6.0 ACCIDENTS AND INCIDENTS AT THE ROCKY FLATS PLANT

One of the objectives of the Rocky Flats Toxicologic Review and Dose Reconstruction project is the identification of any non-routine plant releases that significantly contributed to the off-site dose of chemicals or radionuclides to the public. As a result, a considerable amount of effort was invested in attempting to locate documentation of events not previously publicized that might have resulted in significant off-site exposures. This section discusses the accident investigation process and provides a summary of the available historical information associated with the major accidents or well known events.

6.1 Sources of Accident Information

In investigating accidents, incidents, and "as-found conditions" at the Rocky Flats Plant, the following information sources were used. Many of these resources were also used to reconstruct the history of normal operations:

- Industrial Safety Files (1952-1990)
- Occurrence Managements's Summary of Events Database (1952-1990)
- The Legal/Environmental (Church Litigation) Files
- The Environmental Master File
- Rocky Flats Public Reading Room
- Building 706 Technical Library (classified and unclassified reports)
- Personnel Interviews
- Building 881 Archives
- Denver Federal Records Center

Accident reporting to the U.S. Atomic Energy Commission (AEC), the Energy Research and Development Administration (ERDA), or to the Department of Energy (DOE) has always been mandatory. The criteria for a reportable accident has varied considerably over time. The criteria for a reportable accident are related to worker injuries, worker radiation exposure levels, shutdown of any operations, damage costs, publicity, and the potential for off-site release. Documented accident reporting criteria were identified for the period from 1943-1975 and those currently in effect (effective May 30, 1990). Changes in accident reporting requirements to the federal agency over time has led to the reporting of accidents associated with lower exposure levels and lower damage costs.

Accidents reported to DOE include fatalities (e.g., death from complications following a fall) and high cost damages (e.g., roof blown off a building), which may have little or no potential for any off-site impacts. In this respect, the list of accidents reported to DOE is too broad for the purposes of this study. However, the list does not include minor worker accidents, such as cut fingers, on-site car accidents, and small contained fires which are documented by voluminous reports maintained at the plant. The list also does not include "as found conditions," such as the release of plutonium from leaking drums at the Building 903 drum storage area.

A list of accidents reportable to the AEC is summarized for 1943 to 1970 in an AEC publication (USAEC, 1971) and an updated version of that document for 1943-1975 (USAEC, 1975). A similar listing has not been identified for the period 1975-1990, but numerous other documents and reports cover this period.

Internal Rocky Flats Plant documents and external sources of accident information were reviewed to identify large releases of chemicals or radionuclides that were either not identified in the DOE reports or which did not meet DOE reportable criteria.

Industrial Safety Office Records

Industrial Safety/Occurrence Management records are made up of the following file types:

"Occurrences" from 1952 to 1981
"Supervisor Investigation Reports (SIRs)" from 1982 to 1988
"Unplanned Events (UEs)" from 1988 to 1989
"Unusual Occurrence Reports (UORs)" from 1982 to 1989
"Internal Investigation Reports (IIRs)" for unstated dates

The file contents reflect changes in report names, definitions of accident-related terms, and threshold levels for reportability of events over the years of Rocky Flats Plant operation in response to DOE Orders and plant policy changes. For the major incidents, a committee is formed to conduct an investigation and prepare a report, consisting of findings and recommendations. The Industrial Safety files typically contain the committee's report, documentation of recommended actions, and detailed supporting documentation. The file for a given incident is considered "open" until corrective action plans are completed.

Review of Industrial Safety Office records allowed the project team to document the detail and completeness of Rocky Flats accident and incident records. While background information in the records facilitated evaluation of the significance of particular events from among the wide range of occurrences documented in other sources, no new accidents or incidents were discovered in the Industrial Safety records that appear to have had potential for off-site impact from large releases of chemicals or radionuclides.

Occurrence Management Department Database

The most complete historical record available of all accidents at Rocky Flats is maintained by the Occurrence Management Department of EG&G Rocky Flats in the form of the Summary of Events (SOE) database that covers the period from 1952-1990. The SOE database was created in the early 1980s based on a review of the Industrial Safety files and has been updated on an annual basis since that time. At the time of ChemRisk's review, the database contained approximately 1,767 accident entries.

The SOE database includes all accidents reported to DOE which are listed in <u>Operational Accidents and Radiation Exposure Experience within the U.S. AEC, 1943-1975</u>. The Summary of Events database does not include "as found conditions," such as the 903 Pad, and it does not always provide information on the off-site release potential of an accident.

While the Occurrence Management Department SOE database identified a wide range of events associated with operations at Rocky Flats, a great majority of the events have no significance from an off-site chemical or radionuclide exposure standpoint. No new accidents or incidents were discovered in the Occurrence Management Department records that appear to have had potential for off-site impact from large releases of chemicals or radionuclides.

Legal/Environmental Files

Document titles and summaries from a keyword search of the Legal/Environmental Index (LEI), which references Legal/Environmental File documents from the period 1957-1978, were reviewed to identify any discussion of accidents not listed in the SOE database. The keywords used include "accident," "incident," "unusual occurrence," "unplanned event," and "investigation." Twenty occurrences are mentioned in various documents that are not listed in the SOE database. Seven are small fires, five are localized radioactive contamination, two are small contained spills of radioactive liquid, three involve contaminated outside soils, one involves a worker exposure and two are transportation related incidents.

Two accident summary documents were located in the keyword search of the LEI. The first is Compilation of Incidents Excerpted from the Executive Safety Council Minutes (December 21, 1965) which lists 99 incidents, 77 of which are not listed in the SOE database. However, the 77 incidents are primarily laboratory spills involving small amounts of non-radioactive chemicals. The second document, Report on Reference Material in Reply to Summary of Known Incidents at Rocky Flats (November 11, 1973), identifies one incident that is not listed in the SOE database. The incident involved a nonreportable to DOE enriched uranium fire recorded in a Health Physics Status Report. In addition, the November 11, 1973 document includes "as found conditions," such as on-site burial at 881 Hillside and the 903 Pad.

The Legal/Environmental files, as accessed by the LEI, were a source of much background information on events of environmental significance at Rocky Flats. While they contributed significantly to project team understanding of Rocky Flats operations and activities associated with accident and incident investigation, documentation, evaluation, and clean-up, no new accidents or incidents were discovered in the Legal/Environmental Files that appear to have had potential for off-site impact from large releases of chemicals or radionuclides.

Environmental Master File

The following accident-related reports were found in the Environmental Master File (EMF) at Rocky Flats:

- Review of the Exhaust Air Filtering and Air Sampling, B-771 (1965)

  This document correlates elevated stack effluent emissions and accidents for the period 1953 to 1963. All accidents identified in the document are also listed in the SOE database and the DOE listing. However, some elevated stack releases are associated with damaged filters and filter system configuration changes that are not associated with an accident.

- Compilation of Incidents Excerpted from the Executive Safety Council Minutes (1965)

- Report on Reference Material in Reply to Summary of Known Incidents (1973)

- A Historical Summation of Environmental Incidents Affecting Soils at or Near the U.S. AEC Rocky Flats Plant (1974)

- Comprehensive Environmental Assessment and Response Program (CEARP)- Phase 1, Installation Assessment Rocky Flats Plant (1986)

- Past Accidental Releases of Radioactivity from the Rocky Flats Plant by C.W. Barrick (1981)

- The Past 30 Years at the Rocky Flats Plant by E.A. Putzier (1982)

- Response to CERCLA 104(e) and RCRA 3007 Information Request (1990)

- RCRA Spill Documents (1989, 1990)

    RCRA Spill Documents for the years 1989 and 1990 identified three releases that do not appear on other accident listings. Two of the spills were captured in retention basins and the third was contained in a valve vault. These three spills were therefore not associated with significant off-site releases.

The Environmental Master File was a source of much background information on plant design features, effluent and environmental surveillance practices, and events of potential environmental significance at Rocky Flats. However, no new accidents or incidents were discovered in the EMF that appear to have had a potential for off-site impact from large releases of chemicals or radionuclides.

The Building 706 Technical Library

Both classified and unclassified documents located in the Rocky Flats Technical Library were reviewed. Classified reports of three accidents were noted. One accident is listed in the SOE database as the August 22, 1971 "Smith-Olveda" inhalation exposures of two workers to plutonium. The other two involved a small fire and a localized release of radioactive material that was captured by ventilation filtration systems. Neither of these two incidents appear to have had potential for off-site health impacts. In the "Smith-Olveda" incident, two workers received reportable lung burdens, but the classified report identifies low releases of plutonium to the environment. The 1980 Environmental Impact Statement states that the accident-related plutonium release total for Building 771 for 1971 (including this accident and an incident where contamination resulted from a hole in a barrel liner) was less than four microcuries (USDOE, 1980). A review of the unclassified section of the library led to the identification of three other accidents not listed in the SOE database; two small, contained fires and a hydrogen peroxide spill.

Although the Building 706 Technical Library was the major source of useful information addressing classified aspects of some of the accidents and incidents identified from other sources, no new accidents or incidents were discovered that appear to have had potential for off-site impact from large releases of chemicals or radionuclides.

Broomfield Water Department

The City of Broomfield Water Department prepared a Rocky Flats Fact Sheet, Environmental Impact (1951 to 1989) that identifies 14 accidents not listed in the SOE database. Three of these accidents involve broken radioactive sources, 10 are liquid effluent spills or NPDES violations, and one is the discovery of two trenches used for on-site burial. However, it was reported that no contamination left the site as a result of any of these accidents.

6.2 Accidents of Potential Interest

The extensive review of accident-related databases and documents, both classified and unclassified, resulted in the identification of thousands of small-scale releases and "accidents" over the forty-year operating history of the Rocky Flats Plant. Our investigations did not, however, identify any major events that are likely to have had the potential for significant off-site health impacts that have not already been reported to cognizant agencies or the public in the past. Many of the events reviewed in the course of the investigation resulted in releases that passed through building ventilation systems that included filtration and radioactivity monitoring systems, so the associated releases were recorded as part of normal plant operating emissions. The purpose of this section is to identify and describe many of the widely reported historical events, only a few of which are likely to have any significance with regard to having a potential for off-site health impacts. Any statements regarding the significance of releases or off-site health impacts in the descriptions of these events are quoted from official documents reviewed by the project team, and are not conclusions made by ChemRisk. The magnitude of any potential releases associated with these events, and therefore their relative significance with regard to potential off-site impacts, will be addressed in a report to be developed under Task 5 of this project, which addresses the identification of source terms for both normal operations and for accidents.

The accidents discussed in this section have been grouped under three headings based on the identities of the principal materials involved in the event; plutonium related accidents, tritium related accidents, and accidents associated with the release of non-radioactive chemicals.

Five plutonium accidents and incidents having the highest accidental releases of plutonium (as estimated by the plant; USDOE, 1980) are discussed. The main plutonium release from Rocky Flats resulted from the leakage of contaminated oil from drums stored in the Building 903 drum storage area. Tritium has been released from the plant in both air and water effluents. Three tritium accidents are described. Small-volume releases of non-radioactive chemicals from laboratory operations and spills have been routine occurrences throughout plant history. Several events associated with chemical accidents have drawn public concern and media attention. A number of these are discussed.

Based on extensive investigation of accident records, incidents involving uranium have been relatively rare. One exception was associated with the practice of on-site burning of wood pallets that is described in the discussion of on-site waste disposal in Section 5. In May of 1965, three depleted uranium sheets were accidently burned as a result of their being shipped to Rocky Flats from Medina, Ohio, in a package that resembled a non-standard size wooden pallet. Improper labeling and the non-conventional packaging apparently caused the depleted uranium to go undetected, and the "pallet" containing 60 kilograms of slightly-radioactive depleted uranium was destroyed by burning on May 1, 1965 (Young, 1965).

6.2.1 Plutonium Accidents

Review and analysis of the available classified and unclassified information indicates that accidents having the greatest potential for off-site release of contaminants have been associated with plutonium. Such releases appear to have been primarily associated with the 1957 fire and the leakage of plutonium contaminated oil from drums stored at the 903 Pad. The plant has characterized the contribution of accidental releases relative to normal operational releases in data presented in Table 2.7.2-1 in the Final Environmental Impact Statement (USDOE, 1980). Figure 6-1 presents this information graphically. Figure 6-2 shows the locations of the major Rocky Flats accidents.

INSERT FIGURE 6-1; RELEASE TREND GRAPH

INSERT FIGURE 6-2; SITES OF THE MAJOR ACCIDENTS AT THE ROCKY FLATS PLANT

Hohenemser (1987) states:

> "According to the Department of Energy, the leaking oil drums (from the 903 Pad) produced 99% of all plutonium that ever got off-site... and are responsible for the bulk of the airborne plutonium in the environs of Rocky Flats. Critics Johnson and Chinn suggest that additional environmental deposits may have originated in the 1957 and 1969 fires."

Plutonium is routinely burned under confined and controlled conditions at Rocky Flats to produce plutonium oxide during reprocessing operations. Fire is also a continual accident hazard when working with plutonium. For example, Rocky Flats data (Graves, 1974) indicates 623 reportable fires (most of them small) at Rocky Flats between January, 1955 and December 1974. Of those fires, 387 (62%) occurred within the plutonium processing areas of the plant. Graves also claims that there were no reportable fires from the beginning of construction in 1951 through 1954, even though occupancy of some of the buildings began in 1953.

Discussing fire experience at Rocky Flats between 1966 and May of 1969, the accident report on the 1969 fire (USAEC, 1969), page 99, says:

> "There have been a total of 164 fires that were reported to the Fire Department. Of these, 31 involved plutonium of which 10 occurred in Building 776/777. Of the remaining 133 fires, 17 occurred in Building 776/777. There is no good estimate of the number of plutonium fires during this period which were not reported to the Fire Department."

Chips from plutonium machining operations easily ignite if exposed to the air. Barrick (1981) states that "...plutonium metal burns at a temperature near the 640 C melting point of plutonium and...no odor, smoke or flames are produced until other combustibles are involved." Small plutonium fires are therefore part of normal operations at Rocky Flats, and many such fires are not reported if they remain confined within the production apparatus and there is clearly no risk of human exposure. This subject is discussed further in Appendix J-2 of Volume II-B of the 1969 fire report (USAEC, 1969). Emissions from most plutonium fires occurring during normal operations pass through multi-stage HEPA filter systems and contribute to the normal operational releases of radionuclides from the plant. The 1957 fire was a significant exception.

The September 11, 1957 Fire

The 1957 fire is discussed in an October 7, 1957 report prepared by an accident investigation committee chaired by J.G. Epp of Dow Chemical/Rocky Flats (Epp et al., 1957a). The Epp report has 28 pages of text and 20 pages of drawings and photographs. Dow Chemical (Rocky Flats) also published a "Supplementary Report on Fire in Building 71, September 11, 1957" on December 10, 1957 (Epp et al., 1957b).

The fire began at about 10:10 p.m. on September 11, 1957, when metallic plutonium casting residues spontaneously ignited in a glove box in Room 180 of Building 71 (now Building 771). The fire then spread to an exhaust filter plenum, Rooms 281 and 282, consuming a considerable quantity of filters and damaging the ductwork and fan system.

Pertinent excerpts from Epp et al. (1957a) are as follows:

> "The exhaust filter plenum consisted of a long concrete-block-walled room into which the individual exhaust systems discharged. The 620 CWS (Chemical Warfare Service) 24-inch square filters were held in a structural steel framework. The four exhaust fans connect to the filtered side of the plenum and discharge into a common exhaust duct leading to a concrete tunnel and concrete stack." (page 10)
>
> "At approximately 10:10 p.m., September 11, a fire in a glove box (in Room 180, Building 771) was discovered by two Plant Protection men...on a routine clock tour of the building. The fire, when first discovered, appeared to consist of materials within the glove box, the plexiglas box itself and neoprene gloves.
>
> Since it was known that gross amounts of plutonium were handled and stored in this area, people were delayed in fighting the fire until adequate radioactive contamination protection was put on. Then, attempts to fight the fire with carbon dioxide from hand extinguishers and a hundred pound cart proved to be ineffective; however when a water spray nozzle was brought in and used, it was effective, although there was considerable uncertainty as to the criticality problems which it might produce. During this period, the fire was transmitted to the filters, and hot gases were

introduced through the ventilation booster system and the main exhaust duct.

At about 10:39 p.m., an explosion in the exhaust system, probably due to accumulated unburned gases, occurred; but, by this time, the fire in room 180 had been extinguished.

Thereafter, the filter fire became of prime importance, although there were several minor rekindlings in room 180. Figure 6-3 shows the condition of some of the Building 771 exhaust filters after the 1957 fire.

"It is doubtful that shutting down the fan system would have been the proper action in view of the contamination problems involved; however, the draft undoubtedly contributed to the intensity and spread of the fire in the filters.

...The flammability of the CWS filters had been known for some time; however they were the only commercially available filters adequate to do the job from the contamination point of view." (page 18)

Chronology - September 11, 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. People forced out of room 180. ...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.

September 12, 1957

2:00 a.m. - Filter fire knocked down.

11:28 a.m. - Final fire out" (pages 14-17).

INSERT FIGURE 6-3; PHOTOGRAPH- BUILDING 771 FILTERS AFTER THE 1957 FIRE

Plaintiff arguments during the Church litigation emphasize the confusion at the time of the 1957 fire, the undesirability of turning the exhaust fans on to high speed, and the design features of the building and equipment which contributed to the severity of the fire (Fairfield and Woods, 1978).

Reporting on the 1957 fire, Barrick (1981) says:

> "Smoke from a burning glove, detected in a building hallway, led two watchmen to discover flames extending 18 inches out of a Plexiglas window on a glove box. The time was approximately 10:10 p.m. on Wednesday, September 11, 1957. The fire had 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)... Fires in the box exhaust booster filters and main filter plenum on the second floor may 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...probably contributing to the release of plutonium from the 152 foot tall stack.
>
> 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., September 12th and the fire was officially declared out at 11:30 a.m., Thursday, September 12, 1957."

A Rocky Flats Fact Sheet (Linkon, 1985) says:

> "No major injuries were reported in the 1957 fire. The Atomic Energy Commission reported an estimated property loss of $818,000."

Putzier (1982) notes that the Building 771 exhaust fans shut down at about 10:40 p.m. (Epp et al., 1957, page 16) when power was lost during the 1957 fire. "Therefore the only draft would have been that created by the natural updraft of the stack and through 100 feet or so of horizontal ductwork that leads to the base of the 175 foot stack. There was, however, a possibility that supply fans may have created a positive pressure inside the building for a period of one-half hour or so" (Putzier, 1982, page 10).

Putzier notes that Building 771 "...was designed with a main filter plenum, single stage, with Chemical Warfare Service (CWS) filters..." (page 22). He goes on to say that 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 glove boxes and hoods and also for the production development laboratory on the first floor.

Reporting on an inspection of the duct between Building 771 and the stack "a couple of days after the fire," Putzier (1982, page 46) says:

> "There appeared to be some damage at the very top of the stack. By visual observation, it appeared that something up at the top of the rim had been dislodged. ...someone made the conclusion something might have been blown off from one of the pressure releases associated with the fire."

Putzier concurs that fire propagation was probably enhanced by the increased draft when the Building 771 fans were turned up to high speed at about 10:25 p.m., 200,000 cfm or more according to Epp et al. (1957a, page 15).

Contamination and Dispersal of Soil From the Building 903 Drum Storage Area

Another type of plutonium release, also not subjected to multi-stage HEPA filtration, occurred when plutonium contaminated soil was resuspended from an outside drum storage area at the east end of the plant site between 1957 and 1969. In 1971, Dow Chemical (Rocky Flats) published a 50 page report with five appendices (Seed et al., 1971) describing Building 903 drum storage area events and the resulting soil contamination. The report was produced by a committee appointed by the General Manager of Rocky Flats on August 19, 1970 to assess the long-term potential hazard of plutonium contaminated soil under and around an asphalt pad (the 903 Pad) put in place to prevent further spreading of contaminated soil.

Key excerpts from the Seed et al. report are as follows:

> "In July 1958, at the USAEC Rocky Flats Installation, an area on the plant site was designated as a temporary storage area for contaminated oil drums. Subsequently, some of the drums developed oil leaks and some plutonium contaminated oil was deposited on the soil. The area was later covered by an asphalt pad.

After a fire on May 11, 1969 at Rocky Flats, studies were conducted by the Health and Safety Laboratory (HASL) of the USAEC and by the Colorado Committee on Environmental Information, concerning the possible release of plutonium. These investigations detected measurable amounts of plutonium in the soil around the Rocky Flats Plant. The epicenter quite clearly showed that this contamination could not be attributed to the May 1969 fire but is due to the resuspension and redistribution of contaminated soil from the oil drum storage area" (page 1).

"HISTORY OF PLUTONIUM CONTAMINATED OIL DRUM STORAGE AREA: From the beginning of operations of the Rocky Flats Plant, organic liquids contaminated with radioactive materials were generated in various manufacturing operations. In the initial design of the facilities, very little attention was given to this particular radioactive waste problem. The volumes were very low and it had been assumed that this form of contaminated waste could be either burned or packaged in some manner and shipped for burial as were the low level solid wastes.

...Changes in weapons design and in manufacturing processes significantly increased the amount of contaminated oils being generated. ...The problems of permanent disposal, and of storage of the increasing quantities generated, were recognized in 1956.

As a result of one study, the Part IV addition (completed in 1957) to the plant included a high-speed centrifuge in Building 776 to process plutonium-contaminated organic liquids. The operation was disappointing and resulted in a recommendation made in 1958 that a substitute process be developed for disposal.

...The outside plutonium contaminated oil drum storage areas was first established in July 1958.

Most of the drums transferred to the field were nominal 55-gallon drums, but a significant number were 30-gallon drums. Not all were completely full. Approximately three-fourths of the drums were plutonium-contaminated, whereas most of the balance contained uranium. Of those containing plutonium, most include lathe coolant consisting of straight-chain hydrocarbon mineral oil (Shell Vitrea) and carbon tetrachloride in varying proportions. Other liquids were involved, however, including hydraulic oils, vacuum pump oil, trichloroethylene, perchloroethylene, silicone oils, acetone, still bottoms, etc. Originally, contents of these drums were indicated on the outside, but some of the markings became illegible through weathering, and adequate records were not kept of the specific contents of each barrel. Leakage of the oil was recognized early, and in 1959 ethanolamine was added to the oil to reduce corrosion rate of the steel drums.

Development work on a potential process to dispose and/or reclaim the materials continued. As a result of the development studies which had been initiated, however, a recommendation was issued in December of 1959 that a still be constructed for the separation, purification and reuse of the carbon tetrachloride and the Shell Vitrea. ...The process was set up in Building 771. Because of time and funding problems, surplus stainless steel equipment was used. On May 15, 1960, test runs of this equipment were begun, and shortly afterward drums of currently generated oil, together with some transferred from the field were processed through the system.

...In June of 1960 corrosion of the stainless steel equipment, caused by hydrolysis of the carbon tetrachloride to hydrochloric acid, became a problem and in September the operation was discontinued because of severe corrosion.

...Installation of (a) mixer-extruder system (for processing contaminated liquids) was completed in January 1964, but start-up work revealed major deficiencies which required extensive modifications in the installation. These modifications were not completed until late in 1965.

...After (further delays) and more start-up problems, the final phase of emptying the drum field began on January 23, 1967. By this time the field contained about 5,240 drums of which approximately 3,570 contained plutonium contamination. The oldest drums and those containing plutonium were processed first. To the best of our knowledge, the last of the plutonium-contaminated oil was removed on January 25, 1968. The last of the uranium-contaminated oil was transferred to a new drum on May 28, 1968, and shipped to the disposal plant on June 5, 1968.

...An estimate of leakage, based on a material balance around the drums, indicated that 5,000 gallons of oil containing about 86 grams of plutonium leaked from the drums into the soil.

The significant or pertinent events associated with the Plutonium Contaminated Drum Storage Area (903 Pad) can be summarized as follows:

July, 1958	Drum storage area established. During subsequent years, drums were continually added which primarily contained plutonium contaminated machining oils.
July, 1959	First drum leakage discovered. Rust inhibitor, ethanolamine, was added to drums prior to 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 and 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 2.0 E+05 disintegrations/minute/gram of soil (d/m/g) to over 3.0 E+07 d/m/g reported. Penetration of from 1 inch to 8 inches reported.
September, 1968	Preliminary proposal for containment cover prepared by Rocky Flats 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 deposition of contamination in the soil of the drum storage area began shortly after the drums were placed in the area. Resuspension and redistribution of the contamination, however, was certainly not a simple mathematical function of time. The quantity redistributed was directly associated with the removal of the drums which exposed the contaminated soil, physical activity in the area, and the periodic high winds at Rocky Flats" (pages 5 and 6).

The 1973 tritium release report (USAEC, 1973), page 58, summarizes the 903 Pad events as follows:

"First drums stored - October, 1958
Last drums stored - January, 1967
First drums removed - January, 1967
Last drums removed - June, 1968

Contents: 3,572 drums of oil contaminated with plutonium
1,254 drums of oil contaminated with uranium

Comments:

1. A total number of 5,237 drums were stored in the oil drum storage field. There were 4,826 drums transferred to the plutonium waste processing plant. The difference of 411 drums is attributed to leakage of the oil into the soil and some of the drums were not full when first transferred to the field for temporary storage.

2. The first indication that drums were leaking in the field was in 1964. As a result the storage area was fenced and contents of the leaking drums were transferred to new drums. Approximately 420 drums leaked to some degree and of these about 50 leaked totally empty. Approximately 86 grams of plutonium leaked into the soil.

3. In 1967 a heavy rain storm spread contamination to a ditch near the drum storage field.

4. In November 1968 grading was started for...applying an asphalt cap over the area.

5. In July 1969, installation of an asphalt pad was started and completed in November of 1969.

6. In February, 1970, six inches of road base course was applied east and south of the asphalt pad. This was completed in March 1970."

A letter from Dow Chemical (Rocky Flats) to Dr. Roy L. Cleare, Executive Director of the Colorado Department of Health, (Joshel, 1970) says:

> "In 1964 it was realized that a few of the drums were leaking in the (903 Pad drum storage) field and contaminating the soil beneath. Contamination was detected on air samplers at the east fence following high winds...

> In 1967 a heavy rain storm spread contamination from the drum field to the ditch along the road at the fence line."

A Rockwell International (Rocky Flats) Fact Sheet (Linkon, 1985) states:

> "An estimated 5,000 gallons of used oil containing 150 grams of plutonium leaked into the soil inside the Rocky Flats Plant southeast security fence between 1964 and 1967...
>
> ...by the end of 1967, plant officials discovered that soil contaminated by the leaking drums had been resuspended into the air and redeposited. Most of the resuspension occurred between July 1968 and March 1969. The highest airborne value was 0.34 picocuries per cubic meter. Releases continued into July 1969 when the storage area was covered with a gravel fill. The storage area was coated with asphalt in November 1969."

Much of the plutonium carried off the site in contaminated soil from the 903 Pad oil drum storage area appears to be immobilized in the soil of the buffer zone southeast of the plant. According to a Colorado Department of Health report on Rocky Flats (CDH, 1990):

> "A new round of soil sampling in a seven mile radius around the plant was completed in late 1989. (The survey) showed the following:
>
> 1. There is an overall decline in plutonium concentration in the soils since 1970.
>
> 2. Plutonium concentrations are highest just east of the plant."

The May 11, 1969 Fire

A major plutonium fire started in a glove box in the North Plutonium Foundry glove box line in Building 776 on Sunday, May 11, 1969. The fire burned for several hours, spreading through combustible materials in several hundred inter-connected glove boxes in Building 776 and Building 777.

The U.S. Atomic Energy Commission prepared a five volume report on the 1969 fire (USAEC, 1969a). Pertinent excerpts from the report, summarizing the 1969 fire, are as follows:

> "The first indication of a fire was an alarm in the Fire Station at 2:27 p.m., in the North Foundry Line. Although the Fire Department responded promptly, on arrival the fire was moving rapidly through the Foundry Conveyor Line. It subsequently spread through one of the interconnecting conveyors and into the Center (fabrication) Line. The fire 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 glove box on the South Foundry line. This fire 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 very difficult to fight and extinguish.
>
> ...The fire did not breach the building roof, and only a small part of one exhaust filter system was ruptured. Consequently, most of the smoke and essentially all of the plutonium remained in the building. One fire fighter received a significant internal body burden of plutonium, but has responded well to treatment. There were no disabling injuries to personnel or deaths. There is no evidence that a criticality incident occurred or that any significant amount of plutonium was carried beyond the plant boundaries.

> The damage to Building 776-777 and its equipment was very extensive. In addition to actual fire and smoke damage, the building was grossly contaminated with plutonium. Substantial parts of the utility system serving the building were severely damaged. Some of the adjacent buildings sustained minor exterior and interior contamination" (pages 1-3).

The following excerpts from the report on the 1969 fire (USAEC, 1969a) provide background about operations and ventilation systems in Buildings 776-777 as they were at the time of the 1969 fire:

> "All production operations in Building 776-777 are carried out in glove boxes which are interconnected by a series of conveyors. There are four principal glovebox systems: (1) North Foundry Line, (2) South Foundry Line, (3) Center Line, and (4) North-South-East Machining Lines" (page 23).

> "The conveyors are equipped with pendants or carriers on which containers or plutonium parts are placed" (page 25).

> "The basic philosophy of the building and glove box ventilating systems is that conditioned air will be furnished to all plant areas and any leakage will be from less hazardous into more hazardous areas in order to control contamination spread. To accomplish this, the ventilating system is divided into two major areas (i.e., room and glove box) with several subdivisions under each.

> ...Building 776 is maintained at a negative pressure with respect to outside atmosphere. Within the building the pressure becomes even more negative as one progresses from the office space to the equipment spaces (largely on the second floor) to the operating spaces within which are the glove box lines where the pressure is lowest of all" (pages 26 and 27).

> "There are three basic systems of glove box ventilation: Booster System No. 1, Booster System No. 2, and the Glove box Dry Air System. All maintain a negative pressure with respect to the operating areas of Building 776-777 so that any air leakage will be from the room into the glove box system. Booster System No.1 serves

the Center Line and parts of Building 777. Booster System No. 2 serves the North and South Foundry Lines and some miscellaneous glove boxes at the west end of Building 776. The Glove box Dry Air System serves the North and South Machining Lines in Building 776, and parts of Building 777.

Booster Systems Nos. 1 and 2 draw air into the glove boxes from the first floor of Building 776 through filters on the glove boxes. The air is then drawn from the glove boxes into the connecting conveyors, into ductwork on top of the conveyors, and up to the filters on the second floor whence it is discharged through exhaust vents to the outside of the building. (Pages A-26 and A-27 of Appendix A-13, Volume II-A state that Booster No. 1 had 4-stage bank of filters, while Booster No. 2 had a 6-stage bank of filters). Some of the conveyors on the North and South Foundry Lines contain filters where the return air ducts are connected.

There is no barrier between the parts of the glove box system served by Booster Systems Nos. 1 and 2" (pages 28 and 29).

"The Glove box Dry Air System supplies dehumidified air by ducts attached to the conveyor lines. The air from the conveyors is then drawn through the glove boxes and returned to the filters on the second floor by ducts attached to the glove boxes. From the filters the air is exhausted outside. (Page A-28 of Appendix A-13, Volume II-A, states that the glove box dry air system had a bank of four stages of HEPA filters in the exhaust.) In normal operation, this system is isolated from the Booster Systems Nos. 1 and 2 by means of doors at six places" (page 30).

"On the first floor of Building 776-777 there is approximately 100,000 square feet of open space, without any built-in automatic fire suppression system" (page 34).

"There are three principal operating activities conducted in Building 776-777: (a) foundry, (b) fabrication, and (c) assembly. ...All of this work involves the manufacture of plutonium parts for weapons and test devices. In the foundries, plutonium is cast into either ingots suitable for rolling and further wrought processing or into shapes amenable to direct

> machining operations. The fabrication operation takes the ingots or cast shapes furnished by the foundries and makes the plutonium parts by rolling, forming and machining. The assembly operation involves the assembling of various components into completed units. Primarily, the units contain nuclear materials such as plutonium and uranium. After assembly, completed units are packed and shipped.
>
> ...Charges for the casting furnaces are made up from two general sources of feed material: refined plutonium metal ("buttons") from elsewhere at Rocky Flats or off-site, and scrap from within Building 776-777.
>
> ...Scrap metal and chips generated in the rolling, forming, and machining operations are placed in containers and returned to the foundries by conveyors. This material is briquetted before being incorporated into furnace charges. Since the material is oily, it is first dipped in successive baths of carbon tetrachloride, allowed to dry and then taken to the briquetting press. There it is removed from the containers, and pressed into a briquette about 3 inches in diameter and 1 inch thick" (pages 36 and 37).

The following excerpts from pages 49-57 of the 1969 fire report (USAEC, 1969a) provide additional details about the May 11, 1969 fire in Buildings 776-777:

> "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 firemen, responded to the initial alarm. (He) arrived at the west end of Building 776 at 2:29 p.m. On entering the building he saw smoke coming toward him from the east. ...He proceeded further into the building and observed heavy smoke and fire in the North Foundry Line at about Column K-4 (just west of Glove box 134-24). The fire was out of the top of the line with flames about 18 inches high.
>
> One of the firemen heard two loud reports (like rifle shots) and saw two fireballs (about basketball size) go to the ceiling in the area of the North Foundry Line. This occurred while the firemen were

laying out a fire hose, and before any water had been used on the fire.

...In general, the initial firefighting activities were concentrated on the North Foundry Conveyor Line and glove boxes east from Glove box 134-24. By 2:50 p.m., there was fire along the top of the North-South Conveyor Line (Column Line 8). About this time the firemen on the second floor (over the North Foundry Line) heard a loud noise and felt the floor shake. At approximately 3:20 p.m. the fire was reported moving into 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.

Almost from the beginning it was virtually impossible to see because of the thick black smoke and the loss of lights in the main fire area. The crowded conditions in the fire areas made fire fighting very difficult.

...water was used (on the fire) almost exclusively; although some magnesium oxide was used on plutonium. Since the conveyor lines and glove boxes were now open, it was not possible to avoid getting water on the burning plutonium. In order to fight the fire in the Benelex (radiation shielding material) facing on the conveyor lines it was necessary to put the hose lines into the openings and play water up and down the lines, or to direct a water stream towards the ceiling and bank it toward a burning area. The fire fighters reported seeing burning plutonium erupt with showers of sparks when hit with water. In some instances there were unsuccessful efforts to move piles of burning plutonium by directing streams of water on the material itself.

The persistence of the fire was a matter of serious concern for a period of hours. Attempts to pry or knock the Benelex shielding from glove boxes and conveyor lines (were) not successful. Although the firefighters were generally successful in `knocking down' the fire in particular locations, by the time they returned with new air supplies -or from directing their attention to other areas - the fire would be going as intensely as before.

Some smoke came out the west end doors of Building 776 when they 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. It billowed over the side of the building toward Buildings 778 and 750. Two Dow (Rocky Flats) employees reporting to the plant observed a smoke plume while on the Denver-Boulder turnpike about 10 miles away. Firefighters sent to the roof saw smoke coming from some exhaust vents. Although there were no signs of fire in the roof, the roof did get soft 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 from the building. By 8:00 p.m. the fire was extinguished for all practical purposes, and a fire watch was established. Some small fires continued to reoccur in the North Foundry Line, the North-South Conveyor Line, and the ceiling above the North-South Conveyor Line.

During the early morning hours of Monday, May 12, the storage container in Glove box 134-24 on the North Foundry Line continued to smolder and reignite. Both water and magnesium oxide were used when this occurred. At times, flames five to six feet high appeared along the side of the box. According to the testimony, two cans of burning plutonium were removed from Glove box 134-24 and placed in Glove box 134-25 to decrease the fire potential; another can of burning plutonium was removed and placed to the south of the Benelex storage container on the floor of Glove box 134-24.

Between 8:00 and 9:00 a.m. on Monday the fire watch discovered a fire in the plutonium storage box on the South Foundry Line (Glove box 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."

A Dow Chemical (Rocky Flats) report (Willging, 1969) suggests that the smoke issuing from Building 776 during the May 11, 1969 fire was a combination of contaminated smoke that escaped from the Booster No. 1 filter plenum and uncontaminated smoke from thermal decomposition of roofing material heated from below by fires contained within the building.

A detailed fire chronology is supplied in Volume II-A, Appendix D-1, of USAEC (1969a). This report also says:

> "Most of the plutonium metal in the fire damaged area was completely burned and lying in the bottom of the burned out conveyors and boxes" (page 66).
>
> "One area of the roof of Building 776-777 near the exhaust vent from Booster System No. 1 was contaminated with plutonium. The adjoining ground areas and the exterior of Building 777 also were contaminated" (page 69).
>
> "The ventilating, electrical and other utility systems on the second floor of Building 776 were heavily contaminated with plutonium.
>
> ...Some of the filters on all four stages of Booster System No. 1 were burned or damaged by heat and air pressure" (page 70).
>
> "...During the fire, the gamma (radiation) alarm system in Building 776 was destroyed but the Building 777 alarm system remained operational. Neither this system nor the ones in Buildings 559, 779, and other locations on the plant site were set off during or after the fire. A Hurst dosimeter retrieved from Building 776 after the fire 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" (page 95).
>
> "Since there is no evidence that the roof of Building 776 was breached, and the smoke observed coming from the roof lasted only a

> short time, it is not credible to attribute such smoke to the fire inside the building. There is evidence of fire downstream of the fourth (and final) stage of Booster System No. 1 filters. Accordingly, it appears more likely that the smoke seen outside the building came from this fire.
>
> ...Only an insignificant amount of plutonium appears to have escaped from Building 776-777. It was primarily deposited on the roof of the building, and on the ground and one building adjacent to Building 776-777.
>
> The fact that the building structure, including the roof, was not breached by fire, that most of the ventilating systems continued to operate, and only a part of the final stage of one set of filters (Booster System No. 1) was damaged, appear to have been the controlling factors in limiting the amount of plutonium released" (pages 110-112).

A summary of the 1969 fire report published in an Atomic Energy Commission newsletter (USAEC, 1969b) states:

> "...Because of the concern about the possibility of a nuclear criticality accident (a chain reaction), the standard firefighting procedures then in effect for Building 776-777 did not specify the use of water, except as a last resort. For this reason, there was no automatic sprinkler system in this area of the building. The first attack on the fire...with carbon dioxide...was ineffective. Less than ten minutes after the fire alarm was received, the fire captain initiated the use of water. Thereafter, water was used almost exclusively in the firefighting activities. No nuclear criticality occurred. The fire was brought under control about 6:40 PM, but continued to burn or recur in isolated areas throughout the night.
>
> The fire originated within the North line, moved rapidly through the North-South Overhead Conveyor Line and subsequently spread through one of the interconnecting conveyors and into the Center Line. Some plutonium contained in these lines burned, and as the glove box

> windows burned out, plutonium oxide was released into the room. ...Because of the extensive plutonium contamination and smoke, all personnel entering the area during the fire were required to use self-contained breathing air systems which severely limited...access to, and time in, the fire area...
>
> The damage to Building 776-777 and its equipment was extensive. In addition to...fire and smoke damage, the building was heavily contaminated internally with plutonium. Substantial parts of the utility systems were severely damaged. Some of the interconnected buildings sustained minor interior contamination... The fire did not breach the building roof, but slight exterior contamination was measured on the roof of Building 776 and an adjoining building, apparently due to a minor failure of a filter. Plutonium...was tracked out of Building 776 by the firefighters and was detectable on the ground around the building. There is no evidence that plutonium was carried beyond the plant boundaries. The present estimate of the financial loss for the damage to buildings and equipment, including cost of decontamination is $45,000,000."

An attachment to the Dow Chemical letter to Dr. Roy L. Cleare (Joshel, 1970), says:

> "...It is theorized that the fire started when pressed plutonium briquettes self-ignited in the metal container where (they were) stored within a Benelex and Plexiglas storage cabinet in the north line. Heat from the burning plutonium ignited the Benelex and Plexiglas within the glove box line which created large quantities of smoke.
>
> The fire progressed west within the north line until the dense smoke clogged the Booster 2 ventilation system which serviced the north line. The Booster 1 ventilation system, which serviced the north-south overhead conveyor line and the center line, then took over the air processing function for the north line, reversing the air flow and causing the fire to move east within the north line.

> When the fire reached the junction of the north line and the north-south overhead conveyor line, the fire was forced into the latter by a closed fire door on the north line and the direction of the air flow into the north-south overhead conveyor line. The renewal of the air supply from the Booster 1 system caused the substantial volume of hot, unburned gases given off by the burning materials to ignite, creating a very hot fire...
>
> The fire was drawn into the center line by the ventilation system. When the flames reached the HEPA filter of the Booster 1 system, the intense heat caused breaches of the first and second banks of the four bank HEPA filter system. The gaskets which contain the third and fourth banks of the HEPA filter system were breached, allowing amounts of unfiltered smoke to be released into the environment.
>
> The Booster 1 stack, like all ventilation stacks in Building 776-777 directed the smoke back onto the roof of Building 776 where significant alpha activity was discovered. Plutonium, believed to have been tracked out by firefighters, was also detected on three sides of Building 776."

A letter from General E.B. Giller of the USAEC to Governor Love of Colorado (Giller, 1969) says:

> "A multistage absolute air filtration system was incorporated into each building handling radioactive material during initial construction. In addition, there is a separate absolute filtration system for all air circulated through enclosures containing radioactive materials. All air in the ventilation system is either recirculated so that it does not leave the building or is vented after complete filtration... These filtration systems were not destroyed by the fire and all except one operated as designed both during and after the fire. One was damaged by fire but was deactivated prior to permitting the spread of contamination beyond the immediate area on the roof where it exhausts."

Langer (1979) says that, during the 1969 fire,

> "...plutonium briquets ignited spontaneously and set the glove box shielding (Benelex) on fire. Resulting combustible gases were ignited and burned the first three filter stages. The last one was slightly damaged. Smoke was also released to the room and was collected by the room exhaust filters. As the latter have only two stages, greater overall filter penetration would be expected" (page 30).

After the 1969 fire, processing and production glove boxes at Rocky Flats were converted to an inert nitrogen atmosphere to attempt to prevent spontaneous ignition of plutonium.

The 1965 Glove Box Drain Fire

A plutonium fire that did not attract as much public attention, but was estimated by DOE (USDOE, 1980) to have released more gross alpha activity than the 1969 fire (see Figure 6-1) occurred during a maintenance operation on a plugged glove box drain in Building 776/777 in 1965. The flash fire vented to the room air and was spread throughout the buildings by the normal ventilation system.

A Colorado Committee for Environmental Information report (CCEI, 1970), referencing Mann, J.R. and R.A. Jirchner (1976) says:

> "... plutonium chips caught fire in a large room with about 400 employees, many of who were [potentially] exposed to high airborne concentrations of plutonium dioxide without respirators. Body counter measurements indicated that 25 employees received 1 to 17 times the permissible lung burden."

Putzier (1982, page 54) says that this was "... probably the most serious incident in terms of number of people affected that Rocky Flats has had."

According to the official accident investigation report on the 1965 glove box drain fire (Hammond et al., 1965),

> "At approximately 10:25 a.m. on Friday, October 15, 1965, a fire occurred during a lathe maintenance operation in Building 76-77 of the Rocky Flats Plant. ...fifteen employees ... received significant radiation exposures- greater than 0.008 microcuries in the lung. Plutonium contamination was spread through a major

portion of Building 76 and throughout part of Building 77. Major areas of the buildings were cleaned up by Monday morning, October 18, and nearly all of the production operations were resumed at that time" (page 7).

"the October 15, 1965 fire occurred during a maintenance operation which involved unplugging a coolant recirculation line for a tape-controlled turning machine. Attempts to remove the line obstruction from the glove box end of the line failed and attempts were made to unplug the line through a drain leg located close to the glove box. A cap was removed from the bottom end of the drain leg and a double-bagged center punch was inserted to dislodge the obstruction. Sparking was observed when the punch was struck, and a flash fire resulted, burning the bag enclosure for the punch and igniting a plastic and paper pen directly beneath the drain leg. The fire was extinguished with carbon dioxide...

The source of ignition is presumed to be sparking caused by contacting plutonium settled in the drain leg with a steel center punch. The fire vented to the room atmosphere and the combustion products were widely spread by the normal ventilation pattern" (page 8).

"The fire occurred in Room 130 of Building 77... The location of the fire was at Box 752 on the southeast machining line. ...Contamination from the fire was generally spread throughout Building 76 and over approximately 25,000 square feet of Building 77" (page 9).

"Estimates of duration...of the fire ranged from one half to one and a half minutes" (page 22).

"The first evidence of excessive contamination release at the job was noted by the radiation monitor...when his alpha survey instrument showed an off-scale reading" (page 24).

"...checks of people leaving Building 76-77 revealed contaminated booties on all personnel, with a large majority showing contamination of varying degrees on coveralls and/or exposed portions of the body. This was evidence that the entire area of Building 76-77 was suspect" (page 25).

"Residues of the fire and residues from a drain leg removed from an adjacent lathe have been analyzed. These analyses indicate that, during the fire, a chemical reaction had occurred between plutonium and carbon tetrachloride" (page 28).

"...sparking occurred when a center punch contacted the material collected in the drain leg of the coolant line. Upon the second blow, a considerable amount of sparking was observed immediately before the actual fire occurred at the end of the pipe drain leg. Residues from a drain leg removed from an adjacent lathe have been analyzed as plutonium chips, plutonium dioxide, oil and small amounts of plutonium hydride. There is no reason to assume that these residues differ from the original material in the other drain leg before the fire. However, one difference that did exist was that the drain system which burned had been flushed with carbon tetrachloride before the maintenance operation. Operations on the two lathes are similar and on the same material. Therefore, it was concluded that the sparking resulted from friction caused by contacting plutonium metal or plutonium hydride with a steel center punch.

Chemical reactions considered include the reaction of plutonium (and plutonium oxides) with carbon tetrachloride, the reaction of plutonium with oxygen and the reaction of plutonium metal with hydrocarbon oil.

The expected products of the first reaction would be plutonium trichloride, chlorinated hydrocarbons, carbon, phosgene, and in the presence of oxygen, carbon monoxide, carbon dioxide and plutonium oxychloride. The expected products of the second reaction would be plutonium oxide. The expected products of the third reaction would be hydrogen, plutonium carbide and plutonium hydride.

The burning of plutonium in air is generally non-violent and described as smoldering. The reaction of plutonium and a chlorinated solvent (e.g., carbon tetrachloride) can be quite violent.

> The sparking or fizzling observed immediately before the fire could be expected of a reaction between plutonium and air or carbon tetrachloride. The appearance of a ball of fire suggests the presence of a vapor which was ignited by the burning plutonium or the reaction between plutonium and carbon tetrachloride. This vapor could have been created by the heating of the hydrocarbon oil.
>
> Chemical analyses of the fire residues within the pipe indicate the major crystalline constituents were plutonium oxychloride and plutonium trichloride. Both are products of the plutonium-carbon tetrachloride reaction" (pages 31-33).

The 1974 Control Valve Release

Radioactive particulates escaped from an exhaust stack on the roof of Building 707-A at Rocky Flats following a glove box atmosphere control valve accident at about 9:53 a.m. on April 2, 1974. The reversed flow of contaminated air due to manual operation of a control valve during a maintenance operation was not subject to any HEPA filtration and therefore contaminated ducts normally handling uncontaminated air with plutonium. This accident is discussed in detail in a Rocky Flats accident investigation report (Freiberg et al., 1974).

Inert System No.2 is one of the recirculating nitrogen handling systems designed to maintain the oxygen content of the atmosphere in glove boxes and storage vaults below the levels that will support combustion. To maintain negative pressures in the glove boxes, the system must compensate for the inevitable leakage of room air into the glove boxes and the resulting dilution of the nitrogen-rich inert atmosphere. This is done by purging part of the recirculating system gas after it has passed through the HEPA filter plenums, using purge exhaust fans that release filtered gas to the atmosphere through stacks on the roof of the building. The rest of the recirculating system gas goes through recirculation fans and a chiller where additional nitrogen is added to make up for that lost in the purged gas.

The accident resulted when the inert atmosphere exhaust valve from the Building 707 storage vault was being closed during a glove box maintenance procedure. This was evidently done too quickly, resulting in a pressure surge which forced contaminated gas back upstream through the inert gas supply system. The pressure surge forced contaminated gas back through the chiller and the standby recirculation fan that had been turned off as part of the maintenance procedure. From there, the contaminated gas was pumped into the atmosphere by the purge exhaust fans through the exhaust stack shared by Inert System No. 2 and Downdraft Plenum No. 4. This transport of contaminated gas in turn contaminated the exhaust ducts.

Freiberg et al. (1974) state that:

> "...an [elevated] count was detected on the exhaust stack sample of Inert System No. 2 and Downdraft Plenum No. 4. The detection was at approximately 1300 hours, Wednesday, April 3, 1974. ...At approximately 1030 hours on Thursday April 4, 1972, results of extensive Health Sciences 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" (page 6).

The purge exhaust fans, that were pumping gas through the exhaust ducts contaminated by the events that took place around 10:00 a.m. on Wednesday, continued operating until 2300 hours on Friday, April 5, 1974. However, according to Freiberg et al. (1974), the flow from the purge fans had been "reduced to a minimum...less than 25 cubic feet per minute" late on Thursday.

The pressure surge also caused contaminated gas to flow out the open window of glove box 7-K-65, which had been removed for maintenance, into Module K. This contaminated Module K to levels up to 100,000 counts per minutes and tripped the selective air monitors at 0953 hours on April 2, 1974.

After the 1974 accident, the inert gas systems were modified so that the recirculation pumps draw gas from the filter plenum between the second and fourth stages. Now, contaminated gas from a repeat of the 1974 accident would pass through two stages of HEPA filters before being pumped into the atmosphere by the purge exhaust fans.

6.2.2 Tritium Accidents

As evidenced by effluent monitoring performed since the 1970s (See Appendix B), the Rocky Flats Plant is the source of routine, low-level tritium emissions. Tritium emits only low-energy beta particles and mixes throughout the global pool of hydrogen atoms whenever it is released to the environment. Sources of tritium include disassembly of contaminated returned components and natural generation of tritium from other materials present on the site. Low levels of tritium are generated by non-hazardous spontaneous fissioning of plutonium and uranium and by interaction of neutrons given off by plutonium with other materials, such as beryllium. Tritium from these sources is not released in large quantities.

As will be discussed in this section, there have been a small number of incidents reported in which significantly larger amounts of tritium were released from Rocky Flats. Associated documentation has been reviewed by members of the ChemRisk project team. Some aspects of tritium handling at Rocky Flats are matters of national security, are considered classified information, and therefore cannot be discussed in this report. The identified quantities of tritium release are not typically associated with the potential to cause off-site health impacts. However, the source term estimates for these off-site releases of tritium will be presented in the Task 5 source term report and their significance for off-site health impacts evaluated in Task 6 and 8 activities.

The Final Environmental Impact Statement (USDOE, 1980, page 2-172) acknowledges two accidental releases of tritium from Rocky Flats. Regarding the potential community health risks from these releases, Cuddihy and Newton (1986) say that:

> "Two large release of tritium...occurred from the Rocky Flats Plant. An accident in 1968 led to the release of several hundred curies and another in 1973 released 500 to 2000 Ci. The release in 1973 occurred when material... contaminated with tritium was inadvertently processed. It was estimated that about 60 Ci of tritium was released in water effluents, 100 to 500 Ci was retained in ponds and tanks on-site, and the remainder escaped into the atmosphere. ...airborne tritium disperses widely in the atmosphere and may never redeposit on ground surfaces. In addition, tritium decays by emitting low-energy beta radiation that is less damaging to body tissues than the high-energy alpha radiation emitted by plutonium."

The accident investigation report on the 1974 tritium release (USAEC, 1974, page 24) states:

> "There are five known sources of tritium effluent releases at Rocky Flats. They are Building 779, Building 561, Building 777, which released...tritium in the 1973 incident, Building 774 where tritium contaminated water is evaporated, and the four solar evaporation ponds adjacent to Building 779. The solar ponds are the source of water fed to the Building 774 evaporator."

The February 1968 Tritium Release

In 1968, several hundred curies of tritium were accidentally released. Discussing previous tritium incidents, USAEC (1973) says:

> "There was one incident in 1968 of a 600 curie tritium release from a special project. This incident involved gaseous tritium which was released up the stack. No detectable on or off-site contamination was found" (page 34).

A 1968 tritium release is also briefly discussed on page 2-172 of the Final Environmental Impact Statement (FEIS). The release is described as an accidental release of "several hundred curies", and a statement is made in the FEIS that investigations indicated that "no threat to human health or safety occurred." The details of the incident are classified, and several classified documents describing the event have been reviewed by project team members. Relevant facts about the release will be factored into the Task 5 source term estimation process for tritium.

The 1973 Tritium Release

A shipment of scrap plutonium from Lawrence Livermore Laboratory was received at Rocky Flats on March 19, 1973, for reprocessing. The plutonium "contained an unanticipated and unknown amount of tritium later estimated to range from 500 to 2,000 curies" (Barrick, 1981). The radioactive gas monitoring equipment in the receiving building (B-554) did not detect the tritium. The scrap plutonium was processed from April 9 through April 25 in Building 779A (USAEC, 1973) using procedures appropriate for non-tritiated plutonium, because the plutonium contamination was not discovered prior to processing (Barrick, 1981).

Barrick (1981) says that Rocky Flats (RF) and the Colorado Department of Health (CDH) set up sampling programs for tritium and other radionuclides in 1972. Barrick (1981) goes on to say:

> "Tritium sample results during 1972 showed good agreement at background levels (500-1000 pCi/l) between CDH and RF. In 1973, environmental samples were not checked for tritium by RF prior to September. CDH sampled plant effluent during the entire year, and on April 24, 1973, a routine monthly water sample collected by CDH from Walnut Creek indicated...3,000,000 pCi/l tritium, which equalled the maximum permissible concentration...for uncontrolled areas and which was well above background level.

> CDH questioned RF by telephone...and at a June 26 Information Exchange Meeting. Rocky Flats had no knowledge of any tritium being processed and did not believe the known small quantities of tritium in sources, targets, etc. on the plant site could have accounted for the anomalous results. Colorado Department of Health continued sampling after May 1973 and these samples showed decreasing concentrations each month. The subject of tritium was discussed again by CDH in the July 31 Information Exchange Meeting with RF. It was agreed to request that the Environmental Protection Agency (EPA) perform confirmatory sampling. The EPA confirmed elevated tritium levels (during) the week of September 6, 1973.
>
> On September 13, 1973, CDH and EPA personnel toured Rocky Flats Plant facilities and obtained additional water samples to be analyzed by several EPA and USAEC laboratories. These analyses all verified elevated tritium levels in Rocky Flats effluents.
>
> A letter...by CDH to the Governor of Colorado on September 14 (asserted that)...Rocky Flats was the probable source of ...tritium concentrations equal to the maximum allowable in Walnut Creek waters. The release started in April, reaching the maximum in May and...declined after that. The Broomfield water supply remained at a much lower concentration and had not reached or exceeded the guide levels for drinking water.
>
> Internal searches and audits for a source of tritium by Rocky Flats starting in June and continuing through September were unable to find a probable tritium source.
>
> Finally, on September 20, 1973, H.C. Donnely (USAEC Manager of Albuquerque Operations Office) appointed an AEC investigating committee... The committee...reported the probable source of the tritium (on) 11/26/73."

The official tritium release report (USAEC, 1973) says:

> "Hydrating and oxidizing operations in Building 779A resulted in gaseous discharges of tritium and tritium oxide to the atmosphere

through the building exhausts. The recovery products, contaminated by tritium, were routed through other processing areas probably resulting in the elevated tritium levels observed in other work areas.

Treated liquid wastes from these scrap recovery and waste treatment operations were discharged to the plant waste evaporation ponds and to Walnut Creek, providing a plausible explanation for the contamination levels found in evaporation ponds, holding ponds, Walnut Creek and Great Western Reservoir" (page 5).

Describing the accident in more detail, the report (USAEC, 1973) says:

> "...several items of plutonium scrap were received at Rocky Flats from LLL (Lawrence Livermore Laboratory) which had been exposed to (a) tritium environment. The LLL staff believed that the plutonium scrap had been decontaminated prior to shipment so that alerting Dow (Rocky Flats) to the possibility of tritium contamination was unnecessary.
>
> The plutonium scrap (believed to be free of tritium) was shipped from Lawrence Livermore Laboratory on March 13, 1973, and received by Dow on March 19, 1973. ...A series of experiments, on similar scrap material, has been performed at LLL. The results revealed that the decontamination procedure was ineffective. As a result, rather than trace quantities of tritium, approximately 500 - 2,000 curies were shipped to Rocky Flats" (pages 18 and 19).
>
> "The scrap was received at Rocky Flats in shipment AEC-741-LZB-AWA-293 on March 19, 1973, with hydrating and oxidizing operations performed during April 9-25, 1973 in Room 154 of Building 779A. Contamination surveys in this room revealed elevated tritium levels in equipment and glove boxes.
>
> A subsequent review of tritium contamination in process streams was made. This review revealed a correlation between the locations of elevated tritium levels and the movement of the LLL materials through the recovery process, from the initial recovery area to the plant effluents. The LLL materials were received at Rocky Flats in four 30-gallon shipping containers. The incoming materials consisted of scrap plutonium contaminated with deuterium or tritium. These were unpackaged on a downdraft table, checked for alpha contamination, weighed, repackaged in uncontaminated shipping containers, and transferred to Building 779A, Room 154 for plutonium recovery.
>
> The operations in Building 779A consisted basically of inserting individual portions of the scrap into a hydrating reaction chamber which was filled with hydrogen to convert the plutonium metal at 350 C to plutonium hydride... During the hydrating operations, curie

quantities of tritium were vented through glass wool filters, an oil vacuum pump, an oil demister, a water flame trap, a hydrogen burner and up the stack. The hydrogen burner and the water flame trap are contained in a separate non-inerted glove box. As a result, the hydrating vessel, the pump oil, the flame trap, the associated glove boxes and exhaust plenums were all contaminated with tritium and tritium oxide.

Following the hydrating operation, the plutonium hydride was transferred to an oxidizing vessel (in the same argon inerted glove box) where the hydride was converted to plutonium oxide at 350C by controlled purging of the vessel with room air at reduced pressures. This operation was vented through the same equipment as described for the hydrating vessel, and it is likely that a major portion of the tritium was evolved as HTO (tritiated water) at this time.

Following this operation, the plutonium oxide was reburned at 500 C in a separate non-inerted glove box to assure complete oxidation of the plutonium. All three of the glove boxes (numbered 4933, 1363 and 2025) utilized for these operations in Room 154 were found to be contaminated with tritium...

The "burned" oxide was subsequently transferred to Building 771 for processing to reusable plutonium metal. It appears likely that curie quantities of tritium oxide were transferred to Building 771 with the plutonium oxide, thus providing an explanation for the elevated tritium levels in the process waste streams of Building 771. Process wastes from Building 771 subsequently go to Building 774 for further waste treatment, or to the sanitary sewers or the solar evaporation ponds, providing a plausible explanation for the elevated tritium levels found in Building 774 process wastes and in the solar evaporation ponds.

After the hydrating step in Building 779A, scrap residues were sent to Building 771 for further plutonium reclamation by sulfamic acid leaching. Approximately 16 grams of plutonium were removed during this treatment. The scrap residues, after initial plutonium leaching in Building 771, were transferred to Building 881 for trace

> level plutonium decontamination. Subsequent activities resulted in eventual rework and shipment of these residues as pure product. Sampling data indicate that low levels of tritium remained with these residues, providing an explanation for the elevated tritium levels in the acid tanks and other selected work areas in Buildings 881 and 444 which handled or processed these residues" (pages 20-27).

Discussing previous tritium incidents, the report on the 1973 tritium release (USAEC, 1973) says:

> "...three prior shipments from LLL (Lawrence Livermore Laboratory), not including the March 1973 shipment may have contained curie quantities of tritium. It is believed that these special materials and possibly others in past years may have been a source of occasional curie level releases of tritium to the environment" (pages 34 and 35).

A draft report to the committee investigating the tritium release (Dow, 1973, page 67) estimates that the maximum amounts of tritium that might have been contained in the three shipments from LLL other than the April 1973 shipment are as follows, based on LLL calculations:

Shipping Date	Maximum Estimated Tritium
April, 1969	57 Ci
March, 1971	40 Ci
November, 1971	29 Ci

The magnitude of these three tritium release estimates and their relative significance with regard to potential off-site impacts, compared to the 1968, 1973 and 1974 tritium release estimates, will be addressed in the Task 5 source terms report.

The 1974 Tritium Release

As stated in the 1974 tritium release report (USAEC, 1974, page 28):

> "During the period August 30 - September 4, 1974, about 1.5 Ci of tritium was released from exhaust system 205, Building 777. Tritium concentrations detected in the air effluent exhaust during the period of release were about 50% of the applicable Radioactive Concentration Guidelines (RCG) specified in AEC Appendix 0524, Annex A, Table 1, Column 1...
>
> There was no increase of tritium background levels in the environment outside of Buildings 776/777 as determined by environmental monitoring techniques, both by Dow (Rocky Flats) and the Colorado Department of Health.

An air sample collected in room 452 (Special Assembly Line), Building 777, between 8 am and 4 pm on August 30 was evaluated at about 7 times applicable RCG, and average air concentrations for the 40 hour work week were about 1.5 times above applicable guidelines.

The most probable cause for the high air sample in room 452, Building 777 was an operation conducted at the room 452 downdraft table on August 30. The air sampler is located adjacent to the downdraft table.

The operation involved opening a sample shipping container called a pressure cooker. The pressure cooker was located on September 11th and found to be tritium contaminated.

The pressure cooker was received from Battelle (Northwest) on July 17, 1974, and was not surveyed for tritium contamination at that time."

6.2.3 Chemical Accidents

Rocky Flats never routinely monitored airborne chemical releases, except for special studies of limited duration. Monitoring of chemicals in waterborne emissions has been relatively recent, and has been limited to analytes that provide useful information for only a few of the materials of concern for this project. Small spills of chemicals and radioactive liquids were common throughout the operating history of the plant. For example, in September of 1963, a hydrogen peroxide tank explosion in Building 771 was listed in a compilation of 99 incidents from the Executive Safety Council Minutes occurring between 1953 and 1965 (Hicks, 1965). In most spill cases, affected areas were cleaned, associated waste was processed, and any contaminated soil was excavated and shipped off-site (Dow, 1974 and Hicks, 1965).

The 1989 Chromic Acid Spill

One example of a chemical accident which attracted public interest and media attention was the 1989 chromic acid spill, which passed through sanitary waste treatment systems and reached the on-site retention ponds (EG&G, 1990). At about 4 PM on February 22, 1989, an engineer connected a hose line to a sink to raise the fluid level in a chromic acid plating bath in the Plating Laboratory in Room 245 of Building 444. The engineer accidentally left the hose running when he left the building for the night. During the night, the plating bath overflowed into an acid waste drain system, and then filled an acid waste collection tank in Room 9A in the basement of Building 444. The official report on the accident (USDOE, 1989) states:

> "The acid waste high level alarm was silenced (with a high degree of probability) by persons unknown in the Plating Laboratory with no one taking remedial action. Pipefitters were working in the room and a security guard made routine periodic watchman tours and noted no alarms."

As a result, the acid waste collection tank overflowed into a secondary containment berm, which in turn overflowed onto the floor of the Building 444 basement. The solution then leaked through cracks in the floor into the building foundation drain system, where it was collected in a sump and automatically pumped into the plant's sanitary sewer system. The engineer turned off the hose when he returned to work the next day (7:30 AM on February 23).

A greenish-yellow discoloration was observed in the primary clarifier at the sewage treatment plant, Building 995, at 10:30 AM on February 23. The contamination moved through the treatment plant in about 24 hours and was discharged to retention pond B-3.
The chromic acid-contaminated B-3 pond water was pumped to spray fields, as allowed by the Rocky Flats NPDES permit. Because the surfaces of the spray field and pond were frozen, significant amounts of chromic acid-contaminated spray water ran off the hillsides adjacent to the spray fields. This contaminated runoff water collected in the water impoundment ponds on the Rocky Flats Plant site. Chromium was not identified as the contaminant until February 28th.

A one-time agreement was reached between Jefferson County, Broomfield, Rockwell, and DOE officials to pump the water from pond B-5 into Upper Church Ditch, which flows into a series of ponds near the Jefferson County Airport (EG&G, 1990). The water from pond B-5 was below the Clean Water Standard of 0.05 part per million.

Incidents Involving PCBs

Incidents involving polychlorinated biphenyls (PCBs) and pesticides and herbicides are also discussed here because of public interest in the storage of PCBs at the plant in the early 1980s, and the discovery of Atrazine in an on-site pond in 1989.

PCBs were used in electrical transformers, capacitors, hydraulic presses and diffusion pumps throughout the Rocky Flats Plant (Hanes, 1972). PCBs were widely used throughout industry in electrical transformers and capacitors because of their fire resistance and dielectric properties. Under the Toxic Substances Control Act (TSCA), the manufacture of PCBs was banned after 1979. The plant has not purchased any fluids known to contain PCBs since 1972 (EG&G, 1991a).

In the mid 1980s, 54 transformers containing PCB fluids were either replaced (25) or refilled (29) with non-PCB fluids. The 25 transformers that were replaced were removed by an off-site contractor. One highly specialized PCB transformer remains on site (EG&G, 1991a). PCB dielectric fluids have also been used in electron beam welders as coolants. PCBs from 1 of 6 transformers on the roof of B-707 leaked and water washed the oil through storm vents and a storm pipe to a courtyard below, which was sampled (Demos, 1991).

In 1991, a transformer pad on the roof of Building 707 contained PCBs which had apparently leaked into a nearby roof drain and onto a soil area adjacent to B-707. The transformer was removed in 1983, but the pad was not cleaned. Concentrations of PCBs ranged from 4,500 micrograms per 100 square centimeters on the roof of Building 707 to approximately 920 micrograms per 100 square centimeters in the drain. The plant informed both EPA and CDH of the contamination, and has stated that, in their opinion, no potential for off-site release exists (EG&G, 1991a).

Rocky Flats has initiated an expanded program to sample other areas of the plant site where PCB transformers and equipment were previously located to determine if any further PCB contamination exists (ChemRisk, 1991). Thirty-four sites potentially contaminated with PCBs were examined, a soil sampling program was designed, and sampling began on June 24, 1991. A PCB Action Plan was due to be completed in July of 1991 (EG&G, 1991b).

In summary, no evidence was located that suggests significant off-site release of PCBs or information that could be used to accurately quantify historical releases.

Incidents Involving Pesticides and Herbicides

Many chemicals have been used at the Rocky Flats Plant to control weeds, insects and rodents for security, fire hazard, agricultural, and health reasons. Scattered records documenting the use of various herbicides and pesticides have been located back as far as 1969.

A particular incident in 1989 involving Atrazine is an issue of public concern. From February 1989 until April 1989, Vegetation Services, a private contractor, used 1100 pounds of Aatrex herbicide to control weeds near fences and in the Protected Area of the Rocky Flats Plant. Atrazine, the active ingredient in Aatrex, has a long-term residual of 12 months. In June and July of 1989, Atrazine was detected by the U.S. EPA in retention ponds A-4, B-5 and C-2 at levels of 5 to 46 ppb. Although there was no official limit for allowable levels of Atrazine in water discharged from the ponds at Rocky Flats at the time, CDH asked the plant not to discharge water containing Atrazine at levels above a proposed Federal drinking water standard of 3 ppb. In August of 1989, activated carbon treatment systems were installed at A-4 and B-5 ponds to reduce Atrazine in water discharged to Walnut Creek to levels below the proposed federal standard of 3 ppb (Porter, 1989).

In summary, no evidence was located that suggests significant off-site releases of pesticides or herbicides or information that could be used to accurately quantify historical releases..

6.3 Conclusions Regarding Rocky Flats Accidents and Incidents

The following conclusions emerge from review of the sources and documentation of accident information:

- Most of the voluminous records on accidents at Rocky Flats discuss events having only on-site or worker impacts.
- There is general agreement between disparate sources of information regarding identification of accidents having the potential for off-site impacts.
- Of all accidents identified involving chemicals and radionuclides of concern used at Rocky Flats Plant, plutonium accidents have posed the greatest potential for off-site releases.
- Of all plutonium accidents identified, the 903 Pad and 1957 Fire appear to have the greatest potential for off-site impacts to the public.

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7.0 SUMMARY AND CONCLUSIONS

The work performed for the purposes of Tasks 3 and 4 of the Toxicologic Review and Dose Reconstruction Project which is summarized in this report represents extensive efforts to address a number of project objectives. These objectives are to:

- Document the basic history of the Rocky Flats plant, outlining its physical development and its historical mission,

- Document the nature of the historical use of materials of concern identified in project Task 2,

- Identify any significant historical use of materials not evaluated as part of the selection of materials of concern under Task 2 by locating specific reference to the use of chemicals and radionuclides in plant documents or personnel interviews, or through the examination of major changes in plant mission or processes,

- Identify potential points of significant release of the materials of concern to the air, surface water or soil for which appropriate source terms will be developed in project Task 5,

- Identify the potential for the existence of significant uncontrolled routine releases of radionuclides as a result of normal operations that would not have been detected by the effluent monitoring systems,

- Identify accidents, incidents or waste disposal practices that may have resulted in the release of contaminants with a significant potential to move off-site for which release source terms will be developed under project Task 5.

The extensive review of information repositories located both on and off the plant site and the documents they contain has made it clear that the plant's mission has remained unchanged since its initial operation. Although the plant has grown in physical size; the nature of the processes and the general types of materials used in these processes has remained largely the same since the 1950s. Therefore, the reliance of Task 2 efforts primarily on information on material usage in the past two decades in selecting the materials of concern appears to have resulted in the identification of relevant materials for evaluation of potential off-site impacts.

Environmental monitoring was instituted prior to plant construction and has continued on an ongoing basis since initial plant operation. The initial plant designs included effluent filtering and treatment systems and surface water retention ponds to control radionuclide releases. The records clearly indicate a recognition of the need to control and limit radionuclide releases since the beginning of plant operations, driven by a combination of economic, national security and health concerns. The extensive reviews failed to identify any historical evidence of significant intentional uncontrolled routine releases of radionuclides from the plant to the off-site environment.

A number of materials on the initial list of materials of concern generated as part of project Task 2 were included because no information was immediately available with regards to the nature of their use and potential for release. For a number of these materials, even after the extensive searches and interviews performed as part of this Task 3 and 4 effort, no information could be found with regards to their potential use at the plant. These materials include:

Benzidine
1,3-Butadiene
Ethylene Oxide
Propylene Oxide

In addition, information obtained on a number of the materials of concern has indicated that based on the nature of their use and potential for release they do not warrant further investigation from the standpoint of potential off-site impacts. These include:

Benzene
Cadmium Compounds
Chromium Compounds
Formaldehyde
Hydrazine
Lead Compounds
Mercury
Nickel Compounds
Nitric Acid

With regard to contaminant release points, airborne emission points are identified for each of the materials of concern in this report. Surface water emissions are associated primarily with releases from the terminal surface water retention ponds on the plant site which have collected some plant effluents as well as site runoff. Releases of contaminants to the groundwater may have resulted from seepage from retention or evaporation ponds, as well as from various waste disposal activities or spills.

The review of historical accidents and incidents at the plant site led to the identification of voluminous amounts of information documenting numerous small fires, spills, injuries and property damage. However, none of the documentation indicated the occurrence of any previously unreported major events potentially impacting the off-site public. Major events of potential interest are those that were studied and publicized following the 1969 fire.

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GLOSSARY

Radiological

alpha particles: positively charged particles of discrete energies emitted by certain radioactive materials; alpha particles usually expend their energy in short distances and will usually not penetrate the outer layer of skin; they are a significant hazard only when taken into the body where their energy is absorbed by tissues.

beta particles: negatively charged electrons of a continuous energy spectrum emitted by certain radioactive materials; beta particles have a greater range in tissue than alpha particles, but deposit much less energy to tissues than alphas and are therefore less damaging to tissues.

gamma radiations: photons emitted by certain radioactive elements which are identical in form to x-rays; gamma rays are of most concern as an external hazard due to their high penetration ability.

curie (Ci): the conventional unit of activity equal to 3.7×10^{10} nuclear disintegrations per second.

criticality (p.90): a self-sustaining nuclear fission reaction.

fission: the splitting of a heavy atomic nucleus into approximately equal parts, accompanied by a large amount of energy.

fissionable: material capable of undergoing fission by interaction with fast neutrons.

fusion: formation of a heavier atomic nucleus from two lighter ones, with an attendant release of energy, as in a hydrogen bomb.

HEPA filter: high efficiency particulate air filter

implosion: to collapse inward as if from external pressure; compression.

isotope: elements having the same atomic number but different atomic weights; they have similar chemical properties but different physical properties.

minimum detectable activity (MDA) — limit of detection for radioactivity measurements.

pit — the first stage fission component used to initiate the second stage fusion reaction in a nuclear weapon/hydrogen bomb; also referred to as triggers.

radionuclide — a radioactive nucleus of an element distinguished by their atomic number, atomic weight and energy state.

site returns (p.61) — weapon components that have been retired and returned for disassembly and recovery of materials.

thermoluminescent dosimeter — a dosimeter utilizing one of more phosphors which when heated produce light in proportion to the radiation dose it has absorbed; indicative of external exposure.

transuranic — an element with an atomic number greater than uranium (92); all eleven known are produced artificially and are radioactive.

trigger — see pit.

General

alloy — a substance composed of two or more metals united by being fused together and dissolving in each other when molten.

oralloy (p.77) — enriched uranium (containing 0.7 to 93% uranium 235) named for "O"ak "R"idge alloy.

tuballoy (p.76) — depleted uranium (containing less than 0.7% uranium 235) named for a British project called Tube Alloys Limited.

combustible — material that is difficult to ignite and that will burn slowly.

cooling tower blowdown — the continuous or periodic discharge of a portion of cooling tower water to control the level of solids in the circulating water.

effluent — used or waste gas, liquid or solid discharged from a building or facility.

near-net shape	close to final desired shape.
pesticide	an agent used to destroy pests (a plant or animal detrimental to man).
herbicide	an agent used to destroy or inhibit plant growth.
rodenticide	an agent that kills, repels or controls rodents (small gnawing animals).

Chemical

hydrofluorination	chemical conversion to a form containing fluorine.
calcination	heating to drive off moisture which results in a change in chemical and physical state.
reduction	the addition of electrons to an atom or ion; combustible or flammable agents are often reducing agents.
ion exchange	a reaction between a solid and a liquid solution used to move ions from one substance to another.
solvent extraction	the process of removing a substance from a solution by contacting it with a second liquid that stays separate; used when a substance is more soluble in one solution than in another.
molarity	chemical concentration of a solution (i.e., formula weight per liter).
scrubber	a device for removing impurities from a gas stream.
induction	the process by which an electrical (or magnetic, or electromotive) conductor becomes electrified (or magnetized, or produces an electromotive force) when near a charged body (or in a magnetic field, or in a varying magnetic field).
spray leaching (p.68)	in this case, a spraying of hot nitric acid to remove residual plutonium surface contamination.