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**SOUTHWEST EXPERIMENTAL
FAST OXIDE REACTOR
DEVELOPMENT PROGRAM
EIGHTEENTH QUARTERLY REPORT
AUGUST-OCTOBER 1968**

U.S. ATOMIC ENERGY COMMISSION
CONTRACT AT (04-3)-540

ADVANCED PRODUCTS OPERATION

GENERAL ELECTRIC

SUNNYVALE, CALIFORNIA

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GEAP-5705
AEC Research and
Development Report
November 1968

SOUTHWEST EXPERIMENTAL FAST OXIDE REACTOR DEVELOPMENT PROGRAM

Eighteenth Quarterly Report

August - October 1968

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ABSTRACT

This report summarizes the work performed on the Research and Development Program for the Southwest Experimental Fast Oxide Reactor during the period from May 1, 1968

through July 31, 1968. The work was performed under contract AT(04-3)-540 with the United States Atomic Energy Commission.

SECTION I

INTRODUCTION

SEFOR (Southwest Experimental Fast Oxide Reactor) is a 20 MWt fast, sodium-cooled reactor with characteristics similar to the large, soft spectrum fast breeder reactors fueled with mixed $\text{PuO}_2\text{-U}^{238}\text{O}_2$, for which studies indicate the potential for producing low cost power. SEFOR will be used to obtain physics and engineering data at fuel compositions, temperatures, and crystalline states characteristic of power reactor operating conditions. SEFOR is particularly designed for the systematic determination of the Doppler coefficient of reactivity at temperatures up to the vicinity of fuel melting.

The SEFOR project consists of two major parts: the design and construction of the reactor facility

and the related research and development program. Funds for the design and construction of the facility are being provided by the Southwest Atomic Energy Associates (a group of 17 investor-owned utility companies located in the south and southwest of the United States), together with the Karlsruhe Laboratory of The Federal Republic of Germany, Euratom, and the General Electric Company.

The United States Atomic Energy Commission is supporting the research and development program. The R and D program consists of two phases:

Phase I--Preoperational research and development,

Phase II--The reactor test program after the start of reactor operation.

Phase I consists of 10 major tasks divided into 28 subtasks. This report summarizes the tasks scheduled for activity at this time. The remaining tasks will be included in future reports as the work progresses.

The following periodic reports have been issued in partial fulfillment of United States Atomic Energy Commission Contract AT(04-3)-540.

1. "Southwest Experimental Fast Oxide Reactor Development Program, First Quarterly Report, April-June 1964," GEAP-4594 (July 1964).
2. "Southwest Experimental Fast Oxide Reactor Development Program, Second Quarterly Report, July-September 1964," GEAP-4742 (October 1964).
3. "Southwest Experimental Fast Oxide Reactor Development Program, Third Quarterly Report, October 1964-January 1965," GEAP-4799 (February 1965).
4. "Southwest Experimental Fast Oxide Reactor Development Program, Fourth Quarterly Report, February - April 1965," GEAP-4864 (May 1965).
5. "Southwest Experimental Fast Oxide Reactor Development Program, Fifth Quarterly Report, May - July 1965," GEAP-4934 (August 1965).
6. "Southwest Experimental Fast Oxide Reactor Development Program, Sixth Quarterly Report, August - October 1965," GEAP-4994 (November 1965).
7. "Southwest Experimental Fast Oxide Reactor Development Program, Seventh Quarterly Report, November 1965 - January 1966," GEAP-5108 (February 1966).
8. "Southwest Experimental Fast Oxide Reactor Development Program, Eighth Quarterly Report, February-April 1966," GEAP-5160 (May 1966).
9. "Southwest Experimental Fast Oxide Reactor Development Program, Ninth Quarterly Report, May - July 1966," GEAP-5208 (August 1966).
10. "Southwest Experimental Fast Oxide Reactor Development Program, Tenth Quarterly Report, August - October 1966," GEAP-5301 (November 1967).

11. "Southwest Experimental Fast Oxide Reactor Development Program, Eleventh Quarterly Report, November 1966 - January 1967," GEAP-5442 (February 1967).
 12. "Southwest Experimental Fast Oxide Reactor Development Program, Twelfth Quarterly Report, February-April 1967," GEAP-5498 (May 1967).
 13. "Southwest Experimental Fast Oxide Reactor Development Program, Thirteenth Quarterly Report, May - July 1967," GEAP-5533 (August 1967).
 14. "Southwest Experimental Fast Oxide Reactor Development Program, Fourteenth Quarterly Report, August-October 1967," GEAP-5561 (November 1967).
 15. "Southwest Experimental Fast Oxide Reactor Development Program, Fifteenth Quarterly Report, November 1967 January 1968," GEAP-5595 (February 1968).
 16. "Southwest Experimental Fast Oxide Reactor Development Program, Sixteenth Quarterly Report, February-April 1968," GEAP-5629 (May 1968).
 17. "Southwest Experimental Fast Oxide Reactor Development Program, Seventeenth Quarterly Report, May -July 1968," GEAP-5673 (August 1968).
- In addition, the following topical reports have been issued:
1. Novak, P. E., and Asamoto, R. R., "A Survey for a High Temperature Sensor for SEFOR," GEAP-4903 (July 1965).
 2. Quinn, E. P., "Vibration of SEFOR Fuel Rods in Parallel Flow," GEAP-4966 (September 1965).
 3. Johnson, M. L., "A Description of Fuel and Other Core Materials Procured for SEFOR Critical Experiments in ZPR-III," GEAP-5133 (December 1965).
 4. Protsik, R., "Epithermal Capture and Fission Distribution in a Fuel Rod - The Computer Code REAX," GEAP-4973 (April 1966).
 5. Novak, P. E., and Asamoto, R. R., "An Out-of-Pile Evaluation of W-Re Thermocouple Systems for Use to 4700°F in Mixed Oxide," GEAP-5166 (May 1966).

6. Pflasterer, G. R., "SEFOR Experimental Program Planning, Vols. I and II," GEAP-5092 (August 1966).
7. Morrell, R. P., "SEFOR β/ℓ Measurements by Noise Analysis Techniques," IDO-17210 (August 1966).
8. Williams, R. F., and Polomik, E. E., "Pressure Drop and Dye Tests with Water on the SEFOR Prototype Fuel Bundle," GEAP-5129 (February 1966).
9. Craig, C. N., Ryer, C. M., and Thompson, M. L., "Plutonium-Uranium Mixed Oxide Fuel Pellet Fabrication Development for the Southwest Experimental Fast Oxide Reactor," GEAP-5285 (October 1966).
10. Polomik, E. E., and Williams, R. F., "Coolant Surface Turbulence Study, SEFOR Reactor Vessel," GEAP-5099 (December 1966).
11. Wilkinson, L., "Use of Neutron Filters for Fast Reactor Fuel Irradiations in a Thermal Core," GEAP-5035 (April 1967).
12. Wilkinson, L., et al., "Devices for Cyclic and Transient Power Control in a Steady-State Neutron Flux Gradient," GEAP-5036 (May 1967).
13. Reynolds, A. B., and Stewart, S. L., "Analysis of the SEFOR Mockup Critical Experiments in ZPR-3," GEAP-5294 (March 1967).
14. Wilkinson, D., "Weighted Doppler Analysis Code--WEDOP," GEAP-5513 (October 1967).
15. Craig, E. R., Fulton, R. H., Damon, J. J., "Design and Testing of Solenoid and Instrument Lead Connector for Use in SEFOR Reactor Vessel," GEAP-5307 (March 1967).
16. Asamoto, R. R., Perry, K. J., and Zebroski, E. L., "The Effective and Diametral Thermal Expansion of UO_2 Under a Radial Temperature Gradient," GEAP-5284 (October 1966).
17. McVean, R. L., Weitzberg, A., Kremser, J. A., Leridon, A. M., and Long, J. K., "Critical Studies of the Southwest Experimental Fast Oxide Reactor (SEFOR) in ZPR-3," ANL-7248.
18. Polomik, E., "Fluid Flow and Vibration Tests, 1/2-Scale Model of SEFOR Reactor Vessel," GEAP-5440 (April 1967).

19. Field, J. H., Johnson, M. L., and Novak, P. E., "An Evaluation of the Effect of Design and Operating Variables on SEFOR Fuel and Fuel Cladding," GEAP-5309 (Dec. 1967).
20. Noble, L. D., "Final Specifications for the SEFOR Experimental Program," GEAP-5576 (April 1968).
21. Russell, E. E., "Flow Distribution Measurements in a 3-Scale Model of the SEFOR Fuel Bundle," GEAP-5184 (May 1968).
22. Cochran, J., "SEFOR Core Clamping Model Tests, One-Sixth Segment," GEAP-5465 (May 1968).

SECTION II

SUMMARY

2.1 COMPLETED TASKS

Experimental or analytical work or both have been completed on the tasks listed below, although in some cases work on topical reports is continuing:

TASKTITLE

- 1.1 Specifications for the Reactor and Experimental Program
- 1.2 Final Specifications of the Experimental Program
- 2.0 Experimental Program in ZPR-III
- 3.1 Fuel Cladding Transient Performance

3.2 Specification of Fuel Composition

4.1 Fuel Temperature Measurement

4.3 Failed Fuel Location

4.4 Instrument Lead Connectors

4.5 Special Instrumentation

5.0 Steady State and Transient Characteristics of the Core Assembly

7.0 Fuel Handling

8.0 Core Design

2.2 TASK 4 - SPECIAL INSTRUMENTATION

Assembly of the core flux detector system electronics was completed. The compensated fission chambers were shipped to the SEFOR site. The gamma chambers neared the final assembly stage.

2.3 TASK 6 - REACTIVITY CONTROLS REQUIRED FOR EXPERIMENTATION

Testing of the oscillator mechanism was completed. Shipment to SEFOR is scheduled when the positioner device is available after the Fast Reactivity Excursion Device (FRED) tests. Fabrication of the FRED reactor model was completed and initial checkout tests started.

Fabrication of the balanced oscillator control equipment is continuing.

2.4 TASK 9 - FUEL FABRICATION

All fuel rods, special core rods, and core hardware were delivered to the SEFOR site. Receiving inspection of the fuel rods disclosed 28 fuel rods leaking helium in excess of specification (from 4 to 20 times specification limit) and 22 rods having minor dimensional deficiencies.

The first two instrumented fuel rods are completed, and assembly of the first instrumented fuel assembly has begun.

2.5 TASK 10 - STARTUP TESTING

Reactor neutronics calculations were begun to update existing predictions of some of the more important wet critical measurements using the best available cross sections and methods.

All equipment necessary for the reactor noise measurements was delivered to SEFOR. Pu^{239} and U^{235} foils for power distribution measurements were delivered to SEFOR.

Computer programs for analysis of reactor noise data and oscillator test data were debugged and completed.

2.6 TASK 11 - TRANSIENT TESTING

The shipping cask for this task was rented from the AEC and received from Atomics International. An application is being prepared to license this cask, in accordance with AEC Rules and Regulations, 10 CFR 71, for transportation of irradiated $\text{UO}_2\text{-PuO}_2$ fuel rods for destructive examination.

2.7 SEFOR OPERATION

Procedure writing progressed with the completion of Standard-Operating, Corrective, and Emergency Procedures, SEFOR Plant Regulations, near completion of the Pre-Operation Test Procedures, and the issuance of Test Procedures (Experimental Program) for comment. Pre-Operation Tests were completed on a number of systems: sodium was charged into the primary and secondary drain tanks: cold trapping and sodium system pre-

operation tests were initiated.

All standard and guinea-pig fuel rods were received, inspected, and leak checked. AEC operator license examinations (written) were conducted. Staffing of SEFOR Facility was completed.

2.8 SEFOR CONSTRUCTION

Construction work was completed and all contractors left the site except for a local electrical contractor who was engaged to complete recent electrical changes.

SECTION III

TASK 4 - SPECIAL INSTRUMENTATION

3.1 TASK 4.2 - CORE FLUX DETECTOR SYSTEM

3.1.1 Purpose

The objectives of Task 4.2 are to develop a suitable detector system for recording the transient flux during the SEFOR experimental programs. The data will be used to determine the total power and energy generated and the net reactivity as a function of time during the transient.

3.1.2 Past Accomplishments

Prototype detector systems consisting of detector-amplifier combinations were built and tested. Following completion of testing, final units were released for manufacturing.

3.1.3 Current Accomplishments

3.1.3.1 Electronics

Electronic assembly has been completed with all units tested.

Amplifiers are currently undergoing further tests for linearity and calibration in the nuclear electronics calibration laboratory. After final checkout, they will be installed in the panel. They are scheduled to be shipped to the SEFOR site in late November 1968.

3.1.3.2 Detectors

The compensated fast fission chambers (U-238 coating) have been completed and shipped to the SEFOR site.

The gamma detectors are in final assembly. The latter part of November is the scheduled shipping date for FW47.

SECTION IV

TASK 6 - REACTIVITY CONTROLS REQUIRED FOR EXPERIMENTATION

4.1 - Task 6.1-FAST REACTIVITY EXCURSION DEVICE (FRED)

4.1.1 Purpose

The FRED is being developed to initiate reactor power excursions under controlled conditions. The device developed under this task will be used in SEFOR to carry out the planned excursions during the experimental program.

4.1.2 Past Accomplishments

The FRED Model I Test Program was completed and a detailed analysis carried out on the reactor model design. The detail design and fabrication of the positioner device was completed.

Also, the detail design of the drywell was completed in accordance with Section 3 of the ASME Pressure Vessel Code.

4.1.3 FRED

The fabrication and assembly of the FRED reactor model is complete. Instrumentation wiring and calibration of the signals for position indication and pressure level was completed in preparation for testing to be performed at San Jose.

In preliminary tests, the FRED reactor Model performed as predicted from the FRED model I data. The measured time for the 20-inch motion of the FRED reactor model was very close to the

corresponding time achieved on the earlier FRED test model.

The final phase of testing on the FRED reactor model will be started shortly. This final phase consists of a series of room-temperature and heated tests which will allow a closer determination of the relationship between accumulator pressure and the time required for 20-inch motion. The heated tests will simulate reactor head temperature so that data derived can be directly applied to actual reactor tests with the FRED.

4.1.4 Drywell

Fabrication of the drywell is continuing. Delivery of the upper and lower shield tubes, which are being gun-bored by an outside vendor is over five weeks late. Delivery of the drywell to SEFOR is scheduled for December 1, 1968.

4.1.5 FRED Poison Rod

The experimental program requires poison slugs with three different worths for the FRED tests. The poison rod is a two section design as shown in Figure 1. The upper section is attached to the piston in

the FRED guide tube and provides a connection point at the bottom for any of the three poison slugs or the dummy slug. The lower section consists of any one of the three poison slugs or the dummy rod, all which can be interchanged with the upper section. Figure 1 shows the poison rod with the arc of the poison slugs connected to the upper section. Fabrication of the upper section and the dummy slug was completed and used for running check-out tests with the FRED. The detail design of the three poison slugs will follow measurements of the worth of B_4C in the SEFOR oscillator rod.

4.2 TASK 6.2 - OSCILLATOR DRIVE

4.2.1 Purpose

The purpose of this task is to develop a device for introducing oscillating increments of reactivity into the core. The results of these tests will give information relative to the design requirements including plant dynamic response and full power reactivity (temperature) coefficient.

4.2.2 Past Accomplishments

The oscillator mechanism room temperature tests were completed and

the final phase of testing started, which included a series of heated tests in which the reactor head temperatures were simulated. The procurement of components for the balanced oscillator control system has been completed and fabrication started.

4.2.5 Oscillator Poison Rod

The detailed design of the oscillator poison rod has been started. This poison rod will be worth ~40 cents. After fabrication, the oscillator poison rod will be checked for actual worth in reactor tests. The self-shielding effect (as determined by comparison of calculated and actual worths) will be applied to the design of the FRED poison slugs.

4.2.3 Oscillator Mechanism

The final phase of testing on the oscillator mechanism has been completed.

Heated tests simulating reactor head temperatures showed no significant changes in the oscillator mechanism's operating characteristics. Also, under heated test conditions, no significant change occurred in the time required to raise and lower the positioner drive on either speed with the oscillator mounted on the positioner drive. The oscillator mechanism is being readied for shipment to the SEFOR site and this has been scheduled for the next quarter.

4.2.4 Balanced Oscillator System

The fabrication of the balanced oscillator control system has been delayed by the late delivery of other components for the electrical equipment panel. The balanced oscillator items are all ready for installation when the assembly of the panel is started.

FIGURE 1. ACTUATOR ROD AND POISON SLUG

SECTION V

TASK 9 - FUEL FABRICATION

5.1 PURPOSE

The purpose of Task 9 is to procure fuel rods and associated core components for SEFOR. Fabrication of the hexagonal fuel channel and all of its internal components are a part of this task, as well as the instrumented fuel assembly fabrication.

5.2 PAST ACCOMPLISHMENTS

Following completion of a number of loaded fuel rods at Nuclear Fuel Services, production was halted because of indications of a high volatile content in the fuel pellets. After installation of a vacuum outgas furnace, production was resumed, and 350 fuel rods were delivered to SEFOR.

A total of 743 extension rods had been completed by the end of the last quarter. Because of difficulties and delays experienced by the tube-forming vendor for the tightener rods, alternate means of making the tightener rods were developed. Assembly tooling for the tightener sleeves was completed.

Incorrectly formed fins were reformed by the vendor and returned to GE. Some 120 assemblies of the tightener rods were completed except for the bottom casting.

Machined parts and assembly fixtures for the instrumented fuel assemblies were all essentially completed. Weld and braze development was performed to qualify personnel and establish parameters. Completion of the first two instrumented fuel rods was held back by the delay in receipt of the fuel pellets.

5.3 CURRENT RESULTS

5.3.1 Fuel Rod Production

The complete fuel rod order (756 standard rods and 18 25-percent plutonium enrichment rods) was received at SEFOR. Results of the receiving inspection are shown in Table I. In addition to the planned-dimensional check and room-temperature helium-leak check, a final helium-leak check was performed with the end plugs

TABLE I

<u>Reason for Rejection</u>	<u>Number of Rejected Rods</u>				
	Standard Fuel Rod	Guinea Pig Rods	B ₄ C	Depleted UO ₂	Steel
Leaked (cold)	2	0	2	2	0
Leaked (heated end plugs)	25	1	3	0	1
Dimensions	10	10	0	0	0
Cladding Damage	2	0	0	0	0
Totals	39	11	5	2	1

heated to 600°F-800°F. This was done, because previous leak tests of the end plugs showed evidence of microscopic flaws in some of the end-plug bar stock. It was deemed advisable to make an attempt to minimize the potential fission gas leaks in the core.

Negotiations with Nuclear Fuel Services are underway concerning the disposition of rejected rods.

5.3.2 Fuel Pellet Gas Content

The previous quarterly progress report contained a description of the process and quality control procedures being used by Nuclear Fuel Services (NFS) to outgas the 327 loaded rods. With the exception of two pellets from one production rod the pellet gas

release measurements performed by NFS and GE on samples from 15 pre-production and production outgassed rods showed the pellet gas content to be within specification. The significance of the out-of-specification results (60 to 100 $\mu\text{L/gm}$) obtained by GE and ORNL on the two pellets taken from one production outgassed rod is not yet clear. Additional gas content analyses of rods outgassed in the same and adjacent furnace loads are in progress to determine the extent of the problem indicated by these out-of-specification measurements.

Based on a knowledge of the furnace operating characteristics, it is believed that, at most, 35 rods may be suspected of inadequate outgassing. Records are available to identify all rods with respect to furnace run number and position in the furnace.

5.3.3 Core Hardware

5.3.3.1 Tightener Sleeve

All 120 tightener sleeve assemblies were completed, inspected, and shipped to the SEFOR site during the quarter. Figure 2 shows the completed assembly.

5.3.3.2 Tightener Rod

The tightener rods were completed during the quarter and all 113 assemblies were received at the SEFOR Site. The tightener rod assembly is shown in Figure 3.

Prior to the start of the tightener rod assembly some of the tubing for the BeO section was found to suffer from a slight intergranular attack on the inside diameter of the lower tube. Further metallographic investigations found this attack on the inside diameter of one of the as-received tubes made from heat No. 127700. The tubing order had been made from two heats; 142 pieces from heat No. 137955 and 18 pieces from heat No. 127700. The vendor was contacted regarding this problem and it was learned they had experienced previous difficulty with material made from heat No. 127700. A GE engineer visited the vendor's plant

to discuss this problem and observe the fabrication process. The vendor suspects the intergranular attack started during the cleaning of the tube hollow after air annealing. A new tubing order was placed since all heat identification marks had been removed from the tubes during the final cleaning and a non-destructive testing technique testing was not then available to determine which tubes were affected.

Concurrent with the arrival of the new tubing order an ultrasonic technique was developed to determine tubing surface condition. The new tubes received 100% ultrasonic inspection for surface condition along with the standard wall defect (>0.004 inch) testing. The tubing was found to be acceptable.

5.3.3.3 Extension Rod

All extension rods were completed and shipped to the site during the previous quarter.

Because the extension rod tubing was made from heat No. 127700 (see tightener rod), it was decided to ultrasonically inspect the extension rods to determine the inside-diameter surface condition using the method developed for inspecting the tightener rod

TOP HALF

BOTTOM HALF

FIGURE 2. SEFOR TIGHTENER SLEEVE ASSEMBLY

TOP HALF

BOTTOM HALF

FIGURE 3. SEFOR TIGHTENER ROD ASSEMBLY

tubing. A slight attack was found on some of the material.

Furnace and autoclave tests were run on the tubing material under the expected reactor environments of temperature and moisture. Stress, temperature, and moisture were used as accelerants in the test. The tests showed no further surface degradation in the material used in the extension rods. Based on the experimental results, the material is suitable for use in the SEFOR core.

5.3.3.4 Foil Holder Rods

Seven foil holder rods were shipped to and received at the SEFOR site during the quarter.

5.3.3.5 Surveillance Specification Holder Assembly

Ten surveillance specimen holders and 10 surveillance holder extension rods were shipped and received at the SEFOR site during the quarter.

5.3.4 Instrumented Fuel Assemblies

5.3.4.1 Instrumented Fuel rods

The first two instrumented fuel rods were completed during this quarter. Work continues with these fuel rods and

other components to build the first Instrumented Fuel Assembly. The fabrication of the second set of fuel rods was begun; one of these rods contains a bare wire thermocouple.

Several problems have arisen in the fabrication of the bare wire thermocouples. A break in the W/26Re thermocouple wire (part of a bare wire thermocouple) resulted in delaying the second set of fuel rods. Protection of the bare wire thermocouples from exposure to the air atmosphere was deemed necessary. A container was provided to maintain the helium atmosphere. It was also found necessary to use a 0.005 inch diameter stainless-steel wire as a fuel spring retainer to prevent the spring from loading the bare wire thermocouple while the fuel rod was being assembled.

5.3.4.2 Machined Parts

Some rework of parts has been necessary as detailed assembly work gives indication of fabrication limitations. The comparison, for instance, of Figure 4 with Figure 6-3 of the Sixth Quarterly Report (GEAP-4994) shows the changes required for the electrical lead splices. This splice was added to allow the IFA to be made in two separate subassemblies and then the electrical leads to be spliced together at the final assembly.

FIGURE 4. INSTRUMENTED FUEL ASSEMBLY — AS BUILT

5.3.4.3 Outside Vendor Items

All outside vendors' parts were received. Some minor changes such as the length of the thermocouple ceramic beads has made necessary rework or reorder of vendor parts.

The extension rod tubes for the fuel and the tightener rod tubes were replaced with new tubes after visual inspection showed 10% of the tubes to be affected by intergranular corrosion.

5.3.4.4 Parts in Common with Regular Fuel Assemblies

All parts are on hand for assembly work. An additional joint was made in the hexagon shaped tightener sleeve to facilitate assembly. With this change, the coolant inlet and the outlet thermocouples are brazed into the tightener rod in the same brazing jig.

5.3.4.5 Flowmeters

It was necessary to build several extra flowmeters due to a brazing problem (see the following paragraph).

5.3.4.6 Weld and Braze Development

Weld and braze development continued to be necessary along with the

assembly operations. Unforeseen braze difficulties resulted in the loss of three flowmeters as the braze of the flowmeter lead was made into the bottom of the tightener rod. An intermediate sleeve placed between the lead and the tightener-rod end plug resulted in a successful joint at this point.

Braze development included use of high nickel content material for furnace brazing in vacuum, hydrogen and "forming gas" atmospheres. Induction heating and resistance filament heating were used in all these different atmospheres. Torch brazing development was also performed as a possible alternate to the furnace braze technique. Two brazes remain to be qualified. Mockups and braze qualification are in process for these brazes.

5.3.4.7 Assembly

All major redesign work requested by the assembly shop was completed and drawings were issued.

The assembly of the first Instrumented Fuel Assembly (IFA) was completed in the flowmeter tightener rod and fuel rod areas. Work to be completed includes the upper housing where the fuel and tightener rods are joined together and the part of the

IFA where the 20-pin instrument lead connector is located.

5.3.4.8 Transport Fixtures

All six transport fixtures have been completed and inspected.

5.3.4.9 Shipping Containers

Design was completed on the shipping containers. Preparation of the shipping license application neared completion and is scheduled to be submitted to the AEC in early November.

Fabrication of shipping containers was delayed because of late delivery of honey-comb material used as shock absorbent structure.

5.3.4.10 Fuel Thermocouples

Tests were completed on a thermocouple produced at GE-VNC, which was similar to thermocouples being fabricated for use in SEFOR. Results showed that the thermocouple operated

satisfactorily for over 200 hours at temperatures greater than 2000°C (3632°F) of which approximately 140 hours were at, or above, 2200°C (3992°F). A maximum temperature of 2570°F (4658°F) was recorded. On completion of the steady-state test, the thermocouple was thermally cycled from room temperature to 2235°C in 1-1/2 minutes and then cycled 5 times between 1000°F to 2200°C in 2 minute intervals. Calibration of the thermocouple was performed before and after the thermal cycles, and the results indicated no significant change in calibration.

Metallographic examination of the sheath and thermo-elements after testing, showed them to be in excellent condition. There was no evidence of porosity in the sheath or deterioration of the thermo-elements. These results indicate that the SEFOR thermocouples produced by the present fabrication process should perform satisfactorily.

SECTION VI

TASK 10 - STARTUP TESTING

6.1 PURPOSE

The purpose of Task 10 is to investigate the startup characteristics of a $\text{PuO}_2\text{-UO}_2$ fuel fast reactor and compare the experimental results to the theoretical calculations. The wet critical tests comprise Task 10.3, and Task 10.4 includes the approach to full power.

6.2 PAST PERFORMANCE

Two ion-chamber holders for in-core neutron detectors (noise measurements) were completed and shipped to the site. A storage cask for the cobalt 60 source was completed, loaded with the source, and made ready for shipment to the site. The design of fuel transfer equipment (cask transfer cart, cask-to-cell seal) was essentially completed. A number of changes in the data acquisition program were outlined and sent to programming vendors for bids.

6.3 CURRENT RESULTS

6.3.1 SEFOR Neutronics Calculations

A recalculation of important SEFOR neutronics parameters was started in October, which includes the use of more recent cross section information and more sophisticated computer programs than in previous SEFOR calculations.

Parameters of immediate interest are minimum critical mass, reactivity worth of fuel elements near the core boundary, reflector worth, prompt neutron lifetime, and temperature and expansion coefficients.

The calculational methods and the cross section set will be checked by calculations for the SEFOR mockup in ZPR-3 and comparison with experimental results.

Some of the steps of the recalculation have been completed by the end of this report period; these follow:

- After a critical review of some recent cross section measurements for Pu-239, Pu-240, and U-238, the 60-group cross section set (BAS03)* was modified. The most important modifications are:
 - Pu-239 - ν was increased by 0.77%, ORNL-RPI alpha values were used in the keV region.
 - Pu-240 - $\sigma(n,\gamma)$ was reduced by 1/6 in accordance with a resonance (n,γ) width of 25 MeV.
 - U-238 - $\sigma(n,f)$ was reduced by 5% above 2 MeV.
- The CROF program* was used to determine zone-dependent fuel self-shielding factors for SEFOR and the SEFOR mockup in ZPR-3. Bell approximation corrections due to the respective lattice cell structure were included.
- One-dimensional, 60-group diffusion calculations have been completed. They served as a basis for zone-dependent energy group condensations for the planned BISYN** and two-dimensional S_4 calculations. The reactivity result of the radial 60-group diffusion calculation for the ZPR-3 mockup of SEFOR is $k_{\text{eff}} = 0.992$. High energy heterogeneity corrections and transport corrections will bring the result even closer to unity, which was the experimentally observed value.

6.3.2 Power Distribution and Reaction Rate Measurements

6.3.2.1 Accuracy Requirements for Pu-239 Alpha Measurements

The capture-to-fission ratio (α_9) of Pu-239 is one of the most uncertain integral parameters influencing the neutron balance in SEFOR. One aim of the α_9 measurements in SEFOR is a reduction of the uncertainty in this parameter.

* C. L. Cowan, "A Cross Section Fitting Routine for U-235, U-238, Pu-240 and Tantalum," 1968.

** P. Greebler, et al, "BISYN - A Two-dimensional Synthesis Program," GEAP-4922 (1965).

An investigation was carried out to determine if and under which conditions α_g measurements in SEFOR are of more general interest for the design of fast plutonium reactors. The main results follow:

- About 60% of the Pu-239 capture events in the central SEFOR spectrum occur in the energy range between 0.5 and 25 keV, in which recently measured differential α_g measurements differ by a factor of about 2. The calculated integral α_g value in SEFOR, based on the revised UK differential values, is 48% higher than that based on the BAS02 cross section set. Therefore, α_g measurements in SEFOR will provide an excellent opportunity to get information about α_g in the uncertain energy range. Useful conclusions about α_g values in the uncertain energy range may be possible if the uncertainty in the experimental integral α_g value can be restricted to less than 10% and if spectrum information (uncertainty in the overall shape of the spectrum restricted to about 15%) is available.
- Spectrum measurements have been considered, although they are

not within the scope of the SEFOR contract. (They would also be helpful for the interpretation of Doppler experiments.) The only practicable spectrum measurement method for use in SEFOR appears to be the foil activation method which uses threshold and resonance detectors. This method has been pursued extensively at Battelle Northwest Laboratories (Hanford); based on their work, flux spectrum measurement errors of $\pm 10\%$ to $\pm 30\%$ are expected.

6.3.2.2 Experimental Program for Pu-239 Alpha Measurements

The basic alpha measurement program planned for SEFOR involves, simply, an extended irradiation at high power (approximately 1 week at 15 MW) of high-purity Pu-239, U-235, U-238, and Pu-240 wafers and subsequent analysis of the fission products and neutron capture products in the wafers. Assuming the fission yield to be known in the SEFOR spectrum (current uncertainty appears to be approximately $\pm 10\%$), the experimental Pu-239 alpha value has an associated uncertainty of approximately $\pm 15\%$. High-purity isotopes which are suitable for these measurements are available at ORNL.

AEC authorization to use this material has been obtained.

In order to assess the problems involved in achieving an alpha measurement with an error less than $\pm 15\%$, an expanded experimental program for the measurement of α_9 with an uncertainty limited to about 5% was outlined. It provides for measurement of fission product yield in SEFOR, which otherwise would be the main restriction in the achievable accuracy of α_9 .

The essential steps of the expanded program, outlined for study purposes only, are:

- Measurement of the Pu-239 to U-238 fission ratio with absolutely calibrated fission chambers at low power.
- Measurement of the capture-to-fission ratio for U-238 at low power using the well proved gamma x-ray coincident technique to determine the Np-239 activity of irradiated U-238 foils, which is a measure for the number of capture events. The number of fission events will be obtained by fission-product gamma counting of the

irradiated foils, calibrated by comparison with U-238 fission chamber results.

- High power irradiation (about 1 week at 15 MW) of U-238 and Pu-239 foils and subsequent mass spectrometrical determination of the Pu-239 content in U-238 foils and the Pu-240 content in Pu-239 foils. This step yields the Pu-239 to U-238 capture ratio.
- Neutron energy spectrum measurements as described in paragraph 6.3.2.1.

By combining the results of the first three steps α_9 is then gained. The neutron spectrum measurement is used to improve the estimate of the α_9 value in the low-energy (0.5 to 25 keV) region. This expanded program is being evaluated in terms of the usefulness and timeliness of the data and where it might be scheduled in the SEFOR test program.

Preliminary laboratory work was started to select a suitable method for preparation of the very thin, high-purity foils, which are needed for either the basic or expanded programs.

Several processes for fabricating foils are being considered including electro-deposition and evaporation of a plutonium solution on an aluminum backing material.

6.3.2.3 Power Distribution and Fission Ratio Measurements

Sample foil capsules and spacers for these measurements have been constructed. Manufacturing of a complete set of capsules and spacers for SEFOR is underway.

Fifteen encapsulated plutonium (93% Pu-239) foils and 40 U-235 (93% U-235) foils have been delivered to SEFOR for these measurements. Additional Pu-240, U-238, and U-235 foils are being procured.

6.3.2.4 Prompt Neutron Lifetime (ℓ/β) Measurement

The necessary equipment for the ℓ/β measurement by the noise analysis method was delivered to the SEFOR site. This equipment includes the necessary electronic amplifiers and filters as well as the 10-atmosphere helium-3 chambers (also used for initial loading to critical) and the

two dry wells for inserting these chambers into the core region.

The digital computer program for analyzing the reactor noise data to determine ℓ/β has been written, and a preliminary check showed that the program is working properly.

6.3.2.5 Computer Programs for Test Data Analysis

Three computer programs have been specified for use in analyzing SEFOR oscillator test data. The first of these uses oscillator data from the SEFOR data acquisition system and calculates coefficients of the fundamental and harmonic components of the periodic signal. The second program uses output from the first to calculate transfer functions between any two quantities (e.g. temperature and power). The third determines reactivity coefficients and frequency response parameters by fitting theoretical models to the experimental transfer functions.

The first two computer programs have received limited checkout and appear to be working properly. The third is now being debugged.

Computer programs which will be used to check and correct data tapes containing spurious or missing data have received limited checkout and are working properly.

SEFOR data acquisition computer programs to provide for recording the reactor noise test data and for more flexibility in data handling at the SEFOR site.

An outside software vendor completed the planned changes to the

SECTION VII

TASK 11 - TRANSIENT TESTS

7.1 PURPOSE

The purpose of Task 11 is to investigate the behavior of a $\text{PuO}_2\text{-UO}_2$ fueled fast reactor for reactivity changes less than 1\$ and compare the experiemntal results with theoretical calculations. The types of tests to be conducted at various power levels include static, oscillation, and subprompt-critical transient reactivity changes.

Canoga Park prior to shipment to GE and required repairs.

The preliminary design of a transfer tube between the refueling cell valve and the cask, radiation shielding around the transfer tube, and a cart to transfer the cask from the loading dock to a position beneath the vertical transfer port in the reactor building was completed, except for changes to the cask to adapt it to the fuel transfer operation at SEFOR.

7.2 PAST ACCOMPLISHMENTS

The San Francisco Operations Office of the AEC approved a request to rent an existing AEC cask. The cask and shipping cradle were dropped at

The analysis of the cask for compliance with 10 CFR 71 was begun. Nuclear analysis revealed that 19 fuel rods would be required for criticality, with a spherical geometry and a 4.5 to

1 water to fuel ratio. Since the maximum proposed shipment will be three rods, criticality will not present a problem. The thermal analysis revealed that a problem existed in the temperature caused by decay heat from the fuel rods.

7.3 CURRENT RESULTS

The fuel rod canister design was re-evaluated because of two problems that arose as the design progressed: (1) removal of the decay heat from the fuel rods and (2) the requirement that the fuel rod or rods to be shipped be bagged out of the refueling cell into the cask. The first of these problems was solved by making the inner canister a solid steel insert and boring a hole for each fuel rod, thereby eliminating the large argon gap which had provided the largest heat transfer barrier in the previous canister design. The second problem was solved by specifying that, when the SEFOR refueling cell becomes alpha contaminated, shipments will be limited to one fuel rod per shipment. This decision results in a smaller inner canister diameter, which will allow sufficient room for the bagging-sleeve seal to be made on the inside of the outer canister. The outer canister diameter is in turn con-

trolled by the requirement that it can be inserted into the RML alpha cell through the sphincter tube.

The AEC shipping cask, rented for this task, was received from Atomics International. The cask was visually examined and appeared to be sound. The cask fire shield insulation, however, was in very poor shape. The insulation required to repair the fire shield was ordered and plans were made for the repair work.

A cart has been fabricated at the SEFOR site for hauling heavy (11 tons) shielding blocks. With the addition of a cover plate to this cart, it will be adequate to transport the 8-ton fuel rod shipping cask.

The plan of action for the coming period includes the following:

- the completion of the design of the transfer tube equipment, including the fuel rod shipping canisters, and releasing for fabrication
- the repair of the cask fire shield and shipment of the cask to SEFOR

- modification of the transfer cart to adapt it for hauling the fuel rod shipping cask
- a dry run of the cask loading procedure after receipt of all equipment at SEFOR, and
- completion of the license applications for use of cask B of E 1233 for the shipment of SEFOR fuel rods.

SECTION VIII

SEFOR OPERATIONS

8.1 PRE-OPERATION TESTS

Writing of Pre-Operation Test Procedures was completed except for Sodium System Hydraulics. With the exception of six in review, all other Pre-Operation Test Procedures have been issued.

- Sodium Pump Power Supplies
- Area Radiation Monitoring
- Neutron Monitoring
- Process Radiation Monitoring
- Reflector Control Drives and Instrumentation
- Reactor Safety System
- Reactor and IFST Safety Vessel Leak Test

8.1.1 Pre-Operation Tests Completed

- Inner Containment Leak Rate
- Secondary Sodium Filling and Cold Trapping (Drain Tank and Service System)
- Main and Auxiliary Air Blast Coolers
- Fill Primary Sodium Drain Tank
- Fill Main Secondary System
- Trace Heating on All Sodium Systems

8.1.2 Pre-Operation Tests Nearing Completion

- Nitrogen Cooling
- Freon
- Argon (Primary System)
- Auxiliary IHX Insulation Drop
- Sodium Process Instrumentation
- Refueling Cell Equipment

8.2 FUEL RECEIVING AND INSPECTION

During the quarter, 397 standard fuel rods and 18 guinea pig rods were received for a total of 774. Receiving inspection and leak checks of all fuel rods and special core rods were completed.

8.3 TECHNICAL SPECIFICATIONS

Contributed information to the SEFOR Technical Specifications.

8.4 DATA ACQUISITION SYSTEM

Familiarization and check out of computer programs continued. Several discrepancies were discovered in codes and corrected.

8.5 OPERATOR TRAINING AND LICENSE EXAMINATIONS

A series of formal training sessions were conducted for a two-week period preceding the AEC operator license examinations. Operator license examination was held on October 17 and Senior Operator examination was held on October 18. Oral examinations are scheduled for November 5, 6, and 7.

8.6 STANDARD OPERATING AND CORRECTIVE PROCEDURES

The writing, review, and issuance of Standard Operating and Corrective Procedures were completed.

8.7 EMERGENCY PROCEDURES

The SEFOR Emergency Plan and Procedures have been completed and published. Representatives of the Arkansas State Police visited the site to discuss their participation in the SEFOR Emergency Plan. They were provided copies of the Emergency Procedures in which their assistance is specified.

Dr. John Vinzant, physician retained by General Electric and a member of the Washington County General Hospital Staff, attended the AEC sponsored seminar at Brookhaven (October 21, 22, and 23) on the medical aspects of radiation and contamination treatment.

A feasibility test was conducted with the Fort Smith Weather Bureau, and it was verified that severe weather warnings and tornado alerts issued by the Weather Bureau can be

received at the SEFOR site by radio (154 Mc).

The SEFOR Plant Regulations were completed and issued.

8.8 TEST PROCEDURES (Program)

Writing of Test Procedures for the Experimental Program continued with a number issued for review and comment.

8.9 SEFOR STAFF

The Manager-Plant Engineering and Manager-Operations positions were filled to complete the SEFOR Facility Staff.

8.10 MAINTENANCE

Repair of equipment malfunctions and general site maintenance activities were accomplished.

SECTION IX

SEFOR CONSTRUCTION

9.1 MECHANICAL DEPARTMENT

The inner containment leak test was successfully completed in August with observed leakage at 1.92% a day at 10 psi.

Rework of the male receptacles of the 27-pin electrical power connectors was completed at the vendor's plant. The connectors were installed at the site and satisfactorily tested.

The reactor building external surface was painted following final curing of the insulation.

Each of the two primary sodium cold traps was modified at the cooling gas outlet in order to provide a low pressure drop outlet plenum for better cooling gas distribution.

The liquid radwaste discharge was repiped to drain into the tile field.

The 50 kW backup diesel was received at the site.

9.2 ELECTRICAL DEPARTMENT

A local electrical contractor, Arkansas Electrical Contractors,

initiated work on September 30 to complete recent electrical changes.

The following work items were completed during the quarter:

- Covering of cable trays.
- Installation of fire stops at the base of vertical risers.
- Installation of seismic sway braces in accordance with Sargent & Lundy recommendations.
- Installation of protective fences around containment vessel penetrations.
- Checkout and release of sodium heater circuits in reactor building.
- Installation of nitrogen cell communications system.
- Checkout of nitrogen system wiring.
- Installation of 2 additional calrod heaters under the return bends of the main air blast cooler.

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