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Consolidated Fuel Reprocessing Program Progress Report for Period April 1 to June 30, 1986

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CONSOLIDATED FUEL REPROCESSING PROGRAM PROGRESS REPORT FOR PERIOD APRIL 1 TO JUNE 30, 1986

W. D. Burch, Program Director

M. J. Feldman
Manager, Engineering Systems

W. S. Groenier
Manager, Process and Engineering R&D

J. G. Stradley
Manager, Strategic Planning and Analysis

O. O. Yarbro
Manager, Integrated Equipment Test Facility Operations

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Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
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Contents

Foreword

The U.S. Department of Energy (DOE) sponsors all U.S. civilian research and development (R&D) on fuel reprocessing in one major program—the Consolidated Fuel Reprocessing Program (CFRP)—under the management of the Oak Ridge National Laboratory (ORNL) and the Oak Ridge Operations Office.

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 that would qualify the report for unrestricted distribution in the open literature.

1 Highlights

W. D. BURCH

All research and development (R&D) 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

Tests of the double overhead condenser system and NO_x scrubber were conducted as part of an integrated campaign in the Integrated Equipment Test (IET) facility. Although steady-state operation was not achieved, data indicate that the condensers did provide some degree of NO_x scrubbing.

Campaign 10 in the Solvent Extraction Test Facility (SETF) was completed. Two experiments in the campaign successfully tested a nonreductive partitioning scheme using 10% tributyl phosphate (TBP) and an automatic control system. High-burnup Fast Flux Test Facility (FFTF) fuel was processed.

Modifications to the prototype two-, four-, and eight-stage modules of 5.5-cm-diam centrifugal contactors have been completed, and mechanical performance is now acceptable based on preliminary results. These modules are to be installed in the reliability test stand for operation with a uranium flowsheet on a continuous basis.

Leaching tests in the hot cell using cladding pieces from previous dissolution tests of high-burnup FFTF fuel indicate that little of the ^{106}Ru is soluble in any of the leach solutions.

1.2 ENGINEERING SYSTEMS

M. J. Feldman

Preparations for conducting the remote shear system maintenance demonstration using the Remote Operation and Maintenance Demonstration (ROMD) area maintenance system was completed. Disassembly and reassembly of the system were performed using remote tools locally operated to develop remote-handling procedures and check out special maintenance fixtures and tools. The demonstration should be completed during the fourth quarter of fiscal year (FY) 1986.

Fabrication of the U.S. version of the manipulator test—test stand is complete. The Power Reactor and Nuclear Fuel Corporation (PNC) of Japan is fabricating an identical version. These stands will be used in a comparative test program conducted by each country.

The advanced servomanipulator (ASM) slave arms and master controller are now operational in a force-reflecting mode.

1.3 IET FACILITY OPERATIONS

O. O. Yarbro

An Integrated Process Development (IPD) experimental campaign was completed on schedule. During the campaign, the shear was operated with uranium fuel bundles to provide 500 kg of U/d feed material for the rotary dissolver and the solvent extraction systems. This effort demonstrated the first integrated operation of the remote shear system with the remaining process systems and satisfied an award-fee milestone goal. Automation of various process systems was also demonstrated in the campaign.

The mode of operation for integrating the 14 stages of 5.5-cm centrifugal contactors into the IET solvent extraction system has been established. The new process flow arrangement will allow switching back to the 12-cm contactors with a minimum of piping and electrical changes.

Tie-in of the Environmental Test Chamber (ETC) to the Distributed Data Acquisition and Control System (DDACS) was completed, and acceptance tests were initiated. A new effort has begun to correlate conductivity and density of aqueous nitric acid-uranium solutions.

1.4 STRATEGIC PLANNING AND ANALYSIS

J. G. Stradley

A total of 37 critical experiments have been completed at the Pacific Northwest Laboratory's (PNL) Critical Mass Laboratory (CML) on the U.S. Department of Energy (DOE)/PNC Joint Criticality Data Development Program. Experiments were successfully performed at the CML with the Subcriticality Measurement System (SMS).

2 Process and Engineering R & D

W. S. GROENIER

The Process and Engineering R&D group identifies improved chemical processes and components and develops these concepts from a laboratory scale through full-size engineering prototypes. The primary objectives for FY 1986 are to (1) evaluate operation of the IET rotary dissolver, identify necessary improvements, and assess costs for implementation; (2) complete the evaluation of the improved bushings in the solid-bowl feed clarification centrifuge for extended life service; (3) explore additional centrifugal solvent extraction contactor parameter values for improved performance using an experimental modular rotor; (4) suitably modify the 5.5-cm-diam prototype centrifugal contactors to bring them up to operating specifications; (5) complete the contactor reliability test stand and check out all systems; and (6) complete the tenth and final campaign in the SETF using high-burnup FFTF fuel to explore flowsheet options and control schemes.

2.1 ENGINEERING ANALYSIS, DESIGN, AND SUPPORT

W. S. Groenier

This activity includes task coordination of several activities in the Fuel Recycle Division (FRD) and work in other ORNL divisions, and management of component development activities, the student cooperative education program, and a consulting subcontract with Georgia Tech Research, which will provide an assessment of electrochemical applications for solvent extraction. The maintenance and updating of solvent extraction computer codes (SEPHIS, MATEX, others) are also included as part of solvent extraction task management.

2.2 CONTINUOUS DISSOLUTION METHODS EVALUATION

R. H. Chapman

This activity continues the development and evaluation of continuous dissolution methods for nuclear fuel reprocessing. Objectives for FY 1986 are to complete modifications to the prototype dissolver initiated in FY 1985, evaluate operation from mechanical and solids inventory/throughput perspectives, identify additional necessary improvements (if any) and assess costs for implementation, and provide assistance to IET operations as required.

2.2.1 IET Rotary Dissolver

J. F. Birdwell

The dissolver was operated during this reporting period as part of the integrated campaign that for the first time included the shear. Aside from minor difficulties caused by frequent interruption of the feed material, operation of the dissolver with sheared fuel rods that were filled with depleted uranium pellets was satisfactory.

2.3 SPECIAL CHEMICAL SYSTEMS DEVELOPMENT

B. E. Lewis

Special chemical systems include all R&D efforts on feed clarification centrifuges, fluidic pumps and other devices, steam jets, steam strippers, evaporators, and other chemical systems not included in other tasks. Objectives for FY 1986 are to complete the evaluation of the United Kingdom (U.K.) solid-bowl centrifuge, complete demonstration of pulsatile fluidic pumps in the IET facility, perform a study of fluidics applications for off-gas control, specify where steam jets may be useful in the reference small-plant flowsheet, perform scoping tests of a small-scale steam stripper, and evaluate various dissolver process options such as preheated liquid feed streams and double overhead condensers in the off-gas line.

2.3.1 Centrifuge Development

J. G. Morgan

With the successful completion of the U.K. centrifuge evaluation program, a program has been planned for the development of a clarification unit suitable for use in an intermediate-scale facility. A back-flushable centrifuge is believed to have significant economic advantages over the U.K. design, where the centrifuge bowl is discarded along with the solids. The back-flushable centrifuge will reslurry the cake to allow efficient removal of the solids without disassembling the clarifier. To facilitate the study of the problems associated with the operation of a back-flushable centrifuge, a centrifuge test stand has been constructed. The test stand is equipped with a high-pressure water spray to reslurry the cake from a 12-cm-diam solid-bowl centrifuge. The test stand also has a variable-speed ac motor capable of driving a centrifuge at speeds up to 10,000 rpm.

A preliminary flowsheet for a back-flushable centrifuge has been developed. It provides a rough representation of how a back-flushable centrifuge could be operated assuming that the solids collected in the centrifuge can be sent to the waste vitrification process for disposal. This method of disposal is attractive from the operating standpoint of the centrifuge, but it may be a problem for the vitrification process because the homogeneity of the glass waste form may be difficult to guarantee in the presence of dense fission product insolubles. In the centrifuge flowsheet, the solids are removed using a high-pressure 0.5-*M* HNO_3 spray with gravity flow out of the bowl. The reslurried solids fall into a collection tank where they are agitated and sampled to determine the fissile material content. The solids are periodically transferred to waste from the collection tank. An optional secondary dissolution process can be used if the fissile material content of the reslurried solids is sufficient to warrant such treatment. The solids removal process and slurry transport mechanisms for feeding and removal will be demonstrated experimentally in the centrifuge test stand. A review of commercially available equipment for adaptation to these applications is currently being made.

2.3.2 Fluidics R&D

J. G. Morgan and W. D. Holland

In the current pulsatile fluidic pumping system in the IET, the motivation pressure is exhausted to off-gas through a three-way solenoid valve. If the pumped fuel solution is highly radioactive, the valve must be remotely maintained to avoid contaminating maintenance personnel. A design study was completed on a system to allow direct maintenance of the pneumatic valves by exhausting and pressurizing through a jet pump—vortex amplifier assembly. This primary controller has no moving parts to maintain and provides a shorter refill time cycle. Operating characteristics and limits of the control unit coupled with a bottom-loading fluidic pump will be studied in the laboratory.

2.3.3 Other Special Chemical Systems

B. E. Lewis, W. D. Holland, R. M. Counce,
E. L. Nicholson, and M. A. Conger

Preliminary testing of a disk valve pump has begun. The disk valve pump is similar to a fluidic pump except that it employs two spring-loaded disk valves to control pumping and refill. It is anticipated that this type of pump is less susceptible to cavitation when pumping high-temperature solutions. The initial tests have been conducted with water at ambient temperature to characterize the performance of the pump. Discharge rates ranging from 0.07 to 0.77 L/s have been obtained with a 30-psig air supply and a throttled output line. Tests are planned to study discharge rates as a function of supply pressure, tolerance to slurries, performance during continuous cyclic operation, and the effects of high-temperature solutions.

Plans are being made to run some red-oil experiments to verify and possibly extend some of the results obtained in the GA Technologies, Inc., study on solvent nitration. The GA experiments used uranium and thorium nitrate with various types of diluents, including normal paraffin hydrocarbons, in a few experiments at temperatures up to 197°C. It was concluded in the GA study that concentrator shell temperatures up to 150°C are allowable when adequate safety precautions are followed.* A limited number of experiments have been planned to verify the GA results and then determine if a minimum critical weight ratio of nitrate/TBP for vigorous reaction exists as a function of temperature. It is anticipated that this work will be done in the ORNL Chemical Technology Division laboratories.

2.4 AIRBORNE WASTE MANAGEMENT

R. T. Jubin

This activity includes all residual off-gas treatment efforts in the CFRP. Objectives for FY 1986 are to complete descriptive computer models for the selective absorption and Iodox processes, support IET tests of the Iodox process, and maintain awareness of efforts at PNL to document ion-implantation development and to monitor storage specimens.

2.4.1 Off-Gas Treatment Systems

R. T. Jubin and W. D. Holland

The dissolver off-gas (DOG) system as envisioned for a small reprocessing plant such as the Breeder Reprocessing Engineering Test (BRET) had to deal with a relatively dilute NO_x stream (1 to 2%) saturated with acid and water vapor. To minimize the impact of these vapors on the iodine-removal equipment, a concept involving a double overhead condenser system was developed. This condenser system was installed in the IET DOG system.

Testing of the double overhead condensers and NO_x scrubber occurred during the April IET campaign. The tests were made to determine the NO_x-removal efficiencies of the condensers and scrubber under actual dissolution conditions with both U_3O_8 and UO_2. Gas samples were taken before and after the condensers and from the top of the NO_x-scrubber. The gas samples were analyzed for NO_2 and total NO_x; the liquid samples were analyzed for HNO_2 and HNO_3. A preliminary review of the sample analysis results indicates that some degree of scrubbing of NO_x from the DOG by the condensers may have occurred. A more detailed study of the data is required before the scrubbing efficiency of either the condensers or the NO_x scrubber can be determined. It was hoped that data could be obtained on the time required for the NO_x column to achieve steady-state operation and to determine the off-gas composition from the dissolver. Problems associated with the operation of the shear prevented achieving steady state with UO_2 in the dissolver.

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*R. G. Wilbourn, *Safety Aspects of Solvent Nitration in HTGR Fuel Reprocessing*, GA-A14372, June 1977.

2.5 SOLVENT EXTRACTION PROCESS DEVELOPMENT

R. T. Jubin

2.5.1 SETF

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

A major solvent extraction campaign (SETF Campaign 10) was completed during this report period. Two flowsheet experiments were completed that continued the testing of a nonreductant partitioning scheme using 10% TBP and an automatic control system for the operation of the extraction bank. The fuel for the first run was FFTF fuel pins that had a burnup of ~55 MWd/kg and a cooling time of 3 years; the fuel for the second run consisted of a mixture of FFTF fuel pieces that had burnups of 2, 36, 55 and 90 MWd/kg (average of ~60 MWd/kg) and cooling times ranging from 2 to 5 years. The processing steps for each experiment included dissolution of the fuel in nitric acid, clarification of the solution by filtration, adjustment of the solution concentrations and plutonium valence for solvent extraction, one cycle of solvent extraction with partitioning in the SETF mixer-settlers, purification of the plutonium by one cycle of anion exchange, and conversion of the plutonium product to an oxide form by oxalate precipitation and calcination.

The flowsheet for the first run used 10% TBP as the solvent and included coextraction and coscrubbing in A-bank, U-Pu partitioning in B-bank, and uranium stripping in C-bank. The in-line photometer system was again used to help maintain a high operating efficiency for the A-bank by maximizing the loading of heavy metals (uranium and plutonium) in the solvent while still maintaining low losses of heavy metals to the raffinate. When the extraction bank was at near steady-state conditions, an automatic control system was used to help maintain the extraction bank at high saturation; the control system worked by varying the addition rate of the extraction based on the U-Pu concentration data from the in-line photometer. Good operation was maintained by this system (~25 h) until an electronic problem forced a return to manual control near the end of the run. The overall results showed U-Pu losses of <0.1% and fission product decontamination factors (DFs) for ^{106}Ru, ^{137}Cs, ^{144}Ce, and ^{154}Eu of 3×10^4, $>1 \times 10^7$, $>1 \times 10^7$, and $>2 \times 10^5$, respectively.

Partitioning in the first run was accomplished without using a plutonium reductant. The separation relied entirely on the relative differences between U(VI) and Pu(IV) distribution coefficients. The chosen conditions yielded good results using the 16-stage mixer-settlers. The uranium and plutonium DFs were 1500 and 350, respectively, which yielded an overall separation factor of 5×10^5.

The flowsheet for the second run used 10% TBP for the solvent and included coextraction-coscrubbing in A-bank and partitioning in B-bank and C-bank; uranium stripping was not studied. The in-line photometer and process control systems were again used to help operate the extraction bank after near steady-state conditions were achieved. No major process upsets were noted, and the control system maintained good control while it was in use (~22 h). The overall results showed U-Pu losses of <0.05% and fission product DFs for ^{106}Ru, ^{137}Cs, ^{144}Ce, and ^{154}Eu of 4×10^4, $>1 \times 10^7$, $>5 \times 10^6$, and $>3 \times 10^5$, respectively.

The overall objective of the partitioning in this second flowsheet was to make a plutonium product that contained <1–2% uranium and a final uranium product that contained as low a plutonium content as possible. If the uranium product contained <1 ppm of plutonium, it could be treated as a nontransuranic waste. The bulk of the separation was achieved in B-bank using a nonreductive flowsheet. This flowsheet generated an acceptable plutonium product that contained ~2 mg of U/g of Pu (U DF of 1600) and left ~0.8% of the plutonium with the uranium in the solvent stream. This plutonium was removed from the solvent in C-bank using nitric acid and reductant (hydroxylamine nitrate). To minimize the amount of uranium stripped with this plutonium, a relatively high organic-to-aqueous phase ratio was used, and a large excess of reductant was included to act as an inextractable nitrate salt for the uranium. The solvent from C-bank, which would be sent to a uranium strip contactor in a reprocessing plant, contained <7 μg of Pu/g of U (Pu DF of >4×10^4). The aqueous stream from C-bank, which would be recycled to the feed system in a reprocessing plant, contained ~0.8% of the plutonium and 5% of the uranium.

The two plutonium products from these experiments were purified by anion exchange and converted to an oxide form by an oxalate precipitation-calcination technique. A total of ~400 g of plutonium was prepared for disposal.

2.5.2 Contactor Development and Analysis

R. T. Jubin, R. M. Counce, and S. F. DeMuth

This activity will continue the development and testing of advanced centrifugal solvent extraction contactors. Objectives for FY 1986 are to explore additional improvements in performance by varying the internal geometry in a single-stage unit, evaluate improvements in reliability using a four-stage unit, assist the equipment development group in evaluation tests of prototype units for small reprocessing facilities, and further the understanding and knowledge level of contactors by performing specific tests and evaluations in the laboratory and through the use of descriptive computer models.

Hydraulic performance of the single-stage ORNL experimental centrifugal contactor was demonstrated at extreme organic/aqueous (O/A) ratios such as those used in diluent washing of a product stream or in solvent treatment. Acceptable performance was observed at O/A's of 0.01 and 100.0. The next step will be to verify acceptable mass transfer performance for the appropriate operations.

The Westinghouse Idaho Nuclear Company (WINCO) contactor design package has been transmitted, and a vendor has been selected. A second identical four-pack will be procured for long-term testing at ORNL.

The first attempt to examine the effectiveness of the air purge system on the ORNL four-pack contactor was conducted using a smoke generator. Qualitatively, without the rotor turning, a fairly even distribution of smoke was observed. We are now looking into obtaining photographic evidence of the smoke distribution.

Work has continued toward developing plans for a series of experiments to demonstrate the coextraction of uranium and plutonium, the partitioning of uranium and plutonium, and the extraction and stripping of uranium in centrifugal contactors. In addition to the centrifugal contactor demonstration, the work is intended to validate selected conventional and nonconventional flowsheets by varying the TBP and reductant concentrations. The recommended flowsheets and the final draft test plan are complete except for specifying cascade residence times for steady-state conditions. The use of the SEPHIS computer code for determining the cascade residence time has required additional consideration concerning the selection of criteria for specifying steady-state conditions. It may prove necessary to validate SEPHIS cascade response predictions prior to the demonstration test program.

Detailed tests are under way to determine the uranium mass transfer efficiency operating envelope for the 5.5-cm-diam single-stage centrifugal contactor. The efficiency will be determined for approximately the total range of the flow, the phase ratio, and the rotor speed specified by the hydraulic operating envelope. Currently, 24 of the total 36 planned tests have been completed. As expected, the results to date indicate extraction and strip efficiencies of ~90% or better.

2.6 SOLVENT EXTRACTION PROCESS EQUIPMENT DEVELOPMENT

R. H. Chapman

This activity continues the development and evaluation of prototype solvent extraction contactors. Objectives for FY 1986 are to procure mechanical drives for the 5.5-cm-diam centrifugal contactors fabricated at Savannah River Laboratory (SRL); design, fabricate, and test new prototype rotors; complete modifications to SRL contactors now in progress; complete installation of the contactor reliability test stand; complete modifications and installation of a spare IET contactor to investigate a surge-overflow concept; and provide assistance to IET operations, as required.

2.6.1 Prototype Contactors

L. D. Ladd

As discussed previously, performance testing of the prototype 5.5-cm-diam centrifugal contactors revealed excessive vibrations. The problems are being corrected.

Extensive modifications were completed to upgrade the two-, four-, and eight-stage modules sufficiently to operate at design conditions. Hydraulic testing of the various modules over the full range of operating conditions is under way. Preliminary results indicate acceptable performance by all three modules.

The drive motors supplied with the contactors are not acceptable for long-term applications, but they will be adequate until replacement drives can be procured. Specifications for new drives, which will be smaller versions of the high-quality milling machine spindles now in use on the 12-cm-diam IET centrifugal contactors, were completed, and procurement of prototype drives was initiated. Five motorized and five nonmotorized spindles (the latter will be driven with separate motors) will be procured for evaluation.

Design of an improved prototype rotor was completed. The design includes a number of simplifications and is based on fabrication procedures that will result in a well-aligned and balanced rotor. Two prototype rotors will be fabricated and tested to verify the design concepts.

2.6.2 Contactor Reliability Testing

J. F. Birdwell, L. D. Ladd, and S. P. Singh

Modifications are in progress on the test facility that will be used for long-term testing of the prototype 5.5-cm-diam centrifugal contactors provided by SRL. The modifications will include installation of the two-, four-, and eight-stage modules of 5.5-cm-diam centrifugal contactors and integration of the contactors into the IET process system to permit operation of a complete solvent extraction system on a flowsheet representative of a small-scale reprocessing plant. The test facility is being extensively automated to permit unattended operation. Integrated operation of the test facility is scheduled to begin in the first quarter of FY 1987.

2.6.3 IET Solvent Extraction System

S. P. Singh and J. F. Birdwell

A surveillance program was initiated to monitor the vibration level of the drive units of the IET 12-cm-diam centrifugal contactors to determine if incipient bearing failures could be detected. Based on additional data acquired during this report period, the drives on the 8-2 bank of contactors are now expected to operate at least 14,000 h without failure of the bearings. The 8-1 bank is expected to have an operating life in excess of 4,000 h.

The 8-2 drive spindle that failed last fall has been rebuilt at the factory and returned. It is now available as a spare if needed for either eight-stage bank of contactors.

Nosepiece protector devices, identical to those in the 8-1 contactors, were installed in the 8-2 bank of contactors to improve the effectiveness of the purge air system for protection of the bearings. These devices are considered a major improvement in the bearing-protection system.

When the motor/rotor assembly was removed from the stage 7 position for installation of the nosepiece, a significant quantity of crystallized uranium was found on the splash plate. This was the first time such a deposit has been observed, and its cause is unexplained at this time. This is the same position in the contactor bank (but with a different motor/rotor assembly) that suffered the bearing failure discussed previously.

Several stages of the contactors were inspected as a follow-up to the integrated campaign that was conducted in April. No deposition of uranium was found in stage 7, but a small amount was found in stage 3.

2.7 HOT-CELL STUDIES

D. O. Campbell, J. C. Mailen, and G. C. Young

Limited fuel dissolution and dissolver residue characterization studies are being performed in the hot cell using FFTF fuel of 90,000-MWd/metric-ton peak burnup.

Leaching studies using the hulls from a dissolution study of sheared high-burnup FFTF fuel have been completed. The fuel dissolution used 8 *M* HNO_3 at ~95°C for 1 h; the temperature was then raised to ~99°C for an additional 4 h. The hulls were separated from the dissolver solution and rinsed to remove residue. They were subsequently leached in sequence with 8 *M* HNO_3 at 100°C for 5 h, with 8 *M* HNO_3-0.1-*M* F^- for 5 h at ~60°C, and with 4 *M* HCl for 5 h at 100°C. Table 1 gives the fractions of the initial fuel contents of various elements and isotopes found associated with the cladding.

Table 1. Fractions of elements and isotopes associated with cladding

Element or isotope	Fraction with cladding
U	0.0007
Pu	0.0003
^{106}Ru	0.037[a]
^{134}Cs	0.018
^{137}Cs	0.0002
^{144}Ce	0.007
^{125}Sb	0.006

[a]Estimated from ORIGEN2 value for ^{106}Ru content.

In general, only small fractions of the elements were associated with the cladding; the exceptions are ruthenium and ^{134}Cs. The amount of ^{106}Ru associated with the cladding was significantly greater than ~1.25% dissolved during the fuel dissolution in nitric acid. However, an earlier estimate that up to ~50% of the ruthenium was associated with the cladding was in error. The data for ^{134}Cs are in doubt because of the low amount of ^{137}Cs found with the cladding. Table 2 gives the fraction of the measured contents (elements, isotopes, total weight, or gamma count) associated with the cladding that were dissolved by the various leaches.

Table 2. Quantities dissolved by leaching

Measured	Fraction of cladding recovered by leaches			
	HNO_3	HNO_3-HF	HCl	Remaining
U	0.43	0.57		
Pu	0.89	0.08	0.03	
^{106}Ru	0.25	0.10	0.01	0.63
^{134}Cs	0.65	0.35		
^{137}Cs			0.33	0.67
^{144}Ce	0.84	0.16		
^{125}Sb				1.0
^{60}Co	0.007	0.10	0.89	0.003
^{54}Mn				1.0
Total weight	0.016	0.068	0.914	0.0016
Gamma[a]	0.45	0.10	0.20	0.25

[a]Gamma count on in-cell monitor.

It is noteworthy that little of the ^{106}Ru was soluble in any of the leach solutions. The large fractions of ^{137}Cs (compared with ^{134}Cs), ^{125}Sb, and ^{54}Mn apparently found in the residue may be due to counting inaccuracies resulting from the predominance of ^{106}Ru in the residue.

A new dissolution study of fuel with a burnup of 90,000 MWd/metric ton has begun. The fuel, with the cladding, was first dissolved in 7.3 *M* HNO_3. The residue and cladding were then separated and are being treated in separate series of secondary leaches. The results available to date are given in Table 3. The quantity of residue recovered is somewhat higher than was recovered in tests last year with similar fuel. The residue and cladding are currently being leached with 6 *M* HNO_3 at 112°C and will then be leached with HNO_3-HF solution.

Table 3. Preliminary results of fuel dissolution test

Treatment	Residue			Cladding
	Residue weight (g)	Solution relative count	Percent of initial fuel	Solution relative count
7.3 *M* HNO_3[a]	0.614	375[b]	2.0	
6 *M* HNO_3[c]	0.421	15[b]	1.37	1.0[b]

[a]2 h at 95°C plus 4 h at 100°C.

[b]Counted on the in-cell monitor.

[c]Residue leached for 6.5 h at 100°C. Cladding leached for 5 h at 100°C.

2.8 ANALYTICAL CHEMISTRY DEVELOPMENT

D. A. Costanzo

2.8.1 X-ray Fluorescence (XRF) Development

J. M. Keller

The development of XRF as an analytical technique applicable to fuel reprocessing facilities was continued after a two-month delay from activity on this project. An apparatus to support and align the x-ray tube was redesigned and fabricated. An optical bench with horizontal and vertical position control was designed and fabricated. The optical bench and x-ray tube support were mounted on a table to permit alignment of the sample and spectrometer. Current work involves the design and fabrication of a lead containment box for the sample and x-ray tube. Upon completion of the shielding, the spectrometer will be realigned and tested with a new x-ray tube.

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 combined process equipment system, remote handling equipment, and the remote operation capabilities and characteristics of these components and systems will be tested in the IET facility as well as the Maintenance Systems Test Area (MSTA). The efforts of Engineering Systems are concentrated into three tasks (disassembly and cutting systems, special remote systems, and remote control engineering) and the Program Office for Remote Technology.

3.1 DISASSEMBLY AND CUTTING

J. H. Evans

The disassembly and fuel-cutting task, which is responsible for the mechanical preparation of the fuel for the downstream processing, is developing equipment that will remove the undesired components (such as inlet and outlet nozzles) from a fuel assembly and cut (shear) 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 remote operation and maintenance of a prototype system. A prototype mechanical head-end system consisting of a laser-disassembly system, a shear system, and an overall control system was installed in the ROMD area of Building 7603.

3.1.1 IET/ROMD Disassembly, Shear, and Control Systems

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

The remote shear system (RSS) and the feed station of the remote disassembly system (RDS) were used during the April IET integrated run to shear depleted uranium subassemblies. After seven assemblies were completed, shearing was suspended because of a failure of the feed pusher motor and a hydraulic leak in the in-cell shear actuator. Except for these two problems, the RSS and the control system operated well. After the equipment was decontaminated, tests and measurements were made to determine the causes of the problems. The minor equipment redesign to correct the problem has been completed, and fabrication and procurement of necessary components is well under way.

3.2 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 the CFRP are being developed by this task group. During this fiscal year, these components include remotely operable pipe and electrical connectors, prototype equipment racks and support structure, and a cell transporter to give mobility to the servomanipulators. In addition, the MSTA, Building 7603, has been prepared for testing components of the maintenance system.

3.2.1 Remote Connectors and Jumpers

Several improvements to pipe connectors and jumpers, including tools to handle and operate the connectors, are being developed under this subtask. 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.

In previous periods, handling tests were performed in the ROMD on a variety of commercially available tubing and electrical connectors and fittings using the M-2 servomanipulators. Also during previous periods, the design of a Manipulator Test–Test Stand, which contains a variety of small but common reprocessing equipment items, was completed. The development of this stand is a cooperative effort between the ORNL CFRP and the PNC of Japan. Two stands are being fabricated, one here and one in Japan, and each stand will contain identical U.S. and Japanese equipment items. The stands will be used to compare the performance of various advanced manipulator systems being developed in the United States and Japan. During this period, the fabrication of the stand was completed, and equipment items to be supplied to Japan were packaged and made ready for shipment. The test program will be initiated during the next quarterly period.

3.2.2 Cell Transporter

The transporter supports and provides mobility to the in-cell servomanipulators and consists of a bridge, a trolley mounted on the bridge, and an externally telescoping rigid mast mounted on the trolley. The advanced servomanipulator package is then attached to the lower end of the rigid mast assembly.

During the previous period, the transporter was installed in Building 7603, acceptance testing was performed, and several problems were identified. During this period, all problems were corrected, and the system became fully operational. In addition, resolvers for the bridge and trolley and side-guide rollers for the trolley were placed on order with delivery scheduled during the next quarterly period. The resolvers, in particular, are required to smooth out the bridge operation at low speed and to provide a signal for integration into the Advanced Integrated Maintenance System (AIMS) control system.

3.2.3 Equipment Racks/MSTA

In previous periods, equipment racks (support structures containing remotely maintainable process equipment) were designed, fabricated, and installed in the MSTA. The area was also modified to locate the racks in the proper orientation to the maintenance equipment. Tie-in of the rack's piping system to the simulated penetration plugs was completed.

3.3 REMOTE CONTROL ENGINEERING

J. N. Herndon

3.3.1 Manipulator and Maintenance System Development

J. C. Rowe, D. P. Kuban, E. C. Bradley, C. T. Kring, M. W. Noakes, S. D. Zimmerman, R. F. Spille, R. C. Muller, and S. M. Killough

The purpose of this effort is the design, fabrication, and operation of 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 prototype demonstration of the maintenance concepts that the FRD will use for future demonstrations for remote-handling applications. Key features to be demonstrated in AIMS include: (1) modular remote maintainability of manipulator slave arms; (2) improved operational flexibility through modern digital control techniques; (3) servocontrol for overhead transporter systems; (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 (achieved by menu-driven, programmable displays and controls).

The ASM slave arms and master controllers are now operational in force-reflecting mode. Initial testing indicates that the very low friction and backlash goals for the master controllers were met or exceeded in all joints. The performance of the master controllers is very good.

A formal effort in commercialization of the ASM system began during the last quarter.

The interface package system was installed in the AIMS area during the last quarter. This hardware, incorporating azimuth drive, three cameras mounted on positioners, and an extending auxiliary hoist, were brought into operation in the open-loop control mode during this quarter. Closed-loop control will be implemented during the next quarter. Control of transporter-mounted cameras is also operational, and computer control of the transporter will be implemented in the next quarter after installation of resolvers on the bridge motion.

Development of software for the Operator Control Station continued during this quarter. The pendant controller, used for analog input to the control system, consists of a small, hand-held housing with a 3-degree-of-freedom joystick, two rotary pots, keypad, and display. The pendant controller is configured to allow selective control of the transporter, cameras, crane, and interface package hardware. The first pendant controller was fabricated during the previous quarter and is now operational. Menu software and graphics display software development continues.

The current emphasis in special electronics development is on board-level design, component procurement, fabrication, and bench testing of the full ten-channel microwave system for wireless signal transmission in the AIMS. The major electronic components are on order, and portions of the system, such as the digital demodulators, have been fabricated. The final prototype system will incorporate five video, three digital data at 10^6 baud, and two audio channels on a 10-GHz microwave link.

3.3.2 Studies and Evaluations

J. V. Draper (Clarke Ambrose, Incorporated),
B. S. Weil, and W. E. Moore

The experimental section of the force/nonforce experiment using the M-2 servomanipulators in ROMD was completed during last quarter. The purpose of this testing program is to investigate the relative performance of manipulator operators with varying levels of force reflection while performing realistic remote-handling tasks. Analysis of the data will be completed by the end of July.

Final reports of the Manipulator Comparative Testing Program and High-Definition Television Testing, performed in cooperation with PNC, were completed during this quarter and transmitted to PNC.

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 startup, performance of tests in the facility, and overall facility maintenance. The facility provides a capability for conducting chemical processing and remote equipment demonstrations. The objectives are to provide for the synergistic testing of process equipment and flowsheets prototypic of a pilot-scale fuel reprocessing plant and testing advanced remote handling equipment and techniques. The IET facility consists of two distinct areas: ROMD and IPD. The ROMD area activities focus on testing advanced remote handling equipment and techniques and demonstrating remote maintenance concepts on advanced prototypical reprocessing equipment. The IPD addresses the issues of process operations in the predominantly chemical processing portion of the fuel reprocessing plant.

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 and remote-handling experiments, preparation of procedures, and data storage.

4.1.1 IPD Operations

J. E. Dunn, J. C. Suddath, and P. Welesko

The IPD operations focus on the testing and operation of processes and equipment prototypic of those intended for deployment in an advanced fuel reprocessing facility. An experimental campaign was completed during a 5-d run featuring continuous operations. The campaign demonstrated integrated operation of the remote shear, rotary dissolver, and solvent extraction systems at a uranium throughput of 500 kg/d and satisfied an important milestone. Highlights of the run included the shearing of seven depleted UO_2 simulated fuel bundles, support for a safeguards workshop, and automated concentration adjustment of the dissolver solution to solvent extraction feed conditions.

An effort to automate the steady-state operations of a major portion of the IPD process steps was initiated. The aim of this work was to demonstrate the concept and develop the techniques for similar applications in a full-scale plant. The solvent extraction system (5.5-cm-diam contactors), uranium feed accountability and adjustment systems, uranium product concentration and accountability systems, and high-activity waste (HAW) collection and transfer system will be automated. The various software and documentation packages required for this work have been identified, and the detailed requirements for two of the packages have been established.

4.1.2 ROMD Operations

T. W. Burgess

The ROMD operations focus on testing remote handling equipment and techniques and demonstrating remote maintenance concepts on advanced reprocessing equipment. Primary work efforts concentrated on preparations for the remote shear system remote maintenance demonstration. The in-cell portion of the shear system will be completely disassembled and reassembled using the model M-2 servomanipulator and gantry bridge hoists for verification of the system's remote-maintenance design features and establishment of maintenance times. The shear system internals were decontaminated upon completion of shearing operations in the April process campaign. Disassembly and reassembly of the system were performed using remote tools locally operated for development of remote-handling procedures and preliminary checkout of special maintenance fixtures and tools. Based on the results of this exercise, minor system hardware modifications were made, and various test documents were prepared. Remote maintenance operations were initiated at the end of the quarter and will continue through the fourth quarter.

4.2 IET ENGINEERING

W. W. Evans

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 at the CFRP site.

4.2.1 Facility Engineering Support

W. W. Evans and E. L. Nicholson

The main emphasis in the early part of the quarter was placed on preparing for and assisting in the IET campaign.

Design work was started on the modifications required to incorporate a test stand rack with 14 stages of 5.5-cm centrifugal contactors into the IET process system. The design included arrangements to operate the contactors in an automated and a continuous mode with the option of switching back to the 12-cm contactors with a minimum of piping, electrical, and instrument changes. The waterwheel will be used as the feed metering device to the small contactors. Some process piping changes have already been initiated to incorporate the rack equipment in the IET process systems.

4.2.2 Environmental Test Chamber (ETC)

B. B. Spencer

Acceptance testing of the ETC was initiated. Several minor deficiencies were found, and corrected.

Tie-in of the ETC to the DDACS was completed. This work involved terminating the sensor and control cables in the process control module. Most of the control software has been written, but it has not been tested.

Checkout of the oxygen alarm system was completed. The three gas analyzers procured by Martin Marietta Energy Systems, Inc., were installed. The mass flow meters and rotameters have been calibrated. Calibration of other equipment is under way.

A new effort has been initiated to build a data base correlating conductivity and density of aqueous nitric acid-uranium solutions. This supports automation of plant operation, permitting acid and uranium concentrations to be calculated from remote field measurements of density, temperatures, and conductivity. The ORNL Analytical Chemistry Division is performing the laboratory work, and IET personnel will analyze the data. Approximately 25% of the laboratory work has been completed.

4.3 INSTRUMENTATION AND CONTROLS (I&C) SUPPORT TO IET

J. A. Hawk, M. S. Hileman, R. E. Hutchens, R. M. Tate, and R. G. Upton

4.3.1 DDACS

Checkout of the DDACS/ETC interface was essentially completed. A number of wiring problems were found and corrected. New input/output hardware was installed in DDACS to support the ETC, and documentation of the required modifications was completed. The disk drive for the unused Electron Modules Corporation (EMC) archival program was reassigned for use in automation software development.

Preparation of the data bases for the ETC is 95% complete.

4.3.2 IET Process Equipment Instrumentation

Instrumentation for the contactor test stand upgrade has been ordered. This includes the hardware for the interface between the test stand and the International Business Machines (IBM) personal computer used to archive data and monitor the centrifugal contactors and the interface between the test stand and DDACS.

4.4 IET PLANNING

J. H. Shaffer

The IET planning activity coordinates requests from various R&D groups within the CFRP for experimental tests and demonstrations to be completed within the IET facility operations.

The IET schedule for the last half of FY 1986 is based on the completion of two primary objectives. The demonstration of remote maintenance capabilities of the remote shear system will continue through the balance of the fiscal year. Preliminary tests of remote-maintenance lifting fixtures assembled for this demonstration were conducted during contact maintenance operations required for the decontamination of the shear following the April IPD campaign. The second program objectives provides for the installation of the 5.5-cm centrifugal contactors in the IPD solvent extraction system. A demonstration of performance characteristics of these contactors has been scheduled for September.

The experimental program for operation of the Iodox system and supporting operation of the acid concentration system has been deferred until FY 1987. Current plans support a joint experimental program by the ORNL Analytical Chemistry Division and the CFRP safeguards task to demonstrate an analytical procedure for the accurate determination of solution volumes contained in large tanks.

5 Strategic Planning and Analysis

J. G. STRADLEY

Efforts described in this section provide a focal point for the foreign exchange activities and support in specialized technical areas.

5.1 FOREIGN EXCHANGE AGREEMENTS

The CFRP has active agreements with the Commissariat à l' Energie Atomique (CEA) of France, PNC of Japan, and the United Kingdom Atomic Energy Authority (UKAEA).

5.1.1 U.S./CEA Exchange

This exchange focuses on the area of Remote Systems Technology. A technical specialists meeting was held in the United States in May 1986.

5.1.2. U.S./PNC Exchange

In the Remote Systems Technology area of the exchange, (see Sects. 3.2 and 3.3), review comments were incorporated into the report describing the testing by the CFRP of the PNC high-definition television system. The CFRP manipulator test—test stand was completed. An identical stand is being built in each country for use in establishing the performance of various manipulators. Preparations are under way for a Remote Systems Technology specialists meeting to be held this fall at ORNL.

In the Joint Criticality Data Development area, nine critical experiments were performed at the PNL CML during the quarter, bringing the total performed to 37 of the 77 planned by the program. The SMS was transported to the CML, and the planned experiments with annular and slab geometries were successfully completed. Six PNC staff members observed the slab experiments. One of the six has been assigned to ORNL to help with data analysis and to develop an understanding of the SMS theory. Preparations are under way for an SMS specialists meeting to be held this fall at ORNL.

5.1.3 U.S./UKAEA Exchange

The U.S. fiber-optic spectrophotometry equipment was received by the UKAEA for testing. Testing and operational data will be collected through a jointly developed experimental plan.

Agenda topics were developed for a joint control and instrumentation symposium involving technical specialists from each country. It will be held July 29–31, 1986, at Harwell, England.

5.2 SAFEGUARDS ASSESSMENTS

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

The objective of this task is to assess the availability of appropriate safeguards technology for reprocessing plant application and the safeguards implication of reprocessing plant design and operational features.

The current focus is on the development of advanced safeguards concepts for for monitoring plant operations. A process-monitoring demonstration and workshop was held in conjunction with the April 1986 integrated run of the IET. Several unannounced removals, planned by a group of outside participants and made by IET operations staff, were identified by the safeguards assessment task staff. The successful results clearly demonstrated the sensitivity of current process-monitoring software. The workshop gave the attendees an opportunity to discuss technical issues associated with process monitoring and to identify areas for future work.

The assessment to identify a process-monitoring concept that is feasible within the technical and institutional bounds of international reprocessing plant safeguards continues.

Abbreviations

AIMS	Advanced Integrated Maintenance System
ASM	advanced servomanipulator
BRET	Breeder Reprocessing Engineering Test
CEA	Commissariat à l' Energie Atomique
CFRP	Consolidated Fuel Reprocessing Program
CML	Critical Mass Laboratory
DDACS	Distributed Data Acquisition and Control System
DF	decontamination factor
DOE	U.S. Department of Energy
DOG	dissolver off-gas
EMC	Electronic Modules Corporation
ETC	Environmental Test Chamber
FBR	fast breeder reactor
FFTF	Fast-Flux Test Facility
FRD	Fuel Recycle Division
FY	fiscal year
HAW	high-activity waste
HEDL	Hanford Engineering Development Laboratory
IBM	International Business Machines
I&C	Instrumentation and Controls
IET	Integrated Equipment Test
IPD	Integrated Process Development
METR	man-equivalent telerobot
MOX	mixed oxide

MSTA	Maintenance System Test Area
NASA	National Aeronautics and Space Agency
ORNL	Oak Ridge National Laboratory
PNC	Power Reactor and Nuclear Fuel Development Corporation
PNL	Pacific Northwest Laboratory
R&D	research and development
RDS	Remote Disassembly System
ROMD	Remote Operation and Maintenance Demonstration
RSS	Remote Shear System
SETF	Solvent Extraction Test Facility
SMS	Subcriticality Measurement System
SRL	Savannah River Laboratory
TBP	tributyl phosphate
U.K.	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
WINCO	Westinghouse Idaho Nuclear Company
XRF	X-ray fluorescence

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