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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

PROGRAM 4700

JUNE 1958

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C-85 Reactors - Aircraft
Nuclear Propulsion Systems

ORNL-2564

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OAK RIDGE NATIONAL LABORATORY
SPECIAL PROGRESS REPORT
PROGRAM 4700

June 1958

Date Issued: JUL 7 1958

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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

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OAK RIDGE NATIONAL LABORATORY
SPECIAL PROGRESS REPORT

June 1958

PROGRAM 4700 - REACTOR DEVELOPMENT

AIRCRAFT NUCLEAR PROPULSION PROJECT (AEC Activity 4701)

Lid Tank Shielding Facility (LTSF) Experiments

An investigation of the secondary radiation produced in lead is in progress with gamma-ray dose rates being measured in oil beyond lead thicknesses varying from 1 to 7 1/2 in. The lead is kept dry in all cases. Thermal-neutron flux and the fast-neutron dose rate measurements are also being made beyond some of the configurations.

In another experiment at the LTSF the attenuation of neutrons and gamma rays through a mockup of one face of the Bulk Shielding Facility (BSF) reactor is being determined. The BSF reactor fuel plates are mocked up by 2S aluminum sheets with a metal-to-water ratio similar to that of the BSF reactor.

Tower Shielding Facility (TSF) Experiments

The measurements at the Nuclear Test Airplane (NTA) detector stations were completed in the Aircraft Shield Test Reactor (ASTR) experiment. These measurements included dose rates and thermal-neutron flux determinations in and around the crew compartment and crew shield mockup used in the NTA for several reactor shield configurations of plain or borated water.

Similar measurements were made in the TSF compartmentalized crew compartment as a function of the thickness of plain- or borated-water side shielding of the crew compartment. Several reactor shield configurations of plain or borated water were used for these measurements also. Gamma-ray spectral measurements are now being made in the crew shield mockup and compartmentalized crew compartment for several reactor shield configurations. In addition, preliminary measurements which will lead toward the determination of fast-neutron spectra for these configurations were started with the use of an LiI spectrometer.

Tower Shielding Reactor-II (TSR-II) Development and Fabrication

The test unit for studying hydraulic flow in the TSR-II was completely assembled and pressure tested. The flow-metering devices were calibrated, and a rough estimate of flow distribution in the dummy annular fuel element

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PROGRAM 4700 - REACTOR DEVELOPMENT (Continued)

region was obtained by bubble injection. With the reactor core turned 90 deg from the vertical, the water flow in the outer fuel plates was very low, and there was some evidence of back flow in the annulus between the fuel plates and the lead region. An accurate determination of the actual flow conditions is presently being made with manometers. The overall pressure drop through the core region was 9 psig, which was lower than was expected at a flow rate of 1000 gpm.

In annealing fuel plates fabricated from a new shipment of aluminum, blister formation that caused a 50% rejection of the plates was found to occur as a result of trapped gas. The rejection rate was greatly reduced by using extra care during preheating to eliminate some of the trapped gas.

Minor changes were made in the control mechanism that reduced the wear of the positioning device. The scram time was increased from 90 to 150 msec as a result of the changes, but the increased figure is acceptable. The mechanism, which has operated about 500 times without apparent wear, must operate about 5000 times before it will be considered acceptable. The electrohydraulic transducer which regulates the pressure in the control mechanism according to the signal it receives from a magnet amplifier is being tested along with the control mechanism. The transducer, which was designed and built at ORNL, operates satisfactorily but has not undergone a complete life test.

The 5-Mw cooling system and demineralizer for the TSR-II is about 80% complete, and it is expected that the contractor will be finished early in September. Two items that the Laboratory was to furnish to the contractor, the Trane air cooler and the aluminum holdup tanks, were delivered. The aluminum tanks were damaged in transit but have been repaired in ORNL shops. The items which may delay the contractor are the three-way control valves and flow-metering devices for the 6- and 2-in. lines; these items are being purchased by the Laboratory. The 6-in. rubber hose that will carry water to and from the reactor was received, and the 6-in. swivel connections were ordered. These items are not to be installed by the contractor.

Design work was completed on the ionization chamber support in the central cylinder, and fabrication was started. The reactor support bearing was designed, and requests for bids were sent out. The coaxial swivel joint for the cooling water lines was designed and will be fabricated in the ORNL shops. Brooks & Perkins, Inc., were awarded a contract to provide the spherical boral shells for the reactor. The delivery time for this material, which will be in small segments, will be about 45 days.

Columbium Fabrication

In the study of the brittleness of cast columbium at room temperature, an investigation of the effect of heat-treatment temperature on the properties of notched-bend samples was initiated. Preliminary results indicate that measurement of the ductility in terms of an integrated plot of load vs deflection gives values in energy absorbed that are reproducible to within 2 to 10%. Samples heat-treated at temperature intervals of 50°C from 700 to 1000°C were prepared for testing.

A shipment of drawn columbium tubing was received from Superior Tube Company that included about 40 ft of 0.440-in.-ID, 0.030-in.-wall columbium clad with 0.060 in. of type 446 stainless steel and about 24 ft of 0.500-in.-ID, 0.030-in.-wall unclad columbium. Analyses showed that the as-received columbium tubing had an average of 0.01% C, 0.026% N_2, 0.043% O_2, and 0.0005% H_2. Corrosion testing loops are being constructed with this material.

Six copper-plated columbium billets were received from Wah Chang Corporation. Four billets will be machined for extrusion into tube blanks, one will be extruded as a rod, and one will be saved for future work.

Three extrusions of bare billets that had been heated to 1500°F for 30 min in a muffle furnace with a helium atmosphere were attempted. Two of the billets stalled the press; one extruded, but it was in very poor shape. It is believed that the surfaces of the billets were contaminated either by impurities in the helium or because of insufficient flow of the helium in the furnace. It is probably reasonable to assume that negligible contamination resulted from the transferring of the billet from the furnace to the press container. The billets will be copper-plated for all future extrusions.

Construction work continued on the high-temperature vacuum-annealing furnace described previously. It was erroneously reported that the furnace would operate at temperatures up to 1900°C. The maximum temperature will be 1400°C.

Studies of the purification of columbium by vacuum annealing are being made. Samples were annealed at temperatures ranging from 1400 to 2000°C for 30 min and are now being analyzed. The analysis of one specimen that was heated almost to the melting point for approximately 1 min by resistance heating is compared with the analysis of as-received wire in the following tabulation:

Impurities Analyzed for	Quantity Found (ppm) In As-Received Wire	Quantity Found (ppm) In Wire Heated to ~2400°C in Vacuum
Carbon	290	160
Oxygen	390	61
Hydrogen	7	14
Nitrogen	50	33

As may be seen, there was definite purification of the metal. Longer times at temperature may improve the purification, and it may be possible to use much lower temperatures.

Columbium and Molybdenum Welding and Brazing

High-melting alloys are being investigated for potential use as brazing alloys for joining columbium or molybdenum for service in lithium. The melting and flow characteristics of several zirconium-base alloys were investigated in a vacuum furnace at temperatures up to 1200°C, the temperature limit of the evacuated quartz muffle. A Mullite muffle with a pyrex cooling zone is being fabricated for higher temperature studies.

Brazing alloy buttons of the following composition were corrosion tested in lithium at 1500 and 1700°F for 500 hr: 84% Zr-16% Fe, 75% Zr-25% Cb, 75% Zr-15% Cb-10% Fe, 69% Zr-31% Mo, and 80% Co-20% Cb. Only the cobalt-base alloy showed corrosion attack under these conditions.

A large dry box in which molybdenum- and stainless-steel-clad columbium thermal-convection loops can be welded in an argon atmosphere was completed. A sample of a 1-in.-dia sched-40 molybdenum saddle joint was prepared. Specimens of joints prepared from sheet metal are being machined into bend specimens.

Corrosion Studies

Beryllium specimens were exposed to static lithium in several tests under various conditions in order to check results obtained in previous tests. Specimens held in iron capsules for 400 hr in contact with lithium at 1830°F in the previous tests had been attacked intergranularly to a depth of 127 mils and weight losses had been high. In the recent tests under the same conditions, there was extensive dissimilar metal mass transfer of beryllium from the specimen to the capsule wall. However, beryllium specimens tested in beryllium capsules showed very little intergranular attack to a depth of 2 to 3 mils and no weight losses at either 1500°F or at 1830°F in 100-hr tests. It thus appears that beryllium has good resistance to attack by lithium in a static system.

Mechanical Properties Evaluations

Investigations of the problem of thermal fatigue in reactor materials were continued. Tests were made to determine the effect of strain cycling at 1500°F on the microstructure and strength properties of Inconel rod. In one test series, specimens were cycled at approximately 1% plastic strain per cycle for a selected number of cycles, water-quenched, and examined metallographically. Specimen 1, which had been quenched from 1500°F without strain cycling, had the highest hardness, DPH 170 and 164 in the longitudinal and cross sections of the rod, respectively. The microstructure revealed heavy carbide precipitation that was concentrated in stringers running along the length of the rod specimen. Specimen 2, which was strain cycled 30 times, had the lowest hardness, DPH 153 and 145. No microstructural changes were evident. The hardness values for specimens 3 and 4, strained for 120 and 396 cycles, respectively, showed no significant difference, even though specimen 4 prematurely failed at 396 cycles. Specimen 5 ruptured after 1319 cycles, as expected from strain cycling data. Slight modifications in the microstructure could be detected although the hardness had not changed. A slightly greater degree of carbide precipitation was evident.

A second series of tests was conducted to see whether the creep strength would be altered by prior strain cycling. In these tests, the specimens were cycled for a predetermined number of cycles and then creep-tested at 7000 psi and 1500°F. The first 500 cycles of strain appeared to weaken the material. The creep rates increased slightly and the rupture life decreased. The elongation at rupture dropped from 45 to 7.5%. Unexpectedly, however, 660 and 700 strain cycles resulted in either no damage or a recovery of the material to its initial strength. The creep rates remained nearly the same as for the case of no prior strain cycles. No change in rupture life or elongation at rupture was observed. This extraordinary difference in behavior with only a relatively small change in the number of cycles from 500 to 660 is difficult to understand. From strain cycling data, it is known that Inconel weakens under these same strain conditions during the first few cycles but then seems to maintain a constant strength over the remainder of the test. It was expected, therefore, that the creep strength would show a decrease after the first few cycles and then maintain almost a constant level over a certain cycle interval (from ~400 to 1000 cycles for this series) before weakening was again observed.

Fabrication of Boron-Containing BeO Bodies

In cooperation with GE-ANPD, fabrication studies are being made of dense beryllium oxide for use as a neutron reflector material, and the possibility of adding boron as a secondary-gamma-ray suppressor is being investigated. It was determined that boron (1 wt %) in the form of ZrB_2, when incorporated in BeO, was chemically and thermally stable in air for 638 hr at 1300°C. Attempts to fabricate hot-pressed thermal-conductivity specimens 1 x 1 x 6 in. were successful after lowering the pressing

temperature from 1650 to 1500°C and employing a slower heating schedule to reduce thermal stresses.

Fabrication studies of a beryllium oxide body containing 5 wt % MgO and 1 wt % B_4C were continued. Right-cylinder shapes approximately 1 3/8 in. in diameter and 1 in. in height were cold-pressed in steel dies and sintered in an oxidizing atmosphere to 1500°C. Similar samples of 100% BeO were fabricated and heated at the same time for density comparisons. Density values for the shapes containing the additives were in the range 2.67 to 2.75 g/cm^3, and density values for the 100% BeO shapes were 2.02 to 2.04 g/cm^3. Specimens in the shape of bars ~5 x 1 1/4 x 3/4 in. were fabricated in the same manner as that employed for the slugs and will be sent to GE for additional physical testing.

Bearing and Seal Tests

The centrifugal pump rotary assembly that is being operated under gamma irradiation in the MTR canal continued to function satisfactorily throughout the month. The region of the lower seal and journal bearing had accumulated a gamma dosage of 6×10^9 r as of June 23. The corresponding estimated accumulated dosage to the bulk oil is 1.3×10^8 r.

A bellows-mounted seal installed in a centrifugal pump has accumulated 5900 hr of operation with NaK at 1200°F, a shaft speed of 2500 rpm, and a flow rate of 1200 gpm. The lower seal oil leakage has averaged 2 cm^3 per week, and the upper seal oil leakage has averaged 3 cm^3 per week.

Development of Forced-Circulation Loop for Corrosion Tests of Lithium-Columbium Systems

Minor changes were made in the design of the forced-circulation loop for studying the corrosion of columbium by lithium to permit construction of a stainless steel-sodium prototype loop. A cold trap was added to the prototype loop for removing oxides from the circulating sodium stream. A framework suitable for supporting the loop assembly was moved into place in the hooded test area. Experimental pumps were ordered, one from Allis-Chalmers and one from Findlay Science Engineering Co., which employ rotating magnets for circulating liquid metal.

Thermal Stability of Thin Metal Shells

Routine thermal cycling of a welded thin-shell model continued. The test piece had been subjected to a total of 527 thermal cycles as of June 24, and it was decided to continue the test until the shell model or some major component of the test stand fails. The shell will then be removed and inspected dimensionally and metallurgically.

Heat Transfer Studies

Pulse pump thermal-cycling tests were continued in a study of the effect of thermal-stress cycling on structural materials. Two tests were run at a frequency of 0.1 cps to obtain data for comparison with data being obtained in bulk thermal-cycling experiments at the University of Alabama and in strain cycling experiments of the ORNL Metallurgy Division (see above). The specimens for the two tests were identical heavy-walled Inconel sections (0.5-in.-ID x 1.5-in.-OD) to assure maximum surface thermal stress. The operating conditions were such as to generate a thermal cycle of approximately ±140°F at the inside wall at a mean temperature of 1410°F. In order to investigate the time history of crack propagation, one test was run for a total of 200 hr (72,000 cycles) and the other was terminated after 75 hr (27,000 cycles). The section tested for 200 hr was badly cracked throughout, with one crack 209 mils deep and many at least 100 mils deep. There was one crack as deep as 103 mils in the specimen tested 75 hr, but most of the cracks observed were under 23 mils deep.

Yttrium Production

A commercial source of the MgF_2 required in the production of yttrium metal was found. The material appears to meet the specifications and is available at a reasonable price. Large-scale equipment capable of converting Y_2O_3 to YF_3 was prepared for operation, and the installation of pilot-scale equipment for the manufacture of yttrium metal is nearly complete. If a sufficient supply of Y_2O_3 is available by mid-July, it appears that production operations can begin by mid-August.

Edited by A. W. Savolainen

Approved by Alvin M. Weinberg, Director

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Nuclear Propulsion Systems

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