

SECTION 2 HANFORD SITE HISTORICAL OVERVIEW

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2.0 Hanford Site Historical Overview

2.1 Site Description

The Hanford site was established by the Manhattan Project as the plutonium production site for the U. S. World War II defense effort. The site initially consisted of ~1,735 square kilometers (~670 square miles) of primarily remote, semiarid land. Over time, this has been reduced to ~1,450 square kilometers (~560 square miles) as parcels of land no longer needed by the site were made available for other uses. The site has access to significant water and power supplies and nearby barge shipping, road, air, and rail facilities. Construction was initiated in March 1943 to build facilities to produce plutonium for the first atomic bombs. The principal early facilities included B-, D-, and F-Reactors, the 313 Fuel Fabrication Facility, the T-Plant and B-Plant fuel processing facilities for plutonium separation, and the 231 Isolation Process facility for final plutonium purification and concentration. Waste storage tanks, laboratory facilities, warehousing, roads, power plants, housing, and a myriad of other support facilities were simultaneously built during the construction period. Initial plutonium production commenced in September 1944 when the first reactor was brought on line. The first batch of refined plutonium was available for the war effort in February 1945.

Buildup of the Hanford site continued for many years in support of nuclear weapons program needs. Additional facilities were eventually needed to satisfy planned plutonium production requirements and to improve process efficiencies. An additional six reactors and four processing facilities were constructed and operated, including: the Reduction Oxidation (REDOX) Plant, U-Plant, UO₃ Plant, and the Plutonium-Uranium Extraction (PUREX) Plant. During the plutonium production years at Hanford, uranium was received at the site, fabricated into nuclear fuel, irradiated for plutonium production, and processed to recover the plutonium. Until about 1952, the waste from plutonium separation, which included fission products and unused uranium, was stored in large, underground waste tanks. After 1952, uranium was mined from these tanks and recovered for reuse. All subsequent fuel processing operations included uranium recovery and recycle. Most of this uranium was shipped offsite for recycle and contained residual trace quantities of transuranics and fission products. By 1994, all plutonium production and uranium recovery activities were shutdown and a cleanup mission for the Hanford site was initiated. A brief historical timeline of Hanford's history is provided in Appendix H.

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support functions were located nearby in facilities in the 700, 1100, and 3000 Areas. Completed fuel was shipped to the reactors at the 100 Areas (B, C, D, DR, F, H, KE, KW, and N) located along the south shore of the Columbia River in the northern portion of the Site for use in the reactors. After irradiation, the fuel was stored in pools at the reactors for a cooling period and then transported in special rail cars to the separation processing facilities located in both the 200 W and 200 E Areas. Discarded high level waste from the separation plants were transferred to storage in underground storage tanks located in both the 200 W and 200 E Areas. All recovered solutions of uranium were transported to the UO_3 Plant located in the 200 W Area for conversion to oxide.

2.2 Key Uranium Processing Facilities

As part of the Manhattan Project and its successors, the U. S. Atomic Energy Commission (AEC), Energy Research and Development Administration (ERDA), and the U. S. Department of Energy (DOE), a number of specialized facilities were constructed at the Hanford site and operated between 1943 and 1986 to produce fuel for the nine plutonium production reactors and to recover plutonium and uranium from the irradiated fuel. A historical overview of all the major plants, process flows, and facility interfaces at Hanford is shown in Figure 2-2. All of the uranium received at Hanford for non-research reactor operation was fabricated into fuel in the 300 Area throughout Hanford's production mission. This fuel was used in nine production reactors which operated over various time periods. Essentially all of the irradiated fuel went to one of four separation processing facilities; T-Plant, B-Plant, REDOX, and PUREX. In addition, the U-Plant was operated for a short time period to recover uranium from high level waste from the early T- and B-Plants, which did not have the capability to recover uranium during irradiated fuel processing. All of the high level waste from the processing of irradiated fuel was transferred to underground storage tanks. Recovered plutonium was refined and converted to a suitable chemical form in either the 231-Z Isolation Building or the Plutonium Finishing Plant. Recovered uranium (as recycle uranium) was converted to a stable oxide for shipment in the UO_3 Plant. The remainder of this section provides a brief description of the facilities, processes, and operating history for the major Hanford uranium processing plants.

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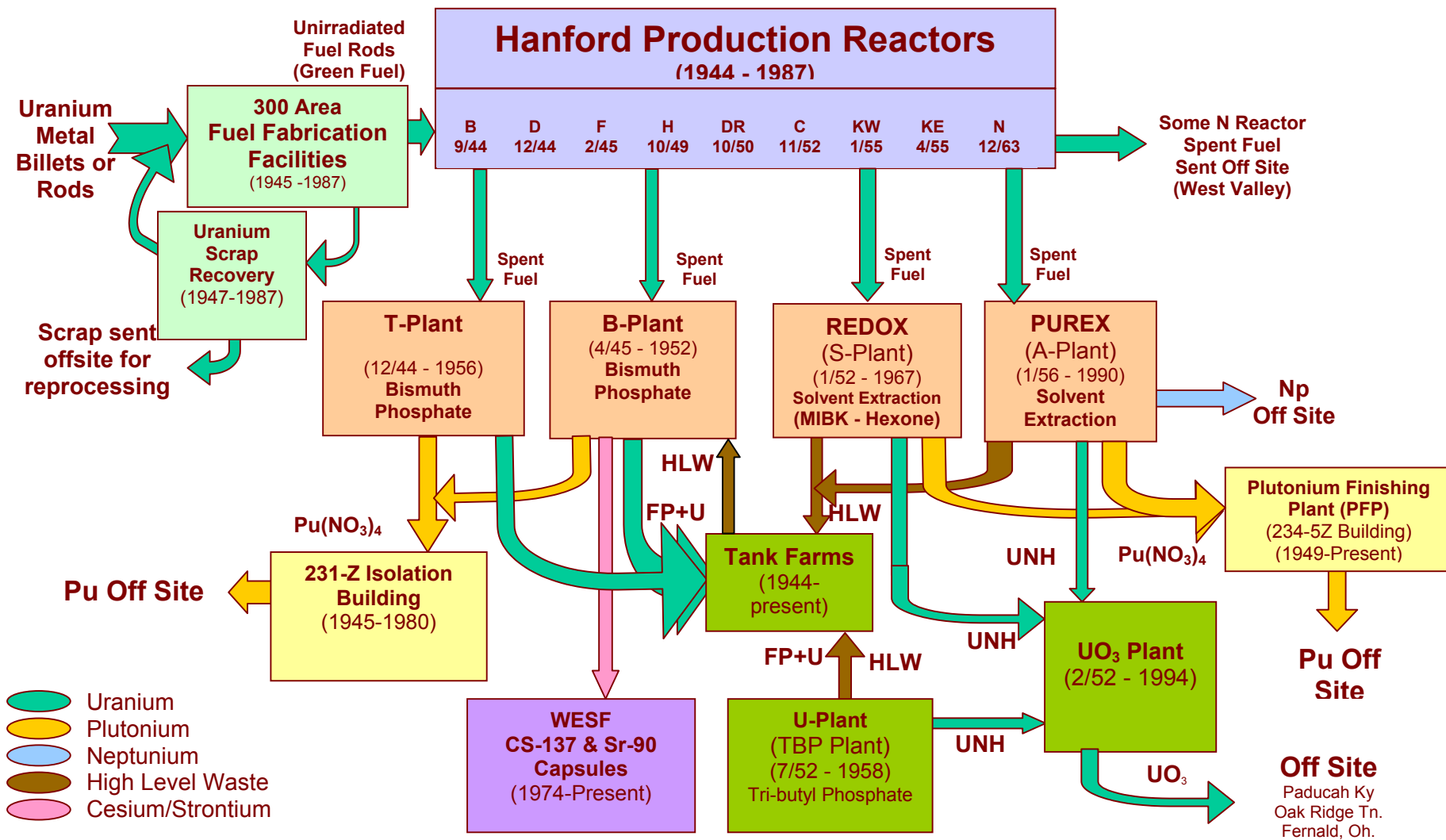
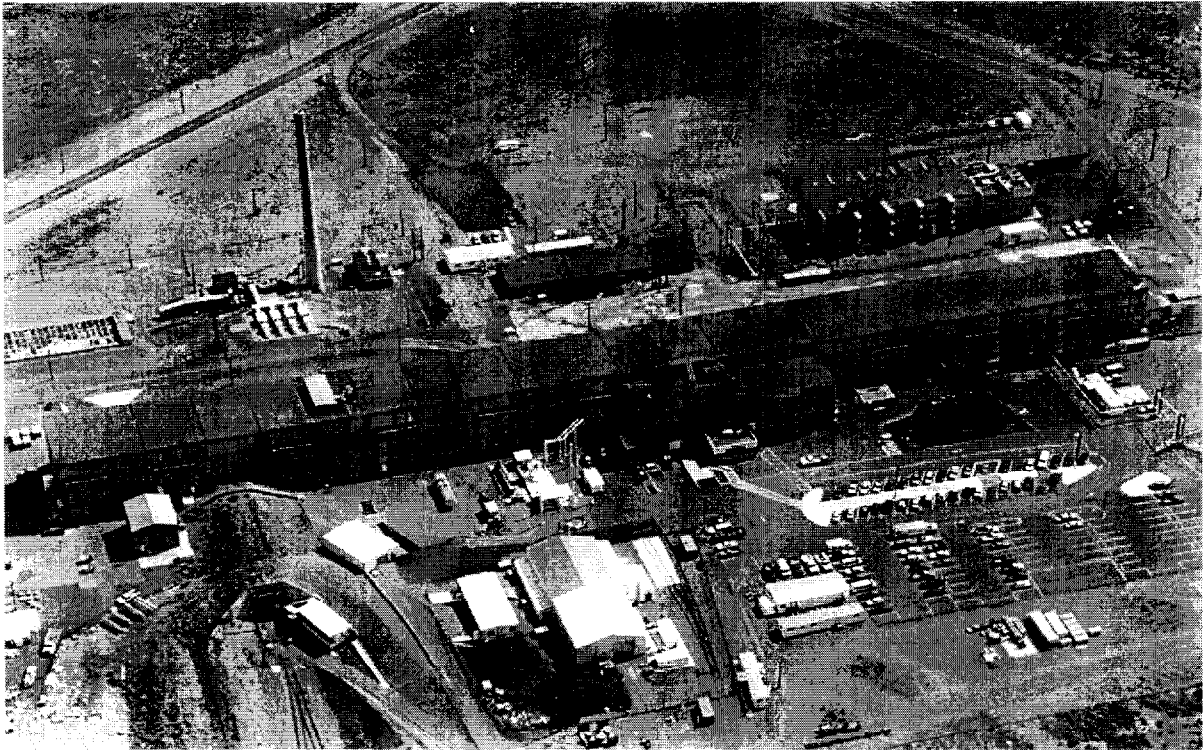


Figure 2-2 Hanford Major Process Flows and Facility Interfaces

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2.2.1 T-Plant

T-Plant was the first of three separations plants built at Hanford by the Manhattan Project.

2.2.1.1 Plant Description

T-Plant (the 221-T Cell Building), located in the 200 West Area of Hanford, is 85 feet wide by 875.5 feet long by 102 feet high. It is a reinforced concrete, windowless structure. Approximately 25% of the building is located below grade. The building enclosed a bismuth phosphate plutonium extraction process. The process equipment was located in 20 heavily shielded cells that provided needed radiation shielding for the personnel processing irradiated uranium fuel. The process involved dissolution of irradiated uranium fuel from the reactors and extraction of plutonium. Process equipment maintenance was accomplished remotely. Shielded transfer piping provided the path for liquid chemical transport between the cells [Gerber 1996].

2.2.1.2 T-Plant Material Flowsheet

The material flowsheet was developed early in the facility construction period. Initially the facility was expected to process about one ton of irradiated uranium per day. Over years of operation, changes to the processes and modification to the bismuth phosphate chemistry resulted in improved performance. A simplified process flow diagram for the bismuth phosphate separation process is depicted in Figure 2-3. This

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process was developed by Glenn T. Seaborg in the early 1940s and applied at Hanford to achieve separation of the plutonium produced from irradiated uranium. Uranium was not recovered, and both the fission products and uranium were sent to large underground waste storage tanks.

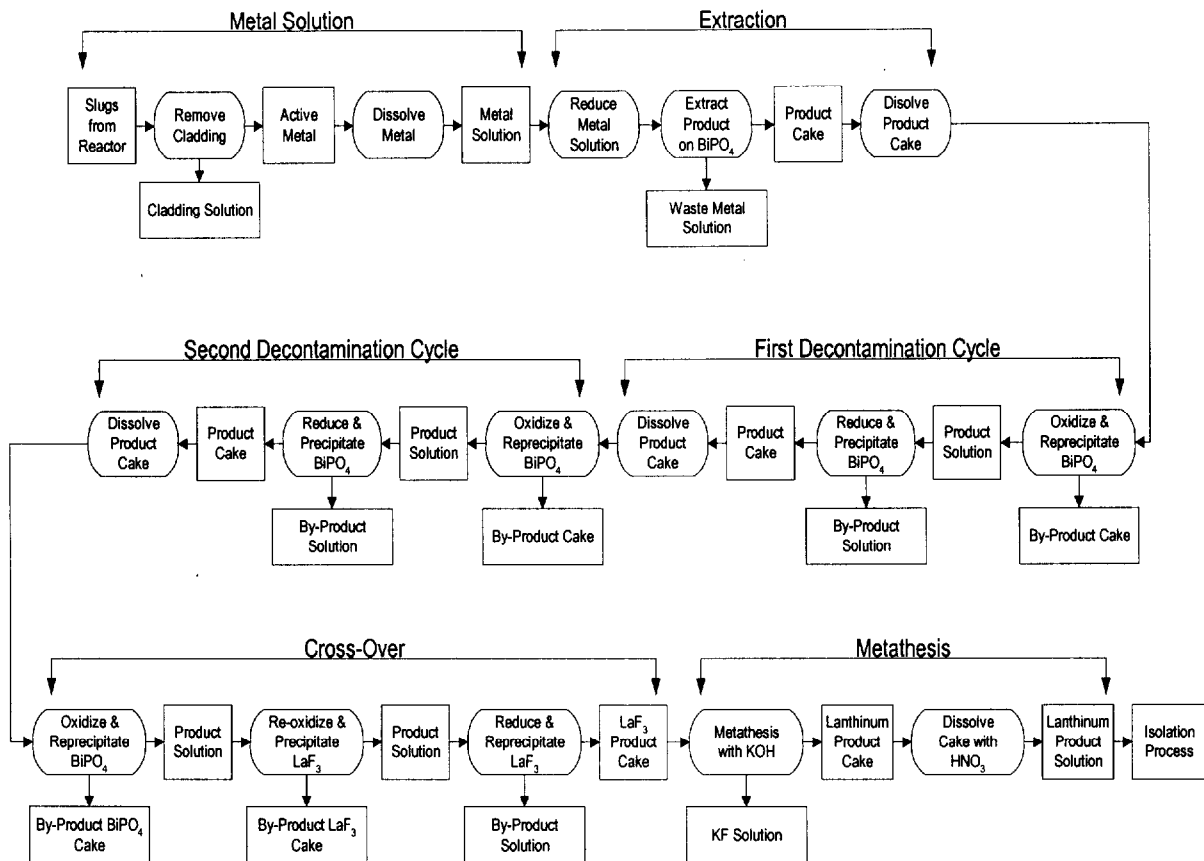


Figure 2-3 T-Plant Process Flow Diagram

The process consisted of removing the aluminum cladding from the irradiated fuel rods (also known as “slugs”) in dissolver tanks using hot sodium hydroxide. The cladding waste was drained from the dissolver tanks and transferred to the underground waste tanks. The declad slugs were washed with water to remove any residual hydroxide. Nitric acid was then added to dissolve the bare uranium slugs and form a uranium nitrate solution. The uranium nitrate solution was chemically adjusted with sulfuric acid and sodium nitrite to assure extractability of the plutonium from the uranium solution. Bismuth nitrate and phosphoric acid were added to co-precipitate plutonium and bismuth as insoluble phosphates. The solution was centrifuged from the bismuth phosphate co-precipitate. Waste solutions containing uranium and fission products were treated and sent to the underground waste tanks. The solid cake was water washed and dissolved in concentrated nitric acid. The nitrate solution was chemically adjusted to permit precipitation of metal contaminants upon addition of bismuth nitrate while maintaining the plutonium in solution. The solution was again chemically treated and

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bismuth nitrate and phosphoric acid added to co-precipitate the plutonium, further reducing the metal contaminants. This precipitation, re-solution and re-precipitation process was repeated two more times to further reduce the metal contaminants and reduce volume. Final purification of the plutonium was accomplished by repeated co-precipitation using lanthanum nitrate and hydrofluoric acid to form the lanthanum fluoride which served as the carrier. Upon completion of the purification steps, the plutonium was dissolved in nitric acid and transferred to the Isolation Process Facility (231-Z building) for final treatment and concentration.

2.2.1.3 Feed Specifications

Feed for the extraction process was irradiated natural uranium and the expected plutonium content was low. During the 10 years of T-Plant operation, the irradiated fuel feedstock varied in plutonium and fission products content as the reactor operations were improved and power levels increased.

2.2.1.4 Product Specifications

Plutonium nitrate solution was the principal product of T-Plant and the nitrate solution was further purified at the 231-Z Facility. The uranium and fission products were discharged to the underground waste tanks. Waste transferred to the underground tanks was chemically adjusted to minimize corrosion of the tanks using specifications based on maintaining alkalinity and nitrate/nitrite concentrations. Since uranium did not play an important role in corrosion control, no purity requirements were established for the waste uranium [HW-10475-ABC 1944].

2.2.1.5 Operating History

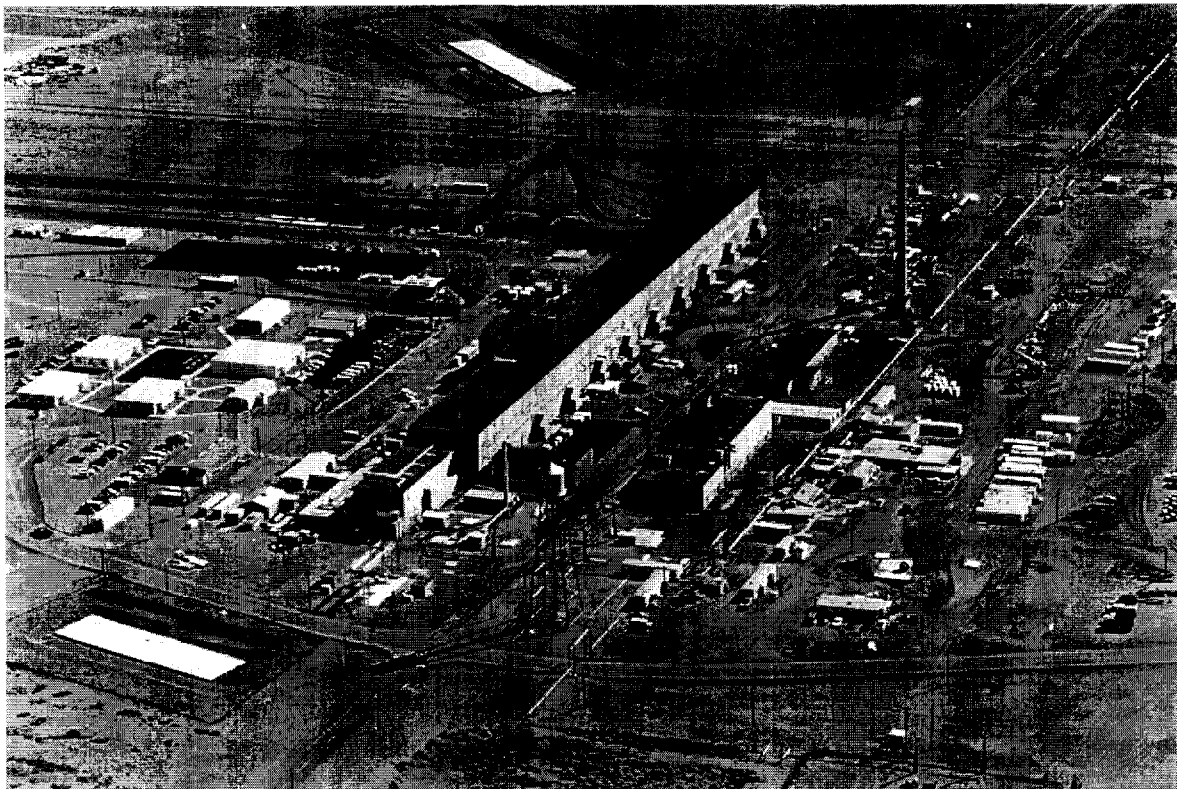
Processing of irradiated uranium fuel commenced on December 26, 1944, in the T-Plant. A number of operational improvements and installation of a third fuel dissolver in 1954 increased plutonium production rates. T-Plant was shut down in March 1956 following startup of the PUREX plant in January 1956.

2.2.1.6 Current Status

T-Plant is used on an irregular basis as an equipment decontamination and repair facility supporting Tank Farms operations. Although recently the 224-T Building was used for TRU waste storage, the TRU has now been removed and 224-T is now being deactivated.

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2.2.2 B Plant

B-Plant was second of the three separations plants initially built by the Manhattan Project.

2.2.2.1 Plant Description

B-Plant (the 221-B Cell Building) is located in the 200 East Area and was constructed in the same time frame as T-Plant. B-Plant started processing irradiated uranium fuel on April 13, 1945. Physically, B-Plant is nearly identical to T-Plant. It is 65 feet shorter in length than T-Plant because it did not include the two equipment development cells provided in T-Plant. Like T-Plant its mission was to recover plutonium from irradiated uranium fuel using the bismuth phosphate process. The process equipment was also located in heavily shielded process cells [Gerber 1996].

2.2.2.2 Material Flowsheet

B-Plant shared the same flowsheet as T-Plant. Process modifications to improve efficiency were similar to those made at T-Plant, but B-Plant did not operate as a plutonium separations plant for as long as T-Plant.

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2.2.2.3 Feed Specifications

The feed specifications for B-Plant were the same as those for T-Plant, described earlier.

2.2.2.4 Product Specifications

Like T-Plant, B-Plant's principal product was plutonium nitrate solution. The uranium and fission product wastes delivered to the underground tanks were chemically adjusted to assure adequate control of expected tank corrosion using specifications based on maintaining alkalinity and nitrate/nitrite concentrations [HW-10475-ABC 1944].

2.2.2.5 Operating History

B-Plant began processing irradiated uranium fuel in April 1945 using the bismuth phosphate process. Plutonium recovery continued until 1952 when the plant capacity became unnecessary once the combined output of T-Plant and REDOX was sufficient to satisfy production needs. In 1968, the plant was converted to a waste fractionation plant. Cesium and strontium were removed from the high level tank wastes and encapsulated [Gerber 1996].

2.2.2.6 Current Status

The cesium and strontium capsules are currently being stored in water filled basins in an addition on the west end of the plant. Present plans call for vitrification of these capsules as high level waste. The remainder of the plant has been shutdown.

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2.2.3 U-Plant

U-Plant was the third of the original three separation plants to be built by the Manhattan Project. This facility was also known as the TBP-Plant and the Metal Recovery Plant. It was initially used to train operators for B- and T-Plants. Later, it was modified to recover uranium in waste slurry “mined” from the high-level wastes in Hanford’s tanks.

2.2.3.1 Plant Description

U-Plant is located in the 200 West Area and is almost identical to T-Plant. It is 65 feet shorter overall because, like B-Plant, it does not include the two development cells provided in T-Plant. It was not used to separate plutonium from irradiated fuel as process improvements and other efficiency improvements in T- and B-Plants were sufficient to meet the plutonium recovery schedule. U-Plant was used as a training facility for the two other plants. By 1952, U-Plant was modified to separate, recover, and recycle uranium from the high-level T-Plant and B-Plant wastes in the underground storage tanks. As such, it was a significant element in the Hanford uranium recycle process [Gerber 1996].

2.2.3.2 Material Flowsheet

A simplified U-Plant process flow diagram for the recovery of uranium from retrieved B-Plant and T-Plant tank waste is depicted in Figure 2-4 and is based upon the use of

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tributyl phosphate (TBP). The TBP was found to complex very well with both uranium and plutonium to allow their separation from fission products and from each other after proper chemical adjustments. The process consisted basically of contacting the clarified and concentrated acidic uranium solution that had been sluiced from the waste storage tanks with TBP carried in a hydrocarbon solvent to complex the uranium with the TBP. This process was done as a one-pass counter-current solvent extraction process using packed columns. The uranium complexed with the TBP and thus transferred to an organic phase, while the fission products remained in the aqueous phase. The acidic aqueous waste from the column was neutralized and returned to the underground waste tanks for storage. The uranium was then stripped from the TBP-uranium complex in the organic phase in another packed column with acid of a specific molarity. The resultant uranium solution was then concentrated in an evaporator to a consistent concentration for feed to the UO_3 Plant. The concentrated uranium nitrate solution (uranyl nitrate hexahydrate (UNH)) was analyzed to assure that it met feed specifications for the UO_3 Plant and then transferred to that facility for conversion to shippable powder. Product solutions not meeting the stringent specification of the UO_3 Plant were recycled back through the extraction process. In order to accommodate the required throughput rate, there were two extraction trains in U-Plant.

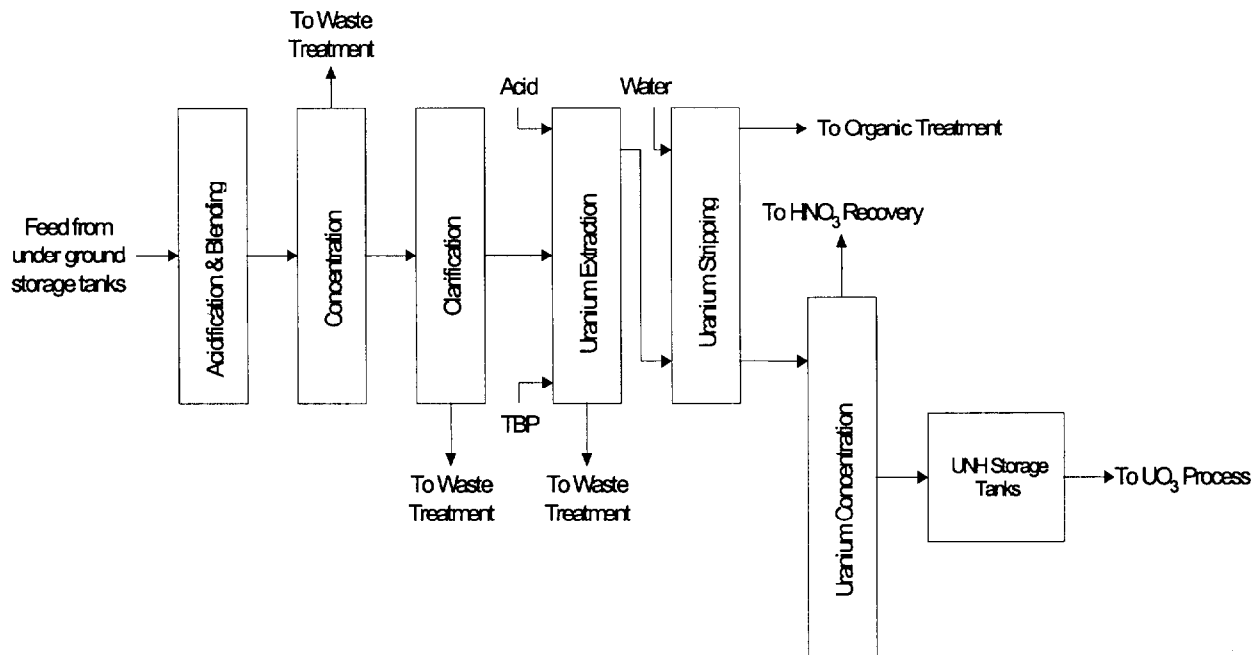


Figure 2-4 Simplified U-Plant Tributyl Phosphate (TBP) Process Flow Diagram

2.2.3.3 Feed Specifications

Feed for U-Plant came from the underground storage tanks which contained high level waste from the B and T separation plants. The uranium-bearing tank wastes consisted

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of sludge and supernatant liquor (sludge washings and solutions). The sludge contained approximately 75 percent of the uranium. The plutonium content of the uranium waste was about two to four grams per metric ton (MT) of uranium (2-4 ppm Pu). Approximately 20 MT of slurried tank waste was required to produce one ton of recovered uranium for conversion to UO_3 . A description of the chemical constituents of the "mined" uranium feed can be found in the Uranium Recovery Technical Manual [HW-19140 1951].

2.2.3.4 Product Specifications

The U-Plant product specifications were dictated by the specifications for the UO_3 powder produced in the UO_3 Plant. The initial specification in the 1951 technical manual [HW-19140 1951] indicated the UNH product from U-Plant should contain less than 80 ppb Pu. The UO_3 Plant did not further refine the UNH product from the U-Plant process. Blending of the U-Plant product with product from REDOX was expected to help assure the concentration of transuranics and fission product impurities were at acceptable levels. U-Plant did have the capability to concentrate the UNH prior to calcination, however this did not alter the ratio of any impurities to uranium.

2.2.3.5 Operating History

Uranium was scarce in the late 1940s. Escalating demand for weapons materials led to the decision to reclaim uranium from the underground storage tanks. This was first discussed in 1947 when a decision was made to develop a process for extracting uranium from the Hanford waste tanks to supplement the scarce uranium supplies [Peterson 1947]. Over the next few years, a uranium recovery process based upon TPB was developed at Hanford and served as the design basis for both the U-Plant conversion and the PUREX separations operations. U-Plant began recovering uranium from tank wastes in 1952 and completed its mission in 1958. UNH product from U-Plant was routinely blended with UNH product from REDOX. During U-Plant's operating period, ~7,200 MTU was recovered from high-level waste for conversion to UO_3 and recycle.

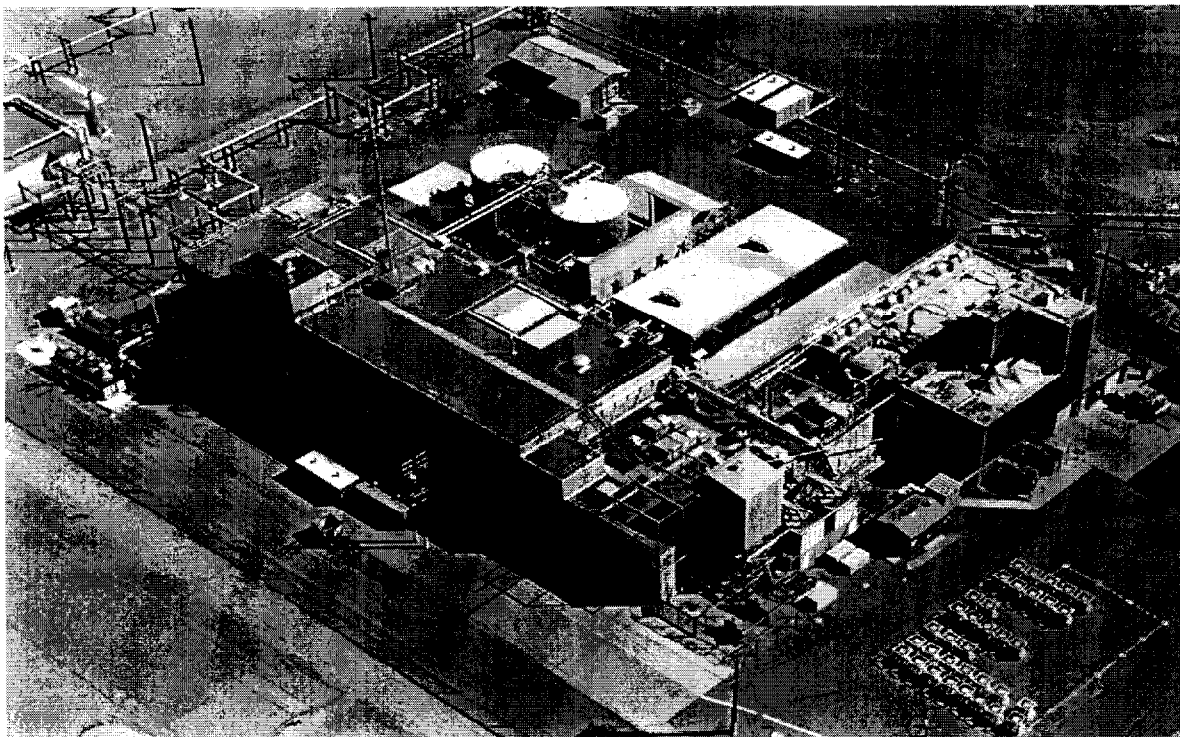
Worker exposure to uranium was normally low, as processing occurred remotely in heavily shielded and ventilated canyon cells. The uranium solutions were of low concentration until the solution was evaporated to create the UNH product. Transfer of concentrated UNH to the UO_3 plant was by pipeline. Liquid wastes containing fission products and plutonium were transferred to underground waste storage tanks. Solid wastes were packaged and sent to the Hanford burial sites for disposal.

2.2.3.6 Current Status

U-Plant is presently undergoing decontamination and decommissioning. It's final state is the subject of an ongoing Canyon Disposition Initiative at Hanford.

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2.2.4 UO₃ Plant

The UO₃ Plant was built to convert UNH solution into shippable uranium trioxide (UO₃) powder.

2.2.4.1 Plant Description

The results of process improvements in the T-Plant and B-Plant operations as early as 1945 demonstrated that U-Plant was not needed to process irradiated fuel. The 224-U Building at the U-Plant complex was subsequently modified to convert UNH into UO₃, hence its designation as the UO₃ Plant. The 224-U Building was a three-story, frame and concrete block structure which had just under 12,000 square feet, and had been constructed to house a part of the plutonium separation and concentration process used at Hanford in the 1940s. Conversion of the 224-U Building into the UO₃ Plant was completed in 1951.

The basic UO₃ process consisted of concentrating and then heating liquid UNH until it was calcined into a stable, orange-yellow UO₃ powder. At the same time, nitric acid was recovered for reuse. It was not possible to operate the UO₃ process at Hanford until a feed supply of UNH became available in 1952 with the startup of the REDOX Plant and then, within a few months, the U-Plant. The earlier separation processes used at B-Plant and T-Plant were unable to recover the uranium for recycle. However, the newer solvent extraction processes used at REDOX and U-Plant allowed recovery of uranium as a concentrated UNH.

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2.2.4.2 Material Flowsheet

The initial UO_3 process operations utilized a batch calcination process involving 18 stirred kettles, as shown in Figure 2-5. The concentrated UNH was initially heated in the stirred kettles until it was dry and then further heated until the UNH decomposed into UO_3 . The nitric acid resulting from the drying and calcining processes was recovered and concentrated. The concentrated nitric acid was returned to the separation plants for reuse. The UO_3 powder was removed from the kettles and pneumatically transferred into storage bins. The air used to transport the UO_3 was filtered before discharge to the atmosphere. The condensate stream was sampled to verify compliance with existing regulations and discharged to the cribs. The UO_3

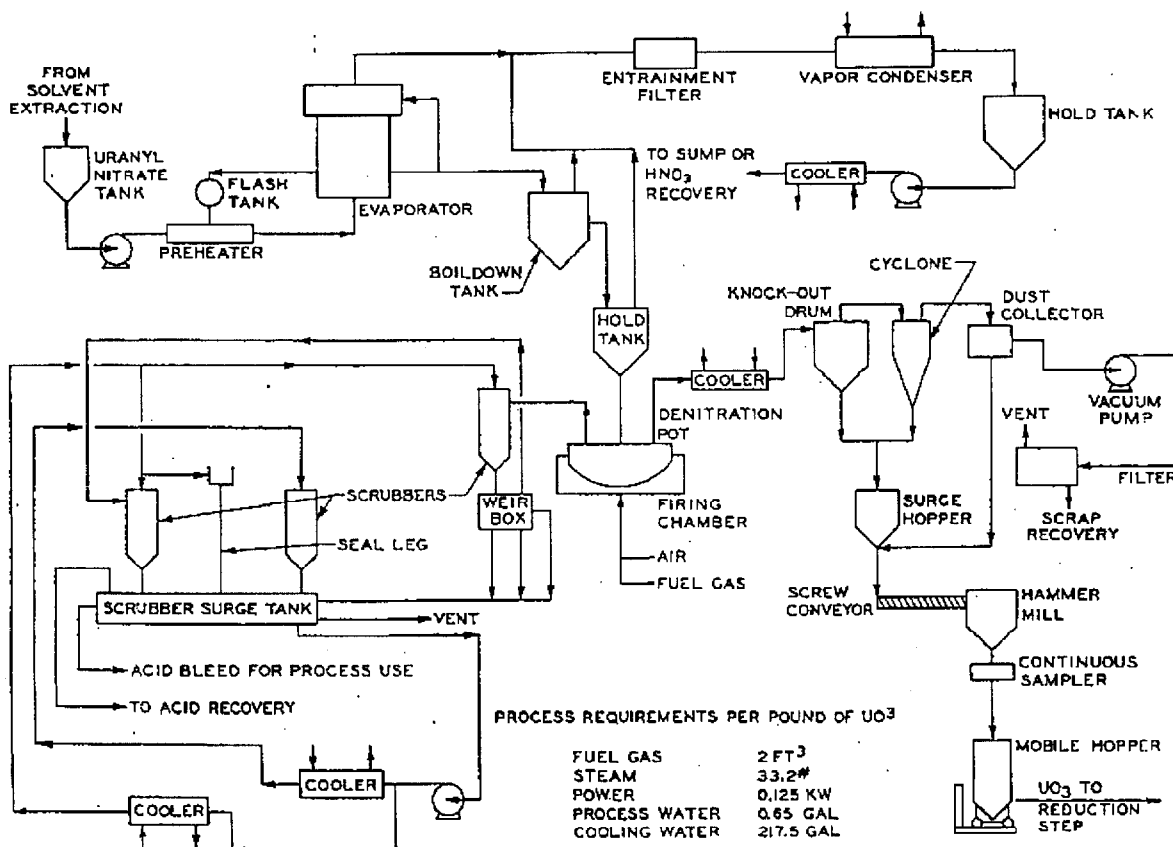


Figure 2-5 UO_3 Plant Process Diagram Involving Batch Pot Calciners

product was sampled and tested to assure compliance with product specifications. At times, the powder was ground to a specific particle size to meet chemical reactivity specifications. Sulfuric acid was added to the UNH to control the hydrofluorination reactivity of the UO_3 powder at the gaseous diffusion plants. Off-specification UO_3

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powder was either blended with acceptable UO_3 product to bring the impurities to within specification requirements, or waivers were obtained before shipment.

In 1956, the 18 kettle calciners were replaced with 6 stirred continuous calciners as shown in Figure 2-6 to improve the product quality and increase the production rate. In addition, an evaporator further concentrated the UNH feed solution from the separation plants to allow more effective calcination. The concentrated UNH was sprayed on a heated UO_3 powder bed in the continuous calciners. The UNH quickly dried, decomposed and was calcined to UO_3 powder. The UO_3 product overflowed the calciner and was pneumatically transferred to the holding bins pending acceptance testing and subsequent packaging into T-hoppers or drums. Nitric acid driven off in the calcination process was recovered and returned to the separation plants for reuse.

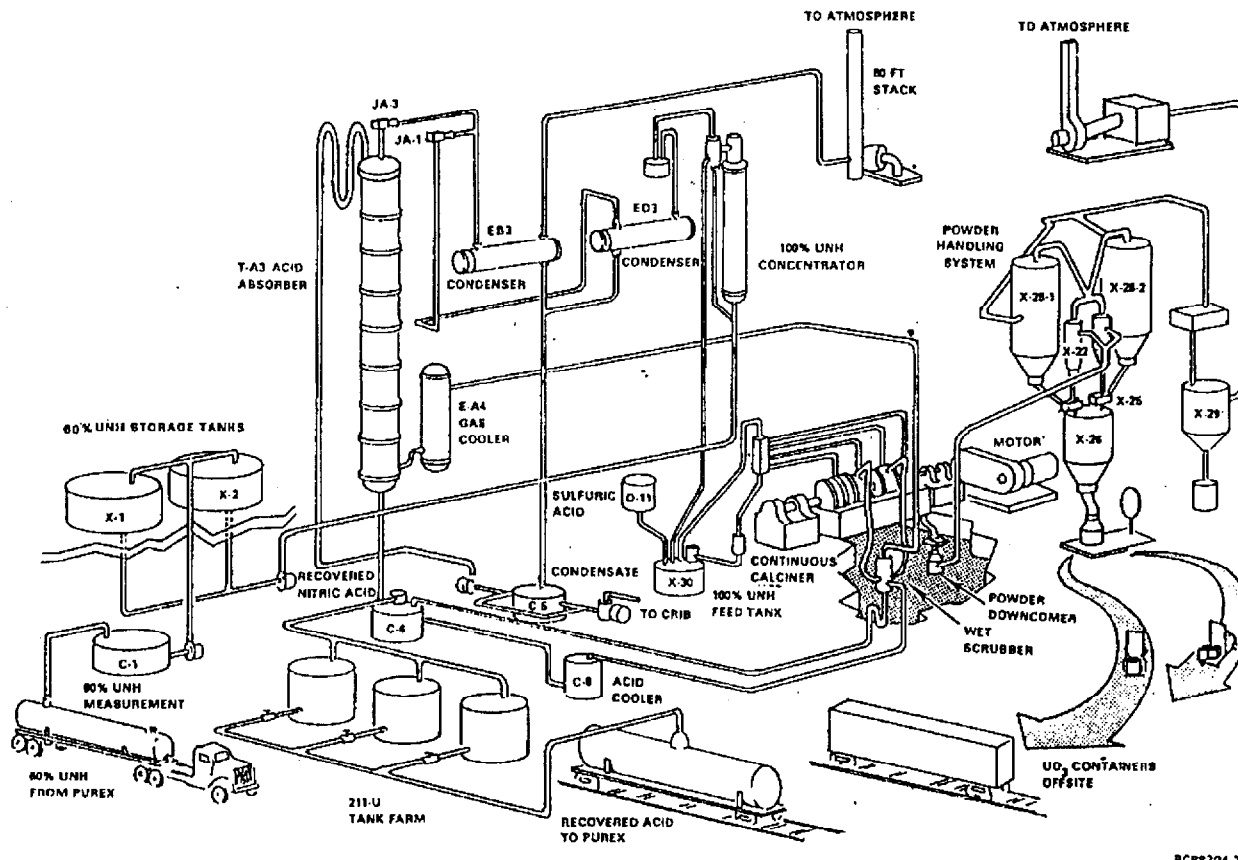


Figure 2-6 UO_3 Plant Process Diagram Involving Continuous Calciners

During the time when UO_3 Plant operated with continuous calciners, the product loadout system was configured approximately as shown in Figure 2-7. Powder in the pickup bin was fluidized and transported to cyclone separators on the fourth floor of the 224-UA tower. The heavy powder dropped out of the cyclone into the storage hopper. The remaining air and powder fines were filtered on primary bag filters, secondary filter

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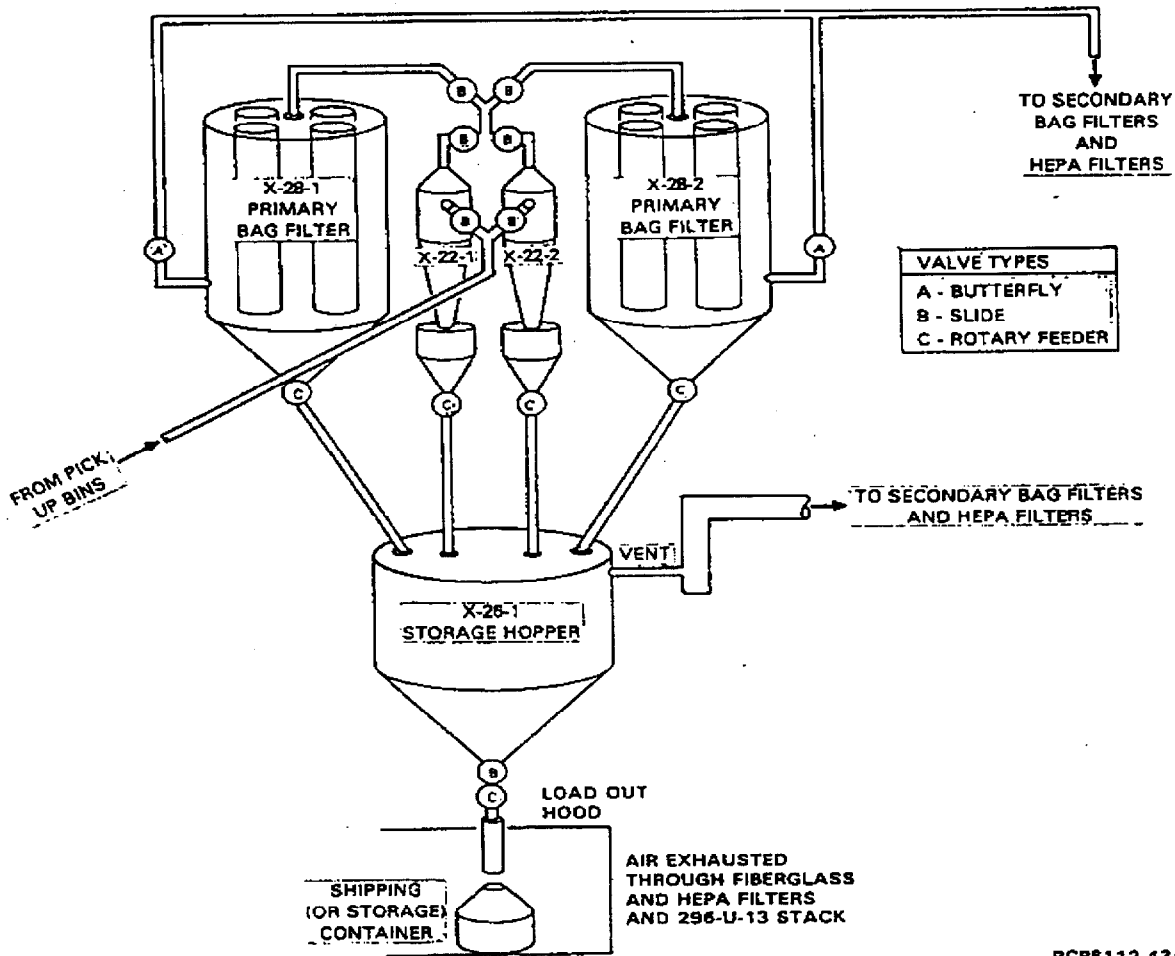


Figure 2-7 UO₃ Product Loadout System

bags, and then on high efficiency particulate air (HEPA) filters, which were added during the 1972 to 1984 shutdown time period. The powder was sampled for acceptance testing [Gustavson 1950].

Acceptable powder in the storage hopper was loaded into approved containers in the 224-UA loadout room. A forklift transported these containers to the 2714-U storage area. From this area, the UO₃ powder was shipped offsite by railcar or truck.

Of all Hanford uranium recycle activities, operation of the UO₃ Plant presented one of the greatest potentials for worker inhalation exposure to uranium and its contaminants because the product was a powder. In this facility, liquid uranium solutions were converted into dry UO₃ powder in ventilated batch kettles or continuous calciners. The calciners were ventilated to recover the nitric acid produced during calcination for reuse. The dry powder was handled pneumatically to minimize worker exposure. Packaging of the UO₃ into drums and T-Hoppers and maintenance on calciners and off-gas filters

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offered the highest potential for exposure to airborne powder. The transfer operation was performed within a ventilated enclosure to assist in dust control.

More detailed information on the UO₃ Plant is provided in Appendix G.

2.2.4.3 Feed Specifications

Feed specifications for the initial operation of the UO₃ Plant are provided in the "Uranium Recovery Technical Manual" [HW-19140 1951]. This specification indicates that the product material from REDOX and U-Plant was tightly controlled, as the UO₃ process provided no further purification of the uranium. The need for process control was recognized in the late 1940s and early 1950s before the plant came on line. The need to maintain the plutonium contamination to very low concentrations was recognized and included in the technical manual. Decisions were made in the late 1940s [Peterson 1947] to enrich the depleted uranium back to normal concentrations. Discussions followed regarding "firm specifications" for the final uranium product to be delivered [Greninger 1950].

The separation plants were originally designed on the basis that the recovered uranium would be sufficiently decontaminated with respect to Pu and gross beta and gamma radiation to permit essentially direct physical handling of the final product in its last form at Hanford. It was also recognized at this early stage that subsequent processing at other plants might result in fractionation or concentration of either fission products or of plutonium and cause a need for more highly specific or greater decontamination than would be required at Hanford. In a 1951 letter [Gamertsfelder 1951], it is stated that "...reclaimed uranium should contain no more than one part plutonium in 7.8×10^6 parts uranium." in order that the hazard due to breathing air contaminated with reclaimed uranium should be no more than 10% greater than for ordinary uranium.

2.2.4.4 Product Specifications:

A "tentative" UO₃ product specification was initially defined in the "REDOX Technical Manual" [HW-18700 1951]. This tentative specification established the following constituent limits:

- | | |
|--|---|
| • Beta Activity from Fission Products | Not more than 30% of beta activity of natural uranium |
| • Gamma Activity from Fission Products | Not more than 300% of gamma activity of natural uranium |
| • UO ₃ Purity | 97% minimum |
| • Plutonium | 100 parts per billion parts of uranium |

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Negotiations continued on UO₃ specifications in 1952, when preliminary specifications were considered which indicated a desired maximum plutonium concentration of 10 ppbp uranium [Hurd 1952]. In 1953, based on operating experience, representatives from Hanford and Oak Ridge agreed upon the properties of the Hanford UO₃ to be included in a firm specification [Smith 1953]. These properties included fission product activity, plutonium content, purity (UO₃ content), particle size, and volatile impurity content, and specified that "The maximum acceptable plutonium concentration shall be ten parts of plutonium per billion parts of uranium. Plutonium shall be determined on each carload composite." The 1953 revised specification is given in [Smith 1953]. The new constituent levels were established as follows:

Firm Specifications Properties:

- Gamma Activity - the average gamma activity for any ten consecutive carload shipments shall be 100% the gamma activity of aged natural uranium. Defined as follows: for the purpose of establishing the average acceptable gamma activity specification, shipments of uranium oxide to K-25 will be considered in designated blocks of ten consecutive carloads. The average acceptable gamma activity due to fission products for a block shall be 100% the gamma activity of aged natural uranium. For the purpose of establishing the maximum gamma activity specification, one carload of oxide shall be considered a unit. The maximum acceptable gamma activity, due to fission products, for a unit shall be 300% the gamma activity of aged natural uranium.
- Beta Activity - the maximum acceptable beta activity, due to fission products, shall be 100% the beta activity of aged natural uranium. Beta activity shall be determined on each carload composite.
- Plutonium Content - the maximum acceptable plutonium concentration shall be ten parts of plutonium per billion parts of uranium. Plutonium shall be determined on each carload composite.
- UO₃ Content - the minimum acceptable UO₃ content shall be 97%. The UO₃ content shall be determined on each lot of 8 drums.

During the operating history of UO₃ production, numerous changes were made to the product specification to better control specific isotopes contributing to beta-gamma exposure of workers. Figure 2-6 shows a copy from one of the early Hanford UO₃ product specifications, indicating an allowed maximum plutonium concentration of 10 ppbp uranium [Smith 1959]. A more complete discussion on specification development and compliance is provided in Section 4.

Product specifications were also discussed, but not adopted, for ²³³U, ²³²U, ²³⁷Np, and ⁹⁹Tc. In 1962 [Judson 1962] it was proposed that the maximum concentration of ²³³U be set at 90 ppm on a ²³⁵U basis, and that ²³²U be set at 110x10⁻⁴ ppm on a ²³⁵U

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HW-59136	
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<u>Analysis</u>	<u>Method Ref.</u>
Sodium	1000.1, 769
Calcium	1000.1
Aluminum	1000.1
Iron	1000.1, 515.25
Chromium	1000.1, 341.1
Nickel	1000.1
Density, bulk	847.2
Density, packed	847.5
3.22 <u>Properties with Established Limits</u>	
3.22.1 <u>Gamma Activity</u>	
Gamma activity due to fission products shall be determined on each carload composite. For the purpose of setting the average acceptable gamma activity, shipments of uranium oxide will be considered in designated blocks of ten consecutive carloads. The average acceptable gamma activity due to fission products for a block shall not exceed 100 percent of the gamma activity for aged normal uranium. For the purpose of setting the maximum acceptable gamma activity specification, one carload shall be considered a unit. The maximum acceptable gamma activity for a unit, due to fission products, shall be 300 percent of the gamma activity of aged normal uranium.	
3.22.2 <u>Beta Activity</u>	
Beta activity due to fission products shall be determined on each carload composite. The maximum acceptable beta activity due to fission products shall be 100 percent of the beta activity of aged normal uranium.	
3.22.3 <u>Plutonium Content</u>	
Plutonium shall be determined on each carload composite. The maximum acceptable plutonium concentration shall be ten parts of plutonium per billion parts of uranium.	

Figure 2-8 Copy Of Early UO₃ Product Specification

basis. In 1971, it was recommended a Np specification of <1 ppm for a lot composite and <0.3 ppm on 10 lot composites [Elgert 1971]. And in 1982 a ⁹⁹Tc specification of 0.4 ppm was proposed [Miskho 1982]. At that time it was implied that there was a 400 ppm limit for ⁹⁹Tc, but it has never been part of the Hanford specifications for UO₃ product.

2.2.4.5 Operating History

The facility began test runs in January 1952, and was in full operation the following month. Thus, for the first time, a full cycle of uranium into and out of Hanford was completed. The first UO₃ calciners simply were large pots that heated the UNH in batches. During the initial operation of U-Plant, the UNH product resulted in UO₃ product which required additional purification to remove non-radioactive impurities. This material was shipped off-site for purification. By the end of 1953, however, process improvements in both the REDOX Plant and U-Plant resulted in UNH so pure that the UO₃ Plant product no longer had to be sent offsite for further purification. This UO₃ was able to be shipped and used directly at Oak Ridge.

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During 1954, UO₃ Plant capacity increased to 18 tons per day with the addition of two gas-fired calciners. Overall production in 1954 was limited, however, by the quantity of feed available from the REDOX and U-Plants. A key improvement that year was the use of vacuum cleaning techniques that enabled the plant to recover 90-95 percent of the oxide powder associated with failed filter bags.

During 1955, monthly UO₃ production averaged 106 percent that of 1954, while the unit costs per ton dropped to 92 percent those of the previous year. In 1956, equipment modifications, including new pot agitators, shafts, seals, bearings and supports, as well as new pot cover assemblies, off-gas systems, and gasketing were employed.

In the same time frame, plans went forward to construct the 224-UA Building, a major addition to the UO₃ Plant, with six large, new, continuous action calciners. These calciners were developed and designed at Hanford. They had large troughs with paddle agitators that turned and mixed the UNH/UO₃ bed throughout the process. The caking and clogging problems that had plagued the pots were obviated by the below-grade valving of the continuous calciners. The new valves used air to agitate the powder, and provided a seal between the calciner and the powder pickup bin, while passing a continuous stream of UO₃.

The new calciners also produced a pebbly product that consisted of spheres with an average diameter of 200 microns (about 1/100th of an inch), as opposed to the granular oxide product of the pots. The first three continuous calciners began operation in the last quarter of 1956 at the same time specially designed T-Hoppers began to replace the 900 pound drums as shipping containers. The T-Hoppers left the site on specially fitted rail flat cars and served as feed hoppers for the Oak Ridge plant customer.

Installation of the last three of the continuous calciners was completed in early 1957. At that time, the 18 pot units were retired from service, and all processing was done through the continuous calciners. Late that year, design was initiated for new facilities which were needed to segregate regular UNH feed from that generated by the processing of enriched metal (E-Metal) in the REDOX Plant. The UO₃ powder that resulted from processing the two types of UNH streams had significantly different nuclear reactivity levels. It was necessary to maintain separation of these streams for the customer at Oak Ridge. Routine transfers of enriched UO₃ from Hanford to Oak Ridge began in early 1959.

In 1958, U-Plant finished its uranium recovery mission and was shut down. However, the quantity of PUREX Plant UNH product being shipped to the UO₃ Plant far surpassed that which had come from U-Plant. Together, the UO₃ and PUREX Plants went on to set and surpass production records almost continually, while the REDOX Plant continued to supply a small stream of enriched UNH until its shutdown in 1967.

During 1959, the concentration equipment and the acid recovery system at the UO₃ Plant were automated. In 1960, the calciners were also automated so that they could be operated and shut down remotely. In 1963, production of UO₃ shipped offsite rose to

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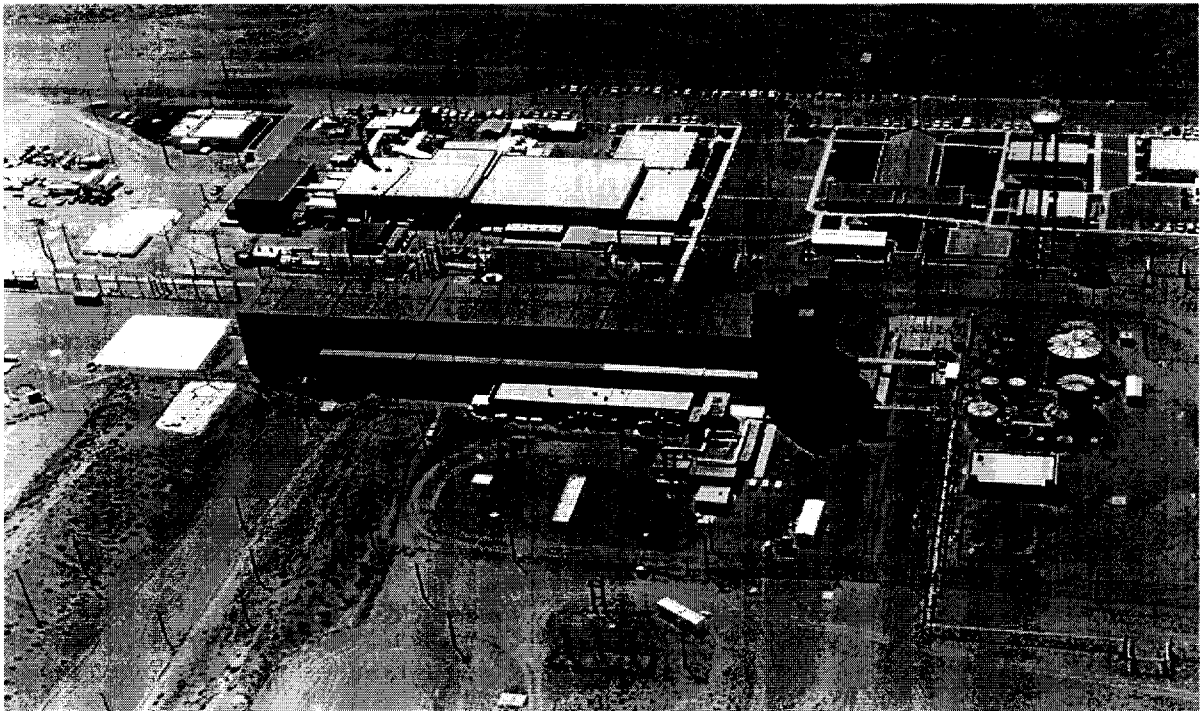
about 12,000 tons per year, and capability was added for processing UNH derived from processing metal enriched to 1.25% ^{235}U (125 Metal).

Beginning in 1967, UO_3 Plant operations were tied exclusively to those of the PUREX Plant. That year, UNH concentrator modifications in the UO_3 Plant improved heat distribution and allowed the calciner feed to maintain a uniformly higher specific gravity, thus producing more powder in the same operating time. Both the UO_3 and PUREX plants closed in 1972, and PUREX resumed operations in late 1983 -- closely followed by UO_3 in early 1984 [Gerber 1996].

In the 1980s, approximately 2-3 campaigns were processed per year. A typical processing campaign was ~22 days at a rate of 34 MTU/day (70% of instantaneous rate). This process rate was based upon all 6 continuous calciners being used. Campaigns would range from 21-32 days.

2.2.4.6 Current Status

The UO_3 Plant has been deactivated and is awaiting decontamination and decommissioning.



2.2.5 REDOX Plant

The REDOX separation plant was the second generation process facility designed to extract plutonium from irradiated uranium fuel. It recovered uranium as a co-product. It

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was the technological answer to the need to increase plutonium production and uranium recovery to satisfy growing national defense needs.

2.2.5.1 Plant Description

Experimentation and design for the REDOX (reduction oxidation) Plant began in 1947 with actual construction beginning in late 1949. The facility commenced operations in 1952. The building is 467 feet long by 161 feet wide by 82 feet high. At one end of the building is a "penthouse", 132 feet high, which housed the extraction columns. It is constructed of thick, steel-reinforced concrete. The processing of irradiated fuel was accomplished in nine below-grade, thickly shielded, concrete cells. Support facilities, including the 222-S laboratory, were constructed in the same time frame. Like the earlier T- and B-Plants, the process first dissolved the irradiated fuel cladding and then dissolved the uranium core. The plutonium was separated from the uranium in a continuous process utilizing methyl isobutyl ketone (hexone). The plant design-basis production rate was about 3 MT uranium per day [Gerber 1996].

2.2.5.2 Material Flowsheet

The REDOX process offered substantial improvement over the T- and B-Plant separation processes by employing continuous solvent extraction. Under specific conditions, plutonium and uranium were found to extract into hexone solvent, allowing separation from the fission products, which remained in aqueous solution. Figure 2-9 shows a simplified flow diagram of the process.

The irradiated reactor fuel was removed from the shipping cask and transferred to a dissolving tank to permit selective removal of the protective aluminum cladding using a caustic solution. The coating waste was neutralized and sent to underground waste tanks for storage. The bare irradiated uranium slugs in the dissolver tank were then reacted with nitric acid to dissolve the uranium and accompanying plutonium and fission products. The resulting uranium nitrate solution was first treated with sodium dichromate and sodium hydroxide to adjust the plutonium valence state and then was contacted with an acidic hexone solvent in a countercurrent extraction column.

The uranium and plutonium formed a complex with the acidified hexone and were separated from the fission products. The aqueous waste was neutralized, treated and transferred to the waste tanks for storage. The plutonium/uranium/hexone complex was treated again to adjust the plutonium and uranium valences to permit separation of the plutonium from the uranium in the next countercurrent extraction column, where the plutonium was stripped from the hexone complex into a nitric acid solution. The uranium/hexone solution was further treated and the uranium removed by a nitric acid wash. Once the separation had been completed, the uranium and plutonium streams were separately treated in two more similar extraction/separation steps through countercurrent extraction columns to further remove impurities and provide product nitrate solutions meeting stringent impurity specifications. Off-specification product

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solutions were sent back into the extraction process for rework. The hexone solvent was washed, neutralized and re-distilled for recycle into the extraction process

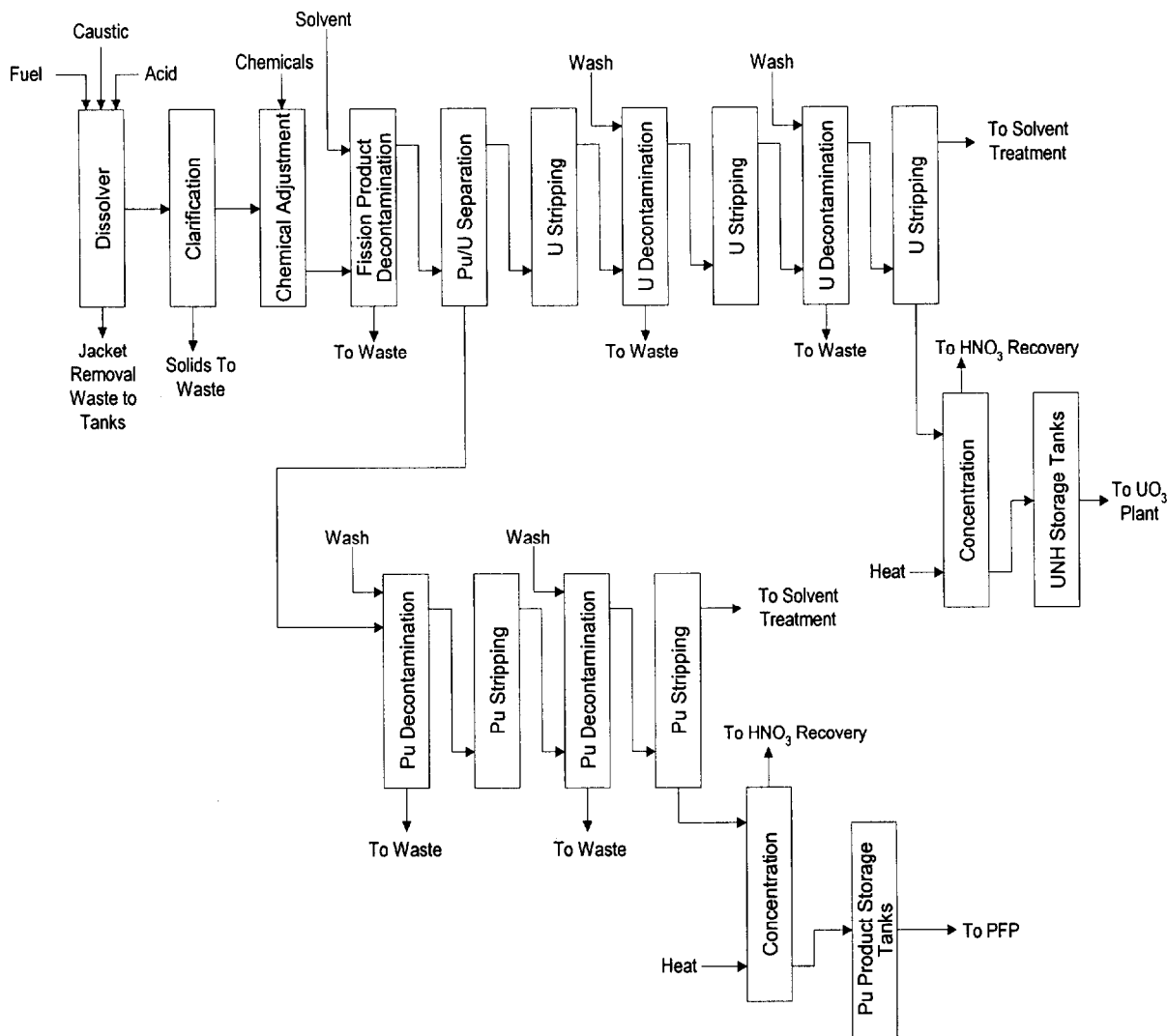


Figure 2-9 REDOX Process Flow Diagram (Simplified)

2.2.5.3 Feed Specifications

The irradiated fuel was aged before processing to eliminate some of the fast decay fission products and to assure that the product beta and gamma radiation limits were met.

2.2.5.4 Product Specifications

The uranium product specifications were driven by the UO₃ product specification requirements. The UO₃ Plant processing of UNH product from REDOX, did not further

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refine the uranium, thus the feed UNH from REDOX had to meet the final UO_3 product specification limits. The plutonium content of three trial lots of UO_3 prepared from material processed through the REDOX Plant in 1952 was less than 5 parts per billion parts (ppbp) uranium [Richards 1952]. It was also reported in June 1952 that the average plutonium concentration in REDOX recovered uranium was less than 1 ppb [HW-24605 1952].

2.2.5.5 Operating History

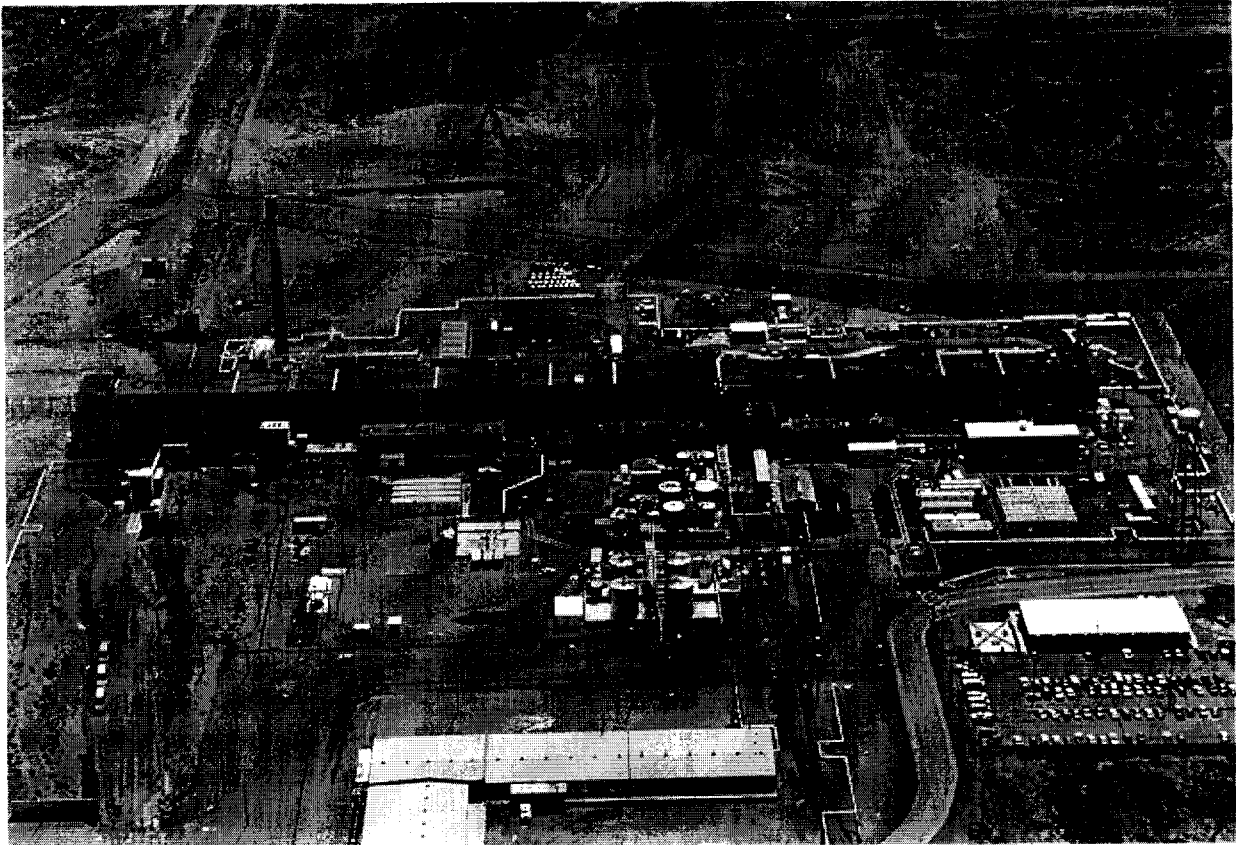
The REDOX plant commenced "hot" operations in January 1952. By April 1952 the plant achieved its design rate production throughput. At the end of 1952 the plant had exceeded its throughput rate by 50% for several months. A series of three "Capacity Increase" projects began in 1953 with the result that the production throughput rate being increased by a factor of 2-3 times that achieved in 1953. By the end of 1954 the throughput rate reached 8 tons per day. Additional improvements brought the throughput rate to 11-12 tons per day by 1958. Part of the capacity increases included construction of the 233-S Plutonium Concentration Building. Completed in 1957, this building carried out the third and final plutonium concentration cycle. Processing of enriched irradiated fuel assemblies (E-metal) began at REDOX in 1958. E-metal throughput initially was limited to 3 tons per day due to criticality considerations in the plant. After installation of multipurpose annular dissolvers and other process improvements, the plant throughput rate reached 12 tons per day for enriched fuel. The REDOX Plant operated until 1967 when it was shut down [Gerber 1996].

2.2.5.6 Current Status

The REDOX Plant is shut down and awaiting decontamination and decommissioning. The 222-S laboratory is currently in operation supporting waste management and environmental control processes.

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2.2.6 PUREX Plant

The PUREX Plant was designed to utilize a third generation separation process to extract plutonium from irradiated uranium fuel. It utilized tributyl phosphate in a continuous separations process to isolate and refine both plutonium and uranium.

2.2.6.1 Plant Description

The PUREX Plant, Building 202-A, as originally built, was a concrete rectangle 1,005 feet long, 104 feet high (with approximately 40 of those feet below grade), and 61.5 feet wide. The shielding capacity of the concrete was designed such that personnel in non-regulated service areas would not receive radiation in excess of 0.1 millirem per hour (mr/hr). The main "canyon" portion, is ~860 feet long and contains twelve major shielded process cells that are 14 feet wide, of varied lengths, and 42.5 feet deep (including the three foot thick cover blocks). Adjoining the north wall of the main 202-A building was a 750-foot long, 60-foot wide service area. It contained three control rooms (central, head end, and power unit), the PUREX process control laboratory, the aqueous make-up and storage area, and the acid concentration vault. An underground solvent storage and make-up facility was located adjacent to the service side of the 202-A Building. Other design features in the PUREX Plant included: (1) an irradiated fuel element storage basin, (2) a railroad tunnel designed to permit unloading of

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contaminated cask cars without compromising the ventilation system, and (3) a "soft wall" at the east end of the building that consisted of concrete blocks. These blocks could be removed for the installation of an additional crane, or to enlarge the building at some future date [Gerber 1996].

2.2.6.2 Material Flowsheet

PUREX operated under a number of different flowsheets that were the result of process and equipment improvements and changing reactor fuel compositions. Additionally, some campaigns involved neptunium and the processing of thorium based reactor fuels. A typical process flow diagram for PUREX processing of N-Reactor irradiated fuel is shown in Figure 2-10. Not shown on this diagram is the Plutonium Oxide Production and Rework Facilities that were added in the PUREX N-cell in the early 1980s. This process allowed conversion of recovered plutonium nitrate to plutonium oxide without having to send the solution to the PFP for conversion to the oxide.

The PUREX process was the next generation separations process. It utilized tributyl phosphate (TBP) to complex with plutonium and uranium under specific conditions and to cleanly separate the uranium and plutonium. The irradiated reactor fuel elements were removed from the storage basin and transferred into three dissolvers. The aluminum cladding was dissolved from the uranium fuel rod with sodium hydroxide. The cladding waste solution was treated to meet waste tank corrosion specifications and transferred to the waste tanks.

The PUREX Plant also processed zirconium clad fuel, which required the use of an ammonium fluoride and ammonium nitrate decladding solution at near boiling conditions. The zirconium-containing decladding waste from the dissolvers was centrifuged and treated to meet Tank Farm waste solution corrosion specifications. The centrifuged solids contained recoverable amounts of uranium and were accumulated and subsequently treated for uranium and plutonium recovery. Next, nitric acid was added in two increments to the dissolvers to dissolve the uranium, plutonium, and fission products into a solution that permitted transfer and separation. The dissolvers were maintained at elevated temperature to facilitate fuel dissolution.

Once the uranium and plutonium and fission products were dissolved, the solution was fed continuously into a pulsed extraction column where the uranium, neptunium, and plutonium were stripped away from the nitric acid solution into a normal-paraffin-hydrocarbon (NPH) solvent containing TBP. The fission products remained in the aqueous solution and were discarded after treatment to the waste tanks. The decontaminated solution of uranium, neptunium and plutonium in the TBP complex was next pumped through a second pulse column where the plutonium was selectively stripped out of the NPH/TBP complex into an aqueous nitric acid solution.

The NPH/TBP complex containing uranium and neptunium was sent to the next pulse column where the uranium and neptunium were stripped from the TBP complex using a weak aqueous nitric acid solution. The uranium/neptunium solution went to the

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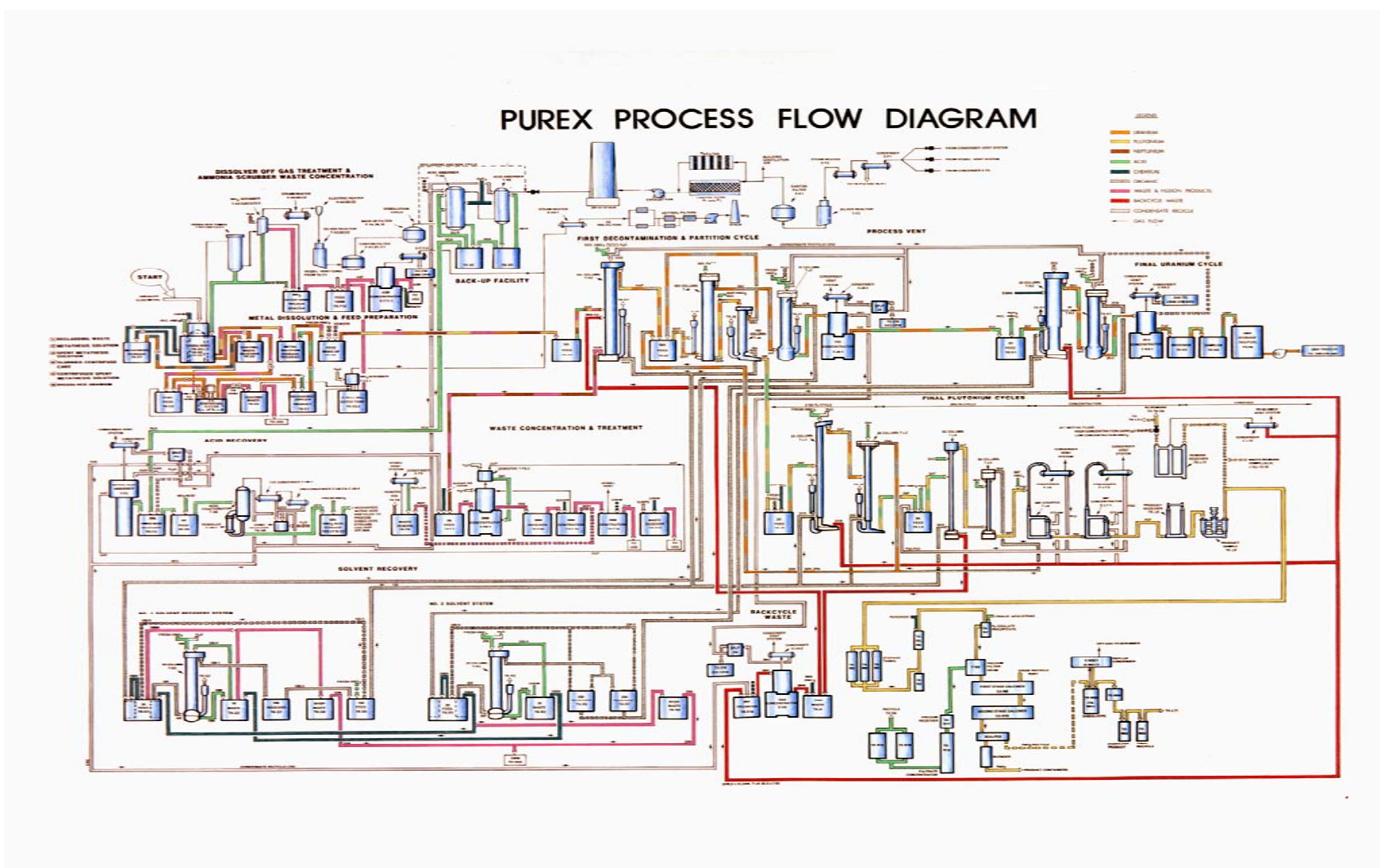


Figure 2-10 PUREX Process Flow Diagram
(excluding the Plutonium Production and Rework Facilities)

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evaporator for concentration before entering the final uranium cycle. The concentrated uranium/neptunium solution was routed to a feed tank for acid adjustment before entering a pulsed stripping column where the uranium/neptunium solution was contacted with NPH/TBP solution. In this column, the uranium was selectively extracted into the NPH/TBP while the neptunium remained with the aqueous flow. The NPH/TBP/uranium complex was then sent to another column for stripping uranium into an aqueous solution which was subsequently concentrated in an evaporator and, after sampling, transferred to the UO_3 feed tank.

The plutonium stream from the second pulsed column was sent to the second and third plutonium cycle extraction columns where it was contacted with NPH/TBP solution repeatedly to remove any residual fission products and trace uranium. Following the completion of the two cleaning cycles the plutonium solution was concentrated to meet product specifications.

Product solutions not meeting specification were recycled back through the process for cleanup. If needed, waste solutions from the columns were scavenged for uranium, plutonium and neptunium before treatment to meet waste tank acceptance criteria. The used NPH/TBP solutions were treated to remove impurities, re-acidified and returned to the process. Nitric acid off-gasses were recovered, concentrated into nitric acid, and returned to the process.

2.2.6.3 Feed Specifications

PUREX feed specifications were driven by the type of reactor fuel that was to be recovered for its plutonium content. The process was flexible and permitted feeds of different enrichment. Criticality control of the fuel dissolution process drove the size and configuration of the plant dissolvers. PUREX processed irradiated fuel initially containing up to 2.1% ^{235}U .

2.2.6.4 Product Specifications

The plutonium and uranium product compositions were derived from the feed requirements imposed by the UO_3 Plant and the Plutonium Finishing Plant (PFP). A typical specification for the UNH product solution is shown in Figure 2-11. For additional information on specification development, see Section 4.

2.2.6.5 Operating History

The PUREX Plant was originally designed to process up to 200 MT of irradiated uranium per month. It achieved this rate and higher over the years it operated. In 1956 alone, the PUREX plant processed 56 percent of the annual plutonium output of Hanford for that year, which was 59% above that of 1955. In September 1956, PUREX demonstrated a sustained, instantaneous rate of 16 MTU/day of irradiated uranium and an on-line efficiency of 99 percent. The following year, the total output of plutonium from Hanford increased by 54 percent over that of 1956, with PUREX processing 71

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percent of this new total. The plant demonstrated an instantaneous production rate of 20 MTU/day, with a reduction in the amount of residual fission product activity in the product of 25 fold below design specifications in 1957.

108	HW-31000
In terms of a Purex-Plant uranium product for inter-area shipment, the following approximate specifications should be met:	
Pu	≤ 10 parts per billion parts of uranium
Gamma activity due to fission-products	≤ 200% of aged natural uranium
Beta activity due to fission-products	≤ 200% of aged natural uranium
Total metallic impurities (T.M.I.)	≤ 200 parts per million parts of uranium
<p><u>Note:</u> The fission-product specification for inter-area shipment is dependent upon the individual fission products present in the uranium product. If, as is expected, Pu constitutes a substantial fraction of the activity, it is permissible to exceed the final UO_2 specification since Pu is largely volatilized in the calcination of uranyl nitrate to the oxide.</p>	
<p>C. <u>PRINCIPLES AND OUTLINE OF THE PUREX PROCESS</u></p> <p>The Purex process is designed to separate uranium and plutonium from each other and from the fission products with which they are associated in irradiated slugs. The process is one of solvent extraction, in which the components are separated from one another by controlling their relative phase distribution between aqueous solutions and an immiscible organic solvent, tributyl phosphate dissolved in a hydrocarbon diluent. In the following subsections the basic principles of the process are briefly described and the several steps which make up the process are outlined. This section is intended only as an introduction to the process, more complete information being contained in Part II (Chapters II through X).</p> <p>1. <u>Basic Principles</u></p> <p>1.1 <u>Properties of uranium of process importance</u></p> <p>The Purex process utilizes the preferential extractability of uranyl nitrate by tributyl phosphate to separate uranium from plutonium and the fission-product elements.</p> <p>Metallic uranium is soluble in nitric acid to form an aqueous solution of $UO_2(NO_3)_2 \cdot xH_2O$. A rapid dissolution rate of the metal in nitric acid is favored by a high concentration of acid, and elevated temperature.</p>	

Figure 2-11 Example of PUREX Product Specification

In 1958, the decision was made to send virtually all of the standard irradiated uranium from the 100 Areas production reactors to PUREX, and to divert processing of enriched uranium containing 0.9475 wt% ^{235}U ("94 Metal") to the REDOX plant. REDOX equipment was reconfigured and handling techniques were changed to accommodate the higher enrichment levels of the 94 Metal. Additionally in 1958, the PUREX facility began the recovery of neptunium (^{237}Np) on an occasional batch basis from its normal product stream. The plant became the AEC's prime supplier of this isotope. For short periods of time, PUREX demonstrated the capacity to operate at 3.6 times its original

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design capacity. In late 1965, other PUREX systems were modified to allow the plant to sustain normal operations at a 4.0 capacity factor, or 33 MTU/day [Gerber 1996].

Beginning in 1963, the PUREX plant was modified to allow for the processing of various fuel types, including fuel from N-Reactor with elements much larger than the four to eight inch long "slugs" from Hanford's single pass reactors. In 1967, the REDOX plant closed, and PUREX became the sole, operating separations facility at Hanford. In 1972, the PUREX plant entered a temporary shutdown period that lasted for 11 years. All of Hanford's single-pass reactors had closed, and most of the available (aged) N-Reactor fuel had been processed. The initial PUREX shutdown was planned for 18 months, to allow the accumulation of N-Reactor fuel. During the shutdown period, other issues arose, including environmental concerns that led to providing upgraded filtration systems, seismic safeguards, backup power sources and many other projects. Increased safety concerns about shipping plutonium in nitrate form from PUREX in the 200-E Area to the Plutonium Finishing Plant in the 200-W Area, led to an additional delay. The shutdown period was extended while facilities were added within the PUREX plant to convert plutonium nitrate to plutonium oxide.

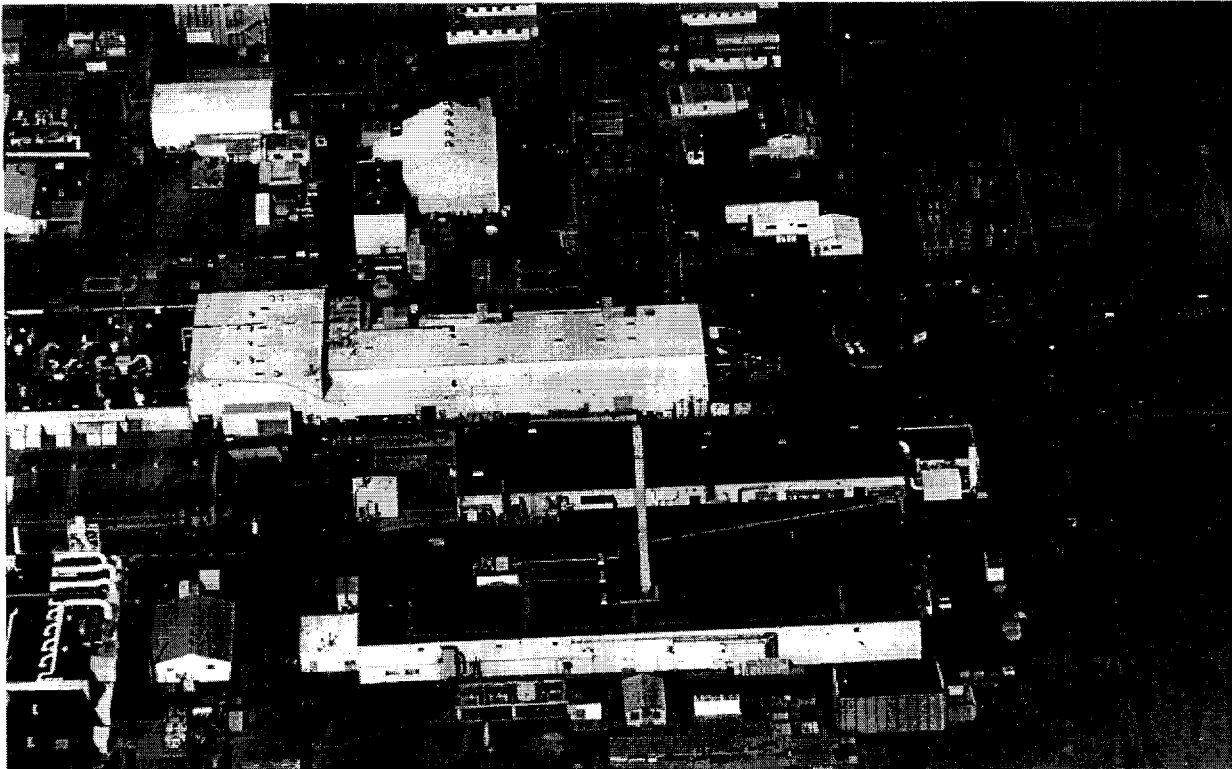
In 1983, the PUREX plant reopened with an operating limit allowing it to process up to 3,000 MTU/year of N-Reactor fuel, or about eight MTU/day. However, the highest sustained (but short-term) production rates in the ensuing years hovered near seven MTU/day, and the highest long-term rates were about three MTU/day. The PUREX facility closed for about six weeks in 1988, for a safety issue, and again for a year beginning in December 1988, after steam pressures briefly fell below levels necessary to support back-up safety equipment. Additional equipment repairs and improvements to waste handling systems also occurred during that closure period. After a stabilization run lasting only a few weeks, the plant again closed in early 1990 in order to prepare additional environmental and safety documentation and facility upgrades. In total, PUREX processed approximately 69 percent of all the irradiated fuel produced at Hanford. In October of that year, the PUREX Plant was placed on standby status by the Secretary of Energy, James Watkins. A final closure order was issued by the DOE in December 1992 [Gerber 1996].

2.2.6.6 Current Status

The PUREX Plant has been deactivated and is awaiting final disposition.

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2.2.7 Fuel Fabrication Complex

The Fuel Fabrication Complex in the 300 Area occupies approximately 3.9 square kilometers (1.5 square miles) or 390 hectares (960 acres) in the southeastern portion of the Hanford Site along the west bank of the Columbia River, approximately 12 kilometers (7 ½ miles) north of the center of Richland.

2.2.7.1 Facility Description

In March 1943, construction of a fuel fabrication complex was started in the 300 Area to support reactor fuel fabrication and other production activities. The first major building was available in autumn of 1943 and housed Hanford's first step in the plutonium production process. Since the 300 Area's fuel fabrication activities were the least likely of the production processes to experience a serious accident, it was considered safe to locate it near populated areas (Richland). An early aerial photograph of the 300 area is provided in Figure 2-12.

Nuclear fuel in the form of solid, rod-like cylinders (fuel slugs) was fabricated from metallic uranium received from off-site production facilities. These fuel fabrication activities consisted of foundry and machining operations to convert uranium metal feed into finished fuel elements.

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Figure 2-12 Early Photograph of Fuel Fabrication Facilities In The 300 Area (Circa 1945)

Initial fuel fabrication activities (1943 through early 1960s) only involved fuel for Hanford's single pass reactors. This fuel-making process was known as the "triple-dip" process. This work took place in two buildings in the 300 Area, known as the 313 Metal Fabrication Building and the 314 Press Building (also known as the Metal Extrusion Building). These were built to perform the fuel fabrication and canning tasks.

The 313 Building contained numerous electrical furnaces and metal presses; three fuel canning areas; a welding area; a can cleaning area; a control room; various supply tanks; a tool room and shop; and various offices, storerooms, and rest rooms. During its operating life, eight major modifications were made adding space required to meet changing needs.

The 314 Press Building enclosed about 17,000 square feet. It contained a 1,000-ton extrusion press, electric furnaces, a rod-straightening machine, a 7.5-ton overhead crane, an autoclave area, a control room, a shop and repair area, pumping units for the press, and various offices and sanitary rest rooms.

The co-extrusion process utilized in the fabrication of N-Reactor fuel was carried out in the 333 Fuels Manufacturing Building, which was constructed of steel frame with double metal insulated panel exterior walls and lightweight metal panels for interior partitions.

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The foundation and floors were poured concrete. The roof consisted of insulated metal paneling covered with felt and roll tarpaper and a tar and gravel surface. The structure was 300 feet by 140 feet, with a total area of 48,817 square feet. In 1980, in response to anticipated increases in production, a small addition was placed on the northwest corner of the 333 Building. It consisted of two stories; the ground level for an open bay shop and the second story for offices. The addition was 33 feet by 104 feet, and extended from the HVAC (heating, cooling and ventilating) supply units on the west side of the building to the north exterior wall.

The co-extrusion process was carried out with various equipment pieces, but the most prominent and unique of these was a Loewy Press that actually pressed all of the fuel components (U core and all of the cladding components) together in one unit. Each N-Reactor fuel element was 26 inches long, weighed approximately 52 pounds and had a tube-in-tube configuration with a coolant channel running down the entire length of the element. Projections also were welded onto each element, as the N-Reactor process tubes were smooth or "ribless." The co-extrusion process provided a better, more uniform bond between core and jacket than had been possible with older methods based on dipping. The new method was beneficial in smoothly cladding the inner and outer tubes.

2.2.7.2 Material Flowsheet

The basic process flow for fuel element preparation for the single pass reactors was to receive and inspect uranium billets from offsite for visual flaws and correct dimensions. Then a sample was irradiated in the 305 Building test reactor. If the reactor tests were acceptable, the lot was accepted and entered the manufacturing process. In the 314 Building, uranium billets were heated in a muffle-type furnace with an interior, inert gas atmosphere. The inert atmosphere, which involved either helium or argon, was used to reduce the oxidation of metal during heating. The uranium was then transferred through a closed passageway to the extrusion press, which also operated in an inert atmosphere. After being extruded, the rods were out-gassed, straightened, and sent to the 313 Building for machining and jacketing. In the 313 Building, uranium fuel rods were machined into fuel cores in lengths of either 4 inches or 8 inches, with 1.3-inch diameters. Known as "slugs," these cores were "canned" or jacketed into finished elements, and then tested and inspected in this building. This jacketed fuel was then sent to the 314 Building for autoclave and radiographic inspection. Figure 2-13 illustrates the fuel fabrication process for the single pass reactors.

Additional fuel fabrication activities were initiated in the early 1960s for the fabrication of N-Reactor fuel. This process, illustrated in Figure 2-14, is significantly different than single pass reactor fuel process. The fuel was larger in diameter, longer, and consisted of two fuel elements, one within the other. It also had a centered annulus that was created by the co-extrusion tube-in-tube process. The two sizes were made, tested and then assembled to form a finished fuel rod.

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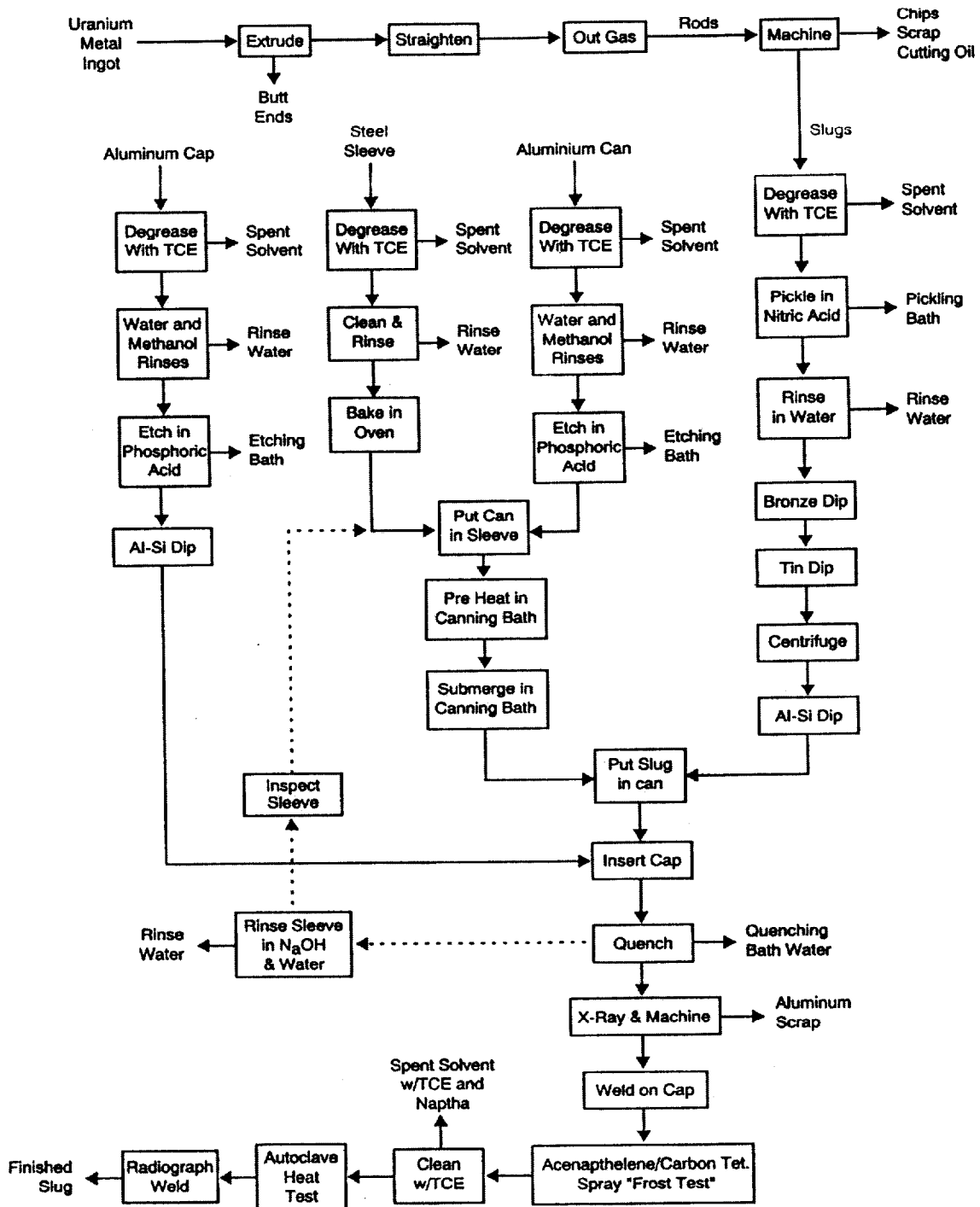


Figure 2-13 Fuel Fabrication Process for Single-Pass Reactors.

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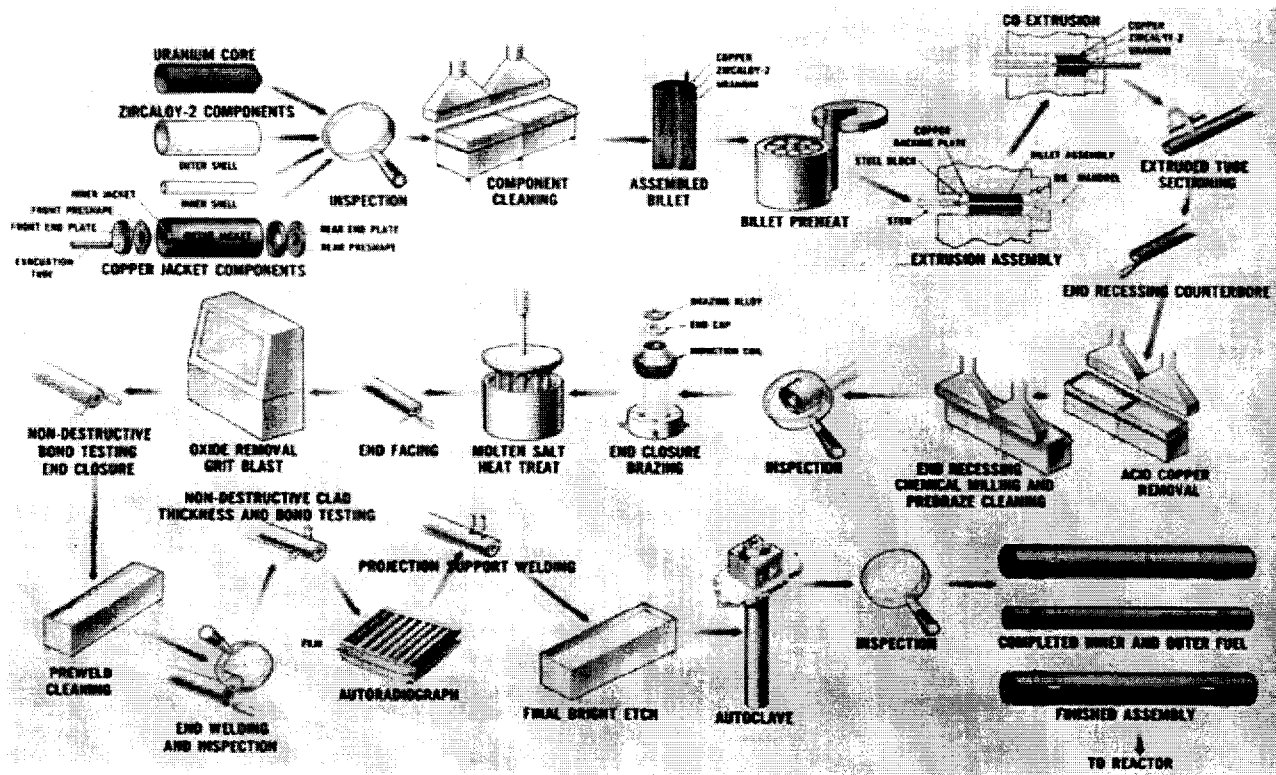


Figure 2-14 N-Reactor Fuel Fabrication Process

More detailed information on past fuel fabrication processes and activities at Hanford can be found in Appendix F.

Over the years, several other ancillary or off-shoot processes have taken place in the 313 and 314 Buildings. Among these have been uranium scrap recovery operations, experimental and/or small-scale fuel making ventures, and waste treatment activities. From its earliest days, concern of the Manhattan Engineer District (MED) about the adequacy of uranium supplies brought strict policies that mandated the reclamation of all possible uranium scraps at federal atomic sites. During the earliest fuel fabrication operations (1943 to mid 1944) at Hanford, difficulties with early fuel canning techniques produced thousands of rejected cores and other scraps, including lathe turnings and metal oxides that formed when canned slugs failed in autoclave tests. In June of 1944, Du Pont reported that "all available space" around the 313 and 314 Buildings was filled with cans of scrap, and the fabrication area fence had to be moved about 30 feet east of the fresh fuel storage building 303-J to allow for more storage space. In addition, beginning with the startup of extrusion press tests in January 1945, extrusion butt ends, oxides, and container residues collected, along with acids from the slug pickling process and from the slug recovery process were generated.

At first, the various types of scrap were shipped to offsite reclamation processing centers. By 1946, the accumulating volume of uranium scraps brought a change in policy at Hanford. This change was the result of scrap storage expense and risks associated with potential fire and security hazards during shipment. Consequently, a

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"chip recovery" operation began in the 314 Building to process scrap. It operated only a few days a month and involved collecting all chips and turnings from machining operations, sorting them, breaking them into small pieces, washing, drying, and then pressing them into briquettes. At first, the briquettes themselves were shipped offsite. In May, however, the MED ordered briquetting to be discontinued due to a number of uranium chip fires within the centrifuging step at other sites.

A "melt plant" was established in the 314 Building in late 1947. In that process, uranium scrap could be recovered as metal for fuel fabrication. This was accomplished by combining uranium tetrafluoride (UF_4 or "green salt") and either calcium chips or magnesium chips, placing this mixture in a dolomite-coated steel vessel, which was then heated until free molten uranium separated from magnesium fluoride or calcium fluoride, and then allowed to cool. The molten uranium settled into large buttons shaped like Derby hats (called "Derbies" by Hanford workers). The Derbies were separated from the slag (calcium fluoride and magnesium fluoride salt) utilizing a jackhammer to break up the slag. These Derbies were then melted in a vacuum furnace, and cast into ingots. These ingots were then rolled into new uranium rods, either offsite or at Hanford, and used to make additional fuel rods.

In the spring of 1946, an additional scrap recovery operation known as the "oxide burner" began on the north side of the 314 Building. All uranium-bearing powder and particulate matter that could be collected from the fuel fabrication facilities, as well as the tailings or settlings from washes and quenches, was burned to convert it to a stable oxide (powder) form. The UO_2 was then collected in 5-gallon containers for shipment offsite [Gerber 1992].

Between 1952 and 1954 both the vacuum furnace melting and the oxide burning processes were phased out and replaced with a process which slurried all the scrap into sodium diuranate, stored it in drums, and returned it to the Feed Materials Processing Center (FMPC), Fernald, Ohio, for recovery [Gerber 1996].

The concentration of any transuranics and fission products in the scrap from fuel fabrication activities would have been the same as that of the uranium metal received at Hanford for fuel fabrication. During our review of historical documentation for this study, we have found no information to suggest that the scrap processing activities would have altered the ratio of impurities to uranium.

2.2.7.3 Feed Specifications

Natural uranium was used for billet fabrication until about 1952 when the use of recycled uranium was phased in. The billets were accepted for use based upon material certification and chemical analysis received from the manufacturer. The scrap material was returned on the basis of the same billet receiving certifications and analysis data since the fuel fabrication process did not make any significant chemical changes.

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2.2.7.4 Product Specifications

Product specifications for the reactor fuel assemblies were based upon conforming to the design requirements of the reactor. Fuel was inspected dimensionally and by radiograph, ultrasonic, and other standard quality measurements. Chemical constituent control was confirmed by supplier certifications. Welds were examined and weld integrity verified.

2.2.7.5 Operating History

The earliest uranium received for the fabrication of reactor fuel arrived at Hanford in October 1943 as extruded rods. The rods were delivered to the Riverland Yards, which were an official part of Hanford and located just east of the Midway power substation and west of the 100-B Reactor Area. Because railroad track had not yet been completed to the 300 Area, the rods were taken by rail to the Construction Camp about 20 miles north of Richland, and then trucked to the 300 Area. Once railroad service to the 300 Area was connected in January 1944, uranium was delivered to the fabrication area by rail.

Newly arrived uranium rods were unpacked and visually inspected (in sample amounts) for cracks and for overall dimensions. A random amount from each lot was taken to the 305 Test Pile Building just west of the 313 Building, and irradiated at a low level to check for warping, cracking, and embrittlement under irradiation. If the sample withstood the process in good form, the entire lot was accepted. Operations began in December 1943. The first uranium fabrication operation at Hanford was machining, in which bare uranium rods were machined to specific core dimensions in the 313 Building. The following month, operators began degreasing the machined cores before inspection, using a commercial product that contained primarily trichloroethylene, Detrex™, a solvent degreaser. Core canning operations actually began in the 313 Building in March 1944.

In the 314 Building, autoclaves for fuel element testing started to operate in July 1944. A scrap recovery process began the following month. Out-gassing and straightening operations started in the 314 Building in September 1944, but Hanford's uranium rods still were being extruded offsite. Beginning in November 1944, uranium was transported to Hanford as billets, which were stored until the extrusion process began to operate in the 314 Building in January 1945. The press testing phase lasted into mid-spring, and then fuel operations commenced. Improved performance ended required shift work in the metal preparation buildings in June 1945, and work proceeded on a straight, 6-day-per-week schedule. From that time until 1948, a complete cycle of metal preparation was conducted at Hanford.

2.2.7.6 Current Status

Fuel and target fabrication in the 300 Area ceased permanently in 1987 with the closure of the N-Reactor. Some of the facilities have been decommissioned. Based on the

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integrated site baseline priorities, cleanup and restoration of the 300 Area presents many challenges. A portion of the 313 building now produces commercial aluminum extrusions. Other buildings are expected to be leased if suitable tenants can be found and after the facilities are decontaminated to guideline levels which allow occupancy by non-rad workers.

2.2.8 Other Uranium Handling Facilities

Several other Hanford facilities were involved in handling depleted uranium. These are discussed below. Much of this work supported reactor research activities at both this and other DOE sites.

2.2.8.1 308 Building Mixed Oxide Fuel Fabrication

The fabrication of mixed oxide (plutonium oxide and uranium oxide) fuel in the 308 building utilized both depleted and natural uranium. Operations were conducted in gloveboxes to protect the workers from inhaling the material.

2.2.8.2 306 Building

Depleted uranium oxide fuel pellets were fabricated in rooms 158 and 159 of this facility. These operations were conducted in open-faced hoods.

2.2.8.3 234-5Z Plutonium Finishing Plant (PFP)

In 1972, the flowsheet and piping in the PFP were modified to allow separation and recovery of plutonium from some plutonium-uranium materials. The separated UNH stream was accumulated and trucked to the PUREX plant. At PUREX, the UNH was offloaded and discarded to the underground waste storage tanks since there was no need for the material.

2.2.8.4 321 Building

Development and testing of a continuous calciner for production calciners to replace the batch kettles at the UO₃ Plant was performed in the 321 Building. The calciner development proved successful and 6 units were installed in 224UA building. About 200,000 pounds of uranium, as UNH, was trucked from the 200 West area to the 321 Building and processed in calciner development activities. The UO₃ product powder was subsequently returned to the UO₃ Plant and blended into the plant's product stream.

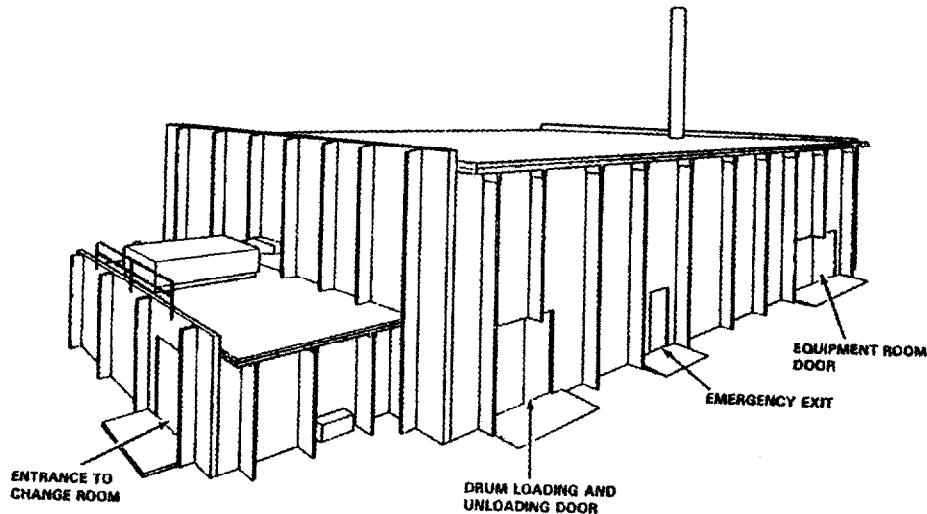
2.2.8.5 303-M Uranium Oxide Facility

A small 303-L Building was constructed in 1961 for burning uranium metal scraps to an oxide form that would be suitable for shipment to the FMPC for recovery. Burning was stopped in 1971 due to operating problems. The building was removed in 1976. In

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1983, a new building, 303-M Uranium Oxide Facility, was constructed on the same site. This high bay, 51 ft by 35 ft by 25 ft (high) concrete structure with a one story extension 20 ft by 13.5 ft on the north side was used to convert more than 115 tons of uranium scrap to oxide during it's brief operating period of 1984 to 1987 [Gerber 1992]. A drawing of this facility is shown in Figure 2-15.



**Figure 2-15 303-M Uranium Oxide Facility
[Prezbindowski 1983]**

2.3 Activity Summary

Hanford operation started in 1943 to support the defense effort of World War II. After W.W.II, it continued to support the growing defense effort. In doing so, the initial facilities were expanded and new facilities built to meet the congressional mandates for defense. In 1993, all production efforts supporting defense were terminated and the site was redirected to a clean-up mission. This clean-up mission is under way and some facilities have already been decontaminated and either removed or turned over to private industry for new uses.

The first major facilities at Hanford included B-, D-, and F-Reactors, T-Plant, B-Plant, a Fuel Fabrication complex and a plutonium purification plant. In addition to these major facilities, supporting structures, steam plants, housing, water, and personnel support facilities were simultaneously built. The first reactor was started in September 1944. The first batch of plutonium was shipped from the site in February 1945 to Los Alamos where it was converted into the first atomic device.

After the war, it was recognized that the uranium needed to continue and expand plutonium production was in short supply and new sources of uranium would be

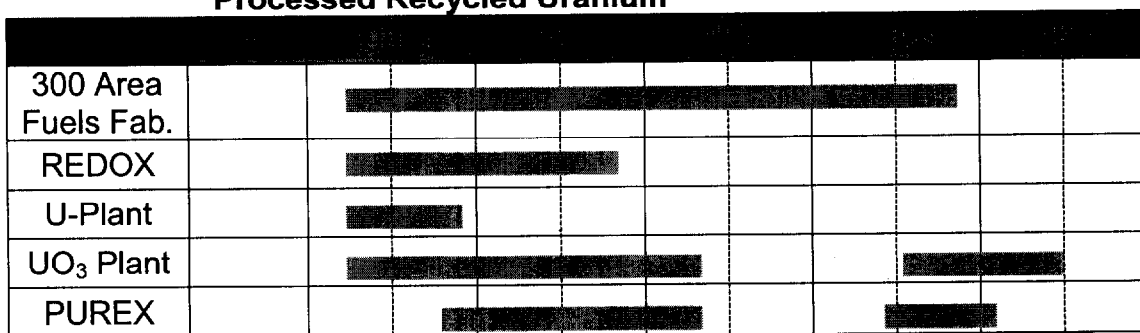
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required. One source was determined to be the irradiated uranium then residing in the high-level waste stored in Hanford's underground waste tanks. In 1947, reuse of this uranium was discussed and actions were taken to develop recovery processes for this waste. By 1952, U-Plant had been converted to process the high-level waste to recover uranium for recycle. The high purity UNH product needed to be converted to a safe, shippable oxide form. Simultaneously with the recovery process development and implementation, a uranium conversion process was developed and the UO₃ Plant built to provide a stable, transportable UO₃ powder. The uranium trioxide powder was to be shipped to the gaseous diffusion plants for enrichment and conversion to uranium metal billets. In the same time frame, the REDOX process was developed and the REDOX Plant was constructed to support the increase in the nation's plutonium needs. The REDOX facility, commissioned in 1952, recovered both plutonium and uranium as co-products. REDOX began transferring recovered uranium as UNH to the UO₃ Plant a month or two before UNH was available from U-Plant.

As increased plutonium product was required to meet defense needs, the PUREX process was developed to support the planned production increases and the PUREX separations plant was built, coming online in 1956. PUREX performance permitted the shut down of the REDOX and T-Plant facilities. The PUREX uranium output was also sent to the UO₃ Plant for conversion to oxide. In 1972, PUREX operations were shut down. In 1983, the PUREX plant was reactivated to meet national plutonium requirements created by congressional direction. The UO₃ Plant was also brought back on line to process the UNH output of the PUREX plant. In 1993, all plutonium operations were halted and PUREX Plant and the UO₃ Plants were shutdown to await decommissioning. Figure 2-16 summarizes the operational periods for the major Hanford Plants.

Figure 2-16 Operating Intervals During Which Major Hanford Facilities Processed Recycled Uranium



Record searches to support the Uranium Mass Balance Project indicated that Hanford produced a high quality uranium product meeting specifications from the beginning of production. The searches indicated that the recognition of a need for specification occurred several years before the first uranium trioxide production batch was produced. This specification need was driven by both reactor and worker health considerations. Detailed information on recycled uranium specifications and measured impurities is presented in Section 4.

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