CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION

1

OAK RIDGE NATIONAL LABORATORY

operated by

UNION CARBIDE CORPORATION

for the

U. S. ATOMIC ENERGY COMMISSION

UNION CARBIDE

ORNL-TM-3176

LOCKHEED MARTIN ENERGY RESEARCH LIBRARIES

3 4456 0514291 2

THORIUM FUEL CYCLE DEVELOPMENT PROGRESS REPORT

SEPTEMBER 1970

NO. 14

OAK RIDGE NATIONAL LABORATORY
CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this document, send in name with document and the library will arrange a loan.
UCN-7969
(3 3-67)

NOTICE This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

ORNL-TM-3176

Contract No. W-7405-eng-26

CHEMICAL TECHNOLOGY DIVISION
METALS AND CERAMICS DIVISION

THORIUM FUEL CYCLE DEVELOPMENT PROGRESS REPORT

September 1970

No. 14

I. HEAD-END REPROCESSING DEVELOPMENT

P. A. Haas, R. S. Lowrie, V. C. A. Vaughen

II. REFABRICATION DEVELOPMENT

R. G. Wymer, A. L. Lotts, R. E. Brooksbank, P. A. Haas
W. D. Bond, J. W. Snider, J. D. Sease

III. TURF EQUIPMENT DESIGN AND ENGINEERING

J. W. Anderson, J. W. Snider, J. D. Sease

IV. MATERIALS IRRADIATION

A. L. Lotts, T. N. Washburn, J. D. Sease, J. H. Coobs

OCTOBER 1970

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

LOCKHEED MARTIN ENERGY RESEARCH LIBRARIES
3 4456 0514291 2

Previous issues of this report are as follows:

1. ORNL-TM-2670, August 1969
2. ORNL-TM-2705, September 1969
3. ORNL-TM-2739, October 1969
4. ORNL-TM-2765, November 1969
5. ORNL-TM-2792, December 1969
6. ORNL-TM-2846, January 1970
7. ORNL-TM-2886, February 1970
8. ORNL-TM-2004, March 1970
9. ORNL-TM-3015, April 1970
10. ORNL-TM-3032, May 1970
11. ORNL-TM-3088, June 1970
12. ORNL-TM-3112, July 1970
13. ORNL-TM-3124, August 1970

CONTENTS

Page

INTRODUCTION 1

I. HEAD-END REPROCESSING DEVELOPMENT

Studies with Irradiated Fuels. 2

Head-End Engineering Studies 3

II. REFABRICATION DEVELOPMENT

Particle Preparation 6

Fueled Graphite Fabrication Development. 10

III. TURF EQUIPMENT DESIGH AND ENGINEERING

Head-End Reprocessing Equipment. 13

Solvent Extraction Equipment 13

Sol-Gel Equipment. 14

Refabrication Equipment. 14

Special Tasks 15

IV. MATERIALS IRRADIATION

HTGR Recycle Fuels Irradiation 15

THORIUM FUEL CYCLE DEVELOPMENT PROGRESS REPORT

SEPTEMBER 1970

No. 14

Compiled by

The Staff of the Chemical Technology and
Metals and Ceramics Divisions

INTRODUCTION

The thorium fuel cycle development at ORNL is directed almost solely at HTGR fuels. These fuels consist of large blocks of graphite containing coolant channels and fuel and blanket holes. The fuel and blanket are made of microspheres of uranium or thorium compounds separately, or of mixtures of them in a single microsphere. The microspheres are coated with layers of pyrolytically deposited carbon and in some cases silicon carbide. The microspheres are retained in the holes in the graphite blocks in a bonded state.

Development work on all aspects of HTGR fuel recycle is in progress at ORNL. In addition, a major recycle development facility, the Thorium-Uranium Recycle Facility (TURF), has been built at ORNL, and the Coated Particle Development Laboratory (CPDL) has been put into operation in Building 4508. TURF is intended to be used as a development facility for fuel recycle. The CPDL is for engineering development studies leading to design of the equipment to be used in TURF.

I. HEAD-END PROCESSING DEVELOPMENT

The objective of this program is to evaluate head-end processes for converting irradiated HTGR fuels to a form suitable for recovery and decontamination of the thorium and uranium by a solvent extraction process. Small samples of irradiated and unirradiated fuel are studied to determine effects of irradiation on fuel reprocessing steps and to correlate with metallographic studies. An important objective is the determination of the amount of breakage of particle coatings and the resultant amount of cross-contamination of the fertile Th-^{233}U and fissile ^{235}U components in alternative processing steps. Mechanical systems are being developed for degrading the fuels and providing a material suitable for use in studies of the burn-leach steps using fluidized-bed or fixed-bed burners. The mechanical and burn-leach engineering development work is carried out using full-scale unirradiated fuel of the type to be used in PSC, and is designed to provide scale-up data for use in the design of pilot or full-scale processing plants.

1. Studies with Irradiated Fuels

(V. C. A. Vaughen, J. H. Goode, G. Davis)

Procurement of Irradiated Dragon Fuels

We have been in negotiations with the UKAEA for the procurement of 9 irradiated Dragon compacts of the $(Th/U)C_2$, ThC_2, UC_{10}, UC_{20}, and $(U/Th)O_2$ varieties, and 7 unirradiated controls for our head-end studies. We have now received notice of shipment of the unirradiated compacts. They should be at ORNL about mid-October. The paperwork for the irradiated Dragon fuel samples is still in the British Ministry of Transport. We are hopeful that the irradiated compacts will be sent shortly.

2. Head-End Engineering Studies
(R. S. Lowrie)

The head-end engineering studies comprise two principal areas of investigation - "mechanical" and "burn-leach." The general approach followed has entailed the comminution of a fuel element to produce suitable feed material for the burn-leach process. A number of changes have occurred in the overall HTGR program during the past year and some of them, such as the recent decision of GGA to use bonded fuel sticks instead of loose particles in HTGR fuel elements, has led to changes in our ideas of the mechanical equipment required to reprocess spent reactor fuel.

2.1 TURF Process Flowsheet Calculations (R. S. Lowrie)

Detailed process flowsheets are being prepared showing the compositions of inlet and outlet streams for the head-end, acid-thorex solvent extraction, sol formation, and microsphere preparation steps during the hot demonstration run in TURF. Major assumptions on which these flowsheets are based are listed below:

1. Production capacity of these steps during the hot demonstration run will be 12 kg/day of $(Th\text{-}U)O_2$ microspheres with a thorium-to-uranium ratio of 4.25/1.
2. All of the ^{233}U will be supplied from spent Ft. St. Vrain fuel elements.
3. Production of $\sim$ 150 recycle fuel elements: this will require reprocessing all the fuel elements discharged from Ft. St. Vrain during the first three years of full-power operation. For simplicity, the uranium concentration and isotopic composition calculated by the ØRIGEN code for fuel discharged after two years exposure were used in these calculations as the average values for all fuel elements.

Using these assumptions, reprocessing $\sim$ 10 fuel elements per day will provide sufficient uranium, when combined with the internal

uranium recycle stream, to produce 12 kg of recycle microspheres per day. The major waste streams consist of barren graphite, burner off-gas (containing small amounts of ^{3}H and ^{85}Kr which must be recovered), fissile particles, leacher residue, and the solvent extraction liquid waste streams containing dissolved fission products and thorium.

2.2 Calculation of the Isotopic Composition, Activity, and Thermal Power of Irradiated Ft. St. Vrain Fuel Elements (M. J. Bell, R. S. Dillon)

The ORIGEN Code[1] has been used to calculate the isotopic composition, activity, and thermal power of the irradiated fuel discharged from the Ft. St. Vrain reactor. Calculations were made for the fertile and fissile particles separately, for exposures of two, four, and six full power years, and for postirradiation times up to 10 years. The fissile particles treated in the calculations consisted of 93% enriched uranium and thorium carbides at a Th/U ratio of 4.25, and the fertile particles contained only ThC_2. The total core loading of heavy metal consisted of 0.882 metric tons of U and 19.2 metric tons of Th.[2] The exposures were carried out to 100,000 Mwd/metric ton of heavy metal using a load factor of 0.8. The normalized volume-averaged neutron spectrum[3] used in the calculation was assumed to have the shape

$$\phi_{th}\ (E < 2.38\ ev)/\phi_{total} = 0.344;\ \phi_{fast}\ (E > 0.18\ Mev)/\phi_{total} = 0.183.$$

The volume averaged fuel temperature was taken at 1450°F.

The isotopic composition of the heavy metal in the fertile material discharged after two full power years exposure is shown as a function of postirradiation time in Table 1. This information will be used to develop the flowsheets for preparation of ^{233}U recycle fuel in the TURF facility.

---

[1] Chem. Technol. Div. Ann. Progr. Rept. May 31, 1969, ORNL-4422, pp. 89-91.

[2] Data taken from Table A-1 in Appendix A of National HTGR Program Plan.

[3] Personal communication from W. Simon, GEES, Aug. 4, 1970.

Table 1. HTGR Fort St. Vrain Reactor--Fertile Particle (2 yr Exposure)*

Power = 9.24 Mw/MT
Burnup = 8437 Mwd/MT
Flux = 4.84 E 13 $n/cm^2 \cdot sec$

	Nuclide Concentrations, g/MT fuel charged to reactor						
	Charge	Discharge					
			30.0 Days	90.0 Days	150. Days	365. Days	3652. Days
^{4}He	0.0	1.68 E 03	1.80 E 03	2.05 E 03	2.31 E 03	3.32 E 03	2.35 E 02
^{208}Pb	0.0	2.20 E 03	2.48 E 03	3.12 E 03	3.85 E 03	7.17 E 03	1.08 E 01
^{228}Th	0.0	9.86 E 03	1.08 E 02	1.26 E 02	1.42 E 02	1.94 E 02	3.79 E 02
^{229}Th	0.0	6.66 E 02	7.03 E 02	7.81 E 02	8.59 E 02	1.14 E 01	5.45 E 01
^{230}Th	0.0	1.85 E 01	1.85 E 01	1.86 E 01	1.87 E 01	1.89 E 01	2.19 E 01
^{232}Th	7.70 E 05	7.50 E 05	7.50 E 05	7.50 E 05	7.50 E 05	7.50 E 05	7.50 E 05
^{231}Pa	0.0	5.42 E 00	5.44 E 00	5.44 E 00	5.44 E 00	5.44 E 00	5.43 E 00
^{233}Pa	0.0	9.33 E 02	4.37 E 02	9.58 E 01	2.10 E 01	1.82 E 01	1.36 E 08
^{232}U	0.0	1.59 E 00	1.59 E 00	1.59 E 00	1.59 E 00	1.58 E 00	1.45 E 00
^{233}U	0.0	1.05 E 04	1.09 E 04	1.13 E 04	1.14 E 04	1.14 E 04	1.14 E 04
^{234}U	0.0	1.24 E 03	1.24 E 03	1.24 E 03	1.24 E 03	1.24 E 03	1.24 E 03
^{235}U	0.0	1.64 E 02	1.64 E 02	1.64 E 02	1.64 E 02	1.64 E 02	1.64 E 02
^{236}U	0.0	1.22 E 01	1.22 E 01	1.22 E 01	1.22 E 01	1.22 E 01	1.22 E 01
^{237}Np	0.0	3.73 E 01	3.94 E 01	3.95 E 01	3.95 E 01	3.95 E 01	3.95 E 01
^{238}Pu	0.0	5.40 E 02	5.52 E 02	5.51 E 02	5.50 E 02	5.48 E 02	5.11 E 02
^{239}Pu	0.0	7.77 E 03	7.77 E 03	7.77 E 03	7.77 E 03	7.77 E 03	7.76 E 03
^{240}Pu	0.0	2.18 E 03	2.18 E 03	2.18 E 03	2.18 E 03	2.18 E 03	2.18 E 03
SUBTOTAL	7.70 E 05	7.63 E 05	7.63 E 05	7.63 E 05	7.63 E 05	7.63 E 05	7.63 E 05
TOTAL	7.70 E 05	7.63 E 05	7.63 E 05	7.63 E 05	7.63 E 05	7.63 E 05	7.63 E 05

*These values are at variance with results obtained from GGA because GGA's results were calculated from a more accurate knowledge of fuel loading and flux patterns in Fort St. Vrain Reactor. They are, nonetheless, suitable for our use and in conjunction with results for other exposures provide us with a self-consistent set of values.

II. REFABRICATION DEVELOPMENT

1. Particle Preparation

The fuel material of primary interest for ORNL recycle studies is the ThO_2-UO_2 particle, which has a thorium-to-uranium ratio of about 4.2. The uncoated fuel particles are to be microspheres 350 ± 100 μ in diameter, made by the sol-gel process. Fuel preparation includes development and demonstration of all process steps involved in making remotely the ThO_2-UO_2 microspheres. The steps include demonstrating reliable, remote processes for reproducibly mixing $Th(NO_3)_4$ and $UO_2(NO_3)_2$ solutions in the desired thorium-to-uranium ratio, preparing the mixed, stable ThO_2-UO_3 sol in concentrations exceeding 1 g-mole of oxides per liter, forming ThO_2-UO_3 gel microspheres, and converting them to dense ThO_2-UO_2 in good yield.

Experimental studies of processes and equipment for preparation of sols and microspheres are reported here. The present emphasis is on processes, procedures, and prototype equipment for preparation of oxide microspheres in the Thorium-Uranium Recycle Facility (TURF). Tests of flowsheets and procedures to be used for test materials preparation are also included.

1.1 Sol and Microsphere Preparation Development (P. A. Haas)

The solvent extraction sol preparation system and the CPDL sphere preparation system will be operated to supply ThO_2-UO_2 spheres for head-end reprocessing test elements. Components of both systems were borrowed or moved to meet needs of the CUSP UO_2 development studies and replacement of these components has started. This production effort will be planned to also meet the following development needs:

(1) Demonstrate the improved 2EH recycle procedures (developed for CUSP UO_2 sols) for ThO_2-UO_3 sols.

(2) Demonstrate the flowsheets for the Th/U ratio required for FSV HTGR fuel elements. The exact ratio depends on revised

calculations of nuclear requirements. While ThO_2-UO_2 spheres of 2.0 to 4.25 Th/U ratio have been prepared, variations in the ratio require variations in the flowsheet conditions.

(3) Check some of the procedures and equipment proposed for remote operation and control of sphere forming systems.

The schedule for these operations will be selected to meet the M&C Division schedule for test element fabrication and to result in a minimum interference with our CUSP development studies.

1.2 Sphere-Forming Column Chemistry (W. D. Bond, J. W. Snider, P. A. Haas)

Our previous studies have shown that pH, surfactant concentration and water content of 2-ethyl-1-hexanol (2EH) are important variables in the microsphere forming process. We are presently examining methods for improving the control of pH and surfactant concentration during continuous operation of sphere forming columns. Our present system for controlling the water content is adequate. For water content control, a portion of the used solvent is heated at 150-160°C to remove most of the water, and the desired water content is obtained by mixing this relatively dry 2EH with the remaining wet solvent.

In the past, sphere forming columns have been operated continuously by making periodic additions of surfactants to off-set the losses of surfactant caused largely by reaction of the nitric acid (extracted from the sol) with the surfactants during removal of water by distillation. In addition to reactions during distillation, a relatively small amount of reaction occurs in the forming column as evidenced by slow discoloration of the solvent when the forming column is batch operated without a distillation system. The pH or acid contents of the 2EH that have been employed in continuous operation, have been mainly those governed by the amount of acid extracted from the sol which can subsequently be maintained in the 2EH with the distillation system operating. When higher acid contents are required, nitric acid must be added to the 2EH and reactions with surfactants and 2EH are increased. Laboratory studies have shown that reactions of nitric

acid during distillation could essentially be eliminated by removal of the acid prior to distillation step by ion exchange. The acid content of the alcohol could then be maintained by adding nitric acid to the alcohol after the removal of water by distillation. We are presently evaluating this procedure as a means of controlling the pH and surfactant concentration of the UNOP sphere forming column during continuous operation. We are also studying a total purification method in which the 2EH is recovered by distillation, the used surfactants are discarded, and the 2EH is recycled to the forming column after surfactants, water and nitric acid are added. Studies are continuing on the effect of surfactant and water content, and the pH of 2EH on sphere forming using different sols in batch operated laboratory forming columns.

Chemistry of 2EH Recycle (W. D. Bond, C. W. Greene)

Previous data had indicated that if nitric acid were removed from the microsphere forming solvent (2EH) prior to recycle to distillation, then the surfactants, Span 80 and Ethomeen S/15, would not be depleted or degraded by the distillation process. When the HNO_3 is removed by a basic ion exchanger prior to the distillation in the UNOP column recycle circuit, we find that periodic addition of Span 80 is still required. The Ethomeen S/15 appears to be unaffected. Laboratory studies have been started to determine the stability of the Span 80, a sorbitan monooleate ester, to acid hydrolysis and to hydrolysis by the basic ion exchanger. Ion exchange resins are reported to be almost as effective catalysts in the hydrolysis of esters as are dissolved acids or bases.[1]

The stability of Span 80 to acids was measured by analyzing a 10 vol % Span 80-2EH solution that was 0.01 N in HCl for free oleic acid after one week at room temperature. In this experiment, 2% of the Span 80 was hydrolyzed as determined by titration of the liberated oleic acid. Analysis of the Span 80 prior to the acid hydrolysis test

[1] H. Samelson and L. P. Hammett, "Structural Studies of Ester Hydrolysis by Strong Base Ion Exchangers," J. Am. Chem. Soc. 78, pp. 524-26,(1955).

showed that 5 mole % oleic acid is originally present. Experiments with basic ion exchangers are in progress.

1.3 Equipment Development and Design (P. A. Haas, B. C. Finney, C. C. Haws, R. S. Lowrie)

Chemical flowsheets based upon recovering the ^{233}U from spent FSVR fuel elements were prepared for the Head-End, Acid-Thorex, Solex and Microsphere Forming processes. The spent elements were assumed to be two-year burnup elements and the feed rate to head-end was 9.6 elements/day. This provides sufficient ^{233}U for 12 kg/day of calcined microspheres with a Th/U mole ratio of 4.25.

The principal waste streams from Head-End include: (1) gaseous waste consisting of CO_2, $^{3}H_2$, ^{85}Kr, I_2 and Ze, and (2) solid waste consisting of graphite and fissile particles.

The principal waste streams from the Acid-Thorex process include: (1) gaseous waste from the dissolver, (2) liquid waste of about 5000 liters/day, and (3) solid waste from the dissolver (SiC hulls and Al_2O_3).

The principal waste stream from the Solex process is a liquid stream consisting of 106 liters/day.

The principal waste streams from the Microsphere Forming process include: (1) gaseous waste from the microsphere drying and calcining operations, (2) liquid waste of about 130 liters/day (The ion exchange treatment to remove nitrate is included in this flowsheet. About one-half of the liquid waste generated is associated with the regeneration of the ion exchange resin.), and (3) solid waste from the ion exchange treatment step.

The periscope purchased for in-cell observation of sol drops and gel spheres was unpacked and inspected as a preliminary to setting it up for testing. The alignment and assembly of controls for the two eye pieces do not appear to be correct and we will consult the manufacturer before proceeding further.

2. Fueled Graphite Fabrication Development

(F. J. Furman, W. H. Pechin, C. B. Pollock,
J. M. Robbins, and J. D. Sease)

We are developing processes and equipment for the refabrication of HTGR fuel as detailed in the National HTGR Recycle Development Program Plan. The fuel consists of microspheres of thorium and/or uranium as the oxide or carbide, coated with multiple layers of pyrolytic carbon and silicon carbide. These particles are loaded into hexagonal graphite logs which contain both fuel and coolant holes.

Our work is divided into particle coating, particle handling and inspection, fuel stick making, and element assembly. Last report period we concentrated on particle coating development. We continued the work reported last period on modifying the prototype coating furnace and continued a series of tests to establish load limits of a 5-in.-diam coating furnace, paying particular attention to coating HTGR reference recycle particles with a minimum of soot inclusions and faceting. We began setting up a fuel stick fabrication line.

2.1 Particle Coating

We are investigating how variation of the parameters used in coating reference recycle HTGR fuel particles affect the quality of coatings and furnace cone life. Specifically, we are interested in minimizing faceting and sooting in propylene coatings. We have coated 8 kg of $(Th,U)O_2$ with buffer coatings for use in these experiments. Initial tests will concentrate on the temperature, hydrocarbon flow, and diluent flow. In subsequent tests the furnace pressure and particle load will be varied. The eventual result will be a description of the range of coating conditions that produce fuel of reference density and anisotropy, and delineation of the subregions within this range of coating conditions which minimize faceting and sooting and maximize cone life.

2.2 Particle Inspection

Particles coated by the thermal decomposition of propylene tend to have faceted surfaces. We desire to limit this faceting because the faceted particles pack in a tighter array than spherical particles and make difficult the injection of bonding material containing high quantities of filler. In addition, the faceted coating may be structurally inferior to a spherical coating, although this has not been demonstrated by experiment.

To develop a coating process that minimizes faceting we must have a good method to measure it. Methods exist for measuring the faceting, such as selecting individual particles imaged by radiography, the maximum and minimum coating thickness, or the diameters of included and excluded circles, but these processes are extremely tedious.

While theoretically capable of determining the amount of faceting, the measurement of the coating thickness on both sides of each particle, without paying attention to the position of maximum and minimum coating thickness, is not as sensitive as other methods and is still somewhat laborious. We have developed a mechanical method which is somewhat insensitive but can be used as a quick quantitative test for sphericity. The device is a tiltable plate, the angle of which can be calculated where 50% of the particles roll off. The surface of the plate has been roughened with coarse abrasive paper to prevent the particles from sliding. A sample of 50 or more particles lined up so they will not interfere with one another is placed on the plate which is tilted a few degrees at a time. A graph is constructed showing the percent particles remaining versus angle of the plate. The procedure is repeated to establish an average.

Some tests were done to establish limits of the method. Particles coated with acetylene-derived pyrolytic carbon (hence highly spherical) averaged 9.7 degrees as the point where 50% of the particles rolled off the plate. Some highly faceted, coated ThC_2 particles averaged

19 degrees at 50% roll off. The worst material, judging from visual inspection, produced in the 5-in.-diam prototype remotely operable coating furnace averaged 16.1 degrees at 50% roll off. Particles with a comparatively thin layer of propylene-derived coating over highly spherical particles with only minor faceting, as determined by visual inspection, averaged 14.8 degrees at 50% roll off. The scatter of the above three tests was greater than the difference in the averages. Thus the test can only indicate large differences in faceting. However, the test is sensitive enough to provide a measure for determining unacceptably high faceting. For instance, an upper limit would be selected for the average degree at 50% roll off and this figure would be used in quality control.

2.3 Fuel Stick Fabrication

We are constructing an HTGR fuel stick fabrication line with a production capacity of up to 400 in. of fuel sticks per day. The line will consist of a coated particle batch blender for preblending the fissile and fertile particles separately, a combination fissile-fertile particle blender and fuel stick mold loader, fuel stick molds, mold heater, pitch injector, and fuel stick ejector. The line will be capable of fabricating fuel sticks of various lengths and will be instrumented to provide data needed for the design of the TURF fuel stick fabrication line. This line will use principally the existing equipment so it would not constitute a major expense.

III. TURF EQUIPMENT DESIGN AND ENGINEERING

(A. L. Lotts, J. W. Anderson, J. D. Sease
J. W. Snider, and J. M. Chandler)

The objective of this part of the program is to design, construct, and to perform operational testing of three pilot plants to demonstrate recycle of HTGR fuels. These pilot plants are the Head-End Reprocessing Pilot Plant, Acid Thorex Pilot Plant, and the Refabrication Pilot Plant. The Head-End Pilot Plant and the Refabrication Pilot Plant

will be installed in Building 7930 and the Acid Thorex Pilot Plant will be installed in Building 3019. The design of these pilot plants will include processing equipment, materials handling equipment, waste treatment and disposal equipment, and modifications to the facilities of Buildings 7930 and 3019. These engineering efforts will include major processes and equipment involved in recycle Head-End, Solvent Extraction, Sol-Gel, and Refabrication, as well as Special Tasks such as waste and material handling and shipping. These are reported subsequently under their respective subsections.

General project activities during the reporting period included a continued effort toward updating the National HTGR Recycle Development Program Plan and the preparation of simplified process flow diagrams to be included in the program plan. The program budget was reviewed and some revised estimates were incorporated into the budget. A basic cost control system with a cost updating procedure was prepared for the program.

1. Head-End Reprocessing Equipment

Efforts continued toward updating the flowsheets proposed for the pilot plant. Plans were made for preparing a space utilization study for the equipment to be installed in Cell G, Building 7930. These studies will result in the preparation of preliminary equipment layouts being prepared within two or three weeks. The materials handling and waste treatment and disposal requirements were reviewed to coordinate between the work plan for this activity and the budget estimates for this part of the program.

2. Solvent Extraction Equipment

Work during this report period was mainly concerned with preparing flowsheets for the Acid Thorex Pilot Plant. Additional planning for material handling took place with some better definition of the requirements for handling the feed material to the plant and packaging and shipping the product from the plant. The budget estimates for the pilot plant were reviewed and updated to reflect current requirements.

3. Sol-Gel Equipment

Updating of flowsheets for this part of the Refabrication Pilot Plant was continued during the report period. The budget estimates for this part of the program were also updated to reflect current requirements.

4. Refabrication Equipment

Included in this subtask is the remainder of the processing equipment to be installed in the Refabrication Pilot Plant, not included in Subsection 3 above. General work in this area during the report period included developing a better definition of the activities to be performed in this subtask and an updating of the budget estimates for these activities to reflect current requirements.

4.1 Refabrication Equipment Design

(W. A. Pate, F. C. Davis, and D. D. Cannon)

Several different methods to fabricate fuel sticks were developed and six approaches were presented to the program personnel in the form of freehand sketches. The ideas presented in these sketches were thoroughly discussed and a decision was made to prepare a conceptual design of one particular approach. The basic approach is a unit that traverses a column of fuel particles axially within a tube past a small annular opening through which hot pitch is forced to fill the void between fuel particles. As the column continues its axial motion, it passes by a cooling coil to solidify the pitch. The final product is a fuel stick that is the correct diameter and length to be inserted into an HTGR fuel element.

A conceptual design of a remotely operated machine to load the fuel sticks into the HTGR element is being prepared. The assumption has been made that the fuel sticks will be 15 in. long, thus requiring two sticks in each fuel hole and 414 fuel sticks per element. To meet the proposed process rate, fuel sticks must be loaded into the element at the rate of approximately two per minute.

5. Special Tasks

5.1 Material Handling

A memo was prepared and distributed outlining the materials handling requirements for the demonstration subtask of the program and evaluating present capabilities of existing facilities for providing these requirements. Very preliminary plans were developed for additions and modifications needed to provide for the handling requirements, and a budget estimate was prepared for performing this work.

5.2 Waste Treatment and Disposal

A preliminary listing of the waste which must be handled from the pilot plants was prepared and a budget estimate for providing for these needs was developed.

IV. MATERIALS IRRADIATION

1. HTGR Recycle Fuels Irradiation

(T. N. Washburn, R. B. Fitts, and A. R. Olsen)

The irradiation tests on the HTGR recycle program have two main objectives: (1) to provide irradiated fuel for head-end process studies, and (2) to provide irradiation proof tests of the products of coated particle process development for the Thorium-Uranium Recycle Facility. The test conditions of interest include fuel temperatures between 600 and 1300°C, burnup to 20% FIMA in the $(Th,U)O_2$ particles, and fast fluence exposures up to 8×10^{21} neutrons/cm^2.

The first two stages in this program were implemented this year. They are: (1) the start of accelerated burnup rate capsule irradiation and (2) irradiation of eight fuel elements in the Peach Bottom Reactor.

1.1 Capsule Irradiation

Fabrication of the experimental capsule components is ∿40% complete. The principal delay in this hardware preparation has been associated with the delivery of the die required to size the thermal neutron shrouds. This was received during the past report period and a stainless steel mockup of the shroud was fabricated and sized satisfactorily to the required outer diameter and ovality. This mockup shroud is currently being reamed for testing the proposed assembly procedure for installing the shrouds on the capsule tubes. A draft of the shroud fabrication procedure has been reviewed and is currently being modified for final review and approval in accordance with the required quality assurance procedures. We have obtained verbal approval from the Idaho Nuclear Corporation to utilize these shrouds without submitting them to the elaborate corrosion test normally given to zirconium and hafnium materials. This approval is based on the low shroud operating temperatures and the fact that they are not part of the capsule containment.

An attempt was made to utilize reject RTE fuel sticks for the loading of the critical mockup capsules. To do this we had to bore a 0.255-in. hole through the center of the sticks. Because of the brittle nature of these sticks after carbonizing, we were unable to drill this hole. We now plan to load loose particles into the fueled regions for these capsules. A nuclear safety review of the proposed loading procedures was made by the ORNL Criticality Review Committee. This review was required because of the interaction of our small quantity (30 g fissile total for all four assemblies) with other currently approved activities in the laboratory involving larger quantities of fissile material. The procedures were approved.

The fuel sticks for these capsules will be fabricated next month during the campaign to produce also the additional sticks for the Recycle Test Elements. All of the particles for fabrication into sticks have been prepared. The particle characterization is ∿80% complete.

A suggestion has been made to include carbonized fueled resin particles in the loose bed sections of these capsules. The use of the (75% enriched) uranium particles prepared for HFIR irradiations blended with similarly produced thorium particles is being evaluated.

1.2 Large Scale Irradiation

The initial set of six RTE's has been inserted into the Peach Bottom Reactor. The reactor went to power on July 14, 1970 and has operated without incident since that date. The accumulated 73 days of irradiation (to September 25, 1970) is 24% of that planned for the low burnup elements and 7.3% of that planned for the highest burnup elements.

INTERNAL DISTRIBUTION

1-3. Central Research Library
4. ORNL - Y-12 Technical Library
Document Reference Section
5-9. Laboratory Records
10. Laboratory (RC)
11. ORNL Patent Office
12. Reactor Division Library
13. R. E. Adams
14. G. M. Adamson, Jr.
15. L. G. Alexander
16. J. W. Anderson
17. R. E. Blanco
18. J. O. Blomeke
19. E. S. Bomar
20. W. D. Bond
21. G. E. Boyd
22. R. A. Bradley
23. R. E. Brooksbank
24. K. B. Brown
25. F. R. Bruce
26. W. L. Carter
27. J. M. Chandler
28. S. D. Clinton
29. C. F. Coleman
30. J. A. Conlin
31. J. H. Coobs
32. C. M. Cox
33. J. A. Cox
34. F. L. Culler
35. J. E. Cunningham
36. H. J. deNordwall
37. S. J. Ditto
38. W. P. Eatherly
39. D. E. Ferguson
40. L. M. Ferris
41. B. C. Finney
42. R. B. Fitts
43. J. H. Frye, Jr.
44. F. J. Furman
45. R. W. Glass
46. H. E. Goeller
47. A. T. Gresky
48. W. R. Grimes
49. P. A. Haas
50. R. G. Haire
51. R. L. Hamner
52. W. O. Harms
53. F. E. Harrington
54. C. C. Haws, Jr.
55. M. R. Hill
56. S. I. Kaplan
57. F. A. Kappelmann
58. P. R. Kasten
59. F. J. Kitts
60. C. E. Lamb
61. J. M. Leitnaker
62. C. S. Lisser
63. R. E. Leuze
64. M. H. Lloyd
65. A. L. Lotts
66. R. S. Lowrie
67. J. P. McBride
68. R. W. McClung
69. K. H. McCorkle
70. W. T. McDuffee
71. A. B. Meservey
72. J. G. Moore
73. W. L. Moore
74. L. E. Morse
75. E. A. Nephew
76. J. P. Nichols
77. E. L. Nicholson
78. K. J. Notz
79. A. R. Olsen
80. J. R. Parrott
81. W. A. Pate
82. P. Patriarca
83. W. L. Pattison
84. W. H. Pechin
85. A. M. Perry
86. J. W. Prados
87. J. T. Roberts
88. A. D. Ryon
89. J. L. Scott
90. J. D. Sease
91. M. D. Silverman
92. O. Sisman
93. J. W. Snider
94. O. K. Tallent
95. E. H. Taylor
96. D. B. Trauger
97. W. E. Unger
98. V. C. A. Vaughen
99. T. N. Washburn
100. C. D. Watson
101. A. M. Weinberg
102. J. R. Weir
103. M. E. Whatley

104. G. D. Whitman
105-106. R. G. Wymer
107. Gale Young

EXTERNAL DISTRIBUTION

108. A. Amorosi, Argonne National Laboratory, LMFBR Program Office 60439
109. R. H. Ball, RDT-OSR, P. O. Box 2325, San Diego, California 92112
110. R. E. Barber, AEC, Washington 20545
111. L. H. Brooks, Gulf Energy & Environmental Systems, Inc., P. O. Box 608, San Diego, California 92112
112. J. A. Buckham, Manager, Chemical Technology Branch, Idaho Nuclear Corporation, P. O. Box 1845, Idaho Falls, Idaho 83401
113. L. J. Colby, Jr., Gulf Energy & Environmental Systems, Inc., P. O. Box 608, San Diego, California 92112
114. J. Crawford, AEC, Washington 20545
115. P. Clark, AEC, Washington 20545
116. D. F. Cope, RDT, ORNL Senior Site Representative, AEC
117. G. W. Cunningham, AEC, Washington 20545
118. W. Devine, Jr., Production Reactor Division, P. O. Box 550, Richland, Washington 99352
119. E. W. Dewell, Babcock & Wilcox, Lynchburg, Virginia 24505
120. S. E. Donelson, Gulf Energy & Environmental Systems, Inc., P. O. Box 608, San Diego, California 92112
121. R. H. Graham, Gulf Energy & Environmental Systems, Inc., P. O. Box 608, San Diego, California 92112
122. J. S. Griffo, AEC, Washington 20545
123. N. Haberman, RDT, AEC, Washington 20545
124. P. G. Holstead, RDT-OSR, P. O. Box 550, Richland, Washington 99352
125. S. Marshall, National Lead Company of Ohio, P. O. Box 39158, Cincinnati, Ohio 45239
126. T. McIntosh, AEC, Washington 20545
127. W. H. McVey, RDT, AEC, Washington 20545
128. R. E. Norman, Gulf Energy & Environmental Systems, Inc., P. O. Box 608, San Diego, California 92112
129. R. E. Pahler, AEC, Washington 20545
130. R. A. Proebstle, GE, KAPL, P. O. Box 1072, Schenectady, N. Y. 12301
131. C. W. Richards, AEC, P. O. Box 591, Canoga Park, Calif. 91305
132. H. Schneider, AEC, Washington 20545
133. K. G. Steyer, Gulf Energy & Environmental Systems, Inc., P. O. Box 608, San Diego, California 92112
134. C. L. Storrs, HPO-AI/CE, P. O. Box 309, Canoga Park, Calif. 91304
135. C. A. Trilling, Atomics International, Canoga Park, Calif. 91304
136. W. R. Voigt, AEC, Washington, 20545
137. J. Weissenberg, RDT, ORNL Site Representative, AEC
138. M. J. Whitman, AEC, Washington 20545
139. Laboratory and University Division, ORO
140-154. Division of Technical Information Extension, OR