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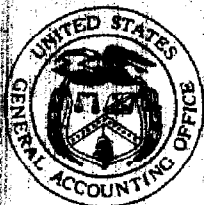
United States General Accounting Office

Report to the Chairman, Subcommittee
on Oversight and Investigations,
Committee on Energy and Commerce,
House of Representatives

December 1994

**NUCLEAR
MATERIALS**

**Plutonium Storage at
DOE's Rocky Flats
Plant**



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United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

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December 29, 1994

The Honorable John D. Dingell
Chairman, Subcommittee on Oversight
and Investigations
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

Since the 1950s, the Department of Energy's (DOE) Rocky Flats Plant has processed material containing plutonium and has fabricated plutonium metal into components for nuclear weapons. Because of its radioactive and toxic properties, plutonium requires special handling. In late 1989, operations to process and fabricate plutonium at Rocky Flats were suspended for various reasons, including concerns about health and safety. These operations were never resumed at the plant, and large quantities of plutonium, in various forms, are currently stored there. You asked us to examine the storage of plutonium at Rocky Flats. Specifically, you asked us to provide information on (1) the safety of plutonium storage at the plant and (2) DOE's current efforts and plans to resolve any problems with the storage.

Results in Brief

DOE's storage of about 12.8 metric tons¹ of plutonium at the Rocky Flats Plant raises a number of important, unresolved safety concerns. When operations were suspended at the plant in 1989, DOE intended to restart them within a few months. As a result, the plutonium was left in place or was packaged for short-term storage.² For example, plutonium liquids were left in tanks, plastic bottles, or piping. However, the operations were never restarted and the plutonium remains either where it was when the plant shut down or packaged for what was intended to be temporary, short-term storage. This situation has resulted in a number of safety concerns, including plutonium liquids leaking from pipes and tanks, fire hazards, and risks of exposing workers to plutonium.

DOE has recognized these safety problems at Rocky Flats and has taken numerous corrective actions over the past 2 years. For example, DOE headquarters has developed criteria for longer-term plutonium storage,

¹A metric ton is 1,000 kilograms, or about 2,200 pounds.

²For the purposes of this report, short-term storage is shorter than 2 years; long-term storage is longer than 2 years.

which should be published in early 1995. Corrective actions to address the more immediate problems at the plant are also under way. For example, plutonium metals are being inspected and, if necessary, brought into compliance with fire safety standards. However, other important decisions, such as what to do with plutonium residues (by-products of past operations), have not yet been made. As a result, it is difficult to accurately project time frames and costs for resolving the problems with plutonium storage at the plant. In any event, on the basis of the programs DOE currently has under way or is proposing, resolving these problems will take many years and will likely cost hundreds of millions of dollars.

Background

DOE's Rocky Flats Plant is a government-owned, contractor-operated facility that recovered and reprocessed nuclear materials and fabricated nuclear and nonnuclear components. It is located approximately 16 miles northwest of Denver, Colorado. For nearly 40 years, the facility's primary mission was to use plutonium to fabricate "pits," the triggers for nuclear weapons. Plutonium is a man-made material produced as a by-product of nuclear reactions. It remains radioactive and highly toxic for tens of thousands of years and must be handled with specialized equipment to protect workers and prevent the material from dispersing into the environment.³

Storing plutonium poses problems for DOE. Plutonium metal reacts with oxygen, hydrogen, and water vapor. As a result of these reactions, plutonium fines and plutonium hydrides are sometimes formed;⁴ they are pyrophoric, having the potential to spontaneously ignite. For any prolonged period, therefore, plutonium should be stored in an oxygen and moisture-controlled environment. Plutonium also should not be stored in direct contact with organic materials such as plastic. The radiation from plutonium can cause the organic material to decompose, producing hydrogen and other substances. The hydrogen can react with the plutonium to produce plutonium hydrides. Finally, although the plutonium metal used in weapons consists mostly of the isotope plutonium-239, small amounts of other plutonium isotopes are also present. One of them,

³Plutonium has a radioactive half-life of 24,000 years, meaning that half of the present amount will still exist 24,000 years from now.

⁴Plutonium fines are very small pieces of plutonium metal similar to steel wool; hydrides are compounds formed when plutonium metal reacts with hydrogen.

plutonium-241, will decay⁵ to americium-241, an isotope that emits a type of radiation that is more difficult to shield against. This process can increase the risk of radiation exposure to workers.

Because of the radioactive and toxic characteristics of plutonium, it must be carefully stored. However, DOE had no criteria for long-term storage because until 1989, the plutonium at Rocky Flats was continually being recycled into new weapons. DOE does have criteria for short-term storage, including various DOE orders and directives as well as requirements specific to the sites. For example, the containers in which plutonium is stored must be periodically monitored and checked to control potential fire hazards. At Rocky Flats, inspections may be required anywhere from every few hours to every 2 years or longer, depending on the form of the plutonium and the container used. The site-specific requirements also address fire safety, the labeling of containers, records management, and criticality safety (preventing a nuclear chain reaction).

All operations for processing plutonium and fabricating plutonium components for weapons at Rocky Flats were shut down in late 1989 for various reasons, including concerns about human health and safety. The shutdown continued for more than 2 years as DOE attempted to develop new safety and management procedures. However, in February 1992 the President canceled the plant's production mission because of dramatic reductions in the U.S. nuclear weapons arsenal. As a result, DOE shifted the plant's mission to site cleanup and environmental restoration, and transferred management responsibility for the plant from the Office of Defense Programs to the Office of Environmental Management.

Plutonium Currently Stored Raises Safety Concerns

The plutonium currently stored at Rocky Flats poses a number of safety concerns, including risks of fire and risks of exposing workers to plutonium as a result of improper packaging and leaking and deteriorating containers. This situation occurred because DOE thought the shutdown would last only a few months and left the plutonium-bearing materials in pipelines, glove boxes,⁶ tanks, or drums—where they were located when operations ceased—or packaged them for short-term storage. As of December 1994, about 12.8 metric tons of plutonium was being stored at

⁵Radioactive decay is a process whereby the unstable atoms of certain elements naturally change into other elements. For example, several isotopes of plutonium are created during the nuclear fission process, and they will naturally decay into other isotopes that are also radioactive.

⁶A glove box is a containment structure fitted with gloves that allow workers to handle material without touching it.

Rocky Flats in four basic forms—plutonium metal, plutonium oxides, plutonium contained in liquids, and plutonium residues.

Plutonium Metal

The plutonium metal is nearly pure plutonium or is alloyed with other metals. It was used to fabricate various parts of nuclear weapons. About 6.6 metric tons of plutonium metal, consisting of over 3,000 items, is currently stored in several different buildings within the Rocky Flats complex.

When operations ceased at the plant, DOE stored the plutonium metal in containers (cans made of stainless steel or tin-plated steel) that (1) were not airtight or (2) had seals that were not designed for long-term storage. According to DOE officials at Rocky Flats, the containers could permit oxygen and/or moisture to enter and react with the plutonium, possibly creating pyrophoric material. Also, according to DOE headquarters officials, oxygen could enter the containers and create plutonium oxides that could expand and rupture the containers. The plutonium has been stored in this manner for over 5 years.⁷

In addition, an undetermined amount of the stored plutonium metals may be in direct contact with plastic. The radiation from the plutonium could react with the plastic and cause hydrogen to form. The hydrogen could then react with the plutonium to form plutonium hydrides, which are pyrophoric. The plutonium metal was packaged in plastic because plant officials anticipated restarting operations within a few months, and they considered plastic to be safe for this period of time.

DOE officials at Rocky Flats admit that the plutonium metal is not stored in compliance with the site's fire safety requirements. They believe that some of the plutonium metal is potentially a fire hazard and are studying the extent of the problem. The Defense Nuclear Facilities Safety Board⁸ reviewed the storage of plutonium metal at Rocky Flats and, in October 1993, reported to DOE that many plutonium items were packaged hastily and are in contact with plastic. The Safety Board labeled the storage of the plutonium metal as a dangerous situation. In a May 1994 formal recommendation to the Secretary of Energy, the Safety Board again

⁷According to DOE and contractor officials at Rocky Flats, recent inspections of containers of plutonium metal have shown that oxidation has occurred at a relatively minor rate.

⁸The Safety Board was created by the Congress in 1988 (P.L. 100-456) to provide independent health and safety oversight of DOE's defense nuclear facilities. The Safety Board conducts investigations and makes recommendations to the Secretary of Energy and the President.

expressed concern about the issues surrounding plutonium storage and recommended corrective actions. The Safety Board specifically cited storage of plutonium metal in contact with plastic, stating that it is "well known that plutonium in contact with plastic can cause formation of hydrogen gas and pyrophoric plutonium compounds leading to a high probability of plutonium fires."⁹

Plutonium Oxide

Plutonium oxide is formed when plutonium metal oxidizes (similar to iron rusting). This material was formed during past production operations or as a result of plutonium metal reacting with air. About 3.2 metric tons of plutonium oxide are stored at Rocky Flats in more than 3,000 containers. At the time operations were shut down in 1989, approximately 97 percent of the plutonium oxides had been thermally treated to remove pyrophoric components. Once plutonium oxide is thermally treated and properly sealed, it is better suited for longer-term storage.

The remaining 3 percent of the oxide, which has not been thermally treated, is stored in stainless steel cans in glove boxes with inert atmospheres. Heat detectors and alarms were placed in the glove boxes as required to detect spontaneous ignitions. According to DOE officials at the plant, some of these cans probably contain oxides mixed with small plutonium fines. The potential risk in storing these cans involves breach of containment and dispersal of the plutonium oxide within the glove box. Contractor officials at Rocky Flats state that without some external stimulus, the danger of spontaneous ignition of the plutonium oxide that has not been thermally treated is minimal. They informed us that the containers, along with the reduced oxygen atmosphere in the glove boxes where the containers are stored, greatly reduce the potential for fire.

Plutonium in Liquids

About 30,000 liters of liquid solutions, containing about 0.1 metric tons of plutonium, are stored at Rocky Flats. When Rocky Flats was operating, the liquids were routinely processed to recover the plutonium and were not generally stored for long periods of time. When Rocky Flats was shut down, the liquids were contained in plastic containers, tanks, and pipelines in several buildings, where they currently remain.

Since the shutdown, there have been 29 reported leaks as a result of plutonium interacting with plastic bottles and natural deterioration of the

⁹A more complete discussion of the Safety Board's concerns is contained in Plutonium Storage Safety at Major Department of Energy Facilities, Defense Nuclear Facilities Safety Board Technical Report (DNFSB/Tech-1, Apr. 14, 1994).

pipings and tanks. One of the most serious of these leaks was the rupture in July 1993 of an overhead oxalic acid line that sprayed plutonium-contaminated liquid over a radius of 6 to 7 meters. No contamination of personnel was reported, and the area has since been decontaminated.

In April 1993, the Los Alamos Technology Office at Rocky Flats, a contractor to DOE, conducted a study to determine the hazards of continuing to store plutonium-bearing liquids at Rocky Flats.¹⁰ The Los Alamos Technology Office concluded that the plutonium stored in tanks and bottles in seven of the Rocky Flats buildings presents a safety hazard from leaks and/or spills and the associated increased risk of workers being exposed to radiation. The study states that as the containers age, the incidence of spills and leaks will increase and could result in increased exposure of workers. The study concluded that continued storage of the plutonium solutions was inadvisable and recommended converting them into solid form "promptly." In a June 1994 DOE headquarters review, officials found the plutonium solutions in plastic bottles to be particularly hazardous because the plastic was becoming brittle from reacting with plutonium.

According to staff of the Defense Nuclear Facilities Safety Board, another important risk arising from continued storage of plutonium solutions in deteriorating equipment is accidental criticality—that is, an accidental nuclear chain reaction. The staff points out that as the equipment and infrastructure deteriorate, it will become more difficult to take representative samples, control the chemistry of the solutions, and move the solutions from one place to another. The staff believes that this awkwardness and uncertainty will tend to make accidental criticality more likely.

Plutonium Residues

The fourth category of plutonium stored at Rocky Flats is 2.9 metric tons of plutonium contained in about 100 metric tons of residues. These residues, the by-products of past production operations, consist of ash, salts, slags, graphites, and other materials. They are contained in over 20,000 packages in 5,000 metal drums located in various buildings at Rocky Flats. If operations had been restarted at Rocky Flats, much of the residues could have been reprocessed to recover the plutonium.

¹⁰Plutonium and Uranium Solutions Safety Study, Los Alamos Technology Office at Rocky Flats (LA-UR-93-3282, Oct. 1993).

The continued storage of the residues has raised concerns about potential safety risks. The drums contain a variety of corrosive, flammable, and possibly reactive materials. A September 1993 study by the plant's contractor identified the predominant safety risks with the residues as gas generation, loss of contamination containment, corrosion of drums and residue packaging, and formation of pyrophoric or unstable compounds.¹¹ Gas generation in residue drums can result in pressurization of the drum or packages in the drum through an accumulation of hydrogen.¹² The study concluded that although stored residues pose no imminent danger, the potential safety risks are sufficiently real to warrant further study.

A June 1994 DOE headquarters review found a number of potential problems with the storage of residues. These included fire hazards, radiation exposure, and gas buildup in the drums. Headquarters officials who participated in this review expressed their concern about the lack of effort to resolve these problems, some of which have been documented for many years. The Defense Nuclear Facilities Safety Board has also reviewed the storage of plutonium residues at Rocky Flats and concluded that it is a "significant immediate safety issue." The Safety Board is concerned that some of the material could explode if the storage drums were dropped, punctured, or otherwise roughly handled. The Safety Board also believes that spontaneous chemical reactions are possible in some of the drums and that the materials in many of the drums have not been well characterized. The Safety Board formally recommended in 1994 that all unstable plutonium residues be processed to stable forms within 2 to 3 years.

DOE's Plans for Reducing Storage Problems

DOE is addressing the problems with plutonium storage at Rocky Flats. DOE headquarters has begun a number of efforts, including developing uniform national criteria for the handling and storage of plutonium metals and oxides. The operating contractor at Rocky Flats has also begun corrective actions to address many of the more immediate problems.

Headquarters' Efforts

Because of concerns about plutonium storage at DOE facilities, in May 1993 the Office of the Assistant Secretary for Defense Programs began looking into the problems. The Office recognized that criteria for long-term storage of plutonium did not exist and that current short-term storage raised

¹¹Evaluation of Residue Drum Storage Safety Risks, EG&G Rocky Flats, Inc. (93-RF-12968, Sept. 27, 1993).

¹²Some drums have been equipped with vents to prevent gas buildup.

safety concerns. This effort led to the drafting of national criteria for handling and storing plutonium metals and oxides.

The national criteria for storage have been incorporated in a DOE technical standard that should be published in early 1995. The criteria establish specific guidelines for DOE facilities to follow.¹³ The criteria specify that the stored plutonium be either solid metal or oxide (powder or solid) and that it be retrievable for future use. The criteria also specify the maximum permitted quantities of plutonium per container. Furthermore, the criteria require that

- plutonium metal be stored in a size and configuration that makes it less prone to being pyrophoric,
- no plastic or organic materials be in direct contact with stored plutonium,
- plutonium be encased in two protective barriers meeting stringent storage and/or transportation criteria, and
- plutonium oxides be thermally treated to remove pyrophoric materials and minimize moisture content, and then be packaged so that the oxides do not reabsorb any moisture.

DOE officials believe that if these criteria are used, plutonium metals and oxides can be safely stored for 50 years.

A number of other, potentially significant efforts are under way at DOE headquarters, but it is not yet clear how they will interface with each other or when they will be implemented. For example, in June 1994 DOE issued a notice of intent to prepare a programmatic environmental impact statement (PEIS) for long-term storage and disposition of weapons-usable fissile materials. The PEIS will be used to make decisions on the long-term storage of such materials (plutonium and enriched uranium) and on alternatives for disposing of surplus plutonium. DOE expects to complete the PEIS in the spring of 1996.

DOE headquarters is also just completing an environmental safety and health vulnerability assessment for plutonium that looked at concerns about plutonium storage at DOE facilities nationwide.¹⁴ Each facility is required to develop action plans to address the vulnerabilities specific to its location. DOE expects this study to be completed early in 1995. Finally, DOE headquarters has developed an implementation plan to address

¹³DOE Standard: Criteria for Storage of Plutonium Metals and Oxides (DOE-STD-3013-94, Dec. 1994).

¹⁴Plutonium Working Group Report on Environmental, Safety and Health Vulnerabilities Associated with the Department's Plutonium Storage, U.S. Dept. of Energy (DOE/EH-0415, Draft, Sept. 1994).

concerns about plutonium storage at Rocky Flats and other sites identified by the Defense Nuclear Facilities Safety Board. According to DOE officials, the actual work plan to correct the deficiencies noted by the Safety Board is not likely to be completed until mid-1995. Again, it is not yet clear how all of these activities will be factored into the Department's decision-making process.

DOE's and Contractor's Field Initiatives

The Rocky Flats operating contractor has initiatives under way to address many of the more immediate problems with plutonium storage at the plant. To address the concern that the plutonium metal is not in compliance with fire safety requirements, the contractor issued a draft management plan in July 1993.¹⁵ Two key purposes of the plan are (1) to identify the risks in continuing to store plutonium metal and in performing corrective actions and (2) to prepare detailed site plans to bring the plutonium into compliance with the plant's existing fire safety requirements. The key component in implementing this plan is to inspect a sample of 10 percent of the containers in which the plutonium metal is stored to characterize the nature and extent of the problems.

The draft plan was approved by the operating contractor in November 1993, and the sampling began in February 1994. As the containers are inspected, they will be brought into compliance with existing fire safety requirements by removing from the plutonium metal any pyrophoric material and/or any organic material, such as plastic, and then repackaging the metal. Contractor officials at Rocky Flats believe the sampling will be completed by September 1995, at a total cost of \$7.4 million. These officials believe it would likely cost an additional \$4.5 million and take 2 years to bring the remaining plutonium metal into compliance with fire safety standards. However, this does not include the cost to package the plutonium metal in accordance with DOE's new criteria for long-term storage (encasement in two protective barriers).

To address the risk of fire from containers of plutonium oxide that also contain plutonium metal fines, the operating contractor proposes to resume thermal stabilization operations in one of the Rocky Flats buildings. In February 1994, DOE completed an environmental assessment for resuming thermal stabilization operations and found no significant

¹⁵Management Plan for Resolution of the Safety Issues Associated with the Storage of Plutonium, EG&G Rocky Flats, Inc. (93-RF-13799, Rev. 3, Nov. 8, 1993).

environmental problems.¹⁶ In November 1994, the contractor received approval from the Secretary of Energy to resume thermal stabilization and is initiating the actions required to start work by January 1995.

Contractor officials estimate that thermally stabilizing the pyrophoric plutonium oxide could take until the end of fiscal year 1997 to complete and will cost about \$4.5 million. This stabilization will bring the oxides into compliance with existing fire safety requirements at the site, but not the new storage criteria. According to DOE headquarters officials, the proposed stabilization efforts will not meet the criterion on moisture content. Rocky Flats currently does not have a facility where it can stabilize the oxides, allow them to cool, and then repackage them in a moisture-free environment to meet this criterion. According to contractor officials, it will cost about \$30 million to purchase the necessary equipment and stabilize all the oxides. They believe this stabilization effort could begin in early 1998 and take 5 years to complete. However, as with the plutonium metal, this amount does not include the cost to package the oxides in accordance with DOE's new criteria for long-term storage.

To address the safety concerns about liquids containing plutonium, the Rocky Flats contractor has implemented a Solution Stabilization Program. The major efforts under this program are two separate plans to remove both high-level and low-level solutions from tanks, piping, and bottles in the two buildings with the more severe problems. The two plans were issued in January 1994. The plans describe several processes to be used to either (1) solidify the low-level solutions and package them for disposal under the program for low-level wastes or (2) extract the plutonium from the high-level solutions so the remaining solutions can be solidified for disposal under the program for low-level wastes. The Solution Stabilization Program, including efforts under both of these plans, is scheduled for completion by the end of fiscal year 1999, at an estimated total cost of between \$122 million and \$144 million.

DOE has been studying what to do with plutonium-bearing residues for many years. In September 1992, we reported that addressing the problems with these residues could cost from about \$650 million to \$1.5 billion, depending on whether the plutonium they contain is recovered or the residues are disposed of as waste.¹⁷ At that time, DOE had a number of

¹⁶Draft Environmental Assessment: Resumption of Thermal Stabilization of Plutonium Oxide in Building 707, Rocky Flats Plant, Golden, Colorado, Rocky Flats Plant, DOE (DOE/EA-887, Sept. 1993).

¹⁷Nuclear Materials: Removing Plutonium Residues From Rocky Flats Will Be Difficult and Costly (GAO/RCED-92-219, Sept. 4, 1992).

initiatives under way that it expected would lead to an overall strategy for plutonium that would specify, among other things, how much plutonium would be recovered from existing residues and how the remainder would be disposed of. DOE still has not developed that strategy. In the interim, operating contractor personnel inspect the drums of residues weekly. The inspections include checking for pressurization, drum or vent corrosion, and other signs of degradation. As problems are observed, corrective actions are taken.

Conclusions

DOE faces a variety of important, unresolved safety problems with plutonium storage at the Rocky Flats Plant. DOE has recognized these problems and has a number of efforts under way at headquarters and at the plant. However, important decisions—such as what to do with the plutonium residues—still need to be made. As a result, it is difficult to accurately estimate the time frames and total cost for resolving the concerns. In any event, fully implementing the programs DOE has under way and is proposing will take many years and will likely cost hundreds of millions of dollars.

Agency Comments

As requested, we did not obtain written agency comments. However, we did discuss the facts in this report with officials in DOE's Office of the Assistant Secretary for Defense Programs and Office of the Assistant Secretary for Environmental Management. We also discussed the facts with DOE officials at Rocky Flats and with the Rocky Flats operating contractor. They generally agreed with the facts presented; we made certain changes in response to their comments, including updating data on the costs and schedules for certain programs. The DOE and contractor officials at Rocky Flats emphasized to us that they consider the issues raised in this report to be very important and believe they have initiated an aggressive program to resolve the concerns. We also discussed the facts in this report with the Defense Nuclear Facilities Safety Board and, at the Safety Board's suggestion, made a number of technical changes concerning the properties of plutonium.

We performed our work between May 1993 and December 1994 in accordance with generally accepted government auditing standards. Appendix I provides a discussion of our objectives, scope, and methodology.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will send copies to the appropriate congressional committees; the Secretary of Energy; and the Director, Office of Management and Budget. We will also make copies available to others upon request.

If you or your staff have any questions, please call me on (202) 512-3841. Major contributors to this report are listed in appendix II.

Sincerely yours,

A handwritten signature in black ink, appearing to read "Victor S. Rezendes". The signature is fluid and cursive, with the first name being the most prominent.

Victor S. Rezendes
Director, Energy and
Science Issues

Objectives, Scope, and Methodology

As requested by the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, the objectives of this review were to provide information on (1) the safety of plutonium storage at the plant and (2) DOE's current efforts and plans to resolve any problems with the storage.

To determine how plutonium is stored at Rocky Flats, we interviewed DOE and contractor officials at the site about the quantity of material stored, its location, and the manner of its storage. We observed locations where plutonium is stored and obtained and reviewed studies and documents on plutonium storage at Rocky Flats and the hazards posed by it. We also examined the extent of compliance with requirements and criteria for storing plutonium. We obtained applicable federal requirements, DOE orders, and the operating contractor's site-specific implementing procedures. We reviewed a variety of safety-related reports done by other organizations—including DOE headquarters, DOE contractors, and the Defense Nuclear Facilities Safety Board—and interviewed the cognizant officials. We then met with DOE and contractor officials at the site and discussed the findings in these other reports.

To determine ongoing and planned actions to resolve the storage problems, we interviewed DOE and contractor officials at the site and obtained and reviewed existing studies and plans. We obtained copies of pertinent documents and interviewed DOE headquarters officials responsible for (1) developing criteria for long-term plutonium storage, (2) performing the programmatic environmental impact statement on long-term storage and disposal of plutonium and other materials, and (3) performing the nationwide environmental safety and health vulnerability assessment for plutonium. We met with officials of the Safety Board and discussed their concerns and the corrective actions they had recommended for Rocky Flats, and attended meetings between the Safety Board and DOE on the Department's plans for implementing the corrective actions.

Major Contributors to This Report

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