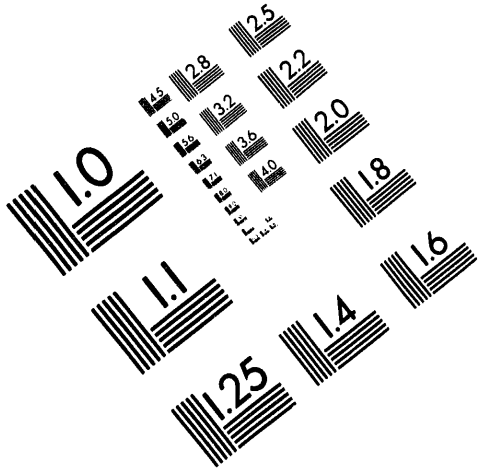
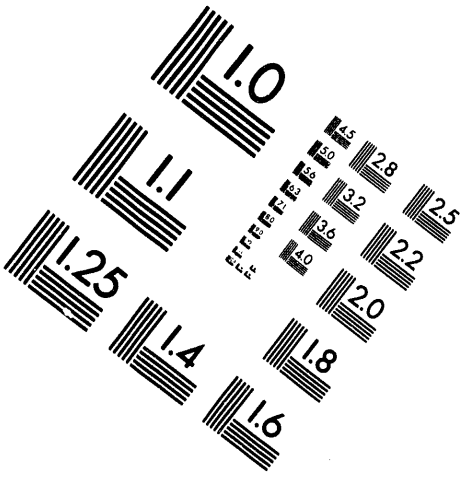
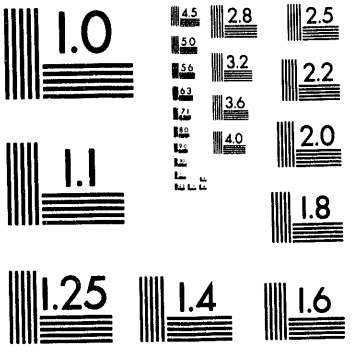


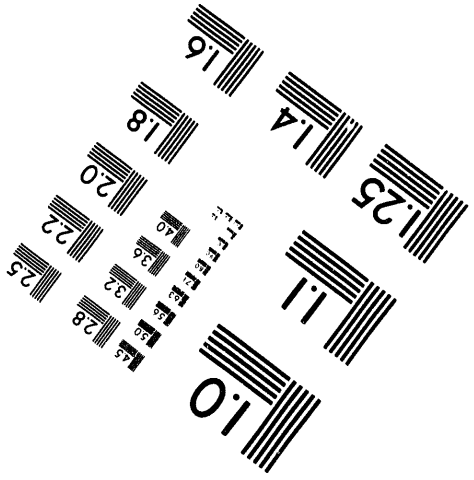
Association for Information and Image Management

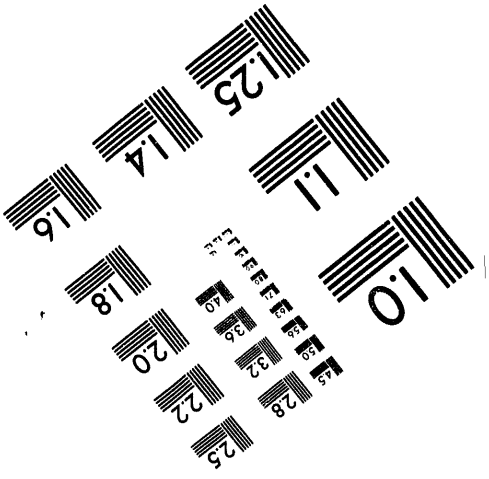
1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202









1 of 1

CONF-940815--74
ANL/TD/CP--82182

STATUS OF THE INTEGRAL FAST REACTOR FUEL CYCLE DEMONSTRATION AND WASTE MANAGEMENT PRACTICES

AUTHORS: Robert W. Benedict
K. Michael Goff
Harold F. McFarlane

Argonne National Laboratory-West
P.O. Box 2528
Building 774
Idaho Falls, ID 83403-2528

(208) 533-7166
(208) 533-7735 (fax)

DISCLAIMER

STATUS OF THE INTEGRAL FAST REACTOR

FUEL CYCLE DEMONSTRATION AND WASTE MANAGEMENT PRACTICES

Robert W. Benedict, K. Michael Goff, & Harold F. McFarlane
Argonne National Laboratory-West
P.O. Box 2528, Building 774
Idaho Falls, ID 83403
(208)533-7166

ABSTRACT

Over the past few years, Argonne National Laboratory has been preparing for the demonstration of the fuel cycle for the Integral Fast Reactor (IFR), an advanced reactor concept that takes advantage of the properties of metallic fuel and liquid metal cooling to offer significant improvements in reactor safety and operations, fuel-cycle economics, environmental protection, and safeguards. The IFR fuel cycle, which will be demonstrated at Argonne-West in Idaho, employs a pyrometallurgical process using molten salts and liquid metals to recover actinides from spent fuel. The required facility modifications and process equipment for the demonstration are nearing completion. Their status and the results from initial fuel fabrication work, including the waste management aspects, are presented. Additionally, estimated compositions of the various process waste streams have been made, and characterization and treatment methods are being developed. The status of advanced waste processing equipment being designed and fabricated is described.

I. INTRODUCTION

During the 1960's fuel from EBR-II was reprocessed and fabricated into new fuel in an attached hot cell facility. In the late 1960's, these operations were discontinued, and the facility was used for fuel examination. In 1986, the decision was made to modify this old facility so the new pyrochemical process could be demonstrated[1].

The Fuel Cycle Facility (FCF) contains two shielded hot cells. One has an air atmosphere, and the other has an argon atmosphere. During the demonstration, irradiated spent fuel from EBR-II will be brought into the air-filled hot cell, where the fuel elements will be disassembled from the subassembly hardware. The fuel elements will be transferred into the adjoining argon-filled hot cell.

In the argon cell, the fuel elements will first be chopped into segments using the element chopper. These segments will be fed into an electrorefiner, where the actinides will be separated from most fission products. The electrorefiner employs an electrochemical process that uses an electrical current at a low voltage to drive oxidation and reduction reactions[2]. A molten salt is used to provide the ionic medium for conducting the current. The molten salt medium will be a mixture of LiCl-KCl eutectic and actinide chlorides. Below this salt phase will be a pool of molten cadmium that can serve as an anode, cathode, or just a collector for nonreactive metals. Uranium that is relatively free of TRU elements will be collected on steel mandrel cathodes (solid cathodes). Cathodes that consist of ceramic crucibles filled with approximately 30 kg of liquid cadmium (liquid cathodes) will be used to collect uranium and the TRU elements simultaneously. A small fraction of the lanthanide fission products will also be collected in the liquid cathodes, making the material unattractive for diversion. The pyrochemicals principles have been described for the interested reader[3].

The cathode products recovered from the electrorefining operations will be processed in a cathode processor which distills adhering salt or cadmium for recycling to the electrorefiner and consolidates the remaining actinide metals into ingots. The element chopper, electrorefiner, and cathode processor comprise the refining equipment.

The recovered ingots were intended to be used to produce new fuel for the IFR prototype reactor using the fuel fabrication equipment. Politics has intervened and storage products may instead be made pending disposition. However, if fuel is made, molten actinide zirconium metal alloy will be injection cast into quartz molds to form a fuel slug at the first fabrication station. At the pin handling station, the glass molds will be broken off the fuel slug. The slug will be sheared to length and inspected for length, diameter and weight and inserted into the new cladding material at the pin processor. The element welder will seal the fuel slug in the cladding by welding a top end plug and automatically inspecting the weld. The fuel slug will be settled to the bottom of the cladding, and the element will then be transferred to an element inspection station for final quality checks. The accepted elements will be assembled into subassemblies for return to the reactor.

II. PROJECT STATUS

In 1988, the basic design of the necessary facility modifications was started. Since a new technology was being tested, the facility was designed to provide the support and safety systems separate from the process equipment. The necessary final safety analysis report, air permit, environmental notifications, and criticality hazards control statement have been approved by the required external organizations.

A. Facility Systems

The facility systems included a new emergency power supply, a safety exhaust system, and new stack monitor. These new systems have completed their acceptance testing. Due to the age of the facility many of the older systems needed modifications so that they would meet current seismic and general design criteria for nuclear facilities. The argon cell was renovated and filled with a new argon atmosphere in December 1993. The reactivation of the argon atmosphere systems, which provide pressure control, heat removal and impurity removal, have encountered many problems during their reactivation. Other facility systems including ventilation systems, radiation monitors, normal power distribution and building modifications have been modified and reactivated. For seismic reasons, the previous hot repair facility, where process equipment is repaired, was moved from the roof to the basement. The new confinement boundary has been complete and final installation of the support equipment will be finished late 1994. All facility modifications and the operational readiness review are scheduled for completion in 1994.

B. Process Equipment

The process equipment has been designed to be operated and repaired remotely. Each item goes through the normal design and fabrication process. In addition, equipment is qualified in three phases: assembly, out-of-cell and in-cell. During assembly qualification, the equipment is assembled and tested for functionality by the equipment design personnel. Out-of-cell qualification is performed by operations technicians and verifies that assembly, operation, and maintenance can be done remotely. The in-cell qualification assembles the equipment in its final location and tests its functionality. After the qualification phases, normal operations are started in a phased approach where depleted uranium is used before irradiated fuel or plutonium is introduced.

The casting furnace has completed the three phases of qualification and four depleted uranium-zirconium castings have been completed. Figure 1 shows the different operations and the primary process variables for a casting. Each casting has produced approximately 130 fuel slugs, and the data have been used to validate the FCF on-line accountability system. The pin processor, element welder, and element settler have been installed in the argon cell and have completed most of their in-cell qualifications. Many of the important process variables were established during the out-of-cell testing and these parameters will be verified in-cell. The element inspection equipment has been tested for its functionality and is currently being assembled. All fabrication equipment could be ready for full operation in 1994.

The element chopper, which is the first refining equipment has been installed in the argon cell since 1992. This summer twenty kilograms of depleted uranium elements will be chopped as the final checkout. The electrorefiner has completed its out-of-cell qualification, and its volume has been calibrated for nuclear accountability requirements. Currently, the electrorefiner is being installed in the argon cell and will start depleted uranium operations this fall. Since the cathode processor is a new process, two identical units were made to assist in testing. The prototype unit which is located at Argonne-Chicago has been operating since the summer of 1993. The FCF cathode processor is being installed in the argon cell and should start remote operations during the summer of 1994. With the completion of the refining and fabrication equipment, full operation should start early 1995. Waste operations and equipment should start operation in late 1995.

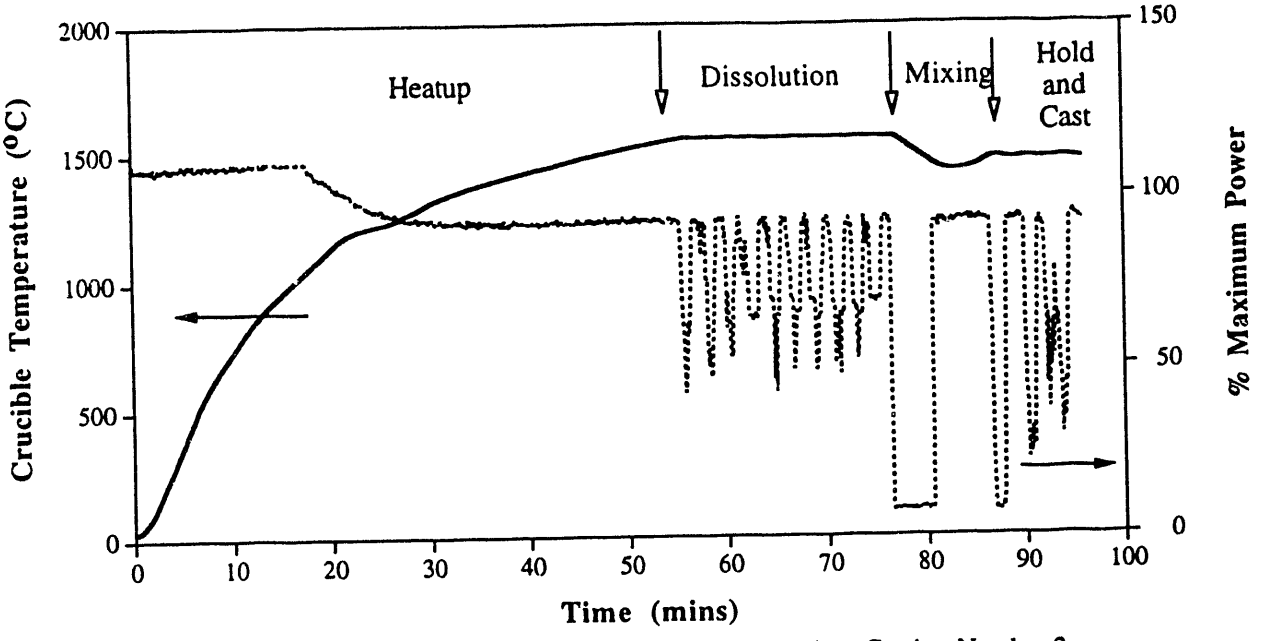


Figure 1: Casting Furnace Cycle for Depleted Uranium Casting Number 2

III. WASTE MANAGEMENT

Extensive efforts are being focused on waste characterization techniques, waste processing operations, and waste treatment equipment. Evaluations of treatment, processing, and potential waste forms have been ongoing for some time. All wastes produced during FCF operations will be characterized to determine storage and treatment options. The waste streams from FCF fall into five categories: direct process waste, gas-borne waste, indirect process liquid waste, indirect process solid waste, and nonradioactive waste. The wastes in the first four categories are considered potentially radioactive. The direct process wastes include those produced from operating the irradiated fuel refining equipment and fuel fabricating equipment. Some characteristics of these wastes are unique to the pyroprocessing and metal fuel systems of the IFR program, so demonstrating the characterization, treatment, and stabilization of the direct process waste stream will be crucial to the success of the IFR fuel cycle. The other four waste categories from FCF operations are processed using methods based on practices at either Argonne-West or other facilities.

Wastes included in the direct process waste stream are the following: subassembly hardware, element hardware, glass/metal scrap from fuel casting operations, uranium dragout, excess salt and the resulting salt from waste treatment operations, metal alloys from treatment operations, and insolubles. Initial waste operations in FCF will concentrate on the characterization of these process streams.

The subassembly hardware will be composed of the subassembly duct and its upper and lower end fixtures. It is principally structural material: 304, D-9, and 316 austenitic stainless steel, or HT-9, AISI 422, or T91 martensitic/ferritic stainless steel. This material will be radioactive from neutron activation. The concentrations of the activation products will be based on standard data files for the reactor. These data files will predict the quantity of each activation product created in each subassembly based on its operating history in the reactor. The subassemblies will be washed in the Interbuilding Cask wash station in FCF, so all adhering sodium coolant will be removed. The washing operations also will serve to remove any TRU contamination prior to bringing the subassembly into the cell. Therefore any TRU contamination on the hardware will be due to surface contamination in the hot cells. The TRU content of the hardware will be assigned based on area contamination levels in the cell obtained from monthly smear samples. If a subassembly is known to be breached, its additional fission product activity will be obtained by smears of the hardware. Subassembly hardware has been processed in this manner in the Hot Fuel Examination Facility at ANL-West since the mid-1970s.

The element hardware will consist of the fuel cladding including the end plugs and spacer wire. In FCF, this stream will be separated into two components

based upon whether or not the hardware was processed in the electrorefiner. Only the portion of the cladding that surrounds the fuel and/or bond sodium will be chopped and processed in the electrorefiner. The upper plenum section of the cladding will not be processed in the electrorefiner. The characteristics of each of these streams will differ substantially. All the element hardware, whether or not it is processed through the electrorefiner, will contain activation products that will be characterized like the subassembly hardware. The cladding hulls that will be processed in the electrorefiner may contain trace quantities of undissolved fuel, an electrorefiner salt coating, and trace amounts of process cadmium. This portion of the element hardware will need further characterization. A random sample of cladding hulls will be taken to characterize a batch of material processed through the electrorefiner. A study will be made to determine the appropriate number of hulls needed in each sample to be representative of the batch. The sample of cladding hulls will be analyzed by wet chemical analysis. Additionally, a pulsed neutron NDA technique based on detection of delayed neutrons is also being developed for determining the actinide content of the hulls.

The glass/metal scrap is produced from fuel casting. The fuel pins will initially be produced by injection casting into quartz molds. The quartz molds are broken to separate the fuel pins, and some metal remains with the broken quartz. This method has long been used for the production of fuel for EBR-II. The fuel produced before FCF becomes operational contains non-irradiated materials, so gamma scanning is used to characterize the stream. This method will also be considered for characterizing the glass/metal waste stream from FCF, but other methods will also be explored. Random grab samples of the glass stream will be used for sampling. Each sample will be analyzed for its actinide, and specifically, its fissile content. The NDA technique being developed for the cladding hulls will also be applied to the glass/metal scrap. Future developments in the glass/metal scrap area will concentrate on eliminating the waste stream. This will be accomplished by eliminating the need for glass molds either by developing re-usable molds or a moldless process such as injection casting directly into zirconium sheaths. As a fallback position, a glass/metal separation process is being developed.

Uranium dragout is the excess uranium recovered during the refining of spent fuel. Since primarily uranium-zirconium fuel will be refined in the first two years but uranium-plutonium-zirconium fuel will be produced, more uranium will be processed than will be needed for fuel production. Because this uranium will have been processed through the electrorefiner and recovered in cathode products, it will have been characterized. No further characterization will be needed.

The more unique direct process wastes are those associated directly with the electrorefining operations. The bulk of the fission products associated with the refined spent fuel will be distributed in the salt and cadmium phases of the electrorefiner. The active metal fission products, including the alkali, alkaline earth, halide, and rare earth elements, will be in the salt phase. The more noble fission products will be in the cadmium phase.

After processing a certain quantity of spent fuel, some of the fission products will be removed from the electrorefiner to lessen the heat content of the vessel, which is passively cooled. The removal will be accomplished through chemical, electrochemical, and zeolite-based operations. A typical electrorefiner composition after processing 90 irradiated subassemblies from EBR-II is given in Table I. These fission products

Table I
Electrorefiner Contents
After Processing 90 Subassemblies

Element(s)	Salt Phase (kg)	Cadmium Phase (kg)
Uranium	8.5	0.0
Plutonium	27.4	0.0
Rare Earth Fission Products	8.8	0.0
Alkali Fission Products	3.6	0.0
Bond Sodium	10.9	0.0
Alkaline Earth Fission Products	2.2	0.0
Halide Fission Products	0.2	0.0
Noble Metal Fission Products	0.0	3.6
Fuel Matrix Zirconium	0.0	57.3

combined with the cladding hulls will be processed into two distinct waste forms, mineral and metal[4]. Because both forms are unique to the IFR program, their stabilization and characterization for disposal will be an extensive part of the fuel cycle demonstration.

Before the fission products are removed from the electrorefiner, most of the actinides are recovered to minimize their loss in the waste stream. They are removed from the salt phase using an anode of LiCd (5.8 weight percent lithium) and liquid-cadmium cathodes. This operation employs electrochemical and chemical reactions from which the net result is the oxidation of lithium at the anode baskets and the reduction of actinide ions to metals in the liquid cathodes. The liquid cathode products from these operations will be used to recharge the actinide concentration in the electrorefiner for the second campaign. The actinide drawdown operations will continue until the amount of TRU material left in the electrorefiner is expendable.

After the actinides are removed from the electrorefiner, the salt and cadmium will be filtered to remove insolubles including the noble metal fission products. The salt will then be contacted with loaded Li-K Zeolite A for sample waste form production. Loaded Li-K Zeolite A is prepared by contacting Na Zeolite A with clean LiCl-KCl eutectic salt. In this preparation process, the lithium and potassium replace the sodium in the zeolite, and clean salt is occluded or loaded into the zeolite matrix. Waste form samples will also be made from anhydrous Na Zeolite A (unloaded) contacted with electrorefiner salt. These zeolite-based waste forms constitute the mineral waste form.

A metal waste form will also be produced from the refining operations. The metal waste stream will contain cladding hulls, metal filters from the filtration operation, and the noble metal fission products including the zirconium. These items will be combined into a steel based waste form. Samples of this type will also be produced after the first campaign in FCF.

These waste form samples will be subjected to various standardized tests to provide a database that can eventually be used to support the qualification of high-level waste forms. Tests to be performed include the Toxicity Characteristic Leaching Procedure (TCLP) and the MCC-1.

IV. SUMMARY

The majority of necessary facility modifications for the fuel cycle demonstration have been completed and are being reviewed for their readiness. Two final facility systems will be completed in the fall of 1994. The fabrication equipment has been installed and initial depleted uranium-zirconium castings have produced acceptable fuel slugs. The refining equipment has been tested out-of-cell and will start the final in-cell testing phase this summer. Although political consideration may change the goals, the pyroprocessing demonstration will be able to start in the fall of 1994.

ACKNOWLEDGEMENT

This work was sponsored by the U.S. Department of Energy, Nuclear Energy Research and Development Program, under Contract W31-109-ENG-38, at the Argonne National Laboratory.

REFERENCES

1. M. J. Lineberry, H. F. McFarlane, and R. D. Phipps, "Status of IFR Fuel Cycle Demonstration." *Proc. Global '93*, Seattle WA, Sept. 12-17, 1993, p 1066, American Nuclear Society, LaGrange Park, IL, 1993.

2. J. J. Laidler, J. E. Battles, and W. E. Miller, "Development of IFR Pyroprocessing Technology," *Proc. Global '93*, Seattle, WA, Sept. 12-17, 1993, p 1061, American Nuclear Society, LaGrange Park, IL, 1993.

3. J. P. Ackerman, "Chemical Basis for Pyrochemical Reprocessing of Nuclear Fuel," I&EC Research, **29**, 141, 1991.

4. J. P. Ackerman and J. R. Johnson, "New High-Level Waste Management Technology for the IFR Pyroprocessing Wastes," *Proc. Global '93*, Seattle, WA, Sept. 12-17, 1993, p 969, American Nuclear Society, LaGrange Park, IL, 1993.

DATE
FILMED
8/26/94
END