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LABORATORY

**Consolidated Fuel
Reprocessing Program
Progress Report for Period
April 1 to June 30, 1983**

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CONSOLIDATED FUEL REPROCESSING PROGRAM PROGRESS REPORT FOR PERIOD APRIL 1 TO JUNE 30, 1983

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ORNL/TM--8817

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OAK RIDGE NATIONAL LABORATORY
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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 the Savannah River Laboratory and GA Technologies, Inc., where reprocessing research and development on the HTGR fuel cycle is done.

The coverage is generally overview in nature. Experimental details and data have been limited (1) to make the report more concise and (2) to 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 fuel reprocessing in the United States is managed under the Consolidated Fuel Reprocessing Program centered at Oak Ridge National Laboratory. Technical progress is reported in overview fashion in this series of quarterly progress reports.

1.1 BRET PROJECT

S. A. Meacham

Conceptual studies for the proposed Breeder Reprocessing Engineering Test (BRET) have continued. The prime objectives are to close the fuel cycles of the Fast-Flux Test Facility and the Clinch River Breeder Reactor and provide a facility in which advanced technology under development in the CFRP would be demonstrated under hot operating conditions.

Studies to date have confirmed the feasibility of modifying an existing DOE facility at Hanford, Washington, the Fuels and Materials Examination Facility. Flowsheets and equipment options are being examined in an effort to further define a project. The studies are being done in cooperation with the Hanford Engineering Development Laboratory.

1.2 PROCESS AND ENGINEERING R&D

W. S. Groenier

The initial results of a study to measure the extent of plutonium polymerization during steam-jet transfers

of nitric acid solutions containing Pu(IV) indicated polymer would appear only after several successive transfers at temperatures of 75°C or higher.

Tests of a three-stage solvent washing system exhibited complete removal of dibutylphosphoric acid (HDBP) and uranium dibutyl phosphate (DBP) complex, >97% removal of lauric acid, and 98% removal of zirconium-DBP complex using 0.25 *M* Na₂CO₃–0.02 *M* sodium tartrate followed by a single-stage water wash.

A general computer program for calculating apparent molar volumes in a two-component system from concentration and density data was developed. The program was used to analyze data for the tributyl phosphate-dodecane system.

Fast-Flux Test Facility (FFTF) fuel was processed for the first time in the Solvent Extraction Test Facility (SETF). The codecontamination and partitioning cycles of the Breeder Reprocessing Engineering Test (BRET) reference flowsheet were successfully demonstrated using hydroxylamine nitrate (HAN) reductant. Partitioning failure occurred in a run using the conventional Purex partitioning method and HAN reductant without

hydrazine. In a second run with a higher HAN concentration, results were good but the system may not have reached steady-state operation.

A steam-jet eductor, designed for emptying dissolver digester tanks, is also effective in removing solid particles from <80 to $1190\text{ }\mu\text{m}$ in size.

Based on a brief study, the use of solid sorbents (such as silver-substituted mordenites) for iodine removal from aqueous solutions is not recommended.

Studies of krypton release from pulverized sputter-deposited Ni-Y-Kr matrices have shown that the release rate is inversely proportional to the particle radius at 200°C . This correlation will be used to estimate the krypton release from deposits of various thicknesses. Other tests have shown a loss of 300 to $600\text{ }\mu\text{Ci}$ of ^{85}Kr from an 11 Ci Ni-La-Kr deposit after 10 months storage in air.

A total of 21 runs have been completed in the continuous gel-sphere (uranium only) preparation line. A recent run demonstrated continuous operation of the entire line for a period of 8 h.

Preparation of the initial 500-g batch of mixed oxide gel-spheres in Bldg. 3019 was completed, and the product was shipped to Hanford in May. Operation of the gel-sphere line was generally satisfactory.

Fabrication processing at HEDL of mixed oxide gel-spheres (DIPRES process) was initiated. The spheres were calcined and pressed into pellets. Test pellet density uniformity was good and met reference FFTF fuel pellet specifications.

1.3 ENGINEERING SYSTEMS

M. J. Feldman

Achievements during this period include the following:

1. Operational testing of both 8-packs of the centrifugal contactor has been completed at SRL, and they have been shipped to ORNL for installation in the Integrated Equipment Test facility. Testing at Savannah River Laboratory included extraction and stripping of uranium solutions.

2. The Central Research Laboratories M-2 electronic servomanipulators (formerly referred to as industry-standard manipulators) have been installed and are in

operation in the ROMD area at ORNL. The manipulators were used to disassemble, then reassemble one of the 8-packs of the centrifugal contactors. This is the first demonstration of use of electronic servomanipulators in conjunction with maintenance of prototype reprocessing equipment.

3. Fabrication of both the prototypical disassembly system and the prototypical shear system has been initiated.

4. Functional and reliability testing of the remote sampling system has been continued, and an endurance test has been started.

1.4 INTEGRATED EQUIPMENT TEST (IET) FACILITY OPERATIONS

O. O. Yarbrow

Three line-item contractors and Oak Ridge National Laboratory (ORNL) field forces were active in the IET facility working on the solvent extraction system, the dissolution system, additional small-scale support line-item projects, and facility related modifications during the quarter.

Planning for FY-1984 installation and modification work in the IET facility was completed. Planning for building modifications to raise the roof over the test area south of the IET facility to provide a Breeder Reprocessing Equipment Test (BRET) area is progressing on schedule.

The acceptance tests of the original Integrated Process Demonstration (IPD) system have been completed. During these tests, the functional performance of components and equipment was verified, proper interfacing of process instrumentation sensors with the distributed digital control system was checked, and satisfactory initial operation of the key subsystem was confirmed.

1.5 INSTRUMENTATION AND CONTROLS

B. G. Eads

The experimental instrumentation and controls work with the prototype multiwavelength uranium photometer was successful and has been expanded to continuously and simultaneously monitor three process

streams (raffinate, aqueous feed, and organic strip) in the secondary extraction cycle. Also, the preliminary instrument requirements for spent fuel and leached hulls assay systems were established.

1.6 HTGR FUEL REPROCESSING

W. S. Groenier

The failed section of the 20-cm burner has been replaced, and two successful shakedown runs have been completed.

Irradiated fuel rods from a Fort St. Vrain (FSV) Segment 2 fuel element were packaged and shipped to Germany for tests in the Joint Hot Fuel Processing Demonstration (JHPD).

The CO/HT oxidizer tests have shown that a catalyst dilution technique was successful for limiting

catalyst temperatures. Using this technique, inlet concentrations of 15% CO were reduced to less than 100 ppm in the outlet.

The High Temperature Gas-Cooled Reactor (HTGR) Spent Fuel Treatment Development Program Plan has been issued. A draft topical report describing a cost estimate for an away-from-reactor storage facility for whole HTGR spent fuel elements has also been completed.

1.7. STRATEGIC PLANNING AND ANALYSIS

J. G. Stradley

Major efforts of the environmental, safeguards, and waste management areas, and part of the nuclear engineering efforts, were directed toward providing data for the Breeder Reprocessing Engineering Test (BRET).

2 BREEDER REPROCESSING ENGINEERING TEST PROJECT

S. A. MEACHAM

At the request of the Department of Energy, conceptual studies for another option for a breeder fuel cycle project were initiated. The proposed project has been termed the Breeder Reprocessing Engineering Test (BRET). The prime objectives are to close the fuel cycles of the Fast-Flux Test Facility and the Clinch River Breeder Reactor and provide a facility in which advanced technology under development in the CFRP would be demonstrated under hot operating conditions. Studies to date have confirmed the feasibility of modifying an existing DOE facility at Hanford, Washington, the Fuels and Materials Examination Facility. Flowsheets and equipment options are being examined in an effort to further define a project. The studies are being done in cooperation with the Hanford Engineering Development Laboratory.

2.1 PRECONCEPTUAL DESIGN STUDIES

O. O. Yarbrow

A quarterly review of the project was conducted at HEDL on April 12, and presentations to the Industrial Review Committee (IRC) were made on April 13. There is general agreement by the DOE and the IRC with the BRET concepts and with the objectives of the project. The top level objectives, functions, and requirements of the project have been prepared by DOE-Headquarters.

The project level 1 schedule was signed by project management and submitted to DOE/RL for review and approval. In compliance with this schedule, a Construction Project Data Sheet was prepared and

submitted to the DOE for inclusion in the budget preparation process. In addition, the architect-engineer selection committee completed its activities, and recommendations have been made to the DOE. The actual selection by the DOE is still pending.

The project Work Breakdown Structure, prepared as a joint effort between ORNL and HEDL personnel, has been used as the control document in assigning project responsibility and for preparing input to the preconceptual design report and cost estimate. Several documents for control of the project conceptual activity have been prepared by HEDL and reviewed by ORNL. These documents include the Project Management Plan, BRET Project Control Manual, and the Quality Assurance Plan.

3 PROCESS AND ENGINEERING R&D

W. S. GROENIER

The primary role of the Process and Engineering R&D group is to identify improved processes and components, develop these concepts on a laboratory and/or bench-engineering scale, and provide process parameters and equipment criteria. These activities include basic studies on proposed processing steps and new process alternatives, demonstration tests in contained hot-cell or glove box facilities, and the first phase of the equipment development program. Important demonstration missions in FY 1983 are to reprocess Fast-Flux Test Facility (FFTF) fuel samples in the SETF and prepare mixed oxide (MOX) gel spheres in the Interim MOX Facility.

Recent chemistry efforts in laboratory and hot-cell studies in the SETF and in the development of analytical chemistry techniques are described below under Chemical Process Characterization. Progress in engineering activities is reported under Unit Process Development and Analysis and includes the development of off-gas fixation steps at the Pacific Northwest Laboratory (PNL), formerly in the Airborne Waste Management Program. Progress in the Conversion Process Development task is reported separately and includes laboratory and engineering activities that occur at the Oak Ridge National Laboratory (ORNL) and through cooperative agreements with the Hanford Engineering Development Laboratory (HEDL), PNL, and Exxon. Flowsheet and conceptual design studies for demonstration reprocessing facilities, described under Verification Testing and Analysis, include efforts at Argonne National Laboratory (ANL).

3.1 CHEMICAL PROCESS CHARACTERIZATION

J. H. Shaffer

Laboratory studies currently emphasize solution behavior in the dissolution and solvent extraction steps and include studies on plutonium chemistry,

solvent cleanup, and the extraction of fission products. Hot-cell studies examine the processing properties of a variety of irradiated fuel materials. Evaluations of solvent extraction flowsheet options occur in the SETF, which has an irradiated fuel capacity in the kilogram-per-day range. New analytical methods for

process control are being developed and adapted where possible for high-level gamma operations.

3.1.1 Laboratory Studies

J. T. Bell

Laboratory development activities have emphasized basic studies of plutonium chemistry and fission product behavior in aqueous process streams, and the development and evaluation of cleanup processes for degraded Purex organic solvents.

Objectives for FY 1983 include: (1) identification of parameters affecting Pu(IV) disproportionation, (2) completion of a kinetics model for Pu(IV) hydrous polymer formation, (3) completion of studies that comprehensively describe technetium behavior in Purex solvent extractions through modeling of published and new experimental data, (4) evaluation of hydrazine for reduction and possible separation of pertechnetate from uranium, (5) solvent cleanup tests in mixer settlers with sodium carbonate and hydroxylamine salt washing reagents, and (6) definition of a recommended solvent cleanup system for use in the Breeder Reprocessing Engineering Test (BRET).

Plutonium Polymerization

L. M. Toth and M. M. Osborne

A small steam-jet transfer system was fabricated for plutonium polymerization studies. Steam is supplied from a stainless steel boiler connected through a ball valve to a glass jet-syphon nozzle. Small (25-mL) samples of plutonium solution can be transferred through the jet-syphon system into another container in 2 to 4 s and with 3 to 4% dilution. Experiments have been conducted using 1 and 3 M HNO₃ solutions containing ~0.3 M Pu(IV) that had been previously heated to 60, 75, or 85°C. Multiple transfers were made on the same solution (heated to these different temperatures) to test when polymer would appear. Tentative results showed that polymer appeared only after several transfers were made on a solution at temperatures of 75°C or higher.

Solvent Cleanup

O. K. Tallent, J. C. Mailen, and C. T. Thompson

The proposed solvent cleanup system for the BRET consists of two stages of sodium carbonate-sodium tartrate scrubbing followed by a water scrub. A system with three mixer-settlers in series has been assembled to study continuous solvent washing and to test proposed solvent cleanup systems. The main series of tests during this quarter examined the removal of dibutylphosphoric acid (HDBP), lauric acid, uranium-DBP complex, and zirconium-DBP complex by passage through two 0.25 M Na₂CO₃—0.02 M sodium tartrate scrubbers and one water scrubber. Residence times in the mixers and settlers were 2 and 2.5 min respectively. The HDBP and the uranium-DBP complex were completely removed by the treatment, and the lauric acid was >97% removed. The removal of zirconium-DBP complex was 98%, but small amounts of interfacial crud formed in each settler; the interfacial crud did not interfere significantly with phase separation. However, during several of the tests with uranium-DBP complex, the phase separation performance of the system was degrading, apparently caused by some impurity in the uranium stock solution. Derivative gas chromatography of the solvent indicated an impurity which had the same appearance time as lauric acid.

Solvent Properties

D. J. Pruett and U. H. McIaggart

A general computer program was developed for calculating apparent molar volumes in a two-component system from concentration and density data. The program was used to analyze data for the tributyl phosphate (TBP)-dodecane system at 25, 40, and 60°C. As expected, the apparent molar volumes varied little from the partial molar volume in this nearly ideal system. However, there appeared to be some variation in the apparent molar volumes of TBP in dilute (<10 vol %) solutions. A more careful study of this region will be made, as deviation of the

solution from ideality could be significant in reprocessing flowsheets calling for the use of dilute solutions of TBP. The computer program is being expanded to analyze data from three- and four-component systems so the additional influence of water and nitric acid can be studied.

The solubility of water in 1 to 6 vol % TBP in *n*-dodecane (NDD) and normal paraffin hydrocarbon (NPH) diluents at 25°C has been determined using both tritium tracer and Karl-Fischer analyses to determine the water concentration. The agreement between the two techniques was excellent. The densities of these solutions were also determined and will be used to calculate the partial and apparent molar volumes of the system components. When the experiments were repeated at 40 and 60°C, the water solubilities determined by Karl-Fischer titration were substantially lower than those obtained using the tritium tracer. This discrepancy is under investigation.

Preliminary experiments were carried out to test the accuracy and precision of methods for determining densities, acid concentrations, and water concentrations in TBP-diluent mixtures that have been equilibrated with aqueous nitric acid solutions of various concentrations. Specifically, there was concern that the nitric acid might interfere with the Karl-Fischer determination of water, or that adjustments would have to be made in the two-phase titration method used to determine the concentration of acid in the organic phase. However, no major problems were identified, and the values obtained were in good agreement with estimates based on results previously reported in the literature. Experiments to determine the distribution of 0.01 to 8 M nitric acid into 1 to 60 vol % TBP in NDD or NPH at 25°C are now in progress.

Fission Product Studies

D. J. Pruett and D. R. McTaggart

The solutions and equipment needed to quantify the influence of Pu(IV) on the extraction of Tc(VII) by TBP were assembled. However, the experiments have again been postponed because of delays in

developing analytical techniques for this system. The time provided by this delay was used to prepare the pellet dissolution apparatus for experiments on mixed (U-Pu)O₂ fuel pellets that were produced at PNL from the product of various MOX gel-sphere runs made at ORNL. The system was successfully tested and is ready for operation.

3.1.2 Hot-Cell Studies

D. O. Campbell

The hot-cell studies provide specific tests that use irradiated fuel samples to evaluate various head-end reprocessing operations. Currently, an emphasis is placed on fuel solubility and insoluble residue characterization using newly developed hot-cell analytical capabilities. The design of process equipment and the development of operating procedures require definition of dissolution parameters for mixed oxide fuels, characterization of dissolver residues, and assessment of plutonium accountability methods.

Specific objectives for FY 1983 include: (1) measurement of chemical and physical properties of insoluble residues from dissolver solutions, (2) development of clarification requirements, and (3) examination of process manipulations to identify potential operational problems. This work will use mixed oxide fuel from the FFTF, experimental fuels prototypical of future breeder reactors, and extended burn-up, low-enriched, light-water reactor (LWR) fuels.

Solution Stability and Solids Characterization

**D. O. Campbell, J. C. Mailen, R. L. Fellows,
and P. C. Arwood**

The measurement of physical properties of dissolver residues (particle size and density) and process solutions (viscosity and density) has been emphasized to define parameters necessary for dissolver solution clarification. A new sedimentation apparatus which removes samples from known depths and at known times from an initially well-mixed suspension has been successfully tested using size-certified glass beads. This system will

be used for determining particle sizes of residues from the dissolution of FFTF fuels.

Hot-cell tests have examined the volatilization of ruthenium during dissolution of Experimental Breeder Reactor-II (EBR-II) fuel in 7 to 13 M HNO_3 , during sparging with air following dissolution and during the slow addition of hydrogen peroxide following sparging. Cerium (IV) was also added to several of the solutions in an attempt to evolve ruthenium; however, no evidence of volatilized ruthenium was detected. The large amount of Pu(IV) present in the solutions probably acted as an oxidation buffer to suppress oxidation and volatilization of the ruthenium.

The bulk of the FFTF fuel which was received at ORNL in March was sheared and delivered to the SETF and to the hot-cell test facilities. One hot-cell dissolution was completed (data analysis is in progress), and another has begun. The Oconee No. 1 LWR fuel and the high-Pu EBR-II fuels were received in April and have been sectioned. Construction has been completed on the necessary tools for the periodic receipt of FFTF fuel in the T3 carrier; this first shipment used loaned tools.

3.1.3 Solvent Extraction Test Facility

L. J. King and D. J. Crouse

The SETF is a contained mixer-settler facility designed to (1) demonstrate the suitability of conceptual flowsheets for the solvent extraction processing of irradiated LWR and breeder fuels (with emphasis on the latter) and (2) evaluate process control instruments and procedures. The tests provide information on uranium and plutonium recoveries, fission product decontamination, comparison of coprocessing options, and general operability of the system.

A specific objective for FY 1983 is to perform a major solvent extraction campaign using irradiated FFTF fuel for the first time.

SETF Campaign 7

D. E. Benker, J. E. Bigelow, W. D. Bond, E. W. Brown, E. B. Cagle, F. R. Chattin, F. G. Kitts, D. B. Owsley, R. G. Ross, R. C. Shipwash, R. G. Stacy, C. E. Waddell, A. V. Wilder, and K. Wilson

The feed for this campaign was FFTF fuel from the DEA-1 series that had been irradiated to ~ 0.26 TJ/kg (3000 MWd/t) and cooled for ~ 1 year. The fuel was divided about equally into two portions for the processing steps, which included (1) dissolution in nitric acid, (2) filtration and adjustment of the dissolver solution to the proper feed conditions for solvent extraction, (3) solvent extraction with total partitioning in the SETF mixer-settlers, (4) one cycle of nitrate anion exchange to purify the plutonium product, (5) Pu(III) oxalate precipitation, and (6) calcination of the plutonium oxalate to plutonium oxide. A total of 433 g of plutonium oxide was packaged for shipment to HEDL for fuel fabrication studies.

The FFTF fuel was dissolved by heating in 8 M HNO_3 at $\sim 95^\circ\text{C}$ for ~ 4 h. The dissolver solution was then clarified by filtration through a deep bed of diatomaceous earth, sparged with NO_x gas to ensure that the plutonium was in the tetravalent state, and adjusted with dilute HNO_3 to the desired acidity and heavy metal concentrations. The adjusted feed was reclarified as it was fed to the mixer-settlers by passing it through an in-line filter.

In the solvent extraction operations, a run was made to demonstrate both the codecontamination first cycle and the partitioning cycle of the present BRET reference flowsheet. The plutonium and uranium were coextracted and scrubbed in the A-bank of the mixer-settlers, costripped in the B-bank, and partitioned in the C-bank. Costripping was accomplished with dilute nitric acid containing HAN and hydrazine to reduce the plutonium during stripping. This solution flowed directly into the C-bank where the uranium was

selectively extracted, leaving Pu(III) in the aqueous effluent. A stream of nitric acid also was fed to the C-bank to provide the desired acid concentration.

The results from this run indicated good uranium-plutonium recovery and separation. The plutonium losses to the two waste solvent streams, B-bank and C-bank, were 0.001 and 0.006% respectively, and the final plutonium product solution contained ~ 9 g/L of plutonium and ~ 0.006 g/L of uranium. Although some reoxidation and reflux of plutonium did occur in the partitioning contactor, it seemed to stabilize at a low level early in the run.

In two other runs, partitioning was accomplished in the conventional Purex manner; that is, by reducing plutonium and back-extracting uranium in the stripping contactor of the first cycle. The metals were coextracted and scrubbed in the A-bank as before and partitioned in the B-bank. The C-bank, which normally would provide uranium stripping, was used only to scavenge any plutonium from the solvent before it went to waste.

In the first run, using a HAN:Pu mole ratio of ~ 2 (no hydrazine), there was obvious reoxidation and reflux of plutonium in the partitioning bank, and eventually significant amounts of plutonium followed the uranium stream.

For the purpose of further flowsheet investigation, a synthetic feed was prepared by adding sufficient depleted uranium to a plutonium product solution to make the plutonium about 20% of the total heavy metals, and then concentrating the solution by evaporation. A rerun of the flowsheet with the synthetic feed solution and a HAN:Pu ratio of ~ 2 verified the unsatisfactory plutonium stripping behavior reported above. The run was interrupted, the heavy metals were purged from the partitioning contactor, and the run was restarted using twice the addition rate of HAN reductant (HAN:Pu = ~ 4). At this reductant level, the remaining feed was processed with a low plutonium loss from the partitioning contactor ($\sim 0.009\%$). The final plutonium product stream contained ~ 30 g/L of plutonium and

~ 0.005 g/L of uranium. This run also exhibited some reoxidation and reflux of plutonium, but whether or not the reflux had stabilized before the end of the run is unclear. The readout of an alpha monitor in the plutonium product stream continued to increase slightly at the end of the run indicating a slightly increasing plutonium concentration.

3.1.4 Analytical Chemistry Development

D. A. Costanzo

The development of analytical methods and equipment supports various CFRP laboratory and engineering activities. Emphasis has been placed on chemical, nuclear, radiochemical, x-ray fluorescence (XRF), and mass spectrometry methods suitable for high burnup and highly radioactive fuel. The remotization and automation of analytical equipment and the identification of sampling requirements are being pursued for specific applications in the BRET.

Specific objectives for FY 1983 include (1) cold-testing and evaluation of the proof-of-principle XRF spectrometer using uranium and strontium (a stand-in for plutonium), (2) evaluation of the above XRF unit with a point source to determine feasibility for measurement on highly gamma-active samples, (3) completion of the development of a high-accuracy, high precision remote titration system applicable to the determination of uranium and plutonium in highly gamma-active samples, and (4) initiation of the development of a prototype hot-cell spectrophotometer.

X-ray Fluorescence (XRF) Systems Development

J. M. Keller

A report entitled *Evaluation of a Wavelength Dispersive X-Ray System for the Determination of Uranium and Plutonium in Highly Radioactive Solutions* has been published. In addition, the design of the XRF system is being considered for possible patent application.

A graphite barrel monochromator designed for 26 keV was employed during proof-of-principle testing

to focus 22.1 keV radiation which excites the uranium and plutonium fluorescence. To approach optimized performance of the XRF system, which permits verification of resolution and sensitivity calculations, a new graphite barrel designed for 22.1 keV is required. Funds have been approved for the purchase of optical grade graphite for a new barrel.

Hot-Cell Analytical Instrumentation Development

L. N. Klatt

Fabrication of the revised hardware for the remote titrator was completed; the terminal and plotter for the system were ordered; and designs of the in-cell transducer electronic systems and elevator control circuit were approved. Software modifications which resulted from the mock-up testing protocol were also completed. These included the addition of a variable time delay feature for the volume predictor algorithm and implementation of an alternate end-point locating algorithm. The variable delay feature should minimize problems caused by finite mixing and chemical reaction times. The modified volume predictor algorithm is designed to eliminate problems encountered when two endpoints are spaced closer than ~8% of the total buret volume. The alternate endpoint locating routine is required for titration curves with very small breaks. All mechanical and electronic drawings were updated to reflect the final design. A report describing the prototype titration system is ~30% complete.

3.2 UNIT PROCESS DEVELOPMENT AND ANALYSIS

W. S. Groenier

The dissolution activities currently emphasize development of equipment for the digestion of the primary dissolver product solution and studies to better understand operation of the rotary dissolver. An evaluation of solid sorbents for iodine retention in off-gas streams has recently been completed. Computer-aided analysis activities are improving existing codes

for solvent extraction and selective absorption processes, as well as extending their range of application. Off-gas fixation activities at PNL emphasize the development of an ion implantation process for krypton.

3.2.1 Dissolution Process Development

B. E. Lewis

The liquid product from the continuous rotary dissolver (primary dissolver) will contain particles of fuel and fission products that must be maintained in suspension during the continued dissolution in the digester tanks. Suspension of solids is necessary to (1) promote the necessary dissolvent contact required for additional dissolution, (2) provide for temperature control, and (3) further ensure nuclear criticality safety. The digester system, including the solids suspension and tank emptying (jet) devices, as well as system instrumentation, is being further developed in preparation for proof testing in the Integrated Equipment Test (IET) facility. A second activity addresses computer modeling of the entire dissolution process for the purpose of studying process startup, control algorithms, nuclear criticality parameters, and general design criteria.

The FY-1983 objectives for the digester tank model are to (1) perform tests of the steam jet eductor and (2) evaluate a modified instrument probe that is designed to minimize the effects of gas bubbles. The FY-1983 objective for the material balance computer model is to refine and upgrade the model to the point where it can be validated from experimental data and used for process sensitivity analyses.

Digester Tests

B. E. Lewis and D. R. Trotter

The digester tank test stand was modified to study the transfer efficiency of a steam-jet eductor system. Anticipated problems with the transfer of hull fragments and wires have been studied. Transfer efficiencies for various types of solids were measured. Tungsten

particles $<80\text{ }\mu\text{m}$ in diameter and stainless steel particles 74 to $1190\text{ }\mu\text{m}$ in diameter transferred with $>99.3\%$ efficiency. Larger material, such as simulated fuel pin spacer wires (2.54 cm long and $\sim 0.15\text{ cm}$ diam), transferred with efficiencies varying from 0 to 43.8%.

A potential plugging problem developed after repeated transfers of water containing $\sim 5\text{ g}$ of spacer wires. It was suspected that a few spacer wires temporarily blocked the flow of liquid through the throat of the jet, although no plug was found when the jet was disassembled. To ensure that no wires flow through the jet, and thus create a potential plugging problem, a screen with $\sim 1/16\text{-in.}$ openings was attached to the end of the suction line. The screen does not appear to interfere with liquid transfer from the tank, although large solids cannot be accommodated. The effect of the screen on solids suspension is presently being studied.

Concentration Profile Studies

B. E. Lewis

The unsteady-state continuous rotary dissolver (USSCRD) material balance code has been developed to model the liquid- and solid-phase inventories in the continuous rotary dissolver. The code provides stagewise values of dissolved heavy metal and particulate concentrations and can be used for predicting dissolver performance under a variety of conditions.

A draft report on the development of and results from the USSCRD material balance model has been completed. The draft was written pertinent to a Hot Experimental Facility (HEF) dissolver; however, the basic assumptions and model are applicable to any scale compartmented dissolver.

3.2.2 Dissolver Studies

J. G. Morgan

A prototypic continuous rotary dissolver has been successfully operated for several years. This

operation has revealed a few areas where improvements are possible, and a better understanding of some operating parameters would be useful. Chief among these is an understanding of higher than normal material inventory experienced in preliminary tests of the IET unit, and of the need for material agitation to improve agitation.

In FY 1983, the benefits of agitation on fuel dissolution will be examined, using a stand-in fuel material and existing equipment.

3.2.3 Solvent Extraction System Analysis

M. E. Whatley

Existing mathematical models of the solvent extraction process are being improved, and new models are being considered for (1) analysis and optimization of solvent extraction process flowsheets, (2) optimization of process control schemes based on specified criteria, (3) analysis of data from operating systems, and (4) differential contactor (pulsed column) applications.

The primary objective for FY 1983 is to continue the task of upgrading and extending the SEPHIS and MATEX codes by accommodating newly available equilibrium data and completing modifications to account for additional components, namely, reduced plutonium and certain key fission product species. A secondary objective is to expand the flowsheet optimization usage of MATEX to include entire solvent extraction cycles.

This activity has continued the development and application of the SEPHIS and MATEX codes for BRET application, maloperation studies, and in support of flowsheet development activities. Currently, efforts are continuing in the area of BRET flowsheet modeling and analysis. Flowsheet studies have been extended to include a total of three solvent extraction layouts and three fuel types. The resulting nine separate flowsheets

require extensive use of the analysis programs for optimization.

3.2.4 Solid Sorbent Evaluations

R. T. Jubin

An optimum silver loading for silver-exchanged mordenites is desired to provide an attractive solid sorbent for iodine removal from off-gas streams. In addition, all of the available data on this material must be summarized and reported to provide an adequate basis for a detailed design of an iodine removal system. A detailed study of all halogen sources in a reprocessing facility is also required to allow proper sizing of the silver mordenite beds. A remotely replaceable filter housing must be designed for use in demonstration facilities.

In FY 1983, the optimum silver loading for silver-exchanged mordenite will be determined to maximize silver utilization and minimize waste volumes. The development and use of both fully exchanged and partially exchanged silver mordenites (AgZ and LAgZ) will be documented. New studies to be initiated include (1) a study to identify the various sources and quantities of halogens entering a reprocessing plant through make-up streams, (2) the preliminary design of a remotely removable filter housing, and (3) a determination of the ability of AgZ and LAgZ to remove iodine from aqueous streams.

This activity has completed testing of low silver-substituted mordenites (LAgZ) for iodine retention and will specify solid sorbent equipment for the BRET, both as primary and back-up off-gas cleanup systems. A new phase of work examined the use of these sorbents for iodine removal from aqueous streams.

Testing of AgZ and LAgZ in aqueous solutions began with an initial series of experiments to measure iodine removal capabilities. These tests indicated a potential leaching problem for both AgZ and LAgZ in solutions containing dissolved iodine. The solutions

appeared cloudy after several hours at elevated temperature, and the time at which cloudiness developed appeared to be a direct function of solution temperature. The solutions were found to contain silver, iodine, and aluminum, indicating a breakdown of the zeolite structure.

A more complete study of the aqueous phase leaching and iodine removal capability was conducted on nine different sorbent materials to determine their reaction to acid-water-iodine solutions. The materials tested were AgZ, AgZ^o (pre-treated with H₂), LAgZ^o, NaZ, AgZ loaded with CH₃I, LAgZ loaded with CH₃I, hydrogen form of Zcolon 900 (HZ), AgHZ, and LAgHZ. The four test solutions were deionized H₂O, H₂O + I₂, H₂O + I₂ + HNO₃ (5 M), and 5 M HNO₃. Following a 24-h contact between 10 mL of the pellets and 50 mL of solution, the liquid was analyzed for Na, Si, Al, and Ag. Three main results were: (1) Pretreating the test material with H₂ greatly reduces the release of silver into the solution. (2) Higher leach rates of all analyzed elements from the pellets are achieved using 5 M HNO₃. (3) The release of silver from the pellets is at such a rate that the formation of AgI in solutions containing I₂ is very obvious and rapid. Overall, it is concluded that silver mordenites should not be used in aqueous streams.

3.2.5 Selective Absorption Process Analysis

D. K. Little and J. M. Varagona

A computer-based model describing the single-column selective absorption process is being developed as a system design aid for demonstration reprocessing facilities. In addition, a detailed list of equipment for this process is desired to adequately transfer the developed process technology to the design engineers.

An objective for FY 1983 is to complete the computer-based model for use in design optimization and for developing operating strategies. A detailed equipment summary, directly applicable to the design

of a demonstration facility, will not be possible at the present funding level, but a reduced summary will be provided.

Work on the computer-based model is continuing but has met with some difficulty. The individual models of the three column sections must be combined, providing a continuous model of concentration and temperature profiles. Adaptation of the single column models with different conditions for each section has not resulted in an agreement of concentration and temperature profiles at section interfaces. The value of the completed model continues to be recognized, and model development is continuing.

Preliminary component designs for BRET were completed for all fluorocarbon process and support equipment. Areas completed include the equipment list, equipment sizing, system interface identification, sampling locations, and instrumentation requirements. While this study is of a preliminary nature, it will serve as a good basis for future revisions.

3.2.6 Krypton Implantation

E. D. McClanahan and G. L. Tingey
Pacific Northwest Laboratory

Present regulations (40 CFR 190) require that ^{85}Kr produced in the nuclear fuel cycle be recovered and isolated until radioactive decay yields only stable isotopes. At present, technology exists for the separation of krypton from gaseous effluents and storage as a compressed gas in steel cylinders. However, the cost of storage and monitoring, and the potential for accidental release, provides great incentive to develop techniques for solid-state storage. Studies under way at the Idaho National Engineering Laboratory (INEL) have evaluated a process for loading krypton in zeolite molecular sieves at high pressure and high temperature, whereas the krypton implantation activity was designed to evaluate storage of krypton in metal matrices. A DOE review of the two encapsulation technologies was conducted in

1981, and ion implantation in sputter-deposited metals was selected for pilot-scale studies beginning in FY 1982.

Development of the process for implanting ^{85}Kr in a metal matrix has been under way at PNL for the past five years. Beginning in FY 1983, direction of this program was transferred from the DOE-Idaho Operations Office to the DOE-Oak Ridge Operations Office.

The objective of this activity, which is now managed by the CFRP, is to develop the process for implanting krypton in a sputter-deposited metal matrix for ultimate storage of ^{85}Kr . Pilot-scale demonstration of the process, using nonradioactive krypton, and small laboratory-scale tests using ^{85}Kr are being conducted in FY 1983.

Fabrication of a new 1500-cm^2 substrate for the one-half commercial scale trapping unit was completed, and the unit, now located in the Research Technology Laboratory near Richland, is operational. The Ni-La target with the additional lanthanum plugs was ion etched briefly with 2400-V krypton ions at a current of 9 A. This was the first run with the new dc filament supply. A console control module, an ac/dc filament supply recording selector, and program modifications to provide computer control of either an ac- or dc-heated filament were also added. Target-limiter tests on the new load bank simulated over 4000 arcs (about 50 to 200 h equivalent running time) with no limiter problems, indicating the ability to make a full length run.

Two attempts at making a full-term Ni-La deposit with the new 1500-cm^2 substrate revealed a problem with the shape of an insertable steel ring in the substrate adjacent to the anode. Lack of sufficient clearance between the anode and the ring is believed to be responsible for an electrical short during the high current stage of the substrate etch cycle. In addition, too much clearance between the steel ring and the substrate caused overheating and lack of adherence of the Ni-La deposit on this structure. The remainder

of the equipment, power supplies, and process control equipment functioned as designed. Modifications to the steel ring have been made.

Tests to determine the krypton release behavior of various particle-size fractions from <5 to $4000\text{ }\mu\text{m}$ from the Ni-Y-Kr alloy have begun. The release rate will be measured isothermally at various temperatures from 200 to 450°C . The first results at 200°C indicate that the release rate is inversely proportional to the particle radius. These experiments will be continued if this functional relationship continues to hold for higher temperatures. From the dependence of the krypton release on particle size, it should be possible to determine the dependence of the krypton-release rate on deposit thickness.

The amount of ^{85}Kr released from a Ni-La alloy storage unit loaded with 11 Ci of ^{85}Kr stored in a static air environment for 10 months was estimated to be 300 to $600\text{ }\mu\text{Ci}$. This measurement was made by passing a known volume of dry nitrogen through the storage container at a fixed flow rate, then through a counting chamber, and recording the radioactive concentration of the gas as a function of time. The measured activity diminished to background level in $\sim 10\text{ h}$ using a flow rate of $35\text{ standard cm}^3/\text{min}$. The maximum release rate which could be detected was $\leq 140\text{ pCi/min}$. This release rate should be considered as a corrosion rate at ambient temperature rather than a thermal release.

No reduction in the gamma radiation readings could be detected in the 11-Ci Fe-Y deposit stored in a static air environment. This deposit is 34 months old.

The release of krypton from a Ni-La-Kr alloy during continuous exposure to Hanford groundwater has been monitored for ~ 1 year. Tests are being conducted in water both at room temperature and at 90°C . In both tests, the release rate appears to be controlled by a diffusion mechanism, and the total release would be 1.8 and 7.2% in 10 years for the samples in cold and hot water respectively. Although the 10-year release

is tolerable, it is nearly 100 times greater than would be expected without exposure to water. This increase is probably due to the release associated with oxidation of the alloy. However, samples exposed to molecular oxygen at 320°C become passive to further oxidation. The tests will be continued to determine if the alloy is stable in water for periods longer than one year and if the alloy becomes passive to further oxidation.

3.3 CONVERSION PROCESS DEVELOPMENT

R. E. Norman

The product conversion task is establishing methods for converting U-Pu nitrate solutions to mixed oxide (MOX) products suitable for pellet fuel fabrication. During the past three years, this task has established that direct press spheroidized (DIPRES) feed has great potential for simplification of the breeder fuel fabrication process. Based on several evaluations of this work, DIPRES has continued in the lead role for advanced conversion development. In DIPRES, gel spheres are prepared by an internal gelation process, calcined and reduced to mixed oxide, and fed directly to a pellet press.

A joint development plan for qualification of this improved feed was prepared in FY 1982 by ORNL, HEDL, and PNL personnel. The plan outlines a five-year program which includes an irradiation confirmation test. Since the plan was developed, plans for the breeder fuel cycle have continued to evolve, and it now appears that the initial application for this process will be as a second-generation conversion line in BRET. The qualification plan has been revised to include this demonstration scenario.

This work, supported by a flowsheet development activity, includes an evaluation of equipment for producing gel spheres on a continuous basis, a demonstration of MOX gel sphere production on an engineering scale, and a cooperative program at PNL and HEDL to prepare and evaluate fuel pellets (with emphasis

on mixed oxide material) on a laboratory and on an engineering scale. Progress in a sphere-pac fuel fabrication activity at Exxon is also reported.

3.3.1 DIPRES Feed Flowsheet Development

**M. H. Lloyd, J. L. Collins, S. H. Shell,
and D. W. Newman**

It is intended that this activity continue basic gel sphere flowsheet studies to support the conversion program and prepare specialty test batches of spheres for use in PNL pellet pressing studies. However, overall task objectives for FY 1983 dictate that this activity concentrate on (1) preparation of materials for pellet pressing studies, (2) technical support to the startup of the Interim MOX facility (Bldg. 3019), and (3) continued flowsheet development as a secondary priority.

The principal effort this quarter was in support of the startup of the mixed oxide DIPRES line in Bldg. 3019 (reported below). In addition, two new feed solutions, each containing ~70 g of Pu, were prepared, and sphere-forming test runs were made with each feed. An additional sample (~70 g) was processed into spheres for use by PNL in flowsheet optimization studies.

3.3.2 DIPRES Feed Process and Equipment Development

**R. M. Canon, P. A. Haas, A. L. Rivera,
V. L. Fowler, and R. C. Lovelace**

The objective of this activity for FY 1983 is to shake down, operate, and evaluate continuous gel sphere production components in Bldg. 3503. Installation of a continuous engineering-scale line with a throughput of ~1.2 kg of uranium per hour was completed at the end of FY 1982. Recent work has been devoted to the shakedown and operation of this line using uranium.

During the quarter, construction, installation, and shakedown of a second-generation organic-wash column

was completed. A total of 21 runs have now been made in this continuous engineering line. A recent run demonstrated integrated continuous operation for a period of 8 h. The organic-wash column was operated in a once-through mode to the liquid-solid separator during this run, and the ammonia wash column was operated on automatic sphere-bed control. Drying of the microspheres was accomplished on the belt dryer. The dried product was evaluated at 1-h intervals; product uniformity appeared to be excellent.

In a subsequent run, operation of the organic-wash column was also under automatic control. The liquid-solid separator was operated satisfactorily with air recycle after installation of a larger blower. Optimum operating conditions for this system will be determined experimentally.

The first draft of a report describing the development of the continuous engineering-scale equipment for the line was essentially completed. The equipment design and operating concepts are described in summary form.

3.3.3 DIPRES Feed MOX Scaleup

**E. D. Collins, B. C. Finney, F. L. Daley, R. G. Nichol,
C. W. Boatman, R. C. Lovelace, and B. W. Starnes**

The major objective of this activity for FY 1983 is to demonstrate the preparation of mixed oxide gel spheres in small engineering-scale equipment. This objective has been met through the startup and operation of the MOX facility in Bldg. 3019, which has been readied to prepare kilogram quantities of mixed oxide gel spheres suitable for DIPRES pellet preparation.

Operation of the Bldg. 3019 MOX Gel Sphere line with plutonium was initiated early this quarter. Preparation of the initial 500-g batch was completed, and the product was shipped to Hanford on May 13. During initial operations, equipment performance has generally been good. Some problems have been encountered during ion exchange (uneven loading) and sphere-forming (filter plugging), but these have been handled without difficulty.

Preparation of the second product from the line is currently under way. About half of the requested 2-kg batch has been prepared.

3.3.4 DIPRES Laboratory-Scale Fabrication Studies

C. W. Griffin and P. E. Hart
Pacific Northwest Laboratory

This activity at PNL addresses the basic development of calcination/reduction, pellet pressing, and sintering steps for DIPRES material as a major objective in support of the engineering-scale fabrication effort at HEDL. In addition, the information is used to guide the gel sphere flowsheet development studies at ORNL.

Pellet fabrication tests were completed on 14 batches of archival spheres prepared by ORNL under a variety of sphere-forming conditions. Final results confirm those reported as preliminary last quarter — that the DIPRES process can provide a flexible and readily adjustable feed for pellet fabrication through the combination of gel sphere preparation and calcination/reduction conditions.

Sphere lots containing 409 and 68 g of MOX were received from ORNL. The larger batch will be used to determine the correlation between PNL lab-scale equipment and HEDL scale-up equipment results. The smaller batch will be used for DIPRES feed optimization studies.

Results with the larger batch indicate that the sphere and pellet properties are very close to earlier lots which this batch intended to duplicate. Results of the correlation test are presented in the following section.

A screening experiment was conducted to determine major parameters affecting the pellet oxygen-to-metal (O:M) ratio. Results indicate that only two of seven variables studied have a major impact on the O:M ratio.

3.3.5 DIPRES Engineering-Scale Fabrication Studies

M. D. Jackson, D. E. Rasmussen, and P. S. Schaus
Hanford Engineering Development Laboratory

The major objective of this engineering-scale activity at HEDL is to demonstrate the control of pellet density and the O:M ratio of DIPRES pellets. Control of these specific properties is considered to be of major importance in fuel fabrication demonstrations. About 3 kg of mixed oxide is required to meet the objective. The material will be prepared at ORNL, and PNL will provide calcination/reduction and pellet pressing data.

Processing of MOX DIPRES feed was initiated early in the quarter. Calcination was performed (using standard procedures developed by PNL) as part of this joint HEDL/PNL equipment correlation test. After calcining, the sample was subdivided for pellet pressing in both HEDL and PNL equipment. The objective of the equipment correlation tests is to check for potential biases in different equipment and then factor those into HEDL engineering scale-up activities. Sintered and ground pellet density measurements and surface inspections were completed. Test pellet density uniformity was good and readily met the reference FFTF fuel pellet specifications. As-pressed pellet durability and sintered pellet durability were better than observed for uranium oxide DIPRES feed. Ground pellet surface characteristics were good. The frequency of pellet chips was essentially the same as experienced for small test groups using conventional powder feed. Follow-on tests are planned to quantify pellet durability characteristics and grinding yield when larger quantities of MOX DIPRES feed become available. Calcined MOX DIPRES feed properties and sintered pellet densities agreed with values for material calcined by PNL, which indicated good

correlation between HEDL and PNL processing equipment for the sample sizes used to date. Follow-on HEDL/PNL equipment correlation tests will be conducted as processing quantities are increased and additional shipments of MOX DIPRES feed are received from ORNL. These tests are essential to permit utilization of the broad data base generated by PNL DIPRES feed fabrication development tests.

Uranium oxide DIPRES feed engineering scale-up testing activities continued. The objective of the current testing activities is to establish processing conditions for a 10-kg density and dimensional control demonstration. Test pellets were fabricated from uranium oxide DIPRES feed calcined under various reducing conditions. Test pellet sintering, density measurements, centerless grinding, and ground pellet density measurements and surface inspections were completed. Detailed engineering analysis of the results is in progress and will be documented in a future report on the activity.

3.3.6 Fuel Fabrication Studies

D. C. Killian, S. S. Koegler, and L. D. Gerral
Exxon Nuclear Company

This activity is directed toward the development of the sphere-pac fabrication process for preparation of improved LWR fuel. The activity was originally funded as part of the DOE/LWR technology program but was transferred to the CFRP in October 1981. The objective of the work has been to convert a series of batch operations developed at ORNL into a continuous process suitable for sphere-pac fuel production. This work is being phased out in FY 1983, according to a DOE contract plan. In FY 1983, the remaining work has been focused on completion of a conceptual design study for a 1-MTU/d sphere production plant. During the quarter, the conceptual design report was completed. Work under this task is now finished, and no further reporting is planned.

3.3.7 Interface Activities

R. E. Norman and M. D. Jackson

An evaluation of the DIPRES program requested by DOE-HQ was completed. The evaluation was a joint effort between ORNL, HEDL, and PNL personnel. Results of the evaluation were presented to ORNL, HEDL, and DOE managements in March 1983 at HEDL. This presentation summarized the current status of the program, described the potential benefits of the technology, and concluded that the joint technical staffs recommend that the program should continue because of its significant potential for providing a simplified and improved conversion/pellet fabrication flowsheet that will minimize difficulties in working with recycled plutonium. The evaluation further recommended that the initial application of DIPRES be as a second-generation conversion line in BRET in the mid-1990's. Results of the evaluation were documented in a letter from ORNL to the DOE in May 1983.

A DIPRES technical exchange meeting was held April 18–19, 1983, in conjunction with the Process and Engineering R&D Section Mid-Year Technical Review. Results presented by HEDL, PNL, and ORNL indicated that the DIPRES concept continues to look extremely promising.

3.4 VERIFICATION TESTING AND ANALYSIS

W. S. Groenier

A series of activities was defined for the purpose of guiding future R&D efforts by (1) identifying areas within established reprocessing flowsheets that require additional development, (2) planning process and equipment tests for the Integrated Process Demonstration (IPD) area of the IET facility, and (3) analyzing operating data on chemical systems obtained in the IPD testing program. The current work is focused on the definition of design reference flowsheets for

the proposed BRET demonstration facility and the initiation of conceptual design assistance for its systems and components.

3.4.1 Reference Flowsheet Studies

W. S. Groenier

Four interrelated flowsheet problems require attention:

1. The HEF Reference Flowsheet requires updating to include new information and ideas.
2. Design reference flowsheets are required for the BRET conceptual design effort.
3. Flowsheet areas of uncertainty need to be identified and integrated into the basic R&D planning process.
4. Flowsheet areas in need of special demonstration efforts need to be identified and integrated into plans for IET facility component and system tests.

An initial objective has been to identify design reference material balance chemical flowsheets for processing FFTF fuel at a rate commensurate with reactor discharge schedules and for processing Clinch River Breeder Reactor (CRBR) fuel at a rate of up to 0.1 t/d of heavy metal. Processing of CRBR fuel will include both core and radial blanket assemblies. Because of the variability expected in U-Pu ratio, fuel burnup, and processing rate, no single reference flowsheet can be expected to be adequate as a basis for plant design.

The initial design reference flowsheet, addressing FFTF fuel, was issued in a letter format on January 17, 1983. Six sets of written comments were received from various individuals at ORNL, Allied-General Nuclear Services (AGNS), and HEDL. A BRET flowsheet workshop was held on April 22, 1983, involving selected technical specialists from HEDL, Rockwell-Hanford Operations, Savannah River Laboratory, AGNS, PNL, and DOE. The discussions were helpful

to the ongoing flowsheet definition activity, which consists of an update of the January 17 flowsheet for FFTF fuel (featuring an Exxon-type extraction layout) and the definition of new flowsheets that address two alternate fuels (CRBR core plus axial blanket and CRBR radial blanket) and two alternate extraction layouts (conventional Purex and Purex preceded by a codecontamination cycle). The overall effort is scheduled to be completed by July 29, 1983.

3.4.2 Conceptual Design Studies

W. S. Groenier

Initial system configurations and component sizes are required for cost analysis activities based on the reference design flowsheets. Alternate configurations, which may be identified from follow-on flowsheet studies, must be identified on a schedule consistent with the design activities. In addition, process control schemes and sampling requirements are needed for the particular systems and components resulting from these studies.

The conceptual design studies are a joint effort involving many CFRP and UCC-ND Engineering personnel. The general objective of this particular activity is to assist the overall effort wherever possible. This can best be accomplished by developing and supplying design criteria on a schedule consistent with the overall design activity. Consequently, the specific objective for FY 1983 is to supply conceptual design specifications for a rotary dissolver, digester, centrifugal clarifier, centrifugal solvent extraction contactor, Iodex unit, and solid sorbent system. Assistance to the BRET project team has been a major activity during this quarter, and design criteria for several of the process systems were issued for comment.

A new area of research and development was identified to assist in demonstrating fluid transfer and metering. Fluidic pumping has application in tank-to-tank transfer and in mixing. Controlling low flows of feed solutions is a problem under investigation. Design was started on a small submersible fluidic

pump to supply the HA solvent extraction contactors (in BRET), which are located on the upper module 20 ft above the HA feed tank.

The Metals and Ceramics Division was contacted to help resolve a question of how well the carbon steel lining in one BRET cell and a zinc-coated carbon steel lining in another will behave when these cells are used for fuel element reprocessing in nitric acid solutions. The assumed cell atmosphere will consist of nitrogen (96 to 98%), oxygen (2 to 4%), HNO_3 and NO_2 (<50 ppm), and humidity (30 to 60%), at a temperature to 60 to 90°F. In the presence of water vapor, nitrogen, and oxygen, low levels of nitric acid are formed. The steady-state nitric acid concentration depends on several variables but is always very low (a few parts per billion). Removal of nitric acid from the gas phase (e.g., by reaction with a metal) allows for continuous production of acid. Experiments conducted in the Argonne CP-3 research reactor in the early 1950's showed that copper and nickel wires became coated with the corresponding nitrate salts. In spite of the above observations, fixation of nitrogen in the hot cells should be insignificant compared to that which enters the cell atmosphere from fuel reprocessing operations.

Extensive experience with processing of fuel elements in hot cells at the Savannah River Plant

(SRP) and INEL has shown patches of rust which eventually spread over the entire surface. The surfaces also become damp. The depth of attack is not great but decontamination is difficult. It is a common practice to epoxy-coat steel items that must be occasionally used in hot cells. Experience with zinc-coated steel in hot cells has been very limited, but galvanized surfaces apparently do not last long. This should probably be expected since zinc is an amphoteric element and has its lowest corrosion rate in the pH range of 8 to 12. At a pH of 4, published data indicate a corrosion rate of 50 mils per year. A pH of 4 corresponds to only 6 ppm HNO_3 in water.

It thus appears that the existing BRET hot-cell walls should be coated before reprocessing spent fuel elements. The most satisfactory, but also the most costly, solution would be to clad the steel with an austenitic stainless steel. Plasma spraying of stainless steel onto the walls is possible, but such coatings tend to be porous. Organic coatings such as epoxies may provide protection to the carbon steel if the integrated radiation dose is not too high. One solution may be to clad most of the flat cell surfaces with stainless steel and use organic coatings within penetrations or at distances remote from the highest radiation sources.

4

ENGINEERING SYSTEMS

M. J. FELDMAN

The scope of the work performed in the area of Engineering Systems includes the design, procurement, and development of prototype equipment for breeder reprocessing facilities. The concept of the prototype equipment is based on other research and development efforts, primarily those of the Process and Engineering Research & Development Section of the CFRP. The work includes the development of individual equipment items and process systems. The Integrated Equipment Test (IET) facility will be used for testing the combined equipment systems and the remote operation capabilities and characteristics of these components and systems. The conceptual design of process equipment and systems will be derived from these development efforts.

4.1 COMPONENT DEVELOPMENT

E. D. North

Component Development work is a follow-on to the Engineering Research effort and is responsible for designing, fabricating, and demonstrating the performance of pilot-plant-scale process equipment capable of being remotely operated and maintained. The dissolution and solvent extraction tasks are currently active.

4.1.1 Dissolution

F. E. Weber and J. E. Wortman

The Component Development effort in the dissolution area is directed toward designing, constructing, and testing a 0.5 t/d, pilot-plant-scale dissolver system.

The system consists of a remotely operable and maintainable rotary dissolver integrated with the support equipment necessary to provide a functional dissolution system.

Prototypical Rotary Dissolver

The 0.5-t/d dissolver was installed in the ROMD area for demonstration of remote maintenance. Remote removal of the major components was demonstrated, albeit with some difficulty. The lower portion of the equipment location in the ROMD pit is below the level of ready access by the manipulators, which increased the difficulty of the operation. Remote maintenance of minor items such as the drum position sensor was not performed since these were not designed for remote maintenance.

Construction was begun on the installation of the auxiliary equipment for the IET dissolver system.

4.1.2 Advanced Centrifugal Contactors

M. E. Hodges and J. C. Chesna
Savannah River Laboratory

Successful operation was demonstrated for a 16-stage extraction array using solvent and nitric acid. The unit performed essentially the same as a single 8-stage array.

Following the 16-stage extraction demonstration, the second 8-pack was shipped to ORNL for installation in the ROMD area for demonstration of remote maintenance. This demonstration is under way and proceeding well using the recently installed bilateral servomechanical manipulators.

The first 8-pack was operated at Savannah River Laboratory where mass transfer tests were performed using 30% TBP in NPH and depleted uranium solutions. Stage efficiencies of 99+% were demonstrated in extraction at three different rotor speeds: 1200, 1760, and 2400 rpm. Operating parameters are very close to those found with solvent and acid. This unit has also been shipped to ORNL for installation in the IET.

4.1.3 Solvent Extraction (IET)

M. V. Keigan

Construction of the IET solvent extraction system is on schedule at about 80% completion. Piping is virtually complete; electrical is about 50% complete. When completed next quarter, the system will consist of two 8-stage centrifugal contactors plus a rosette plate pulse column. The centrifugal contactors can be operated in the extraction, scrub, and strip modes. The pulse column will be operated in the stripping mode.

4.2 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 equipment.

The tasks assigned to this area are the disassembly and cutting systems, receiving and storage systems, special remote systems, and remote engineering systems.

4.2.1 Disassembly and Cutting

J. H. Evans

Personnel in the task area of disassembly and fuel cutting are responsible for the mechanical preparation of the fuel for downstream processing. Equipment is being developed to 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 prototype units in the IET and of similar equipment in a pilot plant.

Disassembly Systems

B. S. Weil and D. R. Wallace

Fabrication of the disassembly system by Pennsylvania Tool and Die has been initiated. All work is being managed by the Westinghouse Advanced Reactors Division under the existing fabrication contract. Delivery of the disassembly system is projected for the fourth quarter of FY 1984.

Laser cutting tests have been suspended temporarily while workers move the 9-kW laser to the basement of Building 7601 and make preparations for integration with the disassembly system.

Disassembly system installation design has been initiated. The final package will be completed next quarter.

Shear System

C. F. Metz III and D. C. Watkin

Fabrication of the shear system has been initiated. Delivery of the system is scheduled for the third quarter of FY 1984.

The design of special handling tools needed to demonstrate remote replacement of shear components has been completed. Design of the installation package has been initiated and should be completed in the next quarter.

Remote Disassembly and Shear Control System

W. F. Johnson and G. R. Wetherington, Jr.

The disassembly and cutting control system remains on schedule. The hardware has been received, and most of the software programs have been written and checked out in the lab.

BRET Head-End Concept

C. F. Metz III and B. S. Weil

Preconceptual designs for the Breeder Reprocessing Engineering Test (BRET) shear and disassembly systems were completed, and cost estimates were prepared. A subcontract was completed to prepare a preconceptual design of a handling machine for feeding small clusters of fuel elements into the shear.

4.2.2 Receiving and Storage

N. R. Grant

It was decided that a TRIGA reactor would not be provided for nondestructive assay (NDA) in BRET. Therefore, further investigations of using the TRIGA were discontinued. Instead NDA will be accomplished using an antimony-beryllium neutron source. Concepts and tests for such equipment had previously been developed for the Hot Experimental Facility (HEF) conceptual design. In order to provide preconceptual cost estimates quickly for this area, the HEF experience was utilized to lay out two design concepts — one for assaying incoming fuel and blanket assemblies and the other for assaying the hulls coming out of the dissolver. The preconceptual design packages have been completed, and conceptual design efforts will be initiated within the next few months.

4.2.3 Special Remote Systems

S. L. Schrock

Westinghouse Advanced Reactors 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 by this task. These include remote pipe and electrical connectors and jumpers, a remote automatic liquid sampling system, and a cell transporter to give support and mobility to the servomanipulators.

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, a load frame was designed, fabricated, and installed to test the sealing reliability and the mechanical integrity of pipe connectors under various types of loading conditions.

Testing of connectors/metallic seals on the load frame was completed in previous periods, and a final report is being prepared.

The emphasis on the subtask has shifted to the qualification of remotely operable electrical connectors. Program and test plans are being prepared leading to qualification tests next fiscal year using the CRL Model M-2 servomanipulators in the ROMD area.

Remote Sampling System

In previous periods, an advanced automatic liquid sampling system for a fuel reprocessing facility was designed and fabricated. The system consisted of a self-propelled vehicle, a track system to support

and guide the vehicle, sampling stations which are the interfaces between the vehicle and the process vessels, and a maintenance stand, on which repair of the vehicle would be performed. A test plan for the vehicle was also prepared and issued, and the testing effort was initiated.

Functional testing of the vehicle and the first half of a 365-h endurance run have been completed. During this first phase of the endurance testing, measurements of the total operating time and the downtime were determined, and an availability factor of 0.93 was obtained. Changes are now being made to the control circuitry to test other methods of position control for the various devices on the vehicle. The effect of these changes on the availability value will be determined following the final phase of the endurance run. All testing on the vehicle will be completed this fiscal year.

Additional track sections for the vehicle are presently being fabricated. Four additional sample stations have been delivered and tested. The track and sample stations will be installed in the ROMD area during the next fiscal year, and the vehicle will be used to obtain samples from the dissolver pit area.

The conceptual design of a second generation sampling system for BRET, including the vehicle, is under way and will be completed by the end of the next quarter. Data sheets have been supplied to an estimator for cost estimates for this system.

Cell Transporter

During previous report periods, a systems design requirements document was prepared for an overhead cell transporter system. A preconceptual design package of this equipment has been completed. The transporter, which supports and provides mobility to the in-cell servomanipulators, consists of a bridge, a trolley mounted on the bridge, and a rigid mast crane mounted on the trolley. The manipulator package will be attached to the lower end of the crane's rigid mast assembly.

It is planned to procure a commercial transporter fabricated to our specifications for supporting the

advanced servomanipulators. This unit will be mounted in a new test area to be prepared adjacent to the ROMD area and will be used to check out remote maintenance features of BRET equipment. This unit will be the basis for a future design of a transporter capable of being used in the BRET.

4.2.4 Remote Control Engineering

W. R. Hamel

Manipulator Development

H. L. Martin, P. E. Satterloe, D. P. Kuban, J. N. Herndon, S. M. Babcock, R. F. Spille, W. E. Holt, J. R. Nichulson, G. E. Byington, C. Wynn, J. E. Phelps, and J. C. Rowe

Development in this area involves two major activities: (1) the Model M-2 Maintenance System (M-2) and (2) the design and fabrication of an advanced servomanipulator (ASM) based system. Each system consists of a set of two manipulator master and slave arms and an interface package that provides television camera positioning, lighting, and auxiliary hoisting capabilities. The M-2 is a state-of-the-art system procured from Central Research Laboratories which features a distributed digital control system and brushless dc servomotor actuators to drive each joint.

The M-2 was received at ORNL during the last week of March 1983. It was installed on the east telescoping tube trolley in the ROMD area and placed into operation on May 19. The maintenance demonstration campaign on the solvent extraction contactor module, using the M-2, began on May 26 and was completed in mid-June. This was the first demonstration of the Remotex concept in which it was shown that prototype process equipment could be maintained using the servomanipulator systems in conjunction with TV viewing. The demonstration ran very smoothly, and only a few problems were encountered.

The objective of the ASM activity is to provide improvements in the present state of the art in servomanipulator systems. The ASM features anthropomorphic kinematics, increased modularity to provide remote maintainability, gear and shaft drives to improve

reliability, and an improved microprocessor-based digital control system. The detail design of ASM development arm modules has proceeded on schedule during this quarter. Two complete slave arm assemblies are being fabricated and will be developed as prototypes for additional units. The shoulder and roll sleeve modules are complete, and the gear pod module is approximately half complete. The elbow and wrist fabrication will begin next quarter.

The servomotor test stand is operational using a Motorola 68000 microprocessor-based control system and the FORTH software language. The software has been written to test a number of control concepts, including a standard position-position bilateral servo-loop algorithm, feed-forward friction compensation, feed-forward inertia compensation, and electronic counterbalancing.

Man/Machine Interface Development

M. M. Clarke and J. V. Draper (Oak Ridge Associated Universities), S. J. Handel (University of Tennessee), R. I. Crutcher, H. L. Martin, and S. M. Babcock

The development of an optimal man/machine interface for advanced teleoperators is critical in terms

of increasing manipulator system efficiency and minimizing reprocessing plant downtime. The master controller has been established, and ORNL is negotiating an interagency agreement with the Jet Propulsion Laboratory to detail and fabricate the dual-arm master controllers to be used in conjunction with the ASM slave development arms. The design of a cable-chain-driven master controller mock-up for the servomotor test stand is complete. When fabricated, it will be used to evaluate cable-chain performance regarding friction, backlash, stiffness, and capacity.

A set of preliminary sketches of the ASM control room concept have been completed and are being reviewed. The concept is based on a two-operator team. The primary operator is responsible for the servomanipulators, and the secondary operator is responsible for the transporter and camera systems. Posture data have been collected and are being analyzed in relation to control room chair requirements. The objective is to reduce operator fatigue associated with poor chair design.

5

INTEGRATED EQUIPMENT TEST (IET) FACILITY OPERATIONS

O. O. YARBRO

The overall objectives of the IET are to provide for the integrated testing of process equipment and flowsheets prototypical of a pilot-scale fuel reprocessing plant and the testing of prototypical remote features of specific complex components in the system. The testing program will increase the probability of success for future reprocessing plants by demonstrating integrated operation of key portions of the process equipment, remote maintenance techniques, materials transfer, liquid recycling, and metallic waste processing.

The IET consists of two operational parts: the Remote Operation and Maintenance Demonstration (ROMD) and the Integrated Process Demonstration (IPD). The IPD will address the issues of process operation in the predominantly chemical processing portion of the system. The ROMD will focus on demonstrating remote maintenance concepts on advanced prototypical reprocessing equipment and operation of key portions of the process equipment.

5.1 PROGRAM PLANNING AND CONTROL

O. O. Yarbrow

Program Planning and Control provides for the overall management of the IET, including planning, scheduling, budgeting, and reporting. The Instrumentation and Controls (I&C) Division support and the organization for the program's Quality Assurance (QA) and safety requirements are also included in this section.

5.1.1 IET Instrumentation and Controls Support

B. G. Eads

This task is responsible for the planning and implementation of the I&C support in operating the IET facility.

IPD Instrumentation and Controls Support

**G. W. Greene, K. P. Manoni, H. V. McAdams,
J. A. McEvers, A. W. Renshaw, and R. G. Upton**

Distributed Data Acquisition and Controls System (DDACS). The system continued to operate well and without significant hardware or software malfunctions. Additional improvements continued to be made in the control software and data bases. The PCM 11 was checked out and, with the exception of replacing two bootstrap ROM chips, was determined to be operational.

The EMCON-D host operating system was reconfigured to redistribute EPNs among PCMs in order to accommodate the 11th PCM and to allow greater interlock coding flexibility in all PCMs. The new system has been running well with needed adjustments

being made as they are identified (i.e., rebuilding group displays, etc.).

A new version of the Microprocessor Debugging Tool (MDT) program was received on tape from EMC Controls, Incorporated, in response to a formal request issued by UCC-ND on February 14, 1983. An unsuccessful attempt at building the program was made during the system configuration. The EMC software engineers will complete the installation of the new program.

The EMC Controls, Incorporated, was notified that they still need to fix three more software bugs — DSPRO1, CAM, and ILK. A new version of DSPRO1 was received and installed (by EMC) on the system, which appears to be working well. A hardware field modification was made to the converter analog-to-digital boards on all PCMs by EMC field service. The expected delivery of two replacement PROMS for PCM-11 have not been received. The EMC warranty period expired during April.

Among the software programs developed for use in support of IET operation's activities were a plotting routine, tank calibration support program, and a flow charting package. The plotting routine and tank calibration support programs were successfully used to ease the labor required in calibration of the process vessels and to permit rapid plotting and examination of data to discover errors while calibration of the corresponding vessel was still in progress.

The flow charting program, which utilizes the LXY-21 printer/plotter in the plotting mode to produce high quality software diagrams, was developed to improve documentation and design of automation software.

Field instrumentation. The main off-gas header pressure control valve was removed and a larger trim installed. Four valves were changed from fail-open to fail-close on tank heat/cooling. All flow loops were calibrated for use in tank calibration activities.

Procedures for the calibration of instruments in IPD were prepared in support of QA requirements and will be on file in Building 7601 for use in future

calibration activities. Seven calibration procedures (of ~12 total) were completed and approved.

Work is continuing on development of automation software for the acid fractionation and the high-activity waste (HAW) evaporator systems. A schedule for HAW evaporator software development has been established, and copies have been provided to IET operations. First draft process operation diagrams were produced, revised, and issued for approval.

Requisitions were issued for a maintenance contract with Digital Equipment Corporation (DEC) to maintain the "host" portion of the system and for a system software maintenance contract for the "host" software supplied by DEC.

Conductivity and pH probes were functionally tested, with actual calibration to be initiated and completed soon. The current-to-pneumatic converters were also calibrated. Minor adjustments to instruments continue to be made as required by IPD operations.

ROMD

H. V. McAdams, J. A. McEvers, and K. P. Manoni

A test plan has been approved to examine the hoist drive on both 10-ton cranes in ROMD to determine the problems with drive slippage under heavy loads. It is anticipated the problem will be corrected by either retuning the controller or modifying the circuits.

Equipment Integration Project (EIP)

K. P. Manoni and H. V. McAdams

A design package to provide cooling tower monitoring by DDACS was completed, and installation of the system is in progress.

5.2 IET ENGINEERING

H. R. Yook

The IET Engineering group is responsible for the EIP and all other engineering/design activities associated with the IET facility. The EIP is responsible for planning, managing, and implementing installation of equipment and systems in the IET facility.

5.2.1 Project Management

H. R. Yook and J. S. Woods

During this quarter, project management focused heavily on coordinating contractor work, equipment installation, and testing in the IET facility. Three contractors and ORNL field forces were active in the facility, working on the solvent extraction system, dissolution system, additional line-item projects, and facility-related modifications. In addition, the industry-standard servomanipulator and the centrifugal contactor unit 8-2 were installed in the remote maintenance area.

Planning for FY-1984 installation and modification work was completed. Previous FY-1984 plans were updated to reflect the current status of equipment and systems to be delivered and installed. Planning for building modifications to raise the roof over the test area south of the IET facility was solidified and integrated with existing plans. The roof raising can proceed during the first half of FY 1984 with minimum impact on other IET activities.

5.2.2 Systems/Equipment Integration

H. R. Yook, R. V. Eberle,
E. L. Nicholson, and B. B. Spencer

The design of facility modifications to provide a BRET equipment test area is progressing on schedule (July 15, 1983, completion date). The contract award is targeted for September 1, and start of construction is scheduled for October 1. The drawing package and specifications were completed and submitted to the Department of Energy-Oak Ridge Operations (DOE-ORO) for review and approval.

Detailed design of the IET feed station was completed. The feed station will provide the capability to operate and test the continuous rotary dissolver and process systems without operating the shear. The feed station will simulate output from the shear for both nominal and off-design conditions.

Detailed design of the solids recycle system was completed. The system will provide the capability to collect solid materials (wires, hulls, and shroud pieces) discharged from the dissolver and to wash, dry, and separate the material for recycle to the feed station.

Design of a dissolver feed chute connecting the shear and feed station to the dissolver was initiated. Work has progressed into Title II design which is 50% complete.

Contractor work on the line-item additional projects has progressed on schedule. Five of the thirteen projects were completed, including installation of the digester pit liner, pit shield walls, emergency egress lighting, temporary wall removal, and voloxidizer demolition. Construction of the shear hydraulic building is well under way. A field change notice was issued to add resurfacing of the ROMD floor to the contract.

Delivery of the Iodex system by Astro-Metallurgical Corporation slipped from June 1 to November 1. The major cause for the delay is piping. The structural steel for levels 1, 2, and 3 is completed, and the equipment is mounted on the three levels. Piping has been completed on levels 1 and 2, and the frames are ready for installation of interconnecting piping. Astro is working three shifts on the job and is optimistic about completing the job by November 1. The revised delivery date does not affect other IET work, but any additional slippage will impact startup and operation of the dissolution system.

Installation of the closed-circuit television (CCTV) lighting fixtures and cabling for the industry-standard manipulator (ISM) was completed, preparing the facility for installation of the ISM system.

The dissolution system installation contractor began work and proceeded on schedule. All government furnished equipment was delivered to the construction site, and the contractor installed the NO_x column and several other tanks and vessels.

Return of the first of the two ROMD square telescoping tubes to Power and Remote (PaR) Systems,

Incorporated, for rework to improve stiffness has been delayed. Results from PaR's testing of their first redesign attempt did not substantiate analysis. Another redesign approach has been modeled and tested and appears to be satisfactory. The first tube will be released for rework if the redesign checks are adequate.

5.2.3 Facility Engineering Support

**H. R. Yook, R. V. Eberle,
H. V. McAdams, and B. B. Spencer**

American Bell has delivered all materials for the IET public address system. Installation began in June.

Design of a wired intercom system for the IET was completed, and a request for quotation for system components was issued. Quotations were received and evaluated, and a purchase order was issued.

5.3 IET OPERATIONS

W. W. Evans

This activity controls, coordinates, and executes operations within the IET facility and is responsible for equipment maintenance in the Consolidated Fuel Reprocessing Facility (CFRF) complex. Major work tasks in IET operations include planning and scheduling of operations, preparation of procedures, data storage, process system operations, and demonstration of remote maintenance concepts. The principal objective of the CFRF complex is to coordinate equipment maintenance activities with routine operations.

A number of line-item construction projects have been completed or are still in progress within the CFRF complex. The emphasis in the ROMD operating area has been to protect the equipment in the area from construction as much as possible, assist the contractor as required, and plan for future remote demonstrations. In the IPD area, the contractor continues to install the solvent extraction system. Since this construction work is mainly in the west end of the area (away from the major portion of the existing operating equipment), there has been only minor interference with

equipment checkout currently in progress. Outside the IET area, the work has been to mainly coordinate the removal or relocation of existing equipment for the contractor.

An estimate of the manpower requirements for work planned by IET operations and routine operations within the complex was completed. This estimate was made on the basis of the current equipment installation schedule in the IPD and ROMD areas and the anticipated routine support in the component development area.

A new standard operating procedure (SOP-DR-002) was issued detailing program-initiating commands (used by personnel to interface with the DDACS host computer when using the IET data retrieval system).

5.3.1 ROMD Operations

J. E. Van Cleve, Jr.

Functions in the ROMD operations area are directed toward demonstrating remote maintenance concepts on advanced prototypical reprocessing equipment and viewing systems.

The initial setup and testing of the ISM on the storage stand proceeded well. The cable handling system was installed on the east square tube and the power supply mounted on the trolley. The manipulator was installed on the square tube, requiring only minor adjustments of the latching pins. The first use of the manipulator was with the maintenance test stand to familiarize the operators with the machine. The maintenance demonstration on the 8-2 centrifugal contactor will begin in the near future.

The centrifugal contactor unit 8-2 was received, assembled, and installed in the ROMD operating area. The procedures to be used in the remote maintenance demonstration were prepared, and special tools (such as impact wrenches and pneumatic crowfoot wrenches) were modified for use with the ISM. A lifting sling to be used with the 10-ton crane was sketched and turned into the shops for fabrication.

The rotary dissolver was reinstalled in the ROMD pit following completion of the contractor work. The idler, driver, and thrust rolls were visually examined and manually rolled and were found to operate satisfactorily. The water lubrication system was hooked up, and the flush water from the bearings was clear, indicating that minimal to no corrosion had occurred during the idle period. The drum rotation drive system was installed and checked — all satisfactory. Testing will be resumed as time permits.

5.3.2 IPD Operations

D. R. Moser and E. L. Nicholson

Functions in the IPD operations area are focused on testing the individual chemical process systems and on developing the techniques necessary for integrating these systems so that they work in unison during plant operational campaigns.

The acceptance tests of the original IPD systems have been completed. During these tests, the functional performance of components and equipment was verified, proper interfacing of process instrumentation sensors with the distributed digital control system was checked, and satisfactory initial operation of key subsystems was confirmed. These IPD processing systems are now ready for initial plant operations.

The acceptance testing effort was successful in finding many minor problems both in hardware and software and verifying that the problems were rectified. In general, the control system and processing systems have performed well.

Preparations are under way for initial operations utilizing the original IPD systems and for acceptance testing of the solvent extraction system which is scheduled to be turned over to IET operations during the next quarter.

5.3.3 CFRF Complex Operations

W. W. Evans and W. T. Bostic

Activities are directed toward maintaining the CFRF support equipment and services as needed by Component Development and IET operations, and coordinating the work of line-item contractors with building service modifications.

The main modifications made in the Building 7603 area were in connection with relocating equipment in the IET and high-bay areas in preparation for work to be completed by the current line-item contractor. This included relocating some equipment transformers, power supplies, sprinkler lines, cable trays, and a support platform used previously for component development equipment. Some of this work was in extending the crane rails in the high-bay and relocating the laser equipment in the basement.

An experiment to process small quantities of depleted uranium with special dissolution equipment located in the No. 2 component development lab was proposed by the Engineering Development group. Modifications have been started to prepare for strict containment within the immediate lab area. This work is approximately 80% complete.

6 INSTRUMENTATION AND CONTROLS

B. G. EADS

This task is responsible for the development of process instruments and data management systems for fuel reprocessing in the areas of process control, accountability, and safeguards.

6.1 ANALYTICAL SENSOR DEVELOPMENT

**D. D. McCue, R. E. Harper, D. T. Bostick,
and J. E. Strain**

Development of the RSX-11M operating system and final documentation of the photometer hardware and software continues.

A review of the instrumentation needs for the Breeder Reprocessing Engineering Test (BRET) solvent extraction cascades has been initiated. The current-design multistream photometer, with some cell modification, is considered to be a strong candidate to satisfy these control needs.

The review and determination of other in-line analytical instrumentation needs for BRET awaits program direction. Future task plans will be based on any development needs identified in this review.

The initial installation of the uranium photometer at Y-12 has been so successful that it has been expanded to continuously and simultaneously monitor three streams (raffinate, aqueous feed, and stripped organic) in the second extraction cycle. Results of all three analyses are available each 8 s.

6.1.1 Nondestructive Assay (NDA)

C. W. Ricker and E. D. Blakeman

During this quarter preliminary instrument requirements for the spent fuel and leached hulls assay systems were established. Also, preliminary sketches showing installation of these systems in BRET were prepared. A joint effort among CFRP, I&C, and Engineering personnel was established to provide information for a cost estimate for installation of these systems.

HTGR FUEL REPROCESSING

W. S. GROENIER and J. H. SHAFFER

Research and development activities in High-Temperature Gas-Cooled Reactor (HTGR) fuel reprocessing technology are being conducted at GA Technologies, Inc. (GA). Head-end process and laboratory-scale development efforts, as well as specialized 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 HTGR DRY HEAD-END

**W. S. Rickman, J. B. Strand, N. D. Holder,
R. N. Drake, and S. A. Sterling
GA Technologies, Inc.**

This task is concerned with the implementation of the United States-Federal Republic of Germany (US-FRG) cooperative program to verify the GA dry head-end pilot plant design concepts. Facilities in the two countries are complementary, with cold engineering-scale development in the FRG being the major effort. A Joint Prototype Head-End Facility (JPHF) is in the conceptual design stage. This will be a cold, remotely maintainable, full-scale facility for both US and FRG reference fuel types.

Major objectives for FY 1983 include (1) the performance of various cold pilot plant operations in the United States as described in jointly prepared technical development plans; (2) the completion of system level design criteria, process flow diagrams, and

future development requirements for the JPHF; and (3) the shipment of a segmented cold US fuel element to the FRG for processing in the AVR-VI facility. Work will also be initiated on segmenting an irradiated Fort St. Vrain fuel element in preparation for shipment and processing in AVR-VI. In addition to the cooperative activities, other cold pilot plant tests at GA support the overall HTGR fuel reprocessing development effort.

7.1.1 Joint Fuel Processing Demonstration (JFPD)

The failed section of the 20-cm-diam burner has been replaced, and two successful shakedown runs (using the reconstructed burner) have been completed. New gas analyzers were also installed to simplify the off-gas analysis system.

An experimental plan for the 100% particle breakage test was completed. Preparations are nearly complete for this joint United States/Federal Republic

of Germany (US/FRG) cold fuel processing demonstration using unirradiated German fuel particles.

7.1.2 Joint Hot Fuel Processing Demonstration (JHPD)

One-hundred thirty-four irradiated fuel rods were removed from a Fort St. Vrain Segment 2 fuel element. These rods were packaged and shipped to Germany in a German cask (BRECO) for use in the JHPD facilities.

Hot cells for the JHPD tests are 80% complete; an identical cold facility has been completed, and shake-down tests are under way using unirradiated FRG fuels.

Samples of irradiated fuel element graphite were retained for analysis for ^{14}C , Pu, I_2 , and ^{233}U . These analyses will be performed to determine if the fuel element graphite blocks can be excluded from the low-level radioactive waste category described by 10 CFR 61.

7.1.3 Pilot Plant Burner Operations

Following design of the 6-cm-diam burner, parts were procured, a test stand was constructed, and the burner was installed on the stand. Final designs of the piping, instrumentation, and control systems are complete, and procurement is under way for burner and off-gas system components.

Two fines-burning tests totaling 130 h were completed in the 40-cm-diam circulating bed burner. Variables were bed height and superficial velocity. One test achieved >98% combustion efficiency. The results of these and previous tests were documented in a draft report on 40-cm-diam burner development.

7.2 LABORATORY STUDIES

R. G. Wilbourn
GA Technologies, Inc.

In FY 1982, a rotary screw dryer was purchased and installed in the pilot plant for drying the SiC hulls remaining after the dissolution of TRISO-coated fuel. Preliminary testing of this unit has been completed. The objectives in FY 1983 will be to purchase

a moisture analyzer for control of the dryer and to perform more detailed testing of the unit. Additional objectives are to (1) initiate a detailed study of safeguards and accountability requirements for an HTGR reprocessing plant (as part of the US-FRG agreement), with particular emphasis on adequate accountability for solid material and safeguards of special nuclear materials; and (2) to initiate bench-scale tests to determine the effects of the TRISO coating on dissolver configurations and time cycles.

7.2.1 Solids Dryer

The Quadra Beam moisture analyzer has been received; however, its use in measuring the moisture content of the silicon carbide dryer product has been delayed because of funding limitations.

7.2.2 Dissolution Studies

Bench-scale experiments have been conducted to examine the effect of silicon carbide hulls on ThO_2 dissolution in the concentration range of 0.5 to 0.8 M Th^{4+} . In Thorex, this corresponds to 50 to 80% ThO_2 dissolution. The presence of the hulls does not create a severe time-cycle penalty in the range studied. The additional dissolution-time requirements in the absence of recirculation are approximately 30%. Additional tests are under way to define time-cycle penalties encountered for complete ThO_2 dissolution (1 M Th^{4+}).

7.2.3 Accountability Studies

A survey was made of state-of-the-art, near real-time accountability methods for use in conjunction with special nuclear material in the solvent extraction portion of the spent fuel treatment plant.

7.3 OFF-GAS SYSTEM

L. J. Olguin, K. Y. Higuchi, and K. P. Norton
GA Technologies, Inc.

The overall objective of this task is to develop and demonstrate processes, equipment, and control systems necessary to treat off-gas streams from nuclear fuel reprocessing plants. Fuel cycle off-gas streams

contain common radioactive or noxious gas components (^3H , ^{14}C , ^{85}Kr , ^{129}I , ^{131}I , semivolatiles, and NO_x), in addition to radioactive particulates and aerosols, which must be isolated from the environment. Treatment methods for these components are generic for all fuel cycles. Off-gas from HTGR fuel reprocessing contains additional components for treatment, which include ^{220}Rn , CO , and SO_2 . In FY 1982, work concentrated on HTGR dissolver off-gas treatment components and integrated testing.

Objectives for FY 1983 include (1) modification of the I_2 removal subsystem to provide for removal immediately upstream of the NO_x scrubber/absorber and to alleviate the potential for system corrosion; (2) design of a CO/HT oxidizer control system to operate with a burner off-gas containing high oxygen content; and (3) design of a modified system for Kr/CO_2 separation.

7.3.1 Dissolver Off-Gas (DOG) Integration

Revisions of the process instrumentation schematic drawings for the integrated DOG system have been completed to reflect the change of moving the iodine bed from a position just after the NO_x converter to a location immediately after the dissolver reflux condenser. Process control and data acquisition programs for the modified DOG treatment system have also been completed.

The new iodine adsorber, iodine adsorber preheater, and supporting instrumentation have been installed. Two caustic scrubbers were included for colorimetric measurement of iodine concentrations in samples from the inlet and outlet of the adsorber.

Four tests with silver mordenite (AgZ) bed material were conducted with simulated DOG streams containing iodine and various concentrations of NO_x . One test was conducted with actual DOG generated from the dissolution of uranium oxide. No iodine could be detected at the outlet of the bed. Analysis of the test results showed that the inlet iodine concentration

was lower than expected. A radioactive iodine tracer will be used to locate the evolved iodine.

7.3.2 CO/HT Oxidizer Tests

The CO/HT oxidizer tests to evaluate a catalyst dilution technique for limiting the temperature of the catalyst to 700°C have been completed. At 700°C the aluminum substrate changes from the gamma form to the alpha form, which greatly reduces the catalyst activity. Tests have shown that the temperature limit can be achieved by limiting the CO conversion to a maximum of 5% in any one stage of the oxidizer. The results of the tests showed that catalyst dilution is an effective technique to control CO to CO_2 conversion under high O_2 concentrations (10%).

In the first phase of these tests, the behavior of one stage of the oxidizer was evaluated and used to predict the catalyst concentration required for all six stages. Data were obtained under conditions of varying inlet CO concentration, O_2 concentration, total flow rate, and catalyst concentration in the range expected from the actual burner operation.

In the second phase, all six stages of the oxidizer were operated under simulated burner off-gas (BOG) conditions. Oxidizer feed streams with CO concentrations up to 15% did not produce an excessive catalyst temperature in any stage. The outlet CO concentrations were <100 ppm, which corresponds to a decontamination factor of 1500 for an inlet CO concentration of 15%.

7.4 STUDIES AND ANALYSES

J. S. Rode

GA Technologies, Inc.

A program plan for the treatment of spent HTGR fuel was last updated in 1977. Since then many changes have occurred which make that plan obsolete. Work on updating the plan was initiated in FY 1982 and completed in FY 1983. A second objective for FY 1983

is to continue design studies on the storage of intact and volume-reduced fuel.

7.4.1 HTGR Spent Fuel Treatment Program Plan

J. S. Rode and M. E. Cohen

As issued, the HTGR Spent Fuel Treatment Development Program Plan differs from its predecessor (1977) in work scope and approach. This plan addresses spent fuel volume reduction, packaging, and disposal, in addition to spent fuel transportation, storage, and reprocessing. Fuel fabrication for recycle, which was addressed in the 1977 plan, is not included in the present plan. Furthermore, this plan incorporates the cooperative activities of the ongoing spent fuel treatment development program between the United States and the Federal Republic of Germany. This plan also supports the commercial HTGR concept and is compatible with the provisions and implications of the Nuclear Waste Policy Act of 1982 and the DOE standard contract for disposal of spent nuclear fuel (10 CFR 961). The current approach is based on a decision process rather than on a single course of action; thus, program commitments are planned only as required by technological, economic, institutional, or political decisions at the appropriate decision times. As a result, priorities can be assigned more effectively, and the chances of longer-range planning redirection can be significantly reduced.

7.4.2 HTGR Spent Fuel Storage, Transportation, and Disposal

R. J. Grenda

A draft topical report describing a cost estimate for an away-from-reactor (AFR) storage facility for whole HTGR spent fuel elements was completed. The facility would have an initial capacity for 25,000 whole HTGR spent fuel elements and an expanded capacity for 75,000.

For the smaller capacity facility, capital costs were estimated at \$173,180,000 in January 1983 dollars. Annual operating and maintenance costs were \$6,690,000. For the larger-capacity facility, costs were

estimated as \$374,860,000 and \$11,810,000, respectively, for capital and operations. Depending on whether government or private financing is available, the per block storage costs will vary between \$12,500 and \$13,800 for the smaller facility and between \$8,350 and \$9,640 for the larger facility. These costs are based on a reasonable scale-up of costs from other comparable facilities such as the HTGR Long-Term Storage Facility (at-reactor), the GA concept for monitored retrievable storage (MRS) of LWR fuel, and an LWR AFR storage facility.

Work continues on the preconceptual design of a system for packaging and shipping stabilized volume-reduced HTGR spent fuel. This system is based on the use of the reference crush/burn process for the volume reduction of HTGR spent fuel and a reference particle stabilization process (cementation) called FUETAP. The system consists of three major elements: (1) a FUETAP canister for holding the stabilized particles, (2) a shipping container for the FUETAP canister, and (3) a shipping cask. Based on rail shipping weight allowances, the shipping cask holds three containers.

Battelle Pacific Northwest Laboratory completed initial testing of their computer code, RECON, for estimating HTGR spent fuel disposal costs. The code is now operational, and GA has requested the code for use in additional parametric studies. These studies would examine the effects of several variables (e.g., disposal package size, decay heat generation rate, and HTGR market size) on disposal costs for whole and volume-reduced HTGR spent fuel.

7.4.3 Volume Reduction and Packaging of HTGR Spent Fuel

J. J. Shefcik and J. B. Strand

Preliminary flowsheets and material balances for volume reducing, stabilizing, and packaging HTGR spent fuel have been issued. In addition, preconceptual layout sketches for a volume-reduction facility were prepared and are being reviewed. Several different process and maintenance cell arrangements are being considered.

STRATEGIC PLANNING AND ANALYSIS

J. G. STRADLEY

The specific efforts described in this section are directed toward long-range strategic planning for the Consolidated Fuel Reprocessing Program (CFRP). They also include the foreign exchange program and the waste management, safeguards, nuclear engineering, and environmental assessments activities of the CFRP. Miscellaneous studies conducted involve analyses in broad areas overlapping many other CFRP tasks and ultimately provide background information and recommendations for decisions pertaining to programmatic guidance and direction.

8.1 STRATEGIC STUDIES

B. E. Prince

A limited effort was continued toward developing an understanding of the strategic basis for closing the light-water reactor (LWR) fuel cycle and subsequently the breeder fuel cycle. The purpose of this study is to develop the rationale for the timing of various fast-breeder reactor (FBR) reprocessing developmental activities and facility requirements.

8.2 FOREIGN EXCHANGE AGREEMENTS

The CFRP has an active exchange agreement with the United Kingdom Atomic Energy Authority (UKAEA) and has continued to develop the components of an exchange with the Power Reactor and Nuclear Fuel Development Corporation (PNC) of Japan.

Preliminary discussions were held with the CEA of France to establish the possibilities for a technical exchange in the remote technology area.

8.2.1 US/UK Exchange Agreement

Design Parameters Study Subtask

J. G. Stradley

Draft documents were prepared by each country describing the design parameters for a demonstration breeder reprocessing facility. This effort is part of ongoing discussions between the US and UK directed toward enlarging the collaboration between the two countries and worldwide on the breeder fuel cycle program. The drafts were discussed in the UK in May. As a result of these discussions, a combined working document will be prepared.

Laser Development Subtask

S. A. Meacham and B. S. Weil

Reports describing past experimental studies were exchanged and reviewed. Laboratory personnel visited the Culham and Springfield Laboratories in the UK in May to develop a joint detailed program plan for laser development activities. When completed, the proposed program will provide the necessary information to design a remotely operable and maintained laser system for the opening of transit containers and the disassembly of irradiated fuel.

Heat Generation and Heat Transfer

M. J. Haire

C. A. Rhodes (University of South Carolina)

D. E. J. Thornton, UK subcorrespondent for this task, visited the United States in May. Discussions covered the heat generation, transfer, and emissivity activities of each country. Thornton described the UK's temperature measurements for Prototype Fast-Reactor fuel irradiated to 0.3 kW. The discussion concluded that fuel temperature measurements at a more representative decay power (~ 3 kW) would be valuable to validate the codes which are used to calculate fuel pin temperatures. Also, measurement of decay heats of fuel assemblies would be valuable because of the sparseness of experimental data in this area and the resulting uncertainty in decay-heat source-term calculations.

8.3 MISCELLANEOUS STUDIES

8.3.1 Reliability, Maintainability, and Availability (RAM) Analysis

M. J. Haire

A study has continued on the effects of various reprocessing plant maintenance concepts on plant availability. The study, being done with support from the NUS Corporation, is in the final stages of completion and has utilized the opinions of experts to establish relative failure rate frequencies and corresponding repair times for three maintenance concepts. The study

suggests that an "inherent availability" of $\sim 85\%$ be considered for an overall reprocessing facility design criteria. This availability corresponds to one failure per week, which causes the whole process line to shut down and allows but one day to recover from that failure. The definition of inherent availability does not include scheduled downtimes such as that for preventive maintenance, logistics, or administrative reasons. The techniques or computer codes employed in this study will be utilized to allocate system availability for Breeder Reprocessing Engineering Test (BRET) equipment.

The Savannah River Plant was visited to exchange data in the areas of reliability and maintainability. A reliability analysis of advanced servomanipulator arms was initiated.

8.4 NUCLEAR ENGINEERING

R. T. Primm III

The objective of this task 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.

8.4.1 PNL Critical U+Pu Nitrate Solution Experiments

R. C. Lloyd (PNL) and R. T. Primm III

K-effectives were calculated from experimental data for five approaches-to-critical experiments conducted at PNL. Experimentation at the PNL Critical Mass Laboratory has been temporarily halted pending review by the DOE of the Laboratory's operating procedures. An investigation of analytical chemistry procedures for determining free acid normality in the solutions used for criticality experiments is continuing.

8.4.2 Interim Validation Report for Mixed Plutonium and Uranium Systems

R. T. Primm III and J. R. Knight

Documentation of calculated k-effectives for approximately 200 benchmarks is proceeding. The

computer code inputs for these cases are being added to the CESAR archival storage code. The completed code package will be contributed to the Radiation Shielding Information Center at ORNL.

8.4.3 Criticality Safety Evaluation of the Continuous Rotary Dissolver

J. A. Bucholz

A report describing the use of B_4C pellets in the rotary dissolver to serve as a second contingency against criticality is still in preparation. A draft of a report describing the use of gadolinium and mass control as a contingency against criticality is being reviewed.

8.4.4 Nuclear Engineering Support for the Breeder Reprocessing Engineering Test (BRET)

**S. N. Cramer, D. T. Ingersoll, and R. T. Primm III
W. R. Waltz (Allied-General Nuclear Services)**

Allied-General has recently completed a study on the use of soluble poisons for criticality control in the BRET head-end systems.

A design study of the BRET plutonium nitrate solution storage tanks has been conducted. Some estimates of shielding wall thicknesses for equipment containing krypton were prepared.

The first draft of a generic report entitled *Survey of Shielding Data and Methods for Nuclear Fuel Reprocessing Applications* has been prepared. A program was initiated to assess radiation levels within the BRET facility and to identify potential shielding deficiencies. The first phase of the program is to obtain, implement, and test an appropriate point kernel code for scoping studies of radiation fields.

8.5 SAFEGUARDS TASK

H. T. Kerr and J. W. Wachter

The Safeguards Task is responsible for ensuring the development and implementation of effective

safeguards technology for reprocessing plants as may be necessary to satisfy both domestic and international safeguards objectives. Recent activities have continued to focus on two major areas: (1) the preconceptual design of a safeguards system for the BRET facility and (2) the planning of a safeguards demonstration to be conducted in the IET.

8.5.1 Safeguards System for the BRET Facility

The Safeguards Task group is continuing to develop the general safeguards requirements for materials control and accounting in the BRET. In addition, consideration has been given to the potential implications of physical security changes required in the FMEF because of the introduction of the BRET. Material balance area boundaries and relevant measurement needs were defined. The design of various equipment items (e.g., plutonium nitrate storage tanks) was reviewed, and safeguards considerations were identified. Proposals for the application of advanced material control and accounting techniques such as near-real-time accounting strategies were considered.

8.5.2 Safeguards Demonstrations in the IET Facility

Analysis and planning continued for safeguards demonstrations in the IET facility. The results of a study initiated last quarter employing the DECANAL code to analyze mass balances in the rotary dissolver indicated that the technique is promising for alerting operators to the possibility that the dissolver is plugging, thereby avoiding a possible criticality hazard. Future efforts will be directed toward allowing the DECANAL code to extend the time of dissolver surveillance, thus reducing the printed output and enabling simplified options; to improve the simulation model of the dissolver system; and to examine the possibility of utilizing more accurate measurements (e.g., chemical analyses) in combination with real-time measurements.

8.6 WASTE MANAGEMENT INTERFACES

J. O. Blomeke, R. T. Jubin, and A. G. Croff

The objective of this task is to develop a waste management flowsheet, based on existing technology, that can be coupled with a reprocessing plant to produce waste forms that are likely to be acceptable for disposal. Work continues on the preparation of preconceptual design packages for the airborne waste and HLW vitrification systems of the BRET. The airborne waste system proposes the use of the Iodex process and silver mordenite for iodine retention, fluorocarbon absorption for the retention of krypton and $^{14}\text{CO}_2$, the fixation of iodine and carbon in concrete, and ion implantation of krypton in a lanthanum-nickel alloy. A design package was prepared by Pacific Northwest Laboratory for the vitrification of HLW as borosilicate glass, using a liquid-fed ceramic melter.

Comments were received from the DOE on a draft Commercial Airborne Waste Management Program Plan that was prepared several months ago. The comments will be incorporated into a final revised document.

8.7 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 facilities being designed will be radiologically and environmentally acceptable.

Preliminary drafts of sections on "Routine Releases and Wastes" and "Alternatives for Effluent Control/Waste Management" have been prepared for use in the BRET environmental assessment. A preliminary analysis of the behavior of neptunium in the BRET flowsheet has been made.

A review and reevaluation of assumptions for tritium release at breeder reactors was completed. The review considered the basic question — What are reasonable assumptions regarding the quantity of tritium delivered to the reprocessing plant? It has been assumed that approximately 3% of the tritium is retained in the core assemblies and >90% is retained in the blanket assemblies. To address the question of tritium release, the models available for describing the noble gas release from both LMFBR and LWR fuels were reviewed and modified to account for the difference in the properties (diffusivity and solubility) of tritium relative to the noble gases. The most recent readily available data on tritium release was also reviewed. Agreement between the core model and the available data was reasonably good, although the model overestimated tritium retention slightly. The blanket model overestimated tritium retention significantly, although the magnitudes were of the same order. It was concluded that the assumptions regarding tritium retention were conservative; however, considering the limited amount of data, this conservatism is appropriate.

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