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Analysis of the Fall-1989 Two-Meter Box Test-Bed Experiments Performed at the Army Pulse Radiation Facility (APRF)

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MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
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Engineering Physics and Mathematics Division

ANALYSIS OF THE FALL-1989 TWO-METER BOX TEST BED EXPERIMENTS PERFORMED AT THE ARMY PULSE RADIATION FACILITY (APRF)

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EXECUTIVE SUMMARY

This report summarizes the results of a "benchmark" analysis of the Monte Carlo Adjoint Shielding Code system (MASH) against a series of experiments performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland. The series of experiments was performed during the period from October 23, 1989 through November 2, 1989 and involved experimentalists from APRF, the Defence Research Establishment Ottawa, Canada (DREO), Bubble Technology Industries, Canada, (BTI), and the Establissement Technique Central de l'Armement, France (ETCA). The "benchmark" analysis of MASH is being performed at Oak Ridge National Laboratory (ORNL) and Science Applications International Corporation (SAIC) and is designed to determine the capability of MASH to reproduce the measured neutron and gamma-ray integral and differential (spectral) data. This effort is one of the primary objectives of the MASH Verification and Validation Subtask of the Defense Nuclear Agency (DNA) Radiation Environments Program (REP). Results of the "benchmark" analyses are to be used in the recommendations to the North Atlantic Treaty Organization (NATO) Panel VII Ad Hoc Group of Shielding Experts for replacing the Vehicle Code System (VCS) with MASH as the reference code of choice for future armored vehicle nuclear vulnerability calculations.

Differential and integral measurements were made at distances of 170 and 400 meters from the APRF reactor. Free-field measurements were made at both distances while measurements made using the "NATO standard test bed" were made only at the "NATO standard reference point" at 400 meters. The "NATO standard test bed" is a large cubical steel walled box with a layer of 5.08-cm-thick steel plates mounted on the top, bottom, and all four sides. The exterior set of plates yield overall outside dimensions for the box of 220.32 cm x 220.32 cm x 220.32 cm, and are removable. The interior steel box has outside dimensions 210.16 cm x 210.16 cm x 210.16 cm with each wall having a thickness of 5.08 cm. This yields an interior air space with dimensions of 200 cm x 200 cm x 200 cm and thus gives the test bed the common name - "the two-meter box." The box also contains lift tabs, drainage holes, a cable access hole at the base on the back side of the box, and two hatches (top and back). The two-meter box test bed was chosen for the "NATO standard test bed" because the geometry provides a simplistic vehicle for experimental and theoretical (MASH) comparisons of radiation transmission through material types and thicknesses indicative of modern armored vehicles. The reactor was operated in the steady state mode for all of the measurements and environmental effects due to terrain, meteorological data, and ground moisture were assessed for inclusion in the MASH analysis.

The sequence of free-field and in-box neutron and gamma-ray measurements was carefully planned and coordinated by the APRF staff to ensure minimum interference between the different experimental teams and achieve optimum reactor-detector-box dispositions. Measurements often involved simultaneous use of several spectrometers/dosimeters and

associated electronics including as many as three NE-213 scintillators, two BGO detectors, and a ROSPEC detector system that were operating concurrently or sequentially by the different experimental teams. Also incorporated in the measurements were tissue equivalent ionization chambers (TE), Geiger-Mueller detectors (GM), Bonner Spheres, Bubble Spectrometers, a CR39 Detector, a Neptunium Ionization Chamber, and thermoluminescent (TLD) dosimeters.

The MASH calculational technique employs a forward discrete ordinates calculation to determine the neutron and gamma-ray flux on a coupling surface surrounding the armored vehicle or shielded structure and an adjoint Monte Carlo calculation to determine the dose importance of the surface flux. MASH then folds the flux together with the dose importance to yield the desired detector response(s). MASH was specifically designed to calculate the neutron and gamma-ray radiation environments and shielding protection factors of vehicles, structures, trenches, and other shield configurations. Consequently, the two-meter box experiments represent a realistic test problem for verifying the MASH code system. All calculation utilized a P_5 Legendre expansion of the cross sections, the reference DNA DABL69 69-group (46n/23γ) cross-section library, and the Kerr fluence-to-dose free-in-air tissue dose conversion factors (from the DABL69 library).

The calculation to experiment (C/E) ratios of the free-field and in-box neutron tissue dose indicate consistent agreement at the 170 and 400 meter test sites for all data except that obtained from the APRF team. (The APRF team has since acknowledged that there were problems with some of their experimental equipment.) Typical agreement (excluding APRF) was within 10% at 170 meters and between 10% and 20% at the 400 meter test site. For gamma rays, the C/E ratios indicate the calculations underestimate the measurements by approximately 35% at 170 meters, 25% at 400 meters, and approximately 10% inside the two-meter box. The consistency of the measured gamma free-field data appear to indicate some source of gammas not adequately accounted for in the calculational model. This "missing" source of gamma rays in the free-field calculation does not penetrate the two-meter box and make a significant contribution to the dose. The fluence spectra comparisons emphasize the results obtained in the integral data comparisons. In particular, the neutron spectral comparisons look reasonable with the calculated results exhibiting a spectral shift relative to the measured results and the gamma-ray spectral comparisons show an area of concern in the MASH analysis. The comparisons of the reduction factor results show calculation to experiment (C/E) ratios ranging from 1.22 to 0.76 with most of the C/E ratios between 1.07 and 0.80. The calculations compare equally well with all of the detector systems used by the different experimental teams. Furthermore, for a given parameter (i.e. fluence, dose, NRF, or GRF), the C/E ratios are generally comparable to the ratio of the different experimentally determined parameters (e.g., NE-213 NRF/TE-GM NRF, BTI n dose/ETCA n dose, etc.). In general, the calculational results were in good agreement with the experimental results measured by the different experimental teams. The agreement was typically within the ±20% limit deemed as acceptable by the DNA.

This was the first concerted effort aimed at benchmarking the MASH code against experimental measurements and there were some glitches in the effort. This series of measurements, however, has been successful in laying the foundation for the next set of measurements which will include duplicates of the measurements made in this series as well as measurements involving a humanoid phantom standing free-field and inside the two-meter box test bed. From this effort, with better communication and understanding between the analysts and experimentalists as to the needs of the other, better agreement is achievable for all comparisons; possibly within a tighter acceptance limit (i.e. 10% - 15%).

ABSTRACT

The capability to accurately assess and predict the effectiveness of radiation shielding materials in vehicles, structures, trenches, and other configurations is of considerable interest to the DoD and the DNA. A research effort involving several institutions has worked towards providing this capability for several years, resulting in the first code system called the Vehicle Code System (VCS) and the successor to VCS, referred to as the Monte Carlo Adjoint Shielding Code system - MASH. The purpose of this report is to present the results of a "benchmark" analysis of the MASH computer code system against the first in a series of experiments performed at the APRF and determine the capability of MASH to reproduce the measured neutron and gamma-ray integral and differential (spectral) data. In particular, free-field environments at 170 and 400 meters were to be calculated along with measurements made using the "NATO standard test bed" (i.e. the two-meter box) at the "NATO standard reference point" at 400 meters.

The calculation to experiment (C/E) ratios of the free-field and in-box neutron tissue dose indicate consistent agreement at the 170 and 400 meter test sites for all data except that obtained from the APRF team. (The APRF team has since acknowledged that there were problems with some of their experimental equipment.) Typical agreement (excluding APRF) was within 10% at 170 meters and between 10% and 20% at the 400 meter test site. For gamma rays, the C/E ratios indicate the calculations underestimate the measurements by approximately 35% at 170 meters, 25% at 400 meters, and approximately 10% inside the two-meter box. The consistency of the measured gamma free-field data appear to indicate some source of gammas not adequately accounted for in the calculational model. This "missing" source of gamma rays in the free-field calculation does not penetrate the two-meter box and make a significant contribution to the dose.

The fluence spectra comparisons support the results obtained in the integral data comparisons. In particular, the neutron spectral comparisons look reasonable with the calculated results exhibiting a spectral shift relative to the measured results and the gamma-ray spectral comparisons show an area of concern in the MASH analysis.

The comparisons of the reduction factor results show C/E ratios ranging from 1.22 to 0.76 with most of the C/E ratios between 1.07 and 0.80. The calculations compare equally well with all of the detector systems used by the different experimental teams. Furthermore, for a given parameter (i.e., NRF or GRF), the C/E ratios are generally comparable to the ratio of the different experimentally determined parameters (e.g., NE-213 NRF/TE-GM NRF, etc.).

In general, the calculated results were in good agreement with the experimental results measured by the different experimental teams. The agreement was typically within the ±20% limit deemed as acceptable by the DNA.

1.0 INTRODUCTION

1.1 Objective

This paper summarizes the results of the new Monte Carlo Adjoint Shielding (MASH) code system[1] calculations designed to model the first in a series of nuclear radiation shielding experiments. These experiments were performed in the Fall of 1989 at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Grounds, Maryland. The MASH results are compared with experimental results obtained using widely different detector systems by experimentalists from APRF, the Defence Research Establishment Ottawa, Canada (DREO), Bubble Technology Industries, Canada, (BTI), and the Establissement Technique Central de l'Armement, France (ETCA). Results of the comparisons are to be used in the recommendations to the North Atlantic Treaty Organization (NATO) Panel VII Ad Hoc Group of Shielding Experts for replacing the Vehicle Code System (VCS)[2,3] with MASH as the reference code of choice for future armored vehicle nuclear vulnerability calculations.

The specific objective of the effort described in this report was to "benchmark" the MASH computer code system against the experiments performed at the APRF and determine the capability of MASH to reproduce the measured neutron and gamma-ray integral and differential (spectral) data. In particular, free-field environments at 170 and 400 meters were to be calculated along with measurements made using the "NATO standard test bed" (i.e. the two-meter box) at the "NATO standard reference point" at 400 meters. Environmental effects due to meteorological and ground moisture data were to be assessed in the MASH analysis of the APRF experimental measurements.

1.2 Purpose of MASH Development

An armored vehicle can provide protection against the effects of a nuclear weapon. In the case of tactical weapons, prompt radiation may be the dominant effect over a considerable area surrounding the detonation. To facilitate the calculation of radiation protection factors for a given vehicle; i.e., the ratio by which the free-field radiation is reduced due to the presence of the vehicle, VCS was developed by Oak Ridge National Laboratory (ORNL). While the title implies the code system was to be used only for vehicles, VCS could be used for other shielded structures also. For over a decade, the Department of Defense (DoD) and NATO have relied almost exclusively on VCS for calculating neutron and gamma-ray radiation fields and shielding protection factors for tactical armored vehicles, buildings, and other shielded configurations from nuclear weapon radiation.

Over the course of time, many different versions of VCS were developed by installations using the code and making modifications and/or improvements to suit their particular purpose. The result of this independent development was a proliferation of different versions of

VCS, most of which were not compatible and yielded different results. The Defense Nuclear Agency (DNA) and Army Foreign Science and Technology Center (AFSTC) expressed concern over the potential for disagreement between independent analyses of the same armored vehicle. As a result, BRL, ORNL, and Science Applications International Corporation (SAIC) were tasked to identify the problems associated with the "current" version(s) of VCS, incorporate the various modifications (which would improve the code) , and create a singular referenced version of VCS. The purpose was to establish a version of VCS which is generally acceptable to the user community, and place this version under responsible custody on the DNA computing network for use on the CRAY computer system at Los Alamos National Laboratory (LANL). This final version of VCS was renamed MASH (to mitigate confusion with the various versions of VCS) and given a version number, i.e. MASH 1.0, for referencing purposes.

MASH is currently being appraised as the "code-of-choice" to replace VCS. However, before it can be adopted, the code system must first be verified and validated through comparisons with experimental data and with previously calculated results using VCS. This effort is one of the primary objectives of the ORNL MASH Verification and Validation Subtask of the DNA Radiation Environments Program (REP).

2.0 THE TWO-METER BOX TEST BED EXPERIMENTS

One of the purposes of the two-meter box test bed experiments was to provide spectral and integral data for use in the verification and validation of the Monte Carlo adjoint shielding code - MASH. The experimental measurements were conducted at the Army Pulse Radiation Facility (APRF) bare fast reactor at Aberdeen Proving Grounds, Maryland. The verification and validation of MASH is being performed at ORNL and SAIC.

2.1 The APRF Reactor Source

The APRF reactor is a bare critical assembly in the form of a right circular cylinder 22.6 cm in diameter and 19.8 cm in height. The reactor is mounted on a transporter and positioned outdoors at a height of 12.7 meters above the borated concrete experiment pad and approximately 14 meters (on the average) above the surrounding terrain to simulate a (low intensity) neutron and gamma-ray radiation environment typical of a tactical nuclear weapon. A topographical map of the APRF area from the reactor building out beyond the 400 meter test site was provided by the APRF staff.[4] This map allowed for an accurate representation of the ground contour along the axis between the reactor and two-meter box to be modeled in the MASH analysis. A schematic diagram of the terrain profile from the reactor experiment pad to the 400 meter test site is shown in Figure 1.

The neutron emission from the reactor is anisotropic, with the angular distribution peaked in the horizontal direction. In early 1989, SAIC performed a detailed analysis of the APRF reactor and produced a new energy- and angle-differential leakage spectrum to be used as a source for all future transport calculations.[5] The leakage spectrum was produced using the reference DNA Defense Applications Broad-group Library (DABL69) 69 group (46n/23γ) cross-section library[6] and a modified S_8 quadrature in which each direction is subdivided into five directions, yielding a 240 angle quadrature. The neutron leakage spectrum integrated over all angles is given in Table 1 and yields an absolute normalization of 1.26×10^{17} source neutrons per kw·hr.

The APRF gamma-ray leakage spectrum is divided into two components, prompt and secondary gamma-ray leakage, and delayed gamma-ray leakage. The prompt and secondary gamma-ray leakage spectrum is a function of the reactor model used in the source analysis and is constant in both number of gamma rays per source neutron and spectral shape. The delayed gamma-ray leakage spectrum changes as a function of time after a fission event and therefore varies in both number and spectral shape. SAIC calculated delayed gamma-ray spectra for three different durations of operation; fifteen minutes, one hour, and four hours. For the purposes of the two-meter box test bed experiments, the one hour delayed gamma spectrum was utilized in the MASH analysis. The prompt and secondary, one hour delayed, and total gamma-ray leakage spectra are given in Table 2, and

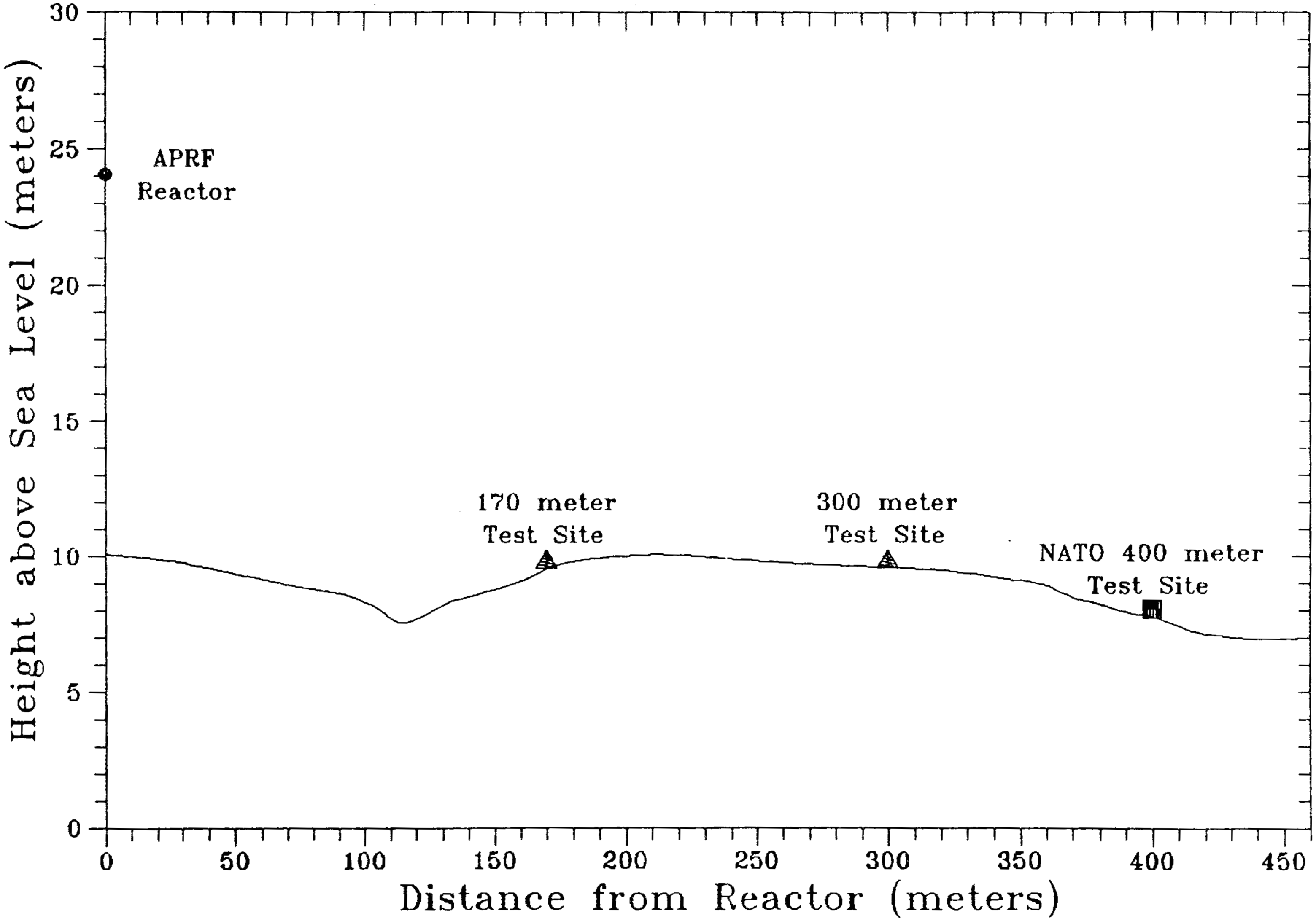

Figure 1. Schematic diagram of the terrain profile from the reactor experiment pad to the 400 meter test site.

Table 1. APRF Reactor Neutron Leakage Source used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments. (Units of particles per group per effective kw-hr)

Group Number	Upper Energy (eV)	Neutron Leakage	Group Number	Upper Energy (eV)	Neutron Leakage
1	1.964+07[a]	3.50+11	24	8.209+05	4.42+15
2	1.691+07	1.38+12	25	7.427+05	6.75+15
3	1.492+07	1.59+12	26	6.393+05	6.36+15
4	1.419+07	1.17+12	27	5.502+05	1.32+16
5	1.384+07	9.02+12	28	3.688+05	9.24+15
6	1.252+07	3.63+12	29	2.472+05	6.03+15
7	1.221+07	2.73+13	30	1.576+05	2.75+15
8	1.105+07	5.90+13	31	1.111+05	2.35+15
9	1.000+07	1.14+14	32	5.248+04	5.52+14
10	9.048+06	2.05+14	33	3.431+04	1.95+14
11	8.187+06	3.37+14	34	2.479+04	5.65+13
12	7.408+06	8.62+14	35	2.188+04	1.18+14
13	6.376+06	2.68+15	36	1.060+04	3.19+13
14	4.966+06	7.66+14	37	3.355+03	4.84+12
15	4.724+06	2.82+15	38	1.234+03	4.36+11
16	4.066+06	8.07+15	39	5.830+02	6.18+10
17	3.012+06	8.45+15	40	2.754+02	1.47+10
18	2.385+06	1.35+15	41	1.013+02	2.44+09
19	2.307+06	9.90+15	42	2.902+01	3.17+08
20	1.827+06	1.16+16	43	1.068+01	5.98+07
21	1.423+06	1.24+16	44	3.059+00	8.73+06
22	1.108+06	6.84+15	45	1.125+00	1.53+06
23	9.616+05	7.57+15	46	4.140-01	2.44+05
				1.000-05	
				Total	1.26+17

[a]Read as 1.964×10^7.

Table 2. APRF Reactor Prompt and Secondary, One Hour Delayed, and Total Gamma-Ray Leakage Sources used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments. (Units of particles per group per effective kw-hr)

Group Number	Upper Energy (eV)	Prompt and Secondary Gamma Leakage	One Hour Delayed Gamma Leakage	Total Gamma-Ray Leakage
1	2.000+07[a]	2.24+09	0.00+00	2.24+09
2	1.400+07	1.11+10	0.00+00	1.11+10
3	1.200+07	5.04+11	0.00+00	5.04+11
4	1.000+07	1.59+13	0.00+00	1.59+13
5	8.000+06	2.12+13	2.00+12	2.32+13
6	7.000+06	4.95+13	8.66+12	5.82+13
7	6.000+06	1.75+14	5.11+13	2.26+14
8	5.000+06	3.78+14	2.01+14	5.79+14
9	4.000+06	1.21+15	6.61+14	1.87+15
10	3.000+06	1.31+15	6.72+14	1.98+15
11	2.500+06	2.27+15	1.09+15	3.36+15
12	2.000+06	3.92+15	1.69+15	5.61+15
13	1.500+06	7.13+15	3.05+15	1.02+16
14	1.000+06	7.06+15	2.40+15	9.46+15
15	7.000+05	6.29+15	2.29+15	8.58+15
16	4.550+05	2.90+15	1.03+15	3.93+15
17	3.000+05	2.38+15	8.02+14	3.18+15
18	1.500+05	4.40+14	1.43+14	5.83+14
19	1.000+05	5.37+13	1.70+13	7.07+13
20	7.000+04	2.27+12	6.79+11	2.95+12
21	4.500+04	7.15+10	6.38+09	7.79+10
22	3.000+04	8.69+09	3.84+07	8.73+09
23	2.000+04	3.12+10	1.13+05	3.12+10
	1.000+04			
	Total	3.56+16	1.41+16	4.97+16
Gamma ray number leaking per leaking neutron		0.282	0.112	0.394

[a]Read as 2.000 x 10^7.

the number of gamma rays per source neutron are 0.282, 0.112, and 0.394 respectively.

2.2 The Two-Meter Box Test Bed

The "NATO standard test bed" is a large cubical steel walled box with a layer of 5.08-cm-thick steel plates mounted on the top, bottom, and all four sides. The exterior set of plates yield overall outside dimensions for the box of 220.32 cm x 220.32 cm x 220.32 cm, and are removable. The interior steel box has outside dimensions 210.16 cm x 210.16 cm x 210.16 cm with each wall having a thickness of 5.08 cm. This yields an interior air space with dimensions of 200 cm x 200 cm x 200 cm and thus gives the test bed the common name - "the two-meter box." The box also contains lift tabs (for movement by crane), drainage holes at the base, a cable access hole at the base on the back side of the box, and two hatches. The hatches are located in the center of the top and back faces of the box and the hatch diameters in the interior box and outside plates are staggered to mitigate radiation streaming paths into the box. The hatches are included for loading and unloading experimental equipment (e.g. detectors, phantoms, etc.) and for simulating open-hatch vehicle experiments. An isometric view of the two-meter box test bed is shown in Figure 2. The two-meter box test bed was chosen for the "NATO standard test bed" because the geometry provides a simplistic vehicle for experimental and analytical (MASH) comparisons of radiation transmission through material types and thicknesses indicative of modern armored vehicles.

2.3 Details of the Measurements

The reactor was operated in the steady state mode for all of the free-field and two-meter box test bed experiments reported in this document. Power levels and run durations were determined for each experiment by the requirements of the detector system being used to assure sufficient statistical accuracy in the measured results. Meteorological data (air temperature, barometric pressure, and relative humidity) was recorded during the course of the experiments by the Aberdeen Proving Grounds Meteorological Observation Station at Poverty Island and provided to the APRF staff. The reactor operation data and the meteorological data are summarized in Table 3 as a function of the date of the measurement and reactor run number. The meteorological data given in the table are mean values (for the duration of that particular experiment) obtained from observations taken every half hour, and in some cases, every quarter hour. Analysis of this data yielded the material data presented in Table 4 and the atom density data given in Table 5 for the air environment present during the course of the experiments. In addition, the APRF staff made several ground moisture measurements throughout the course of the experiments to record the water content of the soil. Table 6 lists the ground moisture data recorded by date and measurement position, and Figure 3 shows the ground moisture measurement positions relative to the reactor and two-meter box. The average soil moisture

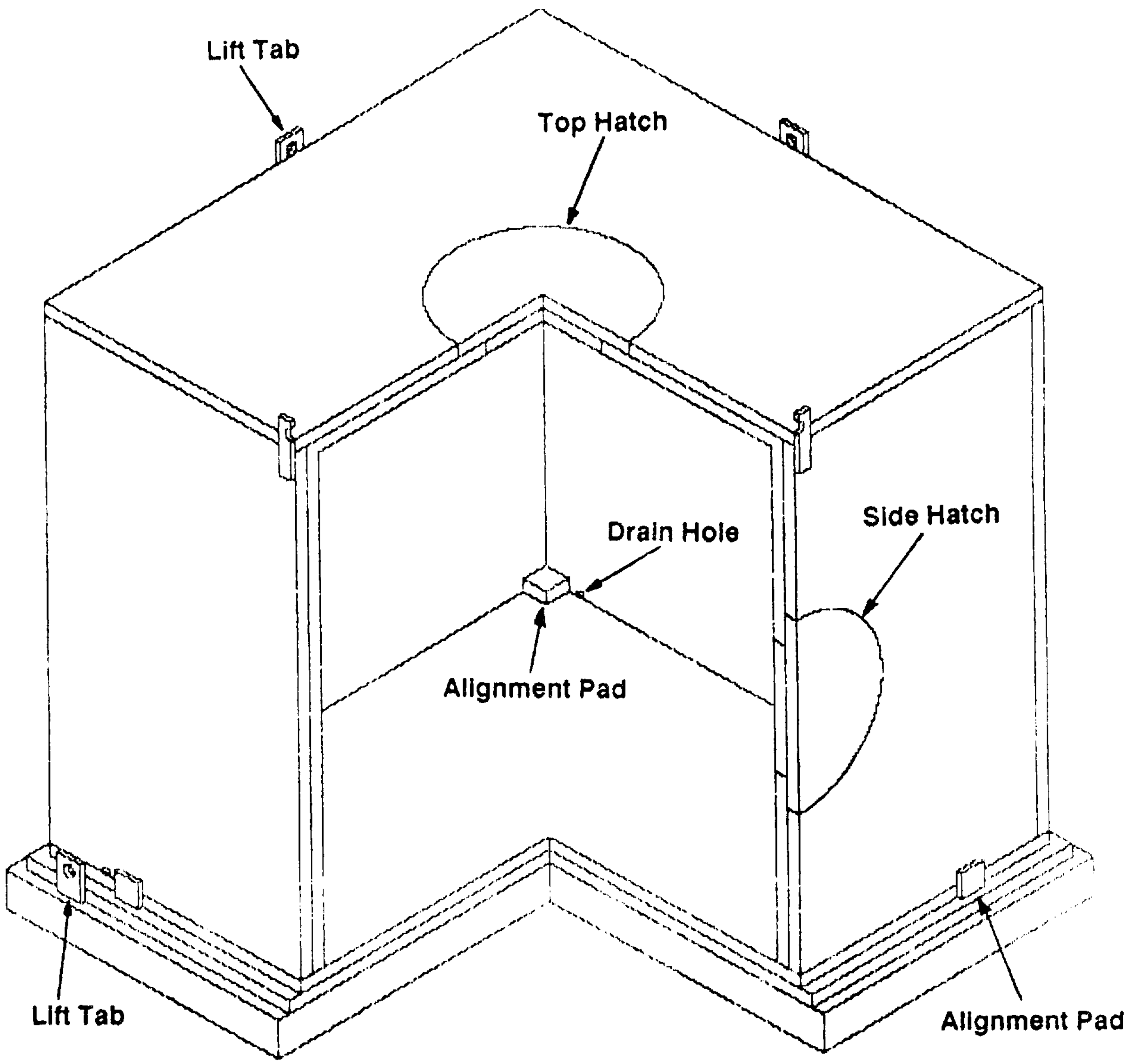

Figure 2. Isometric view of the Two-Meter Box Test Bed.

Table 3. Reactor Operational Data and Meteorological Data for the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

		Reactor Data			Meteorological Data		
Run Number	Date	Operating Time (min)	Power Level (kw)	Integrated Power (kw·min)	Air Temperature (K)	Air Pressure (mm Hg)	Relative Humidity (%)
218	10/23/89	60.00	6.0	360.00	290.4	772.3	47
219	10/24/89	120.00	2.0	240.00	289.2	773.8	67
220	10/24/89	80.50	0.4	32.20	290.7	771.8	37
221	10/24/89	30.50	0.4	12.20	282.3	772.3	78
222	10/25/89	125.00	3.0-6.0[a]	740.00	291.3	771.4	54
223	10/25/89	80.25	0.6	48.15	295.3	770.0	45
224	10/25/89	44.50	0.6-2.0[b]	77.10	289.0	769.9	72
225	10/26/89	125.00	2.0-0.4[c]	170.00	292.2	771.4	75
226	10/26/89	131.00	4.0	524.00	297.5	770.0	41
228	10/27/89	10.00	2.0	20.00	288.5	771.4	93
229	10/27/89	10.00	3.0	30.00	294.3	771.2	67
230	10/27/89	30.00	4.0	120.00	296.0	770.8	55
233	10/30/89	101.00	0.1	10.10	294.0	766.8	77
234	10/30/89	100.00	0.04-0.3[d]	11.80	293.0	766.0	79
235	10/31/89	10.00	0.1	1.00	291.0	761.5	96
236	10/31/89	10.00	0.2	2.00	293.5	758.1	91
237	10/31/89	10.00	0.4	4.00	292.2	756.0	91
238	11/01/89	10.00	5.0	50.00	285.6	766.1	60
239	11/01/89	30.00	3.0	90.00	286.5	766.3	53
240	11/01/89	10.00	5.0	50.00	286.7	765.9	53
241	11/01/89	32.00	6.0	192.00	288.2	765.6	49
242	11/01/89	10.00	5.0	50.00	288.5	765.4	44
243	11/01/89	30.00	6.0	180.00	288.2	765.7	42
244	11/01/89	10.00	0.1	1.00	287.3	766.1	43
245	11/01/89	10.00	6.0	60.00	285.5	766.5	45
246	11/01/89	30.00	6.0	180.00	283.6	766.8	54
247	11/02/89	30.00	6.0	180.00	284.7	767.5	62
248	11/02/89	30.00	6.0	180.00	285.4	767.2	59
249	11/02/89	10.00	2.0	20.00	286.0	766.4	55
250	11/02/89	180.00	6.0	1080.00	285.5	764.9	54

[a] 2 min at 3 kw, 1 min at 4 kw, 2 min at 5 kw, and 120 min at 6 kw
[b] 8.5 min at 600 w and 32 min at 2 kw
[c] 75 min at 2 kw and 50 min at 400 w
[d] 70 min at 40 w and 30 min at 300 w

Table 4. Material Data for the Air Environment Present in the Two Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Date	Air Environment Material Data				
	Sat. Water Vapor Pres (mm Hg)	Real Water Vapor Pres (mm Hg)	Wet Air Density (gm/cm^3)	Dry Air Density (gm/cm^3)	Water Density (gm/cm^3)
10/23/89	1.4762E+01[a]	6.9381E+00	1.2303E-03	1.2234E-03	6.8985E-06
10/24/89	1.3678E+01	9.1641E+00	1.2365E-03	1.2274E-03	9.1495E-06
10/24/89	1.5045E+01	5.5666E+00	1.2291E-03	1.2236E-03	5.5290E-06
10/24/89	8.6975E+00	6.7840E+00	1.2657E-03	1.2588E-03	6.9388E-06
10/25/89	1.5624E+01	8.4370E+00	1.2242E-03	1.2158E-03	8.3628E-06
10/25/89	2.0009E+01	9.0042E+00	1.2051E-03	1.1963E-03	8.8041E-06
10/25/89	1.3504E+01	9.7231E+00	1.2308E-03	1.2210E-03	9.7143E-06
10/26/89	1.6529E+01	1.2397E+01	1.2181E-03	1.2058E-03	1.2250E-05
10/26/89	2.2854E+01	9.3699E+00	1.1960E-03	1.1869E-03	9.0940E-06
10/27/89	1.3079E+01	1.2163E+01	1.2338E-03	1.2216E-03	1.2174E-05
10/27/89	1.8822E+01	1.2611E+01	1.2089E-03	1.1966E-03	1.2373E-05
10/27/89	2.0878E+01	1.1483E+01	1.2020E-03	1.1908E-03	1.1201E-05
10/30/89	1.8479E+01	1.4229E+01	1.2022E-03	1.1883E-03	1.3974E-05
10/30/89	1.7373E+01	1.3725E+01	1.2054E-03	1.1919E-03	1.3525E-05
10/31/89	1.5332E+01	1.4719E+01	1.2059E-03	1.1913E-03	1.4605E-05
10/31/89	1.7919E+01	1.6306E+01	1.1893E-03	1.1732E-03	1.6042E-05
10/31/89	1.6529E+01	1.5041E+01	1.1920E-03	1.1771E-03	1.4863E-05
11/01/89	1.0835E+01	6.5007E+00	1.2412E-03	1.2346E-03	6.5722E-06
11/01/89	1.1491E+01	6.0901E+00	1.2379E-03	1.2318E-03	6.1377E-06
11/01/89	1.1642E+01	6.1703E+00	1.2363E-03	1.2301E-03	6.2141E-06
11/01/89	1.2829E+01	6.2863E+00	1.2293E-03	1.2230E-03	6.2981E-06
11/01/89	1.3079E+01	5.7548E+00	1.2281E-03	1.2223E-03	5.7595E-06
11/01/89	1.2829E+01	5.3883E+00	1.2301E-03	1.2247E-03	5.3984E-06
11/01/89	1.2105E+01	5.2050E+00	1.2347E-03	1.2294E-03	5.2311E-06
11/01/89	1.0764E+01	4.8437E+00	1.2433E-03	1.2384E-03	4.8986E-06
11/01/89	9.4898E+00	5.1245E+00	1.2520E-03	1.2467E-03	5.2173E-06
11/02/89	1.0210E+01	6.3304E+00	1.2475E-03	1.2411E-03	6.4202E-06
11/02/89	1.0693E+01	6.3090E+00	1.2440E-03	1.2376E-03	6.3828E-06
11/02/89	1.1122E+01	6.1168E+00	1.2402E-03	1.2340E-03	6.1754E-06
11/02/89	1.0764E+01	5.8124E+00	1.2401E-03	1.2342E-03	5.8784E-06

[a]Read as 1.4762×10^1.

Table 5. Number Densities for the Air Environment Present in the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Date	Air Number Densities			
	Hydrogen (atoms/b·cm)	Nitrogen (atoms/b·cm)	Oxygen (atoms/b·cm)	Argon (atoms/b·cm)
10/23/89	4.6158E-07[a]	3.9724E-05	1.0888E-05	2.3758E-07
10/24/89	6.1220E-07	3.9851E-05	1.0997E-05	2.3834E-07
10/24/89	3.6995E-07	3.9728E-05	1.0843E-05	2.3760E-07
10/24/89	4.6428E-07	4.0872E-05	1.1197E-05	2.4445E-07
10/25/89	5.5956E-07	3.9477E-05	1.0870E-05	2.3610E-07
10/25/89	5.8909E-07	3.8842E-05	1.0715E-05	2.3230E-07
10/25/89	6.4999E-07	3.9646E-05	1.0961E-05	2.3711E-07
10/26/89	8.1966E-07	3.9151E-05	1.0913E-05	2.3415E-07
10/26/89	6.0849E-07	3.8536E-05	1.0642E-05	2.3048E-07
10/27/89	8.1455E-07	3.9666E-05	1.1048E-05	2.3723E-07
10/27/89	8.2788E-07	3.8851E-05	1.0836E-05	2.3236E-07
10/27/89	7.4950E-07	3.8665E-05	1.0747E-05	2.3124E-07
10/30/89	9.3503E-07	3.8582E-05	1.0818E-05	2.3075E-07
10/30/89	9.0498E-07	3.8698E-05	1.0834E-05	2.3144E-07
10/31/89	9.7721E-07	3.8680E-05	1.0865E-05	2.3133E-07
10/31/89	1.0734E-06	3.8094E-05	1.0756E-05	2.2783E-07
10/31/89	9.9452E-07	3.8221E-05	1.0751E-05	2.2859E-07
11/01/89	4.3975E-07	4.0088E-05	1.0974E-05	2.3975E-07
11/01/89	4.1068E-07	3.9994E-05	1.0934E-05	2.3919E-07
11/01/89	4.1580E-07	3.9941E-05	1.0923E-05	2.3887E-07
11/01/89	4.2141E-07	3.9711E-05	1.0864E-05	2.3750E-07
11/01/89	3.8538E-07	3.9687E-05	1.0840E-05	2.3736E-07
11/01/89	3.6121E-07	3.9763E-05	1.0848E-05	2.3781E-07
11/01/89	3.5002E-07	3.9918E-05	1.0884E-05	2.3874E-07
11/01/89	3.2777E-07	4.0210E-05	1.0951E-05	2.4049E-07
11/01/89	3.4910E-07	4.0481E-05	1.1034E-05	2.4210E-07
11/02/89	4.2958E-07	4.0297E-05	1.1025E-05	2.4101E-07
11/02/89	4.2708E-07	4.0184E-05	1.0994E-05	2.4033E-07
11/02/89	4.1320E-07	4.0068E-05	1.0956E-05	2.3963E-07
11/02/89	3.9333E-07	4.0075E-05	1.0947E-05	2.3968E-07

[a]Read as 4.6158×10^{-7}.

Table 6. Moisture and Density Data for the Ground Present in the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Date	Measurement Position	Bulk Density (gm/cm^3)	Dry Density (gm/cm^3)	Percent Moisture (%)	Distance From Reactor (meters)
10/23/89	3	1.648	1.128	46.1	375
10/23/89	5	1.768	1.347	31.3	385
10/23/89	8	1.881	1.519	23.8	395
10/24/89	1	1.663	1.305	27.4	170
10/24/89	2	1.728	1.179	46.6	300
10/24/89	3	1.651	1.184	39.5	375
10/24/89	4	1.711	1.169	46.5	385[a]
10/24/89	5	1.704	1.326	28.6	385
10/24/89	6	1.959	1.584	23.7	385[b]
10/24/89	7	1.602	1.096	46.1	395[a]
10/24/89	8	1.913	1.551	23.4	395
10/24/89	9	1.909	1.586	20.4	395[b]
10/24/89	10	1.466	1.346	8.8	400[c]
10/24/89	11	1.709	1.160	47.3	415
10/27/89	3	1.619	1.182	37.0	375
10/31/89	1	1.685	1.299	29.7	170

[a]Measurement position is offset 10 meters north from the line of sight between the reactor and two-meter box.

[b]Measurement position is offset 10 meters south from the line of sight between the reactor and two-meter box.

[c]Measurement position is at the two-meter box.

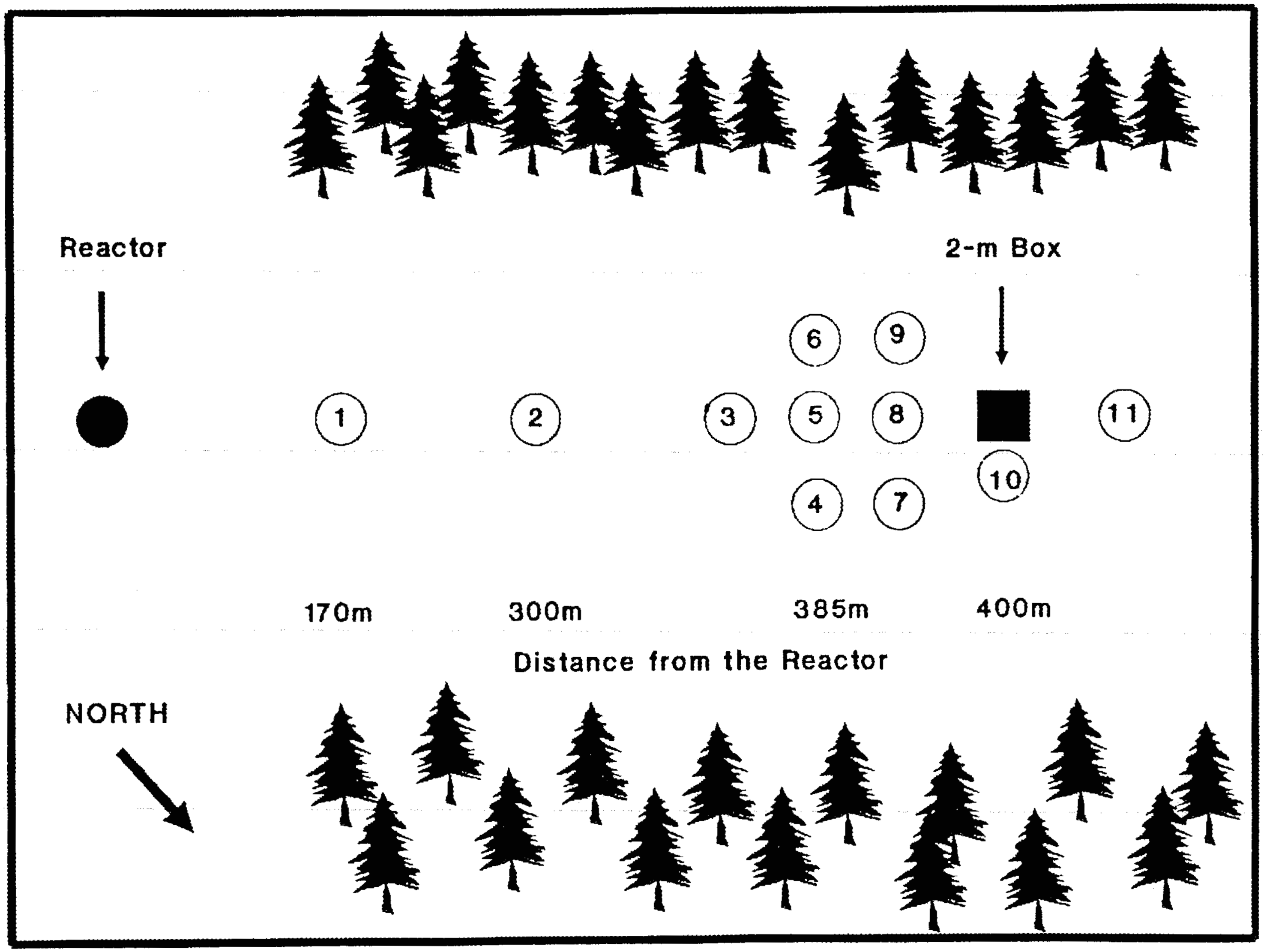

Figure 3. Schematic Diagram of the Ground Moisture Measurement Positions Relative to the APRF Reactor and Two-Meter Box Test Bed at the 400 Meter Test Site.

content over the course of the experiments was approximately 34% by weight of dry soil.

All measurements on the two-meter box test bed were made at a distance of 400 meters from the APRF reactor. This 400 meter test site is referred to as the "NATO standard reference point" and is a sufficient distance for the neutron and gamma-ray spectra to reach equilibrium shapes due to modifications of the reactor source from interactions in the air and ground. The box was oriented with one face normal to the axis from the reactor to the test site and with the hatch on the back face away from the APRF reactor. In all of the measurements both hatches were closed. The box was always present at the 400 meter test site. Free-field measurements were obtained by placing the detectors at a distance of 400 meters from the reactor and separated from the two-meter box by approximately 10 meters. The in-box measurements were obtained by placing the detectors inside the box with the signal and high voltage cables passing through the cable port to data acquisition equipment inside the APRF building or to mobile counting laboratories located near the 400 meter site.

2.4 Experimental Measurement Equipment

Several different detectors were used by the different experimental teams to measure the radiation environments free-field and inside the two-meter box test bed. Some of the detectors measure the same quantities but use different physical principles. Therefore, consistency among the different detector results should be an indicator of the quality of the experimental results.

The sequence of free-field and in-box neutron and gamma-ray measurements was carefully planned and coordinated by the APRF staff to ensure minimum interference between the different experimental teams and achieve optimum reactor-detector-box dispositions. Measurements often involved simultaneous use of several spectrometers/dosimeters and associated electronics including as many as three NE-213 scintillators, two BGO detectors, and a ROSPEC detector system that were operating concurrently or sequentially by the different experimental teams. Also incorporated in the measurements were tissue equivalent ionization chambers (TE), Geiger-Mueller detectors (GM), Bonner Spheres, Bubble Spectrometers, a CR39 Detector, a Neptunium Ionization Chamber, and thermoluminescent (TLD) dosimeters. The detector systems used by each experimental team are listed in Table 7 along with the energy ranges for which the detector system yields valid results.

Each experimental team collected differential (spectral) and integral (kerma) data at the 170 and 400 meter test sites. Kerma values were reported for free-field measurements at 170 and 400 meters and inside the two-meter box at 400 meters. The data summarized in this report were taken primarily from presentation charts and other documents that were distributed at the DNA Radiation Environments Program Review Meeting held on February 20-22, 1990.

Table 7. Detectors Used by the Different Experimentalists in the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

APRF TEAM

NE-213 Liquid Scintillator
 $600 \text{ keV} < E_n < 10 \text{ MeV}$; $300 \text{ keV} < E_\gamma < 9 \text{ MeV}$[a]
Tissue Equivalent Ionization Chamber + Geiger Mueller Counter
 $1 \text{ keV} < E_n < 20 \text{ MeV}$; $10 \text{ keV} < E_\gamma < 20 \text{ MeV}$
Bonner Spheres
 $1 \text{ keV} < E_n < 20 \text{ MeV}$

DREO/BTI TEAM

ROSPEC System (Rotating system of four hydrogen based proportional counters)
 $60 \text{ keV} < E_n < 4.5 \text{ MeV}$
NE-213 Liquid Scintillator/BF_3 System
 NE-213: $600 \text{ keV} < E_n < 7.6 \text{ MeV}$; System: Thermal $< E_n < 20 \text{ MeV}$
Bubble Spectrometer (BD-100R)
 $10 \text{ keV} < E_n < 20 \text{ MeV}$
BGO Spectrometer
 $100 \text{ keV} < E_\gamma < 10 \text{ MeV}$

ETCA TEAM

NE-213 Liquid Scintillator
 $600 \text{ keV} < E_n < 12 \text{ MeV}$
NE-213 Liquid Scintillator/BF_3 System
 NE-213: $600 \text{ keV} < E_n < 12 \text{ MeV}$; System: Thermal $< E_n < 20 \text{ MeV}$
BGO Spectrometer (1 inch x 1 inch)
 $100 \text{ keV} < E_\gamma < 10 \text{ MeV}$
Neptunium Ionization Chamber (Np)
 $700 \text{ keV} < E_n < 20 \text{ MeV}$
Tissue Equivalent Ionization Chamber + Geiger Mueller Counter
 $1 \text{ keV} < E_n < 20 \text{ MeV}$; $80 \text{ keV} < E_\gamma < 20 \text{ MeV}$
Bubble Spectrometer (BD-100R from BTI)
 $10 \text{ keV} < E_n < 20 \text{ MeV}$
CR39 Detector
 $200 \text{ keV} < E_n < 20 \text{ MeV}$
Thermoluminescent Dosimeter (TLD)
 $10 \text{ keV} < E_\gamma < 20 \text{ MeV}$

[a]Energy ranges correspond to those over which the measured data are reported.

3.0 MASH CALCULATIONAL TECHNIQUES

The MASH calculational technique employs a GRTUNCL-DORT[7] forward discrete ordinates calculation to determine the neutron and gamma-ray flux on a coupling surface surrounding the armored vehicle or shielded structure and a MORSE[8] adjoint Monte Carlo calculation to determine the dose importance of the surface flux. MASH then utilizes the Detector Response Code (DRC)[1] to fold the flux together with the dose importance to yield the desired detector response(s). MASH was specifically designed to calculate the neutron and gamma-ray radiation environments and shielding protection factors of vehicles, structures, trenches, and other shield configurations. Consequently, the two-meter box experiments represent a realistic test problem for verifying the MASH code system.

3.1 Definition of Protection and Reduction Factors

Two quantities that are indicative of the ability of a ground combat vehicle to protect its crew members from penetrating nuclear radiation are protection factors (PFs) and reduction factors (RFs). The protection factors are more useful in the characterization of the vehicle shielding, whereas the reduction factors are more useful for comparisons with experimental data.

The total protection factor (TPF) is defined as follows:

$$TPF = D_{FF}/D_{IV} \qquad (3\text{-}1)$$

where:

D_{FF} = the free-field total dose,

and

D_{IV} = the in-vehicle total dose.

Two of the biologically important radiations from the detonation of a nuclear weapon are neutrons and subsequent secondary gamma rays.[9] A more complete shielding analysis is possible by further defining a neutron protection factor (NPF) and gamma protection factor (GPF).

The neutron protection factor (NPF) is defined as:

$$NPF = N_{FF}/(N_{IV} + G_V) \qquad (3\text{-}2)$$

where:

N_{FF} = the free-field neutron dose

N_{IV} = the in-vehicle neutron dose

and

G_V = the in-vehicle dose from gamma rays produced by neutron interactions with the vehicle (secondary gammas).

The gamma protection factors (GPF) is defined as:

$$GPF = G_{FF}/G_{AG} \tag{3-3}$$

where:

G_{FF} = the free-field dose from gamma rays produced by prompt fission and from neutron interactions with the air and ground.

and

G_{AG} = the in-vehicle dose from gamma rays produced by prompt fission and from neutron interactions with the air and ground.

The neutron protection factor considers only the incident radiation field due to neutrons, scattered or unscattered, and secondary gamma radiation arising from (n,γ) reactions with the vehicle. Similarly, the gamma protection factor treats only that incident radiation resulting from gamma rays produced by prompt fission and extra-vehicle (n,γ) reactions (air and ground). The prompt (fission) gamma radiation from the source usually can be neglected relative to the gamma radiation produced by (n,γ) reactions in the air and ground.[9]

Because detector systems are unable to discern the origin of the gamma rays (i.e. source, air secondary gamma ray, vehicle secondary gamma ray, etc.) contributing to the in-vehicle dose, it is anticipated that the calculated reduction factors will be more easily compared with experimental measurements than the protection factors.

The total reduction factor (TRF) is defined as follows:

$$TRF = D_{FF}/D_{IV} \tag{3-4}$$

where:

D_{FF} = the free-field total dose,

and

D_{IV} = the in-vehicle total dose.

It should be noted that the total protection factor (Eq. 3-1) and total reduction factor (Eq. 3-4) are equivalent.

The neutron reduction factor (NRF) is defined as:

$$NRF = N_{FF}/N_{IV} \tag{3-5}$$

where:

N_{FF} = the free-field neutron dose,

and

N_{IV} = the in-vehicle neutron dose.

The gamma reduction factor (GRF) is defined as:

$$GRF = G_{FF}/G_{IV} \tag{3-6}$$

where:

G_{FF} = the total free-field gamma dose from all sources, (i.e. prompt fission, air and ground interactions)

and

G_{IV} = the total in-vehicle gamma dose from all sources, (i.e. prompt fission, air, ground, and vehicle interactions).

DRC bins the contributions to the dose in several arrays (called detectors in the code) to allow for the calculation of protection factors. The detector response definitions used in DRC are given in Table 8, and the definitions of the parameters and protection factors used in DRC to characterize the effectiveness of the vehicle shields are given in Table 9. It should be noted that the definitions of the protection factors and reduction factors are independent of the response function (i.e. tissue dose, silicon dose, etc.) used in the analysis.

Table 8. Detector Response Definitions in DRC.

Detector	Response Definition
1	Direct neutron - a neutron entering the vehicle and contributing a neutron dose.
2	Capture gamma rays from vehicle - a gamma ray resulting from a neutron entering the vehicle and contributing a secondary gamma-ray dose.
3	Capture gamma rays from ground - a gamma ray resulting from a neutron entering the ground without passing through the vehicle and generating a secondary gamma-ray dose from a ground interaction. (This dose is already included in the upward-directed gamma rays that enter the vehicle. This generally is negligible.)
4	Direct gamma rays - a gamma ray entering the vehicle and contributing a gamma-ray dose. This source of gamma rays includes both gamma rays originating from the source, and capture gamma rays from the air.
5	Total gamma-ray dose - Sum of detectors 2, 3, and 4.
6	Gamma-ray dose from gamma rays entering the vehicle (usually dominated by direct gamma rays - Sum of detectors 3 and 4.
7	Neutron and gamma-ray dose from neutrons incident on the vehicle - Sum of detectors 1 and 2.

Table 9. Definitions of Parameters and Protection Factors Used to Characterize the Effectiveness of Vehicle Shields.

Parameter	Response Definition
FFN	Free-Field Neutron Response
FFG	Free-Field Gamma Response
NPF	Neutron Protection Factor NPF = FFN / Det. 7
GPF	Gamma Protection Factor GPF = FFG / Det. 6
TPF	Total Protection Factor TPF = (FFN+FFG)/(Det. 7 + Det. 6)
NRF	Neutron Reduction Factor NRF = FFN / Det. 1
GRF	Gamma Reduction Factor GRF = FFG / Det. 5
TRF	Total Reduction Factor TRF = (FFN+FFG)/(Det. 1 + Det. 5)

3.2 Air-Over-Ground Environment

The APRF radiation environment was modeled in the GRTUNCL and DORT codes to determine the air-over-ground environment from which the flux on the coupling surface could be obtained. GRTUNCL calculates the uncollided component of the flux and DORT calculates the scalar and directional fluxes of the collided component. All three components of the flux are processed through VISTA[1] to obtain the flux on the coupling surface to be folded in DRC.

Preliminary scoping calculations investigated the effects of the APRF topography out to the 400 meter test site, and the effects of ground moisture and meteorological data (temperature, pressure, and relative humidity) on the air environment during measurements made at APRF. Integral and spectral MASH results showed differences less than 2% for the topography model analysis. Consequently, a simple topography model of the APRF source-to-400 meter test site was determined to be sufficient for the analysis. One-dimensional ANISN calculations of the effects of ground moisture yielded 10% to 15% differences in the free-field free-in-air tissue kerma results. Likewise, ANISN calculations of the meteorological environment (relative to the hydrogen content in the air) showed differences on the order of 10% for the free-in-air tissue kerma results for both the free-field environment and the environment behind 10.16 cm of steel. Both of these effects were determined to be significant and warranted consideration in the final analysis using MASH. This was accomplished by modeling multiple air-over-ground environments using the two extreme conditions encountered during the October experiments (most moist air/ground and most dry air/ground) and an average air-over-ground environment.

The air-over-ground model for APRF utilized 66 radial intervals and 98 axial intervals in a flat topographical r-z model. This mesh modeled a 800 meter by 800 meter air environment. Approximately one meter of ground was included in the air-over-ground calculations to model ground scattering. The source height was set at 16.143 meters above the air/ground interface and at the center of the radial mesh (r=0.0). The air-over-ground model utilized a 240 direction forward biased quadrature, a P_5 Legendre expansion of the cross sections, the reference DNA DABL69 69 group (46n/23γ) cross-section library, and three different materials - air, ground, and borated concrete (the reactor pad). Three ground moisture and three air moisture contents were utilized to encompass the full spectrum of ground moisture and meteorological data recorded by APRF. The material compositions and number densities for the various air and ground compositions, and reactor pad used in this analysis are given in Table 10. Five air-over-ground flux files at the coupling surface were calculated using the GRTUNCL-DORT-VISTA code stream. These five environments modeled dry air-dry ground, dry air-wet ground, mean air-mean ground, wet air-dry ground, and wet air-wet ground; where, dry, mean, and wet correspond to the amount of moisture in the material. For ground moisture, dry, mean, and wet correspond to 20%, 34%, and 48% water (by weight) respectively. For air moisture, dry, mean, and wet correspond to 0.63%, 1.18%, and 1.85% hydrogen content (by weight). Utilizing these five flux files enabled the ORNL analysts to choose an air-over-ground environment which closely approximated the environmental conditions for a given experimental measurement.

3.3 The Two-Meter Box Geometry Model

The two-meter box geometry mentioned in Section 2.0 was modeled in the MORSE component of the MASH code system using the GIFT[10,11] geometry package. Results of a preliminary study determined all the details of the box (i.e., lift tabs, drain holes, etc.) made insignificant contributions to the calculation and therefore were omitted in the final computational geometry model. The hatches were retained in the computational model for potential open hatch experiments performed in the future. The walls and roof of the box were comprised of two plates of steel each 5.08-cm thick. This detail was retained in the geometry model for region dependent biasing in the Monte Carlo analysis. The material composition for the steel is given in Table 10. A single detector position, GIFT coordinates (0.0, 0.0, 110.16), was chosen in the center of the box for the determination of the neutron and gamma flux (and dose) spectra in the box. The Kerr neutron and gamma-ray Free-In-Air tissue kerma response functions in the DABL69 cross-section library were utilized in DRC to obtain the dose responses in the free-field and in the two-meter box. A listing of these response functions is given in Table 11.

3.4 The Two-Meter Box Calculations

The MASH calculations also utilized the reference DNA DABL69 69 group (46n/23γ) cross-section library. The Monte Carlo (MORSE) calculation for the detector position generated and tracked 1,500,000 primary source particles (1500 batches of 1000 particles) sampled over the 69 energy groups. An energy dependent relative importance factor was utilized over the 69 groups to increase the frequency of sampling the adjoint source particle from energy groups which have a significant effect on the dose response function. The secondary particle production probability (GWLO) was set to 1.0 for all regions and energy groups in the Monte Carlo calculations, and the in-group energy biasing option in MORSE was switched on. Region dependent and energy independent splitting and Russian Roulette parameters were utilized in the steel to improve the efficiency of the Monte Carlo calculations. This was accomplished by subdividing the 10.16-cm-thickness of steel into two equally thick concentric regions and assigning each of the steel regions different splitting and Russian Roulette parameters which would allow a sufficient number of source particles (and secondary particles) to escape to obtain reasonable statistics. This allowed nominally one escaping particle for each source particle generated. The average air and ground moisture conditions (APRF air for run #219, and 34 wt% H_2O given in Table 10) were chosen for the adjoint MORSE calculations.

As presently configured, DRC assumes the DORT flux on the "coupling surface" is dependent on energy and elevation only, and not on azimuth.

Table 10. Composition of Materials used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at APRF.

	Material Composition (atoms/barn·cm)				
Element	Borated Concrete	SAE-1020 Steel	Ground 20% H_2O	Ground 34% H_2O	Ground 48% H_2O
Hydrogen	7.02-03[a]		2.65-02	4.24-02	5.82-02
Boron-10	2.89-04		1.16-08	9.59-09	7.55-09
Boron-11	1.17-03		4.25-08	3.51-08	2.77-08
Carbon		8.08-04	4.58-04	3.77-04	2.97-04
Nitrogen			5.76-05	4.75-05	3.74-05
Oxygen	5.91-02		3.82-02	4.18-02	4.53-02
Sodium			1.73-04	1.43-04	1.12-04
Magnesium	1.66-03		1.11-04	9.13-05	7.19-05
Aluminum	4.66-03		1.67-03	1.38-03	1.08-03
Silicon	1.08-02	4.21-04	1.15-02	9.51-03	7.50-03
Phosphorus		6.11-05			
Sulfur		7.38-05	4.38-06	3.61-06	2.84-06
Chlorine			4.29-06	3.54-06	2.79-06
Argon					
Potassium			2.48-04	2.05-04	1.61-04
Calcium	3.49-03		3.15-05	2.60-05	2.05-05
Manganese		3.88-04	8.73-06	7.20-06	5.67-06
Iron	1.43-03	8.39-02	3.89-04	3.21-04	2.53-04
Cobalt			3.37-07	2.78-07	2.19-07
Nickel			3.39-07	2.79-07	2.20-07
Copper			5.89-07	4.86-07	3.83-07
Zirconium	7.67-04				
Niobium	6.71-04				
Tin			8.87-08	7.32-08	5.76-08
ρ(gm/cm^3)	3.00+00	7.86+00	1.75+00	1.75+00	1.75+00

[a]Read as 7.02×10^{-3}.

Table 10. Composition of Materials used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at APRF. (continued)

	Material Composition (atoms/barn·cm)				
Element	APRF Air (Run #219)	APRF Air (Run #222)	APRF Air (Run #233)	APRF Air (Run #245)	Hydraulic Oil
Hydrogen	6.12-07[a]	5.60-07	9.35-07	3.28-07	2.15-02
Boron-10					
Boron-11					
Carbon					2.60-02
Nitrogen	3.99-05	3.95-05	3.86-05	4.02-05	
Oxygen	1.10-05	1.09-05	1.08-05	1.10-05	2.60-03
Sodium					
Magnesium					
Aluminum					
Silicon					
Phosphorus					6.50-04
Sulfur					
Chlorine					3.90-03
Argon	2.38-07	2.36-07	2.31-07	2.40-07	
Potassium					
Calcium					
Manganese					
Iron					
Cobalt					
Nickel					
Copper					
Zirconium					
Niobium					
Tin					
ρ(gm/cm^3)	1.24-03	1.22-03	1.20-03	1.24-03	8.87-01

[a]Read as 6.12×10^{-7}.

Table 11. DABL 69 Group (46n-23γ) Library Group Structure and Free-In-Air Tissue Kerma Response Function used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at APRF.

Group Number	Upper Energy	FIA Tissue Kerma ($Gy \cdot cm^2/n$)	Group Number	Upper Energy	FIA Tissue Kerma ($Gy \cdot cm^2/\gamma$)
1	1.9640+07[a]	7.3653-11	1	2.0000+07	4.0111-11
2	1.6905+07	7.0458-11	2	1.4000+07	3.1756-11
3	1.4918+07	6.8589-11	3	1.2000+07	2.7612-11
4	1.4191+07	6.7450-11	4	1.0000+07	2.3517-11
5	1.3840+07	6.6155-11	5	8.0000+06	2.0510-11
6	1.2523+07	6.3814-11	6	7.0000+06	1.8508-11
7	1.2214+07	6.3353-11	7	6.0000+06	1.6436-11
8	1.1052+07	5.9882-11	8	5.0000+06	1.4334-11
9	1.0000+07	5.7632-11	9	4.0000+06	1.2127-11
10	9.0484+06	5.5151-11	10	3.0000+06	1.0360-11
11	8.1873+06	5.4643-11	11	2.5000+06	9.0267-12
12	7.4082+06	5.1265-11	12	2.0000+06	7.5562-12
13	6.3763+06	4.7086-11	13	1.5000+06	5.8532-12
14	4.9658+06	4.5780-11	14	1.0000+06	4.2722-12
15	4.7237+06	4.4359-11	15	7.0000+05	2.9638-12
16	4.0657+06	4.1938-11	16	4.5500+05	1.9297-12
17	3.0119+06	3.5731-11	17	3.0000+05	1.0541-12
18	2.3852+06	3.3249-11	18	1.5000+05	5.2963-13
19	2.3069+06	3.2113-11	19	1.0000+05	3.4819-13
20	1.8268+06	2.9119-11	20	7.0000+04	3.1323-13
21	1.4227+06	2.6344-11	21	4.5000+04	4.8463-13
22	1.1080+06	2.5247-11	22	3.0000+04	1.0497-12
23	9.6164+05	2.2251-11	23	2.0000+04	3.3960-12
24	8.2085+05	2.0593-11		1.0000+04	
25	7.4274+05	1.9368-11			
26	6.3927+05	1.7906-11			
27	5.5023+05	1.6375-11			
28	3.6883+05	1.3007-11			
29	2.4724+05	1.0256-11			
30	1.5764+05	8.0654-12			
31	1.1109+05	5.6340-12			
32	5.2475+04	3.5917-12			
33	3.4307+04	2.5917-12			
34	2.4788+04	2.1303-12			
35	2.1875+04	1.4757-12			
36	1.0595+04	6.2840-13			
37	3.3546+03	2.1994-13			
38	1.2341+03	9.2590-14			
39	5.8295+02	4.4814-14			
40	2.7536+02	2.0734-14			
41	1.0130+02	1.0372-14			
42	2.9023+01	9.3243-15			
43	1.0677+01	1.3587-14			
44	3.0590+00	2.2849-14			
45	1.1253+00	3.7265-14			
46	4.1399-01	1.2913-13			
	1.0000-05				

[a]Read as 1.9640×10^7.

Consequently, DRC only uses the flux at the 170 and 400 meter radii in the DORT mesh and does not use the radii encompassing the box. This assumption is valid for small objects at a great distance from the source. Since the size of the box is small relative to the distance from the source, it was felt this assumption was valid for this analysis and would produce an uncertainty within the statistical deviations of the calculated results.

For documentation purposes, the sample input data streams (decks) for the air-over-ground analysis (GIP, GRTUNCL, DORT, and VISTA), and two-meter box analysis (MORSE and DRC), along with the GIFT5 geometry model for the two-meter box, are included in the appendices. This will enable future versions of MASH to be "benchmarked" to the analysis reported in this document.

4.0 DISCUSSION OF RESULTS

Comparisons of the measured and calculated (MASH) neutron and gamma-ray Free-in-Air (FIA) tissue dose for the 170 meter free-field environment at the APRF are given in Tables 12 and 13 respectively. Likewise, in Tables 14 and 15, comparisons of the measured and calculated neutron and gamma-ray FIA tissue dose for the 400 meter free-field environment are given, and in Tables 16 and 17 comparisons for the environment inside the two-meter box test bed at 400 meters are presented. Finally, comparisons of the measured and calculated neutron reduction factors (NRFs) and gamma-ray reduction factors (GRFs) for the two-meter box test bed at the 400 meter test site are presented in Tables 18 and 19. Calculation to experiment (C/E) ratios are included in each table to help quantify the comparisons.

In Tables 12 through 19, the DREO/BTI and ETCA teams report both "uncorrected" and "corrected" kerma values obtained using the NE-213/BF_3 system. In all cases, the uncorrected data are lower than the corrected results. The primary reason for the lower (uncorrected) values was that the effective neutron energy threshold of the NE-213 detector had increased from 600 keV to 1.0 MeV due to detector and discrimination problems. This resulted in too few counts in the bottom energy bins centered at 700 keV and 900 keV. The procedure for estimating the fluence between thermal energy and 600 keV relies on a power fit (of the form $\nu(E) = AE^{-\alpha}$ between the BF_3 measured thermal fluence and the NE-213 measured fluence in the bottom two bins. (Note that for a perfect 1/E spectrum, $\alpha = 1.0$. In practice, α is usually found to be 0.95 ± 0.05). The correction procedure applied to this data was to overwrite the contents of the bottom two bins based upon extrapolation of a second power fit to the data in the 1.0 to 2.0 MeV energy range, and then proceed as normal. Comparisons are made to both "uncorrected" and "corrected" data for completeness. No attempt was made in this report to justify either of the two sets of data as being more accurate.

MASH integral and spectral fluence and Free-in-Air tissue dose results for the free-field and in-box environments at the two-meter box test bed experiments performed at the APRF are presented in Appendix A. The MASH results are presented for all five air-over-ground environments utilized in the calculational results to model the different environmental conditions present during the course of the experiments performed from October 23, 1989 to November 2, 1989. Included in the integral result tables are the DRC responses (detectors 1 through 7) and the neutron, gamma-ray, and total protection factors and reduction factors. Fractional standard deviations (fsd) are given for the integral and differential results obtained from the adjoint Monte Carlo (MORSE) analysis of the two-meter box test bed. These tables are included for completeness and as a source of information to the interested reader. A detailed discussion of the contents of these tables will not be included in this report.

Table 12. Comparison of Measured and Calculated Neutron Free-In-Air Tissue Kerma for the 170 Meter Free-Field Environment at the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Team	Detector System	Experimental Measurement	MASH Calculation[a]	C/E
APRF				
	NE-213	45.3	63.5	1.40
	TE/GM	54.1	85.5	1.58
DREO/BTI				
	ROSPEC	80.8	78.7	0.97
	NE-213/BF_3[b]	78.9	85.5	1.08
	NE-213/BF_3[c]	93.9	85.5	0.91
	ROSPEC/NE-213[b]	86.5	83.2	0.96
	BD-100R	84.3	80.7	0.96
ETCA				
	NE-213	65.9	63.5	0.96
	NE-213/BF_3[c]	91.0	85.5	0.94
	TE/GM	82.0	85.5	1.04
	Np/BGO	87.0	85.5	0.98

[a]Calculated data integrated over the detector energy ranges specified in Table 7.
[b]Uncorrected NE-213 data
[c]Corrected NE-213 data

Table 13. Comparison of Measured and Calculated Gamma-Ray Free-In-Air Tissue Kerma for the 170 Meter Free-Field Environment at the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Team	Detector System	Experimental Measurement	MASH Calculation[a]	C/E
APRF				
	NE-213	20.5	12.6	0.61
	TE/GM	18.5	13.7	0.74
	TLDs	25.5	13.7	0.54
DREO/BTI				
	BGO	22.6	13.8	0.61
ETCA				
	NE-213/BF_3[b]	21.0	12.6	0.60
	NE-213/BF_3[c]	23.0	13.8	0.60
	TE/GM	20.5	13.7	0.67
	Np/BGO	23.5	13.8	0.59

[a]Calculated data integrated over the detector energy ranges specified in Table 7.
[b]Uncorrected NE-213 data
[b]Corrected NE-213 data

Table 14. Comparison of Measured and Calculated Neutron Free-In-Air Tissue Kerma for the 400 Meter Free-Field Environment at the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Team	Detector System	Experimental Measurement	MASH Calculation[a]	C/E
APRF				
	NE-213	2.28	3.72	1.63
	TE/GM[b]	3.40	5.18	1.52
	Bonner Spheres[c]	3.80	5.18	1.36
DREO/BTI				
	ROSPEC	3.96	4.51	1.14
	NE-213/BF_3[d]	3.86	5.18	1.34
	NE-213/BF_3[e]	4.18	5.18	1.24
	ROSPEC/NE-213[d]	4.22	4.80	1.14
	BD-100R	3.88	4.66	1.20
ETCA				
	NE-213/BF_3[d]	3.20	3.53	1.10
	NE-213/BF_3[e]	4.30	4.85	1.13
	TE/GM	4.00	4.85	1.21
	Np/BGO	4.00	4.85	1.21

[a]Calculated data integrated over the detector energy ranges specified in Table 7.
[b]These data were obtained after the October 1989 experiments due to the suspected presence of a faulty TE gas mixture.
[c]These data were obtained January 31, 1990 and are included for completeness.
[d]Uncorrected NE-213 data
[e]Corrected NE-213 data

Table 15. Comparison of Measured and Calculated Gamma-Ray Free-In-Air Tissue Kerma for the 400 Meter Free-Field Environment at the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Team	Detector System	Experimental Measurement	MASH Calculation[a]	C/E
APRF				
	NE-213	1.54	1.10	0.77
	TE/GM[b]	1.36	1.19	0.88
DREO/BTI				
	BGO	1.56	1.22	0.78
ETCA				
	NE-213/BF_3[c]	1.50	1.08	0.72
	NE-213/BF_3[d]	1.65	1.19	0.72
	TE/GM	1.58	1.17	0.74
	Np/BGO	1.70	1.19	0.70

[a]Calculated data integrated over the detector energy ranges specified in Table 7.
[b]These data were obtained after the October 1989 experiments due to the suspected presence of a faulty TE gas mixture.
[c]Uncorrected NE-213 data
[d]Corrected NE-213 data

Table 16. Comparison of Measured and Calculated Neutron Free-In-Air Tissue Kerma for the 400 Meter In-Box Environment at the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Team	Detector System	Experimental Measurement	MASH Calculation[a]	C/E
APRF				
	NE-213	0.69	1.42	2.06
	TE/GM[b]	1.50	2.97	1.98
	Bonner Spheres[c]	2.20	2.97	1.35
DREO/BTI				
	ROSPEC	2.67	2.83	1.06
	NE-213/BF_3[d]	1.70	2.99	1.76
	NE-213/BF_3[e]	2.87	2.99	1.04
	ROSPEC/NE-213[d]	2.71	2.88	1.06
	BD-100R	2.80	2.76	0.99
ETCA				
	NE-213/BF_3[d]	1.25	1.42	1.14
	NE-213/BF_3[e]	2.32	2.99	1.29
	TE/GM	2.41	2.99	1.24
	Np/BGO	2.30	2.99	1.30

[a]Calculated data integrated over the detector energy ranges specified in Table 7.
[b]These data were obtained after the October 1989 experiments due to the suspected presence of a faulty TE gas mixture.
[c]These data were obtained January 31, 1990 and are included for completeness.
[d]Uncorrected NE-213 data
[e]Corrected NE-213 data

Table 17. Comparison of Measured and Calculated Gamma-Ray Free-In-Air Tissue Kerma for the 400 Meter In-Box Environment at the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Team	Detector System	Experimental Measurement	MASH Calculation[a]	C/E
APRF				
	NE-213	0.38	0.33	0.87
	TE/GM[b]	0.38	0.34	0.89
DREO/BTI				
	BGO	0.38	0.34	0.89
ETCA				
	NE-213/BF_3[c]	0.36	0.34	0.94
	NE-213/BF_3[d]	0.38	0.35	0.92
	TE/GM	0.44	0.35	0.80
	Np/BGO	0.39	0.35	0.90

[a]Calculated data integrated over the detector energy ranges specified in Table 7.
[b]These data were obtained after the October 1989 experiments due to the suspected presence of a faulty TE gas mixture.
[c]Uncorrected NE-213 data
[d]Corrected NE-213 data

Table 18. Comparison of Measured and Calculated Neutron Reduction Factors for the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Team	Detector System	Experimental Measurement	MASH Calculation[a]	C/E
APRF				
	NE-213	3.30	2.62	0.79
	TE/GM[b]	2.27	1.74	0.77
	Bonner Spheres[c]	1.73	1.74	1.01
DREO/BTI				
	ROSPEC	1.48	1.59	1.07
	NE-213/BF_3[d]	2.27	1.73	0.76
	NE-213/BF_3[e]	1.46	1.73	1.18
	ROSPEC/NE-213[d]	1.56	1.67	1.07
	BD-100R	1.39	1.69	1.22
ETCA				
	NE-213/BF_3[d]	2.56	2.49	0.97
	NE-213/BF_3[e]	1.85	1.62	0.88
	TE/GM	1.66	1.62	0.98
	Np/BGO	1.74	1.62	0.93

[a]Calculated data integrated over the detector energy ranges specified in Table 7.
[b]These data were obtained after the October 1989 experiments due to the suspected presence of a faulty TE gas mixture.
[c]These data were obtained January 31, 1990 and are included for completeness.
[d]Uncorrected NE-213 data
[e]Corrected NE-213 data

Table 19. Comparison of Measured and Calculated Gamma-Ray Reduction Factors for the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989.

Team	Detector System	Experimental Measurement	MASH Calculation[a]	C/E
APRF				
	NE-213	4.05	3.33	0.82
	TE/GM[b]	3.58	3.50	0.98
DREO/BTI				
	BGO	4.11	3.59	0.87
ETCA				
	NE-213/BF_3[c]	4.17	3.18	0.76
	NE-213/BF_3[d]	4.34	3.40	0.78
	TE/GM	3.59	3.34	0.93
	Np/BGO	4.36	3.40	0.78

[a]Calculated data integrated over the detector energy ranges specified in Table 7.
[b]These data were obtained after the October 1989 experiments due to the suspected presence of a faulty TE gas mixture.
[c]Uncorrected NE-213 data
[d]Corrected NE-213 data

Appendix B presents comparisons of the experimentally measured and MASH calculated neutron and gamma-ray fluence spectra for the 170 and 400 meter free-field environments, and the in-box environment at the two-meter box test bed experiments performed at the APRF in October 1989. The spectral comparisons are presented both as $E \cdot \Phi(E)$ versus E, and as fluence above energy E versus E (energy integrated fluence) for all measurements for which experimental data were provided. All of the experimental data provided was for NE-213 measurements with the exception of the BTI ROSPEC data, and the spectral comparisons are presented only over the ranges of the experimental data. Error bars corresponding to the fractional standard deviations of the Monte Carlo (MORSE) calculated spectra for the in-box environment are included in the comparisons. The experimental data was reported (by the different teams) without any indication of the uncertainty associated with the data.

4.1 Free-Field Dose

The ratios of the calculated neutron free-field dose over the measured neutron free-field dose (C/E), presented in Tables 12 and 14, indicate consistent agreement at the 170 and 400 meter test sites for all data except that obtained from the APRF team. (The APRF team has since acknowledged that there were problems with some of their experimental equipment which could have led to their results being somewhat lower than either calculation or other experimental measurements obtained by the other participating teams.) Typical agreement (excluding APRF) was within 10% at 170 meters and between 10% and 20% at the 400 meter test site. The ratios further show that the calculations consistently underestimate the measurements by a few percent at 170 meters, and overestimate the dose by nominally 10% to 20% at 400 meters. This indicates the measurements and calculations are determining different spectral shifts as a function of distance from the reactor source. At 170 meters the calculations agreed equally well with all the different detector systems, however, at 400 meters the calculations agreed best with the ROSPEC or NE-213 detector systems. It should be noted that the consistency between the different experimental measurements was approximately the same as the consistency between the measurements and calculations.

In the case of gamma rays, the experimental results indicate the measurements were very consistent among the different teams of experimentalist. Table 13 presents the free-field results at 170 meters and indicates the calculations underestimate the measurements by approximately 35%. Furthermore, Table 15 presents the free-field results at 400 meters, and indicates the calculations underestimate the measurements on the order of 25%. The consistency of the measured gamma free-field data appear to indicate some source of gammas not adequately accounted for in the calculational model. Two potential sources to investigate are the flash X-ray machine located next to the reactor silo and in the line-of-sight to the 400 meter test site and the trees surrounding the corridor to the 400 meter test site. Both of these potential sources contain considerable amounts of hydrogen which upon absorbing a neutron would generate a secondary gamma. A third source could be an inadequate representation of the gamma-ray leakage from the reactor. This quantity has been measured and calculated numerous times over the last two decades and has varied by approximately 40%. The current source calculation normalizes the gamma leakage to approximately 0.4 source gammas per source neutron. If this normalization is low, the calculated results will always underestimate the measured values.

The fluence spectra comparisons presented in Appendix B emphasize the results presented in the integral data in Tables 12 through 14. In particular, the calculated neutron spectra exhibit better agreement with the measurements than the gamma-ray spectra. At 170 meters, one of the calculated neutron spectra is higher than the measured spectra (Figure B-2), but most are lower (Figures B-6, B-8, and B-12). At 400 meters, all of the calculated neutron spectra are greater than the measured spectra. These results further emphasize the spectral shift eluded to in the discussion above. In viewing any of the energy integrated neutron spectra for the free-field results (up through Figure B-28), the comparisons show the curves converging as a function of decreasing energy. This indicates the MASH calculations show more contributions to the high energy fluence and less to the low energy fluence relative to the measurements. In general, the neutron spectral comparisons look reasonable, with the calculated results exhibiting a spectral shift relative to the measured results and the gamma-ray spectral comparisons show an area of concern in the MASH analysis. The reasons for the spectral shift are being investigated at this time. For the gamma rays, at both 170 and 400 meters, the calculated gamma-ray spectra are significantly lower than the measured spectra. It is interesting to note that both the calculated and measured spectra show the hydrogen capture line at approximately 2.2 MeV. Also, it appears that both the calculated and measured gamma-ray spectra exhibit the same shape, further suggesting a "missing" source of gamma-rays in the calculational models.

4.2 In-Box Dose

The comparisons between the calculated and measured neutron tissue dose inside the two-meter box at 400 meters are presented in Table 16 and again show generally good agreement (with the exception of the APRF data). The best agreement (C/E's typically within 10%) occurs with the DREO/BTI data. The effects of correcting the NE-213 data are clearly shown for the DREO/BTI results with the C/E decreasing from 1.76 to 1.04. The NE-213 correction for the ETCA results worsened the comparison with the calculated results but made the ETCA measurement results consistent among themselves. The DREO/BTI results are 20% higher than either the APRF Bonner Sphere or ETCA results. As in the case with the free-field results, the consistency between the different experimental measurements was approximately the same as the consistency between the measurements and calculations.

The comparisons between calculated and measured gamma-ray tissue dose inside the two-meter box are presented in Table 17. Like the free-field results, there is consistent agreement between the different experimental teams. However, in the two-meter box the MASH results compare well with the experimental results. The calculations now only underestimate the gamma-ray dose by approximately 10%. This indicates the "missing" source of gamma rays in the free-field calculation does not penetrate the two-meter box and make a significant contribution to the dose. It should be noted that the "missing" source could be (and probably is) responsible for the continued underestimation of the gamma-ray dose. In other words, the differences observed inside the two-meter box are due to the differences observed in the free-field data.

The fluence spectra comparisons for the neutron and gamma-ray results inside the two-meter box are shown in Figures B-29 through B-42. The results indicate better agreement between the neutron spectra and excellent agreement in the gamma-ray spectra. The neutron spectral shift present in the free-field comparisons is diminished inside the box and the source of "missing" gamma rays are shown to be insignificant inside the box. The worst spectral shift was exhibited with the BTI ROSPEC data even though one of the best integral data comparisons for the neutron tissue dose were obtained with the ROSPEC results. An interesting result shown in Figures B-40 and B-41 indicates a possible fall-off in the high energy sensitivity of the ETCA NE-213 detector. The energy integrated fluence in Figure B-40 exhibits a definite dip in the high energy response. The fall-off starts at approximately 5 MeV and could be responsible for the worse agreement with the ETCA results inside the two-meter box. This anomaly was not present in the 170 and 400 meter free-field data.

4.3 Neutron and Gamma Reduction Factors

The comparisons of the reduction factor results (Tables 18 and 19) show calculation to experiment (C/E) ratios ranging from 1.22 to 0.76 with most of the C/E ratios between 1.07 and 0.80. The calculations compare equally well with all of the detector systems used by the different experimental teams. Furthermore, for a given parameter (i.e., NRF or GRF), the C/E ratios are generally comparable to the ratio of the different experimentally determined parameters (e.g., NE-213 NRF/TE-GM NRF, etc.). The calculations also show a lower gamma-ray reduction factor (GRF) when compared to all of the experimental results. This again is probably due to the discrepancies in the free-field results mentioned earlier. Differences in the free-field spectra will impact both the secondary particle production and energy of the particle, and consequently impact the relative neutron and gamma-ray contributions to the dose.

An interesting point worth mentioning about the reduction factor results presented in Tables 18 and 19 is the relatively good agreement obtained with the APRF neutron data when the comparisons with the absolute doses were so poor in Tables 14 and 16. The reduction factors (defined in Section 3.0) represent ratios of two measurements or calculations. Consequently biases introduced into the measurement or calculation of the absolute dose will essentially negate themselves in the ratios of

the two measurements or calculations. This implies that while the measurement and calculation may not be determining the same quantity of interest in an absolute sense, they may be determining the same relative degree of shielding protection and/or dose reduction. Therefore, if the quantity of interest is the reduction or protection factor, good agreement between measurement and calculation of the absolute fluences or doses which are used to obtain the protection or reduction factor may not be overly critical.

5.0 MONTE CARLO STATISTICAL UNCERTAINTY

Analysis of the MORSE escape history tapes in DRC for the central detector position in the two-meter box test bed yielded statistical uncertainties on the order of ±1% for integral neutron fluence(dose) and ±2% for total gamma-ray fluence(dose), and total fluence(dose). The statistical uncertainties for the vehicle secondary particle production, i.e. vehicle (n,γ), the direct gamma-ray plus air secondary gamma production, i.e. source γ's + air (n,γ), and all contributions from the ground secondary particle production, i.e. ground (n,γ), are typically ±2%, ±3%, and ±8% respectively. Differential fluence(dose) results exhibited statistical uncertainties typically between ±2% and ±15% for neutron energies between 10 MeV and thermal, and between ±4% and ±10% for gamma energies between 10 MeV and 100 keV. These energy ranges contain the energy groups in the DABL69 group structure which make a significant contribution to the response. Tables A-21 through A-35 indicate the exact values for the statistical uncertainties associated with the Monte Carlo calculations.

Unfortunately, there were no concise uncertainties reported with the experimental data utilized in this report. Based on uncertainties reported in numerous previous documents, the absolute accuracy of the detector systems used in this set of experiments ranges from approximately ±10% to ±20%, and the reproducibility of the detector system results on a day-to-day basis is approximately ±5% to ±15%.

6.0 CONCLUSIONS

In general, the calculational results were in good agreement with the experimental results measured by the different experimental teams. The multiple air-over-ground environments yielded an accurate representation of the ground moisture and meteorological data supplied by APRF. Plotting the dose response as a function of hydrogen content in the air, ground moisture, and detector energy range, and correlating the different experimental measurements with the ground moisture and meteorological data, allowed the ORNL analysts to extrapolate between the five base air-over-ground environments to obtain results consistent with the environmental data present at the time of a given experimental measurement. This appears to be the most viable option for representing changing environmental data over the course of a series of experimental measurements. Calculating the flux on the coupling surface for each air-over-ground environment during the course of a series of experimental measurements would be prohibitive. Analyzing 1,500,000 adjoint source particle may appear to be overkill, but it was felt that differential data statistics (by energy group) should be within 10% for all groups since this comparison was to act as a benchmark for the MASH code system. By following this logic, the energy groups contributing 95% of the dose exhibited fractional standard deviations typically less than 5%. Furthermore, comparisons of the differential spectral data would not be subject to criticisms due to poor statistical convergence of the calculated data.

Analyzing the calculated dose responses over the energy range for which the detector generating the measured results is valid yielded excellent comparisons between the calculated and measured responses in almost all cases. This point almost goes without saying but is important in this work since one of the purposes is to validate the MASH code system. The principal exceptions to the above statement are the APRF data and the majority of the free-field gamma data. The APRF experimental team has since concluded that there were problems with their detector systems during the course of these measurements and therefore most of their measured (neutron) results are low. The consistency of the measured gamma free-field data lead the ORNL analysts to believe there is some source of gammas not adequately accounted for in the calculational model. The two potential sources to investigate are the flash X-ray machine located next to the reactor silo and in the line-of-sight to the 400 meter test site and the trees surrounding the corridor to the 400 meter test site. Both of these potential sources contain considerable amounts of hydrogen which upon absorbing a neutron would generate a secondary gamma.

Overall, the calculations agreed quite well with most of the measured data supplied by the experimental teams. Generally speaking, the agreement was within the ±20% limit deemed as acceptable by the DNA.

7.0 RECOMMENDATIONS

This was the first concerted effort aimed at benchmarking the MASH code against experimental measurements and there were some glitches in the effort. This series of measurements, however, has been successful in laying the foundation for the next set of measurements which will include duplicates of the measurements made in this series as well as measurements involving a humanoid phantom standing free-field and inside the two-meter box test bed. From this effort, with better communication and understanding between the analysts and experimentalists as to the needs of the other, better agreement is achievable for all comparisons; possibly within a tighter acceptance limit (i.e. 10% - 15%).

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APPENDIX A

MASH Integral and Spectral Fluence and Free-In-Air Tissue Dose Results for the Free-Field and In-Box Environments at the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989

Table A-1. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 170 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are $n,\gamma\cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	4.050-16	1	2.000+07	2.747-16
2	1.691+07	1.105-15	2	1.400+07	1.722-15
3	1.492+07	1.749-15	3	1.200+07	4.177-13
4	1.419+07	1.278-15	4	1.000+07	5.007-13
5	1.384+07	1.045-14	5	8.000+06	2.965-12
6	1.252+07	3.412-15	6	7.000+06	2.134-12
7	1.221+07	2.933-14	7	6.000+06	4.071-12
8	1.105+07	6.635-14	8	5.000+06	5.542-12
9	1.000+07	1.394-13	9	4.000+06	8.423-12
10	9.048+06	2.585-13	10	3.000+06	4.433-12
11	8.187+06	3.984-13	11	2.500+06	2.315-11
12	7.408+06	1.197-12	12	2.000+06	1.308-11
13	6.376+06	3.948-12	13	1.500+06	1.857-11
14	4.966+06	1.408-12	14	1.000+06	1.685-11
15	4.724+06	3.649-12	15	7.000+05	2.408-11
16	4.066+06	1.089-11	16	4.550+05	2.296-11
17	3.012+06	1.608-11	17	3.000+05	5.805-11
18	2.385+06	3.016-12	18	1.500+05	4.385-11
19	2.307+06	1.888-11	19	1.000+05	3.975-11
20	1.827+06	2.204-11	20	7.000+04	3.178-11
21	1.423+06	2.646-11	21	4.500+04	6.997-12
22	1.108+06	1.256-11	22	3.000+04	3.828-13
23	9.616+05	2.169-11	23	2.000+04	3.253-15
24	8.209+05	1.484-11		1.000+04	
25	7.427+05	1.899-11			
26	6.393+05	2.216-11			
27	5.502+05	3.258-11			
28	3.688+05	3.819-11			
29	2.472+05	3.819-11			
30	1.576+05	2.536-11			
31	1.111+05	3.982-11			
32	5.248+04	1.918-11			
33	3.431+04	1.339-11			
34	2.479+04	4.890-12			
35	2.188+04	2.776-11			
36	1.060+04	3.495-11			
37	3.355+03	2.848-11			
38	1.234+03	2.033-11			
39	5.830+02	1.960-11			
40	2.754+02	2.503-11			
41	1.013+02	2.993-11			
42	2.902+01	2.297-11			
43	1.068+01	2.708-11			
44	3.059+00	2.116-11			
45	1.125+00	2.103-11			
46	4.140-01	1.737-10			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-2. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 170 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	2.983-26	1	2.000+07	1.102-26
2	1.691+07	7.783-26	2	1.400+07	5.468-26
3	1.492+07	1.200-25	3	1.200+07	1.153-23
4	1.419+07	8.623-26	4	1.000+07	1.177-23
5	1.384+07	6.915-25	5	8.000+06	6.082-23
6	1.252+07	2.178-25	6	7.000+06	3.950-23
7	1.221+07	1.858-24	7	6.000+06	6.690-23
8	1.105+07	3.973-24	8	5.000+06	7.943-23
9	1.000+07	8.031-24	9	4.000+06	1.022-22
10	9.048+06	1.426-23	10	3.000+06	4.593-23
11	8.187+06	2.177-23	11	2.500+06	2.090-22
12	7.408+06	6.135-23	12	2.000+06	9.886-23
13	6.376+06	1.859-22	13	1.500+06	1.087-22
14	4.966+06	6.447-23	14	1.000+06	7.198-23
15	4.724+06	1.619-22	15	7.000+05	7.138-23
16	4.066+06	4.568-22	16	4.550+05	4.430-23
17	3.012+06	5.746-22	17	3.000+05	6.119-23
18	2.385+06	1.003-22	18	1.500+05	2.322-23
19	2.307+06	6.063-22	19	1.000+05	1.384-23
20	1.827+06	6.417-22	20	7.000+04	9.956-24
21	1.423+06	6.972-22	21	4.500+04	3.391-24
22	1.108+06	3.172-22	22	3.000+04	4.018-25
23	9.616+05	4.825-22	23	2.000+04	1.105-26
24	8.209+05	3.057-22		1.000+04	
25	7.427+05	3.677-22			
26	6.393+05	3.968-22			
27	5.502+05	5.335-22			
28	3.688+05	4.967-22			
29	2.472+05	3.917-22			
30	1.576+05	2.045-22			
31	1.111+05	2.243-22			
32	5.248+04	6.887-23			
33	3.431+04	3.471-23			
34	2.479+04	1.042-23			
35	2.188+04	4.096-23			
36	1.060+04	2.196-23			
37	3.355+03	6.264-24			
38	1.234+03	1.882-24			
39	5.830+02	8.785-25			
40	2.754+02	5.189-25			
41	1.013+02	3.105-25			
42	2.902+01	2.142-25			
43	1.068+01	3.680-25			
44	3.059+00	4.834-25			
45	1.125+00	7.838-25			
46	4.140-01	2.243-23			
	1.000-05				

[a] Read as 1.964×10^7.

Table A-3. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 170 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are n,$\gamma \cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	4.139-16	1	2.000+07	2.673-16
2	1.691+07	1.140-15	2	1.400+07	1.652-15
3	1.492+07	1.791-15	3	1.200+07	4.302-13
4	1.419+07	1.307-15	4	1.000+07	5.051-13
5	1.384+07	1.067-14	5	8.000+06	2.961-12
6	1.252+07	3.505-15	6	7.000+06	2.145-12
7	1.221+07	2.996-14	7	6.000+06	4.141-12
8	1.105+07	6.766-14	8	5.000+06	5.556-12
9	1.000+07	1.416-13	9	4.000+06	8.478-12
10	9.048+06	2.621-13	10	3.000+06	4.488-12
11	8.187+06	4.051-13	11	2.500+06	2.339-11
12	7.408+06	1.210-12	12	2.000+06	1.325-11
13	6.376+06	3.981-12	13	1.500+06	1.884-11
14	4.966+06	1.409-12	14	1.000+06	1.710-11
15	4.724+06	3.695-12	15	7.000+05	2.433-11
16	4.066+06	1.101-11	16	4.550+05	2.309-11
17	3.012+06	1.609-11	17	3.000+05	5.831-11
18	2.385+06	2.999-12	18	1.500+05	4.391-11
19	2.307+06	1.873-11	19	1.000+05	3.969-11
20	1.827+06	2.184-11	20	7.000+04	3.160-11
21	1.423+06	2.606-11	21	4.500+04	6.941-12
22	1.108+06	1.233-11	22	3.000+04	3.794-13
23	9.616+05	2.108-11	23	2.000+04	3.242-15
24	8.209+05	1.443-11		1.000+04	
25	7.427+05	1.845-11			
26	6.393+05	2.132-11			
27	5.502+05	3.163-11			
28	3.688+05	3.681-11			
29	2.472+05	3.645-11			
30	1.576+05	2.407-11			
31	1.111+05	3.794-11			
32	5.248+04	1.831-11			
33	3.431+04	1.282-11			
34	2.479+04	4.690-12			
35	2.188+04	2.673-11			
36	1.060+04	3.407-11			
37	3.355+03	2.795-11			
38	1.234+03	2.002-11			
39	5.830+02	1.936-11			
40	2.754+02	2.480-11			
41	1.013+02	2.993-11			
42	2.902+01	2.293-11			
43	1.068+01	2.730-11			
44	3.059+00	2.137-11			
45	1.125+00	2.136-11			
46	4.140-01	1.798-10			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-4. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 170 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	3.049-26	1	2.000+07	1.072-26
2	1.691+07	8.035-26	2	1.400+07	5.248-26
3	1.492+07	1.228-25	3	1.200+07	1.188-23
4	1.419+07	8.818-26	4	1.000+07	1.188-23
5	1.384+07	7.060-25	5	8.000+06	6.074-23
6	1.252+07	2.237-25	6	7.000+06	3.970-23
7	1.221+07	1.898-24	7	6.000+06	6.806-23
8	1.105+07	4.051-24	8	5.000+06	7.964-23
9	1.000+07	8.163-24	9	4.000+06	1.028-22
10	9.048+06	1.446-23	10	3.000+06	4.650-23
11	8.187+06	2.213-23	11	2.500+06	2.112-22
12	7.408+06	6.202-23	12	2.000+06	1.001-22
13	6.376+06	1.874-22	13	1.500+06	1.103-22
14	4.966+06	6.448-23	14	1.000+06	7.306-23
15	4.724+06	1.639-22	15	7.000+05	7.211-23
16	4.066+06	4.616-22	16	4.550+05	4.455-23
17	3.012+06	5.747-22	17	3.000+05	6.147-23
18	2.385+06	9.973-23	18	1.500+05	2.326-23
19	2.307+06	6.015-22	19	1.000+05	1.382-23
20	1.827+06	6.360-22	20	7.000+04	9.898-24
21	1.423+06	6.864-22	21	4.500+04	3.364-24
22	1.108+06	3.112-22	22	3.000+04	3.982-25
23	9.616+05	4.691-22	23	2.000+04	1.101-26
24	8.209+05	2.971-22		1.000+04	
25	7.427+05	3.573-22			
26	6.393+05	3.817-22			
27	5.502+05	5.179-22			
28	3.688+05	4.788-22			
29	2.472+05	3.739-22			
30	1.576+05	1.941-22			
31	1.111+05	2.137-22			
32	5.248+04	6.578-23			
33	3.431+04	3.324-23			
34	2.479+04	9.991-24			
35	2.188+04	3.944-23			
36	1.060+04	2.141-23			
37	3.355+03	6.148-24			
38	1.234+03	1.854-24			
39	5.830+02	8.678-25			
40	2.754+02	5.142-25			
41	1.013+02	3.104-25			
42	2.902+01	2.138-25			
43	1.068+01	3.710-25			
44	3.059+00	4.883-25			
45	1.125+00	7.961-25			
46	4.140-01	2.322-23			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-5. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 170 Meters. Environmental Conditions: 1.18 wt% Hydrogen in Air and 34 wt% Ground Moisture. (Units are n,γ·cm^{-2} per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	4.037-16	1	2.000+07	2.650-16
2	1.691+07	1.105-15	2	1.400+07	1.635-15
3	1.492+07	1.744-15	3	1.200+07	4.121-13
4	1.419+07	1.274-15	4	1.000+07	4.239-13
5	1.384+07	1.041-14	5	8.000+06	2.289-12
6	1.252+07	3.407-15	6	7.000+06	1.760-12
7	1.221+07	2.922-14	7	6.000+06	3.706-12
8	1.105+07	6.607-14	8	5.000+06	4.522-12
9	1.000+07	1.386-13	9	4.000+06	7.173-12
10	9.048+06	2.568-13	10	3.000+06	4.042-12
11	8.187+06	3.960-13	11	2.500+06	3.023-11
12	7.408+06	1.186-12	12	2.000+06	1.326-11
13	6.376+06	3.888-12	13	1.500+06	1.888-11
14	4.966+06	1.381-12	14	1.000+06	1.710-11
15	4.724+06	3.570-12	15	7.000+05	2.408-11
16	4.066+06	1.059-11	16	4.550+05	2.331-11
17	3.012+06	1.549-11	17	3.000+05	5.912-11
18	2.385+06	2.892-12	18	1.500+05	4.479-11
19	2.307+06	1.810-11	19	1.000+05	4.130-11
20	1.827+06	2.087-11	20	7.000+04	3.425-11
21	1.423+06	2.477-11	21	4.500+04	7.704-12
22	1.108+06	1.175-11	22	3.000+04	4.265-13
23	9.616+05	2.017-11	23	2.000+04	3.578-15
24	8.209+05	1.359-11		1.000+04	
25	7.427+05	1.725-11			
26	6.393+05	2.014-11			
27	5.502+05	2.943-11			
28	3.688+05	3.383-11			
29	2.472+05	3.311-11			
30	1.576+05	2.191-11			
31	1.111+05	3.448-11			
32	5.248+04	1.653-11			
33	3.431+04	1.150-11			
34	2.479+04	4.214-12			
35	2.188+04	2.399-11			
36	1.060+04	3.039-11			
37	3.355+03	2.483-11			
38	1.234+03	1.784-11			
39	5.830+02	1.726-11			
40	2.754+02	2.211-11			
41	1.013+02	2.653-11			
42	2.902+01	2.052-11			
43	1.068+01	2.421-11			
44	3.059+00	1.914-11			
45	1.125+00	1.916-11			
46	4.140-01	1.729-10			
	1.000-05				

[a]Read as 1.964 x 10^7.

Table A-6. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 170 Meters. Environmental Conditions: 1.18 wt% Hydrogen in Air and 34 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	2.973-26	1	2.000+07	1.063-26
2	1.691+07	7.785-26	2	1.400+07	5.192-26
3	1.492+07	1.196-25	3	1.200+07	1.138-23
4	1.419+07	8.594-26	4	1.000+07	9.970-24
5	1.384+07	6.887-25	5	8.000+06	4.694-23
6	1.252+07	2.174-25	6	7.000+06	3.257-23
7	1.221+07	1.851-24	7	6.000+06	6.090-23
8	1.105+07	3.956-24	8	5.000+06	6.482-23
9	1.000+07	7.990-24	9	4.000+06	8.699-23
10	9.048+06	1.416-23	10	3.000+06	4.188-23
11	8.187+06	2.164-23	11	2.500+06	2.729-22
12	7.408+06	6.079-23	12	2.000+06	1.002-22
13	6.376+06	1.831-22	13	1.500+06	1.105-22
14	4.966+06	6.323-23	14	1.000+06	7.306-23
15	4.724+06	1.584-22	15	7.000+05	7.136-23
16	4.066+06	4.441-22	16	4.550+05	4.498-23
17	3.012+06	5.534-22	17	3.000+05	6.232-23
18	2.385+06	9.614-23	18	1.500+05	2.372-23
19	2.307+06	5.811-22	19	1.000+05	1.438-23
20	1.827+06	6.077-22	20	7.000+04	1.073-23
21	1.423+06	6.524-22	21	4.500+04	3.734-24
22	1.108+06	2.967-22	22	3.000+04	4.477-25
23	9.616+05	4.488-22	23	2.000+04	1.215-26
24	8.209+05	2.798-22		1.000+04	
25	7.427+05	3.340-22			
26	6.393+05	3.606-22			
27	5.502+05	4.819-22			
28	3.688+05	4.401-22			
29	2.472+05	3.396-22			
30	1.576+05	1.767-22			
31	1.111+05	1.942-22			
32	5.248+04	5.936-23			
33	3.431+04	2.981-23			
34	2.479+04	8.977-24			
35	2.188+04	3.540-23			
36	1.060+04	1.910-23			
37	3.355+03	5.462-24			
38	1.234+03	1.652-24			
39	5.830+02	7.733-25			
40	2.754+02	4.583-25			
41	1.013+02	2.751-25			
42	2.902+01	1.914-25			
43	1.068+01	3.289-25			
44	3.059+00	4.373-25			
45	1.125+00	7.141-25			
46	4.140-01	2.233-23			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-7. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 170 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are n,$\gamma \cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	4.009-16	1	2.000+07	2.624-16
2	1.691+07	1.098-15	2	1.400+07	1.620-15
3	1.492+07	1.732-15	3	1.200+07	3.812-13
4	1.419+07	1.266-15	4	1.000+07	3.467-13
5	1.384+07	1.034-14	5	8.000+06	1.682-12
6	1.252+07	3.387-15	6	7.000+06	1.403-12
7	1.221+07	2.906-14	7	6.000+06	3.245-12
8	1.105+07	6.573-14	8	5.000+06	3.582-12
9	1.000+07	1.380-13	9	4.000+06	6.005-12
10	9.048+06	2.558-13	10	3.000+06	3.685-12
11	8.187+06	3.940-13	11	2.500+06	3.494-11
12	7.408+06	1.181-12	12	2.000+06	1.321-11
13	6.376+06	3.862-12	13	1.500+06	1.890-11
14	4.966+06	1.373-12	14	1.000+06	1.711-11
15	4.724+06	3.528-12	15	7.000+05	2.377-11
16	4.066+06	1.045-11	16	4.550+05	2.332-11
17	3.012+06	1.526-11	17	3.000+05	5.927-11
18	2.385+06	2.850-12	18	1.500+05	4.515-11
19	2.307+06	1.788-11	19	1.000+05	4.241-11
20	1.827+06	2.048-11	20	7.000+04	3.674-11
21	1.423+06	2.425-11	21	4.500+04	8.517-12
22	1.108+06	1.154-11	22	3.000+04	4.799-13
23	9.616+05	1.983-11	23	2.000+04	3.964-15
24	8.209+05	1.322-11		1.000+04	
25	7.427+05	1.672-11			
26	6.393+05	1.965-11			
27	5.502+05	2.843-11			
28	3.688+05	3.248-11			
29	2.472+05	3.156-11			
30	1.576+05	2.092-11			
31	1.111+05	3.278-11			
32	5.248+04	1.563-11			
33	3.431+04	1.083-11			
34	2.479+04	3.971-12			
35	2.188+04	2.256-11			
36	1.060+04	2.845-11			
37	3.355+03	2.319-11			
38	1.234+03	1.665-11			
39	5.830+02	1.610-11			
40	2.754+02	2.056-11			
41	1.013+02	2.478-11			
42	2.902+01	1.910-11			
43	1.068+01	2.264-11			
44	3.059+00	1.777-11			
45	1.125+00	1.784-11			
46	4.140-01	1.608-10			
	1.000-05				

[a]Read as 1.964 x 10^7.

Table A-8. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 170 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	2.953-26	1	2.000+07	1.052-26
2	1.691+07	7.736-26	2	1.400+07	5.144-26
3	1.492+07	1.188-25	3	1.200+07	1.053-23
4	1.419+07	8.536-26	4	1.000+07	8.152-24
5	1.384+07	6.842-25	5	8.000+06	3.451-23
6	1.252+07	2.161-25	6	7.000+06	2.597-23
7	1.221+07	1.841-24	7	6.000+06	5.333-23
8	1.105+07	3.936-24	8	5.000+06	5.135-23
9	1.000+07	7.954-24	9	4.000+06	7.282-23
10	9.048+06	1.411-23	10	3.000+06	3.818-23
11	8.187+06	2.153-23	11	2.500+06	3.154-22
12	7.408+06	6.053-23	12	2.000+06	9.979-23
13	6.376+06	1.818-22	13	1.500+06	1.106-22
14	4.966+06	6.284-23	14	1.000+06	7.309-23
15	4.724+06	1.565-22	15	7.000+05	7.045-23
16	4.066+06	4.381-22	16	4.550+05	4.500-23
17	3.012+06	5.454-22	17	3.000+05	6.248-23
18	2.385+06	9.475-23	18	1.500+05	2.391-23
19	2.307+06	5.740-22	19	1.000+05	1.477-23
20	1.827+06	5.965-22	20	7.000+04	1.151-23
21	1.423+06	6.389-22	21	4.500+04	4.128-24
22	1.108+06	2.915-22	22	3.000+04	5.038-25
23	9.616+05	4.412-22	23	2.000+04	1.346-26
24	8.209+05	2.723-22		1.000+04	
25	7.427+05	3.239-22			
26	6.393+05	3.518-22			
27	5.502+05	4.656-22			
28	3.688+05	4.225-22			
29	2.472+05	3.237-22			
30	1.576+05	1.687-22			
31	1.111+05	1.847-22			
32	5.248+04	5.615-23			
33	3.431+04	2.808-23			
34	2.479+04	8.459-24			
35	2.188+04	3.328-23			
36	1.060+04	1.788-23			
37	3.355+03	5.099-24			
38	1.234+03	1.541-24			
39	5.830+02	7.213-25			
40	2.754+02	4.263-25			
41	1.013+02	2.570-25			
42	2.902+01	1.781-25			
43	1.068+01	3.077-25			
44	3.059+00	4.060-25			
45	1.125+00	6.647-25			
46	4.140-01	2.076-23			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-9. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 170 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are n,$\gamma \cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	4.097-16	1	2.000+07	2.551-16
2	1.691+07	1.134-15	2	1.400+07	1.554-15
3	1.492+07	1.773-15	3	1.200+07	3.889-13
4	1.419+07	1.294-15	4	1.000+07	3.487-13
5	1.384+07	1.056-14	5	8.000+06	1.671-12
6	1.252+07	3.479-15	6	7.000+06	1.406-12
7	1.221+07	2.968-14	7	6.000+06	3.286-12
8	1.105+07	6.703-14	8	5.000+06	3.581-12
9	1.000+07	1.403-13	9	4.000+06	6.040-12
10	9.048+06	2.594-13	10	3.000+06	3.738-12
11	8.187+06	4.006-13	11	2.500+06	3.485-11
12	7.408+06	1.194-12	12	2.000+06	1.332-11
13	6.376+06	3.895-12	13	1.500+06	1.913-11
14	4.966+06	1.373-12	14	1.000+06	1.733-11
15	4.724+06	3.573-12	15	7.000+05	2.396-11
16	4.066+06	1.056-11	16	4.550+05	2.339-11
17	3.012+06	1.527-11	17	3.000+05	5.940-11
18	2.385+06	2.836-12	18	1.500+05	4.513-11
19	2.307+06	1.775-11	19	1.000+05	4.228-11
20	1.827+06	2.033-11	20	7.000+04	3.650-11
21	1.423+06	2.391-11	21	4.500+04	8.445-12
22	1.108+06	1.134-11	22	3.000+04	4.754-13
23	9.616+05	1.930-11	23	2.000+04	3.934-15
24	8.209+05	1.287-11		1.000+04	
25	7.427+05	1.628-11			
26	6.393+05	1.893-11			
27	5.502+05	2.769-11			
28	3.688+05	3.141-11			
29	2.472+05	3.024-11			
30	1.576+05	1.994-11			
31	1.111+05	3.140-11			
32	5.248+04	1.502-11			
33	3.431+04	1.044-11			
34	2.479+04	3.832-12			
35	2.188+04	2.185-11			
36	1.060+04	2.793-11			
37	3.355+03	2.288-11			
38	1.234+03	1.647-11			
39	5.830+02	1.596-11			
40	2.754+02	2.045-11			
41	1.013+02	2.468-11			
42	2.902+01	1.906-11			
43	1.068+01	2.265-11			
44	3.059+00	1.789-11			
45	1.125+00	1.806-11			
46	4.140-01	1.642-10			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-10. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 170 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	3.018-26	1	2.000+07	1.023-26
2	1.691+07	7.987-26	2	1.400+07	4.935-26
3	1.492+07	1.216-25	3	1.200+07	1.074-23
4	1.419+07	8.731-26	4	1.000+07	8.200-24
5	1.384+07	6.985-25	5	8.000+06	3.427-23
6	1.252+07	2.220-25	6	7.000+06	2.602-23
7	1.221+07	1.881-24	7	6.000+06	5.400-23
8	1.105+07	4.014-24	8	5.000+06	5.134-23
9	1.000+07	8.084-24	9	4.000+06	7.325-23
10	9.048+06	1.431-23	10	3.000+06	3.872-23
11	8.187+06	2.189-23	11	2.500+06	3.146-22
12	7.408+06	6.119-23	12	2.000+06	1.007-22
13	6.376+06	1.834-22	13	1.500+06	1.120-22
14	4.966+06	6.286-23	14	1.000+06	7.402-23
15	4.724+06	1.585-22	15	7.000+05	7.102-23
16	4.066+06	4.428-22	16	4.550+05	4.514-23
17	3.012+06	5.457-22	17	3.000+05	6.261-23
18	2.385+06	9.428-23	18	1.500+05	2.390-23
19	2.307+06	5.699-22	19	1.000+05	1.472-23
20	1.827+06	5.919-22	20	7.000+04	1.143-23
21	1.423+06	6.298-22	21	4.500+04	4.093-24
22	1.108+06	2.863-22	22	3.000+04	4.991-25
23	9.616+05	4.293-22	23	2.000+04	1.336-26
24	8.209+05	2.650-22		1.000+04	
25	7.427+05	3.153-22			
26	6.393+05	3.391-22			
27	5.502+05	4.534-22			
28	3.688+05	4.085-22			
29	2.472+05	3.102-22			
30	1.576+05	1.608-22			
31	1.111+05	1.769-22			
32	5.248+04	5.395-23			
33	3.431+04	2.705-23			
34	2.479+04	8.163-24			
35	2.188+04	3.225-23			
36	1.060+04	1.755-23			
37	3.355+03	5.032-24			
38	1.234+03	1.525-24			
39	5.830+02	7.154-25			
40	2.754+02	4.240-25			
41	1.013+02	2.560-25			
42	2.902+01	1.777-25			
43	1.068+01	3.078-25			
44	3.059+00	4.088-25			
45	1.125+00	6.730-25			
46	4.140-01	2.120-23			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-11. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are n,$\gamma \cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	2.045-17	1	2.000+07	4.170-17
2	1.691+07	3.902-17	2	1.400+07	2.664-16
3	1.492+07	7.712-17	3	1.200+07	6.699-14
4	1.419+07	5.970-17	4	1.000+07	5.740-14
5	1.384+07	5.214-16	5	8.000+06	2.671-13
6	1.252+07	1.429-16	6	7.000+06	2.204-13
7	1.221+07	1.399-15	7	6.000+06	5.015-13
8	1.105+07	3.397-15	8	5.000+06	5.189-13
9	1.000+07	7.924-15	9	4.000+06	7.618-13
10	9.048+06	1.531-14	10	3.000+06	3.763-13
11	8.187+06	2.109-14	11	2.500+06	1.896-12
12	7.408+06	7.418-14	12	2.000+06	1.021-12
13	6.376+06	2.416-13	13	1.500+06	1.325-12
14	4.966+06	1.075-13	14	1.000+06	1.167-12
15	4.724+06	1.779-13	15	7.000+05	1.873-12
16	4.066+06	4.620-13	16	4.550+05	1.906-12
17	3.012+06	9.249-13	17	3.000+05	4.947-12
18	2.385+06	2.041-13	18	1.500+05	3.931-12
19	2.307+06	1.104-12	19	1.000+05	3.795-12
20	1.827+06	1.169-12	20	7.000+04	3.341-12
21	1.423+06	1.371-12	21	4.500+04	7.708-13
22	1.108+06	5.969-13	22	3.000+04	4.246-14
23	9.616+05	1.227-12	23	2.000+04	3.448-16
24	8.209+05	8.539-13		1.000+04	
25	7.427+05	1.075-12			
26	6.393+05	1.385-12			
27	5.502+05	1.794-12			
28	3.688+05	2.116-12			
29	2.472+05	2.221-12			
30	1.576+05	1.549-12			
31	1.111+05	2.667-12			
32	5.248+04	1.337-12			
33	3.431+04	9.597-13			
34	2.479+04	3.554-13			
35	2.188+04	2.131-12			
36	1.060+04	2.826-12			
37	3.355+03	2.398-12			
38	1.234+03	1.758-12			
39	5.830+02	1.733-12			
40	2.754+02	2.259-12			
41	1.013+02	2.779-12			
42	2.902+01	2.177-12			
43	1.068+01	2.614-12			
44	3.059+00	2.051-12			
45	1.125+00	2.042-12			
46	4.140-01	1.512-11			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-12. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	1.506-27	1	2.000+07	1.673-27
2	1.691+07	2.749-27	2	1.400+07	8.461-27
3	1.492+07	5.290-27	3	1.200+07	1.850-24
4	1.419+07	4.027-27	4	1.000+07	1.350-24
5	1.384+07	3.450-26	5	8.000+06	5.478-24
6	1.252+07	9.116-27	6	7.000+06	4.080-24
7	1.221+07	8.863-26	7	6.000+06	8.242-24
8	1.105+07	2.034-25	8	5.000+06	7.438-24
9	1.000+07	4.567-25	9	4.000+06	9.239-24
10	9.048+06	8.441-25	10	3.000+06	3.898-24
11	8.187+06	1.153-24	11	2.500+06	1.712-23
12	7.408+06	3.803-24	12	2.000+06	7.718-24
13	6.376+06	1.137-23	13	1.500+06	7.754-24
14	4.966+06	4.920-24	14	1.000+06	4.987-24
15	4.724+06	7.892-24	15	7.000+05	5.550-24
16	4.066+06	1.938-23	16	4.550+05	3.678-24
17	3.012+06	3.305-23	17	3.000+05	5.214-24
18	2.385+06	6.786-24	18	1.500+05	2.082-24
19	2.307+06	3.546-23	19	1.000+05	1.321-24
20	1.827+06	3.405-23	20	7.000+04	1.047-24
21	1.423+06	3.613-23	21	4.500+04	3.736-25
22	1.108+06	1.507-23	22	3.000+04	4.457-26
23	9.616+05	2.731-23	23	2.000+04	1.171-27
24	8.209+05	1.758-23		1.000+04	
25	7.427+05	2.083-23			
26	6.393+05	2.480-23			
27	5.502+05	2.938-23			
28	3.688+05	2.753-23			
29	2.472+05	2.278-23			
30	1.576+05	1.250-23			
31	1.111+05	1.503-23			
32	5.248+04	4.802-24			
33	3.431+04	2.487-24			
34	2.479+04	7.571-25			
35	2.188+04	3.144-24			
36	1.060+04	1.776-24			
37	3.355+03	5.274-25			
38	1.234+03	1.628-25			
39	5.830+02	7.765-26			
40	2.754+02	4.683-26			
41	1.013+02	2.882-26			
42	2.902+01	2.030-26			
43	1.068+01	3.552-26			
44	3.059+00	4.686-26			
45	1.125+00	7.610-26			
46	4.140-01	1.953-24			
	1.000-05				

[a]Read as 1.964 x 10^7.

Table A-13. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are $n,\gamma \cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	2.168-17	1	2.000+07	4.135-17
2	1.691+07	4.225-17	2	1.400+07	2.592-16
3	1.492+07	8.237-17	3	1.200+07	6.980-14
4	1.419+07	6.346-17	4	1.000+07	5.786-14
5	1.384+07	5.517-16	5	8.000+06	2.601-13
6	1.252+07	1.529-16	6	7.000+06	2.198-13
7	1.221+07	1.480-15	7	6.000+06	5.136-13
8	1.105+07	3.581-15	8	5.000+06	5.132-13
9	1.000+07	8.287-15	9	4.000+06	7.613-13
10	9.048+06	1.592-14	10	3.000+06	3.839-13
11	8.187+06	2.208-14	11	2.500+06	1.879-12
12	7.408+06	7.672-14	12	2.000+06	1.042-12
13	6.376+06	2.487-13	13	1.500+06	1.359-12
14	4.966+06	1.088-13	14	1.000+06	1.200-12
15	4.724+06	1.843-13	15	7.000+05	1.914-12
16	4.066+06	4.793-13	16	4.550+05	1.949-12
17	3.012+06	9.408-13	17	3.000+05	5.065-12
18	2.385+06	2.057-13	18	1.500+05	4.033-12
19	2.307+06	1.107-12	19	1.000+05	3.903-12
20	1.827+06	1.168-12	20	7.000+04	3.445-12
21	1.423+06	1.354-12	21	4.500+04	7.956-13
22	1.108+06	5.848-13	22	3.000+04	4.378-14
23	9.616+05	1.184-12	23	2.000+04	3.528-16
24	8.209+05	8.224-13		1.000+04	
25	7.427+05	1.034-12			
26	6.393+05	1.310-12			
27	5.502+05	1.706-12			
28	3.688+05	1.993-12			
29	2.472+05	2.061-12			
30	1.576+05	1.423-12			
31	1.111+05	2.430-12			
32	5.248+04	1.216-12			
33	3.431+04	8.720-13			
34	2.479+04	3.229-13			
35	2.188+04	1.929-12			
36	1.060+04	2.582-12			
37	3.355+03	2.204-12			
38	1.234+03	1.624-12			
39	5.830+02	1.607-12			
40	2.754+02	2.105-12			
41	1.013+02	2.607-12			
42	2.902+01	2.054-12			
43	1.068+01	2.489-12			
44	3.059+00	1.972-12			
45	1.125+00	1.987-12			
46	4.140-01	1.507-11			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-14. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	1.597-27	1	2.000+07	1.659-27
2	1.691+07	2.977-27	2	1.400+07	8.232-27
3	1.492+07	5.649-27	3	1.200+07	1.927-24
4	1.419+07	4.281-27	4	1.000+07	1.361-24
5	1.384+07	3.650-26	5	8.000+06	5.335-24
6	1.252+07	9.760-27	6	7.000+06	4.068-24
7	1.221+07	9.379-26	7	6.000+06	8.441-24
8	1.105+07	2.145-25	8	5.000+06	7.356-24
9	1.000+07	4.776-25	9	4.000+06	9.233-24
10	9.048+06	8.782-25	10	3.000+06	3.977-24
11	8.187+06	1.206-24	11	2.500+06	1.696-23
12	7.408+06	3.933-24	12	2.000+06	7.874-24
13	6.376+06	1.171-23	13	1.500+06	7.956-24
14	4.966+06	4.979-24	14	1.000+06	5.126-24
15	4.724+06	8.174-24	15	7.000+05	5.671-24
16	4.066+06	2.010-23	16	4.550+05	3.760-24
17	3.012+06	3.361-23	17	3.000+05	5.339-24
18	2.385+06	6.839-24	18	1.500+05	2.136-24
19	2.307+06	3.554-23	19	1.000+05	1.359-24
20	1.827+06	3.402-23	20	7.000+04	1.079-24
21	1.423+06	3.567-23	21	4.500+04	3.856-25
22	1.108+06	1.476-23	22	3.000+04	4.595-26
23	9.616+05	2.634-23	23	2.000+04	1.198-27
24	8.209+05	1.694-23		1.000+04	
25	7.427+05	2.002-23			
26	6.393+05	2.345-23			
27	5.502+05	2.794-23			
28	3.688+05	2.592-23			
29	2.472+05	2.114-23			
30	1.576+05	1.148-23			
31	1.111+05	1.369-23			
32	5.248+04	4.366-24			
33	3.431+04	2.260-24			
34	2.479+04	6.878-25			
35	2.188+04	2.846-24			
36	1.060+04	1.623-24			
37	3.355+03	4.848-25			
38	1.234+03	1.504-25			
39	5.830+02	7.202-26			
40	2.754+02	4.365-26			
41	1.013+02	2.704-26			
42	2.902+01	1.915-26			
43	1.068+01	3.382-26			
44	3.059+00	4.506-26			
45	1.125+00	7.406-26			
46	4.140-01	1.947-24			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-15. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 1.18 wt% Hydrogen in Air and 34 wt% Ground Moisture. (Units are n,γ·cm^{-2} per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	2.046-17	1	2.000+07	4.060-17
2	1.691+07	3.926-17	2	1.400+07	2.535-16
3	1.492+07	7.727-17	3	1.200+07	6.454-14
4	1.419+07	5.972-17	4	1.000+07	4.933-14
5	1.384+07	5.207-16	5	8.000+06	2.016-13
6	1.252+07	1.432-16	6	7.000+06	1.824-13
7	1.221+07	1.397-15	7	6.000+06	4.560-13
8	1.105+07	3.391-15	8	5.000+06	4.187-13
9	1.000+07	7.890-15	9	4.000+06	6.381-13
10	9.048+06	1.521-14	10	3.000+06	3.376-13
11	8.187+06	2.096-14	11	2.500+06	2.370-12
12	7.408+06	7.338-14	12	2.000+06	1.024-12
13	6.376+06	2.369-13	13	1.500+06	1.342-12
14	4.966+06	1.048-13	14	1.000+06	1.183-12
15	4.724+06	1.723-13	15	7.000+05	1.852-12
16	4.066+06	4.439-13	16	4.550+05	1.918-12
17	3.012+06	8.811-13	17	3.000+05	4.987-12
18	2.385+06	1.938-13	18	1.500+05	3.982-12
19	2.307+06	1.039-12	19	1.000+05	3.913-12
20	1.827+06	1.078-12	20	7.000+04	3.567-12
21	1.423+06	1.243-12	21	4.500+04	8.395-13
22	1.108+06	5.382-13	22	3.000+04	4.681-14
23	9.616+05	1.103-12	23	2.000+04	3.758-16
24	8.209+05	7.540-13		1.000+04	
25	7.427+05	9.380-13			
26	6.393+05	1.210-12			
27	5.502+05	1.543-12			
28	3.688+05	1.781-12			
29	2.472+05	1.830-12			
30	1.576+05	1.273-12			
31	1.111+05	2.189-12			
32	5.248+04	1.092-12			
33	3.431+04	7.801-13			
34	2.479+04	2.897-13			
35	2.188+04	1.735-12			
36	1.060+04	2.320-12			
37	3.355+03	1.973-12			
38	1.234+03	1.453-12			
39	5.830+02	1.436-12			
40	2.754+02	1.878-12			
41	1.013+02	2.321-12			
42	2.902+01	1.829-12			
43	1.068+01	2.204-12			
44	3.059+00	1.750-12			
45	1.125+00	1.757-12			
46	4.140-01	1.427-11			
	1.000-05				

[a]Read as 1.964 x 10^7.

Table A-16. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 1.18 wt% Hydrogen in Air and 34 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	1.507-27	1	2.000+07	1.629-27
2	1.691+07	2.766-27	2	1.400+07	8.049-27
3	1.492+07	5.300-27	3	1.200+07	1.782-24
4	1.419+07	4.028-27	4	1.000+07	1.160-24
5	1.384+07	3.445-26	5	8.000+06	4.135-24
6	1.252+07	9.139-27	6	7.000+06	3.376-24
7	1.221+07	8.850-26	7	6.000+06	7.495-24
8	1.105+07	2.030-25	8	5.000+06	6.002-24
9	1.000+07	4.547-25	9	4.000+06	7.739-24
10	9.048+06	8.387-25	10	3.000+06	3.498-24
11	8.187+06	1.145-24	11	2.500+06	2.140-23
12	7.408+06	3.762-24	12	2.000+06	7.737-24
13	6.376+06	1.115-23	13	1.500+06	7.854-24
14	4.966+06	4.798-24	14	1.000+06	5.056-24
15	4.724+06	7.644-24	15	7.000+05	5.489-24
16	4.066+06	1.862-23	16	4.550+05	3.701-24
17	3.012+06	3.148-23	17	3.000+05	5.256-24
18	2.385+06	6.442-24	18	1.500+05	2.109-24
19	2.307+06	3.337-23	19	1.000+05	1.362-24
20	1.827+06	3.138-23	20	7.000+04	1.117-24
21	1.423+06	3.274-23	21	4.500+04	4.068-25
22	1.108+06	1.359-23	22	3.000+04	4.913-26
23	9.616+05	2.455-23	23	2.000+04	1.276-27
24	8.209+05	1.553-23		1.000+04	
25	7.427+05	1.817-23			
26	6.393+05	2.167-23			
27	5.502+05	2.527-23			
28	3.688+05	2.316-23			
29	2.472+05	1.877-23			
30	1.576+05	1.027-23			
31	1.111+05	1.233-23			
32	5.248+04	3.921-24			
33	3.431+04	2.022-24			
34	2.479+04	6.171-25			
35	2.188+04	2.561-24			
36	1.060+04	1.458-24			
37	3.355+03	4.339-25			
38	1.234+03	1.345-25			
39	5.830+02	6.435-26			
40	2.754+02	3.894-26			
41	1.013+02	2.408-26			
42	2.902+01	1.705-26			
43	1.068+01	2.995-26			
44	3.059+00	3.998-26			
45	1.125+00	6.547-26			
46	4.140-01	1.843-24			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-17. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are $n,\gamma \cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	2.022-17	1	2.000+07	4.044-17
2	1.691+07	3.879-17	2	1.400+07	2.525-16
3	1.492+07	7.641-17	3	1.200+07	5.971-14
4	1.419+07	5.908-17	4	1.000+07	4.236-14
5	1.384+07	5.153-16	5	8.000+06	1.550-13
6	1.252+07	1.417-16	6	7.000+06	1.525-13
7	1.221+07	1.386-15	7	6.000+06	4.088-13
8	1.105+07	3.365-15	8	5.000+06	3.437-13
9	1.000+07	7.847-15	9	4.000+06	5.428-13
10	9.048+06	1.514-14	10	3.000+06	3.059-13
11	8.187+06	2.084-14	11	2.500+06	2.776-12
12	7.408+06	7.310-14	12	2.000+06	1.024-12
13	6.376+06	2.354-13	13	1.500+06	1.350-12
14	4.966+06	1.046-13	14	1.000+06	1.190-12
15	4.724+06	1.698-13	15	7.000+05	1.828-12
16	4.066+06	4.369-13	16	4.550+05	1.919-12
17	3.012+06	8.709-13	17	3.000+05	4.992-12
18	2.385+06	1.918-13	18	1.500+05	4.002-12
19	2.307+06	1.030-12	19	1.000+05	3.995-12
20	1.827+06	1.058-12	20	7.000+04	3.781-12
21	1.423+06	1.219-12	21	4.500+04	9.127-13
22	1.108+06	5.296-13	22	3.000+04	5.180-14
23	9.616+05	1.095-12	23	2.000+04	4.149-16
24	8.209+05	7.407-13		1.000+04	
25	7.427+05	9.168-13			
26	6.393+05	1.197-12			
27	5.502+05	1.503-12			
28	3.688+05	1.726-12			
29	2.472+05	1.771-12			
30	1.576+05	1.241-12			
31	1.111+05	2.144-12			
32	5.248+04	1.067-12			
33	3.431+04	7.612-13			
34	2.479+04	2.832-13			
35	2.188+04	1.700-12			
36	1.060+04	2.264-12			
37	3.355+03	1.917-12			
38	1.234+03	1.410-12			
39	5.830+02	1.391-12			
40	2.754+02	1.814-12			
41	1.013+02	2.237-12			
42	2.902+01	1.757-12			
43	1.068+01	2.112-12			
44	3.059+00	1.667-12			
45	1.125+00	1.667-12			
46	4.140-01	1.354-11			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-18. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	1.490-27	1	2.000+07	1.622-27
2	1.691+07	2.733-27	2	1.400+07	8.018-27
3	1.492+07	5.241-27	3	1.200+07	1.649-24
4	1.419+07	3.985-27	4	1.000+07	9.962-25
5	1.384+07	3.409-26	5	8.000+06	3.179-24
6	1.252+07	9.042-27	6	7.000+06	2.823-24
7	1.221+07	8.779-26	7	6.000+06	6.718-24
8	1.105+07	2.015-25	8	5.000+06	4.926-24
9	1.000+07	4.523-25	9	4.000+06	6.583-24
10	9.048+06	8.353-25	10	3.000+06	3.169-24
11	8.187+06	1.139-24	11	2.500+06	2.506-23
12	7.408+06	3.748-24	12	2.000+06	7.740-24
13	6.376+06	1.108-23	13	1.500+06	7.902-24
14	4.966+06	4.789-24	14	1.000+06	5.082-24
15	4.724+06	7.534-24	15	7.000+05	5.419-24
16	4.066+06	1.832-23	16	4.550+05	3.702-24
17	3.012+06	3.112-23	17	3.000+05	5.262-24
18	2.385+06	6.379-24	18	1.500+05	2.119-24
19	2.307+06	3.307-23	19	1.000+05	1.391-24
20	1.827+06	3.081-23	20	7.000+04	1.184-24
21	1.423+06	3.212-23	21	4.500+04	4.423-25
22	1.108+06	1.337-23	22	3.000+04	5.437-26
23	9.616+05	2.437-23	23	2.000+04	1.409-27
24	8.209+05	1.525-23		1.000+04	
25	7.427+05	1.776-23			
26	6.393+05	2.144-23			
27	5.502+05	2.462-23			
28	3.688+05	2.246-23			
29	2.472+05	1.817-23			
30	1.576+05	1.001-23			
31	1.111+05	1.208-23			
32	5.248+04	3.833-24			
33	3.431+04	1.973-24			
34	2.479+04	6.032-25			
35	2.188+04	2.509-24			
36	1.060+04	1.423-24			
37	3.355+03	4.217-25			
38	1.234+03	1.305-25			
39	5.830+02	6.233-26			
40	2.754+02	3.762-26			
41	1.013+02	2.320-26			
42	2.902+01	1.639-26			
43	1.068+01	2.869-26			
44	3.059+00	3.808-26			
45	1.125+00	6.212-26			
46	4.140-01	1.749-24			
	1.000-05				

[a]Read as 1.964 x 10^7.

Table A-19. Neutron and Gamma-Ray Free-Field Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are n,$\gamma \cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	Group Number	Upper Energy	Gamma Fluence
1	1.964+07[a]	2.145-17	1	2.000+07	4.009-17
2	1.691+07	4.200-17	2	1.400+07	2.457-16
3	1.492+07	8.160-17	3	1.200+07	6.193-14
4	1.419+07	6.282-17	4	1.000+07	4.302-14
5	1.384+07	5.453-16	5	8.000+06	1.519-13
6	1.252+07	1.517-16	6	7.000+06	1.534-13
7	1.221+07	1.466-15	7	6.000+06	4.198-13
8	1.105+07	3.547-15	8	5.000+06	3.433-13
9	1.000+07	8.206-15	9	4.000+06	5.488-13
10	9.048+06	1.576-14	10	3.000+06	3.154-13
11	8.187+06	2.181-14	11	2.500+06	2.710-12
12	7.408+06	7.562-14	12	2.000+06	1.042-12
13	6.376+06	2.424-13	13	1.500+06	1.383-12
14	4.966+06	1.059-13	14	1.000+06	1.221-12
15	4.724+06	1.760-13	15	7.000+05	1.869-12
16	4.066+06	4.536-13	16	4.550+05	1.960-12
17	3.012+06	8.863-13	17	3.000+05	5.107-12
18	2.385+06	1.934-13	18	1.500+05	4.104-12
19	2.307+06	1.033-12	19	1.000+05	4.105-12
20	1.827+06	1.059-12	20	7.000+04	3.893-12
21	1.423+06	1.206-12	21	4.500+04	9.407-13
22	1.108+06	5.197-13	22	3.000+04	5.335-14
23	9.616+05	1.057-12	23	2.000+04	4.247-16
24	8.209+05	7.142-13		1.000+04	
25	7.427+05	8.829-13			
26	6.393+05	1.134-12			
27	5.502+05	1.435-12			
28	3.688+05	1.631-12			
29	2.472+05	1.650-12			
30	1.576+05	1.144-12			
31	1.111+05	1.963-12			
32	5.248+04	9.753-13			
33	3.431+04	6.954-13			
34	2.479+04	2.587-13			
35	2.188+04	1.547-12			
36	1.060+04	2.081-12			
37	3.355+03	1.774-12			
38	1.234+03	1.310-12			
39	5.830+02	1.297-12			
40	2.754+02	1.702-12			
41	1.013+02	2.110-12			
42	2.902+01	1.666-12			
43	1.068+01	2.017-12			
44	3.059+00	1.608-12			
45	1.125+00	1.626-12			
46	4.140-01	1.337-11			
	1.000-05				

[a]Read as 1.964×10^7.

Table A-20. Neutron and Gamma Free-In-Air Free-Field Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	Group Number	Upper Energy	Gamma Dose
1	1.964+07[a]	1.580-27	1	2.000+07	1.608-27
2	1.691+07	2.959-27	2	1.400+07	7.802-27
3	1.492+07	5.597-27	3	1.200+07	1.710-24
4	1.419+07	4.237-27	4	1.000+07	1.012-24
5	1.384+07	3.607-26	5	8.000+06	3.116-24
6	1.252+07	9.681-27	6	7.000+06	2.840-24
7	1.221+07	9.290-26	7	6.000+06	6.900-24
8	1.105+07	2.124-25	8	5.000+06	4.921-24
9	1.000+07	4.730-25	9	4.000+06	6.656-24
10	9.048+06	8.690-25	10	3.000+06	3.268-24
11	8.187+06	1.192-24	11	2.500+06	2.447-23
12	7.408+06	3.877-24	12	2.000+06	7.875-24
13	6.376+06	1.142-23	13	1.500+06	8.094-24
14	4.966+06	4.847-24	14	1.000+06	5.216-24
15	4.724+06	7.809-24	15	7.000+05	5.540-24
16	4.066+06	1.902-23	16	4.550+05	3.782-24
17	3.012+06	3.167-23	17	3.000+05	5.383-24
18	2.385+06	6.432-24	18	1.500+05	2.173-24
19	2.307+06	3.317-23	19	1.000+05	1.429-24
20	1.827+06	3.083-23	20	7.000+04	1.219-24
21	1.423+06	3.176-23	21	4.500+04	4.559-25
22	1.108+06	1.312-23	22	3.000+04	5.600-26
23	9.616+05	2.353-23	23	2.000+04	1.442-27
24	8.209+05	1.471-23		1.000+04	
25	7.427+05	1.710-23			
26	6.393+05	2.030-23			
27	5.502+05	2.349-23			
28	3.688+05	2.122-23			
29	2.472+05	1.692-23			
30	1.576+05	9.228-24			
31	1.111+05	1.106-23			
32	5.248+04	3.503-24			
33	3.431+04	1.802-24			
34	2.479+04	5.510-25			
35	2.188+04	2.283-24			
36	1.060+04	1.308-24			
37	3.355+03	3.901-25			
38	1.234+03	1.213-25			
39	5.830+02	5.814-26			
40	2.754+02	3.528-26			
41	1.013+02	2.188-26			
42	2.902+01	1.554-26			
43	1.068+01	2.741-26			
44	3.059+00	3.675-26			
45	1.125+00	6.058-26			
46	4.140-01	1.727-24			
	1.000-05				

[a]Read as 1.964 x 10^7.

Table A-21. MASH Integral Neutron and Gamma-Ray Fluence and Free-In-Air In-Box Tissue Dose Results at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 20 wt% Ground Moisture.

DRC Parameter	Fluence ($n,\gamma \cdot cm^{-2}$/source n)	Free-In-Air Tissue Dose (Gy/source n)
Detector 1	3.109-11 ± 0.004[a]	2.590-22 ± 0.007
Detector 2	3.787-12 ± 0.013	2.474-23 ± 0.014
Detector 3	3.245-13 ± 0.072	2.041-24 ± 0.070
Detector 4	5.961-13 ± 0.041	3.813-24 ± 0.026
Detector 5	4.708-12 ± 0.013	3.059-23 ± 0.013
Detector 6	9.206-13 ± 0.036	5.854-24 ± 0.030
Detector 7	3.488-11 ± 0.004	2.837-22 ± 0.006
FF n Flux	6.392-11	6.392-11
FF γ Flux	2.880-11	2.880-11
FF t Flux	9.272-11	9.272-11
FF n Dose	6.392-11	4.246-22
FF γ Dose	2.880-11	9.844-23
FF t Dose	9.272-11	5.231-22
NPF	1.833+00	1.497+00
GPF	3.128+01	1.681+01
TPF	2.590+00	1.806+00
NRF	2.056+00	1.639+00
GRF	6.118+00	3.218+00
TRF	2.590+00	1.806+00

[a]Read as $3.109 \times 10^{-11} \pm 0.004$.

Table A-22. Neutron and Gamma-Ray In-Box Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are n,γ·cm^{-2} per source neutron.)

Group Number	Upper Energy	Neutron Fluence	fsd	Group Number	Upper Energy	Gamma Fluence	fsd
1	1.964+07[a]	4.824-18 ±	0.138	1	2.000+07	2.039-18 ±	0.116
2	1.691+07	9.054-18 ±	0.241	2	1.400+07	1.806-17 ±	0.118
3	1.492+07	1.649-17 ±	0.198	3	1.200+07	3.727-15 ±	0.082
4	1.419+07	1.192-17 ±	0.162	4	1.000+07	4.504-14 ±	0.101
5	1.384+07	1.512-16 ±	0.152	5	8.000+06	3.751-13 ±	0.037
6	1.252+07	2.830-17 ±	0.210	6	7.000+06	9.181-14 ±	0.034
7	1.221+07	2.618-16 ±	0.198	7	6.000+06	1.337-13 ±	0.033
8	1.105+07	5.829-16 ±	0.212	8	5.000+06	1.627-13 ±	0.048
9	1.000+07	1.296-15 ±	0.162	9	4.000+06	2.124-13 ±	0.036
10	9.048+06	3.082-15 ±	0.152	10	3.000+06	1.419-13 ±	0.039
11	8.187+06	4.406-15 ±	0.137	11	2.500+06	2.081-13 ±	0.050
12	7.408+06	1.403-14 ±	0.147	12	2.000+06	2.472-13 ±	0.038
13	6.376+06	4.183-14 ±	0.125	13	1.500+06	3.037-13 ±	0.038
14	4.966+06	1.784-14 ±	0.129	14	1.000+06	4.400-13 ±	0.029
15	4.724+06	3.178-14 ±	0.092	15	7.000+05	6.773-13 ±	0.039
16	4.066+06	7.890-14 ±	0.080	16	4.550+05	5.102-13 ±	0.047
17	3.012+06	2.023-13 ±	0.097	17	3.000+05	8.746-13 ±	0.041
18	2.385+06	3.551-14 ±	0.100	18	1.500+05	2.485-13 ±	0.053
19	2.307+06	2.633-13 ±	0.061	19	1.000+05	2.974-14 ±	0.075
20	1.827+06	3.839-13 ±	0.041	20	7.000+04	1.757-15 ±	0.188
21	1.423+06	6.035-13 ±	0.034	21	4.500+04	2.336-16 ±	0.394
22	1.108+06	3.230-13 ±	0.043	22	3.000+04	4.801-17 ±	0.799
23	9.616+05	6.085-13 ±	0.027	23	2.000+04	2.741-17 ±	0.748
24	8.209+05	3.390-13 ±	0.041		1.000+04		
25	7.427+05	9.279-13 ±	0.021				
26	6.393+05	1.131-12 ±	0.018				
27	5.502+05	2.186-12 ±	0.018				
28	3.688+05	2.597-12 ±	0.017				
29	2.472+05	2.872-12 ±	0.018				
30	1.576+05	1.818-12 ±	0.019				
31	1.111+05	1.970-12 ±	0.018				
32	5.248+04	8.218-13 ±	0.031				
33	3.431+04	2.302-12 ±	0.017				
34	2.479+04	6.881-13 ±	0.022				
35	2.188+04	1.741-12 ±	0.016				
36	1.060+04	1.906-12 ±	0.016				
37	3.355+03	1.362-12 ±	0.016				
38	1.234+03	6.585-13 ±	0.017				
39	5.830+02	5.812-13 ±	0.017				
40	2.754+02	9.103-13 ±	0.017				
41	1.013+02	1.160-12 ±	0.015				
42	2.902+01	8.809-13 ±	0.015				
43	1.068+01	8.692-13 ±	0.016				
44	3.059+00	4.606-13 ±	0.017				
45	1.125+00	2.454-13 ±	0.019				
46	4.140-01	5.253-14 ±	0.032				
	1.000-05						

[a]Read as 1.964 x 10^7.

Table A-23. Neutron and Gamma Free-In-Air In-Box Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	fsd	Group Number	Upper Energy	Gamma Dose	fsd
1	1.964+07[a]	3.553-28	± 0.138	1	2.000+07	8.179-29	± 0.116
2	1.691+07	6.379-28	± 0.241	2	1.400+07	5.736-28	± 0.118
3	1.492+07	1.131-27	± 0.198	3	1.200+07	1.029-25	± 0.082
4	1.419+07	8.041-28	± 0.162	4	1.000+07	1.059-24	± 0.101
5	1.384+07	1.001-26	± 0.152	5	8.000+06	7.693-24	± 0.037
6	1.252+07	1.806-27	± 0.210	6	7.000+06	1.699-24	± 0.034
7	1.221+07	1.659-26	± 0.198	7	6.000+06	2.198-24	± 0.033
8	1.105+07	3.490-26	± 0.212	8	5.000+06	2.332-24	± 0.048
9	1.000+07	7.471-26	± 0.162	9	4.000+06	2.575-24	± 0.036
10	9.048+06	1.700-25	± 0.152	10	3.000+06	1.470-24	± 0.039
11	8.187+06	2.407-25	± 0.137	11	2.500+06	1.878-24	± 0.050
12	7.408+06	7.193-25	± 0.147	12	2.000+06	1.868-24	± 0.038
13	6.376+06	1.970-24	± 0.125	13	1.500+06	1.778-24	± 0.038
14	4.966+06	8.165-25	± 0.129	14	1.000+06	1.880-24	± 0.029
15	4.724+06	1.410-24	± 0.092	15	7.000+05	2.007-24	± 0.039
16	4.066+06	3.309-24	± 0.080	16	4.550+05	9.845-25	± 0.047
17	3.012+06	7.230-24	± 0.097	17	3.000+05	9.219-25	± 0.041
18	2.385+06	1.181-24	± 0.100	18	1.500+05	1.316-25	± 0.053
19	2.307+06	8.456-24	± 0.061	19	1.000+05	1.035-26	± 0.075
20	1.827+06	1.118-23	± 0.041	20	7.000+04	5.502-28	± 0.188
21	1.423+06	1.590-23	± 0.034	21	4.500+04	1.132-28	± 0.394
22	1.108+06	8.155-24	± 0.043	22	3.000+04	5.040-29	± 0.799
23	9.616+05	1.354-23	± 0.027	23	2.000+04	9.308-29	± 0.748
24	8.209+05	6.981-24	± 0.041		1.000+04		
25	7.427+05	1.797-23	± 0.021				
26	6.393+05	2.024-23	± 0.018				
27	5.502+05	3.579-23	± 0.018				
28	3.688+05	3.378-23	± 0.017				
29	2.472+05	2.945-23	± 0.018				
30	1.576+05	1.466-23	± 0.019				
31	1.111+05	1.110-23	± 0.018				
32	5.248+04	2.952-24	± 0.031				
33	3.431+04	5.966-24	± 0.017				
34	2.479+04	1.466-24	± 0.022				
35	2.188+04	2.569-24	± 0.016				
36	1.060+04	1.197-24	± 0.016				
37	3.355+03	2.995-25	± 0.016				
38	1.234+03	6.097-26	± 0.017				
39	5.830+02	2.605-26	± 0.017				
40	2.754+02	1.887-26	± 0.017				
41	1.013+02	1.203-26	± 0.015				
42	2.902+01	8.213-27	± 0.015				
43	1.068+01	1.181-26	± 0.016				
44	3.059+00	1.052-26	± 0.017				
45	1.125+00	9.144-27	± 0.019				
46	4.140-01	6.783-27	± 0.032				
	1.000-05						

[a]Read as 1.964×10^7.

Table A-24. MASH Integral Neutron and Gamma-Ray Fluence and Free-In-Air In-Box Tissue Dose Results at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 48 wt% Ground Moisture.

DRC Parameter	Fluence ($n,\gamma \cdot cm^{-2}$/source n)	Free-In-Air Tissue Dose (Gy/source n)
Detector 1	2.939-11 ± 0.004[a]	2.520-22 ± 0.007
Detector 2	3.665-12 ± 0.013	2.380-23 ± 0.015
Detector 3	3.084-13 ± 0.072	1.939-24 ± 0.070
Detector 4	6.212-13 ± 0.042	3.964-24 ± 0.026
Detector 5	4.594-12 ± 0.013	2.971-23 ± 0.013
Detector 6	9.296-13 ± 0.036	5.903-24 ± 0.029
Detector 7	3.306-11 ± 0.004	2.758-22 ± 0.007
FF n Flux	6.112-11	6.112-11
FF γ Flux	2.942-11	2.942-11
FF t Flux	9.055-11	9.055-11
FF n Dose	6.112-11	4.141-22
FF γ Dose	2.942-11	9.937-23
FF t Dose	9.055-11	5.135-22
NPF	1.849+00	1.501+00
GPF	3.165+01	1.683+01
TPF	2.664+00	1.823+00
NRF	2.079+00	1.643+00
GRF	6.405+00	3.345+00
TRF	2.664+00	1.823+00

[a]Read as $2.939 \times 10^{-11} \pm 0.004$.

Table A-25. Neutron and Gamma-Ray In-Box Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are n,γ·cm^{-2} per source neutron.)

Group Number	Upper Energy	Neutron Fluence	fsd	Group Number	Upper Energy	Gamma Fluence	fsd
1	1.964+07[a]	5.121-18	± 0.140	1	2.000+07	2.020-18	± 0.115
2	1.691+07	9.816-18	± 0.243	2	1.400+07	1.761-17	± 0.119
3	1.492+07	1.766-17	± 0.200	3	1.200+07	3.909-15	± 0.082
4	1.419+07	1.267-17	± 0.164	4	1.000+07	4.335-14	± 0.105
5	1.384+07	1.609-16	± 0.154	5	8.000+06	3.590-13	± 0.038
6	1.252+07	3.033-17	± 0.212	6	7.000+06	8.833-14	± 0.034
7	1.221+07	2.772-16	± 0.201	7	6.000+06	1.305-13	± 0.033
8	1.105+07	6.145-16	± 0.215	8	5.000+06	1.572-13	± 0.048
9	1.000+07	1.354-15	± 0.165	9	4.000+06	2.067-13	± 0.036
10	9.048+06	3.214-15	± 0.154	10	3.000+06	1.388-13	± 0.039
11	8.187+06	4.622-15	± 0.139	11	2.500+06	2.039-13	± 0.050
12	7.408+06	1.457-14	± 0.148	12	2.000+06	2.420-13	± 0.039
13	6.376+06	4.325-14	± 0.127	13	1.500+06	2.988-13	± 0.038
14	4.966+06	1.814-14	± 0.131	14	1.000+06	4.371-13	± 0.029
15	4.724+06	3.286-14	± 0.094	15	7.000+05	6.574-13	± 0.039
16	4.066+06	8.188-14	± 0.081	16	4.550+05	4.987-13	± 0.048
17	3.012+06	2.071-13	± 0.098	17	3.000+05	8.553-13	± 0.042
18	2.385+06	3.599-14	± 0.101	18	1.500+05	2.421-13	± 0.054
19	2.307+06	2.658-13	± 0.062	19	1.000+05	2.899-14	± 0.077
20	1.827+06	3.870-13	± 0.042	20	7.000+04	1.676-15	± 0.191
21	1.423+06	6.028-13	± 0.035	21	4.500+04	2.162-16	± 0.396
22	1.108+06	3.216-13	± 0.044	22	3.000+04	4.438-17	± 0.800
23	9.616+05	5.963-13	± 0.028	23	2.000+04	2.638-17	± 0.745
24	8.209+05	3.339-13	± 0.043		1.000+04		
25	7.427+05	9.071-13	± 0.022				
26	6.393+05	1.094-12	± 0.019				
27	5.502+05	2.122-12	± 0.019				
28	3.688+05	2.502-12	± 0.017				
29	2.472+05	2.746-12	± 0.019				
30	1.576+05	1.722-12	± 0.020				
31	1.111+05	1.840-12	± 0.018				
32	5.248+04	7.680-13	± 0.033				
33	3.431+04	2.140-12	± 0.017				
34	2.479+04	6.332-13	± 0.023				
35	2.188+04	1.591-12	± 0.016				
36	1.060+04	1.743-12	± 0.017				
37	3.355+03	1.246-12	± 0.016				
38	1.234+03	6.024-13	± 0.017				
39	5.830+02	5.330-13	± 0.018				
40	2.754+02	8.384-13	± 0.017				
41	1.013+02	1.073-12	± 0.015				
42	2.902+01	8.173-13	± 0.015				
43	1.068+01	8.110-13	± 0.016				
44	3.059+00	4.321-13	± 0.017				
45	1.125+00	2.316-13	± 0.019				
46	4.140-01	4.976-14	± 0.032				
	1.000-05						

[a]Read as 1.964 x 10^7.

Table A-26. Neutron and Gamma Free-In-Air In-Box Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 0.63 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	fsd	Group Number	Upper Energy	Gamma Dose	fsd
1	1.964+07[a]	3.772-28 ±	0.140	1	2.000+07	8.104-29 ±	0.115
2	1.691+07	6.917-28 ±	0.243	2	1.400+07	5.591-28 ±	0.119
3	1.492+07	1.211-27 ±	0.200	3	1.200+07	1.079-25 ±	0.082
4	1.419+07	8.546-28 ±	0.164	4	1.000+07	1.019-24 ±	0.105
5	1.384+07	1.065-26 ±	0.154	5	8.000+06	7.364-24 ±	0.038
6	1.252+07	1.936-27 ±	0.212	6	7.000+06	1.635-24 ±	0.034
7	1.221+07	1.756-26 ±	0.201	7	6.000+06	2.145-24 ±	0.033
8	1.105+07	3.680-26 ±	0.215	8	5.000+06	2.254-24 ±	0.048
9	1.000+07	7.806-26 ±	0.165	9	4.000+06	2.506-24 ±	0.036
10	9.048+06	1.772-25 ±	0.154	10	3.000+06	1.438-24 ±	0.039
11	8.187+06	2.526-25 ±	0.139	11	2.500+06	1.840-24 ±	0.050
12	7.408+06	7.470-25 ±	0.148	12	2.000+06	1.829-24 ±	0.039
13	6.376+06	2.036-24 ±	0.127	13	1.500+06	1.749-24 ±	0.038
14	4.966+06	8.305-25 ±	0.131	14	1.000+06	1.867-24 ±	0.029
15	4.724+06	1.458-24 ±	0.094	15	7.000+05	1.948-24 ±	0.039
16	4.066+06	3.434-24 ±	0.081	16	4.550+05	9.624-25 ±	0.048
17	3.012+06	7.399-24 ±	0.098	17	3.000+05	9.016-25 ±	0.042
18	2.385+06	1.197-24 ±	0.101	18	1.500+05	1.282-25 ±	0.054
19	2.307+06	8.536-24 ±	0.062	19	1.000+05	1.009-26 ±	0.077
20	1.827+06	1.127-23 ±	0.042	20	7.000+04	5.249-28 ±	0.191
21	1.423+06	1.588-23 ±	0.035	21	4.500+04	1.048-28 ±	0.396
22	1.108+06	8.119-24 ±	0.044	22	3.000+04	4.658-29 ±	0.800
23	9.616+05	1.327-23 ±	0.028	23	2.000+04	8.958-29 ±	0.745
24	8.209+05	6.875-24 ±	0.043		1.000+04		
25	7.427+05	1.757-23 ±	0.022				
26	6.393+05	1.959-23 ±	0.019				
27	5.502+05	3.475-23 ±	0.019				
28	3.688+05	3.255-23 ±	0.017				
29	2.472+05	2.817-23 ±	0.019				
30	1.576+05	1.389-23 ±	0.020				
31	1.111+05	1.036-23 ±	0.018				
32	5.248+04	2.758-24 ±	0.033				
33	3.431+04	5.547-24 ±	0.017				
34	2.479+04	1.349-24 ±	0.023				
35	2.188+04	2.347-24 ±	0.016				
36	1.060+04	1.095-24 ±	0.017				
37	3.355+03	2.741-25 ±	0.016				
38	1.234+03	5.578-26 ±	0.017				
39	5.830+02	2.389-26 ±	0.018				
40	2.754+02	1.738-26 ±	0.017				
41	1.013+02	1.112-26 ±	0.015				
42	2.902+01	7.620-27 ±	0.015				
43	1.068+01	1.102-26 ±	0.016				
44	3.059+00	9.873-27 ±	0.017				
45	1.125+00	8.629-27 ±	0.019				
46	4.140-01	6.425-27 ±	0.032				
	1.000-05						

[a]Read as 1.964×10^7.

Table A-27. MASH Integral Neutron and Gamma-Ray Fluence and Free-In-Air In-Box Tissue Dose Results at the APRF at 400 Meters. Environmental Conditions: 1.18 wt% Hydrogen in Air and 34 wt% Ground Moisture.

DRC Parameter	Fluence ($n,\gamma \cdot cm^{-2}$/source n)	Free-In-Air Tissue Dose (Gy/source n)
Detector 1	2.749-11 ± 0.004[a]	2.382-22 ± 0.007
Detector 2	3.389-12 ± 0.014	2.193-23 ± 0.015
Detector 3	2.721-13 ± 0.074	1.714-24 ± 0.072
Detector 4	5.869-13 ± 0.043	3.701-24 ± 0.027
Detector 5	4.248-12 ± 0.013	2.734-23 ± 0.013
Detector 6	8.590-13 ± 0.037	5.415-24 ± 0.029
Detector 7	3.088-11 ± 0.004	2.601-22 ± 0.007
FF n Flux	5.577-11	5.577-11
FF γ Flux	2.939-11	2.939-11
FF t Flux	8.515-11	8.515-11
FF n Dose	5.577-11	3.810-22
FF γ Dose	2.939-11	9.669-23
FF t Dose	8.515-11	4.777-22
NPF	1.806+00	1.465+00
GPF	3.421+01	1.786+01
TPF	2.683+00	1.799+00
NRF	2.029+00	1.600+00
GRF	6.918+00	3.536+00
TRF	2.683+00	1.799+00

[a]Read as $2.749 \times 10^{-11} \pm 0.004$.

Table A-28. Neutron and Gamma-Ray In-Box Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 1.18 wt% Hydrogen in Air and 34 wt% Ground Moisture. (Units are n,$\gamma \cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	fsd	Group Number	Upper Energy	Gamma Fluence	fsd
1	1.964+07[a]	4.837-18	± 0.138	1	2.000+07	1.990-18	± 0.116
2	1.691+07	9.122-18	± 0.241	2	1.400+07	1.731-17	± 0.120
3	1.492+07	1.656-17	± 0.199	3	1.200+07	3.619-15	± 0.084
4	1.419+07	1.195-17	± 0.163	4	1.000+07	4.000-14	± 0.106
5	1.384+07	1.516-16	± 0.153	5	8.000+06	3.290-13	± 0.038
6	1.252+07	2.842-17	± 0.210	6	7.000+06	8.061-14	± 0.035
7	1.221+07	2.621-16	± 0.199	7	6.000+06	1.196-13	± 0.033
8	1.105+07	5.826-16	± 0.213	8	5.000+06	1.434-13	± 0.049
9	1.000+07	1.294-15	± 0.163	9	4.000+06	1.895-13	± 0.036
10	9.048+06	3.071-15	± 0.153	10	3.000+06	1.275-13	± 0.040
11	8.187+06	4.395-15	± 0.138	11	2.500+06	1.889-13	± 0.050
12	7.408+06	1.395-14	± 0.148	12	2.000+06	2.237-13	± 0.039
13	6.376+06	4.135-14	± 0.126	13	1.500+06	2.773-13	± 0.039
14	4.966+06	1.755-14	± 0.130	14	1.000+06	4.092-13	± 0.029
15	4.724+06	3.126-14	± 0.093	15	7.000+05	6.060-13	± 0.039
16	4.066+06	7.710-14	± 0.081	16	4.550+05	4.624-13	± 0.048
17	3.012+06	1.969-13	± 0.098	17	3.000+05	7.948-13	± 0.042
18	2.385+06	3.432-14	± 0.102	18	1.500+05	2.239-13	± 0.054
19	2.307+06	2.532-13	± 0.062	19	1.000+05	2.683-14	± 0.078
20	1.827+06	3.672-13	± 0.042	20	7.000+04	1.532-15	± 0.190
21	1.423+06	5.709-13	± 0.035	21	4.500+04	1.969-16	± 0.395
22	1.108+06	3.045-13	± 0.044	22	3.000+04	4.007-17	± 0.797
23	9.616+05	5.679-13	± 0.028	23	2.000+04	2.358-17	± 0.748
24	8.209+05	3.172-13	± 0.043		1.000+04		
25	7.427+05	8.609-13	± 0.022				
26	6.393+05	1.039-12	± 0.019				
27	5.502+05	2.010-12	± 0.019				
28	3.688+05	2.357-12	± 0.018				
29	2.472+05	2.579-12	± 0.019				
30	1.576+05	1.614-12	± 0.020				
31	1.111+05	1.721-12	± 0.018				
32	5.248+04	7.190-13	± 0.033				
33	3.431+04	2.001-12	± 0.017				
34	2.479+04	5.901-13	± 0.023				
35	2.188+04	1.481-12	± 0.016				
36	1.060+04	1.620-12	± 0.017				
37	3.355+03	1.155-12	± 0.016				
38	1.234+03	5.569-13	± 0.017				
39	5.830+02	4.921-13	± 0.018				
40	2.754+02	7.722-13	± 0.017				
41	1.013+02	9.840-13	± 0.015				
42	2.902+01	7.476-13	± 0.015				
43	1.068+01	7.394-13	± 0.016				
44	3.059+00	3.928-13	± 0.017				
45	1.125+00	2.100-13	± 0.019				
46	4.140-01	4.511-14	± 0.033				
	1.000-05						

[a] Read as 1.964×10^{7}.

Table A-29. Neutron and Gamma Free-In-Air In-Box Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 1.18 wt% Hydrogen in Air and 34 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	fsd	Group Number	Upper Energy	Gamma Dose	fsd
1	1.964+07[a]	3.563-28 ±	0.138	1	2.000+07	7.981-29 ±	0.116
2	1.691+07	6.427-28 ±	0.241	2	1.400+07	5.497-28 ±	0.120
3	1.492+07	1.136-27 ±	0.199	3	1.200+07	9.993-26 ±	0.084
4	1.419+07	8.060-28 ±	0.163	4	1.000+07	9.406-25 ±	0.106
5	1.384+07	1.003-26 ±	0.153	5	8.000+06	6.748-24 ±	0.038
6	1.252+07	1.814-27 ±	0.210	6	7.000+06	1.492-24 ±	0.035
7	1.221+07	1.661-26 ±	0.199	7	6.000+06	1.966-24 ±	0.033
8	1.105+07	3.489-26 ±	0.213	8	5.000+06	2.055-24 ±	0.049
9	1.000+07	7.456-26 ±	0.163	9	4.000+06	2.298-24 ±	0.036
10	9.048+06	1.694-25 ±	0.153	10	3.000+06	1.321-24 ±	0.040
11	8.187+06	2.402-25 ±	0.138	11	2.500+06	1.705-24 ±	0.050
12	7.408+06	7.149-25 ±	0.148	12	2.000+06	1.690-24 ±	0.039
13	6.376+06	1.947-24 ±	0.126	13	1.500+06	1.623-24 ±	0.039
14	4.966+06	8.035-25 ±	0.130	14	1.000+06	1.748-24 ±	0.029
15	4.724+06	1.387-24 ±	0.093	15	7.000+05	1.796-24 ±	0.039
16	4.066+06	3.233-24 ±	0.081	16	4.550+05	8.923-25 ±	0.048
17	3.012+06	7.036-24 ±	0.098	17	3.000+05	8.378-25 ±	0.042
18	2.385+06	1.141-24 ±	0.102	18	1.500+05	1.186-25 ±	0.054
19	2.307+06	8.132-24 ±	0.062	19	1.000+05	9.344-27 ±	0.078
20	1.827+06	1.069-23 ±	0.042	20	7.000+04	4.800-28 ±	0.190
21	1.423+06	1.504-23 ±	0.035	21	4.500+04	9.542-29 ±	0.395
22	1.108+06	7.689-24 ±	0.044	22	3.000+04	4.206-29 ±	0.797
23	9.616+05	1.264-23 ±	0.028	23	2.000+04	8.007-29 ±	0.748
24	8.209+05	6.531-24 ±	0.043		1.000+04		
25	7.427+05	1.667-23 ±	0.022				
26	6.393+05	1.860-23 ±	0.019				
27	5.502+05	3.291-23 ±	0.019				
28	3.688+05	3.066-23 ±	0.018				
29	2.472+05	2.646-23 ±	0.019				
30	1.576+05	1.301-23 ±	0.020				
31	1.111+05	9.699-24 ±	0.018				
32	5.248+04	2.582-24 ±	0.033				
33	3.431+04	5.185-24 ±	0.017				
34	2.479+04	1.257-24 ±	0.023				
35	2.188+04	2.185-24 ±	0.016				
36	1.060+04	1.018-24 ±	0.017				
37	3.355+03	2.540-25 ±	0.016				
38	1.234+03	5.156-26 ±	0.017				
39	5.830+02	2.205-26 ±	0.018				
40	2.754+02	1.601-26 ±	0.017				
41	1.013+02	1.021-26 ±	0.015				
42	2.902+01	6.971-27 ±	0.015				
43	1.068+01	1.005-26 ±	0.016				
44	3.059+00	8.974-27 ±	0.017				
45	1.125+00	7.825-27 ±	0.019				
46	4.140-01	5.825-27 ±	0.033				
	1.000-05						

[a]Read as 1.964×10^7.

Table A-30. MASH Integral Neutron and Gamma-Ray Fluence and Free-In-Air In-Box Tissue Dose Results at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 20 wt% Ground Moisture.

DRC Parameter	Fluence ($n,\gamma \cdot cm^{-2}$/source n)	Free-In-Air Tissue Dose (Gy/source n)
Detector 1	2.738-11 ± 0.004[a]	2.381-22 ± 0.007
Detector 2	3.314-12 ± 0.014	2.137-23 ± 0.015
Detector 3	2.620-13 ± 0.076	1.651-24 ± 0.073
Detector 4	5.708-13 ± 0.044	3.547-24 ± 0.028
Detector 5	4.147-12 ± 0.013	2.657-23 ± 0.013
Detector 6	8.328-13 ± 0.038	5.198-24 ± 0.030
Detector 7	3.069-11 ± 0.004	2.595-22 ± 0.007
FF n Flux	5.390-11	5.390-11
FF γ Flux	2.984-11	2.984-11
FF t Flux	8.375-11	8.375-11
FF n Dose	5.390-11	3.745-22
FF γ Dose	2.984-11	9.537-23
FF t Dose	8.375-11	4.698-22
NPF	1.756+00	1.443+00
GPF	3.584+01	1.835+01
TPF	2.657+00	1.775+00
NRF	1.969+00	1.573+00
GRF	7.197+00	3.590+00
TRF	2.657+00	1.775+00

[a]Read as $2.738 \times 10^{-11} \pm 0.004$.

Table A-31. Neutron and Gamma-Ray In-Box Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are $n,\gamma \cdot cm^{-2}$ per source neutron.)

Group Number	Upper Energy	Neutron Fluence	fsd	Group Number	Upper Energy	Gamma Fluence	fsd
1	1.964+07[a]	4.788-18 ±	0.138	1	2.000+07	1.986-18 ±	0.117
2	1.691+07	9.022-18 ±	0.241	2	1.400+07	1.727-17 ±	0.119
3	1.492+07	1.640-17 ±	0.199	3	1.200+07	3.353-15 ±	0.085
4	1.419+07	1.184-17 ±	0.163	4	1.000+07	3.908-14 ±	0.108
5	1.384+07	1.502-16 ±	0.153	5	8.000+06	3.193-13 ±	0.039
6	1.252+07	2.815-17 ±	0.210	6	7.000+06	7.774-14 ±	0.035
7	1.221+07	2.605-16 ±	0.199	7	6.000+06	1.148-13 ±	0.034
8	1.105+07	5.789-16 ±	0.213	8	5.000+06	1.381-13 ±	0.049
9	1.000+07	1.289-15 ±	0.163	9	4.000+06	1.829-13 ±	0.037
10	9.048+06	3.063-15 ±	0.153	10	3.000+06	1.232-13 ±	0.040
11	8.187+06	4.378-15 ±	0.138	11	2.500+06	1.850-13 ±	0.050
12	7.408+06	1.392-14 ±	0.148	12	2.000+06	2.184-13 ±	0.040
13	6.376+06	4.128-14 ±	0.126	13	1.500+06	2.713-13 ±	0.039
14	4.966+06	1.759-14 ±	0.130	14	1.000+06	4.037-13 ±	0.030
15	4.724+06	3.115-14 ±	0.093	15	7.000+05	5.912-13 ±	0.040
16	4.066+06	7.670-14 ±	0.081	16	4.550+05	4.528-13 ±	0.049
17	3.012+06	1.967-13 ±	0.099	17	3.000+05	7.796-13 ±	0.043
18	2.385+06	3.424-14 ±	0.102	18	1.500+05	2.185-13 ±	0.054
19	2.307+06	2.532-13 ±	0.063	19	1.000+05	2.625-14 ±	0.079
20	1.827+06	3.667-13 ±	0.042	20	7.000+04	1.491-15 ±	0.190
21	1.423+06	5.702-13 ±	0.035	21	4.500+04	1.926-16 ±	0.394
22	1.108+06	3.044-13 ±	0.045	22	3.000+04	3.915-17 ±	0.796
23	9.616+05	5.700-13 ±	0.028	23	2.000+04	2.255-17 ±	0.749
24	8.209+05	3.180-13 ±	0.043		1.000+04		
25	7.427+05	8.626-13 ±	0.022				
26	6.393+05	1.042-12 ±	0.019				
27	5.502+05	2.012-12 ±	0.019				
28	3.688+05	2.354-12 ±	0.018				
29	2.472+05	2.574-12 ±	0.019				
30	1.576+05	1.610-12 ±	0.020				
31	1.111+05	1.719-12 ±	0.018				
32	5.248+04	7.183-13 ±	0.033				
33	3.431+04	1.998-12 ±	0.017				
34	2.479+04	5.887-13 ±	0.023				
35	2.188+04	1.477-12 ±	0.017				
36	1.060+04	1.614-12 ±	0.017				
37	3.355+03	1.147-12 ±	0.016				
38	1.234+03	5.523-13 ±	0.017				
39	5.830+02	4.874-13 ±	0.018				
40	2.754+02	7.627-13 ±	0.017				
41	1.013+02	9.683-13 ±	0.015				
42	2.902+01	7.333-13 ±	0.015				
43	1.068+01	7.228-13 ±	0.016				
44	3.059+00	3.826-13 ±	0.017				
45	1.125+00	2.038-13 ±	0.019				
46	4.140-01	4.369-14 ±	0.033				
	1.000-05						

[a]Read as 1.964×10^7.

Table A-32. Neutron and Gamma Free-In-Air In-Box Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 20 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	fsd	Group Number	Upper Energy	Gamma Dose	fsd
1	1.964+07[a]	3.527-28 ±	0.138	1	2.000+07	7.966-29 ±	0.117
2	1.691+07	6.357-28 ±	0.241	2	1.400+07	5.485-28 ±	0.119
3	1.492+07	1.125-27 ±	0.199	3	1.200+07	9.259-26 ±	0.085
4	1.419+07	7.986-28 ±	0.163	4	1.000+07	9.189-25 ±	0.108
5	1.384+07	9.935-27 ±	0.153	5	8.000+06	6.548-24 ±	0.039
6	1.252+07	1.796-27 ±	0.210	6	7.000+06	1.439-24 ±	0.035
7	1.221+07	1.650-26 ±	0.199	7	6.000+06	1.886-24 ±	0.034
8	1.105+07	3.466-26 ±	0.213	8	5.000+06	1.980-24 ±	0.049
9	1.000+07	7.428-26 ±	0.163	9	4.000+06	2.218-24 ±	0.037
10	9.048+06	1.689-25 ±	0.153	10	3.000+06	1.276-24 ±	0.040
11	8.187+06	2.392-25 ±	0.138	11	2.500+06	1.670-24 ±	0.050
12	7.408+06	7.137-25 ±	0.148	12	2.000+06	1.650-24 ±	0.040
13	6.376+06	1.944-24 ±	0.126	13	1.500+06	1.588-24 ±	0.039
14	4.966+06	8.054-25 ±	0.130	14	1.000+06	1.725-24 ±	0.030
15	4.724+06	1.382-24 ±	0.093	15	7.000+05	1.752-24 ±	0.040
16	4.066+06	3.217-24 ±	0.081	16	4.550+05	8.738-25 ±	0.049
17	3.012+06	7.030-24 ±	0.099	17	3.000+05	8.218-25 ±	0.043
18	2.385+06	1.139-24 ±	0.102	18	1.500+05	1.157-25 ±	0.054
19	2.307+06	8.130-24 ±	0.063	19	1.000+05	9.142-27 ±	0.079
20	1.827+06	1.068-23 ±	0.042	20	7.000+04	4.671-28 ±	0.190
21	1.423+06	1.502-23 ±	0.035	21	4.500+04	9.334-29 ±	0.394
22	1.108+06	7.686-24 ±	0.045	22	3.000+04	4.109-29 ±	0.796
23	9.616+05	1.268-23 ±	0.028	23	2.000+04	7.657-29 ±	0.749
24	8.209+05	6.549-24 ±	0.043		1.000+04		
25	7.427+05	1.671-23 ±	0.022				
26	6.393+05	1.866-23 ±	0.019				
27	5.502+05	3.294-23 ±	0.019				
28	3.688+05	3.062-23 ±	0.018				
29	2.472+05	2.640-23 ±	0.019				
30	1.576+05	1.298-23 ±	0.020				
31	1.111+05	9.682-24 ±	0.018				
32	5.248+04	2.580-24 ±	0.033				
33	3.431+04	5.177-24 ±	0.017				
34	2.479+04	1.254-24 ±	0.023				
35	2.188+04	2.180-24 ±	0.017				
36	1.060+04	1.014-24 ±	0.017				
37	3.355+03	2.523-25 ±	0.016				
38	1.234+03	5.114-26 ±	0.017				
39	5.830+02	2.184-26 ±	0.018				
40	2.754+02	1.581-26 ±	0.017				
41	1.013+02	1.004-26 ±	0.015				
42	2.902+01	6.838-27 ±	0.015				
43	1.068+01	9.821-27 ±	0.016				
44	3.059+00	8.741-27 ±	0.017				
45	1.125+00	7.595-27 ±	0.019				
46	4.140-01	5.642-27 ±	0.033				
	1.000-05						

[a]Read as 1.964 x 10^7.

Table A-33. MASH Integral Neutron and Gamma-Ray Fluence and Free-In-Air In-Box Tissue Dose Results at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 48 wt% Ground Moisture.

DRC Parameter	Fluence ($n,\gamma \cdot cm^{-2}$/source n)	Free-In-Air Tissue Dose (Gy/source n)
Detector 1	2.601-11 ± 0.004[a]	2.324-22 ± 0.007
Detector 2	3.217-12 ± 0.014	2.062-23 ± 0.015
Detector 3	2.501-13 ± 0.075	1.575-24 ± 0.072
Detector 4	5.940-13 ± 0.044	3.685-24 ± 0.028
Detector 5	4.061-12 ± 0.014	2.588-23 ± 0.014
Detector 6	8.441-13 ± 0.038	5.260-24 ± 0.029
Detector 7	2.923-11 ± 0.004	2.531-22 ± 0.007
FF n Flux	5.166-11	5.166-11
FF γ Flux	3.044-11	3.044-11
FF t Flux	8.210-11	8.210-11
FF n Dose	5.166-11	3.666-22
FF γ Dose	3.044-11	9.608-23
FF t Dose	8.210-11	4.627-22
NPF	1.767+00	1.449+00
GPF	3.606+01	1.827+01
TPF	2.730+00	1.791+00
NRF	1.986+00	1.577+00
GRF	7.495+00	3.713+00
TRF	2.730+00	1.791+00

[a]Read as $2.601 \times 10^{-11} \pm 0.004$.

Table A-34. Neutron and Gamma-Ray In-Box Fluence Spectra at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are n,γ·cm^{-2} per source neutron.)

Group Number	Upper Energy	Neutron Fluence	fsd	Group Number	Upper Energy	Gamma Fluence	fsd
1	1.964+07[a]	5.084-18	± 0.141	1	2.000+07	1.968-18	± 0.116
2	1.691+07	9.782-18	± 0.243	2	1.400+07	1.684-17	± 0.120
3	1.492+07	1.756-17	± 0.201	3	1.200+07	3.500-15	± 0.084
4	1.419+07	1.258-17	± 0.165	4	1.000+07	3.773-14	± 0.112
5	1.384+07	1.598-16	± 0.155	5	8.000+06	3.063-13	± 0.040
6	1.252+07	3.017-17	± 0.213	6	7.000+06	7.496-14	± 0.035
7	1.221+07	2.758-16	± 0.202	7	6.000+06	1.122-13	± 0.034
8	1.105+07	6.103-16	± 0.216	8	5.000+06	1.339-13	± 0.049
9	1.000+07	1.347-15	± 0.165	9	4.000+06	1.785-13	± 0.037
10	9.048+06	3.194-15	± 0.155	10	3.000+06	1.209-13	± 0.041
11	8.187+06	4.594-15	± 0.140	11	2.500+06	1.818-13	± 0.050
12	7.408+06	1.446-14	± 0.149	12	2.000+06	2.146-13	± 0.040
13	6.376+06	4.269-14	± 0.129	13	1.500+06	2.678-13	± 0.040
14	4.966+06	1.789-14	± 0.132	14	1.000+06	4.023-13	± 0.030
15	4.724+06	3.221-14	± 0.095	15	7.000+05	5.760-13	± 0.040
16	4.066+06	7.963-14	± 0.083	16	4.550+05	4.443-13	± 0.050
17	3.012+06	2.014-13	± 0.100	17	3.000+05	7.653-13	± 0.044
18	2.385+06	3.472-14	± 0.104	18	1.500+05	2.137-13	± 0.055
19	2.307+06	2.558-13	± 0.064	19	1.000+05	2.569-14	± 0.082
20	1.827+06	3.699-13	± 0.043	20	7.000+04	1.427-15	± 0.192
21	1.423+06	5.702-13	± 0.036	21	4.500+04	1.792-16	± 0.396
22	1.108+06	3.035-13	± 0.046	22	3.000+04	3.644-17	± 0.797
23	9.616+05	5.593-13	± 0.029	23	2.000+04	2.180-17	± 0.746
24	8.209+05	3.137-13	± 0.045		1.000+04		
25	7.427+05	8.446-13	± 0.023				
26	6.393+05	1.010-12	± 0.020				
27	5.502+05	1.958-12	± 0.020				
28	3.688+05	2.275-12	± 0.018				
29	2.472+05	2.471-12	± 0.019				
30	1.576+05	1.532-12	± 0.021				
31	1.111+05	1.612-12	± 0.019				
32	5.248+04	6.747-13	± 0.035				
33	3.431+04	1.866-12	± 0.018				
34	2.479+04	5.446-13	± 0.023				
35	2.188+04	1.357-12	± 0.017				
36	1.060+04	1.484-12	± 0.018				
37	3.355+03	1.055-12	± 0.017				
38	1.234+03	5.080-13	± 0.017				
39	5.830+02	4.493-13	± 0.018				
40	2.754+02	7.063-13	± 0.018				
41	1.013+02	9.000-13	± 0.016				
42	2.902+01	6.840-13	± 0.016				
43	1.068+01	6.777-13	± 0.016				
44	3.059+00	3.606-13	± 0.017				
45	1.125+00	1.931-13	± 0.019				
46	4.140-01	4.154-14	± 0.033				
	1.000-05						

[a]Read as 1.964 x 10^7.

Table A-35. Neutron and Gamma Free-In-Air In-Box Tissue Dose Spectra at the APRF at 400 Meters. Environmental Conditions: 1.85 wt% Hydrogen in Air and 48 wt% Ground Moisture. (Units are Grays per source neutron.)

Group Number	Upper Energy	Neutron Dose	fsd	Group Number	Upper Energy	Gamma Dose	fsd
1	1.964+07[a]	3.744-28 ±	0.141	1	2.000+07	7.892-29 ±	0.116
2	1.691+07	6.892-28 ±	0.243	2	1.400+07	5.349-28 ±	0.120
3	1.492+07	1.204-27 ±	0.201	3	1.200+07	9.663-26 ±	0.084
4	1.419+07	8.487-28 ±	0.165	4	1.000+07	8.873-25 ±	0.112
5	1.384+07	1.057-26 ±	0.155	5	8.000+06	6.282-24 ±	0.040
6	1.252+07	1.925-27 ±	0.213	6	7.000+06	1.387-24 ±	0.035
7	1.221+07	1.747-26 ±	0.202	7	6.000+06	1.843-24 ±	0.034
8	1.105+07	3.655-26 ±	0.216	8	5.000+06	1.919-24 ±	0.049
9	1.000+07	7.762-26 ±	0.165	9	4.000+06	2.165-24 ±	0.037
10	9.048+06	1.762-25 ±	0.155	10	3.000+06	1.253-24 ±	0.041
11	8.187+06	2.510-25 ±	0.140	11	2.500+06	1.641-24 ±	0.050
12	7.408+06	7.413-25 ±	0.149	12	2.000+06	1.622-24 ±	0.040
13	6.376+06	2.010-24 ±	0.129	13	1.500+06	1.568-24 ±	0.040
14	4.966+06	8.192-25 ±	0.132	14	1.000+06	1.719-24 ±	0.030
15	4.724+06	1.429-24 ±	0.095	15	7.000+05	1.707-24 ±	0.040
16	4.066+06	3.340-24 ±	0.083	16	4.550+05	8.574-25 ±	0.050
17	3.012+06	7.198-24 ±	0.100	17	3.000+05	8.067-25 ±	0.044
18	2.385+06	1.155-24 ±	0.104	18	1.500+05	1.132-25 ±	0.055
19	2.307+06	8.213-24 ±	0.064	19	1.000+05	8.946-27 ±	0.082
20	1.827+06	1.077-23 ±	0.043	20	7.000+04	4.470-28 ±	0.192
21	1.423+06	1.502-23 ±	0.036	21	4.500+04	8.686-29 ±	0.396
22	1.108+06	7.663-24 ±	0.046	22	3.000+04	3.825-29 ±	0.797
23	9.616+05	1.245-23 ±	0.029	23	2.000+04	7.404-29 ±	0.746
24	8.209+05	6.460-24 ±	0.045		1.000+04		
25	7.427+05	1.636-23 ±	0.023				
26	6.393+05	1.809-23 ±	0.020				
27	5.502+05	3.206-23 ±	0.020				
28	3.688+05	2.959-23 ±	0.018				
29	2.472+05	2.534-23 ±	0.019				
30	1.576+05	1.235-23 ±	0.021				
31	1.111+05	9.085-24 ±	0.019				
32	5.248+04	2.423-24 ±	0.035				
33	3.431+04	4.837-24 ±	0.018				
34	2.479+04	1.160-24 ±	0.023				
35	2.188+04	2.002-24 ±	0.017				
36	1.060+04	9.324-25 ±	0.018				
37	3.355+03	2.321-25 ±	0.017				
38	1.234+03	4.703-26 ±	0.017				
39	5.830+02	2.014-26 ±	0.018				
40	2.754+02	1.465-26 ±	0.018				
41	1.013+02	9.335-27 ±	0.016				
42	2.902+01	6.378-27 ±	0.016				
43	1.068+01	9.209-27 ±	0.016				
44	3.059+00	8.238-27 ±	0.017				
45	1.125+00	7.197-27 ±	0.019				
46	4.140-01	5.364-27 ±	0.033				
	1.000-05						

[a]Read as 1.964×10^7.

APPENDIX B

Comparisons of Experimentally Measured and MASH Calculated Fluence Spectra and Energy Integrated Fluence Spectra for the Free-Field and In-Box Environments at the Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF) in Aberdeen Proving Ground, Maryland from October 23, 1989 to November 2, 1989

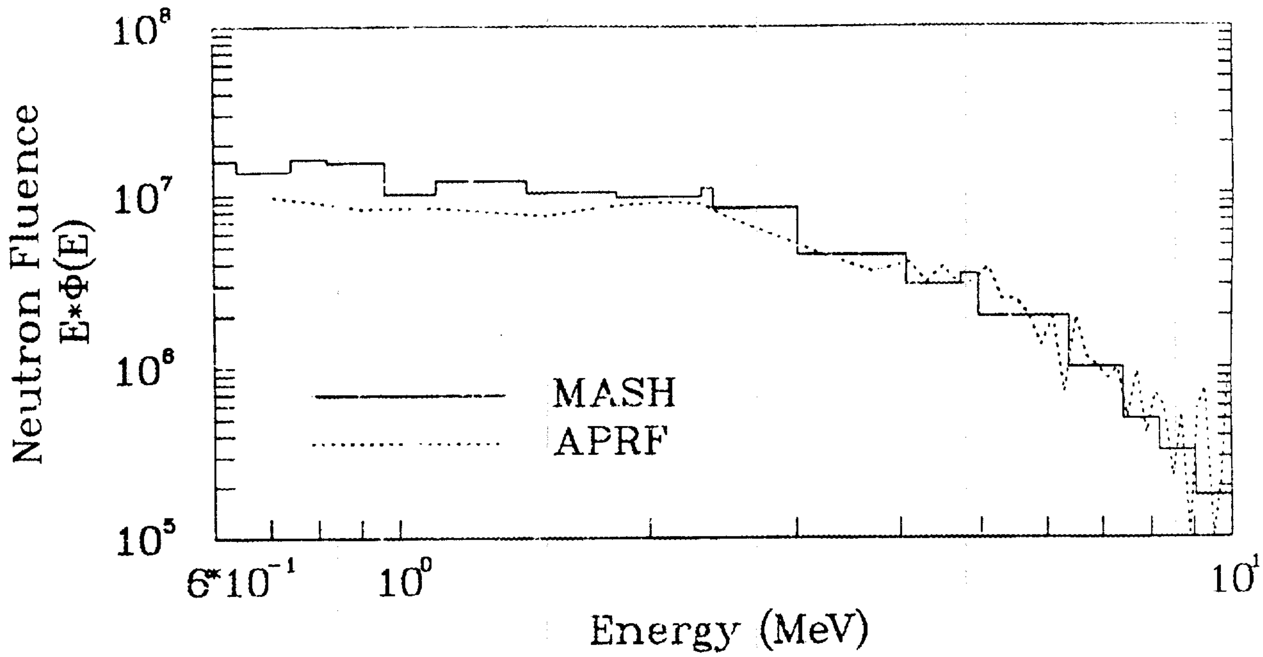

Figure B-1. Comparison of APRF Measured and MASH Calculated Neutron Free-Field Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

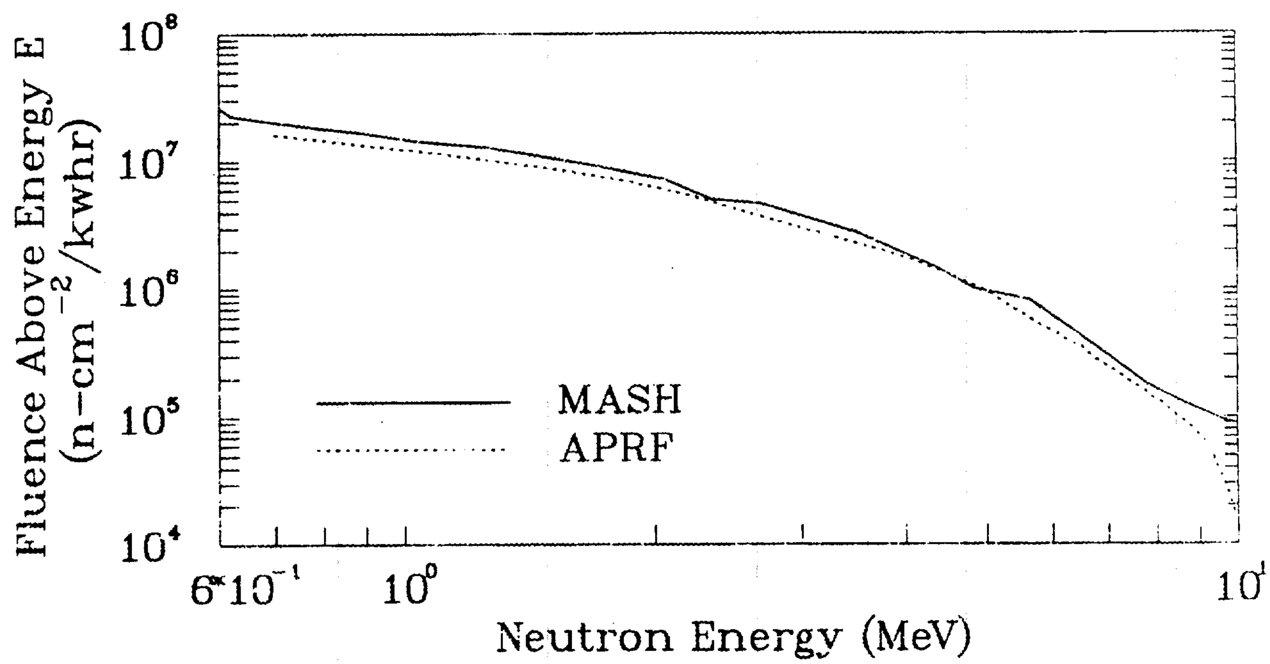

Figure B-2. Comparison of APRF Measured and MASH Calculated Neutron Free-Field Energy Integrated Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

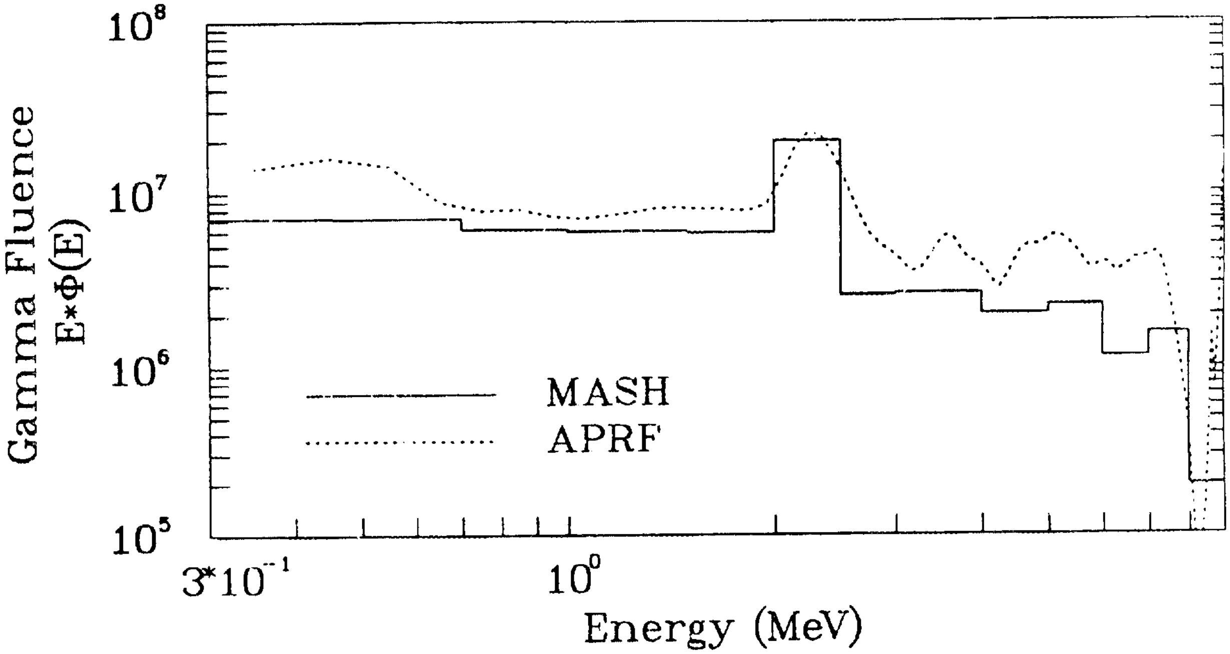

Figure B-3. Comparison of APRF Measured and MASH Calculated Gamma-Ray Free-Field Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

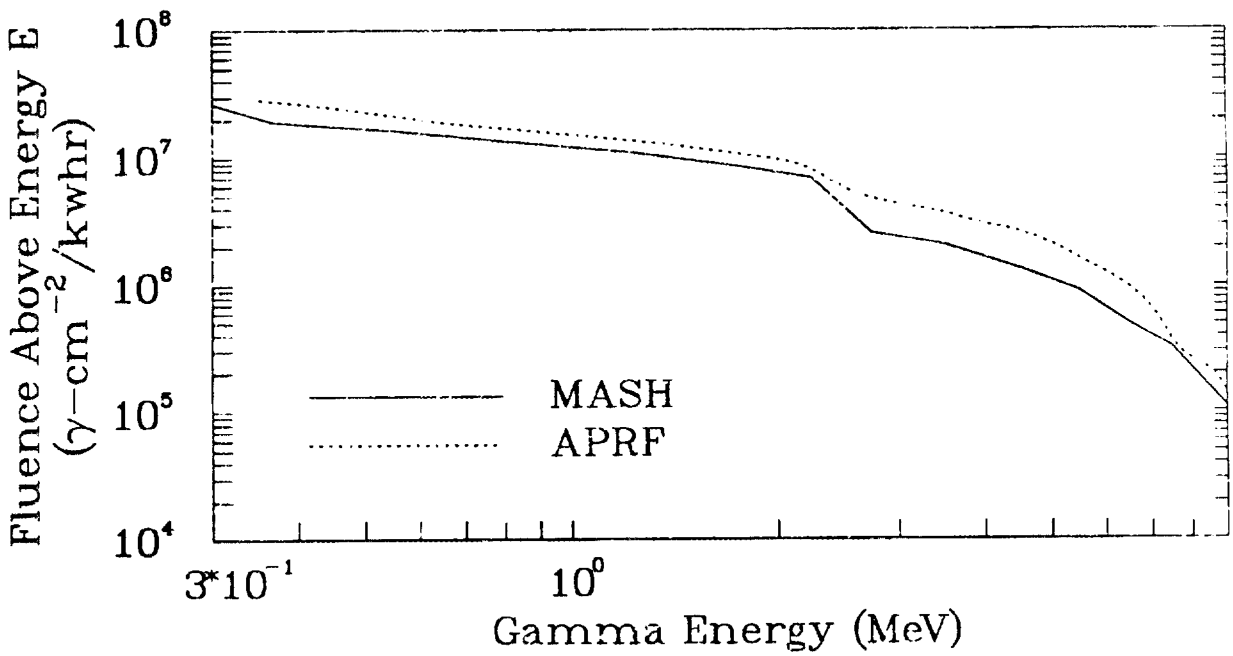

Figure B-4. Comparison of APRF Measured and MASH Calculated Gamma-Ray Free-Field Energy Integrated Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

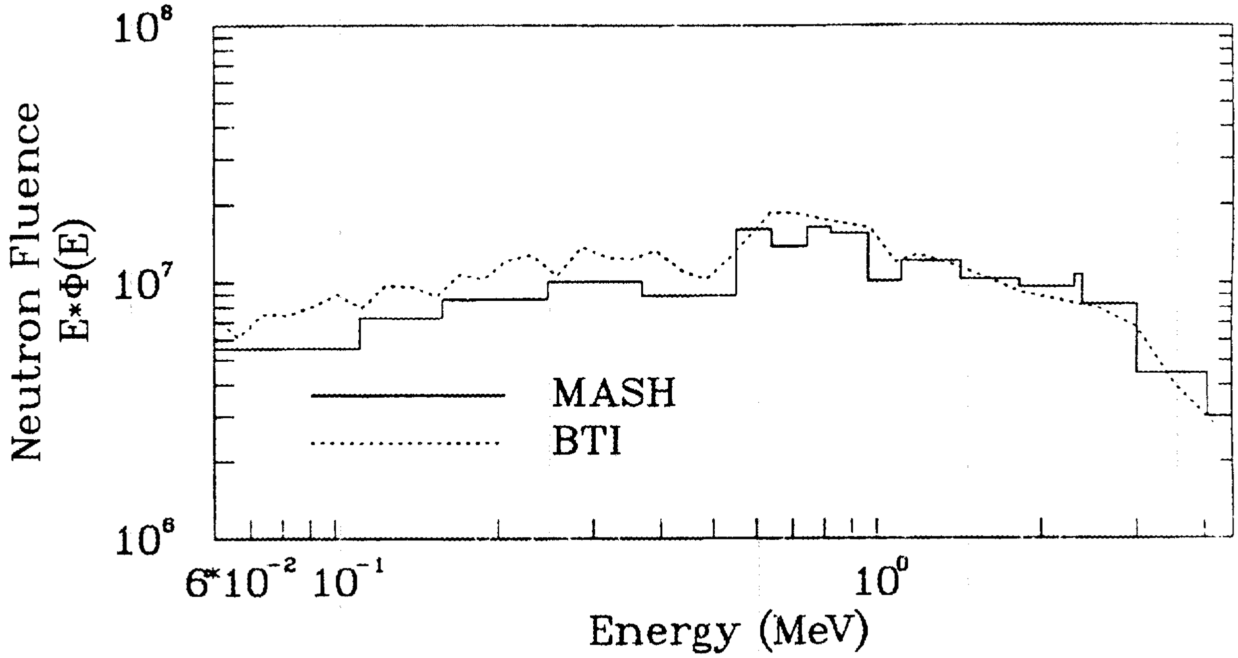

Figure B-5. Comparison of BTI Measured and MASH Calculated Neutron Free-Field Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

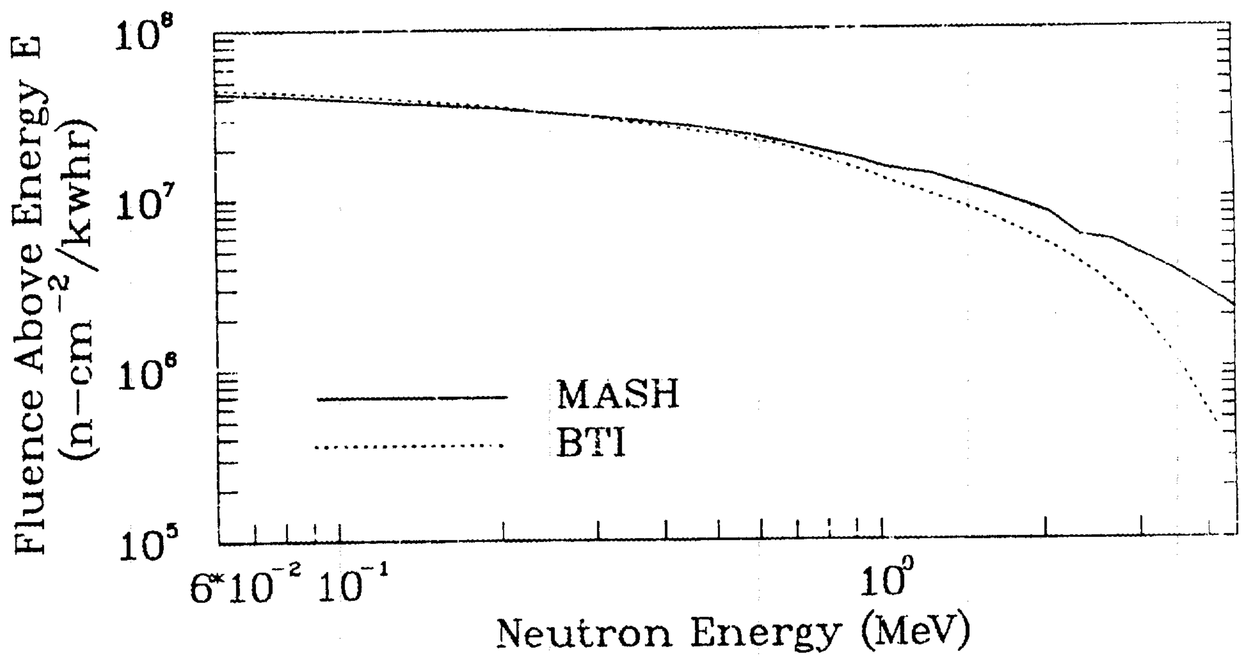

Figure B-6. Comparison of BTI Measured and MASH Calculated Neutron Free-Field Energy Integrated Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

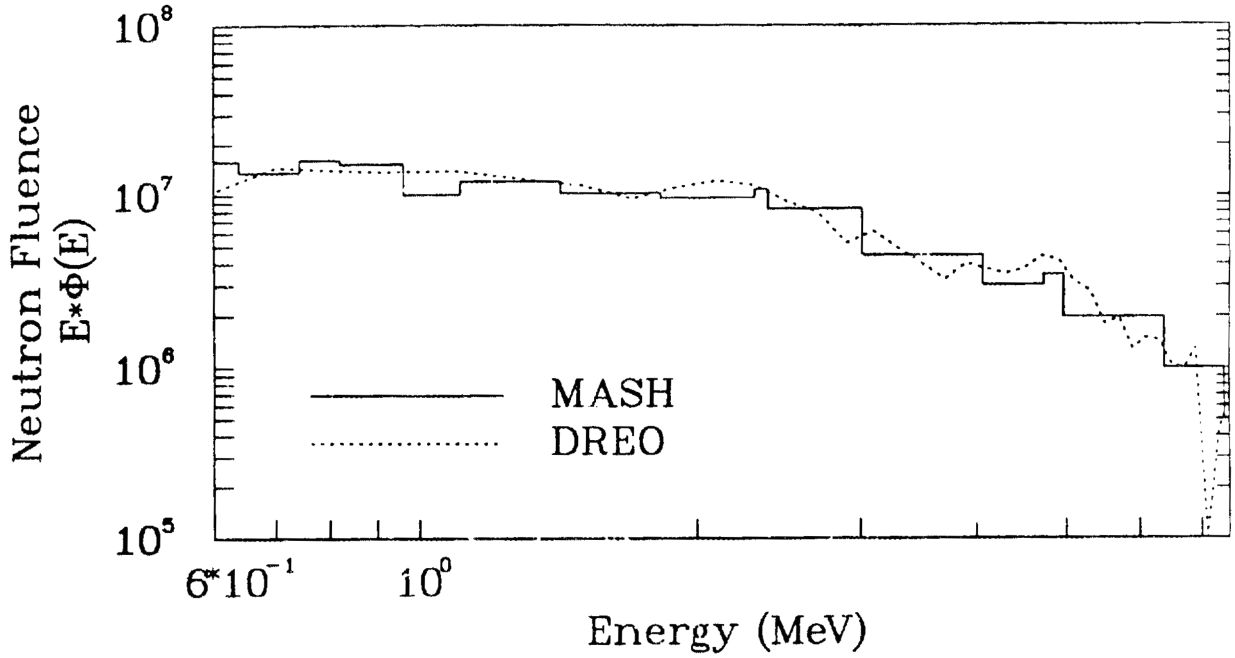

Figure B-7. Comparison of DREO Measured and MASH Calculated Neutron Free-Field Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

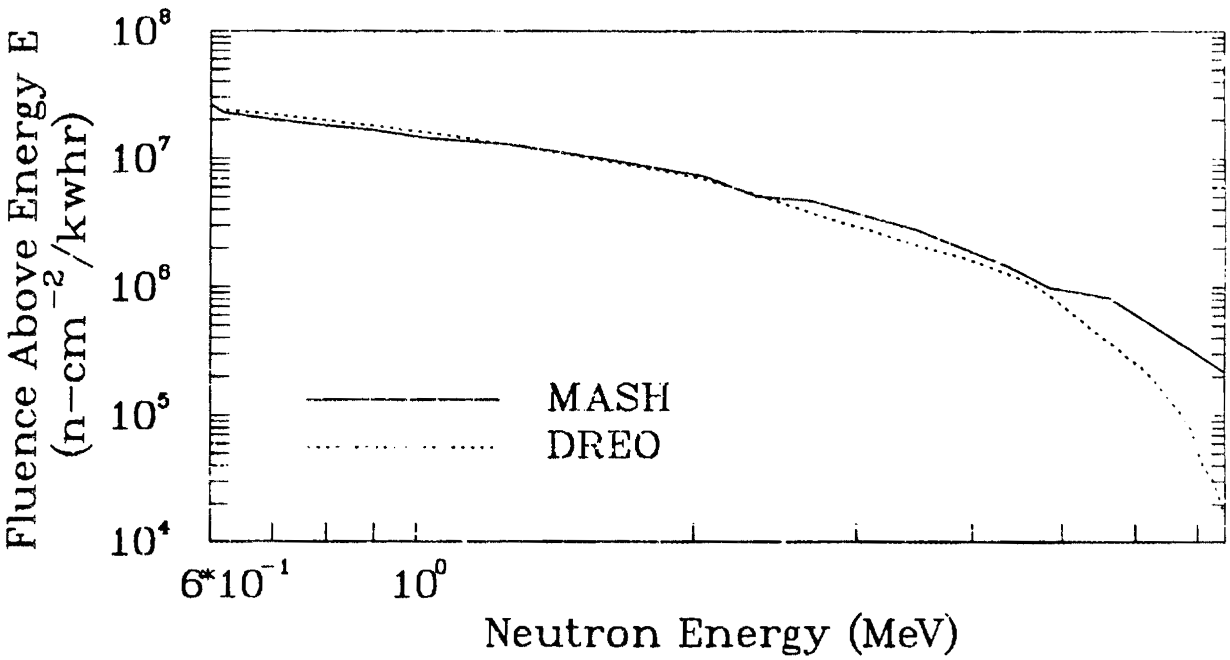

Figure B-8. Comparison of DREO Measured and MASH Calculated Neutron Free-Field Energy Integrated Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

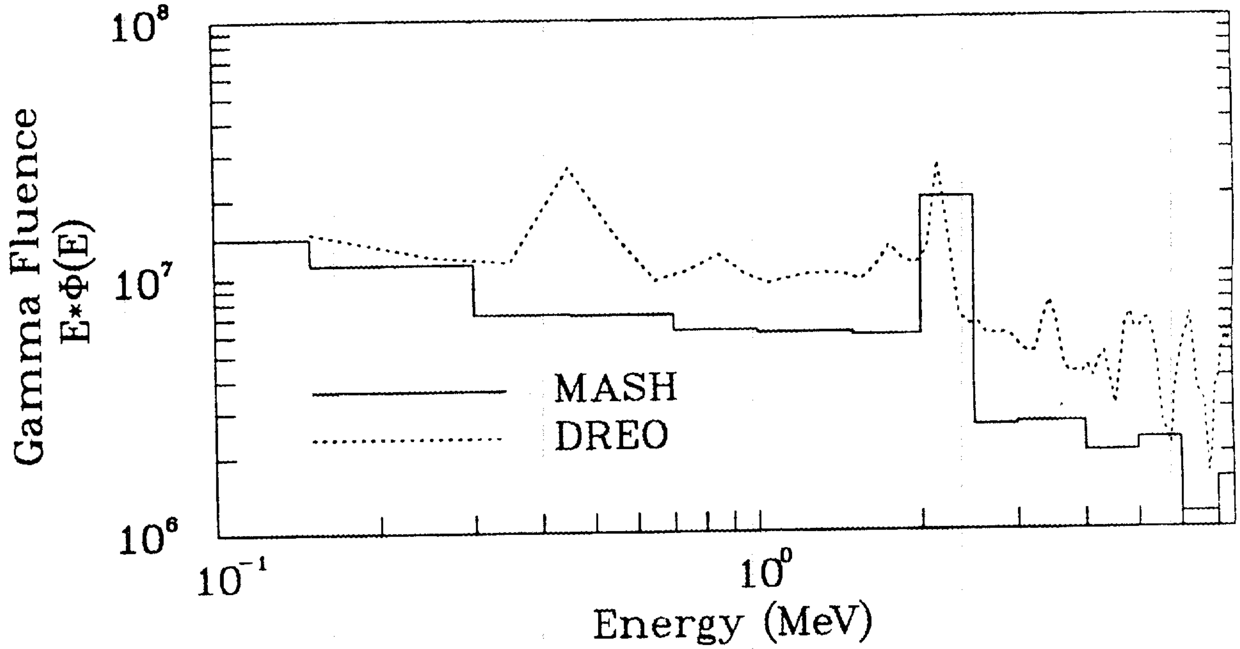

Figure B-9. Comparison of DREO Measured and MASH Calculated Gamma-Ray Free-Field Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

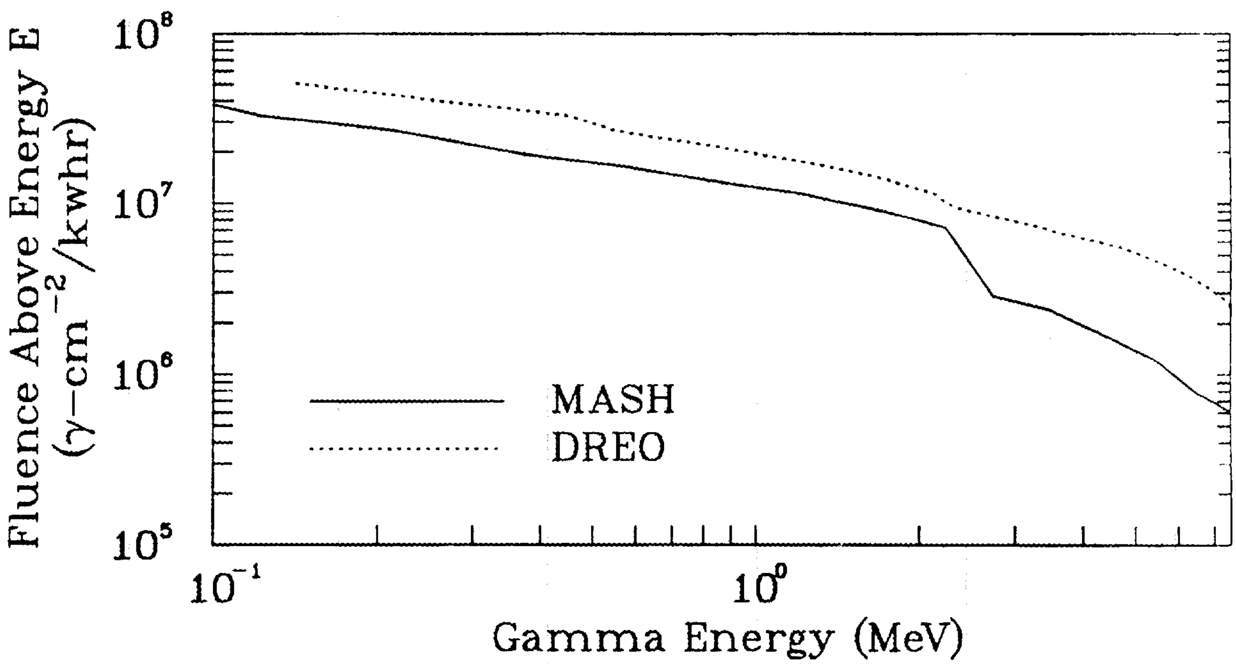

Figure B-10. Comparison of DREO Measured and MASH Calculated Gamma-Ray Free-Field Energy Integrated Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

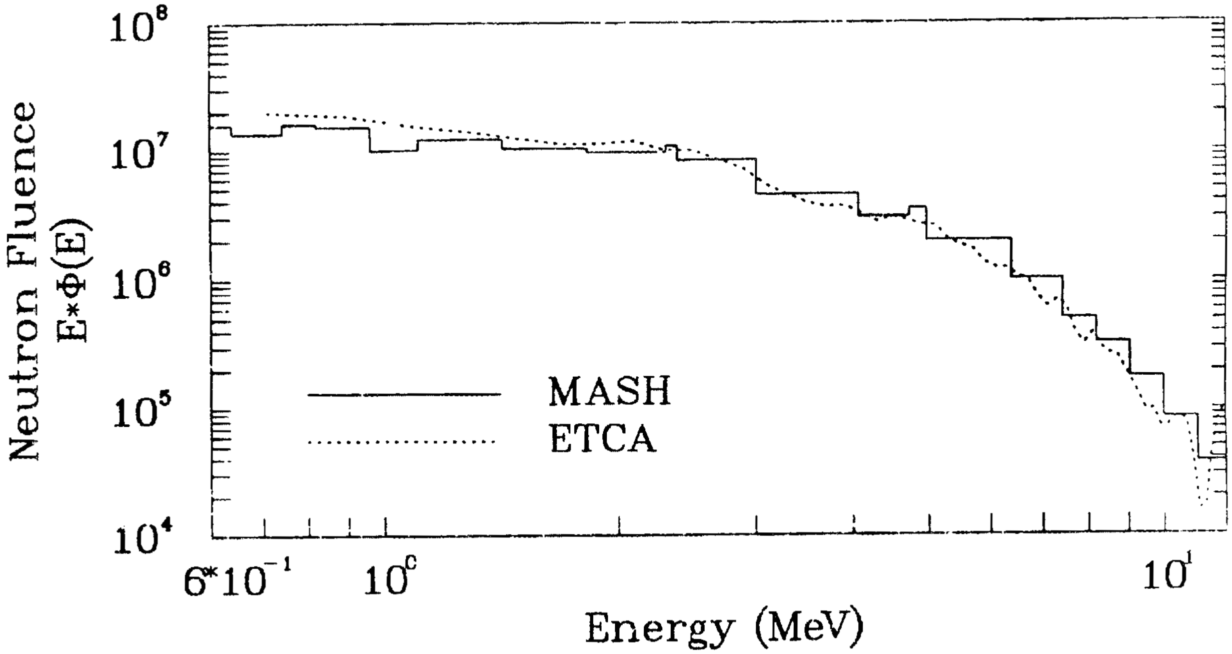

Figure B-11. Comparison of ETCA Measured and MASH Calculated Neutron Free-Field Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

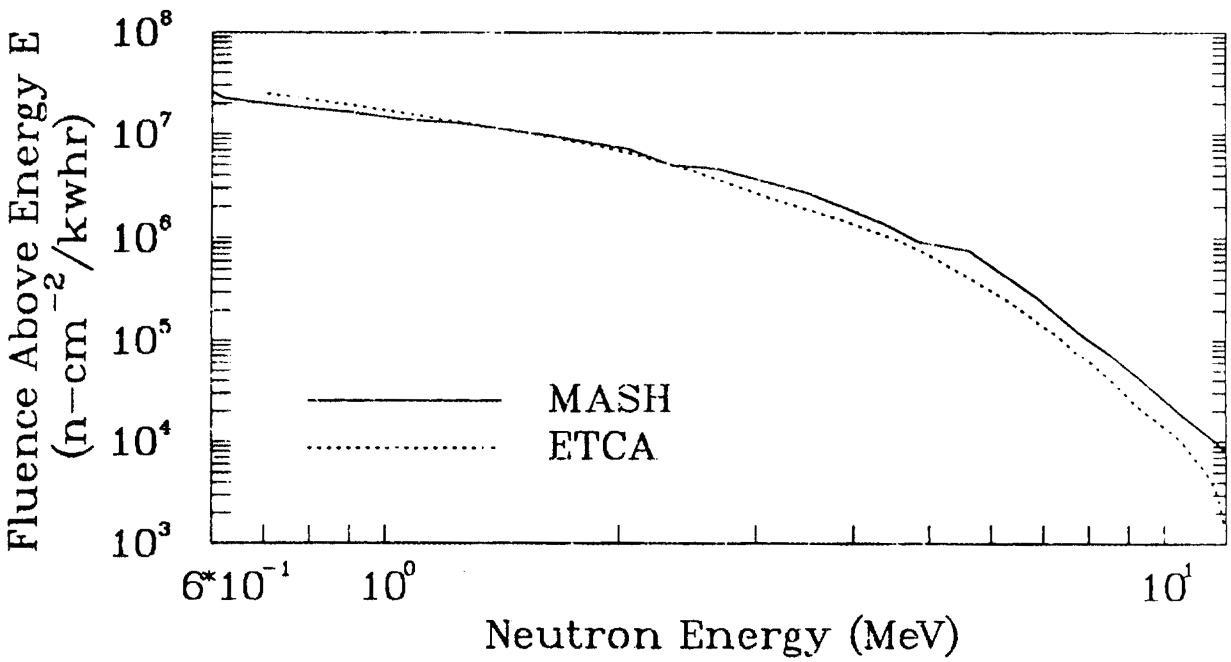

Figure B-12. Comparison of ETCA Measured and MASH Calculated Neutron Free-Field Energy Integrated Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

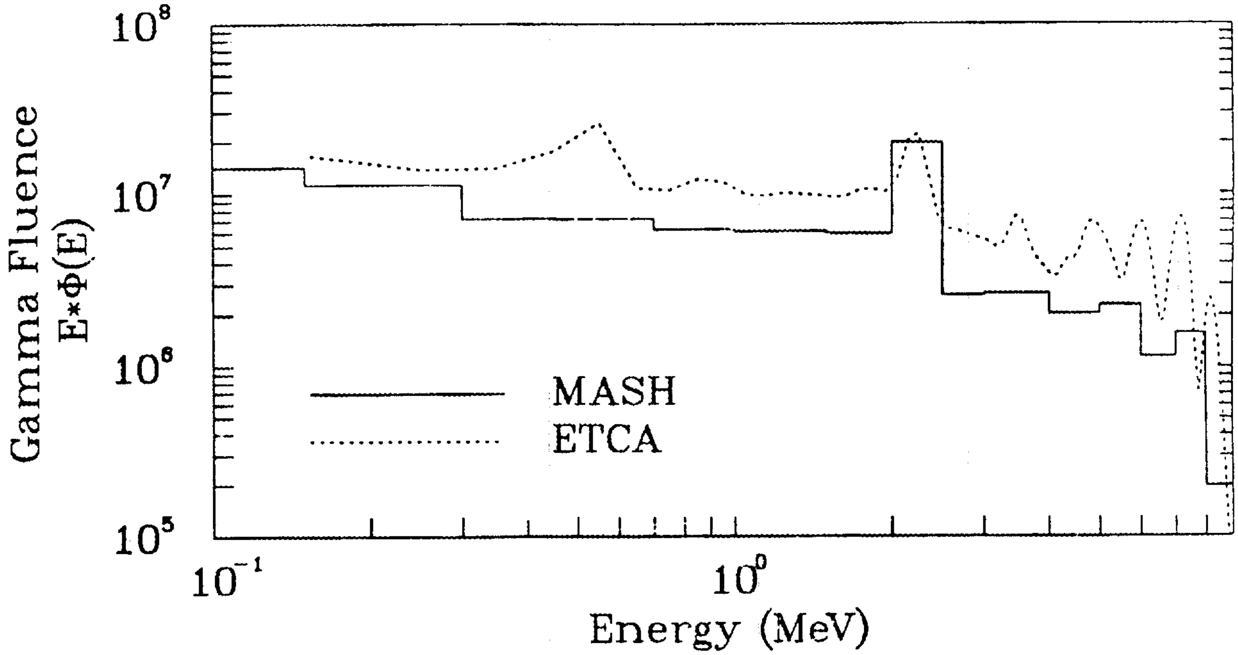

Figure B-13. Comparison of ETCA Measured and MASH Calculated Gamma-Ray Free-Field Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

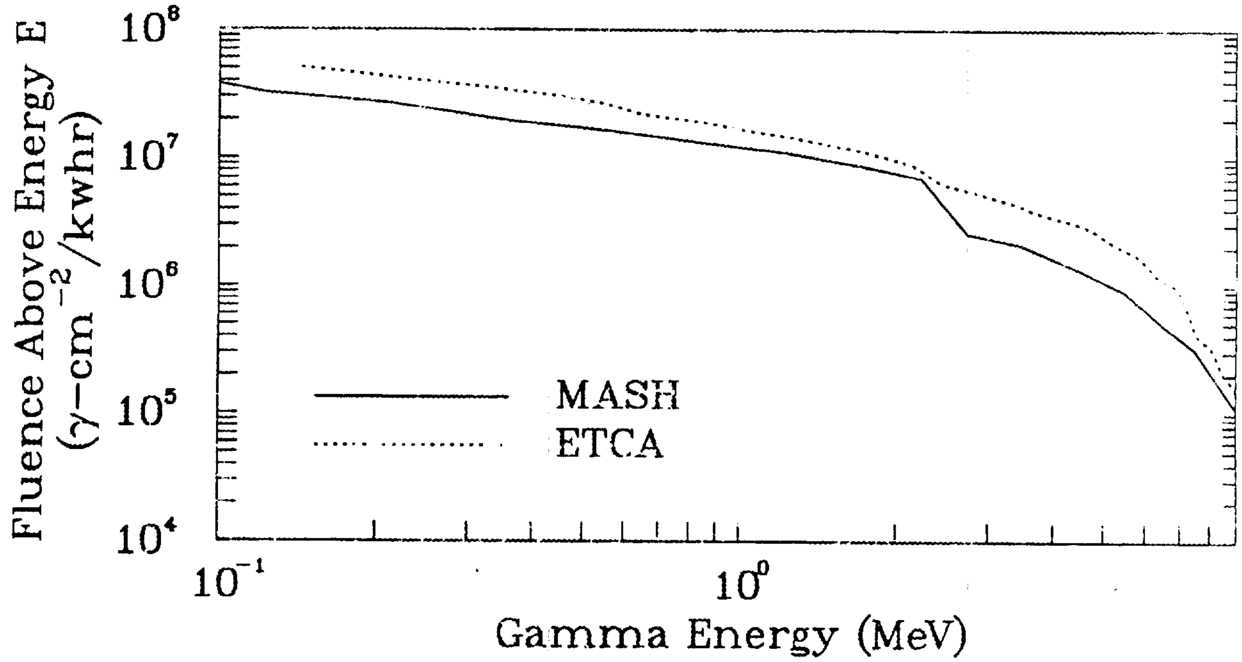

Figure B-14. Comparison of ETCA Measured and MASH Calculated Gamma-Ray Free-Field Energy Integrated Fluence Spectra at 170 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

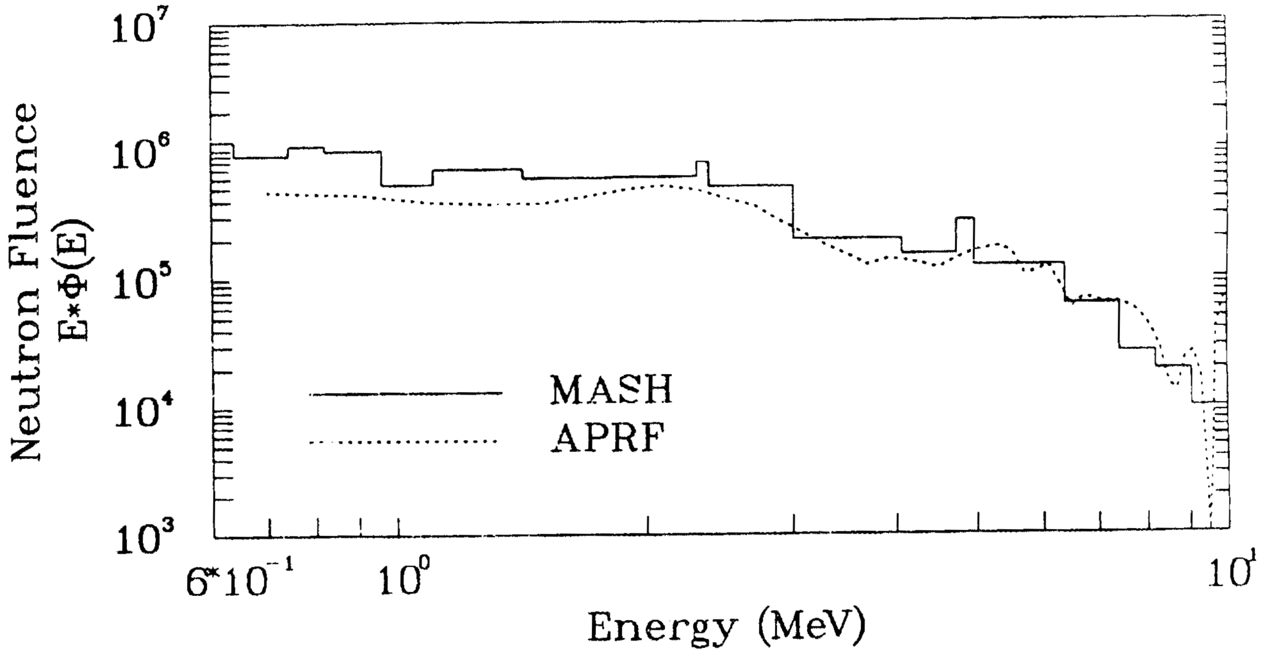

Figure B-15. Comparison of APRF Measured and MASH Calculated Neutron Free-Field Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

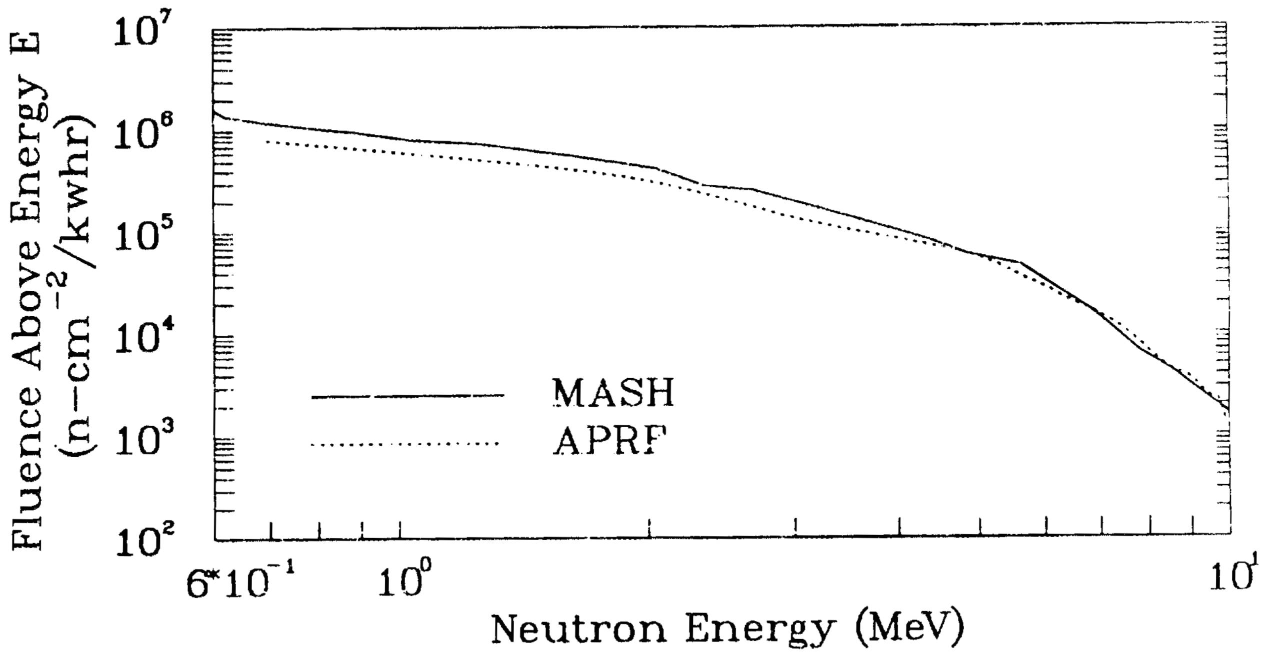

Figure B-16. Comparison of APRF Measured and MASH Calculated Neutron Free-Field Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

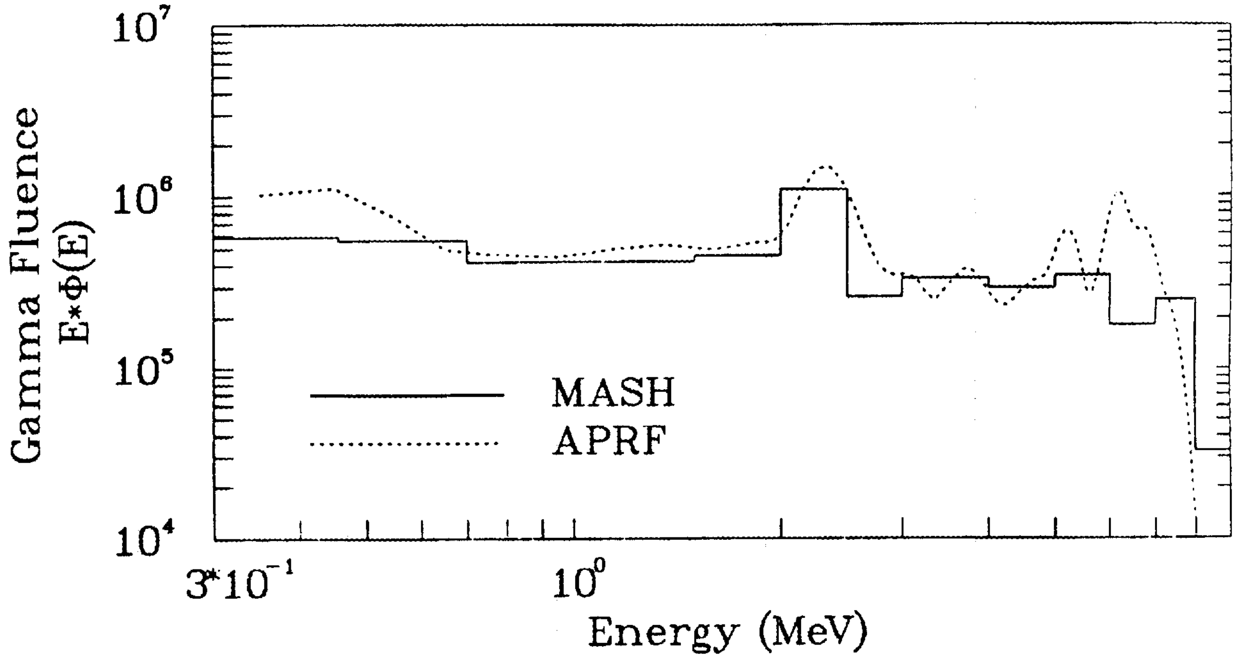

Figure B-17. Comparison of APRF Measured and MASH Calculated Gamma-Ray Free-Field Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

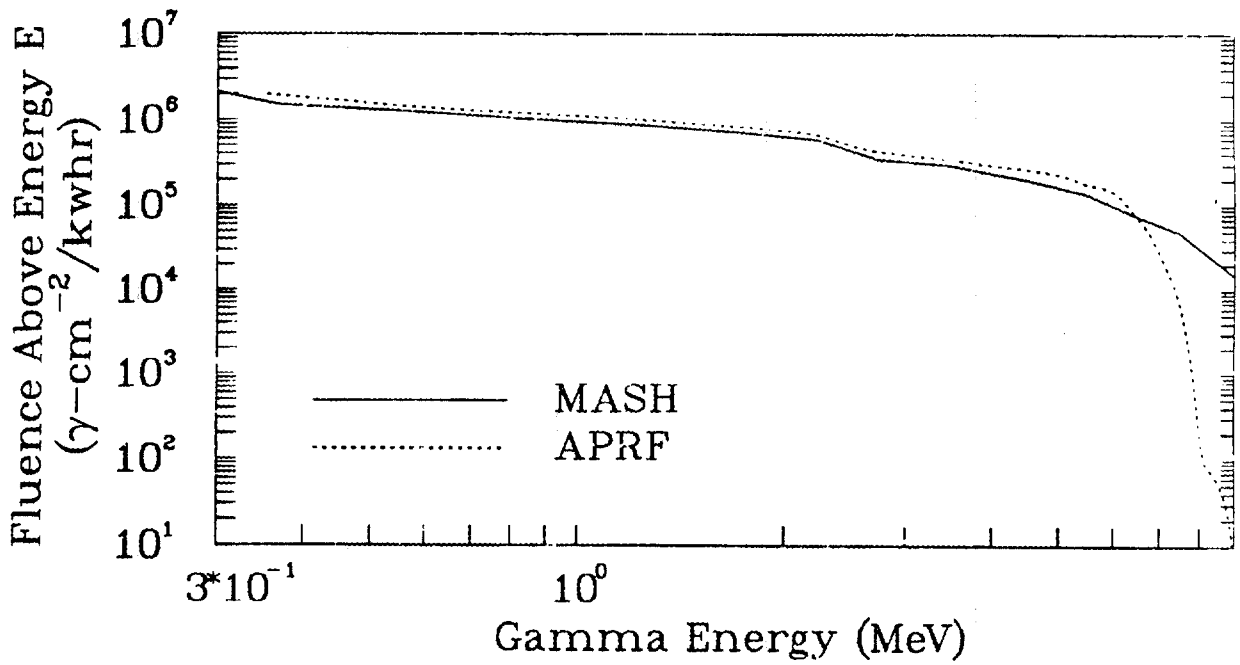

Figure B-18. Comparison of APRF Measured and MASH Calculated Gamma-Ray Free-Field Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

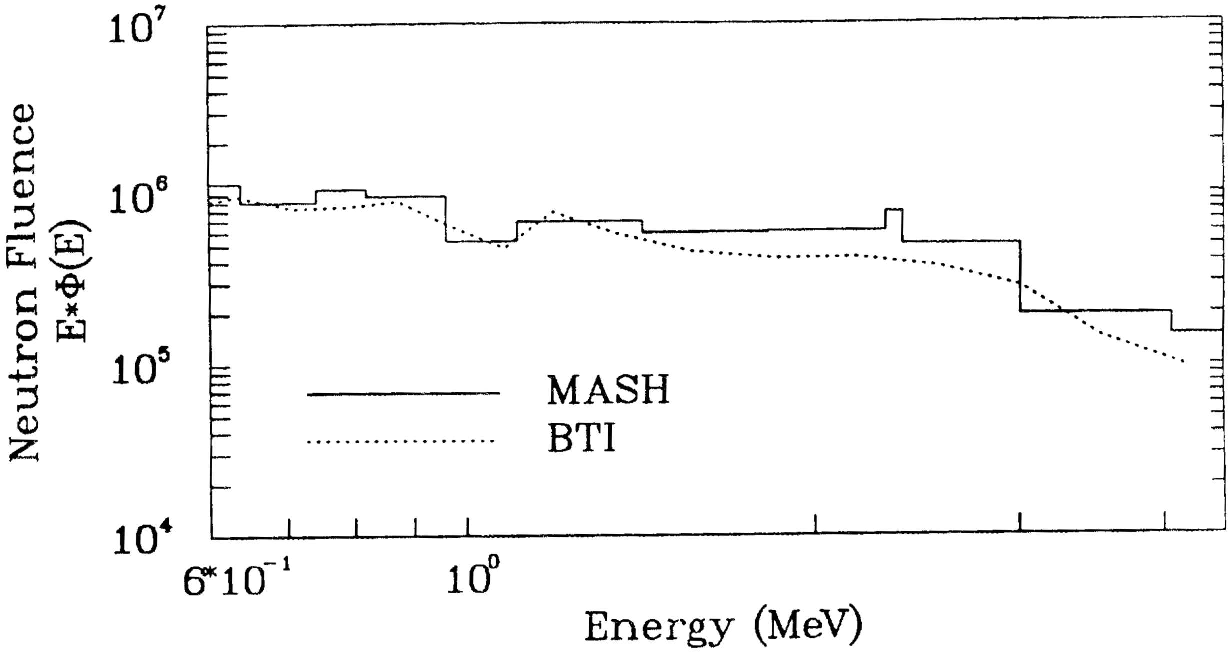

Figure B-19. Comparison of BTI Measured and MASH Calculated Neutron Free-Field Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

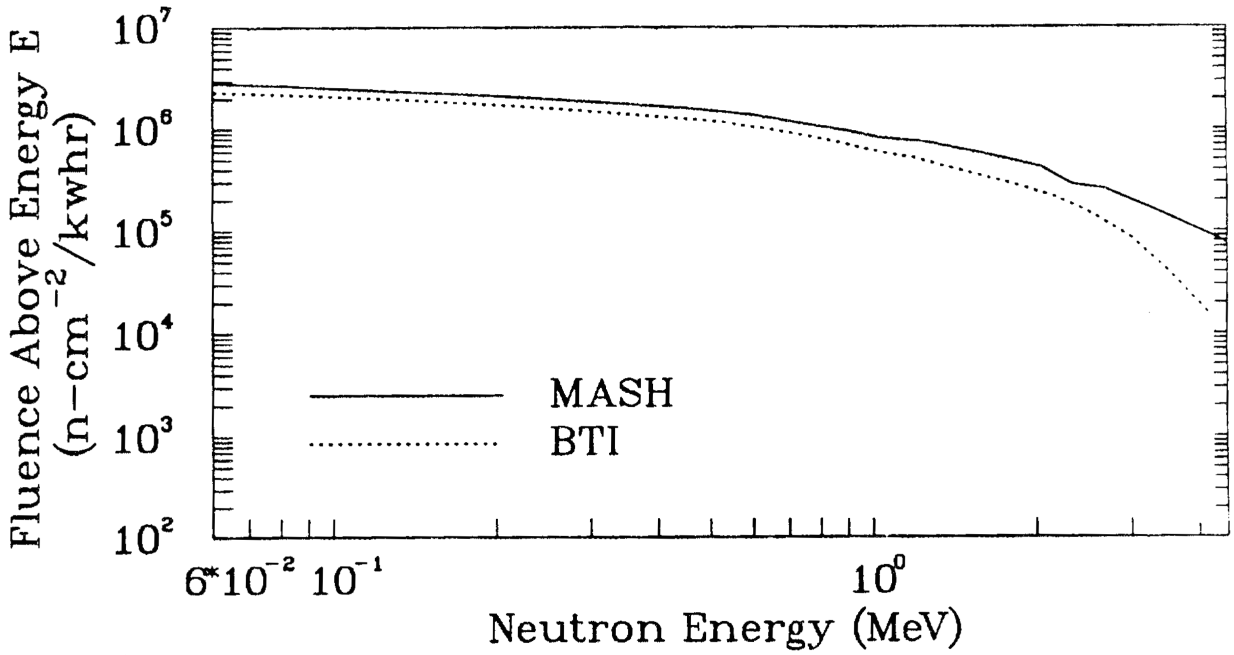

Figure B-20. Comparison of BTI Measured and MASH Calculated Neutron Free-Field Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

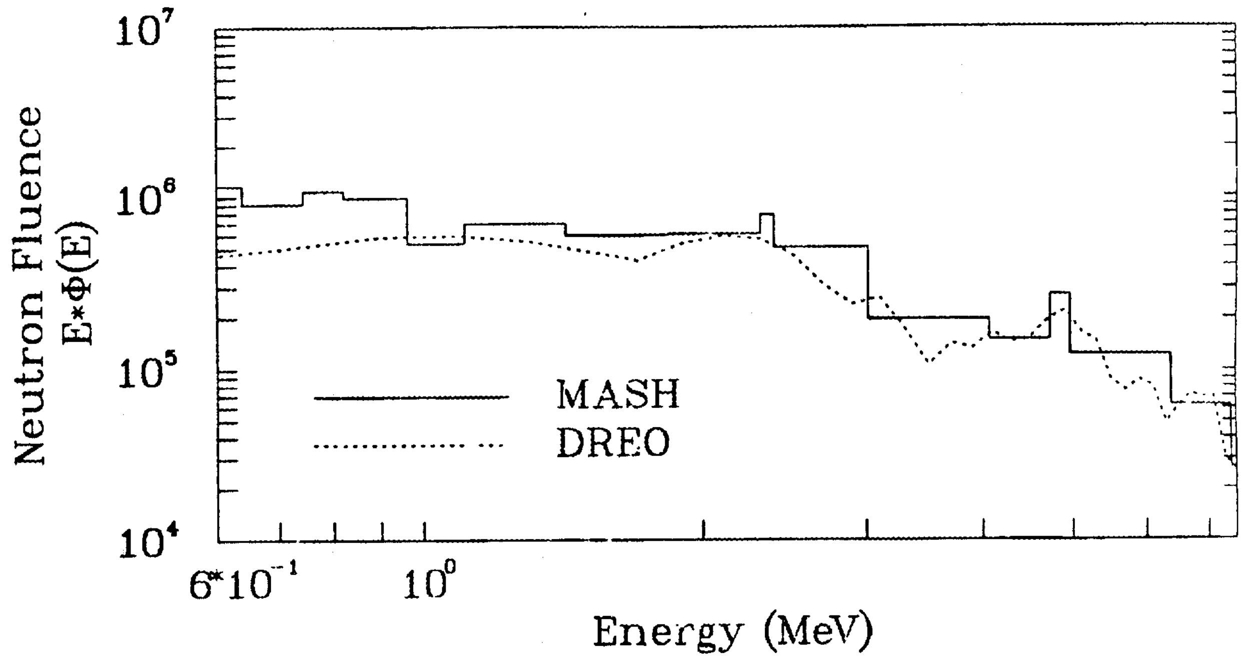

Figure B-21. Comparison of DREO Measured and MASH Calculated Neutron Free-Field Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

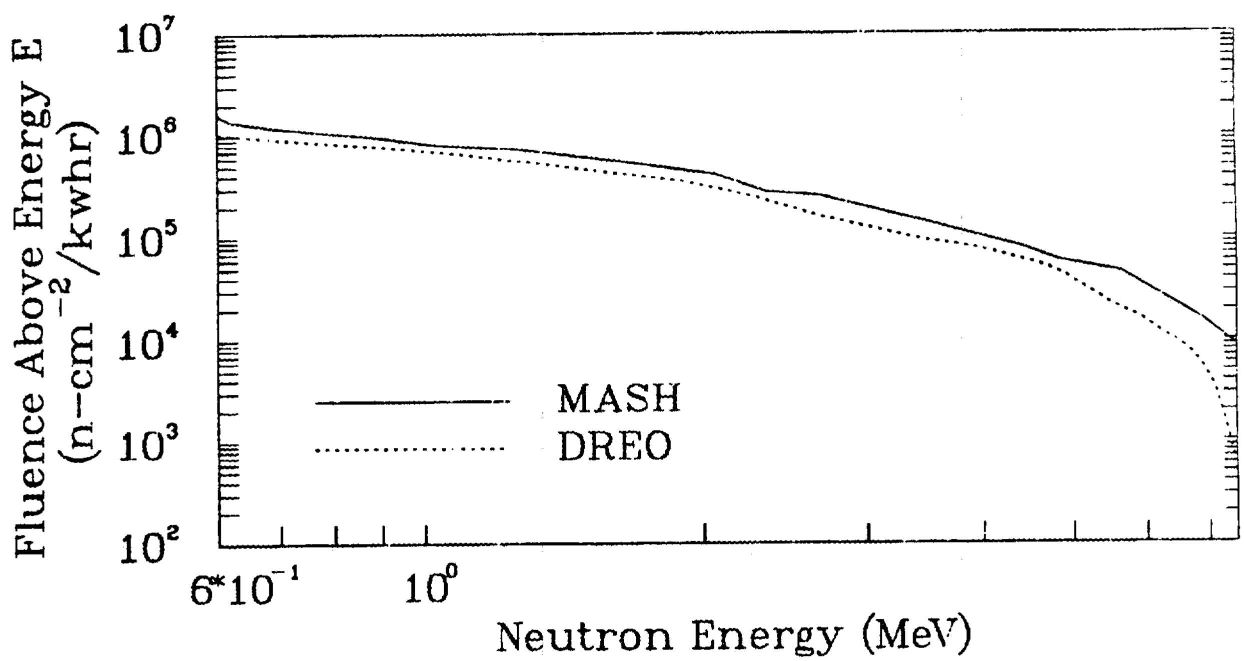

Figure B-22. Comparison of DREO Measured and MASH Calculated Neutron Free-Field Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

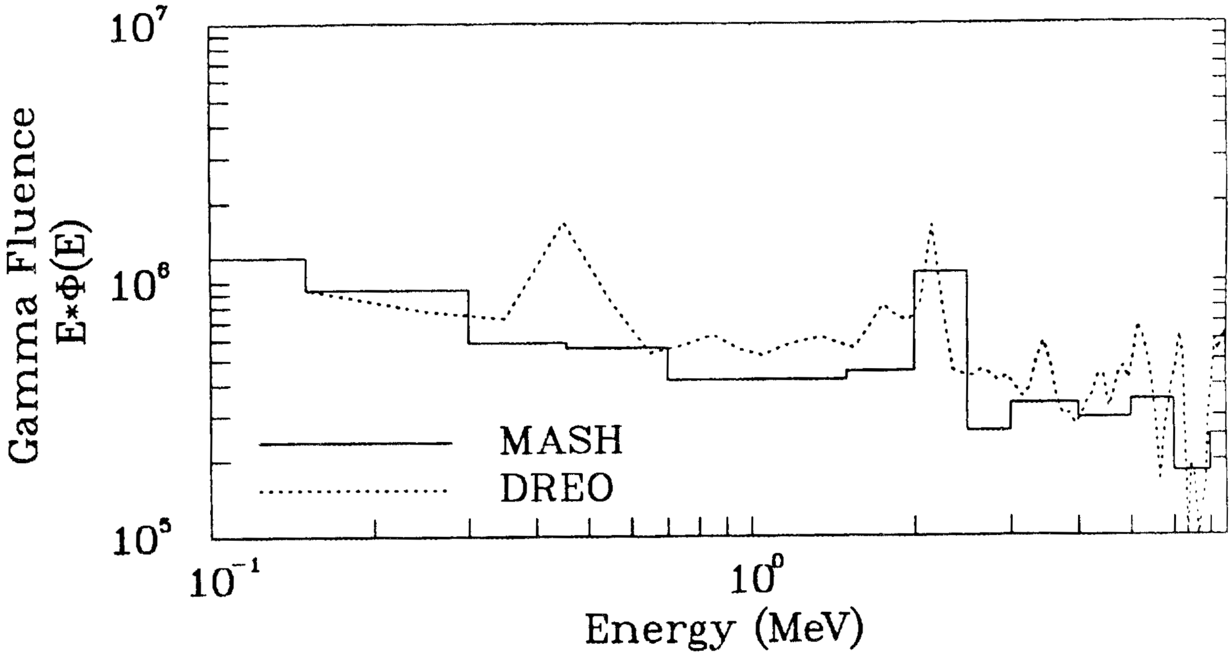

Figure B-23. Comparison of DREO Measured and MASH Calculated Gamma-Ray Free-Field Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

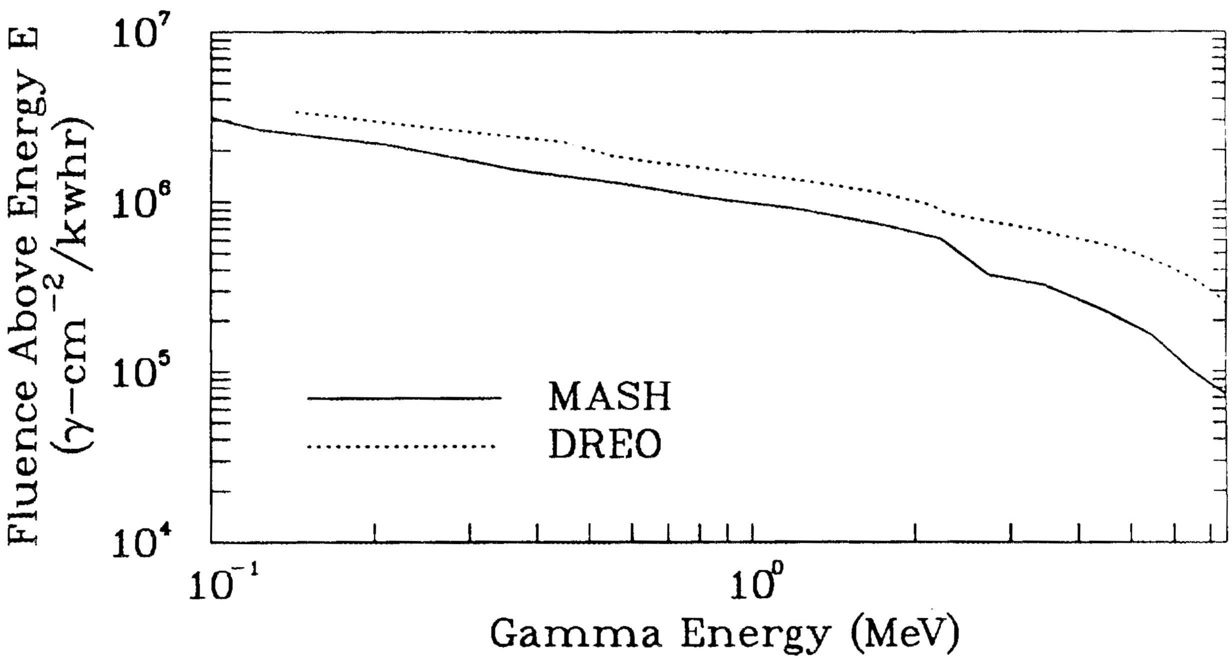

Figure B-24. Comparison of DREO Measured and MASH Calculated Gamma-Ray Free-Field Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

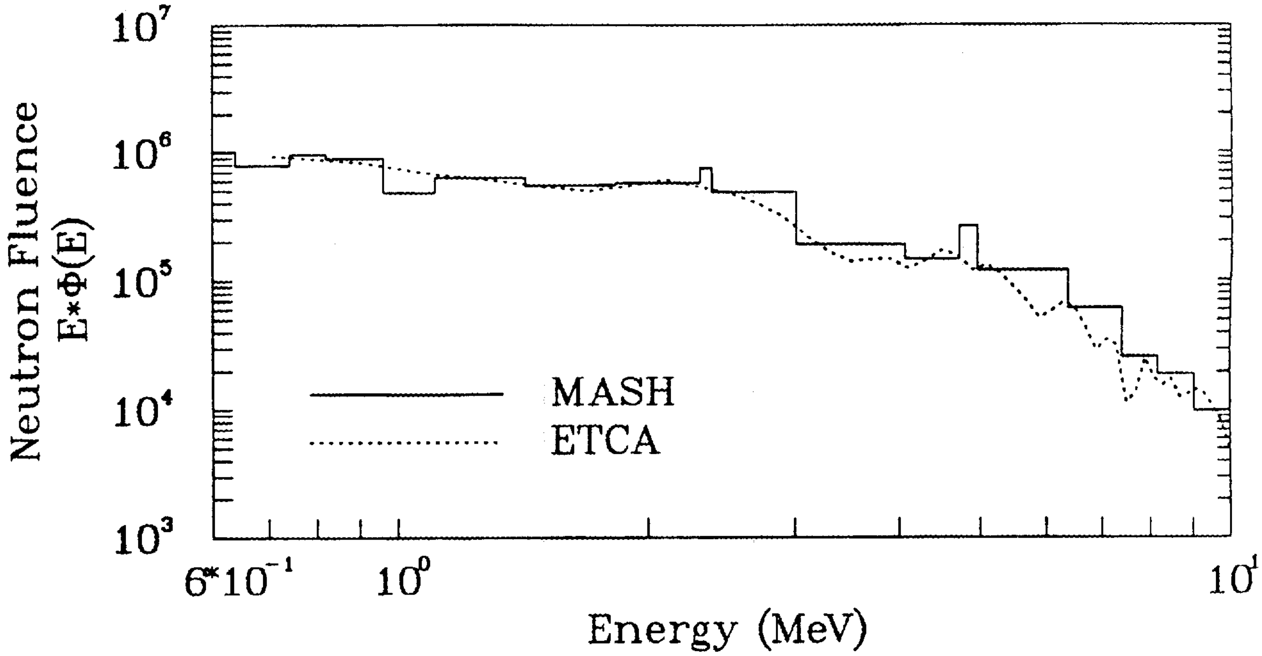

Figure B-25. Comparison of ETCA Measured and MASH Calculated Neutron Free-Field Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

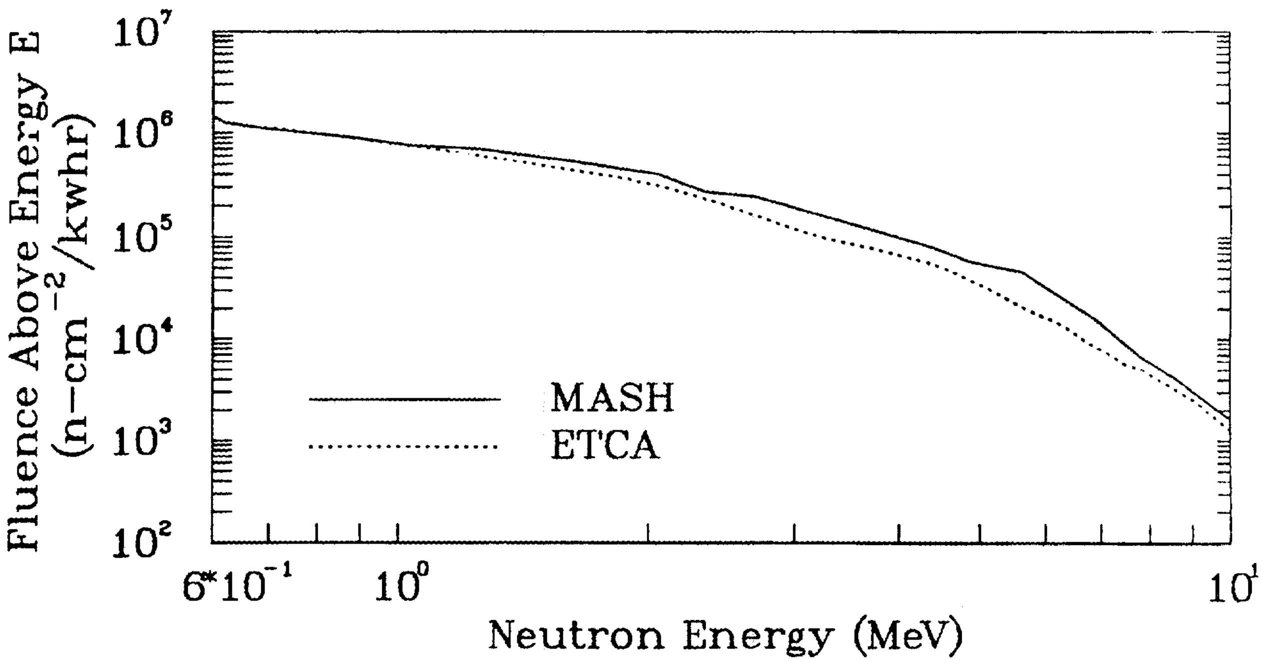

Figure B-26. Comparison of ETCA Measured and MASH Calculated Neutron Free-Field Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

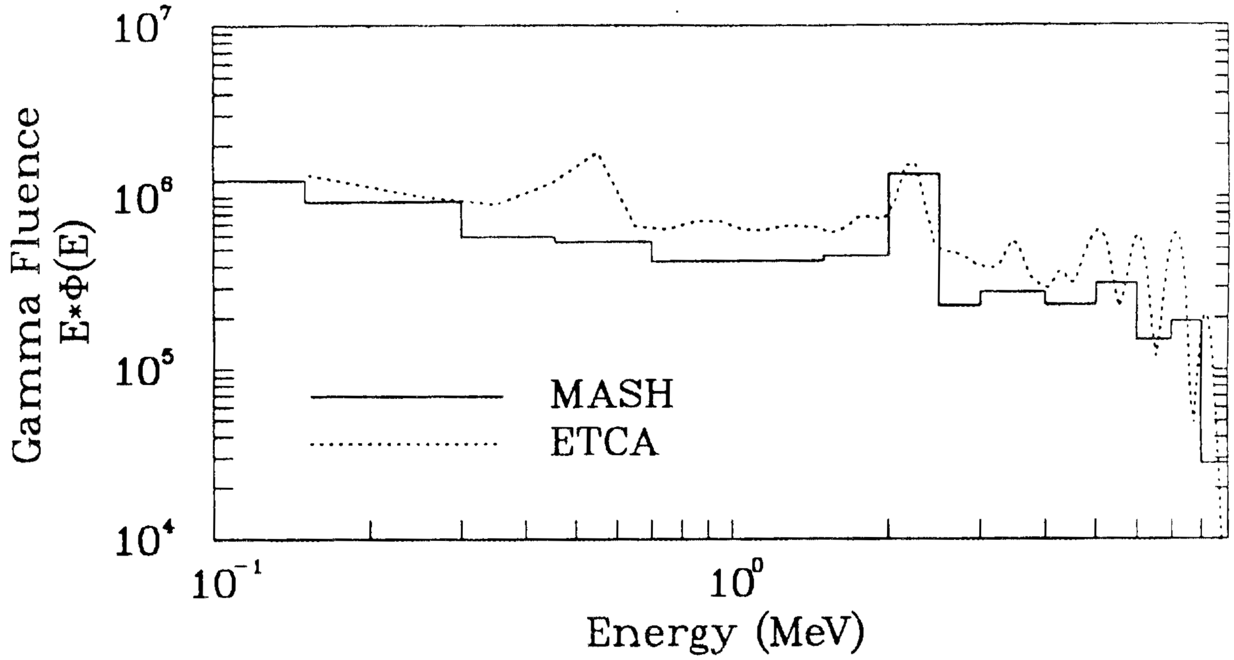

Figure B-27. Comparison of ETCA Measured and MASH Calculated Gamma-Ray Free-Field Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

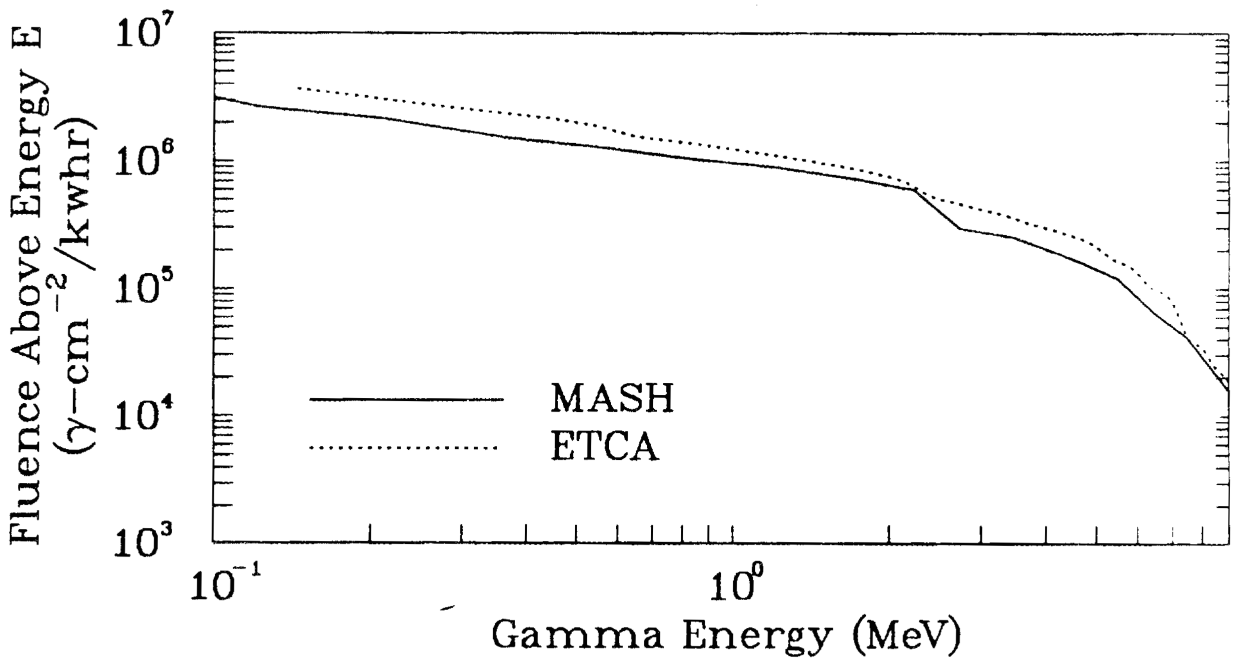

Figure B-28. Comparison of ETCA Measured and MASH Calculated Gamma-Ray Free-Field Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

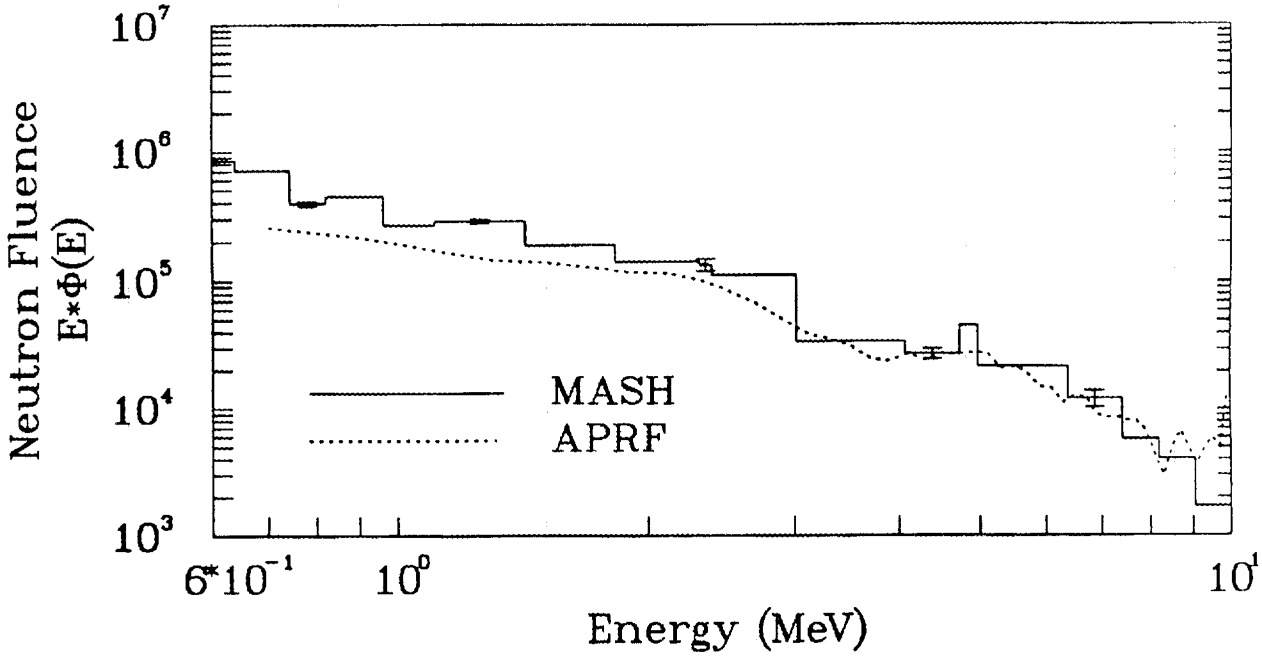

Figure B-29. Comparison of APRF Measured and MASH Calculated Neutron In-Box Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

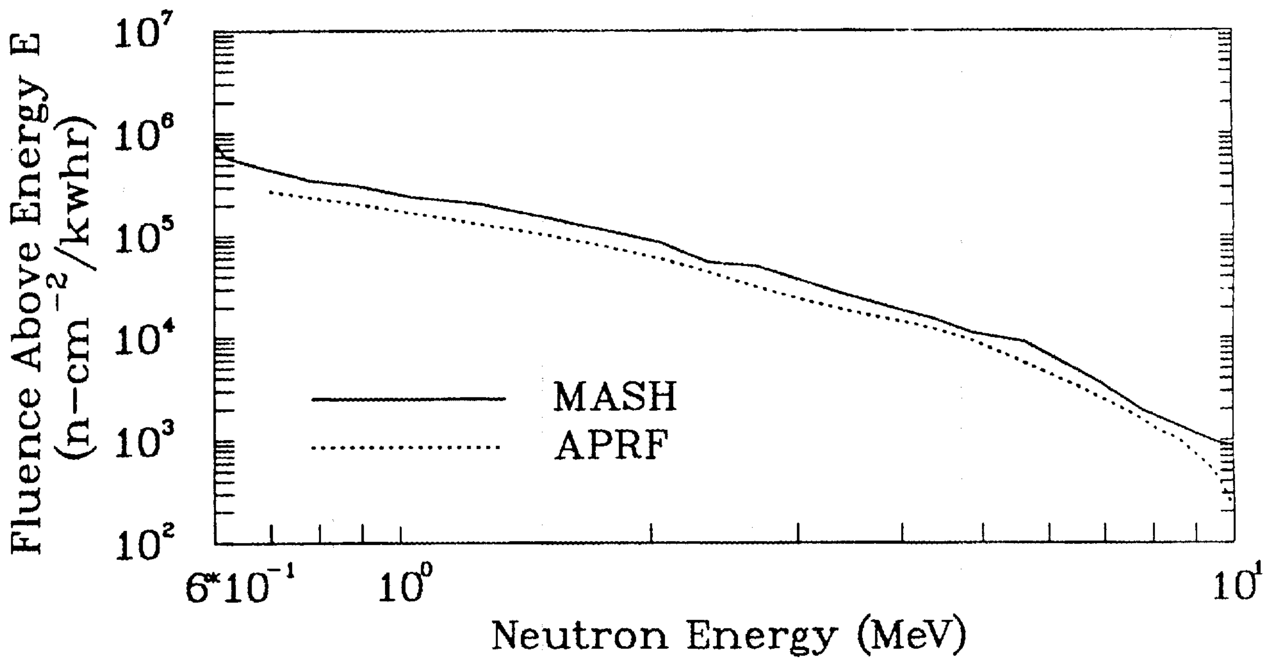

Figure B-30. Comparison of APRF Measured and MASH Calculated Neutron In-Box Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

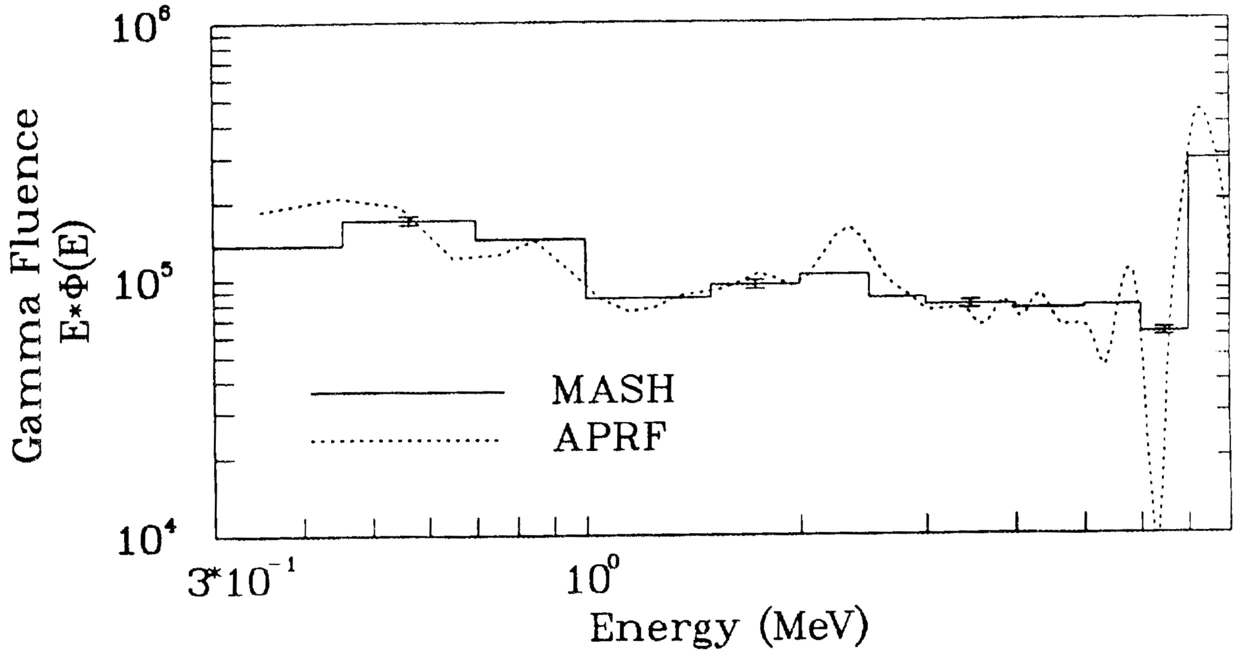

Figure B-31. Comparison of APRF Measured and MASH Calculated Gamma-Ray In-Box Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

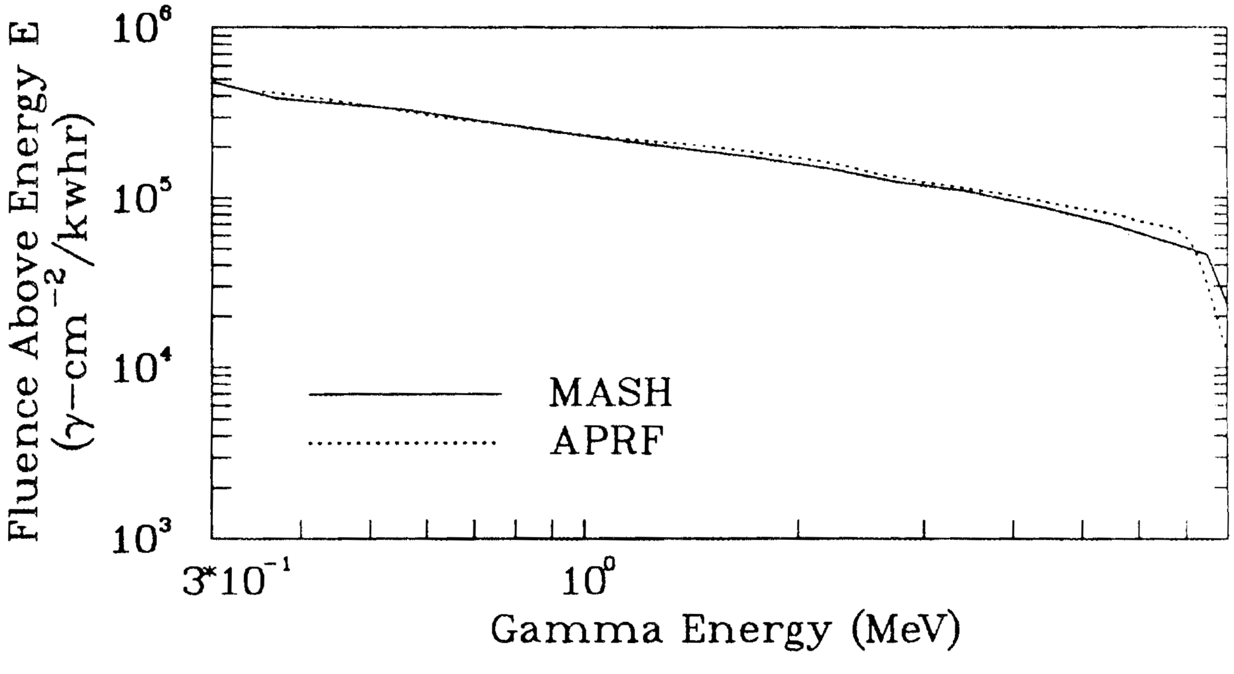

Figure B-32. Comparison of APRF Measured and MASH Calculated Gamma-Ray In-Box Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

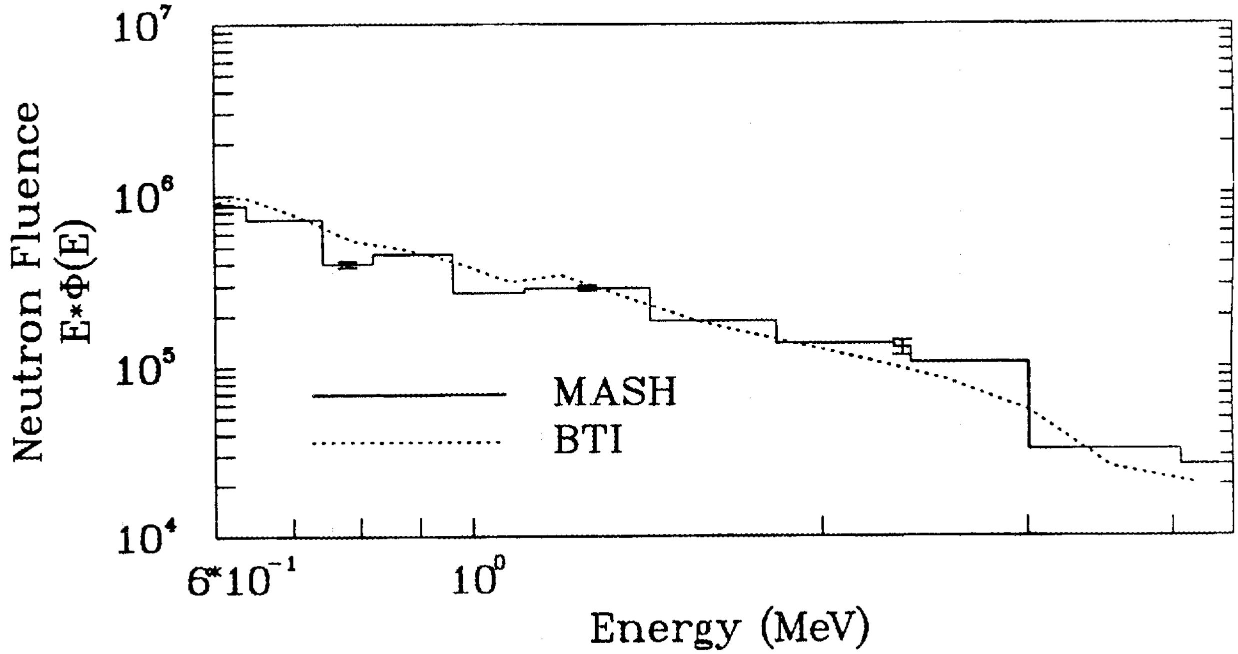

Figure B-33. Comparison of BTI Measured and MASH Calculated Neutron In-Box Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

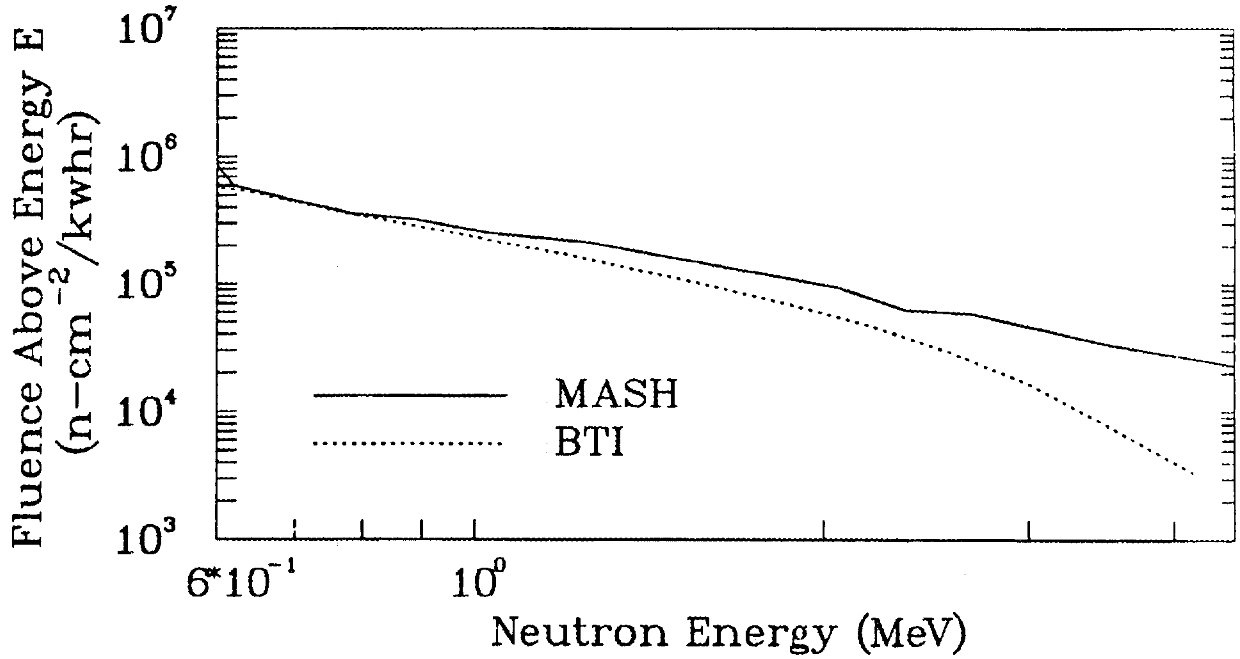

Figure B-34. Comparison of BTI Measured and MASH Calculated Neutron In-Box Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

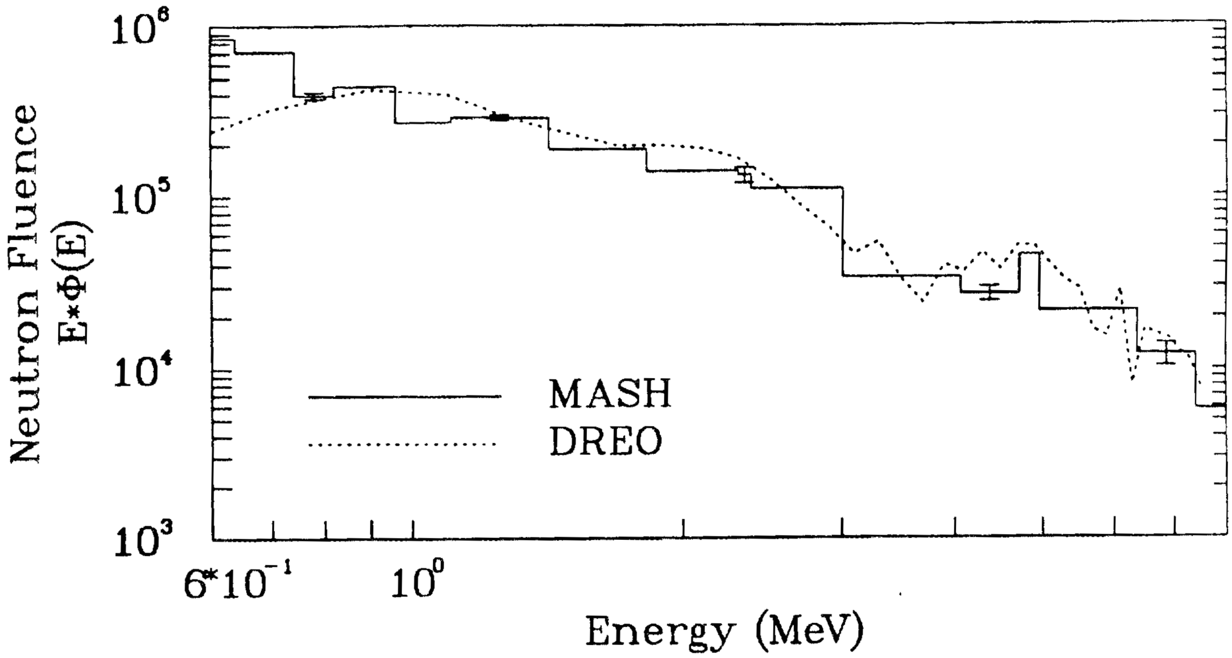

Figure B-35. Comparison of DREO Measured and MASH Calculated Neutron In-Box Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

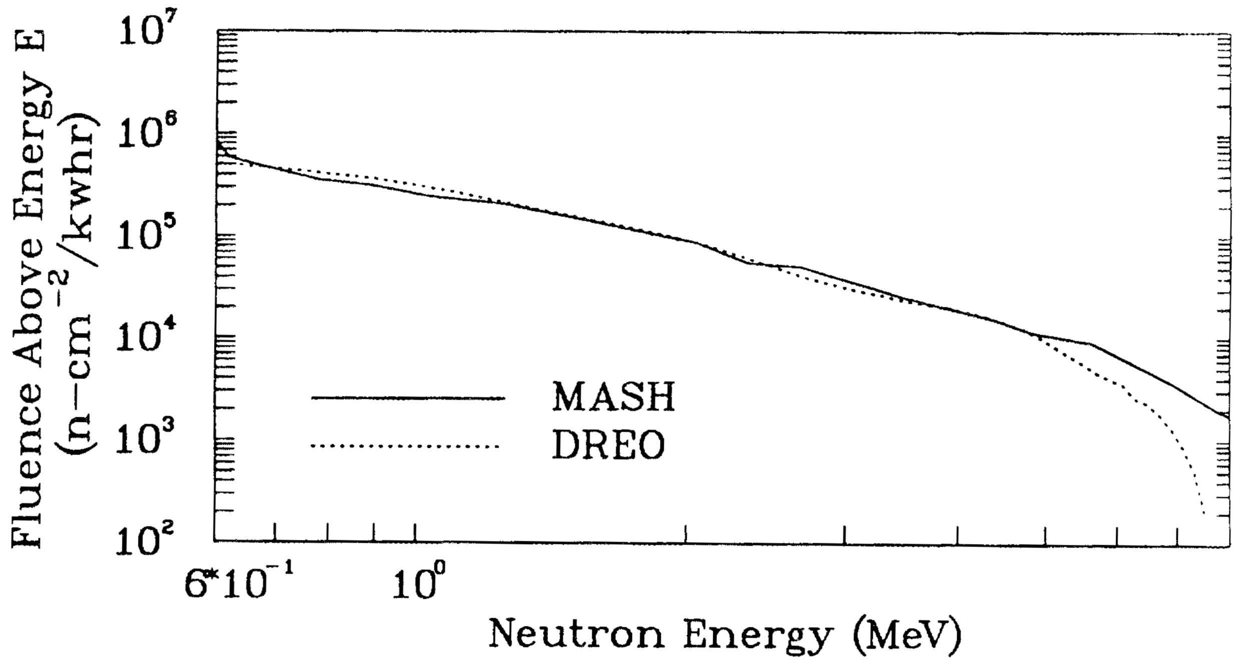

Figure B-36. Comparison of DREO Measured and MASH Calculated Neutron In-Box Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

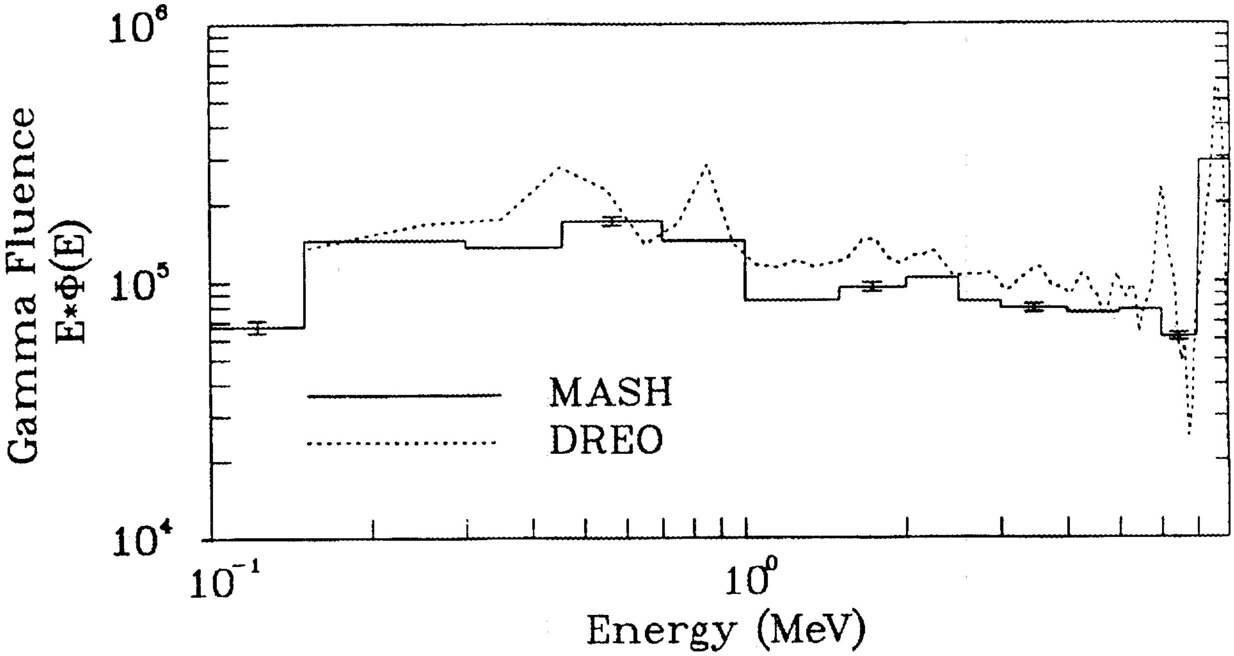

Figure B-37. Comparison of DREO Measured and MASH Calculated Gamma-Ray In-Box Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

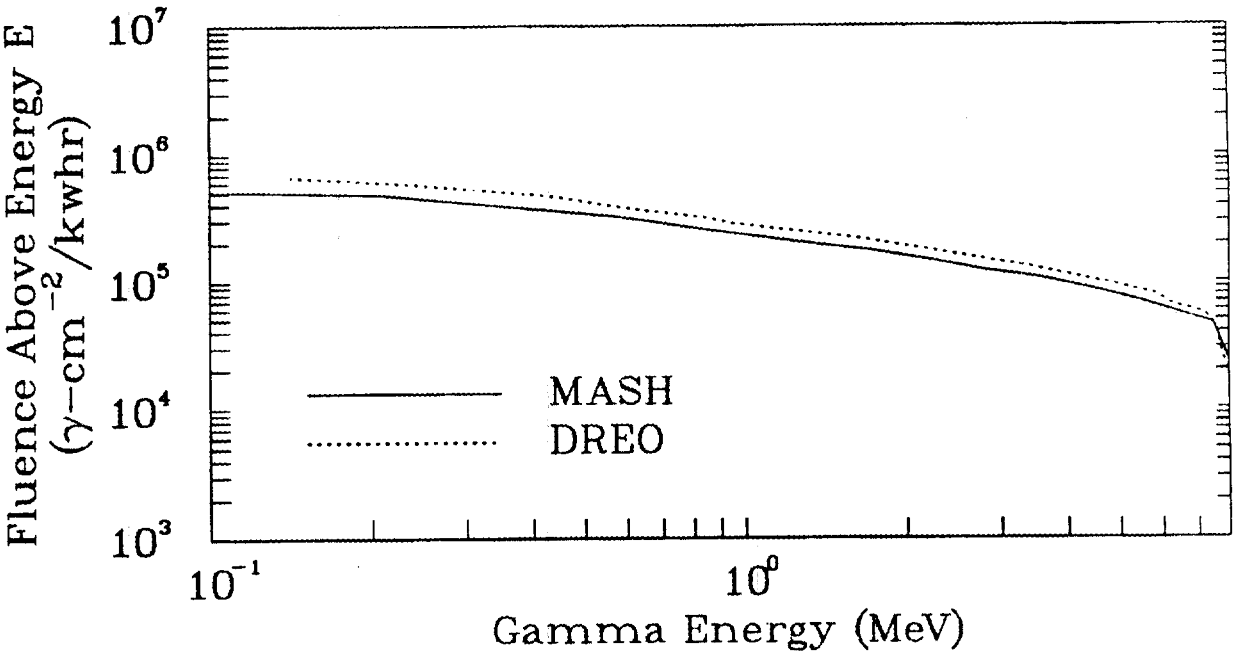

Figure B-38. Comparison of DREO Measured and MASH Calculated Gamma-Ray In-Box Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

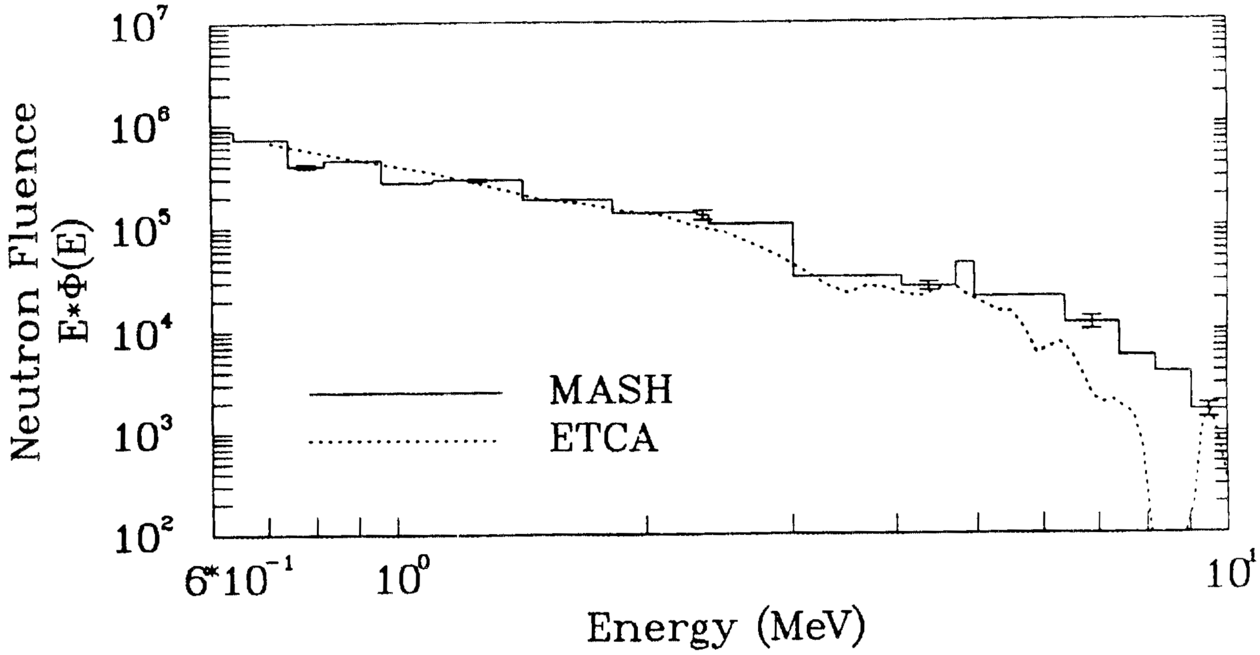

Figure B-39. Comparison of ETCA Measured and MASH Calculated Neutron In-Box Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

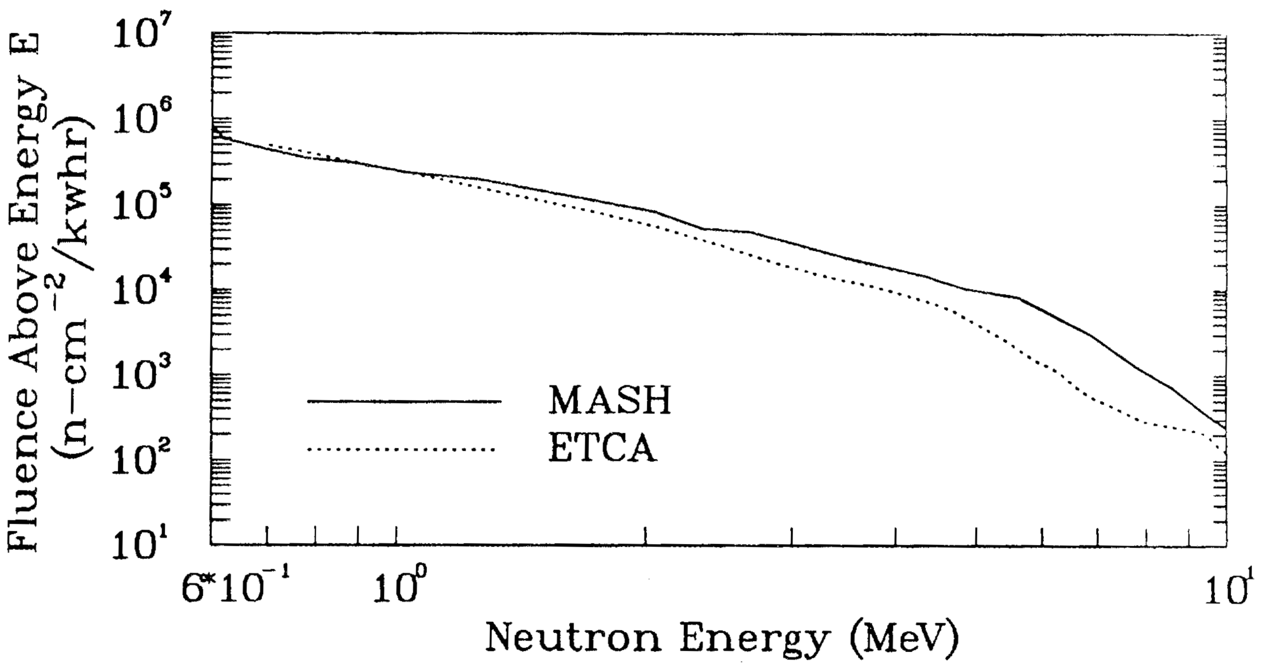

Figure B-40. Comparison of ETCA Measured and MASH Calculated Neutron In-Box Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

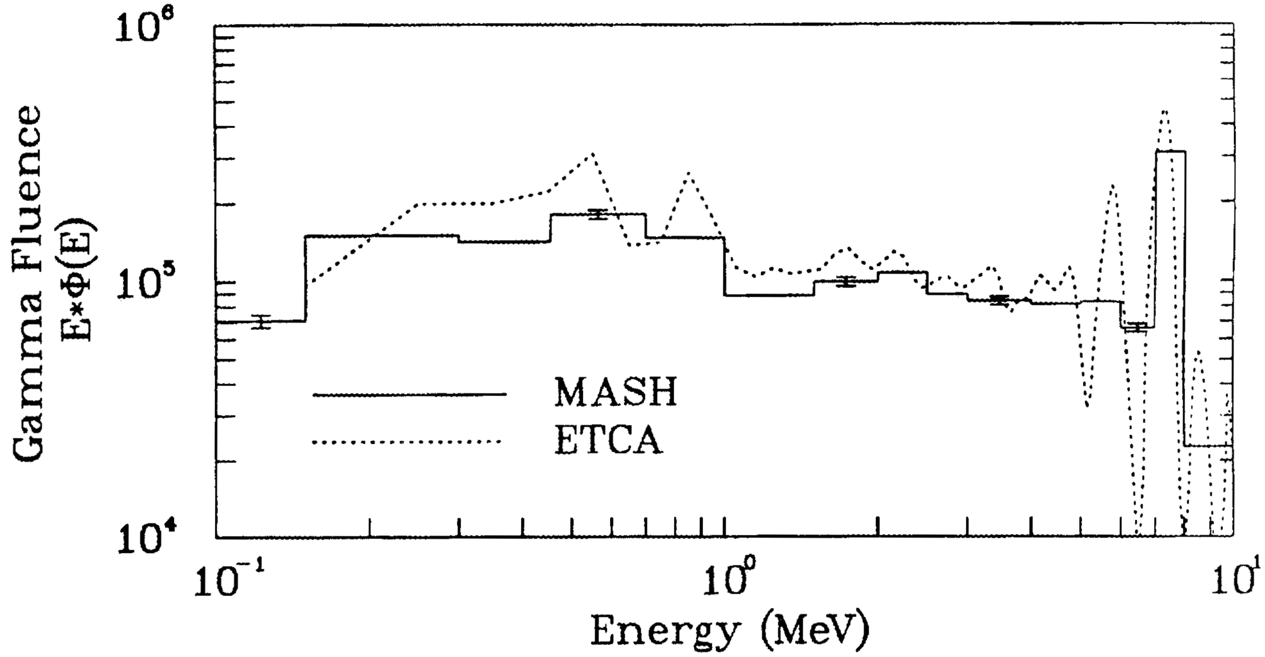

Figure B-41. Comparison of ETCA Measured and MASH Calculated Gamma-Ray In-Box Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

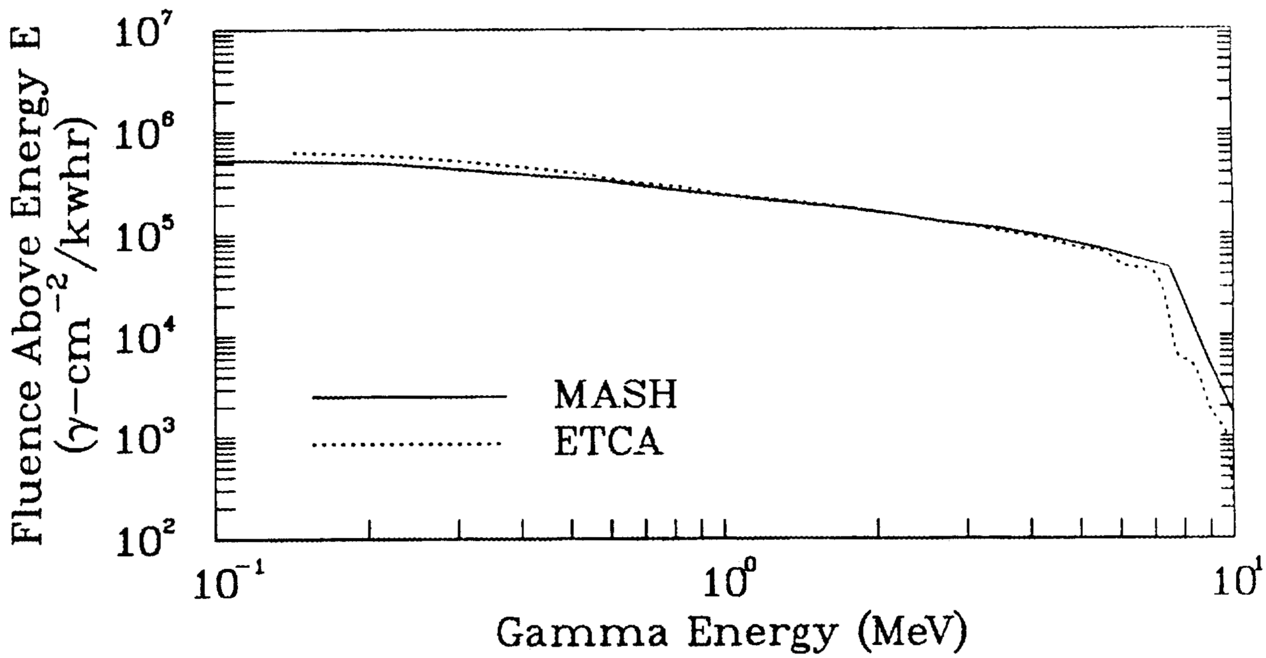

Figure B-42. Comparison of ETCA Measured and MASH Calculated Gamma-Ray In-Box Energy Integrated Fluence Spectra at 400 Meters for the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility.

APPENDIX C

Sample Input Decks for GIP, GRTUNCL, DORT, VISTA, MORSE, and DRC used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF)

```
gip mixtures for the 10/89 two meter box experiments -- p5  forward

1$$  69 3 4 72 588   /igm,iht,ihs,ihm,ms
     0 144 204 0 5   /mcr,mtp,mtm,ith,isct
     1 2 2 120   /iprt,iout,idot,nbuf
e t

10$$ 4i145 150 19q6  4i151 156 10q6  4i157 162 3q6  4i163 168 5q6
 /     aprf ground  borated concrete      air         1020 steel

     4i169 174 19q6  4i175 180 19q6  4i181 186 3q6  4i187 192 3q6
 /     aprf ground    aprf ground         air            air

     4i193 198 3q6  4i199 204 4q6
 /       air       hydraulic oil

11$$  58i1 60 10i67 78 40i85 126 4i139 144   / aprf ground

      16i1 18 4i31 36 16i43 60 4i91 96
      4i103 108 10i127 138   / borated concrete

      4i1 6 10i25 36 4i79 84   / air

      4i19 24 16i55 72 10i97 108   / 1020 steel

      58i1 60 10i67 78 40i85 126 4i139 144   / aprf ground

      58i1 60 10i67 78 40i85 126 4i139 144   / aprf ground

      4i1 6 10i25 36 4i79 84   / air

      4i1 6 10i25 36 4i79 84   / air

      4i1 6 10i25 36 4i79 84   / air

      4i1 6 4i19 24 4i31 36 4i61 66 4i73 78   / hydraulic oil

12**   /number densities (atoms/b-cm)
      6r4.236-02 6r9.586-09 6r3.509-08 6r3.775-04
      6r4.752-05 6r4.178-02 6r1.427-04 6r9.126-05
      6r1.377-03 6r9.514-03 6r3.610-06 6r3.537-06
      6r2.048-04 6r2.599-05 6r7.199-06 6r3.213-04
      6r2.783-07 6r2.793-07 6r4.858-07 6r7.315-08   /aprf ground-34% h2o
```

Figure C-1. Sample GIP Input for the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF).

```
     6r7.020-03 6r2.887-04 6r1.168-03 6r5.908-02
     6r1.659-03 6r4.656-03 6r1.080-02 6r3.486-03
     6r1.431-03 6r7.667-04 6r6.709-04              /borated concrete

     6r6.122-07 6r3.985-05 6r1.100-05 6r2.383-07   /air - 10-24-89(a)

     6r8.078-04 6r4.213-04 6r6.113-05 6r7.381-05
     6r3.877-04 6r8.391-02                        /1020 steel

     6r2.653-02 6r1.162-08 6r4.254-08 6r4.576-04
     6r5.760-05 6r3.823-02 6r1.729-04 6r1.106-04
     6r1.669-03 6r1.153-02 6r4.376-06 6r4.288-06
     6r2.482-04 6r3.151-05 6r8.727-06 6r3.895-04
     6r3.373-07 6r3.386-07 6r5.889-07 6r8.867-08   /aprf ground-20% h2o

     6r5.819-02 6r7.553-09 6r2.765-08 6r2.974-04
     6r3.744-05 6r4.532-02 6r1.124-04 6r7.190-05
     6r1.085-03 6r7.496-03 6r2.845-06 6r2.787-06
     6r1.613-04 6r2.048-05 6r5.672-06 6r2.532-04
     6r2.193-07 6r2.201-07 6r3.828-07 6r5.763-08   /aprf ground-48% h2o

     6r3.278-07 6r4.021-05 6r1.095-05 6r2.405-07   /air - 11-01-89(h)

     6r9.350-07 6r3.858-05 6r1.082-05 6r2.308-07   /air - 10-30-89(a)

     6r5.596-07 6r3.948-05 6r1.087-05 6r2.361-07   /air - 10-25-89(a)

     6r2.145-02 6r2.600-02 6r2.600-03 6r6.499-04
     6r3.901-03                                    /hydraulic oil

13$$ 1 2 3 4 5 6 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
     61 62 63 64 65 66 67 68 69 70 71 72 79 80 81 82 83 84 85 86 87 88
     89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107
     108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
     124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 157
     158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
     174 175 176 177 178 179 180 181 182 183 184 185 186 199 200 201
     202 203 204 205 206 207 208 209 210 223 224 225 226 227 228
 / h,b10,b11,c,n,o,na,mg,al,si,p,s,cl,ar,k,ca,mn,fe,co,ni,cu,zr,nb,sn

  t
```

Figure C-1. (continued)

```
' aprf air-over-ground using new saic 1989 angle-energy leakage source
' 16.143m source height, simple topography out to 400m test site
' 34% ground moisture, 10/24/89(a) air parameters

1$$ 0 5 8 66 98   / ith,isct,izm,im,jm
    69 3 4 72 0   / igm,iht,ihs,ihm,ms
    0 54 54 2 0   / mcr,mtp,mt,idatl,noa
    4 1 0 23 2   / imode,iprtc,nflsv,npso,iprtf
    0 40 0 300 0   / iprts,iz3,idfac,nbuf,ntnpr

2** 0 1614.3 0   / xnf,zpt,rpt
t
1** f0    /fission spectrum

2**   /axii (jm+1)
  -80 -75 -70 -65 -60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 -2.5
  -1 0 50 150 250 489 749 949 1102 1220 1311 1381 1435 1476 1508 1532
  1551 1566 1577 1585 1592 1597 1601 1604 1607 1608.5 1610 1614.3 1619
  1620.5 1622 1624 1627 1631 1636 1643 1651 1662 1677 1696 1720 1752
  1793 1847 1917 2008 2126 2279 2479 2739 3076 3514 4085 4826 5789 7042
  8670 10787 13000 16000 19000 22000 25000 28000 31000 34000 37000 40000
  43000 46000 49000 52000 55000 58000 61000 64000 67000 70000 73000
  76000 78000 80000

4**   /radii (im+1)
  0 4.6 6 7.8 10 13 17 22 29 37 48 63 82 106 138 179 233 303 394 512 665
  865 1125 1462 1900 2471 3212 4175 5428 7056 9000 11000 13000 15000
  16500 17500 19000 21000 23000 25000 27000 28500 29500 30500 31500
  33000 35000 37000 38500 39500 40500 41500 43000 45000 47000 49000
  51000 54000 57000 60000 63000 66000 69000 72000 75000 78000 80000

8$$   / zone numbers by interval
' zones 1, 2, & 3-aprf ground, 4 & 5-borated concrete, 6, 7, & 8-air
  66r1 8q66   /j-ints 1-9
  19r5 47r1 2q66   /j-ints 10-12
  19r4 3r3 8r1 3r3 3r2 5r3 3r2 4r3 3r2 3 14r1 5q66    /j-ints 13-18
  33r7 3r6 5r7 3r6 4r7 3r6 7 14r8  3q66   /j-ints 19-22
  52r7 14r8 3q66   /j-ints 23-26
  66r8 71q66   /j-ints 27-98

9$$ 3r-1 2r-7 3r-13   / mat by zone
```

Figure C-2. Sample GRTUNCL Input for the Reactor Source Used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF).

```
13**   / angular directions of source (-1. is down  +1. is up)
   -.99794 -.98973 -.97337 -.94900 -.91680 -.88117 -.84355 -.80122
   -.75441 -.70316 -.64809 -.58978 -.52822 -.46383 -.39684 -.32761
   -.25670 -.18443 -.11105 -.03705 +.03705 +.11105 +.18443 +.25670
   +.32761 +.39684 +.46383 +.52822 +.58978 +.64809 +.70316 +.75441
   +.80122 +.84355 +.88117 +.91680 +.94900 +.97337 +.98973 +.99794

14**
' aprf angular leakage source, s(angle,energy)/40 angles/dabl69/(3-1-90)
' units are 4*pi*particles/steradian per leaking neutron
 1.41e-06 1.43e-06 1.65e-06 1.85e-06 2.02e-06 2.37e-06 2.49e-06 2.60e-06
 2.67e-06 2.74e-06 2.70e-06 2.75e-06 2.81e-06 2.86e-06 2.91e-06 3.00e-06
 3.03e-06 3.05e-06 3.07e-06 3.07e-06 3.07e-06 3.07e-06 3.07e-06 3.07e-06
 3.05e-06 2.98e-06 2.98e-06 2.96e-06 2.96e-06 2.95e-06 3.00e-06 2.95e-06
 2.79e-06 2.46e-06 2.07e-06 1.53e-06 1.60e-06 1.74e-06 1.92e-06 2.02e-06
 5.18e-06 5.21e-06 6.05e-06 6.90e-06 7.64e-06 9.10e-06 9.61e-06 1.00e-05
 1.04e-05 1.07e-05 1.06e-05 1.08e-05 1.11e-05 1.13e-05 1.15e-05 1.19e-05
 1.20e-05 1.21e-05 1.22e-05 1.22e-05 1.22e-05 1.22e-05 1.22e-05 1.21e-05
 1.21e-05 1.18e-05 1.18e-05 1.17e-05 1.17e-05 1.16e-05 1.18e-05 1.15e-05
 1.08e-05 9.43e-06 7.83e-06 5.58e-06 5.86e-06 6.43e-06 7.17e-06 7.62e-06
 6.15e-06 6.24e-06 7.20e-06 8.18e-06 9.00e-06 1.07e-05 1.12e-05 1.17e-05
 1.21e-05 1.24e-05 1.23e-05 1.25e-05 1.28e-05 1.30e-05 1.32e-05 1.37e-05
 1.38e-05 1.39e-05 1.40e-05 1.40e-05 1.40e-05 1.40e-05 1.40e-05 1.40e-05
 1.39e-05 1.37e-05 1.36e-05 1.36e-05 1.35e-05 1.35e-05 1.37e-05 1.34e-05
 1.26e-05 1.11e-05 9.24e-06 6.68e-06 7.04e-06 7.74e-06 8.56e-06 9.05e-06
 4.48e-06 4.55e-06 5.25e-06 5.96e-06 6.57e-06 7.78e-06 8.21e-06 8.54e-06
 8.82e-06 9.07e-06 8.98e-06 9.17e-06 9.34e-06 9.50e-06 9.66e-06 9.97e-06
 1.01e-05 1.02e-05 1.02e-05 1.02e-05 1.03e-05 1.03e-05 1.02e-05 1.02e-05
 1.02e-05 1.00e-05 9.99e-06 9.95e-06 9.94e-06 9.90e-06 1.01e-05 9.85e-06
 9.26e-06 8.07e-06 6.75e-06 4.86e-06 5.14e-06 5.65e-06 6.26e-06 6.62e-06
 3.45e-05 3.50e-05 4.04e-05 4.60e-05 5.07e-05 6.01e-05 6.33e-05 6.61e-05
 6.82e-05 7.01e-05 6.94e-05 7.10e-05 7.24e-05 7.36e-05 7.48e-05 7.72e-05
 7.81e-05 7.86e-05 7.91e-05 7.91e-05 7.93e-05 7.93e-05 7.93e-05 7.91e-05
 7.90e-05 7.74e-05 7.72e-05 7.71e-05 7.69e-05 7.65e-05 7.78e-05 7.62e-05
 7.15e-05 6.22e-05 5.20e-05 3.73e-05 3.94e-05 4.34e-05 4.81e-05 5.09e-05
 1.34e-05 1.34e-05 1.56e-05 1.80e-05 1.99e-05 2.37e-05 2.51e-05 2.63e-05
 2.72e-05 2.81e-05 2.77e-05 2.84e-05 2.89e-05 2.96e-05 3.02e-05 3.10e-05
 3.16e-05 3.17e-05 3.19e-05 3.21e-05 3.21e-05 3.21e-05 3.21e-05 3.19e-05
 3.19e-05 3.14e-05 3.12e-05 3.12e-05 3.10e-05 3.09e-05 3.14e-05 3.07e-05
 2.88e-05 2.48e-05 2.04e-05 1.44e-05 1.54e-05 1.71e-05 1.90e-05 2.02e-05
 1.01e-04 1.01e-04 1.18e-04 1.35e-04 1.50e-04 1.80e-04 1.90e-04 1.97e-04
 2.04e-04 2.11e-04 2.09e-04 2.14e-04 2.18e-04 2.21e-04 2.27e-04 2.34e-04
 2.35e-04 2.39e-04 2.39e-04 2.41e-04 2.41e-04 2.41e-04 2.41e-04 2.41e-04
 2.41e-04 2.35e-04 2.35e-04 2.35e-04 2.35e-04 2.34e-04 2.37e-04 2.32e-04
 2.18e-04 1.88e-04 1.55e-04 1.09e-04 1.17e-04 1.30e-04 1.45e-04 1.54e-04
 2.14e-04 2.14e-04 2.51e-04 2.88e-04 3.19e-04 3.84e-04 4.08e-04 4.25e-04
 4.41e-04 4.55e-04 4.52e-04 4.62e-04 4.71e-04 4.79e-04 4.88e-04 5.04e-04
 5.11e-04 5.16e-04 5.18e-04 5.20e-04 5.21e-04 5.23e-04 5.21e-04 5.21e-04
```

Figure C-2. (continued)

5.21e-04	5.13e-04	5.13e-04	5.11e-04	5.11e-04	5.09e-04	5.16e-04	5.06e-04
4.71e-04	4.04e-04	3.31e-04	2.32e-04	2.51e-04	2.79e-04	3.12e-04	3.31e-04
4.04e-04	4.06e-04	4.76e-04	5.49e-04	6.10e-04	7.37e-04	7.83e-04	8.21e-04
8.53e-04	8.79e-04	8.72e-04	8.93e-04	9.12e-04	9.29e-04	9.45e-04	9.78e-04
9.88e-04	9.99e-04	1.01e-03	1.01e-03	1.01e-03	1.01e-03	1.01e-03	1.01e-03
1.01e-03	9.97e-04	9.97e-04	9.95e-04	9.94e-04	9.92e-04	1.01e-03	9.82e-04
9.14e-04	7.79e-04	6.36e-04	4.43e-04	4.79e-04	5.37e-04	5.98e-04	6.35e-04
7.11e-04	7.13e-04	8.39e-04	9.69e-04	1.08e-03	1.31e-03	1.40e-03	1.46e-03
1.52e-03	1.57e-03	1.56e-03	1.60e-03	1.63e-03	1.66e-03	1.69e-03	1.76e-03
1.78e-03	1.80e-03	1.80e-03	1.81e-03	1.81e-03	1.81e-03	1.83e-03	1.83e-03
1.83e-03	1.80e-03	1.80e-03	1.80e-03	1.80e-03	1.80e-03	1.81e-03	1.76e-03
1.64e-03	1.39e-03	1.13e-03	7.81e-04	8.51e-04	9.54e-04	1.06e-03	1.13e-03
1.15e-03	1.15e-03	1.35e-03	1.57e-03	1.76e-03	2.14e-03	2.28e-03	2.39e-03
2.49e-03	2.58e-03	2.56e-03	2.63e-03	2.68e-03	2.74e-03	2.79e-03	2.89e-03
2.93e-03	2.95e-03	2.98e-03	2.98e-03	3.00e-03	3.00e-03	3.02e-03	3.02e-03
3.02e-03	2.96e-03	2.96e-03	2.96e-03	2.96e-03	2.96e-03	3.00e-03	2.91e-03
2.70e-03	2.27e-03	1.83e-03	1.26e-03	1.37e-03	1.54e-03	1.72e-03	1.83e-03
2.84e-03	2.82e-03	3.36e-03	3.92e-03	4.41e-03	5.40e-03	5.79e-03	6.08e-03
6.35e-03	6.57e-03	6.56e-03	6.73e-03	6.89e-03	7.03e-03	7.15e-03	7.41e-03
7.50e-03	7.58e-03	7.64e-03	7.65e-03	7.69e-03	7.72e-03	7.72e-03	7.74e-03
7.74e-03	7.62e-03	7.62e-03	7.62e-03	7.60e-03	7.57e-03	7.65e-03	7.43e-03
6.85e-03	5.74e-03	4.60e-03	3.10e-03	3.40e-03	3.82e-03	4.25e-03	4.52e-03
8.58e-03	8.56e-03	1.02e-02	1.19e-02	1.35e-02	1.67e-02	1.80e-02	1.88e-02
1.97e-02	2.06e-02	2.06e-02	2.11e-02	2.16e-02	2.20e-02	2.25e-02	2.32e-02
2.35e-02	2.39e-02	2.39e-02	2.41e-02	2.41e-02	2.42e-02	2.42e-02	2.42e-02
2.42e-02	2.39e-02	2.39e-02	2.39e-02	2.37e-02	2.35e-02	2.37e-02	2.30e-02
2.11e-02	1.76e-02	1.40e-02	9.31e-03	1.01e-02	1.13e-02	1.26e-02	1.34e-02
2.41e-03	2.41e-03	2.86e-03	3.36e-03	3.82e-03	4.72e-03	5.07e-03	5.37e-03
5.63e-03	5.86e-03	5.84e-03	6.01e-03	6.15e-03	6.29e-03	6.42e-03	6.64e-03
6.73e-03	6.80e-03	6.83e-03	6.85e-03	6.89e-03	6.90e-03	6.92e-03	6.92e-03
6.92e-03	6.82e-03	6.80e-03	6.78e-03	6.76e-03	6.71e-03	6.76e-03	6.54e-03
5.98e-03	4.97e-03	3.94e-03	2.58e-03	2.81e-03	3.14e-03	3.49e-03	3.71e-03
8.79e-03	8.79e-03	1.04e-02	1.23e-02	1.40e-02	1.73e-02	1.87e-02	1.97e-02
2.06e-02	2.14e-02	2.14e-02	2.21e-02	2.27e-02	2.32e-02	2.37e-02	2.46e-02
2.48e-02	2.51e-02	2.53e-02	2.53e-02	2.53e-02	2.55e-02	2.55e-02	2.55e-02
2.55e-02	2.51e-02	2.49e-02	2.49e-02	2.48e-02	2.46e-02	2.48e-02	2.39e-02
2.18e-02	1.81e-02	1.43e-02	9.34e-03	1.01e-02	1.13e-02	1.25e-02	1.33e-02
2.58e-02	2.58e-02	3.05e-02	3.59e-02	4.06e-02	5.00e-02	5.39e-02	5.70e-02
5.96e-02	6.21e-02	6.21e-02	6.40e-02	6.56e-02	6.69e-02	6.82e-02	7.06e-02
7.15e-02	7.20e-02	7.25e-02	7.25e-02	7.27e-02	7.29e-02	7.30e-02	7.29e-02
7.29e-02	7.15e-02	7.13e-02	7.10e-02	7.04e-02	6.97e-02	7.01e-02	6.76e-02
6.17e-02	5.16e-02	4.11e-02	2.68e-02	2.86e-02	3.16e-02	3.49e-02	3.71e-02
2.77e-02	2.81e-02	3.28e-02	3.82e-02	4.32e-02	5.28e-02	5.68e-02	6.01e-02
6.29e-02	6.54e-02	6.56e-02	6.73e-02	6.89e-02	7.03e-02	7.15e-02	7.39e-02
7.48e-02	7.53e-02	7.57e-02	7.57e-02	7.58e-02	7.60e-02	7.62e-02	7.62e-02
7.60e-02	7.48e-02	7.44e-02	7.41e-02	7.36e-02	7.29e-02	7.30e-02	7.04e-02
6.43e-02	5.37e-02	4.29e-02	2.82e-02	2.98e-02	3.28e-02	3.59e-02	3.82e-02
4.69e-03	4.76e-03	5.54e-03	6.38e-03	7.17e-03	8.65e-03	9.24e-03	9.73e-03

Figure C-2. (continued)

1.02e-02	1.05e-02	1.05e-02	1.08e-02	1.10e-02	1.12e-02	1.14e-02	1.18e-02
1.19e-02	1.20e-02	1.20e-02	1.20e-02	1.20e-02	1.20e-02	1.21e-02	1.21e-02
1.20e-02	1.18e-02	1.18e-02	1.18e-02	1.17e-02	1.16e-02	1.16e-02	1.12e-02
1.03e-02	8.72e-03	7.10e-03	4.81e-03	5.02e-03	5.44e-03	5.93e-03	6.24e-03
3.47e-02	3.52e-02	4.10e-02	4.71e-02	5.28e-02	6.36e-02	6.78e-02	7.15e-02
7.46e-02	7.74e-02	7.74e-02	7.93e-02	8.11e-02	8.26e-02	8.39e-02	8.65e-02
8.72e-02	8.77e-02	8.80e-02	8.79e-02	8.80e-02	8.84e-02	8.84e-02	8.86e-02
8.84e-02	8.68e-02	8.66e-02	8.63e-02	8.56e-02	8.47e-02	8.51e-02	8.21e-02
7.53e-02	6.36e-02	5.20e-02	3.52e-02	3.66e-02	3.96e-02	4.29e-02	4.53e-02
4.18e-02	4.27e-02	4.93e-02	5.65e-02	6.29e-02	7.53e-02	8.04e-02	8.46e-02
8.80e-02	9.12e-02	9.12e-02	9.34e-02	9.55e-02	9.73e-02	9.87e-02	1.02e-01
1.03e-01	1.03e-01	1.03e-01	1.03e-01	1.03e-01	1.03e-01	1.04e-01	1.04e-01
1.04e-01	1.02e-01	1.01e-01	1.01e-01	1.00e-01	9.90e-02	9.92e-02	9.57e-02
8.79e-02	7.46e-02	6.10e-02	4.18e-02	4.32e-02	4.62e-02	4.99e-02	5.25e-02
4.74e-02	4.85e-02	5.53e-02	6.26e-02	6.94e-02	8.21e-02	8.72e-02	9.14e-02
9.50e-02	9.80e-02	9.82e-02	1.00e-01	1.02e-01	1.04e-01	1.05e-01	1.08e-01
1.09e-01	1.10e-01	1.10e-01	1.09e-01	1.09e-01	1.10e-01	1.10e-01	1.10e-01
1.10e-01	1.08e-01	1.08e-01	1.07e-01	1.06e-01	1.05e-01	1.05e-01	1.02e-01
9.38e-02	8.02e-02	6.64e-02	4.65e-02	4.78e-02	5.06e-02	5.42e-02	5.68e-02
2.62e-02	2.68e-02	3.05e-02	3.45e-02	3.84e-02	4.52e-02	4.79e-02	5.04e-02
5.23e-02	5.40e-02	5.40e-02	5.54e-02	5.65e-02	5.74e-02	5.82e-02	5.98e-02
6.03e-02	6.05e-02	6.05e-02	6.01e-02	6.01e-02	6.05e-02	6.07e-02	6.07e-02
6.07e-02	5.94e-02	5.93e-02	5.89e-02	5.84e-02	5.75e-02	5.77e-02	5.58e-02
5.14e-02	4.41e-02	3.68e-02	2.60e-02	2.65e-02	2.79e-02	2.96e-02	3.10e-02
2.96e-02	3.07e-02	3.47e-02	3.91e-02	4.31e-02	5.06e-02	5.35e-02	5.61e-02
5.82e-02	6.00e-02	6.00e-02	6.14e-02	6.24e-02	6.33e-02	6.42e-02	6.59e-02
6.62e-02	6.64e-02	6.62e-02	6.59e-02	6.59e-02	6.62e-02	6.64e-02	6.66e-02
6.66e-02	6.56e-02	6.54e-02	6.50e-02	6.45e-02	6.38e-02	6.42e-02	6.21e-02
5.74e-02	4.95e-02	4.17e-02	3.02e-02	3.07e-02	3.21e-02	3.40e-02	3.54e-02
1.51e-02	1.55e-02	1.78e-02	2.06e-02	2.32e-02	2.81e-02	3.02e-02	3.19e-02
3.35e-02	3.47e-02	3.50e-02	3.61e-02	3.70e-02	3.77e-02	3.82e-02	3.94e-02
3.97e-02	3.99e-02	3.99e-02	3.97e-02	3.97e-02	3.99e-02	3.99e-02	3.99e-02
3.99e-02	3.91e-02	3.89e-02	3.85e-02	3.82e-02	3.75e-02	3.73e-02	3.57e-02
3.23e-02	2.68e-02	2.16e-02	1.40e-02	1.43e-02	1.53e-02	1.65e-02	1.74e-02
2.67e-02	2.75e-02	3.10e-02	3.49e-02	3.85e-02	4.52e-02	4.79e-02	5.02e-02
5.21e-02	5.39e-02	5.39e-02	5.53e-02	5.61e-02	5.70e-02	5.77e-02	5.93e-02
5.96e-02	5.96e-02	5.94e-02	5.91e-02	5.89e-02	5.93e-02	5.96e-02	5.96e-02
5.96e-02	5.86e-02	5.82e-02	5.79e-02	5.74e-02	5.67e-02	5.67e-02	5.46e-02
5.02e-02	4.31e-02	3.61e-02	2.56e-02	2.60e-02	2.72e-02	2.88e-02	2.98e-02
2.48e-02	2.56e-02	2.89e-02	3.26e-02	3.61e-02	4.24e-02	4.48e-02	4.71e-02
4.88e-02	5.04e-02	5.04e-02	5.16e-02	5.25e-02	5.33e-02	5.39e-02	5.54e-02
5.56e-02	5.58e-02	5.56e-02	5.53e-02	5.51e-02	5.54e-02	5.58e-02	5.58e-02
5.60e-02	5.49e-02	5.47e-02	5.46e-02	5.42e-02	5.35e-02	5.37e-02	5.20e-02
4.79e-02	4.11e-02	3.47e-02	2.51e-02	2.56e-02	2.67e-02	2.81e-02	2.91e-02
4.60e-02	4.71e-02	5.37e-02	6.17e-02	6.94e-02	8.39e-02	9.00e-02	9.54e-02
9.99e-02	1.04e-01	1.05e-01	1.08e-01	1.11e-01	1.13e-01	1.15e-01	1.18e-01
1.19e-01	1.19e-01	1.19e-01	1.19e-01	1.18e-01	1.19e-01	1.19e-01	1.19e-01
1.19e-01	1.16e-01	1.16e-01	1.14e-01	1.13e-01	1.11e-01	1.10e-01	1.05e-01

Figure C-2. (continued)

9.50e-02	7.90e-02	6.38e-02	4.17e-02	4.25e-02	4.52e-02	4.81e-02	5.06e-02
3.43e-02	3.54e-02	4.01e-02	4.53e-02	5.06e-02	6.01e-02	6.42e-02	6.76e-02
7.06e-02	7.30e-02	7.34e-02	7.55e-02	7.71e-02	7.85e-02	7.95e-02	8.19e-02
8.23e-02	8.25e-02	8.23e-02	8.18e-02	8.16e-02	8.21e-02	8.23e-02	8.23e-02
8.23e-02	8.07e-02	8.04e-02	7.97e-02	7.88e-02	7.76e-02	7.74e-02	7.43e-02
6.76e-02	5.70e-02	4.72e-02	3.26e-02	3.33e-02	3.47e-02	3.66e-02	3.80e-02
2.04e-02	2.09e-02	2.39e-02	2.75e-02	3.12e-02	3.80e-02	4.10e-02	4.36e-02
4.59e-02	4.78e-02	4.83e-02	4.99e-02	5.11e-02	5.21e-02	5.30e-02	5.47e-02
5.51e-02	5.53e-02	5.51e-02	5.47e-02	5.46e-02	5.47e-02	5.49e-02	5.47e-02
5.46e-02	5.33e-02	5.28e-02	5.23e-02	5.14e-02	5.04e-02	4.99e-02	4.74e-02
4.24e-02	3.47e-02	2.79e-02	1.76e-02	1.78e-02	1.88e-02	1.99e-02	2.07e-02
9.66e-03	9.87e-03	1.12e-02	1.29e-02	1.46e-02	1.76e-02	1.90e-02	2.02e-02
2.13e-02	2.20e-02	2.23e-02	2.30e-02	2.35e-02	2.41e-02	2.44e-02	2.51e-02
2.53e-02	2.53e-02	2.51e-02	2.49e-02	2.48e-02	2.49e-02	2.49e-02	2.49e-02
2.48e-02	2.42e-02	2.41e-02	2.37e-02	2.34e-02	2.28e-02	2.25e-02	2.14e-02
1.90e-02	1.56e-02	1.25e-02	7.91e-03	7.95e-03	8.39e-03	8.82e-03	9.21e-03
7.67e-03	7.79e-03	8.91e-03	1.03e-02	1.18e-02	1.45e-02	1.58e-02	1.69e-02
1.78e-02	1.87e-02	1.90e-02	1.95e-02	2.02e-02	2.06e-02	2.09e-02	2.16e-02
2.18e-02	2.20e-02	2.18e-02	2.16e-02	2.16e-02	2.16e-02	2.16e-02	2.16e-02
2.14e-02	2.09e-02	2.07e-02	2.04e-02	2.00e-02	1.95e-02	1.92e-02	1.81e-02
1.60e-02	1.28e-02	1.01e-02	6.12e-03	6.10e-03	6.49e-03	6.87e-03	7.18e-03
1.90e-03	1.92e-03	2.18e-03	2.49e-03	2.84e-03	3.47e-03	3.77e-03	4.01e-03
4.24e-03	4.41e-03	4.48e-03	4.64e-03	4.76e-03	4.86e-03	4.93e-03	5.09e-03
5.11e-03	5.11e-03	5.09e-03	5.04e-03	5.02e-03	5.04e-03	5.04e-03	5.02e-03
5.00e-03	4.86e-03	4.81e-03	4.74e-03	4.64e-03	4.52e-03	4.45e-03	4.18e-03
3.68e-03	2.96e-03	2.37e-03	1.46e-03	1.43e-03	1.51e-03	1.58e-03	1.64e-03
6.08e-04	6.19e-04	7.04e-04	8.21e-04	9.55e-04	1.17e-03	1.28e-03	1.39e-03
1.49e-03	1.58e-03	1.61e-03	1.68e-03	1.74e-03	1.78e-03	1.81e-03	1.90e-03
1.90e-03	1.92e-03	1.90e-03	1.88e-03	1.88e-03	1.87e-03	1.85e-03	1.83e-03
1.80e-03	1.71e-03	1.66e-03	1.60e-03	1.53e-03	1.45e-03	1.38e-03	1.25e-03
1.09e-03	9.08e-04	7.69e-04	4.67e-04	3.91e-04	3.87e-04	3.92e-04	3.96e-04
2.58e-04	2.67e-04	2.93e-04	3.21e-04	3.50e-04	4.03e-04	4.24e-04	4.39e-04
4.53e-04	4.62e-04	4.62e-04	4.71e-04	4.78e-04	4.83e-04	4.85e-04	4.95e-04
4.93e-04	4.90e-04	4.85e-04	4.76e-04	4.74e-04	4.78e-04	4.81e-04	4.83e-04
4.85e-04	4.76e-04	4.76e-04	4.74e-04	4.71e-04	4.65e-04	4.65e-04	4.52e-04
4.18e-04	3.63e-04	3.17e-04	2.49e-04	2.55e-04	2.60e-04	2.65e-04	2.68e-04
4.08e-04	4.10e-04	4.60e-04	5.25e-04	6.00e-04	7.32e-04	7.97e-04	8.53e-04
9.00e-04	9.40e-04	9.52e-04	9.85e-04	1.01e-03	1.03e-03	1.05e-03	1.08e-03
1.09e-03	1.09e-03	1.08e-03	1.07e-03	1.07e-03	1.07e-03	1.07e-03	1.07e-03
1.07e-03	1.04e-03	1.03e-03	1.02e-03	9.99e-04	9.75e-04	9.55e-04	9.00e-04
7.91e-04	6.38e-04	5.16e-04	3.29e-04	3.24e-04	3.40e-04	3.54e-04	3.66e-04
1.26e-04	1.22e-04	1.36e-04	1.53e-04	1.73e-04	2.07e-04	2.25e-04	2.41e-04
2.55e-04	2.65e-04	2.68e-04	2.77e-04	2.84e-04	2.88e-04	2.91e-04	2.98e-04
2.98e-04	2.98e-04	2.95e-04	2.89e-04	2.88e-04	2.89e-04	2.89e-04	2.88e-04
2.86e-04	2.77e-04	2.74e-04	2.68e-04	2.62e-04	2.53e-04	2.44e-04	2.28e-04
1.99e-04	1.66e-04	1.40e-04	9.41e-05	8.65e-05	8.77e-05	8.94e-05	9.07e-05
2.34e-05	2.21e-05	2.37e-05	2.60e-05	2.89e-05	3.45e-05	3.70e-05	3.91e-05
4.06e-05	4.20e-05	4.22e-05	4.29e-05	4.34e-05	4.36e-05	4.34e-05	4.39e-05

Figure C-2. (continued)

4.34e-05	4.27e-05	4.17e-05	4.06e-05	4.03e-05	4.06e-05	4.08e-05	4.10e-05
4.11e-05	4.04e-05	4.03e-05	4.01e-05	3.96e-05	3.89e-05	3.82e-05	3.63e-05
3.24e-05	2.75e-05	2.42e-05	1.87e-05	1.81e-05	1.85e-05	1.88e-05	1.90e-05
2.88e-06	2.68e-06	2.77e-06	2.93e-06	3.17e-06	3.66e-06	3.84e-06	3.97e-06
4.06e-06	4.10e-06	4.06e-06	4.04e-06	4.01e-06	3.92e-06	3.84e-06	3.78e-06
3.64e-06	3.49e-06	3.33e-06	3.16e-06	3.10e-06	3.16e-06	3.23e-06	3.29e-06
3.36e-06	3.36e-06	3.42e-06	3.47e-06	3.50e-06	3.52e-06	3.54e-06	3.47e-06
3.24e-06	2.98e-06	2.84e-06	2.53e-06	2.49e-06	2.51e-06	2.53e-06	2.55e-06
4.46e-07	4.08e-07	4.08e-07	4.22e-07	4.46e-07	5.14e-07	5.39e-07	5.56e-07
5.70e-07	5.77e-07	5.74e-07	5.70e-07	5.61e-07	5.47e-07	5.30e-07	5.23e-07
5.00e-07	4.78e-07	4.53e-07	4.29e-07	4.20e-07	4.29e-07	4.38e-07	4.48e-07
4.59e-07	4.60e-07	4.72e-07	4.85e-07	4.93e-07	5.02e-07	5.11e-07	5.09e-07
4.92e-07	4.79e-07	4.74e-07	4.46e-07	4.45e-07	4.48e-07	4.53e-07	4.57e-07
1.18e-07	1.09e-07	1.07e-07	1.10e-07	1.16e-07	1.32e-07	1.37e-07	1.40e-07
1.42e-07	1.43e-07	1.41e-07	1.39e-07	1.35e-07	1.30e-07	1.24e-07	1.19e-07
1.11e-07	1.03e-07	9.50e-08	8.68e-08	8.42e-08	8.80e-08	9.24e-08	9.71e-08
1.02e-07	1.06e-07	1.12e-07	1.17e-07	1.22e-07	1.26e-07	1.30e-07	1.31e-07
1.29e-07	1.27e-07	1.27e-07	1.24e-07	1.25e-07	1.26e-07	1.27e-07	1.28e-07
2.11e-08	1.94e-08	1.88e-08	1.92e-08	2.00e-08	2.23e-08	2.30e-08	2.34e-08
2.34e-08	2.34e-08	2.32e-08	2.27e-08	2.20e-08	2.11e-08	2.00e-08	1.90e-08
1.76e-08	1.63e-08	1.48e-08	1.34e-08	1.30e-08	1.38e-08	1.47e-08	1.57e-08
1.67e-08	1.76e-08	1.87e-08	1.97e-08	2.07e-08	2.16e-08	2.25e-08	2.30e-08
2.28e-08	2.28e-08	2.32e-08	2.28e-08	2.32e-08	2.34e-08	2.37e-08	2.37e-08
2.82e-09	2.60e-09	2.51e-09	2.55e-09	2.65e-09	2.93e-09	3.00e-09	3.03e-09
3.05e-09	3.03e-09	2.98e-09	2.91e-09	2.81e-09	2.68e-09	2.53e-09	2.39e-09
2.21e-09	2.02e-09	1.83e-09	1.64e-09	1.59e-09	1.70e-09	1.83e-09	1.97e-09
2.13e-09	2.27e-09	2.42e-09	2.58e-09	2.74e-09	2.88e-09	3.02e-09	3.09e-09
3.10e-09	3.10e-09	3.16e-09	3.16e-09	3.21e-09	3.24e-09	3.28e-09	3.28e-09
5.33e-10	4.92e-10	4.76e-10	4.85e-10	5.04e-10	5.56e-10	5.72e-10	5.77e-10
5.81e-10	5.77e-10	5.68e-10	5.54e-10	5.35e-10	5.11e-10	4.81e-10	4.55e-10
4.20e-10	3.85e-10	3.49e-10	3.12e-10	3.03e-10	3.24e-10	3.49e-10	3.75e-10
4.04e-10	4.27e-10	4.57e-10	4.86e-10	5.14e-10	5.39e-10	5.63e-10	5.77e-10
5.74e-10	5.74e-10	5.82e-10	5.77e-10	5.86e-10	5.93e-10	6.00e-10	6.01e-10
7.64e-11	7.03e-11	6.92e-11	7.06e-11	7.39e-11	8.25e-11	8.49e-11	8.61e-11
8.66e-11	8.63e-11	8.47e-11	8.26e-11	7.97e-11	7.60e-11	7.17e-11	6.78e-11
6.28e-11	5.75e-11	5.23e-11	4.71e-11	4.57e-11	4.86e-11	5.18e-11	5.54e-11
5.93e-11	6.24e-11	6.64e-11	7.04e-11	7.41e-11	7.72e-11	8.04e-11	8.18e-11
8.09e-11	7.98e-11	8.05e-11	7.93e-11	8.04e-11	8.12e-11	8.21e-11	8.25e-11
1.36e-11	1.25e-11	1.22e-11	1.25e-11	1.29e-11	1.42e-11	1.46e-11	1.47e-11
1.48e-11	1.47e-11	1.45e-11	1.42e-11	1.37e-11	1.31e-11	1.24e-11	1.19e-11
1.11e-11	1.02e-11	9.34e-12	8.49e-12	8.28e-12	8.77e-12	9.31e-12	9.90e-12
1.06e-11	1.11e-11	1.17e-11	1.24e-11	1.30e-11	1.35e-11	1.40e-11	1.42e-11
1.40e-11	1.38e-11	1.39e-11	1.35e-11	1.37e-11	1.38e-11	1.39e-11	1.40e-11
2.18e-12	2.04e-12	2.00e-12	2.06e-12	2.11e-12	2.25e-12	2.28e-12	2.28e-12
2.27e-12	2.27e-12	2.21e-12	2.18e-12	2.11e-12	2.04e-12	1.97e-12	1.92e-12
1.81e-12	1.72e-12	1.62e-12	1.52e-12	1.50e-12	1.57e-12	1.64e-12	1.72e-12
1.80e-12	1.85e-12	1.92e-12	2.00e-12	2.06e-12	2.11e-12	2.18e-12	2.16e-12
2.07e-12	2.02e-12	2.00e-12	1.87e-12	1.85e-12	1.87e-12	1.88e-12	1.90e-12

Figure C-2. (continued)

1.85e-08	1.85e-08	1.85e-08	1.85e-08	1.83e-08	1.83e-08	1.81e-08	1.81e-08
1.80e-08	1.80e-08	1.80e-08	1.80e-08	1.80e-08	1.78e-08	1.78e-08	1.76e-08
1.76e-08	1.76e-08	1.76e-08	1.76e-08	1.76e-08	1.76e-08	1.76e-08	1.76e-08
1.76e-08	1.76e-08	1.76e-08	1.76e-08	1.76e-08	1.76e-08	1.74e-08	1.74e-08
1.74e-08	1.74e-08	1.74e-08	1.76e-08	1.74e-08	1.74e-08	1.73e-08	1.73e-08
8.98e-08	9.08e-08	9.07e-08	9.05e-08	9.05e-08	9.00e-08	8.98e-08	8.94e-08
8.93e-08	8.89e-08	8.93e-08	8.91e-08	8.89e-08	8.87e-08	8.86e-08	8.80e-08
8.80e-08	8.79e-08	8.79e-08	8.79e-08	8.79e-08	8.75e-08	8.73e-08	8.72e-08
8.72e-08	8.73e-08	8.72e-08	8.72e-08	8.70e-08	8.68e-08	8.63e-08	8.61e-08
8.59e-08	8.58e-08	8.56e-08	8.42e-08	8.33e-08	8.28e-08	8.21e-08	8.19e-08
3.42e-06	3.64e-06	3.73e-06	3.84e-06	4.01e-06	4.27e-06	4.38e-06	4.45e-06
4.48e-06	4.52e-06	4.48e-06	4.46e-06	4.43e-06	4.39e-06	4.34e-06	4.29e-06
4.22e-06	4.11e-06	3.99e-06	3.84e-06	3.80e-06	3.87e-06	3.94e-06	3.99e-06
4.04e-06	4.03e-06	4.03e-06	4.04e-06	4.03e-06	3.99e-06	4.01e-06	3.89e-06
3.64e-06	3.31e-06	3.09e-06	2.62e-06	2.58e-06	2.53e-06	2.42e-06	2.35e-06
1.09e-04	1.17e-04	1.19e-04	1.22e-04	1.28e-04	1.37e-04	1.39e-04	1.42e-04
1.43e-04	1.44e-04	1.42e-04	1.42e-04	1.41e-04	1.39e-04	1.37e-04	1.35e-04
1.32e-04	1.28e-04	1.24e-04	1.18e-04	1.16e-04	1.19e-04	1.22e-04	1.24e-04
1.26e-04	1.26e-04	1.27e-04	1.27e-04	1.27e-04	1.27e-04	1.27e-04	1.24e-04
1.16e-04	1.06e-04	9.90e-05	8.51e-05	8.46e-05	8.30e-05	7.98e-05	7.76e-05
1.17e-04	1.24e-04	1.33e-04	1.43e-04	1.55e-04	1.74e-04	1.82e-04	1.88e-04
1.93e-04	1.97e-04	1.97e-04	1.99e-04	2.00e-04	2.00e-04	2.00e-04	2.03e-04
2.00e-04	1.98e-04	1.94e-04	1.89e-04	1.88e-04	1.90e-04	1.92e-04	1.94e-04
1.94e-04	1.92e-04	1.94e-04	1.94e-04	1.92e-04	1.90e-04	1.91e-04	1.85e-04
1.70e-04	1.48e-04	1.32e-04	1.03e-04	1.03e-04	1.02e-04	1.02e-04	1.02e-04
1.97e-04	2.06e-04	2.40e-04	2.80e-04	3.16e-04	3.77e-04	4.04e-04	4.28e-04
4.49e-04	4.66e-04	4.67e-04	4.80e-04	4.89e-04	4.97e-04	5.02e-04	5.17e-04
5.20e-04	5.20e-04	5.17e-04	5.13e-04	5.12e-04	5.16e-04	5.17e-04	5.17e-04
5.17e-04	5.08e-04	5.06e-04	5.03e-04	4.99e-04	4.93e-04	4.93e-04	4.72e-04
4.28e-04	3.61e-04	3.04e-04	2.10e-04	2.11e-04	2.14e-04	2.19e-04	2.28e-04
6.28e-04	6.48e-04	7.94e-04	9.64e-04	1.12e-03	1.38e-03	1.50e-03	1.60e-03
1.69e-03	1.77e-03	1.78e-03	1.83e-03	1.88e-03	1.92e-03	1.95e-03	2.02e-03
2.04e-03	2.05e-03	2.05e-03	2.04e-03	2.04e-03	2.05e-03	2.05e-03	2.05e-03
2.05e-03	2.00e-03	2.00e-03	1.98e-03	1.96e-03	1.93e-03	1.93e-03	1.84e-03
1.66e-03	1.38e-03	1.13e-03	7.36e-04	7.41e-04	7.58e-04	7.97e-04	8.46e-04
1.53e-03	1.58e-03	1.95e-03	2.40e-03	2.81e-03	3.50e-03	3.80e-03	4.07e-03
4.30e-03	4.52e-03	4.53e-03	4.69e-03	4.80e-03	4.91e-03	5.00e-03	5.19e-03
5.25e-03	5.28e-03	5.29e-03	5.27e-03	5.27e-03	5.29e-03	5.29e-03	5.28e-03
5.28e-03	5.15e-03	5.14e-03	5.11e-03	5.06e-03	4.97e-03	4.99e-03	4.75e-03
4.26e-03	3.53e-03	2.87e-03	1.83e-03	1.86e-03	1.92e-03	2.04e-03	2.17e-03
5.02e-03	5.16e-03	6.35e-03	7.74e-03	9.05e-03	1.13e-02	1.22e-02	1.31e-02
1.39e-02	1.46e-02	1.46e-02	1.51e-02	1.55e-02	1.58e-02	1.61e-02	1.67e-02
1.68e-02	1.70e-02	1.70e-02	1.69e-02	1.69e-02	1.70e-02	1.70e-02	1.70e-02
1.70e-02	1.66e-02	1.66e-02	1.65e-02	1.63e-02	1.61e-02	1.62e-02	1.54e-02
1.38e-02	1.14e-02	9.20e-03	5.82e-03	5.96e-03	6.23e-03	6.64e-03	7.07e-03
4.98e-03	5.10e-03	6.33e-03	7.84e-03	9.26e-03	1.17e-02	1.28e-02	1.37e-02
1.45e-02	1.53e-02	1.53e-02	1.59e-02	1.64e-02	1.67e-02	1.71e-02	1.78e-02
1.79e-02	1.81e-02	1.81e-02	1.81e-02	1.81e-02	1.82e-02	1.82e-02	1.82e-02

Figure C-2. (continued)

1.82e-02	1.78e-02	1.77e-02	1.76e-02	1.75e-02	1.72e-02	1.72e-02	1.64e-02
1.46e-02	1.19e-02	9.49e-03	5.80e-03	6.04e-03	6.41e-03	6.90e-03	7.40e-03
8.27e-03	8.41e-03	1.05e-02	1.30e-02	1.54e-02	1.95e-02	2.14e-02	2.30e-02
2.44e-02	2.57e-02	2.58e-02	2.68e-02	2.76e-02	2.82e-02	2.87e-02	3.00e-02
3.03e-02	3.06e-02	3.06e-02	3.06e-02	3.06e-02	3.07e-02	3.06e-02	3.08e-02
3.08e-02	3.00e-02	3.00e-02	3.00e-02	2.97e-02	2.92e-02	2.92e-02	2.79e-02
2.47e-02	2.00e-02	1.58e-02	9.53e-03	1.00e-02	1.08e-02	1.17e-02	1.25e-02
1.35e-02	1.36e-02	1.70e-02	2.12e-02	2.52e-02	3.23e-02	3.54e-02	3.82e-02
4.08e-02	4.30e-02	4.31e-02	4.48e-02	4.62e-02	4.72e-02	4.82e-02	5.01e-02
5.08e-02	5.12e-02	5.14e-02	5.13e-02	5.13e-02	5.15e-02	5.17e-02	5.17e-02
5.19e-02	5.09e-02	5.08e-02	5.08e-02	5.03e-02	4.98e-02	4.96e-02	4.70e-02
4.15e-02	3.31e-02	2.60e-02	1.53e-02	1.63e-02	1.79e-02	1.94e-02	2.07e-02
2.33e-02	2.36e-02	2.93e-02	3.67e-02	4.40e-02	5.72e-02	6.31e-02	6.84e-02
7.31e-02	7.72e-02	7.78e-02	8.09e-02	8.35e-02	8.56e-02	8.72e-02	9.08e-02
9.19e-02	9.26e-02	9.30e-02	9.30e-02	9.31e-02	9.35e-02	9.40e-02	9.44e-02
9.50e-02	9.37e-02	9.39e-02	9.39e-02	9.33e-02	9.21e-02	9.18e-02	8.66e-02
7.58e-02	5.89e-02	4.57e-02	2.61e-02	2.84e-02	3.13e-02	3.39e-02	3.60e-02
2.38e-02	2.50e-02	2.99e-02	3.63e-02	4.29e-02	5.40e-02	5.95e-02	6.42e-02
6.84e-02	7.21e-02	7.27e-02	7.53e-02	7.74e-02	7.90e-02	8.04e-02	8.32e-02
8.39e-02	8.43e-02	8.43e-02	8.41e-02	8.41e-02	8.50e-02	8.58e-02	8.69e-02
8.82e-02	8.76e-02	8.85e-02	8.87e-02	8.85e-02	8.76e-02	8.72e-02	8.21e-02
7.13e-02	5.49e-02	4.35e-02	2.58e-02	2.72e-02	2.96e-02	3.09e-02	3.22e-02
1.83e-02	2.00e-02	2.42e-02	2.97e-02	3.56e-02	4.54e-02	5.02e-02	5.48e-02
5.92e-02	6.29e-02	6.38e-02	6.67e-02	6.92e-02	7.13e-02	7.31e-02	7.61e-02
7.72e-02	7.78e-02	7.81e-02	7.79e-02	7.82e-02	7.89e-02	7.98e-02	8.09e-02
8.20e-02	8.17e-02	8.23e-02	8.23e-02	8.20e-02	8.09e-02	7.99e-02	7.49e-02
6.41e-02	4.85e-02	3.84e-02	2.16e-02	2.21e-02	2.38e-02	2.46e-02	2.54e-02
1.07e-02	1.17e-02	1.37e-02	1.60e-02	1.87e-02	2.26e-02	2.48e-02	2.70e-02
2.89e-02	3.07e-02	3.14e-02	3.28e-02	3.41e-02	3.51e-02	3.60e-02	3.75e-02
3.78e-02	3.78e-02	3.76e-02	3.72e-02	3.72e-02	3.76e-02	3.76e-02	3.73e-02
3.67e-02	3.48e-02	3.40e-02	3.32e-02	3.21e-02	3.06e-02	3.04e-02	2.80e-02
2.49e-02	2.20e-02	1.89e-02	1.07e-02	9.19e-03	8.68e-03	8.47e-03	8.38e-03
1.77e-02	1.90e-02	2.11e-02	2.31e-02	2.50e-02	2.66e-02	2.75e-02	2.82e-02
2.85e-02	2.87e-02	2.80e-02	2.78e-02	2.76e-02	2.73e-02	2.69e-02	2.71e-02
2.64e-02	2.57e-02	2.51e-02	2.44e-02	2.42e-02	2.46e-02	2.52e-02	2.57e-02
2.64e-02	2.64e-02	2.69e-02	2.73e-02	2.74e-02	2.73e-02	2.73e-02	2.61e-02
2.27e-02	1.93e-02	1.76e-02	1.19e-02	9.87e-03	9.73e-03	9.70e-03	9.70e-03
2.97e-03	3.09e-03	3.39e-03	3.77e-03	4.12e-03	4.44e-03	4.66e-03	4.85e-03
4.99e-03	5.11e-03	5.01e-03	5.06e-03	5.09e-03	5.10e-03	5.08e-03	5.20e-03
5.14e-03	5.07e-03	4.96e-03	4.85e-03	4.80e-03	4.85e-03	4.91e-03	4.95e-03
4.99e-03	4.84e-03	4.83e-03	4.80e-03	4.73e-03	4.61e-03	4.60e-03	4.32e-03
3.89e-03	3.55e-03	3.24e-03	2.22e-03	1.96e-03	1.95e-03	1.98e-03	1.99e-03
3.76e-04	3.74e-04	4.03e-04	4.43e-04	4.84e-04	5.27e-04	5.54e-04	5.78e-04
5.98e-04	6.17e-04	6.09e-04	6.21e-04	6.29e-04	6.36e-04	6.39e-04	6.57e-04
6.53e-04	6.48e-04	6.42e-04	6.33e-04	6.26e-04	6.23e-04	6.19e-04	6.16e-04
6.11e-04	5.85e-04	5.71e-04	5.50e-04	5.24e-04	4.90e-04	4.69e-04	4.45e-04
4.23e-04	3.98e-04	3.68e-04	2.67e-04	2.36e-04	2.33e-04	2.35e-04	2.37e-04
1.81e-05	1.73e-05	1.72e-05	1.77e-05	1.91e-05	2.20e-05	2.32e-05	2.41e-05

Figure C-2. (continued)

```
 2.50e-05 2.56e-05 2.58e-05 2.64e-05 2.68e-05 2.72e-05 2.74e-05 2.83e-05
 2.82e-05 2.80e-05 2.78e-05 2.74e-05 2.66e-05 2.59e-05 2.52e-05 2.41e-05
 2.32e-05 2.16e-05 2.08e-05 2.02e-05 1.98e-05 1.94e-05 1.91e-05 1.87e-05
 1.80e-05 1.72e-05 1.66e-05 1.39e-05 1.35e-05 1.34e-05 1.34e-05 1.35e-05
 4.22e-07 4.12e-07 4.23e-07 4.40e-07 4.68e-07 5.49e-07 5.95e-07 6.28e-07
 6.61e-07 6.87e-07 6.94e-07 7.08e-07 7.18e-07 7.25e-07 7.27e-07 7.42e-07
 7.37e-07 7.26e-07 7.07e-07 6.89e-07 6.70e-07 6.66e-07 6.59e-07 6.50e-07
 6.39e-07 6.11e-07 6.00e-07 5.83e-07 5.64e-07 5.44e-07 5.37e-07 5.13e-07
 4.89e-07 4.56e-07 4.21e-07 3.58e-07 3.42e-07 3.22e-07 3.13e-07 3.15e-07
 3.77e-08 4.04e-08 4.36e-08 4.83e-08 5.61e-08 6.53e-08 7.16e-08 7.58e-08
 7.96e-08 8.26e-08 8.14e-08 8.29e-08 8.45e-08 8.50e-08 8.45e-08 8.45e-08
 8.29e-08 8.03e-08 7.74e-08 7.63e-08 7.46e-08 7.32e-08 7.26e-08 7.18e-08
 7.09e-08 6.78e-08 6.69e-08 6.39e-08 6.13e-08 5.84e-08 5.99e-08 5.68e-08
 5.31e-08 4.74e-08 4.21e-08 3.31e-08 2.87e-08 2.49e-08 2.10e-08 1.88e-08
 1.49e-07 1.90e-07 2.28e-07 2.62e-07 2.93e-07 3.19e-07 3.35e-07 3.47e-07
 3.49e-07 3.38e-07 3.31e-07 3.43e-07 3.47e-07 3.36e-07 3.24e-07 3.16e-07
 3.05e-07 2.88e-07 2.60e-07 2.21e-07 1.88e-07 1.88e-07 1.92e-07 1.94e-07
 2.00e-07 1.99e-07 2.02e-07 2.04e-07 2.04e-07 2.02e-07 2.02e-07 2.09e-07
 2.11e-07 2.11e-07 2.04e-07 1.34e-07 9.76e-08 8.75e-08 7.01e-08 6.14e-08

15**    / source multiplier for each energy group
 69r1.0
t
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Figure C-2. (continued)

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' dort - aprf aog using saic 1989 angle-energy leakage source, mm = 240
' 16.143m source height, simple topography out to 400m test site
' 34% ground moisture, 10/24/89(a) air parameters

61$$ 0 21 4 0 23   / ntflx,ntfog,ntsig,ntbsi,ntdsi
     0 0 0 0 22   / ntfci,ntibi,ntibo,ntnpr,ntdir
     0 e   / ntdso

62$$ 0 5 8 66 98   / iadj,isctm,izm,im,jm
     69 3 4 72 0   / igm,iht,ihs,ihm,mixl
     0 54 54 0 240   / mcr,mtp,mtm,idfac,mm
     1 1 0 0 0   / ingeom,ibl,ibr,ibb,ibt
     1 -4 0 4 0   / isrmx,ifxmi,ifxmf,mode,ktype
     2 0 0 0 0   / iacc,kalf,igtype,inpfxm,inpsrm
     0 0 0 0 0   / njntsr,nintsr,njntfx,nintfx,iact
     8 0 1 1 2   / ired,ipdb2,ifxprt,icsprt,idirf
     13 25 120 11 1   / jdirf,jdirl,nbuf,iepsbz,minblk
     1 1 1 1 1   / maxblk,isbt,msbt,msdm,ibfscl
     4 50 2 0 0  / intscl,itmscl,nofis,ifdb2z,iswp
     19 28 0 0 0   / keyjn,keyin,nsigtp,norpos,normat
     0 0 250 250 -20   / mstmax,negfix,locobj,lcmobj,nkeyfx
     4 46 0 0 0   / ncndin,neut,itally,ispl,isp2
     e

63** 120 0.0 1-4 1-2 0.0   / tmax,xnf,eps,epp,epv
     1-3 1.0 0.2 1.5 10.0   /epf,ekobj,evth,evchm,evmax
     1.0 1.0 -1.0 0.3 10.0   /evkmx,evi,devdki,evdelk,sormin
     1.0 1-4 1-2 0.3 -1.5   /conacc,conscl,coneps,wsoloi,wsolii
     1.5 0.6 0.0 1-60 0.0   /wsolcn,orf,fsnacc,flxmin,smooth
     1-2 0.2 0.9   / epo,extrcv,theta
     e  t
     t

81**     / wts mm240
   0 2r102900-8 0 2r307825-8 0 2r510200-8 0 2r708425-8 0
   2r901350-8 0 563869-8 316131-8 n2 0 641385-8 359590-8 n2 0
   714976-8 400849-8 n2 0 784547-8 439853-8 n2 0 857529-8
   480771-8 n2 0 642875-8 293289-8 479164-8 n3 0 681415-8
   310872-8 507890-8 n3 0 716550-8 326901-8 534077-8 n3 0
   745915-8 340298-8 555965-8 n3 0 775565-8 353825-8 578064-8
   n3 0 489468-8 386282-8 513536-8 364389-8 n4 0 500102-8
   394674-8 524693-8 372306-8 n4 0 508580-8 401365-8 533587-8
   378617-8 n4 0 515474-8 406806-8 540820-8 383750-8 n4 0
   517107-8 408094-8 542534-8 384965-8 n4 q120
```

Figure C-3. Sample DORT Input for the Reactor Source Used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF).

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82**     / mus mm240
   -641230-7 -421582-7 ml -142963-6 -939923-7 ml -229252-6
   -150724-6 ml -315291-6 -207291-6 ml -399349-6 -262555-6 ml
   -472796-6 -411087-6 -143488-6 m2 -537046-6 -466952-6
   -162988-6 m2 -598374-6 -520275-6 -181600-6 m2 -656401-6
   -570729-6 -199211-6 m2 -711034-6 -618231-6 -215791-6 m2
   -761567-6 -713133-6 -470428-6 -164201-6 m3 -807567-6
   -756207-6 -498843-6 -174119-6 m3 -849108-6 -795106-6
   -524503-6 -183075-6 m3 -885925-6 -829582-6 -547246-6
   -191013-6 m3 -917890-6 -859514-6 -566991-6 -197905-6 m3
   -944812-6 -922954-6 -765692-6 -505099-6 -176303-6 m4
   -966490-6 -944130-6 -783260-6 -516688-6 -180348-6 m4
   -982847-6 -960108-6 -796516-6 -525433-6 -183400-6 m4
   -993815-6 -970823-6 -805405-6 -531297-6 -185447-6 m4
   -999313-6 -976194-6 -809860-6 -534236-6 -186473-6 m4 q120

83**      / etas mm240
   3r-.997942 3r-.989728 3r-.973367 3r-.948995 3r-.916799
   5r-.881172 5r-.843553 5r-.801217 5r-.754412 5r-.703158
   7r-.648086 7r-.589776 7r-.528222 7r-.463828 7r-.396835
   9r-.327613 9r-.256704 9r-.184425 9r-.111045 9r-.037054 g120

84$$ 1 2 3 4 5 6 7 8   / reg nos by zone
     t
1** f0   / fission spectrum

2**   /axii (jm+1)
  -80 -75 -70 -65 -60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 -2.5
  -1 0 50 150 250 489 749 949 1102 1220 1311 1381 1435 1476 1508 1532
  1551 1566 1577 1585 1592 1597 1601 1604 1607 1608.5 1610 1614.3 1619
  1620.5 1622 1624 1627 1631 1636 1643 1651 1662 1677 1696 1720 1752
  1793 1847 1917 2008 2126 2279 2479 2739 3076 3514 4085 4826 5789 7042
  8670 10787 13000 16000 19000 22000 25000 28000 31000 34000 37000 40000
  43000 46000 49000 52000 55000 58000 61000 64000 67000 70000 73000
  76000 78000 80000

4**   /radii (im+1)
  0 4.6 6 7.8 10 13 17 22 29 37 48 63 82 106 138 179 233 303 394 512 665
  865 1125 1462 1900 2471 3212 4175 5428 7056 9000 11000 13000 15000
  16500 17500 19000 21000 23000 25000 27000 28500 29500 30500 31500
  33000 35000 37000 38500 39500 40500 41500 43000 45000 47000 49000
  51000 54000 57000 60000 63000 66000 69000 72000 75000 78000 80000

5** f1   / energy group boundaries
```

Figure C-3. (continued)

```
8$$   / zone numbers by interval
' zones 1, 2, & 3-aprf ground, 4 & 5-borated concrete, 6, 7, & 8-air
  66r1 8q66   /j-ints 1-9
  19r5 47r1 2q66   /j-ints 10-12
  19r4 3r3 8r1 3r3 3r2 5r3 3r2 4r3 3r2 3 14r1 5q66   /j-ints 13-18
  33r7 3r6 5r7 3r6 4r7 3r6 7 14r8  3q66   /j-ints 19-22
  52r7 14r8 3q66   /j-ints 23-26
  66r8 71q66   /j-ints 27-98

9$$ 3r1 2r7 3r13   / mat by zone

24** 1.-10 1.0 1.-1 1.-2 1.-10 1.0 1.-1 1.-10   / importance by zone

28$$ 35r8 11r25 23r8   / inners by grp

29$$ 13r19 3r20 3r21 22   / key flx j-pos's

30$$ 31 34 35 36 39 42 43 44 49 50 51
     53 56 35 43 50 1q3 50   / key flx i-pos's
     t
```

Figure C-3. (continued)

```
'aprf aog/400m/simple topo/16.14m sh/34% ground moisture/10-24-89(a) air

 1$$ 1 13 25 0 0   /nip,jpl,jpu,ned,norm
     69 21 22 23 24   /isgrp,nflsv,naft,nuncl,ndata
     5 6 13 25 0   /n5,n6,njl,njm,naftm
     0 46 0   /ntype,neui,ngamx
     e t

 2** 1614.3 0 e   /sh,hsa

 4$$ 50 e    /ival
     t
```

Figure C-4. Sample VISTA Input for the Reactor Source Used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF).

```
aprf two meter box calc/4in steel/dabl 46n-23g/detailed geometry model
 $$ 1000 1500 1500    1   46   23   46   69    0    1  120    4    0
 $$   0   69    1    0
 ** 1.0    1.0-05    1.0+04    0.0    2.2+05
 ** 0.0    0.0    110.16    0.0    0.0    0.0    0.0
 ** 69r1.0
 ** 8r1.0 11r2.0 8r4.0 3r2.0 16r1.0 3r3.0 12r6.0 8r3.0
 ** 1.9640+7  1.6905+7  1.4918+7  1.4191+7  1.3840+7  1.2523+7  1.2214+7
    1.1052+7  1.0000+7  9.0484+6  8.1873+6  7.4082+6  6.3763+6  4.9658+6
    4.7237+6  4.0657+6  3.0119+6  2.3852+6  2.3069+6  1.8268+6  1.4227+6
    1.1080+6  9.6164+5  8.2085+5  7.4274+5  6.3927+5  5.5023+5  3.6883+5
    2.4724+5  1.5764+5  1.1109+5  5.2475+4  3.4307+4  2.4788+4  2.1875+4
    1.0595+4  3.3546+3  1.2341+3  5.8295+2  2.7536+2  1.0130+2  2.9023+1
    1.0677+1  3.0590+0  1.12535+0 4.1399-1  2.0000+7  1.4000+7  1.2000+7
    1.0000+7  8.0000+6  7.0000+6  6.0000+6  5.0000+6  4.0000+6  3.0000+6
    2.5000+6  2.0000+6  1.5000+6  1.0.00+6  7.0000+5  4.5500+5  3.0000+5
    1.5000+5  1.0000+5  7.0000+4  4.5000+4  3.0000+4  2.0000+4
    000034327624461 5
 $$    1    1    0    0    0    4   69    1
 $$    1    1   69    1    1    1   **    5.0+00    5.0-02    2.0-01    0.0
 $$    1    1   69    2    1    2   **    2.0+00    2.0-02    1.0-01    0.0
 $$    1    1   69    3    1    3   **    2.0+00    2.0-02    1.0-01    0.0
 $$    1    1   69    4    1    4   **    2.0+00    2.0-02    2.0-01    0.0
 $$   -1   9r0
 $$    0    0    0    0
 ** 23r1.0
 ** 23r1.0
 ** 23r1.0
 ** 23r1.0
0000000000     0.001     0.001    0    0    0
    1    1
   23
    2    6
    1    6    9   12   19   20
    3   16
    2    3    4    5    7    8   10   11   13   14   15   16   17   18
   21   22
    0    1
   24
    1    1    1    1    1    1    1    1    1    1    1    1    1    1
    1    1    1    1    1    1    1    1    1    1
2m box exp/aprf ground (34%),borated concrete,10-24-89(a) air,1020 steel
 $$  46   46   23   23   69   72    4    4   24   41    6    3    0    3
 $$  7z   -8   3z
two meter box/detailed geometry/46n-23g
 ** 4r1.0
 $$   1    2
```

Figure C-5. Sample MORSE Input for the Central Detector Position Used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF).

```
cm   2.0 meter cubic box geometry (4 inches of steel)
  49   24
    1rpp   -120.0000  120.0000 -120.0000  120.0000  -15.0000  230.0000
    2rpp   -115.2398  115.2398 -115.2398  115.2398    0.0000    5.0800
    3rpp   -110.1598  110.1598 -110.1598  110.1598    5.0800   10.1600
    4rpp    -99.9998  -89.8398  -99.9998  -89.8398   10.1600   15.2400
    5rpp     89.8398   99.9998  -99.9998  -89.8398   10.1600   15.2400
    6rpp     89.8398   99.9998   89.8398   99.9998   10.1600   15.2400
    7rpp    -99.9998  -89.8398   89.8398   99.9998   10.1600   15.2400
    8rpp   -105.0798  105.0798 -105.0798  105.0798   10.1600  215.2396
    9rpp    -99.9998   99.9998  -99.9998   99.9998   10.1600  210.1596
   10rpp    -79.6798  -69.5198 -112.0598 -110.1598    5.0800   15.2400
   11rpp     69.5198   79.6798 -112.0598 -110.1598    5.0800   15.2400
   12rpp    110.1598  112.0598  -79.6798  -69.5298    5.0800   15.2400
   13rpp    110.1598  112.0598   69.5298   79.6798    5.0800   15.2400
   14rpp     69.5198   79.6798  110.1598  112.0598    5.0800   15.2400
   15rpp    -79.6798  -69.5198  110.1598  112.0598    5.0800   15.2400
   16rpp   -112.0598 -110.1598   69.5198   79.6798    5.0800   15.2400
   17rpp   -112.0598 -110.1598  -79.6798  -69.5198    5.0800   15.2400
   18rpp    -99.9998  -89.8398 -117.1398 -115.2398    0.0000   15.2400
   19rpp     89.8398   99.9998 -117.1398 -115.2398    0.0000   15.2400
   20rpp     89.8398   99.9998  115.2398  117.1398    0.0000   15.2400
   21rpp    -99.9998  -89.8398  115.2398  117.1398    0.0000   15.2400
   22rcc    -94.9198 -117.1398   10.1600    0.0000    1.9000    0.0000
              2.5400
   23rcc     94.9198 -117.1398   10.1600    0.0000    1.9000    0.0000
              2.5400
   24rcc     94.9198  115.2398   10.1600    0.0000    1.9000    0.0000
              2.5400
   25rcc    -94.9198  115.2398   10.1600    0.0000    1.9000    0.0000
              2.5400
   26rcc      0.0000    0.0000  210.1596    0.0000    0.0000    5.0800
             25.4000
   27rcc     99.9998    0.0000  110.1598    5.0800    0.0000    0.0000
             25.4000
   28rcc     99.9998  -49.1998   10.1600   10.1600    0.0000    0.0000
              5.0800
   29rpp   -110.1598  110.1598 -110.1598 -105.0798   10.1600  215.2396
   30rpp    105.0798  110.1598 -105.0798  105.0798   10.1600  215.2396
   31rpp   -110.1598  110.1598  105.0798  110.1598   10.1600  215.2396
   32rpp   -110.1598 -105.0798 -105.0798  105.0798   10.1600  215.2396
   33rpp   -110.1598  110.1598 -110.1598  110.1598  215.2396  220.3196
   34rcc      0.0000    0.0000  215.2396    0.0000    0.0000    5.0800
             37.4650
```

Figure C-6. Sample GIFT5 Geometry Input for the Two-Meter Box Used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF).

```
35rcc     105.0798    0.0000  110.1598    5.0800    0.0000    0.0000
           37.4650
36rpp      -5.0800    5.0800 -112.0598 -110.1598  205.1596  228.0196
37rpp     110.1598  112.0598   -5.0800    5.0800  205.1596  228.0196
38rpp      -5.0800    5.0800  110.1598  112.0598  205.1596  228.0196
39rpp    -112.0598 -110.1598   -5.0800    5.0800  205.1596  228.0196
40rcc       0.0000 -112.0598  222.9396    0.0000    1.9000    0.0000
            2.5400
41rcc     110.1598    0.0000  222.9396    1.9000    0.0000    0.0000
            2.5400
42rcc       0.0000  110.1598  222.9396    0.0000    1.9000    0.0000
            2.5400
43rcc    -112.0598    0.0000  222.9396    1.9000    0.0000    0.0000
            2.5400
44rcc     -85.0000 -110.1598   11.4300    0.0000   10.1600    0.0000
            1.2700
45rcc      85.0000 -110.1598   11.4300    0.0000   10.1600    0.0000
            1.2700
46rcc      85.0000   99.9998   11.4300    0.0000   10.1600    0.0000
            1.2700
47rcc     -85.0000   99.9998   11.4300    0.0000   10.1600    0.0000
            1.2700
48rpp    -120.0000  120.0000 -120.0000  120.0000  -15.0000    0.0000
49rpp      -125.0   125.0000   -125.0   125.0000   -16.00   235.0000
 1        1     -2     -3     -8     -10    -11    -12    -13    -14     z1001
        -15    -16    -17    -18    -19    -20    -21    -22    -23     air
        -24    -25    -28    -29    -30    -31    -32    -33    -34
        -35    -36    -37    -38    -39    -40    -41    -42    -43
        -44    -45    -46    -47    -48
 2        2     -3    -10    -11    -12    -13    -14    -15    -16     z1002
        -17    -18    -19    -20    -21                                base
 3        3     -4     -5     -6     -7     -8     -9    -10    -11     z1003
        -12    -13    -14    -15    -16    -17    -29    -30    -31     base
        -32
 4 or    4or    5or    6or    7                                        z1004
 5        8     -9    -26    -27    -28    -44    -45    -46    -47     z1005
 6        9     -4     -5     -6     -7    -26    -27    -28    -44     z1006
        -45    -46    -47                                              air
 7 or   10or   11or   12or   13or   14or   15or   16or   17            z1007
 8 or   18     -22or  19     -23or  20     -24or  21     -25           z1008
 9 or   22or   23or   24or   25                                        z1009
10      26                                                             z1010
11      27                                                             z1011
12      28     -3                                                      z1012
13      29     -8     -30    -32    -33    -36    -44    -45           z1013
14      30     -8     -33    -35    -37    -28                         z1014
```

Figure C-6. (continued)

```
15        31      -8    -30    -32    -33    -38    -46    -47          z1015
16        32      -8    -33    -39                                      z1016
17        33      -8    -34    -36    -37    -38    -39                 z1017
18  or    36     -40or   37    -41or   38    -42or   39    -43          z1018
19  or    40or    41or   42or   43                                      z1019
20  or    44or    45or   46or   47                                      z1020
21        34     -26                                                    z1021
22        35     -27                                                    z1022
23        48      -2                                                    z1023
24        49      -1                                                    z1024
-1
 1 1001     0    2    0    /box/z1001/surounding/air
 2 1002     0    3    0    /box/z1002/bottom/base/pad
 3 1003     0    3    0    /box/z1003/upper/base/pad
 4 1004     0    3    0    /box/z1004/inner/alignment/pad
 5 1005     0    3    0    /box/z1005/inner/box
 6 1006     0    2    0    /box/z1006/inner/box/air-void
 7 1007     0    3    0    /box/z1007/outer/wall/alignment/pad
 8 1008     0    3    0    /box/z1008/base/pad/lift/eyelets
 9 1009     0    2    0    /box/z1009/eyelets/voids-air
10 1010     0    3    0    /box/z1010/inner/box/top/hatch
11 1011     0    3    0    /box/z1011/inner/box/side/hatch
12 1012     0    2    0    /box/z1012/inner/outer/cable/run/void-air
13 1013     0    3    0    /box/z1013/outer/wall/negative/y-axis
14 1014     0    3    0    /box/z1014/outer/wall/positive/x-axis
15 1015     0    3    0    /box/z1015/outer/wall/positive/y-axis
16 1016     0    3    0    /box/z1016/outer/wall/negative/x-axis
17 1017     0    3    0    /box/z1017/outer/top
18 1018     0    3    0    /box/z1018/outer/wall/lift/eyelets
19 1019     0    2    0    /box/z1019/outer/wall/lift/eyelets/void-air
20 1020     0    2    0    /box/z1020/inner/outer/drain/holes
21 1021     0    3    0    /box/z1021/outer/top/hatch
22 1022     0    3    0    /box/z1022/outer/wall/side/hatch
23 1023     0    1    0    /box/z1023/ground
24 1024     0    0    0    /box/z1024/external/void
```

Figure C-6. (continued)

```
2m box exp/4in steel/dabl 46n-23g lib/aprf sh=16.143m/10-24-89(a) air
 **   40000.0   0.0   -16.0   235.0   0.0   110.16   2   0
46 neutron - 23 gamma flat and free-in-air tissue kerma response input
 -- 1=neut  2=veh n-g 3=grd n-g 4=photons
mash 46n/23g group flat response
 ** 69r1.0
mash 46n/23g group free-in-air tissue kerma response (gy.cm2/n,g)
 **
736532-16 704584-16 685894-16 674499-16 661555-16 638136-16 633529-16
598822-16 57632-15 551514-16 546431-16 512651-16 470858-16 457805-16
44359-15 419381-16 357307-16 332494-16 321126-16 291193-16 263438-16
252468-16 222507-16 205934-16 193682-16 179065-16 163746-16 130075-16
102563-16 806538-17 563405-17 359169-17 25917-16 213032-17 147572-17
628401-18 219938-18 925902-19 448136-19 20734-18 103718-19 932428-20
135874-19 228494-19 372646-19 129126-18 401109-16 317559-16 27612-15
23517-15 205102-16 185083-16 164356-16 143343-16 121273-16 1036-14
902669-17 755621-17 585321-17 42722-16 296381-17 192968-17 105409-17
529629-18 348187-18 313231-18 484629-18 10497-16 339599-17
energy group totals
```

Figure C-7. Sample DRC Input for the Central Detector Position Used in the MASH Analysis of the October 1989 Two-Meter Box Test Bed Experiments Performed at the Army Pulse Radiation Facility (APRF).

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