLNL established a Dose Reconstruction Committee to determine the official dose of record. The Dose Reconstruction Committee performed radiation surveys of Room "B" on August 1, 2002 to determine if dose rates from the materials were consistent with calculations. Although three other experiments had been conducted in Room "B" since the Researcher completed the June work, the radioactive materials (11 mg of Cf-249, the curium-245 component, the left-over Cf-249, and wastes) were still in the room. The tools used in the work activity were still in Glovebox 65 (see Figure 5).

Figure 6. Tools used in Glovebox 65.

Figure 6 shows the lead pig containing the 11-mg Cf-249 still situated on the workbench while the rest of the materials were in storage in Glovebox 3, behind Glovebox 65.

Figure 7. Lead pig containing 11 mg Cf-249 source.

2.1.4.3 Survey Results

On August 1, 2002, survey measurements were taken at 30 cm above the 6 in. high pig (lid open), using an Eberline RO2 survey meter. With the meter window open, the dose rate was about 50 mR/hr. Measurements were taken around Glovebox 3 where L1197, remnants of L1244, and the curium fraction were stored to look for an unusually high radiation source (the highest dose measured was 40 mR/hr on contact with the underside of the glovebox). The dose rate was 10 mR/hr at 15 cm. Glovebox 65 was also surveyed and through the glove port, the maximum dose rate was 0.6 mR/hr. A subsequent survey taken on September 18, 2002 revealed that L1197 and remnants of L1244 were in one lead pig and a survey taken at about 23 cm from the top of the pig (lid off) gave a dose rate of 42 mR/hr. The surveys pointed to Cf-249 as the only source of significant radiation levels in the room.

2.1.4.4 TLD Studies

Tests were also conducted with several Harshaw 740 ring dosimeters (see Figure 7), including the ones worn by the Researcher in June 2002, to try and simulate the doses at various distances from the source. Ring dosimeters were positioned at various distances around the bare 11 mg Cf-249 (in its centrifuge cone only) and exposed for 2 hours. Four dosimeters placed at 2 cm from the source gave doses ranging from 17.2 rem to 33.5 rem for the 2-hour exposure. Two dosimeters at 1 cm gave 28.6 and 44.4 rem, respectively. One Researcher ring received a dose of 7.03 rem at 5 cm and the other received 1.9 rem at 10 cm. Since the exact mass configuration of the Cf-249 in the cones prior to the purification was not known, the results from these tests were not particularly helpful for evaluating exposures at close contact with the source. This is especially true when one takes into consideration the fact that as one approaches within 5 cm of the source, the inverse square law becomes less valid.

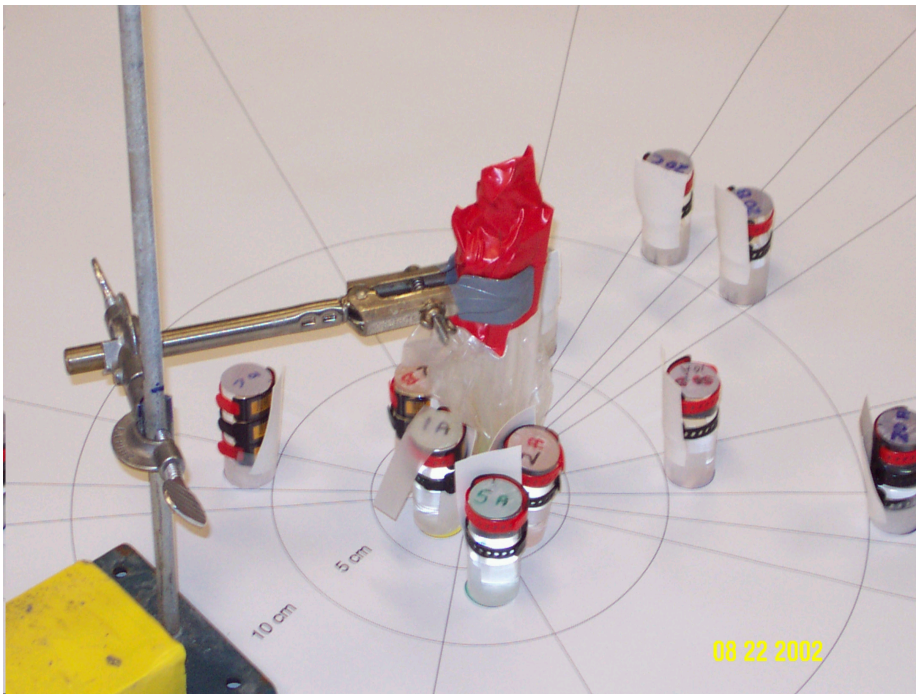


Figure 8. Dose reconstruction with ring dosimeters.

2.1.4.5 Board Evaluation

The Board performed a document review of the Laboratory's DOELAP accredited dosimetry program, focusing on the Harshaw 740 ring dosimeter used for extremity monitoring. The dosimeter is mounted on a color-coded adjustable strap for field use; the red strap is intended for the right finger while the black strap is worn on the left finger (Figure 8).

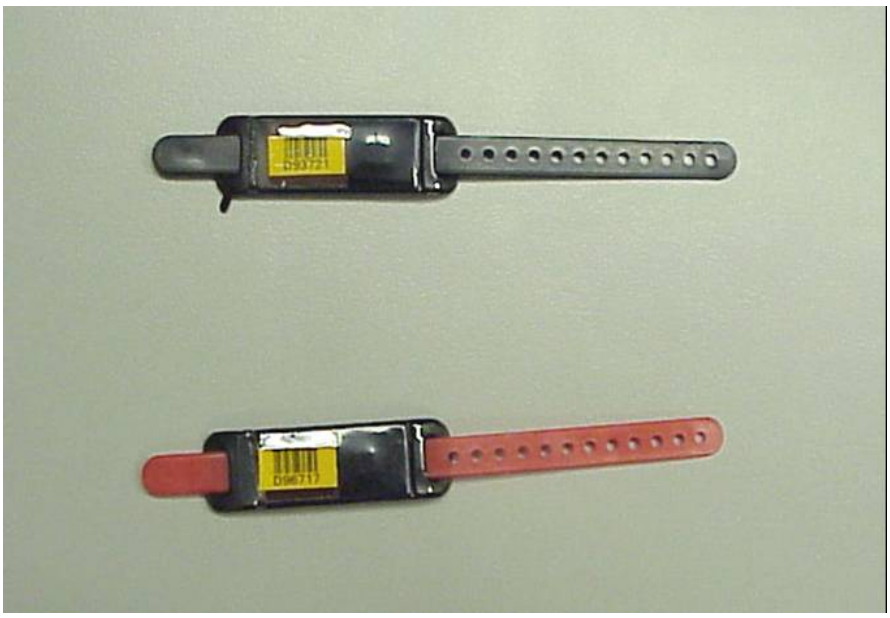


Figure 9. Ring Dosimeters.

The Board reviewed the history of the two ring dosimeters (serial #92783 and #97258) worn on June 2002, dating back to August 1999 and found no anomalies. The Board also reviewed doses assigned to other ring dosimeters processed in the batch (Batch No. 6020722, July 22, 2002) as the two worn by the Researcher; and again found no anomalies.

The Board also reviewed the Researcher's dose history for the Calendar Year (2002). Information from the Dosimetry Office indicated that his cumulative dose for the year (exclusive of the June dose) was zero mrem for wholebody and extremities.

The Researcher estimated that he might have spent about 8 hours in front of the glovebox and 1 to 2 hours handling the vials. He indicated that the Cf-249 work was the only radioactive work he performed in June 2002. He also indicated that based on a 2 hour handling time, he expected a dose of about 10 rem to the extremities based on a contact dose factor of 1 R/hr per mg of Cf-249. This dose factor used by the Researcher is ten times less than the approximate exposure rate of 11 R/hr per mg at 1 cm.

The Board had no way of determining precisely the amount of time the Researcher spent handling materials and how close and for how long he held the centrifuge cones. Through the Dose Reconstruction Committee's efforts, an estimate of the time (and how close) the Researcher's hands were in close contact with the materials was made. This estimate was performed by another nuclear chemist, using the Researcher's notes. Between June 10 and June 14, it was estimated that the Researcher's hands were in

Glovebox 65 and at varying distances from the Cf sources for about 140 minutes. It was also estimated that he would have spent a similar amount of time on June 17, separating the residual Cf -249 (about 10% of the main fraction) from the Cm-245 component. Overall, the estimates indicated that the Researcher's hands were in the glovebox for more than 2 hours.

Although the Researcher's wholebody dosimeter received a dose of 57 mrem for the June 2002 monitoring period, it is the Board's opinion that this was because some of the Cf-249 materials were probably in a lead pig and their radiative emissions were focused away from the wholebody during some of the procedures. The pig lid was not in place (on the 3 inch lead pig) any time a cone was in the pig, therefore the pig did not offer as much shielding to the fingers as it did for the wholebody.

The Researcher's extremity dose did not include the dose he received from handling the materials in Room "A" when he was not wearing his ring dosimeters. The Researcher stated during his interview that he put on the ring dosimeters after the materials were brought into Room "B", Glovebox 65 on June 10, 2002. The Board estimated that the unaccounted dose was not significant relative to the total dose because the materials were still in the lead pigs while they were being handled in Room "A".

The extremity doses would also have been higher if the L1197 stopper had not broken off. L1197 was the first cone to be opened and it contained less than the 3 to 4 mg that was to be added to L5 to meet the needed 11 mg quantity of Cf-249. If L1197 had been opened successfully, the Researcher would have needed to process all three centrifuge cones (L1244, L1197, and L5) before he could meet the 11 to 12 mg needed for his overseas collaborators. Since L1197 was not processed, the Board's estimation is that it did not contribute significantly to the total extremity dose.

2.1.5 Dose Assignment

During the month of June 2002, the californium purification work was the only radiological work performed by the Researcher. Based on the Researcher's notes, it is the Board's opinion that the Researcher's hands were extensively in the glovebox and/or he held the materials closer to the ring dosimeters. The Board's opinion is based on reviews of the Researcher's notes and discussions with the Dose Reconstruction Committee and other experts.

The Board found no evidence of a defect in, or contamination of, any of the two ring dosimeters. The reading of the dosimeters followed the chip and automatic reader manufacturer's instructions.

The Board also found no evidence of foul play or willful or inadvertent exposure of the dosimeters. The Board, therefore, concluded that the extremity doses were due to the Cf-249 work activity, and the doses should be assigned in accordance with the dosimeter Reconstruction Committee findings.

Although the Researcher could not remember whether he wore the red ring on the right or left hand, he was sure he never interchanged them during the work. And since the Researcher is right-handed, the Board assumed that the left hand received the higher of the doses. Therefore, the Board recommends the assignment of the higher of the doses to the left hand.

The Researcher's wholebody dosimeter (clipped to the shirt collar) indicated a dose of 57 mrem. The Board recognizes that the arms probably received a higher dose than that indicated on the wholebody dosimeter. However, any adjustment to the wholebody dose (based on the proximity of the arms to the radioactive materials) will be subject to uncertainties. The Board views any adjustment to the dose to be of little significance and of no health concern. Therefore, the Board recommends that the wholebody dose remain at 57 mrem for the month of June 2002.

2.2 Analysis of the Integrated Safety Management, Personnel Performance, and Management Systems

In reviewing this accident, the Board analyzed the implementation of the Integrated Safety Management System (ISMS), examined the suitability of personnel to perform their functions, and evaluated the management systems used by LLNL.

As part of the Board's analysis, the Occurrence Reporting and Processing System (ORPS) was reviewed. The search did not identify any other similar occurrence reports except for the curium 244 accident in July, 1997 during which an employee inhaled significant quantities of curium while shredding HEPA filters. The current accident has a contributing cause similar to one determined in the 1997 accident, which will be discussed in the ISM and Feedback and Improvement sections (sections 2.2.1 and 2.2.1.5).

2.2.1 Integrated Safety Management (ISM)

The objective of ISM is to assure that the DOE and its contractors systematically integrate safety into management and work practices at all levels. To achieve integrated safety, the DOE has established a policy (DOE P 450.4) that identifies the safety objectives, the set of guiding principles, the core safety management functions and other requirements for the implementation of the policy. The guiding principles are the fundamental policies that guide Department and contractor actions from development of safety directives to the performance of work. The core safety management functions provide the structure for any work activity that could potentially affect safety.

The review of this accident considered all of the systems that implement the guiding principles and core functions at the CMS Directorate and focused on the systems and barriers that were pertinent to the event.

Line management is responsible for safety and is responsible for the establishment and implementation of the ISMS. It is the responsibility of line management to ensure that personnel at all levels understand and implement ISM at all times.

The line management chain for B151 begins with the DOE/NNSA Administrator and through DOE/NNSA OAK, extends to the Laboratory Director, the Associate Director (AD) for CMS, the Division Leader for the Analytical & Nuclear Chemistry Division (ANCD), the Deputy Division Leader for ANCD Operations, and finally the Researcher.

The aforementioned line management chain of command for B151, understands, accepts and implements their safety responsibility as follows:

The DOE/NNSA Assistant Manager for National Security (AMNS)—AMNS provides oversight for the NNSA funded activities, Laboratory Directed Research and Development (LDRD), and Work-for-Others research. AMNS expects LLNL to demonstrate its commitment to line management responsibility for safety and security and that the LLNL ISM System Descriptions and Directorate Implementation Plans, and implementing lower level documents clearly demonstrate that line management has responsibility for safety. AMNS expects that the System Descriptions indicate how safety responsibilities flow from LLNL senior management to the worker. AMNS expects LLNL to follow the seven guiding principles and five core functions of ISM.

The AMNS Operations Team Leaders through the Operations Teams and the use of Subject Matter Experts (SMEs) and Facility Representatives (FR) verify day-to-day ISM implementation. FR and SME oversight is based on a graded approach. In general, high hazard facilities (i.e., facilities with a lot of activity or facilities with declining or inadequate safety performance) get more oversight than low hazard facilities (i.e., facilities that are less active or have demonstrated good safety performance).

B151 is a low hazard, radiological facility. In terms of operating performance, a search of the Occurrence Reporting and Processing System (ORPS) found that from August 2001 to the August 2002, one (1) off-normal event was reported by B151. The direct cause for that event was failure to follow procedure for transfer and disposal of equipment in radiological areas. A search of ORPS for CMS regarding the "failure to follow procedures" found an additional off-normal report whose direct cause was inattention to detail in the preparation of the IWS by the ANCD. This error did not create a safety concern. Another ORPS search did not find any other occurrences relating to overexposures throughout the Laboratory during this period of time.

Although there were no recent events of any significance, there was an accident at LLNL in 1997 that involved internal uptake of curium 244 by an employee. Of all the differences, the most significant between the current accident and that of 1997 is the earlier accident occurred at a different LLNL directorate (Plant Operations) and under a different DOE line management (the Assistant Manager for Environmental Management). The similarity between the two is that neither followed procedures. Specifically, the 1997 accident cited that personnel did not follow procedures and provided a number of examples. For the current accident, the Researcher stated that he did not become familiar with the requirements of the IWS and as a result he did not follow required procedures.

The oversight activities since August 2001 included twelve (12) walkthroughs by AMNS staff (primarily FRs) for the purpose of overseeing various safety aspects of B151. The AMNS oversight activities did not identify any issues with ISM implementation or the IWS process.

In addition to the AMNS oversight, Headquarters Offices such as the Office of Defense Programs (DP) and the Office of Independent Oversight and Performance Assurance (OA) have performed reviews to validate the institutional implementation of ISM. DP assisted AMNS to review the ISMS implementation. The review determined that both OAK and LLNL comply with the ISM directives.

The most recent June 2002 OA review, also did not identify any pertinent programmatic or systemic issues with the implementation of ISM at LLNL. In fact, the draft OA report in the section that discussed the IWS processes stated that, "*....the IWS process provides a comprehensive and integrated method for defining, analyzing, and authorizing work and was effectively implemented for most programmatic work activities that were reviewed...*" In the section that discussed the Core Functions, the OA report

concluded that, "*...Chemistry's implementation of IWS is rigorous and work activities are well specified and controlled in accordance with well defined IWSs."* While the majority of the OA observations were positive regarding the IWS process, the section in the draft OA report that described LLNL's Work Authorization Roles and Responsibilities stated that "*Certain aspects of the IWS need to be improved to ensure that responsibilities are carried out in strict compliance with the requirements."* The OA found that "*...individuals were not strictly adhering to requirements..."* and that *" Additional management attention is needed to ensure that individuals understand that they are responsible and accountable for strict compliance with requirements...."*

Given the low hazard classification of the facility, the facility's operational performance (i.e., no major events or issues associated with the facility), and a score of "good" from the recent HQ ISM verification inspection, it is the Board's opinion that the DOE line management oversight and performance were adequate.

The Associate Director (AD) for CMS—The CMS AD has established safety expectations for the directorate and holds persons accountable for safety performance. Safety performance means that personnel ensure hazards are controlled, work is performed according to plan, and managers are visible in the workplace (i.e., they perform walkthroughs). Accountability for safety performance takes place during the CMS personnel performance evaluation. A part of the AD responsibilities is to ensure that ES&H planning takes place and is integrated into all CMS activities and appropriate documentation is prepared. Also, the AD is responsible to ensure that hazards associated with CMS managed activities are analyzed and appropriate ES&H controls are implemented before CMS work activities are authorized. As part of line management, the AD had set goals, one of which required CMS researchers to perform laboratory walkthroughs to ensure the safety of the laboratories within their area of responsibility. When the goals for these walkthroughs did not materialize, the AD changed posture. Currently, the researchers are expected to perform monthly safety walkthroughs that are meaningful, and if not performed the researchers are to be held accountable. This improvement in the performance expectations (i.e., from walkthrough goals to walkthrough expectations), occurred at about the same time of the accident and therefore did not impact personnel performance or safety.

ES&H planning and integration occurs with the help of the ES&H team which supports CMS. Performance in all areas is assured by the Assurance Manager (AM). The AM reports directly to the AD and is responsible for the development of the CMS Quality Assurance (QA) Plan.

The Division Leader for the Analytical and Nuclear Chemistry Division (ANCD)—The Division Leader while fully accepting her line management responsibility has delegated some day-to-day line management functions to the Deputy Division Leader for ANCD. The Division Leader primarily focuses on budget, program and administrative issues. ES&H responsibilities that were not delegated included: establishing safety expectations for the staff, ensuring that the safety performance of each employee is assessed in individual performance appraisals, ensuring adequate corrective actions to problems and providing feedback, ensuring that required ES&H training of the staff is completed, and resolving ES&H concerns. In addition, the ANCD Division Leader performs facility walkthroughs as required and reviews audit results. The Board's review did not identify any deficiencies regarding the ANCD Division Leader's performance as line management with regard to the accident being investigated.

The Deputy Division Leader for Operations in ANCD—The Deputy Division Leader is the Authorizing Individual (AI) who is line management responsible for the technical and ES&H objectives of the work activity. As such, the AI is authorized to accept and manage the risks associated with the work on the Laboratory's behalf. The AI is line management responsible for ensuring that work is performed safely and all personnel understand and implement all aspects of ISM. The range of the AI's ES&H line management responsibilities and the AI's effectiveness in the performance of these functions as they relate to the event are as follows:

- The AI is responsible for ensuring that the hazards associated with the work activity are analyzed and controlled. The IWS is CMS' primary tool for hazard analyses and hazard controls. The AI is responsible for ensuring that an IWS is prepared, reviewed and authorized for each work activity that is not commonly performed by the public. The AI is also responsible for explicitly communicating the ES&H expectations to the staff. The review found that the ES&H expectations had been communicated to the staff in a variety of ways: orally, through the appropriate ISM training and, when warranted, in writing.

- The ES&H expectations must ultimately be converted to ES&H actions. The AI is responsible for monitoring the researchers who are responsible for implementing the tasks safely, to ensure that the hazards are identified, controls are developed and implemented, and that ES&H requirements are met.

- Per the *ES&H Manual*, Document 2.2, the Authorizing Organization is responsible for several Work Authorization activities. This includes the responsible researchers and ensuring that the work is properly planned and controlled. The Board reviewed the performance of the AI in conducting those functions. The Board determined, as it relates to this accident, that the AI was cognizant of his responsibilities and adequately implemented. For example, via email, the AI asked the researchers under his charge, to ensure that their rooms/laboratories were compliant with their respective IWSs. He informed his researchers that the goals set for monthly laboratory walkthroughs had not been accomplished and, as a result, the AD had changed the way business would be conducted. Instead of being a goal it was now a consequence during performance appraisals. The AI also asked his researchers to read the IWSs applicable to the research they were conducting to ensure their compliance. In addition to written communications, the AI brought up the subject of IWS compliance on numerous occasions and during staff meetings.

Therefore the Board has determined that LLNL management has the appropriate systems in place to implement the IWS process. However, as this event illustrates taken together with the two ORPS reports, compliance with requirements and following procedures is a problem that needs attention.

The Researcher—The Researcher's line management responsibility is to be directly responsible for the work. The Researcher must ensure that the work activity is conducted safely. Hazards are controlled by the implementation of the IWS requirements that includes the performance of a hazards assessment by the ES&H Team 5. (The ES&H team provides ES&H support to the line management.) The Researcher had not been current on the requirements of the IWS, and thus neglected to involve the ES&H team. As a result, hazards were not identified and required ES&H controls were not implemented. The specifics of the Researcher's actions are described within the context of the Core Safety Functions described here.

Hazards Control (HC) ES&H Teams (Line Management Support)—LLNL has developed a system of ES&H teams within the HC Department to provide ES&H support to the various line management organizations at LLNL. ES&H Team 5 provides ES&H support to CMS on request. ES&H technicians also perform routine tasks stipulated in the DAP for CMS such as surveys. (The DAP is a plan for monitoring individuals and facilities to identify sources of exposure of radiation and ensure that doses are kept ALARA, and in compliance with 10 CFR 835.) Team 5, comprised of a number of ES&H professionals, is led by a team leader who works closely with CMS to evaluate the performance of his staff (these discussions take place on a regular basis). Team 5 meets twice a month to discuss safety-related issues and lessons learned events; the ES&H technician supervisor meets monthly with the technicians to communicate job expectations and performances.

While the ES&H team functions as required by the established management systems, it appears that team activities are not fully integrated with those of the line organization. The team provides the support on request and has some routine tasks. The ES&H technicians however are not informed by line management about all ongoing activities and therefore cannot be proactive. For instance, in the Cf-249 purification project, the ES&H technicians had no knowledge of the work going on in Room "B". Had they known about the ongoing work activity, they might have taken the initiative to implement controls.

2.2.1.1 Define the Scope of Work

The Researcher was performing LDRD work. Consistent with this format, the Researcher identified the project to the Laboratory and the Laboratory approved and funded the project. The LDRD work was to be performed under an existing IWS (No. 2284) previously approved in January, 2000. IWS No. 2284 was, and still is, authorized for high level radiochemistry work in a gloveboxed room, Room "B".

The original LDRD proposal called for the purification of 20 mg of americium 243. After the experiments with americium were concluded, a decision was made to conduct the experiments using californium 249. The project plan was to retrieve about 13.2 milligrams (mg) of radioactive californium 249 from the Building 251 vaults, then refine 11 mg of this element, and ship the refined material to a colleague abroad for collaborative scientific experiments. The scope was thus clearly defined. The workers for the project involved the persons in B251 that retrieved the materials and arranged for the transfer, the ES&H team personnel that made the RATS entries and receipt inspections in B151, the personnel involved with the transportation of the material, and the Researcher who performed the work.

The roles, responsibilities, authorities and worker qualifications were all well defined and appropriate for the task. The individuals involved were the Researcher who has both the education and experience to perform the work and the members of the ES&H team that support CMS and Building 151 with tasks such as hazard assessments and surveys. The ES&H team members are all qualified to perform the work assigned to them.

2.2.1.2 Analyze Hazards

The IWS provides general ES&H controls and requirements for a range of similar activities that can be performed under one IWS. The IWS preparation involves managers, ES&H and other specialists, and the workers that would be involved in the task, who review the project/task and together identify the ES&H controls. The ES&H controls specified in the IWS are not specific "step by step" instructions. The IWS

ES&H controls are a prescribed set of requirements that provide the framework for safety. For instance, in the event under review the pertinent IWS ES&H controls is: "*...Work with activities exceeding 100 microcuries requires a hazard assessment by the ES&H Team 3 (sic) Health Physicist...*" It is incumbent upon the person responsible for the activity (the Researcher) to involve the Health Physicist (HP) who would then review the job, ask questions as to what the job entails, and, on the basis of that knowledge, the HP could determine the hazards involved and identify the necessary controls to minimize exposure.

IWS No. 2284 identifies the OSPs which provide additional specific engineering and administrative controls, PPEs, radiation survey and monitoring requirements. The IWS also stipulates that (referenced OSPs notwithstanding) a hazard assessment is required if work activity will involve more than 100 microcuries of radiative materials or work conditions where radiation levels could exceed 5 mR/hr at 30 cm.

OSPs are safety documents that describe the hazards and controls for an activity that is not addressed by the Facility Safety Plan (FSP). The IWS No. 2284 references OSP Nos. 151.11, 151.31, 151.37, and 151.39. Only OSPs 151.31 and 151.39 are currently in effect. These two OSPs (while not specifically addressing work involving Cf-249 and Cm-245) provide information on general Authorization Level 4 work activities, responsibilities, scope of work, hazard assessment requirements and controls, waste generation, training and required reading, maintenance, inspections and quality assurance, emergency response plans and procedures, and review and approval. Both of them lack specifics on radiation surveys and monitoring frequencies on the part of the ES&H technician and the Researcher. OSP 151.39 discusses surveys of incoming packages while 151.31 talks about radiation surveys in front of gloveboxes. Neither of the OSPs addresses ALARA-specific requirements of handling high dose radioactive materials.

By themselves, the IWS and the OSPs were too general and were not intended to analyze the hazards associated with the Cf-249 work activity. The HP did not perform hazard analysis before the work began because the Researcher failed to notify the appropriate ES&H specialists as required by the IWS. The Researcher treated this work as routine, having worked with similar materials in the past, and did not foresee some of the underlying hazards. Therefore, he did not think that he had to take any special precautions. As a result the accident potential was not analyzed.

The Researcher neglected to re-read and become familiar with the IWS. During the interview, the Researcher stated that this was due to the fact that he thought he knew the requirements, he believed that he was implementing the appropriate requirements, and was therefore in compliance with the requirements of the IWS. Additionally, the Researcher (in the past and for similar work), had an assistant[2] who read the IWS and made all pertinent preparations to be in compliance with the IWS. The Researcher thought that he was implementing all of the controls that had been established by his assistant.

Work planning was not performed adequately, because key aspects of work planning were not performed. The work planning did not address the amount of time that the Researcher would spend handling the material; and it failed to identify and implement adequate controls. The result of the inadequate work planning was that the Researcher experienced increased exposure.

[2] *Prior to the beginning of this project, the assistant was transferred to another facility.*

2.2.1.3 Implement Controls

Administrative controls such as the IWS and the OSPs were in existence at the time the accident occurred but in general these are general purpose documents. The Researcher did not familiarize himself with the IWS and OSP requirements for a hazard assessment by the ES&H team HP. Consequently, engineered and administrative controls present for the work activity were inadequate. ALARA controls were not sufficiently implemented. If a hazard assessment was performed by the HP, in all probability, the HP would have identified additional administrative controls or other engineered controls to prevent this event. The administrative controls might have included additional personnel to help with the work, increased survey frequency, increasing the frequent exchange of dosimeters rather than the monthly frequency. Additional engineered controls might have included the use of additional shielding blocks and leaded gloves.

2.2.1.4 Perform the Work

Successful performance of work includes adherence to the Conduct of Operations principles, DOE O 5480.19, *Conduct of Operations Requirements for DOE Facilities*. Reading, understanding and implementing procedures is a basic tenet for good conduct of operations. The work was performed without the use of the pre-approved ES&H controls described in the IWS because the Researcher did not become familiar with i.e., re-read the IWS. ALARA was not sufficiently implemented during the operation.

2.2.1.4.1 The Researcher

With the exception of inadequate ALARA implementation, the Researcher successfully performed the chemical separation and refinement of the material. In addition, he recovered valuable curium 245 and minimized the generation of transuranic wastes. He used his ring dosimeters (although not from the start of materials handling), took radiation measurements and checked the operability of the glovebox appropriately.

While performing the work, the Researcher was not closely monitored or supervised by the AI to ensure that the work was being performed according to plan, e.g., that a hazard assessment had been performed and that ES&H controls were identified and in place. This is normal because both of the individuals involved (the AI and the Researcher) are persons with a considerable experience and education in the field of nuclear chemistry. The Researcher has a PhD in nuclear chemistry with at least 20 years of experience and has performed similar tasks in the past with no incident. The AI had confidence in the Researcher's ability to perform the job with all of the necessary controls based not only on past performance but also because the AI was confident that the Researcher knew the hazards involved. In addition, the AI had communicated his expectations to the Researcher regarding safety in a number of ways.

The Board credits the Researcher for the extensive surveys he performed during the work activity. These surveys, however, found radiation levels in excess of 5 mrem/hr at 30 cm which would have required posting the area as a radiation area (10 CFR 835.603). Besides not posting the survey results, the Researcher did not communicate the survey results to the ES&H team whose actions would precipitate a review of the hazards and implementation of safety controls.

2.2.1.4.2 Hazards Control/ ES&H Team 5

ES&H Team 5 is responsible for performing hazard assessments and identifying the appropriate controls on request from line management. Due to the reasons previously explained in this report, line management did not request such assistance, therefore the team did not perform the hazard assessment. However, the team was involved in the process and their performance in some instances was less than adequate. The examples presented below illustrate that there was lack of inquisitiveness and/or lack of attention to detail. Had these weaknesses been absent there is a possibility that the accident would have been prevented.

- When the ES&H technician received the packages from B251, they were placed in the fumehood in Room "A". The technician was aware of the urgency to perform the work (the technician was copied on an email about the need to process the material in a hurry). Although the technician knew about the amount of radioactivity contained in the packages (the CID tags indicated 54 mCi) and had the opportunity to interact with the Researcher to find out more details about the project, the interaction did not take place. If the technician had questioned the specifics about the project, some flags regarding the adequacy of the radiation controls might have been raised.

- The quarterly radiation survey performed by the ES&H technician on June 11, 2002 measured 2.4 mR/hr on contact with the glovebox window even though all the 13 to 15 mg Cf-249 materials were in Glovebox 65 (either on top of the evaporator, in the column, or located in a 3 in. high lead pig). The main Cf-249 fraction by itself was determined (during a later survey) to read anywhere from 50 to 92 mR/hr at distances ranging from 50 to 30 cm. A more thorough survey may have picked up the high doses in the glovebox.

- The package Control Material ID tags accompanying the Cf-249 packages clearly identified the mass and radioactivity of each package but in updating the facility and Researcher's inventory, the ES&H technician keyed in the milligram quantity into the RATS. Because RATS was programmed with the wrong conversion factor that was provided by LANL per DOE Standard 1027 - 92 reference (the LANL conversion factor error was identified as a result of this accident) the inventory was updated as 5.4 mCi instead of 54 mCi identified on the transfer ID tags. The tech failed to reconcile the discrepancy between the RATS output and the radioactivity information provided on the Material ID tags.

In addition to the ES&H teams performance (i.e. "lack of attention to detail") as described above, the Board identified some weaknesses with the HP DAP for B151 and in the interface/communications between line management and the ES&H team.

The DAP as mentioned earlier is a plan for monitoring individuals and facilities to identify sources of exposure of radiation and ensure that doses are kept ALARA, and in compliance with 10 CFR 835. The DAP is developed by the Team 5 HP, and does not override requirements in other documents. The ES&H Team 5 Leader is responsible for the DAP.

Regarding the DAP weaknesses the DAP calls for the survey of specific areas in a radioactive materials area and in the case of gloveboxes, it requires a contact reading from the glovebox window. However, it does not require a survey of all accessible areas around the gloveboxes. The purpose of the surveys is to

evaluate radiation levels and to implement the proper controls to minimize exposure to personnel. Therefore, if the surveys are not performed where personnel have access, then the surveys do not perform their function. The Board recognizes that in most cases, fumehoods or gloveboxes are normally mounted against the wall and next to each other (or cabinets), therefore "accessibility" is not a concern. However, the situation in Room "B" is different, where most of the gloveboxes are portable and have either all or most of the sides accessible (i.e., Glovebox 65 is portable and in the middle of the room, as shown in Figure 5, and all four sides are accessible). If the Team 5 radiation survey of June 11, 2002 had been comprehensive or done on all accessible areas, the technician might have picked up dose rates exceeding 5 mR/hr around the sides of the glovebox which would have required the area to be posted as a radiation area and the HP notified. The technician was not at fault since the survey was performed per DAP specification.

The DAP also calls for a quarterly (although adjustable to monthly) radiation survey of Room "B". This frequency appears to be inadequate for the level of work activities in the room. Moreover, the specificity of areas to be surveyed (as opposed to a comprehensive survey) is problematic. Such surveys (as was performed on July 11, 2002) may be counterproductive since they can lead to incorrect conclusions thus obscure an unsafe condition.

Regarding the interfacing and communications between line management and the ES&H team, the weakness lies in that the ES&H team relies solely on the request for assistance from the line organization. If line management does not request assistance, the ES&H team does not get involved. The pit fall of this process, as this accident illustrates, is that the OSP contains requirements that are not included in the DAP. For example, the DAP does not call for a radiation survey of incoming packages whereas this requirement is specified in the OSP. The DAP also does not require surveys through the gloveport which is required by the OSP.

In addition to the interface issues, the OSP does not identify the frequencies for a direct and contamination survey. Also, it does not emphasize the ALARA aspects of work activities.

2.2.1.5 Feedback and Improvement

A goal of CMS is for its Researchers to perform safety walkthroughs in their areas. These walkthroughs are to be documented and reported up the line management chain by the AI. These walkthroughs should document any problems found in the facility and what action is to be taken to fix the problem. Documenting the problems and how they are corrected provides management with feedback of what and where the problems are and also provides a trending and learning tool. The review of the event found that although the Researcher claims to have performed the walkthroughs (IWS is current, correct, and being implemented), the Researcher did not document these walkthroughs. The Researcher is not alone in this. According to internal memoranda, it appears that this is an endemic problem within the CMS Directorate. This problem has been identified by CMS management and steps have been taken to correct it.

While CMS appears to have an adequate feedback and improvement process, the LLNL feedback and improvement/lessons learned process may need improvement. The corrective actions to the 1997 accident included "Improve enforcement of compliance with existing operating and safety procedures". These corrective actions were not fully effective here, based on the fact that the Researcher did not follow procedure, identified as a causal factor for this accident. Therefore, the desired "performance improvement" did not occur.

2.2.2. Personnel Performance (Human Factors, Training and Qualifications)

The Board evaluated personnel performance as it relates to this accident by reviewing training and qualifications of involved personnel and human factors performance of the work. The performance evaluation of these areas is for the following personnel: the Researcher; the Team 5 ES&H technician, and the Team 5 HP. Training and performance include the education, formal training and experience of the personnel involved, and any applicable human factors that could have affected an individual's performance. According to the *ES&H Manual*, Document 40.1, LLNL Training Program Manual, it is LLNL policy for personnel to have training commensurate with their responsibilities, to protect health, and to perform work in a safe manner. The ADs are responsible to ensure that their training programs meet the requirements of the LLNL Training Program Manual. The Board reviewed the training programs and conducted interviews and determined the following results.

2.2.2.1 Human Factors

Human factors address external and environmental factors that affect the safe and efficient performance of work by an individual; this includes the interface between humans and machines or equipment. The Board did not discover any external or environmental factors that directly contributed to this accident. However, as discussed elsewhere in this report, the Researcher could have better utilized devices such as tongs/forceps to increase the distance, between his hands and the radioactive material, thus reducing the time he held the materials and the dose that he received.

2.2.2.2 Training

LLNL uses a training profile questionnaire completed by each worker to determine which training classes are appropriate. An individual's training requirements are determined both by the facility that he or she works in and the type of work that the individual performs. The HC Training Manager oversees a large listing of training classes including those for individuals working with radioactive material. Some classes include computer based, lecture, and hands on practice. The Hazards Control classes are often broad, and provide a basis to understand compliance, as opposed to training on a specific task or procedure. The review did not identify any concerns with the HC training program. The CMS Training Manager (TM) is responsible for the CMS facility-specific training.

2.2.2.2.1 Specific Training, Education, and Experience

The Researcher—The Researcher has a PhD in nuclear chemistry and has extensive experience in that field. He last handled californium in quantities similar to those that resulted in this overexposure approximately 10 years ago.

The Board compared the Researcher's LTRAIN listing of completed training as of July 23, 2002 with the LTRAIN listing of Training Needs. The Researcher completed applicable training such as HS6010-CBT Radiological Worker on January 9, 1996 and HS6300-CBT Contamination Control on April 24, 2002. The Researcher also completed training on facility specific documentation, hazardous waste management, criticality safety, health hazards communication, the hazards of specific chemicals, contamination control, and radiation survey instruments. Furthermore, he attended several courses on ISM.

The Board's review showed that the Researcher has not completed CH3000 CMS Supervision III, and HS4660 Respirator Training for Supervisors of Respirator Users and Respirator Issue Point Administrators. Nevertheless, the Board concluded that the absence of these courses in the Researcher's portfolio did not contribute to the accident.

It is the opinion of the Board that although the Researcher had obtained substantial training in ISM and ALARA principles and their application to work activities, he failed to translate what he learned from the training into practical applications.

Hazards Control / ES&H Team—The ES&H Team 5 technicians covering CMS activities have completed the 200-hour Hazards Control Class, HS6993 Health and Safety Technician Radiological Qualification. In addition, they have completed ISM, radiological worker, and hazardous waste management courses. One of the ES&H technicians has an Associate degree in Arts (Chemistry), and the other ES&H technician has an Occupational Safety Certificate. During the time of the accident, one of the ES&H technicians was in transition to another facility.

The HP has a Masters degree in health physics and is certified by the American Board of Health Physics. He has completed classes in Radiation Survey Instruments, Radiological Worker, Health Hazard Communication for Supervisors, Glovebox Safety, Chemical Safety, Anti-Contamination suits, and Criticality Safety including practical as well as other classes related to his role as a health physicist.

2.2.3 Policies and Procedures

2.2.3.1 Hazards Analysis Report

Concurrence of the Hazards Analysis Report (HAR) for the B151 Complex was received from the ES&H Team Leader and the Facility Manager, followed by approval from the CMS AD. The purpose of this HAR is to provide systematic identification of hazards associated with the B151 Complex, which are primarily radiological and chemical in nature. Although the HAR does not specifically include californium 249, it does indicate that any future introduction of radioactive materials shall be evaluated using RATS and the IWS process. The Board considers the HAR to be adequate as it relates to the operation that is the subject of this investigation.

2.2.3.2 Facility Safety Plans (FSP)

According to the B151 FSP, Section 2.1 General, the facility's management chain includes the Facility Point of Contact (FPOC), the Facility Manager, the Deputy Associate Director for Operations, and the CMS AD. Work with radioactive materials is controlled by Appendix E of the FSP. Appendix E, Radiological Operations, Section E.2.1 Unintended Effects on Nearby Researchers, indicates that each experimenter is responsible for remaining aware of work in the vicinity of his experiment, and for keeping nearby researchers informed if there is a possibility that his work may affect other researchers work. In addition, an issue is whether the work would affect the health and safety of nearby personnel. Section E.2.5, Facility 151 Complex ALARA Program, indicates that the ISM process and FSP provisions are considered a means to minimize worker exposure to radiation.

2.2.3.3 Radioactivity Allowance Tracking System (RATS)

CMS uses a system called RATS to control the facility and researchers' inventories to ensure that B151 remains a radiological facility. The CMS Operations Manager is responsible for making material allocation changes in the building. As noted earlier, the RATS had been using incorrect mg to mCi conversion factors, at least for Cf-249. The error comes from a DOE reference to LANL-12846-MS (Specific Activities) document for use in calculating activity thresholds for unidentified isotopes in DOE STD 1027-92.

Following the discovery of the error, LLNL/CMS evaluated the accuracy of the specific activity conversion factors and revised the inventories. Other DOE sites were notified of the error in the LANL document.

2.3 Barrier Analysis

A barrier is defined as anything that is used to control, prevent, or impede process or physical energy flows and that is intended to protect a person or object from hazards. The barrier analysis addressed two types of barriers associated with the overexposure: management barriers and physical barriers. Tables 1 and 2 outline the Barrier Analysis; Figure 9 provides the Summary of the Barrier Analysis.

In performing the barrier analysis, the Board identified 13 failures which could have resulted in, or contributed to, the Researcher's overexposure. The most significant barrier that failed and resulted in the overexposure was the inadequate implementation of ISM and ALARA principles. Failure of the other 12 barriers also contributed to the overexposure of the Researcher. In summary, the categories of the 13 barriers are as follows: 10 were related to management and 3 were physical.

2.3.1 Management Barriers

The management barriers that failed included radiation survey results which the Researcher failed to communicate to the ES&H team. Room "B" and/or the work area was not posted as a radiation area, which would have required notification of the HP. The Researcher did not effectively use the training, knowledge, and skills he possessed to minimize his exposure. Job planning was not comprehensive in that it did not address the amount of time to be spent handling the material. The Researcher was not current on the requirements of the applicable IWS and OSPs. Consequently, a hazard assessment was not requested as required by the IWS and survey results were not posted as required by the OSPs. The inadequate communication between CMS line management and the ES&H team resulted in the latter not having up to date information on the work activities in Room "B" and hence, could not have been proactive in establishing safety controls.

2.3.2 Physical Barriers

Leaded gloves were not included in the glovebox, forceps were underutilized, and additional lead shielding was not used.

The barrier analysis supported the Boards conclusions that the cause of the overexposure was the failure to properly implement ISM and ALARA principles.

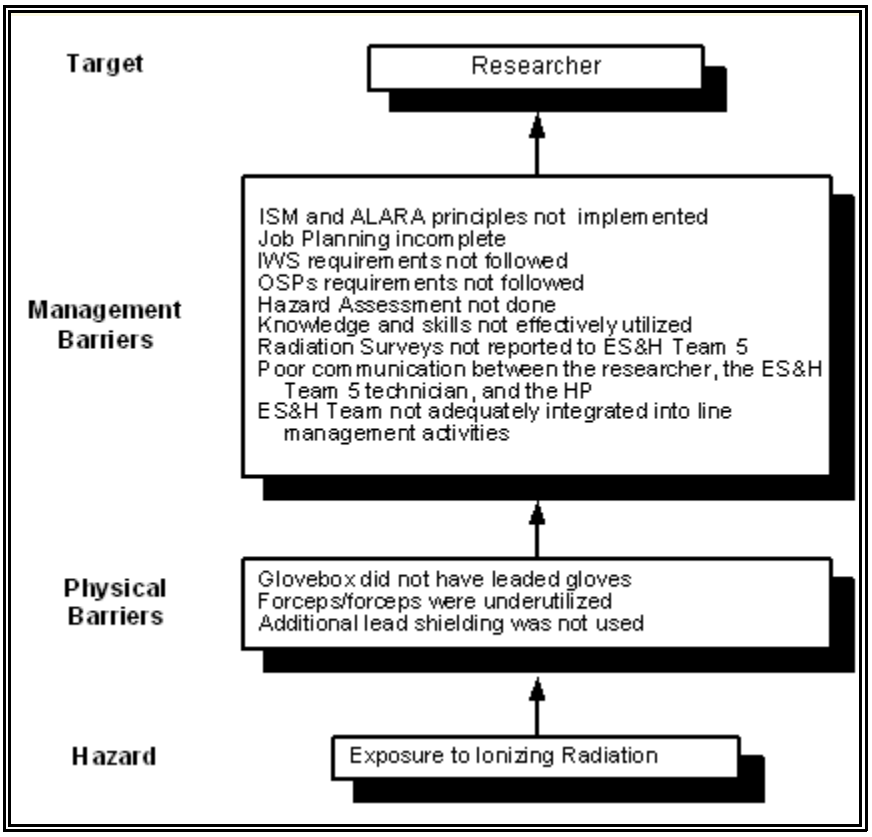


Figure 10. Summary of Barrier Analysis.

Table 1: *Management Barrier Analysis*

Management Barrier Analysis			
Hazard: Exposure to Ionizing Radiation		**Target: Researcher**	
Barriers	**Barrier Performance**	**Barrier Failure**	**Effect of Barrier on Accident**
ISM / ALARA requirements	Less than adequate	ISM and ALARA requirements were not sufficiently implemented.	Led to increased extremity dose.
Job Planning	Less than adequate	The job planning was not comprehensive (e.g., did not address time to be spent handling material; failed to identify and implement adequate controls).	Led to increased extremity dose.
IWS (2284)	Was not followed	Researcher was not current on IWS requirements.	Led to increased extremity dose.
OSP (15.31 and 151.39)	Were not followed	Insufficiently implemented. Researcher survey results not posted as required and area posting not implemented.	Led to increased extremity dose.
Hazard Assessment	Not done	Not requested by Researcher as required by IWS. No additional controls implemented; inadequate dose estimation.	Led to increased extremity dose.
Knowledge and Skills	Did not effectively utilize knowledge and skills	Researcher did not use his training and knowledge & skills effectively, especially the ALARA training and skills.	Led to increased extremity dose.
Communication	Poorly	Researcher did not communicate to the ES&H Team the work activity and his radiation survey results.	Led to increased extremity dose by preventing identification and implementation of additional safety controls.
Radiation Survey and Area Posting	Less than adequate	Survey performed per DAP specifications. Comprehensive survey not done; elevated levels of radiation in the room on June 11, 2002 were not detected. Room “B”/Work Area not posted as radiation area.	Not identifying the high levels of radiation (>5mR/hr) resulted in non-notification of the HP of the hazard present in the room.
Interaction between CMS Line management and ES&H Team	Less than adequate	There is no systematic method of communicating the status of facilities and operational conditions to the ES&H Team.	Inadequate interaction resulted in Team 5 not knowing the operational status/activities in Room “B”. Hence no re-evaluation of ES&H coverage, including direct survey frequency.
Posting of Survey Results	Less than adequate	Researcher survey results were not posted as required by the OSP.	Posting of survey results would have alerted the ES&H technician and necessitated HP involvement.

Table 2: *Physical Barrier Analysis*

Physical Barrier Analysis			
Hazard: Exposure to Ionizing Radiation		**Target: Researcher**	
Barrier	**Barrier Performance**	**Barrier Failure**	**Effect of Barrier on Accident**
Glovebox	Inadequate	Used glovebox with unleaded gloves	Could have reduced the extremity dose if the glovebox had leaded gloves
Tweezers/Forceps	Underutilized	Underutilized	Led to increased extremity dose
Additional Portable Lead Shielding Materials and Lead Gloves	Were not used	Additional shielding materials were not in place. Did not use taller lead pigs and shielding blocks which could have provided better shielding from the 4.5 in. centrifuge cones.	Could have reduced the extremity dose if additional and appropriate shielding materials and containers had been used.

2.4 Root Cause Analysis

2.4.1 Direct Cause

The Board determined that the **direct cause** of the overexposure was the Researcher physically handling radioactive materials over an extended period of time.

2.4.2 Contributing Causes

Contributing causes that increased the likelihood of the overexposure without individually causing the overexposure and that are important enough to warrant corrective action are as follows:

1. The Researcher did not follow administrative requirements, including those in the IWS and OSPs. He did not request and therefore did not receive Hazards Control/ ES&H team support at the beginning of the job. This resulted in insufficient engineering and administrative controls before the work began.
2. The Researcher's radiation survey results were not communicated to the ES&H team so that the area/room could be posted appropriately and the HP notified (per IWS and OSP requirements).
3. The lack of integration of the ES&H team into CMS line management activities prevented the implementation of safety controls.

2.4.3 Root Causes

The **root causes** of the overexposure (the fundamental cause that, if eliminated or modified, would prevent recurrence of this and similar overexposures) include the following:

1. The failure to implement ISM principles, including following documented procedures and work authorization requirements.
2. The failure to implement ALARA principles, including using adequate and appropriate shielding and exposure time considerations.

Analysis of the root and contributing causes indicates that the origin of this overexposure began when the Researcher did not familiarize himself and implement the requirements of the IWS.

3 CONCLUSIONS AND JUDGMENTS OF NEED

Conclusions are a synopsis of those facts and analytical results that the Board considers especially significant. Judgments of Need are managerial controls and safety measures believed necessary to prevent or mitigate the probability or severity of a recurrence. They result from the conclusions and causal factors and are directed at guiding managers in developing follow-up actions. Table 3 summarizes the conclusions of the Board and Judgments of Need.

It is noted that the Researcher attempted to minimize or eliminate TRU waste generation, and attempted to extract a valuable product (Cm-245) from the Cf-249 rather than discarding it. While these efforts are noteworthy, their accomplishment might have contributed to the exposure because of the additional time spent handling the materials.

In summary, based on the Board's investigation and analysis, the primary conclusions are:

- The doses to the Researcher's ring dosimeters represented the doses to his extremities during the June 2002 monitoring period and should be recorded as such. Therefore, his left hand should be assigned a dose of 111 rem while the right hand is assigned 62 rem. The Board further concluded that a whole body dose of 57 mrem should be retained as the dose of record for the whole body for the same monitoring period.
- The high extremities dose occurred because:
  - The Researcher physically handled the radioactive materials for an extended period of time.
  - ISM, ALARA and Conduct of Operations principles were not implemented and safety procedures were not followed.
  - The ES&H team was not fully integrated into ANCD line management and was therefore unable to prospectively implement safety controls with/without Researcher request.
  - ANCD did not ensure that adequate safety procedures were in place.

To prevent a recurrence of this type of accident, the Judgments of Need include that CMS is to ensure that individuals follow procedures, implement ALARA and ISM, integrate the ES&H team into CMS line management activities, and ensure that adequate safety documentation is in place.

The Judgments of Need also states that Hazards Control is to ensure that ES&H Team personnel are aware of applicable IWS and OSP requirements (see Table 3 for a more complete description).

Table 3: Conclusions and Judgments of Need.

Conclusions	*Judgments of Need*
The Researcher did not follow procedures: • Researcher did not become familiar with the IWS requirements. • Researcher did not practice CONOPS.	CMS to ensure that individuals read, understand, and follow procedures.
The Researcher did not implement the knowledge acquired in training: • Researcher did not practice ALARA. • Researcher did not practice ISM as it is related to job planning and hazard analysis. • Researcher did not wear ring dosimeters while handling radioactive materials in Room "A".	CMS to hold individuals accountable for implementing ALARA, ISM and CONOPS. CMS to ensure that individuals wear their dosimeters when handling radioactive materials or radiation generating devices, or entering areas where dosimeters are required.
CMS failed to fully integrate the ES&H functions into line management: • Line management does not adequately interact with the ES&H team thus the ES&H team is not always aware of operations and activities in the facilities. • Line management failed to request the ES&H team assistance for the implementation of the OSP radiological control requirements.	CMS to develop and implement a systematic approach to inform the ES&H team of activities and operations to improve the integration of the ES&H program.
ES&H team displayed lack of "attention to detail" in their service to ANCD: • Package surveys were not performed as required by the OSP. • Dose rates in Room "A" were not updated as required by the OSP. • The discrepancy between RATS curie content and materials transfer tag curie information was not questioned.	HC Management to ensure that the ES&H Team is aware of applicable requirements and complies with them and conducts their ES&H support with attention to detail. CMS to foster an environment that encourages the ES&H team members to be proactive and exercise more initiative when providing ES&H coverage.
ANCD failed to ensure the existence of adequate procedures to perform the work safely: • DAP does not require surveys of incoming radioactive packages. • OSPs and DAP contain conflicting survey requirements. DAP requires dose rates to be obtained at contact with glovebox window; OSP requires the survey at 30 cm from glovebox window. • OSPs do not contain adequate frequency requirements for direct and contamination surveys; do not contain ALARA requirements.	CMS to ensure that safety documents are in place and updated with respect to frequency, methodology, and quality of the surveys. ALARA requirements need to be spelled out for all potentially high dose work activities. CMS to ensure that safety procedures (i.e., OSP and DAP) do not contain conflicting requirements. CMS to ensure that ES&H team responsibilities listed in safety documents (e.g., OSP, IWS) are clearly communicated to the ES&H team.

4 BOARD SIGNATURES

John L. Gonzales Date: 10-10-02

John L. Gonzales
DOE Accident Investigation Board Chairperson
U.S. Department of Energy
Oakland Operations Office

Date: 10-10-02

Edwin Njoku
DOE Accident Investigation Board Member
U.S. Department of Energy
Oakland Operations Office

Keith Warwick Date: 10/10/02

Keith Warwick
DOE Accident Investigation Board Member
U.S. Department of Energy
Oakland Operations Office

Date: 10/10/02

Ari Krasopoulos
DOE Accident Investigation Board Member
U.S. Department of Energy
Oakland Operations Office

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5 BOARD MEMBERS, ADVISORS, AND STAFF

Chairperson	John L. Gonzales, DOE/OAK
Member	Edwin I. Njoku, DOE/OAK
Member	Keith Warwick, DOE/OAK
Member	Ari Krasopoulos, DOE/OAK
Advisor	Diana Ramirez, DOE/OAK
Technical Advisor	Joe Carlson, LLNL
Technical Advisor	Doug Allan, LLNL
Technical Advisor	Christine Hartmann - Siantar, LLNL
Legal Counsel	Janis Parenti, DOE/OAK
Administrative Support	Tiffany Miller, CE2 for DOE/OAK Dabbie Schleich, LLNL, Technical Editor

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Appendix

Appointment and Extension Memorandums for Type B Accident Investigation

Department of Energy
National Nuclear Security Administration
1301 Clay Street
Oakland, California 94612-5208

JUL 26 2002

MEMORANDUM FOR JOHN GONZALES
DIRECTOR, ENGINEERING & FACILITIES
MANAGEMENT DIVISION

FROM: CAMILLE YUAN-SOO HOO, MANAGER
OAKLAND OPERATIONS OFFICE

SUBJECT: Establishing an Oakland Operations Office Type B Accident Investigation Board

I hereby establish a Type B Accident Investigation Board to investigate the accident which occurred at Lawrence Livermore National Laboratory on July 22, 2002. I have determined that this accident meets the requirements for a Type B accident investigation as stated in DOE Order 225.1, Accident Investigations.

I appoint John Gonzales as the Accident Investigation Board Chairperson. The Board Members are Edwin Njoku, Ari Krasopoulos, and Keith Warwick. The Board will be assisted by advisors and other support personnel as deemed necessary by the Chairperson.

The scope of the Board's investigation will include, but is not limited to, identifying and analyzing all facts to determine the direct, contributing, and root causes of the accident, developing conclusions, and determining the judgments of need that, when implemented, should prevent the recurrence of the accident. The investigation will be conducted in accordance with DOE Order 225.1. Additionally, the Board will specifically focus on the management systems, roles, and responsibilities as they may have contributed to the accident. The scope will also include application of lessons learned from similar accidents within the Department.

The Board will provide my office with periodic reports on the status of the investigation. The periodic reports will not include any conclusions until an analysis of all of the causal factors have been completed. The investigation report will be submitted to the Assistant Manager for National Security and the Lawrence Livermore National Laboratory for a factual accuracy review and to the Environment, Safety, and Health Division for a quality assurance review prior to finalizing the report.

The report should be provided to me for acceptance within thirty (30) days from the date of this memo. Any extensions to the delivery date of the report must be submitted with a justification for approval by me. Discussion of the investigation and copies of the draft report will be controlled until I have authorized the release of the final report.

cc: Dave Stadler, EH-2
Dennis Vernon, EH-21
Richard Crowe, NA-53
Doug Minnema, NA-53
David Crandall, NA-11
Mike Anastasio, LLNL
Mike Hooper, AMNS
Ray Corey, DAMNS
Phil Hill, LSOD
Ralph Kopenhaver, ESHD

bcc: Edwin Njoku, ESHD
Ari Krasopoulos, LSOD
Keith Warwick, LSOD

Department of Energy
National Nuclear Security Administration
1301 Clay Street
Oakland, California 94612-5208

AUG 2 2 2002

MEMORANDUM FOR CAMILLE YUAN-SOO HOO, MANGER
OAKLAND OPERATIONS OFFICE

FROM: JOHN L. GONZALES, CHAIRPERSON
TYPE B ACCIDENT INVESTIGATION BOARD

SUBJECT: Extension of Overexposure Type B Accident Investigation

Your memorandum dated July 26, 2002 established the Type B Accident Investigation Board and requested that the investigation report be provided to you with in 30 days from the date of the memorandum. I am requesting that the activities of the Accident Investigation Board be extended to September 13, 2002 based on the following facts.

A dose reconstruction team has been formed to determine the dose received by the laboratory researcher. This activity has been time consuming and has not yet been completed.

We are making good progress and have most of the information needed to prepare our report. We have prepared the events and causal factor analysis and the barrier analysis. The root cause has been completed but not the judgment of needs. Report writing has been started but will not be completed until the dose reconstruction activity is completed. I currently expect to submit our report for your review and acceptance on or before September 13, 2002.

If you have any questions please call me at (925) 422-2405.

cc:
D. Ramirez, ESHD
D. Vernon, EH-21
M. Hooper, AMNNSA