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# OAK RIDGE NATIONAL LABORATORY

## SPECIAL PROGRESS REPORT

PROGRAM 4700

APRIL 1958

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**OAK RIDGE NATIONAL LABORATORY**

operated by

UNION CARBIDE CORPORATION

for the

U.S. ATOMIC ENERGY COMMISSION

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C-85 Reactors - Aircraft
Nuclear Propulsion Systems

ONRL-2526

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# OAK RIDGE NATIONAL LABORATORY
# SPECIAL PROGRESS REPORT
# PROGRAM 4700

April 1958

Date Issued: MAY 5 1958

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
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U.S. ATOMIC ENERGY COMMISSION

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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

April 1958

PROGRAM 4700 - REACTOR DEVELOPMENT

AIRCRAFT NUCLEAR PROPULSION PROJECT (AEC Activity 4701)

Tower Shielding Facility (TSF)

The second phase of the Aircraft Shield Test Reactor (ASTR) experiment at the TSF is near completion. For one series of measurements in this phase the ASTR core was covered with a 1/8-in. layer of boral. Altitude traverses were made to obtain fast-neutron and gamma-ray dose rates and thermal-neutron fluxes. In addition, measurements of air-scattered fast neutrons and gamma rays were made at altitudes of 12.5 and 186 ft as a function of the reactor orientation angle; individual direct-beam shields were used at various distances in front of each counter. Thermal-neutron source terms were also mapped with a collimated counter as a function of the reactor orientation angle. Four different ASTR shield tank configurations were used for these measurements.

The boral surrounding the core was then removed and many of the previous measurements were repeated. In addition, the thermal-neutron fluxes at various locations in space not covered by the reactor angular mappings were measured. For example, the fluxes were measured as a function of the distance directly below the reactor, which was at a fixed altitude. Also, several foil exposures were made to determine the thermal-neutron fluxes on the ASTR shield surface.

The shielded crew compartment and cylindrical crew compartment used in the Nuclear Test Airplane (NTA) are now being mounted on a support truss in preparation for the third phase of the experiment, which is to provide measurements from which the aircraft structure effects can be determined.

Tower Shielding Reactor II (TSR-II)

The critical mass of the TSR-II has been set at 8.1 kg of $U^{235}$. Since the fuel element development work was based on a loading of 8 kg of $U^{235}$, no further development will be necessary. Fabrication of the enriched elements has been under way since the middle of April.

Final assembly of the hydraulic flow test unit, which will be used to study the flow pattern through the various cooling channels, is nearing completion. Considerable difficulty was encountered in attaching manometer

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tubes to the closely spaced flow channels and in mounting the fuel elements with the manometer leads in the test assembly. A second test unit, the water flow test unit, which will be used to observe the action of the control mechanism under full control conditions, has been completely assembled and will be installed in Building 3253. Piping for this test is under way and will be completed as soon as the holdup tank arrives.

A full-scale control mechanism which will operate at reduced pressure was completed. This unit will be subjected to a life test following some preliminary tests.

The drawing of the cubicle which will house the reactor controls was also completed, and fabrication will be started in May. The elementary diagram of the control circuit is completed, and work on wiring diagrams may now be started. The compensated ionization chambers and fission chambers required for reactor control have been obtained. The safety chambers are being fabricated by the ORNL Instrument Department. Bids have been received on the recorders for the control circuits, and bids are out on the fission break monitor for the water system.

Lid Tank Shielding Facility (LTSF)

The investigation of the production of capture gamma radiation in stainless steel was concluded with tests in which all oil gaps between the solid components in the shield were eliminated. A study of capture gamma rays produced in lead is now in progress; the results of these tests will be analyzed by NDA.

Metallurgy - Yttrium Studies

An yttrium rod was cold-swaged various amounts to between 14.75 and 57.11% reduction in area and samples from each reduction were annealed in vacuum for 1 hr at a series of temperatures from 850 to 900°C. Metallographic examination of as-swaged and annealed specimens is now under way.

Studies were initiated to determine the compatibility of yttrium with various metals and alloys which are of interest as cladding materials or as crucibles for yttrium preparation. The first tests were run on iron. A Globe iron tube was cold-swaged around an yttrium rod and samples of this assembly were heated in vacuum for 1/2 hr at temperatures of 850, 875, 900, 925, 950, and 975°C. There was evidence of incipient melting at the iron-yttrium interface at 900°C and at the higher temperatures a phase melted out of the iron tube.

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A bar of yttrium, made up of six finger castings Heliarc-welded together, was melted by the high-vacuum, electron-beam technique at Teneseal Metallurgical Corporation. Chemical and metallographic evaluation of the metal is presently under way.

An attempt to melt an yttrium-magnesium alloy directly by the electron-beam method was not successful. The magnesium came out of the alloy violently as it was heated and caused the alloy ingot to swing back and forth in the furnace; thus focusing of the electrons was not possible. The magnesium also deposited on the tungsten filament electron source and caused it to short circuit.

Metallurgy - Ceramics

The Brush Beryllium Company has discontinued the manufacture of the "Luckey S.P." grade BeO which has been used almost exclusively in this laboratory for BeO development work. It was, therefore, necessary to establish fabrication characteristics of a new material representative of future supplies, and a shipment of the new material, G.C. grade BeO, which is derived from the sulphate and calcined at 1100°C, was obtained.

Specimens of the new material with and without 5.22 wt % $ZrB_2$ added were hot-pressed at temperatures of 1550, 1650, and 1750°C under a pressure of 2000 psi for 15 min. This grade of BeO was found to be much more reactive than the Luckey S.P. grade in that noticeable compaction began at approximately 250 to 300°C lower (about 1250°C). The densities of pure BeO obtained at the temperatures noted were 92, 95, and 98% of theoretical, respectively. Densities obtained for the BeO-$ZrB_2$ mixture were approximately the same for all the temperatures given, being 96.7, 96.4, 96.4%, respectively. Thus $ZrB_2$ appears to be somewhat effective as a densifier. Above 1750°C, a rather vigorous reaction occurred between this mixture and the graphite die, as evidenced by outgassing; the die was attacked and the piece became stuck to the die walls and punch faces and was severely cracked.

Two blocks, 3 x 3 x 1 in., of the BeO-$ZrB_2$ mixture were fabricated with a density of 95% for modulus of rupture and compressive creep determinations by GE-ANPD. Upon machining the billets for test specimens, it was noted that a dark area appeared in the center in the form of an ellipse. This phenomenon was not noted in smaller specimens (1 1/4 in. dia) and is believed to be due to a temperature variation incurred in fabricating a larger specimen according to the same temperature-time schedule. Further work is planned to determine the cause of the dark area.

Attempts were made to fabricate three large blocks of the BeO-$ZrB_2$ mixture (2 x 4 1/2 x 9 in.) for irradiation testing by cold-pressing and sintering; 5 wt % MgO was added for densification. These blocks

were fabricated in a conventional brick die under a pressure of 10,000 psi, with 10% water added as a binder. One block was badly laminated; the others appeared to be good but proved to be defective upon firing.

Long-term oxidation testing was completed on the $BeO-ZrB_2$ mixture hot-pressed to 95% density and fired in air at 1300°C. After 638 hr the specimen had gained only 0.2 wt %. A sample of this specimen, as-tested, is now being analyzed for boron content.

Investigations to determine the effects of additives to cold-pressed G.C. grade BeO bodies are still in progress. Right cylinder shapes of BeO with MgO, $Fe_2O_3$, or $B_4C$ added were fired at six different temperatures (1650 to 1900°C in increments of 50 deg). The furnace consisted of an induction-heated graphite tube with a positive flow-through of helium. In each case, a fast firing schedule of approximately 2 hr was used. From density measurements and visual examinations being made on the fired shapes, the different compositions are being screened to determine which is the most promising for incorporation into a body suitable for fabrication by extrusion.

Specimens with 1 wt % $Fe_2O_3$ or with 1 wt % $Fe_2O_3$ plus 1 wt % $B_4C$ were discarded because of excessive distortion and lamination. Incomplete evaluations of the fired bodies indicate that the MgO additive (5 wt %) acts as a densifier, but at about 1700°C it begins to volatilize rapidly and causes distortion of the shape. If, however, 1 wt % $B_4C$ is added to the BeO-MgO mixture, the body can be fired to 1900°C with little or no distortion.

Metallurgy - Brazing Alloy Development

Ten-gram buttons of the following brazing alloys were prepared for testing in lithium:

| | |
|---|---|
| 84% Zr-16% Fe | 70% Zr-30% V |
| 75% Zr-25% Cb | 65% Zr-25% V-10% Fe |
| 80% Co-20% Cb | 65% Zr-25% V-10% Ge |
| 82% Zr-18% Cr | 75% Zr-15% Cu-10% Fe |
| 69% Zr-31% Mo | 95% Zr-5% Be |
| 45% Zr-55% Ti | |

Vacuum-brazing procedures are being developed for use with alloys such as the zirconium-iron eutectic alloy, which melts at 1715°F. Excellent flow has been obtained on molybdenum T-joints.

PROGRAM 4700 - REACTOR DEVELOPMENT (Continued)

Advanced Design

An analysis of cross-coupling instability in systems in which two or more turboblowers or compressors are operated in parallel was extended to cover the case of turbojet engines coupled in a single heat source. It was shown that a system of parallel units will be less stable than indicated by performance of the individual units. The difference in stability will be greater for closely coupled units, i.e., where the resistance between individual compressors and the point of cross connection is small. With turbojet engines, cross-coupling is most likely to result in instability in the intermediate speed range when accelerating.

The use of the heat of dissociation of a gas as an approach to the problem of heat removal from reactors was explored. Several gases have the property of dissociating at temperatures and pressures in the range of interest for aircraft reactors. The process is endothermic, and the quantities of heat involved in some cases are two or three times the sensible heat capacity. Aluminum chloride, for instance, would have an effective heat capacity of 0.5 to 0.6 Btu/lb·°F in the temperature range from 1000 to 1500°F. Such a heat transfer medium would have the advantages of light weight, noninflammability, probably no mass transfer, and lower secondary activity. In addition, a variable-density cooling medium would permit the power level to be varied with minimum temperature cycling in the reactor. A study has been initiated to determine the potential of nuclear power plants of this type for application to manned aircraft.

Edited by A. W. Savolainen

Approved by Alvin M. Weinberg, Director

C-85 Reactors - Aircraft
Nuclear Propulsion Systems

ORNL-2526

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