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DEVELOPMENT REPORT
FEBRUARY 1968

MASTER

**SOUTHWEST EXPERIMENTAL
FAST OXIDE REACTOR
DEVELOPMENT PROGRAM
FIFTEENTH QUARTERLY REPORT
NOVEMBER 1967-JANUARY 1968**

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

ADVANCED PRODUCTS OPERATION

GENERAL ELECTRIC

SUNNYVALE, CALIFORNIA

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GEAP-5595
AEC Research and
Development Report
February 1968

SOUTHWEST EXPERIMENTAL FAST OXIDE
REACTOR DEVELOPMENT PROGRAM

Fifteenth Quarterly Report
November 1967—January 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

November 1, 1967 through January 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 PuO_2 - U-238 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).

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-5009 (December 1966).

11. Wilkinson, L., "Use of Neutron Filters for Fast Reactor Fuel Irradiations in a Thermal Core," GEAP-5035 (April 1967).
12. Wilkins, 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 (December 1967).

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
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

TASKTITLE

4.4	Instrument Lead Connectors
4.5	Special Instrumentation
5.1	Core Mockup and Heated Fuel Test
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

The primary effort of Task 1.2 has been completed and the final report was typed, which describes the detailed test program specifications. Work was initiated on a plan for nondestructive (in the SEFOR refueling cell) and destructive (off the SEFOR site) irradiated fuel examination during the test program.

2.3 TASK 4—SPECIAL INSTRUMENTATION

Detail design was initiated on support fixtures to hold the neutron detectors in position outside the core. Assembly of both fission and gamma chambers was started.

2.4 TASK 6—REACTIVITY CONTROLS REQUIRED FOR EXPERIMENTATION

A series of FRED tests was carried out with a new method of lift-off indication. The poison rod material compatibility tests were completed and indicate the use of Type 304 stainless steel with boron carbide will be satisfactory. The oscillator mechanism modifications were completed.

2.5 FUEL FABRICATION

Loading and welding of fuel rods ceased on January 9, 1968, pending resolution of the total gas contents of the fuel pellets. Nuclear Fuel Services (NFS) measurements show that the fuel pellets meet the specification in all respects, while independent laboratory tests have shown that the total gas content (excluding moisture) is approximately a factor of 1.5 higher than the specification limit. One-hundred-four rods were shipped to SEFOR and inspected there.

The fuel channels were received at the SEFOR site. Fabrication of the other core

hardware continued with no significant stoppage in schedule, although several fabrication problems were encountered.

Fabrication continued on the instrumented fuel assemblies with some schedule slippage caused by fabrication problems and vendor delays.

2.6 STARTUP TESTING

Tests were performed which indicated that the SEFOR transient amplifiers would be satisfactory for the planned reactor noise measurements. The reactor vessel surveillance specimens were received.

2.7 SEFOR TRAINING

The formalized portion of the SEFOR training program in California was completed and all personnel transferred to the SEFOR site.

2.8 PLANT CONSTRUCTION

The release for construction of the electrical system wiring drawings was completed during this quarter with the exception of several miscellaneous detail drawings.

The general work contractor returned to the site on December 18, 1967 and completed the closure of the refueling cell construction opening.

The insulation work in the field progressed on schedule.

The piping contractor completed the installation of the MCS and ACS sodium piping systems. The contractor expects to complete the installation of all sodium piping within the next month.

SECTION III

TASK 1—PLANNING THE EXPERIMENTAL PROGRAM

3.1 TASK 1.2—FINAL SPECIFICATION OF THE EXPERIMENTAL PROGRAM

computer codes for the analysis of SEFOR oscillator test data have been specified.

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.

The primary effort of task 1.2 has been completed and the final report was typed and reviewed. As the quarter closed; corrections to the final report were being made prior to submission for publication.

3.1.3 Current Results

Work was begun on a plan for non-destructive and destructive examination of irradiated fuel to be performed during the test program. It is intended to provide a detailed plan for use of the 18 "guinea pig" rods which are to be fabricated with 25% PU enrichment (compared with 18.7% Pu enrichment in the normal fuel). A total of 12 fuel rod positions at two radial core locations are accessible via six through-head refueling parts in the vessel head. It is planned to load both guinea pig rods and normal fuel rods into these locations to provide convenient access for fuel examination both in-cell and at a "hot laboratory" equipped for destructive examination.

3.1.2 Past Accomplishments

A reactivity feedback model for use in the analysis of experimental data and procedures for use of static, oscillator, and transient data to determine the Doppler coefficient defined by the model were outlined. An outline of the SEFOR experimental program for Core I was completed. Three

SECTION IV

TASK 4—SPECIAL INSTRUMENTATION

4.1 TASK 4.2—CORE FLUX DETECTOR SYSTEM

tem 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.

4.1.1 Purpose

The objectives of Task 1.2 are to develop and supply a suitable detector sys-

4.1.2 Past Accomplishments

Several detectors and detector concepts were examined. Final system configuration was selected after completion of tests on prototype detectors and amplifiers. The final system selected uses logarithmic amplifiers with a compensated fission chamber covering the low decades of power and a gamma chamber covering the higher ranges of power. In the largest planned transients, the overall transient will be covered by overlaying the results of the two detector-amplifier systems. The system concept has been tested using prototype equipment on transient pulses at Super Kukla.

4.1.3 Current Accomplishments

During the period detail design was initiated on shielding and transporter equipment for the neutron detectors; three of which will be located at core height in guide tubes located in the radial biological shield-

ing beyond the reflector region. Detail design of the shielding and transporter equipment is now 80% complete and procurement of parts is underway. The design situates the detector in a lead-filled capsule which will move on spring loaded slides within the curved 5-inch-diameter guide tubes. Positioning will be accomplished by pushing each assembly up its own guide tube from the reflector drive room below the reactor cavity using a hollow, three-sectioned, hinged pole some 16 feet in length. Detector-signal cables will be carried inside the push pole.

A shield plug with center hole accommodating the push pole will block neutron streaming in each of the three guide tubes to prevent activation of equipment below.

The GE Sensor Shop has begun assembly of both the U-238 fission chambers and the gamma chambers.

SECTION V

TASK 6—REACTIVITY CONTROLS REQUIRED FOR EXPERIMENTATION

5.1 TASK 6.1—FAST REACTIVITY EXCURSION DEVICE (FRED)

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.

5.1.2 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. Plans were developed to test the reactor model under heated conditions.

5.1.3 Test Program

The test model No. 1 was modified for a new lift-off switch design and a position sensor. These were both installed in the test model and several tests carried out to check their basic characteristics before including them in the reactor model design. The results of the test indicate that both of these performed satisfactorily. The lift-off switch indicates when the piston has broken contact between two contact points. The variable reluctance device is an analog signal to indicate the relative motion of the FRED before and after actuation of the lift-off switch.

5.1.4 Poison Rod Design

Preliminary tests to determine the compatibility of boron carbide and Types 304, 430 F, and 446 stainless steels have been completed. The tests were carried out in 1600°F for periods of 100 and 400 hours. The test specimens have been metallographically prepared and examined. The compatibility samples consisted of rods of each type of stainless steel with a hole drilled down the center for the B_4C powder. After loading, each capsule was placed in a Vycor tube, evacuated, back-filled with argon, and sealed. The capsules were placed in a furnace and the temperature slowly raised to 1600°F and maintained for a period of 400 hours. The first group of samples were withdrawn from the furnace at the end of the 100-hour period. The results of the metallographic examinations of these samples indicate an observed reaction depth of 0.004 inch after 100 hours, and 0.10 inch after 400 hours in the Type 304 stainless steel. The Types 430 F and 446 stainless steels were attacked to a lesser degree. The primary conclusion as a result of these tests indicate that Type 304 stainless steel with boron carbide poison can be used for the FRED poison slugs as well as the oscillator poison slug. Since the wall thickness is over 0.060 the effect of losing 0.010 off this wall thickness will not affect the performance of the poison slugs.

In addition to the above-mentioned samples some tests were carried out with a copper diffusion barrier between the B_4C and steel; the results of these tests were inconclusive as the copper was very porous. The copper barrier may be used in the FRED poison slugs for added margin.

5.1.5 FRED Design

The detail fabrication drawings for the FRED Reactor Model have been completed

and are presently being checked before being released for quotations for fabrication.

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.

5.2.2 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 Mechanisms

The oscillator mechanism was dismantled during the past quarter and has been further disassembled, cleaned, lubricated, and reassembly started during this quarter. The modifications as reported earlier have all been made and a checkout test series will be carried out later when the positioner mechanism is being tested.

5.2.4 Balanced Oscillator System

All components for the manual oscillator control system have been received by NEBS, and fabrication assembly of the components has started. It is expected that the system will be complete by the middle of the next quarter. The delay has been in the precision machining of mounting plates for mounting the components.

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

Following a number of rejections of both fuel pellets and fuel rods, GE released fuel production to the vendor, Nuclear Fuel Services Company (NFS).

Fabrication of fuel hardware and instrument fuel assemblies continued during the preceding quarter. Fabrication of channels neared completion.

6.3 CURRENT RESULTS

6.3.1 Pellet Production

All of the third master mix has been coprecipitated, and the fourth master mix was prepared. The fourth master mix will complete the fuel order except for the "guinea pig" rods which have a 34% higher plutonium enrichment than the regular fuel. All NFS quality control results show the pellets to meet the specification.

6.3.1.1 Second Phase Investigations

Pellet batch 609 (approximately 125 kg of material) has been quarantined by NFS pending resolution of apparent impurity particles (or possible second phase) in the fuel oxide matrix. The apparent particle content is less than the specification limit of 5% second phase, and NFS has determined that the pellet batch meets specification in all

respects, including impurities and plutonium homogeneity. The measurement for second phase is performed by estimating the area covered by the second phase from observations through an optical microscope. Thus far, with the possible exception of batch 609, all pellet samples have exhibited no second phase in excess of the 5% specification. NFS has agreed to meet the 5% second phase limitation, as determined by optical microscopy with mixed oxide mounts, both in the as-polished and etched state of preparation. As the quarter ended, these inclusions were being investigated at GE by means of the electron microprobe analyzer.

Several techniques were employed during preproduction evaluation to identify particles which were observed in those pellets. These methods included preferential etching, microhardness measurements, alpha autoradiography, and x-ray diffraction. These methods of investigation yielded uncertain results; with possible identifications ranging from a Pu-U ceramic to iron. Optical microscopy and microprobe examinations are considered the only certain methods of analysis. Results of investigations by these methods on production pellet samples are described below.

6.3.1.1.1 Optical Microscopy

Visible "shiny particles" were examined in the unetched samples of lots 601 to 612. Most of the particles were very minute and randomly dispersed. At 250× magnification, many of these particles looked to be pin head size, but the average size was measured to be about 1 mil by 1 mil.

The following tabulation lists the number of particles found in a total surface 250× scan of one unetched specimen from each pellet batch from 601 to 612.

<u>Pellet Batch</u>	<u>No. of Particles Found</u>
601	46
602	63
603	43
604	10
605	11
606	43
607	19
608	33
609	51
610	26
611	31
612	34

With an average particle size of 1 mil by 1 mil, the average area covered by the particles is less than 0.01% of the cross-sectional pellet surface area. Thus, from observations on hand, the conclusion was reached that the quantity of the second phase was within the specifications and not of magnitude to warrant rejection of these batches.

6.3.1.1.2 Electron-Microprobe Studies

Work completed on a pellet from batch 609 shows that the above-mentioned shiny particles are mainly Fe, Ni, and Cr. The quantitative ratios of these materials suggest that these inclusions are pieces of steel, probably the result of contamination during powder screening prior to pressing. As the total amount of impurity is less than that designated in the specification and determined by chemical analysis, the presence of these inclusions cannot be made a basis on which pellets can be rejected. If one were to assume that the 0.001-inch "shiny second phase" particles are composed of Fe and are dispersed uniformly throughout the pellets 100 particles (largest count of particles in any one cross section was 63) for each 0.001-inch-thick cross section, the total content in the pellets would not exceed 100 parts per million. The specification allows 2500 parts per million of total impurities, and in all cases of NFS pel-

lets this condition was met. Calculations, assuming the particles to be nickel or chromium, yield similar conclusions. Additional work on other apparent impurity particles (or second phase) in this pellet from batch 609 is under way.

A literature survey was made in regard to iron impurities in oxide fuels and their influence upon fuel performance.

The effect of impurities on fuel behavior at high burnup was investigated at the Westinghouse-Bettis Plant during the testing of plate-type element developed for use in PWR Core 2 Seed 1.⁽¹⁾ Iron additions of 0.5 and 1 wt% were made to 96% TD, 40-mil-thick fuel wafers of ZrO₂-36.5 wt% UO₂ composition and irradiated to burnups to 55,000 MWd/Te in pressurized water loops, which is a factor of approximately 20 higher than maximum planned SEFOR fuel exposure. Center temperatures in these thin swelling or fission gas release plates were estimated at 1200°C. No differences were noted between these samples and specimens that did not have the iron additive. The absence of detrimental swelling in these plate elements implies that in this concentration at least, inert impurities do not impair element operation or lifetime.

6.3.1.1.3 Pellet Physical Condition

The average pellet rejection rate at NFS because of surface cracks and chips is 10 to 15% of those processed. The fuel specification allows surface cracks 0.003 inch or less wide and surface pits no more than 0.030 inch in diameter, provided that no more than 5% of the cylindrical surface or 10% of either end surface is missing because of chips, cracks, and pits combined. These limits were based on standards used in commercial UO₂ pellet fabrication.

¹ B. Rubin, B. Bermon, M. Bleiberg, "The Irradiation of ZrO₂-UO₂ Fuels," WAPD-264, (October 1962).

NFS made considerable effort to improve the pellet appearance by adjustment of fabrication conditions using small test runs. Because this proved difficult to accomplish, NFS has been forced to grade the pellets prior to loading, rejecting those which exceeded the above-mentioned specification limits. The grading is based on general appearance, and it is performed by NFS operators who received instructions and training on the job. The results of their selection was observed and checked regularly by NFS quality control personnel, NFS supervisory personnel, and GE on-site inspectors and other personnel making periodic visits there.

Testing was performed at NFS to determine the effect of pellet cracking. Five pellets were selected which appeared to be the worst acceptable pellets in that particular batch. All pellets were intentionally dropped from a height of 2-1/2 feet onto a metal surface. One pellet broke into two pieces on the sixth drop. A second pellet broke into two pieces on the first drop. The remaining pellets were dropped more than six times with no breaking and with no visible damage. It was judged that handling the pellets prior to reactor loading constitutes less abuse than the above tests and that at the time of reactor startup, pellet integrity will be maintained to the level determined at the time of loading. In past experience with both urania and mixed oxide fuels, cracking of the fabricated pellets has never been shown to be detrimental to fuel element performance.

6.3.1.1.4 Pellet Volatile Content

Volatile content tests of preproduction pellets (first master mix) in June-July 1967 indicated that possible surface contamination dictates that the sample should be properly chosen to be representative of the entire pellet diameter. The volatile content of a one-quarter pellet sample was measured to be well below the specification limit of $50 \mu\ell/\text{gm}$.

Initial tests of volatile content conducted by an independent laboratory with a production pellet sample from batch 603 (second master mix) showed that the pellet sample did not meet the total gas release (excluding moisture) specification. In six separate analyses conducted at this laboratory, there is a factor of 10 difference between the highest and lowest gas release results, the lowest being approximately twice the specification limit. Since this variation and the sample preparation raised some doubt concerning the validity of the results, additional identical pellet samples were prepared by GE-VNC and distributed to four independent laboratories. Results of these tests and visits to these laboratories and to NFS by GE analytical chemists indicated the NFS and Oak Ridge National Laboratory (ORNL) have equipment and procedures which should yield reliable results. ORNL results showed that pellet total gas release to be approximately $70 \mu\ell/\text{gm}$, while NFS results have always shown total gas to be in the range 10 to $25 \mu\ell/\text{gm}$. Since the pellet sample preparation is judged to be critical in obtaining comparable results, a series of tests are being conducted at ORNL and NFS on identical samples prepared by NFS. The purpose of these tests is to show the degree of correspondence between the two systems in measurements of low gas, nominal (specification limit) gas, and high gas content. Preparations for these tests were being made as the quarter ended.

6.3.2 Fuel Rod Production

Loading and welding of fuel rods ceased on January 9, 1968, pending resolution of the total gas content in the fuel pellets. A summary of the welded rods is shown below:

- 280 rods welded
- 104 rods shipped to SEFOR site
- 76 rods ready for shipment to SEFOR
- 100 rods rejected (approximately 50% of these are leakers; most of the others were rejected because of various weld deficiencies)

Initial investigation of two rods which were found to have a high helium leak rate showed that the leak path was in the end plugs and not in the weld. Most of the leakers have a relatively low leak rate, thus determination of the location of the leak is not possible with the equipment available at NFS. Since discovery of the end plug leaks, all end plugs are helium leak-checked by NFS prior to welding. As a result of the high incidence of leaking rods, it was decided to add a helium leak-check to the fuel rod receiving inspection at SEFOR. Equipment procurement was initiated as the quarter ended.

Rod repair procedures, involving cutting the rod at the weld and rewelding a new end plug, are being studied. To meet the rod length specification, it may be necessary to leave some weld metal on the rod when cutting off the end plug. NFS has submitted such repair welds to GE for examination, and preliminary study of weld metallography has shown that these repair welds are satisfactory.

Several rods have shown an alpha particle count higher than the specification limit, the high count rate being associated with the weld area. A slag-like particle showing a high count was observed under 40X magnification at the tail-off of these welds. Although it was felt that this particle floated only on the surface of the weld as a slag, it was deemed advisable to section through this area to determine the possibility of finding similar particles leading from the inner surface of the tube, through the weld zone, to the outer surface. Metallography performed at three different levels through the area of the particle revealed no inclusions at any point in the weld.

It is concluded that these particles are an accumulation of minute fuel particles that collect as the weld progresses around the tube, and are finally deposited at the solidified end of the weld tail-off. Further tests show that this particle is easily dis-

lodged by light application of 600-grit abrasive paper. The incidence of high alpha activity on the welded rods decreased as the vendor performed more frequent cleaning of the fuel rod end prior to welding and cleaning of the welding chamber.

Receiving inspection at SEFOR of the 104 delivered rods showed that the rods met the external dimensional specification except that the electron beam weld at the center spacer was approximately 0.001 inch too high. NFS sent personnel to the SEFOR site to remove the excess material by polishing.

6.3.3 Fuel Hardware Fabrication

Fuel hardware fabrication is in progress. The hexagon tubing for the tightener sleeve was received. The as-fabricated hardness of the tubes were found to exceed specification, but because of the relatively low SEFOR operating temperatures, it was judged that the hardness would cause no significant warping and the tubes were released for machining; 95% of the tubes were machined during the quarter. The external springs were fabricated and heat treated. The first prototype internal springs were undergoing fabrication development. Machining of the spiders was completed. The final batch of fins was received.

Work was started on the tooling for the hydro forming of the tightener rod.

All internals for the extension rods were completed. The upper and lower reflectors were machined and the BeO rods and pellets were received. Machining was completed on 75% of the lower end plugs. The tube forming vendor submitted preproduction samples which were found to be oversized. Although the vendor subsequently reworked his dies, the resulting samples were still oversized. Because further reworking of the dies would have resulted in a further delay, it

was decided to direct the vendor to proceed with the forming of the tubes and to swage all oversized tubes.

All parts for the foil-holder rod were placed on order.

The fuel channels were completed and have arrived at the SEFOR site.

Nuclear Fuels Service has completed fabrication of the springs, external tubing, and top and bottom end plugs for the surveillance rods. The extension rod for the surveillance rod was completed in the GE shop.

6.3.4 Instrumented Fuel Assemblies

The fabrication of tungsten rhenium fuel thermocouples continues to be a delay in the overall instrumented fuel assembly fabrication effort. Several thermocouples using 0.005-inch-diameter wires were successfully made and tested but this was accomplished only after a great deal of extra unplanned effort had been applied.

To prevent tungsten-rhenium sheath failure, which occurred during initial fuel thermocouple fabrication, the bending jig was modified to distribute the stress over the complete outside surface of the sheath during the bending operation. A fabrication shop suggestion of crimping rather than brazing for the connection of the tungsten-rhenium thermocouple wire to the compensated lead wire (using the nickel transition sleeve) was evaluated by analysis and thermal cycle test. It was concluded not to use this method and the brazed connection continues to be the final design.

A successful method of fabricating the wire transition by using a spiral wrap of nickel ribbon in place of the solid nickel sleeve

has been developed. It appears that this recent development work has overcome the two large problem areas in fuel thermocouple fabrication: (1) breaking of the W/Re at its braze point into the nickel sleeve, and (2) splitting of the probe sheath as the final bend was made.

The VNC-IPO machine shop continues to machine parts for the instrumented fuel assemblies.

The deliveries of the formed tubes for the extension rods and tightener rods still continue to be limiting items. The latest promises for completed rods and sleeves are:

Extension Rods	February 23, 1968
Tightener Rods	March 22, 1968
Tightener Sleeves	February 16, 1968

All of the clad tubing has been received and ultrasonically inspected. An ultrasonic standard was fabricated with defects in the outside diameter and inside diameter equivalent to 5, 10, and 15% of the wall thickness. No defects in the tubing greater than, or equal to, 10% were found upon inspection.

Fabrication of fuel rod hardware was completed; cleaning and passivation were performed.

Insulator pellets were received from the Fuel and Material Development Shop to be chipped. The pellets will be inspected and acceptance or rejection will be based on the fuel pellet chip specifications.

Inspection and drilling of NFS-fabricated pellets has been initiated; early inspection indicates several pellets with circumferential cracks. Slotting of the fuel pellets has not yet been attempted, but initial drilling appears to present no cracking or chipping problem. Operation of all equipment is judged to be satisfactory.

Trips were made to Oliver Johnson Machine Shop in San Jose, Satham Instrument Co. in Oxnard, Calif., and Aeroquip Marman Division in Los Angeles to deal with problems arising during vendor IFA parts fabrication effort.

Conoseal flanges from Aeroquip are slipping schedule. The latest delivery promise for these flanges is February 29, 1968, and delivery is being expedited. Further slippage of these flanges will jeopardize delivery of the completed fuel connectors to the SEFOR site by May 1, 1968.

GE-APO is continuing to work with Satham Instrument Co. to resolve electrical

connector design problems. Electrical connector drawings were revised to comply with approved vendor suggestions.

The present estimated delivery date of the first IFA to SEFOR is June 15, 1968. This is in advance of the date required for reactor power operation to give the reactor operations group time for familiarization with handling. The delivery date shown above is contingent upon (1) the T/C fabrication procedure now being used by the IPO Shops being a "repeatable" process; (2) sufficient fuel for the first IFA being received almost immediately; (3) no slippage occurring on certain outside vendor items such as Conoseal flanges; and (4) on-schedule delivery of the upper tightener rods.

SECTION VII

TASK 10—STARTUP TESTING

7.1 TASK 10.3—WET CRITICAL TESTING

7.1.1 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.

7.1.2 Past Performance

Work was begun to identify and procure special experimental equipment which includes activation foil materials, foil holder rods, reactor noise analysis equipment and special startup instrumentation, and gamma source and detection equipment for fuel transmission gamma scan.

7.1.3 Current Results

7.1.3.1 Reactor Noise Analysis Equipment

Frequency response and drift tests were performed which demonstrated that the SEFOR transient amplifier in conjunction with an appropriate input filter circuit (see Fourteenth Quarterly, GEAP 5561) would be adequate for the planned noise measurements.

However, the amplifier gain and expected ion chamber currents are so low that an additional voltage amplifier will be needed to provide a signal level high enough for recording.

7.1.3.2 Reactor Vessel Material Surveillance Specimens

The reactor vessel material surveillance specimens were received. As noted in the Task 9 section of this report, the surveillance specimen holder rods have been placed on order and the extension rods have been completed.

SECTION VIII

SEFOR TRAINING

8.1 PURPOSE

The purpose of the SEFOR training is to recruit and train the various technical, operator and maintenance personnel required for the operation of the SEFOR facility, accomplishment of the SEFOR experimental program, and accomplishment of the planning, procurement, and testing functions related to the startup of a new facility.

8.2 PAST ACCOMPLISHMENTS

The SEFOR training program was initiated. Personnel hired totaled 22. Preparation of the preoperation test procedures for each system, corrective procedures, and standard operating procedures was initiated. Initial results of the preoperation environmental survey were reported to the AEC Division of Compliance.

8.3 CURRENT RESULTS

The formalized portion of the SEFOR training program in California was completed and all personnel transferred to the SEFOR site. Training was continued by work assignments and preoperational tests at the site.

The first shipment of SEFOR fuel, 104 rods, was received and mechanical inspection and measurements completed. The writing of preoperational tests and standard operating and corrective procedures was continued. Recruiting of personnel was continued with 29 of the total of 40 personnel hired. All key positions have been filled and all reactor operators recruited except one. The preoperational environmental survey program was continued.

SECTION IX

PLANT CONSTRUCTION

9.1 MECHANICAL DEPARTMENT

9.1.1 System Design and Equipment Procurement

The Mechanical Department system design is completed. Work during the past quarter has consisted of minor drawing changes for corrections and updating for as-built conditions.

On December 15, 1967, the drawings of Nitrogen Cooling Piping, Sheet 1 and Sheet 2, were revised and issued. The issue covered revisions to the halogen leak detector sampling

piping to accommodate the General Electric Company halogen leak detector.

The piping and instrument diagrams are being updated to agree with as-built conditions and field changes.

All items of mechanical equipment have been purchased.

9.1.2 Rupture Discs and Relief Valves

Revised manufacturer's drawings of the rupture disc and relief valve assemblies were received, reviewed, and returned to

the manufacturer. All relief valves and rupture disc assemblies are scheduled for shipment on or before February 7, 1968.

9.2 ELECTRICAL DEPARTMENT

9.2.1 System Design and Equipment Procurement

The release of the electrical system wiring drawings for construction was essentially completed during this report period. Several miscellaneous detail drawings remain and are currently being completed.

A complete recheck of all required cable quantities and penetration hardware is currently under way. The recheck is a normal function which is done upon the completion of the design.

9.2.2 Drawing Release Schedule

The electrical drawing release schedule was revised as of January 20, 1968, showing completion dates for the annunciator schematics, together with other minor changes.

9.3 CONSTRUCTION MANAGEMENT

9.3.1 General Work Contract

Martin K. Eby Construction, Inc. again returned to the site on December 18, 1967. The contractor completed the closure of the refueling cell construction opening.

9.3.2 Insulation

Johns-Mansville Sales Corporation has essentially completed insulation work on the air blast coolers and on sodium piping in that area. Insulation work in the pent-house secondary sodium rooms and pipe tunnel is approximately 95% complete at this time. The mirror insulation and sodium piping out of the reactor is approximately 80% complete.

9.3.3 Reactor Erection

Austin Building has installed the reactor vessel shroud, reflector guide structure and the bottom shield plug. Work continues on the installation of shield plates and liner segments.

9.3.4 Piping

Cherne Contracting Corporation has completed the welding and radiography of MCS and ACS piping systems. Other systems completed during this period include the radioactive liquid radwaste system, service water system, and the diesel fuel oil system. Work has continued on the erection, welding, and radiography of the SSS piping, gaseous radwaste, nitrogen cooling, breathing air, Freon, and argon piping systems. Work has also continued on the reactor building air conditioning system duct work and has been completed as far as possible at this time.

9.3.5 Electrical Work

Commonwealth Electric Company completed the installation of MI cable at the containment vessel penetration area and also completed the liquid radwaste system with the exception of the radiation monitoring interlocks for the transfer and discharge pumps. The contractor set into operation the instrument and breathing air compressor. Commonwealth Electric also completed the installation of the nitrogen cell penetration plugs. The installation of thermocouples on the reactor guide structure, lower shield plug, and the irradiated fuel storage tank is completed. The contractor also continues to work on the installation of Calrod heaters and equipment for the sodium trace heating system and continues to pull and terminate cable throughout the plant. Commonwealth Electric has started the work on the main and auxiliary air blast coolers and pump power supplies.

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The following people contributed to the work performed on the SEFOR Research and Development Program during the quarter ending January 31, 1967.

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