ornl

ORNL/TM-9734

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

Consolidated Fuel Reprocessing Program Progress Report for Period April 1 to June 30, 1985

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A04; Microfiche A01

ORNL/TM-9734
Dist. Category UC-86

CONSOLIDATED FUEL REPROCESSING PROGRAM PROGRESS REPORT FOR PERIOD APRIL 1 TO JUNE 30, 1985

W. D. Burch, Program Director

M. J. Feldman
Manager, Engineering Systems

W. S. Groenier
Manager, Process and Engineering

S. A. Meacham
Manager, BRET Project

J. G. Stradley
Manager, Strategic Planning and Analysis

O. O. Yarbro
Manager, IET Facility Operations

Date Published: August 1985

NOTICE This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tenessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

Contents

Foreword

The DOE has concentrated all U.S. research and development on fuel reprocessing into one major program—the Consolidated Fuel Reprocessing Program (CFRP)—under the management of the Oak Ridge National Laboratory and the Oak Ridge Operations Office. Other major program participants are GA Technologies, Inc., where reprocessing research and development on the HTGR fuel cycle are done, and the Hanford Engineering Development Laboratory (HEDL).

The coverage is generally overview in nature. Experimental details and data have been limited to (1) make the report more concise and (2) meet the requirements which would qualify the report for unrestricted distribution in the open literature.

1 Highlights

W. D. BURCH

All research and development on civilian power reactor fuel reprocessing in the United States is managed under the Consolidated Fuel Reprocessing Program (CFRP) centered at Oak Ridge National Laboratory (ORNL). Technical progress is reported in overview fashion in this series of quarterly progress reports.

1.1 PROCESS AND ENGINEERING R&D

W. S. Groenier

A modification of the SEPHIS computer code (SEPHIS-MOD5) has been developed to describe a solvent extraction contactor having an interstage electrochemical reduction cell. This work was done by subcontract to Georgia Tech Research.

The United Kingdom (U.K.) feed clarification centrifuge has operated in the polishing (continuous) mode for 720 h (30 d) using a Vespel-21 bottom bushing. Exposure of Vespel-21 to 3.5 *M* HNO_3 at 30°C resulted in no detectable dimensional or weight change after 720 h.

Three 150-Ci ^{85}Kr ion implantation runs have been successfully completed at the Battelle-Pacific Northwest Laboratory (PNL). The prepared copper-yttrium matrix specimens were placed in shielded storage casks for long-term release measurements.

The Solvent Extraction Test Facility (SETF) campaign using Fast Flux Test Facility (FFTF) fuel that received a burnup of ~100,000 MWd/t and was cooled for ~1 year has been completed. The campaign consisted of two runs: the first used a conventional Purex flowsheet with 30% tributyl phosphate (TBP) and hydroxylamine nitrate for plutonium reduction in the partitioning contactor, while the second run used 10% TBP, lower temperatures, and no added reductant. Both runs were operated at high solvent loading using computer control from an in-line photometer. Overall decontamination factors (DFs) from ^{95}Zr and ^{106}Ru were $>10^5$ in both runs. Efficient uranium-plutonium separation was achieved. The plutonium product was decontaminated from uranium by factors of 10^5 and ~500, and the uranium product was decontaminated from plutonium by factors of 10^4 and ~500 in runs 1 and 2 respectively.

Tests of of the four-stage experimental centrifugal solvent extraction contactor identified a new critical rotor fabrication parameter, the length of the radial vanes in the passageways between the aqueous underflows and the aqueous weirs. After minor modification to correct vane lengths, the four-stage hydraulic performance matches single-stage results. Further tests have established that the new additional interstage porting allows operation to continue after stoppage of any intermediate stage rotor.

Hot-cell dissolution tests with ~100,000-MWd/t FFTF fuel have shown no increase in the amount of residue remaining after two 5-h treatments in 8 *M* HNO_3 at ~100°C followed by an HNO_3-HF leach from the ~1% value measured earlier for 55,000-MWd/t fuel.

Approval has been received from the DOE for the planned irradiation of direct press spheroidized (DIPRES)-derived fuel in the FFTF. Fuel pellet fabrication can now begin.

1.2 ENGINEERING SYSTEMS

M. J. Feldman

Handling tests for remotely operated electrical connectors were initiated. The tests are being performed on various types and sizes of connectors mounted on a test panel.

The motor brakes on the slave arm of the advanced servomanipulator (ASM) have been replaced, and full electric counterbalancing has been accomplished.

The comparative testing program for three generic types of manipulators has been completed, and the results are being analyzed.

A test stand for use with centrifugal contactors is being constructed. This stand will permit long-term reliability testing of the units.

1.3 INTEGRATED EQUIPMENT TEST FACILITY OPERATIONS

O. O. Yarbro

The first Integrated Process Demonstration (IPD) experimental uranium processing campaign of FY 1985 was completed in April. Feed material was prepared with the dissolver system the week before continuous steady-state operation of the solvent extraction system began. The primary objective of this campaign was to provide operating experience on the various IPD systems under simulated process conditions. Material transfers were monitored for conformance with safeguards standards according to established uranium accountability procedure.

The operations planned for the IPD facility during the remainder of the fiscal year will feature several process and equipment studies in the Integrated Equipment Test (IET) area. The inclusion of research and development (R&D) objectives with normal plant operations provides simulated plant conditions for evaluating various test parameters.

Comparative testing of manipulators in the Remote Operations and Maintenance Demonstration (ROMD) area was completed. Experiments in the remote connector test program to evaluate the remote handling characteristics and performance of selected off-the-shelf electrical and tubing connectors were initiated, and testing of electrical connectors was completed.

Also completed during this reporting period was the design of the Environmental Test Chamber (ETC).

1.4 STRATEGIC PLANNING AND ANALYSIS

J. G. Stradley

An interim status review was held at DOE headquarters in June on the collaborative study being conducted jointly with HEDL to examine fuel cycle options for the liquid-metal reactor (LMR).

Seven additional critical experiments were performed by PNL's Critical Mass Laboratory for the criticality data development program sponsored jointly by the United States and the Power Reactor and Nuclear Fuel Development Corporation (PNC) of Japan.

During the April IPD integrated run, the Safeguards software essentially flagged the process events and quantified the materials transfers as planned.

1.5 BRET PROJECT

S. A. Meacham

Fiscal year 1985 funding for the Breeder Reprocessing Engineering Test (BRET) project has been reduced from FY 1984 levels, and the project has been placed on hold pending DOE direction on future restart. The core project staff and an active interface with the project staff at HEDL are being maintained. During this quarter, technical activities were dedicated to completing documentation for the project design file.

1.6 HTGR FUEL REPROCESSING

W. S. Groenier

In the high-temperature gas-cooled reactor (HTGR) spent fuel storage studies, cost estimates for the three concepts under study (concrete casks, open-field drywells, and air-cooled vaults) have been completed.

Additional results from the semivolatile fission product scoping test show that 50 to 90% of the four semivolatiles added to the burner (Cs, Mo, Rb, and Ru) was recovered in the burner product and fines. The remainder was apparently deposited on the burner walls as none was found on coupons placed throughout the off-gas system. In preparation for an integrated burner and off-gas treatment system test using low-enriched uranium (LEU) fuel, 2000 fuel spheres have been received from the Federal Republic of Germany (F.R.G.).

A modified curing procedure for concreted HTGR waste forms has eliminated the cracking problem experienced earlier. Of five waste forms examined, spent fuel particles stabilized by the FUETAP (formed under elevated temperature and pressure) process represent the most efficient form from a transportation standpoint.

2 Process and Engineering R&D

W. S. GROENIER

The Process and Engineering R&D group identifies improved processes and components, develops these concepts on a laboratory and/or bench engineering scale, and provides process parameters and equipment criteria. Objectives in FY 1985 are to (1) reprocess ultrahigh-burnup (~100,000-MWd/t) FFTF fuel samples in the SETF while evaluating solvent extraction flowsheet options and control schemes, (2) evaluate design options for the BRET-scale centrifugal solvent extraction contactors which have the potential for significantly improving contactor reliability and performance, (3) complete the evaluations of the U.K. centrifuge for dissolver solution and solvent extraction feed clarification and the pulsatile fluidic pumping units for various small reprocessing plant applications, (4) fabricate fuel pins at HEDL for an FFTF irradiation test using DIPRES mixed (U+Pu) oxide feed material prepared by ORNL in FY 1984, and (5) initiate evaluation and/or confirmatory testing of selected special chemical systems required for small plants, which currently lack data-base support because of small-scale or novel features.

2.1 ENGINEERING ANALYSIS, DESIGN, AND SUPPORT

W. S. Groenier

This activity includes task coordination of several activities in the Fuel Recycle Division and work in other ORNL divisions, the student cooperative education program, and other ad hoc CFRP efforts. A consulting subcontract with Georgia Tech Research is also included which provides, among other activities, a review of electrochemical applications for solvent extraction.

2.1.1 Electrochemical Reduction Modeling

A. Schneider and J. Donniacuo (Georgia Tech)

Modifications of the SEPHIS computer code which allow modeling of a solvent extraction cycle with an interstage electrochemical reduction cell were continued, and efforts began to develop an experimental program for verification of the model using short-residence-time contactors.

The modified program, SEPHIS-MOD5, was tested at ORNL and performed satisfactorily. Previously encountered oscillations were corrected. The following processes can now be represented:

1. transfer of up to five components (U^{+6}, U^{+4}, Pu^{+4}, Pu^{+3}, HNO_3),
2. Pu^{+4} + U^{+4} redox reaction in both aqueous and organic phases,
3. electrochemical reduction of U^{+6} to U^{+4} and Pu^{+4} to Pu^{+3} in a continuous-flow reduction cell, and
4. oxidation of Pu^{+3} to Pu^{+4}.

2.2 SPECIAL CHEMICAL SYSTEMS DEVELOPMENT

B. E. Lewis

2.2.1 Centrifuge Development

J. G. Morgan and W. D. Holland

Tests and evaluations of a solid-bowl centrifuge (U.K. design) are continuing, and improvements for the drag bushing to increase its life are being investigated. Assessments of solids inventory and solvent extraction feed polishing are included in the evaluations.

The reference breeder fuel reprocessing flowsheet specifies a polishing centrifuge located immediately before the first solvent extraction contactor. This centrifuge is intended to operate continuously throughout a campaign to remove any solids not removed by the primary centrifuge or any that form during feed adjustment. Using a U.K. centrifuge bowl with a Vespel-21 bottom bushing, 720 h (30 d) of operation at 10,000 rpm was successfully completed. The wear on the bottom bushing was minimal (<2% diametrical change). A companion Vespel-21 bushing was immersed in 3.5 M HNO_3 at 30°C with no detectable change in dimensions or weight after 720 h of exposure.

Tests were also begun using a ZrO_2 centrifuge bowl bushing that has the potential for providing even greater abrasion resistance and longer life.

2.2.2 Fluidics R&D

J. G. Morgan

Evaluation tests of pulsatile fluidic pumps for various applications are continuing. A pulsatile fluidic pump demonstration has begun in the IET facility. The pump, submerged in a feed tank containing uranyl nitrate solution, delivers the feed solution through a vertical height of 13.5 ft and over a 9-ft horizontal distance to a receiving tank. Motivation air pressures range from 25 to 40 psig. Preliminary pumping results agree with the predictive mathematical model. Under conditions of a 7-ft refill head in the host tank, the pump delivers >380 L/h at a motivation pressure of 35 psig. Tests are continuing to evaluate the pump performance as the host tank is emptied.

2.2.3 Special Chemical Systems

B. E. Lewis, W. D. Holland, R. M. Counce, and H. J. Marquess

This activity initiates the study of and subsequent necessary development for the following special chemical systems: (1) steam jets, (2) feed preparation system, (3) fluid pumping units, (4) high-temperature fluid transfer systems, (5) steam stripper, (6) evaporators, and (7) secondary dissolver.

Steam-jet pumps were specified for several locations in the BRET process flow diagram, but some (such as the feed to the primary centrifuge) may require such low flows that steam jets may be impracticable. A commercially available low-flow steam jet has been installed in the IET facility and is being tested. The test plan includes the determination of flow rates, dilution levels, and temperature rise at a variety of operating conditions.

Concentration of the product and waste solution is normally accomplished by continuous evaporation. The plutonium product evaporation process is reasonably well understood, but some disagreement exists over the potential for the formation of "red oil" at operating temperatures >130°C. The product and waste evaporators for the BRET process were specified to operate at a temperature of ≤141°C. A brief review of the literature has indicated that the conditions at which red oil forms are dependent on the type of organic solvent used as well as the temperature. A more detailed review of the literature in this area is proceeding in an effort to verify the safety of the proposed operating conditions. In addition, data on the physical characteristics of the BRET liquid waste solutions, vapor-liquid equilibria, ruthenium volatilization, nitric acid decomposition, and evaporator scaling factors are required to properly design waste evaporators.

Experiments have been proposed to periodically determine the heat-transfer coefficient and material and energy balances for the IET facility uranium product evaporator. This type of analysis will provide information on evaporator performance and scaling factors with relatively clean evaporator feed streams.

The feed preparation system specified for the BRET process requires the addition of either 0.5 or 13.0 *M* HNO_3 to adjust the acid concentration in the solvent extraction feed to 3.5 *M*. Methods for accurately adding small amounts of dilute or concentrated HNO_3 to the solvent extraction feed solution are being reviewed. A computer code has been written to study the effect of measurement errors on concentration adjustment accuracy.

A study of specific pumping requirements for a small (BRET-scale) reprocessing plant is in progress. The results of this study should also be useful for pump selection in larger-scale plants through the use of a scaling factor based on the ratio of throughputs. This study will conclude with a tabulation of specific pumping requirements which may be matched against available pump-type alternatives.

2.3 AIRBORNE WASTE MANAGEMENT

R. T. Jubin

2.3.1 Off-gas Treatment Systems

R. T. Jubin and D. K. Little

The development of improved computer models for various dissolver off-gas treatment systems, which was begun in FY 1984, is being completed. In particular, a model describing the single-column fluorocarbon absorption process for recovery of krypton and xenon from an off-gas stream is being improved. The original model was based on earlier separate-column models for absorption and fractionation, each of which was verified by experimental data. Successful combination of the separate models into a single program has been frustrated by a lack of knowledge concerning feed and product stream compositions at the interfaces between absorption, fractionation, and stripping in the single-column system. The single-column model requires iterative calculations to arrive at a unique set of conditions that enables the concentration profile in each column section to match up with the profile in the adjacent section.

Difficulties with this matching technique have led to the identification of program improvements where a unique concentration profile and DF can be predicted based on feed conditions and the final product concentration. This approach is now being implemented in the computer code.

2.3.2 Ion Implantation Development

E. D. McClanahan (Battelle-Pacific Northwest Laboratory)

Ion-implanted specimens have been prepared at PNL using radioactive krypton in copper-yttrium matrices for the purpose of determining the effects of radiation on both the implantation process and the sputtered product. Three 150-Ci laboratory-scale experiments were performed.

The completion of these tests demonstrated that (1) the high-beta radiation field does not adversely affect the ion implantation/sputtering process; (2) radioactive particulate material was not detected during the disassembly of the unit; (3) the system operated for the entire radioactive portion of the run without the aid of an auxiliary pumping system, hence a 100% recovery factor; (4) the system could be stopped and restarted if necessary; and (5) the pumping speed could be varied continuously from zero to >8 std cm^3/min.

The target modules from the three radioactive tests were placed in shielded storage casks for long-term release measurements. Sampling tubes and pressure gauges have been installed on the modules. The equipment for sampling and measuring the released ^{85}Kr is complete.

Testing evaluation of three commercial power supplies with arc suppression capability using a sputtering load is essentially complete. The design and fabrication of the manifold and modules for the multiple-module gas-trapping experiment were also completed. Three gas-trapping modules, one 1500-cm^2 substrate area unit and two 1000-cm^2 substrate area units, will be tested on the manifold. Operation of the multiple-module system is planned for August.

2.4 SOLVENT EXTRACTION DEVELOPMENT

R. T. Jubin

2.4.1 Solvent Extraction Test Facility

D. J. Crouse, L. J. King, D. E. Benker, and F. R. Chattin

A major solvent extraction campaign was performed in Building 7920 with ultrahigh-burnup (~100,000-MWd/t) FFTF fuel that was cooled ~1 year. The campaign, completed in May, evaluated reference and alternate flowsheets using in-line process control with a feedback loop. The recovered plutonium was converted to PuO_2 by oxalate precipitation for return to HEDL.

The campaign consisted of two flowsheet experiments. The processing steps for each experiment included (1) dissolution of the fuel in nitric acid, (2) clarification of the solution by filtration, (3) feed adjustment, (4) one cycle of solvent extraction with total partitioning in the SETF mixer-settlers, (5) purification of the plutonium by nitrate-based anion exchange, and (6) conversion of the plutonium to the oxide form by oxalate precipitation and calcination. In addition, an experiment was conducted using uranyl nitrate solution as feed to demonstrate a process control system that was later used in the experiments with irradiated fuel.

The solvent extraction flowsheet for the first test used 30% TBP for the organic extractant and included coextraction and coscrubbing in the A-bank mixer-settler, total partitioning in B-bank, and uranium stripping in C-bank. Each bank has 16 stages.

The extraction bank was operated with a high loading of heavy metals by using an in-line photometer to monitor the solvent plutonium concentration in the fourth stage from the raffinate end of the bank. By making small adjustments in the solvent flow rate, solvent heavy-metal loadings >100 g/L and up to 119 g/L were maintained in nine stages of the bank while simultaneously maintaining low losses to the raffinate. In a previous campaign, manual control was used to make the flow adjustments; in this campaign, the adjustments were controlled by computer. The overall first-cycle DFs from ^{95}Zr and ^{106}Ru were $>10^5$ for both the plutonium and uranium products. Significant decontamination was obtained in the partitioning and uranium stripping steps, particularly for ruthenium.

In the partitioning bank, plutonium was reduced with hydroxylamine nitrate, and the aqueous plutonium product was scrubbed with a fresh stream of 30% TBP to improve the separation of uranium, which is a typical Purex process arrangement. Although good results have been obtained with this flowsheet in previous runs, a large excess of reductant was needed to compensate for the significant amount of plutonium reoxidation that occurred in the scrub section. Adding hydrazine as a holding reductant in a previous run mitigated the problem but did not eliminate it. In place of using hydrazine, the acidity of the strip solution in the recent campaign was lowered to ~0.04 *M* HNO_3, and the bank temperature was lowered to 18 to 20°C. Results indicate better plutonium behavior with little reoxidation. The plutonium product was decontaminated from uranium by a factor of 1×10^5, and the uranium product was decontaminated from plutonium by a factor of 2×10^4.

In the second run, 10% TBP was used and partitioning was accomplished with nitric acid alone (no reductant) at temperatures from 14 to 18°C. Again, heavy-metal losses to the raffinate were very low. The ^{95}Zr and ^{106}Ru DFs were $>10^5$ for both products and a little higher than obtained with 30% TBP. Although reductant was not used in this run, fairly efficient uranium-plutonium separation was achieved. The uranium DF for the plutonium product was in the range 200 to 700, and the plutonium DF for the uranium product was ~500.

2.4.2 Contactor Development

R. T. Jubin

This activity continues the basic development of centrifugal solvent extraction contactors utilizing (1) a single-stage unit to explore additional improvements in performance by varying internal geometry and (2) a four-stage unit to evaluate a new design concept that allows operation to continue after failure of one motor drive. A concept for driving the four stages from a single motor is also being evaluated.

Uranium mass-transfer studies have been initiated using the 5.5-cm-diam single-stage laboratory contactor. These studies are part of a series of tests to establish the mass-transfer characteristics of banks of multiple contactors under varied operating conditions and simulated modes of contactor failure. These initial tests use a single contactor unit and are focused on (1) experimentally verifying the mass-transfer characteristics of the contactor and (2) gaining experience in operation of the experimental system. Preliminary results indicate stage efficiencies for extraction that agree with predictions obtained from a correlation by Steindler.* Stage efficiencies for stripping showed some sensitivity to throughput and ranged from 70 to ~100%. During these tests the experimental system functioned well.

When the four-stage experimental contactor was installed in the laboratory for initial hydraulic testing, the throughputs were significantly lower than expected. After extensive testing to determine the source of the problem, it was noted that the radial vanes in the passageways between the aqueous underflows and the aqueous weirs were of different lengths. The rotors with short vanes exhibited lower throughputs than those where the vanes extended to the edge of the aqueous weir. One of the rotors that had radial vanes extending nearly to the aqueous weir and that performed well was modified by cutting the vanes back to match those on the rotors exhibiting the worst performance. Tests of the modified rotor showed a significant degradation in performance, as expected. A further test involved increasing the aqueous weir diameter of the modified rotor; this change restored the performance to match that of the original single-stage unit. Based on these tests, the remaining rotors were machined to the same specifications for the vanes and

---

*M. J. Steindler, R. A. Leonard, R. A. Wigeland, and A. A. Ziegler, *Fuel Cycle Applied Technology Quarterly Progress Report, October–December 1981*, ANL-82-17, April 1982.

aqueous weir. Tests of all four rotors now show similar performance. The rotors were installed in the four-stage unit, and hydraulic testing of the unit was completed. The operating envelope was determined for operation with and without a dead stage (stage two or three stopped). The tests were conducted at flow ratios (organic/aqueous) of 0.1, 1.0, and 10.0. Under normal flow conditions, the product streams showed no cross-phase contamination even with a dead stage. Maximum flow conditions for the four-pack contactor are in agreement with those previously measured for the individual rotors when all four stages are operational. When either the stage two or stage three rotor is stopped (the intermediate stages), higher rotor speeds are necessary to maintain the hydraulic throughput. The shift in rotor speed ranges from ~200 to ~1000 rpm depending on the throughput at the time of rotor stoppage. A report describing these tests has been completed.

The two-stage unit fabricated by the Savannah River Laboratory (SRL) was delivered to ORNL and decontaminated to facilitate modifications of the housing that will allow for interstage sampling. The modifications have been completed. When the unit was installed in the laboratory for detailed hydraulic and mass transfer testing, it vibrated excessively at the rotor speeds of interest. The two rotor-coupling assemblies have been sent to the Oak Ridge Gaseous Diffusion Plant to correct the balance and run-out in an attempt to permit operation at speeds above 3000 rpm.

2.4.3 Solvent Extraction System Analysis

R. T. Jubin and J. C. Mailen

Computer codes for solvent extraction system analysis are being improved by updating the UCOR subroutine within the SEPHIS and MATEX codes to include new equilibrium data. Some recently obtained U.K. distribution data for nitric acid, uranium, and plutonium in low TBP (5 to 20 vol %) at low temperatures (6 to 30°C) have been tabulated using LOTUS 1-2-3 to allow sorting of the data and examination of various data correlations. The nitric acid extraction data (available for about half the tests) have been empirically correlated at each temperature as functions of the free TBP, aqueous acid, and aqueous total nitrate. These correlations have been used to calculate the missing acid extraction data in the data set. It appears that the distribution data for uranium and plutonium at each temperature can be correlated as functions of the free TBP and aqueous total nitrate. These data were compared with values of distribution coefficients as predicted by the original and the recently modified UCOR subroutines. The results of that comparison are shown below.

Distribution coefficient	Average percent error[a]: Original UCOR	Average percent error[a]: Modified UCOR
U	−13.7	−6.90
Pu	−0.304	−21.6
HNO_3	52.9	47.9

[a](Calculated value − experimental value) × 100/experimental value.

Based on the relatively high error in the modified UCOR for plutonium, an effort is under way to improve that portion of the model. The occurrence of the higher error for low TBP values is not unexpected since the earlier modifications were optimized for 30% TBP data only.

2.5 HOT-CELL STUDIES

J. T. Bell

This activity supplies FFTF fuel samples for use in the SETF and performs limited fuel dissolution and dissolver residue characterization studies.

2.5.1 Fuel Characteristics and Dissolution Behavior

D. O. Campbell, J. C. Mailen, and D. R. McTaggart

Two dissolution experiments using high-burnup (100,000-MWd/t) FFTF fuel were completed. In each experiment, sheared fuel was treated with 8 *M* HNO_3 for 5 h at ~100°C. The separated residue (without the cladding hulls) was again leached for 5 h at 100°C with 8 *M* HNO_3 and then with HNO_3-HF solution to dissolve any residual fuel. The final residues in the two tests were 1.02 and 0.78% of the original fuel weight. In earlier studies with FFTF fuel, the quantity of residue was found to increase with increasing burnup (~0.2, ~0.3, and ~1.0% for 2000-, 36,000-, and 55,000-MWd/t fuels respectively). The latest data indicate that the quantity of residue does not increase at high burnups beyond ~1% of the initial fuel weight.

Plutonium values recovered from the residues by leaching with HNO_3-HF were 0.047 and 0.13% of the total plutonium found, indicating that very little of the fuel is insoluble in nitric acid. The corresponding quantities of uranium recovered by HNO_3-HF leaching were 0.0045 and 0.0017%. Total plutonium recoveries were only 80 and 64% of the total plutonium predicted to be present (Westinghouse Hanford prediction modified by the ratio of the burnup for this fuel section relative to the average burnup). The corresponding uranium recoveries were 107 and 89%. The discrepancies in the recovered plutonium are similar to those observed in the recent dissolutions of this fuel in the SETF and are a cause for concern. These low material balances for plutonium are under examination.

The fuel cladding segments, after treatment with nitric acid, varied significantly in color; some pieces were either metallic bronze or metallic blue, and a few pieces were nearly white. Many of the white pieces of cladding and some of the pieces with a metallic appearance have a narrow longitudinal black stripe which may correspond to the position of the spiral wire wrap. The inside surface of the cladding, both before and after dissolution, appears to be roughened; this may be due to fuel-cladding interactions.

2.6 CONVERSION PROCESS DEVELOPMENT

W. S. Groenier

2.6.1 DIPRES Engineering Studies

M. D. Jackson (Hanford Engineering Development Laboratory)

This activity supports fabrication of test pins at HEDL for an irradiation confirmation test of DIPRES feed material in the FFTF. Mixed-oxide (MOX) DIPRES feed calcining tests were performed using the composite feed lot that was cross-blended from ORNL feed lot numbers 9 through 17. This is the DIPRES feed designated for the FFTF irradiation test. Calcining tests were performed at soak temperatures of 825 and 875°C using 11.5 ft^3/h Ar–8% H_2 bubbled through room temperature water. Each group of tests used a heating rate of 200°C/h and a soak time of 4 h. Analyses were obtained for bulk density, oxygen-to-metal ratio, and surface area. This material is now being used for pelletizing tests to define production calcining treatments. Previous work with similar MOX DIPRES feed indicated that a calcining temperature between 800 and 900°C would most likely produce a feed material with a surface area and target sinterability that would result in pellets of 90.4 ± 2% theoretical density.

Approval has been received from the DOE for the planned irradiation of DIPRES-derived fuel in the FFTF. Fuel pellet fabrication can now begin.

2.7 ANALYTICAL CHEMISTRY DEVELOPMENT

D. A. Costanzo

2.7.1 X-ray Fluorescence

J. M. Keller

The development of X-ray fluorescence (XRF) as an analytical technique applicable to reprocessing facilities is continuing. A prototypic system has been designed based on successful proof-of-principle tests. Software utilizing fundamental parameters is under development. The constant-potential X-ray generator for the high-gamma XRF system was shipped to ORNL at the end of June.

2.7.2 Instrument Development

L. N. Klatt

This activity initiates development of a scanning double-beam absorption spectrophotometer that employs fiber optics for signal transmission, has remote electronics and dispersion optics, provides adequate spectral resolution for plutonium measurement, and has a multiwavelength capability. Modifications to a purchased spectrophotometer are under way to provide the double-beam capability.

Modifications to the control program for the amperometric titration system, identified during laboratory evaluation, were completed and successfully tested. This effort completes the planned development activities for the amperometric titration system.

3 Engineering Systems

M. J. FELDMAN

The scope of the work performed in the area of Engineering Systems includes the design, procurement, and development of prototypic equipment for breeder reprocessing facilities. The IET facility will be used for testing the combined equipment systems and the remote operation capabilities and characteristics of these components and systems.

3.1 COMPONENT DEVELOPMENT

R. H. Chapman

Component development activities are directed toward performance demonstration of prototypic process equipment that can be remotely operated and maintained. Work includes designing, fabricating, and testing pilot-plant-scale components under realistic conditions. Current activities in the areas of dissolution and solvent extraction are reported below.

3.1.1 Dissolution

Dissolution system components are being developed for use in the head-end process of a remotely operated and maintained fuel reprocessing plant. This reporting period was devoted to solving minor operating problems with the 0.5-t/d IET rotary dissolver system and to preparing a report that documents dissolver development activities during the past few years.

IET Rotary Dissolver

J. F. Birdwell, J. E. Rutenber, and F. E. Weber

The dissolver, dissolver off-gas, and solids recycle systems and the feed station were operated to dissolve U_3O_8 powder into a feed solution for a subsequent one-week process demonstration run with the solvent extraction system. Although a few minor operational problems were encountered, the equipment performed reliably during the dissolution run.

Corrosion-resistant 17-4 PH stainless steel and Graphitar stock were procured, and fabrication of replacement supporting shafts and bearings for two of the self-aligning drum support rollers was initiated. As noted in the previous report, this combination of materials was used for the other two support rollers with good success, whereas less corrosion-resistant 440-C stainless steel shaft material proved unacceptable in the dissolver environment.

3.1.2 Solvent Extraction

Solvent extraction component development involves work on BRET-sized centrifugal contactors at SRL and additional tests and evaluation of components, primarily the pulse column and the two 8-stage centrifugal contactor units, installed in the IET solvent extraction system. This reporting period was devoted to additional testing of advanced centrifugal contactors at SRL and to minor system modifications that alleviate operating difficulties encountered with the IET solvent extraction system.

Advanced Centrifugal Contactors

M. E. Hodges (Savannah River Laboratory)

Resolution of problems with balancing the rotors of the four-stage and the eight-stage BRET-sized (0.1-t/d) centrifugal contactors proved difficult and extremely time consuming, and, consequently, testing of the units at SRL will be limited to verification of the hydraulic design. The units are scheduled for delivery at ORNL early next quarter for extensive testing as indicated below.

The two-stage SRL prototypic development model was received at ORNL and installed in a laboratory for further characterization of the hydraulic and mass transfer performance.

Contactor Reliability Testing

P. A. Haas

When the eight-stage BRET-sized centrifugal contactor is delivered to ORNL, it will be subjected to long-term testing to evaluate the mechanical reliability of the design. Construction is well under way on a simple facility that can be operated unattended for this purpose.

The four-stage contactor unit will be used for testing the mass transfer performance characteristics for a wide range of operating parameters under carefully controlled laboratory conditions.

IET Solvent Extraction System

S. P. Singh

Several equipment modifications were carried out this reporting period to improve centrifugal contactor operation and to provide more definitive data for analysis of component performance.

The feed conditions to the extraction bank of contactors were adjusted during the most recent IPD run to provide a concentration profile that was easily measured throughout the eight stages and could be used to calculate the efficiency of the individual stages in the bank. Preliminary results indicated that the individual efficiencies approached theoretical values.

3.2 SYSTEMS DEVELOPMENT

N. R. Grant

This work is directed toward the development of certain major mechanical components and systems required for fuel reprocessing. The goal of Systems Development is to design, fabricate, and operate pilot-scale, prototypic, remotely operable and maintainable equipment.

The tasks assigned to this area are the disassembly and cutting systems, receiving and storage systems, special remote systems, and remote control engineering. The receiving and storage task is not funded in FY 1985 and therefore will not be reported.

3.2.1 Disassembly and Cutting

J. H. Evans

The disassembly and fuel cutting task, which is responsible for the mechanical preparation of the fuel for downstream processing, is developing equipment that will remove the undesired components (such as inlet and outlet nozzles) from the fuel assembly and cut the remaining portion of the assembly into short pieces. The sheared product will expose the contained fuel for subsequent dissolution in the dissolver. The goal is to produce the necessary design, equipment, and data required for the successful operation of a prototypic system. A prototypic mechanical head-end consisting of a laser-disassembly system, a shear system, and an overall control system has been installed in the ROMD area of Building 7603.

IET/ROMD Disassembly Shear and Disassembly and Cutting Control Systems

E. C. Bradley, C. F. Metz III, B. S. Weil, and W. F. Johnson

The majority of effort this quarter involved integrating the control system with the mechanical systems and responding to minor problems of design and fabrication origin which surfaced during this initial operating period. Significant progress has been made in improving the smoothness and operability of the shear hydraulic subsystem. Shear tooling has been fabricated, and installation has begun. Considerable laser cutting on skeleton dummy fuel assemblies was performed.

The control system integration is expected to be completed early next quarter. At this juncture, the system will be operational in a prototypic manner, and the first attempt to disassemble and shear prototypic dummy fuel will be made.

3.2.2 Special Remote Systems

S. L. Schrock (Westinghouse Advanced Energy Systems Division)

Special remotely operable components and systems that will be required by a nuclear fuel reprocessing facility or by other tasks in Component Development and Systems Development are being developed. During this fiscal year these include remotely operable pipe and electrical connectors, prototypic equipment racks and support structure, and a cell transporter to give mobility to the servomanipulators. In addition, an area in Building 7603 is being prepared in which the equipment racks will be installed and used to test components of the maintenance system.

Remote Connectors and Jumpers

J. E. Richardson (Westinghouse Advanced Energy Systems Division)

Several improvements to pipe connectors and jumpers, including tools to handle and operate the connectors, are being developed. The primary improvements desired in the pipe connectors are the development of radiation-resistant seals, a decrease in the size and cost of the connectors, and improvements in the reliability and ease of remote handling.

During this reporting period, handling tests using the Central Research Laboratories' (CRL's) Model M-2 servomanipulators were performed on various types and sizes of electrical connectors mounted on a test panel in different orientations. The tests included breaking and remaking each connector a total of 25 times with periodic measurements on the continuity and resistance of each pine. Times to perform each operation were also recorded. These tests will be followed by a similar series of tests on tubing connectors in which the leak tightness of the connection will be checked periodically.

Cell Transporter

D. Macdonald and J. E. Richardson (Westinghouse Advanced Energy Systems Division)

The transporter supports and provides mobility to the in-cell servomanipulators and consists of a bridge, a trolley mounted on the bridge, and a rigid mast crane mounted on the trolley. The manipulator package is then attached to the lower end of the crane's rigid mast assembly. Design and fabrication of a demonstration transporter unit, to be installed in a facility at ORNL, are being performed by the Harnischfeger Corporation. During this period, fabrication of the unit was initiated by Harnischfeger. Completion of fabrication is scheduled for the end of the fiscal year.

Equipment Racks/South Test Area

R. W. Mouring

An area for testing the Advanced Integrated Maintenance System (AIMS) is being developed in Building 7603 adjacent to the ROMD test area. This facility will provide an area for development of rack equipment concepts, servomanipulator repair of such concepts, and space requirements needed for such maintenance. In previous periods, a design criterion for the equipment racks was prepared and approved, the conceptual design of the racks was completed, and necessary building modifications were identified.

During this period, the definitive design of the racks progressed to a point where all long-lead material was ordered and fabrication of specific equipment items was initiated. The design of the building modifications was also completed. Installation of the racks into the test area is scheduled for completion by the end of the calendar year.

3.2.3 Remote Control Engineering

J. N. Herndon

Manipulator and Maintenance System Development

H. L. Martin, D. P. Kuban, J. C. Rowe, A. C. Morris, and E. C. Bradley

The purpose of this effort is to design, fabricate, and operate equipment and facilities for development of improved remote maintenance techniques for fuel reprocessing and other hazardous environments. The basis for this effort is the use of bilateral force-reflecting servomanipulators, television viewing, and man-in-the-loop teleoperation for large-volume, nonrepetitive tasks in unstructured environments. The AIMS represents a prototypic demonstration of the maintenance concepts that will be used in future demonstrations for any remote handling applications. Key features to be demonstrated in AIMS include (1) increased availability through modular remote maintainability of manipulator slave arms, (2) improved operational flexibility through modern digital control techniques, (3) servocontrol for overhead transporter system, (4) wireless signal transmission techniques for reduced cable handling, (5) radiation-resistant television camera development, and (6) improved operator efficiency through flexible man/machine interfaces.

Mechanical testing and evaluation of the ASM pseudo master/slave system continued during this quarter. The slave arm brake upgrade has been completed, and the system has been operated successfully in master/slave mode with full electronic counterbalancing. Development of software compensation routines has essentially been completed. Further developments will await integration of the present slave arms with the master controller arms.

Design of the low-friction/low-inertia master controller arms for the ASM system is complete. Fabrication is continuing and should be completed in August. Design of the AIMS control system has been completed, and most of the hardware has been received. The system is based on the IEEE 796 bus and Motorola 68000 microprocessors. This system incorporates both high-speed, serial direct communication to the in-cell mobile equipment and a local area network system for the out-of-cell hardware.

Construction of the AIMS control room is in progress and should be completed in early August. The consoles for the man/machine interface hardware are being fabricated. Fabrication of the interface package should begin next quarter, and fabrication of the microwave-based signal transmission system should begin in early October.

Studies and Evaluations

J. V. Draper (Clarke Ambrose Incorporated) and Y. Fujita
(Power Reactor and Nuclear Fuel Development Corporation, Japan)

The primary effort in this area is the Manipulator Comparative Testing Program, a cooperative effort with PNC of Japan to evaluate and document the comparative performance of selected manipulator systems in simulated remote handling applications. The testing program, in the ROMD facility at ORNL, involves performance of typical remote handling tasks with various manipulator systems under rigorously controlled conditions. The manipulator systems being tested include a CRL Model M-2, a Japanese Meidensha BILARM 83A, and a Programmed and Remote Systems (PaR) Model 6000. The experimental portion of this program was completed this quarter. The data reduction and analysis have been started and should be completed next quarter.

4 Integrated Equipment Test Facility Operations

O. O. YARBRO

The IET Facility Operations section is responsible for the overall operations of the IET facility, including facility preparation and equipment installation, systems and equipment checkout and start-up, performance of tests in the facility, and overall facility maintenance. The objectives are to provide for the integrated testing of process equipment and flowsheets prototypical of a pilot-scale fuel reprocessing plant, and also for testing prototypical remote features of specific complex components in the system. The IET area consists of two distinct areas: ROMD and IPD. The ROMD activity focuses on demonstrating remote maintenance concepts on advanced prototypical reprocessing equipment and operation of key portions of the process equipment. The IPD addresses the issues of process operations in the predominantly chemical processing portion of the system.

4.1 IET OPERATIONS

D. R. Moser

This activity controls, coordinates, and executes the overall operational experimentation within the IET facility. The major tasks include planning and executing process operation experiments, preparation of procedures, data storage, and demonstration of remote maintenance concepts.

4.1.1 IPD Operations

D. R. Moser, R. D. Spence, and P. Welesko

The IPD operations focus on the testing and operation of processes and equipment prototypical of those intended for deployment in an advanced fuel reprocessing facility.

The initial FY 1985 IPD uranium processing campaign was completed as scheduled during April 15–26. The rotary dissolver was operated for one week, followed by the sustained operation of the solvent extraction system. The operation of these major process units also included the simultaneous operation of their support systems in an integrated process demonstration. The primary objective of this campaign was to provide operating experience on the various IPD systems under simulated process conditions. All material transfer operations were monitored for conformance with safeguards standards according to established uranium accountability procedures. This surveillance provided a measure of system integrity both for expanded safeguards applications and for the fundamental R&D projects that will follow. Process conditions were altered near the end of the campaign so that additional performance data could be obtained. The process systems performed very well during the run, and all primary and secondary objectives were successfully met.

4.1.2 ROMD Operations

T. W. Burgess

The ROMD operations focus on demonstrating remote maintenance concepts on advanced prototypical reprocessing equipment and developing remote maintenance techniques.

Primary efforts continued to concentrate on manipulator comparative testing. The final stage of testing, Test Blocks III, IV, and V, was initiated and completed on schedule. The Meidensha BILARM 83A manipulator, on loan from the PNC for participation in the manipulative comparative test program, was dismantled and crated for shipment to Japan.

Dissolution system digester tank sampling using the ROMD automated sampling system was successfully demonstrated during the April IPD uranium processing campaign. Malfunctions of the vehicle control system were experienced for a small percentage of the sampling operations and are being investigated by the Instrumentation and Controls (I&C) Division.

Testing under the remote connector test program was initiated in the first week of June. Remote handling characteristics and performance of selected off-the-shelf electrical and tubing connectors are being evaluated using the Model M-2 servomanipulator. Connectors are mounted in various orientations on a portable test panel. Testing of electrical connectors was completed. Completion of tests on tubing connectors is scheduled for mid-July.

4.2 IET ENGINEERING

W. W. Evans

The IET Engineering is responsible for the management, planning, and implementation of activities associated with the installation and maintenance of process equipment and service systems in the IET facility and the CFRP site.

4.2.1 Facility Engineering Support

W. W. Evans and R. V. Eberle

The main engineering effort during this reporting period was to assist IET Operations in the scheduled IPD experimental campaign and then to correct equipment operating problems found during the campaign. Also, equipment modifications were initiated in preparation for additional small-scale experiments planned for isolated equipment in the area. Drawings documenting the temporary equipment changes made for the isolated tests were completed and forwarded to IET Operations.

Assistance was provided to the Component Development group in removing the eight stages from the 8-1 centrifugal contactor bank to install stainless steel motor end-plate protectors on six stages and inspect the two stages where the protectors were installed before the campaign. When the stages were reinstalled, the off-gas lines from the motors in the 8-1 contactors were modified to provide added protection for the motors and smoother operation.

4.2.2 Environmental Test Chamber

B. B. Spencer

Design of the ETC was completed, and a quality verification plan for its construction was written and issued for approval.

Efforts to write a user interface to the computer program LFVSS (low-flow ventilation system simulation) were initiated. The interface algorithms permit users to run cases of interest using a simple set of instructions as input. Programming is approximately 90% complete; the remaining work consists mostly of testing. A user's manual for LFVSS is being written.

4.3 INSTRUMENTATION AND CONTROLS SUPPORT TO IET

J. A. Hawk, M. S. Hileman, R. C. Muller, and R. G. Upton

This task is responsible for planning and implementing I&C support in the IET facility and CFRP site.

4.3.1 Distributed Data Acquisition and Control System (DDACS)

M. S. Hileman and R. G. Upton

The I&C engineering support was provided on a 24-h basis during the April IPD campaign. Prior to the campaign, all process control module (PCM) data bases were recompiled and downloaded to the PCMs. Normal software development continued during the uranium run without any noticeable impact on the process control functions of the system. The new archival and retrieval software package was used successfully during the campaign. Minor modifications and enhancements to this package will be implemented prior to the next uranium run in September.

The following software was written and tested during this reporting period:

1. A program that provides system task monitoring. This routine runs at 5-min intervals, checks the status of critical system tasks, and reports any irregularities on the system alarm terminal;
2. A software routine for controlling the pulse-column operation from the uranium concentration (photometer signal);
3. A FORTRAN task that allows the operators to interact with the DDACS process control system through a computer terminal; and
4. An "interlock" task that controls the fluidic pump experiment.

During this reporting period, work commenced on the software needed to complete the I&C September milestone to demonstrate automated sampling of the digester tanks.

The I&C staff has provided Operations with a means of placing all IPD actuators in a safe "off" condition for nights and weekends by using the existing scram switch to disable input/output power from the PCMs and actuators.

4.3.2 Component Development Data Acquisition and Control System (CODEDACS)

R. C. Muller and R. G. Upton

A new operating system was generated this quarter to bring the current software level up to Revision D of RSX11M+. Some difficulty was encountered in installing the FORTRAN software, but the problems were solved after discussions with Digital Equipment Corporation personnel.

4.3.3 IET Process Equipment Instrumentation

J. A. Hawk and M. S. Hileman

Instrumentation was installed and calibrated to support and control the fluidic pump experiment.

Considerable work was performed on the shear and disassembly fuel grapple motor controller. It was recommended to the Disassembly and Cutting Development group that the 240-V dc motor be replaced with a 120-V dc motor.

4.4 IET PLANNING

J. H. Shaffer

The IET planning activity coordinates the experimental demonstration of various CFRP R&D projects in the IET facility.

The IET facility provides the capability for conducting major process and equipment development studies and for demonstrating technical developments in remote operating and maintenance procedures. All tasks of the CFRP share a mutual responsibility with the IET operations staff for the various R&D programs that will be conducted in the two experimental areas. The planning and scheduling of these activities will pursue the most beneficial program for the overall commitments of the CFRP.

The IET operations schedule for the balance of the fiscal year is essentially complete. The ROMD operations have completed an expanded test program for comparing three manipulative systems. A program for testing conventional electrical and tubing connectors under remote maintenance conditions is in progress. Tests of the Model M-2 manipulator system, under force and nonforce feedback conditions, are scheduled for the last quarter of the fiscal year.

The IPD operations schedule includes two pump test programs, now in progress, and tests on a gadolinium monitor under simulated process conditions. Modifications to the rotary dissolver and to the centrifugal contactors in the solvent extraction system will be completed in time for the next integrated IPD campaign.

5 Strategic Planning and Analysis

J. G. STRADLEY

Efforts described in this section provide (1) information to guide the long-range activities of the CFRP, (2) a focal point for foreign exchange activities, and (3) support in specialized technical areas.

5.1 STRATEGIC STUDIES

5.1.1 Fuel Cycle

H. R. Yook

A collaborative study is being conducted with HEDL to examine fuel cycle options for the LMR fuel cycle. Three options are being evaluated in FY 1985 including (1) expansion of the Fuels and Materials Examination Facility (FMEF)/Secure Automated Fabrication (SAF)/BRET complex for use as the LMR fuel cycle, (2) a new LMR fuel cycle facility to be colocated with the LMR complex, and (3) delayed closure of the fuel cycle for five to ten years.

The BRET as originally designed for developmental purposes can accommodate an initial LMR module. BRET could be expanded and completed and the SAF utilized in FMEF to service the needs [up to 35 metric tons of heavy metal (MTHM) per year] of an initial 1300-MW(e) reactor station. This can be accomplished for only a modest (5 to 15%) cost increase over the cost estimated for BRET (15-MTHM/year capacity).

A scoping design has been completed for a colocated fuel cycle facility with a 35-MTHM/year reprocessing capability. A rough order-of-magnitude cost estimate ($300 million) was developed.

Results of these activities were reviewed with DOE and participating reactor manufacturers. Parametric studies based on the initial colocated facility design and cost estimate were initiated.

5.2 FOREIGN EXCHANGE AGREEMENTS

The CFRP has active exchange agreements with the United Kingdom Atomic Energy Authority (UKAEA) and the PNC of Japan, and with the Federal Republic of Germany on HTGR spent fuel treatment (see Sect. 7).

5.2.1 U.S./U.K. Exchange Agreement

This agreement covers the areas of design parameters for a reprocessing plant demonstration; mechanical head-end, dissolution, and flowsheet technology; process control; instrumentation; and analytical chemistry.

Tests continued on the centrifugal contactor that is on loan from the United Kingdom (Sect. 2.2.1).

A U.S. team visited Dounreay Nuclear Power Development Establishment in May to initiate discussions concerning technical exchange in remote photometer technology.

5.2.2 U.S./PNC Exchange Agreement

The major activities in the remote systems technology area dealt with a technical specialists meeting held at ORNL on April 26–May 3 and completion of a comparative experimental testing program involving the Japanese BILARM 83A power manipulator, the M-2, and the PaR 6000 power manipulator.

In the Joint U.S./PNC Criticality Data Development area, seven additional criticals of the total 77 planned for the joint program were performed at PNL's Critical Mass Laboratory. The PNC staff member participating in this program returned to Japan, and a new PNC staff member arrived.

The equipment for the subcriticality measurement system arrived and is undergoing verification testing. Some difficulties were encountered with both the hardware and software and are currently being studied.

5.3 MISCELLANEOUS STUDIES

5.3.1 RAM Analysis

M. J. Haire and J. E. Richardson

A RAM analysis of the ASM transporter systems (i.e., bridge cranes and hoists) was completed and a report drafted.

5.3.2 ASPEN Code Development

J. M. Begovich, J. F. Birdwell, J. O. Blomeke, J. H. Clinton, R. T. Jubin, M. V. Keigan, B. E. Lewis, E. L. Nicholson, T. D. Welch, M. E. Whatley, O. O. Yarbro, K. R. Zabelsky, and C. W. Forsberg

Work continued on a report describing the ASPEN material balance simulation of the preliminary BRET flowsheets. All report sections have been assembled and reviewed, and comments are now being incorporated.

5.4 NUCLEAR ENGINEERING

M. J. Haire

The objective is to provide calculational support and technical guidance for the design of reprocessing equipment to be used where criticality and radiation damage are significant problems.

5.4.1 Nuclear Engineering Support for BRET

J. A. Bucholz, S. N. Cramer, M. J. Haire, and D. T. Ingersoll

Criticality Analysis

J. A. Bucholz

A document describing the criticality safety analysis of the BRET main process cell during normal conditions continues in technical review.

Radiation Shielding Analysis

D. T. Ingersoll and S. N. Cramer

A draft report on the PUTZ point kernel radiation transport code was completed.

5.4.2 Gadolinium Monitor

M. J. Haire

A gadolinium monitor has been installed in IET for a demonstration test. The test objectives are to (1) verify the long-term stability, (2) accomplish in-line calibrations without disturbing the process, and (3) verify the low-level or gadolinium content alarm system.

5.5 SAFEGUARDS ASSESSMENTS

H. T. Kerr, M. H. Ehinger, T. L. Hebble, and J. W. Wachter

The primary near-term objective of this work is to demonstrate in the IET facility uranium loss detection capabilities achievable with advanced material control and accounting techniques. An integrated run of IET dissolution and solvent extraction systems was conducted in April (Sect. 4.1). During the dissolution phase and solvent extraction phase of the IET run, extensive data archival arrays were generated, and safeguards tests were applied to these data. Essentially all process events were flagged as planned, and all material transfers were quantified. Preliminary analyses have included mass and volume transfer comparisons, mass balances, flow rate evaluations, and statistical parameter determinations. Plans are being developed for a second integrated run in September. A task was initiated to develop a process monitoring concept appropriate for a safeguards program for the International Atomic Energy Agency.

5.6 SAFETY AND ENVIRONMENTAL MATTERS

M. B. Sears and T. D. Welch

This task provides guidance and coordinates assessments in support of CFRP activities to ensure that the facilities being designed will be radiologically and environmentally acceptable.

Work continued on the study to define the nuclide characteristics of BRET process streams. An ORIGEN2 spent fuel case for the FFTF is under development. The standard code was modified to provide a more detailed breakdown of the structural material into the active core region, reflector region, and end hardware. The UO_2 insulators have been added, and a tabulation of the core composition charged to the reactor is included. The spent fuel case study, the basis for the ORIGEN2 reprocess stream models, includes head-end operations, solvent extractions, and waste streams, and was run for FFTF fuel with burnups of 60, 75, and 95 MWd/kg.

6 Breeder Reprocessing Engineering Test Project

S. A. MEACHAM

The BRET project had as its prime objectives the closing of the fuel cycle for the FFTF and demonstrating advances in reprocessing and remote maintenance technology under development in the CFRP. These objectives were to be accomplished by modifying an existing DOE facility, the FMEF, at Richland, Washington, to accommodate the reprocessing and maintenance equipment. BRET is a project undertaken in collaboration with HEDL.

6.1 PRELIMINARY DESIGN STUDIES

BRET project funding for FY 1985 has been reduced from FY 1984 levels. The project is being phased down and deferred pending DOE direction on future restart. Technical activities related to BRET are being brought to logical stopping points, and both results and status are being documented. Where work carried out under the base program was being applied to BRET, that work is continuing consistent with base program funding and guidance.

During this quarter work continued on a series of reports documenting BRET conceptual designs and the results of analyses performed in FY 1984. All but two reports were completed and forwarded to the BRET design file. Status summaries for the two reports in preparation (ASPEN material balance analysis and criticality analysis results) were prepared for the design file. These two reports are in review and are scheduled for completion next quarter.

Project staff also provided support to the Fuel Cycle Strategy Study this quarter in preparation of a study of potential FMEF/SAF/BRET expansion to support innovative LMR concepts and design of a fuel cycle facility to be colocated with an LMR complex.

7 HTGR Fuel Reprocessing

W. S. GROENIER

Research and development activities in HTGR fuel treatment technology are being conducted at GA Technologies, Inc. (GA). Head-end process and laboratory-scale development efforts, as well as studies specific to HTGR fuel, are reported. The development of off-gas treatment processes has generic application to fuel reprocessing; progress in this work is also reported.

7.1 SPENT FUEL STUDIES AND ANALYSES

B. J. Baxter and M. E. Cohen (GA Technologies, Inc.)

Design and cost studies are performed on the storage, transportation, and disposal of spent HTGR fuel. In addition, economic studies are conducted to assess various spent fuel treatment techniques and to evaluate the impact of the new HTGR reactor concepts on spent fuel treatment. New reactor concepts under consideration in the HTGR development program include modular plant designs in the range 250 to 350 MW(t) and integrated plant designs in the range 1000 to 1300 MW(t). Both prismatic and spherical fuels are being considered in these concepts.

7.1.1 Storage Studies

The HTGR spent fuel storage studies develop preconceptual designs and cost estimates for concrete storage casks, open-field drywells, and air-cooled vaults. Cost estimates of concrete cask storage facilities were completed. These estimates address only those portions of the facility which are unique to the concrete cask concept. The cost of the onsite cask manufacturing facility includes both fixed and variable costs that are necessary to perform economic analysis for various spent fuel mass flows. Cost estimates of the drywell storage facilities were also completed. For this concept, site construction is limited to drilling and installing drywells and will not involve a manufacturing facility. From the preliminary estimates, drywells appear to be the lowest cost concept. The preconceptual design and design description of the air-cooled vault have been recently developed, and cost estimates for the storage facility were completed.

7.1.2 Transportation Studies

The HTGR spent fuel shipping studies determine the maximum amount of spent fuel waste of each form that can be transported in a legal weight truck cask, develop preconceptual designs for the most efficient truck transportation cask for each waste form, and estimate total shipping costs for each waste form. The waste forms being considered are intact spherical or prismatic fuel elements, pushed-out fuel rods from prismatic elements (stabilized or unstabilized), and stabilized fuel particles from crush/burn or crush/separate volume reduction of spherical or prismatic fuel elements.

Shielding analyses for intact spherical and prismatic fuel elements and for pushed-out rods have been completed. The shielding analysis for truck shipment of stabilized fuel particles resulting from crush/burn or crush/separate volume-reduction processing was also completed. Of five waste forms examined, the stabilized fuel particles waste form (FUETAP process) is the most efficient package from a transportation standpoint. Compared to intact spherical fuel elements, the cask fuel capacity for stabilized fuel particles is larger by a factor of 8.7 or 7.4 for 100-d- and 5-year-cooled fuel respectively. A package of pushed-out fuel rods (from prismatic fuel elements) stabilized in a matrix of tin/lead alloy is not an efficient package to transport. The amount of shielding provided by this package does not compensate for its relatively heavy weight. Aging the spent fuel from 100 d to 5 years out of the reactor prior to shipment increases the cask capacity by 40 to 100% depending on the waste form.

7.2 DRY HEAD-END DEVELOPMENT

B. J. Baxter and N. D. Holder (GA Technologies, Inc.)

The objective of this task is to develop candidate head-end processes for HTGR spent fuel treatment. The primary emphasis is on crush/burn processes applicable to any graphite fuel element design. Effort is concentrated on integrated testing of the burner and burner off-gas (BOG) system. Joint U.S./F.R.G. development work includes the processing of irradiated Fort St. Vrain (FSV) fuel in German hot cells and processing LEU spherical fuel in an integrated burner and BOG test in the United States.

7.2.1 Alternative Volume-Reduction Techniques

The rod release mechanism is the most important part of the fuel rod pushout machine because each of the six rods must independently cease pushing whenever the fuel rod stack resistance exceeds ~50 lb. Two mechanisms have been investigated. One uses a spring-loaded detent pin and the other a rare-earth permanent magnet. The detent pin approach was simulated in a rod release test fixture to permit proof-of-concept testing. Tests of this approach were successfully completed, and confidence in this approach is high. Detailed design of the fuel rod pushout machine was completed.

The matching magnet concept is still being developed with the help of several vendors because it may permit a significant simplification in the design.

7.2.2 Semivolatile Tracer Studies

The results of the scoping study of semivolatile fission products during head-end burning of HTGR fuel have been summarized in a topical report. The 7.5-h scoping test studied the behavior of stable oxides of four fission products (Cs, Mo, Rb, and Ru) during combustion in a fluidized-bed burner. Neutron activation analyses of collected samples indicate that 50 to 90% of the semivolatiles was recovered in the burner product and fines. Plateout profiles determined from coupon placement showed that the fission product concentration beyond the cyclone outlet was negligible (within the limits of detection sensitivity); thus, for the four fission products studied, the need for semivolatile trapping in the off-gas system should be reevaluated. An additional test is planned for verification of these results.

7.2.3 U.S./F.R.G. Cooperative Program on Gas-Cooled Reactor Spent Fuel Treatment Development

In FY 1986, head-end treatment tests of irradiated FSV fuel are planned in the German AVR-6 facilities. Irradiated graphite has already been shipped to Germany, and a shipment of 648 fuel rods remains to be completed. Drawings of proposed fuel rod shipping containers were sent to Germany for review. Two major changes were recommended. First, Germany is not considering underwater unloading of the fuel cask, so watertight containers are not needed. Second, the Material Test Reactor (MTR) fuel shipping cage must remain in the cask for the return trip to Germany, which requires that fuel rod shipping canisters fit into the MTR fuel cells. Baskets are also required for easy removal of the canisters from the cask. Consequently, fuel rod shipping canisters have been redesigned to fit into baskets that slip into the MTR fuel cells. Each canister will hold 36 fuel rods, and each basket can hold up to eight canisters.

A total of 2000 LEU fuel spheres has been received from Germany. A hammer mill was also received for crushing fuel spheres.

7.3 OFF-GAS SYSTEM

B. J. Baxter and J. Razvi (GA Technologies, Inc.)

This activity emphasizes the testing of integrated fluidized-bed burner and BOG systems designed as part of HTGR spent fuel volume-reduction processes. The BOG system has been updated to ensure increasingly realistic testing for verification of the reference design criteria. Integrated testing is performed with semivolatiles, including iodine, in the burner feed, and a final test will utilize F.R.G. LEU UO_2 fuel as burner fuel.

7.3.1 Integrated BOG Testing

An analysis of data from the first integrated burner–BOG system test is continuing. Neutron activation analyses of samples taken from the silver mordenite (AgZ) iodine sorption bed and burner product show that only ~50% of the iodine originally spiked into the burner feed could be accounted for in the product and BOG streams. Iodine loadings in the sorption bed were seen to be ~30% higher than noted under comparable conditions in bench-scale tests. This difference can be attributed to shutoff of the SO_2 flow prior to bed breakthrough by iodine, which caused a displacement of physisorbed SO_2 on AgZ by continued flow of iodine. During this test, SO_2 was introduced into the CO/HT oxidizer as a result of sorption bed breakthrough occurring earlier than expected, causing incomplete CO conversion in the oxidizer. This is postulated to be caused by partial poisoning of the platinum catalyst by sulfur. Combustion analysis of total sulfur in samples of the exposed catalyst has shown >1% sulfur at the oxidizer inlet zone. The possible reaction mechanisms for this effect are being investigated. An SO_2 backup sorption bed has been installed to preclude the poisoning effect in future tests.

Preparations were initiated for the July 1985 integrated test. This test will process off-gas from the combustion of graphite feed containing, in addition to iodine, four semivolatile oxides (Cs, Mo, Rb, and Ru). To measure possible semivolatile depositions in the off-gas lines, a semivolatile sampling system has been installed downstream of the burner leading to the BOG treatment system. Sample collection coupons made from 99.5% porous alumina wafers with high surface areas have been installed to collect the deposited semivolatiles for analysis by neutron activation/gamma spectrometry.

7.3.2 Bench-Scale Iodine Adsorption Tests

A topical report on iodine bench-scale sorption tests was completed and issued. Conclusions are as follows:

1. I_2 loadings are significantly less than values reported in other tests at ORNL. This may be due in part to the absence of a hydrogen pretreatment step for the AgZ, as well as a different test atmosphere (CO_2 carrier gas with CO, O_2, and SO_2).

2. In terms of total silver utilization, 5% AgZ appears preferable to fully exchanged mordenite (19% AgZ).

3. I_2 adsorption was significantly reduced by the presence of SO_2, which apparently displaces physisorbed iodine.

4. Iodine loadings on 5% AgZ were not significantly different at the two temperatures investigated (100 and 150°C). However, 19% AgZ exhibited higher loadings at the higher temperature.

5. At the CO levels normally expected in BOG compositions, no thermal excursions were observed. However, high levels of CO, such as those that may be present in burner transients, need to be investigated for thermal effects.

7.4 WASTE HANDLING

B. J. Baxter, T. Roemer, and R. G. Wilbourn (GA Technologies, Inc.)

A reference process for stabilizing volume-reduced spent HTGR fuel prior to disposal is being developed. The characterization of separated HTGR fuel components, evaluation of prepared simulated waste forms, and definition of nondestruction assay techniques are integral parts of this task.

The radial cracking of concrete HTGR waste forms which occurred during the curing operation of the stabilization process has been eliminated. Previous forms cured at 10 psi and heated to temperatures between 50 and 100°C cracked. Tests showed that usable forms can be made at an applied pressure of 20 psi and a temperature of up to 70°C. Higher curing temperatures (in the range of 100°C) produced deformed monoliths. Plastic versus glass containment vessels were evaluated, and no difference was found in the cured forms. The effects of various sample preparation techniques on final product acceptability were also compared, and there appeared to be no meaningful difference in the cured forms. It was concluded that as long as the proper, prescribed curing conditions are met, all forms, regardless of prior treatment, can be cured successfully.

Using the modified cure procedure, a series of equivalent forms was made from a single batch of grout. Careful mass records were kept for each specimen. Results showed that the grout density with 48 wt % waste product was 2.49 g/cm^3 at an initial water level of 13.17 wt %. After curing at 70°C and 20 psi for 15 h, the water content was 13.15 wt %, and the monoliths were hard and uniform. Dewatering was completed after 4 h in vacuum at 235 to 240°C. Final water levels were 2.2 $\pm$ 0.2 wt %. The average form density was 2.27 $\pm$ 0.01 g/cm^3. Samples for leach tests and density determination were cut from each monolith using a dry diamond cut-off wheel. Sample ends were polished using a 15-μm diamond grinding wheel.

Preliminary leach tests were run using distilled water at 90°C. Atomic absorption spectrometric analyses of the leachate were obtained. Five similar specimens were run in parallel to evaluate the uniformity and reproducibility of the concrete forms with respect to the concentration of the simulated fission products. In subsequent experiments, waste forms containing two different clay additives were processed through the dewatering step for a long-term (28-d) leach test. These experiments are designed to evaluate the effects of Indian red and bentonite clay additives on fission product retention at the 5 wt % level. Inventories of simulated fission products are being updated for use in scale-up experiments on concrete forms. The search for surfactant/plasticizer additives to improve grout handling characteristics continues.

Abbreviations

AIMS	Advanced Integrated Maintenance System
ASM	advanced servomanipulator
BOG	burner off-gas
BRET	Breeder Reprocessing Engineering Test
CFRP	Consolidated Fuel Reprocessing Program
CODEDACS	Component Development Data Acquisition and Control System
CRL	Central Research Laboratories
DDACS	Distributed Data Acquisition and Controls System
DF	decontamination factor
DIPRES	direct press spheroidized
DOE	U.S. Department of Energy
ETC	Environmental Test Chamber
FFTF	Fast-Flux Test Facility
FMEF	Fuels and Materials Examination Facility
F.R.G.	Federal Republic of Germany
FSV	Fort St. Vrain
FUETAP	formed under elevated temperature and pressure
GA	GA Technologies, Inc.
HEDL	Hanford Engineering Development Laboratory
HTGR	High-Temperature Gas-Cooled Reactor
I&C	instrumentation and controls
IET	Integrated Equipment Test
IPD	Integrated Process Demonstration

LEU	low-enriched uranium
LMR	liquid-metal reactor
MOX	mixed oxide
MTHM	metric ton of heavy metal
MTR	Material Test Reactor
PaR	Programmed and Remote Systems
PCM	process control module
PNC	Power Reactor and Nuclear Fuel Development Corporation
PNL	Battelle-Pacific Northwest Laboratory
RAM	reliability, availability, and maintainability
R&D	research and development
ROMD	Remote Operation and Maintenance Demonstration
SAF	Secure Automated Fabrication
SETF	Solvent Extraction Test Facility
SRL	Savannah River Laboratory
TBP	tributyl phosphate
U.K.	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
XRF	X-ray fluorescence

ORNL/TM-9734
Dist. Category UC-86

INTERNAL DISTRIBUTION

1–2. S. G. Barnes
3. J. T. Bell
4. D. E. Benker
5. J. F. Birdwell
6. J. O. Blomeke
7. E. C. Bradley
8. C. B. Brooks
9–23. W. D. Burch
24. T. W. Burgess
25. D. O. Campbell
26. J. Y. Chang
27. R. H. Chapman
28. E. D. Collins
29. D. A. Costanzo
30. R. M. Counce
31. S. F. DeMuth
32. D. E. Dunning
33. R. V. Eberle
34 R. D. Ehrlich
35. J. H. Evans
36. W. W. Evans
37. M. J. Feldman
38. R. W. Glass
39. N. R. Grant
40. W. S. Groenier
41. R. G. Grubb
42. P. A. Haas
43. M. J. Haire
44. W. R. Hamel
45. D. C. Hampson
46–48. A. L. Harkey
49. J. N. Herndon
50. W. D. Holland
51. R. A. Jacobus
52. R. T. Jubin
53. P. R. Kasten
54. M. V. Keigan
55. H. T. Kerr
56 L. J. King
57. E. H. Krieg, Jr.
58. C. T. Kring
59. L. D. Ladd
60. R. E. Leuze
61. B. E. Lewis
62. J. C. Mailen
63. S. A. Meacham
64. C. F. Metz
65. J. G. Morgan
66. D. R. Moser
67. E. L. Nicholson
68. F. L. Peishel
69. B. E. Prince
70. R. H. Rainey
71. D. P. Reid
72. S. L. Schrock
73. M. B. Sears
74. J. H. Shaffer
75. S. P. Singh
76. G. E. Smith
77. G. R. Smolen
78. R. D. Spence
79. B. B. Spencer
80–89. J. G. Stradley
90. J. E. Swift
91. V. C. A. Vaughen
92. J. W. Wachter
93. F. E. Weber
94. B. S. Weil
95. T. D. Welch
96. P. Welesko
97. M. E. Whatley
98. O. O. Yarbro
99. H. R. Yook
100–101. Laboratory Records
102. Laboratory Records, ORNL-RC
103. ORNL Patent Section
104. Central Research Library
105. ORNL–Y-12 Technical Library Document Reference Section

EXTERNAL DISTRIBUTION

106. D. E. Bailey, Director, Division of Fuels and Reprocessing, U.S. Department of Energy, Washington, DC 20545
107. F. P. Baranowski, 1110 Dapple Grey Court, Great Falls, VA 22066
108. S. J. Beard, Vice President, Marketing and Uranium Operations, Exxon Nuclear Company, Inc., 600 108th Avenue, N.E., C-00777, Bellevue, WA 98009
109. M. Benedict, Department of Nuclear Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139
110. C. A. Burgess, Westinghouse Hanford Company, P.O. Box 1970-W-B108, Richland, WA 99352
111. J. Chang, WHQ 82-2-3, Ralph M. Parsons Company, 100 West Walnut Street, Pasadena, CA, 91124

112. R. E. Dahl, Jr., Hanford Engineering Development Laboratory, P.O. Box 1970, Richland, WA 99352
113. R. Little, Princeton Plasma Physics Laboratory, James Forrestal Campus, P.O. Box 451, Princeton, NJ 08544
114. J. L. McElroy, Pacific Northwest Laboratories, P.O. Box 999, Richland, WA 99352
115. M. J. Ohanian, Associate Dean for Research, College of Engineering, 300 Weil Hall, University of Florida, Gainesville, FL 32611
116. J. F. Proctor, Senior Technical Specialist, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, SC 29801
117. M. J. Rohr, Program Manager, Consolidated Fuel Reprocessing Program, Energy Programs Division, Energy Technology Branch, DOE-ORO, Oak Ridge, TN 37831
118. Office of Assistant Manager for Energy Research and Development, DOE-ORO, Oak Ridge, TN 37831

119–225. Given distribution as shown in TIC-4500 under UC-86, Consolidated Fuel Reprocessing Category