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ELECTRONUCLEAR RESEARCH DIVISION

SEMIANNUAL PROGRESS REPORT

FOR PERIOD ENDING MARCH 20, 1956

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For Period Ending March 20, 1956

Robert S. Livingston, Director
Edited by F. T. Howard

DATE ISSUED

SEP 7 1956

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ELECTRONUCLEAR RESEARCH DIVISION SEMIANNUAL PROGRESS REPORT

ABSTRACT[1]

The Army Package Power Reactor 1, which is under construction at Fort Belvoir, Virginia, was essentially 11% complete as of March 1, 1956. Postirradiation examination of eight APPR-type fuel element samples indicated no failure of the clad or matrix material. Other irradiations of sample- and full-size fuel elements are in progress. Results are given on the APPR-1 Critical Experiment Program recently completed. Measurements were made on the critical mass with and without boron poison additives, on control rod values, and on other porameters. The proposed Gas-Cooled Reactor Development Program is discussed.

PACKAGE POWER REACTOR PROGRAM

The Laboratory's Package Power Reactor Program consists of research and development work for the Army Reactors Branch in support of the Army Package Power Reactor 1 now under construction and also of participation in the AEC Gas-Cooled Reactor Development Program.

ARMY PACKAGE POWER REACTOR

Work on the design, development, and construction of the APPR-1 by the Alco Products, Inc., is progressing satisfactorily and on schedule. Engineering design of the building facility and major components for the plant is essentially 75% complete. Ground at Fort Belvoir, Virginia, was broken in October 1955, and as of March 1, 1956, construction was approximately 11% complete (Fig. 1). The completion date for the project, including the performance testing period, is July 1957.

The Laboratory is continuing to furnish technical support and evaluations to the Army Reactors Branch (ARB) in addition to the scheduled development programs in support of the APPR-1 contract.

Fuel Irradiation Experiment

The fuel irradiation program at the MTR in support of the APPR-1 is divided into three phases.

Phase I. – The first series of irradiations is composed of 26 samples of fuel plates clad with stainless steel and irradiated in the reflector of the MTR to 30 and 50% burnup. The samples differed from one another principally in the particle size and the percentage of the UO_2 in the samples.

All samples were placed in the MTR reflector on June 24, 1955. The eight samples requiring 30% burnup have been returned to the Laboratory and inspected by the Solid State Division. Photomicrographs indicated no failure of the clad or matrix material. Bend, hardness, and annealing tests were completed on the samples, and a report of this work will be issued shortly.

Two of the 50% burnup samples have been received from the MTR. The remaining 16 samples are expected by the end of the next quarter. Upon receipt of the remaining samples a similar post-irradiation test program will be initiated.

Phase II. – At the time that the above small samples were placed in the MTR reflector, a full-size 18-plate APPR-1 type of fuel assembly mounted in an aluminum adapter to fit the core was inserted into the MTR. Three different UO_2 concentrations were used in the fabrication of the plates. Six plates each were composed of 18.75, 22.18, and 26.89% UO_2 in a stainless steel matrix. The assembly was irradiated to an estimated peak burnup of 40%, then removed from the core on August 22, 1955.

Inspection of the assembly in the MTR canal showed no abnormal surface conditions. On January 17, 1956, four plates were machined from the assembly in the MTR hot cell facility. The plates

[1] Activities of the Division in unclassified areas of research are summarized in ORNL-2139.

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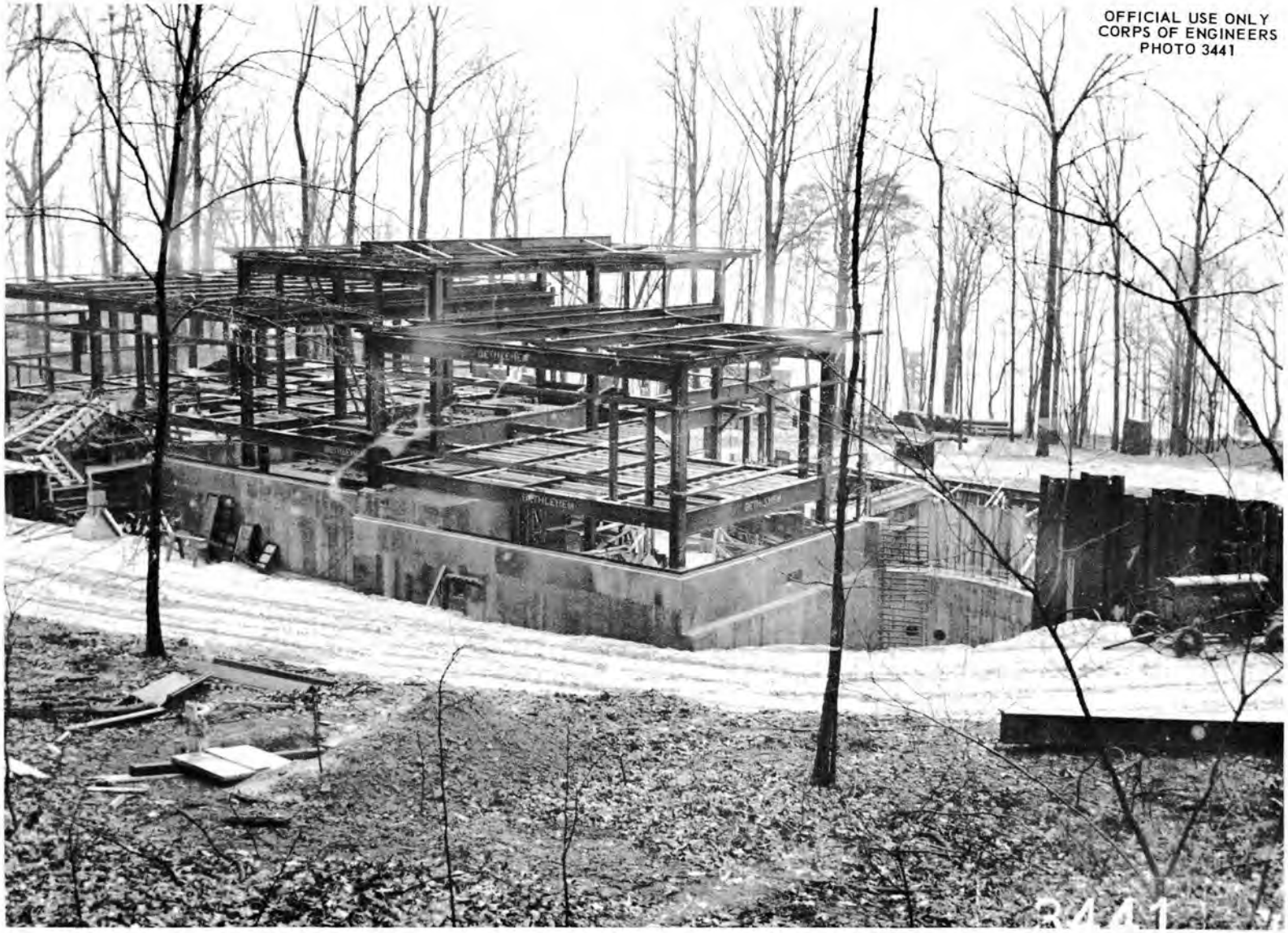

Fig. 1. Construction Status of APPR-1, March 1, 1956

were examined by the Metallurgy Division. A light reddish-brown film which outlined the fuel core covered the surfaces of all the plates. There was no evidence of blisters or other defects. The fillets of the brazed joints were carefully examined; no evidence of corrosion could be attributed to the irradiation. A more complete report of this examination was issued.[2] The remaining plates were turned over to the Chemical Technology Division to use in its fuel reprocessing program.

Phase III. – In Phase III of the irradiation program, involving 12 miniature fuel plates approximately $\frac{7}{8} \times 4 \times 0.030$ in. thick, uranium dioxide produced by the following four methods was used in the fabrication of the plates:

1. steam oxidation,
2. reduction of burned uranium chips,
3. reduction of uranium trioxide,
4. hydrogen peroxide precipitation.

In addition, three different degrees of cold rolling were used; hence each plate is composed of a different oxide and was subjected to a different degree of cold rolling. A report giving a more detailed description of the Phase III plates was issued.[3]

The fabrication of the plates was completed, and they are ready for shipment to the MTR. It is planned to irradiate all samples to approximately 40% burnup.

Fuel Melting Experiment

To gain information on the gaseous fission products released when a fuel element melts, a program was initiated to melt 100-mg uranium samples of APPR-type fuel plate material and then to capture and analyze the resultant discharged gases. Approximately 50 sample fuel plates were prepared by the Metallurgical Group. A chemical hot cell facility is nearing completion in which the fuel melting apparatus will be set up. The fuel samples will be irradiated in the ORNL Graphite Reactor and in the MTR.

During the past year small fuel slivers were irradiated to low levels and melted in order to develop procedures and equipment.

[2]R. J. Beaver, *Post-Irradiation Macroscopic Examination of APPR Stainless Steel Plates Removed from APPR Fuel Element Irradiated in the MTR*, ORNL CF-56-1-116 (Jan. 25, 1956).

[3]R. C. Waugh, *Preliminary Specifications for APPR Phase III MTR Irradiation Experiment*, ORNL CF-55-10-111 (Oct. 21, 1955).

Critical Experiments

A zero power mockup of the APPR was constructed in the ORNL Critical Facility.[4] The assembly consisted of 45 fuel elements, in a 7 by 7 array with the corners removed, and was contained in a large water tank. The over-all core dimensions were $21 \times 21 \times 22$ in. Enriched uranium metal foils, $2.5 \times 0.002 \times 22.0$ in. and each containing 31.1 g of U^{235}, were encased in stainless steel sheets to form the fuel plates. Additional plates of stainless steel and of boron encased in stainless steel were used to simulate materials of the APPR-1 core. Each type of plate contained essentially the same amount of steel. When the 18 slots of each element were loaded with plates, the metal volume fraction was 0.197; this fraction was kept constant throughout the experimental program. The number of fuel plates per element varied from 7.5 for the clean reactor to 14.5 for a boron-poisoned assembly. The critical mass of the clean reactor was 10.35 ± 0.05 kg of U^{235}. The addition of 255 g of natural boron to the core, distributed among three plates in each element, increased the critical mass to 20.1 kg of U^{235}.

Reactivity coefficients of fuel plates, measured in the clean reactor as a function of position, gave an average fuel value of 0.526¢/g. The specific mass reactivity coefficient, $m\Delta k/k\Delta m$, was determined over a wide range of reactor loadings.

The effects of the heterogeneous distributions of the uranium and boron on the critical masses of the reactor were studied by exchanging special fuel elements with assembly elements in several locations and noting the resulting changes in reactivity. These data and the assumption that the specific mass reactivity coefficient is constant with fuel loading were used to calculate a value of 9.1 kg of U^{235} for the critical mass of an unpoisoned array of APPR-type elements.

Measurements were made of the value of the APPR control rods in various locations, both individually and collectively, in terms of the additional mass of U^{235} necessary to maintain criticality. One eccentric control rod fully inserted was worth 0.68 kg of U^{235}, the central control rod was worth 1.70 kg, and five rods fully inserted were worth 12.23 kg. In addition, the calibration of one eccentric rod by the integrated period method gave a value of $3.8.

[4]Operated under the supervision of the Applied Nuclear Physics Division.

Power and neutron flux distribution measurements were made in all major configurations of the critical assembly. Macroscopic neutron flux distributions were measured by exposing bare gold and cadmium-covered gold foils at various points in the reactor. Intercell flux distributions were obtained by using dysprosium as the neutron detector. The power distributions were found by measuring the fission-fragment activity on aluminum catcher foils placed in contact with the uranium in special fuel plates. Catcher foils, exposed both bare and cadmium-covered in the mid-plane of the clean reactor, indicated 91% of the fissions to have been produced by neutrons having energies less than about 0.5 ev.

Fabrication of APPR-1 Fuel Assemblies

ORNL has been charged with the responsibility for the development work necessary to permit final mechanical design and fabrication of the fuel and control rod elements for the first core of the APPR and for fabrication of these elements. The major development task associated with the fuel assemblies has been completed, and only minor refinements still remain. It is presently planned to start production fabrication of the fuel assemblies on about March 19. It is estimated that the fuel assembly fabrication for the initial loading can be completed by the summer of 1956. The major effort at present is on obtaining a satisfactory design for the control rod absorber plates.

GAS-COOLED REACTOR DEVELOPMENT PROGRAM

The Package Power Reactor Group is participating in the AEC Gas-Cooled Reactor Development Program to the extent permitted by the presently authorized level of the group. It is expected that this program will soon be the group's major effort. The over-all program will include both military and civilian applications, but the initial emphasis will be on systems of military interest.

There is an important military need for highly portable electric power sources with capacities in the order of 500 kw and requiring a minimum amount of maintenance and logistic support. A sufficiently simple nuclear reactor power plant which is portable in the shutdown condition would meet the requirements, and preliminary studies indicated that a gas-cooled reactor coupled with a gas-turbine-driven generator is the most promising system for this application. The small size and mechanical simplicity of gas-turbine machinery and freedom from water requirements are important considerations.

A typical system of interest is described in an ORSORT feasibility study,[5] which was done under the guidance of the Package Power Reactor Group. This study proposed a 2-Mw closed-cycle nitrogen-cooled reactor utilizing stainless steel–UO_2 fuel elements and a solid hydride moderator. Nitrogen leaving the reactor at 1150°F passes through a gas turbine driving a 400-kw generator.

It is considered inadvisable to undertake construction of a prototype power plant of this type immediately. Background experience in operating small, high-temperature, gas-cooled reactors is lacking, and additional development of materials and gas turbines is needed. A three-phase program to provide the necessary background technology has been initiated by the Army Reactors Branch of the Division of Reactor Development (AEC):

1. The Engineering Research and Development Laboratories (ERDL) of the Corps of Engineers has let contracts for design and construction of a 400-kw gas turbine and will conduct testing operations at Fort Belvoir, Virginia.
2. Battelle Memorial Institute has been engaged to conduct the necessary materials development program.
3. A Gas-Cooled Reactor Experiment (GCRE) is planned for construction at the National Reactor Testing Station, Idaho. A design contractor will be selected by the Chicago Operations Office. Initially this facility will consist of a 2-Mw gas-cooled reactor based on existing technology. Provisions will be made for addition of turbogenerator machinery at a later date and for substitution and test of advanced core designs.

Experience gained in this development program will also be useful in utilizing gas-cooled reactors for civilian applications. Package Power Reactor Group participation is primarily in the areas of materials development and in the Gas-Cooled Reactor Experiment, but technical support in other areas is also provided to the Army Reactors Branch as required.

The design of a gas-cooled loop for installation in the Oak Ridge Research Reactor is being undertaken. This loop will occupy two lattice positions

[5] C. J. Heindl *et al.*, *Portable Trailer-Mounted Reactor System*, ORNL CF-55-8-192 (Aug. 1955).

in the ORR and will provide a much-needed irradiation test facility for evaluation of materials proposed for use in gas-cooled reactors. A preliminary design study performed by a group of MIT Practice School graduate students indicated feasibility. The possibility of engaging an outside engineering firm to assist in preparing a detailed design is being investigated.

Assistance was provided to the Army Reactors Branch in defining the concept of the Gas-Cooled Reactor Experiment and in establishing design specifications to be furnished to prospective contractors. Additional technical assistance will be furnished to the Contractor Selection Board.