[redacted]

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION

# AEC RESEARCH AND DEVELOPMENT REPORT

ORNL-2356 53A
C-85 - Reactors-Aircraft
Nuclear Propulsion Systems

DECLASSIFIED
CLASSIFICATION CHANGED TO: AEC 5.770
BY AUTHORITY OF: Goldberg 12.7.70
BY: C. Goldberg

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0350514 2

OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

PROGRAM 4400

JUNE 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.

[redacted]

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]

C-85 Reactors - Aircraft
Nuclear Propulsion Systems

ORNL-2356

This document consists of 13 pages.
Copy 53 of 68, Series A.

Contract No. W-7405-Eng-26

# OAK RIDGE NATIONAL LABORATORY
# SPECIAL PROGRESS REPORT
# PROGRAM 4400

June 1957

Date Issued: JUL 5 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

[redacted]

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0350514 2

[redacted]

C-85 - Reactors - Aircraft
Nuclear Propulsion Systems

ORNL-2356

OAK RIDGE NATIONAL LABORATORY
SPECIAL PROGRESS REPORT
June 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 (WCORT)
18. Power Plant Laboratory - WADC (WCLPW)
19. Pratt & Whitney Aircraft Company

### Oak Ridge National Laboratory

20. A. L. Boch
21. E. P. Blizard
22. C. J. Borkowski
23. W. F. Boudreau
24. G. E. Boyd
25. F. R. Bruce
26. A. D. Callihan
27. R. A. Charpie
28. C. E. Clifford
29. S. Cromer
30. F. L. Culler
31. D. E. Ferguson
32. J. L. Fowler
33. A. P. Fraas
34. J. H. Frye, Jr.
35. W. R. Grimes
36. E. Guth
37. M. R. Hill
38. H. W. Hoffman
39. A. Hollaender
40. J. T. Howe
41. W. H. Jordan
42. G. W. Keilholtz
43. C. P. Keim
44. M. T. Kelley
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. A. H. Snell
58. W. H. Sullivan
59. J. A. Swartout
60. E. H. Taylor
61. D. B. Trauger
62. C. S. Walker
63. A. M. Weinberg
64. J. C. White
65. C. E. Winters
66. W. Zobel
67-68. Laboratory Records Dept.



[redacted]

[redacted]

OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

TABLE OF CONTENTS


| | Page |
|---|---|
| PROGRAM 4400 - REACTOR DEVELOPMENT | 4 |
| AIRCRAFT NUCLEAR PROPULSION PROJECT | 4 |
| Aircraft Reactor Test (ART) | 4 |
| Engineering Test Unit (ETU) | 4 |
| ART Facility Design and Construction | 5 |
| Reactor Component Testing | 5 |
| Power Plant Engineering | 6 |
| Metallurgy - Corrosion | 7 |
| Metallurgy - Fabrication | 8 |
| Metallurgy - Welding and Brazing | 9 |
| Metallurgy - Nondestructive Testing | 9 |
| Metallurgy - Mechanical Properties | 9 |
| Metallurgy - Ceramics | 10 |
| Chemistry - Fuel Research | 10 |
| Chemistry - Fuel and Coolant Production | 11 |
| Chemistry - Analytical Studies | 11 |
| Tower Shielding Reactor-II (TSR-II) | 11 |
| Lid Tank Shielding Facility (LTSF) | 11 |
| Bulk Shielding Facility (BSF) | 12 |
| Tower Shielding Facility (TSF) | 12 |


Reports in this series issued during the past year:

| | |
|---|---|
| June 1956 | ORNL-2124 |
| July 1956 | ORNL-2145 |
| August 1956 | ORNL-2167 |
| 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 |



[redacted]

[redacted]

OAK RIDGE NATIONAL LABORATORY

SPECIAL PROGRESS REPORT

June 1957

PROGRAM 4400 - REACTOR DEVELOPMENT

AIRCRAFT NUCLEAR PROPULSION PROJECT (AEC Activity 4401)

Aircraft Reactor Test (ART)

Design tests of the various components in the sodium circuit of the reactor were completed. The characteristics of that circuit are now well defined. Detailed sizing of key orifices was accomplished, and the orifice plugs are being made for installation in the ETU. Fabrication of these parts was delayed until they were needed so that the best possible information could be used in establishing the final dimensions.

The fuel-to-NaK heat exchanger fabrication work at Black, Sivalls & Bryson has been under intensive re-examination. The tooling, fabrication procedures, and checking procedures were examined carefully in an effort to minimize costs and to expedite the job as much as possible. A well-defined course of action has been evolved, and the first experimental tube bundle should be produced in July.

Engineering Test Unit (ETU)

Two sodium-to-NaK heat exchangers were received from Griscom Russell and were given a metallurgical examination. Except for minor defects that are being corrected the units are satisfactory. Installation of the exchangers in the north head will proceed. The inner core shell was welded around the beryllium island without difficulty. The design clearance between the spacers and the shell was held, and the weld has passed visual, liquid penetrant, and x-ray examination. The strut ring was welded to the load ring forging, and the assembly was stress relieved.

No satisfactory reactor shells have yet been produced by the shear spinning process, and the possibility of using a cold-pressing method to produce the 1/16-in.-thick Inconel shells that will surround the fuel annulus is being investigated. A cold-formed lower half of the outer reflector-moderator shell was received and is being set up for contour machining.

Work continued on the ETU NaK piping. The cold trap circuits are being installed in the two furnace circuits, and the main piping in the two isothermal systems is being welded into position. A high-temperature



[redacted]

air leakage test was run on the louvers in the ETU test facility, and the data obtained are being evaluated. The results indicate that the leakage increases as the louver temperature increases, and the implications for ART design are being studied.

ART Facility Design and Construction

Package 3A contract work was further extended to include a hydraulic pumping unit for the drives of the control louvers, a filter for the process water system, and a wall to enclose the auxiliary control room.

Design work continued on the arrangement of equipment in the radiator pit in an attempt to provide adequate space for installation and replacement of equipment. A more compact model of the NaK purification equipment and piping was made which appears to provide adequate space for removing cold traps and for access to the flowmeters and valves.

Disassembly planning studies were continued. Further experimental measurements of a simulated reactor part with the use of a cathetometer in back of a 4-ft-thick lead-glass window indicate that satisfactory dimensional measurements can be obtained.

Three types of cutting techniques were tried: dry grinding, electric disintegration, and ultrasonic. A 1/8-in.-thick, 16-in.-dia wheel cut through three concentric Inconel pipes ranging in size from 3 1/2- to 2 1/2-in. IPS in slightly more than 1 min. Particles were spread over a wide area, but the advantages of the good cutting speed might offset the disadvantages of the additional decontamination and air-filtering systems that would be required. The electric disintegration (Elox) cutting was slow but might have limited application where fragile parts must be severed with minimum damage. Ultrasonic cutting (Sheffield Cavitron) is extremely slow on Inconel and is not recommended. The only possible application for ultrasonic cutting would be the cutting of the boron carbide blocks, which are very hard and brittle.

Reactor Component Testing

The fuel pump which is being tested for endurance with $NaF-ZrF_4-UF_4$ (50-46-4 mole %, fuel 30) was shut down after completing 3550 hr and 652 thermal cycles from 1100 to 1400°F. This pump will be disassembled and inspected and then reassembled for further test operation.

A probable cause was found for the increase in system pressure and pump tank liquid level which brought about the termination last month of a primary NaK pump test after six months of uninterrupted operation. Oil leaked from the rotary seal on the lower shaft bearing housing and entered the NaK in the pump tank, which was at a temperature of 1200°F.

The oil vaporized and increased the pump tank pressure. Some of the cracked oil and its vapors apparently were entrained in the NaK and were circulated in the loop. When gas was vented to reduce the pump tank pressure, the expansion of oil vapors compressed in the fluid raised the liquid level in the pump tank.

A reactor pump rotary assembly was shipped to NRTS for irradiation, while operating, in a special gamma-ray facility in the MTR canal. Tests of the assembly will be made to determine the extent of radiation damage to the lubricating oil and any consequent effect on seal performance, on scavenging of leakage oil, and on heat transfer. A total dose of $1.2 \times 10^{10}$ rep will be obtained in approximately ten weeks.

An ART-prototype NaK-to-air radiator is being tested in accordance with the operating program for the ART. Preliminary examination of the data indicates that the heat transfer exceeds the ART requirements. The NaK friction factor increased as predicted from 0.05 to 0.09 during 488 hr of power operation. The testing program has been interrupted temporarily in order to replace the spring loading which simulates ART wind and gravity stresses with new units that meet the latest design requirements.

The guided-plug prototype fuel dump valve, previously reported to have been tested at 1300°F for 1500 hr without measurable leakage, was tested for an additional 960 hr at 1500°F. Leakage of the fuel mixture $NaF-ZrF_4-UF_4$ (50-46-4 mole %, fuel 30), was within acceptable limits. An increase in the force required for opening was noted, and the valve is now being disassembled for examination.

The temperature at the inlet to the ART prototype $ZrF_4$-vapor trap was increased to 1400°F, and 500 hr of testing were completed without plug formation. The trap was completely effective in removing the $ZrF_4$ from the off-gas line. The amount of $ZrF_4$ deposited in the downstream heat exchanger section of the trap was considerably in excess of that expected, however, and design changes will be required to provide additional volume in the heat exchanger region.

Power Plant Engineering

Advanced design studies of weapons systems indicate that a high-payload-capacity subsonic aircraft capable of operating for long periods away from its base would be a useful application of a nuclear-powered airplane. Such an aircraft would require essentially a unit shield with dose rates in the crew compartment not greater than 0.1 r/hr.

The problems associated with the installation of a powerplant employing a circulating-fuel reactor coupled to a turbojet engine which would serve as a gas generator supplying high pressure air to free

turbines for driving propellers are being investigated. This system would have the advantage that it would eliminate the need for NaK pipes passing through the wings and would replace these NaK pipes with air ducts for high-pressure air. It would also make it possible to place the reactor shield between the radiators and the crew. The amount of air that would have to be handled by the power turbines would be only about one-fourth that handled by an equivalent turboprop engine, because these turbines would not have to drive their own compressors.

Equipment is being designed for the in-pile testing of materials suitable for fuel-cooled-moderators for reactors. A parametric study of the effects of a volume heat source on the temperature differences and stresses within fuel-cooled moderator rods and on the temperature difference between the bulk free-stream fluid and the moderator rod surface was completed. The results of this study will be used in estimating the temperature differences that will exist in the system under any combinations of conditions.

Data being obtained at NACA in tests of a standard 1/2-Mw NaK-to-air radiator over a somewhat wider range of air velocities than that covered by ORNL tests agree well with the ORNL data, except that the scatter band for the Nusselt vs Reynolds number relation indicates a considerably steeper slope. The ORNL and NACA data were examined jointly, and NACA has agreed to carry out further tests with particular emphasis on the high airflow region.

Metallurgy - Corrosion

Seesaw-furnace corrosion tests were conducted in which molybdenum and niobium liner cups were held in the hot zone of Type 316 stainless steel tubes in contact with lithium for 500 hr. The lithium was in contact with the refractory metal only while in the hot zone (1500°F) and with the stainless steel only when in the cold zone (950°F). No corrosion attack and no temperature-gradient or composition-gradient mass transfer of refractory metal to stainless steel or stainless steel to refractory metal was detected after these experiments. A stainless steel, inert-atmosphere chamber was constructed in which thermal-convection loops made of refractory metals can be tested without providing oxidation-resistant claddings.

A forced-circulation loop fabricated of an experimental nickel-molybdenum alloy with the nominal composition 17% Mo-6% Fe-bal Ni was operated for 1000 hr with the fuel mixture NaF-KF-LiF-$UF_4$ (11.2-41-45.3-2.5 mole %, fuel 107) without incident. The maximum fuel-metal interface temperature was 1760°F. Metallographic examination of the loop is not yet complete.

A second forced-circulation loop fabricated of an experimental nickel-molybdenum alloy with the nominal composition 17% Mo-10% Cr-bal Ni was placed in operation, but a crack developed in the Hastelloy B pump bowl during the cleaning cycle and repairs are now under way. The intended maximum fuel-metal interface temperature of this loop is 1900°F.

Evidence was found in postoperative examinations of several heat exchangers that the metallurgical changes which accompany the grain coarsening of Inconel can seriously affect corrosion resistance. Similar evidence of preferential grain-boundary attack of coarse-grained material was found in a forced-circulation loop which included annealed hot-leg sections. Re-examinations of the results of thermal-convection loop tests operated some years ago to evaluate grain-size effects indicated that subsurface voids were more concentrated in the grain boundaries of coarse-grained tubing than in the grain boundaries of fine-grained tubing, although the depths of attack were similar.

Metallurgy - Fabrication

Three pilot heats of INOR-8 have been produced by Westinghouse. Although the first heat was high in carbon content, it was forged successfully, but ingots of this heat contained internal flaws and were scrapped. The other two heats were poured into redesigned molds in an attempt to eliminate the flaws, which were attributed to solidification voids. The second heat was contaminated with mold wash and was not forged; however, the third heat was press forged successfully and is being inspected.

Three runs were made in the new equipment for the production of yttrium metal with lithium metal as the reductant. Yields of clean yttrium-magnesium alloy ranged from 60 to 83% of theoretical. A quantity of the alloy from the first run was purified by vacuum distillation and melted in a molybdenum crucible. This melt was analyzed and found to contain about 1800 ppm of oxygen, which compares favorably with the 2000 ppm reported for metal obtained from the Ames Laboratory.

A tubular control rod containing a core of high-fired Lindsay oxide in nickel was successfully extruded. The use of high-fired oxide with 44-105 micron particles eliminated the cracking and poor ductility found in earlier extrusions. The recently extruded tube, which was extruded at a ratio of 13:1, has quite uniform layer thickness and good bonding between the core and the Inconel cladding.

Tube and rod extrusions were prepared from niobium pellets and from vanadium chips canned in stainless steel or in mild steel. These extrusions are being evaluated for workability and recovery in order to determine the feasibility of the extrusion process for direct fabrication of these materials.

Metallurgy - Welding and Brazing

An Inconel heat exchanger mockup is being fabricated for stress tests. All components for a 20-tube Inconel-type 316 stainless steel duplex heat exchanger were obtained, and the welding of some of the stainless steel fittings is under way.

An automatic inert-gas tungsten-arc welding head is being installed for use in weld-shrinkage experiments. This equipment incorporates automatic arc-length control and an automatic filler-wire addition mechanism, and a wide range of welding speeds is available.

The possibility of using nitrogen as a back-up gas for welding Inconel is being investigated. Some preliminary welds were made, and samples are being tested in fused salt fuels and in NaK.

Metallurgy - Nondestructive Testing

A new encircling-coil eddy-current system for tubing inspection is being developed which sweeps or "steps" through ten different frequencies at a rate of 100 to 200 decades/sec. The necessary timing circuitry and ten miniaturized plug-in transistor signal generators were constructed.

A new instrument for eddy-current thickness measurement was completed that is much more stable than its predecessor and almost completely free of drift. Further, it is much more sensitive and versatile in that it will accommodate a greater number of probe coils and test frequencies; the controls are simpler, and the signals are more easily interpreted.

Metallurgy - Mechanical Properties

A sample of a vacuum-melted 30-lb heat of INOR-8 with 0.15% zirconium added was found to have a rupture life of 1200 hr at 8000 psi and 1500°F, whereas samples of vacuum-melted heats without zirconium failed in about 650 hr. The additional life reflected the increased ductility of 66%, as compared with 30% for the heats without zirconium. Rupture times and ductilities for samples of 6-lb heats without zirconium were comparable to those for the zirconium-bearing material, and thus it appears that the zirconium merely aids in the degassing process and does not directly contribute to the strength.

The addition of carbon, which results in carbide formation, appears to be one of the most potent ways of increasing the strength of structural-metal alloys at high temperatures. Unfortunately, increasing the carbon content adversely affects the fabricability. This difficulty might be avoided by fabricating a low-carbon-content material and then strengthening it by adding carbon. In order to test this procedure, creep specimens

of Inconel were pack carburized and then solution annealed to achieve a homogeneous distribution of the carbides. Preliminary tests of these specimens at 1300, 1500, and 1650°F in argon and in $NaF-ZrF-UF_4$ (50-46-4 mole %, fuel 30) indicate very marked increases in creep strength and rupture life at all temperatures.

Metallurgy - Ceramics

Eight pairs of zirconium hydride samples were prepared for physical tests. The hydrogen present in these samples varied from 0.19 to 1.15 wt %.

Chemistry - Fuel Research

X-ray diffraction patterns of $NaF-HfF_4$ samples obtained from slowly cooled and from quenched melts have shown $NaF-HfF_4$ compounds very similar to those found in the $NaF-ZrF_4$ system. Unit cell parameters of the complex hafnium compounds are very slightly smaller than those of their zirconium analogs. In addition, the melting behavior of the analogous compounds is very similar. The slight difference between Hf and Zr is apparently sufficient to stabilize $NaF \cdot HfF_4$.

Optical and x-ray examinations of $NaF-BeF_2-RbF$ quenches have shown the existence of two more ternary compounds in the system. One of these has a refractive index of 1.360, and its composition is near 19 mole % NaF-43 mole % $BeF_2$-38 mole % RbF. This compound and the compounds $NaF \cdot BeF_2$ and $2NaF \cdot BeF_2$ form the sides of a compatibility triangle with a ternary eutectic or peritectic at about 273°C. The composition of this invariant point has not yet been located. Very little is known about the other ternary compound, except that its refractive index is 1.325 and that it contains more than 50 mole % $BeF_2$.

Filtration studies of the reduction of $UF_4$ (8.9 wt %, 4 mole %) by Fe in the reaction medium $RbF-ZrF_4$ (52-48 mole %) yielded iron concentrations of 490 and 140 ppm at 600 and 800°C, respectively. These values approximate those found in the other alkali fluoride-$ZrF_4$ binary mixtures studied at these temperatures. This behavior of the $Fe^{o}-UF_4$ system is in marked contrast to that found for the $Cr^{o}-UF_4$ system. For the latter system, the chromium concentration decreases as the cation radius increases in the series $Li^+$, $Na^+$, $K^+$, $Rb^+$ at both 600 and 800°C.

As a possible method of elimination of fission products from $NaF-KF-LiF-UF_4$ fuels, the precipitation of cerium as cerium oxide was carried out in a solution containing 10 wt % $CeF_3$ in the solvent KF-LiF (50-50 mole %) by the addition of the stoichiometric amount of LiOH. Filtrates of the remaining liquid after addition of the precipitant contained less than 0.1% cerium. The precipitate had a grayish color. This behavior may be useful in the reprocessing of $NaF-KF-LiF-UF_4$ fuels.

## Chemistry - Fuel and Coolant Production

The production-scale facility was shutdown and put in standby condition. A sufficient quantity of material is now on hand to meet the estimated fiscal year 1958 requirements. About 18,000 lb of various materials are now stored.

## Chemistry - Analytical Studies

Experiments were carried out to determine whether a serious corrosion problem would result from the addition of lead to the aluminum tank for the water shield of the ART. Galvanic currents as high as 200 μa were generated between 50-$cm^2$ electrodes of lead and 2S aluminum when the electrodes were immersed in demineralized water at a temperature of 40 to 50°C. The surface of the aluminum was noticeably attacked within a period of 24 hr, and a dispersed crystalline deposit was formed on the surface of the lead electrode. The corrosion rate was significantly diminished when an atmosphere of argon was maintained over the cell and reduced to negligible values when flowing tap water was substituted for the demineralized water.

An apparatus for the determination of combined oxygen in fluoride salts and metals was assembled. The determination is based on the quantitative evolution of elemental oxygen when the samples are heated with addition compounds of $BrF_3$, such as $KBrF_4$ and $BrF_2 \cdot SbF_6$, at a temperature of 400°C. The liberated oxygen is then transferred to an evacuated vessel of known volume, where it is measured by determining its pressure with a differential manometer. The components of the apparatus, which include nickel reaction vessels, fluorothene cold traps, and an automatic Toepler pump, have been fabricated. The apparatus will be used for the determination of traces of oxygen in compounds such as $YF_3$ and $ZrF_4$.

## Tower Shielding Reactor-II (TSR-II)

Three dummy aluminum fuel elements for the central cylinder region of the TSR-II were assembled by different methods. Tack welding the fuel plates after peening them into the side plates produced the best results. This method was also used to fabricate an outer-region element. (Central elements are those above and below the internal water reflector when the fuel plates are in a vertical geometry; all other elements are outer elements.) The initial core sizes and rolling sequences were established for about one-half the fuel plates in the central elements.

## Lid Tank Shielding Facility (LTSF)

Measurements were made to aid in the optimization of the design of a unit shield for a circulating-fuel reactor. The data obtained included thermal-neutron flux and gamma-ray dose rate measurements beyond shield

configurations containing up to 10 1/2 in. of lead at different spacings in borated water behind a reflector-moderated reactor mockup. Additional experiments designed to aid in interpretation of the results are in progress.

Bulk Shielding Facility (BSF)

The 9 3/4-in.-dia thallium-activated sodium iodide crystal which will be used with the BSF gamma-ray spectrometer was returned by the vendor after a 2-in.-deep, 3/4-in.-dia well was drilled into the truncated end of the cone. Since the time of purchase of the crystal, the vendor has found that the cast aluminum housing containing the crystal was porous and allowed leakage into the crystal. While the crystal was being modified, the housing was treated to prevent leakage. After return of the crystal, gamma rays from $Cs^{137}$ (0.662 Mev) and $Y^{88}$ (0.908 and 1.85 Mev) were collimated into the well, and resolutions of 17, 17, and 15.6%, respectively, were obtained. These data may be influenced by instrument malfunctions or misalignment of the collimator, since previously the crystals gave 12% resolution at 0.662 Mev. These possibilities of error are being investigated.

The drawings for the complete spectrometer tube assembly for the ART shielding measurements were completed, except those for the calibration source holders and positioners and the movable shields for background measurements. Recent information indicates that when the reactor is operated at high temperatures the point of convergence for the lines of sight through the first four spectrometer tubes will be 13/16 in. above the reactor equator and the centerline of the hole penetrating the reactor shield (tube 5) will be 1/2 in. above the cold reactor equator. It is believed that the flexibility of the design for aligning the spectrometer tubes will permit adjustment to these conditions, and therefore no changes in the current component designs are anticipated.

Tower Shielding Facility (TSF)

Measurements of the fast-neutron dose rate in the air approximately 60 ft from the TSF reactor were completed for reactor water shield thickness of 20 and 40 cm. In order to reduce the penumbra effect of the neutron collimation and to minimize the contribution of air-scattered neutrons to the measurements, the 3-ft-dia collimator surrounded by a 2 ft thickness of water was located halfway

[redacted]



between the detector and the reactor tank. The detector was shielded on all sides except that facing the reactor. In addition, the probability of neutrons scattering in air to an unshielded detector 60 ft from the reactor were determined. The penetration of air-scattered neutrons through the water side shielding of a cylindrical crew compartment is now being investigated.

Edited by A. W. Savolainen

Approved by Alvin M. Weinberg, Director



[redacted]