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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

PROGRAM 4700

MARCH 1958

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PROGRAM 4700

March 1958

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SPECIAL PROGRESS REPORT

TABLE OF CONTENTS

	Page
PROGRAM 4700 - REACTOR DEVELOPMENT	4
AIRCRAFT NUCLEAR PROPULSION PROJECT	4
Shielding Theory	4
Tower Shielding Facility (TSF)	4
Tower Shielding Reactor-II (TSR-II)	4
Metallurgy - Niobium Inspection and Fabrication	5
Metallurgy - Yttrium Fabrication	6
Metallurgy - Lithium Purification	6
Chemistry	7
Radiation Damage	7
Experimental Engineering	8

Reports in this series issued during the past year:

March 1957	ORNL-2300
April 1957	ORNL-2317
May 1957	ORNL-2343
June 1957	ORNL-2356
July 1957	ORNL-2371
August 1957	ORNL-2394
September 1957	ORNL-2412
October 1957	ORNL-2427
November 1957	ORNL-2438
December 1957	ORNL-2459
January 1958	ORNL-2472
February 1958	ORNL-2488

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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

March 1958

PROGRAM 4700 - REACTOR DEVELOPMENT

AIRCRAFT NUCLEAR PROPULSION PROJECT (AEC Activity 4701)

Shielding Theory

Calculations were made of the spectra of air-capture gamma rays and gamma rays from inelastic neutron scattering in air to be expected at the detector position in the recent Tower Shielding Facility (TSF) measurements of secondary gamma-ray production in air. When these calculated spectra were transformed to represent spectrometer pulse-height distributions, the shapes of the resulting curves were in extremely good agreement with the shapes of the experimentally measured pulse-height distributions.

Tower Shielding Facility (TSF)

The first phase of the Aircraft Shield Test Reactor (ASTR) experiment at the TSF was substantially completed. One of the major objectives of this phase of the experiment was to obtain total fast-neutron and gamma-ray dose rates and thermal-neutron fluxes with the reactor-detector centerline 12.5 ft above ground level in order to make comparison with similar measurements taken at Fort Worth. The measurements were made at distances of 33, 59, and 100 ft from the reactor center as a function of reactor angular orientation for four reactor shield configurations. The magnitude of the perturbation caused by the pool was determined by taking measurements with the reactor-detector system at various distances from the pool. Measurements were also made with and without the cradle which supported the reactor in the Fort Worth ground level measurements in order to determine its effect. Mapping measurements, as a function of reactor angular orientation, were repeated at full altitude for the four reactor shield configurations. Measurements of the scattered radiation as a function of reactor angle and neutron spectral measurements are under way.

Tower Shielding Reactor-II (TSR-II)

A contract for installation of the water-cooling system of the TSR-II was awarded to Charles Hobson Company and ground was broken for the footings. ORNL is to furnish the contractor with an air-cooled heat exchanger, Trane Model 2GCG, and two aluminum tanks, one a 1500-gal

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water-detention tank and the other a 250-gal water-level-indicating tank. Both tanks are being fabricated by R. D. Cole Company of Newman, Georgia.

A test section of the lead-boral shield region was fabricated for gamma-ray heating tests. Ultrasonic tests of the lead-aluminum bonding indicated a 100% bond. The engineering drawings of the lead-boral hemisphere and the reactor tank were approved for construction. The first full-scale control mechanism was completed and successfully operated over 300 times. The operating pressures and the plate velocity during the scram condition agreed with calculations and previous tests. The design was modified to permit operation at a lower pressure and to provide more strength in the positioning and guiding assembly. Fabrication of the actual mechanism was started.

In order to ensure that the reactor design and fuel loading were on a firm basis, the multigroup calculations made with the use of the Cornwash code (eyewash code modified for use on the Oracle) were extended to ascertain how well the code could calculate previously operated spherical critical experiments. In addition, symmetrical slab-geometry experiments were set up at the Critical Experiments Facility with Bulk Shielding Facility fuel elements. The lead and boral shells of the TSR-II were mocked up in the experiments, and temperature coefficients of reactivity were measured. The measured temperature coefficient of reactivity was negative. The temperature coefficient calculated with the Cornwash code was also negative and agreement to within 1.5% in k was observed between the experiment and the Cornwash calculations. Cornwash calculations also confirmed the critical mass calculations made with the 3G3R Oracle code after errors in the Cornwash code were corrected.

Metallurgy - Niobium Inspection and Fabrication

Four 3-in.-dia, 4-in.-high niobium billets were inspected by the immersed ultrasonic technique. Each piece was inspected twice; once by transmitting the ultrasound parallel to the axis and once with the ultrasound beam transmitted diametrically. When the sound was transmitted axially, no discrete discontinuities were detected. However, a symmetrical variation in the ultrasonic attenuation was observed as the billets were scanned, with the lowest attenuation occurring in the center and increasing in all radial directions. Because of the variation in attenuation, the smallest detectable discontinuity was approximately 1/32 in. in diameter in the center and 1/8 in. in diameter, or greater, near the outer surface. Visual examinations of the surfaces of these billets revealed variations in grain size that may explain the variations in attenuation. The diametrical inspection revealed one small, discrete discontinuity in each of the billets. These discontinuities were estimated to be between 1/32 and 1/16 in. in diameter. Background noises in the billets indicated the presence of very small discontinuities, which may be pores.

PROGRAM 4700 - REACTOR DEVELOPMENT (Continued)

Efforts were made to fabricate niobium at room temperature because of its reactivity with gases at high temperatures. Metal prepared by the powder metallurgy process, in which relatively large quantities of oxides, nitrides, and carbides were present, was successfully fabricated, but arc-cast material, in which the level of the impurities was much lower, was brittle when fabricated at room temperature. It appeared therefore that the form in which the impurities were present in the metal was as important as the quantity present. The impurities are taken into solution in the melting step and, if they do not precipitate significantly during cooling, a subsequent, suitable heat treatment of the material should improve its fabricability. Thus heat treatment of the metal at temperatures above the solubility limit of the impurity should have no effect on the fabricability, whereas, at a lower temperature, precipitation should occur and result in a ductile metal because of overaging. In order to test this hypothesis, sections of an arc-cast ingot prepared by the electron-beam process were heat treated at 750, 850, and 1000°C for 24 hr. The lower temperatures were selected to cause precipitation, whereas, the higher temperature was selected to be above that at which the impurities would be retained in solution. Samples from the as-cast ingot and the sample annealed at 1000°C could not be cold-rolled; however, the other samples were cold-rolled to foil. On the basis of solubility data for gases in niobium, these heat treatments indicate that nitrogen causes the embrittlement.

Metallurgy - Yttrium Fabrication

A study of the recrystallization of yttrium castings prepared from sponge material was initiated, but attempts to correlate mechanical properties with the purity of melts were unsuccessful because of large differences in the grain sizes of the finger castings. Cold working by swaging to reductions of 25 to 40%, followed by annealing, has produced samples with fairly uniform, controlled grain size, and tensile tests of such specimens are to be made.

Metallurgy - Lithium Purification

Purification studies of lithium have involved low-temperature filtration, solubility determinations of lithium oxide and lithium nitride in lithium, vacuum distillation, and gettering tests. The results of these studies indicate that gettering of the impurities with active metals such as zirconium, titanium, calcium, and yttrium offers the most practical and efficient method of purification. Vacuum distillation without gettering has thus far failed to produce lithium with less than 100 ppm of nitrogen or oxygen. Gettering with titanium and zirconium has produced lithium of low-nitrogen content. In a recent experiment, 10.4 kg of heavily contaminated lithium (2250 ppm nitrogen) was gettered with 1.7 kg of titanium for 100 hr at 1400°F. The nitrogen content of the lithium

was reduced to 33 ppm by this treatment. The oxygen content of lithium has not been reduced to any appreciable extent by gettering with either zirconium or titanium, and other materials will be tried.

Chemistry

A simple experimental procedure for determining diffusion coefficients of chromium in nickel-based alloys was developed and tested. This procedure, in which a measurement is made of the rate of depletion of radiotracer CrF_2 from molten fluoride mixtures in contact with the alloy, appears to be readily adaptable to studies of niobium and molybdenum alloys.

Optimum processing conditions were established for conversion of 1- to 3-lb batches of Y_2O_3 and MgO or $Mg(OH)_2$ to fluorides. A 10-hr treatment at 1000°F with 134 liters/hour of anhydrous HF and gentle agitation of the powder is used. Optimum flow rates for larger scale equipment must be determined in the actual experiment.

The ease of hydrofluorination of solid Y_2O_3 was found to vary considerably from sample to sample. Of the preparations tested, "metallurgical-grade" Y_2O_3 from Ames Research Laboratory has consistently yielded a fluoride with the highest Y_2O_3 content. To date, however, the liquid phase hydrofluorination of the $LiF-MgF_2-YF_3$ mixture has produced satisfactory material for the reduction process regardless of the origin of the Y_2O_3 used.

Radiation Damage

Irradiation-induced changes in semiconductor diodes were studied in relation to the two principal barrier theories, that is, the Shockley diffusion theory and the charge recombination-generation theory. Experimental evidence was obtained that irradiation causes the predominate mechanism of rectification of germanium p-n junctions to change from diffusion to recombination-generation. This shift in the mechanism of rectification explains the difficulty heretofore encountered in explaining the radiation-induced changes.

Metallographic examination of an Inconel tube-burst specimen with a 20-mil wall that had been tested in the fused-salt mixture $NaF-ZrF_4-UF_4$ (62.5-12.5-25 mole %) in the LITR for 625 hr at 2000 psi and 1500°F showed that rupture occurred outside the gage length where the temperature may have exceeded 1500°F. No evidence of increased corrosion as a result of irradiation was found in the gage length where the temperature was monitored.

PROGRAM 4700 - REACTOR DEVELOPMENT (Continued)

The forced-circulation loop fabricated of Inconel which operated for 235 hr at a maximum temperature of 1600°F with a temperature differential of 230 to 250°F in a vertical position in the LITR was examined. The corrosion of the hot leg by the circulated fused-salt mixture $NaF-ZrF_4-UF_4$ (63-25-12 mole %) was the same as that which would be expected in the absence of radiation; that is, there was corrosion to a maximum depth of 4 mils. In the examination of this loop it was found that the salt could be removed from pieces of tubing of the loop by rapid induction heating without affecting metallographic observations or radiochemical analysis of the salt.

Experimental Engineering

Design work continued on equipment for lithium-niobium corrosion studies. A rotating-magnet pump which will induce a lithium flow of about 1 gpm inside the 1/2-in.-OD, 0.040-in.-wall niobium tubing is being produced.

The welded quarter-scale outer-core-shell model for the third core shell thermal stability test was completed and installed in the test housing. High-temperature thermal cycling of this core shell will be initiated after all dimensional data have been obtained.

Edited by A. W. Savolainen

Approved by Alvin M. Weinberg, Director