

Development of Pu-239 Processes and Facilities

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Abstract

During the last several decades, the Savannah River Site (SRS) substantially contributed to the DOE mission success by safely operating and continuously improving the processes and facilities used to make plutonium metal used in nuclear weapons. This paper addresses the noteworthy improvements that contributed to the success of the Pu-239 finishing processes—those that convert plutonium solution produced from recovery of plutonium from irradiated reactor targets into high-quality plutonium metal. The SRS contribution has been to take laboratory-proven processes and convert them into production-proven processes that can safely and efficiently meet DOE mission requirements. The success speaks for itself. *First*, the SRS finishing facilities remain the only Pu-239 production capability in the nation. *Second*, the plutonium efficiency, low waste generation, and excellent product quality from these facilities is unmatched. *Third*, SRS is the only major DOE processing site without a nuclear criticality incident. *Fourth*, although originally built for producing plutonium metal, SRS demonstrated processes that can convert surplus nuclear weapons into oxide for use in fuels. *Fifth*, through SRS equipment and process engineering improvements, the process capacity increased to several times of the original facility design. *Sixth*, the SRS safety record is unmatched.

Overview

The Pu-239 finishing processes convert dilute plutonium solution from solvent extraction processes to a high-purity metal ingot, or button, of plutonium suitable to cast as weapons parts. During World War II, plutonium-finishing technology developed rapidly from the microgram to the multi-hundred gram scale. The initial finishing strategy, which lasted until several years after World War II, was to ship plutonium nitrate solution, produced at Hanford, to the Los Alamos Site, where it was converted into finished product metal. Cold War expansion, accelerated in the late 1940s, prompted constructing additional finishing capability at Hanford and the Savannah River Site. Included at SRS were additional reactors and new processing facilities, each with a plutonium finishing capability referred to as a B Line.

The SRS canyons and associated B Lines were the first facilities in the world where all the processes to separate plutonium from irradiated reactor elements and convert to high-purity

metal buttons were housed in one structure. The initial design of the SRS B Lines was piecemeal, pilot-scale development and lessons learned at other sites including Los Alamos, Hanford, Knolls Atomic Power Laboratory, and Oak Ridge. The challenge for SRS was to modify or adapt the processes and equipment into an integrated process to convert dilute plutonium solution into finished product plutonium metal, meeting the desired start-up capacity and product specifications. Not only was this accomplished, but, through in-plant process improvements based on gained knowledge and understanding of the process chemistry, capacity and efficiency increased significantly. In fact, the process improvements in the three original B Lines (two in F Area and one in H Area, located in the 3rd and 4th levels of the canyon) permitted shutdown of the two F-Area lines to construct the new finishing line while the single H-Area line maintained and exceeded the initial total production output of the original three lines.

The initial processes included:

- Concentration of the plutonium using cation exchange
- Precipitation using hydrogen peroxide
- Drying using warm air
- Conversion to plutonium tetrafluoride using hydrofluorination
- Reduction to plutonium metal using calcium and iodine in an induction-heated furnace

After cooling, the plutonium coalesced in the rounded bottom of the crucible to form the characteristic “button” shape (see Figure 1). A dumping operation separated the button, which



Figure 1. Plutonium metal button

was then pickled in nitric acid to remove surface contaminants and packaged for shipping. The resulting plutonium metal product was high quality, with only a small fraction requiring recycle. The slag and crucible separated from the button were packaged for transfer to a recovery process located on the fourth level of Building 221-F.

By the late 1950s, improvements increased throughput reactor fuel fabrication technology

(allowing high output per reactor) coupled with increased demand by the Defense Department. To meet this demand, a two-story finishing facility, referred to as JB Line (see Figures 2 and 3), was completed in 1959 on top of the F-Canyon building. The new JB Line used the SRS-developed trifluoride precipitation process and incorporated many facility design improvements from the lessons learned in the original B Lines. In-plant process and equipment improvements continued over the years and allowed JB Line to exceed the government requirements for product output and quality, and to adapt to changing missions. The all-time annual production output record was established in 1983, many times the original output of the initial B Lines. The following sections discuss the substantial improvements (grouped in five areas) made by SRS to the finishing processes and facilities.

Coupling (Cation Exchange)

The thermal evaporation coupling process used at Hanford had several drawbacks, including safety concerns (potential explosive components formed from entrained organic solvent) and process concerns (formation of corrosion products detrimental to the peroxide process and final product purity). The explosion of an evaporator processing uranium nitrate solution at the SRP test facility, TNX, in the early 1950s emphasized the need for an alternative process. Consequently, SRS selected a cation exchange process developed at Oak Ridge, which had several advantages: (1) capability of concentrating the canyon product fiftyfold or more; (2) additional decontamination from uranium, fission products, and anionic impurities; (3) no requirements for high temperature or pressure; (4) no mechanism for formation of explosive compounds from entrained organic solvent; and (5) ability to maintain plutonium in the three (+3) valence state, which proved to be favorable for downstream processing.

The original cation exchange process used at Savannah River Site was developed at ORNL by D.C. Overholt, F. W. Tober, D. A. Orth, and



Figure 2. Building 221-F Canyon with JB-Line

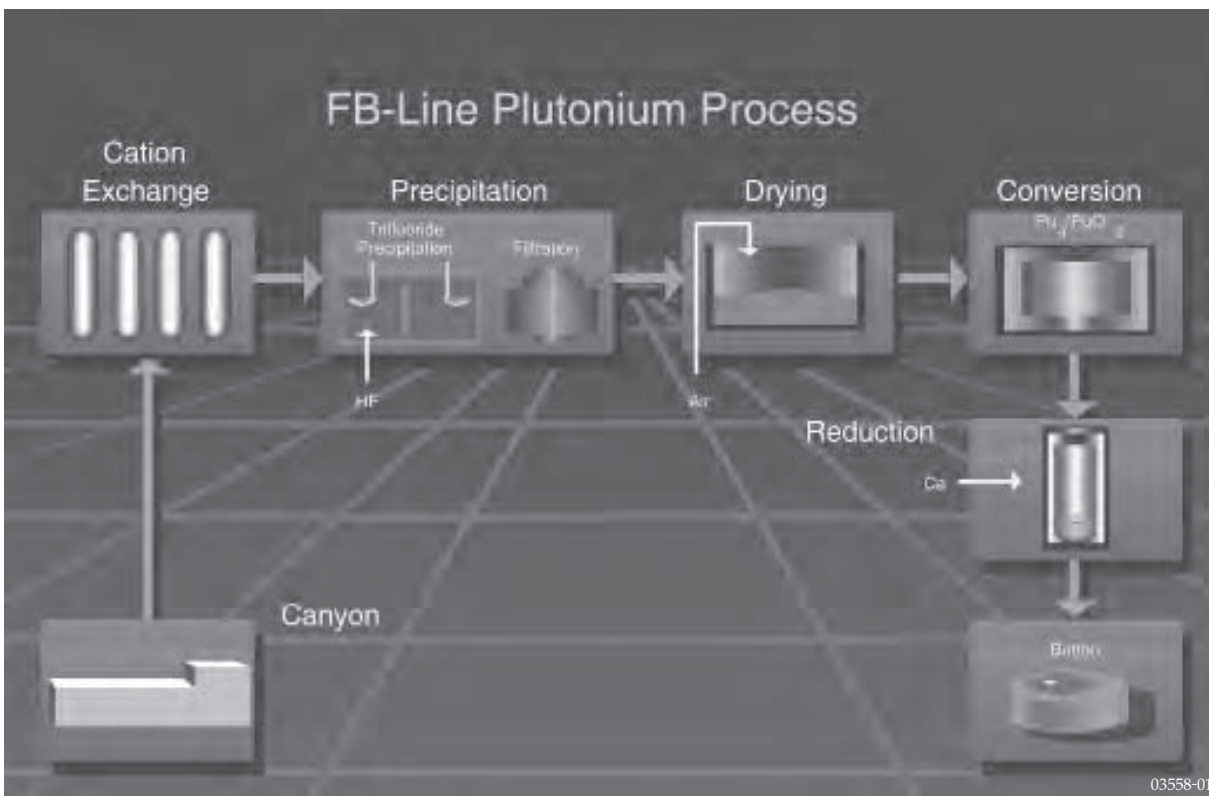


Figure 3. JB Line Finishing Process

others. The process was modified further at Savannah River by Tober and G. W. Burney. Once optimized for plant operation, the basic process has remained unchanged for nearly 50 years and is simple, reliable, and efficient. The resin used is Dowex 50, polystyrene-divinylbenzene beads with exchange sites that are strongly ionized sulfonic acid groups. The plutonium cations, in the three-valence state, exchange with the hydrogen ions during absorption in weak nitric acid solution and are removed during elution with moderate strength acid solution. The optimum resin size, 50-100 mesh, is a compromise between capacity and absorption rates versus bed pressure drop.

The columns are operated on a batch basis with counterflow absorption and elution. The dilute plutonium feed solution, produced by canyon solvent extraction, flows down through the column, until a desired load of plutonium has been absorbed. If necessary, residual uranium and fission products (ruthenium, zirconium, and niobium) that were absorbed with the plutonium are removed using a wash of dilute sulfuric acid. The plutonium is eluted (removed) from the column using an elutriant solution of 5.7 Molar nitric acid and 0.3 Molar sulfamic acid flowing up through the column. A reconditioning wash then flows up through the column to restore the low acid condition for the next absorption cycle. Specific major improvements are as follows:

1. Counterflow operation (i.e., down-flow absorption and upflow elution) was employed to obtain a nearly plutonium-free stripping section at the bottom of the column that produces an effluent waste stream with discard losses, $\ll 0.1\%$. This approach also reduced the required elution volume and permitted higher concentration in the eluted product.
2. Equipment engineering solutions were employed to increase capacity and improve safety. The use of spring-loaded compressed beds allowed normal bed expansion and contraction ($\sim 10\%$) without deforming or

damaging resin beads and without fluidizing the bed, which can reduce column operating efficiency. Increasing the column diameter (10-inch versus 7-inch) and using two short (5-inch versus 1/15-inch) beds in series shortened absorption time while maintaining favorable geometry for nuclear safety control. Using gravity feed systems for all streams fed to the columns eliminated use of a pressurized feed system and associated safety problems. Using ever-open vents alleviates gas buildup in the column, and refrigerated washes, as needed, removed gas pockets, which can reduce bed absorption efficiency.

3. Optimization of column load and elutriant compositions precluded auto-catalytic oxidation of the plutonium, which can produce rapid gas generation and pressurization of the column. The use of sulfamic acid in the elutriant provided a stable holding reductant in the moderately high acid concentration.

Precipitation

Peroxide Precipitation

The initial SRS process employed peroxide precipitation, developed at LANL. Unfortunately, the LANL flowsheet was demonstrated on concentrated plutonium solutions; hence, substantial effort was required to adapt this flowsheet and equipment for the lower concentration SRS feed solutions. The peroxide process was selected because of

- Its excellent decontamination for cationic impurities
- Its minimum introduction of foreign material
- Its readily filterable precipitate (if the chemistry is adequately controlled)
- The excellent reactivity of its precipitate in the subsequent hydrofluorination process

After adjusting the plutonium nitrate feed solution to +3 valence and 4.7 molar nitric acid, the solution is fed to a cooled vessel where

concentrated hydrogen peroxide is slowly added to form plutonium peroxide. After a digestion period, the plutonium peroxide is separated from the filtrate by filtration. To aid filtration, a small amount of sulfate is added as a coagulant for colloidal particles, and is incorporated in the crystal structure. Cooling is necessary to minimize catalytic decomposition of the hydrogen peroxide from trace impurities (e.g., iron) in the feed. The initial process involved washing the cake with dilute hydrogen peroxide, then with ethyl alcohol to aid drying, which is performed using dry, heated air. Any residual peroxide present in the filtrate is destroyed by heating the solution at 50 degrees C, then at 90 degrees C prior to recycle.

If conditions were not properly controlled, long filtrations and high plutonium losses would result. Considering that the original precipitator vessel was simply a larger (to allow for more dilute SRS feed) version of the one used at LANL, with the same agitator as used at LANL, the original poor performance is not surprising. Process improvements are as follows:

1. Overall process yields of 99.5% and reduced filtration times were achieved by optimizing precipitator vessel design, reagent addition rate, and agitator speed, eliminating zones of localized low acid conditions, which favored the formation of fine, difficult-to-filter particles. These changes produced a precipitate six times as dense that filtered six times as fast and eliminated sulfate additions, which substantially reduced in subsequent high-temperature roasting and hydrofluorination time cycles, otherwise required to remove sulfate and its interference with reduction to metal.
2. Air-drying improvement eliminated alcohol (a fire hazard) washes of precipitate that gave temperature and pressure excursions in the hydrofluorination furnaces.
3. By 1957, the cycle time was reduced to almost half that of the original system. Other improvements include a larger batch

size, made possible by higher nuclear safety limits following neutron multiplication studies, and increased precipitant concentrations resulting from using 50% versus 30% hydrogen peroxide. In addition, improvements in filter boat design and materials of construction (stainless steel versus platinum) enhanced filter life and improved filtration and drying.

Trifluoride Precipitation

In the late 1950s, the trifluoride process was developed at SRS and installed as the precipitation process in the JB Line. The trifluoride process was selected because it eliminated stability and corrosion concerns with the hydrogen peroxide and hydrofluorination processes, and because it produced a more readily dried precipitate and with less plutonium loss to the filtrate. However, the trifluoride process proved less capable of decontamination of impurities and resulted in higher operator radiation exposure. Corrosion issues with using concentrated hydrofluoric acid in precipitation offset the elimination of corrosion issues associated with HF gas. The process proved very sensitive to upsets; hence, careful control of chemistry and equipment engineering proved crucial. Nevertheless, this process has proven reliable and has served SRS effectively for several decades.

Before precipitation, the plutonium nitrate solution is adjusted to +3 valence and 4 molar nitric acid. Precipitation takes place in a two-stage precipitator. Hydrofluoric acid and plutonium nitrate solution are simultaneously added to the first stage under conditions that favor crystal growth. The resultant slurry overflows to a second-stage precipitation vessel where conditions are controlled by adding more hydrofluoric acid to reduce the solubility of the plutonium fluoride and to complete the precipitation. The resultant slurry is then filtered to collect a plutonium trifluoride cake in a filter boat. The cake is washed with dilute hydrofluoric acid and then dried using warm (70-100 degrees C) air for 3-4 hours, resulting in a cake

with 2-3% moisture content. Process improvements are as follows:

1. The use of geometrically favorable vessels, with higher criticality limits, permitted an increase in the precipitation batch size from a few hundred grams of plutonium in the original B Line to over a kilogram in the JB Line.
2. Process development identified the ideal conditions for filtration, which required control of the free fluoride concentration (F^-) as measured by a ratio of HNO_3/HF in the first stage precipitator around 7 to 1. A higher ratio promotes too much crystal growth, resulting in excessive solids accumulation on the vessel walls, which necessitates more frequent equipment clean-out. A lower ratio results in fine particles that are difficult to filter. A ratio of 3 or less is necessary in the second stage to reduce losses.
3. Improved vessel and agitator design eliminated dead zones and provided adequate suspension without breaking up particles. Improved materials of construction (Teflon™ and polypropylene) reduced corrosion, improved performance, and extended life of filters and agitators. Further, ascorbic acid proved an effective agent in maintaining the plutonium valence in the +3 state, which is necessary to avoid solids buildup and filtration problems.

Oxalate Precipitation

During the 1960s, plutonium oxide was produced to fabricate into fuels to use in the SRS reactors to make heavy isotopes and in the Hanford pilot breeder reactor. The oxalate process was adapted for use at SRS by John Porter and Albert Symonds. In this process, the plutonium solution is first adjusted to an acid concentration of less than 1.5 M (preferably less than 1 M), and the plutonium valence is reduced to +3 using sulfamic and ascorbic acid. The plutonium is then precipitated in a single-stage vessel by the slow addition of 1 M oxalic

acid. After a brief period of digestion, the plutonium oxalate is collected on a filter boat and washed to remove excess acid. The “pool table green” filter cake is then dried to remove free moisture, heated to remove excess waters of hydration, and then converted to plutonium oxide in a oxygen atmosphere at around 700 degrees C. The resultant oxide has particle properties that are ideal for fuel fabrication use. Further, the properties of the final oxide can be controlled as required by controlling the precipitation parameters.

New Precipitators

A replacement trifluoride precipitator system (see Figure 4) was installed and started up on May 13, 1987. Replacement was necessary because of the high radiation exposure from plutonium trifluoride (300 times greater than from plutonium metal) and extensive corrosion from HF, which severely damaged the equipment and glovebox containment. The new system incorporated the following improvements.

1. Remotely operable, electrically operable valves and instruments allowed operation of the system from a distributed control system. These enhancements substantially reduced exposure and improved process control. The new design resulted in a 75% reduction in radiation exposure and process downtime.
2. The new design virtually eliminated removing glovebox windows for maintenance. All equipment, with the exception of large vessels, was designed to be maintained through gloves. This improvement greatly reduced the Pu assimilation risk in maintenance using temporary plastic containment enclosures.
3. Design improvements enhanced control over system chemistry resulting in uniform, consistent operation. New instruments and valves with remote, chemically resistant sensors and seals allowed remote process



Figure 4. Modern control room for replacement precipitators

operation. An electrical connector allowed quick disconnect of electrical lines and glovebox penetrations without exposing sensitive electronics to a corrosive acid environment. In addition, advances in construction materials (e.g., Kynar) and improved vessel and agitator design allowed more uniform operation.

Conversion/Reduction

Hydrofluorination/Reduction of Plutonium Peroxide

The original SRS process dried plutonium peroxide and then converted it to plutonium tetrafluoride. This process, called hydrofluorination, took place in a furnace at 600 degrees in anhydrous hydrogen fluoride (HF) gas. The resulting tetrafluoride was mixed with metallic calcium and an iodine booster and placed in a magnesia crucible, which is nested within magnesia sand within a steel pressure chamber. This vessel is heated in an induction coil until an initiation of a highly exothermic reaction, which reduces the plutonium to metal. After cooling and disassembly,

the plutonium metal button was separated from slag and crucible, which contains residual plutonium, which requires recovery. Improvements are as follows:

1. During the first few years of operation, SRS substantially improved this process, doubling of the batch size and reducing the time cycle fourfold. This large increase in capacity concurrently improved the precipitator, drying system, and eliminated sulfate, as previously discussed, coupled with improved furnace cooling and sealing. The net result was that hydrofluorination was no longer a limiting step.
2. The larger batch sizes eliminated iodine in 1957. Using iodine caused molten reaction products to fuse through the ceramic liner of the reduction pressure vessel, making button dumping very difficult. Iodine in the reduction slag also gave problems in subsequent plutonium recovery processing.
3. Dramatic improvements in supporting systems were also achieved. Low reduction yields in the early years of operation were

presumed due to deviation from procedures; hence, technical engineers were assigned to each shift to oversee operation. However, upon investigation, it was found that reduction yields are extremely sensitive to glovebox humidity, a problem not encountered at LANL or Hanford. Replacing degraded reagents and fixing the air drying system, which was not cycling properly, restored high yields. Other improvements included redesigned induction coils, which greatly reduced coil failures, and ultrasonic pickling, improving button quality.

Conversion/Reduction of Plutonium Trifluoride

In the initial JB-Line process, plutonium trifluoride precipitate was dried and roasted in an argon atmosphere at high temperatures to remove any volatile impurities. The roasted trifluoride was then mixed with calcium and an iodine "booster" for reduction to plutonium metal. Equipment engineering improvements, including improved criticality safety design and a remotely operable dry-processing line, tripled batch size and reduced radiation exposure to the operators. Although this new process eliminated the need to use gaseous HF, it introduced other problems, such as the reintroduction of iodine additions. Specific improvements include the following:

1. Thermodynamic analysis and test indicated that the addition of oxygen to the roasting step would convert the trifluoride to a mixture of plutonium tetrafluoride and plutonium oxide, which could be reduced without the addition of an iodine booster. Adoption of this procedure resulted in reduction yields that were about 5% lower than those using iodine. This lower yield was considered an acceptable price to pay to eliminate iodine and coincident reduction in recovery time cycle, corrosion, and offgas concern.

2. In recent upgrade projects, new roasting/conversion furnaces have been installed with improved shielding, offgas handling, and process controls.

Recovery and Special Recovery

The B Lines, both old and new, had facilities to recover plutonium from solid and liquid residues resulted from the main finishing processes. This precluded accumulating and indefinite storage of these residues. These residues consisted primarily of

- Slag and crucibles from the reduction process
- Floor sweepings from the dry cabinets
- Scrap plutonium metal (reject buttons or sample turnings)
- Button pickling solutions
- JB-Line precipitator flushes

The original recovery facilities were located on the fourth level of the 221-F Canyon Building. After JB Line start-up, a replacement recovery facility was installed in JB Line. The original facility employed various recovery processes.

In the original B Lines, slag and crucibles and/or cabinet sweepings were recovered in a dissolver vessel containing concentrated nitric acid, aluminum nitrate, and water. Aluminum nitrate is added to partially complex the free fluoride normally present from dissolving solids. Free fluoride is necessary, and added as needed, during the dissolution step to dissolve entrained particles of plutonium metal or any high-fired oxide that may be present. The dissolver is purged with nitrogen during the initial phase of dissolution to safely remove hydrogen produced from the dissolution of excess calcium metal in the slag. After the dissolution cycle at the simmering temperature, the solution is slightly cooled, and aluminum nitrate is added to completely complex the fluoride and to minimize downstream corro-

sion. The solution is digested at the elevated temperature to coagulate silica, introduced as an impurity in the crucible. After cooling, the solution is filtered to remove the coagulated silica and other insoluble materials. The filtered solution is purified by solvent extraction or anion exchange. JB-Line precipitator flushes and pickling solutions are filtered and added with the dissolver solutions for purification. The original recovery process used PUREX solvent extraction in small mixer-settler banks inside wet process cabinets. Process improvements are as follows:

1. Dissolving slag and crucibles with iodine released copious quantities of iodine, corroding the dissolver offgas system. Eliminating iodine coupled with hot caustic flushes to clean the filters substantially improved recovery operations and reduced the cycle time by over a factor of two.
2. Sulfamic acid was accidentally discovered to be an excellent dissolution media for plutonium metal in 1957, which greatly reduced the cycle time and corrosion encountered with boiling nitric/hydrofluoric acid dissolution. SRS effectively used this process for years to recover on- and off-site metal. The dissolution takes place at slightly elevated (about 45°C) temperatures, producing hydrogen gas, and in some cases, pyrophoric sludge. In the mid 1980s, discovery indicated adding a small amount of hydrofluoric acid to the sulfamic acid dissolving solution eliminated pyrophoric sludge formation.
3. The solvent extraction system was replaced by a simpler, more-compact anion exchange process. The feed solutions for anion exchange are adjusted to a total nitrate concentration of about 8–9 M to form an anionic complex that is readily absorbed by anion resin (e.g., Dowex 21K). The column is eluted with dilute nitric acid to produce a plutonium product solution, which is diluted to a safe concentration and transferred to the canyon.
4. As early process and equipment difficulties were overcome, the throughput capacity and versatility of the recovery facilities became sufficient to not only process the SRS residues, but also to process various residues from other sites including Los Alamos, Hanford, Argonne, and Rocky Flats. Many types of non-routine residues were processed including: Lampre fuel (tantalum-clad plutonium); ZPPR fuel containing oxides of plutonium, uranium, and molybdenum; high chloride solutions; plutonium/aluminum alloy; plutonium containing neptunium; test residues containing fused mixtures of plutonium, or alloy, and extraneous materials; plutonium sludge recovered from the F-Canyon air tunnel; and plutonium residue from offgas filters. SRS became the “can do” plutonium recovery facility for much of the AEC/DOE complex.
5. A New Special Recovery Facility was built and ready for startup in 1991; however, the reduced demand for plutonium for defense eliminated this facility. It was constructed to process 2 MT (metric tons) of plutonium oxide per year, and was being modified, when shutdown, for handling up to 3 MT/year of either oxide or metal feed. Processes were developed to separate plutonium from various pit types, to eliminate concerns with pyrophoric sludge that plagued earlier metal dissolving efforts, and to reduce hydrogen generation. The facility was designed for remote control room operation similar to that described for the New Precipitators.
6. In recent years, concerns over hydrogen generation with existing recovery flowsheet for calcium-laden reduction residues led to developing direct canyon dissolving processes, which are currently in use.

Facility Engineering Improvements

Old “B” Lines

Many design features of the first-generation facilities built at LANL were not suitable for full-scale production facilities (e.g., many operations took place in open face hoods). Consequently, many operators assimilated small amounts of plutonium. The situation was further complicated in that surfaces within the facility were difficult to decontaminate. The initial SRS finishing lines, called “B” lines were just a step up from the laboratory stage. For example, some reagents used in the process were added using calibrated pails. Worse, the equipment was not designed for easy maintenance (e.g., only six gloveports were installed in each line for routine operations). In the original facilities, the process equipment was located in two types of negative pressure enclosures—wet cabinets surrounding aqueous processes and dry cabinets surrounding powder-handling processes. The wet cabinets used valve extension handles operate valves without using gloveports and employed air in-leakage for contamination control. The dry cabinets were hermetically sealed and supplied with dry air through inlet and outlet HEPA filters. Although a mechanical conveyor system was provided in the dry cabinets to remotely move materials among stations, it proved unreliable; hence, material movements were done manually. Although some design improvements (more gloves for maintenance, new central vacuum system, and localized radiation shielding) were incorporated, maintenance frequently required removing cabinet panels, which required constructing plastic huts for contamination control. Nuclear criticality safety in the original button lines was maintained with small batch sizes, about 300 grams plutonium, and with vessel size controls.

New JB Line

The new JB Line had many facility and equipment engineering improvements to correct lessons learned in the original B Lines. Within

the first year of operation, these improvements provided the capacity to handle in 15 shifts of operation the output from the canyon in 21 shifts of operation. The new facility used vessels with neutron-scattering geometry and other controls for nuclear criticality safety that permitted processing batches seven times larger than in the original lines. For the dry process, duplicate stations for every process step existed within wing gloveboxes along a main, mechanical conveyor line to prevent failure of a single station from shutting down the entire process line. Where possible, gloveports accessed equipment for maintenance. Room partitions compartmentalized work areas for contamination control. The gloveboxes were designed for routine operations on one side and maintenance on the opposite side, allowing simultaneous maintenance and processing and helped to control contamination. Improved construction materials (e.g., plastic tanks and coated agitators) improved equipment life in the corrosive hydrofluoric and nitric acid glovebox atmosphere. In addition, at- and in-line plutonium solution monitoring systems increased throughput by providing results in one-half hour, and in some cases real-time, that had previously taken 4 hours from the Laboratory. Improved assay instruments detected mis-operation (filter failure, over-batching, etc.), which substantially improved safety and process efficiency.

Restoration Program and Recent Improvements

During the 1980s, extensive facility restoration activities were performed, like replacing some process operations (i.e., precipitators, conversions furnaces, vent and vacuum systems, and the neutralization system) and restoring facility piping systems, cabinet panel seals, and ventilation systems. During the last decade, the facility underwent extensive outside review and improvement in integrated safety management and conduct of operations. Materials control, accountability, fire protection, materials characterization, waste management, security, and safeguards were upgraded. Installing a bagless transfer system enabled metals packaging in

welded containers, eliminating storing plastic bags for containment. Additional improvements to package plutonium to meet new storage standards are under development. The current facility mission is to characterize and stabilize onsite and selected off-site surplus plutonium inventories.

The Future of Finishing Processes

Continuing use of finishing technologies is essential to convert surplus plutonium metal to oxide suitable for Mixed Oxide Fuel, as currently planned. Many of the SRS developed technologies and engineering approaches may prove useful in this purpose. For example, SRS developed processes to dissolve the plutonium metal or oxide away from other materials and

to produce a high quality oxide with minimal radiation exposure and waste generation. Most the engineering technology to perform process operations remotely has been developed. Evidencing the efficiency of the SRS process is the fact that there is less plutonium in transuranic solid waste at SRS than at any other major DOE site. The successful improvement over the years to the finishing processes is directly due to the SRS determination to understand and apply equipment-engineering solutions to improve processes.

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