NASA TECHNICAL MEMORANDUM

NASA TM X-1828

NASA TM X-1828

USE OF "FASTER" CODE FOR SIGNIFICANTLY REDUCING DUCTED REACTOR SHIELD COMPUTATION TIME

by

Millard L. Wohl

Lewis Research Center

and

Thomas M. Jordan

ART Research Corporation

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JULY 1969

NASA TM X-1828

USE OF "FASTER" CODE FOR SIGNIFICANTLY REDUCING DUCTED REACTOR SHIELD COMPUTATION TIME

By Millard L. Wohl

Lewis Research Center
Cleveland, Ohio

and

Thomas M. Jordan

ART Research Corporation
Los Angeles, Calif.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – CFSTI price $3.00

ABSTRACT

The neutron number spectrum computed by the FASTER code at point detectors in a ducted water slab configuration is compared with similar results generated by the 05R code. Excellent agreement is found, verifying the quick-running FASTER code for this type of shielding analysis.

USE OF "FASTER" CODE FOR SIGNIFICANTLY REDUCING DUCTED REACTOR SHIELD COMPUTATION TIME

by Millard L. Wohl and Thomas M. Jordan*
Lewis Research Center

SUMMARY

The neutron number spectrum computed by the FASTER code at point detectors in a ducted water slab configuration is compared with similar results generated by the 05R code. Excellent agreement is found, verifying the quick-running FASTER code for this type of shielding analysis.

INTRODUCTION

One of the major engineering perturbations on the weight of mobile reactor shields is additional shielding due to the presence of ducts and voids in the shield configuration. Exact calculations of neutron and gamma-ray transport in unducted shields are difficult enough and quite time consuming. The effects of ducts in realistic shields is a problem which has never been treated thoroughly.

A method has been tested, for a simplified ducted shield problem, which appears to offer promise of significantly reducing computer time. The method is incorporated in the computer code FASTER (ref. 1) and has sometimes been referred to as multigroup Monte Carlo. It has been used extensively in the analysis of shields for nuclear rocket configurations (ref. 2).

Results of ducted shield calculations with FASTER were compared with results of similar calculations with 05R (ref. 3). Excellent agreement was obtained; this constitutes a verification of the usefulness of FASTER for the analysis of simply ducted shields. FASTER has the advantage of substantial computer time savings over Monte Carlo codes such as 05R.

---

*ART Research Corporation, Los Angeles, California.

ANALYSIS

The code FASTER was used to compute the differential neutron number flux at four point detectors in and near a 10-centimeter-diameter cylindrical duct penetrating water slabs of 20- and 100-centimeter thickness, respectively. A point fission neutron source was located at the center of one end of the duct. The geometric configuration for the 20-centimeter-slab calculation is shown in figure 1.

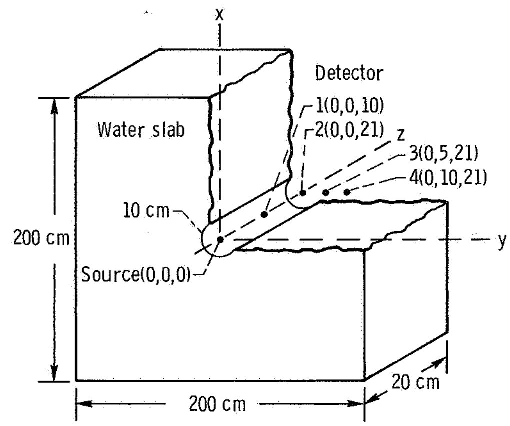

Figure 1. - Problem configuration.

In the 100-centimeter-slab thickness calculations the point detectors were located at (0, 0, 50), (0, 0, 105), (0, 5, 105), and (0, 10, 105), respectively.

This ducted slab configuration was used because the geometry and problem definition are relatively simple and the 20-centimeter-slab thickness problem has been solved many times at Oak Ridge National Laboratory by means of the 05R neutron Monte Carlo code. Oak Ridge solutions were obtained from 1000, 10 000, and 40 000 neutron case histories for the 20-centimeter shield and 2000 histories for the 100-centimeter shield.

For the 100-centimeter-slab calculations, an importance sampling method known as the exponential transformation had to be built into 05R to enhance deep penetration of neutrons in the direction of the detectors. Only 2000 case histories were run in 05R for the 100-centimeter slab.

In the comparisons of the 05R and FASTER results, only the scattered spectra are compared (the uncollided contribution is left out), so that the argument of expected agreement because of the overpowering effect of the large uncollided contributions is not valid - the agreement is therefore meaningful.

PROBLEM DESCRIPTION

Geometry

The problem geometry was very clean, consisting of a water slab (fig. 1) bounded by planes at x and $y = \pm 100$ centimeters. The slab thickness was assigned the values 20 and 100 centimeters in the two sets of calculations. The entrance face of the slab was the $z = 0$ plane. The exit faces were the $z = 20$ and 100 centimeter planes. The water slab was penetrated by a right circular cylindrical void duct, with axis normal to the entrance and exit faces of the slab, and with a 10-centimeter diameter.

Source Definition

The neutron source was a unit point isotropic source at the origin, emitting 1 neutron per second, as is standard in shielding calculations of this type. To conserve histories, initial source particle trajectories were defined only over the half-space containing the water slab. The neutron energy spectrum was defined by

$$n(E) = \exp(-E/0.965) \sinh \sqrt{2.29\,E} \qquad 0.01 < E < 10 \text{ MeV}$$

This spectrum was represented by 21 energy groups. The energy groups spanned the range from 0.01 to 10 MeV in 0.5-MeV increments.

Detector Locations

For the 20-centimeter-thick slab, detectors were located at (0, 0, 10), (0, 0, 21), (0, 5, 21), and (0, 10, 21). For the 100-centimeter-thick slab, detectors were located at (0, 0, 50), (0, 0, 105), (0, 5, 105), and (0, 10, 105).

RESULTS AND DISCUSSION

The neutron number spectra computed with 05R for the 1000- and 40 000-case-history, 20-centimeter-slab cases are shown at three of the detectors in figures 2 to 4. The corresponding spectra computed with FASTER are also shown in these figures. The agreement between the 40 000-case-history 05R results and the FASTER results is excellent. The decreasing slope of the FASTER spectra at about 2.3 MeV in energy accurately

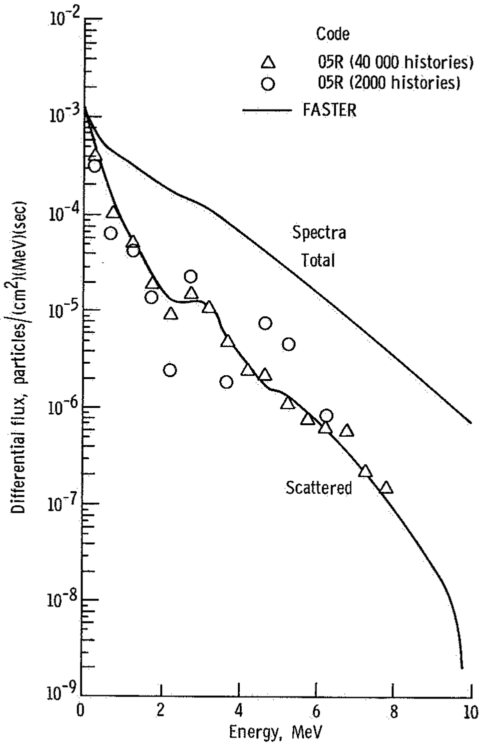

Figure 2. - Differential flux as function of energy for 20-centimeter slab at detector 1.

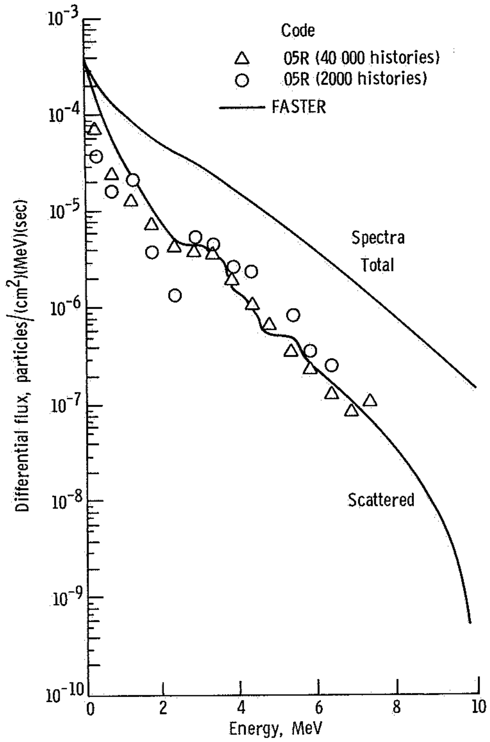

Figure 3. - Differential flux as function of energy for 20-centimeter slab at detector 2.

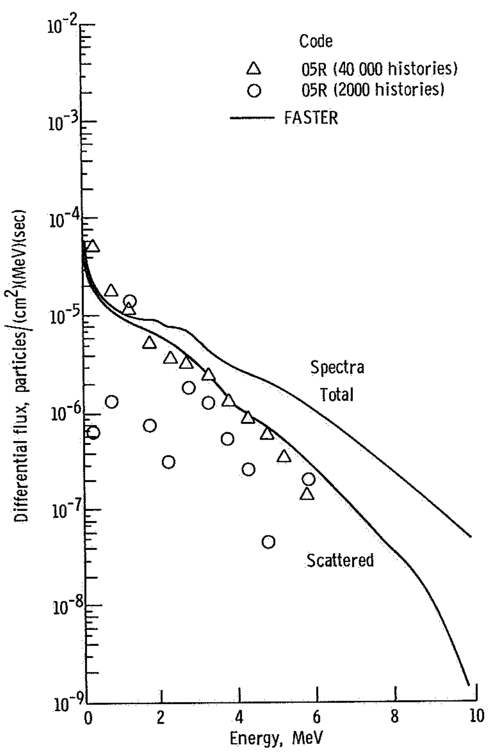

Figure 4. - Differential flux as function of energy for 20-centimeter slab at detector 4.

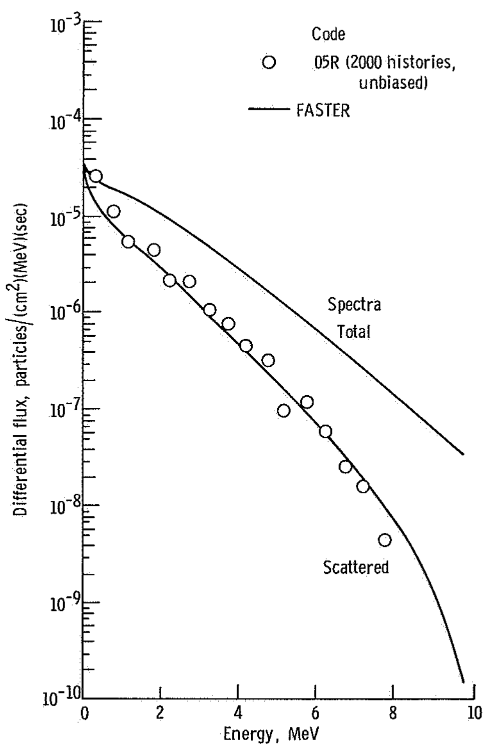

Figure 5. - Differential flux as function of energy for 100-centimeter slab at detector 1.

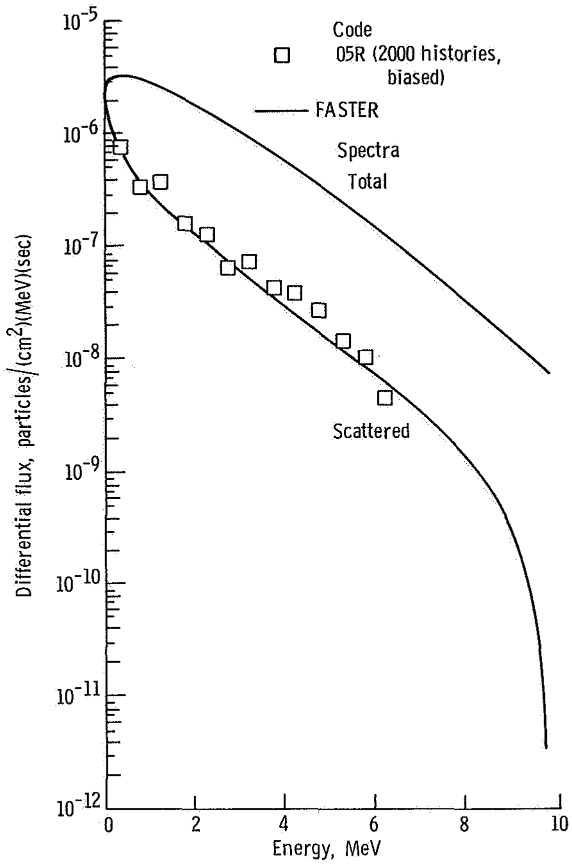

Figure 6. - Differential flux as function of energy for 100-centimeter slab at detector 2.

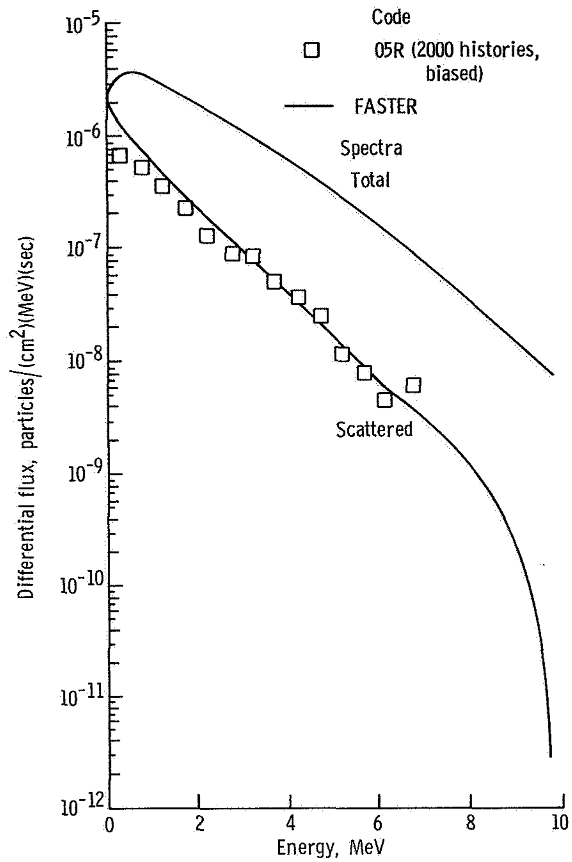

Figure 7. - Differential flux as function of energy for 100-centimeter slab at detector 3.

reflects the window in the oxygen cross section at this energy.

In carrying out the 05R 100-centimeter-slab calculations, an importance sampling method known as the exponential transformation was built into 05R to enhance deep penetration of neutrons in the direction of the detectors. Only 2000 case histories were run in 05R for the 100-centimeter slab, but sufficient accuracy was obtained. The FASTER results are in good agreement with these 05R results also. The neutron number spectrum comparison is displayed in figures 5 to 7. The agreement is excellent - much better than is normally observed in this type of spectral comparison.

In all the comparisons (figs. 2 to 7) of 05R and FASTER spectra, only the scattered spectra are compared, so that the argument of expected agreement due to large uncollided contributions is not valid - the agreement of 05R and FASTER is meaningful and constitutes a verification of FASTER for these ducted shield calculations.

For these FASTER calculations, the computing time is about 11 minutes per detector and was relatively insensitive to slab thickness. The 05R calculations presented in figures 2 to 7 required computing times a factor of 2 greater than FASTER for the 1000-case-history 20-centimeter-slab calculations, and an order of magnitude greater than

FASTER for the 2000-case-history 100-centimeter-slab calculations. The saving in computer time is the big advantage of FASTER.

CONCLUSIONS

Based on the results obtained with FASTER, it appears that the code offers a definite reduction in computing time in the analysis of ducted reactor shields. If FASTER works as well in more practical geometric duct configurations, it may be the first Monte Carlo code which can actually be used as a quick-running engineering tool in parametric ducted shield analytic studies.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, May 15, 1969,
126-15-01-03-22.

REFERENCES

1. Jordan, T. M.: FASTER, A Fortran Analytic Solution to the Transport Equation by Random Sampling. Vol. 9 of Synthesis of Calculational Methods for the Design and Analysis of Radiation Shields for Nuclear Rocket Systems. Rep. WANL-PR-(LL)-010, Westinghouse Astronuclear Lab., June 1967.
2. Anon.: Synthesis of Calculational Methods for the Design and Analysis of Radiation Shields for Nuclear Rocket Systems. Vol. 2. Rep. WANL-PR-(LL)-010, Westinghouse Astronuclear Lab., 1967.
3. Anon.: 05R. General Purpose Monte Carlo Neutron Transport Code. Rep. CCC-17, Neutron Physics Div., Oak Ridge National Lab., 1968.

NASA-Langley, 1969 —— 22 E-4829

National Aeronautics and Space Administration
Washington, D.C. 20546
OFFICIAL BUSINESS

FIRST CLASS MAIL

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

POSTMASTER: If Undeliverable (Section 158 Postal Manual) Do Not Return

---

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—National Aeronautics and Space Act of 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Notes, and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546