[redacted]

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0361319 6

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION

ORNL-2707
C-85 - Reactors-Aircraft Nuclear Propulsion Systems

Cy. 56A

# OAK RIDGE NATIONAL LABORATORY

## STATUS AND PROGRESS REPORT

## PROGRAM 4700

## FEBRUARY 1959

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this document, send in name with document and the library will arrange a loan.

[redacted]

**OAK RIDGE NATIONAL LABORATORY**
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

DECLASSIFIED
CLASSIFICATION CHANGED TO:
BY AUTHORITY OF: GEC 5-6-70
BY: E. Goldberg 12-8-70

[redacted]

[redacted]

[redacted]

C-85 Reactors—Aircraft
Nuclear Propulsion Systems

ORNL-2707

This document consists of 11 pages.
Copy 56 of 58, Series A.

Contract No. W-7405-eng-26

# OAK RIDGE NATIONAL LABORATORY
# STATUS AND PROGRESS REPORT
# PROGRAM 4700

February 1959

Date Issued: MAR 5 1959

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0361319 6

[redacted]

[redacted]



OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

TABLE OF CONTENTS


| | Page |
|---|---|
| PROGRAM 4700 - REACTOR DEVELOPMENT | 3 |
| AIRCRAFT NUCLEAR PROPULSION PROJECT | 3 |
| Tower Shielding Reactor II (TSR-II) Development and Fabrication | 3 |
| Bulk Shielding Facility (BSF) | 4 |
| Lid Tank Shielding Facility (LTSF) | 4 |
| Shielding Theory | 4 |
| Radiation Effects in Electronic Components | 5 |
| Analytical Chemistry Studies | 5 |
| Basic Problems in Elasticity | 6 |
| Advanced Design Studies | 6 |
| Heat Transfer and Physical Properties | 6 |
| Studies of Columbium-Base Alloys | 7 |
| Welding of Columbium | 7 |
| Mechanical Properties of Columbium-Base Alloys | 7 |
| Refractory Metal Brazing Alloys | 8 |
| Corrosion Tests of Vanadium in Lithium | 8 |
| Rhenium Fabrication | 8 |
| Chemical Studies | 8 |
| Beryllium Oxide Investigations | 9 |
| Development of Pump Seals | 9 |


Reports in this series issued during the past year:

| | |
|---|---|
| February 1958 | ORNL-2488 |
| March 1958 | ORNL-2507 |
| April 1958 | ORNL-2526 |
| May 1958 | ORNL-2547 |
| June 1958 | ORNL-2564 |
| July 1958 | ORNL-2580 |
| August 1958 | ORNL-2596 |
| September 1958 | ORNL-2624 |
| October 1958 | ORNL-2637 |
| November 1958 | ORNL-2646 |
| December 1958 | ORNL-2665 |
| January 1959 | ORNL-2692 |

[redacted]

[redacted]



OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

February 1959

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

Plexiglas impregnated with $B_4C$ was used as the neutron absorber in recent control and safety experiments with the water-reflected TSR-II fuel elements. With such an assembly, a negative change in reactivity occurred when Styrofoam was introduced into the water in the internal reflector region to simulate air voids. In all experiments in which cadmium had been used as the neutron absorber, a positive change in reactivity had been observed when Styrofoam displaced water.

On the basis of these experiments, the control mechanism is being modified to incorporate $B_4C$ rather than cadmium. The control devices will operate inside a 17-in.-dia aluminum sphere filled with aluminum and water which will occupy the major portion of the internal water reflector region. When the amount of excess reactivity required for operation is determined in the final critical experiments, adjustments in the reactivity will be made by inserting $B_4C$-loaded aluminum plugs into the sphere. The $B_4C$-loaded plugs can be removed to compensate for burnup. The size of the sphere was chosen so that the displacing water outside the sphere or around the control plates inside the sphere would produce only small negative changes in reactivity.

The cooling water for the fuel elements will flow outside the 17-in.-dia sphere. Preliminary flow experiments indicate that the pressure drop around the sphere and through the lower central fuel elements will be only about 2 psi.

Studies have continued on the distribution of flow in the second pass region of the TSR-II. It has been found to be possible to obtain the minimum required flow in all channels by locating multilayered 120

[redacted]

mesh screens in the channel entrances. An alternate approach of using a partially perforated baffle at the exit end of the channels also appears to be successful in providing the necessary flows.

Machining of the upper lead-boral shield sections has been completed, and the lower lead-boral hemisphere is being machined. Final machining of the outer surface of the reactor tank is under way.

Bulk Shielding Facility (BSF)

The repeat measurements requested in the GE-ANP heating experiment at the BSF have been completed, and all results have been forwarded to GE for analysis.

During the accumulation of data to determine the spectrum of prompt gamma rays associated with the thermal fission of $U^{235}$, gamma rays from several radioisotopes were used as energy standards. Because the energies of some of these gamma rays were not known well enough to allow an optimum analysis of the experimental data, scintillation spectroscopy methods have been used recently to calibrate against well-known sources. The results show that the gamma rays given off by three of the isotopes have the following energies: $Y^{88}$, 1.837 ± 0.002 Mev and 0.899 ± 0.002 Mev; $Zn^{65}$, 1.114 ± 0.003 Mev; and $Mn^{54}$, 0.835 ± 0.002 Mev.

Lid Tank Shielding Facility (LTSF)

In the experiment to determine the depression of thermal-neutron fluxes in water by gold foils, a series of very thin foils was exposed. Preliminary analyses of the data indicate that the correction factor for 0.002-in.-thick foils is 1.35 ± 0.20. Calculated values vary from 1.08 to 1.30.

Radiation measurements have been made in water beyond 1-in. and 3-in. thicknesses of iron spaced at various distances from the source plate. In addition, gold-foil measurements were made in all configurations between the source plate and the iron at about 1/2-in. intervals. These data will be compared with similar British data.

Shielding Theory

Predictions of the thermal-neutron fluxes to be expected near the Bulk Shielding Reactor (BSR) were made on the basis of Lid Tank Shielding Facility experimental data suitably transformed to the BSR geometry. The predicted fluxes were consistently higher than the measured fluxes; for example, they were higher by a factor of 2.73 at a distance of 40 cm and a factor of 1.54 at a distance of 115 cm. These discrepancies are of the same order of magnitude as those found in earlier calculations

(Reactor Sci. Tech. 2, No. 2, p 73, 1952) that compared the fast-neutron dose rates, but they are in the opposite direction.

In conjunction with the LTSF program, the Cornpone reactor code is being used for calculations of centerline neutron fluxes in shielding configurations. Calculated and measured dose-rate curves for plain water agree both in shape and in absolute magnitude to within experimental error for distances as large as 70 cm from the source plate. For a borated water medium, however, the calculations indicate that the thermal-neutron flux in the region close to the source is much more suppressed than was shown by the measurements. The flux is being remeasured by foil techniques, and preliminary results indicate that the true curve shape is in much better agreement with the calculated curve shape than was previously indicated. It appears, however, that the absolute value of the calculated curve may be slightly low.

## Radiation Effects in Electronic Components

A single-crystal, grown-junction, silicon diode has been irradiated in hole 51N of the ORNL Graphite Reactor, and the current, $I_o$, has been measured as a function of temperature. The current has become a diffusion type of current, with an activation energy that approaches one-half the band gap as exposure progresses. The sample has now received additional reactor exposure, but the measurement of the current as a function of temperature must await availability of the cryostat.

An experiment for determining the change in dielectric constant produced by reactor-induced disorder in regions of a solid dielectric has been performed with germanium as the dielectric. A change in dielectric constant was observed, but, because of the low d-c resistance of the dielectric, precision measurements were not feasible. Germanium has been obtained that has low-lying levels produced by gold doping, and it is expected that this material will permit more quantitative measurements.

A study of irradiation effects on the thermoelectric power of germanium has been initiated. The experimental arrangement has been set up and checked.

## Analytical Chemistry Studies

The neocuproine (2,9-dimethyl-1,10-phenanthroline) colorimetric method for the determination of copper in yttrium was evaluated and found to be satisfactory. The neocuproine reagent is essentially specific for copper.

## Basic Problems in Elasticity

The elastic behavior of a cylindrical shell subjected to a thermal loading has been studied and a method of analysis has been developed. The analytical method provides (1) for analysis of a cylindrical shell subjected to a temperature variation in the axial direction or to a linear temperature variation through the thickness and (2) for application of the analytical results to stress analyses of reactors.

## Advanced Design Studies

A preliminary design analysis has been completed on nine different working fluids that seemed to show promise for use in nuclear power plants for satellite applications. The results of the study indicate that rubidium should give the lightest system. The study includes the effects of power output on component size and weight, the effects of shielding requirements on shield weight, and a fairly comprehensive preliminary design of a rubidium-vapor-cycle plant intented to produce 20 kw of electric power.

Experimental studies are being conducted for determining the feasibility of a vortex propulsion reactor concept which combines the principles of gaseous fission heating and separation of the fissionable material. The applicability of this concept depends largely on the nature and strength of the vortex field which can be generated at mass flow rates permitted by a binary diffusion process. The radial distribution of the concentration of a heavy tracer gas in a 2-in.-dia vortex tube with helium as the supply gas was measured by means of a 0.008-in.-dia sample probe inserted radially through the wall of the tube. The tracer gas was $C_8F_{16}$ (molecular weight, 400), and analyses were made by measuring the thermal conductivity of the mixture withdrawn from the tube. By operating with a large fraction of the inlet mass flow bled off axially at a distance of 0.4 in. from the tube center, it was possible to achieve sufficiently high velocities at an allowable exit mass flow rate for a concentration peak to be observed at a radial distance of 0.2 in.; there was a sharp decrease in concentration of the heavy gas nearer the center. A comparison of these results with the results of theoretical calculations for laminar flow indicates that the concentration peaks at a radius greater than would be expected. This is readily explained, however, by the existence of turbulence, which increases the effective "eddy" diffusivity of the light gas through the heavy gas and thus reduces the inward flow of the heavy gas.

## Heat Transfer and Physical Properties

Studies of vortex heat transfer were continued in four tests in which a twisted Inconel tape was used to generate swirl flow in copper tubes. Test section length-to-diameter ratios varied from 62 to 84, and

the tape twist varied from 2.2 to 2.9 tube diameters per twist. The low electrical resistance of the test sections resulted in excessive currents and overheating of the electrodes, and thus test-section thermal fluxes were limited to 2 to 6 x $10^6$ Btu/hr·ft$^2$.

A system was assembled and instrumented for obtaining heat-transfer coefficients for molten lithium. Also in connection with studies of molten lithium, an apparatus was assembled for determining thermal conductivity at temperatures up to 2000°F.

An apparatus is being assembled for measuring the thermal conductivity of columbium-zirconium alloys. An alloy sample has been received from Pratt & Whitney Aircraft and is being machined to fit the apparatus and to provide the required thermowells.

## Studies of Columbium-Base Alloys

Work has continued on the arc-melting of columbium-base alloys containing 0.5 to 5 wt % cerium, lathanum, or misch metal. The largest buttons which can be produced with the present facilities are 40 to 50 g. The rare-earth additions reduced the hardness of the alloys so that little difficulty was encountered in cold rolling the material to strip.

## Welding of Columbium

Butt welds have been made on 0.040-in.-thick columbium sheet material in air by the techniques of inert-gas-shielded tungsten-arc welding. Helium was used as the cover gas and backup gas and was found to be superior to argon as the cover gas. The weld surfaces were excellent, and the welds were ductile upon longitudinal and transverse bending. No increase in hardness was noted in the weld or heat-affected zones.

Trial welds of both the head-on-plate and square-butt types have also been made. The techniques of inert-gas-shielded consumable-metal-arc welding were used in the preparation of these welds. The welds were found to have high ductility, and there was good penetration of the weld metal.

## Mechanical Properties of Columbium-Base Alloys

Creep and tensile tests are continuing on columbium-base alloys at 1800°F in static argon. The tests indicate that one heat has a yield strength of approximately 16,500 psi based on a step-load curve. Another heat appears to have a yield strength of only 3,500 psi based on tensile tests. The latter heat has a much lower impurity level and will be used in an attempt to determine the influence of oxygen on creep strength by controlled contamination of the heat with oxygen.

## Refractory Metal Brazing Alloys

Seven titanium- and zirconium-base ternary alloys, containing iron and molybdenum, iron and vanadium, molybdenum and vanadium, or columbium and vanadium, have been tested in lithium at 1700°F for 500 hr in titanium capsules. All alloys containing iron exhibited cracks upon metallographic examination after testing and were even more brittle if they also contained molybdenum. Zirconium-base alloys containing chromium and vanadium and columbium and vanadium showed no attack and no cracks. Thirteen additional titanium-base and zirconium-base ternary alloys containing various combinations of iron, vanadium, beryllium, columbium, and molybdenum have been prepared and will be similarly tested.

## Corrosion Tests of Vanadium in Lithium

A seesaw-furnace test has been conducted on vanadium specimens in a vanadium capsule containing lithium. The hot-zone temperature used for the 100-hr test was 1500°F. A vanadium specimen held in the cold zone (900°F) showed no weight change or attack. The hot-zone specimen showed a weight loss of 1.5 mg/in.$^2$ despite the small pieces of lithium that adhered to it. Voids just below the surface (to approximately 0.5 mil deep) which had caused small surface blisters were observed metallographically in the hot-zone specimen. The lithium bath contained less than 25 ppm of vanadium after the test. A similar 500-hr test is currently under way.

## Rhenium Fabrication

An arc-melted button of rhenium has been rolled into strip after nine cycles of cold working followed by anneals of 1 hr at 1650 to 1675°C. The final hardness of the annealed strip was 280 DPH. The maximum hardness after cold working was 660 DPH.

## Chemical Studies

A phase diagram of the system LiF-$YF_3$ has been completed; the system contains a single eutectic at 19 mole % $YF_3$, m.p. 697°C. The single compound LiF·$YF_3$ which occurs in the system melts incongruently at 816°C to $YF_3$ and liquid. The liquidus boundary of the $YF_3$ primary phase field must be considered to be an approximation, since only a few compositions are completely molten below the 1000°C temperature which is the present limit of the quenching furnaces.

Apparatus for contacting molten lithium with a mixture of lithium halides in a closed system has been constructed and given preliminary testing. A 700-g charge of lithium was circulated at 250 cm$^3$/min for 25 min through a single batch of 1300 g of LiCl-LiF eutectic held at

600°C. During this extraction the molten salt developed alkalinity corresponding to the removal of 2300 ppm $O_2$ from the molten lithium. Completion of the experiment was interrupted by a plug in the flowmeter tube.

The efficiency of removal of specific impurities from beryllium by the process of fusing BeO with hydrated oxalic acid is under study. Substitution of Teflon or polypropylene containers for Pyrex containers in the fusion process reduced the concentration of silicon and of calcium in the resulting BeO from 110 to considerably less than 80 ppm and from 180 to 50 to 70 ppm, respectively. Material of this quality has been supplied for preparation of improved spectrographic standards for evaluation of future research preparations.

Beryllium Oxide Investigations

Five batches of beryllium oxalate prepared by the Reactor Chemistry Division have been converted to beryllium oxide for use in sintering studies.

Results obtained by varying the calcination temperatures of the oxalate from 600 to 900°C show that densities of cold-pressed and sintered BeO bodies decrease if the oxalate is calcined below 800°C. The oxide obtained by calcining at 600°C was very fine and could not be fabricated by cold-pressing and sintering.

Procedures for cold-forming and sintering have been standardized to comply with those used by GE and finished pieces having the densities ($\sim$ 94% theoretical) of the GE standards have been made with the ORNL oxide. Three batches of slightly greater purity oxalate have been prepared and are being converted to oxide for additional experiments.

An oxide, the density of which was not satisfactorily increased by sintering, has been cold-pressed and quenched from 900°C to liquid nitrogen temperature in an effort to induce lattice defects and thereby change its sintering characteristics. The treated material was ground and cold-pressed into samples for sintering experiments and density measurements and an x-ray diffraction analysis of the powder is being made.

Development of Pump Seals

A preliminary design of a precision dynamic seal tester has been completed. This equipment will permit an experimental study of the various parameters which affect the performance of a face seal. Studies of the effects of such variables as seal-plate separation, seal-land width, surface speed, lubricant viscosity, and surface tension on seal-leakage rates and on the torque required to drive the seal, should yield

data which will permit the extension of hydrodynamic and boundary lubrication bearing theories, or which, alternately, may lead to the development of new theories. The mechanisms which determine the temperature rise in various portions of a seal are poorly understood, and this equipment should also shed light on this subject.

[redacted]



C-85 Reactors – Aircraft
Nuclear Propulsion Systems

ORNL-2707

## DISTRIBUTION

### Oak Ridge Operations Office

1-10. Research and Development Division (Attn: H. M. Roth)
11. Technical Information Service Extension

### External

12. Atomic Energy Commission, Washington
13. Lockland Aircraft Reactor Operation Office
14. Hartford Area Office
15. Wright Air Development Center (Attn: Materials Laboratory, SCORTO)
16. Wright Air Development Center (Attn: Power Plant Laboratory, WCLPW)
17. General Electric Company (ANPD)
18. Pratt & Whitney Aircraft Division (CANEL)
19. ANP Project Office, Convair, Fort Worth
20. AFPR, Lockheed, Marietta
21. Los Alamos Scientific Laboratory
22. University of California Radiation Laboratory, Livermore

### Internal

23. D. S. Billington
24. E. P. Blizard
25. A. L. Boch
26. G. E. Boyd
27. C. E. Center
28. R. A. Charpie
29. E. E. Clifford
30. A. P. Fraas
31. J. H. Frye
32. B. L. Greenstreet
33. W. R. Grimes
34. E. Guth
35. T. Hikido
36. C. S. Harrill
37. H. W. Hoffman
38. G. W. Keilholtz
39. F. C. Maienschein
40. W. D. Manly
41. H. J. Metz
42. A. J. Miller
43. E. J. Murphy
44. G. J. Nessle
45. H. W. Savage
46. A. W. Savolainen
47. W. H Sullivan
48. J. A. Swartout
49. E. H. Taylor
50. A. M. Weinberg
51. J. C. White
52. C. E. Winters
53. W. Zobel
54-55. Laboratory Records
56-57. Central Research Library
58. ORNL Y-12 Technical Library
Document Reference Section

[redacted]