[redacted]

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0361199 1

file
CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION

ORNL-2412 22A
C-84 - Reactors-Special
Features of Aircraft Reactors

DECLASSIFIED
CLASSIFICATION CHANGED TO:
BY AUTHORITY OF: UCC 5.7.70
BY: C. Goldberg 12.8.70

OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

PROGRAM 4700

SEPTEMBER 1957

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.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
A Division of Union Carbide and Carbon Corporation
UCC
POST OFFICE BOX X · OAK RIDGE, TENNESSEE

[redacted]

[redacted]

[redacted]

C-84 - Reactors-Special Features
of Aircraft Reactors

ORNL-2412

This document consists of 10 pages.
Copy 22 of 68, Series A.

Contract No. W-7405-Eng-26

OAK RIDGE NATIONAL LABORATORY
SPECIAL PROGRESS REPORT
PROGRAM 4700

September 1957

Date Issued: OCT 4 - 1957

OAK RIDGE NATIONAL LABORATORY
Operated by
UNION CARBIDE NUCLEAR COMPANY
A Division of Union Carbide and Carbon Corporation
Post Office Box X
Oak Ridge, Tennessee

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0361199 1

[redacted]

[redacted]

[redacted]

C-84 - Reactors-Special Features of Aircraft Reactors

ORNL-2412

OAK RIDGE NATIONAL LABORATORY
SPECIAL PROGRESS REPORT
September 1957

DISTRIBUTION

Office of Directed Operations

1-10. H. M. Roth — Oak Ridge, Tennessee
11. Technical Information Service — Oak Ridge, Tennessee

AEC Installations

12. Classified Technical Library — Washington
13. N. E. Bradbury — Los Alamos Scientific Laboratory
14. C. E. Center — Union Carbide Nuclear Company
15. N. S. Hilberry — Argonne National Laboratory

External Distribution

16. Col. C. D. Gasser (WCSN)
17. Materials Laboratory (SMRTO)
18. Power Plant Laboratory, WADC (WCLPW)
19. Pratt & Whitney Aircraft Company

Oak Ridge National Laboratory

20. E. P. Blizard
21. C. J. Borkowski
22. W. F. Boudreau
23. G. E. Boyd
24. F. R. Bruce
25. A. D. Callihan
26. R. A. Charpie
27. C. E. Clifford
28. S. Cromer
29. F. L. Culler
30. D. E. Fergus
31. J. L. Fowle
32. A. P. Fraas
33. J. H. Frye, Jr.
34. W. R. Gri
35. E. Guth
36. M. R. Hi
37. H. W. H man
38. A. Hol nder
39. J. T. we
40. W. H. ordan
41. G. W eilholtz
42. C. Keim
43. M. Kelley
44. R. S. Livingston
45. H. G. MacPherson
46. F. C. Maienschein
47. E. R. Mann
48. W. D. Manly
49. R. P. Milford
50. K. Z. Morgan
51. E. J. Murphy
52. A. M. Perry
53. M. E. Ramsey
54. H. W. Savage
55. A. W. Savolainen
56. E. D. Shipley
57. H. Snell
58. H. Sullivan
59. A. Swartout
60. E. H. Taylor
61. D. B. Trauger
62. C. Walker
63. A. Weinberg
64. J. White
65. C. E. Winters
66. W. Zo el
67-68. Laboratory Records Dept.

[redacted]

[redacted]

OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

TABLE OF CONTENTS

	Page
PROGRAM 4700 - REACTOR DEVELOPMENT	4
AIRCRAFT NUCLEAR PROPULSION PROJECT	4
Aircraft Reactor Test (ART)	4
Reactor Component Development and Testing	5
Design Physics	5
Heat Transfer Research	6
Physical Properties Research	6
Metallurgy - Corrosion	6
Metallurgy - Welding and Brazing	7
Metallurgy - Fabrication	7
Metallurgy - Mechanical Properties	7
Metallurgy - Nondestructive Testing	8
Reactor Chemistry	8
Bulk Shielding Facility (BSF)	9
Tower Shielding Reactor-II (TSR-II)	9
Tower Shielding Facility (TSF)	10

Reports in this series issued during the past year:

September 1956	ORNL-2186
October 1956	ORNL-2206
November 1956	ORNL-2233
December 1956	ORNL-2249
January 1957	ORNL-2262
February 1957	ORNL-2282
March 1957	ORNL-2300
April 1957	ORNL-2317
May 1957	ORNL-2343
June 1957	ORNL-2356
July 1957	ORNL-2371
August 1957	ORNL-2394

[redacted]

[redacted]

OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

September 1957

PROGRAM 4700 - REACTOR DEVELOPMENT

AIRCRAFT NUCLEAR PROPULSION PROJECT (AEC Activity 4701)

Aircraft Reactor Test (ART)

Early in September it was announced by the AEC that work on the ART was to be suspended immediately. Since the ART program included the construction of the Engineering Test Unit (ETU), work on that project has also been stopped. Work orders for construction have been cancelled, including those assigned to outside vendors. Job status reports, material inventories, and cancellation cost estimates have been requested. The reactor assemblies, component parts, and materials on hand are being stored. Summary reports are being prepared on all phases of ART and ETU work.

All work on the ART and ETU facility design and construction was also stopped. The ART building and surrounding area are being placed in a standby condition. Radiator closures, louver closures, and unit heaters were installed in the diesel-generator house. A sheet metal cover is being fabricated for the stack. All materials not permanently installed are being arranged for adequate storage within the building. The basic materials for the heat dump model will be completed in order to assemble the major equipment items.

A report was completed on a stress analysis of the ART radiators. This work included the effects of and justification for final modifications which would assure a sound design.

The differential expansion and thermal stress analysis of the main heat exchanger was also completed, and a report was prepared. The results indicated that the heat exchanger would be satisfactory for a very much larger number of thermal cycles than that defined by the ART test program.

Reports on various phases of the ART design are being completed to provide a comprehensive record of the design work together with an evaluation of component test results.

Work under way on methods for disassembly of the ART included a demonstration of optical devices for making measurements through hot cell windows. An optical reference bar was tested in conjunction with a 24 x 36 in. accurately scribed aluminum grid plate. In a linear measurement of 34 in., the error was 0.033 in., which can possibly be attributed to differences in thermal expansion.

[redacted]

[redacted]

Reactor Component Development and Testing

A prototype reactor fuel pump completed 500 hr of operation with $NaF-ZrF_4-UF_4$ (50-46-4 mole %, fuel 30) as the circulated fluid at a flow rate of 645 gpm and a temperature of 1200°F; the liquid level was 3 in. above the expansion tank floor. Performance was satisfactory throughout the test period.

Tests of dual pump performance with water were completed in the aluminum mockup of the reactor north head. Acceptable performance was obtained for all anticipated reactor conditions.

The second ART prototype NaK-to-air radiator completed 162 of the proposed 300 thermal cycles alternating between design full power at 1500°F inlet and 1070°F outlet NaK temperature and 1200°F isothermal operation. In all facets, performance data have somewhat exceeded the design requirements, with the greater differences occurring for the higher power levels near the design point.

Design Physics

Work under way on shielding problems in and about the ART cell is being concluded. The shielding around the fill-and-drain tank was designed to produce a dose rate of 0.2 r/hr at the shield surface 9 days after shutdown following 100 hr of operation at 60 Mw. The main problem in shielding the tank arises from the numerous penetrations for pipes and instrumentation. For example, the dose rate just outside the tank shield opposite the NaK pipe penetrations would be 2×10^5 r/hr under the conditions specified above, if no special shielding were provided. A shielded offset geometry for the emergent NaK pipes was arrived at that adequately allowed for direct and scattered gamma rays.

In connection with the problem of replacing a fuel or sodium pump, a preliminary estimate was made of the dose rate at a point 62.5 in. above the reactor midplane and 22.5 in. from the axis, that is, about at the bottom of the fuel pump motor, under the same after-shutdown conditions as those specified above. The dose rate was found, for the present shielding geometry, to be around 800 r/hr, and the radiation was mostly from residual fuel in the heat exchangers viewed through the NaK pipe penetrations in the north head.

The problem of thermal-neutron utilization in a cylindrical cell arises frequently in reactor studies. A program has been written for the IBM 650 computer which treats this problem by numerical integration of the Boltzmann equation (S_n method). The present program allows three different concentric regions, 20 space points, and four intervals in each of the two angle variables describing the neutron trajectory. The program is presently being checked and should be available shortly for routine use.

[redacted]

[redacted]

Heat Transfer Research

A high-frequency pulse-pump thermal-cycling loop was successfully operated with the fuel mixture $NaF-ZrF_4-UF_4$ (56-39-5 mole %) as the fluid medium. The mean fluid temperature was in the range 1300 to 1350°F, and hot-to-cold-leg temperature differences of as much as 175°F were achieved. The first two runs each extended over about 72 hr of intermittent operation and were terminated to effect modifications of the liquid-level control system. After installation of a new Inconel test section, a third run completed the specified 100-hr test period with a pulse frequency of 1 cps and a fluid flow rate of 8 gpm. It is estimated that the inner surface temperature oscillation was between ±67 and ±95°F. This variation exists because of uncertainties in establishing the boundary condition at the outer surface in the equation describing the decay of the radial temperature wave. The metallurgical examination of the Inconel test section has not yet been completed; however, standard dye stain and radiographic examinations showed no superficial damage. A test scheduled for termination after 250 hr of operation is in progress at a cyclic frequency of 1 cps and temperatures comparable to those of the 100-hr run.

Physical Properties Research

The variable-gap thermal-conductivity apparatus, modified to include a large guard heating ring around the heat meter, was used to determine the thermal conductivity of the salt mixture $NaNO_2-NaNO_3-KNO_3$ (40-7-53 wt %). The results obtained show increased consistency both within runs and between runs. Over the temperature range of 450 to 700°F, the thermal conductivity of this nitrate-nitrite salt was found to vary from 0.33 to 0.35 Btu/hr·ft·°F.

The density of a sample of zirconium fluoride powder collected in a vapor trap was measured. Samples of thicknesses between 0.05 and 0.4 in. were used, and it was found that the density ranged from 0.55 and 0.8 g/cm^3 and varied inversely with the sample thickness. A measurement of the thermal conductivity of this material, which was made by using a "hot wire," gave a value of 0.45 Btu/hr·ft·°F.

Metallurgy - Corrosion

Three thermal-convection loops fabricated of unclad niobium and installed in a vacuum chamber were tested with lithium as the circulated fluid. One loop operated for 155 hr at a hot-leg temperature of 1550°F and a cold-leg temperature of 1100°F. This test was terminated by a leak in the hot-leg saddle weld. No attack or mass-transferred material was found, and a specimen suspended in the top of the hot leg showed no weight change.

Operation of the second loop was terminated after 22 1/2 hr by a leak in the cold-leg saddle weld. This loop, which operated at a hot-leg temperature of 1600°F and a cold-leg temperature of 1250°F, has not

[redacted]

[redacted]

yet been examined. The third loop had operated for 44 hr at a hot-leg temperature of 1600°F when the test was terminated because of a heater failure. Operation of this loop will be continued after new heating elements are installed.

Metallurgy - Welding and Brazing

Carburized Inconel tubes were welded into carburized Inconel headers, and metallographic examination of the welds revealed no adverse effects as a result of the presence of the carburized material. Similar joints were then heated to 1080°C for 1/2 hr to simulate a brazing cycle. No increase in grain size was evident as a result of this treatment, which would have caused extensive grain growth in standard Inconel. It is felt that carburization should be investigated further as a possible means of controlling grain size in Inconel tubing.

Metallurgy - Fabrication

Three 45- to 50-g finger castings of yttrium were arc-melted under an argon atmosphere. The first two castings were machined to a cylindrical shape and cold-swaged. One sample was inserted into a brass jacket and reduced approximately 30% in two passes. The second sample was cold-swaged bare to a 13% reduction in the first pass. A further reduction of 15% resulted in some surface cracks. Since considerable metal is lost in machining a roughly elliptical casting to a cylindrical shape, the third melt was sized by cold-swaging in the as-cast condition. Although there was a small amount of foldover of the rough surface, no cracks were found. A very light machining cut cleaned the surface, and metal recovery was improved greatly.

A further investigation was made of the effect of composition variations on the mechanical properties of alloys based on the Ni-Mo-Cr-Fe system. For one series of tests alloys were prepared with various amounts of Cr added to an Ni-15% Mo base, and for a second series various amounts of Fe were added to an Ni-15% Mo-7% Cr base. Creep tests of these materials at 1500°F and a stress of 10,000 psi in an argon atmosphere showed that increasing the Cr content up to 10% in an Ni-15% Mo base increased the strength of the material. The addition of 4% Fe to the Ni-15% Mo-7 Cr base did not significantly affect the strength, but some strengthening occurred with 7 to 10% Fe additions.

Metallurgy - Mechanical Properties

A specimen of the Haynes Alloy SP-16 (16% Mo-7% Cr-5% Fe-0.02% C-bal Ni) which was packed carburized and then solution annealed is currently being creep tested at 8000 psi and 1500°F in order to determine whether carburization will increase the creep strength and the rupture life as it did in the case of Inconel. At the present time the specimen has 6.8% elongation at 1194 hr. The unmodified alloy had a rupture life of 540 hr

[redacted]

[redacted]

with 13% elongation, and the time to 1% strain was 32 hr as compared with 92 hr for the carburized specimen.

A test series is being conducted to determine the effect of the frequency of strain cycling on the rupture life of Inconel at 1500°F. Fine-grained Inconel tubes have been strain cycled at 2 and 30 min/cycle in argon and in fuel 30 ($NaF-ZrF_4-UF_4$, 50-46-4 mole %). Comparison of data at a constant strain per cycle indicates that the longer cycling period, 30 min/cycle, has the more damaging effect on the ability of the material to withstand cyclic strain. This effect is shown by a reduction in both the number of cycles to failure and the total plastic strain absorbed prior to failure. Thus, along with temperature, grain size, and environment, the time held at a given strain level is an important variable and must be taken into consideration when plastic strain absorption is employed as a criterion for high-temperature design. Whether plastic strain cycles occurring over a period greater than 30 min will further reduce the total ductility and number of cycles to failure has not yet been determined. Data are not yet complete for the 30-min cycling tests of coarse-grained material, but there are indications that grain size does not strongly affect the strain-cycle properties at this frequency.

Metallurgy - Nondestructive Testing

Study was continued of the technique of measuring cladding thickness of three-layer composites by eddy-current methods. The accuracy of the equipment was increased by the substitution of a drift-free transistor oscillator for the variable-frequency signal generator previously employed. Although transistors are sensitive to thermal changes, they have a high degree of frequency stability in a controlled temperature.

The Mark I Metal Identification Meter was modified to add a second resistivity range. Originally the instrument measured resistivities between 5 and 150 micro-ohm centimeters; the addition of the second range extends the application of the instrument to approximately 1 micro-ohm centimeter. The converted instrument was used to separate 61S, 24S, and 2S aluminum plate in the Laboratory's stores.

Reactor Chemistry

The use of cold traps for the removal of oxides from circulating alkali metals led to a need for information regarding the composition of the deposited oxides. A method for determining the composition of the oxides in equilibrium with liquid metal compositions was therefore developed. At room temperature, the ratio of sodium to potassium in the oxides was found to be 50 to 75 times greater than the ratio in typical sodium-potassium alloys.

The effect of oxide ions as precipitating agents in fluoride fuels was studied further. In this study it was found that the solubility of BaO in LiF-KF (50-50 mole %) at 600°C is at least 2 mole %, which is higher than anticipated.

[redacted]

Two methods for obtaining oxide-free fluoride melts containing YF_3 from the starting material Y_2O_3 are being investigated. The melts are required for the production of oxide-free yttrium metal to be used in the fabrication of yttrium hydride moderating material. One method involves the treatment of solid Y_2O_3 with HF at elevated temperatures, and the other carries out the same reaction in a molten salt bath ($LiF-MgF_2$). Optimum processing conditions are being sought.

Recently published Russian work (Kirkina, Novoselova, and Simanov, 1956) described a new high-melting modification of BeF_2 which would considerably alter the currently accepted phase diagrams for BeF_2 fuel systems. Attempts to confirm the Russian work by using the quenching techniques employed for obtaining fuel phase diagrams have been unsuccessful. The results confirmed the currently accepted 550°C melting point for BeF_2.

Comparative studies to guide the search for improved fuels have established the essential features of the $LiF-BeF_2-ThF_4$ phase diagram. The low melting eutectics are at 350°C ($LiF-BeF_2-ThF_4$, 46-52-2 mole %) and 440°C ($LiF-BeF_2-ThF_4$, 67-25-8 mole %) and there are no ternary compounds. Also, the solubility of PuF_3 in BeF_2 fuels appears to be about the same as the solubilities of UF_3 and SmF_3. There is considerable incentive, from a corrosion standpoint, to incorporate trivalent fissionable cations in the fuel because of their reducing action.

Bulk Shielding Facility (BSF)

One of the problems confronting shield designers is the production of gamma rays by neutron capture in lead. An experiment was performed at the BSF to determine the effectiveness of reducing this source of gamma rays by adding lithium to the lead. In the experiment, gamma-ray dose rates beyond eight 1/2-in.-thick lead slabs containing 0.74 wt % lithium were compared with those beyond ordinary lead slabs, the slabs being normalized to the same number of grams per cubic centimeter. The experiment was designed to emphasize the capture gamma rays in lead by minimizing the straight-through gamma rays, the water capture gamma rays, and the scattered gamma rays. The results indicated that the capture gamma rays from the lithiated lead were a factor of 4 fewer than those from ordinary lead.

Tower Shielding Reactor-II (TSR-II)

The calculations required for determining the heat generation in the lead adjacent to the core of the TSR-II were repeated with the gamma-ray energy distribution for the core, as well as that for the lead, being taken into account in the Monte Carlo method used. This removed the uncertainty arising from the assumed angular and energy distribution of the gamma-ray flux at the core-lead interface. Since the values thus obtained for each energy group were lower than those obtained in the first calculation by about 30%, a conservative design will be obtained through the use of the results obtained in the previous calculations.

[redacted]

Three dummy annular fuel elements have been assembled with plates formed with the forming rolls that were modified to reduce the flexure. These elements meet the tolerance requirements for plate spacing and are now being used for flow studies.

Final development tests on the prototype control mechanism show that the mechanism operates with a pressure of 72 psi in the cylinder and scrams when the pressure is reduced to 53 psi. The calculated values for these pressures were 66 and 50 psi, respectively. The actual operating time for 1 in. of travel was found to be 37 msec, which is to be compared with a calculated time of 27 msec. Design work has started on a full-scale control mechanism.

Tower Shielding Facility (TSF)

Qualitative measurements of the spectrum of gamma rays resulting from neutron capture and inelastic scattering in the nitrogen of the atmosphere are still being made. The detector collimator described previously has been replaced with a more effective shield of lead bricks and concrete blocks. Collimation of the radiation entering the detector is achieved with a 4-in.-wide slit which permits the detector to see the beam from an angle of 90 deg from the vertical to an angle of 10 deg; that is, the collimator sweeps an angle of 80 deg. Neutrons are filtered out with 4 ft of water held in the slit by plastic bags.

Edited by A. W. Savolainen

Approved by Alvin M. Weinberg, Director

[redacted]