External Transmittal Authorized
ORNL
Central Files Number
58-2-11

**PRELIMINARY REPORT ON THE RESULTS OF
THE OAK RIDGE RESEARCH REACTOR HYDRAULIC TEST**

F. T. Binford

NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

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

498-001

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

NOTOTSTAT

2/25/58

CD BR. REVIEW BY: _____ DATE: _____ REPORT TYPE: _____ SUBJECT CATEGORY C: _____

☐ ABSTRACT ☐ LTD. ABST. ☐ LIST ☐ OMIT CARD DISTN. CATEGORY C: _____ MICROCARD CAT. C: _____

TISE EVALUATION BY: DATE: 2/24/58 SUBJECT CATEGORY C: 80 CARD DIST. CATEGORY: _____

☐ ABSTRACT ☐ LIMITED DIST. CARDS EVALUATION RATING ER 1X 5 10 15 NONE

☐ TITLE LIST ☐ INDEX FOR TIS ONLY INITIAL PRINT ORDER: _____ PHOTOSTAT: _____

☐ PRINTED CARDS ONLY ☐ RECORD CARD FOR TISE RE-EVALUATION BY: _____ DATE: _____ REPRINT: _____

CLASS. DIST. BR. COMMENTS & DENIALS

☐ SITE APPROVAL _____

☐ DOD APPROVAL _____

☐ CAP CAT. _____

☐ CAP DELETED CAT. _____

BY: _____

☐ NON PROJECT

☐ NOT CAP

PRICING:

☐ PRINTED _____

☐ PHOTOSTAT _____

☐ MICROFILM _____

☐ MICROCARD _____

☐ OTHER (SPECIFY) _____

OTHER TISE COMMENTS:

project

1.80 PL
1.80 MY

CODES

REPRODUCIBLE TYPE CODES
(IF MORE THAN ONE TYPE RECEIVED LIST ALL APPLICABLE CODES)

P PLATES (ALL KINDS) M MIMEOGRAPH STENCILS

N NEGATIVES (ALL KINDS) PP PHOTO PRINTS

OM OZALID MASTERS OA ORIGINAL ART

REPORT TYPES

A RESEARCH AND DEVELOPMENT REPORTS APPROPRIATELY CATEGORIZED FOR STANDARD DISTRIBUTION BY ORIGINAL INSTALLATION OR CD BR.

B REPORTS CONTAINING INFORMATION OF A NON-R&D NATURE WHICH CD BR. WILL CATEGORIZE FOR DELETED DISTRIBUTION OR INDICATE FOR LIMITED DISTRIBUTION.

C ADMINISTRATIVE REPORTS CONTAINING ESSENTIALLY NO R&D INFORMATION AND ARE NOT APPROPRIATE FOR CATEGORIZATION.

MICROCARD ORDER FORM

MICROCARD CORPORATION ORDER FORM						TISE RECORD OF RECEIPT	
MICROCARD NEGATIVES/CARDS OF THIS REPORT WILL BE PREPARED IN THE QUANTITY INDICATED						NEGATIVE AVAILABLE, PAYMENT NOT REQUIRED ☐	
NEGATIVE ONLY ☐ FRAMES _____ BY _____ DATE _____						MICROCARD NEGATIVES/CARDS AS ORDERED HAVE BEEN RECEIVED FROM THE MICROCARD CORPORATION	
CARD PRINT ORDER	SERIES	CARD SETS BY TITLE	INDIVIDUAL CARDS MADE	COMPLETED BY	DATE	CARDS AS ORDERED	COMMENTS
INITIAL PRINTING		295	295	gc	3-13	RECEIVED BY	DATE
SUBSEQUENT PRINTING						P. T. SPILERS	MAR 1 1958
SUBSEQUENT PRINTING							

FD-302a (Rev. 4-15-64)

[illegible]

External Transmittal Authorized
ORNL
Central Files Number
58-2-11

34

**PRELIMINARY REPORT ON THE RESULTS OF
THE OAK RIDGE RESEARCH REACTOR HYDRAULIC TEST**

F. T. Binford

DATE ISSUED

FEB 17 1958

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

498-002

PRELIMINARY REPORT ON THE RESULTS OF THE OAK RIDGE RESEARCH REACTOR HYDRAULIC TEST

F. T. Binford

INTRODUCTION

In order to evaluate the performance of the Oak Ridge Research Reactor, an extensive program of hydraulic testing was carried out during November and December of 1957. The purpose of this report is to set forth in brief fashion the results of these tests. The procedures used will not be discussed here, but will be presented later in a final report presently being prepared.

The testing program was planned and carried out by the Operations Division under the direction of the writer, and the experimental work was performed under the direct supervision of W. H. Tabor and R. D. MacFarren. For the most part, direct flow measurements were taken by using an electrolytic method suggested by E. S. Bettis.

PLAN OF THE TESTS

As a part of the ORR design effort, the coolant velocities required through various core channels were calculated. These results are summarized in ORNL CF-55-5-157.¹ The testing program consisted primarily in determining the actual flow through these channels. The ORR core has been adequately described elsewhere.^{2,3} It consists of a 9×7 lattice containing 19-plate Mark II, MTR-type fuel elements; two types of beryllium reflector pieces; solid aluminum reflector pieces; and fuel-poison-type control elements. In addition to the flow through the fuel elements and the control elements, flows between adjacent components and through the various other core orifices were determined.

EXPERIMENTAL RESULTS

The results of measurements of flow through and around core components are given in Figs. 1 through 6. Here the water velocity has been plotted as a function of the total pressure loss

through the fuel elements. The measurements were taken at a variety of temperatures ranging from 60 to 95°F. The velocities were measured electrolytically, and the pressures were obtained by using static pressure taps installed for that purpose in specially designed fuel test elements. The pressures have all been corrected to 120°F, the operating design temperature, by making the proper adjustment for viscosity and density. The design points are also displayed on the graphs.

Figure 7 gives the relationship between total reactor flow and velocity through the fuel elements, thus permitting the relationship between flow and fuel pressure loss to be deduced. It was also possible to determine the actual distribution of pressure loss throughout the fuel elements as well as the distribution of pressure loss in the channel between adjacent curved sides of two fuel elements. These results are given in Table 1.

In addition, measurements of flow through the other core orifices were made. The distribution of coolant for several typical flows is displayed in Table 2.

DISCUSSION OF RESULTS

An examination of Figs. 1 through 6 discloses that with the exception of one type of channel, all channels measured perform in substantial agreement with the original design criteria. The design work was based on a 4×7 core containing 24 fuel elements and 4 shim rods. The maximum heat flux at 30 Mw was assumed to be $600,000 \text{ Btu-ft}^{-2}\text{-hr}^{-1}$. This required a velocity of 32 fps through the fuel at a total flow of 18,000 gpm in order to maintain maximum surface temperature at approximately 210°F (30 deg below the saturation temperature). The present work was done by using a core containing 26 fuel elements and 4 shim rods. The velocity attained through the fuel was 29 fps at 18,000 gpm. If this is extrapolated to the original design basis, it corresponds to a velocity of 31 fps through the fuel elements of a 24-fuel-element, 4-control-rod core. This is in agreement with the original work.

It should also be pointed out here that at no time during the tests was it possible to approximate the design operating temperature of 120°F. Most of

¹F. T. Binford, *Hydraulic and Thermal Characteristics of the ORR Core*, ORNL CF-55-5-157 (Dec. 7, 1956).

²F. T. Binford, T. E. Cole, and J. P. Gill, *The Oak Ridge National Laboratory Research Reactor Safeguard Report, Volume 1*, ORNL-1794 (Oct. 7, 1954).

³J. P. Sanders, *Heat Transfer and Pressure Loss in Proposed ORR Fuel Assemblies*, ORNL CF-54-3-57 (March 11, 1954).

Fig. 1. ORR Hydraulic Test. Water velocity in fuel plates vs pressure loss in fuel element (pressures corrected to 120°F).

Fig. 2. ORR Hydraulic Test. Water velocity through plate section of shim rod vs pressure loss in fuel element (pressures corrected to 120°F).

Fig. 3. ORR Hydraulic Test. Water velocity past adjacent curved sides of fuel vs pressure loss in fuel element (pressures corrected to 120°F).

Fig. 4. ORR Hydraulic Test. Water velocity past adjacent curved sides of reflector and fuel plates vs pressure loss in fuel element (pressures corrected to 120°F).

Fig. 5. ORR Hydraulic Test. Water velocity between core elements and core housing vs pressure loss in fuel element (pressures corrected to 120°F).

Fig. 6. ORR Hydraulic Test. Water velocity between adjacent curved sides of reflector pieces vs pressure loss in fuel element (pressures corrected to 120°F).

Fig. 7. Velocity Through Fuel Plates vs Total Reactor Flow.

Table 1. Distribution (%) of Fuel Element Pressure Loss

	Upper End Box	Fuel Section	Lower End Box
Inside element	31.2	64.9	3.9
Outside element	10.7	59.3	30.0

the work was done at temperatures 35 to 50°F lower than this. Since the increase in temperature will result in a decrease in friction losses, there may be some changes in the total flow available. In general it is believed that some increase over the maximum cold flow may be attained. This will be determined at power.

Some uncertainty exists concerning the coolant velocity between the curved sides of adjacent fuel and reflector pieces. As can be seen in Fig. 4, the velocities at a given pressure loss varied in some cases by as much as a factor of

2. These measurements were taken in a variety of locations by using several different test elements, and the variation appears to be quite random. Whether this was due to variations in the test procedure or variations in the spacing of the elements was not determined.

During the initial measurements of flow through the control rods, it was found that the aluminum cladding in the poison sections of three of the rods had expanded as a result of internal water pressure. This caused restriction of the flow passage and resulted in lower flows than had been anticipated. The condition was corrected, and subsequent measurements confirmed that the rods met the design criteria.

CONCLUSIONS

On the basis of these results it is clear that the reactor can be operated without difficulty from the water system at the 20-Mw level. In order to estimate the maximum power level which can be attained, several factors must be considered:

1. The original design presupposed a limitation of 210°F on the maximum surface temperature. This could be extended to 225°F with no danger of boiling.

2. The maximum heat flux, 600,000 Btu-ft⁻²·hr⁻¹, was based on the assumption that the maximum flux in a 28-element core would be twice the average flux. While this may be true early in the life of the core, calculations indicate that a factor of 1.7 is more realistic for a partially burned core.

3. The actual total flows attainable at operating temperature are unknown and will depend upon the core configuration used, but it is believed that they will be slightly higher than those attained during the test.

4. Restriction of the control-rod flow as described above has been observed during the operation of the MTR with no apparent effect on operation.

5. Water velocity in the outermost channels of a fuel element may be as much as 17% lower than the flow through the central channels.⁴

In view of the foregoing it appears that, with respect to maximum power level, the limiting factor will be either the temperature of the outer-

⁴E. S. Bettis, *Hydraulic Test of ORR Dummy Fuel Element*, ORNL CF-56-4-27 (April 5, 1956).

most fuel plate in those fuel elements which are adjacent to reflector pieces, or the temperature of the outermost fuel plates in fuel elements located at the point of maximum flux. Which of these will predominate will depend upon the flux distribution. If the assumption is made that the heat flux at the

fuel reflector interface does not exceed the average flux in the fuel core, and that the maximum flux in the fuel does not exceed 1.7 times the average, then it appears reasonable to predict that power levels of 35 Mw can be attained without exceeding a plate temperature of 225°F.

Table 2. Distribution of Flow Through ORR Core (at 120°F)

	Flows (gpm) at Pressure Losses of			
	4.1 psi	8.9 psi	13.6 psi	19.2 psi
Through 26 fuel elements	5643	8,733	10,972	13,435
Through 4 shim rods	703	1,085	1,425	1,759
Through 15 reflector annuli	210	315	390	480
Through 12 reflector holes	23	34	43	54
Between 23 fuel-fuel curved sides	301	462	533	628
Between 25 fuel-fuel flat sides*	68	98	122	144
Between 3 fuel-housing curved sides	26	38	46	54
Between 4 fuel-housing flat sides*	6	10	12	15
Between 15 fuel-reflector curved sides	95	152	198	240
Between 6 fuel-reflector flat sides*	10	15	19	22
Between 18 reflector-reflector curved sides	100	155	179	350
Between 25 reflector-reflector flat sides*	23	33	41	49
Between 15 reflector-housing curved sides	34	53	69	84
Between 10 reflector-housing flat sides*	9	13	17	20
Rifle-drilled holes	174	245	303	359
Large facility annuli	221	317	368	469
Exterior ion chamber shield	22	32	38	46
Interior ion chamber shield	8	13	15	21
Beam holes HB1-HB6	224	288	407	513
D ₂ O system	138	204	254	312
Total	8038	12,295	15,451	19,054
Metered flow	8000	12,200	15,300	18,700

*Calculated values from ORNL CF-55-S-157; these values represent at most about 2½% total flow.

External Transmittal Authorized
ORNL
Central Files Number
58-2-11

INTERNAL DISTRIBUTION

1. A. M. Weinberg
2. R. A. Chorppe
3. C. E. Winters
4. T. E. Cole
5. M. E. Ramsey
6. A. F. Rupp
7. R. B. Briggs
8. J. P. Gill
9. H. Watts
10. J. A. Cox
11. W. Mruk
12. E. P. Epler
13. E. S. Bettis
14. W. R. Costo
15. R. A. Weeks
16. W. H. Tabor
17. C. D. Cogle
18. H. V. Klaus
19. P. M. Reyling
- 20-29. F. T. Binford
- 30-32. Laboratory Records
33. Laboratory Records, ORNL R.C.

EXTERNAL DISTRIBUTION

- 34-48. Technical Information Service Extension, Oak Ridge

**DO NOT
PHOTOSTAT**