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Rocky Flats Plant – Site Description

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02/01/2007	01	Approved Revision 01 revised in response to formal OCAS and ORAU comments. Includes additional incidents and occurrences post-1981. This revision addresses Worker Outreach comments as described in CT-0200 and CT-0204, in Section 2.4.5. Revised to consider attribution per ORAU direction and to respond to Union member comments. Incorporates NIOSH formal review comments. No further changes occurred as a result of formal internal review. Constitutes a total rewrite of document. Training required: As determined by the Task Manager. Initiated by Robert Meyer.
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ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
AED	aerodynamic equivalent diameter
AWE	atomic weapons employer
BVO	boiler vent operator
CAM	continuous air monitor
CEDE	committed effective dose equivalent
cfm	cubic feet per minute
Ci	curie
cm	centimeter
cpm	counts per minute
D&D	decontamination and decommissioning
DAC	derived air concentration
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
dpm	disintegrations per minute
DU	depleted uranium
ECM	electrochemical milling
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
EPA	U.S. Environmental Protection Agency
ft	foot
FY	fiscal year
g	gram
gal	gallon
HEPA	high-efficiency particulate air
HEU	highly enriched uranium
in.	inch
kg	kilogram
L	liter
lb	pound
m	meter
mCi	millicurie
MeV	megaelectron-volt, 1 million electron-volts
mi	mile
min	minute
mo	month
mrem	millirem
MSE	molten salt extraction
mW	milliwatt
MWM	metal working manager

nCi	nanocurie
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
OCAS	Office of Compensation Analysis and Support
pCi	picocurie
pH	negative logarithm of the hydrogen ion concentration, a measure of alkalinity or acidity
PPE	personal protection equipment
PS	process specialist
R&D	research and development
RCT	radiation control technician
RFCA	Rocky Flats Cleanup Agreement
RFETS	Rocky Flats Environmental Technology Site
RFP	Rocky Flats Plant
RMRS	Rocky Mountain Remediation Service
RPT	radiation protection technologist
SAAM	special alpha air monitor
SEC	Special Exposure Cohort
SNM	special nuclear material
SOE	Stationary Operating Engineer
SRDB Ref ID	Site Research Database Reference Identification (number)
SRS	Savannah River Site
TBD	technical basis document
TCA	1,1,1-trichloroethane
TLD	thermoluminescent dosimeter
TRU	transuranic
U.S.C.	United States Code
yr	year
ZPPR	Zero Power Plutonium (later Physics) Reactor
α	alpha particle
µCi	microcurie
µg	microgram
µm	micrometer
§	section or sections

2.1 INTRODUCTION

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historical background information and guidance to assist in the preparation of dose reconstructions at particular Department of Energy (DOE) or Atomic Weapons Employer (AWE) facilities or categories of DOE or AWE facilities. They will be revised in the event additional relevant information is obtained about the affected DOE or AWE facility(ies). These documents may be used to assist NIOSH staff in the evaluation of Special Exposure Cohort (SEC) petitions and the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used to refer to an area, building, or group of buildings that served a specific purpose at a DOE or AWE facility. It does not mean nor should it be equated to an "AWE facility" or a "DOE facility." The terms AWE and DOE facility are defined in sections 7384l(5) and (12) of the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), respectively. An AWE facility means "a facility, owned by an atomic weapons employer, that is or was used to process or produce, for use by the United States, material that emitted radiation and was used in the production of an atomic weapon, excluding uranium mining or milling." 42 U.S.C. § 7384l(5). On the other hand, a DOE facility is defined as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the [DOE] (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program);" and with regard to which DOE has or had a proprietary interest, or "entered into a contract with an entity to provide management and operation, management and integration, environmental remediation services, construction, or maintenance services." 42 U.S.C. § 7384l(12). The Department of Energy (DOE) determines whether a site meets the statutory definition of an AWE facility and the Department of Labor (DOL) determines if a site is a DOE facility and, if it is, designates it as such.

Accordingly, a Part B claim for benefits must be based on an energy employee's eligible employment and occupational radiation exposure at a DOE or AWE facility during the facility's designated time period and location (i.e., covered employee). After DOL determines that a claim meets the eligibility requirements under EEOICPA, DOL transmits the claim to NIOSH for a dose reconstruction. EEOICPA provides, among other things, guidance on eligible employment and the types of radiation exposure to be included in an individual dose reconstruction. Under EEOICPA, eligible employment at a DOE facility includes individuals who are or were employed by DOE and its predecessor agencies, as well as their contractors and subcontractors at the facility. Unlike the abovementioned statutory provisions on DOE facility definitions that contain specific descriptions or exclusions on facility designation, the statutory provision governing types of exposure to be included in dose reconstructions for DOE covered employees only requires that such exposures be incurred in the performance of duty. As such, NIOSH broadly construes radiation exposures incurred in the performance of duty to include all radiation exposures received as a condition of employment at covered DOE facilities in its dose reconstructions for covered employees. For covered employees at DOE facilities, individual dose reconstructions may also include radiation exposures related to the Naval Nuclear Propulsion Program at DOE facilities, if applicable. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction.

NIOSH does not consider the following types of exposure as those incurred in the performance of duty as a condition of employment at a DOE facility. Therefore these exposures are not included in dose reconstructions for covered employees (NIOSH 2010):

- Background radiation, including radiation from naturally occurring radon present in conventional structures
- Radiation from X-rays received in the diagnosis of injuries or illnesses or for therapeutic reasons

2.1.1 Purpose

The purpose of this technical basis document (TBD) is to provide a Rocky Flats Plant (RFP) profile that contains technical basis information used by the Oak Ridge Associated Universities (ORAU) Team to evaluate the total occupational dose for EEOICPA claimants. This section provides information on RFP facilities and operations.

2.1.2 Scope

RFP operations played an important role in the U.S. nuclear weapons program. Operations included production of fissionable material components. This TBD contains supporting documentation to assist in the evaluation of worker dose from RFP operations and processes. Additional guidance is found in OCAS-IG-001, *External Dose Reconstruction Implementation Guideline* (NIOSH 2007) and OCAS-IG-002, *Internal Dose Reconstruction Implementation Guideline* (NIOSH 2002).

The methods used to measure radiation exposure to workers have evolved since the beginning of RFP operations. An objective of this TBD is to provide supporting technical data to evaluate the total RFP occupational dose that can reasonably be associated with worker radiation exposure as covered under EEOICPA. This dose includes occupational external and internal exposure in RFP facilities, RFP occupationally required diagnostic X-ray examinations, and onsite exposure to RFP environmental releases (ORAUT 2012).

Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 2.6. Attachments related to those TBDs provide detailed data and tables for dose reconstructors.

2.1.3 Special Exposure Cohort

The Secretary of the U.S. Department of Health and Human Services has designated the following class of employees for addition to the SEC (NIOSH 2013):

> *All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Rocky Flats Plant in Golden, Colorado, from April 1, 1952 through December 31, 1983, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.*

NIOSH determined that doses to unmonitored RFP workers from neptunium, thorium, and ^{233}U (and its associated ^{232}U and ^{228}Th progeny) cannot be reconstructed from April 1, 1952, through December 31, 1983. In addition, unmonitored neutron doses before 1967 have been identified as infeasible and therefore cannot be bounded. It is not feasible to reconstruct unmonitored neutron doses in a bounding manner before 1967 (NIOSH 2013).

The class includes all workers during the SEC period. Because of the identified dose reconstruction infeasibility, all dose reconstructions for monitored workers during the SEC period are considered partial dose reconstructions. If monitoring data are available for workers in the SEC, dose is to be assigned as appropriate based on that data. However, such dose reconstructions are still considered partial dose reconstructions because of the determination that exposure to neptunium, thorium, and ^{233}U (and its associated ^{232}U and ^{228}Th progeny) during the SEC period cannot be bounded (NIOSH 2013).

2.2 SITE ACTIVITIES AND PROCESSES

A comprehensive history of the RFP was prepared as part of health studies conducted by the Colorado Department of Public Health and Environment during the 1990s (see ChemRisk 1992, 1994a, 1994b). Information in this TBD section is from these 1990s reports except as otherwise noted.

2.2.1 History and Mission

The U.S. Atomic Energy Commission (AEC) announced its decision on March 23, 1951, to build the RFP in Colorado (see Figure 2-1). Groundbreaking occurred in July 1951 for what was later known as Building 991. In general, the primary mission and activities at the plant remained essentially the same from the time the plant opened until 1989, when DOE suspended plutonium operations. The RFP had two major missions – production of plutonium triggers (or "pits") for nuclear weapons and processing of retired weapons for plutonium recovery. From the beginning the plant was a manufacturing facility. Plutonium triggers are components of fission bombs, used to initiate the second-stage fusion reaction in hydrogen bombs. The plant received plutonium from production sites (the Savannah River and Hanford Sites) and from retired warheads and residues. Parts were formed and machined from plutonium and uranium, and beryllium, stainless steel, and other nonradioactive materials (ChemRisk 1992).

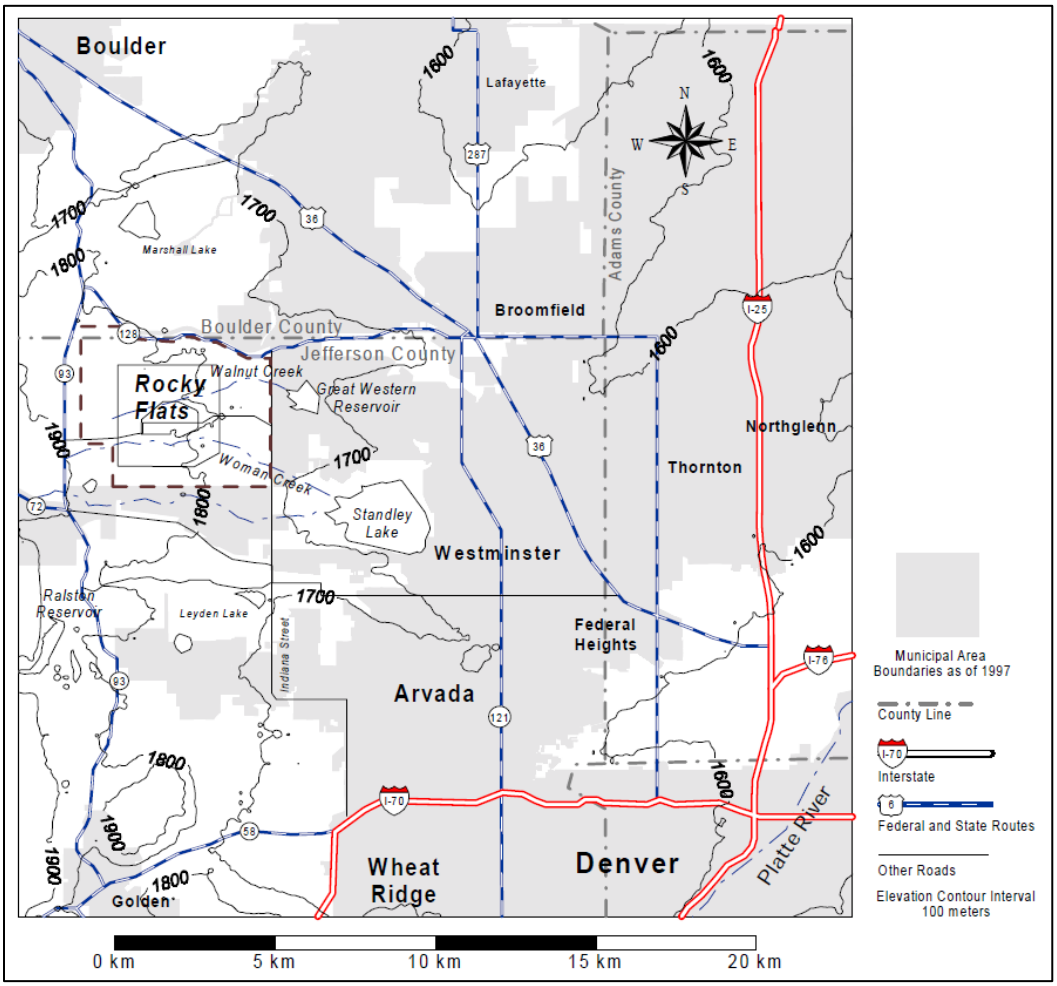

Figure 2-1. Location of RFP in Colorado (Grogan et al. 1999, p. 8).

In 1984, the site was proposed as a Superfund site and, in 1989, it was included on the National Priorities List for cleanup of environmental contamination. In December 1989, DOE suspended plutonium processing to review and upgrade the plant's safety systems. EG&G, Inc., assumed operation of the site on January 1, 1990, working toward the resumption of operations in the plutonium buildings.

With the President's 1992 announcement of cancellation of the W-88 Trident Warhead Program, the RFP production mission ended permanently. In 1993, the Secretary of Energy formally announced the end of nuclear production at RFP. In 1994, the last defense production-related shipment was sent from Building 460. Remediation was completed at the former RFP site in late 2005.

There have been only three basic pit designs since the beginning of plant operations, with manufacturing of the first two designs phased out within the first 5 years of production. The first two designs built at RFP were solid units made mostly of uranium. The design changed around 1957 to focus primarily on plutonium (ChemRisk 1992).

2.2.2 Site Development

The following paragraphs describe the chronological development of RFP facilities and operations. Figures at the end of this section show the location of these facilities as they were constructed. Attachment A lists facility functions by building.

1951 to 1954
Groundbreaking for the first permanent buildings at the RFP began in July 1951 for what was later known as Building 991. Later that year, construction began on Buildings 771, 444, and 881. By April 1952, production operations reportedly had begun, but no production or shipment details are available for 1952 or the first part of 1953. At the beginning of 1953, some of the onsite utility facilities were still incomplete; water came from Boulder in tank trucks, and a locomotive brought to the site provided steam heat. Nevertheless, the first products were completed and shipped that year. By 1954, the plant was fully operational and initial construction essentially complete with about 700,000 ft^2 of building space. Employment grew steadily from 133 people in 1951 to 3,101 in 1963.

Originally, the plant had four operations areas – A, B, C, and D Plants – identified according to four primary types of work. The A Plant included Building 444 operations, which involved the fabrication of depleted uranium (DU) parts. Later known as Building 881, the B Plant recovered enriched uranium and manufactured enriched uranium components. The C Plant (later Building 771) housed plutonium operations, and the D Plant in Building 991 was the center of final product assembly operations. There were large spans of meadow between the areas, with gravel roads connecting them. Very few people had clearances to get into more than one building, and most employees had no idea what occurred in areas other than their own. Plant employees were bused from the front gate to their buildings, because personal vehicles were not allowed on the site.

1955
A major facility expansion began in 1955, referred to as Part IV construction.

1956 to 1957
This period saw the construction of Buildings 447, 776, 777, 883, 997, 998, and 999 and the expansion of Buildings 444, 881, and 771. These additions were directly related to the change of the weapon concept to a hollow unit and anticipated production increases. A few years later, roughly coincident with the onset of the Cold War, RFP became the primary manufacturer of pits under the single-mission concept. The result was a dramatic rise in production at the plant in the 1960s. By 1964, the workforce reached a level of around 3,000 people that lasted for about 15 years.

1967 to Early 1970s
Buildings 559, 440, 707, 750, and 865 were constructed.

Late 1970s to 2006
DOE built Buildings 371 and 460 during this period. The period showed a significant upturn in RFP employment, with a peak at 5,990 in 1984.

By 1990, total building space had grown to approximately 2.5 million ft^2. Figure 2-2 shows the 1990 RFP layout, including the structures identified in the previous paragraphs.

By late 2005, remedial action was complete at the former RFP.

2.2.3 Functional Areas

RFP operations included the following functional areas:

- Component Manufacturing and Assembly,
- Material Recovery and Purification,
- Research and Development (R&D),
- Waste Processing, and
- Plant Support.

To manufacture a fissionable product, RFP developed facilities, equipment, and personnel to conduct precision metalworking and to assemble fissionable and non-fissionable materials. Key non-fissionable components were made of beryllium, aluminum, and stainless steel.

Early work at the plant involved both ^{235}U and ^{239}Pu as fissionable materials. Enriched uranium contract work transferred to the Oak Ridge Reservation in 1964. Americium-241 recovery did not start until 1957, functioning as a step in the plutonium recovery process and producing a marketable product. Beryllium was not used in full-scale production operations until 1958. Stainless-steel component work began in 1966. Stainless-steel operations (known as the "J Line") took place in Building 881 until 1984, when they moved to Building 460.

2.2.3.1 Component Manufacturing

When the A Plant (Building 444) started operations in 1953, it was devoted entirely to DU manufacturing. Operations included casting and machining of components. While no details are available, processing of DU is not generally considered to be a significant hazard from either an external (photon) or internal (alpha-emitter) perspective. RFP originally received DU from Paducah, Kentucky, and later as feed material from the Feed Materials Production Center in Fernald, Ohio, as ingots in sealed cans. While Paducah was processing recycled uranium beginning in 1953, available RFP records do not indicate whether fission product or transuranic (TRU)-contaminated uranium was processed at RFP.

Enriched uranium operations occurred in B Plant (Building 881) and initially involved a heavy workload. The basic operations involved casting and machining. The components were solid pieces of uranium, machined to particular shapes, which were assembled with plutonium, stainless-steel, and DU components in D Plant.

With development of new designs, the revised concept required a significant amount of rolling and forming of depleted and enriched uranium, and space in existing facilities became inadequate. Building 883 was built to handle the rolling and forming of uranium. DU was cast in Building 444 and transferred to Building 883 to be heated and rolled into sheets from which blanks were cut and formed

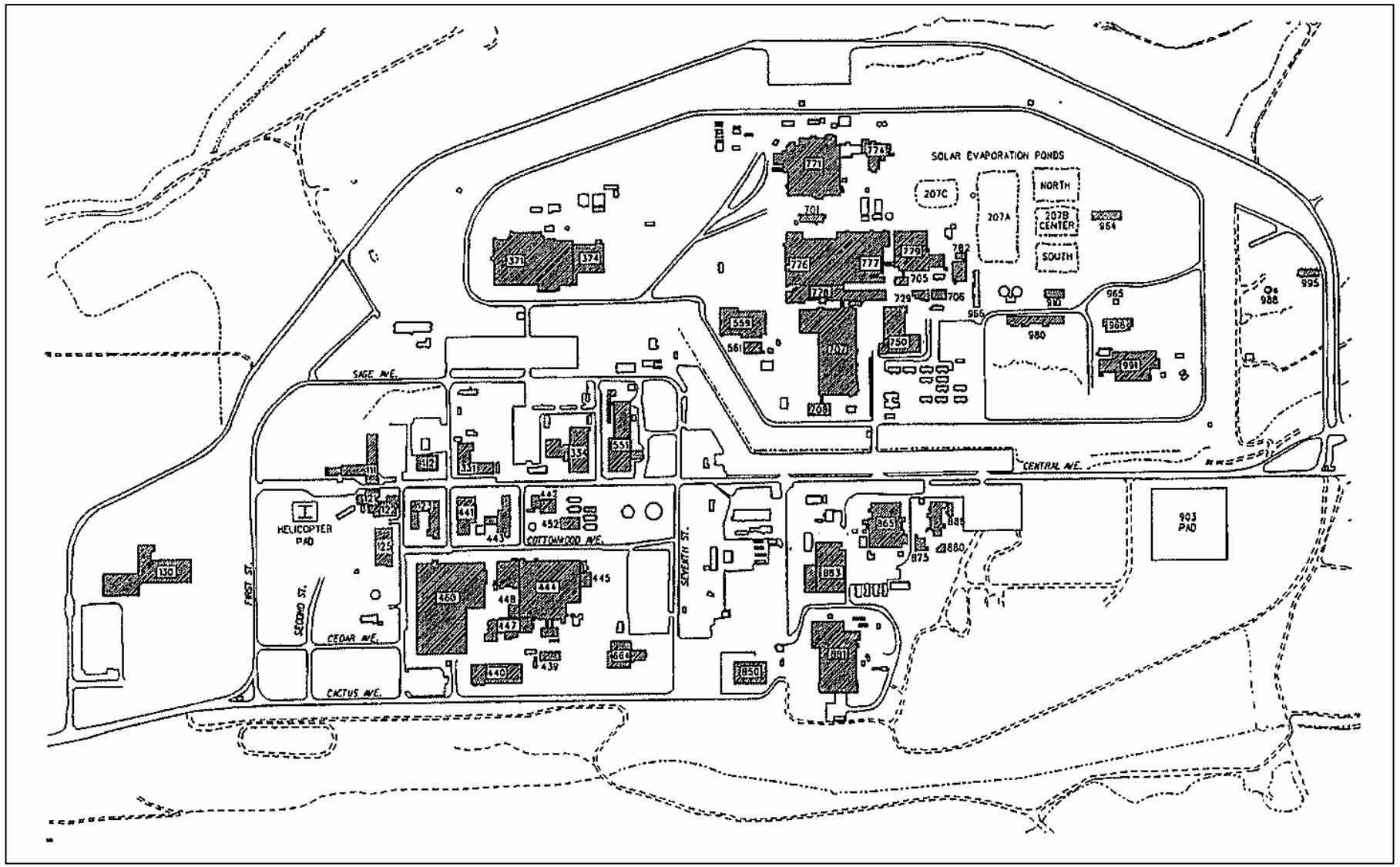

Figure 2-2. 1990 site map (ChemRisk 1992, p. 68).

to the required shape. The shaped pieces were shipped back to Building 444 to be turned, trimmed, and polished. In some cases, the component was coated with protective materials.

Building 883 was designed with two functional areas to prevent cross-contamination; the B side handled enriched uranium, and the A side rolled and formed DU. The plant was so pressed to begin production of the new type of weapon components that operations began in Building 883 before the roof was completed. To prevent emissions from these early operations and to protect machinery and materials from the elements, enclosures were placed around the process equipment. Details concerning early ventilation and other worker protection systems during this period were not found in the available literature.

R&D of DU-niobium alloys involved an electron-beam furnace. Alloying work began in 1966, although full-scale production did not occur until the early 1970s. An arc furnace installed in the mid-1970s provided the capability to produce DU-niobium alloys. This furnace melted elements such as zirconium and niobium more effectively than induction casting furnaces, thereby creating a more homogenous alloy casting.

In the early 1960s, Building 881 was idle while the enriched uranium areas were decontaminated and decommissioned. Conversion to accommodate stainless-steel operations began in 1966. Machining of DU continued in Building 444. In 1964, the B side of Building 883 was converted to beryllium rolling and forming.

After the Oak Ridge Reservation took over enriched uranium operations in 1964, it supplied RFP with finished uranium components for incorporation in final pit assemblies. RFP still received site returns that contained enriched uranium components. The plant processed those components with a spray leaching process to remove external plutonium contamination, and returned the oralloy parts to Oak Ridge for reprocessing. Oralloy leaching operations originally took place in Building 881 but were moved to Building 771 in the mid-1960s. The oralloy leaching process remained in Building 771 through 1989 (ChemRisk 1992).

Early during facility operations, C Plant (Building 771) housed essentially all plutonium manufacturing and recovery. In the early years, plutonium metal was machined in a dry state (i.e., without oils, using only carbon tetrachloride as a coolant), with as little machining as possible. Handling the dry material required extra care to prevent spontaneous combustion. Plutonium components were cast, pressed into shapes, minimally machined to true them, and plated with cadmium, which enabled handling with reduced personnel exposure to neutrons and alpha particles. The first weapons were designed to be armed (final assembly) in the aircraft on the way to the target. The protective coating grounded the parts against static electricity that might be generated while handling them in the field. The coating changed to nickel within a few years, using a process that employed nickel carbonyl. The use of nickel carbonyl lasted at least into the late 1960s, although its use in later years was reduced due to design changes that enabled remote arming.

Building 776 Machining Operations (involves Buildings 771, 777, 881, 460, 991, 707, and 444)
Higher-volume machining of plutonium began in 1958, with new operations in Building 776 using Shell Vitrea, a cutting oil, followed by washing with carbon tetrachloride. Building 776 housed a centralized collection and separation point, and the solid and liquid fractions were sent separately to Building 771. In Building 771 most of the carbon tetrachloride was distilled from the oil, and the plutonium cuttings were recovered from the solids. At that time, Building 777 was the focal point for assembly operations. Facility staff members were unable to develop a satisfactory method for handling spent oils and residual solvents, which were placed in storage barrels outdoors to the east of the plant.

Buildings 776 and 777 went into service in 1958 to handle the increased plutonium workload, and Building 771 undertook recovery operations. Building 776 performed plutonium machining;

Building 777 handled assembly operations. Building 991 was used for storage and R&D, although it was several years (records indicate 1960) before all assembly operations had left the building. In 1969, a major fire in Buildings 776 and 777 resulted in some operations moving to other buildings. The machining and foundry operations in the fire-damaged areas of Building 776 became part of the operations in the new 707 assembly building. Those operations remained in Building 707, and solid waste treatment operations and size reduction moved into Building 707 after Building 776 returned to operation in 1972. (Building 776 was being used for waste storage and waste size reduction in 1972.)

Final assembly of the early products was initially a relatively simple operation. The original final assembly building was D Plant, later known as Building 991. Later, the hollow-core weapons design involved more assembly complexity. As a result, Building 777 in 1957 began to provide assembly facilities. Operations involved drilling, welding, brazing, turning, and polishing. Building 707 began final assembly operations shortly after the 1969 fire that shut down Buildings 776 and 777. Final assembly operations occurred in Building 707 through 1989.

Stainless-steel operations, the J Line, began in Building 881 in 1966 and remained there until the completion of Building 460 in 1985. Stainless-steel operations from Building 881 and some operations from Building 444 were consolidated in Building 460 at that time. A significant portion of the stainless-steel work was the fabrication of empty tritium reservoirs. The reservoirs were later filled with tritium gas under high pressure at the Savannah River Site (SRS).

In 1957, the new weapon design required beryllium components. There had been some beryllium operations in Building 444 in preparation for regular pit production, and in 1958 beryllium operations became a significant portion of RFP activities. The components manufactured in Building 444 no longer went directly to the Pantex Plant. Rather, they were incorporated in the final assembly operations in Building 777. The DU workload decreased significantly as beryllium use increased (ChemRisk 1992).

Beginning in 1952, thorium was used on site in quantities small enough that effluents were not routinely analyzed for thorium. Thorium quantities varied from as little as none to as much as 238 kg in a given month. The principal use was fabrication of metal parts from natural thorium metal (^{232}Th) and from various thorium alloys. Thorium oxide might have been used as a mold-coating compound in limited experiments. Thorium compounds were used in analytical procedures. In addition, twice between 1964 and 1969, thorium “strikes” were performed to remove gamma-emitting ^{228}Th from ^{233}U metal needed for fabrication of test devices. The strikes involved a fluoride precipitation and filtration process using natural thorium. Photon radiation from ^{228}Th decay products would have been monitored by standard gamma dosimetry badges in use at the plant. In addition, thorium was used as a stand-in for plutonium or uranium components in development programs (ChemRisk 1992).

2.2.3.2 Material Recovery and Purification

Manufacturing produced wastes that consisted of fissionable and non-fissionable materials, associated lubricating and cleaning compounds, and other materials such as rags, slags, clothing, tools, and paints. Wastes were stored in barrels in the 903 area just outside the main fence. In the late 1960s, waste oils were eventually treated by fixation in concrete and shipped off the site for burial. Cleanup of the 903 area resulted in some potential for worker exposure to airborne plutonium from disturbance of contaminated soil.

Plutonium Recovery and Purification
When Building 771 became operational in 1953, operations included plutonium recovery (from weapons manufacturing and later from weapons recycling) and purification and plutonium component manufacturing. Plutonium operations patterned after Los Alamos plutonium facility work began in the spring of 1953. Only one “Chem Line” was in operation; it had the capacity to produce plutonium

"buttons" of approximately 300-g mass. Later, in 1955, an "East Chem Line" started, with the capability to produce 2-kg buttons. Eventually, operational capacity reached 12 kg per day. In 1965, an expanded production area added five dissolution lines, increasing plutonium recovery by a factor of 20 over that of the original line (ChemRisk 1992). In 1968, the decision was made to replace Building 771 recovery operations. Groundbreaking took place in 1973 for what was to become Building 371. The new facility was plagued with problems from the onset of construction, and delays prevented cold startup before 1981. Design flaws resulted in the shutdown of Building 371 chemical processing in 1985 before full-scale operation occurred.

Originally, plutonium at RFP came from Hanford as plutonium nitrate in small stainless-steel flasks packaged in cylindrical steel carrying cases. The nitrate was vacuum-transferred into a vessel in which plutonium dioxide was precipitated. Chemical reduction converted the dioxide to metal buttons. Later, plutonium was received from Hanford in the form of buttons. Occasionally, plutonium nitrate feed was received from the Oak Ridge Reservation. In 1959, these shipments were reduced, and most of the plutonium feed to recovery and purification operations became recycled material from site returns and the foundry or waste products from the recovery operation. Some plutonium that went through the system at this time came from outside sources in the form of plutonium dioxide. Later shipments of plutonium consisted of metal buttons from SRS.

RFP produced components from other metallic radionuclides on a limited basis for incorporation in pits for special-order operations. The inclusion of these radionuclides (^{237}Np, ^{241}Am, ^{238}Pu, and ^{244}Cm) as tracers into the makeup of the pits enabled research elsewhere. The Special Recovery area processed the plutonium tracer materials. Eventually, leftover tracer materials had to be removed from the plutonium streams, which became part of Special Recovery operations. Special Recovery operations included the Oralloy and Part V Leaching lines, in which surface impurities were removed from enriched uranium and plutonium components.

The recovery process was often described in terms of functional divisions – "fast" and "slow" recovery operations. The fast cycle processed plutonium nitrate solution, turning the liquid to a solid (powder) and then to metal. The slow cycle received materials with higher concentrations of impurities that required a greater degree of preprocessing before entering the fast cycle metal conversion process. Before the implementation of the molten salt extraction (MSE) process in 1968, almost all plutonium-bearing materials went through slow recovery operations. These materials had to be converted to plutonium nitrate via the slow cycle and then introduced into the fast cycle line for conversion to a solid and reduction to metal. After the introduction of the MSE process in 1968, some of the essentially pure plutonium metal, such as the metal from site returns, went through MSE to remove americium ingrowth and then directly to plutonium foundry operations in Building 777 for casting and subsequent processing into plutonium components. As a result, slow cycle recovery received such materials as effluents and waste products from the fast cycle, rags, paper goods, sweepings, and other wastes. It no longer processed the purer forms of plutonium.

Slow recovery operations involved a variety of processes. For example, combustible residues such as plastic bags and Kimwipes were incinerated to reduce material bulk and to convert the plutonium into an oxide form. Before 1960, dissolution was followed by a solvent extraction step that used tributylphosphate as the solvent and dodecane as the diluent. The solvent extraction was followed by cation exchange. Around 1960, solvent extraction was eliminated from the recovery process line because the materials going through the recovery process were becoming more and more varied (ChemRisk 1992).

Uranium Recovery and Purification

Building 881 was built in 1952 and housed enriched uranium component manufacturing, including machining and fabrication of parts. When the chemical recovery line began enriched uranium recovery from metal residues created in the manufacturing processes in 1954, Building 881 housed all

enriched uranium operations, from casting to forming, machining, assembly, recovery, and purification. The raw material came from the Oak Ridge Reservation, primarily in the form of hockey-puck-size buttons of pure metal.

Uranium recovery operations in Building 881 were modeled after processes developed during and after World War II at Los Alamos National Laboratory and the Oak Ridge Reservation. The Building 881 process was similar to the 1950s plutonium recovery process that included solvent extraction. Uranium recovery had fast and slow sides and involved similar chemistry, but dibutylethylcarbutol was used as the solvent, rather than the tributylphosphate and dodecane used as the solvent and diluent, respectively, in plutonium recovery. Overall, the basic plutonium and uranium recovery operations were similar (ChemRisk 1992).

Americium Recovery

There was a pressing need to deal with the americium in the plutonium handled at RFP, because ingrowth of ^{241}Am from ^{241}Pu decreases the effectiveness of the plutonium and creates a gamma exposure problem. The plant had a backlog of americium-containing sludge generated from a plutonium recovery process. As a result, in 1957 an americium line began operation in Building 771. From the late 1950s until the late 1970s, americium was recovered and purified at the plant for sale. The demand for americium declined in the late 1970s, and the americium removed in the plutonium purification process went to Building 774 for processing as a radioactive waste. Information for this period concerning the chemical form of extracted ^{241}Am was not discovered during this TBD review. Americium operations were limited to MSE operations needed to purify plutonium metal.

In 1962, a slight change was made to the ammonium thiocyanate process by adding oxalate precipitation and calcination steps, which resulted in an americium oxide product that was preferred because of its stability. The process during this period was cumbersome, resulted in a disproportionate quantity of waste solutions, and created personnel alpha-contamination exposure problems due to required manual operations and maintenance.

In 1967, the MSE process became the feed source for americium purification. In MSE, molten americium-bearing plutonium came into contact with molten NaCl-KCl-$MgCl_2$ salt. Oxidation-reduction reactions with the salt separated the americium from the plutonium by equilibrium partitioning. There were alpha-contamination personnel exposure problems associated with the hydroxide precipitation step, and in 1973 it was replaced with a cation-exchange procedure. The entire process underwent another major change in 1975, when the ammonium thiocyanate steps were eliminated and the americium was recovered from the anion effluent by oxalate precipitation with subsequent calcination to form the more stable oxide.

After 1976, MSE salts were sent to a “salt scrub” process rather than to americium purification. (A salt scrub removes americium and plutonium from MSE salts.) The salt scrub made a “scrub alloy” of americium, plutonium, and gallium that was shipped to Oak Ridge for further processing. Americium recovery and purification operations shut down in 1980, and work was limited to that required to extract americium from plutonium metal in site returns (ChemRisk 1992).

Neptunium Recovery

Neptunium Processing at the Rocky Flats Plant (Conner 1981) included preparation of pure neptunium oxide, metal, and metal alloys as well as ^{237}Np recovery from a variety of residues. Processes included dissolution, anion exchange, precipitation, filtration, calcination, conversion to fluoride, and reduction to metal. Fabrication steps such as casting and rolling were also sometimes performed for the production of high-purity metal shapes and foils. Neptunium was recovered from residual materials including sand, slag, crucibles, casting skulls, and various alloys containing plutonium, tin, uranium, or zirconium. This description of RFP neptunium operations is echoed in a 1984 document, *Actinide Processing at Rocky Flats* (Conner 1984).

2.2.3.3 Process Waste

When Building 774 was built in 1952, its primary purpose was to support Building 771 by treating its radioactive aqueous waste. The general mission of the waste operations was to reduce the volume of wastes. Liquids transferred to Building 774 were subjected to pH adjustment and sent through a precipitation step to remove radionuclides. The resulting slurry was sent to vacuum filters. The solids removed from the filters were combined with cement or another solidifying agent and shipped to long-term storage as TRU mixed waste. The aqueous waste from this first stage went through the process again. Before 1973, aqueous wastes from this process went to either the solar evaporation ponds or the "B" series of holding ponds, depending on the concentrations of radioactivity. Maintenance and eventual cleanup of the solar ponds introduced potential worker exposure scenarios (Meyer and Till 1999).

Around 1965, an evaporator was installed in Building 774 to treat liquids that had accumulated in the solar evaporation ponds. Water and volatiles evolved from the evaporation process were discharged to the atmosphere. The concentrate from the evaporator was fed to a double drum dryer, on which the salt solution dried for removal by a scraping blade. Water vapor and volatiles from the dryer went through a scrubber and demister before venting to the stack, with the liquids from the scrubber and demister returning to the aqueous treatment process. The evaporator was removed from service in 1979, and liquids from the second stage of treatment and the solar ponds were transferred to Building 374. Figure 2-3 shows the locations of these ponds.

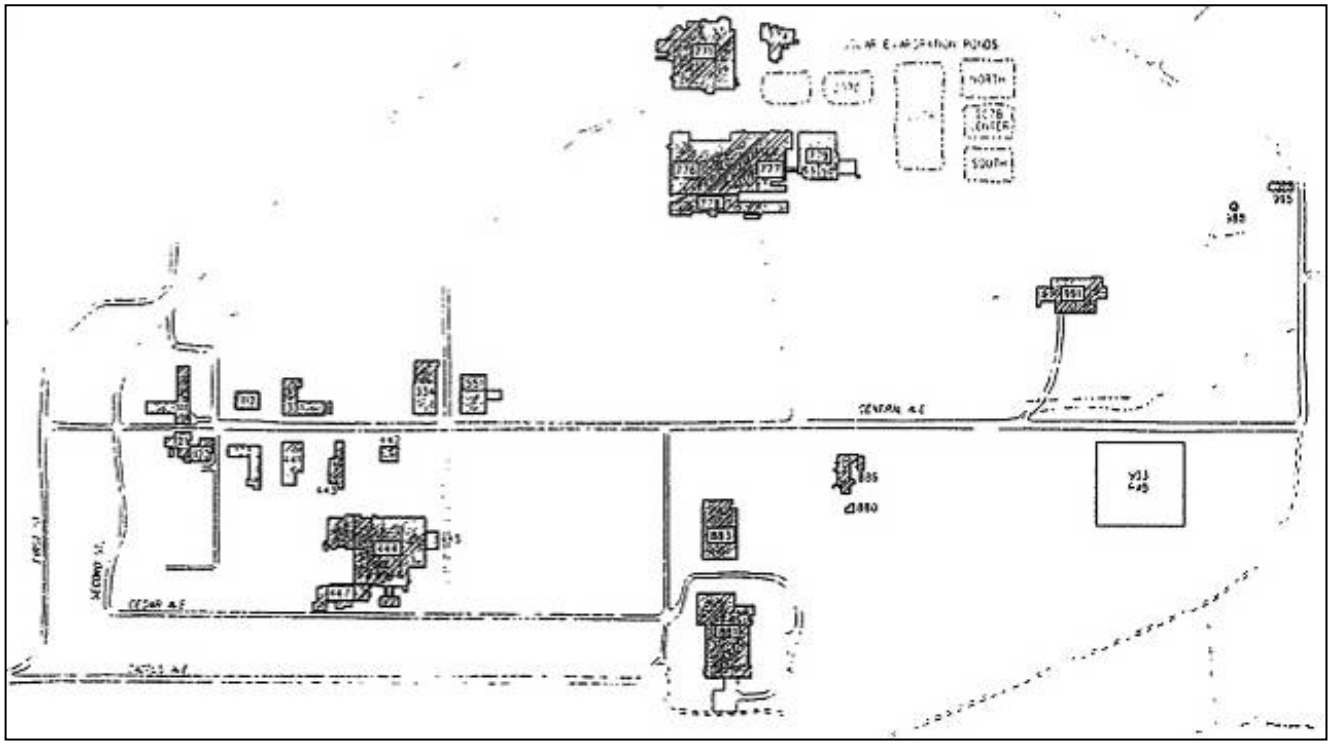

Figure 2-3. 1964 site map (ChemRisk 1992, p. 63).

Building 374 went into operation in 1978 as an integral part of the new plutonium recovery facility, Building 371. Building 374 was designed to handle wastes generated in Building 371. The processes used in Building 374 were essentially the same as those used in Building 774, with more efficient equipment. Building 374 was also designed to provide greater safety of operation through improved containment, control systems, and separation of workers from operations.

While most hazardous and radioactive wastes were shipped off the site for disposal, approximately 178 inactive waste sites existed within the plant boundaries as production operations were completed in the late 1980s, some of which had been the sites of burial, incineration, and land application (ChemRisk 1992).

Liquid sanitary waste operations were kept separate from the liquid process waste operations to prevent contamination of the sanitary waste streams. Holding tanks upstream from the treatment plant were sampled to check for plutonium contamination. Standard waste treatment was provided. Final disposition of sludges has changed over the years. From 1954 to 1968, 100 tons of sanitary sludges were disposed of in onsite trenches (T-2 through T-8). At that time, some floor drains in the manufacturing buildings were not isolated from the sewage treatment plant, and the sanitary sludge became contaminated with uranium and plutonium. A second landfill that opened in 1968 received sludges until 1969. At that time, the sludge was declared low-level radioactive waste and shipped off the site to approved disposal sites.

There were instances of onsite burial of contaminated materials, most notably soils that were contaminated as a result of the 1969 fire and other soils excavated during cleanup of the laundry waste outfall formerly located on the north side of Building 771. In the early years of plant operation, laundry waste was discharged directly to Walnut Creek. The released water met then-current standards for concentrations of plutonium and uranium. On December 21, 1973, the release of laundry waste to Walnut Creek ended.

The original RFP landfill, on the south side of the plant, opened in 1952 and closed in August 1968. An incinerator was in operation at that time, in Facility 219 on the west access road. With a few exceptions, nonradioactive combustible waste was burned in the incinerator and the resultant ashes were buried adjacent to the incinerator. It is estimated that fewer than 100 g of DU were incinerated in general plant waste between 1952 and 1968 (ChemRisk 1992).

Figure 2-4 shows the locations of waste disposal areas at the site.

2.2.3.4 Research and Development

Rolling of enriched uranium foil was conducted in 1964 in the northeast comer of the plant garage, Building 331. Interviews suggest that this area was also used for the development of DU and uranium alloy casting techniques, using electron beam heating, and uranium coating studies until Building 865 came on line in 1970 (ChemRisk 1992).

In the mid-1960s, R&D work became a larger part of the activities at the plant, as Buildings 779, 559, and 865 were constructed. Much of this work focused on examining site returns to determine the effects of time and field conditions on the weapons, including corrosion and other forms of deterioration.

Building 779, a plutonium R&D facility, was constructed in 1965. Its purpose was to study the chemistry and metallurgy of plutonium and its interactions with other materials. In addition, Building 779 housed efforts to develop improvements to manufacturing processes, to find new ways to recover plutonium and associated actinides, to better understand the aging characteristics and shelf lives of RFP products, and to house the Gammacell 220 Cobalt-60 Irradiator (RFETS 1993, p. 4, 1999, p. 3).

Building 865 began operations in 1970. It served as an R&D facility primarily for manufacturing processes using uranium and beryllium. The work involved metalworking and metallurgy techniques. The metallurgical operations involved the development of alloys and alloying processes, and fabrication of prototype hardware. Metalworking operations include melting and casting, forging,

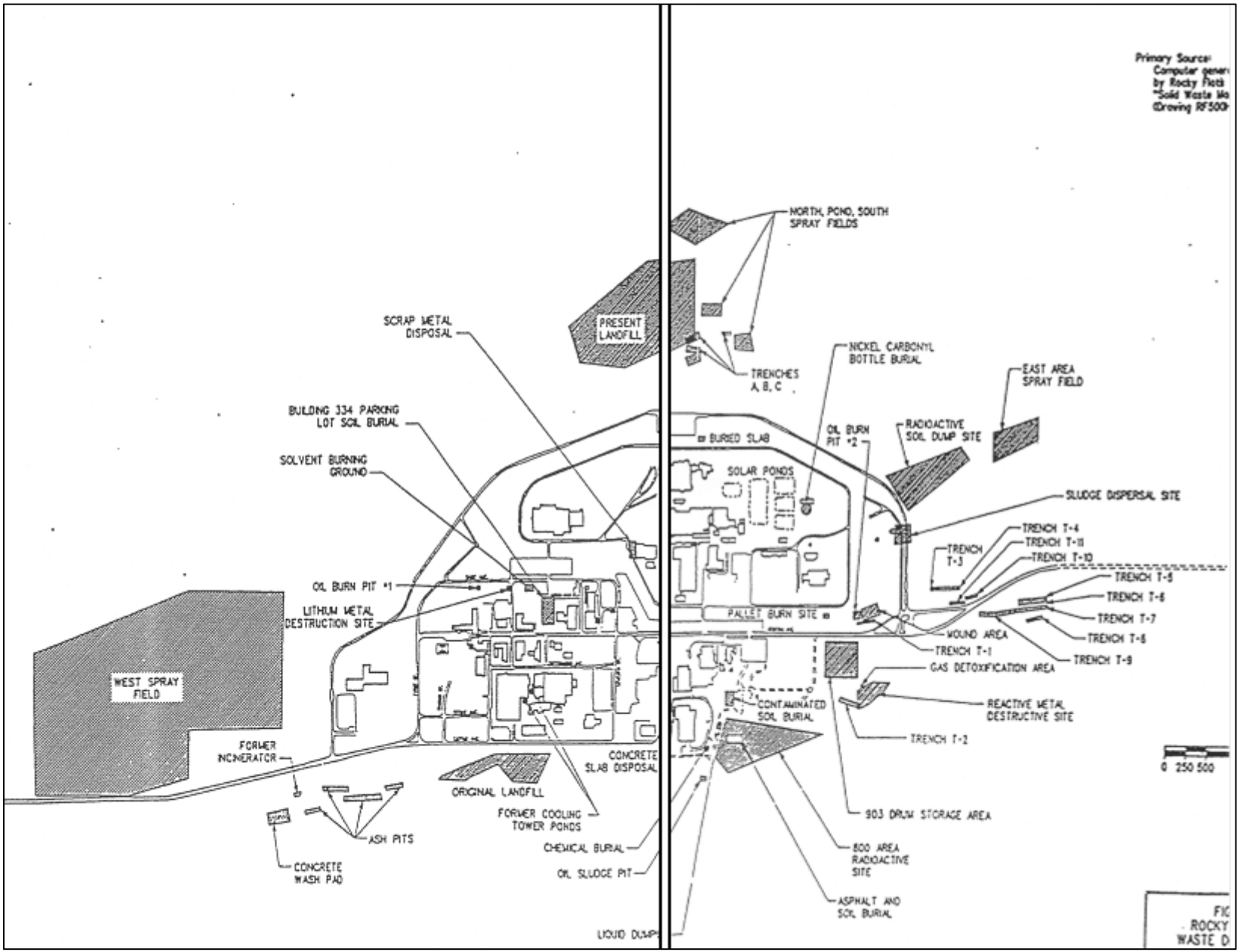

Figure 2-4. Site waste disposal areas (ChemRisk 1992, pp. 198-199).

press forming, extrusion, drawing, rolling, diffusion bonding, hydrospinning, swaging, cutting and shearing, and heat-treating. In addition, glovebox operations involved high-purity beryllium powder and machining operations that generally involved non-fissionable materials.

After 1964, Building 881 became a multipurpose facility for R&D, analytical work, plant support, and administrative offices. Operations included analytical laboratories, generation of chemical standards, activities to machine small parts for weapons and energy generation research, gold plating of parts, assembling microscopic parts, and large machining operations. The Special Weapons Projects group was involved in the development of engineering prototypes and full-scale models for military training.

Recovery Technology activities included materials development, process instrumentation and control, and equipment design and development. The Waste Chemistry group supported engineering and development of onsite waste treatment processes, and the Joining Technology group conducted operations to join non-nuclear metals including beryllium, in some cases using brazing alloys including nickel. Other operations in Building 881 included Nondestructive Testing, Records Management and Storage, and maintenance shops and activities.

Explosive bonding experiments occurred at the explosive forming area near Building 993 from 1965 until approximately 1968. The experiments were designed to explosively bond together flat plates of stainless-steel and uranium alloy using high explosives. The explosive events took place below grade. No information was identified to indicate whether releases to the environment occurred during these tests, which typically involved relatively small amounts of explosives (192 g of 40% dynamite were routinely used in the bonding tests). While available records do not indicate the isotopic composition of uranium used in these tests, the tests were designed to examine the chemical and physical characteristics of the explosive bonding process, and it is unlikely that enriched uranium would have been used in such tests.

Work for Others

The plant conducted Special Order work for other facilities in the weapons complex, the U.S. Department of Defense, or other agencies. Most Special Order work did not involve materials other than types used in production activities. The tracer work noted above was an exception. Neptunium-237 tracer work associated with uranium and plutonium components took place in Buildings 771 and 881. Exact dates of production and later recovery of these tracers (from recycled materials) are not readily available. Based on interpretation of available information, the work occurred from the mid-1960s to the late 1970s. There was considerable effort devoted to keeping tracer materials separate from the regular production material streams, and Special Recovery operations focused on recovering the materials.

For the Zero Power Plutonium Reactor (ZPPR) project, RFP manufactured approximately 4,000 stainless-steel-clad fuel elements consisting of plutonium, molybdenum, and uranium during 1967 and 1968. The plant manufactured the fuel rods for installation in the reactor at Argonne National Laboratory – West. These elements were made by alloying uranium and molybdenum in Building 444. The uranium-molybdenum alloy was sent to Building 771, where it was alloyed with plutonium by casting into plates of various sizes. The “ternary alloy” plates were clad in stainless-steel envelopes in Buildings 776 and 777 and sealed by welding. The plutonium used in this project originated in the United Kingdom and contained a higher percentage of ^{240}Pu than most RFP plutonium, so the project took care to keep it separate from other plutonium recovery and waste streams. ORAUT (2020b) provides additional details concerning the radionuclide makeup of ZPPR fuel.

During the late 1970s and early 1980s, RFP made thousands of calorimeter plates from DU for Sweden, Harvard University, and Brookhaven National Laboratory. In a large project that involved processing hundreds of tons of DU in Building 883 in the mid- to late 1980s, the plant made armor

plates for the M1A1 tank. In the mid-1980s, the U.S. Army developed an advanced type of layered Burlington armor that incorporated DU.

RFP was involved in Project Plowshare, the effort to develop technology for using nuclear explosives for peaceful applications, such as excavation and uncovering of deep mineral deposits. This involvement lasted from 1959 to the mid-1970s. An objective of the project was to use as little fissionable material as possible to limit fission product production.

2.2.3.5 Plant Support

The plant had a number of support organizations, including administration and finance, utilities, facilities management, and health and safety personnel. The plant also had some unusual support organizations, including the Criticality Laboratory (or Nuclear Safety Group), which was responsible for identifying and directing control of the potential for criticalities in plant activities. Another unique support function was provided by the Filter Testing group formed in 1979, which performed pre- and post-installation testing of the high-efficiency particulate air (HEPA) filters used in ventilation exhaust systems and of personnel respirators.

The Nuclear Safety Group was at the plant beginning in 1953. At that time, the group did not have its own facility. In the early years, the group performed its work in the areas in which production materials were handled. The in situ experiments were always subcritical; neutron count rates were observed as criticality was approached (ChemRisk 1992).

In more recent years, the Nuclear Safety Group conducted its work in Building 886, which was commissioned in 1965. Since that time, this group conducted about 1,600 critical mass experiments using enriched uranium, and plutonium, in solutions (800 tests), compacted powder (300 tests), and metallic forms (500 tests). After 1983, criticality experiments were not conducted with solid materials; they were conducted primarily with uranyl nitrate solutions, which were reused. Building 886 housed the Critical Mass Laboratory, offices, and a small electronics and machine shop.

Approximately half of the 1,600 criticality experiments in Building 886 achieved criticality. Experiments in the RFP laboratory generally involved power levels of no more than 10 mW, for no more than an hour. See Attachment H of ORAUT-TKBS-0011-5, *Rocky Flats Plant – Occupational Internal Dose* (ORAUT 2020b) for additional information on the Critical Mass Laboratory.

Beginning in 1965, airborne effluents from Building 886 were sampled for radioactive particulates. Between 1971 and 1989, reported plutonium effluents from Building 886 were no more than 5% of the site total (in 1978) and enriched uranium emissions were no more than 10% of the site total (in 1976).

Release of waterborne radioactivity from the Critical Mass Laboratory was limited to several incidents involving spills of uranyl nitrate solution (enriched uranium) and disposal of wastewater from such activities as mopping floors. The laboratory floors were sealed and bermed to contain such spills. From the late 1960s to the late 1970s, wastewater from activities such as mopping was collected and periodically transferred to the solar evaporation ponds, after sampling and analysis indicated that the enriched uranium content of the water was much less than 1 g/L.

The Health Physics Laboratories, located in Building 123, performed analyses of personnel dosimeters and all airborne sample analyses, including stack samples and general room air samples. The laboratories were originally in Building 441. The Standards Laboratory in Building 125 prepared analytical stock solutions for the other laboratories and performed analyses on incoming radiological sources for quality assurance and quality control purposes. In addition, the Standards Laboratory performed equipment calibration and standardization. The Plutonium Analytical Laboratory, in Building 559, conducted analyses to determine the purity of plutonium, concentrations of impurities,

and makeup of plutonium alloys. The Building 881 Laboratories, also called the General Laboratories, opened in 1952 to perform wastewater, sludge, surface water, and groundwater sample analyses. These laboratories analyzed production control samples from Buildings 460 and 444. When enriched uranium processes were in operation in Building 881, the laboratories also performed analyses of the products.

The Filter Testing Group was formed in 1979 after an audit identified the need for independent in-place leak testing of HEPA filters. In-place testing began in response to a filter change, when there was visible damage to the filter or the supporting framework, when plenum monitoring indicated a problem, and according to the routine testing schedule for that particular bank of filters. In addition, the Filter Testing Group conducted quality assurance testing on a fraction of new filters (pre-installation testing).

Laundry Services provided cleaning, sorting, and distribution of coveralls and other reusable garments required in the manufacturing areas. Available information does not indicate whether there were contamination concentration limits on laundry to be processed. Laundry water was sent to the forced evaporation operations in Building 374. Before Building 374 became operational in 1980, laundry water was sent to the second stage of Building 774 aqueous waste operations and then through the Building 774 evaporator if (presumably alpha-emitter) concentrations were above 1,667 pCi/L. Below this level, laundry water was sent to Pond B-2. In the very early days, Buildings 881, 771, and 991 had their own laundry facilities, and Building 444 laundry went to Building 442. Around 1958, Building 778 became the laundry facility for all plutonium-handling buildings. When enriched uranium processing ended at RFP in 1964, laundry from Building 881 went to Building 778. Beginning in 1976, laundry from Building 444 DU operations was sent to Building 778 (ChemRisk 1992).

Attachment B lists RFP job categories and descriptions. Attachment C is a partial list of types of radiation exposures associated with various job categories. This information is not presumed to be comprehensive, but was developed from several readily available documents.

2.3 RELEASES TO THE OUTDOOR ENVIRONMENT

2.3.1 Airborne Emissions

ORAUT (2020a) contains details concerning stack and other effluent monitoring operations through the life of the facility. RFP began onsite ambient air monitoring at a single station in 1952. By early 1953, 10 onsite stations had been established. The July 1953 monthly site survey report states that calibration and regulation of samplers to a flow rate of 2 cfm was underway. In February 1954, Whatman 41 filter paper was substituted for HV70 paper on all offsite samplers because HV70 filters ruptured during the weeklong sampling. This implies that the use of HV70 filters continued for onsite (daily) sampling. In March 1956, manometers were installed on onsite units. In 1969, two more stations were added, for a total of 12 stations (ChemRisk 1992). Figure 2-5 shows key operations and notes plutonium air emissions associated with each facility during 1988.

For a large part of the operational history of the RFP, emissions were measured in terms of long-lived alpha radioactivity. This was true from 1953 to 1973 for plutonium and americium, and from 1953 to 1977 for uranium. From 1974 through 1984, $^{239/240}$Pu releases through routine operations were monitored by analytical techniques specific for the radionuclides. Americium-241 was not included in

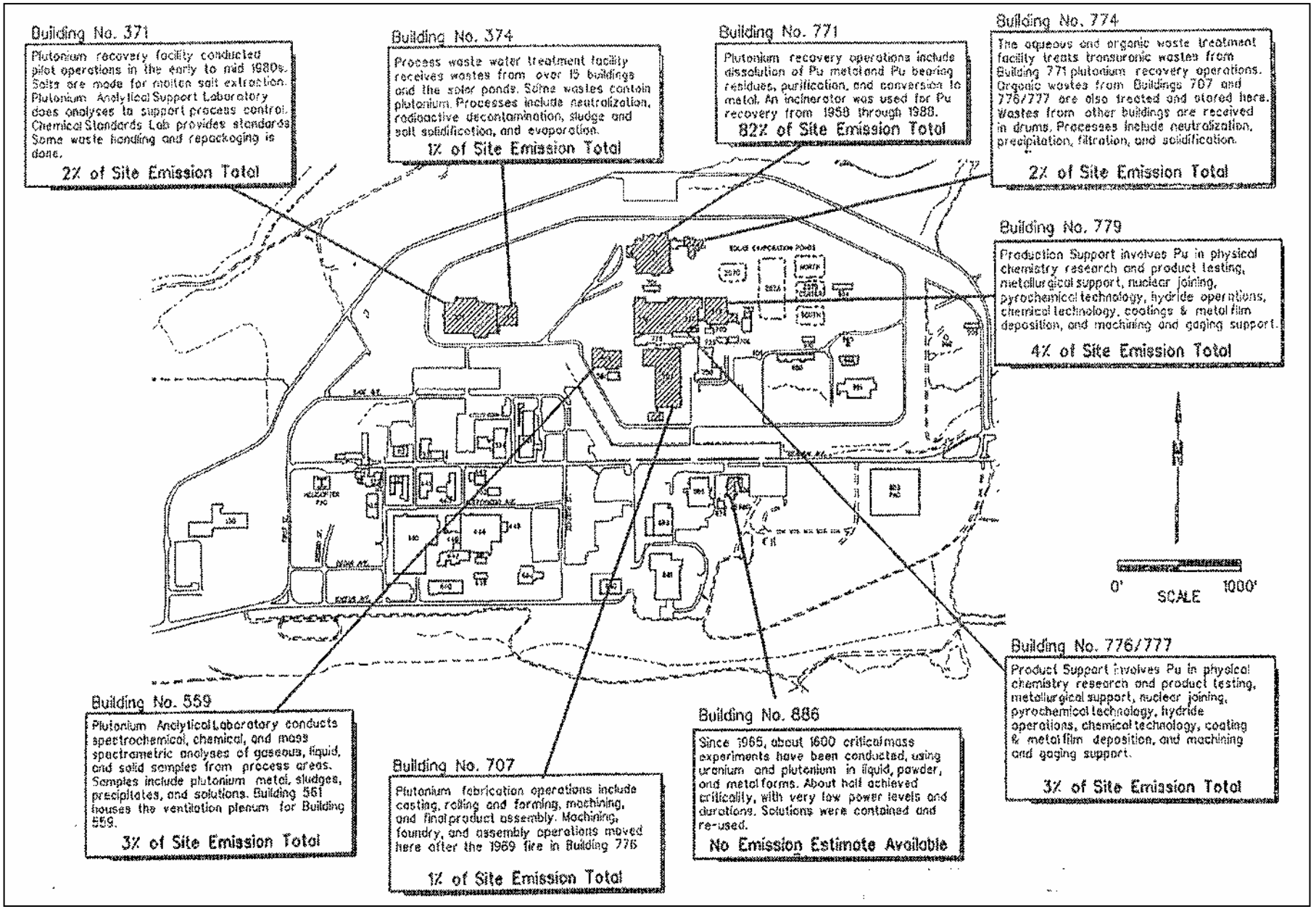

Figure 2-5. Plutonium air emission sources in 1988 (ChemRisk 1992, p. 131).

the monitoring scheme. Between 1985 and 1989, $^{239/240}$Pu and ^{241}Am were routinely sampled and monitored by alpha spectrometry after radiochemical separation but ^{241}Pu was not included. Reporting of total long-lived alpha activity continued for uranium facilities until about 1977. Even after 1978, not all uranium isotopes were routinely analyzed. For example, only ^{238}U and $^{233/234}$U emissions were reported for 1978 to 1980 and 1984 to 1989. For 1981 to 1983, only total uranium emissions were reported. Beginning in 1974, annual airborne tritium release totals were reported in annual RFP environmental reports. In 1974, data were reported for 12 vents, which expanded to 18 in 1977 and 23 in 1981 (ChemRisk 1992).

The largest routine releases of plutonium from RFP facilities occurred before 1975, primarily from the Building 771 stack and roof vents on Buildings 776 and 777. The largest routine plutonium releases from Building 771 occurred between 1957 and 1965; median release quantities after 1965 were below 1,500 µCi. After 1970, median annual releases were below 500 µCi. Estimated total plutonium emissions, summed from the late 1950s to the mid-1960s, range between 1.3 and 6.5 mCi (Grogan et al. 1999).

2.3.2 Waterborne Emissions

There were two series of ponds at the site. The uncovered and unlined holding ponds were constructed on Woman Creek and on the north and south branches of Walnut Creek. The first three holding ponds were built in the early 1950s; eight more ponds were added over the years. The second series of ponds, called solar evaporation ponds, were built in the mid-1950s to enable the evaporation of liquids with low levels of radioactivity but high concentrations of nitrates.

Beginning in 1953, liquid effluent samples from RFP were collected and analyzed. The extent of the monitoring program, the spatial distribution of sampling, and the types of materials measured were limited until the early 1970s. Under the auspices of the Waste Disposal Unit, the Water Laboratory, which was part of the General Laboratory, conducted the analyses. The major focus of the analyses in the 1950s was on monitoring total solids and nitrates. With the exception of special circumstances, only gross alpha measurements were made before 1970. In general, there was no monitoring of plutonium, beryllium, or organic chemicals during this time, even though laundry wastes from Building 771 and effluents from the sanitary sewer system were discharged directly to Walnut Creek until 1974. As a result of the May 1969 fire, routine analyses of effluent and environmental water samples for plutonium began in September 1969. Plutonium and uranium were isolated from other long-lived alpha emitters by ion exchange, and their concentrations determined by alpha pulse-height spectrometry. Uranium recovery was determined by ^{232}U tracers.

2.4 ACCIDENTS

An extensive review of the RFP accident history occurred during Phases 1 and 2 of the environmental dose reconstruction. Researchers evaluated classified and unclassified accident-related databases and documents, resulting in the identification of thousands of small-scale releases and “accidents” over the 40-year operating history. Many events reviewed during the investigation resulted in releases that passed through filtered building ventilation systems.

Attachment D is a list of some accidents and incidents with potential for worker exposures; the list is not complete at this time, particularly for years after 1977. Details are being sought for several of the listed incidents and more current incidents are being researched. Not all of the accidents listed in Attachment D are known to have been associated with worker exposures; several are included only because they were likely to have involved significant disruptive mechanical force.

Figure 2-6 shows gross alpha releases to the environment from 1953 to 1977.

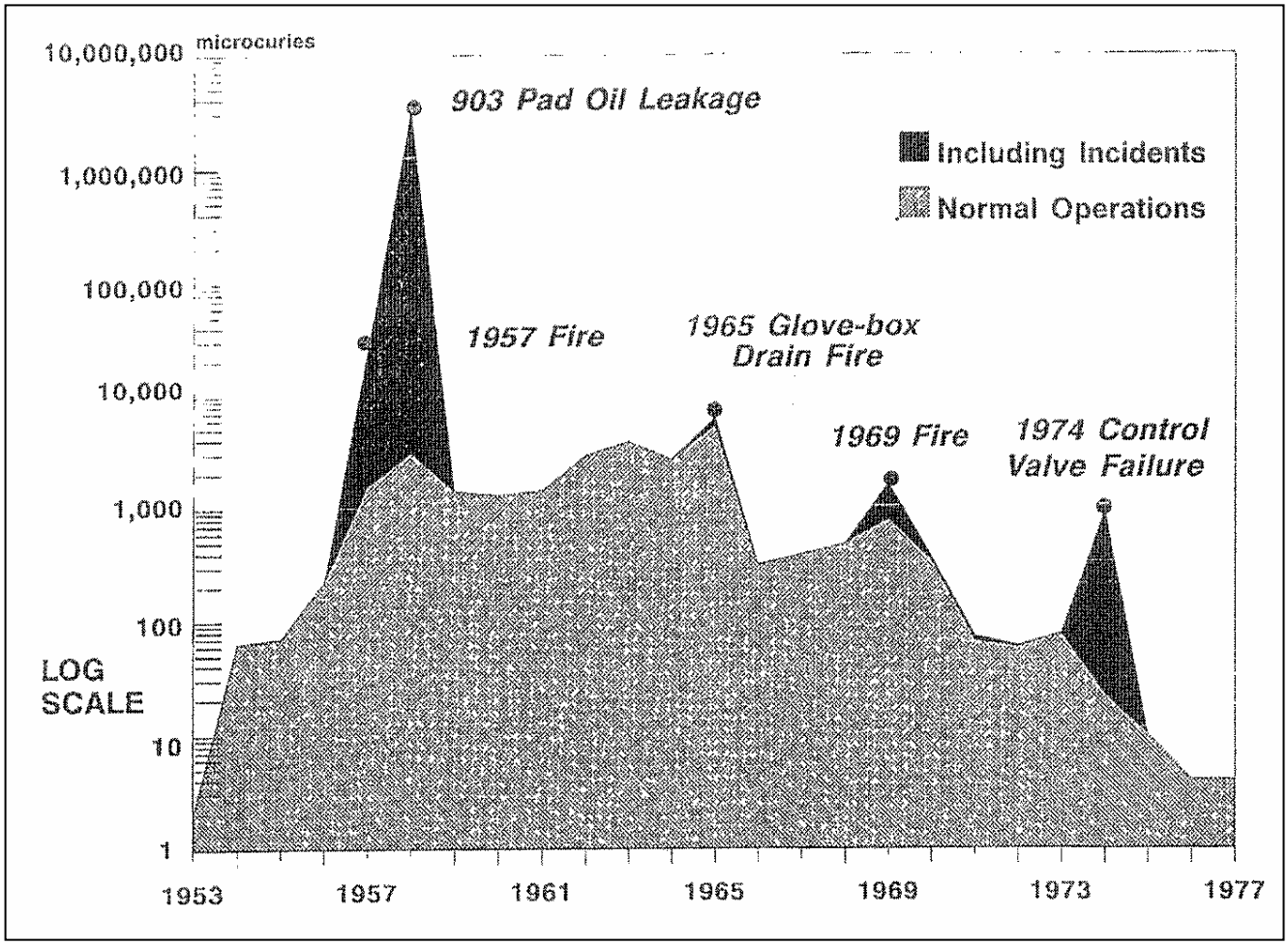

Figure 2-6. Reported gross alpha radioactivity emissions from plutonium facilities (ChemRisk 1992, p. 227).

2.4.1 Accidents and Contamination Control

In 1958, site personnel developed a gamma spectrometer wound counter to confirm the presence of plutonium in wounds. In August 1961, 55 Alpha Flashers (later Alpha-Mets) were placed on gloveboxes in plutonium areas for workers to self-monitor their hands and identify a failed glove before spreading contamination. Introduction of "COMBOs," combination hand and foot monitors, included floor areas in the contamination control program. Twenty continuous air monitors (CAMs) were in operation by April 1966 (locations unknown). Room air samplers were placed near exhaust ducts. Details concerning monitor types, introduction dates, minimum detectable amounts, alarm characteristics, and related information are provided in ORAUT (2020b) where available.

After the two fires that caused major damage to production buildings in 1957 and 1969, there were changes to minimize the occurrence and consequences of fires. To reduce the probability of a fire, nitrogen atmospheres, minimal combustible loading in all areas, and improvement of fire detection and suppression systems were emphasized. In 1967, the controlled use of automatic water fire suppression systems was included in the design of a new plutonium facility, Building 707. Criticality concerns were addressed by enforcement of fissile limits and prevention of water accumulation.

Figure 2-7 shows the locations of major accidents at RFP.

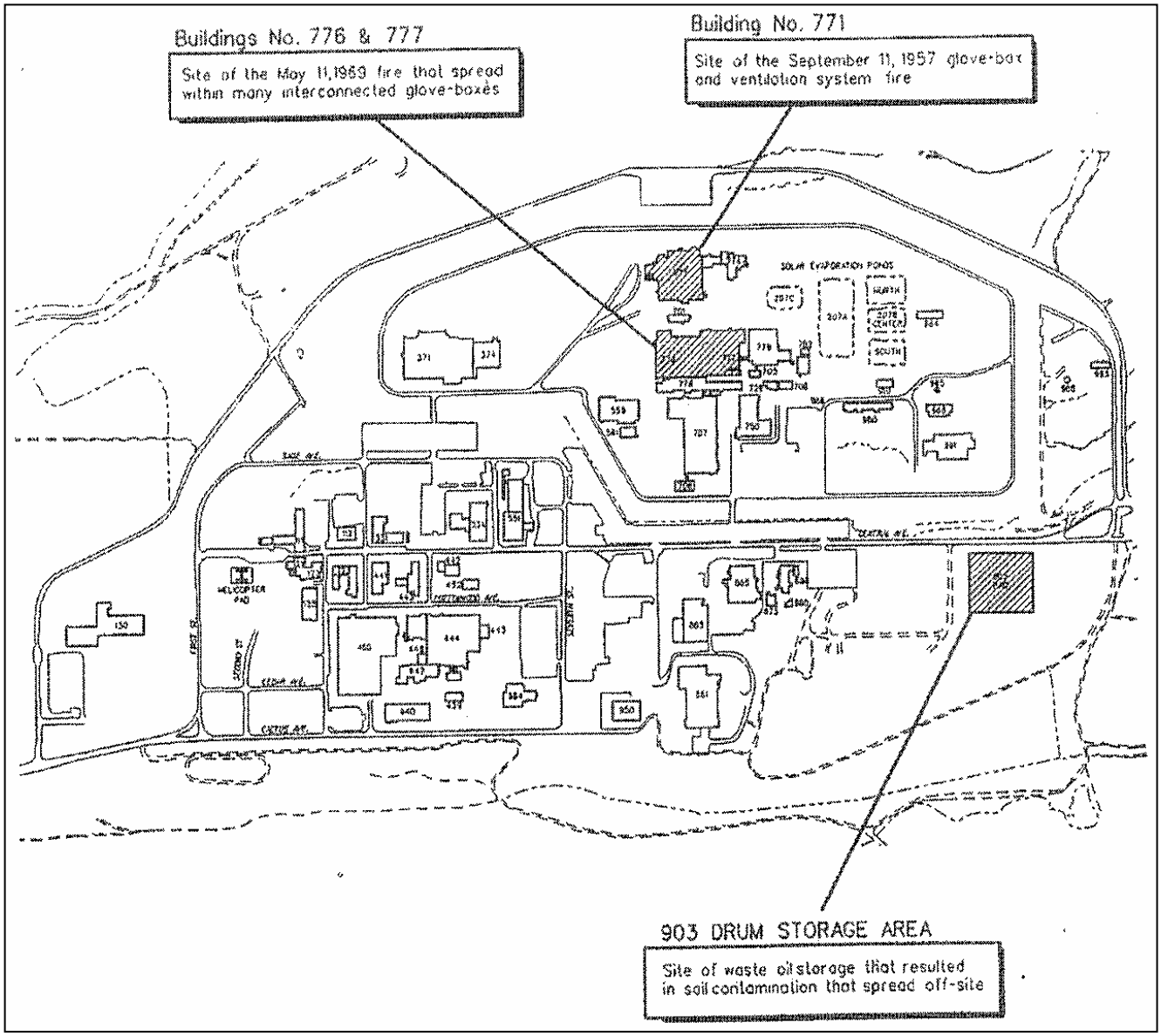

Figure 2-7. Sites of the major accidents (ChemRisk 1992, p. 228).

2.4.2 Accidents Involving Plutonium

(NOTE: The information in this section is from ChemRisk 1992.) Fire was a continuous hazard when working with plutonium at the plant. For example, RFP data indicate 623 reportable fires (most small) between January 1955 and December 1974. Of those fires, 387 occurred in plutonium processing areas. For perspective, records and interviews indicate that most fires were small and controlled, contained in glovebox or other airflow-controlled systems, and resulted in no inhalation exposure hazards to workers.

The figure shows the sites of the major accidents at the Rocky Flats Plant. It identifies three locations: Building 771 (site of the 1957 fire), Building 776/777 (site of the 1969 fire), and 903 Drum Storage Area (site of an oil leakage).

The accident report on the 1969 fire states that 164 fires were reported to the Fire Department from 1966 until the 1969 fire. Of these, 31 involved plutonium, of which 10 occurred in Buildings 776 and

777. Of the remaining 133 fires, 17 occurred in Buildings 776 and 777. There is no reliable estimate of the number of plutonium fires not reported to the Fire Department.

Chips from plutonium machining operations ignite easily if exposed to the air. Plutonium metal burns at a temperature near the 640°C melting point of plutonium, and there is no odor, smoke, or flames until other combustibles are involved. Small, relatively insignificant plutonium fires were part of normal operations at RFP, and many such fires were not reported if they were confined to the production apparatus and there was no evident risk of human exposure. Emissions from most plutonium fires occurring during normal operations passed through multistage HEPA filter systems and contributed to normal operational releases of radionuclides. The 1957 fire was a significant exception.

September 11, 1957, Fire

The September 11, 1957, fire (see Voillequé and Till 1999a) began when metallic plutonium casting residues spontaneously ignited in a glovebox in Room 180 of Building 71 (later Building 771). The fire spread to an exhaust filter plenum, Rooms 281 and 282, consuming a considerable quantity of filters and damaging the ductwork and fan system. No major injuries were reported in this fire.

Chronology of September 11 and 12, 1957:

10:10 p.m.	Fire discovered in Room 180.
10:12 p.m.	First fire truck arrived.
10:24 p.m.	Carbon dioxide extinguishers first discharged at fire.
10:25 p.m.	Fan system ordered on high speed.
10:37 p.m.	Water spray nozzles discharged at fire.
10:38 p.m.	Water shut off. Fire extinguished in Room 180.
10:39 p.m.	Explosion in exhaust system; building evacuated due to contamination.
10:40 p.m.	Fans went off.
10:58 p.m.	Second fire truck called.
11:10 p.m.	Electrical power failed in entire building.
11:15 p.m.	Water sprayed on filter bank.
2:00 a.m.	Filter fire “knocked down.”
11:28 a.m.	Final fire out.

Smoke from a burning glovebox detected in a building hallway led two watchmen to discover flames extending 18 in. from a Plexiglas window on a glovebox at 10:10 p.m. on Wednesday, September 11, 1957. The fire started in a can of plutonium turnings in the “fabrication development line” in Room 180 (first floor) of the plutonium processing and fabrication building (Building 771). Because large quantities of plutonium were handled and stored in this area, people were delayed in fighting the fire until they could don adequate radioactive contamination protection. Attempts to fight the fire with carbon dioxide from hand extinguishers and a 100-lb cart were ineffective. A water spray nozzle was effective, although there was considerable uncertainty at the time about the potential for criticality.

During this time, the fire spread to the filters, which introduced hot gases through the ventilation booster system and the main exhaust duct. Fires in the box exhaust booster filters and main filter plenum on the second floor might have started around this time, but were not discovered until 10:28 p.m. An explosion of collected flammable vapors in the main exhaust duct at 10:39 p.m. resulted in spreading plutonium throughout most of the building. The Building 771 exhaust fans shut down at about 10:40 p.m. when power was lost. The only draft would have been that created by the natural updraft of the stack and through 100 ft or so of horizontal ductwork that leads to the base of the 150–175-ft stack. Supply fans might have created a positive pressure inside the building for about one-half hour. The fire in Room 180 was controlled at 10:38 p.m., but rekindled several times. The

main filter fire was controlled at 2:00 a.m., and the fire was officially declared out at 11:30 a.m., Thursday, September 12, 1957.

One of the two prefilter systems leading to the main plenum burned through during the 1957 fire. This was a two-stage prefilter system for laboratory gloveboxes and hoods and for the production development laboratory on the first floor. The exhaust filter plenum consisted of a long concrete-block-walled room into which individual exhaust systems discharged. The 620 Chemical Warfare Service 24-in.-square filters were held in a structural steel framework.

Contamination and Dispersal of Soil from the Building 903 Drum Storage Area
In July 1958, an area just east of the main plant site was designated a temporary storage area for contaminated oil drums. Many drums developed leaks due to stored chemical interactions, and plutonium-contaminated oil was deposited on the soil. Primarily between 1964 and 1969, the contaminated soil was suspended during windstorms (see Meyer at al. 1996; Weber et al. 1999). The area was later covered by an asphalt pad.

The following significant events were associated with the Plutonium-Contaminated Drum Storage (903) Area:

- July 1958. Drum storage area established. During subsequent years, drums that contained primarily plutonium-contaminated machining oils were continually added.
- July 1959. First drum leakage discovered. Rust inhibitor, ethanolamine, was added to drums before storage to minimize corrosion.
- January 1964. First evidence of large-scale deterioration of drums reported. Soil contamination reported increasing.
- January 1966. Small building added to filter and transfer contaminated oil from leaking drums to new drums.
- January 1967. Last drums added to storage area; removal to Building 774 began. Oldest drums shipped first.
- June 1968. Last drum shipped to Building 774 for processing. High winds spread some contamination.
- July 1968. Radiation monitoring and mapping of area completed. Levels of 2×10^5 dpm/g of soil to more than 3×10^7 dpm/g were reported. Penetration from 1 in. to 8 in. was reported.
- September 1968. Preliminary proposal for containment cover prepared by RFP Facilities Engineering.
- July 1969. First coat of fill material applied.
- August 1969. Fill work completed, paving contract let.
- September 1969. Overlay material, soil sterilant, and asphalt prime coat completed.
- November 1969. Asphalt containment cover completed, including four sampling wells.

The first indication that drums were leaking in the field was in 1964. Contamination was detected on air samplers at the east fence after high winds. As a result, the storage area was fenced and contents

of leaking drums were transferred to new drums. Approximately 420 drums leaked to some extent; of these, about 50 were totally empty. By the end of 1967, plant officials discovered that soil contaminated by the leaking drums had been resuspended in the air and redeposited.

The redistributed quantity was directly associated with the removal of the drums, which exposed contaminated soil, physical activity in the area, and periodic high winds. In November 1968, grading began for applying an asphalt cap over the area. Most of the resuspension occurred between July 1968 and July 1969. The highest airborne concentration was 0.34 pCi/m^3, measured at a monitor approximately 100 m east of the 903 pad, in the prevailing wind direction. Installation of an asphalt pad began in July 1969 and ended in November 1969. A round of soil sampling in a 7-mi radius around the plant was completed in late 1989. Plutonium concentrations were highest just east of the plant (ChemRisk 1992).

1965 Glovebox Drain Fire

In 1965, a plutonium fire occurred during a maintenance operation on a plugged glovebox drain in Buildings 776 and 777 (see Voillequé and Till 1999c). The fire vented to the room air and spread throughout the buildings through the normal ventilation system. About 400 employees, many without respirators, were potentially exposed to airborne plutonium dioxide. Body counter measurements indicated that 25 employees received 1 to 17 times the permissible lung burden. Lung concentrations greater than 0.008 µCi were found in 15 employees.

At approximately 10:25 a.m. on Friday, October 15, 1965, a fire occurred during a lathe maintenance operation in Room 130 of Building 777. The operation involved unplugging a coolant recirculation line for a tape-controlled turning machine. Attempts to remove the obstruction from the glovebox end of the line failed; attempts were made to unplug the line through a drain leg near the glovebox. A cap was removed from the bottom end of the drain leg and a center punch was inserted to dislodge the obstruction. Sparking was observed when the punch was struck, and a fire resulted, burning the bag enclosure for the punch and igniting a plastic and paper pen directly beneath the drain leg.

The fire lasted for one-half to 1-and-a-half minutes and was extinguished with carbon dioxide. It vented to the room atmosphere, and combustion products were widely spread by the normal ventilation pattern. Residues of the fire and a drain leg removed from an adjacent lathe were analyzed. The analyses indicated that, during the fire, a chemical reaction occurred between plutonium and carbon tetrachloride. The burning of plutonium in air is generally nonviolent and described as smoldering. The reaction of plutonium and carbon tetrachloride can be violent.

Fifteen employees had greater than 0.008 µCi of plutonium in their chest counts. Plutonium contamination was spread through a major portion of Building 776 and through 25,000 ft^2 of Building 777. Major areas of the buildings were cleaned up by Monday morning, October 18, and nearly all production operations resumed at that time (ChemRisk 1992).

May 11, 1969, Fire

A major plutonium fire started in a glovebox in the North Foundry Line in Building 776 on Sunday, May 11, 1969 (see Voillequé and Till 1999b). The fire burned for several hours, spreading through combustible materials in several hundred interconnected gloveboxes in Buildings 776 and 777. The first indication of a fire was an alarm in the Fire Station in the North Foundry Line at 2:27 p.m. The Fire Department responded promptly, but on its arrival the fire was moving rapidly through the Foundry Conveyor Line. The fire spread through an interconnecting conveyor to the Center Fabrication Line. It was brought under control about 6:40 p.m., but continued to burn or reoccur in isolated areas through the night. On Monday morning, a fire was discovered in a glovebox on the South Foundry Line, which was quickly extinguished and caused little damage.

The dense smoke, crowded conditions, and presence of large quantities of combustible material in the form of Plexiglas windows and Benelex-Plexiglas shielding made the fire difficult to fight and extinguish. The fire did not breach the building roof and ruptured only a minor part of one exhaust filter system. As a consequence, most of the smoke and essentially all of the plutonium remained in the building. One firefighter received a significant internal body burden of plutonium. There is no evidence that a criticality incident occurred. The damage to Buildings 776 and 777 and equipment was extensive. In addition to actual fire and smoke damage, the buildings were grossly contaminated with plutonium. Adjacent buildings sustained minor exterior and interior contamination. After the fire, processing and production gloveboxes at RFP were converted to an inert nitrogen atmosphere to prevent the spontaneous ignition of plutonium.

The first indication of a fire in Building 776 came from an alarm received in the Fire Station at 2:27 p.m. The fire captain on duty and three firefighters responded to the initial alarm. They arrived at the west end of Building 776 at 2:29 p.m. On entering the building, they saw smoke coming toward them from the east. They proceeded farther into the building and observed heavy smoke and fire in the North Foundry Line. The fire was out of the top of the line with flames about 18 in. high. One of the firefighters heard two loud reports and saw two fireballs about basketball size go to the ceiling in the area of the North Foundry Line. This occurred while the firefighters were laying out a fire hose, and before any water had been used on the fire. By 2:50 p.m., there was fire along the top of the North-South Conveyor Line. About this time the firefighters on the second floor heard a loud noise and felt the floor shake. At approximately 3:20 p.m., the fire was spreading to the rolling mill on the Center Line, and at 3:40 p.m. the entire area from Columns G–J and 11–13 was glowing orange through dense smoke. There was also a fire in the ceiling in the vicinity of the North-South Conveyor Line.

Pressed plutonium briquettes composed of scrap metal and chips generated during rolling, forming, and machining operations self-ignited in metal storage containers in a Benelex and Plexiglas (transparent plastic materials) storage cabinet in the north line. Heat from the burning plutonium ignited the Benelex and Plexiglas in the glovebox line, which created large quantities of smoke. Visibility was nonexistent due to thick black smoke and the loss of lights in the main fire area. The crowded conditions in the fire areas made firefighting very difficult. The first attack on the fire with carbon dioxide was ineffective. Less than 10 minutes after the fire alarm was received, the fire captain initiated the use of water. Water was used on the fire almost exclusively, although some magnesium oxide was used on plutonium.

Because the conveyor lines and gloveboxes were open, it was impossible to avoid getting water on the burning plutonium. As the glovebox windows burned, plutonium oxide was released to the room. Because of the extensive plutonium contamination and smoke, personnel entering the area during the fire were required to use self-contained breathing systems, which severely limited their time in the fire area. Attempts to pry or knock Benelex shielding from gloveboxes and conveyor lines were not successful. Although the firefighters were generally successful in knocking down the fire in some locations, by the time they returned with new air supplies or from directing their attention to other areas, the fire had reintensified.

Some smoke came out the west end doors of Building 776, which were opened at about 2:29 p.m. Between 3:20 p.m. and 4:10 p.m., smoke was observed coming from the roof of Building 776. The smoke billowed over the side of the building toward Buildings 778 and 750. Firefighters sent to the roof saw smoke coming from exhaust vents. Although there were no signs of fire in the roof, the roof did soften in one area near the location of the 4 High Mill, Columns H–G and 6–7. The roof was sprayed with water and a fire watch maintained until after 5:00 p.m. By 6:40 p.m., the fire was contained. Between 7:00 p.m. and 8:00 p.m., a door on the second floor of Building 776 was opened and the main building exhaust system was changed from recirculating to single-pass in an effort to help clear the heat and smoke. By 8:00 p.m., the fire was largely extinguished, and a fire watch was

established. During the early morning hours of Monday, May 12, the storage container in Glovebox 134-24 on the North Foundry Line continued to smolder and reignite. Water and magnesium oxide were used on this container. Between 8:00 a.m. and 9:00 a.m. on Monday, the fire watch discovered a fire in the plutonium storage box on the South Foundry Line (Glovebox 134-70). This fire was quickly extinguished by breaking the Plexiglas windows and using water on both the inside and outside of the box. This was the only fire in the South Foundry Line.

The fire destroyed the gamma radiation alarm system in Building 776, but the Building 777 alarm system remained operational. Neither this system nor those in Buildings 559, 779, and other locations on the plant were set off during or after the fire. A Hurst dosimeter retrieved from Building 776 showed no evidence of being exposed to neutrons or gamma radiation. No one reported seeing a visible flash or any other sensory evidence that a nuclear criticality had taken place.

One area of the roof of Buildings 776 and 777 near the exhaust vent from Booster System No. 1 was contaminated with plutonium in the range of 1×10^5 to 1×10^6 cpm, which corresponded to 0.2 µCi/100 cm^2. Adjoining ground areas and the exterior of Building 777 were contaminated. The ventilating, electrical, and other utility systems on the second floor of Building 776 were similarly contaminated with plutonium. Approximately 8 mCi of plutonium appears to have escaped from Buildings 776 and 777 and deposited on the roof or adjoining soil (Voillequé and Till 1999b). It was primarily deposited on the roof of the building and on the ground and one building adjacent to Buildings 776 and 777 (ChemRisk 1992).

1974 Control Valve Release

Radioactive particulates escaped from an exhaust stack on the roof of Building 707-A after a glovebox atmosphere control valve accident at about 9:53 a.m. on April 2, 1974 (see ChemRisk 1992). At approximately 1:00 p.m., Wednesday, April 3, 1974, an elevated count was detected on the exhaust stack sample of Inert System No. 2 and Downdraft Plenum No. 4. Results of surveys showed the path of contamination movement in the inert system. A flow reversal had apparently occurred through the recirculating fans resulting in a release to the environment.

The accident resulted when the inert atmosphere exhaust valve from the Building 707 storage vault was being closed during a glovebox maintenance procedure. This resulted in a pressure surge that forced contaminated gas back upstream through the inert gas supply system. The contaminated gas was pumped into the atmosphere by the purge exhaust fans through the exhaust stack shared by Inert System 2 and Downdraft Plenum 4. This transport of contaminated gas in turn contaminated the exhaust ducts. In addition, the pressure surge caused contaminated gas to flow out the open window of glovebox 7-K-65, which had been removed for maintenance. This contaminated a nearby module to levels up to 100,000 cpm and tripped the air monitors.

Table 2-1 summarizes releases to the environment for several RFP events.

Table 2-1. Plutonium release estimate distributions by event (Ci).[a]

Release event	5th percentile	50th percentile	95th percentile
1957 fire	11	21	36
1969 fire	0.013	0.037	0.062
903 Area[b]	1.4	3.1	15

a. Modified from Grogan et al. (1999).
b. Releases to air, primarily 1964–1969. Includes particles up to 30 µm aerodynamic equivalent diameter (AED); ~20% were estimated to be in the respirable size fraction (<15 µm AED). ORAUT (2020b) considers particle size conventions and methods to convert from one system to another. Work remains to be done in this area for the RFP site profile, and this has been noted in ORAUT (2020b).

2.4.3 Tritium at Rocky Flats

Tritium has been present at RFP since 1964 as transshipments, for "special order" work, as standards, in contaminated materials, and as nondestructive testing sources (ChemRisk 1992). Two measurable releases of tritium occurred at RFP (ChemRisk 1992, 1994a, 1994b). An accident in 1968 led to the release of several hundred curies and another in 1973 released 500 to 2,000 Ci. The 1973 release occurred when tritium-contaminated material was inadvertently processed. An estimated 60 Ci of tritium was released in water effluents, 100 to 500 Ci was retained in onsite ponds and tanks, and the remainder escaped to the atmosphere. There were five known sources of tritium effluent releases at RFP: Building 779; Building 561; Building 777, which released tritium in the 1973 incident; Building 774, where tritium-contaminated water was evaporated; and the four solar evaporation ponds adjacent to Building 779. The solar ponds were the source of water fed to the Building 774 evaporator (ChemRisk 1992). In addition, approximately 1.5 Ci of tritium was released in Room 452 of Building 777 in 1974. Figure 2-8 illustrates tritium operations locations.

2.4.4 Accidents Involving Uranium

Based on information gathered during an extensive investigation of accident records during the Phase 1 and 2 environmental dose reconstruction project, it is believed that incidents involving uranium at RFP have been relatively rare. One exception was associated with the practice of onsite burning of wood pallets. In May 1965, three DU sheets were accidentally burned as a result of shipment to RFP from Medina, Ohio, in a package that resembled a nonstandard-size wooden pallet. Improper labeling and the unconventional packaging apparently caused the DU to go undetected, and the pallet containing 60 kg of slightly radioactive DU was destroyed by burning on May 1, 1965.

Figure 2-9 illustrates the locations of uranium operations on the site.

2.4.5 Accidents and Occurrences after 1981

Attachment D contains information from a variety of reports. Incidents reported after 1981 were compiled in occurrence reports (RFETS 1981–2005) by RFP management. Over 10,000 pages of reports have been located at the Rocky Flats Reading Room in Westminster, Colorado. Attachment D includes certain incidents involving radiation exposure to workers that required submittal of bioassay samples or more than one employee. The list should not be considered comprehensive for the following reasons:

1. Many occurrence reports, numbered sequentially for each building and year, were found to be missing from the available collection at the Rocky Flats Reading Room, the only known repository at this time. Some of the reports might have been reserved for security reasons or because they contained classified information. Others are missing all but the first page, which does not provide sufficient detail to determine whether an exposure occurred. Note that the reports do not contain information that would identify the individual(s) involved. Only the supervisor and report authors are identified in the incident reports.

2. It is not known whether all incidents of potential interest to dose reconstruction are captured in the reports. All available records were searched but it is possible that other incident reports are located elsewhere. Also, reports from the 1980s appeared to capture only occurrences that could have resulted in employee exposure to radiation, but reports from the 1990s captured any off-normal occurrence, from accidental radiation exposure and replacement of worn or defective equipment to employee disputes and procedural violations that did not involve any radiation exposure. Given the different reporting requirements through the years, a different number of reportable events are documented.

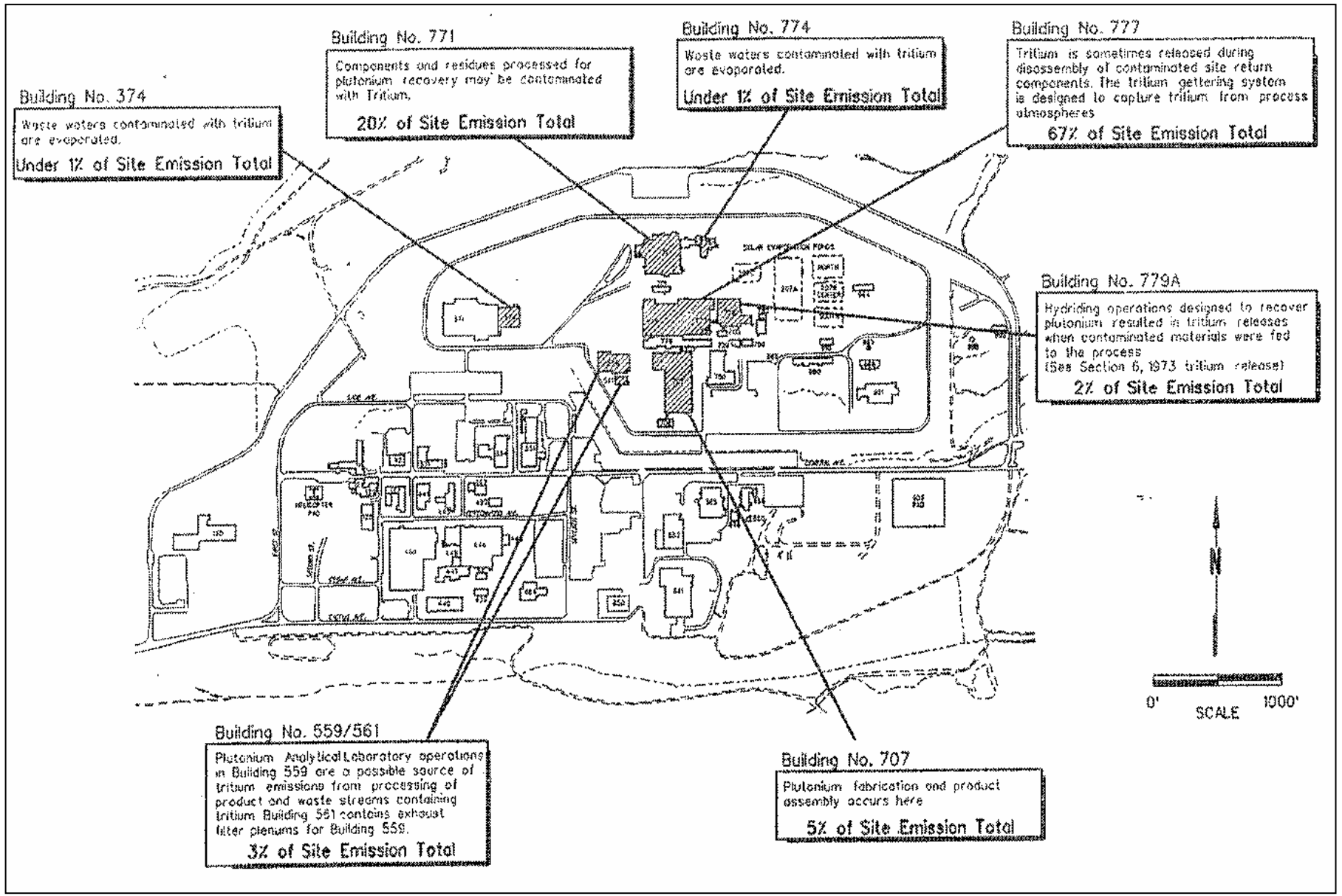

Figure 2-8. Tritium air emissions sources (ChemRisk 1992, p. 141).

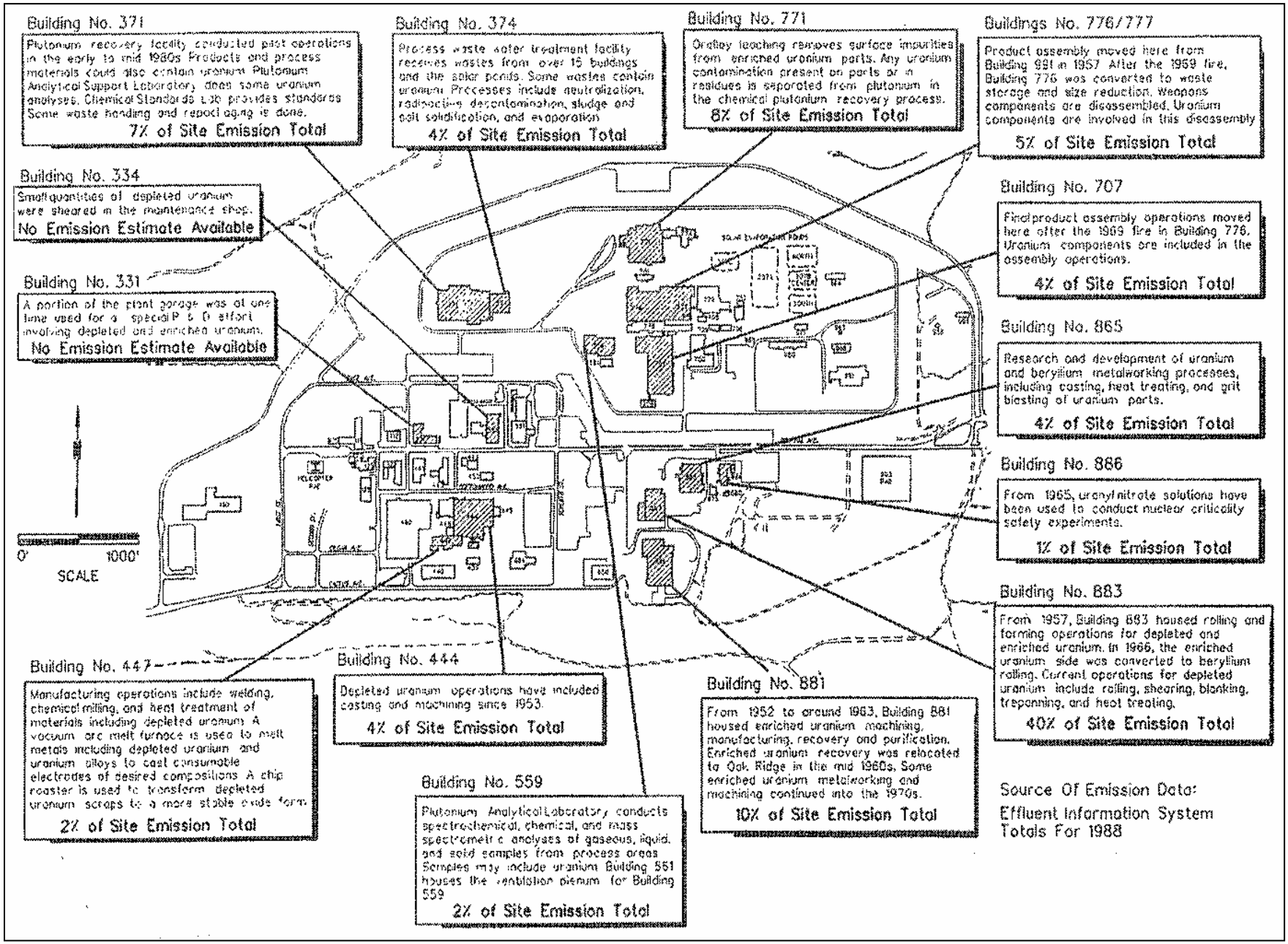

Figure 2-9. Uranium air emissions sources (ChemRisk 1992, p. 143).

3. There was a lag time between incident reporting (usually done quickly) and reporting of bioassay results (due to processing). It is possible that an exposure was not captured in an occurrence report because bioassay results were not provided in the incident report or in a followup report.

In addition to the occurrence reports, the Price-Anderson Act enforcement actions were reviewed. The Price-Anderson enforcement actions overlap in time with the occurrence reports. However, three enforcement actions that did not appear to have concurrent occurrence reports are noted here. The enforcement action notices withhold certain information, like building numbers and dose received, that will make using this information difficult for the dose reconstructors; however, to be complete, the incidents are reported below:

- Enforcement Action 98-03 (DOE 1998):

  An unplanned uptake of radioactive material by [redacted] workers during a Comprehensive Environmental Response, Compensation, and Liability Act of 1980 tank remediation project of August 12, 1996, conducted by Rocky Mountain Remediation Service (RMRS):

  – 17 workers received small radiation exposures (6 in 1996 and 11 in 1997) as a result of inadequate assessment of area dosimetry data for several offices adjacent to rooms containing radioactive material; and

  – An [redacted] received unnecessary exposure while performing a radioactive source inventory and leak test on January 14, 1998.

- Enforcement Actions 97-03 (DOE 1997a) and 97-04 (DOE 1997b). Unplanned dispersal of radioactive material during remediation of trenches (September 19, 1996). The radioactive material was dispersed when a radioactively contaminated drum carcass was compacted by a backhoe in support of trench remediation being performed by RMRS. Approximately 1 to 2 lb of an unnamed radioactive material was released. The release was identified several hours later and the release area secured. "A subsequent dose determination using air dispersion modeling and conservative assumptions estimated that onsite and offsite doses were minor."

- Enforcement Actions 96-04 (DOE 1996a) and 96-05 (DOE 1996b). [Redacted] incidents involving radiological exposure to workers. On [redacted], a release of radiation in excess of unnamed limits occurred, and work was not stopped even though the work permit required it. [Redacted] workers and others nearby continued to work in increasingly hazardous conditions. Similar violations occurred on [redacted], in another building. [Redacted] workers received varying levels of unexpected radiation contamination while performing [redacted] activities. Workers were not wearing required respiratory protection at the time.

2.5 SITE CLOSURE AND DECOMMISSIONING

In December 1988, an aircraft on a routine operation equipped with an infrared camera recorded a heat plume from the Building 771 Incinerator. U.S. Environmental Protection Agency (EPA) officials believed that illegal incinerator operations were being conducted, and on June 6, 1989, the Federal Bureau of Investigation raided RFP based on allegations of Resource Conservation and Recovery Act of 1976 and Clean Water Act violations. Although the allegations could not be confirmed, other safety concerns led to curtailment of operations in 1989 (KHC 2004a). Cleanup of the site started in December 1995 after a grand jury hearing in 1992.

The Rocky Flats Cleanup Agreement (RFCA) between DOE, EPA, and the Colorado Department of Public Health and Environment was finalized July 19, 1996. The RFCA set out a timeline and goals

for site remediation and included demolition of buildings that could not be safely remediated and reused. The agreement specified that remediation of chemical and radioactive waste, buildings, equipment, soil, groundwater, and surface water would need to be accomplished with the goal of returning the site to a wildlife preserve. Attachments to this agreement with specific remediation goals were finalized in June 2003 (KHC 2003a).

Closure of the Rocky Flats Environmental Technology Site (RFETS), as it was called during the remediation and decommissioning process, was a complicated matter due to the presence of TRU waste, TRU mixed waste, low-level radioactive waste, low-level mixed waste, sanitary waste, and chemical waste. "Orphaned" waste was also present on the site and had been stored there in the absence of a final disposal site. In addition, decontamination of buildings and equipment was necessary before buildings could be demolished. Soil and water also required remediation and restoration. Highlights of the decommissioning projects, which included demolition of all buildings on RFETS, are described below (KHC 2003a to 2003o, 2004a to 2004n, and 2005a to 2005g). Only two major incidents were reflected in reports that covered about 2.5 years: one is described in Section 2.5.1 and included in Table D-3 of Attachment D; the other is described in Section 2.5.8 and did not involve radiation.

In general, the buildings were subdivided into groups for the purposes of remediation and decontamination and decommissioning (D&D), in general conforming to their uses during the production years. The building clusters were further subdivided into dismantlement sets (or Sets) based on similarity of remediation work to be performed, and decommissioning areas, referring to demolition proceedings. Buildings and areas were ranked by level of contamination. Type 1 denoted being free of contamination, Type 3 denoted high levels of contamination or hazard. Type 2 denoted the need for remediation but without significant hazard or contamination (DOE 2001a).

2.5.1 Building 371

The Building 371/374 Closure Project was comprised of Buildings 371, 374, 373, 374A, 377, 378, and 381, and 14 aboveground storage tanks, located within the Protected Area. All were slated for demolition to be consistent with the goal of permanent closure of RFP. The closure project had to deal with both radiological and chemical cleanup of the buildings, but only Buildings 371 and 374 were classified as highly contaminated (DOE 2001b).

All special nuclear material (SNM) was removed from Building 371 Central Storage Vault on December 30, 2002. All plutonium oxide was removed from Building 371 and sent to SRS, and the International Atomic Energy Agency closed building surveillance in December 2002 (KHC 2003b). On May 6, 2003, a fire occurred in glovebox 8 of Building 371 (KHC 2003c); this incident, which resulted in a Price-Anderson Enforcement Action Investigation, is included in Table D-2 of Attachment D. Raschig ring removal was completed on June 16, 2003 (KHC 2003d). On August 8, 2003, the Building 371 Material Access Area was closed, paving the way for the elimination of the Protected Area (KHC 2003e); the Protected Area was eliminated by November 2003 (KHC 2003f).

Also by November 2003, all weapons-usable material from Building 371 had been shipped off the site and removal of more than 36,000 gal of sludge from 28 tanks was completed (KHC 2003f). The remaining sludge was removed from Buildings 371/374 by February 2004 (KHC 2004b), and the buildings were declared "criticality incredible" [free of the risk of criticality by August 2004 (KHC 2004c)]. All TRU equipment had been removed from Building 374 by August 2004. Remaining Plutonium Stabilization and Packing System equipment was removed from Building 371 on July 21, 2004 (KHC 2004c).

The last glovebox was removed from Building 371 on November 22, 2004, and the last TRU waste from the building was shipped on November 17, 2004 (KHC 2004d). By mid-December 2004, the

Central Vault had been reduced in size and partially removed (KHC 2004e). D&D continued in January 2005 (KHC 2005a), and the last phase of Building 371 demolition began in June 2005 (KHC 2005b). It was completed by September 2005 (KHC 2005c).

2.5.2 Building 444

The beryllium plenum of Building 444 was removed by December 2003 (KHC 2003g). Demolition of the Building 444 structure was completed by April 2005 (KHC 2005d). Decommissioning posed significant challenges due to the extent of beryllium contamination (KHC 2005d), but no details of any radiation issues have been found to date.

2.5.3 Building 707 Closure Project

The Decommissioning Operations Plan (DOE 2002) states that the Building 707 Closure Project included Buildings 707, T-707S, 708, 709, 711, 711A, 718, 731, 732, and 778 along with 21 aboveground storage tanks in the Protected Area. Some areas within the Building 707 Project had levels of radiological contamination exceeding 2,000 dpm/cm^2 removable and 50,000 dpm/100 cm^2 fixed plus removable. All facilities within the Building 707 Cluster were slated for demolition (DOE 2002).

The remediation of the C-pit of Building 707 was completed by January 2003 (KHC 2003h). By September 5, 2003, the X-Y retriever was emptied of all contents and part holders (KHC 2003i). The J-module was dismantled in early 2004 (KHC 2004f) and free of criticality risk by March 2004 (KHC 2005a). The X-Y retriever vault was decontaminated and removed by November 2004 (KHC 2004g).

Decontamination of Building 707 was accomplished using dry techniques (concrete shavings). Decontamination and final surveys of 228,000 ft^2 were finalized (KHC 2005a) and Building 707 was demolished on December 7, 2004 (KHC 2004e). By the time the demolition was complete, no criticality infractions or deficiencies had occurred in the preceding 20 months, and no recordable injuries had occurred in the preceding 9 months (KHC 2005a).

2.5.4 771 Closure Project

The original Decommissioning Operating Plan for Building 771 was approved in January 1999; modification 5 dated August 8, 2003 (DOE 2003), is referenced here. The 771 Closure Project included Buildings 771 and 774. Facilities within the 771 Closure Project were slated for D&D. Thirty-three dismantlement sets and 13 decommissioning areas were defined for this project and, as of August 8, 2003, most of the sets and some of the areas had been dispositioned (DOE 2003).

Through FY 2003, all 240 gloveboxes and 397 tanks from Buildings 771 and 774 were removed and both buildings were declared criticality incredible. Plenums FU-2B and FU-2C were dismantled and removed. The main filter plenum was decommissioned. Two of the 13 decommissioning areas were surveyed and certified for demolition. The maintenance shop, tank shed, guard shack, and trailers were demolished. Removal of two underground storage tanks had begun (KHC 2003f).

Building 774, the “infinity room,” and the Building 771 stack were demolished in June 2004 (KHC 2004h). The infinity room was so named because the measured derived air concentrations (DACs) were greater than 2,000 times the maximum limit for safe entry 25 years after it had been sealed and abandoned due to contamination (KHC 2004a). Building 771 demolition began in July 2004 and ended October 12, 2004 (KHC 2004g).

2.5.5 Building 776/777 Cluster

The Building 776/777 cluster was comprised of Buildings 701, 702, 703, 710, 712, 712A, 713, 713A, 730, 776, 777, and 781. Decommissioning (including demolition) was chosen as the best alternative for this cluster to support the goal of a safe, accelerated, cost-effective closure (DOE 2001a). The buildings were classified as to level of contamination, and remediation began.

By January 2003, Building 776/777 was declared free of criticality risk. By the end of FY 2003, D&D of all buried equipment was completed. Building 776/777 went "cold and dark" by October 2003, meaning all radioactive material and permanent power sources were removed. By November 2003, Plenums 204, 205, and 206 had been removed, and decontamination of the Advanced Size Reduction Facility was completed. Workers made more than 900 entries wearing supplied air breathing suits while demolishing and removing the facilities (KHC 2003f). All major equipment and gloveboxes were removed by the end of 2003 (KHC 2004a).

Piping, conduit, and ducts were removed in 2004 and all 10 support buildings were demolished (KHC 2005a). Strip-out of all equipment was completed in 2004, and encapsulation of floor space began in preparation for controlled demolition (KHC 2005a). As of the end of 2004, no Technical Safety Requirements violations had occurred for 42 months, no criticality infractions or deficiencies had occurred for 19 months, and no recordable incidents had occurred for the preceding 15 months (KHC 2005a). Demolition of Building 776/777 began in January 2005 and was complete by June 2005 (KHC 2005c).

2.5.6 Building 881

Few details on the D&D of Building 881 have been found. However, D&D began in January 2003 (KHC 2004a). Strip-out operations had removed 460 tons of low-level and low-level mixed wastes by June 2003 (KHC 2003j). The Building 881 ventilation stack was removed on November 8, 2003 (KHC 2003k). Demolition was completed on July 17, 2004 (KHC 2004a).

2.5.7 903 Pad and Lip

Drums stored at the 903 Pad had leaked 5,000 gal of plutonium-contaminated liquid between 1958 and 1967. The 903 Pad was removed, and excavation was a 13-month project that was completed by December 2003. More than 32,000 tons of plutonium-contaminated soil and asphalt were removed from the pad area during that period. It was one of the largest and most visible environmental restoration projects at RFP (KHC 2003g).

D&D continued on the 903 Pad Lip Area (36 acres east of the pad that had been affected by wind-dispersed contamination) and was completed by September 2004 (KHC 2004i).

2.5.8 Building 991

The west tunnels and three vaults were closed on April 23, 2003 (KHC 2003l), but a fire had occurred in one tunnel during closure on February 12, 2003. The cause was determined to be smoldering foam (foam had been used to permanently fill and seal the tunnels) (KHC 2004f). No personal exposure to radiation resulted from this incident because no radioactive material was present in that area (KHC 2004f).

The last TRU waste shipment from Building 991 occurred on September 12, 2003 (KHC 2003m). Remaining tunnels were closed and full-scale demolition of Building 991 began on March 9, 2004 (KHC 2004f). By March 24, 2004, essentially all of Building 991 had been demolished (KHC 2004j).

2.5.9 Other Buildings

The following information was located for buildings that did not fall into the major D&D groups. All details found have been provided in chronological order.

- Building 779 was demolished in January 2000 (KHC 2003f).
- Remediation of the Solar Ponds was completed in January 2003 (KHC 2003b). The ponds were emptied and soil, building slabs, supporting equipment, and pumps were removed. Clean soil was used as backfill for the ponds. Topsoil was added and the area was reseeded in March 2003 (KHC 2003b).
- The following structures were demolished as of March 12, 2003 (KHC 2003n): Building 112, T441A, T121A, T886D, Building 992, Building 449, Building 449A, Building 449C, shed 449, Building 427, Building 427A, Building 453, and the paint shed of Building 444.
- The 280 landfill was closed by January 29, 2003 (KHC 2003o).
- Building 441 was demolished on March 13, 2003 (KHC 2003h).
- Building 443 was demolished on June 14, 2004 (KHC 2004h).
- The following structures were demolished as of October 1, 2003 (KHC 2003i): 790, 112, 441, 334, 55, 552, 865, PACs 2, and valve vaults of Building 428.
- The Water Tower was removed on November 8, 2003 (KHC 2003k).
- Three guard towers were removed in 2002, the last in November 2003 (KHC 2003k).
- Building 779 was demolished as of March 2004 but the exact date is unclear (KHC 2004k).
- Buildings 130 and 131 were demolished in March and April of 2004 (KHC 2004l). These buildings housed offices, administrative functions, and a kitchen.
- The nitrogen plant, Building 223, was demolished on May 11, 2004 (KHC 2004h).
- Additional FY 2004 demolitions were Buildings 116, 119, 128, and 443, and Trailers T119B and T117A.
- The last TRU waste shipment from Building 664 left the site on July 30, 2004 (KHC 2004c). Building 664 was demolished on November 6, 2004 (KHC 2004d).
- Building 750 (the cafeteria) was demolished on August 10, 2004 (KHC 2004m).
- Demolition of Buildings 121 and 122 started on September 13, 2004, and ended within days (KHC 2004i).
- The Firing Range was demolished on October 12, 2004 (KHC 2004n).
- The Building 447 Foundry was demolished by November 2004 (KHC 2004n).
- Building 331 (Fire Department) closed on July 1, 2005 (KHC 2005e) and was demolished in late July (KHC 2005f).

- The last buildings on the site were T130H (demolished September 9, 2005) and T130 (demolished September 8, 2005) (KHC 2005g).

2.6 ATTRIBUTIONS AND ANNOTATIONS

All information requiring identification was addressed via references integrated into the reference section of this document.

REFERENCES

AEC (U.S. Atomic Energy Commission), 1975, *Operational Accidents and Radiation Exposure Experience Within the United States Atomic Energy Commission, 1943 - 1975*, WASH-1192 (Rev.), Washington, D.C., Fall. [SRDB Ref ID: 79427]

ChemRisk, 1992, *Project Tasks 3 & 4, Final Draft Report, Reconstruction of Historical Rocky Flats Operations & Identification of Release Points,* Alameda, California, August. [SRDB Ref ID: 8016]

ChemRisk, 1994a, *Project Task 5 Report, Estimating Historical Emissions from Rocky Flats 1952–1989*, Alameda, California, March. [SRDB Ref ID: 8017]

ChemRisk, 1994b, *Project Task 8 Report, Dose Assessment for Historical Contaminant Releases from Rocky Flats*, Alameda, California, September. [SRDB Ref ID: 8018]

Conner, W. V., and D. L. Baaso, 1981, *Neptunium Processing at the Rocky Flats Plant*, RFP-2899, R.D. Howerton, editor, Rockwell International, Rocky Flats Plant, Golden, Colorado, September 20. [SRDB Ref ID: 24722, p. 7]

Conner, W. V., and D. L. Baaso, 1984, "Chapter 15, Neptunium Recovery Process," *Actinide Processing at Rocky Flats*, Navratil, J. D., and F. J. Miner, editors, Rockwell International, Rocky Flats Plant, Golden, Colorado, July 1. [SRDB Ref ID: 24798, p. 327]

DeMaiori, A. W., 2005, untitled letter to National Institute for Occupational Safety and Health, United Steelworkers of America, Local 8031, Golden, Colorado, February 15. [SRDB Ref ID: 26757]

DOE (U.S. Department of Energy), 1980, *Final Environmental Impact Statement, Rocky Flats Plant Site, Golden, Jefferson County, Colorado*, DOE/EIS-064, Washington, D.C., April. [SRDB Ref ID: 11505]

DOE (U.S. Department of Energy), 1992, *Final Rocky Flats Plant Sitewide Process Descriptions, Material Mass Balances, and Operational Emissions Support Document, Volume I, Methodology and Process Descriptions*, Rocky Flats Environmental Technology Site, Golden, Colorado, March 31. [SRDB Ref ID: 104880]

DOE (U.S. Department of Energy), 1996a, *Preliminary Notice of Violation and Proposed Imposition of Civil Penalty*, EA 96-05, Rocky Flats Environmental Technology Site, Golden, Colorado. [SRDB Ref ID: 176595, p. 5]

DOE (U.S. Department of Energy), 1996b, *Preliminary Notice of Violation and Proposed Imposition of Civil Penalty*, EA 96-05, Rocky Flats Environmental Technology Site, Golden, Colorado. [SRDB Ref ID: 176596, p. 5]

DOE (U.S. Department of Energy), 1997a, *Preliminary Notice of Violation NTS-RFO--KHLL-ENVOPS-1996-0001*, EA 97-03, Rocky Flats Environmental Technology Site, Golden, Colorado. [SRDB Ref ID: 176597, p. 5]

DOE (U.S. Department of Energy), 1997b, *Preliminary Notice of Violation NTS-RFO--KHLL-ENVOPS-1996-0001*, EA 97-04, Rocky Flats Environmental Technology Site, Golden, Colorado. [SRDB Ref ID: 176598, p. 5]

DOE (U.S. Department of Energy), 1998, *Enforcement Action 98-03, Consent Order Incorporating Agreement Between U.S. Department of Energy and Kaiser-Hill Company, L.L.C.*, NTS-RFO-KHLL, Office of Enforcement and Investigation, Rocky Flats Environmental Technology Site, Golden, Colorado. [SRDB Ref ID: 175116, p. 4]

DOE (U.S. Department of Energy), 2000, *Report on the Flow of Recycled Uranium at the Department of Energy's Rock Flats Plant 1953-1993*, Rocky Flats Environmental Technology Site, Golden, Colorado, June 30. [SRDB Ref ID: 16227, p. 5]

DOE (U.S. Department of Energy), 2001a, *Building 776/777 Closure Project Decommissioning Operations Plan*, Rev. 0, Mod #7, Rocky Flats Environmental Technology Site, Golden, Colorado, June 27. [SRDB Ref ID: 24494]

DOE (U.S. Department of Energy), 2001b, *Building 371/374 Closure Project Decommissioning Operations Plan*, Rev. 0, Rocky Flats Environmental Technology Site, Golden, Colorado, March 26. [SRDB Ref ID: 24482]

DOE (U.S. Department of Energy), 2002, *Building 707 Closure Project Decommissioning Operations Plan*, MSF-070-01, Rev. 0, Mod. #2, Rocky Flats Environmental Technology Site, Golden, Colorado, March 26. [SRDB Ref ID: 24483]

DOE (U.S. Department of Energy), 2003, *771 Closure Project Decommissioning Operations Plan*, Modification 5, Rocky Flats Environmental Technology Site, Golden, Colorado, August 25. [SRDB Ref ID: 24491]

Grogan, H. A., P. A. McGavran, K. R. Meyer, H. R. Meyer, J. Mohler, A. S. Rood, W. K. Sinclair, P. G. Voillequé, J. M. Weber, and J. E. Till, 1999, *Final Report, Technical Summary Report for the Historical Public Exposures Studies for Rocky Flats Phase II*, RAC Report No. 14-CDPHE-RFP-1999-FINAL, Radiological Assessments Corporation, Neeses, South Carolina, September. [SRDB Ref ID: 7994]

KHC (Kaiser-Hill Company), 2003a, *endvision*, volume 9, number 12, Broomfield, Colorado, June 18. [SRDB Ref ID: 24600]

KHC (Kaiser-Hill Company), 2003b, *endvision*, volume 9, number 2, Broomfield, Colorado, January 29. [SRDB Ref ID: 24514]

KHC (Kaiser-Hill Company), 2003c, *endvision*, volume 9, number 17, Broomfield, Colorado, September 3. [SRDB Ref ID: 24604]

KHC (Kaiser-Hill Company), 2003d, *endvision*, volume 9, number 13, Broomfield, Colorado, July 2. [SRDB Ref ID: 24601]

KHC (Kaiser-Hill Company), 2003e, *endvision*, volume 9, number 16, Broomfield, Colorado, August 19. [SRDB Ref ID: 24603]

KHC (Kaiser-Hill Company), 2003f, *endvision*, volume 9, number 21, Broomfield, Colorado, November 14. [SRDB Ref ID: 24617]

KHC (Kaiser-Hill Company), 2003g, *endvision*, volume 9, number 23, Broomfield, Colorado, December 17. [SRDB Ref ID: 24619]

KHC (Kaiser-Hill Company), 2003h, *endvision*, volume 9, number 6, Broomfield, Colorado, March 26. [SRDB Ref ID: 24593]

KHC (Kaiser-Hill Company), 2003i, *endvision*, volume 9, number 19, Broomfield, Colorado, October 1. [SRDB Ref ID: 24606]

KHC (Kaiser-Hill Company), 2003j, *endvision*, volume 9, number 11, Broomfield, Colorado, June 4. [SRDB Ref ID: 24599]

KHC (Kaiser-Hill Company), 2003k, *endvision*, volume 9, number 22, Broomfield, Colorado, November 25. [SRDB Ref ID: 24618]

KHC (Kaiser-Hill Company), 2003l, *endvision*, volume 9, number 7, Broomfield, Colorado, April 23. [SRDB Ref ID: 24596]

KHC (Kaiser-Hill Company), 2003m, *endvision*, volume 9, number 20, Broomfield, Colorado, October 22. [SRDB Ref ID: 24616]

KHC (Kaiser-Hill Company), 2003n, *endvision*, volume 9, number 5, Broomfield, Colorado, March 12. [SRDB Ref ID: 24518]

KHC (Kaiser-Hill Company), 2003o, *endvision*, volume 9, number 1, Broomfield, Colorado, January 8. [SRDB Ref ID: 24513]

KHC (Kaiser-Hill Company), 2004a, *endvision*, volume 10, number 11, Broomfield, Colorado, July 26. [SRDB Ref ID: 24711]

KHC (Kaiser-Hill Company), 2004b, *endvision*, volume 10, number 3, Broomfield, Colorado, February 19. [SRDB Ref ID: 24696]

KHC (Kaiser-Hill Company), 2004c, *endvision*, volume 10, number 12, Broomfield, Colorado, August 12. [SRDB Ref ID: 24712]

KHC (Kaiser-Hill Company), 2004d, *endvision*, volume 10, number 17, Broomfield, Colorado, December 1. [SRDB Ref ID: 24717]

KHC (Kaiser-Hill Company), 2004e, *endvision*, volume 10, number 18, Broomfield, Colorado, December 15. [SRDB Ref ID: 24499]

KHC (Kaiser-Hill Company), 2004f, *endvision*, volume 10, number 5, Broomfield, Colorado, March 16. [SRDB Ref ID: 24700]

KHC (Kaiser-Hill Company), 2004g, *endvision*, volume 10, number 15, Broomfield, Colorado, October 20. [SRDB Ref ID: 24715]

KHC (Kaiser-Hill Company), 2004h, *endvision*, volume 10, number 9, Broomfield, Colorado, June 23. [SRDB Ref ID: 24709]

KHC (Kaiser-Hill Company), 2004i, *endvision*, volume 10, number 14, Broomfield, Colorado, September 30. [SRDB Ref ID: 24714]

KHC (Kaiser-Hill Company), 2004j, *endvision*, volume 10, number 6, Broomfield, Colorado, March 25. [SRDB Ref ID: 24701]

KHC (Kaiser-Hill Company), 2004k, *endvision*, volume 10, number 4, Broomfield, Colorado, March 3. [SRDB Ref ID: 24697]

KHC (Kaiser-Hill Company), 2004l, *endvision*, volume 10, number 7, Broomfield, Colorado, May 10. [SRDB Ref ID: 24704]

KHC (Kaiser-Hill Company), 2004m, *endvision*, volume 10, number 13, Broomfield, Colorado, September 7. [SRDB Ref ID: 24713]

KHC (Kaiser-Hill Company), 2004n, *endvision*, volume 10, number 16, Broomfield, Colorado, November 3. [SRDB Ref ID: 24716]

KHC (Kaiser-Hill Company), 2005a, *endvision*, volume 11, number 1, Broomfield, Colorado, January 19. [SRDB Ref ID: 24509]

KHC (Kaiser-Hill Company), 2005b, *endvision*, volume 11, number 3, Broomfield, Colorado, May 11. [SRDB Ref ID: 24511]

KHC (Kaiser-Hill Company), 2005c, *endvision*, volume 11, unnumbered, Broomfield, Colorado, June 15. [SRDB Ref ID: 24512]

KHC (Kaiser-Hill Company), 2005d, *endvision*, volume 11, number 2, Broomfield, Colorado, April 18. [SRDB Ref ID: 24510]

KHC (Kaiser-Hill Company), 2005e, *endvision*, volume 11, number 5, Broomfield, Colorado, June 30. [SRDB Ref ID: 24718]

KHC (Kaiser-Hill Company), 2005f, *endvision*, volume 11, number 6, Broomfield, Colorado, August 10. [SRDB Ref ID: 24719]

KHC (Kaiser-Hill Company), 2005g, *endvision*, volume 11, number 7, Broomfield, Colorado, September 19. [SRDB Ref ID: 24720]

McLaughlin, T. P., S. P. Monahan, and N. L. Pruvost, 2000, *A Review of Criticality Accidents*, LA-13638, Los Alamos National Laboratory, Los Alamos, New Mexico, May. [SRDB Ref ID: 895]

Meyer, H. R., S. K. Rope, T. F. Winsor, P. G. Voillequé, K. R. Meyer, L. A. Stetar, J. M. Weber, and J. E. Till, 1996, *Final Report, The Rocky Flats Plant 903 Area Characterization*, RAC Report 2-CDPHE-RFP-1996-FINAL, Radiological Assessments Corporation, Neeses, South Carolina, December. [SRDB Ref ID: 8001]

Meyer, K. R., and J. E. Till, 1999, *Final Report, Characterization of Releases to Surface Water from the Rocky Flats Plant*, RAC Report 7-CDPHE-RFP-1996-FINAL, Rev. 1, Radiological Assessments Corporation, Neeses, South Carolina, August. [SRDB Ref ID: 7969]

NIOSH (National Institute for Occupational Safety and Health), 2002, *Internal Dose Reconstruction Implementation Guideline*, OCAS-IG-002, Rev. 0, Office of Compensation Analysis and Support, Cincinnati, Ohio, August. [SRDB Ref ID: 22402]

NIOSH (National Institute for Occupational Safety and Health), 2007, *External Dose Reconstruction Implementation Guideline*, OCAS-IG-001, Rev. 3, Office of Compensation Analysis and Support, Cincinnati, Ohio, November 21. [SRDB Ref ID: 38864]

NIOSH (National Institute for Occupational Safety and Health), 2010, *Radiation Exposures Covered for Dose Reconstructions Under Part B of the Energy Employees Occupational Illness Compensation Program Act*, DCAS-IG-003, Rev. 1, Division of Compensation Analysis and Support, Cincinnati, Ohio, October 5. [SRDB Ref ID: 88929]

NIOSH (National Institute for Occupational Safety and Health), 2013, *SEC Petition Evaluation Report, Petition SEC-00192*, Office of Compensation Analysis and Support, Cincinnati, Ohio, September 30. [SRDB Ref ID: 132776]

ORAUT (Oak Ridge Associated Universities Team), 2012, *Site Profile and Technical Basis Document Development,* ORAUT-PROC-0031, Rev. 04, Oak Ridge, Tennessee, November 5. [SRDB Ref ID: 166849]

ORAUT (Oak Ridge Associated Universities Team), 2019, *Rocky Flats Plant – Occupational External Dose*, ORAUT-TKBS-0011-6, Rev. 03, Oak Ridge, Tennessee, January 14. [SRDB Ref ID: 175317]

ORAUT (Oak Ridge Associated Universities Team), 2020a, *Rocky Flats Plant – Occupational Environmental Dose*, ORAUT-TKBS-0011-4. Rev. 03, Oak Ridge, Tennessee, September 1. [SRDB Ref ID: 180379]

ORAUT (Oak Ridge Associated Universities Team), 2020b, *Rocky Flats Plant – Occupational Internal Dose*, ORAUT-TKBS-0011-5, Rev. 04, Oak Ridge, Tennessee, September 1. [SRDB Ref ID: 178626]

Putzier, E. A., 1982, *The Past 30 Years at Rocky Flats Plant*, Rockwell International, Rocky Flats Plant, Golden, Colorado, November. [SRDB Ref ID: 4632]

RFETS (Rocky Flats Environmental Technology Site), 1981–2005, collection of occurrence reports, Golden, Colorado. [SRDB Ref IDs: 17811 to 17837]

RFETS (Rocky Flats Environmental Technology Site), 1993, *Registry of Radioactive Sealed Sources and Devices, Safety Evaluation of Device*, NR-220-D-107-S, Rocky Flats Plant, Golden, Colorado, June 29. [SRDB Ref ID: 165234]

RFETS (Rocky Flats Environmental Technology Site), 1999, *Radioactive Source Report,* Reg. No. 105, Rocky Flats Plant, Golden, Colorado, June 17. [SRDB Ref ID: 165236]

Voillequé, P. G, and J. E. Till, 1999a, *Final Report, Estimated Airborne Releases of Plutonium During the 1957 Fire in Building 71*, RAC Report 10-CDPHE-RFP-1999-FINAL, Radiological Assessments Corporation, Neeses, South Carolina, August. [SRDB Ref ID: 8006]

Voillequé, P. G, and J. E. Till, 1999b, *Final Report, Estimated Airborne Releases of Plutonium During the 1969 Fire in Buildings 776-777*, RAC Report 9-CDPHE-RFP-1999-FINAL, Radiological Assessments Corporation, Neeses, South Carolina, August. [SRDB Ref ID: 8779, p. 6]

Voillequé, P. G, and J. E. Till, 1999c, *Final Report, Review of Routine Releases of Plutonium in Airborne Effluents at Rocky Flats*, RAC Report 6-CDPHE-RFP-1998-FINAL, Radiological Assessments Corporation, Neeses, South Carolina, August. [SRDB Ref ID: 8007]

Weber, J. M., A. S. Rood, H. R. Meyer, and J. E. Till, 1999, *Final Report, Development of the Rocky Flats Plant 903 Area Plutonium Source Term*, RAC Report 8-CDPHE-RFP-1998-FINAL, Rev. 1, Radiological Assessments Corporation, Neeses, South Carolina, August. [SRDB Ref ID: 8012]

GLOSSARY

alloy
A mixture of two or more materials with one or more of components of the mixture being a metal.

alpha particle (α)
See *alpha radiation*.

alpha radiation
Positively charged particle emitted from the nuclei of some radioactive elements. An alpha particle consists of two neutrons and two protons (a helium nucleus) and has an electrostatic charge of +2.

criticality
State of a radioactive mass (e.g., the core of a nuclear reactor) when the fission reaction becomes self-sustaining.

curie (Ci)
Traditional unit of radioactivity equal to 37 billion (3.7×10^{10}) becquerels, which is approximately equal to the activity of 1 gram of pure ^{226}Ra.

dose equivalent
In units of rem or sievert, product of absorbed dose in tissue multiplied by a weighting factor and sometimes by other modifying factors to account for the potential for a biological effect from the absorbed dose.

dosimeter
Device that measures the quantity of received radiation, usually a holder with radiation-absorbing filters and radiation-sensitive inserts packaged to provide a record of absorbed dose received by an individual. See *thermoluminescent dosimeter*.

dosimetry
Measurement and calculation of internal and external radiation doses.

exposure
(1) In general, the act of being exposed to ionizing radiation. (2) Measure of the ionization produced by X- and gamma-ray photons in air in units of roentgens.

fission
Splitting of the nucleus of an atom (usually of a heavy element) into at least two other nuclei and the release of a relatively large amount of energy. This transformation usually releases two or three neutrons.

fissionable
Capable of undergoing fission by capturing neutrons, including fast neutrons. Uranium-238 is fissionable. Fissionable indicates both spontaneous and induced fission.

gamma radiation
Electromagnetic radiation (photons) of short wavelength and high energy (10 kiloelectron-volts to 9 megaelectron-volts) that originates in atomic nuclei and accompanies many nuclear reactions (e.g., fission, radioactive decay, and neutron capture). Gamma photons are identical to X-ray photons of high energy; the difference is that X-rays do not originate in the nucleus.

high-efficiency particulate air (HEPA) filter
Dense filter that removes contaminants from air flows before return to the working environment or discharge to the outside air (exhaust).

hydrofluorination
Chemical conversion of a substance to a form containing fluorine.

isotope
One of two or more atoms of a particular element that have the same number of protons (atomic number) but different numbers of neutrons in their nuclei (e.g., ^{234}U, ^{235}U, and ^{238}U). Isotopes have very nearly the same chemical properties.

neutron radiation
Radiation that consists of free neutrons unattached to other subatomic particles emitted from a decaying radionuclide. Neutron radiation can cause further fission in fissionable material such as the chain reactions in nuclear reactors, and nonradioactive nuclides can become radioactive by absorbing free neutrons.

neutron, fast
A neutron with energy equal or greater than 10 kiloelectron-volts.

neutron, intermediate
A neutron with energy between 0.5 kiloelectron-volts and 10 kiloelectron-volts.

neutron, thermal
Strictly, a neutron in thermal equilibrium with surroundings. In general, a neutron with energy less than about 0.5 electron-volt.

oralloy
Uranium enriched to 40% or 93% ^{235}U. The name derives from Oak Ridge alloy.

photon
Quantum of electromagnetic energy generally regarded as a discrete particle having zero rest mass, no electric charge, and an indefinitely long lifetime. The entire range of electromagnetic radiation that extends in frequency from 10^{23} cycles per second (hertz) to 0 hertz.

pit
Package at the center of an implosion weapon that contains the machined fissile material that begins the fission chain reaction. Also called primary.

radiation
Subatomic particles and electromagnetic rays (photons) with kinetic energy that interact with matter through various mechanisms that involve energy transfer.

radioactivity
Property possessed by some elements (e.g., uranium) or isotopes (e.g., ^{14}C) of spontaneously emitting energetic particles (electrons or alpha particles) by the disintegration of their atomic nuclei.

radionuclide
Radioactive nuclide.

rem

Traditional unit of radiation dose equivalent that indicates the biological damage caused by radiation equivalent to that caused by 1 rad of high-penetration X-rays multiplied by a quality factor. The sievert is the International System unit; 1 rem equals 0.01 sievert. The word derives from roentgen equivalent in man; rem is also the plural.

salt scrub

Process that removes americium and plutonium from the products of molten salt extraction.

shielding

Material or obstruction that absorbs ionizing radiation and tends to protect personnel or materials from its effects.

site returns

At Rocky Flats, weapons components returned from other sites for disassembly and recovery of materials.

thermoluminescent dosimeter (TLD)

Device for measuring radiation dose that consists of a holder containing solid chips of material that, when heated, release the stored energy as light. The measurement of this light provides a measurement of absorbed dose. TLDs replaced film dosimeters at essentially all U.S. Department of Energy sites beginning in the 1960s.

transuranic (TRU) elements

Elements with atomic numbers above 92 (uranium). Examples include plutonium and americium.

trigger

(1) Fissionable core of nuclear weapon. (2) To start a fusion energy release. See *pit*.

U.S. Atomic Energy Commission (AEC)

Federal agency created in 1946 to assume the responsibilities of the Manhattan Engineer District (nuclear weapons) and to manage the development, use, and control of nuclear energy for military and civilian applications. The U.S. Energy Research and Development Administration and the U.S. Nuclear Regulatory Commission assumed separate duties from the AEC in 1974. The U.S. Department of Energy succeeded the U.S. Energy Research and Development Administration in 1979.

X-ray

See *X-ray radiation.*

X-ray radiation

Electromagnetic radiation (photons) produced by bombardment of atoms by accelerated particles. X-rays are produced by various mechanisms including bremsstrahlung and electron shell transitions within atoms (characteristic X-rays). Once formed, there is no difference between X-rays and gamma rays, but gamma photons originate inside the nucleus of an atom.

ATTACHMENT A
BUILDINGS AND OPERATIONS

Buildings 122 and 122S

1953 Building constructed. Use designated as medical.

Building 218

Building 218 was actually two 10,000-gal aboveground nonradioactive nitric acid storage tanks.

Building 371: Plutonium Recovery Facility

1968 A decision was made to replace the Plutonium Recovery Facility (Building 771) with a new building (Building 371).

1972 Construction began on Building 371.

1976 Building 371 originally scheduled for startup.

1978 Some equipment moved to Building 371.

1981 Pilot-scale operations conducted. Due to engineering design problems, production processes in this building never operated beyond pilot scale. Plutonium recovery (electrorefining) operations remained in Building 771.

1982–1989 No accidents of any significance occurred in this building. In addition, effluent emissions were most likely of little significance to the offsite population because this building only ran on a pilot-scale basis. Monitoring data for radionuclides are available for the life of this building. Emissions data are available for tritium, ^{238}Pu, $^{239/240}$Pu, ^{241}Am, $^{233/234}$U, and ^{238}U through 1989.

Building 374: Process Waste Treatment Facility

1978 Building brought on line as the process waste treatment facility for many of the production buildings. Emissions data available for tritium, ^{238}Pu, $^{239/240}$Pu, ^{241}Am, $^{233/234}$U, and ^{238}U through 1991.

1980 Second stage of HEPA filters added.

1986–1988 An increase in waste load.

1988–1989 Condensate from the evaporator went to the cooling tower and was discharged to Pond B5. In 1989 this discharge was remedied by not allowing the cooling tower to overflow.

1991 The waste treatment facility supported the cleanup of the solar evaporation ponds and processing waste for Buildings 122, 123, 443, 444, 460, 559, 707, 774, 776, 778, 779, 865, 881, 883, and 889.

Building 439: Modification Facility

1971 Building constructed. Building 439 housed a machine shop, upholstery shop, battery, and office space for Building 439/440 support personnel. No radionuclides were known to have been handled here.

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

Building 440: Fabrication Facility

1971 Building constructed. Building 440 was a fabrication facility for rebuild and rework operations to modify and maintain DOE vehicles and rail cars. Operations in the building included metalworking, painting, electrical fabrication, and assembly. No radioactive material is known to have been present.

Buildings 444, 445, 450, and 455: Depleted Uranium and Beryllium Metallurgy

1953 Building 444 came on line in August, beginning DU processing.

1957 Building 445 added.

1958 Beryllium operations began in Building 444. Blanks received from commercial supplier were machined.

1968 Buildings 444 and 445 connected.

1980 Beryllium casting ended.

1981 Production plating laboratory began operations.

1983 Construction of new filter system for Building 444.

1984–1985 New filter system came on line.

1987 Titanium stripping began.

1989 Uranium foundry shut down.

1990 Production plating lab shut down after a fire.

Building 450. Date of construction unknown. Building 450 housed the exhaust filter plenum and exhaust fans that handled a major portion of the air exhausted from Building 444. The plenum was comprised of a demister section and two stages of HEPA filters. Each stage contained 192 HEPA filter units mounted 32 units wide by 6 units high. Three exhaust fans pulled the exhaust air through the filter plenum and discharged the air through vent 200 to the atmosphere. Additional facility history and/or equipment modification details are not available.

Building 455. Date of construction unknown. This building was an exterior exhaust filter plenum consisting of a demister section and two stages of HEPA filtration. The plenum served the production plating laboratory in Building 444. Each stage contained 16 HEPA filter units mounted 4 units high by 4 units wide. The exhaust fan for the plenum exhaust system was mounted on the roof of Building 444. The fan discharged through vent 82 to the atmosphere.

Foundry. Eight vacuum induction furnaces were used to produce ingots from scrap DU, DU alloys, silver, aluminum, and copper. Casting processes produced small quantities of particulates from mold coating compounds and metal oxidation reactions. All off gases discharged through the Building 44 exhaust system to the Building 450 exhaust filter plenum vent 200. Particulate emission control consisted of two stages of HEPA filtration.

Mold Cleaning. Graphite molds used in the foundry area in Building 444 for casting ingots were manually cleaned using wire brushes and other hand tools. The molds were recycled for reuse.

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

Residual material in the mold after ingot removal included Y_2O_3, DU oxide, graphite, and trace quantities of iron, silica, and other cast metals. This material was collected and transferred by house vacuum to a cyclone collector in the Building 444 Utilities Area. The cyclone collector was 85% efficient in removing particles greater than 15 microns. According to plant personnel, approximately 5% of the material was less than 15 microns. Particulates from mold cleaning discharged through vent 200 after passing through a vacuum cyclone separator and two stages of HEPA filtration.

Robot Crucible Cleaning. A robot device in Building 444 cleaned the graphite crucibles used for heating and melting metals in foundry furnaces. The removed residue contained DU oxide with trace amounts of iron, silica Y_2O_3, graphite, and other cast metals from the crucible. Controls consisted of the cyclone separator and two stages of HEPA filtration.

Depleted Uranium Machining. DU machining operations in Building 444 included turning, facing, boring, milling, and sawing using numerically controlled lathes and conventional machine tools. Parts were fabricated from DU, DU alloy, DU with trace amounts of iron, silica, aluminum, and stainless steel.

Buildings 447, 448, and 451

1956 Building 447 constructed. Manufacturing building for a variety of uranium and beryllium parts for production or special orders.

1962 Building 448 constructed. Shipping, receiving, and storage building. Handling of radioactive materials not indicated in information reviewed.

1983 Construction of a new filter system for Building 447.

Building 451. Exhaust Filter Plenum Building served processes and facilities in Buildings 447 and 448.

Electron Beam Welding. An electron beam welder was used for welding vanadium, beryllium, aluminum, DU, and stainless steel. Welding operations were performed inside a vacuum chamber.

ECM Operations. The ECM machine was used for a variety of production and special order jobs. Some work involved milling tungsten, brass, copper, aluminum, and DU.

Vacuum Arc Melt Furnace. The vacuum arc melt furnace was used to melt material for casting consumable electrodes in 6-in. and 8-in. diameter copper molds. The metals melted include DU and DU alloy with 6% niobium. The molds could be up to 5 ft long.

Chip Roaster. The chip roaster was used to oxidize DU scrap metal. The chip roaster was a four-tier single chamber vertical roaster.

Building 460: Consolidated Manufacturing Facility

1984 Building constructed. This building was a non-nuclear facility for war reserve and special order parts and assemblies.

Building 549

1957 Building constructed. This building contained the alarm systems.

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

1991 This building was used exclusively as an electrical maintenance shop and general staging support.

Building 559 and 561: Plutonium Analytical Laboratory

1968 Building constructed. The building contained laboratory facilities for conducting spectrochemical, chemical, and mass spectrometric analyses. Provided analytical support to SNM management projects.

1973 Building 561 constructed. This building housed the exhaust plenums for Building 559. Metals, liquids, oxides, oils, and sludges were analyzed for uranium content.

Plutonium Oxidation. Plutonium scraps and oxides remaining after sample analyses were oxidized in one of two gloveboxes before shipping the PuO_2 to another process on the plant. Scrap and oxide from all processes were collected in the two gloveboxes, and the oxidation process was run as needed (about once a month).

Building 566: Laundry Facility

Construction date unknown. This building was designed as a laundry facility for clothing and respirators contaminated with radioactive materials.

Building 701: Waste Treatment R&D Facility

1965 Building constructed. Pilot Plant Development. Building 701 was an R&D facility used to design, build, and evaluate bench scale and pilot scale waste handling and treatment processes.

Building 705: Coatings Laboratory

1966 Building constructed. This building included coatings laboratories and associated offices. No evidence of radioactive materials use in Building 705 was found:

- Vapor deposition,
- Beryllium vapor deposition,
- Parts cleaning,
- Beryllium parts cleaning,
- Polishing,
- Sand blasting, and
- Water cooling.

Building 707: Plutonium Fabrication/Pyrochemical Operations

1972 Construction completed. This building provided metallurgical support in the form of foundry and casting operations, as well as product assembly. The machining and foundry operations for plutonium came from Building 776 after the 1969 fire. Plutonium was stored in the building on an interim basis.

Plutonium Fabrication/Pyrochemical Operations. This building contained foundry and casting operations and products assembly.

Module A–Casting Operations. Carbon tetrachloride was used to clean interior glovebox walls in the location of casting furnaces where plutonium ingots were made.

Module J–Casting Operations. Plutonium ingots were made.

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

Module K–Casting Operations and Stacker Retriever. This operation stored and retrieved plutonium metal for distribution to other processes. Metal was weighed, melted in a furnace, and formed into ingots.

Module B–Rolling and Forming. This process involved the forming and thermal treatment of plutonium metal ingots.

Module C–Briquetting. Metal turnings from Module C machining process and Module B scrap cutters were put in metal baskets and dipped in five carbon tetrachloride baths.

Module C–Machining Operations. Plutonium parts were machined.

Modules C and D–Inspection. Parts were cleaned with carbon tetrachloride.

Casting Operations–Module A. Plutonium ingots were cast into feed or production ingots in Casting Operations. Ingots were transported by enclosed, interconnected chain conveyors from storage to the foundry gloveboxes. The ingots were placed in crucibles and melted in electric induction furnaces, which operated under vacuum. Metal was poured through a funnel into the molds, which were allowed to cool. Crucibles and funnels were scraped clean and reused until worn.

Casting Operations–Module J. Two types of particulate emissions resulted from operations in this module. The first was from plutonium oxidation and the second was from casting operations.

Casting Operations and Stacker Retriever–Module K. Module K contained the stacker retriever, also known as the X-Y retriever, and casting furnaces. These operations were performed in an inert nitrogen atmosphere. The stacker retriever was used to store and retrieve plutonium metal for distribution to other processes in Building 707.

Module E, Assembly Operations. Cleaning of plutonium parts.

Module F, Assembly Superdry. Cleaning of plutonium parts before they were assembled and welded into a weapons product.

Module G, Assembly Welding and Cleaning. Ultrasonic cleaner used to clean plutonium parts after welding.

Module G, Assembly Electron Bombardment Brazing/Scanning. Cleaning of waste materials deposited on the walls of a bell jar during brazing of metals in the jar.

Module H Assembly Testing. Cleaning parts before testing.

Modules D, E, and G. Assembly ultrasonic cleaners.

Room 173, Radiography. Cleaning plutonium parts before radiography (X-ray examination of parts).

Module D, Weighing. Cleaning before weighing of parts.

Module E, Eddy Current Testing. To check the depth of weld penetration on plutonium parts moved to and from gloveboxes.

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

Weld Scanners and Fluorescent Penetrant Operations. Area used to qualify welds on plutonium parts.

Module D, Production Control Operations. Cleaning plutonium parts after grit blasting.

Modules D and G, Calibration Laboratory. Cleaning gauges before precision measurements.

Building 771: Plutonium Recovery Operations

1953	Building constructed. The principal operation of Building 771 was the recovery of plutonium from plutonium-bearing residues.
1957	Americium line started.
1958	Carbon tetrachloride distilled out of the cutting oil and plutonium recovered from solids. The cutting oil and carbon tetrachloride mixture came from plutonium machining in Building 776.
1958–1988	Incinerator used for the recovery of fissile material.
1953–1959	Plutonium–uranium extraction process used for plutonium purification.
1959	Began using ion exchange for plutonium purification.
1968	Caustic scrubber installed.
1963–1975	Ammonium thiocyanate used for recovery of americium.
1975–1980s	Oxalate precipitation process used for recovery of americium.
Early 1980s	Discontinued americium purification but not recovery.

Building 771 was designed for plutonium recovery from scrap or residue materials. Recovery operations were terminated in 1989. The facility was also used for the interim storage of large quantities of SNM and waste, laboratory analyses, HEPA filter counting, low specific activity counting, and conduct of risk reduction activities. In addition the building was used to solidify ion exchange resins through cementation and used microwave vitrification for solid residue treatment.

Dissolution. Dissolution processes were all similar in concept. The equipment consisted of a series of cascade dissolver vessels. Plutonium-bearing material was fed into the first dissolver at a controlled rate by a special screw feeder.

Feed Evaporation. Feed evaporation was used to concentrate some solutions from previous operations. Concentration of these solutions was necessary to yield precipitation feed of an acceptable plutonium concentration.

Peroxide Precipitation. The peroxide precipitation process converted the plutonium pit in solution to a solid form.

Chemical Technology. Plutonium chemistry technology in Building 771 supported and developed improved methods for recovering, separating, and purifying actinides from acidic streams.

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

Calcination. The calcination process converted PuO_4 to PuO_2 and drove out residual water and HNO_3, leaving a dry, powdered product. The primary contaminant released from calcination was PuO_2 particulates.

Hydrofluorination. Plutonium oxide was converted to plutonium tetrafluoride (PuF_4) in a continuous rotary-tube hydrofluorinator.

Plutonium Oxidation. Plutonium oxidation converted pure plutonium metal, which is pyrophoric, to a more stable PuO_2. The PuO_2 was used as a feed to the dissolution operation.

Plutonium Metallurgy and Research and Air Emissions. The plutonium metallurgy group assisted the design agency and plant production in the development of processes that required metallurgical production of materials and related techniques. All plutonium metallurgy operations were conducted in gloveboxes.

Building 774: Process Waste Treatment Facility

1953 Building constructed to support Building 771. Originally designed as a nuclear waste packaging facility, used for low-level liquid waste treatment operations. Modifications and additions in 1963, 1965, 1966, 1967, 1970, and 1974.

1981 Converted to storage for Building 771 (drums).

Radioactive Decontamination Treatment. Nitric acid was used in the first stage of this process. This caustic precipitation process reduced plutonium and americium concentrations.

Caustic Precipitation. This process was the first stage in radioactive decontamination treatment. It was designed to reduce the plutonium and americium concentrations.

OASIS (organic and sludge immobilization system). TRU waste from 707 and 776/777. 1,1,1-trichloroethane (TCA) oils mixed with carbon tetrachloride were solidified with gypsum cement in a glovebox.

Buildings 776 and 777: Assembly and Manufacturing Buildings

1957 Buildings 776 and 777 constructed. Building 776: Manufacturing building; Building 777: Assembly Building. Assembly operations transferred from Building 991.

1958 First significant machining of plutonium begins using cutting oil, followed by washing with carbon tetrachloride.

1969 Fire in Building 776 on May 11, 1969.

1972 Operations in Building 776 transferred to Building 707. Building 776 converted to waste storage and waste size reduction. Building 776 housed drums containing plutonium residue and supported drum venting activities to prevent the buildup of hydrogen gas.

1957–1969 Building 776 was the major user of carbon tetrachloride and trichloroethylene at RFP.

This complex was the major plutonium fabrication and assembly facility until 1970. Operations in the building were shut down for several months after the 1969 fire and the production operations remained shut down. Large amounts of plutonium had been stored at the facility. Operations after

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

the 1969 fire included testing and inspection, disassembly of site returns, special projects, plutonium recovery, and pyrochemical operations (electrorefining, molten salt extract, direct oxide reduction, and salt scrub processes). Waste operations were initiated after the 1969 fire and continued for the life of the building. The Supercompactor and size-reduction facilities were used to minimize the total volume of radioactive waste at the complex.

Building 777. Briquetting. The pressing of plutonium metal machine turnings into pucks using a hydraulic press. Turnings were cleaned in metal baskets that are dipped into four CCl_4 baths.

Machining, Rooms 131 and 134A. Parts were cleaned with CCl_4 on towels before machining.

Inspection, Rooms 130 and 430. Parts were cleaned with CCl_4.

Disassembly operations. Disassembly occurred in Room 430 and involved the disassembling of plutonium parts for further processing in the MSE Operation.

Special Weapons Projects. Special weapons projects performed R&D for fabricating classified parts and fitting specialty parts and materials. Plutonium oxidation was conducted to convert pyrophoric plutonium residues to nonpyrophoric PuO_2.

Tritium Environmental Control. Tritium was released during the disassembly of some types of contaminated parts. The tritium environmental control system removed tritium from gas sampling and glovebox exhausts by converting it to tritiated water and desiccating the air stream. Tritium water was collected in special containers for further processing.

Building 777. Foundry Operations, Coatings.

- Disassembly Operations, Room 430. Plutonium parts were disassembled for further processing.
- Assembly Superdry, TCA Wash.
- Ultrasonic Cleaning System, Room 430.
- Ultrasonic Cleaning System, Room 440.
- Plutonium Metallography Laboratory. TCA was used as a cutting agent for grinding with carbide grit to cut plutonium.
- Special Weapons Projects. R&D for fabricating classified parts and fitting specialty parts and materials.

Building 778: Support Building for Plutonium Processing Buildings

1957 Constructed in 1957, Building 778 was a support building for plutonium processing buildings (776, 777, and 707). It was located directly south of Buildings 776/777 and was connected to these buildings, as well as Building 707, by enclosed walkways. Over its history, Building 778 was mainly used as a protective clothing (anticontamination) laundry for all the plutonium process buildings; it contained a locker room and shower area and housed maintenance shops.

Building 779: Plutonium Development Building

1965 Building constructed. Building 779 was an R&D facility that supported production. Research activities included process chemistry technology, physical metallurgy, machining and gauging, joining technology, hydrating operations, and the Gammacell 220 Cobalt-60 Irradiator. All activities were terminated in 1989 but D&D activities

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

occurred through the mid-1990s. The facility had been used for storing SNM and waste. Glovebox activities in support of plutonium storage included inspection, metal brushing, and repackaging. Limited laboratory activities included waste characterization and minimization, stockpile reliability evaluations, and surface analysis.

Building 865, 867, and 868: R&D of Uranium and Beryllium
Building 865. 1972 Building constructed. Material and process development.

Building 867. Date of construction unknown. Contained filter plenums for process exhaust routed from Building 865.

Building 868. Date of construction unknown. Contained filter plenums for process exhaust routed from Building 865.

High Bay. The High Bay area of Building 865 supported production through the R&D of metalworking processes. Most work was done with DU, beryllium, copper, tungsten, stainless steel, and other steel alloys. Processes included metal casting, machining, rolling, heat treating, and isostatic pressing. Chemical etching and cleaning were performed to prepare the part for inspection and to remove oily residues, respectively.

Metallography Laboratory. The Metallography Laboratory in Rooms 102, 106, and 108 conducted quality control analyses on metal samples.

High Bay. Production through R&D of metalworking processes.

Grit Blasters, Room 172. Surface cleaning of parts containing DU.

Building 866
Date of construction unknown. Building 866 was a transfer station. It received wastes from Buildings 865 and 889 and transferred them to Building 374.

Building 881: Laboratories, maintenance shops, and plant support facilities
1953 Building constructed. Building 881 contained laboratories, maintenance shops, and plant support facilities. The original building was designed and built for processing enriched uranium. Small quantities of other radioactive materials such as ^{233}U and plutonium were also handled in the building.

Buildings 883 and 879: Beryllium and Uranium Machining Facility
1957 Building constructed as a rolling and forming (more commonly referred to as machining) facility for both enriched and DU. The building was divided into two sides: A side and B side. The A side rolled enriched uranium while the B side rolled DU.

1966 Enriched uranium operations curtailed at RFP. The A side of Building 883 was converted to beryllium rolling (this process was not enclosed). DU rolling continued on the B side.

Mid 1970s Beryllium machining stopped.

1957–1989 Nitric acid commonly used in a 50:50 water/nitric acid mixture for pickling uranium.

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

1980–1985 Increased processing of DU.

Rolling. Metal ingots, including uranium, were rolled in a rolling mill to reduce thickness and establish desirable grain structures.

Shearing. Uranium plates were mechanically cut into smaller pieces before being shaped in other mechanical processes. Uranium scrap was recycled by sending it to Building 444 for recasting.

Blanking/Trepanning. Uranium cut from a sheet with a press and die, and desired shapes were cut with trepanning tool. Uranium turnings were placed in a drum and sent to Building 447/448 for uranium chip roasting.

Forming. Uranium parts were formed into useful shapes.

Buildings 886 and 875: Nuclear Safety Facility

1965 Building 886 constructed. More than 1,600 criticality experiments were performed until 1987. Materials used in the experiments (uranyl nitrate metal powder) were reused. Short-lived fission products were produced, and there was no indication they were released to the work or outdoor environment. The isotopes decayed rapidly and were contained until stable.

Building 910 and Solar Ponds 207A, B, and C

1957 Solar evaporation pond 207A put into use. Used to store and evaporate low-level contaminated waste containing nitrates and radioactive substances (laundry wastewater including plutonium and uranium). The history of the ponds is developed further in ORAUT (2020a).

1960 Solar Evaporation Ponds 207B and C put into service.

1977 Building 910 (reverse osmosis facility) constructed.

Building 991

1951 Construction began on D Plant, now known as Building 991. This was the first building constructed at RFP.

1952 Final product assembly operations conducted.

1958 Building 777 becomes focal point for assembly operations.

1960 Building 991 used for storage and R&D. Emissions data for Building 991 include ^{238}Pu, $^{239/240}$Pu, ^{241}Am, $^{233/234}$U, and ^{238}U.

Building 995: Air Handling System

1974 Building constructed. Building 985 housed the air handling system that supported underground storage vaults 996, 997, and 999.

Buildings 990, 990a, 995, 988, 228a, 228b

These buildings are listed for completeness. No information is readily available concerning the potential for worker exposure in these facilities:

- B 990–Pre Aeration Building,

ATTACHMENT A
BUILDINGS AND OPERATIONS (continued)

- B 995–Sewage Treatment Facility, and
- B 988–Tertiary Treatment Pump House.

ATTACHMENT B
JOB TITLES AND DESCRIPTIONS

Chemical Operators
Primary job duties included highly enriched uranium (HEU) (Building 881) and plutonium (Buildings 771 and 371) metal reprocessing using dissolution, fluorination, calcine, and other wet chemistry methods to purify metal in preparation for foundry casting operations. Molten salt processing (Building 776) was an exceptionally high-neutron process. Other typical job duties included waste treatment (Buildings 774 and 374) for waste solutions generated on the plant.

Metallurgical Operators
Primary job duties included casting (Building 881), rolling, and pressing HEU (Building 883), plutonium (Buildings 776 and 707), and DU (Buildings 444, 447, and 883). Exposures tended to be less than those to chemical operators. Machinists, assemblers, material analysts, and welders had similar exposures. Nondestructive testing technicians had similar, but probably lower, exposures because work was often done on completed pits that inherently shielded the fissile materials. Experimental operators had similar, but probably higher, exposures because they often worked with prototype systems or processes that lacked shielding and other radiological controls as the regular production processes.

Maintenance Workers
Typical trades (i.e., machinists, pipe fitters, welders, carpenters, painters, and electricians) had varied exposures because they often did more intrusive work on contaminated systems than production personnel. Examples of intrusive work included repairing leaks on process lines (pipe fitters), refractory replacement in casting and heat treat furnaces (carpenters), repair of mechanical systems (machinists), repair of instruments and controllers inside gloveboxes and other systems (electricians), and painting over contamination (painters).

Support Personnel
Support personnel included clerk packers, metrology technicians, janitors, and handymen who worked in process areas but did little or no hands-on work with radioactive materials. Exposures would be incidental to working in rooms with process equipment (metallurgical and chemical operations).

Analytical Laboratory Technicians
Analytical laboratory technicians worked primarily in Building 559 (plutonium samples) or 881 (HEU or DU samples) and probably had lower exposures than operators performing hands-on work with significantly larger radioactive material quantities.

Site Support Personnel
Stationary operating engineers ([SOEs], also known as boiler vent operators [BVOs]), security guards, shift managers, and configuration control authority personnel performed little if any hands-on radioactive material or radiation work but had routine access to process areas. SOEs monitored the operation of exhaust systems, waste tanks, and process waste lines. Exposures would be incidental to working in rooms with process equipment (metallurgical and chemical operations).

Radiation Control Technicians
Radiation Control Technicians (RCTs) probably had exposures from supporting production chemical and metallurgical processes. Some significant exposures probably occurred during decontamination activities, surveys of contaminated areas, and upset conditions. There was no hands-on work per se, but RCTs generally worked side-by-side with production operators.

ATTACHMENT B
JOB TITLES AND DESCRIPTIONS (continued)

Decontamination and Decommissioning Workers
D&D work included draining actinide systems, decontamination, size reduction, and removal of contaminated equipment, gloveboxes, piping, ductwork, exhaust systems, waste packaging of removed equipment, and low-level and TRU wastes. Work was often in high (>2,000 dpm alpha) removable contamination areas with high air concentrations [see ORAUT (2020b) for exposure details]. Personal protection equipment (PPE) included air purifying respirators, powered air purifying respirators, or PremAir supplied air systems. There were some high exposures due to direct work with highly radioactive equipment and contamination events (see ORAUT 2020b and 2019 for details).

ATTACHMENT C
PARTIAL LIST OF POTENTIAL HAZARDS ASSOCIATED WITH VARIOUS JOB DESCRIPTIONS AND LOCATIONS

Much of the data in the following table is taken from DOE Uranium Mass Balance Project report (DOE 2000, 1992). This table is not a comprehensive listing of potential radiological exposures associated with RFP, but is a summary of data readily available at this time.

Table C-1. Partial list of potential hazards associated with various job descriptions and locations.

Job title	Process description	Building	Type of work	Begin	End	Material	Primary radiation type	Maximum energy
Analytical Laboratory Technicians	Sample processing	559	Plutonium sample analysis	Unknown	Unknown	Pu	α	5.16 MeV
Analytical Laboratory Technicians	Sample processing	881	HEU or DU sample analysis	1953	1965	HEU	α	4.6 MeV
Assemblers	Pit assembly	700	Handled “War Reserve” components	Unknown	Unknown	No data	No data	No data
Assemblers	Varied–similar to Metallurgical Operators depending on location	Varied	Handled metal parts	Unknown	Unknown	No data	No data	No data
BVOs	Varied–depending on location	Varied	Monitored exhaust systems, waste tanks, and process waste lines	Unknown	Unknown	No data	No data	No data
Carpenters	Varied–depending on location	Varied	Refractory replacement in casting and heat treatment furnaces	Unknown	Unknown	No data	No data	No data
Chemical Operators	Pu metal reprocessing	371	Handled contaminated reagents	Unknown	Unknown	No data	No data	No data
Chemical Operators	Waste treatment	374	Handled contaminated reagents	Unknown	Unknown	No data	No data	No data
Chemical Operators	Waste handling	447	Handled contaminated reagents	1956	1989	DU	α	4.2 MeV
Chemical Operators	Component cleaning	447	Handled contaminated reagents	1956	1989	DU	α	4.2 MeV
Chemical Operators	Waste handling	447	Processed waste materials	Unknown	Unknown	DU chips	α	4.2 MeV
Chemical Operators	Electrolytic decon of legacy HEU contaminated with Pu	707	Handled contaminated reagents	1997	1999	HEU Pu	α	4.6 MeV 5.6 MeV
Chemical Operators	Pu metal reprocessing	771	Handled contaminated reagents; Pu-contaminated $^{235}U_3O_8$ oxide	ca. 1965	1989	Pu-239 U oxide	α	5.16 MeV 4.2 MeV

ATTACHMENT C
PARTIAL LIST OF POTENTIAL HAZARDS ASSOCIATED WITH VARIOUS JOB DESCRIPTIONS AND LOCATIONS (continued)

Job title	Process description	Building	Type of work	Begin	End	Material	Primary radiation type	Maximum energy
Chemical Operators	Waste treatment	774	Handled contaminated reagents, liquid wastes from Building 881	1953	1989	HEU liquid wastes	α	4.6 MeV
Chemical Operators	Molten salt processing	776	Handled contaminated reagents	1958	1969	Pu-239	α	5.16 MeV
Chemical Operators	Process DU metal	865	Handled contaminated reagents	1953	1989	DU	α	4.2 MeV
Chemical Operators	HEU metal reprocessing	881	Handled contaminated reagents	1953	1965	HEU	α	4.6 MeV
Chemical Operators	Uranyl nitrate processing	886	Handled contaminated reagents	Unknown	Unknown	No data	No data	No data
Clerk Packers	Varied–depending on location	Varied	Little hands-on work with radioactive materials	Unknown	Unknown	No data	No data	No data
Configuration Control Authority Personnel	Varied–depending on location	Varied	Routine access to process areas; little hands-on work	Unknown	Unknown	No data	No data	No data
D&D Workers	Varied–depending on location	883	Deconned	1993	1995	HEU DU	α	4.6 MeV 4.2 MeV
D&D Workers	Varied–depending on location	881 B side	Deconned	1965	1967	HEU	α	4.6 MeV
D&D Workers	Varied–depending on location	Varied	Drained systems, removed contaminated equipment. Often in high airborne contamination areas. Often wore PPE, including respirators with or without supplied air.	Unknown	Unknown	No data	No data	No data
Electricians	Varied–depending on location	Varied	Repair of instruments and controllers inside gloveboxes and other systems	Unknown	Unknown	No data	No data	No data
Experimental Operators	Varied–depending on location	Varied	Operated prototype systems, often unshielded	Unknown	Unknown	No data	No data	No data
Handymen	Varied–depending on location	Varied	Little hands-on work with radioactive materials	Unknown	Unknown	No data	No data	No data
Inspection Technicians	Dimensional Inspection	881	HEU	1953	1965	HEU	α	4.6 MeV

ATTACHMENT C
PARTIAL LIST OF POTENTIAL HAZARDS ASSOCIATED WITH VARIOUS JOB DESCRIPTIONS AND LOCATIONS (continued)

Job title	Process description	Building	Type of work	Begin	End	Material	Primary radiation type	Maximum energy
Inspectors	Testing	444	Inspected completed parts	1953	1994	DU	α	4.2 MeV
Janitors	Varied–depending on location	Varied	Little hands-on work with radioactive materials	Unknown	Unknown	No data	No data	No data
Machinists	Pit Assembly	700	Handled “War Reserve” components	Unknown	Unknown	No data	No data	No data
Machinists	Machining of Pu parts	776	Operated machining equipment	1958	1969	Pu-239	α	5.16 MeV
Machinists	Plutonium assembly	777	Drilling, turning, polishing	Unknown	1969	Pu-239	α	5.16 MeV
Machinists	Process DU metal	865	Machined DU and DU alloys	1953	1989	DU	α	4.2 MeV
Machinists	?	881	Stainless-steel boost reservoirs, etc.	1966	1967	No data	No data	No data
Machinists	Rod mill grinding	881	Machined HEU parts	1953	1965	HEU	α	4.6 MeV
Machinists	Rolling, forming, machining	881	HEU	1953	1965	HEU	α	4.6 MeV
Machinists	Presses, rolling mills	883-B	Operated machining equipment	1957	1965	HEU	α	4.6 MeV
Machinists	Roll and press DU into sheets	883-C	Rolling mills, shears	1983	1992	DU	α	4.2 MeV
Machinists	Rolling, forming, machining	883-A	Operated machining equipment	1957	1992	DU, DU alloys	α	4.2 MeV
Machinists	Varied–similar to Metallurgical Operators depending on location	Varied	Repair of mechanical systems	Unknown	Unknown	No data	No data	No data
Material Analysts	Varied–similar to Metallurgical Operators depending on location	Varied	Collected metal samples	Unknown	Unknown	No data	No data	No data
Metallurgical Operators	Casting and machining	444	Operated metal handling equipment	1956	1989	DU	α	4.2 MeV
Metallurgical Operators	Casting and machining	444	Operated metal handling equipment	1980	1984	DU	α	4.2 MeV
Metallurgical Operators	Casting and cleaning	444	Operated metal handling equipment	1967	1969	DU/Mo	α	4.2 MeV
Metallurgical Operators	Trim and polish DU sheets	444	Operated metal handling equipment	1953	1989	DU	α	4.2 MeV
Metallurgical Operators	Roll and press DU	447	Operated metal handling equipment	1956	1989	DU	α	4.2 MeV
Metallurgical Operators	Roll and press Pu	707	Operated metal handling equipment	Unknown	Unknown	Pu-239	α	5.16 MeV
Metallurgical Operators	Roll and press Pu	776	Operated metal handling equipment	1958	1969	Pu-239	α	5.16 MeV

ATTACHMENT C
PARTIAL LIST OF POTENTIAL HAZARDS ASSOCIATED WITH VARIOUS JOB DESCRIPTIONS AND LOCATIONS (continued)

Job title	Process description	Building	Type of work	Begin	End	Material	Primary radiation type	Maximum energy
Metallurgical Operators	Plutonium assembly	777	Unknown	Unknown	1969	Pu-239	α	5.16 MeV
Metallurgical Operators	Casting, rolling, forming, shearing, and cleaning	865	Operated metal handling equipment	1979	1988	DU, DU alloys	α	4.2 MeV
Metallurgical Operators	Casting, extruding, machining	865	Operated metal handling equipment	1979	1988	DU, DU alloys	α	4.2 MeV
Metallurgical Operators	Process DU metal	865	Machined DU and DU alloys	1953	1989	DU	α	4.2 MeV
Metallurgical Operators	Uranium casting	881	Operated metal handling equipment	1953	1965	Uranium	α	4.6 MeV
Metallurgical Operators	Melting and casting	881	HEU	1953	1965	HEU	α	4.6 MeV
Metallurgical Operators	Annealing	883-B	Operated metal handling equipment	1957	1965	HEU	α	4.6 MeV
Metallurgical Operators	Roll and press DU into sheets	883-C	Operated metal handling equipment	1983	1992	DU	α	4.2 MeV
Metallurgical Operators	Roll and press DU	883 A side	Operated metal handling equipment	Unknown	Unknown	DU	α	4.2 MeV
Metallurgical Operators	Roll and press HEU	883 B side	Operated metal handling equipment	1953	1964	HEU	α	4.6 MeV
Metallurgical Operators	Roll and press beryllium	883 B side	Operated metal handling equipment	1964	Unknown	Be metal	No data	No data
Metallurgical Operators	Casting, rolling, forming, shearing, and cleaning	883-A	Operated metal handling equipment	1957	1992	DU, DU alloys	α	4.2 MeV
Metrology Technicians	Varied–depending on location	Varied	Little hands-on work with radioactive materials	Unknown	Unknown	No data	No data	No data
Nondestructive Testing Technicians	Testing	444	Tested parts	1953	1994	DU	α	4.2 MeV
Nondestructive Testing Technicians	Tensile testing, etc.	447	Tested parts	1956	1989	DU	α	4.2 MeV

ATTACHMENT C
PARTIAL LIST OF POTENTIAL HAZARDS ASSOCIATED WITH VARIOUS JOB DESCRIPTIONS AND LOCATIONS (continued)

Job title	Process description	Building	Type of work	Begin	End	Material	Primary radiation type	Maximum energy
Nondestructive Testing Technicians	Varied–depending on location	700	Sampled completed pits	Unknown	Unknown	No data	No data	No data
Nondestructive Testing Technicians	Casting, extruding, machining	865	Operated metal handling equipment	1979	1988	DU, DU alloys	α	4.2 MeV
Nondestructive Testing Technicians	Testing	881	HEU	1953	1965	HEU	α	4.6 MeV
Nondestructive Testing Technicians	Varied–depending on location	Varied	Sampled completed pits	Unknown	Unknown	No data	No data	No data
Painters	Varied–depending on location	Varied	Paint over contamination	Unknown	Unknown	No data	No data	No data
Pipefitters	Varied–depending on location	Varied	Repair leaks on process lines	Unknown	Unknown	No data	No data	No data
RCTs	Varied–depending on location	Varied	Monitoring in support of chemical and metallurgical processes; exposures similar to Chemical and Metallurgical Operators	Unknown	Unknown	No data	No data	No data
Security Guards	Varied–depending on location	Varied	Routine security patrols	Unknown	Unknown	No data	No data	No data
Shift Managers	Varied–depending on location	Varied	Routine access to process areas; little hands-on work	Unknown	Unknown	No data	No data	No data
SOEs	Varied–depending on location	Varied	Monitor exhaust systems, waste tanks, and process waste lines	Unknown	Unknown	No data	No data	No data
Welders	Welding	444	Welded parts as necessary	1953	1994	DU	α	4.2 MeV
Welders	Electron-beam, tungsten-inert gas welding	447	Welded parts as necessary	1956	1989	DU	α	4.2 MeV
Welders	Plutonium assembly	777	Welding, brazing	Unknown	1969	Pu-239	α	5.16 MeV
Welders	Varied–similar to Metallurgical Operators depending on location	Varied	Welded metal parts	Unknown	Unknown	No data	No data	No data

ATTACHMENT D
OPERATIONAL ACCIDENTS AND INCIDENTS

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OPERATIONAL ACCIDENTS AND INCIDENTS (continued)

Table D-1. Operational accidents and incidents.[a]

Date	Location	Description [exposure details–see also ORAUT (2020b)]
11/21/1952	Not specified	Boiler explosion (disruptive force, no known radionuclide involvement)
06/14/1957	Not specified	Explosion from chemical reaction (3.2 µg Pu lodged in finger)
09/11/1957	Bldg. 771, Rm. 180	Fire in a manufacturing building; Pu airborne release.
10/25/1961	Not specified	Boiler explosion (disruptive force, no known radionuclide involvement)
04-06/1962	Not specified	Involved internal Pu exposures to [redacted] operators
03/16/1963	Not specified	Substation failure due to high-velocity winds and fire (none)
03/19/1963	Not specified	Failure of engine in building's compressor house (none)
04/23/1963	Not specified	Contamination from nitric acid spill (none)
06/20/1963	Not specified	Contamination leak and spill in line carrying high-level Pu solution (none)
07/01/1963	Bldg. 771	Filtrate recovery box fire; direct readings of up to 25,000 cpm measured from respirator filters.
02/01/1964	Beryllium Shop	Fire in Aero-Tech unit attributed to oil that then caused Be oxidation
06/12/1964	Building 776	Chemical explosion in [redacted] (Pu lodged in [redacted], [redacted]).
09/25/1964	Bldg. 771, Rm. 180-A	Americium explosion. Stored Am in solution and in oxide forms from Lawrence Livermore National Laboratory. No exposures.
12/21/1964	Bldg. 771 Stack	Abnormal concentration of material released from Bldg. 771 stack during latter part of December.
03/19/1965	Not specified	Glove failed in a [redacted], releasing Pu resulting in measured [redacted] deposition, [redacted] worker.
02/26/1965	Not specified	Pu released from defective [redacted]. [Redacted] worker exposed via inhalation and skin. Lung burden estimate is 0.02 µCi.
04/08/1965	Not specified	Inspected parts knocked off shelf (none)
05/01/1965	Not specified	3 DU sheets destroyed by burning due to improper labeling (approximately 60 kg DU)
05/05/1965	Roadway	Box H-22 was removed from Bldg. 76. Contaminated oil leaked from box onto roadway between Bldg. 76 and waste storage area south of Bldg. 51 (no exposure reported).
05/06/1965	Not specified	Product feed sprayed out of loose flange, decontamination of [redacted] workers, details unavailable.
10/15/1965	Bldg. 777, Rm. 130 and Bldg. 776	Glovebox drain fire releasing Pu resulting in measured lung depositions, 10 workers known exposed (up to 400 might have been exposed)
11/09/1965	Not specified	Glovebox fire (12 skin decontaminations; no significant internal exposures)
11/27/1965	Not specified	Wind damage to building roof (none)
01-03/1967	Not specified	Pu and Am residues accumulated in a fluorinator glovebox and required moving. Resulted in [redacted] worker exposures, details unavailable.
01-03/1967	Not specified	A [redacted] handled large Pu charges and castings and large amounts of material containing Am-241
04/05/1967	Not specified	[Redacted] No known radionuclide exposures.
04-06/1967	Not specified	[Redacted] Significant exposures (see ORAUT 2020b).
07-09/1967	Not specified	A DU-Pu-Mo alloy was processed as normal Pu but high gamma readings were reported. Details unavailable – 7 external exposures.
09/29/1967	Not specified	Contamination spill from blowout of pipe plug. Nuclide data unavailable.
02/01/1968	Not specified	Tritium release of 600 Ci.

ATTACHMENT D
OPERATIONAL ACCIDENTS AND INCIDENTS (continued)

Date	Location	Description [exposure details–see also ORAUT (2020b)]
10/14/1968	Not specified	An employee [redacted] from a [redacted] in a hot [redacted]. Details unavailable.
11/28/1968	Bldg. 444	[Redacted] Details unavailable.
12/1968	Not specified	Storage area east of nitrate pads contaminated by leaking drums containing recoverable solids awaiting processing in Building 71. High winds blew drums over (no exposure noted).
01/07/1969	Not specified	High wind damage to buildings.
04/23/1969	Not specified	Employee showed an unexplained [redacted] (0.065 µCi).
05/11/1969	Bldg. 776	Glovebox fire in plutonium processing area. See ORAUT (2020b) for details.
06/20/1969	Not specified	Molten metal released into furnace interior. Details unavailable.
07/30/1969	Not specified	Fire in tunnel between buildings. Details unavailable.
07/30/1969	Not specified	[Redacted]
04/20/1970	Not specified	Contamination release from a plugged drain line. Details unavailable.
08/15/1970	Not specified	Power lead short-circuited to bus bar.
09/11/1970	Not specified	Acid leaked from storage tank.
01/20/1971	Not specified	[Redacted]
04/12/1971	Not specified	Corrosion caused steam condensate line to leak contamination. Details unavailable.
04/19/1971	Not specified	Contamination spread from reduction furnace gasket failure. Details unavailable.
06/15/1971	Not specified	A fire started in a shipment of drummed radioactive waste on its way to Idaho and self-extinguished (no exposures).
08/22/1971	Not specified	Small container exploded and contamination spread by ignited [redacted]. Measured lung burdens, [redacted] employees.
09/02/1971	Not specified	Hole in a barrel liner allowed plutonium oxide to escape into room (<4 µCi).
01/05/1972	Not specified	Electrical faulting of three main substations due to winds and snow.
01/11/1972	Not specified	Cell shrouding of cooling tower blew away.
04/10/1972	Not specified	Incinerator glovebox fire. Details unavailable.
02/08/1972	Not specified	Incinerator fire and contamination caused by a punctured aerosol can (no exposures).
09/06/1972	Not specified	[Redacted]
02/02/1973	Not specified	Supplied air suits contaminated by ignition of a paper filter in the compressor. Details unavailable.
04/01/1973	Not specified	Tritium release of 500 to 2,000 Ci to atmosphere and waste streams during the processing of metal scrap.
09/17/1973	Not specified	Elevated levels of tritium were found in Walnut Creek and Great Western.
11/01/1973	Bldg. 995	Several drums of contaminated soil removed from streambed below Bldg. 995 outfall. No exposure noted.
04/02/1974	Bldg. 707	Control valve release due to filter system design error. Details unavailable.
08/30/1974	Bldg. 777, Rm. 452	Tritium release, 1.5 Ci.
11/30/1975	Not specified	Trailer blown over by high winds. Details unavailable.
05/19/1976	Not specified	Contamination of R&D equipment and instruments. Details unavailable.
08/18/1976	Not specified	Overheating caused coils in induction furnace to melt.
11/18/1976	Not specified	Source dropped in office area. Details unavailable.
1996–1997	Bldg. 371	Unmonitored exposure of office workers might have occurred; details being sought.

ATTACHMENT D
OPERATIONAL ACCIDENTS AND INCIDENTS (continued)

Date	Location	Description [exposure details–see also ORAUT (2020b)]
10/16/2000	Bldg. 771, Rm. 186	Air measurements in [redacted] not properly documented from Sept 7, 2000, to Oct 16, 2000. Ten workers showed unexpectedly high levels of exposure.
10/20/2000	Not specified	CAM alarm event. At least one worker exposed.
04/20/2004	Unspecified	An individual was assigned a dose for November 1993 of 1,900 mrem committed effective dose equivalent (CEDE), potentially occurring from five incidents between June 1986 through Nov 1993; details being sought.

a. Most of the summaries above were taken from AEC (1975). We have not discovered a similar accident summary for later periods but have decided to incorporate this partial listing. Other sources include DOE (1980); McLaughlin, Monahan, and Pruvost (2000); Putzier (1982); DeMaiori (2005).

Table D-2. Incidents reported in occurrence reports, 1983 to 2003 (RFETS 1981–2005).

Date of occurrence	Building/ room	Details	Dose	# Persons involved
07/08/1983–07/11/1983	771, main exhaust system	Effluent filters on main exhaust duct had elevated, long-lived alpha counts. Evaluation of the occurrence through August 1983 led to conclusion that there was a discharge to the atmosphere that was not within the ranges expected from Bldg. 771 Main Plenum but also that it was not significant.	Not reported	Unknown
On or about 12/21/1983 or 01/09/1984	Probably 779, Rms. 133 and 776, Rm. 225	[Redacted] had body count that showed 1 and 1/2 [redacted]. Fifteen others received body counts but only the [redacted] had positive results.	[Redacted]	Up to 16
12/03/1985	[Redacted]	[Redacted]	[Redacted]	[Redacted]
04/03/1985	[Redacted]	[Redacted]	[Redacted]	[Redacted]
07/17/1985–07/18/1985	779, Rm. 160, Glovebox 865 Stationary Furnace 1	Furnace released radioactive contamination causing special alpha air monitor (SAAM) alarm and smoke, Room 160 and those nearby had air contamination.	Not reported	3
08/07/1995	707, Module K	SAAM alarms; airborne alpha contamination.	835 dpm alpha	9
09/19/1985	771, Rm. 149	Pu release to room environment.	Not reported; “negative body counts” reported.	3
11/26/1985	707, modules J and K ventilation systems	SAAMs alarmed after glovebox was breached. Body counts of the 12 workers were reported as background; no report of release quantity.	Not reported	12
11/06/1986	[Redacted]	[Redacted]	[Redacted]	[Redacted]
01/11/1990	881 Annex Plenum System	Levels of 1,000 dpm/100 cm^2 were found on downstream side of plenum filters after filter change and effluent monitoring head change in December 1989. Cause determined to be contamination that was liberated from old filters during change-out.	Maximum dose to the public estimated to be less than 0.3 mrem and to onsite worker less than 25 mrem.	Unknown

ATTACHMENT D
OPERATIONAL ACCIDENTS AND INCIDENTS (continued)

Date of occurrence	Building/ room	Details	Dose	# Persons involved
01/25/1990	771, Port 17 Line 7	[Redacted]	[Redacted]	[Redacted]
03/08/1990	[Redacted]	[Redacted]	[Redacted]	[Redacted]
03/13/1990	[Redacted]	[Redacted]	[Redacted]	[Redacted]
03/20/1990	[Redacted]	[Redacted]	[Redacted]	[Redacted]
04/10/1990	[Redacted]	[Redacted]	[Redacted]	[Redacted]
04/24/1990	776, Rm. 134	Radiation protection technologist (RPT) found contamination of 1,000 cpm on floor during pre-maintenance job survey. Decontamination was stopped and room designated for respirator use to allow a tour to go through area. Members of tour and five building personnel passed within 50 ft of contaminated area, potentially being exposed to airborne contamination.	Operational health physics department estimated dose to be less than 10E-4 mrem.	More than 5
04/30/1990	[Redacted]	[Redacted]	[Redacted]	[Redacted]
05/24/1990	707, 776/777, 779, 771/774, 371/364, and 991	Noncompliance to filter surveillance: filters were less than 99.5% effective PL-101 releases in pCi/m^3 1988: 6.1E-5 + 1.4E-4; 1989: 9.0E-5 + 1.21E-4; 1990: 2.0E-6 + 2.5E-5 FU-25 releases in pCi/m^3; 1988: 7.9E-5 +1.71E-4; 1989: 4.0E-5 + 4E-5; 1990: 2.0E-6 + 2.5E-4.	Pu-239 releases; see details	Environmental
04-05/1990	Pu operations	Inadequate posting of respiratory protection requirements resulted in several employees entering rooms without respirators; five separate incidents.	Apparently none	More than 9
10/11/1991	[Redacted]	[Redacted]	[Redacted]	[Redacted]
12/31/1991	[Redacted]	[Redacted]	[Redacted]	[Redacted]
01/29/1992	[Redacted]	[Redacted]	[Redacted]	[Redacted]
01/29/1992	[Redacted]	[Redacted]	[Redacted]	[Redacted]
02/05/1992	[Redacted]	[Redacted]	[Redacted]	[Redacted]
03/11/1992	707, Module J	Window change on glovebox J60 resulted in SAAM alarm. Workers were already wearing full-face respirators and protective clothing. Contamination of 2,000 dpm was found on SAAM paper. Respirator cartridges had levels of 14,000 to 20,000 dpm. All personnel were issued bioassay kits as a precautionary measure.	Not reported	Unspecified but at least 4
03/17/1992	[Redacted]	[Redacted]	[Redacted]	[Redacted]
04/08/1992	[Redacted]	[Redacted]	[Redacted]	[Redacted]

ATTACHMENT D
OPERATIONAL ACCIDENTS AND INCIDENTS (continued)

Date of occurrence	Building/ room	Details	Dose	# Persons involved
06/09/1992	707, Module J, Glovebox J-60	Ductwork removal resulted in contamination of personnel and high DAC.	SAAM filter = 1,080 DAC. Bioassays performed but results not reported. Employee's hand at 2,000 dpm; one worker's respirator filter at 1,500 dpm alpha; RCT's respirator filter at 1,000 dpm.	4
11/10/1992	771, Rm. 180F	Radiological contamination found during survey of Room 182. On 11/11/1992, exhaust fixed air sampler for Room 180F had 80% of one DAC (400 dpm). Levels of 330 dpm and 366 dpm were found on floor.	None reported	Unknown
01/15/1993	[Redacted]	[Redacted]	[Redacted]	[Redacted]
07/02/1993	Internal Dosimetry	Change in lung count measurements due to a positive analysis; testing occurred 08/06/1992 and 08/07/1992; exposure occurred in 1973.	11 rem CEDE; 220 mrem annual effective dose equivalent	1
08/18/1995	[Redacted]	[Redacted]	[Redacted]	[Redacted]
09/15/1995	883, Hydroform Press	During dismantling of a hydroform press, 8,000 dpm of fixed and removable alpha detected as well as spikes of Am. Possible that duct had been contaminated before use in building because interviews with past employees indicated no use of Am in building.	Unknown	Unknown
07/18/1997	771, Rm. 154	Portable CAM alarm when laboratory personnel were preparing particle size samples. No source found. Three workers in area.	Filter = 2,052 dpm alpha Worker shoe = 9,000 dpm/ 100 cm^2	3
07/16/1998	779, Rms. 152 and 154	Skin contamination >2,000 dpm, SAAM alarm at 4 DAC.	Up to 6,000 dpm/100 cm^2 on head and shoulders	3
10/22/1998	[Redacted]	[Redacted]	[Redacted]	[Redacted]
01/13/1999	[Redacted]	[Redacted]	[Redacted]	[Redacted]
02/02/1999	[Redacted]	[Redacted]	[Redacted]	[Redacted]
09/08/1999	[Redacted]	[Redacted]	[Redacted]	[Redacted]
10/26/1999	[Redacted]	[Redacted]	[Redacted]	[Redacted]
10/28/1999	[Redacted]	[Redacted]	[Redacted]	[Redacted]
11/05/1999	771, Trailer T771H	Clam shells found in plastic bag outside trailer with contamination levels as high as 23,700 dpm/100 cm^2 fixed and 830 dpm/100 cm^2 removable. Contamination determined to be Pu. Determined that shells had been in Bldg. 774 in a cargo container.	23,700 dpm/100 cm^2 fixed	Unknown
11/17/1999	[Redacted]	[Redacted]	[Redacted]	[Redacted]

ATTACHMENT D
OPERATIONAL ACCIDENTS AND INCIDENTS (continued)

Date of occurrence	Building/ room	Details	Dose	# Persons involved
01/24/2000	[Redacted]	[Redacted]	[Redacted]	[Redacted]
03/09/2000	[Redacted]	[Redacted]	[Redacted]	[Redacted]
06/08/2000	[Redacted]	[Redacted]	[Redacted]	[Redacted]
09/06/2000	[Redacted]	[Redacted]	[Redacted]	[Redacted]
09/07/2000	[Redacted]	[Redacted]	[Redacted]	[Redacted]
11/30/2000	771	Bioassay samples were requested of 11 employees after radiological documentation deficiencies were found on 10/16/2000. The first bioassay results were returned on 11/27/2000 and 10 were above the decision level, so a second set was requested. At that time, 44 employees who worked in the building volunteered to provide samples.	Results of 9 of the original 11 workers ranged from 6 to 60 mrem; other results not reported.	11+
02/09/2001	[Redacted]	[Redacted]	[Redacted]	[Redacted]
02/12/2001	[Redacted]	[Redacted]	[Redacted]	[Redacted]
03/19/2001	[Redacted]	[Redacted]	[Redacted]	[Redacted]
07/27/2001	[Redacted]	[Redacted]	[Redacted]	[Redacted]
10/03/2001	[Redacted]	[Redacted]	[Redacted]	[Redacted]
12/12/2001	[Redacted]	[Redacted]	[Redacted]	[Redacted]
01/02/2002	[Redacted]	[Redacted]	[Redacted]	[Redacted]
01/15/2002	[Redacted]	[Redacted]	[Redacted]	[Redacted]
01/26/2002	[Redacted]	[Redacted]	[Redacted]	[Redacted]
01/28/2002	[Redacted]	[Redacted]	[Redacted]	[Redacted]
03/21/2002	[Redacted]	[Redacted]	[Redacted]	[Redacted]
05/07/2002	[Redacted]	[Redacted]	[Redacted]	[Redacted]

Table D-3. Incidents reported in the quarterly total project summary reports, April 2003 to December 2005.

Date	Building	Description	Dose	# involved
Third quarter (Q3)	[Redacted]	[Redacted]	Not reported	2
Q3 2003	[Redacted]	[Redacted]	Not reported	4
Q4 2003 (07–09/2003)	[Redacted]	Zone I duct removal in E module resulted in ventilation anomaly and CAM alarms sounded. Module E evacuated; contamination was found on the shoes of [redacted] workers and in an adjacent corridor.	[Redacted]	[Redacted]
First quarter (Q1) 2004 (10–12/2003)	[Redacted]	[Redacted]	[Redacted]	[Redacted]
Q3 2004	[Redacted]	[Redacted]	[Redacted]	[Redacted]
Q3 2004	[Redacted]	[Redacted]	[Redacted]	[Redacted]
Q4 2004	[Redacted]	[Redacted]	[Redacted]	[Redacted]
Q4 2004	[Redacted]	[Redacted]	[Redacted]	[Redacted]
Q4 2004	[Redacted]	[Redacted]	[Redacted]	[Redacted]
Q4 2004	[Redacted]	[Redacted]	[Redacted]	[Redacted]
Q4 2004	[Redacted]	[Redacted]	[Redacted]	[Redacted]
Q1 2005 ([redacted])	Not reported	Two events of skin contamination [redacted] (one in [redacted] and one in [redacted]). No details reported.	[Redacted]	2