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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

PROGRAM 4700

MAY, 1958

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C-85 Reactors - Aircraft
Nuclear Propulsion Systems

ORNL-2547

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OAK RIDGE NATIONAL LABORATORY
SPECIAL PROGRESS REPORT
PROGRAM 4700

May 1958

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SPECIAL PROGRESS REPORT

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OAK RIDGE NATIONAL LABORATORY
SPECIAL PROGRESS REPORT

May 1958

PROGRAM 4700 - REACTOR DEVELOPMENT

AIRCRAFT NUCLEAR PROPULSION PROJECT (AEC Activity 4701)

Shielding Theory

A Monte Carlo code was prepared which incorporates special Monte Carlo techniques for trying to obtain reasonable estimates of the depth of penetration in an infinite medium of gamma rays emitted from a point monoenergetic source. The code is presently being tried out on the IBM 704 computer.

Calculations of gamma rays produced by inelastic scattering of neutrons in air indicated that for unit shields and thinly divided shields the dose rate from the inelastic gamma rays may be neglected when compared with the dose rate resulting from the neutrons which produced the gamma rays. The inelastic gamma-ray dose rate, however, attenuates in water with a relaxation length of about 39 cm, while the fast-neutron dose rate attenuates with a relaxation length of about 10 cm; therefore, for very thick crew shields the inelastic gamma-ray dose contribution can become very important. For a fission spectrum of neutrons in air the ratio of the scattered neutron dose (rem) at an unshielded detector in air to the inelastic gamma-ray dose (r) is approximately 3000. For a spectrum typical of a fission spectrum filtered through 120 cm of water, this ratio is approximately 300.

Calculations are being made to determine dose rates produced in air around a lithium-cooled reactor of the Pratt & Whitney design from the bremsstrahlung gamma rays which are produced by the fast electrons emitted in the decay of Li^8 in the coolant pipes and heat exchangers of the lithium cooling system.

Tower Shielding Facility (TSF) Experiments

The first two phases of the Aircraft Shield Test Reactor (ASTR) experiments at the TSF have been completed (see ORNL reports 2507 and 2526), and the third phase of the experiments was started. Measurements have been made in the cylindrical crew-shield mockup used in the Nuclear Test Airplane (NTA) as a function of the variable rubber side shielding, and the measurements to be made in and around shielded compartment occupied by the crew of the NTA are under way. The instruments (fast- and thermal-neutron and gamma-ray detectors) and the shielded compartment

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are mounted in positions corresponding to those used in the NTA so that the relative effects of the air, ground, and aircraft structure can be determined.

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

Fabrication of the fuel plates for the 8.1-kg highly enriched core of the TSR-II was 25% completed. A successful method for attaching the manometer tubes to the hydraulic flow test unit was established, and the unit should be ready for operation within a week. The power per fuel channel and the peak-to-average power per fuel channel were established from the nuclear calculations so that the proper flow distribution can be determined as soon as the first flow tests are completed.

The water flow test unit which will be used to observe the control mechanism under full flow conditions was completely installed and is ready for testing. The control mechanism is undergoing further design changes to reduce the wear in the positioning drive. The scram action was found to be satisfactory.

Bids were received on the aluminum shells from which the reactor tank and the lead reflector region will be fabricated. These items will be made in ORNL shops.

Columbium Welding and Fabrication

Experiments were continued in an effort to develop welding materials and techniques with which to produce joints in columbium systems that will resist corrosion by lithium metal at high temperatures (1500°F and above). A dry box equipped with a motor-driven carriage to permit automatic welding was used for test welding 0.040-in.-thick arc-cast columbium sheet (1) by fusion (no filler metal added), (2) by using columbium filler metal, (3) by using an 85% Zr-15% Cb alloy as the filler metal, and (4) by using an 80% Zr-15% Cb-5% Mo alloy as the filler metal. The samples prepared in these tests are being examined metallographically and will be subjected to room-temperature guided bend tests in order to evaluate their ductility.

A series of tests was also made to study the effect of the various welding environments on the subsequent corrosion resistance of the joint and the base metal. Joints made with both the 85% Zr-15% Cb alloy filler metal and the fusion techniques were tested for 100 hr in static lithium at 1500°F. Three specimens of each type of weld were tested that had each been prepared in a different environment. The specimen prepared with zirconium-columbium alloy filler metal in air with inert-gas (argon) shielding was completely penetrated by lithium in the heat-affected zone.

A similar specimen prepared in an inert atmosphere with partially contaminated argon (400 ppm N_2 + CO and 1600 ppm O_2) as the atmosphere was slightly attacked in the heat-affected zone. The third specimen, which was prepared in the inert-atmosphere chamber with high-purity argon (67 ppm N_2 + CO and 3 ppm O_2) as the environment, was not attacked. The welding alloy was not attacked in any of the tests. The three specimens prepared by fusion welding in the three environments described above were all heavily attacked in both the weld and the heat-affected zones, but the severity of the attack decreased as the purity of the environment increased.

Five electron-beam-melted columbium billets were extruded and sent to Superior Tube Company for redrawing into tubing. The tubing will be drawn to 0.500-in. ID by 0.030-in. wall, and three of the five lengths will be clad with 0.060 in. of type 446 stainless steel. The over-all yield should be approximately 50 ft of tubing.

Before extrusion, the five billets were copper plated as a protection against contamination from residual impurities in the argon heating atmosphere and from oxidation while being transferred from the furnace to the extrusion container. The copper plate also acted as a lubricant during the extrusion process. The extrusion temperature was 1500°F.

Four additional columbium billets are now available for extruding in the bare condition. It is hoped that by using induction heating the heating time for the billets will be short enough that a negligible amount of contamination from the argon will result.

Work was started on the construction of a high-temperature vacuum furnace for annealing the extrusions before shipment for redrawing. This furnace will be able to accommodate billets up to 30 in. long and will operate at temperatures up to 1900°C. Provisions will be made for inserting and removing the extrusions from the hot zone. It is hoped that vacuums of the order of 1×10^{-4} to 1×10^{-5} mm Hg can be obtained at the annealing temperature.

Mechanical Properties Evaluations

Equipment is being developed for studying the mechanical properties of refractory metals and moderator materials at temperatures from 1800 to 2500°F in controlled gaseous environments. Accurate stress-strain curves were obtained in preliminary control tests with tensile testing apparatus designed for use at temperatures up to 2000°F. Molybdenum and columbium specimens tested at 2000°F were bright when removed from the apparatus, and ductile, cup-cone types of fracture were found. Minor modifications of the equipment are being made to decrease the time

required to reach the test temperature. Apparatus for tests at temperatures above 2000°F is being developed.

Radiation Damage Experiments

Stress-rupture tests of internally pressurized Inconel tubing were carried out at 1500°F in the MTR in an air environment. Rupture times for duplicate specimens of 95 hr at 5000 psi and 355 hr at 4000 psi were obtained. These rupture times are 1/5 and 2/5, respectively, of the rupture times in air in the absence of irradiation. A third set of specimens has not ruptured in 375 hr at 3000 psi, and the test is continuing. Earlier tests had indicated that a much greater reduction in time to rupture resulted from irradiation, but at least part of the reduction was attributed to changes in thermocouple calibration during operation of the apparatus in a helium atmosphere. The present experiment is being conducted in air to minimize deterioration of thermocouple wires.

Component Development and Testing

A design was prepared of a forced-circulation loop for studying the corrosion of columbium by lithium metal circulating at high temperatures in a system with a temperature gradient. In order to protect the columbium tubing from air oxidation, the auxiliary portions of the loop, that is, the fill and drain lines, the line to the lithium expansion tank, and the loop which includes the rotating-magnet pump, will be clad with type 446 stainless steel. The tubing that will be at high temperatures in the test section will be surrounded with static sodium which will transfer heat to or remove heat from the columbium tubing in the hot and cold legs of the loop. The cladding of the external portion of the columbium loop will be joined with the stainless steel expansion tank of the sodium system. An all-stainless-steel loop of this design is being constructed in which NaK will be circulated in order to obtain operating data with which to validate assumptions made in heat transfer and flow calculations.

The centrifugal pump rotary assembly that is being operated under gamma irradiation in the canal at the MTR has now received an accumulated gamma-ray dose of more than 5.1×10^9 r, that is, about one-half the planned dose. The equipment continues to operate satisfactorily, and no gross changes have been observed in the oil (Gulfcrest-34) which is used to lubricate the bearing and seal. Oil-lubricated pumps of this type are being tested for applicability to liquid-metal circulation in radiation fields.

One phase of the development and testing of shut-off valves for high-temperature service was completed. A valve was developed which is satisfactory for operation in NaK at temperatures up to 1300°F. Cermet

combinations which are known to be compatible with lithium were used as seat and plug materials. The valve will be satisfactory for lithium service if fabricated from columbium or another material that is compatible with lithium.

Yttrium Production and Lithium Purification

Equipment for the production of yttrium has been ordered and space is being readied for its installation. This facility, which will be operated jointly by the ORNL Metallurgy and Chemistry Divisions, will produce monthly about 200 lb of low-oxide-content yttrium. It is now believed that the equipment will be ready for operation early in July. The Chemistry Division will be responsible for the conversion of Y_2O_3 to YF_3 and preparation of a purified $LiF-MgF_2-YF_3$ (25-21.1-53.9 wt %) mixture. The Metallurgy Division will reduce this mixture to an yttrium-magnesium alloy and ultimately to massive yttrium metal.

The possibility of purifying lithium metal by extraction of oxide impurities with LiF-LiBr (12-88 mole %) was explored. Analyses showed that after three salt extractions a batch of lithium metal contained no oxides and less than 50 ppm of nitrides.

Edited by A. W. Savolainen

Approved by Alvin M. Weinberg, Director

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