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August 2, 2006

Mr. David Staudt
Centers for Disease Control and Prevention
Acquisition and Assistance Field Branch
Post Office Box 18070
626 Cochrans Mill Road – B-140
Pittsburgh, PA 15236-0295

Subject: Contract No. 200-2004-03805, Task Order 1: Transmittal of Revised Attachment 2 of the Draft Review of the NIOSH Site Profile for the Rocky Flats Plant

Dear Mr. Staudt:

Enclosed is a revised version of Attachment 2, Site Expert Review Summary, of the Draft Review of the NIOSH Site Profile for the Rocky Flats Plant, which was originally transmitted to you on May 9, 2006. The draft site profile review, itself, was delivered to you on December 8, 2005; as you may recall, Attachment 2 was not included in that deliverable, as it had not yet been completed or subjected to the appropriate clearance for classified information.

This revised version of Attachment 2 contains some specific editing that SC&A performed in response to Advisory Board member comments. A commitment was made by SC&A at the June 14–16, 2006, Board meeting to resubmit this revised version.

Please insert this Attachment in the appropriate place in your draft copy of SCA-TR-TASK1-0008. Should you have any questions regarding this deliverable, please contact me at 732-530-0104.

Sincerely,

John Mauro, PhD, CHP
Project Manager

cc: P. Ziemer, PhD, Board Chairperson
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# ATTACHMENT 2: SITE EXPERT INTERVIEW SUMMARY

Interviews were conducted with 14 former Rocky Flats Plant (RFP) workers, Department of Energy – Rocky Flats Office (DOE-RFO) oversight personnel, and individuals involved in independent investigations of site operations. Years represented by those interviewed range from 1952–2005. The interviews were conducted by Dr. Abe Zeitoun and Ms. Kathryn Robertson-DeMers, "Q"-cleared members of the SC&A RFP review team. The purpose of these interviews was to receive first-hand accounts of past radiological control and personnel monitoring practices at RFP, and better understand how operations were conducted. These personnel interviews were conducted from September 6–9, 2005. Other interviews were carried out via telephone for those who were housebound, following a security briefing by DOE. Interviewees were selected to represent a reasonable cross-section of production areas and job categories. Interviewees were originally obtained through the RFP DOE Office, National Institute for Occupational Safety and Health (NIOSH) worker outreach meeting minutes, worker outreach groups, and former health physics staff.

Workers were briefed on the purpose of the interviews and the Rocky Flats Plant Site Profile. They were asked to provide their names, in case there were follow-up questions. Participants were reminded that they would be provided the opportunity to review the interview summaries prior to inclusion into this report. Interviewees were told that there were aspects of operations that were classified and this information could not be divulged. To ensure classified information had not been included in the interview notes, the notes were reviewed by a classification officer prior to release.

Former RFP employees interviewed worked throughout the RFP. Some of the primary buildings associated with their work included Buildings 117, 122, 123, 371, 374, 440, 444, 460, 559, 707, 771, 774, 776, 777, 779, 881, 883, 865, 991, 903 Pad, and the Mountain View Facility. Some individuals had access to all areas of the plant. The job categories represented included the following:

- Associate Scientist
- Chemical Control Operator
- Chemical Operator
- Clerk Packer
- Crew Leader
- Decontamination Foreman
- DOE Radiation Safety Officer
- Experimental Operator
- Firefighter
- Health Physicist Research Scientist
- Industrial Engineer
- Laborer
- Machinist
- Millwright
- Process Control Foreman

- Quality Engineer
- Radiation Monitor/Radiological Control Technician
- Technical Foreman

The information the workers provided to SC&A has been invaluable in providing us with a working knowledge of the various site operations and the safety program. All interviews have been documented and summarized below. This is not a verbatim discussion, but is a summary of information from multiple interviews with many individuals. The information provided by the interviewees was based entirely on their personal experience at the RFP. It is recognized that site expert and former RFP workers' recollections and statements may need to be further substantiated. However, they stand as critical operational feedback and reality reference checks. These interview summaries are provided in that context. Rocky Flats Plant site expert input is similarly reflected in our discussion. With the preceding qualifications in mind, this summary has contributed to our findings and observations.

**General Information**

The primary goal at RFP was to meet the commitment made to the government to make a pre-established number of pits. According to workers interviewed, there was less concern with safety in the production years than in the decontamination and decommissioning (D&D) years.

Initially, personnel training was provided by an individual's supervisor. There was initially no formal Radiation Worker training. Early training involved learning about radiation related to a job task and required reading of procedures. The people writing the procedures did not work in operations. They were often not followed for the sake of practicality and for the sake of increased production. Periodic safety meetings were held that included watching films of major accidents. In general, they were not aware of the relative consequences of radiation exposure in the early years.

**Workforce**

There was movement of the workforce between the uranium and plutonium areas. It seemed that the lower an individual was on the totem pole, the more likely they were to stay in a particular job. The plant maintained 7-day shifts during production years. Some hourly employees worked an average of 50–60 hours per week. An average workweek for exempt staff ranged from 40–45 hours.

**Security**

Rocky Flats had a Perimeter Security Zone (PSZ) to help maintain security onsite. The Special Nuclear Material (SNM) was stored within this area. The Clerk Packers and security personnel were responsible for handling the shipment of materials. The plant protective force was responsible for escorting components within the PSZ.

Materials were stored in the production areas as well as vaults. Some areas required that two persons be present for security reasons. On occasion, maintenance workers would enter these areas to perform maintenance.

The SNM group was responsible for working with plant protection to set up security scenarios, where they would attempt to steal plutonium components and test the effectiveness of plant security. They also designed terrorist-like scenarios and responded to similar audits performed by their DOE counterparts. Essentially, they served as the Safeguards portion of Safeguards and Security. This job required approximately 5%–10% hands-on work with radioactive material.

**Operations**

Operations at RFP involved chemical recovery of plutonium and uranium, assembly and disassembly of weapons components, other actinide recovery, research and development, D&D, and waste management.

The 700 area of the facility was associated with actinide activities. Building 371 was used as a plutonium storage area. Building 559 housed the analytical laboratory, where process samples were analyzed. Building 707 was involved in cleaning components, radiography, final inspection, and assembly of components containing plutonium. Retired weapons disassembly was completed in Buildings 776, 777, and 779. Those working with plutonium were also exposed to uranium from the raffinate. The plutonium area was referred to as the “hot side.”

Uranium operations took place in what is referred to as the “cold side” of the plant. There was a criticality laboratory housed in Building 886 that was used to perform subcriticality experiments.

Radioactive materials handled at the Rocky Flats Plant included $^{235}$U, $^{238}$U, $^{238}$Pu, $^{239}$Pu, $^{241}$Am, $^{242}$Am, $^{237}$Np, depleted uranium (tuballoy), enriched uranium (oralloy), $^{233}$U, tritium, and alloys of plutonium with enhanced impurity radionuclides. The details of the plutonium alloys could not be discussed, although some workers were cognizant of the constituents of the components. To the south of Central Avenue, the primary contaminants of concern included $^{235}$U, $^{238}$U, and beryllium. To the north of Central Avenue, the primary contaminants of concern were $^{238}$Pu, $^{239}$Pu, $^{241}$Am, $^{242}$Am, $^{237}$Np, and $^{235}$U from site returns. Recycled pits posed a source of potential exposure from tritium.

Recovery of plutonium was performed through chemical processing in gloveboxes. Initially, operations were done in an oxygen atmosphere. After the explosion in 1964, RFP converted to the use of an argon atmosphere. The process turned the plutonium fluoride into metal buttons. The conversion of $PuF_4$ to metal (reduction) heated the plutonium compound to in excess of 600°C. Plutonium tetrafluoride (pink cake), plutonium peroxide (green cake), plutonium nitrate, plutonium chlorides, and plutonium dioxide were handled during RFP operations. The war reserve weapons-grade plutonium was processed at the plant through 1989.

Processing was not limited to plutonium recovery. Prior to the 1980s, americium was worth more money than plutonium to the company. There were campaigns involving the purification of $^{241}$Am in Building 771, Line 1. This process was associated with higher gamma exposures. The processing for americium was similar to that for plutonium. This process produced a pure product. Chemical forms produced during processing included americium chloride, americium nitrate, and americium oxide. An additional source of exposure to americium was the buildup in the Recovery Area in the 1960s. The dose rates became more of an issue.

Building 881 housed the oralloy and leaking operations, and $^{233}U$ production in the 1960s. Oralloy was processed at RFP until 1965, when this responsibility was transferred to Oak Ridge. In Building 779, they handled some exotic materials, such as $^{237}Np$, and performed experiments that bombarded materials with radiation to determine the effects. There were metallurgical laboratories in Buildings 771, 883, and 444. Building 865 contained a high bay with a small steel mill. Experiments were conducted with steel, beryllium, and uranium.

The site was involved in both assembly and disassembly operations. Disassembly of returned weapons occurred in Buildings 776, 777, and 779. During the assembly process, uranium and plutonium were handled in the immediate vicinity of beryllium. Work with returned components constituted about 10% of the operations at RFP. Returns typically had a lot of americium impurities and were very hot to the touch. The age of the weapons varied.

During disassembly, the nuclear component had to be separated to recover materials. It was put into a carrier and called up on the pendent line. The pit was put in the machine and the outermost layer was scored with a scribe mark. The shell was pounded with a chisel on the scored line. The sphere was torn apart and the valuable materials were reclaimed for later processing. Some pits were contaminated with tritium. Uranium was present in finished components.

Each operation conducted at RFP had an associated procedure. The Operations groups used what was referred to as Process Operation Sheets (POS), which provided specific detail on a particular operation. For example, the POS would specify the chemicals used for cleaning or the rotations per minute used in machining. These POS documents could assist in understanding the operations; however, they may be classified.

There were field auditors on staff who monitored the compliance with these procedures. Auditors would physically enter the area and observe operations. For example, for work in a glovebox, they may be standing next to the operator looking through the window. One particular auditing manager had the habit of editing audit reports. At times audit reports were simply ignored. For example, when EG&G managed the site, the use of inadequate bolts was identified. The auditors were told this issue would be dealt with by management. Later, one of the auditors returned as a consultant and found that the condition still existed.

**Research and Development Projects**

Research and Development (R&D) activities at the site included research related to mechanical metallurgy, heat treatment of materials, melting of plutonium, alloying of plutonium, rolling and forming metal, tensile strength testing, and metallography. Some plutonium used in R&D activities was handled outside gloveboxes. Depleted uranium was used during studies on tensile strength and metallography. Detailed logbooks were kept of R&D activities.

A project referred to as Dicesium Hexochloroplutinate (DCHP) was conducted in Building 371 during 1988 and 1989. This process was a shortcut to retrieve plutonium from oxides that did not meet specifications for reduction and turn it into more pure plutonium. This project involved exposure to very high neutron and photon radiation. There were few workers who wanted to participate in this task due to the radiation exposure. Work on this project caused at least one individual to receive skin burns, loss of hair, bruising, diarrhea, vomiting, and an increased white blood cell count. Penetrating radiation rates outside the closed door to the room, from the hallway, were so high, that support groups for the DCHP workers refused to enter the room. Although a grievance was filed, according to one worker interviewed, Rockwell would not recognize the grievance and stated, "Rockwell does not recognize the skin as an organ." Rockwell further stated the burnt skin of the worker was due to the lye in which the coveralls were laundered, although the worker had been wearing coveralls washed in the same lye solution for many years previous to the incident. Therefore, the solution to the excessive exposure was to provide the worker with new coveralls.

**Contract Employees**

A portion of the maintenance workforce was brought in from the local unions. Those with clearances in place were put to work in the more restricted areas. These areas of the plant were associated with production and included potential exposure to plutonium, uranium, and beryllium. Many were also involved in construction activities, including erecting and setting up machinery in the production areas. Their job tasks varied by the craft.

**Decontamination and Decommissioning (D&D)**

The D&D activities at RFP have concentrated on stabilization of material and shipment of radioactive waste and materials offsite. The industrial area was cleaned up and will be maintained as a legacy management area. This area has not been cleaned up to pre-operational standards and, therefore, is not accessible to the public. The 5,000-acre buffer zone around the industrial area will be cleaned up to more stringent standards and will become a wildlife refuge.

The D&D process involves many operations that included compromising potentially contaminated closed systems and dealing with unexpected materials. Several techniques were used during the D&D process. For example, RFP used fixatives like latex paint with the addition of surfactant-enhanced water for demolition dust suppression. Prebuilding demolition involved partial or complete removal of non-load bearing walls, ceilings, and floors; the use of shaving concrete; hydrolasing (high pressure washing); and size reduction, sealing, and burial of decontaminated (< actions levels) areas with clean dirt.

The ductwork within the many process buildings were contaminated with plutonium holdup from years of operations. Maintenance would often run into unexpected "hot" conditions. Material would spew unexpectedly out of pipes during routine maintenance or demolition. Individuals in the area may or may not have been monitored, depending on the location of the system.

Building 771, labeled as the most radioactive building in the world by DOE, was dismantled during the D&D process. The soil under and in the immediate vicinity of this building was contaminated from years of operation. Instead of removing the soil, the area was covered with 20–30 feet of dirt. The weight of the dirt caused contamination to seep into the holding ponds. The existence of radioactive pockets at RFP can be identified with aerial surveys. Soil contamination was also found around Building 776.

**903 Pad**

Due to the lack of storage areas, RFP began storing a large quantity of drums at a site referred to as the 903 Pad. During a quality assurance audit of this area in 1967, the drums were noted to be so rusted that the serial numbers were not readable. The drums were leaking; however, it was uncertain how long the drums had been this way. Radioactive material seeped through the asphalt pad and into the soil.

Following removal of the drums from the 903 Pad, the asphalt was ripped up. Tents were used over the pad during this process. The soil sampling results were used to estimate the release outside the immediate area of the pad (e.g., > 100–200 yards). During remediation, the asphalt and the top 3 feet of dirt were removed. Where contamination still existed, they removed an additional 2 feet of dirt.

**Waste Management and Incinerator**

The incinerator was used as a method of waste minimization for combustible materials (e.g., paper, plastics, rags, rubber, sludges). It was operational from 1952 to 1989. The process of incineration would create a polymer around the plutonium, making it extremely insoluble. The ash following burning was removed from the incinerator, pulverized in a ball mill, put into containers, and then stacked into drums for storage. The pulverization of the ashes at the ball mill created a finer powder. This allowed more material to be put into a container. Storage space was at a premium at RFP. There was a great deal of pressure from the DOE to recover plutonium from the ash. Several methods were tried. One method of attempting recovery of the plutonium was to put it through a nitric acid dissolution process. In an effort to speed the incineration of material, operators would spike the temperature, allowing it to exceed procedural values. This would cause filter plenums to burn. Periodic audits were conducted of the incineration process, including the temperature used, how much material was loaded at a time, and disposal of ashes.

The Waste Isolation Pilot Plant (WIPP) in New Mexico would not allow RFP waste to be shipped to their facility initially. The plant had to create several makeshift storage areas. For example, RFP converted the 991 tunnels into a source material storage area. In 1990, the site had to construct several tents for the storage of waste, because there was no place to send it. There were 15 tents with contaminated waste. When the high wind storms came along, the tents were blown down along with the drums. The drums would roll down hills.

When high-level radioactive waste could be shipped offsite, material was loaded into a drum liner, the lid was sealed, the liner was put into a 55-gallon drum, and the drums were checked for contamination.

Waste from the gloveboxes and dry boxes were removed via a bag in/bag out process. During this process, all nonessential personnel exited the immediate area to prevent potential exposures. Mixed waste was also generated from the production operations.

**Radiological Control**

There was a notable difference in the radiation controls in the plutonium area versus the uranium area. With respect to uranium, the management told the workers they didn't have to worry about uranium and could even eat it.

Neutron surveys were done on a periodic basis in the plutonium areas. The neutron survey instrument of choice in this area was the Rem Ball. Although there was a presence of uranium and beryllium in the uranium production area, Radiation Monitors interviewed did not recall any neutron surveys being completed in this area.

The Rocky Flats Environmental Technology Site (RFETS) calibration facility used many National Institute of Standards and Technology (NIST) traceable sources for their work, including $^{60}$Co and $^{252}$Cf sources, along with the instrument calibration sources associated with weapons-grade plutonium. There were also sources used in the Nuclear Chemistry Laboratory.

As a part of the quality assurance process, there was a special group responsible for Non-destructive Testing (NDT). Portable x-ray cameras and radiography-installed sources were used throughout the plant. This group utilized sources and x-ray units to validate the quality of manufactured parts and the contents of storage containers. There was a $^{60}$Co well source used for these purposes. The source was located in a secure area with 3-foot thick walls. The source was brought up from out of the floor. Personnel were stationed outside the immediate area of the source. Historically, a Pee Wee detector (alpha counter) was used to assign an estimated gram value of plutonium in a particular drum. Radiation Monitors were responsible for surveying radiation-generating devices (e.g., Electron Beam Welders, sources, etc.).

There was no formal Radiation Work Permit (RWP) program prior to the mid-1990s. Before RWPs, job requirements were communicated verbally, via postings, or in operating procedures, including requirements for respiratory protection.

There were a number of jobs at RFP that involved handling of SNM. The descriptions below describe a few of these jobs.

- A Clerk Packer worked handling plutonium in gloveboxes. The parts were put on a chain conveyor system inside the glovebox system, the plutonium component was removed and cleaned with carbon tetrachloride, each part had a serial number etched on it, and parts were put into a stacker and transferred to radiography. The part was radiographed and removed for staging along the glove line. From here, it was transferred to Building 771 for final inspection. They also received retirement components for serial number verification. These components were very radioactive and hot to the touch. There was a log of gammas and neutrons emitted by these units.

- A Scheduler toured the area to take inventory of the quantity of material in each particular operation at a given time. Reports from fabrication inspections of the production control and foundry area were provided to management. This job required approximately 30% hands-on work.

- A Coordinator provided status reports similar to those of a Scheduler to upper management. These reports provided information on how the plant was progressing toward production requirements and schedules.

- Decontamination Foreman/Workers were responsible for decontamination of production areas, including those areas where major accidents had occurred, such as the 1969 fire. Although it was not expected of them, foremen would accompany their workers into radiological areas and assist. This job required nearly 100% hands-on work with radioactive material.

- Production Control Foreman trained Clerk Packers in the handling of material, etching serial numbers on parts, and conducting inventories of SNM in the line. They provided supervision and oversight. This job required approximately 5% hands-on work with radioactive material.

- Process Material Control Coordinators set up and participated in inventories. They were active in performing segregation of drums in the storage areas and validating transuranic contents of these drums. The segregation of materials was based on form and location. This job required approximately 5% hands-on work with radioactive material.

- Engineers or scientists would design experiments, and experimental operators would assist the engineers in conducting these experiments. This involved hands-on work.

- Metallurgical and foundry personnel handled material outside gloveboxes. Inspectors and chemical operators also did a significant amount of hands-on work.

There were jobs associated with higher risk than others. Some of these jobs are listed below.

- Entry into the "Snake Pit," which contained sampling lines for taking process samples. It was located in the Recovery Area. The lines often leaked and the area was contaminated with plutonium. Entry into this area required a full-face respirator or even supplied air, depending on the task.

- Chemical operations would enter the gloveboxes to clean the lines. This required the use of supplied air. This practice was continued through the 1950s.

- Filter change outs, especially after the major fires.

- Emergency response to fires.

**Contamination Control**

Personnel Protective Equipment (PPE) for individuals routinely working in plutonium areas varied in the processing areas, dependent on your job responsibility. Typical PPE for hands-on workers included company clothing (e.g., coveralls), modesty clothing, booties, safety glasses, and a mask, as necessary. The "official" dress of engineers was coveralls or a lab coat, a half-face respirator, booties, and sometimes caps. Auditors entering the area were required to wear suits, although the workforce was wearing coveralls. They were not always afforded the same PPE as hands-on workers. Health Physics would communicate PPE requirements more stringent than routine requirements.

Personnel were allowed to self-monitor during the course of the day. At the end of the day, Radiation Monitors were responsible for monitoring personnel. Ludlum alpha counters were used to check for alpha radiation. Individuals showered at the end of the day and changed clothes. Workers were instructed to frisk during the day if they left the area, such as during their lunch break. They did not necessarily frisk prior to breaks. Self-monitoring was not policed, resulting in inadequate self-monitoring or failure to monitor. Safety rule enforcement was a low priority. The uranium buildings had self-monitoring stations at the doors to check hands and feet. Workers were asked to monitor their respirator before they went home. If the respirator was contaminated, it was disposed of.

Eating, drinking, and smoking were not allowed in the immediate vicinity of radioactive material in the plutonium areas. Drinks and popcorn were allowed in the uranium processing area. They were not allowed to eat or drink during the machining of parts. The food and beverages were set 5–10 feet away from the actual machine. Although eating, drinking, and smoking were not allowed in the plutonium, individuals smoked in the bathrooms in the processing areas. There were times when Radiation Monitors found contamination in the cafeteria.

Respiratory protection was not worn all the time during processing of material. Some specific jobs required the use of respirators. Full-face and airline respirators were used for jobs requiring respiratory protection (e.g., breaching systems, beryllium work, etc.). A job such as a retriever may require the use of an airline respirator.

Workers also carried respirators around their neck, in their pocket, or on a belt for the purposes of emergency egress from production areas. When Selective Alpha Air Monitors (SAAMs) alarmed or personnel were directed to by the Radiation Monitor, individuals were required to don their respirator. This procedure was not always effective, as the SAAM alarms in the areas were bypassed many times or not properly located.

The original respirators had single straps and would come loose easily. This resulted in personnel contamination incidents periodically. Initially, smoke tests were used for sizing a respirator. When the more mature respiratory protection program was implemented, there was extensive testing for respirators. Respirators were hung in the locker for storage. What was previously done in full-face respirators, they did in supplied air in more recent years. This was also true if there was damage to the gloves in the gloveboxes or there were leaks discovered.

Nasal and mouth smears were not a routine part of the contamination control program during the years of processing.

Contamination from damage or leaks in the gloveboxes was not uncommon. Loss of contamination from gloveboxes resulted from holes in gloves, degradation of gloves, and leaky pipes and ducts. There was occasional contamination found on material stored in the glovebox areas. On more than one occasion, radioactive product actually went through the walls and contaminated the vending machines on the other side in the hallway. There were situations where contamination was spread outside the immediate production area. Decontamination efforts did not always include all surfaces of an object.

There were daily occurrences of personnel and PPE contamination. Sources of these incidents included glove changes, punctures or penetrations in gloveboxes, leaks, spills, etc. There were 5–10 glove changes per day. At times, personnel complained because gloves didn't get changed often enough. Personnel contamination incidents requiring treatment were documented in the medical file. Skin contamination forms were placed in the health physics files.

The Infinity Room in B771 was so named because the alpha activity present on the equipment and material in the room exceeded instrument reading capability at the time. This room was sealed in 1971. The contamination was generated from leaks of material onto the floor, fires, and spills from the process. It became a storage area for highly contaminated material. Buildings 776 and 777 were also used for storage of contaminated material.

Painters reported instances where purple paint was found under the layers of regular paint in non-radiological areas. The purple paint, which indicated some type of radiation, was mistakenly painted over at some point. As these were uncontrolled areas, these workers were potentially exposed while most likely not wearing a dosimeter.

**Engineering Controls**

Plutonium operations were typically conducted in gloveboxes. The gloveboxes had lead-lined gloves to reduce exposure to extremities. Originally, 30-mm lead-lined gloves were used. The lead-lining thickness was eventually switched to gloves with 45 mm. During the americium processing, operations used 90-mm lead-lined gloves. Gloves were changed if they were torn, punctured, developed holes, or became too worn. The company was not diligent in fixing leaking lines and replacing Plexiglas when it developed cracks.

Gloveboxes had shielding to reduce exposure; however, this was not always effective for all parts of the body. There were areas of the body that received more exposure than others. Work in gloveboxes primarily exposed the hands, arms, chest, and face. The glovebox shielding was more effective in shielding gamma exposure than neutron exposure.

The plutonium buildings were set up so that an individual had to pass through an airlock to enter the processing area. Once in the production area, the building design depended on the particular building. For example, Building 776 had a wide-open area that was not compartmentalized. The gloveboxes and rooms were maintained under negative pressure. In general, the filtration was good in the plutonium areas. About 2–3 times per year, there were pressure reversals causing positive pressure.

**Internal Monitoring**

Rocky Flats had a routine and incidental bioassay program. Hands-on workers (e.g., chemical operators, machinists, technicians, experimental operators, associate scientists) received an annual lung count near their birthday. Periodic urine samples were submitted monthly, quarterly, semi-annually, or annually, depending on the particular job responsibilities. In-vitro samples were collected upon receipt of the bioassay kits. Field support workers (e.g., auditors, engineers) received "routine lung counts;" however, the supervisor made the ultimate determination of what was routine. In the case of an incident, individuals received lung counts, submitted urine samples, and/or submitted fecal samples. There was no routine fecal-sampling program. An individual with a confirmed uptake, regardless of job title, would be put on a routine bioassay program for continued monitoring of the uptake. In the case of short-term workers or subcontractors, urine samples were submitted with no routine frequency. These individuals may have multiple bioassay samples (e.g., in vitro and/or in vivo) or only a single bioassay sample for their course of work at the site. Uranium urinalysis was not considered as important as plutonium urinalysis, although the in-vivo counts did consider uranium.

Initially, lung counts were completed with a sodium iodide detector, which had poor resolution. Phoswich detectors replaced sodium iodide detectors, followed by planar-drifted germanium lithium (GeLi) detectors. The GeLi had high resolution, making the identification of americium in the spectrum easier. Americium-241 was used as an indicator for plutonium in the lungs. Fresh weapons-grade plutonium contained 0.5% $^{241}$Pu, which decayed to $^{241}$Am at a rate of 20 ppm per month.

A silicon lithium detector was used for wound counting. The 13- keV, 17- keV and 20-keV peaks were used to identify americium and plutonium. The ratio of these peaks assisted in determining the depth of plutonium in the wound. This helped Medical excise the correct amount of tissue.

Some production processes heated plutonium in excess of 600°–800°C, creating high-fired plutonium oxides. These processes included incineration of waste, plutonium fires, and metal reduction. It is important to note that plutonium oxide in general has a component that appears to act like high-fired oxide. The same can be said for plutonium nitrate and plutonium chloride. This is primarily due to air oxidation. The high-fired oxides do not dissolve readily in body fluids, but can be dissolved by strong acids. The existence and behavior of high-fired oxides have been documented at other facilities, such as the Savannah River Site and Los Alamos National Laboratory. Uranium fires also may have produced high-fired uranium oxide.

The typical particle size encountered at RFP is 0.12 micron Mass Median Diameter (MMD) or 1–1.5 micron AMAD particles. Environmental particles were usually associated with substrates and were in the 5 micron size range. Seventy to eighty percent of inhaled radioactive material will work its way up out of the lungs via the cilia and mucus. The smaller particles are embedded in the deep lung and are highly insoluble, so they stay put.

Some workers with plutonium uptakes were offered chelation therapy with diethyltriaminepentaacetic acid (DTPA). Most refused, as the drug caused loss of other minerals in the body, and they witnessed other workers who did accept the shot become very ill. In other cases, individuals were involved in incidents and the option of chelation was not discussed with them. There were approximately 120 individuals at RFP that were chelated with either DTPA or Ethylenediaminetetraacetic acid (EDTA).

**External Monitoring**

The original exposure limit at RFP was 300 mrem per week. Work with Zero Power Plutonium Reactor (ZPPR) fuels was associated with high doses. Individuals working on the project approached the 12 rem limit per year.

Security badges and dosimeters were originally separate. In 1964, the site combined the security badge and dosimeter into one unit. In the early 1990s, the dosimeters and security badges were separate again. There were dosimeter storage racks at the facility to store the dosimeter when not in use. Individuals were allowed to take dosimeter badges home from the late 1950s through 1980. All site experts interviewed, who worked in both the plutonium and uranium area, were monitored for beta/gamma exposure. Dosimeters were worn on the lapel. At times, health physics would direct individuals in the Recovery Area to move their film badge to their waist. Thermoluminescent dosimeters (TLDs) were exchanged as frequently as biweekly.

Although beta/gamma monitoring was extensive, many individuals working in process areas didn't received neutron dosimeters. Prior to 1957, eighteen individuals involved in final assembly operations received neutron dosimeters. In 1957, a Los Alamos National Laboratory scientist discovered the substantial neutron exposure associated with the fluorination process. Around this time, the site started badging individuals working or visiting this area. The neutron-to-photon ratio in this area was approximately 3 to 1. In the early to mid-1960s, neutron dosimeters were assigned to those working in the metallurgical areas. The neutron-to-photon ratio in this area was approximately 1 to 3. There were individuals in the fluorination and metallurgical areas who were exposed to neutrons prior to the implementation of neutron monitoring. Everyone in the immediate area of machining operations involving uranium and beryllium had a beta/gamma badge, although site experts did not know whether neutron dosimetry was assigned to these individuals.

Lead aprons were used in operations where dose rates were high, such as manual transport of components and/or completed units, the Building 771 Chemistry areas, the downdrafts, and during Non-Destructive Testing. Lead aprons were not initially worn for these operations, but were implemented at a later date. The maximum exposures could be to the legs, arms, face, head, waist, or trunk. For example, components or units were carried at about waist level. Dosimeters were worn on the chest. Over the period of lead apron use, dosimeters were sometimes worn under the apron and sometimes worn on top of the apron. There was a potential for partial body exposure to areas of the body that may not have been reflected on a dosimeter worn on the trunk.

Extremity dosimetry was implemented in the later years. Plutonium operations workers remember beginning to use wrist badges in the mid-1980s. Machinists wore wrist dosimeters when working with special alloys. Multiple dosimetry packs were not routinely assigned for any operations.

There were jobs at RFP that required individuals to accompany hands-on workers into radiological areas. For example, one site expert accompanied maintenance workers (i.e., electricians, welders, painters, pipefitters, etc.) into both "cold" (60, 111, 112, 115, 130, 131, 331, 334, 460, etc.) and "hot" buildings (371, 441, 443, 554, 771, 776, 881, etc.). Individuals of this type were not necessarily assigned a routine dosimeter. EG&G, as well as Kaiser-Hill, were required by DOE to reduce costs. There was some concern over the reduction in dosimeters (i.e., resulting in cost cuts and less plant exposure in the worker population) at RFP, because so many members of the workforce were not issued dosimetry.

Building 334 housed the maintenance shop. There was a concern about the excessive dosimetry readings of the maintenance crew working in the area. The dosimetry rack was moved to another area in an attempt to lower the potential exposure from unknown sources. The ventilation in the "cold buildings" was usually not separated between areas and not HEPA filtered. The air circulated throughout the building from the production areas (e.g., shops) to the non-production areas. Maintenance crew dosimetry readings were also excessive in Building 331, which contained the maintenance garage. Soil and waste transport vehicles were stored in this area during inclement weather.

One site expert had to demand that a dosimeter be issued after years of entering radiological areas without being assigned one. The dosimeter came back with a positive result. When site experts visited other DOE sites, they were issued dosimeters, whereas similar operations at RFP did not require dosimetry. Workers were also exposed to radioactive sources, stored material, and waste drums intermittently as they passed through areas or as the materials were transported past them.

There were situations where individuals reported receiving a "no data available"(NDA) when dose was reported to them. Dosimetry indicated that gaps existed in records where films were blackened, lost, or simply not turned in. When dosimeters became contaminated, they were either decontaminated or replaced with a new dosimeter. Workers were directed to let the Radiation Monitors know when this occurred. Workers were uncertain of what happened to these contaminated badges, and whether the dose was reflected in their dosimetry record. They reported that the dose of record was often zero or low for situations where they were exposed to significant dose rates. Eventually, dosimetry decided to have workers wrap their dosimeters in baggies to prevent dosimeter contamination. Health physics indicated that a dose was estimated when badges were lost, damaged, or the results did not make sense.

To further complicate matters, the plant was sometimes 2 months behind in processing dosimeters. There was no formal real-time external dose tracking. Highly skilled workers were often sent to the same area day after day. With the delay in dosimeter processing and the lack of a formal real-time external dose tracking program, overexposures were discovered after the fact.

The availability of dose records for short-term employees is uncertain. For example, one site expert was clearly involved in "hot" work; yet, no dosimeter or bioassay records were located.

**Environmental**

There were releases of radioactive material into both the workplace and the environment. A plenum filter was 99.97% efficient when it was new, and about 90% efficient over its lifetime. There were typically a series of filters installed in the production areas. When a lowering of pressure differential was indicated, the filters were replaced. After the 1957 fire, Building 771 also had a pre-filter with 3 filters after it. The activity on the third filter was low. Filter plenums periodically got wet and would sag, causing potential releases to the environment. Approximately 10% of the material passing through the filtration system was deposited in the duct system. This deposition of material in the ducts and filters was attributed to the loss of plutonium noted during mass balance determinations.

Unlike the plutonium area, there was no plenum system setup above the machines in the uranium area during the early production years. Machining was done in the open. The use of respiratory protection was up to the machinist, unless there was an alarm. Enough filtration in the building existed to prevent airborne uranium release to the environment.

Rockwell held a wastewater discharge permit allowing discharge at the standard Colorado surface-water discharge limits. Rockwell and DOE did not report radioactive and hazardous materials being discharged from the Sewage Treatment Plant (STP). Furthermore, Rockwell and DOE had volumes more wastewater than the STP permit allowed, so the Environmental Protection Agency (EPA)/Colorado Department of Public Health and Environment (CDPHE) allowed Rockwell and DOE to discharge the excess to the environment at the spray fields and trenches. The raffinate from processing went through the water treatment plant. The company concentrated on meeting the drinking water standards, and had little concern with contamination of onsite surface water sources. There were releases to the onsite creeks. Stanley Lake has detectable plutonium in the sediment. Tritiated water was released to the environment at one point.

Building 995 effluent was transferred to Pond B-3. This was then pumped to the sprinklers in the East and North Spray fields. The effluent was sprayed on the fields daily and millions of gallons were sprayed there per year. This included both hazardous and radioactive materials. The east trenches contained a uranium burial site. Liquid effluent was also sprayed over these trenches.

The site had evaporator ponds where contaminated liquid effluent was sent. In the case of the 207 A, B, and C ponds, the water was allowed to evaporate until only sludge remained. This sludge was mixed with concrete and made into blocks. The blocks were about the size of a pallet and 3-feet high. They were wrapped in plastic for storage at the 750 and 903 Area Pads. The process of turning sludge into solid concrete did not work effectively, and the blocks would slough. During the concreting process, workers would push their fingers into the concrete to check the solidification. The blocks were not properly contained and liquid collected in the plastic. Eventually this leaked. As a result of the leakage, approximately 100 individuals worked overtime to clean up the mess. This was primarily an issue during the period when Dow and Rockwell were contractors at the site.

The solar ponds on the north side of the plant leaked and were closed. There continued to be a transfer of waste from Building 774 and other buildings to the solar ponds after their closure. The site had a shallow aquifer. As a result of the solar pond leakage, Walnut Creek was affected. Animals would drink from the ponds, get contaminated, and contaminate the area with their elimination. There were dead geese and ducks found in the ponds.

There were 25 air samplers within the perimeter of the site, including the buffer zone. These samplers were positioned 6 feet above the ground. Although new technology was developed through the years, the air-sampling systems were not upgraded.

Soil contamination was common at RFP. The Historical Release Report (HRR) provides some soil-concentration data, although this data is primarily from the buffer zone. Site experts were unable to provide soil-sampling data in the industrial area. When asked about contamination external to the building, site experts recalled seeing green material in the soil surrounding the molten salt area. The source of this material was the raffinate from Building 771. There was a potential for the spread of contamination due to weather conditions in the area, such as periodic high wind storms (90–100 mph).

The RFETS has an elevated level of natural uranium and thorium in the soil, as compared to other DOE weapons complex sites. These levels, however, are consistent with the levels found along the front range of the Rocky Mountains in Colorado.

**Medical**

Complete physicals were given once per year in the earlier years. Standard chest x-rays were given on an annual basis.

Health physics and radiological protection were involved in performing oversight and validating the surveys of the Medical x-ray units used at RFP over the years. These surveys would be located with Radiation Protection records. The state did additional inspections of the x-ray unit equipment.

New medical x-ray equipment was procured in 1992 and in 2002. The machines were replaced, because film for the beryllium medical surveillance program required specific x-ray energies that old x-ray equipment was not capable of resolving. Those plant workers who were working with beryllium, and specifically those starting in more recent years, were required to have both an LPT blood test and beryllium screening x-rays. If the LPT test was negative for beryllium sensitivity, the worker was authorized to work in the beryllium production areas and would receive a chest x-ray and LPT beryllium screening sensitivity test once every 3 years. However, if the LPT beryllium sensitivity test was positive, the individual was restricted from working in any of the beryllium production facilities.

**1957 Fire**

During September 1957, a fire was discovered in a development laboratory in Building 771. Plutonium residues had self-ignited and then ignited the Plexiglas wall of the glovebox. After a period of time, an explosion occurred in the plenum, igniting the combustible portion of the plenum filter. In this case, one-third of the filters were burned and there was an atmospheric release from the building. There was disagreement among site experts regarding the quantity of material released to the atmosphere. Some indicated that the NIOSH estimates in the site profiles were reasonable for the 1957 fire. Others felt the release values were higher. The 1957 fire resulted in the largest airborne release at RFP.

**1965 Fire**

In 1965, there was a fire in a glovebox oil recycle line associated with machining operations in Building 776. The equipment was designed to pass oil through a drain and recycle it. In this particular case, the drain became plugged with fines. There was a stainless steel bolt in the drain that had to be removed. Eventually, maintenance had to take the cap off the T-joint and use a center punch to try to knock the material out. This particular material was soaked with carbon tetrachloride and machining oil. The combination of mechanical friction, plutonium, and chemicals caused a fire. There were about 30 personnel in the room at the time. When the fire started, most individuals put on their respirators, although some individuals didn't put theirs on right away, and went sniffing around for the smoke. As a result of not donning their respirator right away, they received lung burdens and were transferred to the "cold side." The Radiation Monitors frisked all individuals involved, and found some individuals contaminated and others uncontaminated.

**1969 Fire**

On May 11, 1969, on the off-shift, a large fire broke out in Building 776. There was severe damage to the building. When the 1969 fire started, there were three or four individuals in this area. The fire burned the gloves right out of the glovebox. The machinist working at the glovebox removed his hands just in time. Personnel grabbed the water fire extinguisher rather than the carbon dioxide extinguisher to put out the fire. They tried to extinguish the fire without success. The building ventilation picked up the contamination and caused a spread through the whole building. The fire alarm sounded, and individuals on the line started donning respirators and exiting the area.

One site expert was present in the office area of Building 776 when the fire started. The office area was in the same immediate area as the production lines in Building 776. This area had no ceiling and was in the same air space as the production line. The personnel in the office area did not hear the alarm and were not told to don their respirator for 5–10 minutes into the fire. By this time, there was a potential for respirator contamination.

The individuals in the office area put on their respirators when alerted by a Radiation Monitor and were frisked. The individuals were grossly contaminated. One individual involved indicated he had to strip and take 7–8 showers to remove most of the contamination. He was transferred to Medical, where they scrubbed him until he was pink and sent him home with a pair of coveralls. Prior to going home, he had to call his wife and mother for a ride. In the process, he contaminated the phone. Upon return to work the next day, this individual was asked to submit a urine and fecal sample, and to go for an in-vivo count.

There was visible smoke coming out of the roof above the glovebox area; however, many contend the roof was not compromised during the 1969 fire in Building 776. The fire spread to the 777 Building prior to being extinguished. It also affected Building 779. There were several firefighters involved in trying to extinguish the fire. Security also responded to the incident. Following the fire, one could hit a drill press with a stick and it would collapse into ashes.

After the fire, personnel went in and swept the debris, ashes, and oxide into drums. There was no consideration of material limits during this process. The cleanup was a long, drawn-out process. From May to the fall of 1969, there were multiple teams working up to 12 hours per day on the cleanup. The cleanup was run around the clock, since the company wanted the process restarted as soon as possible.

There were issues with contamination spread by the firefighters to the outside of the building. Some contamination deposited on the roof of the building. Environmental air samples showed no activity post-fire. There is some disagreement among site experts regarding the quantity of material released to the atmosphere from the 1969 fire.

Following the 1969 fire, the exact location of each item and the quantities along the production line were reconstructed. Several improvements in the process were made to prevent a reoccurrence. Foundry operations were encased, so people walking down the hall would not get exposed. Benelex impregnated with boron was installed on gloveboxes to reduce exposure.

In 1989, the Federal Bureau of Investigation (FBI) ordered the drums accumulated from the 1969 fire cleanup repacked to determine the contents. The drums were opened and the contents bagged into a glovebox in B371. The material was to be sorted (wood with wood, glass with glass, etc.). These drums had to be repacked into 55-gallon drums to sort the contents in the original drums and ensure they met the 200-gram plutonium limit. However, bagging the contents back out of the glovebox to be placed into separate drums was allegedly a violation of the regulations of RCRA, and at least two workers refused to bag the material out and violate the law, despite discipline from management.

Waste from the 1969 fire was put into pits that previously contained hydroform presses. These presses were removed, the waste from the fire was added, and a concrete slab was pored over the pits to encase the waste. This posed a potential alpha hazard.

**Other Incidents**

Incidents or unusual occurrences were not uncommon at RFP. There were both major and minor incidents. The major incidents involved uptake of radioactive material and, in some cases, chelation.

- In 1964, at the 776 Building, an individual accidentally dropped plutonium into a degreasing bath. The plutonium caught on fire, heated the carbon tetrachloride, and caused an explosion. The operator working the process was in a half-mask respirator at the time. He was grossly contaminated and lost a portion of his hand as a result of the explosion. The room was also contaminated from floor to ceiling. There were about 24 individuals involved in one way or another at Building 776 at the time of the explosion. An additional 11 individuals were involved in treatment of injured personnel. Individuals present at the explosion and those providing medical treatment were required to submit special bioassay samples.

- During June 1957 in Building 771, an explosion occurred during a plutonium peroxide precipitation and filtration process. There were seven individuals in the room at the time of the explosion. Five of these individuals were contaminated. Two individuals received significant intakes. The mode of intake for the operator involved was determined to be inhalation and absorption due to the chemicals present. The operator was spitting greater than 100,000 dpm into a Kem-wipe following the incident. Both individuals involved were chelated.

Several smaller incidents were communicated during the interviews. These issues involved the following.

- Personnel and personal effects contamination
- Dosimeter contamination
- Glovebox failures, including gasket failures and torn or punctured gloves
- Puncture wounds and chemical burns
- Spills of radioactive material
- Exposure to improperly stored materials
- Exposure to ripped bags containing radioactive material
- Smaller plutonium and uranium fires, including both the machining and processing areas
- Continuous Air Monitor (CAM)/SAAM alarms

Plutonium and uranium in some chemical forms are pyrophoric. As a result, uranium and plutonium fires could occur as frequently as daily. Residues and chips from processing were particularly prone to fires. There were many fires that were simply extinguished and not documented as an incident. If incidents are not reported, special bioassay cannot be conducted.

Issues associated with loss of containment (e.g., failure of glovebox gaskets, failure of gloves, spills) were common. A number of these events resulted in inhalation of plutonium. There were situations where intakes can be associated with a particular event, and others that have been discovered after the fact.

Personnel or personal effects contamination occurred frequently. Dosimeter contamination was an issue during certain high-contamination jobs, such as changing filters. Other individuals inadvertently got contaminated. This was an issue with passage through inappropriate storage locations. The results of special sampling or special processing of dosimeters were not effectively communicated to the workers involved.

When they were aware of incidents, health physics documented them. There should be personnel contamination and incident reports available in dosimetry files if they were reported. In later years, the site developed what was referred to as Radiological Improvement Reports (RIRs). These reports were designed to document radiological control violations and/or incidents.

**Radiation Protection Audits**

Rocky Flats Environmental Technology Site implemented the occupational Radiation Protections requirements of 10 CFR 835 through the RFETS Radiation Protection Program Plan (RPP), as specified in the Site Specific Radiological Control Manual (SSRCM). DOE Radiation

Safety Officers provided compliance and performance reviews of the RFETS Radiation Protection Program. Performance-based evaluations were conducted on all aspects for implementation of the program. If there were repetitive or widespread occurrences, the assessment became an issue of Conduct of Operations (COOps). There was a further review by conducting compliance-based assessments against the requirements of 10 CFR 835, as specified in the RFETS RPP. For example, a performance assessment would review the adequacy of a program, such as posting of radiological areas, in accordance with the RFETS SSRCM. An example of a compliance assessment is a review of the effectiveness of the dosimetry program in monitoring personnel for the applicable types of radiation that exist at RFETS, considering the types of operations taking place at the plant.

Rocky Flats has developed a Radiation Protection Rescission plan allowing them to apply a graded approach to radiation protection involving the decontamination, decommissioning, and demolition of nuclear facilities. This has prevented them from having to repeatedly revise the RFETS RPP plan and wait for DOE/RFPO approval prior to commencing work.

In 1990, there was no Radioactive Material Accountability and Control Tracking Program. This program was revised in 1991, to provide for a more stringent control over the transfer and disposition of radioactively contaminated material.

Conduct of Operations issues identified since 1990 have included lack of adequate DAC-hour tracking, working outside the Job Hazards Analysis (JHA), and no real-time chronic airborne monitoring. The goal is to know what individuals are receiving in real-time, and prevent an after-the-fact discovery of chronic intakes or over-exposures from airborne sources. This also helped identify additional dosimetry needs, such as lapel samplers, or additional needs for workplace monitoring and trending. Another example was the failure to follow appropriate airborne monitoring and workplace indicator procedures.

**Radiation Biology and Research**

When plutonium enters the body, the macrophages try to break down the particles. If this is unsuccessful, the cell might die as a result of the radiation dose received. The dead macrophage will be replaced by new macrophages eventually causing an agglomeration of particles. When a plutonium uptake occurs via a wound, material initially enters the lymphatic system. The material is partially soluble and is transferred to the liver and endosteal surface of the bone. Over a long period of time, a very small percentage of the plutonium is recycled and is embedded inside the bone matrix. The same cells that incorporate iron in the liver are responsible for incorporating plutonium.

Chromosomal studies were completed on workers at RFP to evaluate the response of plutonium in the body; 10 cc of blood were taken from individuals with plutonium uptakes, and 4,200 chromosomes per individual were analyzed. There was a direct correlation between chromosomal damage and exposure. In an effort to validate the results, an independent calculation of dose determined by bioassay versus chromosomal damage was completed. There was good agreement. Further studies completed as a student Masters research project noted that there was no radiation repair mechanism in some cells, while 12 % of the white blood cells were found to be extremely radioresistant.

Neutrons interact with cells in the body via elastic and inelastic scattering. Neutrons can cause mutations by the interactions with hydrogen in the Deoxyribonucleic acid of the cells or cause activation of chemicals in the body.

**Unauthorized Practices**

According to a number of workers interviewed, the ultimate goal of most workers was to maintain job security. As a result, workers did not always look out for the safety of co-workers. Horseplay was a real issue in the production areas. Individuals would throw around Kim-wipes used for decontamination. Workers thought it was funny to remove their co-worker's coveralls in the area. One individual stuck a pencil eraser in contaminated material and flicked the material at the SAAM as a prank. Other workers took uranium chips home. Individuals were seen juggling plutonium boxes. If there was a shortcut to increase production, workers would use it until they got caught. Management was not aware of this misconduct.

There was no overtime if an individual reached the administrative limit, leading to some poor practices. Workers would leave their dosimeter in their lockers or put them in their back pockets to minimize the external exposure recorded by the badge. The Dosimetry group became suspicious of the high doses received by production workers. These workers were accused of purposely overexposing their badges (e.g., placing them in gloves). If the badge exceeded the authorized limit for the period, production employees would be disciplined. As a result, some of the operators didn't wear their dosimeters all the time, or they put the dosimeter in the back pocket of their coveralls. Although some individuals over-exposed their badges on purpose (e.g., putting the badge in the glove or on a waste container) to get out of working in a particular area, this cannot explain all high badge readings. Among the site experts interviewed, no one reported being directed to remove their badge while around radioactive materials.

Apparently, there was a great deal of animosity between exempt and hourly workers, especially after the union went on strike. This animosity affected the safety of exempt employees. Exempt employees reported that they were not effectively monitored and were provided with contaminated shoe covers only part of the time.

In some cases, individuals purposely tried to sabotage production. According to worker accounts, there was a situation in Building 777 in 1970 where a culprit went in and knowingly slit the gloves in a glovebox line. This resulted in a number of individuals being contaminated. In another situation, a round part was placed in a stainless steel carrier and passed to the machinist on a pendent system. Someone had put a gouge in the stainless steel container and covered it with a cloth. When the individual removed the cloth, he discovered the gouge. The incident was reported to the DOE, who was asked to come down and look at the damaged container. Ultimately, there was no report issued about the incident to the individual's knowledge.

According to workers interviewed, when special visitors (e.g., DOE officials) came, the respiratory protection signs were removed and the place was cleaned up. For example, there was a box referred to as the Chalk River Box. It had a leakage problem and respiratory protection was required for work in this box. The 'respiratory protection required' sign was removed during a visitor tour. There was still a need for respiratory protection, although the signs had been taken down.

**Rocky Flats Investigations**

In 1989, the FBI raided the Rocky Flats Plant, because Rockwell (the contractor) was allegedly violating environmental law. The affidavit, approved by a magistrate, included the location of the property, a description of the items to be seized, and what laws were violated. The focus of the raid was on violations of the Resource Conservation and Recovery Act (RCRA), the Clean Water Act (CWA), and false statements made to regulators. This was a unique situation, since no Federal agency had raided another Federal agency prior to this. This raid was the result of tips provided by individuals about both environmental and occupational issues at the site. However, the focus of the raid was environmental issues and the FBI was not authorized to investigate occupational safety issues.

Laws such as RCRA were not strictly enforceable until about 1984; from 1980–1984 it, was a voluntary process. Rocky Flats Plant tried to file for various exemptions to the law. First they tried to claim they were a small-quantity generator (SQG). They applied for but did not receive a presidential exemption.

The FBI investigated allegations of illegal incineration after direction by DOE to discontinue operations. Management considered the incinerator a vessel for recovery of plutonium from the ash. Since the incinerator (in Building 771) was used for waste minimization, it should have been governed by the regulations of RCRA all along. Management continued this denial all the way through the FBI interviews.

The RFP told the State that the groundwater program was in compliance with the CWA, and that they had an appropriate monitoring program in place. The evidence collected from the raid indicated this was not the case. Other issues investigated were the improper storage of drums containing plutonium-contaminated residues and materials, and buried drums that were later determined to be leaking.

Witnesses reported that workers would punch holes in High Efficiency Particulate Air filters. This allowed large quantities (~76 lbs) of plutonium to enter the duct system, which was self-contained. With this quantity of missing plutonium, RFP was obligated to make appropriate notifications.

When the FBI raided the RFP, there was a total shutdown of all nuclear processing operations. This was not, in many of the process buildings, a stable situation for all of the forms of plutonium, such as aqueous plutonium.

Several unauthorized practices were identified during the course of the investigation. For example, one worker did not return her dosimeter. She later received a report that the dosimeter was tested and came back okay. There was little trust in the ability of the Building 123 labs to correctly analyze radiation-monitoring data.

The FBI took records from the site; however, copies were provided to both Rockwell and the DOE. Around 1998, the Justice Department was allowed to return original records to RFP, with the exception of Safeguards and Security records.

**Other Safety Hazards**

The RFP process involved work with a number of hazardous materials in addition to radiation. Chemical hazards were also associated with the D&D process. Some of the chemicals used during production and/or remediation are listed in Table A-1.

**Table A 1: Chemical and Compounds Used During Operations at the RFP Plant**

| | | |
|---|---|---|
| Trichloroethylene | Acetone | Cyanide |
| Carbon Tetrachloride | Ethanolamine | Lead (various forms) |
| Sulfuric Acid | Dibutylethylcarbutol | Asbestos |
| Nitric Acid | Benzene | Beryllium |
| Chromic Acid | Chloroform | Mercury |
| Methylene Chloride | Dodecane | |
| Nickel (various forms) | Hydrofluoric Acid | |
| Cutting and Hydraulic Oils | Ammonium Hydroxide | |
| Perchloroethylene | Hydrogen Peroxide | |
| Silicone Oils | Acetic Acid | |

Many of the chemicals used impacted workers. As an example, the chemical compound of Trichloroethylene (used for decontamination) is readily absorbed through personal protective equipment and gloves, which can take the radionuclide, if present, with it. The radionuclide is not deposited very deep, but does require decontamination.

Carbon tetrachloride was used as a degreaser in the plutonium glovebox lines. Previous to this, the site used Perchloroethylene. The switch was made following an explosion in Building 776, which was the result of incompatible chemicals. Also following this accident, the site changed to the use of argon in its gloveboxes; $CCl_4$ vapors would permeate the gloveboxes.

Trichloroethylene was the degreaser of choice in the open machining operations, such as in the uranium areas. Trichloroethylene was used to clean tools and parts. The chemicals were handled with bare hands.

Maintenance shops were located in Buildings 444 and 374. The beryllium shop was located in Building 444. Maintenance personnel who were not qualified to work around plutonium stayed in the uranium areas. The standards for PPE have changed over time.

During D&D operations, the predominant hazard was industrial safety because of the extensive work with heavy equipment in the outside environment. Some examples of industrial hazards encountered were increased vehicular traffic of heavy construction equipment and the close proximity to the workers to multiple pieces of heavy tracked equipment. There was a health hazard associated with heat stress and heat stroke. The implementation of the integrated safety concept affected the protective equipment (Anti-Cs) requirements for a particular job. The integrated safety concept required that there be a balance between radiation protection safety and industrial safety (e.g., heat exhaustion). "Nobody gets credit for a clean corpse."

**Criticality Safety**

There were various methods used to prevent criticalities. Materials were stored in an "egg crate" sort of arrangement to prevent criticality accidents.

An inventory control system was set up to track the plutonium. The field maintained movement logs, which were entered into the system. This system was designed so the plant could determine where items were in the process and what the chemical form of the material was. A Process Material Control Coordinator coordinated and participated in inventories. They were active in performing segregation of drums in the storage areas and validating transuranic contents of these drums. The segregation of materials was based on form and location.

Criticality safety was not stringently controlled at the site. For example, there were liquid tanks of plutonium that required draining. The work order authorized drainage of only a single tank. Prior to analyzing the content of the second tank, they decided to drain this tank also. This allowed two different concentrations of plutonium to come in close proximity to each other. This was not reported until completion of the assay several days later**.** Due to the criticality safety violation, an occurrence report was filed and two high-level supervisors lost their job.

**Miscellaneous**

According to discussions with site experts, there were situations where individuals were exposed to a particular hazard; however, they were not monitored. In order to complete a dose assessment, one would need to identify an individual's work location, skill or task, materials in the area, hours of work per day, and past and present uptakes. Without all these components in place, an accurate dose assessment is not possible.

Site experts are concerned about the completeness and adequacy of the records (i.e., work history, medical, and dosimetry). For example, one individual had no record of personnel decontamination at Medical after a major incident. In fact, there was a gap in his records from 1966–1970. The incident occurred during this period of time. Another site expert indicated that RFP was unable to initially locate work history records for him. In fact, radiological records personnel indicated to the individual that his records were incomplete. There was also indication that records may have been lost or destroyed. A number of individuals noted that DOE had difficulty in finding records, including work history. In one case, the dosimetry records of an individual involved in maintenance activities under subcontract were missing, although he wore a dosimeter. Health Physics personnel, however, indicated that RFP had the most complete records of any DOE site.