EXECUTIVE SUMMARY

The goal of Task 3 of the Toxicologic Review and Dose Reconstruction Project is to describe the history of operations at the facility as it might relate to off-site exposures. Task 4 activities support the characterization of emission points for releases to the environment. Tasks 3 and 4 involved extensive investigations to address project needs for information describing past operations of the Rocky Flats Plant. The specific objectives of Tasks 3 and 4 are:

- Document the history of the Rocky Flats Plant relevant to off-site releases.
- Describe the historical uses of the materials of concern.
- Further evaluate the potential for release of the materials of concern selected as a result of Task 1 and 2 activities.
- Identify release points for the materials of concern from routine and non-routine (accidental) operations.

This Task 3 and 4 report is divided into the following sections:

Section 1.0 - Introduction to Task 3 and 4 activities.

Section 2.0 - Description of the investigative process used.

Section 3.0 - A general history of routine plant operations.

Section 4.0 - Historical use profiles of the materials of concern.

Section 5.0 - Historical release points of the materials of concern.

Section 6.0 - Historical non-routine (accidental) operations.

Section 7.0 - Summary and conclusions.

Appendices - Interview process (interviewees, questions and preparation).

An index to locate topics of interest which are discussed in the report and a glossary of terminology are provided following Section 7.0. A draft version of the Task 3 and 4 Historical Operations and Release Points Report was reviewed by the Health Advisory Panel, regulatory agencies, plant employees and retirees, and members of the public. Comments received as a result of these reviews resulted in revisions that have been included in this report.

Extensive reviews of information repositories located both on and off the plant site have demonstrated that the mission of the Rocky Flats Plant has remained essentially unchanged since its initial operation until the shutdown of plutonium operations in 1990. Although the plant has grown in physical size, the nature of the processes and the general types of materials used in these processes have remained largely the same since the 1950s. However, environmental health and safety practices have changed to meet new regulatory requirements. The historical investigation did not identify any

additional materials of concern beyond those selected in Task 2.

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 undocumented or unmonitored routine airborne releases of radionuclides from the plant to the off-site environment, and this was also generally true for waterborne releases with a few exceptions. In contrast to the extensive monitoring program conducted for airborne releases, the plant typically monitored only known release points of liquid effluents.

Some materials were included on the initial Task 2 list of materials of concern because no information was immediately available concerning the nature of their use and associated potentials for release. Even after the extensive searches and interviews performed as part of this Task 3 and 4 effort, uses of four materials at the plant could not be documented. These materials are benzidine, ethylene oxide, propylene oxide, and 1,3-butadiene. Documentation of the uses and potentials for release of nine other materials of concern indicates that they do not warrant further quantitative evaluation of potential off-site exposures. These materials are benzene, formaldehyde, hydrazine, nitric acid, and compounds of cadmium, chromium, lead, and nickel. The twelve remaining materials of concern, which include seven chemicals and five radioactive elements and their isotopes, will be the subject of the project Task 5 source term development process based on knowledge of their historical uses and routine and accident-related emission sources.

Airborne emission points for each material of concern are described in this report. Surface water emissions have been associated primarily with releases from the terminal surface water retention ponds on the plant site, which have received some plant effluents as well as site runoff. Releases of contaminants to the groundwater may have resulted from seepage from retention or evaporation ponds and from various waste disposal activities or spills.

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 incidents leading to 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 May 11, 1969 fire in Rocky Flats Buildings 776 and 777, namely the 1957 fire in Building 771 and the resuspension of plutonium contaminated soil from the 903 pad.

1.0 INTRODUCTION

The U.S. Atomic Energy Commission announced its decision on March 23rd of 1951 to build the Rocky Flats plant (Buffer, 1991). The plant was built to increase the quantity and quality of the nation's nuclear arsenal, and has played an important role in the U.S. nuclear weapons complex in the years that have followed. Early plant operations were for the most part kept behind a "cloak of secrecy", with the main off-site concern being centered around two fire incidents in 1957 and 1969 that received public attention, an inadvertent release of tritium to surface waters in 1973, and a waste storage practice that resulted in the spread of contamination to nearby soil during the late fifties and sixties. After the 1969 fire, the public learned for the first time that plutonium had been released routinely and accidently from the plant. In 1984, the site was proposed to be a Superfund site, and in 1989, it was included on the National Priorities List for cleanup of environmental contamination.

Public concern came to a high point in June of 1989 when approximately 100 FBI and EPA agents raided the plant seeking documentation of alleged criminal acts and mismanagement. The Department of Energy subsequently suspended plutonium processing to review and upgrade the plant's safety systems. Following the raid, Colorado's Governor Roy Romer negotiated with Energy Secretary Admiral James Watkins to secure funding for closer scrutiny of the plant's activities by the State to reassure concerned citizens and for health studies to address the public fears of potential health effects.

In June of 1989, an Agreement in Principle was signed by Governor Romer and Secretary Watkins which included DOE funding for increased environmental surveillance and oversight, remediation, emergency preparedness measures, accelerated cleanup in areas of imminent threat, and health studies. Phase I of the health studies is now underway in the form of the Toxicologic Review and Dose Reconstruction study being conducted by ChemRisk for the Colorado Department of Health.

1.1 The Rocky Flats Toxicologic Review and Dose Reconstruction Project

The primary purpose of this project is to reconstruct doses of the materials of concern received by off-site individuals as a result of past Rocky Flats Plant operations. Two points should be emphasized regarding the project scope. First, this project is designed to address exposures from historical operation, not to estimate doses from present and future operations or anticipate future exposure potentials. Secondly, this project is concerned with doses to individuals off the plant site, as opposed to occupational exposures to plant workers. Information pertaining to work-place exposures or control devices will in general only be considered if it is also relevant to prediction of off-site releases or exposures. The period of interest for this study begins in April, 1952, when "operations began on regular production materials" (Buffer, 1991), and covers the 453 months of plant activities through calendar year 1989.

The Toxicologic Review and Dose Reconstruction Project is broken into the twelve tasks depicted in Figure 1-1. The first several tasks center around what was thought to be the most important contribution that the project could make to further understanding of the potential health impacts of the Rocky Flats Plant, that being a more comprehensive look at all the materials and amounts of materials which have been used at the plant since 1952.

1. **Identify Chemicals & Radionuclides Used**
2. **Select Materials of Concern**
3. **Reconstruct History of Operations**
4. **Identify Release Points**
5. **Estimate Source Terms**
6. **Select and Model Exposure Pathways**
7. **Characterize Land Uses and Demographics**
8. **Perform Dose Assessment**
9. **Prepare Computerized Database**
10. **Prepare Annotated Bibliography**
11. **Assemble Information Repository**
12. **Provide for Scientific Oversight and Public Involvement**

FIGURE 1-1: TASKS OF THE ROCKY FLATS TOXICOLOGIC REVIEW AND DOSE RECONSTRUCTION PROJECT

Task 1 involved identification of the chemicals and radionuclides that have been used on the Rocky Flats site. Unlike some similar dose reconstruction studies which have been undertaken for federal nuclear facilities, this project is concerned with not only radionuclide emissions, but also releases of hazardous chemicals and mixed wastes that are both radioactive and chemically hazardous. To identify the materials used on the site, the ChemRisk team first reviewed radioactive source registries and inventories and chemical inventories produced by the plant staff. The chemical inventories included thousands of chemicals present in very small quantities and some chemicals used in very large quantities. Examples range from 4 milliliters of vinyl chloride kept in a laboratory refrigerator to over 400,000 pounds of nitric acid used at the plant each year. Classified and unclassified records were also reviewed for evidence of other materials used on the Rocky Flats site. The result of Task 1 was a list of over 8000 materials used on the Rocky Flats site (ChemRisk, 1991a).

The objective of **Task 2** was to select the chemicals and radionuclides that were most likely to have posed an off-site human health hazard under historical routine plant operations. Radionuclides that have been included as materials of concern are all those which were handled in substantial quantity, were associated with production activities, were found in forms that are likely to be released, or were found to be present in plant effluents or in the environment. With the exception of tritium, monitoring data are consistent with the release of only the main production radionuclides from the facility. Tritium is included as a material of concern primarily because of a well-publicized incident in the early 1970s involving off-site release of tritium.

For chemicals, a three-stage screening process was developed to narrow down the list of potential materials of concern. In the first stage, 629 compounds were identified for further, more refined screening as potential materials of concern based on their known toxicologic properties, Rocky Flats release histories, or reported inventory quantities. A second stage of screening was performed to roughly estimate if the quantity of a chemical on-site was sufficient to pose an off-site health hazard. Forty-six potential chemicals of concern emerged from Stage 2 Screening. In the final stage of screening, these chemicals were individually evaluated to determine the likelihood of their release and potential quantity of release based on actual storage and usage practices, likely routes of release, and known behavior in the environment.

Using both qualitative and quantitative screening criteria, and taking into account preliminary knowledge of actual storage and usage practices, it was believed that the materials of concern in Table 1-1 could have potentially been associated with off-site impact from normal operations of the Rocky Flats Plant (ChemRisk, 1991b). The list of materials of concern has not been cast in stone. As the project continues, any newly identified compounds will be evaluated for possible addition to the list of materials of concern. The grouping of the materials of concern in Table 1-1 as Solvents, Metals, or "Others" reflects some knowledge about the most commonly encountered forms of some of the materials, but should not be taken to indicate any assumptions that will be made by the project team in investigating material uses. For example, although chromium is a metal, it will be evaluated in all elemental or metallic forms encountered at Rocky Flats, including salts, ionic solutions, and any other forms revealed during records reviews or interviews.

Pesticides and herbicides have also been used on the site. These materials are not unique to the plant and are not directly related to production processes at the facility. However, the historical presence of these compounds in holding ponds on the site has been the subject of public concern. For this reason, pesticides and herbicides were retained as a group of compounds to be further addressed in this study, but not as materials of concern.

TABLE 1-1: MATERIALS OF CONCERN AS SELECTED IN TASK 2

SOLVENTS	METALS	OTHERS
Benzene	Americium-241	Benzidine
Carbon Tetrachloride	Beryllium	1,3-Butadiene
Chloroform	Cadmium	Ethylene Oxide
Methylene Chloride	Chromium	Formaldehyde
Tetrachloroethylene	Lead	Hydrazine
1,1,1-Trichloroethane	Mercury	Nitric Acid
Trichloroethylene	Nickel	Propylene Oxide
	Plutonium-238,239,240,241,242	Tritium
	Thorium-232	
	Uranium-233, 234, 235, and 238	

Concurrent with the work on identifying materials used on the Rocky Flats site, efforts were underway on **Task 3** activities to recreate the history of operations at the facility as it might relate to off-site exposures and on **Task 4** activities to characterize the emission points for associated releases to the environment (ChemRisk, 1990). **Tasks 3 and 4** of the Rocky Flats Toxicologic Review and Dose Reconstruction Project involved extensive historical investigations to address project needs for information describing past operations of the Rocky Flats Plant. The objectives of the historical investigation are to:

> Document the basic history of the Rocky Flats facility, outlining its physical development and its historical mission,

Document the nature of historical uses of the materials of concern that were identified in Project Task 2,

Identify any significant historical material uses not evaluated as part of the Task 2 selection of materials of concern,

Identify potential points of significant release of materials of concern to the air, surface water, or soil,

To support work to be performed in Project Tasks 5 and 6 by characterizing the potential for the existence of significant uncontrolled radionuclide emissions from normal operations in the past that may have gone undetected by effluent monitoring systems, and to

Identify any accidents, incidents, or waste disposal practices that resulted in contaminant releases with significant potential for off-site transport, also for use in Tasks 5 and 6.

The investigations consisted of an extensive campaign of document reviews and interviews targeting active and retired Rocky Flats employees, local citizens, and other interested parties. The major outcomes of this investigation are an understanding of the historical uses of the materials of concern, identification of accidents which warrant detailed evaluation, and documentation of the nature of associated emission points. This report summarizes the results of these Task 3 and 4 investigations.

1.2 Documentation of Rocky Flats History

The Task 3 and 4 historical investigation is not intended to be a complete history of the Rocky Flats Plant, but rather a documentation of historical plant operations and the identification of release points for chemicals and radionuclides which may have been released to off-site areas. Task 5 activities are aimed at developing estimates of source terms (release quantities) for the materials of concern using the historical information obtained as a result of Task 3 and 4 activities. Relevant exposure pathways for the materials of concern will be selected in Task 6. In addition, the source term estimates from Task 5 will be used to model the transport of the materials of concern to off-site locations in Task 6.

The ChemRisk investigation of Rocky Flats history can be conceptually divided into the areas shown in Figure 1-2. The investigative process that was designed to address these key aspects of Rocky Flats history is described in detail in **Section 2** of this report.

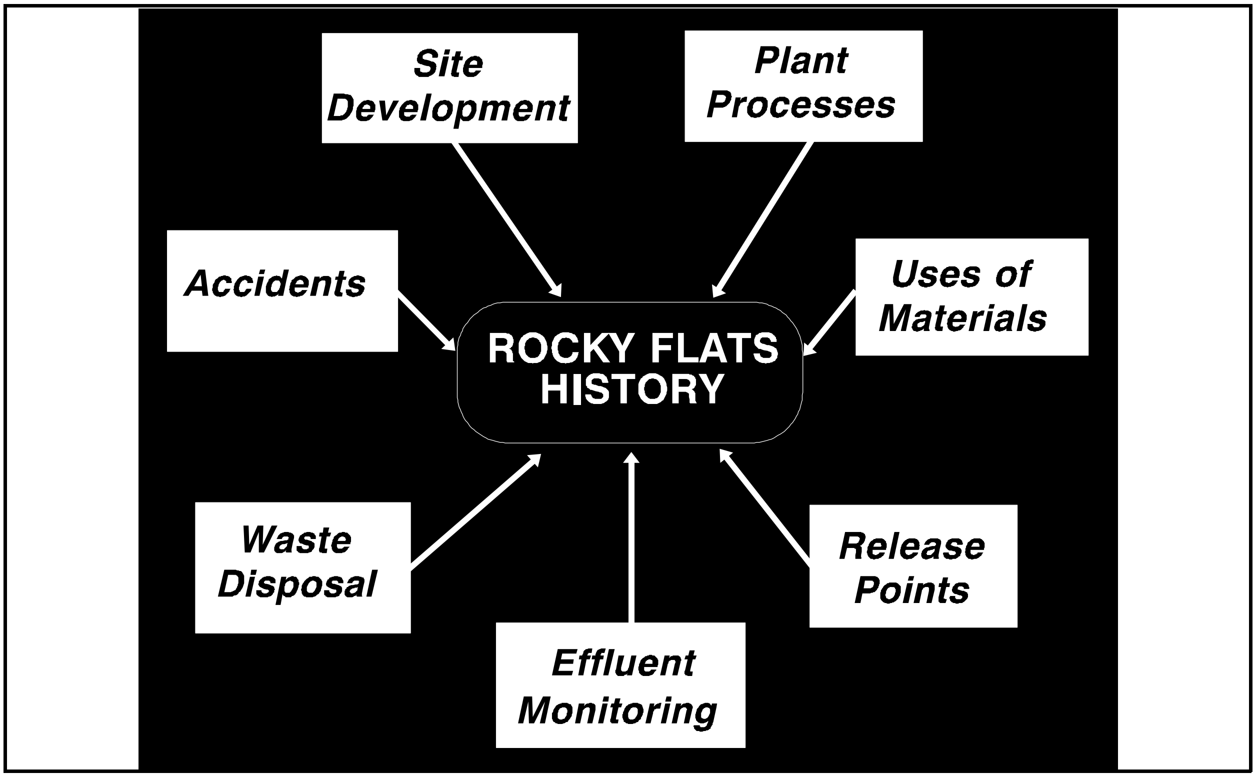

FIGURE 1-2: ELEMENTS OF THE ROCKY FLATS HISTORICAL INVESTIGATION

Site development details were gathered from many varied records, from personnel interviews, and from inspection of aerial photographs. The general history of the development of the Rocky Flats Plant and the evolution of the facilities and processes used at the site to support fulfillment of the mission of the plant are described in **Section 3**.

Current-day plant processes are described in recent unclassified reports prepared for each building to characterize airborne emissions and waste streams. These reports provide a level of detail generally adequate to support a preliminary understanding of uses of key materials. The big challenge has been to go backwards in time and describe how processes and facilities have changed over the years as material substitutions were made and better technology became available.

Uses of the materials of concern were first characterized based on the air emission and waste stream reports mentioned above, chemical use inventories, and other plant records. Interviews and inspections were then used to add to the picture of how each material has been used. Historical profiles of the uses of each material of concern are contained in **Section 4**.

Materials were routinely released to the environment from Rocky Flats via numerous airborne release points and several series of surface water ponds. Historical practices related to release of materials to the environment are described in **Section 5**, as are treatment and monitoring practices that have been applied to each release point.

There are records of numerous waste disposal sites within the Rocky Flats Plant boundary. While most hazardous and radioactive wastes are shipped off-site for disposal, there remain about 178 inactive waste sites within the plant boundaries, some of which have been the sites of burial, incineration, and land application. Chemical and radioactive contamination has spread to the ground water, has been released to soils, and has resuspended to the air and to wider areas of ground surfaces. These disposal practices have not necessarily resulted in off-site exposures to members of the public, but are being documented and evaluated as part of this project.

Accidents, incidents, occurrences, and "as-found conditions" of many types have been documented at Rocky Flats over the years. Details of the investigation of Rocky Flats accidents and incidents are contained in **Section 6**. Lists have been compiled of hundreds of accidents of widely varying significance, ranging from cut fingers to major fires in 1957 and 1969. Information evaluated to-date indicates that three major incidents warrant detailed evaluation as part of this study. These three incidents are the 1957 fire, the 1969 fire, and the 903 pad release. In evaluating the effects of releases associated with the identified accidents, consideration is not being limited to the selected Materials of Concern. All identified constituents of the releases will be evaluated as part of the Task 5 source term assessment process.

The Draft Task 3 and 4 Report was reviewed by the Health Advisory Panel, members of the public, regulatory agencies such as CDH and EPA, and by several plant historians for accuracy. These comments were addressed and individual responses were sent to each person or organization. All corrections and many of the suggestions for improvement made by the various reviewers were incorporated into this final version of the report.

REFERENCES

Buffer. (1991). Buffer, P. "Highlights in Rocky Flats Plant History". May, 1991. Repository Document CR-30.

ChemRisk (1990). Integrated Task Plan for Tasks 3,4, and 5. Repository Document TW-71.

ChemRisk (1991a). Task 1 Report (R1), Identification of Chemicals and Radionuclides Used at Rocky Flats. Repository Document TW-362.

ChemRisk (1991b). Task 2 Report, Selection of the Chemicals and Radionuclides of Concern. Repository Document TA-723.

2.0 DESCRIPTION OF THE INVESTIGATIVE PROCESS

To date, a general history of the Rocky Flats Plant has not been prepared by the Department of Energy or the various plant contractors. ChemRisk was tasked to create a historical account of facility development and operational processes and practices to support characterization of material uses and estimation of associated emissions. The addition of this information to a general history of the Rocky Flats Plant may be one of the most important contributions of the Toxicologic Review and Dose Reconstruction Project, in that it will serve to further public understanding of historical operations at the facility. The historical knowledge of plant activities will also serve as the basis for the source term (Task 5), transport and pathway modeling (Task 6), and dose assessment (Task 8) that will translate the historical investigation results into a realistic assessment of off-site exposures and shed light on the potential for any public health impacts.

ChemRisk has approached the characterization of Rocky Flats history, and addressed the public perceptions of unreported activities leading to possible off-site hazards, through an extensive program of document reviews and personnel interviews that is described in the following pages. It should be noted that document databases were searched in the most efficient yet comprehensive manner possible. For example, appropriate keywords were often defined during the data entry process and were often different for each database. Therefore, searches were conducted using keywords which most closely matched the subjects of interest for a particular database. In all cases keywords were chosen that incorporated Rocky Flats Plant terminology to ensure that document lists would be as complete as possible.

2.1 Review of Classified and Controlled Access Records

The project team for historical investigations included individuals with Department of Energy "Q" clearances. Team members with Q clearances were given access to all areas of the plant, and were not denied access to any information sources specifically requested for review. Locations of the information sources on the Rocky Flats site that were most important for the historical investigations are shown in Figure 2-1. Searches were performed in the two centralized areas of the plant where documents are officially stored,
the Building 706 Technical Library and the Building 881 Archives. Through the interview process, team members were made aware of other useful documents that might not have made it into the 706 library or the 881 archives.

The library and archives hold an enormous amount of documentation, most of which is not of interest to the Project. A large fraction of the records that were found were detailed production records, research and development reports, and weapons stockpile analyses. Not

INSERT FIGURE 2-1 HERE; ON-SITE INFORMATION SOURCES

every document filed at Rocky Flats was read in its entirety, rather the repositories were systematically searched using both directed and random techniques to optimize review of relevant information within the time and budget available to this phase of the project.

2.1.1 The Building 706 Technical Library

At the Building 706 Technical Library, three individuals independently reviewed the 1200 page classified document index in its entirety. Approximately 64,000 classified document entries were reviewed for possible relevance to the project. Each entry consists of a central keyword, other associated keywords, and a document ID number. The index contains multiple listings for some documents under various keywords, so there are less than 64,000 documents contained in the index. For the following keywords from the printed index, the number of "hits" was specifically recorded in investigation field notes to assist in identification of documents of possible relevance to the project:

Material of Concern names	accidents	air pollution
fire	cleaning solvents	compatibility
coolant	corrosion	degreasing
elimination	exposure	filters
health physics	incident	liquid
material balance	solvent	wastes
soils	solidification	ultrasonic cleaning

The most heavily documented keyword searched was "beryllium", which had 689 entries; the next highest was "nickel", with 28 entries. Over a thousand entries were selected as being of potential interest. Titles that appeared to be of use to project team members focusing on different aspects of the investigation were identified for follow-up. In addition, thirty-three classified documents were requested and read in detail while the library search was in progress. Many return trips to the Building 706 Library were made throughout the duration of the historical investigation for researching specific topics within and beyond the areas indicated by the keywords listed above. Relevant information was extracted via note taking or requests for page copies. Notes were reviewed by a classification officer prior to their removal from the site.

The Building 706 Technical Library also contains unclassified records. The unclassified report index consists of six volumes of entries organized by subject categories. This index was independently reviewed for pertinent records by three members of the project team.

2.1.2 The Building 881 Archives

The Building 881 Archives contain written material and photographs sent from many areas of the Rocky Flats Plant and include a wide variety of material, ranging from original hand written notebooks, data sheets, memos, letters and rough draft reports to weekly, monthly, and yearly progress reports, summaries of concerns and problems, formal reports, papers, complete documentation of procedures, and reports on incidents and accidents. These records are stored much the same way as they were sent to Building 881 - in cardboard boxes. The total number of boxes stored in Building 881 is approximately 2,500. In some boxes the content is uniform and similar in nature; in others the material varies widely both in format and in subject matter.

Each box in the Building 881 Archives has a "records storage receipt" inside and also in a file cabinet with all other records storage receipts. Each records storage receipt is essentially an index of the contents of the associated box. In some cases this index is accurate and complete. In other cases, the index may not cover everything in the box. It appears that some box contents might have been generated by employees cleaning their desks or files of written material, with little thought about how this material might later be of interest to another person.

The boxes are assigned and identified by a letter and three digit number, such as "A137", and are stored according to that designation. Words are extracted from the records storage receipts and used as keywords in a secure computer system to facilitate keyword searches.

Based on knowledge of the general areas of interest within the historical investigation and plant terminology, the following keywords were selected and used to identify boxes containing documents of potential relevance to the project:

accident	alpha	carbon tet	chemistry or chemicals
chloroform	compounds	communications files	concentration
contamination	fire	1969 fire	health physics
HS&E	lip	N&FS	industrial hygiene
nuclear safety	PCE	pipe	organic compounds
pollution	release	review	soil
summary	traffic	waste	tetrachloroethylene
waste	waste ops	trichloroethylene	

Keyword searches identified boxes containing records related to the indicated keywords. Approximately 80 boxes were retrieved for inspection. Information of relevance to the project was transferred to hand-written notes which were reviewed by a plant classification officer prior to leaving the plant site. Approximately 20 boxes surrounding the selected boxes on the shelves were also retrieved and reviewed to add to the random aspect of the search process and to judge the effectiveness of the keyword search process. No records of relevance to the project were found in these randomly selected boxes.

2.1.3 Classified Safety Analysis Files

The Safety Analysis group maintains a file of classified documents to support conduct of safety analyses of plant operations. The documentation includes information concerning accidents and incidents that have occurred at the Rocky Flats facility. Documents within the associated files were reviewed in search of information pertaining to possible chemical or radionuclide emissions from the events. Five documents were reviewed in detail, of which two were determined to be relevant to the project. These two documents deal with historical tritium releases from Rocky Flats, and the information they contain will be included in Task 5 investigations of source terms of the materials of concern.

2.2 Unclassified Rocky Flats Information Sources

Three unclassified repositories relevant to the project have been identified at Rocky Flats. They include the Environmental Master File, Industrial Safety Office files, and Occurrence Management Department records. Each of these information sources is described in the following sections.

2.2.1 The Environmental Master File

The Rocky Flats Environmental Master File (EMF) consists of two powered horizontal file machines, located on-site in Trailer 130C. They are locked by key and combination, with a very limited number of individuals having the key and combination. The primary file machine has sixteen 6-foot long shelves. The second machine has nine 6-foot long shelves.

The EMF was originally set up around 1975, primarily to address the every-day reference and administrative needs of the Environmental Management Group. It still serves that purpose to some extent today, but its primary use is for historical reference purposes. The documents contained in the EMF include summary reports, memorandums generated at Rocky Flats, letter reports and studies, copies of state and federal regulations, DOE reports, copies of documentation seized during the FBI's investigation, sets of monthly and annual environmental reports, and many other miscellaneous documents. No classified documents are kept here as the file is in an unsecured area and, generally, environmental documents do not contain information regarding the design or manufacture of nuclear weapons and therefore are not classified.

Most of the Rocky Flats documents on file in the EMF were generated in the 1970s and the first half of the 1980s, although some documents go back as far as 1953 and some are dated as recently as 1990.

Arrangement of the EMF

When the EMF review began, it was reported that about 75% of the contents had been catalogued and arranged according to a numbering system. Review of the file resulted in an estimate closer to 50%. The remainder was in no apparent order and uncataloged. Consequently, project team access to the EMF was initially somewhat limited. However, since May of 1991, the EMF has been undergoing a complete identification and organization of its contents, and electronic scanning and cataloging by technicians from Los Alamos. The work has involved up to five people and associated computer equipment. While the cataloging was taking place, EG&G personnel have on occasion retrieved specified documents and have alerted the project team to documents of potential interest. The cataloging was subsequently completed.

Because of the incomplete manner in which the EMF was originally cataloged, there is no way to identify whether all of the documents which were once in the EMF are still present. However, it has been noted that documents of significance were commonly distributed to several people at the time of their generation. Consequently, copies of important documents can usually be found elsewhere. Many of the frequently-cited documents have also been found in the Legal/Environmental Index and/or at the Federal Records Center.

Searches Performed in the Card Catalog

Several searches were performed of the EMF and its card catalog during the time ChemRisk had free, uninhibited access. An initial review of the entire card catalog was conducted to gain familiarity with the various types of topic categories utilized. Then, specific topics were searched with the intent of identifying key documents for the various tasks of the project. The topics and titles found corroborate the report that the file was originally set up to serve as an administrative repository and reference center.

The majority of the contents of the primary horizontal file machine were examined, along with the entire contents of the second. The EMF contains an estimated 15,000 to 16,000 documents. The number rises to over 20,000 if the associated Clean Water files, which were also reviewed, are included (Helgerson, 1992). The documentation reviewed has been of significant benefit to the project in that it not only documents emissions, but also provides a perspective on many of the environmental activities which have taken place at the plant. In general, most data at the EMF is summary data, consisting of annual and monthly environmental reports.

The following examples of EMF catalog topics were noted in investigation field notes to indicate the content and structure of the file:

Accidents	Carbon Tetrachloride
Air Contamination	Construction
Air Pollution	Contamination
Air Sampling	Cattle
Air Monitoring	Discharges
Americium	Ecology
Analysis	Ecology Council
Beryllium	Effluent Information Systems
Beta	Effluent Monitoring
Biological Data	Effluent Release
Biological Effects	Effluent Reporting
Biological Samples	Effluents
Broomfield	Emergency Response Plan
Burial Sites	Environmental Control

Emissions Data in the EMF

In the review of documents at the Federal Records Center, it was noted that environmental monitoring at the plant has focused on certain portions of the plant; namely, those production buildings in which radionuclides posing a recognized hazard were handled. The data in the EMF largely represent the same areas, but are somewhat more broadly encompassing; presumably due to the changing environmental regulatory requirements which were taking place around the time of the development of the EMF. The data in the EMF also differ in that they are summarized, as opposed to the almost exclusive presence of raw data found in the Federal Records Center.

Accident Information in the EMF

There are few documents pertaining to accidents in the EMF. The reasons for this are two-fold. First, there is a repository on the plant site (the Occurrence Management Files) specifically established for the purpose of maintaining accident records. Secondly, the accident information which is kept at the EMF generally involves only those incidents which were thought at the time to have resulted in offsite impact. A great majority of recorded incidents do not fall in this category.

Historical Information in the EMF

A few documents were found which provided an excellent history of some environmental issues on the plant site. In addition, bits and pieces of historical information were found in related documentation, such as internal memos and other correspondence. However, no summary documents were found in the EMF that provide information on the operational history of the plant.

2.2.2 Industrial Safety Office Files

Industrial Safety records are made up of files documenting "Occurrences", "Supervisor Investigation Reports", "Unplanned Events", "Unusual Occurrence Reports", and "Internal Investigation Reports" covering varying time periods between 1952 and 1989. For the major incidents, a committee was typically formed to perform an investigation and issue a report. The Industrial Safety files typically contain committee reports and detailed supporting documentation. The file for a given incident was considered "open" until corrective actions were identified and scheduled.

2.2.3 Occurrence Management Department Records

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 Unusual Occurrence Report files and has been updated on an annual basis since that time. At the time of review, the SOE database contained approximately 1,767 accident entries. The Summary of Events database does not include "as found conditions," such as the 903 Pad oil leakage, and it does not always provide information on the off-site release potential of an accident.

2.2.4 Federal Government Information Sources

The Federal Government information resources utilized by the project include the Denver Federal Records Center, the DOE Effluent Information System, the DOE On-site Discharge Information System, the DOE Library in Germantown, Maryland and the Region VIII Office of the U.S. Environmental Protection Agency. Each of these resources is described in the following sections. Off-site information sources which were utilized during the historical investigation are summarized in Figure 2-2.

2.2.4.1 The Federal Records Center

A number of repositories were identified during Task 1 activities which were believed to hold information relevant to the subsequent Tasks of the Toxicological Review and Dose Reconstruction Project. The Denver Federal Records Center (FRC) was identified as a repository holding a large amount of documentation from the plant. To support Tasks 3 through 5, it was necessary to gain an early understanding of the contents of the FRC.

The plant sends its inactive, unclassified documents to be stored at the Denver Federal Records Center until the specified date of destruction. Documents generated at the plant which fall under categories specified in the National Archives and Records Administration (NARA) protocol, are kept at the FRC until their retention period specified in the protocol expires. The General Records and the DOE Records Schedule govern the types of documents to be submitted. Classified documents remain on the plant site. According to official sources at the FRC, any Rocky Flats document which does not come under the jurisdiction of the NARA protocol must, by law, be retained indefinitely as it is the property of the Government. However, the scope of the NARA protocol is so extensive that there are probably very few documents which would fall into this category.

The Rocky Flats documents on file at the FRC were generated under the auspices of three federal agencies; the AEC (Atomic Energy Commission), the ERDA (Energy Research and Development Agency), and the DOE (Department of Energy). Documents are segregated into groups, according to the governing agency at the time of each submittal. Rocky Flats began submitting records to the Federal Records Center in the 1960s, although some of the documents at the repository were generated at an earlier date.

INSERT FIGURE 2-2 HERE; OFF-SITE INFORMATION SOURCES

Tracking of Documentation

The FRC maintains a listing called an "Accession Number Master List" which contains the type and amount (in cubic feet or number of boxes) of documents on file. The entries on the Accession Number Master List include the category of documents the boxes contain, the amount, the disposal date, and the year(s) of the documentation involved. The listing does not provide the titles of the documents. To gain more detailed information about what kinds of documentation are in a particular accession, one turns to the "Standard Form 135" of that accession. The information contained on the Form 135s is more detailed than that on the Accession Number Master List, but is still rather generic. To obtain further information about the documentation in a given accession, the documents themselves must be accessed. Access to these two types of listings is uncontrolled, but access to the actual boxes of documents requires written approval from the Rocky Flats Records Group. Photocopying of the records requires additional approval. All requests for access to FRC boxes and document copying were promptly granted.

The documents in storage at the FRC are generally grouped according to the agency governing at the time of the documents' submittal. The October, 1990 printouts of the Accession Number Master Lists show a total volume of 622 cubic feet of documents from the AEC era, 277 cubic feet from the ERDA era, and 2338 cubic feet from the DOE time period, yielding a total volume of about 3237 cubic feet of Rocky Flats documents. The number of documents at the Federal Records Center fluctuates as a result of the various retention times for the documents on-hand and the submission of additional documents from the plant.

Submitted documents are maintained in groups tracked by accession numbers. A thorough review of the Accession Number Master Lists and examination of several groups of documents revealed that the majority of the documentation was not directly relevant to the Toxicologic Review and Dose Reconstruction Project. In fact, only 18.5% of the boxes (594) were initially thought to have potential application to the project. Those which were determined to be of limited or no use to the project include personnel and medical files, time cards, visitor records, gate logs, personnel exposure records, retirement plan files, insurance files, and vendor drawings.

The types of documentation that could potentially be of use to the project include air sample records; radiological survey records; scientific, technical, and research and development reports; waste disposal records; construction completion reports; and some of the general correspondence concerning environmental, health and safety issues.

NARA Protocol Retention Schedules

Most of the documentation has a specified retention period of less than five years. Consequently, potentially useful documentation such as purchasing records provides only a recent record, with no comparable documentation from earlier years.

Even raw analytical data, of which there is a considerable amount in the FRC, has a specified retention period under the current NARA protocol of five years or until the data are verified and entered into a summary document, whichever comes first. Laboratory analysts' log books, found in abundance at the FRC, fall under a similar retention schedule, but in practice are being retained for longer than five years. It was suggested that the governing NARA protocol at the time of the documents' submission probably specified a lengthier retention period.

Some of the types of records have indefinite retention times or times of 75 years. Most of these, however, are medical records of plant employees which are not relevant to this project.

Review of the Form 135s

Although the Form 135s provide a more detailed description of FRC document contents than the Accession Number Master List, they largely consist of information of a general nature. This is particularly true of the earlier years. In some cases, however, the Form 135s provided enough additional information to warrant further investigation in the form of box retrieval and review, to single out a few boxes of interest, or to remove boxes from further consideration altogether.

Documents No Longer at the FRC

Once an accession has undergone some action such as destruction or removal from the FRC, it is moved to another listing called the "Accession Number History List". This listing identifies the documents which were at one time in storage at the FRC but which no longer are there due to destruction, removal or transferral to the 881 Archives or another records center. The History List shows the date of action and a code for what action was taken.

Examination of Rocky Flats Documentation at the FRC

Upon first review, the amount of documentation determined to be of potential use to the Toxicologic Review and Dose Reconstruction Project was approximately 18% of the total Rocky Flats documentation in the FRC. Upon closer examination, the amount of truly useful documentation has been determined to be significantly lower. Out of the approximately 600 boxes of records originally believed to be relevant, the project team has examined the contents of 176. Much of the documentation in these files includes employee medical and exposure records, injury reports, and analytical reports.

The most relevant documentation at the FRC is in the form of raw data, consisting of laboratory analytical reports of individual samples. This type of data makes up a significant fraction of the approximately 3200 cubic feet of Rocky Flats records stored at the FRC. Although some of this documentation may be usable, the quantity of the records and their format would require an extensive amount of effort and time to derive meaningful information from it. For example, it appears that the analytical reports for just about every environmental sample taken on and off the Rocky Flats site are in the FRC. However, no documents were found which explain how the thousands of data points were processed to arrive in their final, summary form in the Site Survey and Environmental Monitoring Reports located in the other repositories.

Emissions Data at the FRC

Since the beginning of operations, effluent monitoring at the plant has focused on certain portions of the plant, namely those areas in which radionuclides or recognized hazardous materials were handled. As general awareness and scientific understanding of various types of hazards and chemicals increased, the number of sampling points and parameters increased or changed to reflect the knowledge and regulatory requirements of the day. Nonetheless, the bulk of the attention has always been on certain manufacturing areas or buildings at the plant. Consequently, the emissions data that resides in the FRC is largely composed of data from less than a dozen buildings: 771, 774, 707, 559, 776, 779, 881, 444, 447, 991, and 995. Sampling data are present for other buildings and areas, but are not as numerous.

The manner in which the information was recorded changed dramatically over the years, not only with regard to format, but also from a content standpoint. In the earlier years, the laboratory information apparently was recorded only in ledger-sized logbooks which consist of little more than sample point, sample date, and a resulting value. Additional information such as the person taking the sample, the person analyzing the sample, the methodology used, control blanks, background samples, number of counts per minute, counting duration, and pre-analysis decay time are not found in the documentation. Improvements in the reporting were made over the years and the information recorded eventually became more complete. However, regardless of the improvements to the analytical reports, none of the reports were accompanied by information describing the sampling methodology, location of the sampling points or devices, analytical methodologies, or confidence levels.

Summary data were not present at the FRC. Most summary data have been found in the EMF and in other repositories, such as the Rocky Flats Reading Room at the Front Range Community College and the Colorado Department of Health.

Accident Information at the FRC

Also found in abundance were incident and injury reports. Most of these were relatively minor incidents such as cut fingers and minor spills confined to the interior of the buildings. A rough estimate of the number of these reports is in the thousands. Almost without exception, the reports were one-page forms, regardless of the relative significance of the incident. It is known that incidents of a serious nature were investigated more thoroughly than these report forms would indicate. The in-depth investigation reports and supporting documentation are located on the plant site.

Equipment Vendor Drawings at the FRC

There are a number of boxes of vendor drawings and associated information. Much of the documentation included owner's manuals and operating instructions for various pieces of equipment used at the plant. The types of equipment for which there is documentation includes heating and ventilation controls, lathes, milling machines, drill presses, plumbing fixtures, boiler vessels, gasoline pumps, public address system components, stair stringers, and building footings. In most cases, there is no date included on the documentation or identification of the building in which the equipment was installed.

TLD Badge Records and Personnel Exposure Histories at the FRC

There are many boxes of thermoluminescent dosimeter (TLD) and other personnel exposure monitoring records at the FRC. These exposure records are relevant to the indoor, plant environment and worker exposures, and are not directly relevant to this study. Problem areas for worker exposure are not related to off-site releases.

Procurement Files at the FRC

Procurement files do exist and are located at the FRC. However, they have a specified retention period of three to six years, depending upon the dollar amount involved in the particular contract. Consequently, the information which would be available from these types of records is limited to a few years' time. A review of the Accession Number History List verified that procurement records from the years prior to 1984 had been sent to the FRC and eventually destroyed according to schedule.

Project Construction/Completion Files at the FRC

These contain historical information insofar as identifying when major projects were completed. Projects noted on the Form 135s included buildings, waste treatment facilities, and production lines. These files only go back to 1971. Additionally, it was not determined whether these files are all-inclusive of the years represented.

Summary of FRC Content and Utility

Overall, the amount of information at the FRC that would be directly useful to the project is quite limited in comparison to the total volume of documentation. Many relevant records found in the FRC were also found in other repositories on the plant site.

2.2.4.2 DOE Effluent Information System

The DOE Effluent Information System (DOE EIS) is a computer-based management information system for recording and reporting radioactive effluent data for airborne and waterborne discharges that travel off-site from facilities under DOE control. One must be careful to not confuse this EIS with a significant document commonly given the same acronym, the 1980 Final Environmental Impact Statement for the Rocky Flats plant site. The Effluent Information System was developed by Aerojet Nuclear Company (ANC), with the first reports being produced in 1972. Since that time, the system has been revised, and Aerojet, which has been renamed EG&G Idaho, Inc., has operated the system for the DOE Division of Operational and Environmental Safety (Batchelder et al., 1977).

ChemRisk has obtained DOE EIS reports of the effluent data for the Rocky Flats Plant. The EIS presents annual release totals by individual release point for plutonium-239/240 and -238, uranium-233/234 and -238, americium-241, and tritium. The earliest data are for 1956. Early airborne effluent analyses were strictly non-specific measurements of long-lived alpha emitters. At various points in time since the 1950s, more advanced analytical techniques facilitated identification of specific elements and their radioactive isotopes.

The DOE EIS contains effluent data as reported by the DOE based on annual reporting from Rocky Flats. ChemRisk has not yet completed the independent verification process for the data or the necessary review of the associated monitoring systems, analytical procedures, quality control practices, or reporting conventions. These areas of data quality and interpretation are being addressed as part of Task 5 source term investigations. To provide a historical context for the emission monitoring data which will be a critical part of the basis for radionuclide source term estimation, key elements in the data quality evaluation are discussed here.

The data provided in the DOE EIS do not provide a complete emission history for each Rocky Flats building over its operational history. Some effluent data reporting lags behind or pre-dates the initial operation of some buildings. In some cases, apparent mismatches between reported construction dates of a building and appearance of associated effluent data arises from the fact that construction took several years to complete. In other cases, a building was structurally complete, with effluent monitoring in place, before the time that the production processes destined for the building became fully operational. The above situations notwithstanding, there are cases when a building is known to have been operational for some period before data are reported in the DOE EIS. There are also gaps in the data for certain analyses of some buildings.

Conventions for inclusion of measurements below the limits of detection are not clear. For some time period, DOE instructions reportedly called for results measured below the minimum detectable activity (MDA) to be assumed to be present *at* the MDA. A common practice in effluent reports is to affix a "less than" sign to totals which include results assumed to be at the MDA. There are no provisions in the EIS reports provided to us for identification of "less than" values. Reports that comment fields within the EIS have been used to somehow indicate inclusion of "less than" values have not been substantiated.

Contents of the comments fields, which also have been alleged to contain beryllium emission data, have not been made available. The extent to which incident related emissions have been included in the DOE EIS is also not clear. It is apparent that some major accidental emissions have been excluded, while some more minor accident-related emissions have been included. The criteria for inclusion of accident related emissions is therefore unclear.

The transitions between analytical methods and reporting conventions are also not clear. For example, in the early years, airborne effluent analyses were non-specific long-lived alpha emitter measurements. In the DOE EIS, the results were in some cases attributed to plutonium-239/240 by association of the materials handled in the building in question. Over the years, analytical methods and reporting conventions evolved substantially. The record provided by the DOE EIS does not by itself provide enough information to support interpretation of the data. The history of Rocky Flats effluent quantification practices is being characterized as part of Task 5 activities.

Information obtained from EG&G Idaho includes a Narrative Information Database Master List which describes each release point entered in the system for the Rocky Flats site (USDOE, 1991). For each release point, the narrative database describes the discharge point name, operations generating associated pollutants, waste treatment systems provided, monitoring systems, and sample collection frequency. This information is utilized in the discussion of historical release points in Section 5 of this report.

2.2.4.3 DOE On-Site Discharge Information System

The DOE On-site Discharge Information System (ODIS) is a computer-based management information system for recording and reporting radioactive effluent data for *on-site* airborne and waterborne discharges at facilities under DOE control. The system was developed by Aerojet Nuclear Company (ANC), with the first reports being produced in 1972. Since that time, the system has been revised, and Aerojet, which has been renamed EG&G Idaho, Inc., has operated the system for the DOE Division of Operational and Environmental Safety. (Batchelder et al., 1977). Since the focus of this study is on exposures to off-site individuals, the ODIS contains information that is not directly applicable to this project, but may prove to be useful in source term development efforts to characterize emission sources of interest.

2.2.4.4 The DOE Energy Library in Germantown, Maryland

In the early stages of the project, a computer search of the Department of Energy's Energy Database was performed to identify publicly available reports relating to the Rocky Flats site specifically and more general reports addressing topics applicable to assessment of potential environmental impacts of the plant. Based on the results of that search, documents at the DOE Energy Library in Germantown, Maryland were reviewed. A number of documents of relevance to the Toxicologic Review and Dose Reconstruction Project were located and were added to the project information repository.

2.2.5 Pertinent Regulatory Documents

Rocky Flats Plant operators have produced a number of documents in response to regulatory requirements that compile information that is potentially relevant to dose reconstruction efforts. A number of these documents are identified in the following sections.

2.2.5.1 Colorado Department of Health Files

The Rocky Flats documentation in the various departmental files at the CDH is relatively recent and consists primarily of responses to regulatory requirements and inquiries made by the Department of Health. ChemRisk has access to much of the same documentation in the repositories on site and has sought this information concurrent with accessing other documents onsite.

The CDH Department records which have been reviewed include:

- Air Division Files,
- Hazardous Materials and Waste Management Division Files, and
- Radiation Control Division Files.

2.2.5.2 Air Pollution Emission Notices

Air Pollution Emission Notices (APENs) are reports which the State of Colorado requires be submitted to their Air Pollution Control Division to document significant sources of emissions of key pollutants within the State. An APEN is required for any process or activity which has the potential for an uncontrolled emission greater than one ton per year for any pollutant, or greater than 1 pound per day for any hazardous or toxic pollutant.

Hazardous pollutants are listed in applicable Air Quality Control Commission regulations, and toxic pollutants are taken as those on the "Massachusetts List" (Beckham, 1990). Criteria air pollutants are carbon monoxide, lead, nitrogen oxides, sulfur oxides, ozone, and particulate matter less than ten microns in size. ChemRisk has reviewed all APEN reports prepared by EG&G Rocky Flats.

APEN reports have been prepared for essentially all Rocky Flats buildings, or groups of buildings or facilities. These reports document the configurations of the air handling systems, the processes conducted in the building, vents and/or stacks associated with emissions, and assumptions and factors used to calculate controlled and uncontrolled emissions. The APENs describe modern-day plant processes and activities, and are, except for a few inserted statements about past activities in several buildings, not useful sources of historical information.

Based on reviews of the APENs, building summaries were generated that identified the processes associated with airborne emissions of the materials of concern selected in Task 2. The Massachusetts List includes all of the chemicals identified as materials of concern for the project, but all of the materials of concern have not been identified by the Rocky Flats Plant as having emissions that qualify for reporting under the APEN program. The building summaries were used to assist the project team in conducting interviews of active or past employees knowledgeable in the operations of each building.

2.2.5.3 Waste Stream & Residue Identification and Characterization Reports

The Waste Stream and Residue Identification and Characterization (WSRIC) Program was undertaken for EG&G Rocky Flats to identify and characterize waste streams and residues generated or stored at the Rocky Flats Plant. The series of approximately 100 WSRIC reports was prepared to fulfill requirements contained in the Agreement in Principle between the DOE and the State of Colorado.

A WSRIC report was prepared for each major building, describing the associated waste streams and residues based on field investigations and waste sample analyses. The information includes details on the nature, quantities, and hazards associated with hazardous, radioactive, and mixed hazardous and radioactive wastes. One of the main goals of the WSRIC was to determine which wastes and residues should be land disposal restricted (LDR), in other words excluded from land burial as a disposal method.

ChemRisk reviewed selected WSRIC reports for process descriptions and details on the uses of the materials of concern, primarily for those buildings for which APEN reports were not yet complete at the time interviews were conducted.

2.2.5.4 Information Related to Section 104(e) of CERCLA

The "104 E Report" consists of Rocky Flats' response to EPA's request for additional information under Section 104(e) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (Rockwell, 1990). The information sought by the EPA was requested under very broad, all-encompassing questions. Rocky Flats provided a twelve-volume reply document, which provided fairly detailed information in response to some of the question areas, and identified where the information to answer many of the other question areas could be located. Most of the twelve volumes of supporting documentation includes samples of documentation kept at the plant site.

The greatest benefit to the Rocky Flats historical investigation from the 104(e) documentation was confirmation that the project team had been independently conducting its information searches in what were identified in the 104(e) report as the most effective places to acquire the identified information.

2.2.5.5 Safety Analysis Reports

Safety Analysis Reports (SAR's) provide a detailed examination of a facility with respect to the likelihood of significant accidents occurring in that facility and the resulting consequences, for the purposes of designing and determining the adequacy of engineered safety features. Preparation of an SAR includes examination of the facility's physical characteristics (age, type, and materials of construction), the underlying geological conditions, and the processes and activities within the facility. An SAR also determines how all of these factors could affect or be affected under various catastrophic circumstances. The Reports summarize this examination, the information gathered, and the conclusions drawn regarding the adequacy of the facility's safeguards.

The SAR analyses also include investigations of the facility's past accident and incident history and the histories of similar facilities, but the Safety Analysis Reports themselves do not elaborate on or provide references for those accidents reviewed.

The first regulatory requirement for SARs was established in the 1970s, so none date from earlier years. At the time that Rocky Flats SARs were reviewed for this study, approximately a dozen had been written, primarily for the major production buildings and their related auxiliary buildings. An individual currently involved with the SAR process indicated that about half of the SAR's were in draft form and half were finalized. Currently, the plant is attempting to prepare SAR's for all of the major production processes and production buildings.

The following is a listing of the SAR documents which were available for review:

707 Appendices, Draft, 1/84
774 Report, Revised 10/81
444 Report, Revised 2/82 (includes 445, 446, 447, 448, 449, 427, 453, 454, 457)
991 Report, Revised 11/81 (includes 996, 997, 998, 999, Tunnels, 985, 989)
881 Report, Revised 2/82 (includes 830, 864, 882, 885, 887, & 890)
865 Report, Revised 2/82 (includes 827)
374 Report, Revised 8/1/81
559 Report, Final 6/87 (includes 560, 561, 562, 563, 528)
776/777 Report, Final 6/87

Review of the SAR's revealed that they contain little historical information and no emissions data. Because the SAR's were produced at different times, the format and content is inconsistent. Some contain a general chronology of the construction years of the building and its subsequent additions, and some do not. Some contain detailed descriptions of the processes within the buildings, and some are very generalized.

The SAR's have some utility for the project, in that a few provide a good snapshot of the processes within a building at a particular point in time, and some provide historical construction information.

2.2.6 Records Related to Litigation

Litigation associated with the plant has generated the need for information and the creation of a number of significant resources. The following sections identify some of the resources that were created as a result of litigation activities.

2.2.6.1 The Legal Database

This database represents the documents seized by the FBI and subpoenaed by the Grand Jury in the environmental criminal investigations against Rockwell. The database consists of an index and electronic images of the documents seized and subpoenaed. The documents were recorded by optical character recognition techniques and stored on magnetic tape. A copy of the database is maintained by the EG&G Legal Group in Trailer T-334C.

ChemRisk cannot view the database itself or have free access to its use because it is attorney-client privileged in nature. However, the Rocky Flats Plant Legal Department has performed searches on the database while team members were present and allowed the documents to be previewed on the terminal screen to support selection of those documents which were of apparent utility to the project. Because of the focus of the FBI and the Grand Jury, the documents generally cover the 1980 to 1989 time frame. As a result, the database has little historical value and as a result relatively few documents were retrieved.

2.2.6.2 The Legal/Environmental (Church Litigation) Files

The Legal/Environmental File was established around 1975 by Rockwell and DOE attorneys in preparation for lawsuits brought against the plant by neighboring landowners. It is sometimes referred to as the Church Litigation File.

During the file's development, the plant was canvassed for any documentation which related to environmental issues. The files of various operational groups on the plant site were reviewed for pertinent information, such as the "Medical, Health and Safety" files, and "Materials" files. Any information found which was felt to be related to environmental issues was entered into the collection. Entries of documentation into the file continued for approximately three years. As a result, the Legal/Environmental File consists of a large variety of documentation, covering the time period between 1952 and approximately 1978.

Because the information in the file was to be accessed by attorneys for the plaintiffs and eventually become public information, the file contains no classified documents. Several of the documents are declassified versions of classified records. Nonetheless, the file is not short on documentation. It contains approximately 20,000 documents in five four-drawer filing cabinets.

A review of the "source" field in the database shows that documents were obtained from Dow, Rockwell, the AEC, ERDA, and DOE. Documents originating from offsite groups were also found, including Los Alamos and Lawrence Livermore Laboratories and subcontractors who performed environmental work for the plant. In addition, the files in the Federal Records Center were searched at the time of the file's development to locate and retrieve any documentation from this resource. As a result, the types of documentation in the file is quite varied. The content includes annual and monthly reports, internal memos, letters, charts, graphs, and photographs. Some of the documents listed in the file's index have been seen in other repositories, such as the EMF and FRC, during other phases of the investigation.

The Legal/Environmental File documents were at one time located in the Building 706 Library on the plant site, but were moved to Las Vegas in 1990 to be copied for archival and legal purposes. A copy of the files was returned to the plant site in May, 1991 and is currently located in legal offices in T-334C. ChemRisk was provided unimpeded access to these files as soon as they were returned to the plant.

Legal/Environmental Index

The documents which went into the Legal/Environmental File were cataloged and indexed into a database, called the Legal/Environmental Index (LEI), which has been placed on the plant's central VAX computer network. Because the database is located on the plant's central computer, access can only be obtained by authorized persons. Some training is also necessary for users to become proficient in use of the system. Nonetheless, the LEI is the key to efficiently identifying any documents in the Legal/Environmental File pertaining to a particular subject.

Searches Performed On The Legal/Environmental Index

Numerous searches of documents in the LEI have been performed. The listings on printouts from the database are arranged according to accession number (assigned to a document according to the order in which it was received), and includes the title, author, source, Bates numbers (chronological numbering of the individual pages in the file), and a description of the document.

The first search included a number of keywords, word roots and various permutations, for example "effluent, radionuclide, pluton, americium, beryllium, uran, tritium, carbon tetrachloride, and tetrachloromethane". The resulting printout was sixteen inches thick and listed over seven thousand documents. The Bates numbers, which indicate the cumulative page numbers of all pages contained in the file, indicated in the associated printout that there were over 80,000 pages of documentation in the Legal/Environmental File. Because this first search was performed on all of these keywords as a group, the printout was unwieldy and poorly organized for effective index review.

Subsequent searches were performed in an effort to separate the issues relative to the various project tasks and to make the resulting printouts more manageable. This was done by performing searches on single keywords, word roots or abbreviations, or keywords that belong to a common group.

The selective searches that were performed on the LEI included:

1. CHEMICAL
2. INVENT(ORY)
3. ACCIDENT, INCIDENT, UNUSUAL, OCCURRENCE, EVENT, UNPLANNED,INVESTIGATE
4. SITE SURVEY
5. ENVIRONMENTAL MONITORING REPORT
6. HIST(ORY)
7. ANNUAL
8. MONTHLY
9. HEALTH PHYSICS
10. SAFETY
11. EMISSION, RELEASE, STACK, SOURCE
12. LAND, DEMOGRAPH, POPULATION
13. WASTE, BURIAL
14. SAMPLE
15. BERYLLIUM
16. HIGHLIGHT
17. HISTORY
18. 1957 FIRE
19. 1969 FIRE
20. 903 PAD, HELICOPTER PAD, LIP AREA
21. BENZIDINE, P-DIAMINODIPHENYL
22. PROPYLENE OXIDE, METHYLOXIRANE, PROPENE OXIDE
23. BUTADIENE, BIETHYLENE, VINYLETHYLENE, ERYTHRENE, PYRROLYLENE, BIVINYL
24. ETHYLENE OXIDE, OXIRANE, ANPROLENE
25. BENZENE, BENZOL
26. HYDRAZINE, DIAMIDE, DIAMINE, HYDRAZYNA
27. CADMIUM
28. NICKEL
29. CHROMI(UM,C)
30. MERCURY
31. LEAD
32. METHYLENE CHLORIDE, DICHLOROMETHANE, METHYLENE DICHLORIDE, DCM
33. CHLOROFORM, TRICHLOROMETHANE
34. TETRACHLOROETHYLENE, PERCHLOROETHYLENE, PCE, TETRACHLOROETHENE
35. TRICHLOROETHENE, TRICHLOROETHYLENE, ETHINYL TRICHLORIDE, TCE
36. 1,1,1-TRICHLOROETHANE, METHYL CHLOROFORM, CHLOROTHENE
37. FORMALDEHYDE, METHANAL, OXOMETH, FORMIC ALDEHYDE, METHYLENE GLYCOL
38. NITRIC, AZOTIC, HYDROGEN NITRATE
39. PESTICIDE/HERBICIDE

The resulting printouts, totalling over three feet thick, were first reviewed to identify summary documents that were produced with regularity, such as annual, monthly and weekly reports. A listing was made of each type of document and which issues of periodic reports were in the Legal/Environmental File. This list served to identify any issues that were missing and to provide a specific listing of documents to be obtained for the project. Issues of a document that were determined to be missing from the L/E File were sought in the other repositories. Examination of the printouts created from the searches identified several types of summary documents which were produced with regularity.

Some of the types of periodical documentation found in the LEI include:

Site Survey Monthly Progress Reports, starting in 1953
Site Survey Annual Progress Reports, starting in 1952
Monthly Summary - Accident, Occupational Disease and Fire Experience, 1968-1974
Annual Summary - Accident, Occupational Disease and Fire Experience, 1968-1974
Annual Summary of Industrial Fire and Property Damage Reports, 1968-1974
Minutes of Executive Safety Council Meetings (monthly), 1954-1975.
Industrial Hygiene Monthly Progress Reports, starting in 1953
Health Physics Status Report for Buildings 440, 444, 881, 883, 886, and 991: 1966-1975.
Weekly Highlights for Health, Safety and Environment

The printouts were also reviewed to identify any one-time or limited-issue documents that appeared to be of significance to the particular project tasks. Listings of these were created for retrieval. Overall, the Legal/Environmental File has been the single most useful repository, primarily because of the extent of documentation from the early years of Rocky Flats activities. ChemRisk has requested and received over 635 documents from the Legal/Environmental File to-date.

2.2.6.3 Files Gathered by Attorneys for Jim Stone

In 1986, former Rocky Flats employee Jim Stone filed a suit against the plant for wrongful discharge, and in 1988 Requests for Discovery were filed by attorneys for Jim Stone which involved a number of issues. By December of 1988, a total of approximately 60 boxes of documents were gathered by EG&G Legal Department staff in response to the Requests for Discovery for review by the plaintiff. Thirty-seven of the boxes came from the 881 Archives and the Federal Records Center. At the time of this report, the documents still remained in storage in Building 130 but will soon be returned to their origins, as the Court has rendered a decision in the case.

Review of the listings of the contents of the boxes indicated that the records largely consisted of indoor air samples, documentation of employee exposures, and records pertaining to the employment history of Mr. Stone and his co-workers at Rocky Flats. A relatively small portion appeared to have some historical information useful to the project. The contents of those boxes which appeared from the listings to be of use were reviewed. The review of the selected boxes verified that there was limited useful information in this assembly of documents. Copies of relevant documents from this source have been entered into the project repository.

2.2.7 Records of Concerned Individuals and Organizations

Records generated or held by groups or individuals not affiliated with the plant were also sought as part of the investigations for this project. The following sections describe these resources.

2.2.7.1 The Cobb Files

Currently retired in New Mexico, Dr. John C. ("Jock") Cobb has been involved in a number of health issues in Colorado. His career included service as Professor of Preventive Medicine at the University of Colorado (CU), member of the Governor's Scientific Advisory Panel of Colorado, member of the Wirth Task Force on Rocky Flats, member of the Air Pollution Control Commission of Colorado, and member of the Governor's Task Force on Uranium Enrichment.

Approximately 10 linear feet of Dr. Cobb's files were loaned to the project team by Health Advisory Panel member Dr. Ken Lichtenstein for review and extraction of material pertinent to the project. The files are accompanied by two metal boxes of 3"x5" index cards, containing approximately 350 cards. The files were provided to ChemRisk prior to their submittal to the CU Western History Archives by the American Friends Service Committee. They have been examined and subsequently forwarded on to CU.

The entire contents of the Cobb Files were reviewed. Most of the documents did not pertain specifically to Rocky Flats. Approximately 15 documents were identified in the Cobb Files as relevant to the project that were not already in the project information repository.

2.2.7.2 The Johnson Files

Dr. Carl J. Johnson (1929-1988) was the Director of the Jefferson County Health Department from 1973 to 1981. During that time, he was an outspoken critic of the Rocky Flats Plant, authoring several papers concerning the radioactive contamination of, and cancer incidence in, the Denver and Jefferson County areas. His papers and files now reside at the Western History Archives in the Norlin Library on the Boulder campus of the University of Colorado. A guide to his files has been put together by the staff, and is useful in locating items of interest.

Overall, there are 167 boxes of Johnson's files plus numerous travel maps and posters which are described in the guide. Upon review of the guide, 17 boxes were determined to be pertinent to this study; the contents of these were examined. Many of the documents found in the Johnson files had previously been obtained by the project team. A total of 21 documents were identified as useful to the study and copies were obtained for addition to the project repository.

2.2.7.3 The Martell Files

Edward A. Martell has long been an outspoken scientist and concerned citizen about nuclear issues. He became well known in the Denver area as a result of his participation in and subsequent subcommittee work for the Colorado Commission for Environmental Information (CCEI). It was during his chairing of the CCEI subcommittee on Rocky Flats that the soil contamination east of the plant became widely known.

Mr. Martell was interviewed by ChemRisk to discuss many historical issues and obtain access to his files concerning Rocky Flats. In addition to the verbal information, he provided ChemRisk with copies of pertinent documents relating to his CCEI work on Rocky Flats. Copies of these documents also reside in the Western History Archives of the CU Norlin Library in Boulder.

2.2.7.4 Rocky Flats Environmental Monitoring Council

The library at the Rocky Flats Environmental Monitoring Council offices contains approximately 200 documents. Many documents are several volumes in length, and many are also in the Rocky Flats Public Reading Room. A few located here were not found in the Rocky Flats Public Reading Room, but virtually all have been identified in at least one of the repositories on the plant site, as the majority originated from the plant. The Environmental Monitoring Council's documents are not catalogued.

2.2.8 Citizen Contributions

A few citizens in the communities near Rocky Flats have contributed documents for the Toxicological Review and Dose Reconstruction Project. Most notably, Paula Elofson-Gardine supplied the project with a listing of the most significant incidents which have occurred at the plant, and Jan Pilcher provided documents pertaining to plant history and emissions during the early years.

2.2.9 Other Information Sources

A number of information resources consulted by the project staff did not fall in any of the above categories. These sources of information are described here.

2.2.9.1 CSU Dept of Radiology and Radiation Biology

Staff and graduate students of the Colorado State University at Fort Collins Department of Radiology and Radiation Biology have performed a number studies at Rocky Flats beginning in the 1970s. The Department maintains a library associated with these studies, along with a selection of international works on radiation issues not specific to Rocky Flats. The documentation maintained provides little historical information, but may provide useful information for upcoming tasks dealing with environmental transport and dose assessment.

2.2.9.2 The City of Broomfield Water Department

The City of Broomfield Water Department provided a document which outlines the history of the Rocky Flats Plant and other plant related issues. The Water Department has a file of background information on which it was based. Most of the information is comprised of events from the 1980s, with relatively few entries from earlier years. The document provides a good account of the controversies arising from and surrounding Dr. Carl Johnson's work.

2.2.9.3 Aerial Photographs

Aerial photographs from various sources have been reviewed to assist in documentation of the Rocky Flats Plant development and to provide confirmation of some activities affecting the environment. The initial photographs reviewed were assembled as part of an "Aerial Photographic Analysis Comparison Report, US DOE Rocky Flats" prepared by Lockheed Engineering and Sciences (Helmstadt, 1988). That report includes 13 aerial photographs, with dates ranging from 1953 to 1988. The purpose of the study was to compare waste disposal and environmental management practices described by the Rocky Flats Plant with visual evidence of such practices obtained from the black and white, color, and infrared photographs obtained at the various steps in plant development.

The maps of site development contained in Section 3 of this report were spaced in time to coincide with certain photographs from the above report. The maps were initially prepared based on modern-day computer drafting files of Rocky Flats facilities and building construction and initial operation dates obtained from various plant records. The maps were then checked against the aerial photographs in the report by Helmstadt, and were modified to reflect appearances of roads, ponds, and other recognizable features.

A series of additional aerial photographs were obtained from the Rocky Flats Photography Department. The dates of these photographs range from 1957 to 1991, and for the most part the photographs provide a close-in view of plant configuration or appearance of selected areas of the facility. These photographs, like those described earlier, were examined to verify written accounts of site development and environmental activities.

2.2.9.4 EG&G Employee Communications Department

In preparation for the 40th anniversary of the plant, the Employee Communications Group has been tasked to develop a history of the plant. The resulting document is "Highlights in Rocky Flats Plant History" by Pat Buffer (Buffer, 1991). Although limited in the amount of information concerning production operations, the document contained some information which has been utilized by the project.

2.2.10 Interviews

In addition to the review of documentation from repositories and other sources, extensive interview activities were mounted to verify the collected data and to obtain additional information. This section describes this interview process.

Interviews to Support Selection of Materials of Concern

A series of brief interviews was conducted to characterize the likelihood of release of selected chemicals based on actual storage and usage practices as a part of Task 2 efforts.

To determine whether a chemical should be identified as a material of concern, the following questions were posed to individuals familiar with the use of the chemical:

- Is the quantity of the chemical on hand reported in the chemical inventories reasonably accurate?

- Is there any indication that the reported quantities are not representative of years prior to 1974?

- How is annual usage quantity related to quantity kept on hand?

- For initial screening, annual use was assumed to be 10 times the quantity on hand. Is that assumption reasonable?

- What fraction of the annual usage quantity is released to the environment? (For initial screening, 25% of annual usage was assumed to be released.)

Some chemicals were eliminated from further consideration as Materials of Concern based on knowledge of actual use characteristics collected during this phase of preliminary chemical usage investigations. A complete discussion of this process can be found in the Task 2 report (ChemRisk, 1991a).

Interviews to Document Historical Uses of Materials of Concern

To supplement the information gathered from written document reviews, an extensive program of interviews with current and past Rocky Flats Plant workers was conducted. The interview process involved a concentrated effort in August and early September of 1991. Interviews aimed at specific question areas of Rocky Flats history have continued at a decreased frequency up to the date of report preparation. As summarized in Figure 2-3, ChemRisk teams interviewed over 80 individuals, with a combined total of over 1900 years of experience at the Rocky Flats Plant. The average interviewee had 24 years of work experience at Rocky Flats. Many started as part of the 1969 fire cleanup, and a significant fraction began in entry level positions and worked their way up to managerial positions.

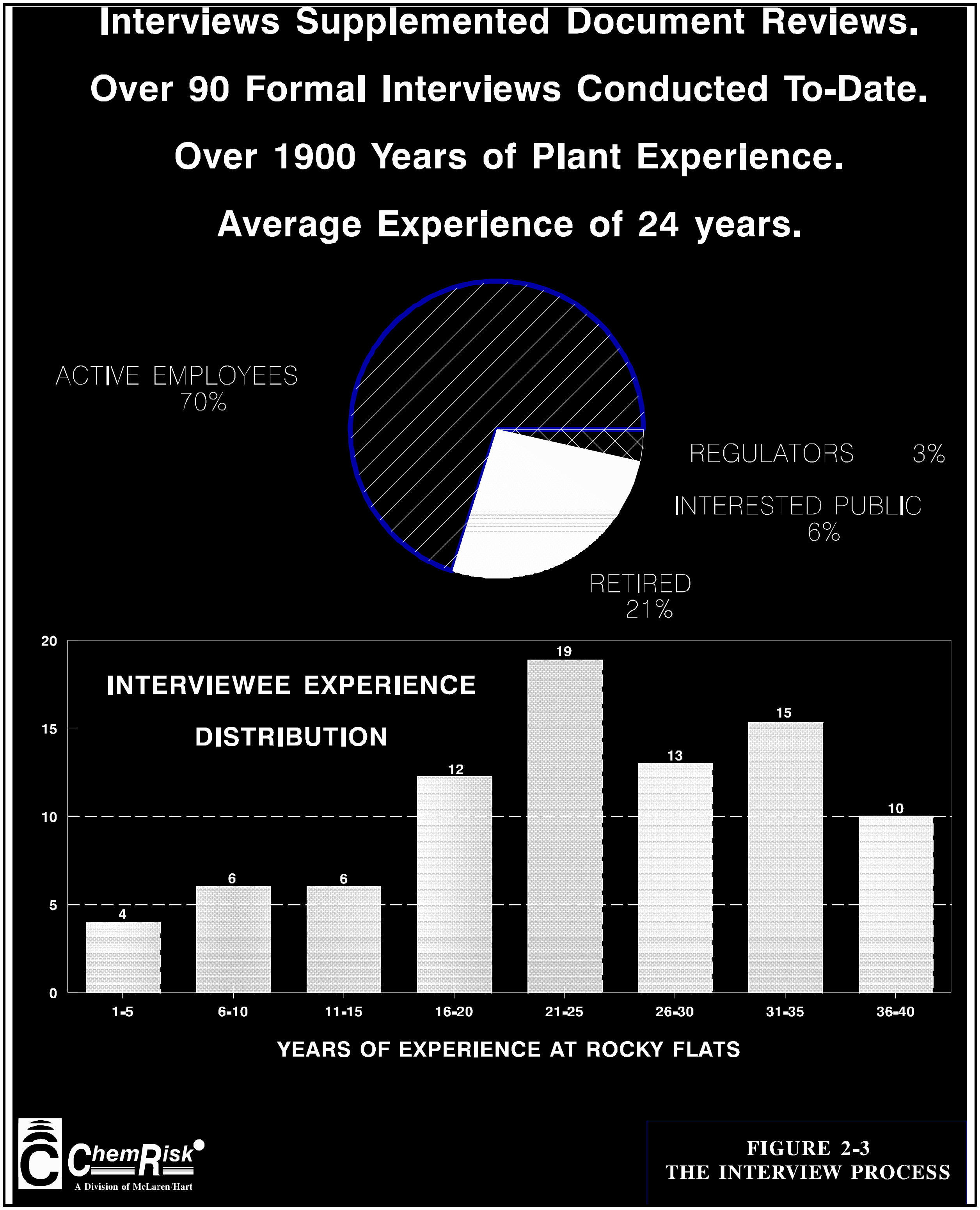

FIGURE 2-3
THE INTERVIEW PROCESS

There was wide variation in the level of detail remembered with regard to historical practices and events. For the most part, individuals were very cooperative and helpful and willing to share what they knew relative to the project. There were between eight and twelve individuals who declined to be interviewed on the advice of their attorneys because of the on-going Grand Jury investigation. There have been at least 75 individuals who have testified before the Grand Jury. ChemRisk interviewed some of them. It does not appear that any of the individuals who declined interviews are exclusive sources of the information needed for the project.

Two teams of two interviewers were used for the most part, to allow for optimal efficiency in covering the areas of concern and recording the information offered. A description of the project and an outline of the interview questions were provided to the interviewees in advance of the day of their interview. Each interview lasted about one hour, but some were longer (up to three hours in length), and a couple were shorter. Some individuals were interviewed in groups. The group approach was found to be helpful, as individuals were able to jog each others' memories and bring out additional information that probably would not have surfaced in individual interviews.

To assist in preparing for the interviews, summaries were prepared of the information available for each of the key buildings. The information in the building summaries included descriptions of the processes in each building that used materials of concern based on information in the Air Pollution Emission Notices, radioactive effluent data from the DOE Effluent Information System, chemical inventory records from 1974 and 1988/89, and items of historical significance obtained from various records. Interview questions were prepared and sent to interviewees in advance of the scheduled interview. As a result, interviewees often arrived at the interview with notes to answer our questions and in some cases, with copies of documents and information on additional persons to interview. A copy of the interview questions is presented as Appendix C. It should be noted that the interview questions were prepared to focus the interviews on key issues and areas where ChemRisk was lacking information at that time. Interviewees were also encouraged to discuss any topics outside of the specific questions which they felt might be of interest to us.

During the interviews, information was recorded in hand-written notes which were later reviewed by EG&G Classification Officers. In a few cases, classified information was physically cut out of the interview notes. All items excised from interview notes dealt with, or might enhance one's knowledge of the configurations of materials within the Rocky Flats Plant's main product, the bomb triggers. None of the items that were cut from interview notes have been important to the conduct of the project.

Historical information relevant to the project is generally not classified. However, in some cases, cleared members of the project team were offered information about design features of Rocky Flats products or production processes that related to some of the Materials of Concern. These details are not important to the general history of Rocky Flats operations, but a certain level of knowledge of the types of products produced by the plant and the associated processes was found to enhance the ability of the project team to properly focus efforts for characterizing uses of the materials of concern.

The hand-written interview notes have since been typed and reorganized into a standardized format corresponding to the key areas of investigation. Interview statements based on rumors or hearsay that were discredited when individuals directly involved with the event in question were interviewed, were not retained in the record. A complete set of interview records is included in the project information repository (ChemRisk, 1991b).

After the interviews were conducted, key pieces of information gained were added to the appropriate building summaries. The information contained in the building summaries has also been rearranged into summaries for each material of concern. These summaries formed the bases for the material use profiles presented in Section 4 of this report.

A list was also prepared of materials that were mentioned as being used at the plant, but that are not on the list of Materials of Concern. Each chemical was reviewed to determine if it had been evaluated and eliminated in the Task 2 chemical selection screening process, or if it needed to be further evaluated at that time. Statements people made about relative production levels at various points in time were also assembled so that any recurring themes could be extracted. Sample statements include "by 1964 they had the pedal to the metal and going full bore" and "the addition of Room 114 to building 771 increased throughput by a factor of from 20 to 25 times".

ChemRisk is also tracking all the potential points of contact recommended by interviewees, noting those which have already been interviewed and those which might be useful for future follow-up questioning. Many of the people named are retired, some have passed away, others have proven difficult to locate, especially when they have been commonly known at the plant by nicknames which do not correspond to their actual names.

REFERENCES

Batchelder et al. (1977). Batchelder, H.M., Passmore, R.W., EG&G Idaho, Inc. Effluent Information System (EIS) and Onsite Discharge Information System (ODIS) Users Manual, October, 1977. Repository Document RE-936.

Beckham. (1990). Beckham, B.J. Letter from Bradley J. Beckham, Director of CDH Air Pollution Control Division, to Robert Nelson, Rocky Flats Area Office, February 2, 1990.

Buffer. (1991). Buffer, P. "Highlights in Rocky Flats Plant History". Repository Document RE-30.

ChemRisk. (1991a). Task 2 Report, Selection of the Chemicals and Radionuclides of Concern. Repository Document TA-723.

ChemRisk. (1991b). "Rocky Flats Historical Investigation Personnel Interviews." Repository Document RE-891.

Helgerson. (1992). Personal communication with Bob Helgerson. January 3, 1992.

Helmstadt. (1988). Helmstadt, R.W. "Aerial Photographic Analysis Comparison Report, US DOE Rocky Flats". Lockheed Engineering and Sciences, 1988. Repository Document EN-589.

Rockwell. (1990). Rockwell International. "Response to CERCLA 104(e) and RCRA 3007 Information Request, Final Response". April 16, 1990.

USDOE (1991). "U.S. Department of Energy Effluent Information System Narrative Information Database Master List for Calendar Year 1991". November 4, 1991.

3.0 A HISTORY OF ROCKY FLATS PLANT OPERATIONS

The history of the Rocky Flats facility is described in this section in terms of its mission, the progression of site development, and the various functions the plant has performed.

3.1 Missions

The Rocky Flats site had two main historical missions during the period of operations from 1952 until 1990, production of "triggers" for nuclear weapons and processing of retired weapons for plutonium recovery. The plutonium triggers, also known as "pits", are the first-stage fission bombs used to set off the second-stage fusion reaction in hydrogen bombs. Plutonium has historically been imported from the Hanford Reservation in Washington State and the Savannah River Plant in South Carolina, and is also recovered at Rocky Flats from retired warheads and manufacturing residues. Parts are formed and machined from plutonium, uranium, beryllium, stainless steel, and various other materials.

In general, the mission and activities at the plant have remained essentially the same since the plant began until 1990 when plutonium operations were suspended. The plant was intended from the beginning to be a manufacturing facility, not a facility to design or conduct elaborate or exotic experimentation for nuclear weapons or components. Such research was intended to be performed at Los Alamos and Lawrence Livermore Laboratories, with the two of them competing in the development of designs for new nuclear weapons. Interviews and documentation have confirmed that the primary activities at the Rocky Flats Plant have involved the manufacture of nuclear weapons components; specifically, triggers.

The phases in the life of a nuclear weapon are described in Table 3-1. The primary mission of Rocky Flats has historically involved Phases 4, production engineering, through 7, retirement of the weapon. The bulk of the manufacturing work at Rocky Flats, however, involves the production start-up and quantity production of Phases 5 and 6. Phase 4 production engineering work is conducted at the plant and is very intensive, but does not last as long as the two phases that follow it. Rocky Flats also has a role in the retirement of the weapons, dismantling the components it originally produced to retrieve and recycle the materials.

Phase 1 - Weapon Conception: studies which indicate that a weapon concept warrants a formal study for a weapon program.
Phase 2 - Program Feasibility Study: If the concept of the weapon proves to be feasible, the result is a DOD-DOE agreement on the division of responsibilities for the weapon's development and procurement.
Phase 3 - Development Engineering: The weapon is developed according to military requirements, resulting in complete design information.
Phase 4 - Production Engineering: The design information is adapted to a manufacturing system. The adaptation involves product and process engineering, tooling, prototype production and inspection, and test and handling procedures.
Phase 5 - First Production: Production of the weapon begins according to the specifications developed in Phases 3 and 4. Success of this phase results in the authorization for stockpile production.
Phase 6 - Quantity Production and Stockpile: Weapons are produced in quantities specified. Evaluation of the weapon continues during production to identify and incorporate potential improvements or technical advances.
Phase 7 - Retirement: The weapon is removed from the arsenal stockpile and dismantled (USDOE, 1977).

TABLE 3-1: THE SEVEN PHASES IN THE LIFE OF A NUCLEAR WEAPON

Although the mission of the plant and the activities to carry out that mission have generally remained the same, three events have had a significant impact on the operations at the plant. The first was a change in the concept of the weapon in the late 1950s which required additional manufacturing facilities and placed a heavier emphasis on plutonium. The second was the Department of Defense's decision to have a "single mission" weapons manufacturing complex, eliminating the redundancy of operations between the plants. The third was the advent of the Cold War which fueled the nuclear arms race.

In the early years of the U.S. nuclear weapons program, the manufacturing complex was set up to provide redundancy of facilities. Hanford at one time manufactured plutonium pit components. Hanford's plutonium component production facilities reportedly mirrored those of Rocky Flats, and the two plants were manufacturing essentially the same product. At the same time, the Oak Ridge

Y-12 plant was manufacturing uranium components similar to those at Rocky Flats. Los Alamos also had a small facility for production of triggers.

In the early 1960s, the government decided it was too expensive to maintain the duplicate weapons manufacturing facilities, and converted to the "single mission" concept, where the various facilities became specialized providers of the key weapons components and services. Hanford lost all contract work for the pits in the early 1960s, and Rocky Flats became the primary facility for that facet of weapons production. The single mission concept was also responsible for Rocky Flats' enriched uranium work being relocated to the Oak Ridge Reservation in 1964 (ChemRisk, 1991; RE-891[31,67,39,36]).

Historical investigations have indicated that the overall manufacturing facilities and production processes have remained largely the same over the years, although with periodic refinements. The lack of major changes is primarily because there have been only three basic trigger designs since the beginning of plant operations, with the manufacturing of the first two designs phasing out within the first five years of production. The major changes to trigger design have been to increase yield with less fissionable material, a miniaturization effort. Major changes in more recent years have been in the areas of delivery, guidance, and tracking systems - not the trigger concepts.

The first two basic pit designs built at Rocky Flats were solid units made mostly of uranium. They were essentially derivations of the "Fat Man" and "Little Boy" weapons dropped on Japan. The Fat Man design made at Rocky Flats had a small plutonium core surrounded by a large amount of enriched uranium and then by high explosives. Detonation of the explosives was precisely timed so that the uranium and plutonium would be compressed to a reduced volume to induce criticality. The Little Boy was also called the "gun assembly" because it incorporated two opposing, cylindrical-shaped masses of enriched uranium which were forced together by an explosive charge on one end. When forced together, criticality was achieved.

The concept and design of the unit changed around 1957 to a sealed hollow unit which used much less uranium while incorporating more plutonium (ChemRisk, 1991; RE-891[31,48,50,67,55]). Like previous designs, the sealed unit used high explosives to force the materials together, but the geometry and the larger amounts of plutonium used created a more powerful explosion with a smaller, lighter design. This enabled the finished weapon to be carried by missile and, with further miniaturization, could even be delivered by artillery. Schematic diagrams of the gun type and implosion weapon systems are shown in Figure 3-1 (Cuddihy and Newton, 1985).

INSERT FIGURE 3-1; SCHEMATIC DIAGRAMS OF GUN-TYPE AND IMPLOSION WEAPONS

Since 1958, pit designs have remained largely the same, although the relative amounts of the materials used, dimensions, and a few other design features of the units have varied from model to model. The primary materials of construction have generally remained plutonium, uranium, beryllium, aluminum, and stainless steel, however the relative proportions have varied between models. Some models incorporated some more exotic materials, such as cadmium, vanadium, silver, and gold, but the amounts have been relatively minor in comparison to the primary five materials. The plant has also performed "Special Order" work. This type of work is outside the production of weapon components, but most often involved prototype development work. Special fabrication, testing, and assembly are provided for weapons development programs. For example, the work may involve the production of a prototype pit that incorporates different materials or geometries. In some cases, Special Order work has involved work indirectly related to war reserve programs, such as the development of safer shipping containers and transportation vehicles for nuclear materials and weapons (USDOE, 1980).

The plant's mission often included manufacturing of components for other portions of the weapon because it had the facilities and expertise to handle the materials involved. For example, the stainless steel reservoirs which hold the tritium for "boosting" weapon yield are manufactured at Rocky Flats, even though they are not a part of the pit. Beryllium components are also manufactured at Rocky Flats for other parts of the weapon.

3.2 Site Development

Construction activities relating to the Rocky Flats site began in 1951 in a building converted from an old garage at 13th and Glenarm in Denver, where the Austin Company and Rocky Flats employees initially worked. Ground-breaking for the first permanent buildings at the site of the Rocky Flats Plant began in July of 1951 for what is now known as Building 991. Later that year, construction also began on Buildings 771, 444, and 881. By April of 1952, the first operations began on regular production materials. At the beginning of 1953, some of the utility facilities on site were still incomplete; water was being brought in from Boulder in tank trucks and heat was provided to the occupied buildings by a locomotive which was temporarily brought on-site for generating steam. Nonetheless, the first production products were completed and shipped off-site that year from a plant that appeared as shown in Figure 3-2.

By 1954, the plant appeared as shown in Figure 3-3 and was fully operational, with initial plant construction essentially completed with a total of about 700,000 square feet of building space. As shown in Figure 3-4, plant employment grew steadily from 133 people in 1951 to 3,101 in 1963 (Buffer, 1991; USDOE, 1980; Putzier, 1982).

INSERT FIGURE 3-2; 1953 SITE MAP

INSERT FIGURE 3-3; 1954 SITE PHOTO

INSERT FIGURE 3-4; ROCKY FLATS EMPLOYMENT

Originally, the plant was separated into four areas of operation. These areas were known as the A, B, C, and D Plants, and were established according to the four primary types of work which took place at Rocky Flats. The site was so undeveloped at that time that there were still large spans of meadow between the four plants, with gravel roads connecting them. The A Plant included Building 444 operations, which involved almost exclusively the fabrication of depleted uranium parts. What is now known as Building 881 was known as the B Plant, which recovered enriched uranium and manufactured components from the same. What was known as the C Plant is now Building 771. The C Plant housed plutonium operations, and the D Plant in Building 991 was the center of final product assembly operations. Each building was designed to be self-contained so that if any of the plants became inoperative, the remainder could continue to fulfill their functions (Putzier, 1982; ChemRisk, 1991; RE-891[39]).

Security in the 1950s was so tight that only a handful of people had clearances to get into more than one building, and most employees had no idea what went on in areas of the plant other than their own. Plant employees were bussed from the front gate to their buildings, since no personal vehicles were allowed on-site. It has even been reported that some managers couldn't gain access to their own production personnel in the areas in which they worked (Putzier, 1982; Buffer, 1990).

Additions to the facilities at Rocky Flats have been almost continuous since 1951. A few periods, however, have involved more construction than others. A major facility expansion was initiated in 1955 and was referred to as Part IV construction. A second major plant expansion, Part V construction, began in 1967 **(USDOE, 1992)**. Another was in 1956 and 1957, with the addition of ten buildings, most of which were directly related to the change of the weapon concept to a hollow unit and anticipated production increases. This buildup included the construction of Buildings 447, 776, 777, 883, 997, 998, and 999, along with additions to Buildings 444, 881, and 771.

A few years later, Rocky Flats became the primary manufacturer of triggers under the single mission concept, at a time roughly coincident with the onset of the Cold War. The result was a dramatic rise in production at Rocky Flats in the 1960s. By 1964, the plant appeared as shown in Figure 3-5, and the work force reached a plateau of around 3,000 people that lasted about 15 years. Other build-ups included the beginning of an expansion including Building 559 in 1967, and several significant buildings coming on-line in the early 1970s (Buildings 440, 707, 750, and 865) and at the beginning of the 1980s (Buildings 371 and 460) (Buffer, 1991; unknown author, HS-404).

INSERT FIGURE 3-5; 1964 SITE MAP

The early 1980s also showed a significant upturn in Rocky Flats employment, with a peak at 5,990 in 1984. Representations of the developing plant as it appeared in 1971, 1980, and 1990 are shown in Figures 3-6 through 3-8. By 1990, the total building space grew to approximately 2.5 million square feet. Today, the Rocky Flats site appears as shown in Figure 3-9.

3.3 The Main Functions of Rocky Flats and their Development

Stated in the simplest terms, the Rocky Flats Plant is largely a manufacturing facility consolidating the production and support activities necessary for fabrication of nuclear weapon components. This discussion of Rocky Flats operational history is broken down into the following main functional areas of plant activity:

- Component Manufacturing and Assembly
- Material Recovery and Purification
- Research and Development
- Waste Processing
- Plant Support

To manufacture a trigger, facilities, equipment, and personnel must be developed to conduct precision metalworking and assemble fissionable and non-fissionable materials. In the case of Rocky Flats, the fissionable materials have nearly always involved uranium and plutonium, and the key non-fissionable components have for the most part been beryllium, aluminum, and stainless steel. The primary production materials used at Rocky Flats are among the most expensive and tightly controlled in the world.

Although the general types of activities performed at the plant have not significantly changed during the course of its history, there have been a few notable changes in specific operations at the plant. In the late 1950s there came a greater emphasis on the use of plutonium in the weapon design rather than the heavier amount of enriched uranium used in earlier models. This, coupled with the transfer of enriched uranium contract work to the Oak Ridge Reservation in 1963, resulted in most of the enriched uranium work moving out of Rocky Flats by 1964. Beryllium has nearly always been present at Rocky Flats, but it wasn't actually used in full-scale, production operations until 1958. Prior to that, it was involved in the earlier phases of weapons development. Americium recovery also did not start until 1957 (Putzier, 1982). In addition to functioning as a step in the plutonium recovery process, the americium line was actually a cash producer. Until the americium market demand fell off in the 1980s, americium was widely used in smoke detectors, batteries, and medical diagnostic tracers (ChemRisk, 1991; RE-891[34,43,62,65]). Stainless steel component work came to Rocky Flats in 1964 from the American Car and Foundry Company in Albuquerque. That contractor lost its agreement with the Atomic Energy Commission for economic reasons and the contract went to Dow at Rocky Flats. Stainless steel operations (known as the "J Line") began in Building 881 and were there until 1984, when they were moved into Building 460, which was newly constructed to house those operations and some from Building 444. These "consolidated manufacturing" operations remain in Building 460 today (ChemRisk, 1991; RE-891[31,35,39,27]).

During the course of manufacturing these metal products, wastes are produced which consist of the fissionable and non-fissionable materials, associated lubricating and cleaning compounds, and other materials such as rags, slags, clothing, tools, and paints. Since these wastes include materials that are extraordinarily costly to procure and are sensitive in terms of national security, it was economically imperative to recover these materials from wastes prior to their disposal.

Since the plant opened, there has been a heavy emphasis on recovering fissionable materials from manufacturing residues. During the period of waste oil storage in the area now known as the 903 pad, the scientists and engineers at the plant were attempting to develop means to recover both the fissionable materials and the oils which they contaminated (Seed et al., 1971). For various reasons, acceptable recovery methods were never devised, and the waste oils were finally treated by fixation with cement and shipped off-site for burial. Facilities to perform recovery and purification of plutonium and uranium were among the first to go into operation at Rocky Flats.

Research and development has always been a part of the activities at the plant (Campbell, 1986; USDOE, 1980). The focus of the work, however, has not been in the area of weapons design or development. Rather, it has been directed toward three areas: 1) basic understanding of the materials handled at the plant (for example, metallurgy of plutonium and uranium), 2) improving the recovery and purification of those materials, and 3) improving the manufacturing operations and assembly techniques.

INSERT FIGURE 3-6; 1971 SITE MAP

INSERT FIGURE 3-7; 1980 SITE MAP

INSERT FIGURE 3-8; 1990 SITE MAP

INSERT FIGURE 3-9; 1991 SITE PHOTO

Research and development activities have also focused on understanding the causes of accidents, thereby reducing the potential for future injuries and liability. One example of this was the 1964 plutonium/carbon tetrachloride explosion in Building 776, which sparked a number of R & D projects that examined the interaction of plutonium with a variety of solvents.

Waste processing, to varying degrees, has always been a part of the activities at the plant. The Atomic Energy Commission recognized the potential health impact posed by releases of radioactive contaminants into the environment, and set requirements for monitoring airborne and waterborne effluents and recordkeeping under which the plant was required to operate since the day it opened. The waste processing practices have varied over time as scientists' understanding of radiation improved, knowledge in the area of waste technology progressed, and tighter regulatory requirements were enacted. Because of its size and location, the plant has always had its own sanitary waste treatment facilities in addition to those handling industrial wastes.

The plant has a number of support groups which are typical to many large manufacturing facilities, such as administrative and finance organizations, utilities and facilities management groups, and health and safety personnel. The plant has some support organizations which are unique because the plant handles a large amount of radioactive materials in various forms. One is the Criticality Lab, or Nuclear Safety Group, which is dedicated to identifying and directing control of the potential for spontaneous nuclear fission chain reactions (criticalities) in the conduct of plant activities. Another unique support function has been provided by the Filter Testing group, which provides pre- and post-installation testing of the high efficiency particulate air (HEPA) filters used in ventilation exhaust systems and performs testing of personnel respirators. These and other support activities are discussed in Section 3.3.5, Plant Support.

3.3.1 Material Recovery and Purification

The purpose of Recovery Operations is to recover and purify the fissionable material used in the weapon systems which are of strategic importance. As much of the material as is economically feasible is recovered from wastes generated during the manufacturing processes, since these materials are extremely expensive, difficult to obtain, and controlled for national security reasons. The manufacturing wastes can vary from rags contaminated with a small concentration of material to almost pure metal turnings generated by machining operations.

At Rocky Flats, recovery has always been a part of operations, and the plant has always operated under requirements which dictate how much nuclear material could be present in the various types of wastes discarded by the plant. For some time Rocky Flats performed recovery on manufacturing wastes bearing plutonium, americium, and uranium. Recovery operations in recent years were limited to plutonium materials, as enriched uranium operations were moved to the Oak Ridge Reservation, and americium operations have been scaled back due to the lack of a market for the radionuclide.

Plutonium Recovery and Purification

When Building 771 became operational in 1953, the operations performed there included both plutonium recovery and purification and plutonium component manufacturing. Plutonium operations began in the spring of 1953, and were designed as a copy of the Los Alamos plutonium facility. The first personnel hired to operate the 771 recovery line were sent to Los Alamos to learn the operations there prior to working in the building. In 1953, there was only one "Chem Line" in operation. It had the capacity to produce plutonium buttons of approximately 300 gram size. Later, in 1955, an "East Chem Line" started up which had the capability of producing buttons of a two kilogram size. Both lines operated for a while, producing plutonium metal. Eventually, the capacity of the operations reached approximately 12 kilograms per day. Around 1965, the complexity and demand on the operations had increased to a point that the original cafeteria was taken over as a production area and a new cafeteria and offices were built on to the north end of the building (Putzier, 1982; Navratil and Miner, 1984). The expanded production area was used for the addition of five dissolution lines, which roughly increased the plutonium recovery throughput by a factor of 20 over that of the original facility (ChemRisk, 1991; RE-891[65]).

In 1968, the decision was made to replace Building 771 recovery operations. Ground-breaking took place in 1973 for what was to become Building 371. The new facility was plagued with problems from the onset of construction, and delays prevented "cold start-up" before 1981. Design flaws finally resulted in Building 371 chemical processing being shut down in 1985 before ever achieving full-scale operation (ChemRisk, 1991; RE-891[33,65] and Crisler, 1991).

In the very early years, Building 771 housed essentially all of the plutonium operations; recovery, fabrication of metal buttons from plutonium nitrate solution, and component fabrication and storage. At that time, assembly of the plutonium components with non-plutonium components was done in Building 991. Many of the plutonium fabrication operations were moved from Building 771 to building 776 when it came on line in 1958, with the recovery operations staying in 771 (Putzier, 1982).

Originally, plutonium at Rocky Flats came from Hanford as plutonium nitrate in small, stainless steel florence flasks packaged in cylindrical steel carrying cases shaped like small telephone cable reels. The nitrate was vacuum-transferred into a vessel where plutonium dioxide was precipitated by the addition of hydrogen peroxide. The dioxide was converted to fluoride, which was converted to a metal button by calcium-iodine reduction. Later, plutonium also came in the form of buttons from Hanford. Occasionally, plutonium nitrate feed was also received from the Oak Ridge Reservation. Around 1959, these shipments dropped off, and the majority of the plutonium feed to recovery and purification operations was recycled material, either from site returns, the foundry, or the waste products from the recovery operation itself. Site returns are weapon components that have been retired and returned to Rocky Flats for disassembly and recovery of materials. Some of the plutonium which went through the system at this time came from outside sources in the form of plutonium dioxide (Putzier, 1982; Navratil and Miner, 1984). Later shipments of plutonium were made in the form of metal buttons from Savannah River.

Plutonium recovery has always been a batch-oriented process, conducted in glove-boxes similar to those in Building 707 shown in Figure 3-10. Capabilities of some of the associated facilities and equipment have changed to produce larger batches more efficiently. For example, around 1963, a continuous rotary fluorinator was installed which allowed greater control and more consistency in that step of the process. As a result, larger batches of plutonium could be handled. Since the beginning of operations, the basic recovery process has undergone relatively little change (Tesitor, 1971). Most changes have been refinements to provide for more throughput and changes to the facilities to improve worker safety. Those changes to the recovery operation processes which could have impacted emissions are discussed below.

In the mid 1960s, Rocky Flats made pits and other components for "Safety Shots" in addition to routine production. The Safety Shot testing was done to characterize the potential hazards that could arise from accidents involving nuclear weapons, that is accidents in which no nuclear explosion occurs, for example as a result of airplane crashes or missile malfunctions. This testing was not conducted at the Rocky Flats Plant. The nuclear weapons or weapon components were placed alongside conventional explosives, and the conventional explosives were then detonated. These "shots" were performed under varying conditions to assess the potential for dispersal of radioactive material or nuclear weapon detonation. Some of the tests involved placing other nuclear weapons or pits at various proximities to a nuclear explosion to determine if the components would

INSERT FIGURE 3-10; TYPICAL GLOVE-BOX LINE

remain functional, would be rendered inoperable, or would detonate. Still other tests involved detonating only a single point of the high-explosives cluster surrounding the pit to determine if the design was "one-point safe", in other words did not yield a nuclear explosion.

Rocky Flats also produced components from other metallic radionuclides on a limited basis for incorporation into pits for "Special Order" operations. The inclusion of these radionuclides as tracers (namely neptunium -237, americium-240, plutonium-238, and an isotope of curium) into the makeup of the triggers allowed scientists to track the reactions of the detonation (ChemRisk, 1991; RE-891[9,31,43,52]).

"Special Recovery" processed the plutonium tracer materials. Eventually, leftover tracer materials had to be taken out of the plutonium streams, and that too became part of Special Recovery operations. Today Special Recovery operations include the Oralloy and Part V Leaching lines, in which surface impurities are removed from enriched uranium and plutonium components (Rockwell, 1981; ChemRisk, 1991; RE-891[9,27,43]).

Plutonium recovery operations are depicted in Figure 3-11. The recovery process is often described in terms of functional divisions - "fast" and "slow" recovery operations. The fast side basically processes plutonium nitrate solution, turning the liquid to a solid (powder) and then to metal. The slow side receives those materials which have more impurities, and as a result require more pre-processing before entering the fast side process of conversion to metal (Crisler, 1991).

Prior to implementation of the molten salt extraction process in 1968, almost all plutonium-bearing materials went through slow recovery operations, for example reactor generated plutonium, site returns, metal chips, and foundry skull and other forms of high purity metal residues generated by machining operations. These materials had to first be put into a plutonium nitrate form via the slow side operations and then introduced into the fast cycle line for conversion to a solid and reduction to metal. Since the introduction of the molten salt extraction (MSE) process in 1968, some of the essentially pure plutonium metal, such as the metal from site returns, has gone through MSE to remove americium ingrowth and has then been forwarded directly to plutonium foundry operations in Building 777 for casting and subsequent processing into plutonium components. The need for these materials to go through the chemical recovery process was eliminated. As a result, slow cycle recovery now receives materials such as effluents and waste products from the fast cycle, rags, paper goods, sweepings, and other wastes. It no longer processes the purer forms of plutonium. As before, though, materials which have gone through the slow recovery cycle are then sent through the fast cycle for further purification.

INSERT FIGURE 3-11; PLUTONIUM RECOVERY OPERATIONS FLOWCHART

One of the primary objectives of the recovery operation is to process the waste material until it can be safely and economically discarded. To provide a quantitative target by which to measure the discardability of wastes, limits have been set which define concentrations of radioactive contaminants in materials which will be discarded or processed for recovery. These economic discard limits (EDLs) identify the concentration of a particular nuclear material present in a waste product, below which it is not economically feasible to attempt recovery. Below the EDL, the material can be disposed of as radioactive waste.

In plutonium operations, the basic fast cycle recovery operations involve an aqueous dissolution process, followed by precipitation, calcination, hydrofluorination, and reduction steps to return the solute back into metallic form. Nitric acid is the primary chemical used in the dissolution steps, although the operation also involves aluminum nitrate, calcium fluoride, and water. After dissolution, the nitrate mixture undergoes a peroxide precipitation step which converts the plutonium to solid plutonium peroxide, which in turn is heated (calcined) to change it to plutonium dioxide, a powder that is often called "green cake". The plutonium dioxide is then reacted with anhydrous hydrogen fluoride vapor in a rotary tube to convert it to plutonium tetrafluoride, "pink cake." The PuF_4 is then reduced by reaction with calcium to convert it to plutonium metal. The final product "button" is washed and moved to storage until needed for production feedstock. Liquid wastes which are generated by fast cycle recovery are either transferred over to slow cycle recovery or sent to building 774 for treatment, provided duplicate sampling demonstrates that residual radioactivity concentrations are within acceptable levels.

Slow recovery operations involve different types of processes, depending upon the nature of the wastes to be handled. For example, combustible residues, such as plastic bags and Kimwipes, are incinerated to reduce the bulk of the materials and convert the plutonium to an oxide form. The slow side also receives effluents from the fast cycle for further recovery of any plutonium in those streams. Other processes are designed to recover plutonium from lab wastes, molten salt process residues, and other solutions by various methods including dissolution and cation or anion exchange. The resulting nitrate solutions from the slow cycle processes are then introduced into fast cycle operations prior to the peroxide precipitation step.

There are three primary recovery processes in slow recovery: anion exchange, dissolution, and cation exchange. The most significant of these is probably the anion exchange process, which receives effluents from the other two. Anion exchange primarily receives effluents from the fast cycle precipitation operation, with the dissolution and cation exchange operations contributing to a lesser degree. Dissolution gets its feed, in part, in the form of incinerator ash. The feed may also be made up of plutonium dioxide from oxidation operations in Building 771 and other buildings. The resulting effluent goes to anion exchange. Cation exchange feed comes from lab wastes and the chloride salt processes. The main reason for the cation exchange operation is to remove chlorides, which can create severe corrosion problems for the anion exchange equipment, from plutonium bearing materials that contain them. Once these materials go through the cation exchange, they can then be transferred to anion exchange without complications.

Prior to 1960, dissolution was followed by a solvent extraction step which used tributylphosphate as the solvent and dodecane as the diluent. The solvent extraction was followed by cation exchange. Around 1960, solvent extraction was eliminated from the recovery process line because the materials going through the recovery process were becoming more and more varied. A new process was required which could handle the variety of feed materials. The solvent extraction process was replaced by anion exchange. This was made possible by raising the molarity of the solution following dissolution by adding higher molarity nitric acid. The resulting solution could then be sent directly on to anion exchange. The process has since remained the same (Crisler, 1991; ChemRisk, 1991; RE-891[11,43,9,49]).

Liquid wastes which were generated from the plutonium recovery processes that were below established concentration limits for radioactivity were sent to liquid waste processing operations in Building 774 to be processed. Liquid waste generated by the recovery processes which exceeded radioactivity limits were reintroduced into the feed materials for the recovery operations and run through the process again.

The airborne emissions from Building 771 have always been controlled to some degree since the building came on line in 1953. In the early years, control was primarily achieved by a double stage of HEPA filtration to capture particulate materials. Since the production radionuclides were generally in particulate form, the HEPA filters were well suited for control of radioactive emissions.

For the most part, however, there were no control devices for the non-radioactive chemical vapors or gaseous materials, with the exception of scrubbers on the hydrofluorinator and the calciner, which have always been in place to reduce acid emissions from these processes. The Building 771 incinerator has always been equipped with a scrubber as well, and has a separate plenum with HEPA filtration (Navratil and Miner, 1984; ChemRisk, 1991; RE-891[47,49,50, 63,13,27,21]).

There is a large, double tower scrubber on the main plenum system which was installed in the late 1960s to control nitric acid emissions. After the large scrubber was installed, it was noticed that the cooled scrubbing wash did an excellent job of drying out the plenums; it was cooled to 6 °C, and so would dehumidify the glove-box air. As a result, all of the "wet" glove-boxes were switched over to this plenum a few years after the scrubber went into service (ChemRisk, 1991; RE-891[21]).

For the most part, emissions from 771 have been controlled by HEPA filtration. Originally, the building filtration consisted of two stages of HEPAs. Following the 1969 fire in Buildings 776 and 777, two more stages were added for protection against a similar fire in Building 771. The production area glove-boxes are on plenum systems with yet two more stages of HEPA filtration, for a total of six stages of filtration. Laboratory operations in Building 771 go through a total of four stages of filtration (ChemRisk, 1991; RE-891[47, 49,50,63,13,27,21]).

Uranium Recovery and Purification

Rocky Flats at one time had a recovery line for enriched uranium. Enriched uranium is defined as uranium having a larger fraction of fissionable U-235 than the approximate 0.7% found in naturally-occurring uranium. The enriched uranium processed at Rocky Flats has typically contained about 93% U-235 by weight. Enriched uranium was processed at Rocky Flats during the period when the Department of Defense maintained duplicate facilities to manufacture each major weapon component or material. The Oak Ridge Y-12 Plant was the other enriched uranium facility.

Building 881 was constructed in 1952, and at that time housed enriched uranium component manufacturing, including machining and fabrication of parts. When the chemical recovery line began enriched uranium recovery from metal residues created in the manufacturing processes in 1954, Building 881 then housed all enriched uranium operations, from casting to forming, machining, assembly, recovery, and purification. The raw material came from the Oak Ridge Reservation, primarily in the form of hockey puck-size "buttons" of pure metal, although other forms were also provided in smaller quantities, such as uranyl nitrate and alloy scraps (Crisler, 1991).

Uranium recovery operations in Building 881 were modeled after processes developed during and after World War II at Los Alamos and the Oak Ridge Reservation. The Building 881 process was similar to the 1950s plutonium recovery process that included solvent extraction. Uranium recovery had fast and slow sides and involved similar chemistry, but dibutylethylcarbutol was used as the solvent instead of the tributyl phosphate and dodecane used as the solvent and diluent in plutonium recovery. Overall, the basic plutonium and uranium recovery operations were similar in almost all respects (Navratil and Miner, 1984).

Building 881 also operated solvent stills to enable the plant to discard spent solvents, oils, and mixtures of the two. The "heels" of the stills were scrubbed with nitric acid to reclaim the uranium, and then were discarded as well. There have been reports that some of the distilled solvent was reused, but it has been estimated that the amount of distilled solvent which was accepted for reuse was only about ten percent. The discarded oil was drummed and sent to an area known as the "Mound" and was later moved to the Building 903 drum storage area.

For some time, the 881 chemical recovery operations included an "oralloy leaching" operation, in which returned or rejected enriched uranium weapons parts were subjected to a spraying of hot nitric acid to remove residual plutonium surface contamination. Some amount of uranium would also be removed by the acid leaching. Associated solutions were evaporated, and the concentrate precipitated with ammonia gas, calcined to a dry oxide form, and analyzed for plutonium content. Oxide that was sufficiently high in plutonium content was sent to the Savannah River Plant, while that which was low in plutonium content was sent to the Oak Ridge Y-12 Plant for recovery of the uranium. Over time, the exhaust system associated with the oralloy leach process accumulated a build-up of plutonium, which was eventually removed with the plenum filters and treated as plutonium waste.

Building 881 was constructed with the intention of conducting enriched uranium machining operations. To minimize the escape of radioactivity to the atmosphere, manufacturing and laboratory operations were exhausted through a main plenum equipped with HEPA filtration prior to release through a stack. The floors in the process areas were surfaced with stainless steel sheeting with welded seams to contain spills and facilitate cleaning.

When chemical recovery operations were installed a short time later, they were equipped with scrubber systems to treat air streams prior to release to the main, HEPA-filtered plenum. There were three types of scrubber systems; acid, caustic, and hydrofluoric acid (HF). Each was downstream of the processes for which they were suited. The dissolvers, vacuum stills, and several of the storage tanks exhausted to the acid scrubber. The hydrofluorinator was the only process on the HF scrubber. The caustic scrubber received the gasses from the two other scrubbers and sent them on to the building exhaust system. The spent scrubbing solutions were recycled through the recovery process to further reclaim any uranium collected.

When the Department of Defense decided to eliminate the redundancy in the weapons manufacturing facilities, enriched uranium operations were given entirely to the Oak Ridge Reservation. Consequently, uranium operations in Building 881 were shut down in 1962 and subsequently decontaminated and decommissioned. The building was "completely idle" from approximately 1964 to 1966, at which time stainless steel operations became operational after relocation from Albuquerque, New Mexico (ChemRisk, 1991; RE-891[39,48,31,67,36]).

Americium Recovery and Purification

The need to process americium at Rocky Flats resulted from increases in both production at the plant in the mid-1950s and the number of site returns. There was a pressing need to deal with the americium being encountered in the plutonium handled at Rocky Flats, since in-growth of Am-241 from Pu-241 decreases the effectiveness of the plutonium and creates a personnel exposure problem stemming from its gamma ray emissions. The plant had a backlog of americium-containing sludge which was being generated from the plutonium recovery peroxide precipitation step effluent. As a result, in 1957 an americium line was put into Building 771. From the late 1950s until the late 1970s, americium was recovered and purified at the plant for resale. Americium was used in medical diagnostic tracer procedures, in ionization type smoke detectors, and in static eliminators. The Atomic Energy Commission requested that Rocky Flats provide americium for use as a medical tracer. The demand for americium dropped off in the late 1970s, and the americium removed in the plutonium purification process subsequently went to Building 774 to be processed as a radioactive waste. Currently, americium operations are limited to those molten salt extraction operations needed to purify plutonium metal (Putzier, 1982; ChemRisk, 1991; RE-891[65,62,43,4, 49]). In 1986, DOE declared americium a waste product and the material has since been discarded in associated waste streams.

The processes historically used at Rocky Flats for extraction, purification, and recovery of americium are depicted in Figure 3-12. Americium operations have evolved through three methods of recovery and purification. From the time the americium recovery operation started up in 1957 to 1967, the feed for the process was the filtrate from the peroxide precipitation step on the plutonium recovery line. This was the era of the first method used for americium recovery and saw little change, except for the addition of a few additional steps in 1962 to create a more stable product form. In 1967, the feed for americium recovery became the salts from the new Molten Salt Extraction (MSE) process. From 1967 to the late 1970s, the processes used for americium recovery evolved. The original recovery process evaporated the plutonium peroxide precipitation effluent and separated the americium that remained in solution by anion exchange. The americium-containing column effluent went on to a very tedious and complicated operation known as the ammonium thiocyanate process. The resulting product was pale pink americium chloride.

INSERT FIGURE 3-12; AMERICIUM RECOVERY PROCESS FLOWCHART

A slight change was made to the ammonium thiocyanate process in 1962 by adding oxalate precipitation and calcination steps, which resulted in an americium oxide product that was preferred because of its stability. Nonetheless, the process during this entire period was "messy," resulted in a disproportionate amount of waste solutions, and created personnel exposure problems due to the relatively large amount of manual operations and maintenance required. Worst of all, the americium recovery rate was as low as ten to twenty percent (Crisler, 1991).

In 1967, the Molten Salt Extraction process came into being and became the feed source for americium purification. In MSE, molten americium-bearing plutonium is brought into contact with molten $NaCl$-KCl-$MgCl_2$ salt, and the Am is separated from the Pu by equilibrium partitioning with the salt by oxidation-reduction reactions. The advantage to the MSE process was that the plutonium metal from site returns could go through MSE and then directly to the foundry for re-casting without the need for the plutonium metal to be oxidized (burned), dissolved, and sent through the chemical plutonium purification process (fast recovery) before it could go to the foundry.

The americium-bearing MSE salts presented a new feed source for americium purification. In preparation for the ammonium thiocyanate process, the salts went through dissolution, hydroxide precipitation, and anion exchange. There were personnel exposure problems associated with the hydroxide precipitation step, and in 1973 it was replaced with a cation-exchange procedure. The entire process underwent one more major change in 1975, in which the ammonium thiocyanate steps were eliminated and the americium was recovered from the anion effluent by oxalate precipitation with subsequent calcination to form the more stable oxide (Putzier, 1982).

Since 1976, MSE salts have gone to the salt scrub process instead of to americium purification. Salt scrub makes a "scrub alloy" of Am, Pu, and gallium that is shipped to Oak Ridge for further processing. By 1979, the demand for americium had dropped to a point where it was no longer economically feasible to recover and purify. Americium was still present in site returns and needed to be extracted to maintain acceptable plutonium purity. MSE operations had kept the americium isolated from the plutonium recovery operations in Building 771 for several years, resulting in a cleaner stream of plutonium entering recovery operations. Americium recovery and purification operations were shut down in 1980, and americium work was limited to that required to extract americium from the plutonium metal in site returns.

3.3.2 Component Manufacturing and Assembly

When the plant began operations in the early 1950s, the majority of the components were enriched uranium, depleted uranium, and plutonium. The plutonium fraction was considerably smaller than the other two materials. When the "A Plant" (now Building 444) started operating in 1953, it was devoted entirely to depleted uranium manufacturing. A short time later, limited beryllium operations went in on a pre-production scale to prepare for the upcoming changes in the weapon. Enriched uranium operations were in "B Plant", now Building 881. There was a heavy workload of enriched uranium operations during those first few years because the design of the pit incorporated a relatively large amount of the material. The plutonium operations at that time were relatively small, and Building 771 (then "C Plant") housed essentially all plutonium manufacturing and recovery. All of the components from these three areas were assembled in what is now Building 991, then called the "D Plant" (Crisler, 1991).

During this time frame, the nation's weapon manufacturing complex consisted of dual facilities for the fabrication of weapon components. Hanford was manufacturing plutonium components like those made at Rocky Flats, and the Oak Ridge Reservation was manufacturing uranium components. The components from these two other plants were shipped to "D" Plant (Building 991) at Rocky Flats for assembly, as were components from "B" and "C" Plants on site. At the time, the majority of depleted uranium components manufactured in "A" Plant went directly to the Pantex Plant in Texas (ChemRisk, 1991; RE-891 [74, 75, 78]).

In 1957, there was a change in the concept of the weapon which resulted in a shift in the relative amounts of the materials used in the pits. More plutonium was called for, in a design that required considerably more plutonium machining and handling. Consequently, Buildings 776 and 777 went into service to handle the increased plutonium workload and 771 became primarily recovery operations. Building 776 was the plutonium machining facility and Building 777 took over most of the assembly operations from 991. Building 991 was then destined to be utilized for storage and research and development, although it was a few more years before all assembly operations had moved out.

The new concept also required beryllium components. There had been some beryllium operations in Building 444 in preparation for regular pit production, and in 1958 beryllium operations became a significant portion of Rocky Flats' work (Campbell, 1986). The components manufactured in Building 444 no longer went directly to Pantex. Instead, they began to be incorporated into the final assembly operations in Building 777. The depleted uranium workload decreased significantly as beryllium became more prevalent in the new design.

The shape of the components in the new weapon concept required a significant amount of rolling and forming of both types of uranium, and space in existing facilities became inadequate. Building 883 was constructed to handle the rolling and forming of uranium. Building 883 was designed with two functional areas ("sides") to prevent cross-contamination; the "B" side handled enriched uranium and the "A" side rolled and formed depleted uranium. The plant was so pressed to begin production of the new type of weapon component that operations began in Building 883 before the roof was completed. To prevent emissions from these early operations and to protect the machinery and materials from the elements, enclosures were placed around the process equipment.

Because of the single mission concept that came about in the early 1960s, Rocky Flats lost its enriched uranium work to the Oak Ridge Reservation in 1962. Building 881 laid idle for a few years until 1964, when the enriched uranium areas were decontaminated and decommissioned and conversion began to accommodate stainless steel operations when they moved to Rocky Flats in 1966. During the period of stainless steel operations, depleted uranium continued to be machined in Building 444. Another result of the enriched uranium operations moving out of Rocky Flats in 1964 was that the B side of Building 883 was converted to beryllium rolling and forming (ChemRisk, 1991; RE-891[36]).

The stainless steel operations, known as the "J Line", came to Rocky Flats from Albuquerque in 1966. The AEC curtailed its contract with the original contractor, American Car and Foundry, for economic reasons at that time, and the work became part of Rocky Flats' mission. The operations went into then-vacant Building 881. The operations have since moved to another building on-site, but remain a significant part of component manufacturing operations in modern-day times.

In 1969, a major fire in Buildings 776 and 777 resulted in some of the operations moving to other buildings in order to keep up with production demands. The machining and foundry operations which were involved in the fire-damaged areas of 776 became part of the operations in the new 707 assembly building. Those operations remained in 707 and solid waste treatment operations and size reduction moved in after 776 was restored to operation. That is why plutonium component manufacturing today seems to flow in such a circuitous route between buildings, travelling from 776 to 707 to 776/777 and back to 707 because of these fire-related changes (ChemRisk, 1991;RE-891[31,6,17,52,60,65]).

In 1984, Building 460 was completed and stainless steel operations were transferred from Building 881 along with some non-nuclear metalworking operations from Building 444. Building 460 has since been called "Consolidated Manufacturing" (ChemRisk, 1991; RE-891[35]).

Many of the manufacturing operations conducted in the various buildings are similar. Some of the components which have gone into pits have the same approximate shape and relative dimensions, and undergo similar machining and metalworking processes regardless of their elemental make-up. Many beryllium fabrication processes are essentially the same as those for uranium and stainless steel components. The same processes are regularly employed in the plutonium operations as well.

As mentioned earlier, the plant also manufactures components for other portions of the weapons, including some for ultimate installation outside of the pit. These operations often employ the same machining applications as those used for pit production, but also involve some unique operations. One example is the reservoir product manufactured at Rocky Flats to hold a supply of tritium outside the pit in another part of the finished weapon. Just prior to use of the weapon, the tritium is introduced into the first stage to "boost" it, increasing the explosive yield. These tritium reservoirs have a limited shelf life, and need to be replaced periodically.

The reservoirs are manufactured in greater numbers than the pits because of this limited shelf life, so they represent an important portion of the work (and revenue) at the plant. The reservoirs are difficult to manufacture, requiring additional equipment beyond that used in pit production because of their complexity. Because Rocky Flats had proven capabilities for high quality machining work and had stainless steel facilities in place, the contract for reservoir production went to the plant. Apparently similar circumstances resulted in Rocky Flats being chosen to perform beryllium and uranium operations.

Today, the flow of all the components that go into the pit is to Building 707, where they are assembled into the finished Rocky Flats product. As described earlier, final assembly operations were at one time in Building 991, and later were housed in Building 777. Weapons components not involved with production of pits go to Shipping, and eventually on to the Pantex Plant in Texas for incorporation into the finished weapon.

Beryllium Component Manufacturing

Beryllium operations were not part of the manufacturing process in the first years of plant operation, but were part of Production Engineering (Phase 4 of weapon development) of the new, sealed hollow core concept which was soon to be integrated into the nation's nuclear arsenal. Originally, beryllium material was received from Brush Industries in the shape of bowls which had been "chevron-cut" from "logs" of pressed-powder beryllium. These bowls were heat-treated and then machined to the required dimensions in the southeast corner of Building 444, in a room only big enough for six to eight lathes. For some time, the plant experimented with casting beryllium components into "near-net-shapes" which went directly from the foundry to the machine shop for finish machining. When beryllium operations became part of the primary production line in 1958, the process had changed to eliminate the near-net-shape casting, and components were shaped from blanks that were supplied by an outside vendor. These blanks were pressed into shapes and then machined into final forms. The plant soon thereafter began conducting its own casting of beryllium ingots for economic reasons. These ingots were cut up into puck-like billets around which an airtight steel casing was welded. The "canned" billet could then be heated and rolled to the desired thickness, the can cut away, and the remaining blank machined as before. Machining operations include milling, turning, drilling, and polishing (USDOE, 1986; Barrick, 1982; Campbell, 1986; ChemRisk, 1991: RE-891 [56, 71, 72, 78, 81, 82]).

During the mid 1970s, the design agencies (Lawrence Livermore and Los Alamos) made the decision to change over from the wrought process described above to molding of parts from sintered (pressed powder) blanks. The plant then began receiving blanks from outside suppliers, and beryllium foundry operations ceased in 1975. By 1980, the foundry had been cleaned up of all beryllium and only depleted uranium casting was being conducted in Building 444 (Campbell, 1986; ChemRisk, 1991; RE-891[56]).

Over the course of operations, the beryllium area has undergone three ventilation changes. When manufacturing started in 1958, the ventilation system consisted of "Aero-Tech" cyclone separator units placed at each machine to filter the air at the point of operation. The Aero-Tech units exhausted to the main building exhaust serving the uranium operations. This system was updated in 1964 by installing a central Aero-Tech unit in the basement of the building that connected to the main building exhaust. The new system was arranged so that each machine's local ventilation went down through the floor and to a drop box which collected the heavier debris. The air then went on through the central plenum to a cyclone separator and then through a single bank of HEPA filters prior to reaching the building's filter units (USDOE, 1984).

In 1974, this system was taken out of service and replaced by an overhead duct system which led to an external chip cyclone and HEPA filtration unit. This system operated until 1986 when the building's ventilation system was again upgraded.

In 1986, the HEPA filters serving Buildings 444, 447, and 865 were upgraded to include two stages of HEPA filtration. Prior to this, the systems contained only one stage in conjunction with oil-impingement pre-filters. The new system in Building 444 included two types of conveyance systems - a "low vacuum" local exhaust system to carry the fine particulates and a "high vacuum" local exhaust to carry the heavier particulates. Each subsystem had its own cyclone separator, which was then connected to its own HEPA filtration unit.

Depleted Uranium Component Manufacturing

Depleted uranium is by definition uranium which has less of the fissionable U-235 isotope than the approximate 0.7 percent by weight found in natural uranium. Depleted uranium is rich in the U-238 isotope, and is often called D-38 or Tuballoy. The term Tuballoy originated from the name of a British wartime atomic energy project called Tube Alloys Limited. Depleted uranium was originally received from Paducah, Kentucky in the form of derby-shaped parts. Later, feed material was received from the Feed Materials Production Center in Fernald, Ohio as ingots in sealed cans. Depleted uranium operations were a significant part of the original manufacturing performed at the plant. They were located entirely within the A Plant, now Building 444. Operations included casting and machining of the components from the uranium rich in the U-238 isotope. Adoption of the implosion weapon concept brought about changes in fabrication operations that required additional processing of components. Building 883 was built to fill the need for additional rolling and forming operations. Depleted uranium was still cast in Building 444, but was shipped to 883 to be heated and rolled into sheets, from which blanks were cut and then formed to the required shape. The shaped pieces were shipped back to Building 444 to be turned, trimmed, and polished as necessary. In some cases, the component was coated with other materials. From there, the component was shipped on-site to final assembly. The operations have remained basically the same for the last 34 years (Rockwell, 1981b).

One of the changes in the depleted uranium operations came when an arc furnace was installed in the mid-1970s, providing the capability to produce depleted uranium-niobium alloys. Elements such as zirconium and niobium could be melted more effectively than was possible with the induction casting furnaces, thereby creating a more homogenous alloy casting. Prior to use of the arc furnace, research and development of depleted uranium-niobium alloys involved an electron beam furnace. This alloying work began in 1966, although full-scale production didn't occur until the early 1970s (Brekken, 1965 and ChemRisk, 1991; RE-891[56]).

Enriched Uranium Component Manufacturing

As discussed earlier, enriched uranium is defined as uranium having a larger fraction of the fissile U-235 isotope than the approximate 0.7% found in naturally-occurring uranium. Enriched uranium is often called Oralloy, a term derived from Oak Ridge Alloy. The enriched uranium processed at Rocky Flats has typically contained about 93% U-235 by weight. Originally located in Building 881, enriched uranium operations included production chemistry, foundry operations, fabrication, and scrap material recycling. Building 881 now primarily houses support laboratories, offices, data processing, and record keeping.

The original concept for the nation's nuclear weapons incorporated, by today's standards, a large amount of enriched uranium. When the plant first opened, Building 881 had a very heavy workload of enriched uranium component production and enriched uranium recovery. At first, the components were solid pieces of uranium, machined to certain shapes, which were then assembled with plutonium, stainless steel, and depleted uranium components in D Plant, now known as Building 991 (Putzier, 1982).

The change in the weapon concept which came about in the late 1950s resulted in a significant downturn in the amount of uranium required in the pit, but actually increased the amount of machining which went into making the new, hollow components. The basic operations for the original components involved casting and machining. The hollow design involved the same, but added rolling, forming, and turning operations as well. The processes used in the latter design remained basically the same throughout the life of enriched uranium operations at Rocky Flats. Many other components involving beryllium, stainless steel, aluminum, plutonium, and depleted uranium employ the same processes.

Enriched uranium (oralloy) component operations left the plant in 1964, along with the uranium recovery operations. The Oak Ridge Reservation took over all enriched uranium operations, supplying Rocky Flats with the finished uranium components which were incorporated into the final pit assembly. After Oak Ridge took over the enriched uranium operations, Rocky Flats still received site returns which contained enriched uranium components. The plant processed those components with a spray leaching process to remove any external plutonium contamination, and returned the oralloy parts back to Oak Ridge for reprocessing. Oralloy leaching operations were originally conducted in Building 881, but were relocated to Building 771 a few years after Oak Ridge acquired the enriched uranium contract. Oralloy leaching remained in Building 771 through 1989.

Plutonium Component Manufacturing

In the early years, plutonium metal was reportedly machined in a "dry" state (i.e., without any oils, using only carbon tetrachloride as a coolant), with as little machining taking place as possible. Handling the material dry required extra care to prevent spontaneous combustion. Plutonium components were cast, pressed into shapes, minimally machined to "true" them, and then plated with cadmium to allow for easier handling. Cadmium was often used to coat the plutonium so that it could be handled out in the open with reduced personnel exposure to neutrons and alpha particles. The first weapons were designed such that they were armed (final assembled) on the way to the target, and so certain parts of the weapon were coated to allow them to be handled without containment. The protective coating also served to ground the parts against static electricity that might be generated while handling them in the field. The protective coating was changed to nickel within a few years time, using a process that employed nickel carbonyl. The use of nickel carbonyl lasted at least into the late 1960s, although its use in the later years was significantly less than in the 1950s, due in part to design changes in the weapons which allowed for remote arming of the warhead prior to delivery (ChemRisk, 1991; RE-891[3,31,50,63,67,40,48]).

By 1958, because of the change in the weapon concept that demanded a greater amount of plutonium and different shapes with closer dimensional tolerances, plutonium was no longer cast to a near-net shape. It was rolled, formed, and machined considerably more than under the previous weapon concept. Production demand and increases in the machinery required for manufacturing plutonium components necessitated increasing the associated manufacturing space. Buildings 776 and 777 were built by 1957 for casting, fabrication, assembly and quality assurance testing. Some of these processes came from Building 771, but many were new functions.

It was a natural progression for lubricating oil to be added to the machining operations to facilitate speeding up plutonium machining. The first really significant machining of plutonium began in 1958 with the new operations in Building 776 using Shell Vitrea cutting oil, followed by a washing with carbon tetrachloride (CCL_4). Building 776 housed a centralized oil collection and separation point, with the solid and liquid fractions sent separately to Building 771. In Building 771, the Ccl_4 was distilled out of the oil, and the plutonium recovered from the solids. Building 777 at that time was the focal point for assembly operations. The practice of using oil coolant during plutonium machining still exists today. Parts which have been in contact with the coolant are subsequently degreased using carbon tetrachloride. During those early years, however, the plant did not have a satisfactory method for handling the spent oils and solvents, and they became one of the biggest environmental issues for the plant. Now, the spent organic liquids are filtered and then solidified for disposal (Joshel, 1970; Crisler, 1991).

In 1969, a major fire in Building 776/777 resulted in relocation of some of the foundry, fabrication, and assembly operations into Building 707 as soon as it was completed. Some of the operations remained behind, and after Building 776/777 was repaired, other operations moved in, most notably waste size reduction operations. The general processes involved in manufacturing of plutonium components are very similar to those employed in other portions of the plant using other metals. The plutonium is cast into ingots which are rolled to the desired thickness. A blank is stamped out of the sheet. The blank is then formed to the desired rough shape, turned, and then polished. Components are often joined with other components, polished, and tested for integrity (Rockwell, 1987a; Rockwell, 1981a).

Stainless Steel Component Manufacturing

Stainless steel operations, known as the "J Line", went into Building 881 in 1966 and remained there until the completion of Building 460 in 1985. Stainless steel operations from 881 and some of the operations from 444 were consolidated into Building 460, which is often referred to as "Consolidated Manufacturing".

A significant portion of the stainless steel work is the fabrication of the reservoirs for the tritium used in the weapon external to the pit. These containers hold a certain amount of tritium gas which is introduced into the pit just prior to detonation to boost the yield of the explosion. Other stainless steel work includes the tubes and fasteners associated with the tritium reservoir-to-pit delivery system (Rockwell, 1981a).

Finished Machine (FM) Components

Some of the components which go into the pit are supplied by vendors or from other plants in the weapons manufacturing complex. These components are verified in number and quality and typically go on to final assembly with little or no further machining (Rockwell, 1981a).

Final Product Assembly

The original final assembly building was the "D Plant", now known as Building 991. The final assembly operations at that time are reported to have used a small amount of solvent for one last wipe-down of the components and finished product. Final assembly of the early concept design products was apparently a relatively simple operation. Later, the hollow-core design required more operations to assemble the pit and greater controls for safety. As a result, Building 777 came on-line to provide the requisite facilities. The operations involved in final assembly of the hollow-core design include drilling, welding, brazing, turning and polishing. Instead of a few components, the hollow design may have many, in an arrangement which requires more complex fabrication. Building 707 received the final assembly operations shortly after the 1969 fire, which shut down Building 776/777. Final assembly operations remain in Building 707 today.

3.3.3 Waste Processing

Waste processing at Rocky Flats has included both liquid and solid process wastes as well as sanitary wastes. Processing of each of these waste types is discussed in this section.

Liquid Process Wastes

Perhaps the primary function at Rocky Flats which has involved the fewest process changes over the years is the area of liquid waste treatment operations. The processes involved are relatively simple and have been proven effective in industry and at Rocky Flats.

When Building 774 was built in 1952, its primary purpose was to support Building 771 by treating its radioactive aqueous waste. The general mission of the waste operations was to reduce the volume of wastes and put them in a form acceptable for transportation to off-site burial grounds. The processing of liquid wastes has involved relatively consistent technology over the years, with some refinements to achieve greater treatment capacity and eliminate off-site discharges (Crisler, 1991).

Liquids transferred to Building 774 are subjected to any necessary Ph adjustment and then go through a precipitation step to remove radionuclides. The resulting slurry is sent to vacuum filters. The solids removed from the filters are combined with cement or another solidifying agent and then shipped to long term storage as transuranic (TRU) mixed (chemically and radioactively hazardous) waste. The aqueous waste from this first stage goes through a second stage, which is essentially a repeat of the first. Prior to establishment in 1973 of the policy that Rocky Flats would attempt to discharge no process waste to off-site surface waters (a "zero discharge" policy), the aqueous wastes from this process went to either the solar evaporation ponds or to the "B" series of holding ponds, depending upon the concentrations of radioactivity present. Below a specified level, waste water could be discharged to the ponds. The water in the "B" ponds went on to Great Western Reservoir.

Around 1965, an evaporator was installed in 774 to treat the liquids that had accumulated in the solar evaporation ponds. Its limited capacity was not able to eliminate the need for the solar ponds. Water and any volatiles evolved from the evaporation process were untreated and discharged to the atmosphere. The concentrate from the evaporator was fed to a double drum dryer, on which the salt solution dried and was removed by a scraping blade. Water vapor and volatiles evolved from the dryer went through a scrubber and demister before venting to the stack, with the liquids from the scrubber and demister returning to the aqueous treatment process. The evaporator was taken out in 1979, and the liquids from the second stage of treatment and the solar ponds have since been transferred to Building 374 (ChemRisk, 1991; RE-891[42,13,61]).

Building 774 also processes organic liquid wastes. When Building 776 went into service in 1957, the plant experimented unsuccessfully with a centrifuge in an attempt to process the plutonium-contaminated organic liquids from machining operations. In 1958, the pace of plutonium machining and the volume of associated waste oils increased significantly. Building 776 became the central collection point for the oils where the liquids and solids were separated and sent on to Building 771. In Building 771, carbon tetrachloride was distilled out of the oil, and plutonium was recovered from the solids. The still bottoms then became a problem. The spent oil and carbon tetrachloride were put into drums for storage until a satisfactory method of treatment of the contaminated material could be found. Those drums were at first buried, and then later were stored at a location now known as the 903 Pad. The drums that were buried were later unearthed and disposed of under observation of the Colorado Department of Health (Seed et al., 1971; Joshel, 1970).

There was a considerable effort over several years to find an effective method to treat the oil so that it could be re-used or disposed of as non-radioactive waste. Attempts to separate the carbon tetrachloride from the oil for re-use were unsuccessful and, eventually, the organic liquids were simply treated by filtration and solidification and sent on to long-term storage as transuranic (TRU) mixed wastes (Biles, 1970).

The method finally developed involved filtering the spent liquids to remove particulate matter larger than one micron and then mixing it with calcium silicate to create a gel. In addition, the oil coolant and carbon tetrachloride were continuously recirculated at the point of use through 30 micron filters. When the liquids are no longer suitable for continued use, they are filtered through a one micron filter and then mixed with the solidifying agent. The mixer-extruder operation was sometimes referred to as the "Jelly Factory" or the "Grease Plant". The process is essentially the same today, a one-step process in which the organic liquids are mixed with Envirostone® and allowed to set up before shipment (ChemRisk, 1991; RE-891[44,61]; Seed et al., 1971).

Two other small waste streams are treated by Building 774. One is silver recovery from spent photo solutions and the other is a variety of miscellaneous wastes, primarily from laboratory operations. The latter is simply mixed with cement to solidify it for long-term storage.

Building 374 went into operation in 1980 as an integral part of the new plutonium recovery facility, Building 371. It was designed to handle primarily the wastes which would be generated by Building 371, but would also help to relieve the demand on 774 and eventually eliminate the need to use the solar evaporation ponds as part of the waste operations (Navratil and Miner, 1984).

The processes in Building 374 are essentially the same as those used in Building 774, but newer, more efficient equipment is used. For example, a four-stage forced evaporation unit is used. As a result, Building 374 can process more liquid wastes in less time than what was possible with the old operations in 774. The new facilities were also designed to provide greater safety of operation through improved containment, control systems, and separation of workers from the operations. Two of the processes in operation in 774 have not been performed in Building 374. Those are silver recovery and organic liquid treatment operations.

The chemicals used in liquid waste treatment processes are primarily caustics for Ph adjustment, reagents such as ferric and magnesium sulfate, and flocculating agents. They are typically mixed with water and then added to the wastes. No organic solvents are used, but they do treat organic liquid waste streams.

Depending upon the amount of contamination in the waste product, the resulting sludges or solids are packaged in drums or large wooden boxes and shipped as TRU waste or low specific activity (LSA) wastes to approved national storage sites (Navratil and Miner, 1984).

Solid Wastes

Radioactive solid wastes generated at Rocky Flats can be placed into two categories; retrievable and non-retrievable. The retrievable wastes are those which contain greater than 10 nanocuries (0.00000001 Ci) of radioactivity per gram of material. These wastes are packaged and stored to enable them to be repackaged if necessary, or if technology warrants, to enable their retrieval and the subsequent recovery or treatment of the contained radioactive and/or chemical toxins. The kinds of waste which typically fall into this category are the solidified sludges and salts generated by the liquid waste treatment operations, line-generated wastes such as gloves, clothing, and other small items, and plutonium-contaminated wastes such as decommissioned glove-boxes, HEPA filters, or machine tools (Crisler, 1991).

Line generated wastes are placed in a drum until it is full. It is then assayed to determine the amount of radioactivity within the drum. If the drum content exceeds preestablished criteria, the drum is unpacked, the items with recoverable plutonium removed, and then the drum is re-packed with waste of a lower radioactivity. Plutonium-contaminated wastes first go through the size reduction facilities in Building 776, where attempts are made to remove surface contamination, and the waste is then cut up or crushed to reduce its volume and packaged in sealed, reinforced boxes which are about four feet square.

Non-retrievable wastes are non-line-generated wastes which have less than 10 nanocuries per gram contamination, and can include chairs, tables, and cabinets. These items are also reduced in volume in the size reduction facilities and packaged in 55-gallon drums or wooden boxes.

In almost every case, radioactive solid wastes have been shipped off-site to a federally approved storage or disposal facility. However, as documented in Section 5 of this report, there have been some cases in which on-site disposal of solid waste was practiced. Up until 1970, sanitary waste sludges were buried on-site, usually in the plant landfill. Since then, sanitary sludge has been shipped to a federally approved facility for disposal as radioactive waste. There were other instances of on-site burial of contaminated materials, most notably soils which were contaminated as a result of the 1969 fire and other soils excavated during cleanup of the laundry waste outfall formerly located on the north side of Building 771 (USDOE, 1986; Yoder, 1984).

Non-radioactive solid wastes generated at Rocky Flats include the typical types of materials found in municipal garbage: paper, food items, office waste, lumber, and so on. This material is disposed in the plant's on-site landfill. The original Plant landfill, located on the south side of the plant, opened in 1952 and closed in August, 1968 (see Figure 5-4). An incinerator was also in operation at that time, in Facility 219 on the west access road. With a few exceptions, non-radioactive combustible waste was burned in the incinerator and the resultant ashes were dumped on the ground adjacent to it and covered with dirt (Seastone, 1973; Owen and Steward, 1974). It has been estimated that less than 100 grams of slightly radioactive depleted uranium contaminated combustibles were burned along with the general plant waste during the period from 1952 to 1968 (Piltingsrud, 1973).

The second landfill, which is in operation today, opened in August, 1968, and is on the north side of the plant. In 1971, the plant instituted a program which required that all ordinary wastes originating in plutonium areas be monitored for radioactivity prior to placement in the dumpsters destined for the landfill (Rockwell, 1988; Yoder, 1984).

Sanitary Wastes

Liquid sanitary wastes at the Rocky Flats Plant are comprised of the sewage resulting from treatment of wastes from rest rooms, showers and sinks, food service areas, and cooling tower blowdown. The liquid sanitary waste operations are kept separate from the liquid process waste operations to prevent contamination of the sanitary waste streams. In addition, the sanitary wastes which originate from plutonium areas are kept separate from those from other areas until they reach two holding tanks upstream from the treatment plant. At that point, they can be retained and sampled to check for contamination. From those holding tanks, the sewage is processed as in many other municipal wastewater treatment facilities, through a series of clarifiers, aerators, and digesters, with the sludges becoming a waste and the liquids going through a final disinfection step before release. This basic process has remained essentially the same throughout the operation of the plant (Rockwell, 1981a).

The final disposition of the sludges has changed over the years. In the early years, the sanitary sludges were disposed on-site in trenches constructed for their disposal. These were trenches T-2 through T-8 (see Figure 5-4). At that time, some of the floor drains in the manufacturing buildings were not isolated from the sewage treatment plant, and the sanitary sludge became contaminated with uranium and plutonium. From 1954 to 1968, trenches T-2 through T-8 received approximately 100 tons of sewage sludge. When the second landfill opened in 1968, it began receiving the sludges, and continued to receive them until 1969. At that time, the sludges were declared to be low-level radioactive waste and have since been shipped off-site for disposal at federally approved disposal sites (Facer, 1970; Putzier, 1970; Hazle, 1985; Steward, 1973).

The final disposition of treated sanitary liquid effluent has also undergone some changes since the plant first opened. As discussed in Section 5, in the early years of plant operation, low-level process waste, specifically laundry waste, was discharged directly to Walnut Creek. While the water released was reported as not exceeding applicable radioactivity concentration guides, it did contain some low-level concentrations of plutonium and uranium. The Building 771 outfall became contaminated from this practice. Later, it was decided to send laundry waste to the sewage treatment plant. As a result, sewage treatment plant sludge became contaminated. On December 21, 1973, the release of laundry waste into Walnut Creek was stopped. The plant has attempted to comply with a "zero-discharge" policy, wherein all liquids are evaporated or solidified for off-site disposal (ChemRisk, 1991; RE-891[5,7,32] and USERDA, 1975).

3.3.4 Research and Development

Under the general heading of Research and Development, this section discusses some activities which have taken place at the Rocky Flats facility which are not directly related to the plant's main mission, the production of nuclear weapon triggers. A significant fraction of the historical investigation was devoted to studying the research, development, "Special Order", and "cash sales" activities which have been a part of Rocky Flats history by way of extensive document reviews and interviews. Such activities were reviewed in search of any associated processes, practices, or events which could have potentially affected the off-site public, and might not have received the usual level of scrutiny because they were not associated with primary plant production. This investigation has revealed several projects which have involved large quantities of some of the materials of concern in production of products other than weapon triggers. These projects are described in this section.

Funds available within the weapons complex in the early years for research and development were very limited and the subject of intense competition. Most of the money went to Los Alamos and Lawrence Livermore, and even these two laboratories were in tough competition with each other. At Rocky Flats, some activities that were actually research and development in nature were incorporated as an extension of production engineering. Since these expenditures weren't specifically identified as R&D, they were not as likely to be questioned or taken away by the other AEC/ERDA contractors who had R&D as a primary role. One area that Rocky Flats was encouraged to pursue R&D activities in was plutonium science. Plutonium was still such a new and relatively unfamiliar element that much research was needed to fully identify its properties, limitations, and interactions with other materials (ChemRisk, 1991; RE-891[31]).

An example of research and development work as an extension of production engineering is the early beryllium work. From 1953 to 1958, beryllium operations were in the developmental stages. The work was geared toward developing and refining production techniques and tooling requirements. Beryllium has a number of qualities which can make it difficult to tool, and considerable effort went into understanding how to best machine it into the required shape and dimensions. This was the pre-production work associated with Phase 4 of weapon programs. The work involved a lot of R&D to develop and fine-tune the manufacturing processes which were to be used, but was not weapon R & D in the strictest sense (Campbell, 1986).

Another example of production related R&D work occurred in the northeast part of Building 331, which was for some time a uranium R&D area. Rolling of enriched uranium foil was conducted in 1964 in the northeast corner of the plant garage, Building 331 (Putzier, 1982). Interviews have also suggested that this area was used for the development of depleted uranium and uranium alloy casting techniques, using electron beam energy, and uranium coating studies. The area was later converted for the development of remote handling techniques such as robotics and remote manipulator arms after Building 865 came on-line in 1970. Interviewees noted that exhaust from the area was filtered (Putzier, 1982; ChemRisk, 1991; RE-891[31, 71, 72, 78, 83]).

In the mid-1960s, more money was made available and R&D work became a larger part of the activities at the plant. As a result, Buildings 779, 559, and 865 were constructed. Much of the R&D work became focused on examining the site returns to determine what effects time and field conditions were having on the weapons. Studies on corrosion and other forms of deterioration were vital to making improvements in the reliability and shelf-life of the weapon materials (USDOE, 1980).

Today there are two main groups conducting research and developmental activities at Rocky Flats. One is geared toward improving current manufacturing techniques and methods and the development of new ones. Areas of study include metallurgy, coatings development, joining of materials, machining and gaging, and non-destructive and destructive testing. The other group focuses on chemistry-related matters such as corrosion and surface chemistry, effects of radiation on materials, actinide recovery and purification, waste treatment, and environmental detection systems (Rockwell, 1981a).

"Special Orders"

The plant has conducted "Special Order" work for other facilities in the weapons complex, the Department of Defense, or to fulfill needs of other Federal departments or agencies. Most of the Special Order work at Rocky Flats has not involved materials outside those used in regular production activities. The tracer work is one of the few exceptions. Radionuclide tracers were introduced into manufactured components and/or pits destined for off-site test shots. These materials, for example neptunium, curium, and cerium, were blended in with the regular component materials so that scientists could study performance of the different weapon components based on post-test distribution of the rare tracers. For example, neptunium might be added to one component of the pit and cerium added to another. After the test shot, the scientists could then core through the site and find out how each tracer reacted, enabling them to calculate how each of the components acted in the detonation. Neptunium tracer was associated with both uranium and plutonium components, so its manufacture took place in Buildings 771 and 881. There was considerable effort devoted to keeping these tracer materials separate from the regular production material streams, and Special Recovery operations specialized in recovering these more exotic materials (ChemRisk, 1991; RE-891[31,9,43,52]).

Most of the Special Order work has also been relatively short-lived. Perhaps the biggest exception to this would be the Zero Power Plutonium Reactor (ZPPR or "zipper") project, in which Rocky Flats manufactured approximately 4,000 stainless-steel-clad fuel elements consisting of plutonium, molybdenum, and uranium from 1967 to 1968. The plant manufactured the fuel rods for installation in the reactor at Argonne National Laboratory (Knighton, 1983; Willging, 1970; ChemRisk, 1991; RE-891[48,31,50,63]). The ZPPR fuel elements were made by first alloying the uranium and molybdenum in Building 444. The U-Mo alloy was then sent to Building 771, where it was alloyed with plutonium by casting into plates of various sizes. The ternary alloy plates were clad in stainless steel envelopes in Buildings 776/777 and sealed by welding. The plutonium used in this project originated in the United Kingdom and contained a higher percentage of Pu-240 than most Rocky Flats plutonium, so great care was taken to keep the material separate from other plutonium recovery and waste streams (Knighton, 1983; Patterson, 1982; Leebl and Patterson, 1982).

There was also a series of projects in the late 1970s and the first half of the 1980s in which the plant manufactured thousands of calorimeter plates out of depleted uranium for Sweden, Harvard University, and Brookhaven National Laboratory. In a project that involved processing hundreds of tons of depleted uranium in Building 883 in the mid-to-late 1980s, the plant also made armor plates for the M1A1 tank (ChemRisk, 1991; RE-891[36,13,31,69]). In the mid-1980s, the U.S. Army developed an advanced type of layered "Burlington" armor that incorporates a depleted uranium mesh in its still-secret inner configuration. The new armor on the M1A1 gives the tank protection equivalent to about 24 inches of steel armor (Zaloga and Green, 1991).

Rocky Flats was also involved in "Project Plowshare", the effort to develop technology for using nuclear explosives for peaceful applications, such as excavation and uncovering of deep mineral deposits. Example applications envisioned for the technology included excavation of a sea-level alternative to the Panama Canal and west coast harbors for Africa, Australia, and South America (Seaborg et al., 1966). Rocky Flats' involvement in making components for Project Plowshare lasted from around 1959 to the mid-1970s. No detonations of Plowshare devices occurred on the plant site. The portion of the program designed for large-scale excavation saw Rocky Flats involvement from about 1962 or 1963 to the mid-1970s. An objective of the Plowshare project was to use as little fissionable material, e.g. plutonium, as necessary so as to limit the amount of fission products produced by the detonation and thereby minimize environmental impacts (Hoffman, 1992).

Plutonium R&D (Building 779)

In the mid-1960s, research and development activities were escalated in the U.S. nuclear weapons complex. At Rocky Flats, the escalation included construction of Building 779, a plutonium R & D facility. The purpose of the facility was to gain more knowledge of the chemistry and metallurgy of plutonium and its interactions with other materials which might be used in the manufacturing processes. Building 779 also housed efforts to develop improvements to the manufacturing processes and find new ways to recover plutonium and associated actinides. Yet another function has been to better understand the aging and shelf-life limitations of Rocky Flats products. Some of the processes which have been in the building have changed over the years, but the primary purpose of the activities has not. Most of the materials used in this facility are the same as those in the manufacturing buildings, as much of the work conducted involves improvement of existing processes and understanding of the materials employed.

Building 779 has nearly doubled in size since it was built in 1965, with two major additions coming in 1968 and 1973. The first addition was the larger of the two, and provided office, laboratory, and mechanical equipment space. The second addition supplied more office and laboratory space plus an environmental storage facility for studies of aging under various environmental extremes and a storage vault. A filter plenum facility (Building 729) was also constructed in 1973 next to Building 779 and linked by a second-story bridge for the ducting. The new plenum facility serves the second addition to the main building and houses an emergency generator. A year later, a new filter plenum facility was added on to the east end of 779 to serve the original building and that portion added in 1968 (Rockwell, 1987b).

The primary activities conducted in Building 779 include (Kneale, 1989):

- Product Physical Chemistry, which involves testing of various material compatibilities, stockpile reliability, and plutonium aging under various environmental conditions.

- Physical Metallurgy, which includes tensile testing, study of casting dynamics, electron microscopy, X-ray analyses, hardness testing, and dimensional dynamics.

- Joining, which involves methods such as welding and brazing.

- Pyrochemistry, the study of molten salt extraction and electrorefining processes.

- Hydriding, the nondestructive recovery of plutonium from substrates using hydrogen.

- Chemical Technology, which is concerned with improvement of aqueous material recovery techniques.

- Coatings, which involves various methods to coat substrates, such as vapor deposition.

- Machining and Gaging, which involves manufacturing of special order parts, tools, and test components.

Building 865 R&D

Building 865 began operations in 1970. It serves as a research and development facility primarily for the manufacturing processes using uranium and beryllium. The work involves metalworking and metallurgy techniques. The metallurgical operations involve the development of alloys, alloying processes, and fabrication of prototype hardware. Some of the metals employed in the alloying development include aluminum, copper, magnesium, molybdenum, niobium, platinum, stainless steel, tantalum, titanium, and vanadium.

Metalworking operations include melting and casting, forging, press forming, extrusion, drawing, rolling, diffusion bonding, hydrospinning, swaging, cutting and shearing, and heat treating. In addition, there are glove-box operations involving high-purity beryllium powder and machining operations which typically involve the materials listed above (Rockwell, 1982).

Building 881 R&D

No longer used for enriched uranium operations or stainless steel manufacturing as it had been in the past, Building 881 now is a multipurpose research and development, analytical, plant support, and administrative facility (EG&G, 1991). Operations conducted in Building 881 include analytical laboratories devoted to atomic absorption spectroscopy, inductively coupled plasma and direct current plasma emission spectroscopy, various chemical analyses, x-ray spectroscopy, furnace combustion analyses, semivolatile chemical analyses, ion chromatography, gas chromatography/mass spectrometry, radiochemistry, various organic chemical analyses, ion chromatography, anion and cation analyses, water analyses, and waste stream characterization analyses.

Other functions supported in Building 881 include generation of chemical standards and "inertial fusion" activities to machine small parts for weapons and energy generation research, gold plate the parts, assemble microscopic parts, along with some large machining operations. The Special Weapons Projects group is involved in development of engineering prototypes and full-scale models for military training.

Recovery Technology activities in Building 881 include materials development, process instrumentation and control, and equipment design and development. The Waste Chemistry group supports engineering and development of on-site waste treatment processes, and Joining Technology conducts operations to join non-nuclear metals including beryllium, in some cases using brazing alloys including nickel.

Other operations housed in Building 881 include Nondestructive Testing, Records Management and Storage, and various maintenance shops and activities.

Explosive Bonding

Explosive bonding experiments were conducted at the explosive forming area near Building 993 from 1965 until approximately 1968. The experiments were designed to explosively bond together flat plates of stainless steel and uranium alloy. The explosive consisted of 192 grams of 40% dynamite. The energy released from the dynamite drove the stainless steel plate into the radioactive material to form a bonded laminate. The explosive events took place below grade. No documentation was found which detailed the characteristics of any releases to the environment from this activity (HRR, 1992).

3.3.5 Plant Support

Plant Support activities of potential relevance to off-site exposures include Criticality Safety, the various service Laboratories, Filter Testing, and Laundry Services.

Criticality Safety

Nuclear criticality safety can be defined as practices associated with avoiding an accidental nuclear criticality event. A criticality is a spontaneous nuclear fission chain reaction caused when a sufficient quantity of fissile material is placed within a given area. The presence of large quantities of fissile materials in numerous forms on the Rocky Flats site makes it necessary to maintain an active criticality safety program. The criticality safety group at Rocky Flats performs experiments and calculations to identify container or vessel geometries or arrays of nuclear material which have the potential to spontaneously fission. Experiments and calculations are conducted to evaluate the potential for criticality under varying conditions and to validate computer programs used for criticality safety analysis (EG&G, 1991a). A criticality event would not result in a nuclear explosion, but could liberate a tremendous amount of energy and high levels of radiation. While criticality events can vary widely in power level and duration, the amount of radiation which could be generated in a criticality could be fatal to nearby personnel, and the intense forces liberated could cause severe property damage. From the beginning of the atomic energy industry to 1967, there were no less than 34 incidents where the power level of fissionable materials became uncontrollable because of unplanned or unexpected changes in the reactivity of the assembled materials (Stratton, 1967). These extensively-studied incidents, none of which occurred at the Rocky Flats Plant, caused eight deaths and in some cases resulted in significant property damage.

The Nuclear Safety Group has been in existence at the plant since 1953. At that time, however, the group did not have its own facility. In those early years, the group performed its work in the areas in which the materials were actually handled, using the actual materials which went into the production of the product. Investigators would set up the production materials in various arrays to perform multiplication-type experiments and make predictions with respect to safe geometries for various kinds of production vessels, spacing parameters, shipping containers, and other items (Putzier, 1982). These "in situ" experiments conducted outside of Building 886 were always subcritical; neutron count rates were observed as criticality was approached but not reached (Rothe, 1992).

In more recent years, the Nuclear Safety Group conducts its work in Building 886, which was commissioned in 1965. Since that time, the Nuclear Safety Group has conducted about 1600 critical mass experiments using uranium and plutonium in solutions (800 tests), compacted powder

(300), and metallic forms (500) (Rothe, 1992). Since 1983, criticality experiments have not been conducted with solid materials. They are now conducted primarily with uranyl nitrate solutions, which are re-used (ChemRisk, 1991; RE-891[53]). In 1969, the critical mass program at Lawrence Radiation Laboratories (LRL) was shut down, and Rocky Flats was notified that criticality studies that LRL considered necessary for their purposes would be performed at Rocky Flats (Schuske, 1969). While LRL materials were transferred to Rocky Flats, no significant increase in work load resulted (Rothe, 1992).

Building 886 houses the Critical Mass Laboratory, some offices, and a small electronics and machine shop. Building 875, which was constructed in 1974, is connected to Building 886 by an underground passageway containing air ducts and houses two exhaust filter plenums handling air from Building 886. Building 886 laboratory space includes a "test cell" area where experiments are conducted and two rooms for storage of radioactive materials. One of the radioactive material storage rooms houses nine tanks which contain the solutions of uranyl nitrate in dilute nitric acid that are used for criticality experiments. These tanks contain borosilicate-glass raschig rings that absorb neutrons and prevent criticality events. To conduct experiments, solution is transferred to the test cell. The solution is not heated (EG&G, 1991a). The uranyl nitrate solutions from these tests are not discarded; they are pumped back to the storage tanks for reuse in future tests. Therefore, these testing activities do not contribute to the plants liquid waste stream.

Approximately half of the 1600 criticality experiments conducted in Building 886 actually achieved criticality. The experiments were conducted in a manner to control the level of fissioning, for example by varying distance between pieces of metals and depths of solutions, and only very rarely were the radiation levels and the associated heat generated such that it was not possible to directly touch the reaction vessels immediately after the experiments. The experiments conducted in the RFP laboratory generally involved power levels and the associated heat generated of no more than 10 milliwatts for no more than one hour (ChemRisk, 1991; RE-891[53]). There were approximately six "high power" experiments that were taken to between 10 and 100 times the power of typical tests (Rothe, 1992). Using a conversion factor of $3x10^{16}$ fissions per megawatt second (Thomas, 1978), this power level and duration corresponds to a maximum of $1.08x10^{12}$ fissions from a typical RFP criticality experiment and a maximum of 1×10^{14} fissions from a high power experiment.

Prior to the addition of four stages of HEPA filtration in Building 875, exhaust from Building 886 passed through a two-stage filter plenum before release. Since the addition of the Building 875 filters, exhausted air, which includes off-gas from the test cell reaction vessel vents, passes through a HEPA filter in Building 886 and the 4 stages of HEPA filtration in Building 875 prior to release via the "stack" (ChemRisk, 1991; RE-891[53]). The vent "stack" is rectangular (24" x 48") and extends 1.5 feet above the Building 875 roof (Los Alamos, 1991). The vessels vents are always open; they are not controlled by valves or pressure relief valves, and hold-up of off-gases was not practiced (Rothe, 1992). Airborne effluents from Building 886 have been sampled for radioactive particulates since 1965. Over the period from 1971 through 1989, reported plutonium effluents from Building 886 were at most 5% of the site total (in 1978) and enriched uranium emissions were at most 10% of the site total (in 1976) (EG&G, 1991b).

Potential pathways for release of waterborne radioactivity from the Critical Mass Laboratory appear to be limited to several incidents involving spills of uranyl nitrate solution and disposal of waste water from activities such as mopping of floors. There reportedly have been between two and five incidents where uranyl nitrate was spilled onto the floor outside the tanks in the Critical Mass Laboratory (ChemRisk, 1991; RE-891[53]). The largest spill involved between 50 and 60 gallons of solution. The Laboratory floors are sealed and bermed to contain such spills, and in no case did solution escape the building. Except for small quantities absorbed on paper used in clean-up and disposed of as radioactive waste, the solution was recovered for further use (Rothe, 1992). In one incident in the late 1960s, an accumulation of uranyl nitrate salt was found inside the base of the ventilation system filter plenum outside of building 886 (ChemRisk, 1992; RE-891[53]. This accumulation (about one foot square and one-quarter inch thick) is thought to have most likely resulted from an incident in which some solution overflowed into a vent line and dried, with subsequent air flow over the vent carrying the salt to the filter plenum (Rothe, 1992). Over the period from the late 1960s to the late 1970s, waste water from activities such as mopping was collected and periodically transferred to the solar evaporation ponds. A raschig ring filled tank was used ten or fewer times to transfer batches of less than 1000 liters of waste water to the ponds after sampling and analysis indicated that the uranium content of the water was much less than one gram per liter (ChemRisk, 1991; RE-891[53]). These waste water solutions contained concentrations of uranium far below those that would have made raschig rings necessary in the transfer tank (Rothe, 1992).

Radioactivity potentially released from the Critical Mass Laboratory would include enriched uranium and plutonium and fission products formed in fission of these materials. Fission products in the RFP solutions have been nearly unmeasurable; there has been no need for monitoring of fission product levels, administrative limitation of concentrations, or purification treatment of the solutions because fission products build-up has been insignificant (Rothe, 1992). While fission products are generally liberated from test solutions, they largely remain trapped in metal and compacted powder test specimens. The power levels of the RFP experiments have been much less than those required to vaporize metals (Rothe, 1992). Releases from Building 886 will be included in the assessment of routine effluents from the Rocky Flats site.

Laboratories in Buildings 123, 125, 559, and 881

There are four main service laboratories at Rocky Flats; the Health Physics Laboratory, the Standards Laboratory, the Plutonium Laboratory, and the General Laboratories (Rockwell, 1981).

The Health Physics Laboratories are located in Building 123. They perform analyses of personnel dosimeters and all airborne sample analyses, including stack samples and general room air samples. Originally, these labs were in Building 441.

The Standards Laboratory is located in Building 125. It prepares analytical stock solutions for the other labs and performs analyses on incoming radiological sources for quality assurance/quality control purposes. It also performs calibration and standardization of equipment to assure it is operating according to the manufacturer's specifications. One section of the Standard Lab certifies dimensional measurements such as length, angles, and roundness.

The Building 559 Lab is the Plutonium Analytical Laboratory. The lab conducts analyses to determine the purity of plutonium, what the impurities are and in what concentrations, and the concentrations of plutonium alloys, whether in metal, liquid, or oxide form. The lab can also analyze gases and organics. The primary purpose of the lab is to sample incoming plutonium site returns and feed material, and that which is recovered/purified and cast at the plant site for the production of weapons.

The Building 881 Labs are also called the General Labs. They went in as part of initial construction of the building in 1952. A number of analyses on a variety of materials are performed here. Waste water and National Pollutant Discharge Elimination System (NPDES) permit sample analyses are performed here, as well as sludge, surface water, and groundwater sample analyses. Production control samples from Buildings 460 and 444 are analyzed by the General Labs. When the enriched uranium processes were in operation in 881, the laboratories also performed analyses of the materials generated on that line (ChemRisk, 1991; RE-891[7,46,12,34,32]).

Filter Testing

The Filter Testing Group was formed in 1979 after an audit identified the need for a group to perform in-place leak testing of HEPA filters; a group separate from the group that installs the filters. In-place testing of the filters reportedly has always been conducted at the plant site, but prior to the formation of the Filter Testing Group, in-place leak testing of filters was performed by the same group that installed the filters (ChemRisk, 1991; RE-891[24]).

In-place testing of filters is not only initiated in response to a filter change. Testing may also be required when there is visible damage to the filter or the supporting framework, when plenum monitoring indicates there may be a problem, and when the routine testing schedule for that particular bank of filters dictates. Filter changes are initiated by an increase in the pressure differential across the filter, visible damage to the filter, or when they become visibly overloaded.

The Filter Testing Group also conducts quality assurance testing on the filters (out of place testing). When a new lot of filters is received from the supplier, the Filter Testing Group conducts a series of tests on a percentage of the filters to determine that they are of acceptable quality. The tests include pressure resistance trials, in which filters are placed under a pressure of 10 inches of water for one hour, high temperature resistance testing at 750° F for 5 minutes, a drop test (180 cycles per minute for 15 minutes), and high humidity resistance. Before the filters are shipped to the plant, the manufacturer also tests each filter for efficiency and resistance. Filter Testing also conducts testing of each of the HEPA filters which go into the respirators worn by site personnel (Rockwell, 1981a).

Laundry Services

Laundry Services provides cleaning, sorting, and distribution of the coveralls and other reusable garments that are required in the manufacturing areas containing potential contamination. The clothing includes coveralls, shirts, shorts, undergarments, socks, caps, and booties. Laundry services also launders respirators and bath towels. Exhaust air from the dryers and washers is vented through HEPA filter plenums. Laundry water is sent to the forced evaporation operations in Building 374 (Rockwell, 1981). Prior to Building 374 becoming operational in 1980, laundry waters were sent to the second stage of Building 774's aqueous waste operations and then through the evaporator located there if the radioactivity of the water was above 1667 pCi/l. Below this level, it was sent on to Pond B-2. When the plant first began operations, laundry wastes were discharged directly to North Walnut Creek.

In the very early days, Buildings 881, 771, and 991 had their own laundry facilities, while Building 444's laundry went to Building 442. Around 1958, Building 778 became the laundry facility for all plutonium-related buildings. When enriched uranium moved away from Rocky Flats in the mid-1960s, all laundry remaining from those operations went to the Building 778 laundry. In 1976, Building 442 was turned over to the Filter Installation group, and since that time all laundry from the plant site has been processed in Building 778 (ChemRisk, 1991; RE-891 [75, 78, 79]).

REFERENCES

Barrick (1982). Barrick, C.W. Summary: Beryllium Levels in Surficial Soils Near the Rocky Flats Plant. September 20, 1982. Repository Document AC-329.

Biles (1970). Biles, M.B. "Summary of Contaminated Waste Storage Burial at the Rocky Flats Plant Site." December 22, 1970. Repository Document RE-510.

Brekken (1965). Brekken, T. Memorandum re "Installation of E-Beam Furnace." July, 1965.

Buffer (1990). Buffer, P. Highlights in Rocky Flats Plant History. May, 1991. Repository Document RE-30.

Campbell (1986). Campbell, G. "Beryllium At Rocky Flats Plant." Letter to A. E. Whitman, August 26, 1986. Repository Document CH-332.

ChemRisk (1991). Rocky Flats Historical Investigation Interviews. Repository Document RE-891. The numerals in brackets identify the individual interviewees; See Appendix A for a complete listing of interviewees.

Crisler (1991). Crisler, L.R. A History of the Rocky Flats Plutonium/Actinide Recovery Plant 1952 to 1991. October 30, 1991 Draft. Not For Public Dissemination.

Cuddihy and Newton (1985). Cuddihy, R.G., Newton, G.J. Human Radiation Exposures Related to Nuclear Weapons Industries. Repository Document IN-448.

EG&G (1991a). EG&G Rocky Flats. Air Pollution Emission Notice Building 881. May 9, 1991. Repository Document RE-773

EG&G (1991b). EG&G Idaho, Inc. Effluent Information System Report of Rocky Flats Airborne Effluents. 1991.

Facer (1970). Facer, G.C. Contaminated Waste Storage Burial at the Rocky Flats Plant Site. August 7, 1970. Repository Document HS-346.

Hazle (1985). Hazle, A.J. Interoffice Communication Re: "Groundwater Contamination Sources." September 3, 1985. Repository Document RE-354.

Hoffman (1992). Hoffman, R.B. Personal Communication with Rodney B. Hoffman, January 6, 1992.

Joshel (1970). Joshel, L. M. TWX to H. C. Donnelly re "Chronological History Regarding Leakage in Drum Storage Area." February 17, 1970. Repository Document IN-423.

Kneale (1989). Kneale, P.A. Tour Briefing Booklet, "Building 779." November 1, 1989. Repository Document RE-929.

Knighton (1983). Knighton, J.B. "Conceptual Process for Recovery of Plutonium from ZPPR Fuels", Chemical Research Group Internal Report CRD 83-015, Rockwell International-Rocky Flats. March 15, 1983. Repository Document RE-970.

Leebl and Patterson (1982). Leebl, R.G. and T.B. Patterson. "Plutonium Recovery from a U-Pu-Mo Alloy", Rockwell International Energy Systems, Rocky Flats Plant, Special Processing Plutonium Operations Report CHOP-9243-82-09. May 14, 1982. Repository Document RE-689.

Los Alamos (1991). Report Deliverables for the Subtask for Radioactive Sampling Evaluation Project. EG&G Contract 80399-GD. December 3, 1991. Table 2, 3, and 4.

Navratil and Miner (1984). Navratil, J.D. and F.J. Miner. Actinide Processing at Rocky Flats. Rockwell International, July, 1984. Not For Public Dissemination.

Owen and Steward (1974). Owen, J.B. and L.M. Steward. Environmental Inventory: A Historical Summation of Environmental Incidents Affecting Soil At or Near the USAEC Rocky Flats Plant. January, 1974. Repository Document RE-318.

Patterson (1982). Patterson, T.B. "Ion Exchange Processing of a U-Pu-Mo Alloy", Rockwell International Energy Systems Group, Rocky Flats Plant, Special Processing Plutonium Operations Report CHOP-9242-82-07. May 12, 1982. Repository Document RE-969.

Piltingsrud (1973). Piltingsrud, C.W. Untitled Burial Site Summary. September 28, 1973. Repository Document RE-547.

Putzier (1970). Putzier, E.A. A Summary of On-Site Radioactive Waste Disposal. April 22, 1970. Repository Document RE-317.

Putzier (1982). Putzier, E.A. The Past 30 Years at the Rocky Flats Plant. November, 1982. Repository Document HS-371.

Rockwell (1988). Rockwell International. Present Landfill Closure Plan. July 1, 1988, Rev. No. 1. Repository Document HS-482.

Rockwell (1987a). Rockwell International. Building 707 Final Safety Analysis Report. June, 1987. Not For Public Dissemination.

Rockwell (1987b). Rockwell International. Building 779 Final Safety Analysis Report. July, 1987. Not For Public Dissemination.

Rockwell (1982). Rockwell International. Building 865 Draft Safety Analysis Report. February, 1982. Not For Public Dissemination.

Rockwell (1981a). Rockwell International. Rocky Flats Plant Interim Safety Analysis Report. March 13, 1981. Not For Public Dissemination.

Rockwell (1981b). Rockwell International. Building 883 Draft Safety Analysis Report. November, 1981. Not For Public Dissemination.

Rothe (1992). Personal communication with Robert Rothe, EG&G Rocky Flats Critical Mass Laboratory. July 31, 1992.

Schuske (1969). Schuske, C.L. "Request for Plutonium Experimental Components from LRL for Nuclear Safety". Letter to L. D. Hazelton, December 12, 1969. Repository Document CH-313.

Seaborg et al. (1966). Seaborg, G.T., J.G. Palfrey, J.T. Ramey, and G.F. Tape (1966). Plowshare. United States Atomic Energy Commission, Oak Ridge, TN.

Seastone (1973). Seastone, J. History of Incineration and Landfill Operations, Rocky Flats Plant. October 9, 1973. Repository Document RE-146/RF-110.

Seed et al. (1971). Seed, J.R., K.W. Calkins, C. T. Illsley, F.J. Miner, and J.B. Owen. Committee Evaluation of Plutonium Levels in Soil Within and Surrounding USAEC Installation at Rocky Flats - Colorado. July 9, 1971, RFP-INV-10. Repository Document AC-726.

Steward (1973). Steward, L.M. Areas of Concern at Rocky Flats: Soil Contamination and Related Incidents - Part I: Plutonium. June 29, 1973. Repository Document RE-529.

Stratton (1967). Stratton, William R. A Review of Criticality Accidents. Los Alamos Scientific Laboratory of the University of California, Report LA-3611, UC-46, Criticality Studies TID-4500. January, 1967.

Tesitor (1971). Tesitor, C.N. Reduction Gasket Failure Studies. May 17, 1971, CRDL 950348-05. Repository Document HS-552.

Thomas (1978). Thomas, J.T., Editor. Nuclear Safety Guide, TID-7016, Revision 2. Prepared for the U.S. Nuclear Regulatory Commission by Union Carbide Corporation, Nuclear Division. NUREG/CR-0095, ORNL/NUREG/CSD-6. June, 1978.

Unknown. "Chronology of RFP Major Incidents." Repository Document HS-404.

Unknown. "Radioactive Waste Disposal, Dow Rocky Flats Division." Distribution: Abbott, E. Repository Document RE-515.

USDOE. (1977). "Phase Designations for Weapons Activities"; AL Appendix 72XA, Chapter 3.1, August 19, 1977. Repository Document RF-944.

USDOE. (1980). Final Environmental Impact Statement for the Rocky Flats Plant Site. April, 1980. Repository Document EN-1.

USDOE. (1984). Investigation Report: Beryllium Disease Case at Rocky Flats Plant, Golden, Colorado. October 1984. Repository Document HS-816.

USDOE. (1986). Comprehensive Environmental Assessment Response Program, Phase 1 Installation Assessment. Albuquerque Operations Office, Environment, Safety and Health Division, April 1986. Repository Document RE-33.

USDOE. (1992). Historical Release Draft Report for the Rocky Flats Plant- Volume I and II. January 1992. Repository Document RE-1139.

USERDA (1975). Omnibus Environmental Assessment for the Rocky Flats Plant of the U.S. Energy Research and Development Administration, Contract AT (29-1)-1106. May, 1975. Repository Document EN-812.

Willging (1970). Willging, J.F. Letter regarding "ZPPR Residue Resume." February 12, 1970. Repository Document HS-341.

Yoder (1984). Yoder, R.E. "Actions to Improve Environmental Posture at Rocky Flats." August 8, 1984, Letter to DOE Area Manager J.R. Nicks. Repository Document HS-484.

Zaloga and Green (1991). Zaloga, S. J. and M. Green. Tank Attack; A Primer of Modern Tank Warfare. Motorbooks International Publishers, Osceola, WI.

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