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IFR FUEL CYCLE*

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reactor R&D program. At the present time, both the process equipment and the Fuel Cycle Facility (FCF) at Argonne's Experimental Breeder Reactor-II (EBR-II) test facility complex in Idaho are in the final stages of preparation. A one-year startup period began in September 1991. When in full operation, FCF, operating in conjunction with EBR-II, will provide an integrated demonstration of all key characteristics of the IFR concept. This paper will describe the pyroprocess, with emphasis on the status of the key reprocessing step (electrorefining), and will discuss the features of the FCF.

ABSTRACT

The next major milestone of the IFR program is engineering-scale demonstration of the pyroprocess fuel cycle. The EBR-II Fuel Cycle Facility has just entered a startup phase, which includes completion of facility modifications and installation and cold checkout of process equipment. This paper reviews the development of the electrorefining pyroprocess, the design and construction of the facility for the hot demonstration, the design and fabrication of the equipment, and the schedule and initial plan for its operation.

INTRODUCTION

Engineering-scale demonstration of Argonne National Laboratory's Integral Fast Reactor (IFR) pyroprocess fuel cycle is the next major milestone in the U.S. advanced

PYROPROCESS

The pyroprocess is a new fuel cycle technology with significant potential advantages over more traditional approaches, particularly in the U.S. context. It is a very simple, compact, and hopefully inexpensive route to separation and recovery of heavy metals (including essentially all transuranics) from spent fuel, and their recasting into new fuel rods for return to the reactor. The term "pyroprocess" was coined from the more descriptive "pyrometallurgical" process--implying high-temperature processing of metals. Indeed, metal alloy fuel is another distinctive feature of the IFR, and its use basically enables the use of the pyroprocess for the fuel cycle. Additionally, metal fuel brings with it significant safety features over the oxide, as demonstrated in EBR-II testing [1]. Argonne's experience with metal fuels--both their manufacture in glovebox facilities and their performance within the reactor--is the subject of a companion paper at this conference by L. C. Walters et al. [2].

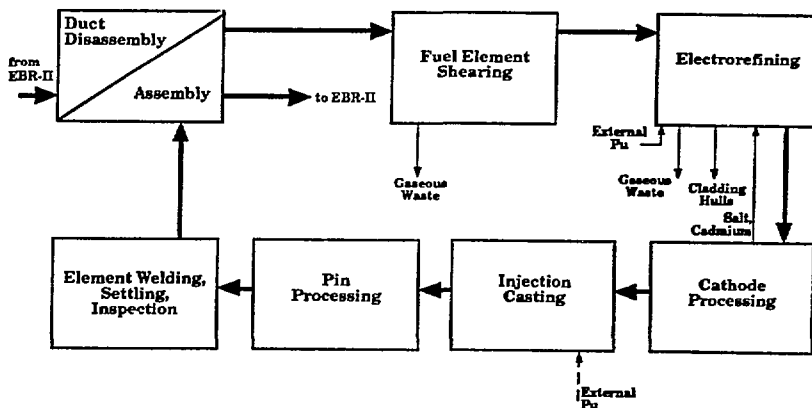


Figure 1. Basic Pyroprocess in EBR-II Application

In application to the specific case of EBR-II, the overall steps in the pyroprocess are as shown in Figure 1.

Electrorefining and subsequent retorting of the product cathode ("cathode processing" above) are the heart of the separations and recovery steps of this fuel cycle. Further, this is new technology. Because of this, the state of the R&D related to these process steps will be reviewed in some detail, then FCF demonstration itself will be described.

ELECTROREFINING PROCESS

Process Basis

Electrorefining employs a cadmium anode and a molten salt electrolyte (LiCl-KCl-U/PuCl_3) at 500°C for processing spent metal fuels [3, 4, 5]. A simplified schematic of the electrorefining apparatus for processing the IFR fuel and blanket material is given in Figure 2. Spent fuel pins are chopped and put in a basket for anodic dissolution in the electrorefiner (ER) at 500°C . Cadmium dichloride (CdCl_2) is then added to oxidize alkali, alkaline earth, and most rare earth metals to their chlorides. Essentially pure uranium is electrotransported to the solid cathode; a mixed U-Pu product is electrotransported to a liquid cadmium cathode (not shown in Figure 2). These cathodes are removed from the ER cell and retorted to vaporize the cadmium and any occluded salt and to consolidate the product by melting.

The chemistry of the pyroprocess is based on the relative ease of oxidation of the elements that make up the metal fuel. This was determined from the free energies of formation of chlorides of these elements, which show that alkali and alkaline earth metals are readily oxidized into the salt, and less easily oxidized (noble) elements remain as metals. The cadmium pool is periodically removed

from the electrorefiner and the cadmium is distilled to separate the noble metal. The elements subject to electrotransport are U, Pu, Np, Am, Cm, and Zr.

A process model based on thermodynamic data has been developed for predicting the electrotransport of uranium, plutonium, and rare earth fission products [6]. The model also predicts the compositions of the solid cathode and liquid cadmium cathode. A series of experiments was conducted for model verification. The results of these experiments indicated that little or no rare earths are deposited with uranium; the uranium deposit is essentially free of plutonium and other actinides until the uranium inventory reaches a low level; the minor actinides (Np, Am, Cm) follow plutonium; and minor quantities of zirconium are electrotransported. The agreement between this observed behavior and that predicted by the model was very good.

Process and Equipment Development

Initial (starting in 1983) process development and process feasibility and flowsheet verification studies were carried out in an unshielded plutonium glovebox facility. The major equipment used was a laboratory-scale (0.5 kg U, Pu) electrorefiner and a fuel melter-retort. Late in 1987, a Mark-III engineering-scale electrorefining facility (10 kg of uranium on a single solid cathode) was constructed to demonstrate the electrolytic transport of uranium at plant-scale levels and to measure the anodic dissolution rate of clad segments of uranium-zirconium alloy. The electrorefiner assembly is enclosed by a non-plutonium glovebox (with ovens, transfer locks, wells, and lifting systems), which has a system for controlling gas pressure, temperature, and gas purity. Major equipment components for this facility are discussed below.

Electrorefiner Assembly

The electrorefiner assembly consists of a 32-in. diameter crucible, crucible insert and cover, electrolyte stirrer assembly, cadmium stirrer assembly, cathode assembly, and anodic dissolver assembly. The crucible is fabricated from low-carbon steel. The crucible cover is constructed of 5-cm-thick low-carbon steel; four large holes are used as mounting positions for a cathode, cadmium stirrer assembly, electrolyte stirrer assembly, and anodic dissolver assembly.

Enclosure System

The glovebox enclosure assembly is 4.9 m wide x 2.4 m deep x 3.7 m high and is supported 1.5 m off the floor so that the electrorefiner crucible flange can rest on top of a similar flange on the enclosure floor. The enclosure is equipped with an electrically powered bridge crane with a capacity of ~2010 kg for equipment and materials

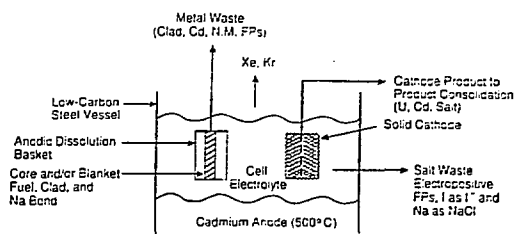


Figure 2. Schematic Representation of Electrorefiner Operation with Anodic Dissolution of Fuel and Electrotransport to a Solid Cathode. (The abbreviation N.M. FPs represents noble metal fission products.)

handling. The environmental control system consists of a main purification and pressure control subsystem, a backup pressure control subsystem, and a temperature control subsystem. Levels of oxygen, nitrogen, and moisture are controlled to less than 15 ppm each.

EXPERIMENTAL RESULTS

Anodic Dissolution

Small-scale laboratory tests were conducted with individual clad fuel (unirradiated) segments to determine the advantages of anodic dissolution vs. direct dissolution. The results showed that both methods were suitable, and that anodic dissolution provided a higher dissolution rate. The voltage used was sufficient to oxidize the heavy metal pin but leave the cladding shell intact. Based on the laboratory tests, anodic dissolution was chosen for scale-up to plant scale (10 kg batch size).

In the fuel dissolution step, uranium and plutonium metals are oxidized at the anode (fuel segments in perforated, prismatic anode baskets), and uranium/plutonium chlorides are simultaneously reduced at the cathode (either a metal mandrel or a ceramic vessel with liquid cadmium). (The Cl^- balance is maintained.) Table I shows the oxidation-reduction reactions for uranium, the bulk of the fuel. Cylindrical baskets gave very low current efficiency, since the U^{4+} ions formed on the outside shell, reaction (2), of the basket could not be brought into contact with fuel and were reduced parasitically, reaction (5), at the cathode. With four prismatic baskets arranged on an anode shaft in the shape of a plus (+), each basket follows in the wake of another basket when the anode shaft is rotated, and the U^{4+} rich salt is continuously contacted with fuel as the salt flows through the openings in the basket shell, reaction (3).

TABLE I. Anodic Dissolution Reactions

<u>Anode</u>			
(1)	$U^0 - 3e$	\longrightarrow	U^{3+} (USEFUL)
(2)	$U^{3+} - e$	\longrightarrow	U^{4+} (PARASITIC)
(3)	$3U^{4+} + U^0$	\longrightarrow	$4U^{3+}$ (USEFUL)
<u>Cathode</u>			
(4)	$U^{3+} + 3e$	\longrightarrow	U^0 (USEFUL)
(5)	$U^{4+} + e$	\longrightarrow	U^{3+} (PARASITIC)

In the anodic dissolution tests with the Mark-III engineering-scale electrorefiner, the anode baskets were used in more than 10 runs to dissolve 10 kg batches of uranium and showed little visual evidence of corrosion. In these tests, ten kilogram batches of clad heavy metal pins were completely dissolved in 24-30 hours. The current efficiency for this anodic process was greater than

50%. An important feature of the anode design is the capability for removing most of the residual electrolyte (after dissolution) from the empty cladding hulls in the anode baskets by spinning the assembly in the space above the salt level. The centrifugal force produced in the assembly strips residual liquid electrolyte from the baskets. The cladding hulls, essentially salt free, are easily removed from the anode baskets, which are then reused.

The anodic dissolution of simulated fuel in the Mark-III engineering-scale electrorefiner is now a routine operation. However, it was not certain whether our results were applicable to the dissolution of irradiated fuels. For this reason, experiments [7] with sodium-bonded irradiated fuel (both anodic dissolution and electrotransport to solid cathodes) of about 10% burnup were conducted using a small electrorefining cell in the Hot Fuel Examination Facility at EBR-II. Of particular importance is the quantity of uranium, plutonium, and fission products remaining with the cladding hulls at the completion of the anodic dissolution operation. These materials were quantified for 10 cladding hulls resulting from 10 anodic dissolution tests of single segments (0.64-cm long) of irradiated fuel from EBR-II. Binary fuel, U-10 wt % Zr, was used in the first six tests and ternary fuel, U-19 wt % Pu-10 wt % Zr, in the last four tests. Results for the U-Pu-Zr fuel (expressed as the percentage of initial material or isotope of the material which remained in the remnant after anodic dissolution) are as follows: ^{95}Nb , 0.02; ^{95}Zr , 0.03; ^{106}Ru , 0.02; ^{137}Cs , 0.003; ^{144}Ce , 0.5; U, 0.03; and Pu, 0.005. The removal of some of the other fission products was slightly less complete. Similar results were obtained for the U-Zr fuel. Essentially all the fuel dissolves.

Electrotransport to Solid Cathode

In the IFR process, solid cathodes are used to collect uranium and exclude plutonium metal from the product. For this operation, uranium is electrotransported from the cadmium pool in the electrorefiner to a solid cathode. Prior to this, uranium is electrotransported from anodic dissolution baskets to the cadmium pool. Alternatively, uranium can be electrotransported directly from the anodic dissolution baskets to a solid cathode. This latter mode of operation reduces overall processing time, since the dissolution and collection processes occur simultaneously.

A single cylindrical iron mandrel has been tested as a cathode. The uranium deposit collected on this cathode is physically removed from the iron mandrel in a product recovery step. During formation of a deposit, the cathode shaft is rotated, and scrapers (BeO and steel plates located in the electrolyte phase) limit the overall diameter and length of the deposit. Dendrites that grow beyond these

limits are broken off by the scrapers, fall into the cadmium pool, and are recycled. The density of the dendritic deposit is increased as the electrotransport of uranium and the shaping operations are continued; however, the current efficiency is lowered because of the physical loss of uranium from the cathode.

Twenty-five cathode runs were conducted to determine the process parameters for electrotransport of uranium to single mandrel cathodes. The weights of cathode deposit collected are as high as 12 kg. The deposits are uniform in shape and showed the highest density at the lower end of the deposit. The single steel mandrel has been selected as the reference solid cathode because of above success and ease of removing the dendritic product.

Electrotransport to Liquid Cadmium Cathode

A plutonium/uranium mixture is collected in a cadmium pool contained in a ceramic crucible suspended in the electrolyte phase. To keep reasonable size, it is necessary to collect an amount of plutonium in the cadmium pool in excess of the solubility limit of plutonium in cadmium (3.62 wt % at 500°C). When the plutonium solubility limit is exceeded, the plutonium precipitates as the intermetallic compound, PuCd₆. In small-scale laboratory work (0.2 kg plutonium scale), cadmium cathodes which contain about 15 vol % plutonium solid have been produced. For the FCF electrorefiner, the processing of a single 10 kg heavy metal fuel batch will provide about 2.5 kg plutonium to be transported to the cadmium cathode. A cathode pool containing about 30 kg of cadmium is required for this plutonium collection (a 5 L ceramic crucible is required).

Electrochemical transport of kilogram quantities of uranium to a liquid cadmium cathode (LCC) is being studied in the Mark-III electrorefiner. The experiments conducted have used uranium to simulate the behavior of uranium-plutonium mixtures. Limitations in these experiments include: (1) one metal (uranium) is electrotransported rather than two metals simultaneously (uranium and plutonium), and (2) without plutonium, the effect of PuCd₆ on the process was not determined. On the other hand, the containment of uranium dendrites in the product ingot was a major concern and was sufficient reason for using uranium to simulate the behavior of uranium-plutonium mixtures.

Four liquid-cadmium cathode runs have been completed. The weight of uranium in the product from these runs was 3.0, 2.8, 4.4, and 3.0 kg, respectively. The cadmium concentration in the products (68-75 wt %) was about that needed to form PuCd₆ (74 wt % cadmium), if the uranium were replaced with plutonium. If the distribution of heavy metal in cadmium achieved in these runs can be obtained with this hardware during electrotransport of

uranium-plutonium mixtures, a product with 3 kg of heavy metal can be collected in about 30 hours, and this would meet the IFR processing needs for uranium-plutonium mixtures.

Product Consolidation

Both the plutonium-uranium products electrotransported to liquid cadmium cathodes and the uranium products electrodeposited on a solid mandrel cathode have to be processed to remove salt and cadmium and recover the uranium and plutonium for recycle. Tests have shown that high-purity uranium (<80 ppm Cd) can be obtained by retorting a uranium product deposited on a solid cathode that contains about 12 wt % salt and 2 wt % cadmium. Consolidation tests with up to about 7 kg of uranium dendrites have produced well-formed, high-purity uranium ingots. Tests have also shown that high-purity uranium-plutonium (<54 ppm Cd) can be obtained by retorting a uranium-plutonium product codeposited in a liquid cadmium cathode that contains about 68 wt % cadmium, 26.1 wt % uranium, and 5.7 wt % plutonium.

FUEL CYCLE FACILITY (FCF)

Early in the IFR program, it was clear that any demonstration of the IFR fuel cycle process would need to be achieved at minimum cost. Fortunately, the process is very compact, and demonstration requires only a small hot cell facility. This led to the plan to modify the original FCF. However, to meet the current safety standards for facilities processing nuclear fuels, especially plutonium, many improvements to the facility were needed, principally to improve confinement.

The FCF was originally constructed in the early 1960s along with EBR-II and was used from 1964 through 1969 to demonstrate an early and incomplete version of the pyroprocess [8]. In subsequent years the facility was used for examination of irradiated fuels and materials and was then known as the Hot Fuel Examination Facility/South. In 1990 the facility was given back its original name in anticipation of the new demonstration.

The FCF will provide complete fuel cycle service for EBR-II. In addition, it will serve as an experimental facility where process alternatives and advanced concepts can be developed. A primary program objective is to establish the reactor performance of IFR metal fuel remotely refabricated in FCF. In pursuing this objective, the feasibility of utilizing extraordinarily compact facilities (FCF has two shielded hot cells: one with an air atmosphere, one with argon--the total floor area is only 240 m²) for the pyroprocess will be established, and costs, safety record, and reliability and maintainability of the equipment and facility systems will be quantified.

The key process equipment has significant capacity beyond the 250 kg per year needed to serve EBR-II. This is being done so that no significant scale-up of the equipment will be needed in any follow-on project. Moreover, by the time that fabrication operations commence (expected in September 1992), over 100 spent EBR-II fuel assemblies with IFR metal fuel will be in storage. This backlog of assemblies will permit the process to be run for brief periods at a throughput rate significantly higher than that associated with steady-state service to EBR-II.

PROCESS EQUIPMENT

The pyroprocess itself is described in the previous section. In application to the specific case of EBR-II, the main steps are as shown in Figure 1. Each of the boxes shown in Figure 1 is a function involving one machine with the exception of element welding, settling, and inspection, which will be done on three separate machines. Thus, nine machines comprise the basic process. When one considers that most of these devices will pass through an argon cell airlock which permits a maximum size envelope of just under 2 m in dia and 2.5 m long, the compact nature of the pyroprocess is further illustrated.

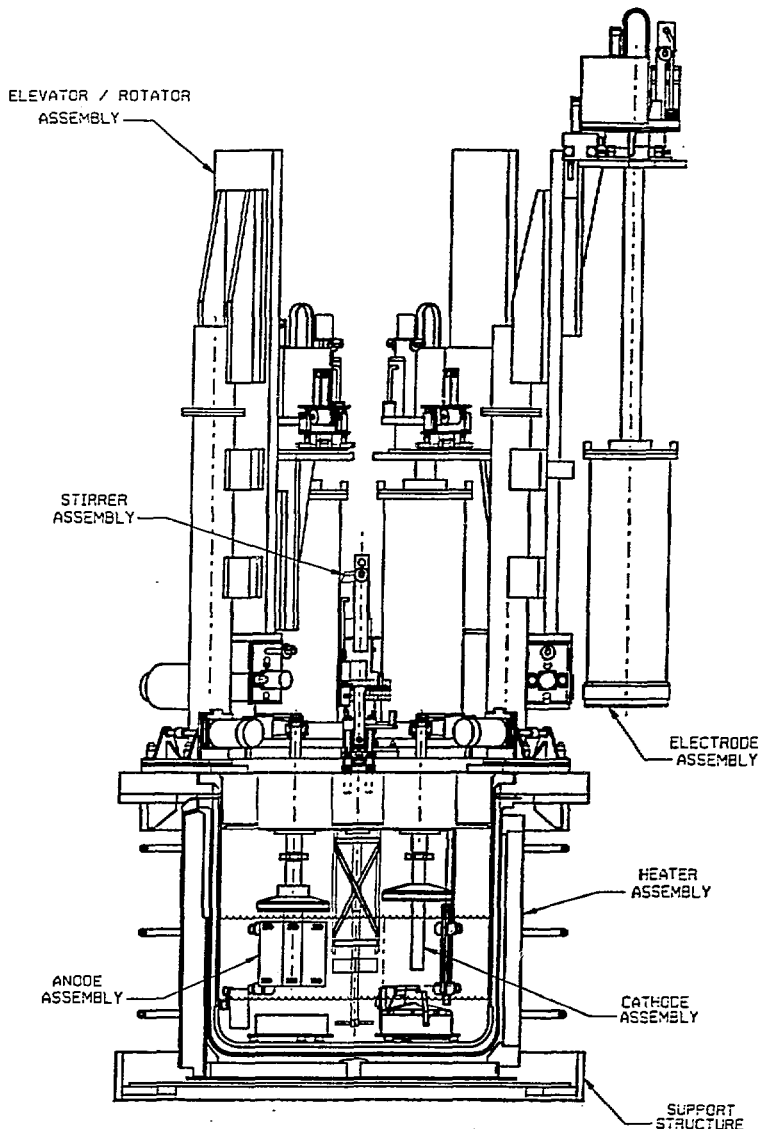


Figure 3. Electrorefiner

Note that for EBR-II application, there are no blankets to be processed. Plutonium instead is introduced from an external source at the electrorefiner (or, less desirably, at the injection casting furnace). All fuel processing occurs in the argon cell, while element inspection and assembly/disassembly occur in the air cell. In sections below, each piece of process equipment is discussed, starting with the three key machines.

Electrorefiner

The design of the FCF electrorefiner (Figure 3) is based on that of the Mark-III device discussed in the previous section. The process vessel is approximately 1.0 m deep, made with a 2 1/4% Cr- 1% Mo steel alloy. The device operates at a temperature of 500°C. It contains a 15 cm layer of molten cadmium and a 30 cm layer of molten salt. Circular ports in the steel cover and thermal radiation baffles provide access for four electrodes (28 cm in dia) and one stirrer (20 cm in dia). Other smaller ports allow material additions, sampling measurement, and cover gas control.

The electrode assemblies are independent structures consisting of a long shaft with an adapter for either an anode or a cathode. The containment housing mates with a slide valve mounted on the electrorefiner cover and maintains isolation of the cover gas from the general cell atmosphere. The electrode assemblies are maneuvered into and out of the process vessel by elevator/rotator mechanisms mounted on the support structure.

Spent fuel element segments are put into baskets and attached to anode assemblies. The anodes and the cathode assemblies are then inserted into the electrorefiner. At the end of an electrotransport run, the electrodes are removed, and transferred back to a support station for removal of the cladding hulls from the baskets and for removal of either the dendritic solid cathode deposit or the cadmium-uranium-plutonium ingot resulting from use of the liquid cadmium cathode. The cathode products are sent on for further processing, the cladding hulls are retained for later waste treatment, and the electrode assemblies are prepared for the next batch.

Based on results from the electrorefining research described before, it appears that 10 kg solid uranium cathodes can be deposited in about 24 hours. The liquid cadmium cathodes containing 4 kg heavy metal are expected to require a 36-hour deposition period.

Cathode Processor

Cathodes from the electrorefiner include the recovered heavy metals with some salt and/or cadmium. At the cathode processor, (1) the cadmium and salts are separated from the solid- and cadmium-cathode products,

and (2) the purified metals are consolidated into ingots of acceptable size, shape, and composition for casting.

A process crucible is loaded and heated under vacuum to temperatures which cause the sequential evaporation of cadmium, decomposition and evaporation of cadmium from various cadmium and heavy metal intermetallic compounds, and finally evaporation of salts. During the heating, the distillate is transported from the process crucible to the condenser region, where it condenses and runs down into the receiver crucible. Then the heavy metal in the process crucible is heated to melt and consolidate it into fuel ingots in shaped recesses in the bottom of the crucible.

The major features of the cathode processor (Figure 4) are the induction-heated furnace region inside the vessel at the top and the condenser region inside the vessel at the bottom. The furnace region uses a passively cooled induction coil and a graphite furnace liner that acts as the susceptor. The liner heats the cathode charge contained in the charge crucible by thermal radiation.

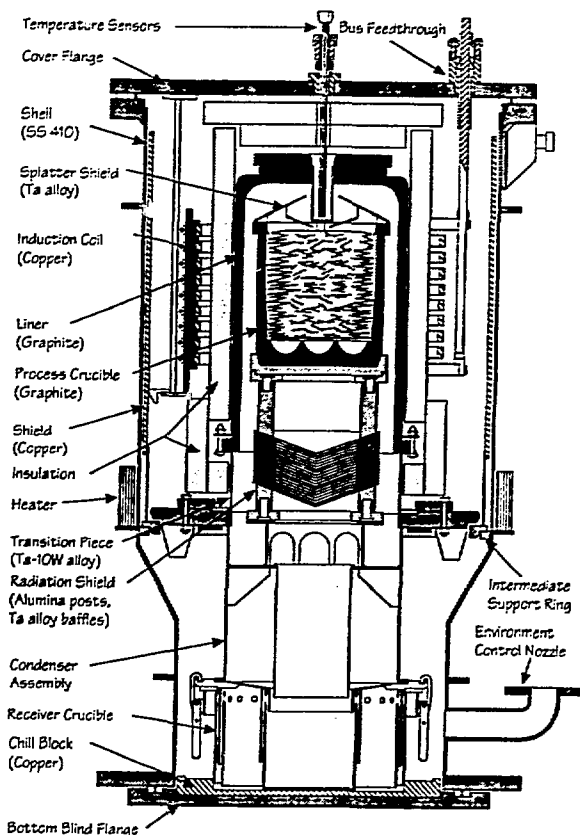


Figure 4. Cathode Processor

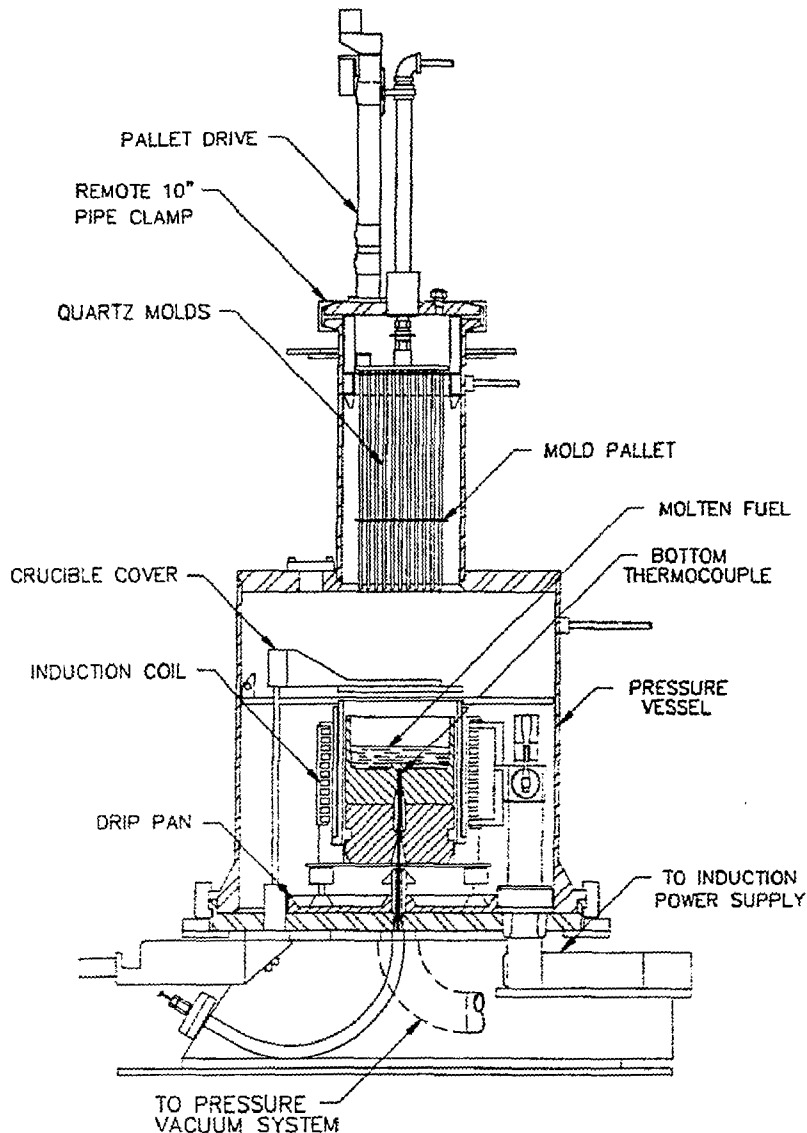


Figure 5. Schematic Representation of the Casting Furnace

It is anticipated that the process time will be about 8 hours to purify and consolidate either type of cathode, but the entire cycle time is longer because of the time required to cool the vessel and its contents.

Injection Casting Furnace

The function of the casting furnace (Figure 5) is to blend uranium, plutonium, alloying metals, and recycle materials in the proper proportions to achieve a homogeneous and uniform fuel composition. The design batch size is a 25 kg charge (22.5 kg heavy metal), set by criticality-safety constraints. About 12 kg of useful fuel pins will result from an 8-hour casting cycle. The

remaining heavy metals (heels and ends of pins) are routed to another casting batch. The alloy charge is heated inductively in a graphite crucible until fully melted, held at a temperature for a prescribed period to ensure homogeneity, and then injection cast into closed-end quartz molds.

To inject the alloy into the molds, the furnace is evacuated by a vacuum system, and the molds (open-end down) are lowered into the charge. The furnace is rapidly pressurized, injecting the molten alloy into the evacuated molds. Argon gas from a mold cooling system then flows over the molds to expedite freezing the alloy.

Fuel Pin Processor

After fuel pin casting and removal from the mold pallet, the pin processor removes the quartz molds from the cast fuel pins, shears the pins to length, and inspects them for length, diameter, straightness, and weight. Acceptable pins are then inserted into sodium-loaded fuel element jackets positioned in an element fabrication magazine. Fuel element jackets are fabricated, loaded with sodium which acts as a thermal bond, and installed in the magazine in a clean, out-of-cell environment.

Element Welding, Settling, and Inspection

The element welder is an automated device that loads and welds top-end plugs onto fuel element jackets which had been previously loaded with fuel slugs and bond sodium.

The element welder functions are to: (1) load element end plugs into the top of fuel element jackets, (2) for specific fuel elements, fill the plenum with unique isotope mixtures of identifying tag gas, (3) weld the end plugs to the element jackets, and (4) perform automated visual inspections of the welded fuel elements. Once the fuel elements have been welded and inspected, they are transferred to the settling and bonding station which is adjacent to the element welder.

The settler machine ensures that the fuel is seated at the bottom of the element, and that the bond sodium is relatively free of voids in the annulus between the fuel and the cladding. This is done by heating the elements to 500°C and providing an impact load.

The element inspection station verifies (1) by x-ray imaging that the fuel pin is settled and that the bond sodium level is acceptable, and (2) by leak testing that the closure weld integrity of the fuel elements meets the specifications.

Assembly and Disassembly

A single machine is used to assemble and dismantle fuel assemblies coming from and going back to EBR-II. It is located in the air cell and is an existing machine that was refurbished and improved. Fuel elements are installed on or removed from a support grid with master-slave manipulators, and fuel bundle ducts are installed on or removed from the assembled bundle with a drivescrew mechanism and load cell.

Fuel Element Shearing

The fuel element shear uses a small, commercially available electromagnetic punch press to chop individual fuel elements into segments approximately 6 mm long. The elements are fed from a 44-position magazine into a

standard machine tool collet. The collet advances the element into the shear, and the individual segments fall into electrorefiner anode baskets or sample containers positioned on a turntable located below the shear.

Process Control and Accountability

A control system is being installed to monitor and log data from instrumentation from the different facility and fuel processing systems, control the equipment operations, track the movement of fissile materials, and maintain an archival record of selected data. Three different types of computers are used in this system: programmable logic controllers (PLCs), personal computers for the operator control stations (OCSs), and engineering workstation computers for the mass tracking system (MTG). The PLCs operate the equipment and provide the input/output interface to the instrumentation. The OCSs provide the operator interface to monitor the process parameters, change control parameters for the equipment, interact with the MTG system, and log data for transfer operations. The mass tracking system tracks the movement and location of fissile material in the FCF and assists operations personnel with process control, fissile material accountability, and compliance with the facility operating limits and criticality specifications.

WASTE PROGRAM

The objectives of the IFR waste program are to: (1) quantitatively recover and recycle plutonium and minor actinides from as much of the waste as possible, (2) develop practical and NRC-certifiable waste forms, and (3) ensure a disposition path for all wastes generated in FCF.

Actinide recovery will first be demonstrated from the two principal high-level waste streams, the electrorefiner electrolyte salts and cadmium. R&D activities to accomplish this are at the laboratory scale, and more work is needed. There is, however, time available to complete this work, since at the earliest it will be sometime in 1993 before sufficient waste materials accumulate. Design work and laboratory-scale development are proceeding on a salt stripper to remove actinides and rare earth fission products from the electrolyte, a salt extractor to separate TRU elements from rare earths, and a metal retort to recover cadmium from various streams.

The development of licensable and practical waste forms is an important part of the IFR fuel cycle program. Work thus far in the laboratory has centered on licensable forms of (1) electrolyte salt waste, and (2) cadmium, cladding hulls, and other metal forms. For the electrolyte, adsorption in a zeolite matrix appears promising [9]. For metal wastes, alloying the metal matrix with copper or

other alloy and then encapsulating in a compact form is the favored approach. When these technologies are more advanced, they will be brought to engineering scale in FCF.

During the initial operations with irradiated fuel, the waste streams will be stored in storage pits in the argon cell or in a separate Argonne facility, which can store radioactive materials on a temporary basis. Wastes will be stored under passively cooled conditions and in a manner that allows remote recovery of the material. The principal focus of this early stage of operations is to gather information on actual irradiated fuel processing, accumulate sufficient materials for the actinide recovery phase, and determine waste characteristics.

STATUS AND PLANS FOR OPERATION

The FCF project has entered a startup phase, with the goal that spent fuel operations will begin in September 1992. Milestones achieved thus far include:

Preliminary Safety Analysis Report (SAR) submitted to DOE	January 1988
Start of limited construction	July 1988
Authorization for full-scale construction	May 1990
Final SAR submitted to DOE	July 1991
Startup phase began	September 1991
Plutonium fabrications operations to begin	September 1992

The startup activities include installing the process equipment identified above into the hot cells and conducting pre-operational testing using depleted uranium or other surrogate materials. Meanwhile, the final facility modifications are being completed. Equipment installation started with the fuel element shear. The electrorefiner and cathode processor are among the last of the process equipment to be installed, and operation of this equipment with spent fuel and extracted cathodes, respectively, will lag the initial facility operation. Ternary fuel (U-Pu-Zr) fabrication operations will start in September 1992 with externally supplied plutonium and uranium.

ACKNOWLEDGMENTS

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