United States General Accounting Office

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Fact Sheet for the Chairman, Environment, Energy, and Natural Resources Subcommittee, Committee on Government Operations, House of Representatives

August 1992

NUCLEAR MATERIALS

Plutonium Processing in the Nuclear Weapons Complex

GAO/RCED-92-109FS

GAO

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

Resources, Community, and
Economic Development Division

B-247220

August 20, 1992

The Honorable Mike Synar
Chairman, Environment, Energy,
and Natural Resources Subcommittee
Committee on Government Operations
House of Representatives

Dear Mr. Chairman:

The Department of Energy (DOE) processes plutonium for use in nuclear weapons. This fact sheet responds to your September 6, 1991, request, that we describe the methods and facilities for DOE's plutonium processing. Plutonium, which is used to make nuclear weapons, does not exist in nature and has to be produced. However, DOE no longer produces plutonium for use in nuclear weapons. Instead, DOE processes and recycles the plutonium from retired nuclear weapons and the plutonium that remains as scrap or residue from plutonium processing.

In summary, DOE recovers plutonium through two basic processes—aqueous and pyrochemical—at four processing sites—Rocky Flats, Savannah River, Hanford, and Los Alamos. However, because of environmental and safety concerns and reductions in nuclear weapons, DOE has closed or may close most of the processing facilities. Only Los Alamos' processing facilities are currently operating.

Plutonium Processes

DOE recovers plutonium through aqueous and pyrochemical processes. The aqueous process uses water and is carried out at low temperatures. Acids initially dissolve the plutonium scrap. Then solvent extraction or ion exchange is used to separate the plutonium from other constituents through the use of substances that attract or capture the plutonium. The plutonium emerges in liquid form, undergoes some final steps, and finally requires a pyrochemical process for the finished product.

Pyrochemical processes require higher temperatures and are conducted in furnaces. DOE uses five pyrochemical processes—bomb reduction, direct oxide reduction, molten salt extraction, electrorefining, and scrub alloy production. Pyrochemical processes are used not only to complete the aqueous process but also to process other kinds of plutonium scrap or retired weapons. Although the objective of these processes is to get uncontaminated plutonium metal as the end product, generally only the metal from bomb reduction and electrorefining does not need additional refining.

Thus, all of these processes work in some combination with each other, depending on the plutonium material that must be processed, to finally produce uncontaminated plutonium.

Plutonium Processing Facilities

Before so much of the nuclear weapons complex was shut down, four sites were processing plutonium—the Los Alamos National Laboratory in New Mexico, the Rocky Flats Plant in Colorado, the Savannah River Site in South Carolina, and the Hanford Site in Washington State. These sites, which formerly produced plutonium or processed it into nuclear weapons components, all used aqueous processing and bomb reduction but varied in their use of the other pyrochemical processes.

Today, however, for several reasons, only Los Alamos is processing plutonium. The degradation of the nuclear weapons complex has necessitated the closing of several facilities for safety and environmental reasons. In addition, the ending of the Cold War has reduced the need for nuclear weapons and thus plutonium. These factors will affect the decisions as to which plutonium processing plants at these facilities will resume operations.

The status of plutonium processing at the four facilities is that the Rocky Flats facility is currently shut down and not expected to resume operation. At Hanford, the Plutonium Finishing Plant is also shut down for safety upgrades and a redefinition of its mission. At Savannah River, a recently completed plutonium recovery facility will not be put into service because of the reduced need for plutonium. Finally, only Los Alamos' plutonium processing facilities are operating.

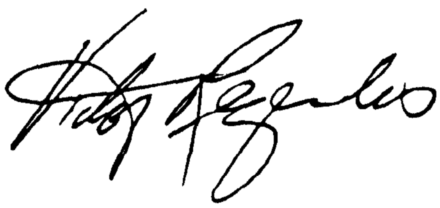
For a graphic representation of DOE's plutonium processes and locations, see figure 3.2. Section 1 provides background; section 2 describes DOE's processes for recovering plutonium; and section 3 identifies DOE's sites and facilities for processing plutonium.

The information in this fact sheet was obtained through visits to DOE's plutonium-processing sites, through interviews with DOE and DOE contractor officials responsible for the design, operation, and modification of plutonium facilities; and through reviews of technical documents. (See app. I for more details.) DOE officials reviewed a draft of this fact sheet and generally agreed with its technical accuracy. We incorporated their comments and suggested changes where appropriate. As requested, we did not obtain written agency comments on this fact sheet.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this fact sheet until 10 days after the date of this letter. At that time, we will send copies of this fact sheet to the appropriate Senate and House committees, the Secretary of Energy, and the Director, Office of Management and Budget. We will make copies available to other interested parties on request.

Should you have questions or need additional information, please contact me on (202) 275-1441. Duane G. Fitzgerald, Assistant Director, was the major contributor to this fact sheet.

Sincerely yours,



Victor S. Rezendes
Director, Energy and
Science Issues

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DOE	Department of Energy

Background

Plutonium, one of the materials used in nuclear weapons, does not occur naturally, so it has had to be produced. However, plutonium is no longer produced for use in nuclear weapons in the United States. Instead, DOE processes and recycles the plutonium that remains as scrap or residue from plutonium production and processing and the plutonium that is in retired nuclear weapons.

Plutonium scrap or residue occurs because the processes used to prepare plutonium metal for weapons components are not 100 percent efficient. Nor is plutonium processing totally efficient. That is, not all of the plutonium that goes into the process comes out as the desired end product. The terms "scrap" or "residue" refer both to the plutonium itself that is not the desired product (e.g., processed plutonium not meeting specifications for weapons components and plutonium left over from machining and shaping processes) and to articles containing plutonium (e.g., items used for shaping, molding, and containing molten plutonium; filters used to collect plutonium-bearing dust; and miscellaneous paper and plastic materials used for handling and storing plutonium). Appendix II provides a more detailed description of scrap or residue materials. For simplicity, we will refer to such materials as scrap.

The largest quantity of plutonium scrap is at the Rocky Flats Plant because that is where the weapons components were actually manufactured. Some scrap material has accumulated at Los Alamos, where nuclear weapons are designed and developed, and at the Savannah River Site and the Hanford Site, where the plutonium was originally produced in nuclear reactors. Some of the scrap generated at Rocky Flats has been shipped to the other sites for processing.

The decision as to whether or not a particular type of scrap will be processed to recover plutonium depends on how the cost to process the plutonium compares with the cost to dispose of the scrap as radioactive waste. It also depends on the need for weapons-grade plutonium. And, finally, it is also important to consider whether the processing can be done at the facility where the scrap is stored or whether the scrap can be taken economically and safely to another facility.

The supply of plutonium for processing also comes from retired nuclear weapons. The Department of Defense returns nuclear weapons to DOE to be dismantled. The plutonium components are removed from the weapons and can then be processed.

In our view, two conditions currently affect DOE's plutonium processing and will affect its future. One is the degeneration of the facilities in the nuclear weapons complex. Today, the complex is virtually shut down for safety and environmental problems. This includes plants that formerly processed plutonium. In addition, the ending of the Cold War will likely translate to the need for fewer nuclear weapons. Therefore, less plutonium will be needed and possibly fewer facilities.

Plutonium Processes

DOE's processes for recovering and purifying plutonium fall into two broad categories: aqueous and pyrochemical. Aqueous processing involves the use of water and is carried out at low temperatures. Pyrochemical processing does not involve water and is carried out at higher temperatures. Aqueous processing of the type discussed in this study was employed on a large scale in the early 1950s. Pyrochemical processing was developed more recently but has been in use for about 25 years. Although both types of processes have been improved, they remain basically the same as they were when first developed.

DOE uses both an aqueous process and five pyrochemical processes. The central feature of aqueous processing, the purification step, is the separation of a plutonium compound from other constituents that enter the process. The two methods used for this are solvent extraction and ion exchange. The five pyrochemical processes that DOE uses are bomb reduction (also known as the thermite process), direct oxide reduction, molten salt extraction, electrorefining, and scrub alloy production.

Bomb reduction and electrorefining are the only processes that usually produce pure[1] plutonium. Aqueous processes yield a product that requires bomb reduction to produce pure plutonium. Molten salt extraction and direct oxide reduction generally require subsequent electrorefining. Scrub alloy production converts scrap from other pyrochemical processes to a product that can then undergo aqueous processing. Thus, all of these processes work in some combination with each other, depending on the plutonium material that must be processed.

Aqueous Processing

Aqueous processing is used to separate plutonium from other materials so that a purified plutonium compound emerges. As mentioned, this compound must undergo a pyrochemical process in order to obtain plutonium in the pure metal form needed for making weapons components.

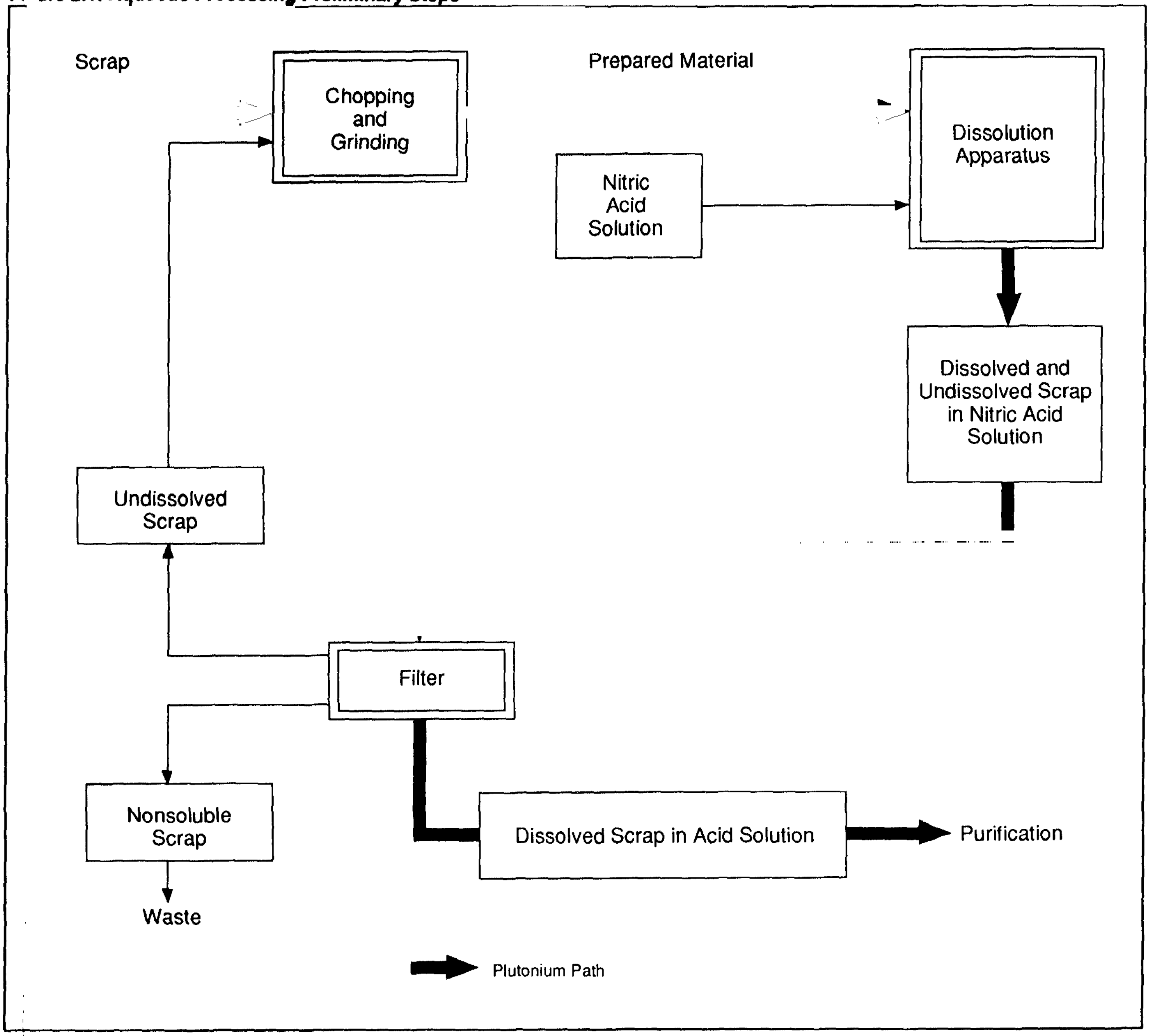
Preliminary Steps

The first step in an aqueous process is to dissolve the scrap material. But before the dissolution begins, the material to be processed must be chopped, ground, or powdered so that there are no large pieces or so that pieces are of a uniform size. The prepared material is then put into a dissolution apparatus with a strong solution of nitric acid, other solvents,

[1]The word "pure" is used to describe plutonium metal that satisfies specifications for use in weapons components.

and water. For certain kinds of scrap, hydrochloric acid is used in place of nitric acid. Because not all of the scrap will be dissolved in this step, the resulting solution must be filtered to remove the remaining solid material, which may then be returned to the beginning of the process or stored as scrap or waste. (See fig. 2.1.)

Figure 2.1: Aqueous Processing Preliminary Steps



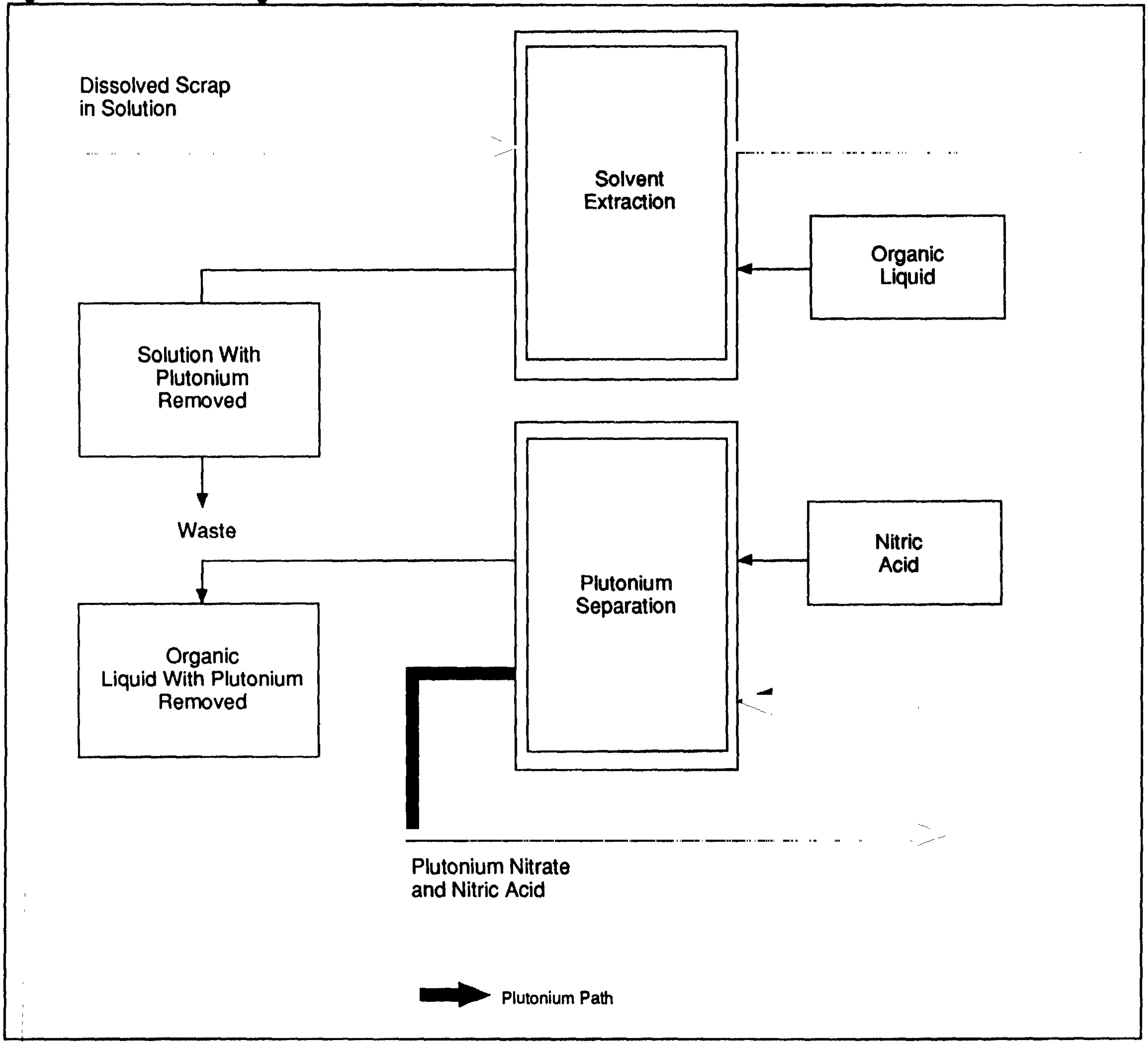
Purification Step

The next step is the separation of the plutonium compound from the other compounds in the solution by means of either solvent extraction or ion exchange. All aqueous processes use one of these two methods to purify the plutonium.

Solvent Extraction

In solvent extraction, the dissolved scrap is mixed with an organic liquid, which selectively attracts the plutonium from the compound. The organic liquid, along with the plutonium it has attracted, is subsequently separated from the mixture. Then the purified plutonium is removed from the organic liquid by a weak nitric acid solution or other chemical solution that has the same effect. The plutonium is then in a solution that is free of undesirable materials. (See fig. 2.2.)

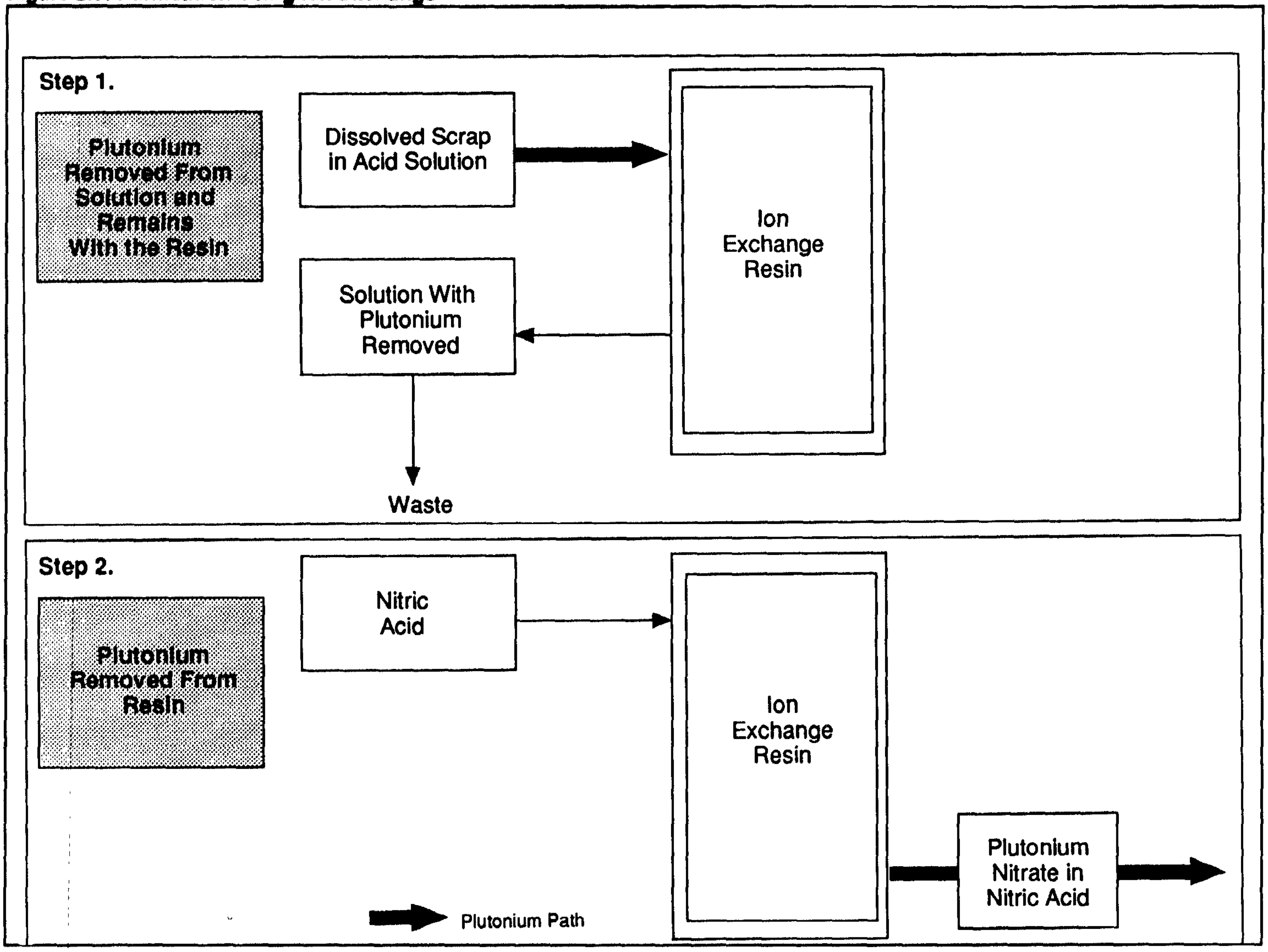
Figure 2.2: Purification Using Solvent Extraction



Ion Exchange

In ion exchange, the dissolved scrap is passed through a resin that selectively captures the plutonium from the compound on its surface. The purified plutonium is subsequently removed from the resin by washing it with a weak nitric acid solution or another chemical solution that has the same effect. This plutonium is then in a solution that is free of undesirable materials. (See fig. 2.3.)

Figure 2.3: Purification Using Ion Exchange



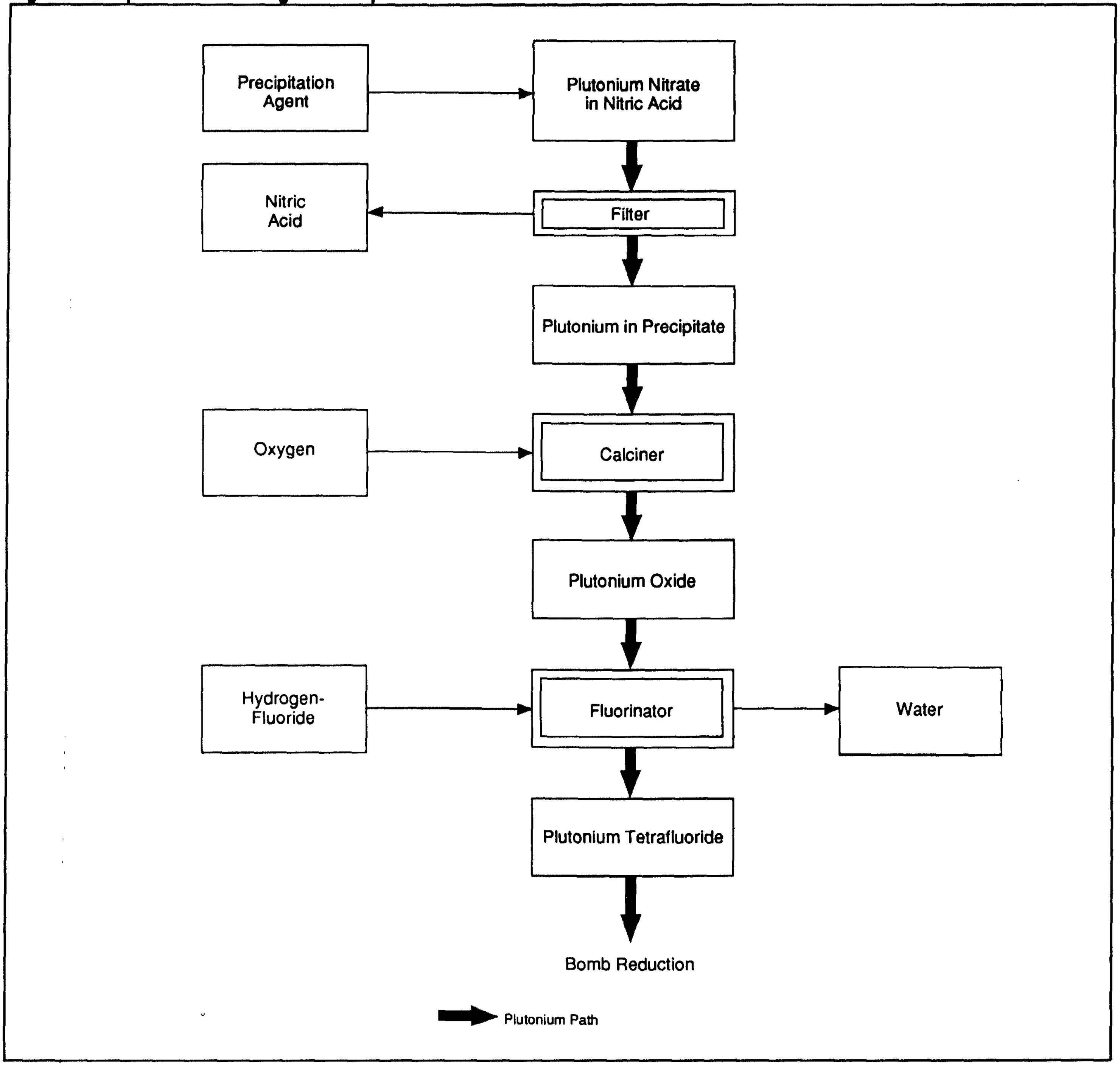
Final Steps

Following the purification step, by either solvent extraction or ion exchange, the plutonium is removed from the solution in which it is carried. Adding a chemical compound to the solution that combines with the plutonium forms a new compound that is not soluble and therefore precipitates from the solution. The precipitate containing the plutonium is collected on a filter for further processing. Depending on the chemical used to precipitate the plutonium, the remainder of the procedure may be done either of two ways, but the end result is the same.

In one type of process, the plutonium precipitate is next put into a calciner, a vessel in which the plutonium is heated and dried, and the plutonium is combined with oxygen to make plutonium oxide. Next, the plutonium oxide is reacted with hydrogen-fluoride gas, and plutonium tetrafluoride and water are formed. Plutonium tetrafluoride is the chemical compound needed for the pyrochemical process, bomb reduction, that follows. (See fig. 2.4.)

In another type of process, the precipitation is caused by adding hydrofluoric acid to the plutonium solution. The resulting precipitate is plutonium trifluoride. The plutonium trifluoride is dried and then heated in an oven with oxygen. This operation converts the plutonium trifluoride to a mixture of plutonium tetrafluoride and plutonium oxide. This mixture is used in the bomb reduction process.

Figure 2.4: Aqueous Processing Final Steps



Pyrochemical Processing

All of the pyrochemical processes—bomb reduction, direct oxide reduction, molten salt extraction, electrorefining, and scrub alloy production—are carried out in a furnace and, except for scrub alloy production, have plutonium metal as the end product. Although the objective of pyrochemical processing is to obtain uncontaminated plutonium metal, the products of molten salt extraction and direct oxide reduction generally, although not always, require additional refining. Scrub alloy production generates an intermediate material that can then undergo further aqueous processing to get the metal.

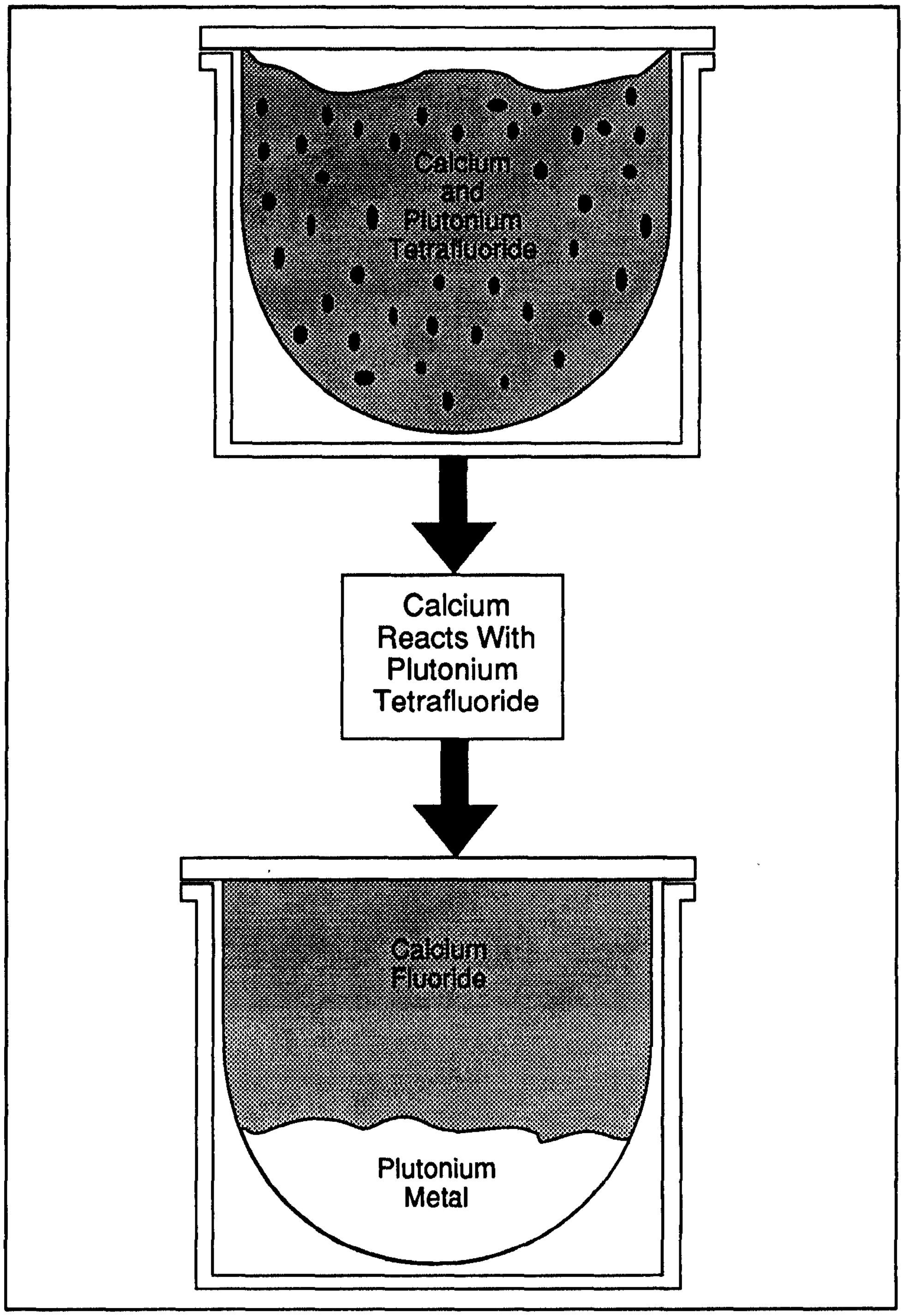
Bomb Reduction

Bomb reduction is the process used to get plutonium metal from plutonium tetrafluoride. The reduction is accomplished by stimulating a chemical reaction between plutonium tetrafluoride and calcium metal. These substances are put in a crucible[2] and then sealed in a pressure vessel. The pressure vessel is then placed in a furnace and heated until the reaction occurs. Generally, the products of this reaction are pure plutonium metal and calcium fluoride. (See figs. 2.5, 2.6, 2.7, and 2.8.)

Bomb reduction is also used to get plutonium from mixtures of plutonium tetrafluoride and plutonium oxide. The process is like that described in the preceding paragraph except that the products of the reaction are plutonium metal, calcium fluoride, and calcium oxide.

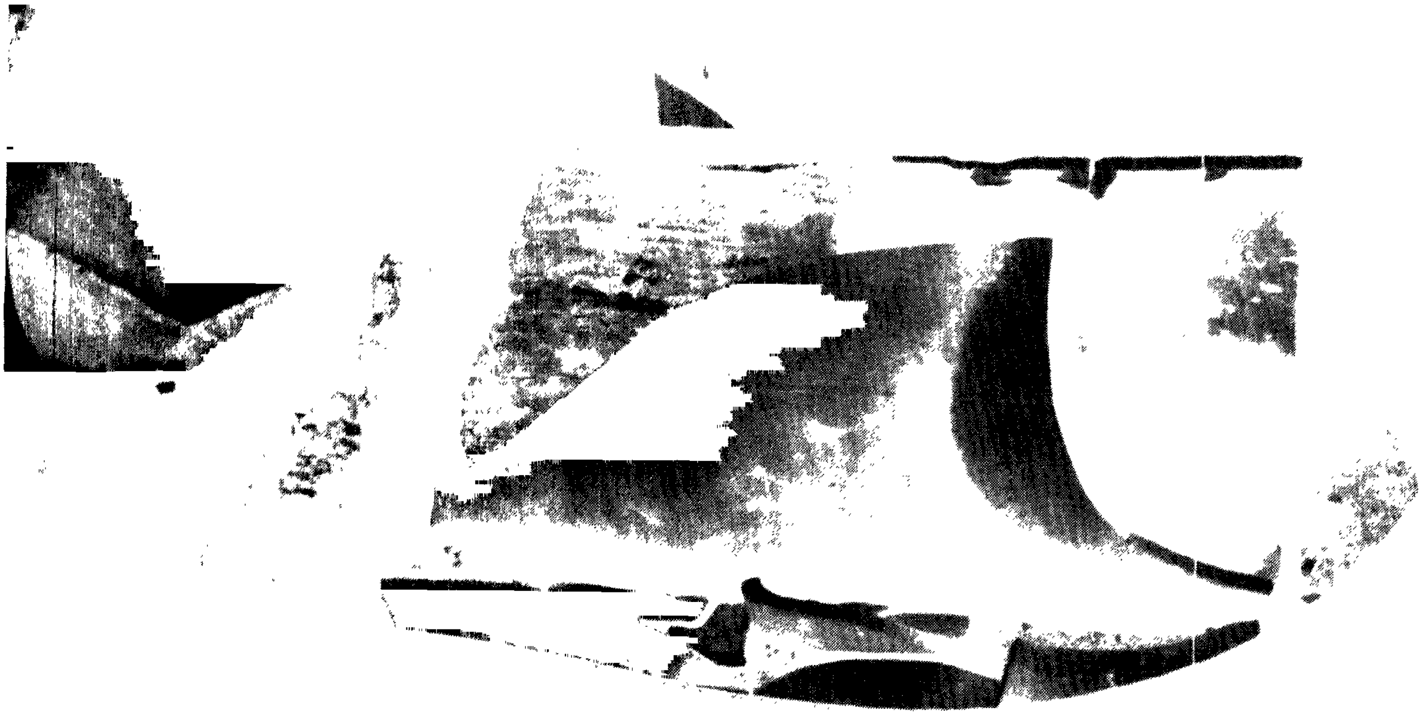
[2]A crucible is a container used for melting materials at high temperatures.

Figure 2.5: Bomb Reduction



Source: GAO artwork created from DOE source.

Figure 2.6: Bomb Reduction Crucible Broken to Remove the Plutonium

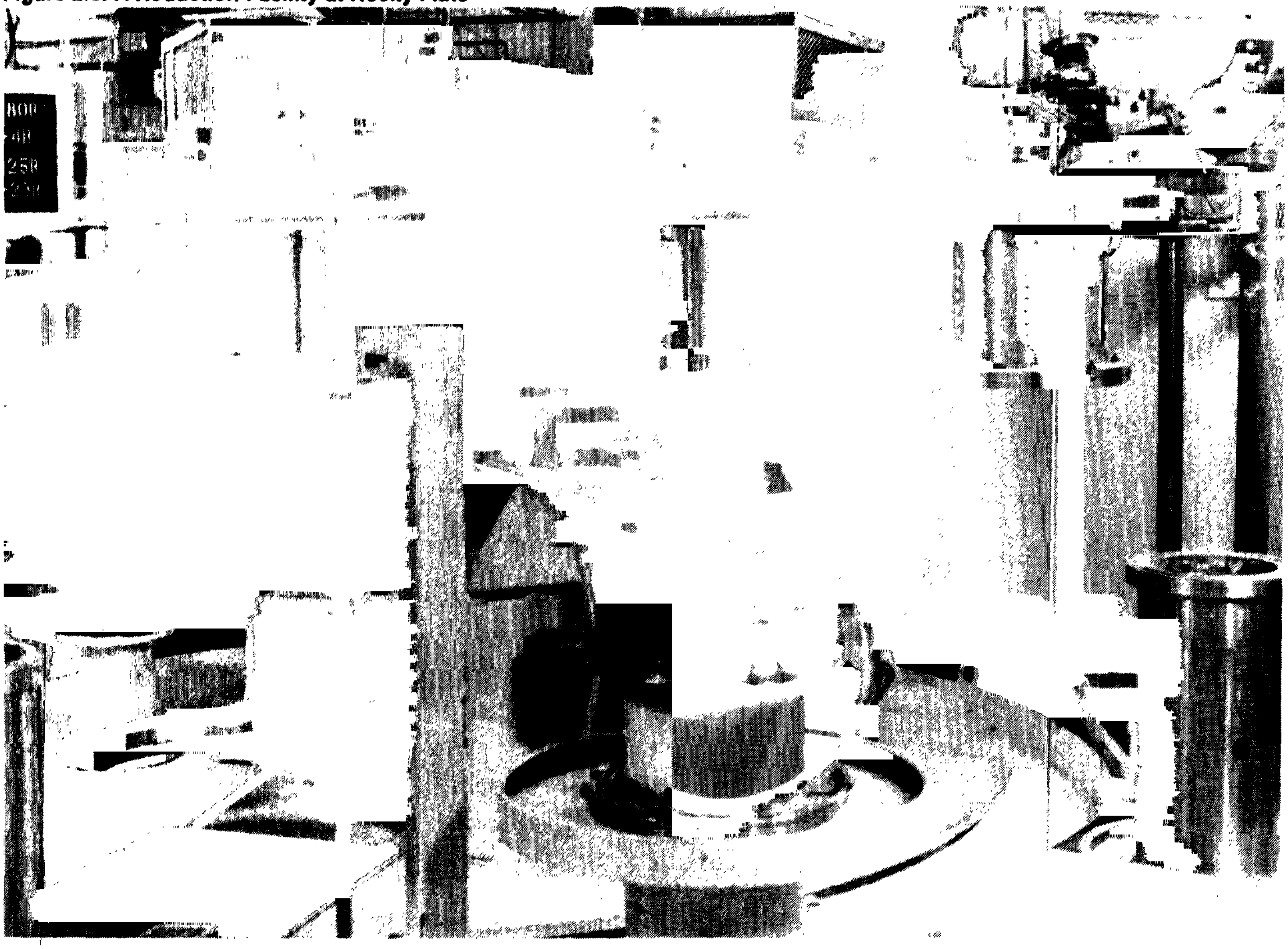


Source: DOE.

Figure 2.7: Technician at Rocky Flats Inspecting a Plutonium-239 Button

Source: DOE.

Figure 2.8: A Reduction Facility at Rocky Flats



Source: DOE.

The bomb reduction process has two disadvantages. First, one of its ingredients, plutonium tetrafluoride, emits neutron radiation. Second, preparation of that compound involves the use of hazardous hydrogen-fluoride gas. Special safety precautions have to be taken to avoid worker exposure to the radiation or to the gas.

Another process, which avoids the use of plutonium tetrafluoride, is direct oxide reduction. It begins with plutonium oxide, which is an intermediate product in the process of making plutonium tetrafluoride.

Direct Oxide Reduction

In the direct oxide reduction process, plutonium oxide is mixed with calcium metal in a crucible. The crucible is placed in a furnace, and the mixture is heated to a molten condition and vigorously stirred. In this condition, the oxide reacts with the calcium to form calcium oxide and plutonium metal. After the stirring is stopped, the metal settles to the bottom of the crucible.

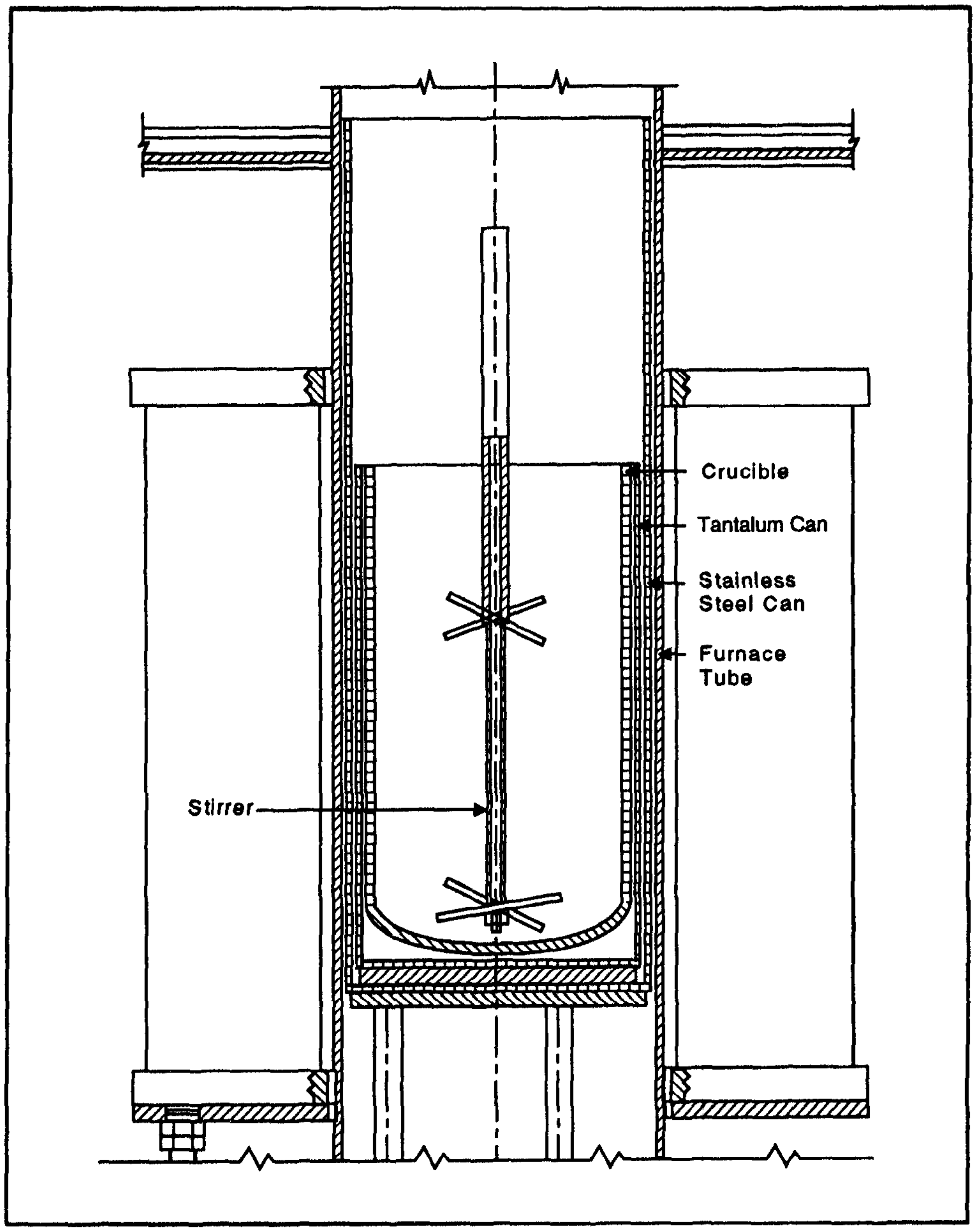
The disadvantages of direct oxide reduction are that the plutonium metal is not pure enough to be used directly for weapons components and that the residual calcium oxide retains a significant amount of plutonium. The metal must be further purified by electrorefining, and the calcium oxide must be saved to recover the plutonium. Because of these disadvantages, the direct oxide reduction process is not currently in general use. However, an improved process that overcomes many of the disadvantages, called multicycle direct oxide reduction, has been researched and demonstrated.

Molten Salt Extraction

Another process that may require subsequent electrorefining is molten salt extraction. This process is used to remove americium-241 from plutonium components of nuclear weapons. After nuclear weapons have aged for several years, they accumulate a radioactive element, americium-241, which is the product of the radioactive decay of plutonium-241. The presence of the americium-241 increases the radiation hazards from handling the weapons. When weapons are retired, however, the americium-241 can be removed and the plutonium reused. Although an aqueous process can be used to separate americium from plutonium, molten salt extraction is the preferred process.

In molten salt extraction, the plutonium metal with the americium in it is mixed with a combination of salts, such as sodium chloride, potassium chloride, magnesium chloride, or calcium chloride. This mixture is put into a crucible and heated in a furnace until the mixture of salts and metal becomes molten. While the molten mixture is being stirred, the americium reacts with the salts to form americium chloride. Then the plutonium metal, with the americium removed, settles to the bottom of the crucible. (See fig. 2.9.)

Figure 2.9: Apparatus Used for Direct Oxide Reduction and Molten Salt Extraction



Source: GAO artwork created from DOE source.

After cooling and removal from the furnace, the crucible is broken to remove the contents. The plutonium metal is then separated from the hardened salts, which now contain the americium chloride and some residual plutonium. The leftover salts and the used crucible are saved and stored so that the plutonium in them can be recovered.

The purity of the plutonium product from the molten salt extraction process depends on the quality of the input material. Because many impurities are not removed by the process, further purification is usually required. The final purification is done using another pyrochemical process, electrorefining.

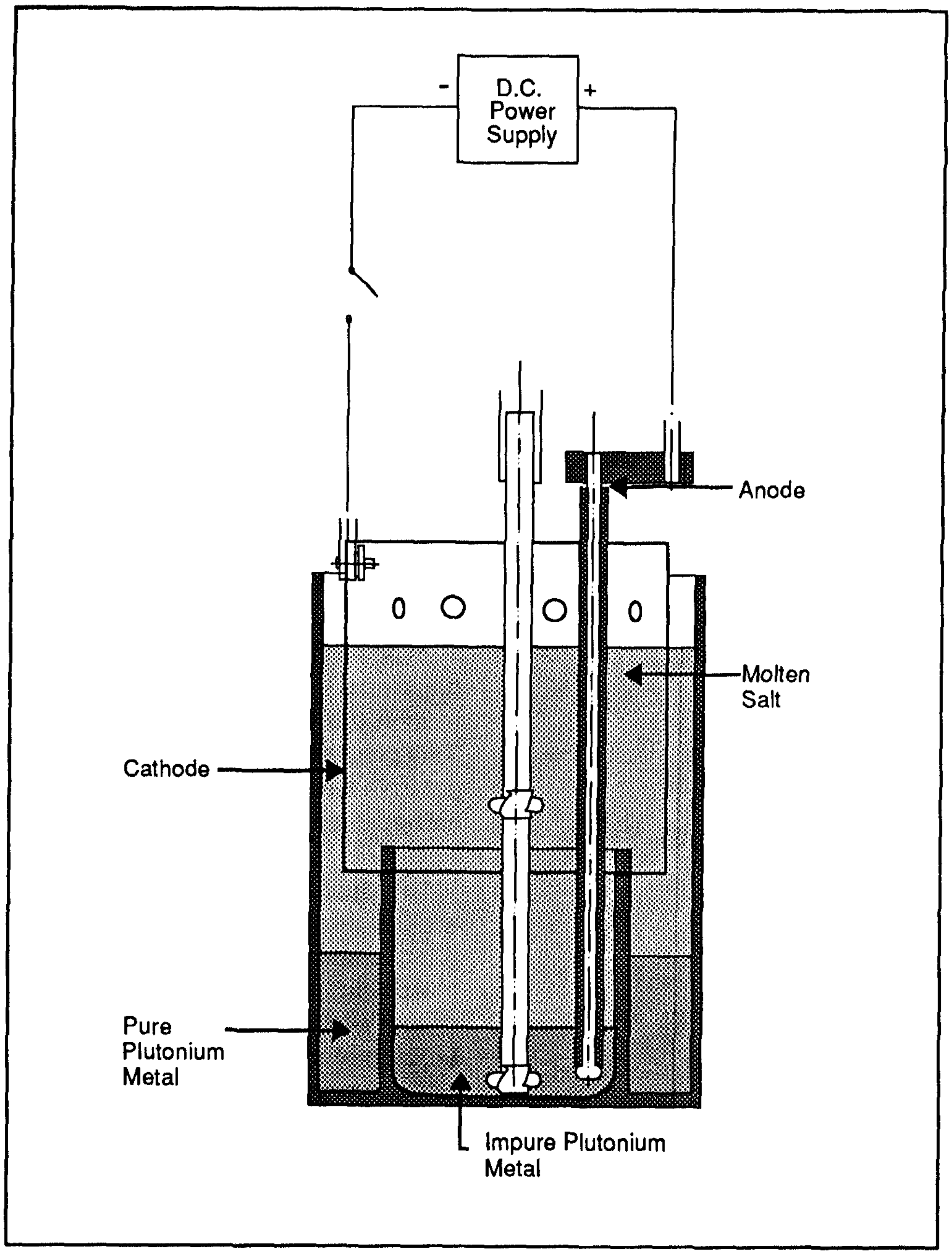
Electrorefining

Electrorefining, as the name implies, uses a controlled electric current to produce pure plutonium that is acceptable for use in weapons components. Like the other pyrochemical processes, the purity of the plutonium metal produced depends on the purity of the initial plutonium. The ingredients are a mixture of salts, such as magnesium chloride, potassium chloride, and sodium chloride, and plutonium metal mixed or alloyed with other metals that are undesirable. An electrorefining apparatus consists of a crucible for containing the ingredients, a furnace to melt the ingredients, a motor-driven stirrer, and an electrorefining cell. This cell, which operates immersed in the molten ingredients, consists of a positive electrode, called the anode; a negative electrode, called the cathode; and a cup for collecting the purified metal.

In the electrorefining process, an electric current passes between the anode and the cathode. The current is controlled in such a way that the plutonium is carried through the molten solution to the cathode, where the plutonium is collected in the cup. The other metals remain in the solution or move to the anode. The electrorefining process is continued until the buildup of unwanted metals at the anode begins to reduce the effectiveness of the process.

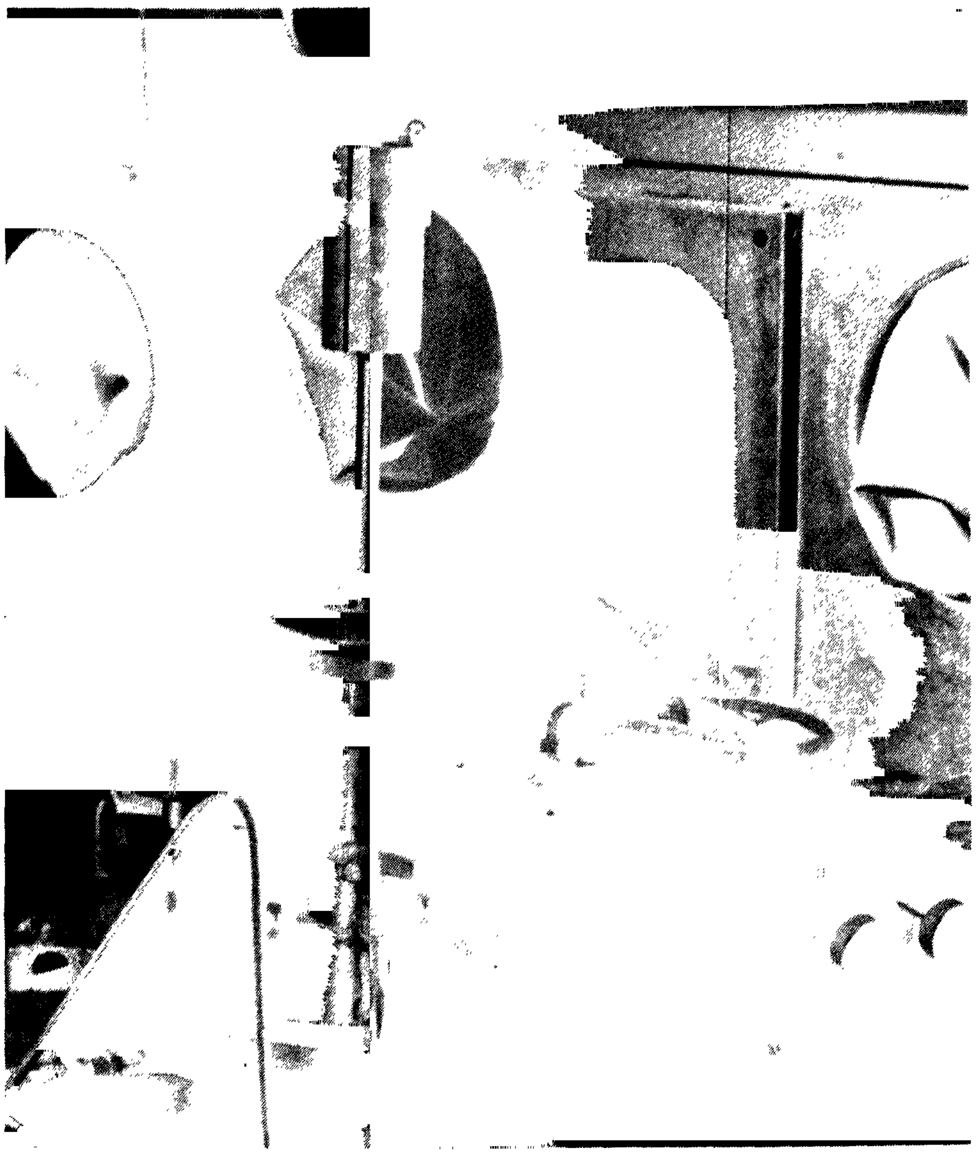
After the electrorefining cycle is done, the furnace is cooled and the cup containing the plutonium is broken away from the other materials. The pure plutonium is saved for future use. The solidified salt and the crucible parts are saved and stored for future processing to recover residual plutonium. (See figs. 2.10 and 2.11.)

Figure 2.10: Simplified Diagram of Electrorefining Equipment



Source: GAO artwork created from DOE source.

Figure 2.11: An Electrorefining Cell



Source: DOE.

Production of Scrub Alloy

Scrub alloy production is employed as an interim step between other pyrochemical processes and an aqueous process. The scrap plutonium in the chloride salts that are formed during electrorefining and molten salt extraction cannot be dissolved by using nitric acid. Therefore, these salts must undergo an intermediate process to produce a soluble material.

The salts are mixed with aluminum metal in a crucible and heated until the mixture is molten. As the molten mixture is stirred, the plutonium alloys with the aluminum. The alloy then settles to the bottom of the crucible. After cooling, the excess aluminum and the chloride salts are separated from the alloy and processed as waste.

Now the aluminum-plutonium alloy—the scrub alloy—can be put through a nitric-acid-based aqueous process to separate out and purify the plutonium.

Plutonium Processing Facilities

Four sites in DOE's nuclear weapons complex have facilities that use or have used the plutonium processes described in section 2. These same sites also formerly produced plutonium or processed it into nuclear weapons components. They are the Los Alamos National Laboratory in New Mexico, the Rocky Flats Plant in Colorado, the Savannah River Site in South Carolina, and the Hanford Site in Washington State. Before sites and facilities were shut down for environmental and safety reasons over the last several years, each of the four sites had the capability to process retired weapons components or the different kinds of plutonium scrap. All four sites used aqueous processing and bomb reduction but varied in their use of the other pyrochemical processes. (See fig. 3.2.)

Los Alamos National Laboratory

The Los Alamos National Laboratory, which designs and develops nuclear weapons containing plutonium, uses aqueous processing, followed by bomb reduction and three other pyrochemical processes. It processes its own scrap from earlier plutonium processing activities and scrap from Rocky Flats. Currently, it is the only facility processing plutonium.

Los Alamos uses both solvent extraction and ion exchange in its aqueous processing and the pyrochemical processes of bomb reduction, molten salt extraction, and electrorefining. In addition, Los Alamos is the only facility that is using the direct oxide reduction process. Multicycle direct oxide reduction has been researched and is being demonstrated there.

For the initial dissolving of scrap from the electrorefining and molten salt extraction processes (plutonium in chloride salts), Los Alamos uses a chloride-based solvent, such as hydrochloric acid. Because the chloride-based solvents are very corrosive, the equipment is made of corrosion-resistant plastic and glass. Los Alamos then uses solvent extraction or ion exchange, followed by a conversion to plutonium tetrafluoride and finally bomb reduction. For other materials, such as foundry oxides, incinerator ash, cleaning materials, and metal parts, Los Alamos uses ion exchange, after having dissolved the scrap with nitric acid.

Sixteen of Los Alamos' pyrochemical furnaces are used for direct oxide reduction, electrorefining, and molten salt extraction. Six of them are used for research and development of the direct oxide reduction processes, and the other 10 are used for electrorefining and molten salt extraction. Los Alamos has other furnaces that are used for bomb reduction.

Rocky Flats

Rocky Flats, the site where nuclear weapons components were produced, has used aqueous processing, followed by bomb reduction and three other pyrochemical processes. It processed both retired weapons that were sent there and scrap from its weapons production. Building 707, where the final alloying, molding, shaping, and machining of the weapons components was done, produced much of the scrap. All plutonium processing operations for recovering metal are currently shut down and are not expected to be resumed.

Plutonium processing at Rocky Flats was conducted in two buildings—one for aqueous processing by means of ion exchange, followed by bomb reduction, and the other for the pyrochemical processes of electrorefining, molten salt extraction, and scrub alloy production. Molten salt extraction was used to remove the americium from retired weapons sent to Rocky Flats. Because the plutonium from this process is generally not pure, electrorefining was used to remove the contaminants. Scrub alloy was produced to recover plutonium from the chloride salts formed during the pyrochemical processes.

Rocky Flats' aqueous processing and bomb reduction were conducted in building 771, which may not be restarted for plutonium metal recovery. According to a DOE official, building 771 has five nitric-acid-based aqueous processing lines that include ion exchange. However, two of the lines are not operational, and, as of November 1991, the remaining three were shut down for repairs and upgrades.

Rocky Flats' pyrochemical processes of molten salt extraction, electrorefining, and scrub alloy production were conducted in building 776/777, which is not expected to be restarted. The building has 16 furnaces that can be used for these processes; however, the equipment that goes into the furnace varies with each process. According to the project manager, about 70 percent of the furnace time was used for electrorefining (which requires a great deal of furnace time), 20 percent for molten salt extraction, and 10 percent for scrub alloy production.

Savannah River

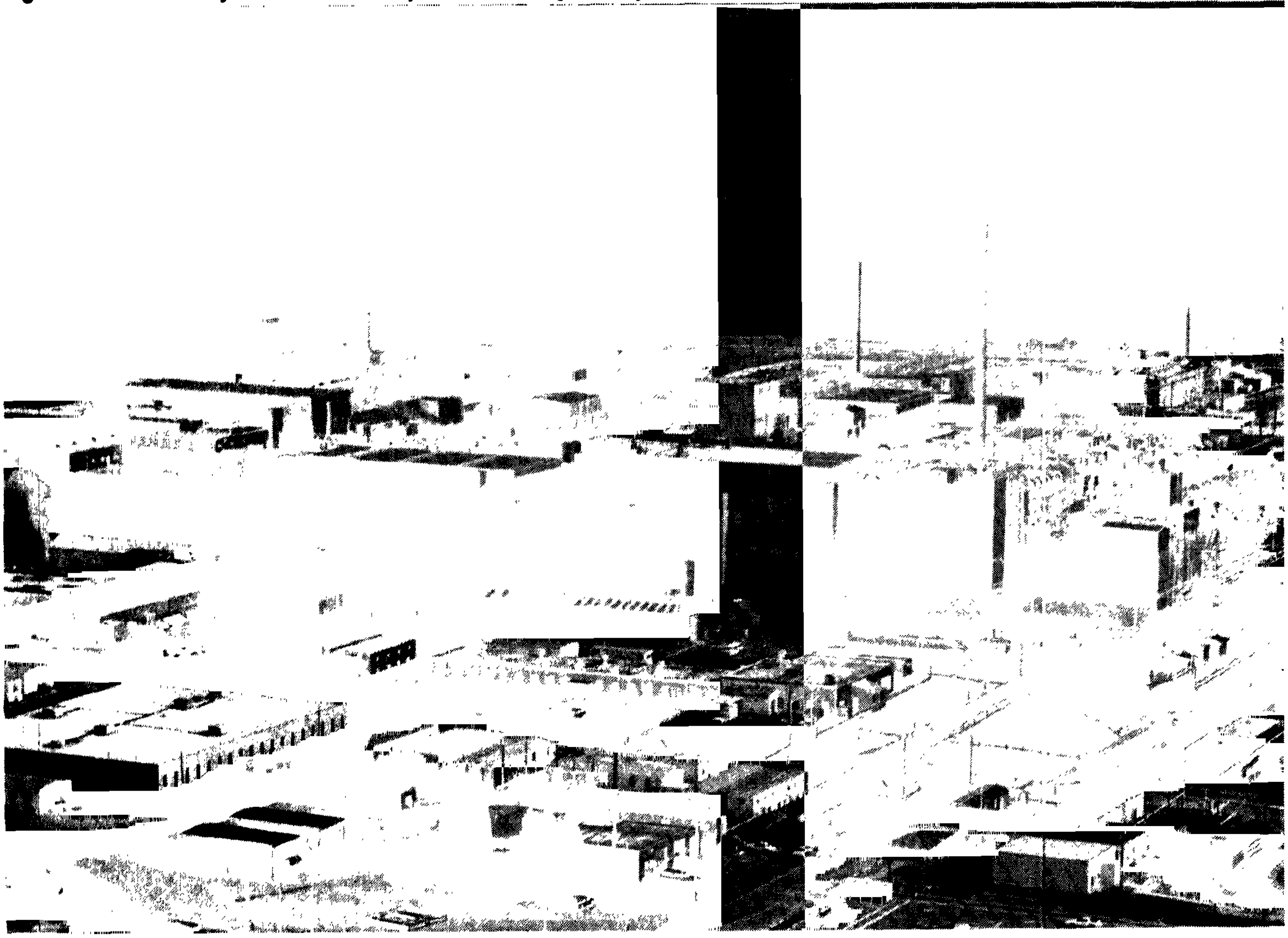
Savannah River, one of two sites that produced plutonium in nuclear reactors, used only aqueous processing and bomb reduction. Savannah River has processed plutonium scrap from other parts of the defense complex. It is also the only site in the complex that processed scrub alloy. However, its facilities are currently shut down, and future use of the facilities will depend on what is to be done with plutonium scrap, how much plutonium will be needed, and how the defense complex will be reconfigured.

The facilities at Savannah River for processing plutonium are the F-canyon[1] and the New Special Recovery Facility. The F-canyon was designed for separating newly produced plutonium from unused uranium and radioactive waste. The F-canyon, which may be restarted, houses facilities for aqueous processing using solvent extraction, followed by bomb reduction. The end product of solvent extraction, plutonium nitrate, was then piped to the FB-line within the F-canyon. Here the plutonium was precipitated from the solution and made into a mixture of plutonium oxide and plutonium tetrafluoride. Bomb reduction was then used to get pure plutonium metal from the mixture. Although the F-canyon is currently shut down while operating procedures and equipment are being improved, plutonium processing may be started up again when the improvements are done.

The New Special Recovery Facility has been constructed on top of the F-canyon but is not expected to be put into service. It has two processing lines—one to process metal; the other, oxides. The end product from this facility was to be piped back to the FB-line for final processing. Although the plant was to recover plutonium from scrap throughout the weapons complex, according to a DOE official, a decision has been made not to put the New Special Recovery Facility into service. For one reason, the processing that needs to be done can be done at other facilities. In addition, by not putting the facility into service, DOE avoids contaminating it. Once it is contaminated, the facility would, at the end of its useful life, likely have to be decontaminated at a high cost.

[1]The "F" refers to a geographical area in the Savannah River Site, and "canyon" loosely describes the long, narrow, and rectangular building.

Figure 3.1: The F-Canyon and the New Special Recovery Facility



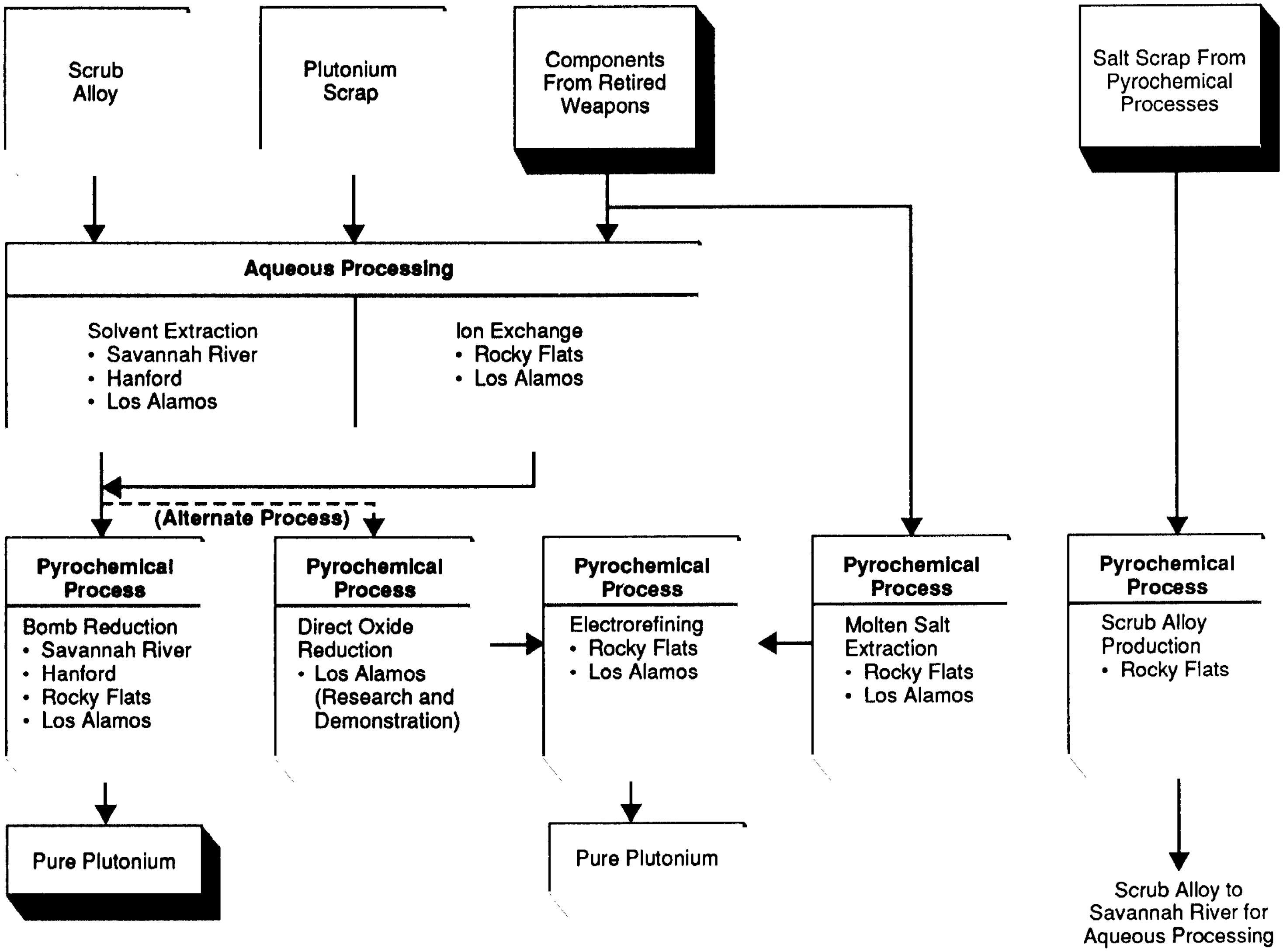
Source: DOE.

Hanford

The Hanford Site, which is the other site that produced plutonium in nuclear reactors, similarly used only aqueous processing, followed by bomb reduction. It, too, processed the scrap from the plutonium production. However, its plutonium processing plant has been shut down pending a redefinition of its mission.

Hanford's plutonium processing was done at the Plutonium Finishing Plant, which has two divisions: the Plutonium Reclamation Facility and the Remote Mechanical C-line. The Plutonium Reclamation Facility used solvent extraction. The end product of this process, plutonium nitrate, was then sent to the Remote Mechanical C-line. There the plutonium was precipitated from the nitrate solution and then made into plutonium tetrafluoride. Bomb reduction was used to get pure plutonium metal from the plutonium tetrafluoride.

Figure 3.2: Summary Diagram of Plutonium Processing Relationships and Locations



Objectives, Scope, and Methodology

In response to a September 6, 1991, request from the Chairman, Environment, Energy, and Natural Resources Subcommittee, House Committee on Government Operations, we reviewed DOE's methods and facilities for processing plutonium, either to purify or recover plutonium for the fabrication of new weapons components or to reduce the backlog of plutonium residues to a better form for storage.

Our review included the Los Alamos National Laboratory, near Santa Fe, New Mexico; Rocky Flats Plant, near Denver, Colorado; Savannah River Site, near Aiken, South Carolina; and Hanford Site, near Richland, Washington.

The information used in this study was obtained from

- technical documents that describe plutonium processing in general,
- safety analyses of specific systems,
- interviews with DOE headquarters officials responsible for managing the production of nuclear materials and weapons, and
- interviews with technical staff responsible for plutonium processing at the DOE facilities in the field.

Sources of Plutonium Residue and Scrap

Throughout DOE's complex, over 100 different types of plutonium residues are generated—about 100 specific types at Rocky Flats alone. Plutonium concentrations vary from less than 0.01 percent in contaminated materials to greater than 99 percent in impure plutonium metal. For the purposes of this report, the various types of scrap or residue are compiled into 14 general categories.[1]

Graphite

Typical residue types in this category include

- crucibles, molds, and shapes;
- scrapings, fines, and powder; and
- filters.

Combustibles

Residue types that make up this category include

- cotton and paper wipes;
- paper and cardboard;
- polyvinylchloride plastic, polyethylene, vinyl, Teflon,[2] and other nonpolyvinylchloride plastic material;
- mixed and wet combustibles; and
- filter segments.

Incinerator Ash

Residue types that make up this category include

- fresh and aged virgin ash,
- recalcined ash, and
- fluidized bed ash.

Heels

Residue types that make up this category include

- grit;
- sand, slag, and crucible heels;
- incinerator ash heels;
- soot and soot heels;
- filter residues; and

[1]Material in this appendix was excerpted from Evaluation of Existing Head-End Plutonium Residue Processes in the Defense Program Complex, Westinghouse Hanford Co. (WHC-SP-0324, June 1988).

[2]Teflon is a trademark of E.I. DuPont de Nemours and Company, Inc.

- hydroxide precipitates.

Sand, Slag, and Crucible

Sand, slag, and crucible are the residues from the calcium reduction of aqueous process end products.

Filters and Insulation

Residue types that make up this category include

- high efficiency air particulate filters,
- CWS filter,
- asbestos, and
- heating mantles.

Ceramics

Typical residue types that make up this category include

- magnesium oxide crucibles,
- zirconium oxide crucibles, and
- miscellaneous crucibles.

Scrap Metal

Scrap metal includes processing equipment and glovebox parts. Special research and development projects may also yield scrap metal. The scrap may be heavy metals such as tantalum, tungsten, platinum or lead; light metals such as iron, copper, or aluminum; nonferrous alloy metals such as zinc-magnesium, lithium-aluminum, or magnesium-aluminum; or stainless steel.

Glass

Typically these materials are processed by leaching.

Residue types that make up this category include

- glass,
- raschig rings,
- fused silica, and
- some plastics.

Chloride Salts

This category includes chloride salt residues from molten salt extraction, electrorefining, and direct oxide reduction.

Impure Plutonium Metal

Impure metal arises from the following sources:

- plutonium from returned weapons (site returns),
- reject buttons from molten salt extraction processing of site returns,
- reject buttons from the plutonium fluoride-calcium metal reduction process,
- plutonium fabrication scrap,
- metallurgical development programs, and
- spent anodes (anode heels) from electrorefining.

Typical residues types that make up this category include

- Plutonium metal turnings, buttons and pieces;
- alloyed metal turnings, buttons, and pieces;
- direct oxide reduction buttons;
- nonroutine electrorefining plutonium metal; and
- anode heels.

More Than 85 Percent Oxide

Plutonium oxide containing more than 85 percent plutonium has several sources:

- Hanford Site "PUREX oxide" produced via oxalate precipitation and calcination,
- "foundry oxide" produced via oxidation of molten plutonium metal in foundry operations at both Rocky Flats and Los Alamos, and
- oxide produced via peroxide precipitation at Rocky Flats and oxalate precipitation at Los Alamos. The precipitation is followed by calcination.

Less Than 85 Percent Oxide

Residue types that make up this category include

- impure oxalate-precipitated oxide,
- impure peroxide-precipitated oxide,
- foundry oxide (burned metal),
- mixed screenings and sweepings,
- glovebox sweepings,
- leached oxide, and
- burned furnace scrape-outs.

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