8-2-72
135
Fast Reactor
Journal

LG

MASTER

LMFBR SHIELDING DESIGN EXPERIMENTS AND METHODS EVALUATION

FIRST QUARTERLY PROGRESS REPORT

JANUARY-MARCH 1972

U.S. ATOMIC ENERGY COMMISSION
CONTRACT AT(04-3)-189 PROJECT AGREEMENT 62

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

GENERAL ELECTRIC

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.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or 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.

**LMFBR SHIELDING DESIGN EXPERIMENTS
AND METHODS EVALUATION**

**First Quarterly Progress Report
January-March 1972**

Approved:

D. R. Wilkins

D. R. Wilkins
Program Manager

Approved:

M. L. Weiss

M. L. Weiss
Technical Project Engineer

Approved:

P. Greebler

P. Greebler, Manager
Nuclear Engineering

U.S. Atomic Energy Commission
Contract AT(04-3)-189
Project Agreement 62

BREEDER REACTOR DEPARTMENT • GENERAL ELECTRIC COMPANY
SUNNYVALE, CALIFORNIA 94086

33/350-NE
AG - 6/72

GENERAL ELECTRIC

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *leg*

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or 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.

TABLE OF CONTENTS

ABSTRACT	v
1. INTRODUCTION	1-1
2. SUMMARY	2-1
3. TECHNICAL ACCOMPLISHMENTS	3-1
3.1 Program Definition and Scheduling	3-1
3.2 Test Assembly Design and Fabrication	3-1
3.3 Analytical Studies	3-12
3.4 Quality Assurance	3-17
4. ADMINISTRATIVE	4-1
4-1 Trips	4-1
4-2 Visits	4-1
4-3 List of Contributors	4-1
REFERENCES	R-1
DISTRIBUTION	1

LIST OF ILLUSTRATIONS

Figure	Title	Page
1-1	Near-Core Upper Axial and Radial Neutron Shields	1-2
3-1	Axial 5-1/4-inch-o.d. Solid Type-304 Stainless Steel Rods	3-5
3-2	Radial Shielding Experiment: 5-1/4-inch-o.d. B ₄ C-Filled Tubes and Slab Equivalents	3-6
3-3	Radial Shielding Experiment: 2-inch-o.d. B ₄ C-Filled Tubes	3-7
3-4	Radial Shielding Experiment: 1-inch-o.d. B ₄ C-Filled Tubes and Slab Equivalents	3-7
3-5	Axial Shielding Test Assembly	3-8
3-6	Radial Shielding Tubular Test Assembly	3-9
3-7	Homogeneous Slab Test Assembly	3-10
3-8	Shipping Containers for Radial Tubular and Homogeneous Slab Test Assemblies	3-11
3-9	P.A. 62 Neutron Spectrum Modifier Analysis	3-15
3-10	P.A. 62 Neutron Spectrum Modifier Analysis	3-16
3-11	P.A. 62 Pre Experiment Analysis	3-18
3-12	TSR-II Source Geometry	3-19

ABSTRACT

This report is the first in a series of quarterly progress reports published under the LMFBR shielding development program (PA-62). Both experimental and analytical work on axial and radial shields is being conducted, with the experimental part being performed at the ORNL Tower Shielding Facility. Activities and technical progress for the period January through March 1972, are reported. The major topics include program definition and scheduling, test assembly design and fabrication, analytical studies, and quality assurance.

1. INTRODUCTION

The LMBFR shielding program is based on design requirements for reduced uncertainties in critical parameters of the plant shielding design. In the current P.A. 62 program, shielding experiments and their analyses are being conducted to reduce calculational uncertainties for the following neutron shields (Figure 1-1):

- Reactor closure lower neutron shield (this is the principal bulk shield for reducing the neutron flux level above the reactor closure head)
- Radial neutron shield (this shield limits neutron fluences at the lateral core support and at the reactor vessel)

An important calculational uncertainty for these two neutron shields arises from their actual heterogeneous form as opposed to their approximated homogeneous form in calculations. Configurations simulating the actual shields have been designed and are being fabricated for testing at the ORNL Tower Shielding Reactor to provide accurate data on neutron transmission through heterogeneous near-core neutron shields. These measurements will also provide neutron flux inputs to calculations and/or experiments for regions farther from the core.

Figure 1-1. Near-Core Upper Axial and Radial Neutron Shields

2. SUMMARY

The engineering design for the shielding configurations to be tested was completed. Drawings were issued.

Procurement and fabrication activities are progressing according to schedule, except that the B₄C delivery date has slipped about 1 month. Despite this slippage, however, delivery of all experimental hardware to ORNL will be sufficiently timely (before June 30, 1972) to ensure full utilization of the Tower Shielding Reactor. Quality-assurance requirements have been defined; a verification plan was issued.

More than 50% of the pre-measurement analytical studies were completed during the January–March 1972 quarter. Following selection of cross sections and methods to be utilized, an approximate determination of spectrum modifier/diffuser materials and thicknesses was made.

An experimental program for the P.A. 62 axial and radial shield tests at the Tower Shielding Facility was developed jointly with ORNL's Neutron Physics Division.

3. TECHNICAL ACCOMPLISHMENTS

3.1 PROGRAM DEFINITION AND SCHEDULING

3.1.1 Objectives

The major objectives of the current P.A. 62 program are to reduce calculational uncertainties for (a) the reactor closure lower neutron shield and (b) the radial neutron shield (Figure 1-1). Important calculational uncertainties for these two shields arise from their actual heterogeneous form as compared with their assumed homogeneous form in calculations. The planned measurements will provide accurate data on neutron transmission through heterogeneous near-core neutron shields. Results of the measurements will be compared with the calculated results as a means of assessing accuracy of the calculational methods. These measurements also provide neutron flux inputs to calculations and/or experiments for regions farther from the core.

3.1.2 Experimental Hardware

The axial experiment, composed of solid Type-304 stainless steel rods immersed in sodium, simulates the reactor closure lower neutron shield. Neutron streaming through the sodium interstitial spaces requires measurement. Figure 3-1 illustrates the geometry of this experiment. The solid Type-304 stainless steel rods are 5-1/4 inches in diameter and 2 feet in length.

The radial experiment, consisting of rows of B_4C -filled tubes and their homogeneous slab equivalents, simulates the radial neutron shield surrounding the radial blanket. The "transverse leakage effect"—which is the fraction of neutrons that leak or "stream" through minimum B_4C thicknesses in shields consisting of one or more rows of B_4C -filled tubes—requires measurement. Figures 3-2, 3-3, and 3-4 illustrate the geometries for this set of measurements. For the 1-inch and 2-inch tubes, the number of rows will be varied from one to four; for the 5-1/4-inch tubes, measurements will be made for a maximum of three rows. Additionally, neutron attenuation measurements through homogeneous slab equivalents of the 1-inch- and 5-1/4-inch-diameter tube experiments will be made. The latter measurements provide a means of evaluating calculational errors due to methods, cross sections, geometric modeling, etc., as opposed to differences in measured versus calculated results due to the "transverse streaming effect."

3.1.3 Measurements

All measurements will be carried out using the Tower Shielding Reactor at ORNL as a neutron source. Table 3-1 illustrates the experimental program for completing these measurements. This program is the result of a joint planning effort between ORNL's Neutron Physics Division and GE-BRD. ORNL expects this program will require 4 months of facility time, with an additional month for spectrum modifier measurements.

3.1.4 Schedule

Table 3-2 illustrates the significant milestones of the P.A. 62 schedule. The axial experiments will be ready for testing by May 1. However, spectrum modifier tests are scheduled during May. Hence, neutron attenuation measurements for the axial experiment are expected to be conducted during the month of June. All experimental hardware for the current program will be delivered to ORNL before the end of fiscal year 1972 (June 30, 1972). Delivery will be sufficiently timely to ensure full utilization of the Tower Shielding Facility (TSF).

3.2 TEST ASSEMBLY DESIGN AND FABRICATION

The engineering design for the shielding configurations was completed. Figures 3-5, 3-6, 3-7, and 3-8 are reduced-size drawings for the four major assemblies to be fabricated.

The following procurement and fabrication activities were accomplished during the January–March 1972 quarter.

a. Axial Shielding Test Assembly (Drawing 816E280, Figure 3-5)

All materials ordered. The following materials were received at ORNL:

1. Container, cover, cover bolts, and gasket
2. 5-1/4-inch-diameter stainless steel bar stock
3. Sodium-filling cover fabricated at ORNL

All other necessary materials (to be supplied by GE-BRD) have been shipped.

Table 3-1
EXPERIMENTAL PROGRAM FOR GENERAL ELECTRIC AXIAL
AND RADIAL SHIELD MEASUREMENTS AT TSF

Configuration No.	Configuration Description	Neutron Measurements					
		NE-213	H ₂ Counter	Axial Traverse ^a		Radial Traverse ^b	
				All 9 Balls	3, 6 and 10 in.	All 9 Balls	3, 6 and 10 in.
1	Modifier, Axial	☑, Close ^c 45°, Close	☑, 12 and 144 in. 45°, 144 in.	☑, 12 to 144 in.			12 in.; 0 to 36 in. on each side of ☑. 144 in.; 0 to 144 in. on one side of ☑
2	Modifier, Radial			Same Measurements as for Axial Modifier			
3a	Axial Shield	☑, Close	---	☑, 12 to 144 in.	---	---	12 in.; 0 to 36 in. on each side of ☑. 144 in.; 0 to 60 in. on one side of ☑.
3b	Axial Shield Reflected ^d	☑, Close	---	☑, 12 in.	---	---	12 in.; 0 to 36 in. on each side of ☑
4a	1-in. dia. B ₄ C Rods; 1 and 4 Rows	☑, Close	☑, 12 in.	☑, 12 to 144 in.	---	---	12 in.; 0 to 36 in. on each side of ☑. 144 in.; 0 to 144 in. on one side of ☑
4b	1-in. dia. B ₄ C Rods; 2 and 3 Rows	☑, Close	---	---	☑, 12 to 144 in.	---	12 in.; 0 to 36 in. on each side of ☑. 144 in.; 0 to 144 in. on one side of ☑
5a	2-in. dia. B ₄ C Rods; 1 and 4 Rows			Same Measurements as for 4a — 1-Inch B ₄ C Rods			
5b	2-in. dia. B ₄ C Rods; 2 and 3 Rows			Same Measurements as for 4b — 1-Inch B ₄ C Rods			
5c	2-in. dia. B ₄ C Rods;	---	Horiz. Traverse, close; spectra at adjacent "peak" and "valley"				144 in.; 0 to 144 in. on each side of ☑
6a	5¼-in. dia. B ₄ C Rods; 1 and 3 Rows	☑, Close	☑, 12 in.	☑, 12 to 144 in.	---	---	12 in.; 0 to 36 in. on each side of ☑. 144 in.; 0 to 144 in. on one side of ☑
6b	5¼-in. dia. B ₄ C Rods; 2 Rows	☑, Close	---	---	☑, 12 to 144 in.		12 in.; 0 to 36 in. on each side of ☑. 144 in.; 0 to 144 in. on one side of ☑

GEAP-13822-1

Table 3-1 (Continued)

Configuration No.	Configuration Description	Neutron Measurements					
		NE-213	H ₂ Counter	Axial Traverse ^a		Radial Traverse ^b	
				All 9 Balls	3, 6 and 10 in.	All 9 Balls	3, 6 and 10 in.
6c	5¼-in. dia. B ₄ C Rods; 3 Rows, Reflected with 1-in. SS Slab	---	Horiz. Traverse to locate "peaks" and "valleys"	---	---	---	
6d	5¼-in. dia. B ₄ C Rods; 3 Rows, Reflected by Axial Shield	---	Horiz. Traverse to locate "peaks" and "valleys"	---	---	---	
7a	1-in. equiv. homogeneous B ₄ C Slab; 1 Row	Q, Close	Q, 12 in.	---	Q, 12 to 144 in.	---	12 in.; 0 to 36 in. on each side of Q 144 in.; 0 to 144 in. on one side of Q
7b	1-in. equiv. homogeneous B ₄ C Slab; 2 Rows						
7c	1-in. equiv. homogeneous B ₄ C Slab; 3 Rows						
7d	1-in. equiv. homogeneous B ₄ C Slab; 4 Rows						
8a	5¼-in. equiv. homogeneous B ₄ C Slab; 1 Row						
8b	5¼-in. equiv. homogeneous B ₄ C Slab; 2 Rows						
8c	5¼-in. equiv. homogeneous B ₄ C Slab; 3 Rows						

a Axially out beam centerline from back of configuration.

b Radially from beam centerline.

c At closest point behind sample possible due to x-ray sensitivity of scintillator.

d Axial shield with a 2-1/2-foot thickness tank of sodium as a reflector behind detector.

Table 3-2
SIGNIFICANT MILESTONES

FY-72						FY-73														
O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1	2	3	4	5	6	7	8	9	10											

MILESTONES:

1. Complete preliminary design and cost estimate for shielding configurations to be tested. Obtain agreement with AEC-RDT and ORNL on design details, program scope, and schedule.
2. Order all long-delivery materials. Initiate detailed engineering design and pre-measurement analytical program.
3. Initiate fabrication following RDT approval of system design description.
4. Assemble hardware for axial experiment at ORNL (includes sodium filling).
5. Deliver 1-inch experiments to ORNL.
6. Deliver all other experimental hardware to ORNL.
7. Complete measurements (ORNL).
8. Complete post-measurement analysis.
9. Complete draft of final report.
10. Issue final report.

Figure 3-1. Axial 5-1/4-inch-o.d. Solid Type-304 Stainless Steel Rods

**HOMOGENEOUS EQUIVALENT OF
5-1/4 in.-O.D. B₄C-FILLED TUBES**

Figure 3-2. Radial Shielding Experiment: 5-1/4-inch-o.d. B₄C-Filled Tubes and Slab Equivalents

Figure 3-5. Axial Shielding Test Assembly

Figure 3-3. Radial Shielding Experiment: 2-inch-o.d. B_4C -Filled Tubes

1-in.-O.D. B_4C -FILLED TUBES

**HOMOGENEOUS SLAB EQUIVALENTS OF
1 in.-O.D. B_4C -FILLED TUBES**

Figure 3-4. Radial Shielding Experiment: 1-inch-o.d. B_4C -Filled Tubes and Slab Equivalents

Figure 3-6. Radial Shielding Tubular Test Assembly

Figure 3-7. Homogeneous Slab Test Assembly

Figure 3-8. Shipping Containers for Radial Tubular and Homogeneous Slab Test Assemblies

3-11

b. Radial Shielding Tubular Test Assemblies (Drawing 816E278, Figure 3-6)

All materials ordered. All tubing received at GE-NFD, San Jose. Frame fabrication initiated. B_4C is being procured in three different grain sizes. Smallest grain size has been received. Medium and coarse grain sizes not yet shipped. Delivery of latter expected week of April 24—about 2 weeks behind schedule.

c. Homogeneous Slab Test Assemblies (Drawing 816E279, Figure 3-7)

All materials ordered. Fabrication initiated. Some difficulties being experienced in obtaining necessary flatness, thereby requiring design changes. Anticipate no problem in completing fabrication prior to B_4C availability.

d. Shipping Containers for Radial Tubular and Homogeneous Slab Test Assemblies (Drawing 816E281, Figure 3-8)

Containers ordered. Delivery expected April 28, which is prior to completion of fabrication of radial tubular and homogeneous slab test assemblies.

3.3 ANALYTICAL STUDIES

The following analytical activities were accomplished during the January—March 1972 quarter:

- a. Preliminary selection of neutron cross section and other material data to be used in the 1D- S_n and Monte Carlo calculations
- b. Determination and verification of approximations to be used in simulating the TSR-II source
- c. Preliminary evaluation of geometry and background approximations for analytical mock-up of experiments
- d. Approximate determination of spectrum modifier/diffuser materials and thicknesses
- e. Comparison of transmitted neutron spectrum shape between GE 1D- S_n 24-group calculation and ORNL DOT-III 50-group calculation for 2.5 feet of sodium
- f. Adaptation of the Morse Monte Carlo computer program for local use on an IBM 370 model 165 computer.

The foregoing items constitute more than 50% of the pre-measurement analysis (Table 3-3) for P.A. 62.

3.3.1 Neutron Cross Sections and Other Material Data

In general, the best available cross sections will be used as determined by consultation between GE and ORNL personnel.

3.3.1.1 Cross Sections for 1D- S_n Calculations

At present, the 1D- S_n neutron calculations use a 24-group shielding cross section library compiled and edited at GE from several external sources.¹⁻⁷ Table 3-4 gives the specific references for elements that will be used in initial P.A. 62 calculations and until the next in-house updating occurs.

3.3.1.2 Cross Sections for 3-D Monte Carlo Calculations

At present, it appears that for aluminum and sodium, Mod 0 ENDF/B-III data will be used.⁸ For boron and carbon, ENDF/B-III data will also be used. The cross sections for Type-304 stainless steel are currently being examined by ORNL personnel to determine a best set for MORSE and DOT calculations (done for the ORNL iron bench mark experiment). ORNL will provide the best available cross-section sets for our P.A. 62 MORSE calculations. One likely prospect for Type-304 stainless steel uses ENDF 4124 (DNA) Fe with $1/E\sigma_T$ weighting + ENDF/B-I, Cr, Ni, Mo, Mn weighted with a GAM-II spectrum for stainless steel.⁹

Table 3-3
ANALYTICAL STUDIES PLAN

Pre-Measurement Analysis

1. Determine neutron cross sections and other material data.
2. Specify 1-D approximation of TSR-II source (energy and angular dependence).
3. Determine geometry and background approximations for analytical mock-up of experiments.
4. Determine spectrum modifier/diffuser materials and thicknesses.
5. Do 1-D and 3-D calculations to check the source approximation.
6. Computational tools and data:
 - GE 1-D discrete ordinates code
 - ORNL 3-D Monte Carlo code
 - ORNL measurements for TSR-II source
 - ORNL sodium and iron bench mark calculations and data
 - ORNL spectrum modifier calculations

Table 3-4
POINTWISE DATA REFERENCES FOR 1D-S_n CROSS SECTIONS

Element	Cross Section Reference
Boron-10	1, 2
Carbon	1, 2
Sodium	1, 2
Aluminum	1, 2
Silicon	3
Chromium	1, 2, 4, 5, 6
Manganese	1, 2
Iron	1, 2
Nickel	1, 2
Molybdenum	1, 2

3.3.1.3 Material Densities and Thickness Specifications

Aluminum, sodium, B₄C, Boral, Type-304 stainless steel, and Type-321 stainless steel densities will be determined from ORNL and GE data for the components to be used in the experiments. The materials that will be used in the radial and axial spectrum modifiers are to be provided from on-hand stock at ORNL, with densities as specified by ORNL. Densities used in the preliminary spectrum modifier design are the same as those used in determining the GE Demo reference spectra and are: 2.702, 0.8512, 1.850, 2.530, 7.930, 7.900, respectively, for aluminum, sodium, B₄C, Boral, Type-304 stainless steel, and Type-321 stainless steel. Aluminum, B₄C, and Type-304 stainless steel thicknesses and dimensions required in the experimental configurations are subject to quality-control inspection as specified by GE-BRD.

3.3.2 1-D Approximation of TSR-II Source

The neutron source (bare TSR-II reactor) was approximated for 1-D calculations by collapsing the flux data used by ORNL in their sodium bench mark calculations^{10, 11, 12} from 100 to 24 energy groups. The neutrons transmitted through the modifier are primarily those entering in a very forward direction. Also, the neutron source is collimated. Therefore, an S₁₆ symmetric quadrature set was constructed, according to the scheme of Cerbone and Lathrop,¹³ containing two quadrature angles within the divergence of the neutron source. A fixed-shell source option was then used to input the neutron source only into these two angles. Anisotropic scattering is approximated by expansion through P₃ in the angular distribution.

3.3.3 Geometry and Background Approximations for Analytical Mock-Up of Experiments

A slab geometry option is being used for the spectrum modifier (spectrum shape) calculations, with the source angular distribution as previously described.

It has been assumed that the concrete around the periphery of the spectrum modifier and around the periphery of the experimental configurations may be neglected in the spectrum modifier design calculations, but this approximation must be investigated. ORNL did trial calculations through 5 and 10 feet of sodium surrounded by concrete.¹⁴ In these trial calculations, the effect of the concrete was approximated by the use of an albedo with reflected energy and total albedo properties generated for an incident angle of 45 degrees using specular reflection. It was concluded that the effect of the concrete around the periphery of the sodium was negligible on the neutron transport through up to 10 feet of sodium.

Measurements of the background due to ground scattering have been made at ORNL for the 2.5-foot sodium bench mark configuration.¹⁵ For a 3-inch Bonner ball positioned 24 inches behind the 2.5-foot sodium tank, the background was only 1.7% of the foreground. Because of the similarity of the geometry of the GE experiments to the geometry of these sodium bench mark experiments, ground scattering has been neglected in the spectrum modifier design calculations.

3.3.4 Determination of Spectrum Modifier/Diffuser Materials and Thicknesses

Preliminary 1D-S_N calculations have been completed for both the radial and axial spectrum modifiers. Figures 3-9 and 3-10 show the results of these calculations for two possible radial modifier configurations. Both figures give a comparison of the GE Demo radial reference spectrum (at the front face of the B₄C shield) with the spectrum at the modifier/B₄C shield interface. The TSR + modifier spectrum has been normalized in each case to the total flux of the GE Demo reference spectrum. It is clear from these comparisons that the thicker modifier (10-inch Type-304 stainless steel + 18-inch Na + 2-inch Boral) gives the better approximation to the reference spectrum. However, it is noted that the reference spectrum is softer than the spectrum provided by either of these two modifiers. Additional calculations are in process to give a better radial approximation, but consideration is being given to selecting a modifier that provides a conservative (hard) spectrum relative to the GE Demo reference design.

Calculations are also in progress on the axial modifier, with the best approximation to date being given by 14-inch Type-304 stainless steel + 4-inch Type-321 stainless steel + 54-inch Na + 1-inch Boral. However, the spectrum provided by this modifier is somewhat harder than desired. Further design calculations are being performed.

PL 4

Figure 3-9. P.A. 62 Neutron Spectrum Modifier Analysis

PL 1

Figure 3-10. P.A. 62 Neutron Spectrum: Modifier Analysis

3.3.5 Comparison of Spectrum Shape Between 1D-S_n and DOT-III 2.5-Foot Na Calculations

As a part of the analysis of P.A. 62 experiments, frequent checks and comparisons are being made with ORNL bench mark or other calculations that relate to the GE calculations. One example of this is shown in Figure 3-11 which gives a spectrum shape comparison between a GE 1D-S_n 24-group, S₁₆ P₃, slab geometry, TSR-II source through 2.5-foot Na calculation with a similar calculation done at ORNL with DOT-III.¹⁶ Figure 3-12 shows schematically the TSR source geometry which was approximated by an S₁₆ quadrature. The shape of the 24-group 1D-S_n transmitted neutron spectrum is seen to agree well with the 50-group DOT-III spectrum although, of course, some of the smaller Na resonances at high energy must be treated in an approximate way due to fewer groups.

3.3.6 Implementation of the Monte Carlo Code

During the past quarter, a MORSE Monte Carlo program tape was obtained from RSIC and is now being adapted for use on the IBM 370 Model 165 computer. The program was compiled successfully.

In addition, a listing of some specialized routines and other input data for the 2.5-foot bench mark experiment calculation was provided by the ORNL Neutron Physics Division. After a standard sample problem from the RSIC code package has been run, the 2.5-foot sodium bench mark calculation will be done as a checkout of the program, special routines, and a geometry which is very similar to that which will be used in the P.A. 62 Monte Carlo calculations.

3.4 QUALITY ASSURANCE

3.4.1 Quality Assurance Planning Status

The Quality Assurance requirements for the P.A. 62 project have been defined in BR QCI 900, "Quality Assurance Verification Plan for P.A. 62 Axial and Radial Experiments." The concept behind this planning effort is "direct verification" of Quality Assurance requirements. Generic quality requirements from the P.A. 10 Quality Plan have been applied as specific directives for the components of the P.A. 62 project.

Quality Control Instructions (QCI's) have been prepared to specify detailed inspection requirements which will define the accept or reject criteria for materials, hardware, and assemblies used in the P.A. 62 experiments. Listed are the QCI's applicable to P.A. 62 experimental material and components.

- QCI 6200 — BRD Receiving Inspection and Qualification of Boron Carbide Powder
- QCI 6201 — BRD Receiving Inspection of Triflute Extrusions, P/N 181B3486, P1, P2, and P3
- QCI 6202 — BRD Receiving Inspection of Welded SST Tubing for P/N 151C5151
- QCI 6203 — BRD Receiving Inspection of Shipping Containers P/N 816E281
- QCI 6204 — BRD Receiving Inspection of Frame Assys P/N 118D9899, G1, G2, and G3
- QCI 6205 — BRD Source Inspection of Container Axial Shield Test Assy P/N 816E289
- QCI 6206 — BRD Receiving Inspection for Slab Frames, Radial Experiment P/N 816E279
- QCI 6207 — BRD Receiving Inspection of Stainless Steel Barstock per ASTM A-276, Type 304
- QCI 6208 — ORNL Receiving Inspection of BRD Hardware, Project P.A. 62

3.4.2 Axial Container Acceptance

The axial container P/N 816E289, Rev. 0, was accepted for shipment to ORNL on March 27, 1972 by the responsible BRD Quality Assurance Surveillance representative. Shipment was then arranged and completed by the vendor. The acceptance of the subject container was based upon the characteristics and requirements listed in QCI 6205.

PL 1

Figure 3-11. P.A. 62 Pre-Experiment Analysis

Figure 3-12. TSR-II Source Geometry

3.4.3 ORNL Receiving Inspection

QCI 6208, "ORNL Receiving Inspection of BRD Hardware," was prepared as a request for inspection services, to be performed by ORNL personnel. Included in the QCI is an inventory list of hardware to be accounted for and the minimum amount of inspection attention necessary to verify safe arrival. Visual inspections to identify items and document freedom from shipping change are deemed adequate.

3.4.4 Eyebolt Strength Test

Verification of eyebolt strength was accomplished through the destructive test of a selected sample. A laboratory test was performed to verify the load-carrying ability of the lifting eyebolts in their weakest possible position. The test sample was subjected to increasing loads directed 90 degrees from the axis of the threads (to simulate the position used when turning the axial container 90 degrees). At 10,000 pounds of force, the eye was bent to an angle of 45 degrees, and at that point a failure of the thread root occurred in the form of a crack. Breakage did not occur. Records of the above test are on file at BRD Quality Assurance which verify the acceptable results.

3.4.5 Standards Input

The stainless materials used for fabrication of the experiment are A1S1 Type 304 and were purchased to the following ASTM specifications:

Dai Stick	A-276
Tubing	A-269
Plate	A-240

Thorough consideration was given to the use of RDT and other standards for this application, and the above standards were determined appropriate.

4. ADMINISTRATIVE

4.1 TRIPS

W. H. Harless and B. A. Hutchins to ORNL, February 23–24, 1972.

M. L. Weiss and D. R. Wilkins to AEC-RDT, Germantown, Md., March 9–10, 1972.

4.2 VISITS

None.

4.3 LIST OF CONTRIBUTORS

J. C. Amos
M. A. Bell
W. E. Butler
R. G. Copeman
P. Greebler
W. H. Harless

J. J. Hayashi
B. A. Hutchins
C. R. McMillan
R. Protsik
F. C. Rally
P. Steck

H. J. Stock
T. F. Thompson
N. W. Wallace
M. L. Weiss
D. R. Wilkins

REFERENCES

1. Honeck, H. C., *ENDF/B Specifications for an Evaluated Nuclear Data File for Reactor Applications*, May 1966, revised July 1967, [BNL-50066 (T-467)].
2. *ENDF/B Summary Documentation*, ENDF Newsletter, Vol. 3, No. 2, Brookhaven National Laboratory, National Neutron Cross Section Center (October 2, 1967). This reference contains summary documentation for about one-half of the ENDF/B materials.
3. Ray, J. H., et al., *Neutron Cross Sections of Nitrogen, Oxygen, Aluminum, Silicon, Iron, Deuterium, and Beryllium*, November 1965 (UNC-5139).
4. Bertin, M. C., et al., *Neutron Cross Sections of U-238, U-235, U-237, U-239, U-234, U-236, Pu-239, Pu-240, W, Pb, Ni, Cr, C, Li⁶, Li⁷, and T*, December 1964 (UNC-5099).
5. Schmidt, J. J., *Neutron Cross Sections for Fast Reactor Materials, Part I: Evaluation*, February 1966 [KFK-120 (EANDC-E-35 U)].
6. Ravier, J., and Vastel, M., "Sections Efficaces Neutroniques du Chrome Dans Le Domaine .0001 eV à 15 MeV," *PNR/SEPR-65-041/JR/MV/am* (November 1965).
7. ENDF/B-II or III Libraries, National Neutron Cross Section Center, Brookhaven National Laboratory.
8. Mynatt, F. R., et al., *Fast Reactor Shielding Monthly Progress Report for November 1971*, December 31, 1971 (ORNL-TM-3666), p. 18.
9. Mynatt, F. R., et al., *Fast Reactor Shielding Monthly Progress Report for July 1971*, August 25, 1971 (ORNL-TM-3538), p. 10.
10. Mynatt, F. R. et al., *Fast Reactor Shielding Monthly Progress Report for September 1971*, October 18, 1971 (ORNL-TM-3606), pp. 8-15.
11. Mynatt, F. R., et al., *Fast Reactor Shielding Monthly Progress Report for October 1971*, November 24, 1971 (ORNL-TM-3639), pp. 12-21.
12. Mynatt, F. R., et al., *Fast Reactor Shielding Monthly Progress Report for November 1971*, December 31, 1971 (ORNL-TM-3666), pp. 11-14.
13. Cerbone, R. J., and Lathrop, K. D., "S_n Calculation of Highly Forward Peaked Neutron Angular Fluxes Using Asymmetrical Quadrature Sets," *Nuclear Sci. and Eng.*, **35**, 1, 139-141 (1969).
14. Mynatt, F. R., et al., *Fast Reactor Shielding Monthly Progress Report for July 1971*, August 25, 1971 (ORNL-TM-3538), pp. 6, 7.
15. Mynatt, F. R., et al., *Fast Reactor Shielding Monthly Progress Report for October 1971*, November 24, 1971 (ORNL-TM-3639), p. 32.
16. Letter from M. L. Gritzner (ORNL) to M. L. Weiss (GE) dated December 13, 1971.

DISTRIBUTION

Director, Contracts Division U.S. Atomic Energy Commission San Francisco Operations Office 2111 Bancroft Way Berkeley, California 94704	1	Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Assistant Director, Reactor Engineering	2
RDT Site Office U.S. Atomic Energy Commission General Electric Company 310 DeGuigne Drive Sunnyvale, California 94086	1	Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Assistant Director, Reactor Technology	1
Chief, California Patent Group U.S. Atomic Energy Commission San Francisco Operations Office P.O. Box 808 Livermore, California 94550	1	Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Chief, Reactor Physics Branch	2
Manager Westinghouse Electric Corporation Advanced Reactors Division P.O. Box 158 Madison, Pennsylvania 15663	1	Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Chief, Liquid Metal Projects Branch	1
Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Assistant Director, Engineering Standards	1	Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Chief, Core Design Branch	2
Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Assistant Director, Nuclear Safety	1	Manager, Systems Analysis Dept. Hanford Engineering Development Laboratory P.O. Box 1970 Richland, Washington 99352	1
Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Assistant Director, Plant Engineering	1	RDT Site Office U.S. Atomic Energy Commission Argonne National Laboratory 9800 South Cass Avenue Argonne, Illinois 60439	1
Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Assistant Director, Program Analysis	1	RDT Senior Site Representative U.S. Atomic Energy Commission P.O. Box 2325 San Diego, California 92112	1
Division of Reactor Development and Technology, Headquarters U.S. Atomic Energy Commission Washington, D.C. 20545 Attn: Assistant Director, Project Management	2	Division of Naval Reactors Chief, Nuclear Materials Branch U.S. Atomic Energy Commission Washington, D.C. 20545	1

Director Division of Reactor Licensing U.S. Atomic Energy Commission Washington, D.C. 20545	3	RDT Site Office U.S. Atomic Energy Commission Argonne National Laboratory P.O. Box 2108 Idaho Falls, Idaho 83401	1
Director Applied Physics Division Argonne National Laboratory 9700 South Cass Avenue Argonne, Illinois 60439	2	Director Reactor Safety & Analysis Division Argonne National Laboratory 9700 South Cass Avenue Argonne, Illinois 60439	9
RDT Site Office U.S. Atomic Energy Commission P.O. Box 550 Richland, Washington 99352	1	Director National Neutron Cross Section Center Brookhaven National Laboratory Upton, New York 11973	1
Director, Neutron Physics Division Oak Ridge National Laboratory P.O. Box X Oak Ridge, Tennessee 37830	1	Technical Director, FFTF Project Hanford Engineering Development Laboratory P.O. Box 1970 Richland, Washington 99352	1
RDT Site Office U. S. Atomic Energy Commission Oak Ridge National Laboratory P.O. Box X Oak Ridge, Tennessee 37830 Attn: K. O. Laughon	1	General Manager Westinghouse Electric Corporation Bettis Atomic Power Laboratory P.O. Box 79 West Mifflin, Pennsylvania 15122	1
Director Division of Reactor Standards U.S. Atomic Energy Commission Washington, D.C. 20545	2	Laboratory Assistant Director Gulf General Atomic Incorporated P.O. Box 608 San Diego, California 92112	1
Division of Technical Information Extension U.S. Atomic Energy Commission P.O. Box 62 Oak Ridge, Tennessee 37831	135	Manager, Nuclear Laboratories Combustion Engineering Inc. Nuclear Division Prospect Hill Road Windsor, Connecticut 06095	1
Director LMFBR Program Office Argonne National Laboratory 9700 South Cass Avenue Argonne, Illinois 60439	2	John Nims Atomic Power Development Associates 1911 First Street Detroit, Michigan 48226	1
C.E. Clifford Oak Ridge National Laboratory P.O. Box X Oak Ridge, Tennessee 37830	3	F. Maienschein Oak Ridge National Laboratory P.O. Box X Oak Ridge, Tennessee 37830	1
F. W. Thalgott Argonne National Laboratory P.O. Box 2528 Idaho Falls, Idaho 83401	1	Director, Liquid Metal Engineering Center Atomics International P.O. Box 1449 Canoga Park, California 91304	1
RDT Site Office U.S. Atomic Energy Commission Atomics International P.O. Box 1446 Canoga Park, California 91304	1	Manager—Advanced Development Activity General Electric Company Knolls Atomic Power Laboratory P.O. Box 1072 Schenectady, New York 12301	1

Director, LMFBR Technology Program
 Atomics International
 P.O. Box 309
 Canoga Park, California 91304

1

U.S. Atomic Energy Commission
 Region II - Division of Compliance
 Suite 818
 230 Peach Tree Street, N.W.
 Atlanta, Georgia 30303

1

Director
 Nuclear Development Center
 The Babcock and Wilcox Company
 Atomic Energy Division
 Lynchburg, Virginia 24501

1

George H. Best
 Los Alamos Scientific Laboratory
 P.O. Box 1663
 Los Alamos, New Mexico 87544

1

Manager, Research
 United Nuclear Corporation
 Research and Engineering Center
 Grasslands Road
 Elmsford, New York 10523

1

Division of Reactor Development
 and Technology, Headquarters
 U.S. Atomic Energy Commission
 Washington, D.C. 20545
 Attn: T. E. Murley

1

Director
 Nuclear Safety Program
 Oak Ridge National Laboratory
 P.O. Box Y
 Oak Ridge, Tennessee 37830

3

BREEDER REACTOR DEPARTMENT
SUNNYVALE, CALIFORNIA 94086

Expanding the World's Energy Reserves

GENERAL ELECTRIC