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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

PROGRAM 4700

OCTOBER 1957

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October 1957

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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

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OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

October 1957

PROGRAM 4700 - REACTOR DEVELOPMENT

AIRCRAFT NUCLEAR PROPULSION PROJECT (AEC Activity 4701)

In October, word was received from the Atomic Energy Commission that all work on the ART and ETU was to be terminated. As stated in the previous report, all construction and procurement had been suspended in September. Related studies and test programs are being brought to an orderly conclusion.

Considerable progress was made in terminating research and development activities associated with the molten fluoride type of reactor and in initiating support programs for direct-cycle and lithium-cooled reactors. As a consequence the report for the month of November will be prepared under a revised list of budget activities that reflect the program changes.

Aircraft Reactor Test (ART)

Summary statements and final reports on the applied mechanics and stress analysis of the ART are being prepared. A description of the calculational method used and a summary of the results obtained in the thermal and pressure analyses of shells V and VI were completed. A summary was also written of the results of the calculation of the fluid forces in the channel of the main heat exchanger. Memoranda were written that describe the analysis of the north head pressure stress distribution and present a general relaxation method for determining two-dimensional temperature distributions on an IBM-650. A report was completed on the temperature distribution in the reflector-moderator assembly.

Reactor Component Development and Testing

The second ART prototype NaK-to-air radiator failed during thermal cycling endurance tests on the 182nd cycle. Testing consisted of alternate operation at 1200°F (isothermal) and ART design-power NaK-temperature conditions (NaK in at 1500°F and out at 1070°F). The number of cycles endured by this radiator was six times the maximum number expected for the ART.

Testing of a semicircular 20-tube fuel-to-NaK heat exchanger designed to verify the stress analysis methods applied to reactor heat exchangers of low stress design was started October 9, 1957. A thermal cycling program is currently under way with the heat exchanger test conditions alternating between ART design power values, with a fuel inlet temperature of 1600°F, and isothermal operation at 1200°F. As of October 29, 114 thermal cycles had been completed.

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A guided-plug NaK valve was rebuilt to provide a seat design similar to that used in the fuel valve. The valve was counterbored and a Stellite-coated Inconel ring was brazed in place, ground, and lapped. Stellite was over-laid on the entire spherical poppet plug, rather than being placed only on the seating area. These changes appear to have eliminated the stress distortion of the seat area which previously caused leakage in high-temperature NaK tests. Initial tests show leakage rates of only 1 1/2 cm^3/hr at 1000°F with a 50-psi pressure differential across the seat and a 1300-lb seating force.

Metallurgy - Metallographic Examinations of Tested Components

A metallographic examination is being made of a Black, Sivalls & Bryson (No. 3) NaK-to-fuel test heat exchanger that operated a total of 1131 hr at 1200°F and above. The heat exchanger, which was removed from the test system because of a furnace failure, experienced 168 temperature cycles and operated 253 hr with a temperature differential imposed. The maximum operating temperature was 1700°F. The maximum fuel side corrosion was found in the hot header area and was to a depth of 16 mils. The maximum NaK side corrosion was in the same area and was to a depth of 2 mils. No intergranular voids were found that extended completely through the tube wall. The maximum mass transfer deposit was found in the mid-section of the tube bundle and was 12 mils thick. Weld specimens showed a maximum penetration of 10 mils, since the welds had favorable orientation of the grains.

The similar fuel-to-NaK heat exchanger (Black, Sivalls & Bryson unit No. 2) operated in the same system is also being examined. This heat exchanger had operated 2122 hr at 1200°F and above, had experienced 173 thermal cycles, and had operated 800 hr with a temperature differential imposed. The maximum operating temperature was 1600°F. Only the hot header samples have been examined. The maximum fuel-side corrosion found was 12 mils in depth, and the maximum NaK-side corrosion was 2 mils deep.

Metallurgy - Corrosion

A report that MgO is penetrated by lithium but otherwise not attacked by it brought about the testing of samples from single crystals of MgO in lithium in an effort to find a material to be used in lithium service for valves, bearings, container materials, or other structural components. Three samples from single crystals of MgO that were exposed to lithium for 100 hr at a temperature of 1500°F were, however, attacked.

The specimen tested in an iron container was attacked most severely where the specimen was in contact with the iron. A similar specimen in a molybdenum container was attacked most severely where it did not touch the container. In a test of a specimen in a dense, sintered MgO crucible in an attempt to avoid any contact of the specimen with metal, the crucible was severely attacked (spalled and broken) and the specimen of MgO from

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a single crystal stuck to the bottom of the crucible in such a way that measurements could not be taken. The single crystal was attacked but not so severely as were the specimens tested in metal containers. The attack on the crucible probably acted as a limiting influence.

The attack in all three tests appeared to be a function of the area of the MgO single crystal exposed to the lithium. The MgO losses were 1.00 and 0.99 g/in.^{2}, respectively, for the specimens tested in the iron and molybdenum containers.

Metallurgy - Welding and Brazing

Investigations of the weldability of niobium by the inert-arc-fusion process were started. Welds fabricated by Fansteel Metallurgical Corporation and welds fabricated at ORNL by using conventional techniques were examined metallographically, and the only difference found was in the grain sizes of the two welds. Welding investigations of arc-cast and powder-metallurgy niobium in an inert atmosphere dry box are being planned to determine differences in weldability of the two materials. Studies are also being made of joint designs applicable to fusion welding techniques on thin-walled niobium tubing.

Metallurgy - Ceramics

A highly sinterable BeO powder was obtained by calcining $BeSO_4$ at 950°C; the sintered powder had a surface area of 20 to 25 m^2/g. A theoretical density of 96% was obtained by hot pressing at 1525°C, which is 400°C lower than the temperature required to densify commercial grades to the same extent. This material was densified to 91 and 92% respectively, at 1325 and 1425°C.

Two zirconium metal samples to be used in cladding development work were treated in the hydriding furnace. The finished pieces were approximately 1 1/4 in. in diameter by 3 in. in length and contained 1.15 and 1.16 wt % hydrogen. A new hydriding technique is being tried on a series of zirconium metal samples contained within closed nickel capsules that will eliminate the necessity of taking precautions against exposing the samples to the air during loading and unloading of the furnace retort.

In cooperation with the American Lava Corporation (Chattanooga) attempts are being made to produce ceramic bodies of MgO and BeO for use in thermocouples and level indicators. An extrusion process has been developed.

Metallurgy - Mechanical Properties

The strain-cycling properties of Inconel at 1500°F are still being investigated with regard to the effect of cycling frequency. A series of tests was completed on coarse-grained material tested in a fused salt

($NaF-ZrF_4-UF_4$, 50-46-4 mole %) at a rate of 30 min/cycle. Results of these tests were compared with those of 2 min/cycle tests.

As with fine-grained material, there was a marked difference in the time to failure, the number of cycles to failure, and the total plastic strain absorbed prior to failure between the 2 and 30 min/cycle data. Again, the difference was most pronounced at low strains per cycle. Comparison of the data for the coarse-grained material with data for fine-grained material revealed that, although the coarse-grained material was somewhat inferior to the fine-grained Inconel, the magnitude of the grain-size effect was much less than that of the frequency effect.

Several tests were conducted to determine the effect of boron penetration on the strain absorption capacity of Inconel at 1500°F. The data obtained, in comparison with similar data for Inconel not exposed to boron-containing brazing material, show clearly that any boron which may penetrate Inconel during brazing, annealing, welding, and strain-cycling operations does not seriously affect the strain-cycling properties.

Metallurgy - Nondestructive Testing

Correlation of eddy-current measurements of cladding thicknesses on clad tubing with corresponding metallographic measurements was attempted. The results were inconclusive, since the metallographic measurements were made in only one transverse section cut on a diameter of the circular area covered by the probe coil; it is doubtful that the sample was adequate. An added factor that complicates the correlation is that the field of the coil is neither uniform nor symmetrical around its axis.

Attempts are being made to fabricate smaller coils with uniform fields, at a minimum sacrifice of sensitivity, and to obtain more complete and representative sampling for metallographic measurements. Since the inductance of a coil decreases rapidly as a function of its size, sensitivity inherently decreases. Small coils are also difficult to fabricate, so an optimum coil size will be determined.

Studies of an x-ray sensitive closed-circuit television system showed that the selenium receptor was essentially insensitive to radiation energies in the 1-Mev range. A cobalt source in an aluminum capsule was viewed successfully with a 300-kv x-ray source. The cobalt source delivers more than 300 r/hr to the receptor with an energy of about 1.2 Mev, and the x-ray sources deliver about 40 r/hr with an energy of about 0.2 Mev. The dose ratio at the receptor is about 10:1, but the high energy radiation is totally ignored.

Chemical Research

A process being studied for the preparation of high purity yttrium metal utilizes lithium metal reduction of a $LiF-MgF_2-YF_3$ mixture. The YF_3 used in the mixture is prepared by hydrofluorination at about 600°C

of Y_2O_3; the LiF and the MgF_2 used in initial studies were commercial preparations. The $26.00/lb cost of MgF_2 is so high, however, that attempts have been made to prepare MgF_2 from inexpensive and readily available material. Hydrofluorination of $MgCl_2 \cdot 6H_2O$ proceeds smoothly and completely at 1000°F; the MgF_2 produced is satisfactory, but evolution of large amounts of H_2O and HCl poses serious corrosion problems. Hydrofluorination of chemically pure MgO at 1000°F and at 1400°F has produced MgF_2 containing less than 5% MgO. This purity may prove to be adequate for preparation of the mixture for reduction; it is likely that the purity can be improved by longer hydrofluorination times.

Tower Shielding Facility (TSF)

The experiment for determining the relative importance of inelastic scattering and air capture of fast neutrons in nitrogen is still in progress. It was found to be necessary to increase the thermal-neutron flux from the reactor in order to increase the counting rate for the 10.8-Mev nitrogen capture gamma ray. This was done by removing the 2-in.-thick B_4C plug from the reactor collimator. The performance of the detector collimator for the condition in which the collimated beam from the reactor is perpendicular to the detector collimator was improved by extending the 4-ft-thick east wall of the collimator to a height of 10 ft and a distance of 7 ft beyond the slit.

Shield Design

One of the major problems in aircraft shield design is the calculation of the contribution to the dose rate of secondary gamma rays which are produced by neutron capture in the N^{14} of the air. In an attempt to determine this contribution, the Monte Carlo air-scattering code, with which the slowing down and diffusion of neutrons in air can be calculated, was modified to include a statistical estimate of the capture gamma-ray dose rate at a detector located a specific distance away from either a line beam or a point isotropic monoenergetic neutron source in air. For this calculation the capture cross section in nitrogen was taken to have a 1/v dependence.

Tower Shielding Reactor-II (TSR-II)

Specifications for the cooling system were written and are ready to be sent to prospective bidders. The design was completed for a hydraulic test stand to study control plate stability under full flow conditions. A second flow-study apparatus is being assembled for measuring the water flow in the annular fuel elements.

A new control mechanism test assembly is being constructed which will permit 3 in. of travel of a control plate. This mechanism will be tested in the Bulk Shielding Facility reactor.

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An analysis of the additional loading placed on the towers by the water lines and additional control cables was completed and is ready for review by the original architect. Some time was devoted to studying methods of suspending reactor shields which would permit a collimator to sweep a vertical arc as well as a horizontal arc.

Edited by A. W. Savolainen

Approved by Alvin M. Weinberg, Director

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