GEAP-5629
AEC RESEARCH AND
DEVELOPMENT REPORT
MAY 1968

MASTER

**SOUTHWEST EXPERIMENTAL
FAST OXIDE REACTOR
DEVELOPMENT PROGRAM
SIXTEENTH QUARTERLY REPORT
FEBRUARY - APRIL 1968**

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

ADVANCED PRODUCTS OPERATION

GENERAL ELECTRIC

SUNNYVALE, CALIFORNIA

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Development Report
May 1968

SOUTHWEST EXPERIMENTAL FAST OXIDE
REACTOR DEVELOPMENT PROGRAM

Sixteenth Quarterly Report
February—April 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

February 1, 1968 through April 30, 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 $\text{PuO}_2\text{-U-238O}_2$, 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).
- 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. 1 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). Under a Radial Temperature Gradient," GEAP-5284 (October 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
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 (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).

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

TASKTITLE

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
5.1	Core Mockup and Heated Fuel Test

<u>TASK</u>	<u>TITLE</u>
5.2	Hydraulic Flow Tests—Vessel
5.3	Hydraulic Flow Tests—Fuel Rods
5.4	Sodium Performance Tests
5.5	Thermal Shock
5.6	Sodium Heat Transfer Tests
7.0	Fuel Handling
8.1	Nuclear Analysis
8.2	Nuclear Design

2.2 TASK 1—PLANNING THE EXPERIMENTAL PROGRAM

A plan was completed for examination of SEFOR fuel rods during the reactor test program.

2.3 TASK 4—SPECIAL INSTRUMENTATION

Two compensated fission chambers were tested for gamma compensation and calculations made for adjustment of compensation volume.

2.4 TASK 6—REACTIVITY CONTROLS REQUIRED FOR EXPERIMENTATION

The detail design of FRED Reactor Model was completed. The oscillator mechanism was reassembled and used to provide the driving signal for checking out the manual balanced oscillator control system.

2.5 TASK 9—FUEL FABRICATION

Nuclear Fuel Services resumed fuel production after installation and successful testing of a vacuum outgas furnace for fuel pellet processing. Results of total gas content tests on pellets from 266 existing welded rods indicate that these pellets do not meet the gas content specification.

Extension rods are being assembled. Assembly development work has started on the tightener sleeve. Because of the vendor's inability to meet the required delivery schedule, work has begun on developing alternate tube forming methods for the tightener rod.

The instrumented fuel assembly electrical connectors and caps were completed. Work on the fuel rods and other components continues.

2.6 PLANT CONSTRUCTION

The general contractor, Martin K. Eby, has completed work and is cleaning the site and storing material.

The piping contractor has completed installation for the following systems; sodium service, nitrogen cooling, argon, breathing air, air conditioning, Freon systems, gaseous radwaste, and reflector control drive systems. He is also setting several pieces of equipment, installing instrumentation and maintaining clean rooms, cleaning nitrogen supply systems and cleaning the construction site.

SECTION III

TASK 1—PLANNING THE EXPERIMENTAL PROGRAM

3.1 TASK 1.2—FINAL SPECIFICATION OF THE EXPERIMENTAL PROGRAM

3.1.1 Purpose

The purpose of Task 1.2 is to provide a detailed specification of the experimental

program. This will include the planning of the number and sequence of tests, the specification of reactor conditions (power, temperature, flow, etc.), and the preparation of procedures for data reduction and interpretation. In addition, the specifications of the

reactor equipment prepared under Task 1.1 will be reviewed as required to take into account results from the detailed design of equipment and from the preoperational research and development program.

3.1.2 Past Accomplishments

The primary effort of Task 1.2 has been completed, and the final report was submitted for publication and distribution.

3.1.3 Current Results

For program planning purposes, an irradiated fuel rod inspection plan was developed.

Fifteen special fuel rods (guinea pig rods) containing fuel pellets of 25% fissile plutonium (compared with the normal 18.7% enrichment for standard fuel rods) will be removed from the core at prescribed intervals during the test program and inspected for evidence of damage. These rods will be located under the through-head refueling ports to provide easy access to them.

Six refueling ports in the SEFOR reactor vessel head are located with three ports on each of two radii. Two fuel rods can be removed through each of these ports. Table 3-1 lists the fuel rod locations and power densities normalized to a standard fuel rod nearest the core center.

TABLE 3-1

REFUELING PORT LOCATION

<u>Rod Position</u>	<u>Distance from Core Center</u>	<u>Relative Power</u>	
		<u>Standard Rod</u>	<u>Guinea Pig Rod</u>
1A, 1B, 1C	7.31-inch radius	0.863	1.153
2A, 2B, 2C	7.70-inch radius	0.850	1.137
3D, 3E, 3F	9.93-inch radius	0.750	1.002
4D, 4E, 4F	10.50-inch radius	0.721	0.965

3.1.4 Initial Inspection of Guinea Pig Rods

record rod bow and cladding surface irregularities.

The guinea pig rods will be examined in the in-cell dimensional inspection equipment prior to installation in the reactor in order to completely characterize the rods. Inspections made are planned to include:

- a. Transmission gamma scan to determine exact fuel column lengths and gas plenum lengths.
- b. Length measurement
- c. Axial traverse with profilometer at 0, 90, 180, and 360 degrees. This will

- d. Axial traverse, measuring cladding diameter at 0 and 90 degrees.
- e. Rotational traverse at 2-inch intervals over the fuel length to measure cladding diameter at all orientations from 0 degrees to 360 degrees.
- f. Spiral traverse to provide for detection of any diameter irregularities.
- g. Cladding temperature will be measured and recorded during all of the above measurements.

3.1.5 Planned Destructive Fuel Rod Examination

- a. Fuel rods will be photographed to document all external features.
- b. Neutron radiography will be performed to provide information on the changes that may have occurred to the pellets such as cracking, center voiding, fuel redistribution, column length change, etc.
- c. Fission gas will be collected from both upper and lower plenums if the fuel burnup is enough to provide significant amounts of fission products. The amount of gas collected will be measured.
- d. Cladding will be sectioned through the upper and lower gas plenums. Plenum length will be measured.
- e. Pellet columns will be checked for freedom to move axially in the cladding by pushing at one end of the column and observing pellet motion at the opposite end. This will give an indication of the fraction of fuel and cladding to expand independently during irradiation.
- f. Each fuel column will be circumferentially sectioned at three places. All sections will be photographed. Studies of these sections will provide information on fuel performance.
- g. Cladding sections will be examined on the inside surfaces to check for evidence of ridging or other fuel cladding interaction.
- h. One section of fuel will be cut axially and photographed.
- i. A sample of fuel will be analyzed for burnup if irradiation level is high enough to yield results.

- j. Beta-gamma and alpha autoradiographs will be made of one selected fuel section.

3.1.6 Planned Fuel Rod Measurements in the SEFOR Cell After Irradiation

- a. Either a transmission gamma scan or conventional gamma scan using the contained fuel as the source will be made, depending on the activation level of the fuel. The transmission scan will be used whenever possible to provide a direct comparison with the pre-irradiation measurement.
- b. Spiral traverses, axial traverses for bow and diameter, rotational traverses for diameter, and length measurements will be made as described in the pre-irradiation measurements. Pre- and post results will be compared to determine if cladding distortions have occurred. Temperature will be measured and all dimensions will be corrected for temperature change.
- c. Sodium, if present on the cladding surfaces, will be removed by wiping or by cleaning in the vacuum distillation cleaning station.
- d. Fuel rods to be shipped from SEFOR will be helium mass spectrometer leak checked.

3.1.7 Summary of Rods Examined

The proposed fuel location and examination program provides for examination of rods which have been irradiated under the exposure conditions of most interest. It also provides a group of rods which have been subjected to other exposures. These rods will be available for examination if results of rods already examined indicate a need for the information. For example, it may be interesting to compare rods that have been exposed to

steady-state plus transients with rods that have been exposed to transient only. Table 3-2

summarizes the exposure history of the fifteen guinea pig rods.

TABLE 3-2

EXPOSURE HISTORY OF GUINEA PIG RODS

Rods Planned to be Examined

<u>Rod No.</u>	<u>Type of Examination</u>	<u>Exposure</u>	<u>Relative Power</u>
A01	In-Cell	All tests through 5 MW Steady-State	1. 153
A02	In-Cell	All tests through 10 MW Steady-State	1. 153
A03	In-Cell + Destructive	All tests through 15 MW Steady-State	1. 153
A04	In-Cell + Destructive	All tests through 20 MW Steady-State	1. 002
A05	In-Cell	All tests through familiarization transients	1. 002 for Steady-State 1. 153 for Transients
A06	In-Cell + Destructive	All tests through prompt transients	1. 002 for Steady-State 1. 153 for Transients
A07	In-Cell + Destructive	All tests through sub-prompt transients	0. 965 for Steady-State 1. 153 for Transients

Rods Available for Examination if Necessary

<u>Rod No.</u>	<u>Exposure</u>	<u>Relative Power</u>
A01	5 Mw Steady-State	1. 153
A02	10 MW Steady-State	1. 153
A05	All tests through familiarization transients	1. 002 for Steady-State 1. 153 for Transients
A08	All tests	0. 965
A09	All tests	0. 965
A10	All transient tests	1. 002
A11	All transient tests	1. 002
A12	All transient tests	1. 002
A13	All transient tests	0. 965
A14	Sub-Prompt and Prompt Transients	1. 153
A15	Prompt Transients	1. 153
Std. Rods	All Tests	0. 850

SECTION IV

TASK 4—SPECIAL INSTRUMENTATION

4.1 PURPOSE

The objectives of Task 4.2 are to develop and supply a suitable detector system for recording the transient flux during the SEFOR Experimental Program. 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.

4.2 PAST ACCOMPLISHMENTS

Design and necessary testing of all electrical equipment was completed, and fabrication was begun.

4.3 CURRENT ACCOMPLISHMENTS

Two compensated fission chambers have been tested for gamma compensation and calculations made for adjustment of compensating volume. They are presently being machined, and will be reassembled and tested prior to final coating. Work is progressing on the gamma detectors and the control panel. Design of the transporter equipment for the neutron detectors was completed and fabrication drawings were issued.

SECTION V

TASK 6—REACTIVITY CONTROLS REQUIRED FOR EXPERIMENTATION

5.1 TASK 6.1—FAST REACTIVITY EXCURSION DEVICE (FRED)

quotation by vendors. This design is essentially the same as reported earlier.

5.1.1 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.

5.1.4 Drywell Design

The design of the drywell for the reactor operations has been started and is being carried out in accordance with the ASME pressure vessel code, Section III. The drywell and required shielding are being designed as one piece.

5.1.2 Past Accomplishments

The FRED I model test program was completed and a detailed analysis of the reactor model was carried out. The detailed design and fabrication of the positioner device was completed.

5.2 TASK 6.2—OSCILLATOR DRIVE

5.2.1 Purpose

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

5.1.3 FRED Design

The detail design of the FRED reactor model was completed and drawings issued for

5.2.2 Past Accomplishments

The oscillator mechanism room temperature tests have been completed. The positioner drive fabrication has been completed. Procurement of components for the balanced oscillator control system has been completed and fabrication started.

5.2.3 Oscillator Mechanism

The oscillator mechanism, which was reassembled during the past quarter, was initially checked out.

5.2.4 Balanced Oscillator System

The preliminary fabrication of the balanced oscillator manual control system was completed and an initial test carried out in conjunction with the oscillator mechanism. This test showed that the system would function as expected; a detailed system checkout will be carried out following the final fabrication of the control system into panel 11 prior to shipment to SEFOR.

SECTION VI

TASK 9—FUEL FABRICATION

6.1 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.

6.2 PAST ACCOMPLISHMENTS

Loading and welding of fuel rods was halted during the previous quarter because of an apparently high volatile content in the pellets. Plans were made to conduct tests at both Nuclear Fuel Services (NFS) and Oak Ridge National Laboratories (ORNL) to determine the extent of the problem.

The fuel channels were completed and shipped to the SEFOR site.

A number of delays were encountered on fabrication of hardware for the instrumented fuel assemblies with consequent slipping of delivery schedules.

6.3 CURRENT RESULTS

6.3.1 Fuel Rod Production

As the quarter ended NFS resumed fuel rod production using a vacuum outgas furnace, which was tested and installed during the quarter in the pellet production line. Results of total gas content tests on pellets taken from rods loaded and welded prior to use of the pellet vacuum outgas furnace indicated that the majority of these pellets do not meet the gas content specification of 50 microliters per gram.

6.3.1.1 Pellet Volatile Content

Comparison gas release measurements were performed at ORNL and NFS, with a GE analytical chemist acting as observer. In these tests, the total gas evolution was measured at 1200°C. Table 6-1 shows the results of these measurements, which were performed on pellet samples carefully prepared by NFS.

TABLE 6-1

NFS - ORNL PELLET GAS CONTENT RESULTS

<u>Pellet Sample</u>	<u>NFS</u>	<u>ORNL</u>
	(microliters per gram)	
1	46	33
		51
2	31	40
	24	41
3*	7	7
	21	5

*Sample 3 was vacuum outgassed at 900°C prior to the measurements

These results indicated that previous ORNL measurements (which indicated 70 microliters per gram) were reliable, and that previous NFS results (which indicated 10 to 20 microliters per gram), were probably not representative of a significant number of production pellets.

NFS also performed an additional measurement which indicated 50 microliters per gram gas evolved from room temperature to 800°C, and 26.8 microliters per gram evolved from 800° to 1400°C.

Concurrent with this ORNL and NFS work, studies with UO_2 pellets at GE indicated that the pellet grinder coolant used at NFS was a potential source of volatile material contamination, which could be removed by vacuum outgassing the pellets at 800°F for 1 hour.

Two vacuum furnaces for the pellet production line were constructed at NFS, each capable of holding 15 kilograms of fuel pellets. Initial tests on UO_2 pellets at NFS indicated a gas content reduction from 90 microliters per

gram to 20 microliters per gram after 1 hour at 1000°F under 1 micron Hg pressure. Results of gas content and oxygen-to-metal ratio analysis on pellets processed in these furnaces for 1 hour at 1000°F under 1 micron Hg pressure are shown in Table 6-2.

TABLE 6-2

GAS CONTENT AND OXYGEN/METAL RESULTS
FOR PELLETS AFTER
VACUUM FURNACE PROCESSING

	<u>Position in</u> <u>Furnace and</u> <u>Furnace Number</u>	<u>Pellet Gas</u> <u>Content</u> <u>($\mu\text{l/gm}$)</u>	<u>Oxygen-</u> <u>to-Metal</u> <u>Ratio</u>
Top	1	12	1.986
Top	1	14	
Top	2	22	1.987
Top	2	24	
Bottom	1	14	1.990
Bottom	2	44	1.987
Center	1	21	1.985
Center	2	12	1.986

Prior to processing in the vacuum furnace, the pellet oxygen-to-metal values ranged from 1.986 to 1.988, thus, no significant change in the oxygen-to-metal occurred as a result of vacuum furnace processing.

NFS unloaded one rod from each of the pellet batches that had been previously loaded and welded into rods. Two pellets were taken from each rod (one pellet from each fuel segment) for gas analysis. Table 6-3 shows the results of these analyses, together with several results obtained at ORNL; it is clear that a large portion of the fabricated pellets would not meet the gas content specification. ORNL performed mass spectrometer analysis of several gas samples and found the composition

to be 50 to 68% H_2 and 48 to 31% CO (the variation is that observed between two samples tested at ORNL), with trace amounts of other gases.

TABLE 6-3

GAS CONTENT OF PELLETS TAKEN
FROM WELDED RODS

<u>Pellet Batch</u>	<u>Gas Release (μl / gm)</u>
600	226, 391 57
601	156 47
602	54 45
603	70 25
604	99 39
605	57 116
606	119, 68 (ORNL-110, 120) 102
607	72 51 (ORNL-70)
608	62 54
610	83 54

To determine the source of the high gas content shown in Table 6-3 NFS analyzed the gas evolution from four 10-gram samples taken from an unground pellet, and four samples taken from a ground pellet. Table 6-4 shows the results of these measurements.

TABLE 6-4

COMPARISON OF GAS RELEASE FROM
GROUND AND UNGROUND PELLETS

<u>Unground Pellet (μl / gm)</u>	<u>Ground Pellet (μl / gm)</u>
22.1	38.0
27.9	31.8
8.3	27.3
3.9	19.4

While Table 6-4 shows that the variation among samples taken from the same pellet is rather large, it is clear that the ground pellet has an average gas content approximately twice that of the unground pellet.

Tests were performed at GE to determine whether the pellets in existing welded rods could be outgassed while in the rods. The tests were conducted on UO_2 -fueled rods obtained from NFS. The tests showed that a good vacuum (15 to 25 microns) could be obtained at the closed end of a fuel rod by establishing a 1-micron pressure condition at the open end. Further, it was shown that a significant quantity of gas was released from the UO_2 pellets after the rod was heated to 800°F.

As the quarter ended, NFS was conducting similar tests on a SEFOR fuel rod and measuring the gas content of pellets before and after vacuum outgassing in the rod.

On the basis of the information discussed above, GE and NFS concluded that the vacuum furnace process (800° to 1000°F at 1 micron pressure for 1 hour) should reduce the pellet gas content to an acceptable value, and NFS resumed fuel rod production using this process. A decision on the method of outgassing the pellets in the 266 existing welded rods (whether to unload the rods or outgas in site) will be made in the next quarter. NFS estimates that the balance of the fuel order will be complete

June 30, 1968, with re-work of the 266 existing welded rods being completed July 30, 1968.

6.3.1.2 Pellet Plutonium Content and Homogeneity

To check the pellet Pu/U + Pu ratio (the weights and assays of the nitrate solutions are used to obtain the reference value for Master-Mix makeup) it is necessary to perform wet chemistry analysis of the oxide material. NFS has made 18 separate determinations of

the Pu/U + Pu weight ratio on an oxide sample to ascertain the true variation in this measurement method. The mean and fractional standard deviation of the 18 sample values are 0.2046 and 0.000423 Pu/U + Pu, respectively; the Master-Mix data yielded 0.2042. This indicates that the analytical technique is capable of showing whether the pellet Pu/U + Pu ratio meets the specification of ± 0.01 on homogeneity and ± 0.003 on average value. The Pu/U + Pu weight ratio values obtained by NFS for several pellet batches are shown in Table 6-5.

TABLE 6-5

COMPARISON OF PELLETT Pu/U + Pu WEIGHT RATIO WITH MASTER-MIX VALUES

<u>Pellet Batch</u>	<u>Pellet Center</u>	<u>Pellet Edge</u>	<u>Master-Mix Value</u>
600	0.2050	0.2053	0.2040
601	0.2067	0.2066	0.2041
603	0.2064	0.2064	0.2041
605	0.2029	0.2027	0.2041
608	0.2022	0.2024	0.2041

Table 6-5 shows that there is a detectable difference among pellet batches made from the same Master-Mix, but this difference is not significant to reactor design and operation.

The following Master-Mix makeup data show that the specification requirement of 0.1870 ± 0.0005 Pu fissile/U + Pu total for the project grand average is being met.

<u>Master-Mix</u>	<u>Pu fissile/U + Pu total</u>
101	0.18728
102	0.18705
103	0.18686
104	0.18698

These values are based on an average of NFS, Isochem, and New Brunswick Laboratory (in event of dispute between NFS and Isochem) plutonium nitrate assays, NFS nitrate weights, and Isochem plutonium isotopic analyses.

6.3.1.4 Impurity Particles and Microscale Plutonium - Uranium Distribution

As the quarter ended, electron-microprobe studies indicated that small (0.001-inch diameter) particles, which had been previously observed but unidentified, were aluminum (probably in oxide form). In previously reported microprobe work, stainless steel

particles had been indentified. (1) The observed frequency of occurrence of the alumina particles is considerably less than that observed for the stainless steel particles.

Preliminary analysis of the microprobe results showed no significant plutonium or uranium concentration (resolution limited by 1 micron electron beam diameter). Results of fission track etching studies using the method described in (2) showed no plutonium rich areas larger than approximately 10 microns (the resolution limited by 5 micron fission track length).

6.3.1.5 Fuel Receiving Inspection at SEFOR

Fuel rod leak checking equipment was set up at SEFOR, and the initial shipment of 104 rods were leak checked. Five rods were found to be leaking helium in excess of the specification limit of 10^{-8} cc/sec. Also, fuel stack weights quoted by NFS were found to be in error for four fuel rods. These rods will be returned to NFS at the time of the next fuel shipment.

6.3.2 Fuel Hardware

6.3.2.1 Extension Rod

During the quarter production began on the electrohydraulic forming of the extension rods. An arc-burn created during the electric-arc forming process was detected. The vendor corrected the problem but with a subsequent slow-down of production. Investigation of the arc-burned areas shows no apparent detrimental effects on the material. Five hundred and sixty-three pieces were delivered leaving a balance of 202 pieces to be produced. Of those delivered 300 have been swaged to final size,

measured, and cleaned. To date B_4C has been vibratory compacted into 130 tubes.

6.3.2.2 Tightener Rod

The vendor worked on the die for forming the shortest interior section of the tightener rod. After a visit was made to the vendor to discuss his proposed production schedule and his fabrication difficulties, plans were started for developing alternate fabrication methods. These methods include tube expansion by tube rolling and die drawing and tube reduction by spinning. Other methods under investigation are an all-welded assembly and machining the shield portion out of solid Type 304 bar stock. To date the combination of solid bar stock for the shield portion and spinning of the "necked-in" regions on the tubing for the BeO portion appears to be the best alternates. Work is continuing into the next quarter on these alternate fabrication methods.

6.3.2.3 Tightener Sleeve

All components for the tightener sleeve were received by the end of the quarter. The assembly stations have been set up in the assembly building. All assembly tooling is complete. Developmental assembly was begun the last week of the quarter. Two problems are apparent from this latter effort; the fins may require reforming and the depth of the interior dimples may be reduced.

6.3.3 Instrumented Fuel Assemblies

On August 15, 1968, delivery of the first instrumented fuel assembly (IFA) to the SEFOR site is contingent on the completion of two fuel rods with thermocouples by May 15, 1968. Several problems in fuel rod fabrication continue to indicate a possible delay in fuel rod completion as scheduled.

Two shipments of fuel pellets were received from Nuclear Fuel Services (NFS). The first shipment was not properly packaged, resulting appreciable chipping and breaking

(1) GEAP-5595, "SEFOR Fifteenth Quarterly R&D Progress Report, February 1968.

(2) Rosembaum, H., and Armijo, I. S. "Fission Track Etching as a Metallographic Tool," J. Nucl. Mat., 22, 1 115—116 (1968).

of several pellets. Also, a number of pellets in this first shipment did not meet chip and crack standards. Consequently, only one fuel rod was obtained from material intended for two rods.

The second fuel pellet shipment from NFS was received and partial inspection indicated no broken pellets. This shipment included two long pellets (required for the fuel middle section). Figure 6-1 shows typical standard and long pellets to be used in the fuel rods. Pellet modification (slots and holes for thermocouple penetrations) continued (see Figure 6-2). Design and fabrication of the chamber and pellet basket for outgassing was completed and installation was initiated. Fuel samples will be submitted to analytical chemistry for gas analysis before and after outgassing.

The special weld fixture for making the cladding-to-spacer welds (see Figure 6-3) was installed in the weld box. Preliminary weld test and evaluation were initiated. Figure 6-4 shows neutron radiographs of such welds. Fuel thermocouple fabrication continues. Figure 6-5 shows details of the transition joint between the tungsten-rhenium thermocouple wires and the compensated lead wire. Figure 6-6 shows a complete fuel thermocouple assembly. The first bare wire thermocouple was accomplished with minor fabrication problems and production continues. Figure 6-7 shows details of the bare wire thermocouple construction.

The instrumented fuel assembly part machining effort continued, and parts are approximately 50% complete. Outside vendor

parts other than the "spiders" were received. One "spider" was received and the balance will be completed when the vendor strike is ended.

The extension rod parts and the tubes have been completed and delivered to San Jose for assembly. The present delivery promised to IPO is May 3, 1968. The tightener sleeve parts and tubes have also been completed and delivered to San Jose for assembly. The present delivery promised to IPO is May 10, 1968.

Six instrumented fuel electrical connectors were completed. Figure 6-8 shows the connection of the lead out conductors to the 20-pin electrical connector. These assemblies and the blind flange caps (used as a seal when an instrumented fuel assembly is not inserted in the reactor) were approved by the State Code Inspector under Section III of the ASME Code. Figure 6-9 shows the completed instrumented fuel connector and cap ready for shipment.

A gasket pre-setting tool was received from Aeroquip Corp. and tested. This tool is used to seat the gaskets in the connector flange and connector cap so that the gaskets will be retained during reactor insertion and removal operations.

A prototype of the upper portion of the IFA has been started in fabrication to identify problems and develop assembly skill such as brazing and testing techniques.

Engineering shop follow continues on this task.

STANDARD LENGTH PELLETS

LONG PELLET

FIGURE 6-1. NFS BATCH 612 PELLETS TO BE USED IN INSTRUMENTED FUEL ASSEMBLY

MODIFIED FUEL PELLETS

FIGURE 6-2. SEFOR PELLETS MODIFIED FOR INSTRUMENTED FUEL RODS

WELDING CHUCKS
SET UP WITH TUBE
AND INSERT

WELDING HEAD
ATTACHED AND OPEN

WELDING HEAD
CLOSED

DRIVE MOTOR ATTACHED
TO WELDING HEAD

ESR ISOWELDER

a. WELDING TIMER MODULES

b. CURRENT CONTROL MODULE

c. WELDING HEAD SPEED CONTROL
MODULE

d. GAS CONTROL MODULE

FIGURE 6-3. WELDING FIXTURES

SPACER WELD

END PLUG WELD
(NOTE FLOWED LAP
LEFT-HAND SIDE OF
JOINT)

FIGURE 6-4. NEUTRON RADIOGRAPHS OF SEFOR WELDS

SHOWING BERYLLIA INSULATORS, ALUMINA TRANSITION INSULATORS, END OF LEAD CABLE, NICKEL SPIRAL WRAP JOINT, TUNGSTEN-RHENIUM PROBE WIRES, SHEATH, AND TRANSITION TUBE.

FIGURE 6-5. 0.010-inch-DIAMETER TUNGSTEN-RHENIUM THERMOCOUPLE

NEG. NO. 46567

TWO 0.005-inch-DIAMETER TUNGSTEN-RHENIUM THERMOCOUPLES WELDED
INTO SPACER READY FOR ASSEMBLY INTO FUEL ROD

FIGURE 6-6. THERMOCOUPLE WELDMENT

SHOWING TUNGSTEN-RHENIUM PROBE SHEATH, ALUMINA SINGLE BORE INSULATORS, THORIA DOUBLE BORE INSULATORS, AND TUNGSTEN-RHENIUM WIRE TWISTED AND WELDED INTO HOT JUNCTION.

FIGURE 6-7. BARE WIRE TUNGSTEN-RHENIUM THERMOCOUPLE

ELECTRICAL CONNECTOR SOCKET WITH 1/8-inch THERMOCOUPLE LEADS ATTACHED

FIGURE 6-8. FUEL CONNECTOR

SHOWING MARMAN FLANGE WITH ELECTRICAL CONNECTOR SOCKET
INSTALLED, CONOSEAL CAP, AND CERAMIC INSERT

FIGURE 6-9. FUEL CONNECTOR

SECTION VII

TASK 10—STARTUP TESTING

7.1 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, and Task 10.4 includes the initial approach to full power.

7.2 PAST PERFORMANCE

Tests of the reactor noise analysis equipment showed that an additional voltage amplifier will be required because ion chamber currents are so low.

The reactor vessel material surveillance specimens were received.

7.3 CURRENT RESULTS

7.3.1 Task 10.3—Wet Critical Testing

Design of an ion-chamber drywell was initiated during the period. This assembly will be used during fuel loading and reactor noise tests to house neutron detectors in the core.

One concept of the assembly consists of a leak tight tube constructed of Type 304 stainless steel which is 2-7/8-inches-outside diameter with a 0.065-inch-thick wall to form the drywell. Except for the space needed for the chambers and leads, the drywell is filled with stainless steel shield blocks and aluminum spacer blocks in the core region.

Another concept is to make the chamber itself leak tight and compatible with sodium.

This concept is presently being reviewed for meeting the design criteria and functional requirements.

Two helium-3 ion chambers in a side-by-side configuration are planned for the center channel with the chamber center line at the elevation of the fuel segmenting gap. The chambers will be held in position so that coolant flow does not cause vibration during tests. They must also be positioned so as not to interfere with fuel loading.

7.3.2 Task 10.4—Approach to Power7.3.2.1 Gamma Source and Storage Cask

Gamma ray transmission measurements made at SEFOR indicated that a 20-curie Cobalt-60 source would be required for fuel rod transmission gamma scanning. The measurements indicated that the calculated gamma-attenuation factor through the collimator slot was a factor of two too low.

To allow man-access into the SEFOR refueling cell it is necessary to provide a storage cask for the 20-curie Cobalt-60 source used in fuel rod gamma scanning.

Vendor bids were requested for a container with 6-1/2 inches of lead shielding and a 1-inch-diameter by 5-inch-long cavity. The container is to comply with paragraph 78.250 "Specification 55" of Title 49 Code of Federal Regulation so that the source can be shipped in this container. This is to eliminate the task of transferring the source from a shipping container to the storage container at SEFOR.

SECTION VIII

TASK 11—TRANSIENT TESTS

8.1 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 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.

8.2 CURRENT RESULTS

8.2.1 Irradiated Fuel Shipping Cask

As a part of the SEFOR R&D Program selected fuel rods are to be shipped from SEFOR to a radioactive materials laboratory for detailed examination. The purpose of this task is the procurement of the equipment and preparation of the procedures necessary for shipping fuel rods from SEFOR.

During this period the design of the required equipment was initiated and is now approximately 80% complete. A survey of existing AEC casks was undertaken, and negotiations initiated with the AEC to borrow a cask for the expected duration of the SEFOR R&D Program. Preparation of the License Application has been initiated, anticipating AEC commitment of this cask to SEFOR.

The equipment required includes:

- a. A container to be licensed in accordance with USAEC Rules and Regulations Title 10 Part 71 "Packaging of Radioactive Materials for Transport," and Department of Transportation (DOT) Regulations (49 CFR Parts 170—179).

- b. An extension from the SEFOR refueling cell to the cask which will assure maintenance of the inert atmosphere in the cell during the fuel rod transfer (vertical transfer mechanism).
- c. Shielding between the cell and the cask.
- d. A cart to transfer the cask into and out of the reactor building.
- e. A fuel rod shipping canister capable of holding one to three fuel rods.

The cask licensing regulations are of relatively recent origin (the DOT regulations are still proposed and not finalized) and licensed casks which would be available when required at SEFOR are nonexistent. Therefore, a request has been sent to the AEC to borrow an AEC cask (B of E 1233) for assignment to SEFOR for the duration of the program. This cask is held by Atomics International and they have no scheduled use projected for it at this time. To adapt the cask for use at SEFOR a new top lid will be fabricated. The lid will be made in two sections to permit removal and replacement of the inner lid with the fuel rod grapple located in-cell. The outer portion of the lid will be removed when the hookup to the cell is accomplished. The present top lid will be stored and no other changes to the cask are anticipated.

The vertical transfer mechanism required for connection of the cask to the cell, including the cell valve, is at SEFOR. The telescoping transfer tube as designed and built is too long for use with the B of E 1233 cask and a new one will need to be designed and fabricated.

The shielding for the vertical transfer mechanism will consist of 6 inches of lead to reduce the radiation level at 10 feet to 230mR/h. This amounts to only 4 mR during the expected time required for passage of a fuel rod through the VTM. Small lead bricks will be used for ease in handling.

The transfer cart consists of a simple structural steel frame supported on crane

wheels with a steel plate top level with the operating floor. The cask will be transported in a vertical position on the cart and will require tender loving care to ensure that it does not overturn. The design will include a means of fastening the cask securely to the cart and also idler bars on the cart which will slide along under the rails and ensure against the cart tipping.

SECTION IX

SEFOR OPERATIONS

9.1 PREOPERATIONAL TESTS

Writing of preoperational test procedures continued. Procedures for the following major systems were issued or were in review prior to issuance:

- Liquid Radwaste
- Gaseous Radwaste
- Breathing/Instrument Air
- Instrument Nitrogen
- Health Physics, Instrumentation, and Area Radiation Monitoring
- Refueling Cell Lighting, Man Access, and Viewing Devices
- Freon
- Argon
- Nitrogen Cooling/Nitrogen Dryers
- Sodium System Preheat
- Inner Containment

Preoperational tests on the following major systems were initiated as the systems were completed by Construction and released to Operations:

- Liquid Radwaste
- Gaseous Radwaste
- Instrument Nitrogen
- Health Physics Instrumentation

The use of Malfunction Reports and Modification Requests has been initiated on the equipment released to Operations. System leak checks were performed in conjunction with construction contractors.

9.2 FUEL INSPECTION

Five depleted uranium fuel rods, 18 steel rods, and 40 B₄C rods were received and inspected for mechanical integrity and dimensions. These rods, together with the 104 PuO₂-UO₂ fuel rods received in January, were leak-checked by mass spectrometry. Five fuel rods were determined to be leaking in excess of specification. One B₄C rod was rejected because of an incorrect top end plug.

9.3 TECHNICAL SPECIFICATIONS

The generation of Technical Specifications for the plant was initiated.

9.4 DATA ACQUISITION CHECK-OUT

Familiarization with Data Acquisition System operation and check-out of programs was begun and fuel weight discrepancies were found in the NFS records for four fuel rods.

9.5 ENVIRONMENTAL SURVEY

The 1-year preoperation Environmental Survey program was completed, background and warning levels established, and the results reported to the Compliance Division, USAEC, and the Arkansas State Board of Health.

9.6 OPERATOR TRAINING

The training of Operation personnel continued by familiarization with plant systems, group instructions, and study assignments.

9.7 STANDARD OPERATING AND CORRECTIVE PROCEDURES

The writing, review, and issuance of Standard Operating Procedures (SOP) and Corrective Procedures (CP) continued. Printing of procedures was initiated.

9.8 EMERGENCY PROCEDURES

An outline of the SEFOR Emergency Plan was prepared and the writing of Emergency Procedures was initiated.

SECTION X

PLANT CONSTRUCTION

10.1 MECHANICAL DEPARTMENT

10.1.1 Piping and Instrument Diagrams

The piping and instrument diagrams were updated to agree with as built conditions and field changes.

General Electric drawing of the argon gas piping at refueling cell was received and issued to complete distribution of the piping and instrument diagrams. The diagram of instrument nitrogen piping was also reissued for updating to as built conditions.

10.1.2 Sodium Service Piping Sway Braces

During this quarter design sketches were prepared in the field for the sodium service piping horizontal sway braces. The design sketch for each sway brace is based on the previously engineered spacing requirements and selected locations and a typical sway brace design. The sway braces are designed to prevent excessive movement and overstress of the piping during an earthquake.

10.1.3 Removable Insulation

The method of releasing the removable insulation from the auxiliary intermediate heat exchanger was revised to ensure that the removable insulation will fall clear of the heat exchanger.

10.2 ELECTRICAL DEPARTMENT

10.2.1 System Design and Equipment Procurement

The design of the electrical system is complete and all construction drawings have been released in final form. All remaining miscellaneous electrical materials have been placed on order.

10.3 CONSTRUCTION MANAGEMENT

10.3.1 General Work Contract

Martin K. Eby Construction, Inc. completed installing the seal ring and the stainless steel plate work at the refueling cell floor.

The contractor made corrections to the primary sodium drain tank supports. He also graded the ramp down to final elevation and installed protective plywood covering on work windows N1 and W1. The contractor has installed work windows and an equipment hatch at elevation 1639 feet, together with concrete blocks at the large construction opening, elevation 1639 feet.

The contractor is working on cleaning the site and storing material.

10.3.2 Piping

Cherne Contracting Corporation completed installation for the following systems; sodium service, nitrogen cooling, argon, breathing air, air conditioning, Freon systems, gaseous radwaste, and reflector control drive systems. He is also setting several pieces of equipment, installing instrumentation and maintaining clean rooms, cleaning nitrogen supply systems, and cleaning the construction site.

10.3.3 Electrical

Commonwealth Electric Company had a work force by the end of March of 25 men and are installing conduit for instrumentation system, hooking up Calrods and thermocouples for sodium heating system. The contractor is terminating cables and pulling cables throughout the plant. He is welding sleeves in the flange plates for containment vessel penetration in pipe runs A and B. The contractor is hooking up nitrogen gas penetrations A and C. He is also checking out the gas system and hooking up the trace heating system. The contractor has installed relays in panels 22 and 23 for the annunciator system and checking the breathing air system. The contractor installed current transformers in 480-volt switchgear for units 2A, 2B and 2C for nitrogen blower breakers.

10.3.4 Insulation

John-Mansville Sales Corporation completed insulation installation on the secondary sodium systems and is installing insulation in the primary sodium regions.

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