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AEC RESEARCH AND DEVELOPMENT REPORT
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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

PROGRAM 4700

OCTOBER 1958

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C-85 Reactors - Aircraft
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OAK RIDGE NATIONAL LABORATORY
STATUS AND PROGRESS REPORT
PROGRAM 4700

October 1958

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Oak Ridge, Tennessee
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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

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OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

October 1958

This monthly report covers those AEC activities which fall under program 4700, categories C-84 and C-85, classified SECRET. Some of the topics are reported every month, but the majority are reported bimonthly.

PROGRAM 4700 - REACTOR DEVELOPMENT

AIRCRAFT NUCLEAR PROPULSION PROJECT

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

The fuel elements of the TSR-II were moved to the Critical Experiments Facility for the first critical experiment, which will be conducted with a water-reflected fuel annulus. The assembly was modified so that the control mechanism support assembly will not be needed in the critical experiment.

Heat transfer calculations showed that the 1000-gpm flow rate would be adequate for cooling the annular fuel elements if transitional flow which is produced in the rectangular channels is stable. The measurements for determining the friction factor versus the Reynolds number indicated that there was no sharp break in the curve in the transition region, and therefore the transitional flow region is stable.

An experiment has been set up for determining the types of screens which will properly disperse the flow from the helical tubes in the central region. The test stand contains three helical tubes with a mount for various screens 1/4 in. below the tubes. A pitot tube will be used to determine whether the velocity distribution 1/4 in. below the screens is uniform. The pitot tube assembly for measuring the flow ratio between the fuel plates in the central fuel elements has been fabricated by an outside vendor and shipped to ORNL.

The last piece of equipment needed for the heat removal system, that is, the main circulatory pump, was delivered to the contractor. Completion of the acceptance tests of the whole system is expected by the middle of November.

The relays are being mounted in the control cubicle at the TSF site. The wiring diagrams are being drawn and should be ready by the time the relays have been installed. The batteries for standby power for the circulating pump are being set up in the new building so that they may be charged and put on the line before they are damaged by cold weather.

The 1/4-in.-thick aluminum hemispherical shells for the lead-boral region are to be shipped from Superior Products on November 14. Phoenix Products has promised delivery of the 3/4-in.-thick aluminum hemispherical shells for the pressure vessel by the end of October. As insurance, another hemisphere has been ordered from Church Spinning Co. of Milwaukee. They use a reverse spinning technique and have promised delivery by the end of October.

Designs of the shim-safety grids and the control grid were completed. The grids will be fabricated from rolled Inconel-clad cadmium.

The lower section of the central cylinder to which the fuel elements are to be mounted was found to be out of tolerance. A new cylinder was formed out of 5052-0 aluminum, and test results indicate that it is satisfactory. The cylinder originally fabricated can be used for the critical experiments, but the closer tolerance will be required for full-flow conditions.

Tower Shielding Facility (TSF)

The mapping of radiation around the GE reactor shield was completed. Fast-neutron dose-rate, gamma-ray dose-rate, and thermal-neutron flux measurements were obtained for reactor-detector separation distances of 33, 59, and 100 ft at an altitude of 177 ft. The Convair reactor rotator and truss systems were used to rotate the reactor and shield, and thus continuous measurements could be made in the horizontal midplane at all three separation distances from 0 to 360 deg. Additional measurements were obtained in horizontal planes both above and below the reactor system. Gamma-ray spectral measurements are now in progress, the first having been obtained in the GE crew shield as a function of the crew shield water thickness. A 200-channel analyzer is being used to obtain these data.

Bulk Shielding Facility (BSF)

Recent measurements in the GE-ANP heating experiment with laminated shield mockups have included calorimetric measurements in the beryllium-iron--lithium hydride configuration for various thicknesses of water between the reactor face and the wall of the tank holding the shield. New heating samples were used for this series of measurements. Fast-neutron dosimetric and gamma-ray ionization measurements were also made in one instrument well as a check on previous results.

In the experiment to investigate the spectrum of prompt gamma rays from U^{235} fission, work has for some time been centered on the measurement of spectrometer efficiency as a function of energy. The work is performed with radioactive sources whose disintegration rates are normally determined with the aid of a high-pressure ionization chamber. A Na^{24} source was calibrated by absolute coincidence-counting techniques with an estimated uncertainty of 1%. Results derived from ion chamber measurements were within 1% of the absolute results for this single case; these data substantiate the ion chamber calibration techniques. A steady-state source of 7.4-sec N^{16} was similarly absolutely calibrated within about 5% to permit an efficiency determination with the 6.1-Mev gamma rays from this decay. Considerably more work of this type will be necessary to evaluate properly the spectrometer efficiency.

Lid Tank Shielding Facility (LTSF)

The study of secondary gamma-ray production in lead is being continued. Gamma-ray dose-rate, thermal-neutron flux, and fast-neutron dose rate measurements were made beyond 4.5- to 9-in. thicknesses of lead preceded by 4 in. of beryllium or 12 in. of lithium hydride or by 4 in. of beryllium and 12 in. of lithium hydride. Thermal-neutron flux and gamma-ray dose-rate measurements were also made beyond configurations in which the lead was preceded by 4 in. of beryllium and 12 in. of lithium hydride and followed by 12 in. of lithium hydride. Configurations in which the lead was preceded by 4 in. of beryllium and followed by 24 in. of lithium hydride were also tested. The solid components of the configuration were kept dry in all cases, and the measurements were made in oil contained in an aluminum tank behind the configurations.

Oxidation Studies of Columbium

Two additional tests were run in which columbium was exposed to oxygen at a pressure of 1.4×10^{-4} mm Hg at 1000°C. The results of these tests show that the reaction rate is linear with respect to time. The reaction apparently occurs wholly by diffusion of oxygen into the metal, since the only physical evidence of a reaction is the weight gained by the metal. Calculations based on the experimental results obtained thus far indicate that columbium and oxygen will not react if the O_2 pressure is 3×10^{-5} mm Hg at 850°C or $\sim 1 \times 10^{-5}$ mm Hg at 1000°C.

Metallographic specimens for the identification of oxides in columbium were prepared. Specimens containing 0.124 to 0.447% O_2 were prepared by exposing them to oxygen at 850°C, homogeneizing for 3 hr at 1200°C, and aging for 336 hr at 500°C to precipitate the oxides.

The accuracy of the vacuum-fusion method for the analysis of O_2 in columbium was tested by analyzing specimens that had been exposed to low-pressure purified O_2 at 850°C and then comparing the results with the

theoretical oxygen content calculated from the weight gain. If it is assumed that the theoretical values are correct, the analytical values are about 25% high.

Columbium Tubing Evaluation

The 0.620-in.-OD, 0.090-in.-wall, type 446 stainless steel-clad columbium tubing, which was previously inspected by nondestructive techniques, was evaluated metallographically. The tube sections examined were those in which discontinuities had been detected by the pulse-echo ultrasonic technique. Cracks and folds in the inner layer of columbium were observed. Therefore, it may be assumed that despite the lack of a metallurgical bond, some of the ultrasound was transmitted through the unbonded interface into the columbium layer. Such transmission is, however, very dependent on the spacing between the layers. Consequently the confidence level for the ultrasonic inspection of the inner layer is low.

Corrosion Tests of Columbium-Lithium Systems

A comprehensive effort has been initiated to determine the effect of various amounts of oxygen and nitrogen in columbium on its corrosion resistance to lithium. Oxygen and nitrogen were added by treating arc-cast, annealed columbium sheet at high temperatures in either oxygen or nitrogen at very low partial pressures (1 μ or less). The contaminated specimens were then given the following treatments: (1) homogeneized (heated) for 2.5 hr at 1832°F, (2) homogeneized and aged at 1000°F for 338 hr, or (3) homogeneized and welded in "pure" argon. The 25 specimens prepared as indicated were then tested in a single columbium container filled with lithium at 1500°F for 100 hr. The weight-loss data obtained indicate that oxygen, in particular, has an effect on the corrosion of columbium by lithium. Extensive hardness data, phase identifications (with the use of both optical metallography and electron microscopy), and depth-of-attack measurements will be obtained on these specimens. A determination will be made of the extent to which oxygen is gettered from the columbium by the lithium.

Yttrium Zone-Refining Studies

An attempt was made to grow a single crystal of yttrium by the zone-refining method described previously. The specimen used was about 1/2 in. in diameter and 8 in. long. The zone-refining apparatus was evacuated thoroughly and sealed off under vacuum, whereas in previous experiments a partial atmosphere of argon was used. The zone travel rate used was about 2.5 mm/min. During the first pass a heavy deposit was formed on the sides of the apparatus, and it was necessary to clean the apparatus before another pass could be made. Visual inspection of the specimen

at this time showed several large grains, one of which was approximately 1 in. long and 1/2 in. wide. Preliminary x-ray examination of the deposit on the sides of the apparatus showed primarily yttrium, yttrium oxide, and yttrium oxyfluoride. During the second pass of the sample, a heavy deposit again formed on the sides of the apparatus; however, the second deposit was quite different from the first. Whereas the first deposit was quite dull, the second was bright and metallic in appearance. Visual inspection showed a few medium-sized grains at the beginning and the end of the specimen with a single crystal about 3 1/2 to 4 in. long in between. Etching of the specimen did not reveal additional grains in the area of interest.

Yttrium Preparation Experiments

Three additional reduction experiments were conducted in the new yttrium-preparation facility. In these runs efforts were made to prepare yttrium-magnesium alloy rather than yttrium metal, as in the first run. The first of these three runs proceeded satisfactorily to the point where the slag was poured away from the alloy. The alloy-slag mixture was not cooled sufficiently for complete solidification of the alloy, and therefore some alloy poured with the slag and froze on the spout. This obstruction later prevented successful pouring of the alloy. When the furnace was opened, the tantalum crucible was found to be severely embrittled.

In the next run, a titanium crucible was used. The separation of slag and alloy was somewhat more successful, but only about one-third the theoretical yield of alloy was recovered in the cast ingot. Another third was found imbedded as approximately spherical particles in the slag. The balance was either not reduced from the fluoride charge or was in the high-melting layer formed on top of the reactant mixture and was not poured either with the slag or the alloy. The alloy particles imbedded in the slag were bright and clean and were relatively easily separated from the slag by crushing the mixture in a jaw crusher, but some slag remained adhered to the particles. An attempt will be made to vacuum distill these particles and to allow the remaining slag to drip off and separate from the sponge.

The third run was also made in a titanium crucible, but no provision was made for pouring the alloy. The alloy-slag mixture was allowed to solidify into separate layers in the crucible, and these were later cracked out with hammer and chisel. The 14 lb of alloy produced in this run is being vacuum distilled.

High-Temperature Mechanical Testing of Refractory Alloys

Considerable difficulty was encountered in obtaining accurate strain measurements in the tests of refractory alloys at very high temperatures. Tests are now being conducted on Hastelloy B at 1800°F in conventional testing equipment and in the new apparatus to check the reliability of the strain-sensing techniques being used. Severe oxidation of the molybdenum pull-rods in one test as a result of outgassing of the metal and ceramic parts emphasized the extreme care required for adequate environment control. Creep tests of extruded and annealed columbium rod are in progress at 1800°F in argon.

Welding Investigations

An electron-beam welder built at ORNL was operated successfully in the welding laboratory. Beads were run on thin sheets of columbium, molybdenum, and type 430 stainless steel. Presently, the filament of the electron gun is being redesigned in an attempt to avoid the use of projection bulb filaments, which are quite fragile. Preliminary steps are also being taken to build a much larger, more flexible, and higher powered unit.

Three 100-g ingots of an 85% Zr-15% Cb alloy were arc melted and are being swaged into welding wire at the request of Pratt & Whitney Aircraft.

Brazing Alloy Development

Additional zirconium and titanium-base binary and ternary alloys were evaluated in the high-temperature brazing alloy development program. On the basis of flow and joint integrity observed in T-joint tests on columbium, molybdenum, zirconium, and titanium, the following alloys are the most promising at this time: 95% Zr-5% Be, 48% Zr-48% Ti-4% Be, 63% Ti-27% Fe-10% V, 68% Ti-28% V-4% Be, and possibly 80% Zr-15% Fe-5% Be.

An apparatus for mechanical tests of brazed joints was designed in which butt-brazed joints will be tested in torsion at elevated temperatures. Assembly of the equipment is presently under way.

Stress Analyses

Equations for calculating stresses, displacements, and rotations of cylindrical shells and tapered circular plates were formulated, and tables of numerical values for all the functions involved were prepared. Cylindrical shells can now be analyzed for any combination of axisymmetrical edge forces and displacements, in addition to axial loads and uniform pressure. The equations are applicable to shells where the behavior at one end is dependent upon the conditions at the other end, as well as to shells where the two ends behave independently.

The results of the tapered-plate studies can be used to examine a plate with or without a central hole. Like the cylindrical shell, the complete analysis of a plate with uniform pressure, a membrane force, and any combination of axisymmetrical edge loadings can be made.

Thermal Stress Cycling Experiments

One additional test was completed in the study of surface thermal-stress cycling of Inconel with the use of a pulse-pump apparatus. Test 13 was operated under experimental conditions identical to those of test 12 except for the test duration; namely, cyclic frequency 1.0 cps; flow rate, 3.7 gpm; and temperature fluctuation amplitude, ±289°F. The run duration was somewhat in excess of 200 hr or 770,000 cycles. The inner surface temperature amplitude was estimated to be ±76°F on the basis of the measured outer surface temperature. The test piece was machined from a solid rod to include an upper section of 0.147-in. wall thickness and a lower section of 0.091-in. wall thickness with a constant inside diameter of 0.485 in. The strains at the inner fibers were calculated to be 0.058 and 0.048% per one-fourth cycle for the two regions, respectively. Metallographic examination of test piece 12 (360,000 cycles exposure) revealed no evidence of cracking, but similar examination of test piece 13 showed heavy damage. As previously noted, the depth of cracking diminished in the direction of flow, ranging from a maximum of 0.006 in. at the inlet end of the upper heavy-walled region to 0.0015 in. near the outlet end of the lower thin-walled portion. A marked increase in the number of cracks was observed in the stressed region of the transition between the upper and lower sections.

Pump Bearing and Seal Tests

The gamma irradiation test in the MTR canal of a pump bearing housing with a rotating shaft supported by one hydrodynamic journal bearing and one ball bearing lubricated with circulating Gulfcrest 34 oil and retained by rotating face seals was terminated on October 16, 1958. The lower journal bearing, seal, and leakage catch basin region had been subjected to an estimated gamma dose of 10^{10} r. The bulk of the circulating oil had received an estimated 2×10^{8} r gamma dosage. The test apparatus will be disassembled and inspected at MTR and then returned to ORNL.

A centrifugal pump with oil-lubricated bellows-mounted shaft seal has operated for more than 8800 hr with NaK at 1200°F, a shaft speed of 2500 rpm, and a flow rate of 1200 gpm. Operation continues to be satisfactory.

Edited by A. W. Savolainen

Approved by Alvin M. Weinberg, Director

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ORNL-2637

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