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**Consolidated Fuel-Reprocessing
Program Progress Report
for Period April 1
to June 30, 1982**

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**CONSOLIDATED FUEL REPROCESSING PROGRAM
PROGRESS REPORT
FOR PERIOD APRIL 1 TO JUNE 30, 1982**

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Date Published: September 1982

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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 General Atomic, 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

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 quarterly in overview fashion.

1.1 PROCESS DEVELOPMENT

W. S. Groenier

Progress was made in the following areas: (1) the development of a suitable flowsheet for preparing UO_3 spheres in continuous engineering-scale equipment by the gel-sphere process, and (2) a two-step process for calcining direct-press spheroidized mixed oxide dry gel spheres.

In addition, a continuous 100-kg U/d line is being designed and fabricated for UO_3 gel spheres production.

1.2 LABORATORY R&D

W. S. Groenier

Solvent impurities produced by chemical degradation of the diluent are primarily long-chain organic acids. These acids impair phase separations in sodium carbonate scrubbers and may extract metal ions into the organic phase as tributyl phosphate (TBP) complexes by displacing the nitrate ion.

Experimental studies of the enhanced extraction of technetium by TBP in the presence of thorium were completed. The pertechnetate anion replaces a nitrate ion in the organic phase to form complexes such as $\text{Th}(\text{NO}_3)_3\text{TcO}_4 \cdot 2\text{TBP}$.

A partial partitioning test was completed in the Savannah River Laboratory Pulsed Column Facility using hydroxylamine nitrate (HAN) for plutonium reduction. Gas evolution from the reduction reaction did not appear to adversely affect column performance.

The relative sensitivities of fission product elements for analysis by spark-source mass spectrometry (SSMS) were determined by an analysis of a standard laboratory mixture of fission product elements having natural isotopic abundances.

1.3 ENGINEERING RESEARCH

W. S. Groenier

An air-lift device for suspending solids in the digester tank has been demonstrated in a 2.3-m-tall (prototypic) test tank. Approximately 88% of the tungsten particles ($<88 \mu\text{m}$) added to the tank were maintained in suspension. Operation of the pulsed air-lift device has little adverse effect on instrument response during liquid-level measurements. Deviations in density measurements may be used as a means of detecting lift-tube blockage.

Two tests of the dissolver off-gas treatment system at General Atomic Company (GA) included series operation of the 0.5-m-diam dissolver, an NO_x scrubber,

a condenser/demister, a compressor, and an NO_x converter. The decontamination factor for NO_x conversion exceeded 1000 throughout the last run. Maximum NO_x concentration in the scrubber effluent was about 5500 ppm; the effluent from the NO_x converter contained less than 3 ppm NO_x .

1.4 ENGINEERING SYSTEMS

M. J. Feldman

Testing of the 8-stage advanced centrifugal contactor has continued at Savannah River Laboratories. The units continue to show good phase separations over a wide range of operability when used with tributyl phosphate and acid.

The prototype automatic liquid sampling system has been assembled and installed on the process module mock-up in the Remote Operation and Maintenance Demonstration area. Testing of this system will be initiated next quarter.

A pair of electronic force-reflecting master/slave manipulator arms has been installed in the Remote Systems Development Facility. These will be used in the man/machine interface development program.

1.5 INTEGRATED EQUIPMENT TEST (IET) FACILITY OPERATION

O. O. Yarbrow

The current IET line-item construction is approximately 96% complete. Beneficial occupancy in the Integrated Process Demonstration (IPD) area is still expected near the end of July. Modifications to the IET control room have been completed, and the distributed data acquisition and control system (DDACS) has been installed and technically accepted. Loading and updating of the DDACS process data base software has begun.

Remote maintenance demonstrations were started on the process module mock-up midway through this

report period, following a partial fix on the remote handling equipment supplied by PaR and the installation of new CCTV cameras and equipment in the facility remote viewing system.

1.6 INSTRUMENT DEVELOPMENT

O. O. Yarbrow and S. M. Babcock

A dual wavelength method is being tested for the measurement of uranium in streams where solvent degradation can adversely affect absorbance methods. A novel method is under study for measuring low levels of uranium in aqueous streams. The method is a combination of electrochemical and spectral analysis. Work is continuing on techniques to enhance the high-level uranium photometer. All materials are on hand, and the software is complete for the photometer to be fabricated for field testing on the centrifugal contactors at the Savannah River Plant.

1.7 HTGR FUEL REPROCESSING

W. S. Groenier

Detailed design and expedited procurement was started to provide a separate bed, fines-burner system to complement the United States-Federal Republic of Germany (US-FRG) primary burner test program.

The rotary screw dryer to be used for silicon carbide (SiC) hull-dryer tests is being installed.

A draft report was completed on the reprocessing research and development requirements and costs imposed by the new high-temperature gas-cooled reactor low-enriched uranium (HTGR-LEU) fuel. The R&D costs were increased by about 5%.

The conceptual design of a 21-element rail cask for shipping spent HTGR-LEU fuel has been completed. The design meets the requirements for unrestricted railroad interchange.

2. Process Development

W. S. Groenier and D. J. Crouse

Process development activities provide processing parameters and recommended materials of construction for both the Integrated Equipment Test (IET) facility and future demonstration facilities. The use of partial partitioning in solvent extraction flowsheets is being evaluated at ORNL in the Solvent Extraction Test Facility (SETF), which has an irradiated fuel capacity in the kilogram-per-day range. The product conversion program is establishing methods for converting U-Pu nitrate solutions to mixed oxide (MOX) products suitable for pellet fuel fabrication. Candidate materials of construction have been evaluated in experimental corrosion studies.

Cooperative work in the product conversion program at Hanford Engineering Development Laboratory (HEDL), Pacific Northwest Laboratory (PNL), and the Exxon Nuclear Company is now included in the Consolidated Fuel Reprocessing Program; progress of that work is reported.

2.1 SOLVENT EXTRACTION TEST FACILITY

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

The Solvent Extraction Test Facility (SETF) is a contained mixer settler facility designed to (1) demonstrate the suitability of conceptual flowsheets for the solvent extraction processing of irradiated light-water reactor (LWR) and breeder reactor 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.

The new titanium evaporator which will be used to concentrate plutonium product solutions for recycle was tested, calibrated, and installed in the SETF tank pit. A stainless steel evaporator used previously for this purpose corroded appreciably. Processing operations during the past quarter were limited to solution transfers and decontamination activities associated with the evaporator change.

2.2 PRODUCT CONVERSION

R. E. Norman

This task focuses on the development of engineering technologies for converting U-Pu in nitrate process streams to solid oxides suitable for fuel pellet fabrication. Two product conversion methods, gel-sphere

and direct thermal denitration, were selected for development at ORNL. During FY 1980 and FY 1981, emphasis was placed on the evaluation of gel spheres as a direct-press spheroidized (DIPRES) feed for fast breeder reactor pellet fabrication. At the end of FY 1981, a three-laboratory (ORNL/HEDL/PNL) joint decision was made that the DIPRES concept should continue in the lead role of the joint conversion/fabrication development program in FY 1982. Work at ORNL in FY 1982 is totally committed to this concept.

2.2.1 Gel-Sphere Conversion Development

The gel-sphere conversion process utilizes internal gelation in the preparation of $\text{UO}_2\text{-PuO}_2$ spheres. An ammonia donor and a complexing agent are mixed with the heavy-metal nitrate solution at a temperature near 0°C to form a broth. Gelation of broth droplets occurs rapidly in a heated immiscible liquid. Previous work on this process under the Fuel Refabrication and Development Program provides a good base for specific equipment concepts and technology required for preparation of mixed oxide spheres in a reprocessing plant. The U-Pu gel-sphere conversion studies are a joint effort with PNL and HEDL for DIPRES fuel pellet development.

Chemical Flowsheet Development

M. H. Lloyd, J. L. Collins, R. L. Fellows, S. H. Shell, D. W. Newman, and W. B. Stines

Studies to relate gel-sphere preparation methods and sphere drying and heat treatment methods to product properties and pellet pressing behavior have continued, and results have been promising. Techniques developed during these studies have led to the first successful examination of dry gel-sphere microstructures by microscopy. A variety of uranium gel-sphere products have been examined by microscopy and x-ray scattering during the work. These results indicate a definite relationship between crystallite shapes, size and size distribution, and void size and shape distribution.

Process and Equipment Development

A. D. Ryon, P. A. Haas, A. L. Rivera, S. M. Robinson, V. L. Fowler, R. C. Lovelace, R. D. Arthur, and W. B. Stines

Equipment development for the engineering line in Bldg. 3503 was continued. The combination sphere-formation and aging column was modified to improve

particle discharge in the silicone oil. The continuous washer was tested for removal of silicone oil from the gel spheres using trichloroethylene (TCE). Gel particle flow was well controlled, and both liquid-solid contact and removal of the silicone oil appeared to be good. A belt separator system for the sphere-TCE separation has been fabricated, and the aqueous ammonia wash column has been installed in a well in the cubicle floor to provide the elevation differences needed for gravity flows. Preliminary testing of interface detection devices was made to determine methods for automatically controlling the flow rate of spheres through the continuous aging, rinsing, and washing systems. Results indicate that promising methods are available for further testing.

Progress was made in defining a suitable flowsheet for preparing UO_3 spheres in continuous equipment. For gelation in silicone oil, washing with TCE and drying in the continuous belt dryer, UO_3 gel spheres of acceptable visual appearance and bulk density were prepared at two different conditions. The second condition provided better sinterability test results for fabricating UO_2 pellets and can also be used with TCE as the gelation medium.

Binary mixtures of a dense and a light organic liquid as gelation media would allow selection of an optimum density and perhaps other optimum properties. Therefore, a proposed set of selection criteria was prepared and initial work completed with a binary mixture with promising results.

Building 3019 Gel-Sphere Facility

F. E. Harrington, B. C. Finney, F. L. Daley, C. C. Haws, C. W. Boatman, and V. L. Fowler

A facility is being readied in Bldg. 3019 to prepare kilogram quantities of mixed heavy-metal (U-Pu) gel spheres suitable for pellet preparation by the DIPRES process.

Cold testing of the feed preparation and sphere-forming glove boxes, using uranium, was successfully completed. Several feed preparation, sphere-forming, and washing and drying runs were performed. These runs allowed definition of the required times for performing each operation.

Based on these results and those from the checkout of the remaining process and service systems using water and/or nitric acid, the operation of the Bldg. 3019 gel-sphere facility has been satisfactorily demonstrated.

2.2.2 Interface Activities

The major interface activity during the past quarter was on the preparation of a joint (ORNL/HEDL/PNL) development plan for continuing work on the DIPRES concept. A meeting was held with HEDL and PNL technical and management personnel to finalize this plan (including cost projections) and agree on the FY 1982 work scope. The joint development plan submitted to the DOE in early April proposes a five-year, \$18-million effort to qualify DIPRES feed.

2.2.3 DIPRES Fabrication Process Development

M. C. J. Carlson (Hanford Engineering Development Laboratory)

Fabrication studies are directed toward the development of a pellet fabrication process using DIPRES feed prepared at ORNL. Laboratory-scale work concerned with initial flowsheet definition is being performed at PNL, and scale-up studies are being performed at HEDL.

Process Development

**C. W. Griffith and P. E. Hart
(Pacific Northwest Laboratory)**

A major ongoing effort is concerned with identifying calcination conditions that yield good press feed and are amenable to continuous operations. A two-step calcination process has emerged from these studies with DIPRES MOX dry gel-sphere feed. The process appears to provide a stable product suitable for shipment and storage following DIPRES feed powder preparation.

Process Scale-Up

**D. E. Rasmussen
(Hanford Engineering Development Laboratory)**

Modifications to a full-scale calcining furnace and fabrication of a modified calcining boat were completed. Design of a full-scale single-cavity press utilizing die-wall lubrication is in progress following successful low-throughput tests.

The draft MOX DIPRES specification was updated based on process experience over the past year. Analytical procedures supporting the specification were drafted and submitted to program participants for review.

2.2.4 Sphere-Pac Fabrication Studies

**D. C. Killian, S. S. Koegler, and L. D. Genald
(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 emphasis of the work is to convert a series of batch operations developed at ORNL into a continuous process suitable for sphere-pac fuel production.

Design and fabrication of various equipment components for the continuous 100-kg/d U gel-sphere line continued. Fabrication was completed on the prototype continuous fines filter. Design and fabrication was completed on the TCE sphere separator, and work continues on the design of a continuous belt washer (~90% complete). Installation of the mechanical and electrical components of the continuous sphere dryer is in progress. The continuous 100-kg/d U sphere production line, from sphere forming through sphere drying, should be operational in the next few weeks.

A series of tests to establish the acceptable operating window for producing mono-sized large spheres was completed. Additional tests will be necessary to achieve a better resolution of this window and to better establish the allowable range of sphere forming nozzle diameters. The data scatter also indicates a need for improved control accuracy for the nozzle vibration instrumentation.

3. Laboratory R&D

W. S. Groenier and J. H. Shaffer

Laboratory research and development activities provide basic studies on proposed processing steps and explore new process options. An emphasis is placed on solution properties in dissolution and solvent extraction steps, and attention is being given to several aspects of plutonium chemistry and solvent extraction technology. Hot-cell and glove box activities examine the processing properties of a variety of fuel materials and include solvent extraction process testing. New analytical methods for process control are being developed and adapted where possible for high-level gamma operations.

3.1 LABORATORY DEVELOPMENT

J. T. Bell

Laboratory development activities have been concerned with basic studies of plutonium chemistry and fission product behavior in aqueous process streams. The development and evaluation of cleanup processes for degraded organic solvents was also pursued.

3.1.1 Plutonium Polymerization

L. M. Toth and M. M. Osborne

Polymer studies have concentrated on the depolymerization of aged polymer preparations. The major cause of differences in stability observed between polymer preparations lies not with the room-temperature NaOH precipitation operation but with the reflux rate used when aging the polymer. Polymer held at the reflux temperature with minimal boiling and condensate formation ages far less than that held at the same temperature with high reflux rates.

The effect of solution acidity on plutonium polymer aged in 0.1, 0.3, and 0.5 *M* HNO₃ solutions at 100°C in sealed capsules was examined by depolymerization experiments in 5 *M* HNO₃ at 95°C. Plutonium (IV) polymer aged in 0.5 *M* HNO₃ depolymerized at slower rates than a corresponding polymer aged in 0.1 *M* HNO₃. This phenomenon can be explained by the change in PuO₂ crystallite size that occurs during the aging process.

3.1.2 Solvent Cleanup

**O. K. Tallent, J. C. Mailen,
K. D. Pannell, and C. T. Thompson**

Solvent degradation products that are formed by chemical degradation of the diluent and produce major deleterious effects on solvent extraction operations are primarily long-chain organic acids and esters formed by reactions with alcohols. The esters have been observed by gas chromatographic analyses of chemically degraded solvent, and both acids and esters have been detected

by titration. Solvent from the Savannah River Plant also contained esters and dissolved sodium salts of the long-chain acids. Although the esters probably do not interfere directly with solvent extraction operations, they are very difficult to remove and will continuously hydrolyze to form acids. The long-chain acids impair phase separations in sodium carbonate scrubbers by forming their sodium salts (soaps). These salts are not normally removed by standard scrubbing systems in which the organic-to-aqueous phase ratio is high. Uranium and probably other cations may also form laurate compounds that can be extracted into the organic phase as, for example, tributyl phosphate complexes in which laurate ions displace nitrate ions. The effects of these metal-ion, long-chain-acid salts on solvent extraction operations are under investigation. Argon sparging, which has been shown to decrease the overall degradation of tributyl phosphate-normal paraffin hydrocarbon (TBP-NPH) solvent by HNO_3 and HNO_2 , may also limit the formation of these long-chain acids and esters.

3.1.3 Fission Product Studies

D. J. Pruett and D. R. McTaggart

Experimental studies of the enhanced extraction of technetium by TBP in the presence of thorium have been completed. The pertechnetate anion exchanges for a nitrate ion in the organic phase to form complexes such as $\text{Th}(\text{NO}_3)_3 \cdot \text{UO}_2 \cdot 2\text{TBP}$. Analysis of the extraction data is not fully completed, but it appears that the distribution coefficient of technetium in the presence of thorium can be calculated from the following equation:

$$D_{\text{Tc}} = -0.560 + 1398/T + 0.921 \ln [\text{Th}]_{\text{org}} - 0.780 \ln [\text{NO}_3^-]_{\text{aq}}$$

This equation was developed for temperatures between 298 and 333 K, nitric acid concentrations of 0.1 to 4.0 M, and aqueous thorium concentrations of 0.05 to 0.2 M. The coefficients may change slightly as final refinements are made in the data analysis. A similar correlation has been developed for rhenium extraction, which serves as an excellent model for technetium behavior.

Studies of the mixed Pu(IV)/Tc(VII) system have been carried out in a manner similar to those described above for the Th(IV)/Tc(VII) system. However, unexpected problems were encountered in the simultaneous analyses of plutonium and technetium by x-ray fluorescence. Although alternate analytical methods have not produced accurate quantitative results, it is clear that the effect of Pu(IV) on technetium distribution is qualitatively similar to that of Th(IV).

Preliminary results of a study of the effect of reductants on technetium distributions indicate that 0.1 M hydroxylamine nitrate has no effect on distribution coefficients in the system 0.5 M HNO_3 –0.005 M KTcO_4 –0.5 M $\text{UO}_2(\text{NO}_3)_2$ –30% TBP-NDD at 20°C, or the system 0.1 M HNO_3 –0.005 M KTcO_4 –0.1 M $\text{UO}_2(\text{NO}_3)_2$ –30% TBP-NDD at 50°C.

3.1.4 Fuel Dissolution

D. J. Pruett, J. C. Mailen, and D. R. McTaggart

A series of dissolution tests on pellets pressed at Pacific Northwest Laboratory (PNL) from sol-gel and mechanically blended mixed oxide feed stocks has been completed. Four pellets of each type (all 25% PuO_2 –75% UO_2) were dissolved using the Parkinson test (7 M initial nitric acid concentration, 8 h reflux, and 3 M final nitric acid concentration). All eight pellets dissolved completely, leaving no measurable residues.

A few experiments were carried out to determine the minimum dissolution time using the same chemical conditions as the Parkinson test. In duplicate tests with pellets from two batches of sol-gel derived pellets and one batch of mechanically blended mixed oxide pellets, dissolution was complete in 4 to 5 h. Approximately 6 h were required to dissolve a second batch of mechanically blended mixed oxide pellets. The reason for this difference is not clear.

3.2 HOT-CELL DEVELOPMENT

D. O. Campbell

The hot-cell development task includes tests of solvent extraction flowsheet options in alpha-contained pulsed column equipment at SRL and specific tests in

hot cells using irradiated fuel samples to study various reprocessing operations. This program places an emphasis on fuel solubility and insoluble residue characterization using newly developed hot-cell analytical capabilities.

3.2.1 Solution Stability and Solids Characterization

D. O. Campbell, J. H. Goode,
J. W. Roddy, and P. C. Arwood

Dissolution of (U,Pu)O₂

A series of experiments has been initiated to ascertain the feasibility of electrolytic oxidation as a technique for the catalytic dissolution of residual plutonium following a nitric acid leach of mixed oxide fuel. Scouting tests were performed in a compartmented cell using 6 M HNO₃ to determine the dissolution characteristics of refractory fission products in the residue represented by ruthenium metal, ruthenium dioxide, and a mixture of platinum family metals. The tests were made in the presence and absence of 0.005 M silver. When silver was present as a catalyst, all materials dissolved more readily and ruthenium volatilization was observed.

Solids characterization

Studies have been initiated to evaluate the effect of centrifugal forces on the clarification of dissolver solutions. Preliminary results from the first three tests indicate that there is little difference in the amount of residual material remaining suspended in solution after being subjected to forces varying between 500 and 1000 G for 30 min. Additional experiments will be made to substantiate these conclusions and to verify the testing procedure.

Fuel procurement

Arrangements were made for the procurement of irradiated LWR fuels for hot-cell dissolution and solids characterization studies. The fuels have been irradiated to burnups ranging from 35 000 to 60 000 MWd/t and have been collected from four different reactors. They will be supplied through Savannah River Laboratory after receiving them from Babcock and Wilcox and Battelle-Columbus Laboratories. A July delivery is expected.

3.2.2 Pulsed Column Facility

H.D. Harmon, M.B. Hughes, M.E. Hodges, and D.J. Reif
(Savannah River Laboratory)

A pulsed column run to coprocess uranium and plutonium using hydroxylamine nitrate (HAN) as the plutonium reductant has been completed. The plutonium concentration simulated a breeder fuel level, and although gas evolution from the reduction was obvious in the partitioning column, operation was acceptable.

The simulated breeder reactor feed for the run contained 16 g/L Pu and 130 g/L U in 3 M HNO₃. One-fourth of the extraction column (2-m cartridge section) was used for acid scrubbing with 0.3 M HNO₃. Uranium extraction was essentially complete but plutonium loss to the raffinate was relatively high, apparently because a significant amount of the Pu in the feed was hexavalent. The partial partitioning column was fed with a HAN-N₂H₄-HNO₃ strip solution and the organic extract from the extraction column. The Pu/HAN ratio in the column was about 1.2. Phase disengagement appeared normal and gas pockets did not form beneath the column internal plates. Gas evolution was calculated to be $\sim 37 \text{ L min}^{-1} \text{ m}^{-2}$ ($\sim 0.12 \text{ cfm/ft}^2$). The product stream was enriched to 21% Pu, and Pu loss to the organic stream was $\sim 0.5\%$.

Two additional runs were made following the partial partitioning run to recover uranium and plutonium from the organic and aqueous waste streams for recycle. The recovered metals from all three runs were recombined and concentrated for use as feed in future runs.

3.3 ANALYTICAL DEVELOPMENT

D. A. Costanzo

This task is concerned with the development of analytical methods, equipment, and support facilities for the overall program. Included are (1) the development of chemical, nuclear, radiochemical, x-ray fluorescence, and mass spectrometry methods suitable for high-burnup, highly radioactive fuel; (2) the remotization and automation of analytical equipment; and (3) the development of sampling requirements, mechanisms, and laboratory investigations to support future demonstration facility design studies.

3.3.1 X-Ray Fluorescence (XRF)

Systems Development

J. H. Stewart, Jr.

The central anode wire for the linear position-sensitive detector in the proof-of-principle x-ray spectrometer failed and required replacement. The repaired detector has been reinstalled. The x-ray generator and silver target x-ray tube are now to be optically aligned with the spectrometer to permit a full-scale test of the system.

The updating of the Building 3525 scanning electron microscope to permit quantitative XRF analyses of metal alloys has continued. The new computer disk drives were installed, and a test of the entire XRF system is under way.

3.3.2 Spark-Source Mass Spectrometry (SSMS) Development

J. R. Sites and J. A. Carter

The ORNL-prepared laboratory standard designated SF-7-9 is a mixture of fission product elements of natural isotopic abundances. It has been used for SSMS analyses to determine the sensitivities of the fission product elements relative to erbium. Erbium has been employed extensively over the past several years as an internal standard in SSMS investigations.

Use of the generated sensitivity values when analyzing breeder fuel dissolver residue samples results in relative isotopic abundances for Nd, Ce, Te, and Zr

that are consistent with ORIGEN code calculations. Values for Cs and Sr are somewhat erratic. Apparently, Ba, Sm, Mo, and Pd have isotopes that are significantly out of line. Even after considering possible isomer problems, Ba-137, Mo-96, and Sm-148 values remain much too large, and Sm-152 and Pd-106 values are too small. It was observed that the insoluble residues are essentially all Mo and Pd, with smaller amounts of the rare earth elements.

3.3.3 Hot-Cell Analytical Instrumentation

L. N. Klatt

The first phase of a laboratory evaluation of the remote titrator has been completed. Performance of the prototype hardware and the software systems was evaluated using the titration of several acids with standard NaOH solution. Based on collected data, a precision and accuracy $\leq 0.05\%$ can be achieved if the equilibrium constant for the titration reaction is $\geq 10^8$. A typical titration requires 70 to 100 data points and is completed in ~ 5 min, including plotting of the data, calculating the end-point volume, and outputting relevant sample information.

Other activities completed include the design of a signal conditioning circuit required for an amperometric end-point detection system, design and fabrication of intermodule cabling, and fabrication of a remotely operated elevator for positioning the titration vessel under the titrant delivery tube and sensing electrodes.

4. Engineering Research

W. S. Groenier and J. H. Shaffer

The engineering research studies represent the first phase of the equipment development program and provide a basis for further design and development of specific engineering test components. Emphasis is placed on the identification, study, selection, development, and characterization of unit processes through the application of basic or fundamental experimental engineering techniques.

Studies of the dissolution, feed preparation, solvent extraction, and off-gas treatment processes are in progress, and development efforts are described.

4.1 DISSOLUTION

F. E. Weber

The objective of this task is to develop the technology for the dissolution of liquid-metal fast breeder reactor fuels in nitric acid that will provide high metal recoveries and maximize the volatilization of iodine from dissolver solutions. Nuclear criticality and off-gas control considerations are two of several important factors that have led to the selection of continuous dissolving methods for breeder fuels. A compartmentalized rotary dissolver will be demonstrated in the Integrated Equipment Test (IET) facility as a primary dissolver. The development of a method for providing solids agitation in a downstream digester tank is emphasized in the current development effort. A material balance model for compartmentalized rotary dissolvers is also being developed.

4.1.1 Solids Suspension Tests

B. E. Lewis and J. F. Lockmiller

The digester tank test stand was fabricated to study various means of suspending solids in simulated digester operation. Start-up tests on the 2.3-m-tall prototypic height digester tank have concentrated on the development of an air-lift device for solids suspension. These tests will establish a reliable operating procedure and an air outlet design that will ensure lift startup. Four air outlet designs have been tested using water and large (1190 to 4750 μm) stainless steel particles. These constitute the air outlets used in the multi-air supply pulsed lift tubes.

The first design, an open pipe cut perpendicularly to its axis, did not function satisfactorily at lower air flows and smaller gaps between the lift tube and tank bottom. The second design involved sealing off half of

the air outlet to increase the velocity of air leaving the tube. Although this was more successful than the first design, start-up performance was still unreliable. The third design, which had a sealed end and a 6-mm by 1.5-mm slit in one side for an air outlet, experienced some difficulty in initiating solids suspension when the large stainless steel particles were allowed to pack into the lift tube.

The fourth and present design is one with a 0.16-cm (1/16-in.)-diam air outlet hole at the bottom of a 3/8-in. IPS sched 40 pipe (1.25-cm ID by 0.23-cm wall). The hole in each of the three air supply tubes is drilled at a 30° angle to the horizontal and oriented ~5° from the center of the tank. This configuration induces a swirling motion to the liquid at the bottom of the tank and improves solids movement.

Blockage removal tests were conducted in which the lift tube was deliberately plugged using 450 g of stainless steel particles and 120 g of 2.54-cm-long spacer wires. In general, a plug in the bottom of the lift tube could be removed by air supplied by the present three-tube design in less than 5 min using pulsed air flows greater than ~94 L/min. As expected, higher air flows remove plugs more quickly. A faster method for removing a plug in the lift tube required the use of a pulsed air flow greater than ~58 L/min down the central jet suction line. This method for plug removal might be preferred since it requires considerably less air. However, a valve is required on the discharge side of the jet to allow air admittance to the digester tank. The disadvantage of valve reliability probably outweighs the advantage of any air savings realized during plug removal over the life of the tank.

Solids suspension tests in the 2.3-m-tall prototypic height digester tank have also been completed using 20 g/L tungsten particles (<88 μm) in water. The initial tests were made at air flows of ~61 and 81 L/min. Analyses of samples taken from the tank indicated that only 76 to 78% of the solids were suspended. These values were decidedly less than those attained in earlier experiments with a shorter tank. This anomaly has been attributed to a blockage in one of the three air supply lines used for the lift tube. A small fragment of stainless steel from the previous experiment had become lodged in the air outlet hole of one of the air

supply lines. The blockage probably occurred during installation of the lift tube into the tank containing a bed of settled solids. With the air supply line unplugged, the average quantity of solids found in suspension increased to ~88%.

A preliminary study of instrument response during liquid level and density measurements using water and large stainless steel solids has shown that the pulsed air lift operation has relatively little effect on the level readings. Variations of only 1.3% of full scale were noted when the end of the level probe was located at the bottom of the lift tube. However, it was necessary to raise the density probes ~30.5 cm above the end of the lift tube to decrease the deviation of density measurements to 1.3% of full scale during normal operation of the tank. With tungsten solids in the tank, density deviations of ~3.4% of full scale were observed. During the blockage removal tests and while the lift tube was plugged, deviations for the density readings ranged from 8 to ~20% of full scale for all elevations studied. This condition could be used as a means of detecting lift tube blockage.

4.1.2 Concentration Profile Studies

B. E. Lewis

A computer 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 is useful for (1) predicting dissolver performance under upset conditions for control purposes and (2) providing information for criticality calculations.

The unsteady-state continuous rotary dissolver material balance code (USSCRD) has been modified to incorporate operation of the isolation valve. An isolation valve simulator is used in the code to denote breakup of the continuous solids feed into discrete units of mass based on an input cycle time for valve operation.

Significant cost savings have been realized by reducing the number of particle size groups (for which the model must account) from 500 to 20. However, this change may have introduced errors into the code. At the end of a simulated run, the sum of the stage inventories of heavy metals was less than that predicted

by the difference between total mass fed and total mass discharged. The discrepancy appears to be directly related to the predicted rates for particle dissolution in each particle size group. Attempts are being made to further determine the source of these errors.

4.2 FEED PREPARATION

W. S. Groenier

The fuel solution discharged from the continuous dissolver system will contain solids (undissolved fission products, corrosion products, etc.) and will require clarification prior to solvent extraction. Preparation of the aqueous feed for solvent extraction includes additional conditioning steps, such as adjustment of the plutonium valence and the nitric acid concentration, and treatment to remove iodine. This task also encompasses the development of secondary dissolution of fuel constituents not soluble in the primary dissolver system.

Present emphasis includes tests of an improved extractive distillation system that provides hyperazeotropic nitric acid for the Iodex off-gas treatment process, as well as development of fluidic pumping technology and feed clarification methods.

4.2.1 Extractive Distillation of Nitric Acids

R. T. Jubin and L. S. Woods

The system under investigation represents a simplified concept for the concentration of nitric acid by extractive distillation. This step converts low-strength nitric acid to the hyperazeotropic concentrations necessary for the Iodex process. The current two-pot experimental system uses $\text{Mg}(\text{NO}_3)_2$ as a dehydrating agent.

The computer code which uses the empirically correlated equilibrium data for the $\text{Mg}(\text{NO}_3)_2\text{-HNO}_3\text{-H}_2\text{O}$ system showed problems in extrapolating these data into the 150 to 170°C temperature range. Consequently, a limited study has been undertaken to develop a thermodynamically consistent equilibrium model for this system. This involves gathering some additional data in the range of interest.

The work to obtain density data for the three-component system has been completed. Initial modeling of these data has begun.

4.2.2 Fluidic Pump Development

R. M. Counce, G. V. Smith, and L. S. Woods

Fluidic pumps offer advantages for the movement of radioactive fluids. One major advantage is the feature of no moving parts being exposed to the liquid phase. Fluidic pumps utilizing a reverse-flow-diverter (RFD) and producing a pulsatile flow have been developed and are now ready for process application. Some experimental work on the variation of RFD design for the pulsatile flow unit has continued, but the emphasis of fluidic pump development is shifting to units that provide a steady flow.

Potential designs for steady-flow pump units require flow junctions for merging the flows from two or more pulsatile RFD units. Much of the previous RFD work will be useful in steady-flow pump development, but further development needs are anticipated. Experimental studies have recently verified flow junction design calculations. Future activities will address integration of the RFD and flow junction experimental information into a mathematical model for a steady-flow fluidic pump. This model will be used to refine the steady-flow pump design and guide further development.

4.2.3 Feed Clarification Equipment Development

H. D. Harmon, L. R. Austin,
M. E. Hodges, and G. C. Rodrigues
(Savannah River Laboratory)

Studies are under way at Savannah River Laboratory (SRL) to evaluate alternatives for clarification of dissolver solutions for subsequent solvent extraction operations. This activity uses both nonradioactive solutions and dissolved light-water reactor (LWR) fuel solutions to test alternative equipment.

Arrangements were completed to obtain high-burnup, short-cooled LWR fuels. These fuels will provide feed material for bottle centrifuge studies to determine the variation in settling velocity of the residues obtained from dissolution of different fuels. Interfacial solids formation on contact with a Purex solvent will also be examined with these fuels. Babcock and Wilcox will provide four-cycle Oconee-1 fuel with 40 000 MWd/t burnup and cooled 2.5 years. Battelle-Columbus Laboratories will provide three different fuels (each cooled for two years) — Calvert Cliffs

(45 000 MWd/t), Monticello (60 000 MWd/t), and Quad Cities-1 (35 000 MWd/t).

4.3 SOLVENT EXTRACTION

M. E. Whatley

The development of solvent extraction techniques for the Purex process recovery of advanced fuels has been conducted at several sites. The primary objective of an activity at the Argonne National Laboratory (ANL) has been to design, fabricate, and test annular centrifugal contactors of critically safe dimension. At ORNL, efforts are under way to improve and apply the SEPHIS and MATEX computer codes for flowsheet engineering studies. Additional work is being completed at the General Atomic Company (GA) on pulsed column contactor improvement studies.

4.3.1 HTGR Solvent Extraction System

G. E. Benedict (General Atomic Company)

Thorium-Uranium Coextraction

D. R. Engler

A topical report is being prepared on the results of the pilot-plant pulsed column tests of uranium and thorium coextraction, in which possible interactions of the two heavy metals were studied.

4.4 OFF-GAS PROCESSING

R. T. Jubin

This task develops various processes for the treatment of off-gases from reprocessing spent nuclear reactor fuels. Work includes the continued development of the noble gas and ^{14}C selective absorption process and the formulation of plant engineering design criteria. The use of solid sorbents for various off-gas purification applications is also being evaluated. Tests of advanced sorbent materials are under way at ORNL, and work on an integrated high-temperature gas-cooled reactor (HTGR) off-gas treatment system is proceeding at GA.

4.4.1 Fluorocarbon Absorption Process Development

D. K. Little, R. S. Eby, and J. L. Patton (ORGDP)

Current product purification tests involve the verification of R-12 removal in 13X molecular sieve, CO_2 in 5A molecular sieve, and xenon in silver mordenite. During loading studies, the beds were not cooled. As a result, bed temperatures increased as

much as 33°C (60°F) with both CO_2 and R-12 loading on 5A and 13X sieves respectively. Loadings of xenon on silver mordenite showed little or no temperature increase. Estimated bed loadings (% of bed weight) prior to breakthrough were 14% for R-12 on 13X, 17% for CO_2 on 5A, and 8.8% for xenon on silver mordenite.

A paper entitled "Single Column Based Absorption Process for Treating Dissolver Off-Gas" was presented at a workshop on dissolver off-gas at Karlsruhe, Germany. Performance summaries, emphasized in krypton concentration profiles, showed that decontamination factors (DF's) as high as 500 were obtained simultaneously with concentration factors (CF's) of $\sim 10^3$. The effects of xenon, CO_2 , and gas flow rate on the DF were also included. Lastly, the current proposed product purification system was presented in its updated form. This system utilizes solid sorbents for specific gas removal and concentration.

4.4.2 Integrated Hot Off-Gas Facility

H. D. Harmon, M. E. Hodges, A. L. Blancett,
M. C. Thompson, and R. C. Waggoner
(Savannah River Laboratory)

A report entitled *Engineering Design of Integrated Hot Off-Gas Facility* was issued as the final document on the original program. Writing continues on a report covering an economic and engineering analysis of three major processes for removal of ^{85}Kr .

4.4.3 Solid Sorbent Tests

R. T. Jubin and J. D. Randolph

There are several locations within the Demonstration Reprocessing Plant (DRP) reference flowsheet where solid sorbents are being proposed to treat off-gases. Sorbents, such as metal-substituted mordenites, are being evaluated for those applications.

Tests have been conducted to evaluate the methyl iodide loading performance of low silver-exchanged mordenites (LAgZ). Silver utilization of this material is $\sim 100\%$ under many loading conditions, whereas with fully exchanged silver mordenite (AgZ), silver utilization is $\sim 60\%$. The scoping studies to evaluate the effects of silver content showed a marked decrease in silver utilization above the 5% level. This decrease was later linked to a new shipment of sodium mordenite, which was the base material for the 9% LAgZ.

The manufacturer of this sodium mordenite indicated that the material came from the first production run at a new facility and may have been off-specification. Efforts are now under way to determine the nature of the differences between the NaZ, which achieved high silver utilization, and this new material which did not.

A paper describing development work related to the use of the LAgZ material for iodine retention has been prepared for presentation at the 17th DOE Nuclear Air Cleaning Conference.

4.4.4 Integrated HTGR Off-Gas Treatment System

**G. E. Benedict and L. Abraham
(General Atomic Company)**

Iodine Removal Test

P. M. Hirsch

A seven-day continuous run was completed to obtain an iodine breakthrough curve in the engineering-scale silver-exchanged mordenite (AgZ) solid sorbent bed. Data obtained in this run will determine the loading capacity of AgZ in the primary iodine adsorber.

Simulated Dissolver Off-Gas (DOG) Treatment/ Component Integration Test

L. Abraham and P. M. Hirsch

A 12-h continuous test was conducted with simulated dissolver off-gas using a condenser/demister, an NO_x converter, primary (AgZ) and back-up (AgX) iodine adsorption beds, and a molecular sieve moisture adsorber. The purpose of the test was to observe the performance of the off-gas treatment system under extended near steady-state conditions. All process components provided decontamination or conversion efficiencies in excess of design requirements.

Several thermocouples monitoring the NO_x converter temperature profile failed during the run. Failure was clearly attributable to long-term corrosion (probably from I₂ and H₂O) of the Inconel-600 thermocouple sheaths. Consequently, all NO_x converter thermocouples have been replaced with titanium-sheathed thermocouples. Titanium was chosen over other suitable sheath materials (e.g., Inconel 625, zirconium, or Hastelloy C) because of much shorter delivery time.

Dissolver Off-Gas Treatment System Integration Tests **L. Abraham, K. Y. Higuchi, and P. M. Hirsch**

The first two of a planned series of tests have been completed. The DOG treatment system included

series operation of the 0.5-m-diam dissolver, an NO_x scrubber, a condenser/demister, a compressor, and an NO_x converter.

The initial run served as a shakedown of the integrated system to identify and correct operational or component problems. A Diogenes* microprocessor process control loop was subsequently set up to maintain constant dissolver operating pressure by employing a recirculating flow system through the DOG compressor. Diogenes was also programmed for automatic control of the ammonia feed to the NO_x converter by continuous monitoring of incoming NO_x concentration and DOG flow rate.

Following incorporation of these modifications, the second run was carried out. The off-gas treatment system DF for NO_x conversion exceeded 1000 throughout the run. Maximum NO_x concentration in the scrubber effluent gas stream was about 5500 ppm, and the DOG effluent from the NO_x converter contained <3 ppm NO_x throughout the run. Because of a suspected microprocessor interfacing problem, the ammonia supply to the NO_x converter had to be manually controlled. No ammonia breakthrough from the converter was observed in this test.

4.4.5 Iodex Column Tests

B. E. Lewis and J. G. Morgan

The Massachusetts Institute of Technology Practice School team has completed its project entitled "Transport Evaluation of a Gas-Liquid Scrubber" and is preparing a final report for publication. The abstract of this report follows:

A five-tray, single bubble-cap, single downcomer gas-liquid contactor was studied for use as a gas scrubber. Hydraulics and mass transfer studies were carried out on the column. Flooding was not observed even at the maximum available liquid and gas flow rates of 0.32 and 464 L/min respectively. The maximum liquid entrainment observed was 33% at a total gross liquid flow rate of 0.05 L/min. Absorption studies using dilute CO₂ in air (0.05%) and demineralized water gave Murphree tray efficiencies of 0.14 to 0.74 and $k_L a$ values of 0.088 to 0.35 min⁻¹ for L/G ratios of 4 X 10⁻⁴ and 2 X 10⁻⁴ respectively.

*Trademark of Rosemount, Incorporated.

5. Engineering Systems

M. J. Feldman

The scope of the work performed in the area of Engineering Systems includes the development of prototype equipment and conceptual design and studies for breeder reprocessing facilities. The design of prototype equipment is based on other research and development efforts, primarily those of the Process and Engineering Research & Development Section of the CFRP. These efforts include 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 equipment and systems will be derived from these development efforts. Work is also being conducted in the areas of safeguards, nuclear engineering, and environment and safety. These areas are in support of the equipment, systems, and conceptual design efforts.

5.1 ENGINEERING STUDIES AND ANALYSIS

J. G. Stradley

The various studies reported in this section are not specific to any one functional research and development area but are important to the overall fuel reprocessing program. Specific generic areas being studied are safeguards, nuclear engineering, and environment and safety. Other studies involve analyses in broad areas that overlap individual tasks and provide background and recommendations for decisions pertaining to programmatic guidance and direction.

5.1.1 Engineering Analysis

US/UK Exchange Agreement Subtask: Mechanical Head-End, Heat Generation, and Heat Transfer
M. J. Haire, J. C. Ryman, and T. D. Welch
C. A. Rhodes (University of South Carolina)

The United Kingdom is measuring concentrations of important nuclides and the heat generation rate in irradiated Prototype Fast Reactor (PFR) fuel. This data will be used to validate calculations made with the U.S. ORIGEN code. The U.S. COXPRO code will be used to calculate discharged PFR fuel assembly temperatures in a stagnant gas environment utilizing

the heat source term from the decay heat calculations. The COXPRO code has been modified to give it the capability of accounting for thermal conduction in the gas-phase environment of a fuel reprocessing cell. Irradiated PFR fuel assembly temperature measurements and nuclide library input data used by the UK to calculate decay heats are also expected to be received from the UK as part of the exchange agreement. Fuel assembly temperatures calculated by the COXPRO code will be compared against the UK-measured temperatures for purposes of validation. While awaiting the UK data, some analyses have been done on the Fast Flux Test Facility (FFTF) fuels utilizing the COXPRO computer code.

Temperature measurements were received on irradiated FFTF fuels from Hanford Engineering Development Laboratory. The data were collected at relatively low decay power (i.e., 308 W) in an insulated cylinder with a stagnant argon gas annulus between the fuel assembly shroud and inner cylinder surface. Preliminary analysis using the COXPRO computer code indicates that calculated temperatures are within 3% of the peak fuel assembly temperatures when a radiation emissivity value of 0.3 is used. This emissivity value assumes the fuel assembly pin surfaces are coated with an unoxidized film of sodium.

Heat Transfer Experimental Program

M. J. Haire and T. D. Welch

C. A. Rhodes (University of South Carolina)

The objective of this work is to obtain experimental information required to support the design of cooling methods for deshrouded fast breeder reactor fuel assemblies during disassembly and shearing. Experiments have demonstrated that cooling can be successfully accomplished using 1- to 10-psig supply pressures. Experiments are being conducted to verify the feasibility of motivating coolant flow using the dissolver off-gas system vacuum.

Reliability, Availability, and Maintainability (RAM) Analyses

M. J. Haire

A framework for RAM data acquisition for component development, test stands, and the Integrated Equipment Test has been defined. Specifically, the format for acquiring three types of data has been

defined. Inventory and technical data describing the equipment will be compiled when the design is finished or the equipment is received. Forms have been designed for collecting maintainability information. Emphasis is now being placed on defining tests and data analysis programs and on the development of analytical models for assessing reprocessing facility availability.

5.1.2 Nuclear Engineering

R. T. Primm III

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

PNL Critical U+Pu Solution Experiments

R. C. Lloyd (Pacific Northwest Laboratory) and

R. T. Primm III

Work continued to define the analytical chemistry procedures to be used to accurately analyze the acid molarity and plutonium concentration of high plutonium content nitric acid solutions. Pacific Northwest Laboratory (PNL) has utilized the analytical laboratories at Rockwell International and at Hanford Engineering Development Laboratory in this study. In addition, standard samples (reference) have been sent to the analytical laboratories at New Brunswick and at ORNL. The results of these analyses were inconclusive so additional tests are planned.

Los Alamos National Laboratory (LANL)

U+Pu Mixed Oxide Critical Experiments

R. T. Primm III and R. E. Malenfant (LANL)

Fast breeder reactor reprocessing requires the storage of considerable quantities of uranium- and plutonium-oxide powder prior to shipment to a fuel fabrication facility. The water content (resulting from absorption of room humidity and incomplete drying) is expected to be low — less than 3 wt % water in the mixed oxide. Currently, no critical experimental data exist for very low moderated [H/(U+Pu) atom ratios <2.8] mixed oxides. Additionally, critical experimental data for arrays of oxide mixtures for various degrees of moderation are needed.

As previously reported, some work was done to establish an experimental setup suitable for obtaining the desired data. Preliminary computation efforts have

been initiated. A report describing testing of a prototype mixed oxide canister is in preparation.

Survey of Shielding Computational Methods and Data Needs

D. T. Ingersoll

Work continued on a survey to determine the status of shielding-related computational methods and data for a breeder reprocessing facility. This effort is devoted entirely to searching the open literature for papers relating to shielding and radiation protection in reprocessing plants, gamma-ray transport methods, and relevant nuclear data. When this search is completed, an appropriate shielding program will be developed and documented based on reprocessing needs, available methods and data, and economics.

Criticality Safety Evaluation of the Continuous, Rotary Dissolver

J. A. Bucholz and R. T. Primm III

Preparation of a document describing a preliminary criticality safety evaluation of the dissolver was begun this quarter. The document describes the design of the dissolver and the philosophy for ensuring subcritical operation.

5.1.3 Environment and Safety

M. B. Sears and D. W. Williams

This task provides guidance and assessment to (1) ensure that the breeder head-end reprocessing facility meets statutory health, safety, and environmental requirements, and (2) minimize the potential on- and off-site impact of the facility.

A dose calculation study has been initiated using the ORIGEN2 computer code to generate source terms. One phase of the study will employ meteorological data obtained from the Barnwell Nuclear Fuel Plant (BNFP) to evaluate the effect of a breeder reprocessing facility colocated at the BNFP.

Work was initiated on establishing a data base to support a Health and Environmental Effects Document being prepared by the ORNL Health and Safety Research Division.

5.1.4 Safeguards Task

H. T. Kerr

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. The current focus is on the development of advanced material control and accounting concepts and on planned demonstrations in the IET.

IET Safeguards Demonstrations

H. T. Kerr and J. W. Wachter

An overview document has been completed which generally describes the IET facilities and advanced safeguards concepts that could be used for meaningful demonstrations to enhance safeguards technology. These demonstrations in the IET will emphasize development of (1) near-real-time accounting and (2) process monitoring capabilities; limited attention will be given to operations monitoring and penetration monitoring. An integrated assessment capability involving these advanced concepts will be implemented in the IET.

An additional document has been completed describing preliminary detailed plans for the near-real-time accounting demonstrations in the IET. Proposed measurements and accounting strategies were identified, and an assessment was made to determine if additional measurements and instruments were required for each strategy; no additional items were identified.

Microscopic Process Monitoring (MPM)

J. W. Wachter and T. L. Hebble

Some limitations were observed in earlier MPM developments because simple linear predictors were used for all process variables. Consequently, an assessment was made to determine if other predictive models were more appropriate for different types of process variables. The assessment revealed that the MPM capability could be greatly enhanced by using improved predictors for some types of variables.

Near-Real-Time Accounting

H. T. Kerr and T. L. Hebble

Efforts continued on the near-real-time accounting assessment utilizing the HEF conceptual design. The basic assessment for the process area has now been completed. A sensitivity study for the process area is in progress and will be completed during this fiscal year.

5.2 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 process equipment capable of being remotely operated and maintained. The dissolution and solvent extraction tasks are currently active.

5.2.1 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 maintainable rotary dissolver integrated with the support equipment necessary to provide a functional dissolution system.

Prototypical Rotary Dissolver

Removal of the dissolver and its roller support system from the component development area was completed. These components will be installed in the Remote Operations and Maintenance Demonstration (ROMD) facility. Only components requiring modification or repair were removed.

The fabrication and installation of the test stand for the GEMCO valves was completed. These valves are used to isolate the acid fumes of the dissolver from the shear components. Testing of the valves at 30° from vertical has begun. Both functional operation and leak rate deterioration will be evaluated.

Dissolver Roller Support Systems and Process Equipment

Fabrication of the new drive and roller support system is 80% complete. The new support rollers have been received from the outside contractor.

Detailed design of the piping and electrical systems required for installation of the dissolver in ROMD is proceeding. The design portion that is independent of dissolver location has been issued for approval. Because of the tight schedule, the remainder of the design has started, based on an assumed location.

5.2.2 Advanced Centrifugal Contactor Program

M. E. Hodges and M. G. Riley
(Savannah River Laboratory)

The test program with diluent and with 3 M nitric acid has been completed, and testing with 30% tributyl phosphate (TBP) and 3 M nitric acid has begun. The unit continues to show good phase separation with a wide range of operability. Satisfactory

operation has been demonstrated at 20 L/min of 30% TBP and with an O:A ratio of 1.4 at 1750 rpm.

The design of the second, remotely maintainable, 8-stage unit was completed, and fabrication is well under way. Stainless steel end bells have been added to the motors to protect against the mild corrosion that was observed during the testing of the first unit. Weir air pressure will be supplied to the motor housing rather than to a rotating seal attached to the draw bar, thus eliminating a maintenance-prone item from the design.

5.2.3 Solvent Extraction (IET)

M. V. Keigan

Design of the IET solvent extraction system has been completed, and a bid package for the installation is being prepared.

The design of the pulse column has been completed, and a bid package for fabrication is being prepared.

A purchase order has been issued for rosette plates for the pulse column.

5.3 SYSTEMS DEVELOPMENT

N. R. Grant

The 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, voloxidation equipment,* receiving and storage systems,* special remote systems, remote engineering systems, waste handling systems, and procurement* of depleted uranium fuel for use in equipment and process development. The waste handling task is funded only to provide an overview of what is being accomplished at other laboratory sites in this area, and no report is provided here.

5.3.1 Disassembly and Cutting

S. A. Meacham

The disassembly and fuel cutting efforts are responsible for the mechanical preparation of the fuel for the downstream processing. The task will develop equipment to remove the undesired components (such

*Not funded for FY 1982.

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 of this task is to produce the necessary design, equipment, and data required for the successful operation of prototype units in the IET and similar equipment in a pilot plant.

Disassembly Systems

Remote disassembly system (E. C. Bradley, J. H. Evans, and T. W. Semple). Detailed design of the remote disassembly system at Westinghouse Advanced Reactors Division (WARD) is progressing satisfactorily according to schedule projections and is ~95% complete. Documentation and design drawing submittals are being received from WARD as scheduled.

During the progress review meetings held this quarter, WARD presented a proposed design modification for the laser cutting focus head's Z-drive table, which has several advantages including: improved remote maintainability, improved operational stability, and improved electrical cabling design. This modification was approved and the design is now nearly complete.

Laser cutting development (B. S. Weil). Laser cutting tests were initiated to evaluate various commercially available gas jet nozzles whose purpose is to blow the molten metal out of the cut. Feasibility tests were completed on a detector that will verify that the laser beam successfully reaches the laser focus head during a cutting operation.

Shear Systems

Remote shear project (D. K. Lorenzo, B. S. Weil, D. C. Watkin, and T. W. Semple). After an overview check of the remote shear system drawings revealed numerous errors in dimensions, tolerances, notes, and interfaces, the project team concluded that the drawings would require extensive modifications prior to being approved for fabrication. To minimize delay, the drawing modifications are being made by ORNL. It is anticipated that fabrication will start in October or November.

Remote disassembly and shear control system (W. F. Johnson and G. R. Wetherington, Jr.). The Modicon control equipment has been delivered on

schedule. Control system software development has begun for the shear and disassembly systems. A purchase order was placed with Modicon for an operator's control station.

5.3.2 Special Remote Systems

S. L. Schrock

(Westinghouse Advanced Reactors Division)

F. L. Peishel and W. F. Schaffer, Jr.

Special remotely operable components and systems required by the Demonstration Reprocessing Plant (DRP) conceptual design 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 piping repair system, and a remote automatic liquid sampling system.

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 test stand 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 to the requirements of a formal test plan was continued during this period. In previous periods, qualification tests on Hanford-Purex connectors with two types of metallic seals were completed. During this period, tests were performed on a Walker connector also equipped with a metallic seal. The Walker connector has several advantages over the Hanford-Purex connector, including a smaller space envelope and more uniform loading of the seal for greater sealing reliability. Over 10 000 stress cycles have been applied to the Walker connector under various axial, bending, and torsional loading combinations at both ambient and elevated (149°C) temperatures. From these data, those combinations that give excessive leak rates through the seal are

being defined. During the next quarter similar tests will be performed on Hanford-Purex connectors allowing a direct comparison of the performance of the two types of connectors equipped with identical seals.

Remote Sampling System

The design of an advanced automatic liquid sampling system for a fuel reprocessing facility is completed. The facility will consist 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.

Fabrication of all components for the sampling system has been completed; the track sections, which include pneumatic shock absorbers, have been equipped with end stops; the cabling has been installed on the vehicle; the on-board control system for the vehicle has gone through its preliminary checkout; and all items have been installed on the process module mockup in the ROMD. Shakedown testing will begin during the next quarter.

5.3.3 Remote Control Engineering

W. R. Hamel

Servomanipulators

H. L. Martin, P. E. Satterlee, D. P. Kuban, J. N. Herndon, W. E. Holt, J. R. Nicholson, D. R. Wallace, and D. Baker

Servomanipulator development involves two major activities: (1) the procurement of a commercially available, industry-standard system and (2) the development of an advanced servomanipulator system. Each system consists of a set of two manipulator master and slave arms and an interface package that has positioning equipment for television cameras, lighting, and an auxiliary hoist. The industry-standard servomanipulator system is being procured from Central Research Laboratories (CRL). This system will be used to demonstrate and evaluate servomanipulator remote maintenance on prototype remote reprocessing equipment in the ROMD. The industry-standard servomanipulator system features a distributed digital control system and brushless dc servomotor actuators that drive each joint.

The industry-standard manipulator system mechanical fabrication is essentially complete. The slave manipulators and interface package mechanical system can be seen in Fig. 5.1. The control system fabrication is behind schedule; noise immunity problems, associated with the pulse-width modulation motor amplifiers, is the major source of delay. An in-depth review of the industry-standard manipulator production schedule was conducted during this quarter, and acceptance testing for this system is now scheduled to begin November 1982.

Forward-reflecting, position-position control of a single master/slave loop was demonstrated during this quarter on the single loop test stand at ORNL. The system monitor has been interfaced with the loop to allow the operator to select and initiate control modes. Also, the ability to change system and individual joint gain parameters has been developed to permit tuning of each joint.

Planning continued for the installation of an industry-standard manipulator in the ROMD. An engineering drawing specifying the required cable routing and power supply interfaces with the ROMD facility has been prepared. The balance of the documentation required for a fixed-price subcontract bid package is being prepared.

A demonstration of the anthropomorphic manipulator stance is planned for the ROMD. (Anthropomorphic stance provides the "elbows" of the slave down, allowing the slave to reach into tight areas. Normal manipulator stance is with the "elbow" up for table top work.) The demonstration will utilize the industry-standard manipulator. An alternate wrist must be provided to reduce the kinematics singularity problems associated with the present industry-standard manipulator wrist when used in the anthropomorphic stance. The necessary parts to modify the existing three degree-of-freedom wrist concept for this application are being procured.

The objective of the advanced servomanipulator development is to provide improvements over the industry-standard servomanipulator system. The advanced system features anthropomorphic kinematics, increased modularity for improved remote maintainability, gear and torque tube drives, and an electronics

Fig. 5.1. Industry-standard manipulator slave package.

control package designed to accommodate future radiation hardening. The detailed mechanical concept drawings for the advanced servomanipulator shoulder gear box, pitch sleeve module, and forearm/wrist interface were completed during this quarter. Revised layouts of a four degree-of-freedom wrist, depicting a reduced wrist profile, were also completed. The advanced servomanipulator prototype mechanical conceptual design is on schedule, with the conceptual design report and cost estimate to be completed during September 1982.

The advanced servomanipulator man/machine interface studies are continuing at Jet Propulsion Laboratories. The feasibility of electronic counterbalancing of the advanced servomanipulator was verified from a scoping study and an estimate of computational requirements. Nonsimilar kinematics for master and slave wrists was demonstrated to not be advisable from computational requirements and operator performance considerations.

Man/Machine Interface, Hand/Eye Coordination

J. E. Van Cleve, Jr., M. M. Clarke (Oak Ridge Associated Universities), S. Handel (University of Tennessee), and R. Crutcher

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 Tele-Operator Systems (TOS) servomanipulator arms on loan to ORNL from Princeton Plasma Physics Laboratory were received during this quarter. As shown in Fig. 5.2, the system has been installed on the three-axis transporter system in the Remote Systems Development Facility (RSDF) since it will be used in the next series of man/machine interface experiments.

Reliability problems with the RSDF transporter system electronics were improved during this quarter. A reduction in the number of printed circuit boards in the Intel 8080 system was possible by the use of higher density memory. Also, the joystick control software was simplified and improved.

Efforts to add a data logging system to record manipulator duty cycle information on the RSDF electronics were begun. Also, the necessary hardware additions to allow the development of a system for camera tracking the manipulator end effector are being identified.

The transmission line/coupler system development continued. The 110-MHz data channel is operational and some feedback and carrier leakage problems were resolved on the 21.5-MHz data channel. An interference between the 21.5-MHz data channel and the 45.75-MHz television channel was solved by installing several new filters in those channels. Resolution of a slight interference between the two television channels and documentation of the system remain to be done prior to installation in the RSDF for demonstration and testing.

Floor Transporter System Prototype

G. E. Smith and D. Macdonald

The conceptual design report and the cost estimate for the floor transporter system have been completed. The concept can be seen in Fig. 5.3. Because of budget limitations, no further efforts are planned at this time.

5.4 REPROCESSING FACILITY STUDIES

**B. F. Bottenfield, D. C. Hampson, D. Macdonald,
E. D. North, F. L. Peishel, R. H. Rainey (ORAU),
D. P. Reid, and J. G. Stradley**

An engineering study was conducted in FY 1981 to establish the feasibility and to estimate the capital cost impact of colocating a breeder head-end facility with the Barnwell Nuclear Fuel Plant (BNFP) in Barnwell, South Carolina. As a follow-up to that study, a series of engineering trade-off studies are in progress; most of these studies are generic to any remotely maintained and operated reprocessing plant. None of the studies are complete at this time, although the basic concept engineering and rough cost estimating work for some of the studies has been completed by Bechtel Group, Inc., and submitted in draft form.

Fig. 5.2. Remote Systems Development Facility servomanipulator system.

Fig. 5.3. Prototype floor transporter conceptual design.

6. Integrated Equipment Test (IET) Facility Operations

O. O. Yarbrow

The overall objectives of the IET include (1) providing for the integrated testing of process equipment and flowsheets prototypical of the advanced concepts being developed in the CFRP and (2) testing prototypical remotization aspects of specific complex components in the system. Accomplishing these objectives will increase the probability of success by demonstrating integrated operation of key portions of the process equipment, including remote maintenance techniques, materials transfer, liquid recycling, and metallic waste processing.

Construction of the General Plant Facility (GPF) portion of IET was completed during FY 1980. This GPF construction area and utility modifications in existing buildings provided the area for the location of the two operational parts of the IET — the Remote Operation and Maintenance Demonstration (ROMD) and the Integrated Process Demonstration (IPD). The IPD will address the issues of integrated operation in the predominantly chemical processing portion of the system. The ROMD will focus upon testing the remote aspects of the complex mechanical head-end processing equipment. The process equipment located in ROMD and IPD will be Integrated to permit overall simulated reprocessing system operations.

6.1 PROGRAM PLANNING AND CONTROL

O. O. Yarbrow

Program Planning and Control provides for the overall management of the IET program including planning, scheduling, budgeting, reporting, milestones, and cost control. 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.

6.1.1 Instrumentation and Controls Support

B. G. Eads

This task is responsible for I&C support for IET planning, implementation, and operations and for coordinating the line-item I&C with the total facility I&C systems.

A report on the long-range computer resource requirements for the CFRP was completed and is under consideration by Program management. The report

addresses mini- and microcomputer needs and does not include central computing facility needs which would be supplied by the Computer Sciences Division.

Since the IET line-item I&C system efforts are now in a transition from delivery and acceptance to early phases of operations, beginning with this report, no further effort will be made to distinguish between line-item and all other IET I&C efforts.

Integrated Process Demonstration (I&C)

**H. E. Cochran, D. M. Fleischer, K. P. Manoni,
H. V. McAdams, J. A. McEvers, R. G. Upton,
and W. D. Zuehsow**

Distributed data acquisition and controls systems (DDACS). Physical modifications to the control room and electrical wiring have been completed. Equipment that had been in storage since its February delivery from EMC Controls (EMCC) was moved into the computer and control rooms. All interconnecting cables between the buffer/transmitter, computer, control, and printer rooms were installed by the construction contractor and connected by EMCC. Host computers, consoles, disc and tape drives, and all peripherals have been successfully tested as an installed integral system. The DDACS was technically accepted in April. Final contractual acceptance, however, depends on resolving punch-list items, correlating items received vs packing lists, completing scheduled training, and various minor items. The major punch-list items relate to the Printronix long-line option for the DEC LXY-21 printer and parts replacements for those used during installation and testing by EMCC. The major deficiency relative to the packing list is the DEC hardware documentation.

Technical acceptance of the DDACS has removed EMCC's contractual restrictions on operation; therefore, loading and updating process data bases has begun. On-site operator training is continuing.

Field instrumentation. Construction contractor procedures for checking out the DDACS were completed, and the checkout was started. Wiring/tubing continuity checks of the field instrumentation for the chemical makeup area were successfully completed and documented. The different types of instrument control loops were identified, and written functional test procedures for each type are being jointly prepared by IET operations and instrumentation personnel. The procedures will be used specifically to test instrument control loops and (in part) to verify construction

contractor installation. They will become part of a larger documentation library on process checkout.

Remote Operation and Maintenance Demonstration H. E. Cochran

Bridge/trolley/manipulator. Two manipulator arms were scheduled to be returned to PaR for needed adjustment. One manipulator arm was corrected and reinstalled. The other arm is now scheduled to be returned at a later time to be determined by operational activities. Other punch-list items are essentially complete except for a modification of the circuit (5 to 30 A) available at the manipulator arms. The fabricator (PaR) has determined the installed supply will be sufficient after the modification.

Closed circuit television. The Panasonic cameras procured to replace the unstable Arvin/Diamond cameras were received, checked out, and installed. The entire CCTV system has been checked out. Correcting a punch list of minor items and documenting the associated installation changes are yet to be completed. One major item yet to be finally resolved concerns the coiled cables (supplied by PaR) in the CCTV trolley arm that were damaged at the upper end by the hoist movement. The cables have been temporarily repaired by cutting off the damaged end sections and reconnecting. The design has since been changed to prevent future damage, and new cables were scheduled to be installed by PaR representatives early in July.

6.2 EQUIPMENT INTEGRATION PROJECT (EIP)

H. R. Yook

The EIP is responsible for planning, managing, and implementing activities associated with the integration of equipment and systems into the IET facility. The project provides coordination and interfacing with IET management, operations, engineering, and I&C. The EIP is also responsible for coordinating IET line-item capital projects.

6.2.1 Project Management

H. R. Yook, A. J. Klein, and R. L. Beatty

Implementation of project management activities recommended by the IET Task Force continued. Activities associated with system/equipment schedules, status monitoring and evaluation, and reporting have been established on a monthly routine.

Activity sequence diagrams were prepared for the dissolver system, disassembly system, and the industry-standard servomanipulator system. These diagrams provide the basis for (1) identifying the activities necessary for installing and operating equipment and systems, (2) determining the logic and sequence of those activities relative to one another, and (3) establishing need dates and schedules.

A thorough assessment of FY 1983 projects in construction, modification, preparation, and installation was prepared. Factors such as project overlaps, multiple contractors, facility work locations, funding sources, and potential interferences were considered. Preliminary planning was completed based on the assessment, and the results were reviewed with CFRP staff, ORNL Engineering, UCC-ND Construction Engineering, and DOE-ORO. This information will be used as a basis for scheduling and implementing the FY 1983 activities.

Work has begun on the preparation of listings and schedules for documentation that would support system/equipment installation and operation in the IET. The documents include remote maintenance demonstration plans and procedures, component development plans and procedures, and equipment operation/maintenance information. This documentation is an integral part of equipment integration since it is required for both planning and allocating IET time and resources and for equipment operation and testing. The lists and schedules will be used to guide the preparation of necessary documents and to determine where delays could occur because of the absence of proper documentation.

An evaluation of interface control for the IET was performed. The general approach being considered uses controlled interface boundaries on process and instrument drawings supplemented by interface specifications.

6.2.2 Remote Maintenance Area Equipment and Systems Integration

H. R. Yook and R. V. Eberle

Acceptance testing of the PaR remote manipulator system was completed. Final acceptance has been withheld pending the technical resolution of several outstanding discrepancies by the vendor. The equipment is operational, and final vendor modifications are scheduled for the next quarter.

All cameras for the remote CCTV viewing system were received, installed, and checked out. The system is fully operational.

The dissolver support stand was received assembled and has been installed in the remote maintenance area pit.

The continuous rotary dissolver was sent to the shop for modification prior to installation in the IET. Shop work is proceeding on schedule, and delivery to the IET is now scheduled for mid-July. The dissolver will be placed on its support stand for remote maintenance demonstrations. The remainder of the process system will be installed in FY 1983.

The remote sampler vehicle was received and installed on the process module mock-up. Component development testing was initiated.

A permanent remote maintenance control room location was selected and approved. Control room design was completed, and construction/modification work was initiated. The control room will contain the remote maintenance and viewing system control console, the industry-standard manipulator system control station, and the remote sampler vehicle control station. The control room provides total direct visual isolation from the remote maintenance area; therefore, all operations from the control consoles must be performed via the remote CCTV viewing system.

6.2.3 Process Systems and Equipment Integration

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

A contract for fabricating the Iodex acid concentration system was placed with Astro Metallurgical Corporation (AMC), Wooster, Ohio, and work has started. Shop drawings from the vendor are being reviewed. The vendor is proceeding on schedule and has ordered the long delivery items. Delivery of the complete system is scheduled for the last quarter of FY 1983.

The solvent extraction system design was completed, and a bid package was prepared. The contractor start date is targeted for this September.

6.2.4 Facility and Support System Integration

H. R. Yook and R. V. Eberle

The DDACS equipment has been checked out. Programming and startup are under way.

Line-item contractor work in the process equipment area is nearing completion. A five-week construction workers' strike during this period delayed the piping

installation; however, the electrical and insulation work continued, and a delay in completing the work is not anticipated.

Work on final tie-ins between the process systems and equipment and the DDACS process control modules was initiated.

Bids for air conditioning and office space modifications associated with DDACS and the IET control room were received. Contractor work was started near the end of this report period.

6.3 IET OPERATIONS

J. Q. Kirkman

This activity controls, coordinates, and executes all operations within the IET facility. The major work tasks include planning and scheduling of operations, preparation of procedures, specification of data recording requirements, performance of process system operations, and demonstration of remote maintenance concepts.

6.3.1 ROMD Operations

J. M. McNair

Functions in the ROMD operations area are focused on demonstrating remote maintenance concepts, equipment, viewing systems, and procedures.

Remote maintenance operations were started mid-way through this report period, following completion of additional service work on the remote handling equipment supplied by PaR and the installation of new CCTV cameras, lenses, and equipment in the facility remote viewing system. Prior to initiating the major operations involving remote maintenance demonstrations on the process module mock-up, satisfactory functional operations of the repaired remote handling equipment and the modified remote viewing system were verified by performing checkout procedures specifically designed to test the acceptability of these facility systems.

The major operations this period consists of demonstrations verifying the remote operability of six of the seven key maintenance subsystems contained in the process mock-up. The specific demonstrations completed involved remote removal and replacement of large pipe jumpers at the top of the module, remote

removal and replacement of internal pipe jumpers, an attempt to remotely remove and replace the large diameter crossover piping elbows, remote removal and replacement of the heat exchanger, remote removal and replacement of the recirculation pump, and remote removal and replacement of the entire module frame. Data pertaining to the maintainability of each subsystem were recorded and are presently being reviewed to determine modifications necessary to correct the maintenance problems encountered. Demonstrations on the tubing jumpers, which constitute the final module subsystem to be tested, and a sequential demonstration of all remote features of the module will be accomplished next report period.

To support the remote maintenance testing described previously, a considerable amount of procedure development work has been completed. This work has produced twelve equipment operating procedures for controlled operations of the remote handling equipment and remote viewing systems in the facility, ten remote operating procedures for demonstrating specific maintenance operations on the process module and other test stands, and two special checkout procedures for periodically testing the acceptability of the remote handling equipment and the remote viewing systems. In addition, a test instruction system has been implemented to provide a formal, documented method of communicating specific test requirements to the operations staff for execution. Eleven test instructions have been produced to define the purpose, special requirements, procedures, and data recording requirements for remote maintenance demonstrations conducted in ROMD.

6.3.2 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.

Work to verify that the IPD process systems are installed in accordance with the process and instrumentation design drawings was completed this report period. These efforts were effective in identifying several discrepancies between design drawing and actual

installations. Changes necessary for safety or correct plant operation are presently being accomplished by the line-item contractor. In conjunction with the verification work, six new process and instrumentation drawings were developed to document and describe the various service systems (cooling water, steam, air, off-gas, hot water, and chilled water) providing support to the main-line process systems.

Work continued to define the scope of the preoperational testing phase to be initiated immediately following completion of process systems installation. Approximately 85 separate acceptance test procedures have now been identified for accomplishment during this testing phase. The acceptance tests are preparatory steps for normal operations and will be conducted to test the functional performance of components and equipment, verify proper interfacing of process instrumentation sensors with the distributed digital control system, and confirm satisfactory initial operation of key subsystems and process system units. To date, 20 of the acceptance test procedures have been prepared and approved to be performed once construction is completed.

A new activity initiated this report period involves the systematic review and updating of the graphics displays that are available for viewing on the color CRTs at the control system operator console. The displays provide simplified schematic representations of the various IPD process systems and utilize symbols, colors, and key data to present an easily understood picture of overall system status to an operator. It is anticipated that work in this area will significantly improve the ability to remotely operate the integrated process systems.

The IET system design descriptions were completed for all systems except Iodex. The Iodex design description will be done after the detailed design of the system is completed by the vendor.

6.4 OPERATIONAL ENGINEERING AND MAINTENANCE

W. W. Evans

This activity includes the operational engineering and equipment maintenance responsibilities for the Consolidated Fuel Reprocessing Facility (CFRF)

complex. The main objectives are to provide engineering assistance and coordinate equipment maintenance activities for IET operations and component development tasks and to plan other routine operations within the 7600 area.

6.4.1 Facility Operations (CFRF Complex)

W. W. Evans and W. T. Bostic

The principal interaction between the IET line-item contractor and facility operations was arranging for steam, water, and air services to be available as needed in the IPD area during checkout of new piping. This required a close working relationship between the field engineer, contractor, and facility operations to safely isolate leaks for repair. In addition, the contractor installed a 4-in. water header to provide fire water for the modified sprinkler piping in the expanded IET control room area.

Major CFRF operating equipment requiring cooling water was switched from process once-through water to the IET cooling tower system. This will reduce once-through cooling water usage to only small-scale laboratory bench-type work. A new split-unit heat pump for a section of the office area on the second floor of Building 7601 was installed. This change gives better control of the heating, ventilation, and air conditioning system in the office area.

6.4.2 IET Engineering and Maintenance

W. W. Evans

The new IET cooling tower system was cleaned, flushed, and placed in service during this report period. The controls for the fans were modified to allow starting the fans based on the basin temperature and changing the speed from low to high if the temperature increased beyond the predetermined setpoint. The cooling water as well as CFRF services (air, steam, demineralized, and condensate system) were connected with the service piping for the IPD area, and the leaks were repaired by the line-item contractor.

Arrangements were made to transfer 884 kg of normal uranium, 6 kg of depleted uranium, and 110 kg of thorium (contained in stainless-steel-clad fuel rods) from ORNL excess material into the Fuel Recycle Division accountability account. The material will

remain stored in Building 7019. A total of 3062 kg of depleted uranium in Zircaloy-clad fuel rods were also received from Exxon Nuclear Company for the cost (total \$1000) of packing and shipping from Richland, Washington. The material was stored in the fuel storage cell at the CFRF complex. Plans are to use the stainless-steel and the Zircaloy-clad fuel rods to replace a portion of the rods to be purchased for shear demonstrations during the Integrated Equipment Test in FY 1985 or FY 1986.

IET Operations participated in the design and adaptation of equipment for special remote operations on the acid fractionator module mock-up in the ROMD area. The major modifications completed were the

installation of two monorails and a portable chain hoist (modified for use with PaR equipment) to allow relocating the pump remotely between two separate positions on the module. A triangle-type lifting device was also designed for transferring the pump between the chain hoist and the 10-t PaR crane. In addition, a pulling device designed by Engineering Systems was installed for removing the heat exchanger. Three new impact wrenches were ordered (two have been received) and will be adapted for operation with the PaR equipment. As-built drawings were made on the equipment modifications and the special designs required on the impact wrenches, triangle lifting device, and the chain hoist.

7. Instrument Development

O. O. Yarbrow and S. M. Babcock

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.

7.1 ANALYTICAL SENSOR DEVELOPMENT

**D. A. Bostick, R. E. Harper, D. D. McCue,
H. H. Ross, W. B. Dress, and J. E. Strain**

A dual wavelength method for the measurement of uranium in degraded solvent streams has been devised and is being evaluated. In a 30% TBP-NPH solution, the absorbance spectrum of U(VI) has several distinct absorbance maxima between 403 and 450 nm, with the peak at 416 nm possessing the highest absorbance. As the TBP-NPH is degraded by radiation, an intensely absorbing uranium complex is formed that cannot be extracted into aqueous systems. This new uranium complex forms a featureless absorption background that is almost opaque at <370 nm and becomes increasingly transparent at longer wavelengths.

Presently the absorbance of the normal uranium complex is measured at 403, 416, and 426 nm. With no degradation products, the absorbance ratio of the 403- and 416-nm absorbance maxima is 0.82. In a degraded solvent containing no strippable uranium complex, the ratio of absorbance at 402 and 416 nm is 1.7. The possibility of using this ratio as an indicator of the contribution of solvent degradation is being evaluated.

A new method of measuring low levels of uranium is being developed for use on aqueous streams. The method is based on spectral measurement at 645 nm [U(IV)] before and after electrochemical reduction of the uranium. With a 5-cm optical path, uranium can be measured down to 0.10 g/L. Acid and impurity effects and the accuracy of the method are still under study.

A turbid stream sampler designed to provide a clear stream for analytical measurement has been fabricated and is under test. The active element is a pulsed stainless steel filter designed to pass particles smaller than $2\text{ }\mu\text{m}$ in diameter.

Work is continuing on the multiwavelength uranium photometer. A 14-bit analog-to-digital converter was installed to enhance the measurement resolution. The computer program to perform digital integration of the photomultiplier signals was completed and tested. An analog integrator PC card was fabricated and also used to integrate the signals. These two processing techniques will be critically compared for their ability to suppress photomultiplier noise in conjunction with the new photometer. The technique showing the best performance (whether analog or digital) will be incorporated

in the instrument system. All PC cards for the electronics package have been fabricated and tested. The final package configuration depends on which processing method is deemed most suitable.

All components, both purchased and fabricated, are on hand for the assembly of the multiwavelength photometer to be used in the testing of the centrifugal contactors at Savannah River Plant. The system software for utilizing DECnet to communicate via telephone line between the photometer's LSI-11 microcomputer at Savannah River Laboratory (SRL) and a computer at ORNL is complete. This system will link directly into the DDACS system when the contactors are installed in the IET.

The design of the stainless steel prototype free acid monitor has been completed.

The final report on the development, prototype design, and performance of the neutron poison monitor is ready for publication.

7.2 NONDESTRUCTIVE ASSAY

**C. W. Ricker, E. D. Blakeman,
G. G. Slaughter, and F. C. Difilippo**

The termination of the nondestructive assay development project was in process during this quarter. Six final reports and other termination documentation are now in the final stages of preparation.

8. 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 General Atomic Company (GA). These activities are limited to HTGR-specific head-end process and laboratory studies. Additional activities at GA on solvent extraction and off-gas treatment processes have generic applications in fuel reprocessing and are described in previous sections of this report.

8.1 HEAD-END STUDIES

**W. S. Rickman
(GA)**

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 using fuel produced by the FRG. The task also involves the design of a Joint Prototype Head-End Processing Facility (JPHF).

8.1.1 United States-Federal Republic of Germany Cooperation on Gas-Cooled Reactor Spent Fuel Treatment

**W. S. Rickman, J. B. Strand,
N. D. Holder, and R. N. Drake**

The semiannual meeting on the US-FRG Cooperative Program for spent fuel treatment development was held in Julich, Germany, March 23 through March 25. Technical activities of the past six months at GA, Kernforschungsanlage (KFA), and NUKEM* were

presented, and progress and planning for the cooperative activities were discussed. No major problems are foreseen in continuing the program.

Joint Prototype Head-End Facility

The crushed fuel element (primary) burner design criteria for the JPHF design validation task has been completed and submitted to the FRG for comment. In addition, draft analysis summaries (design requirements) and decision records (equipment selection logic) for the JPHF systems, fuel element crushing, fuel particle separation, crushed fuel particle burning, and feed adjustment were submitted to the FRG for review.

As part of the JPHF design validation task, a process flow diagram for the crushed fuel element (primary) burner was completed and approved. The first drafts of the piping and instrumentation diagrams for the design plan validation (primary burner) were reviewed, and the steady-state material and energy balances have been completed for all four reference fuels. Future development requirements for the primary burner system have been issued for review by the FRG project staff.

*A private company in the FRG.

Technical development plans for (1) fuel element size reduction, (2) the fuel particle separation, (3) fuel particle crushing and burning, and (4) solids transport were revised as necessary to incorporate FRG comments.

Joint Fuel Processing Demonstration

Cost estimates were obtained for segmenting a Fort St. Vrain spent fuel element for tests in the KFA AVR-6* facility and for cask transportation. One kilogram of 4-cm cubes cut from a large high-temperature gas-cooled reactor fuel block was shipped to the FRG for AVR-6 cold testing of U.S. fuel.

Pilot Plant Burner Operations

A successful 0.2-m-diam burner run was completed using a newly developed fines injector/preheater. On-line mass and energy flow summary calculations were used to guide operator control of the combustor cycle. All of the fines generated during the run were burned, and the bed product had no detectable carbon content.

An above-bed fines recycle system incorporating a downcomer from the top of the burner was installed.

Two designs were developed for using excess burner heat to heat plenum gas. Methods were identified for semivolatile fission products in the off-gas, such as Ru, Rb, Cs, and Mo.

8.2 LABORATORY STUDIES

G. E. Benedict, R. G. Wilbourn, and G. J. Hostbjoer
(GA)

This task includes the specific development and evaluation of technology for dissolving high-density FRG fuel and separating the solids from the dissolver product using a vertical centrifuge. A supporting effort for solvent extraction development is also included.

8.2.1 Silicon Carbide Hull Dryer

G. J. Hostbjoer

A rotary-screw dryer was recently purchased and is being installed. The dissolver system repulp tank has been shortened to accommodate the new dryer. A 7.6-cm stainless steel full-port ball valve will be installed

at the bottom of the tank cone and coupled to the dryer, thereby eliminating wet solids handling.

8.2.2 Nitric Acid Graphite Reaction Studies in Low-Enriched Uranium (LEU) Spent Fuel Treatment

S. A. Dunlap and R. G. Wilbourn

The LEU fuel/graphite matrix and particles will be crushed and the carbon burned off in a single burning operation. The efficiency of the burning operation is expected to approach 100%. However, small amounts of residual, unburned carbon may be present in the burner ash, which will be composed mainly of U_3O_8 and SiC hulls. These traces of carbon may react with the nitric acid dissolvent during dissolution and form soluble organic compounds. These organic compounds could potentially react with metal ions (e.g., fission products) to form stable complexes. The formation of organic-fission product complexes may adversely affect subsequent solvent extraction uranium-fission product decontamination.

In initial tests, nitric acid-zirconium solutions were heated to boiling and refluxed for 3 h with crushed graphite present. The aqueous nitric acid-zirconium phase was then contacted with 30% TBP-NPH. The zirconium distribution between the tributyl phosphate (TBP) and the aqueous phases was measured using a colorimetric zirconium-arsenazo III method. These initial tests indicated that the zirconium distribution ratio increases as the nitric acid concentration is increased.

8.3 STUDIES AND ANALYSES

H. C. Carney
(GA)

8.3.1 Assessment of New Reference HTGR-LEU Fuel Design

J. J. Shefcik

A draft report assessing the effects of the HTGR-LEU fuel on reprocessing R&D requirements and costs was completed and is being reviewed. Additional reprocessing requirements add ~5% to R&D costs.

8.3.2 Spent HTGR Fuel Storage and Transportation Studies

R. J. Grenda

The conceptual design of a rail cask for shipping spent HTGR fuel elements was completed. The transportation system consists of a rail cask, rail car, and

*Arbeitsgemeinschaft Versuch Reaktor (small German pebble-bed reactor).

fuel shipping containers. The cask will be transported in a vertical position on a drop-center, flat-bed rail car. The car, which is designed to carry 21 spent fuel elements in 7 shipping containers, will interface with the fuel handling equipment of the HTGR.

The gross vehicle weight and envelope dimensions of the rail transport system meet the requirements for

unrestricted interchange service, as defined by the Association of American Railroads. These requirements can be met using either depleted uranium or stainless steel as the shielding material. Preliminary unit costs for shipping the spent fuel have been calculated.

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