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AEC RESEARCH AND
DEVELOPMENT REPORT
MAY 1969

**SOUTHWEST EXPERIMENTAL
FAST OXIDE REACTOR
DEVELOPMENT PROGRAM
TWENTIETH QUARTERLY REPORT
FEBRUARY - APRIL 1969**

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

BREEDER REACTOR DEVELOPMENT OPERATION

GENERAL ELECTRIC

SUNNYVALE, CALIFORNIA

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GEAP-10010
AEC Research and
Development Report
May 1969

SOUTHWEST EXPERIMENTAL FAST OXIDE REACTOR DEVELOPMENT PROGRAM

Twentieth Quarterly Report
February—April 1969

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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

February 1, through April 30, 1969. 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, sodium-cooled fast reactor with characteristics similar to the large, soft spectrum fast breeder reactors fueled with mixed $\text{PuO}_2\text{-U-238O}_2$, 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).
 18. "Southwest Experimental Fast Oxide Reactor Development Program, Eighteenth Quarterly Report, August - October 1968," GEAP-5705 (November 1968).
 19. "Southwest Experimental Fast Oxide Reactor Development Program, Nineteenth Quarterly Report, November 1968-January 1969," GEAP-5754.
- 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 XPR-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-7348.
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 (December 1967).
20. Noble, L. D., "Final Specifications for the SEFOR Experimental Program," GEAP-5576 (April 1968).
21. Russell, C. 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).
23. Asamoto, R. R., and Novak, P. E., "An In-Pile Evaluation of W-R3

- Thermocouple Systems for Use to 4700°F in SEFOR Fuel," GEAP-5466 (October 1968).
24. Cochran, J. T., "SEFOR Fuel Assembly Sodium Flow Tests," GEAP-5466 (September 1968).
25. Cochran, J. T., "SEFOR Fuel Rod Sodium Thermal Shock Tests," GEAP-5467 (August 1968).
26. Craig, E. R., "SEFOR Instrumented Fuel Assembly Design and Development," GEAP-5615, (April 1968).

SECTION II

SUMMARY

2.1 COMPLETED TASKS

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

<u>TASK</u>	<u>TITLE</u>
1.1	Specifications for the Reactor and Experimental Program
1.2	Final Specifications of the Experimental Program
2.0	Experimental Program in ZPR-III
3.0	Fuel Development
4.0	Special Instrumentation
5.0	Steady-State and Transient Characteristics of the Core Assembly
7.0	Fuel Handling
8.0	Core Design
2.2	TASK 6—REACTIVITY CONTROLS REQUIRED FOR EXPERIMENTATION

All items have been completed except for the shipment of the Fast Reactivity Excursion Device (FRED) and the writing of a topical report.

2.3 TASK 9—FUEL FABRICATION

2.3.1 Fuel Rods

The work continued in the measurement of gas pressure developed in a fuel rod heated between 800°F and 1000°F. Initial results indicated 10 to 15 microliters per gram of fuel.

2.3.2 Instrumented Fuel Assemblies

The two fuel rods for the second instrumented fuel assembly (IFA) were completed. Assembly work continued on additional fuel rods, the second IFA, and subassemblies for subsequent IFAs.

2.4 TASK 10—STARTUP TESTING

The major components of the reactivity feedback coefficients for the SEFOR minimum critical core at 350°F and zero power were calculated. The predicted Doppler coefficient ($T dk/dT$) is -0.0086, while the predicted total expansion coefficient is -0.44 cent/°F. The total calculated feedback coefficient for the minimum critical core, including the Doppler effect, is -0.77 cent/°F. These coefficients are in good agreement with earlier calculations of the feedback coefficients in the full size core.

The computer programs and procedures which will be used for the analysis of the SEFOR noise and oscillator test data are being checked out on simulated test data tapes which were generated at the SEFOR site. Preliminary results indicate that the programs are working satisfactorily.

2.5 TASK 11—TRANSIENT TESTS

General Electric Co. has received authorization from the AEC to rent a fuel transfer cask from Atomics International. The cask will be used to ship used fuel rods from SEFOR to a "hot lab" for examination. The cask (B of E 1233) has been received, inspected, and cleaned by GE, and is currently being stored at the SEFOR site.

The work on completion of the design continues. Fabrication of the equipment required for the transfer of fuel rods out of the refueling cell to the transfer cask is beginning.

2.6 SEFOR OPERATIONS

Pre-operation tests were completed. The main primary sodium system was operated at greater than full flow conditions, the strainers were removed, and the system were restored to an operational status. The refueling cell was filled with argon, the purification loop placed in service, and the cell pressure control established. The nitrogen zones were filled with nitrogen and pressure control was established. Fuel loading was initiated, coming within one rod of criticality. All of the Group I—Zero Power Test Procedures have been issued.

SECTION III

TASK 6—REACTIVITY CONTROLS REQUIRED FOR EXPERIMENTATION

3.1 TASK 6.1—FAST REACTIVITY EXCURSION DEVICE (FRED)

3.1.1 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.

3.1.2 Past Accomplishments

The FRED reactor model development testing was completed. The positioner drive mechanism and drywell were shipped to SEFOR.

3.1.3 Current Results

3.1.3.1 FRED

The FRED has been dismantled, inspected, and prepared for shipment. It is expected that the FRED will be shipped during May 1969.

3.1.3.2 Topical Report

The preparation of a topical report has been started.

3.2 OSCILLATOR DRIVE

3.2.1 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.

been completed and shipped to the SEFOR site.

3.2.2 Past Accomplishments

The oscillator mechanism, poison rod, and balanced oscillator control system have

3.2.3 Current Results

The preparation of a topical report has been started.

SECTION IV

TASK 9—FUEL FABRICATION

4.1 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.

4.2 PAST ACCOMPLISHMENTS

The complete fuel-rod order had been received at SEFOR in previous quarters. Of 50 rods rejected for helium leaks and dimensional deficiencies, some 20 were corrected in the last quarter. The first instrumented fuel assembly (IFA) was completed and shipped to SEFOR.

4.3 FUEL RODS

Because of wide variation (factor of two on some pellet samples) in the fuel-gas release results obtained by GE using small (3 grams) pellet samples, work was initiated to obtain gas release measurements on an entire column of fuel pellets (10 to 25 pellets). While the small sample gas release results indicate (on a statistical basis) that fuel rod cladding stresses are acceptable, several gas release values from Batch 617 samples (32 rods in the batch) in excess of the

fuel specification limit have been obtained by GE (NFS results on 10-gram samples were all below the specification limit). It is believed that the source of wide variation in gas release results lies in pellet surface contamination from the pellet grinding coolant. Past measurements have shown an association between high gas release and grinder coolant contamination, but have not been entirely conclusive. Since the value of interest for cladding stress analysis is the average gas release for an entire fuel column, it was decided to perform a measurement of this quantity at 1000°F (earlier results show most of the gas is evolved at 800°F).

During the quarter, two different approaches to the gas-pressure measurement were pursued. One method uses a diaphragm-type pressure transducer (strain gage) connected to the fuel tube by a capillary tube. This arrangement reduces the unheated volume (transducer and part of the capillary tube are at room temperature) to approximately 10% of the total free volume in the heated tube (30 cc). The second measurement method uses a metal bellows attached to the fuel tube inside the furnace; a pressure increase in the fuel rod is translated to linear motion of the bellows, which is registered by a dial indicator. The total bellows

motion is of the order of 0.020 inch for 50 psi rise in the fuel tube. Initial tests showed that the bellows method was less subject to leaks than the electrical transducer method because of the differences in tube fittings. Obtaining a uniform temperature over the fuel tube and bellows within the tube furnace has also been a problem. An initial result indicated an average gas release of approximately 15 microliters per gram at 100°F for a 10-pellet column. However, evidence of gas leaks and severe temperature gradients in the furnace make the initial results suspect.

A new furnace was fabricated because measurements of temperature distribution in the previously used furnace (an off-the-shelf item) showed 200°C to 300°C temperature variation along the fuel rod length. A series of gas pressure measurements was then made using the bellows-type pressure gage. While the results of the tests were encouraging, since the measurements showed no gas pressure in excess of that expected from a fuel pellet gas content of 10-15 μ liters/gm, there were anomalies associated with each test which made the results somewhat less than conclusive. For example, the results of a test in which the tube was filled with steel rather than fuel followed the "perfect gas" pressure versus temperature relation up to 700°C; but upon cooling, a hysteresis effect was observed in the indicated bellows expansion. Similar anomalies, all apparently resulting from problems in the functioning of the mechanical linkage arrangement, occurred in the fueled tube tests. The strain gage method also has not been successful because of apparent leaks in the tubing connecting the fuel tube to the transducer.

Work continues on obtaining a meaningful gas pressure measurement, using both the bellows-type measuring system and the electrical strain gage device.

4.4 INSTRUMENTED FUEL ASSEMBLIES

4.4.1 Instrumented Fuel Rods

Fabrication of fuel rods containing fuel thermocouples continued. The two fuel rods required to build the second instrumented fuel assembly (IFA) were completed and delivered to the assembly shop, but only after some delay which was caused by a broken bare-wire thermocouple (reported in the 19th Quarterly Report).

4.4.2 Thermocouples

Six fuel thermocouple weldments for IFAs 2, 3, and 4 were delivered for assembly into fuel rods. Two bare-wire thermocouple mockups were made and delivered to Pu Lab for in-process assembly practice. Assembly of a bare-wire thermocouple into a fuel rod proceeded smoothly after this practice. Fabrication of the remaining thermocouple weldments continues. As a result of assembly problems and to ensure a more reliable end product, several changes were made on the bare-wire thermocouple design. These changes involve retaining the double-bore insulators in the W/Re tube in the upper section, reducing the length of the single-bore insulators and providing closer control of the spacing between the single-bore insulators where the wire flexing accommodates the fuel stack thermal expansion.

4.4.3 Braze Development

Final braze development was completed. The time at temperature was set at between 10 and 20 seconds. With this limited time at temperature, the braze metal makes complete penetration into the joint without significant grain growth of the Inconel sheath as shown by metallographic examination.

4.4.4 Assembly

Effort was applied on the assembly of five IFA pressure vessel portions (for IFA numbers 2 through 6) during this report period. Three of these subassemblies will require rework due to grounded

or open leads caused by welding and grinding operations on these units. One tightener rod and two fuel-rod extension rods were assembled for the second IFA. At the end of this report period delivery of the second IFA was predicted to be 3 weeks away.

As a result of a number of fabrication problems experienced, the shop quality control is being strengthened and more in-process inspections will be conducted. In addition to normal supervision of shop operations by manufacturing engineering personnel, the IFA design engineers will maintain closer contact with shop operations.

SECTION V

TASK 10—STARTUP TESTING

5.1 PURPOSE

The purpose of Task 10 is to investigate the startup characteristics of a $\text{PuO}_2\text{-UO}_2$ fueled fast reactor and compare

the experimental results to the theoretical calculations. The wet critical tests comprise Task 10.3. Task 10.4 includes the initial approach to full power.

5.2 PAST PERFORMANCE

Calculations were done prior to SEFOR fuel loading to check the earlier predictions made of the size of the minimum critical configuration in SEFOR and to recheck the calculated worth of the SEFOR reflector control system. The calculated minimum critical size (519 rods with an expected range between 482 and 559 rods) as well as the expected control worth (3.6% $\Delta k/k$) were in good agreement with previous predictions. The reactivity versus period relationship was recalculated; the venturi flowmeter flow versus pressure drop was calculated from water flow test data, and debugging of data analysis codes continued.

5.3 REACTIVITY COEFFICIENTS

The U-238 contribution to the Doppler coefficient ($T dk/dT$) was calculated for the SEFOR minimum critical core using a uniform fuel temperature change between 300°K and 700°K. It was assumed that the coefficient defined as $T dk/dT$ is a constant. Temperature dependent cross sections for U-238 were obtained from a cross-section fitting routine. The reactivity effect associated with the change in

fuel temperature was calculated by perturbation of a 60-group, one-dimensional, radial problem using the DEMON⁽¹⁾ computer program. In addition, the Doppler coefficient was evaluated from calculations using 13 groups and the two-dimensional synthesis computer program BISYN.⁽²⁾ The results of these two calculations are summarized in Table 1. These results are in good agreement and provide the present best estimate of the U-238 contribution to the Doppler coefficient in the minimum critical core. The calculated contribution of U-238 to $T dk/dT$ (-0.0083) is in good agreement with the earlier calculation of -0.0082 for the full size core. The predicted Doppler $T dk/dT$ is -0.0086. This value is obtained by combining the U-238 contribution calculated above with the previously calculated value of -0.0003 for the Pu-240 contribution. It is assumed that the Pu-239 contribution to the Doppler effect is zero.

The expansion coefficients are defined as follows:

- (a) Axial Fuel Expansion: The reactivity effect due to increasing the length of the fuel segments with a corresponding reduction in fuel density and size of the gap.

TABLE 1

U-238 DOPPLER CALCULATIONS FOR MINIMUM CRITICAL CORE

<u>Method of Calculation</u>	<u>ΔK (300°K to 700°K)</u>	<u>$T \frac{dk}{dT}$</u>
Perturbation of 60 group radial DEMON problem	-0.00707	-0.00835
Change in reactivity between two 13 group BISYN problems	-0.00692	-0.00817
	Average	-0.0083

- (b) **Axial Fuel-Cladding Expansion:** The reactivity effect due to axial expansion of the fuel cladding. Most of this reactivity effect is caused by the upper fuel segment moving with the fuel cladding and there is a smaller contribution due to the reduction in cladding density.
- (c) **BeO Axial Expansion:** The reactivity effect due to extending the length of the BeO in the tightener rods with a corresponding reduction in BeO density.
- (d) **Structure Axial Expansion:** The reactivity effect due to extending the length of the channels, steel side rods, tightener rod cladding, tightener sleeve, axial reflectors, and the inner vessel wall with a corresponding reduction in the respective material densities.
- (e) **Structure Radial Expansion:** The reactivity effect caused by radial expansion of the channels. Since the structure temperature change is accompanied by the same change in fuel and BeO cladding temperatures, core volume fractions remain unchanged during radial expansion. Displacement of sodium surrounding the core is included in this effect. Change of sodium density is not included; this appears in a separate coefficient.
- (f) **Sodium Density Effect in Core and Axial Reflectors:** The reactivity effect due to a change of sodium density in the core and axial reflectors.
- (g) **Sodium Density Effect Between Core and Vessel:** The reactivity effect due to a change of sodium density in the region between the core and the vessel wall.

A model for recalculation of the coefficients for fuel axial expansion and fuel-cladding axial expansion is currently being evaluated. All other expansion coefficients

were calculated from the results of a series of 13 group BISYN⁽²⁾ problems. All expansion reactivity effects are assumed to vary linearly with respect to the dominating variable, i.e., change in height, radius, etc. The expansion reactivity coefficients obtained from the BISYN calculations are summarized in Table 2.

The total expansion coefficient in Table 2 is in good agreement with the average value of the expansion coefficient (-0.465 cent/°F) as previously calculated for the full power core.

5.4 DATA ANALYSIS CODES

The computer program that will be used to determine the ratio of the delayed neutron fraction to the neutron lifetime (β/ℓ) from the SEFOR noise experiments is being checked out and debugged. A sample data tape containing "noise" in the proper data format was received from the SEFOR site and is now being used as a debugging aid. Preliminary results indicate that octal characters on the data tape need to be modified, but that the analysis code, itself, once the modification is made, is working satisfactorily.

A sample data tape containing signals in the oscillator test format has also been received from the SEFOR site and this data will be used as a debugging aid for the programs that will be used in the analysis of the SEFOR oscillator tests.

5.5 REFERENCES

1. Davis, R. A., and Kelley, M. D., "DEMON—A System of One-Dimensional Multigroup Diffusion Calculation," December 1965, (GEAO-0007).
2. Greebler, P., et al., "BISYN—A Two-Dimensional Synthesis Program," July 1965, (GEAP-4922).

TABLE 2

EXPANSION REACTIVITY COEFFICIENTS FOR MINIMUM CRITICAL CORE

<u>Effects</u>	<u>Percentage Change per Degree Fahrenheit (%/°F)</u>	<u>Reactivity Effect (cent/°F)</u>
Fuel Axial Expansion	+0.000461	-0.009
Fuel-Cladding Axial Expansion	+0.000980	-0.072
BeO Axial Expansion	+0.000580	-0.004
Structure Axial Expansion	+0.000980	-0.014
Structure Radial Expansion	+0.000980	-0.130
Sodium Density in Core and Axial Reflector	-0.015789	-0.093
Sodium Density Between Core and Vessel	-0.015789	<u>-0.122</u>
		-0.444 (total)

SECTION VI

TASK 11—TRANSIENT TESTS

6.1 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 dollar and compare the experimental results with theoretical calculations. The types of tests to be conducted at various power levels include static, oscillation, and subprompt-critical transient reactivity changes.

of selected SEFOR fuel rods to a "hot lab" for destructive examination. The cask has been received and inspected by GE and all deficiencies have been corrected. The inside of the cask has been cleaned and the outside painted in preparation for shipment to the SEFOR site.

The license application for AEC and DOT authorization to use cask B of E 1233 for shipment of irradiated SEFOR fuel rods has been completed.

6.2 PAST PERFORMANCE

The San Francisco Operations Office of the AEC authorized rental of cask B of E 1233 which is intended to be used for the shipment

The design of the equipment required for the fuel transfer operation was completed. The equipment includes the transfer tube and seals between the refueling cell valve and transfer cask, and the single fuel rod shipping canister.

6.3 CURRENT RESULTS

The fuel transfer cask (B of E 1233) was shipped to the SEFOR site and is currently stored there.

Drawings of the fuel transfer equipment have been submitted to vendors for bids. The equipment specifications and drawings which are out for bids include the parts for the transfer tube connecting the refueling cell valve to the transfer cask and the fuel rod shipping canisters.

The design of a three-fuel-rod shipping canister was initiated and is nearly complete.

A drawing was made showing modifications to be made to the cask cart. The modifications will add strength to the cart axle making it safe to carry the 7-1/2 ton cask.

Additional work has been done on the design of the radiation shielding around the refueling cell valve and transfer tube. The purpose of the work is to reduce the time and effort required to install the shielding before each fuel transfer operation.

SECTION VII

SEFOR OPERATIONS

7.1 PRE-OPERATION TESTS

Performance of Pre-operation Tests No. 54, Sodium Flush; Nos. 55, 56, and 57, Sodium Hydraulics; Nos. 22 and 23, Nitrogen Cooling; and No. 20, Freon System were accomplished. Testing of the Refueling Cell Argon Purification Loop was also completed. These completed the Pre-operation Tests.

7.1.1 Sodium Systems

Strainer No. 3 (50-mesh screen) was installed in the Main Primary Sodium System. The flush and hydraulics tests were performed at various flow rates up to 5700 gpm. The strainer was removed and replaced with pipe sections. All welds were inspected by radiographs. The heaters and insulation were installed.

During preparations to replace two resistance temperature devices (RTD) in the

reactor vessel outlet of the Main Primary System, it was discovered that the wells had "weeped" sodium. The wells were cut from the pipe. Examination revealed that a small crack had developed in each from fatigue. Consequently, all RTD and TC wells in the Main Primary and Main Secondary Systems were replaced with a new design. The systems were filled with sodium and cold trapping was performed until the plugging temperatures were $< 225^{\circ}\text{F}$. Sodium level instrumentation was calibrated.

7.1.2 Argon System—Refueling Cell and Purification Loop

The seal between the refueling cell and nitrogen zone was repaired; cell leak checks were performed; the refueling cell was purged with argon; the argon purification loop circulation and the pressure control were established. With these tests completed, the refueling cell and Argon System were ready for operation. After purging, the oxygen content was less than

0.1% which was reduced to the ppm range with operation of the purification loop. Moisture content was reduced to the ppm range.

Following establishment of the argon atmosphere, entries were made with man-access suits to install the orifice in the center channel, remove the reactor vessel immersion heaters, obtain sodium samples, remove the nuts from the reactor vessel head studs and attach the head lifting sling. The head was removed for fuel loading.

7.1.3 Nitrogen Cooling System

Prior to the closing of the nitrogen cells, the emergency nitrogen circulator was installed; cable trays were covered; protective covers were placed over the actuators for those sodium valves required to reprime the primary-auxiliary loop; modifications to the nitrogen-system piping to the radiation monitors were completed; final inspection of wiring to thermocouples, leak detectors, and valve solenoids were made; filter elements were replaced in the nitrogen blowers; and the nitrogen zones were cleaned.

A total of nearly 200,000 scf of nitrogen was purged through the nitrogen zones which reduced the oxygen content below 1%. Cell pressure control was established. An ALINOR dewpointer was installed and the dewpoint measured less than 40°F.

7.2 OPERATIONS AND MAINTENANCE

The reactor-building-personnel and emergency-access locks were placed in service and the reactor-building-air-zone pressure control established at 30 inches of mercury.

A major overhaul of the emergency diesel was performed by Waukesha after the engine developed leaks from the water cooling system into the crankcase and cylinder scoring occurred. Sleeves and pistons were replaced on eight cylinders and the piston rings modified

to prevent scoring. Both turbochargers were replaced because metal particles from the scored pistons has passed through them. Subsequent operation of the emergency diesel was satisfactory. The auxiliary emergency diesel was operated satisfactorily under a 30 kW load.

To meet the surveillance requirements of the Technical Specifications, 152 license test procedures were performed. Locking of "locked-closed" and "locked open" valves was accomplished. The review of Standard Operating, Corrective and License Test Procedures continued. Operations-records storage facilities were established.

The installation of cables, connectors, and containment penetrations between the reactor building and the control room for the oscillator, FRED, and Data Acquisition System was completed except for wiring internal to panels 1 and 15.

All neutron sensors were installed and calibrated, ready for fuel loading. Check out of the He³ chambers (used in the initial core loading) in the pulse and current modes, and the response to gamma radiation were completed.

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

7.3 EXPERIMENTAL PROGRAM

7.3.1 Procedures

Procedures for all tests in Group I—Zero Power Tests were completed and issued. Writing of final drafts of procedures for tests in Group II—Power Ascension was initiated. SEFOR Fuel Surveillance Plan was revised and resubmitted for comments. Planning for fission track counting for the fission-ratio measurements was started with procurement of materials and contact with the Bacteriology Department of the University of Arkansas.

7.3.2 Fuel Loading

The reactor-vessel head was removed on April 6 and fuel loading commenced on April 8. Some malfunctions of the fuel grapples were experienced and repaired. The grapples were bagged out of the refueling cell for the repair. The two low speeds on the 10-ton hoist became inoperative. Man entry into the cell will be required to make the repair. Fuel loading was suspended for about three shifts while cold traps were operated to reduce the Primary System plugging temperature from approximately 300°F to < 225°F. Subsequently, cold traps were operated frequently to assure the plugging temperature remained at this low value. The sodium level in the reactor vessel was slightly above the top of the fuel channel with approximately 500 gpm flow in the Primary System which maintained a very clean sodium surface.

Fuel was transferred from the new-fuel-storage area in a transfer can containing six fuel rods with attached extension rods and one tightener rod. After the transfer can was bagged into the refueling cell and positioned in a floor well, the fuel rods were transferred one at a time into the reactor core.

At the end of the period, 549 fuel rods had been loaded into the core. This quantity is estimated to be within one rod of criticality.

7.4 MAN ENTRY SUIT SYSTEM MODIFICATION

On April 5, two operators working within the refueling cell were preparing to make a routine exit. To maintain the cell argon atmosphere, the suit life-support system was in use. During redocking at the entry panel, one suit collapsed around its operator. While this operator was assisted through the emergency exit, the other operator made a routine exit.

Subsequent investigation revealed that a double failure had occurred as follows: (a) The normal air supply line had iced closed in the air cooling system, requiring both suits to rely on their emergency air bottles. (b) One or more of the three modulating vacuum exhaust valves in one of the two suits had become clogged with lint and was unable to fully close upon loss of normal suit cooling air flow. This permitted the vacuum exhaust system to reduce the pressure within the failing suit to a level sufficiently below ambient that collapsed suit pressure, squeezing the operator, and he could not raise his chest to breathe.

Corrective action to prevent reoccurrence of this event is as follows:

- A valve will be placed in the vacuum exhaust line which carries air from the two suits. This valve will close upon loss of normal air supply to the suits.
- A low pressure alarm will be installed to result in an audible alarm signal upon loss of normal pressure in the suit air supply line.
- A manually valved bypass of the air refrigeration system will be made available to make possible the regaining of normal air flow should the cooling line ice closed.
- Lint free undergarments are to be worn in the suits to reduce the chances of exhaust valve clogging.
- The operator training program has been expanded to develop more fully the normal and emergency procedures required during entry into the various inert gas zones of the reactor building.
- The operators have been instructed to remove the vacuum hose upon loss of air.

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