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Neutron Spectra, Fluence and Dose Rates from Bare and Moderated Cf-252 Sources

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Section 1

Overview and Summary

Overview

Lawrence Livermore National Laboratory's (LLNL's) Radiation Calibration Lab (RCL) provides radiation standards and calibration services for all gamma, neutron, alpha and beta radiation survey instrumentation as well as personal dosimeters used at LLNL. The radiation fields from RCL's calibration sources need to be characterized in terms of energy, fluence and dose rates. In 2008 the existing two ^{252}Cf sources were characterized when 10 CFR 835 radiation weighting factors and neutron fluence-to-dose coefficients were revised and a new pneumatic transport system was installed [21].

Purpose

A new, stronger ^{252}Cf source (serial number SR-CF-3050-OR) was obtained from Oak Ridge National Laboratory (ORNL) in 2014 to supplement the existing ^{252}Cf sources which had significantly decayed. A new instrument positioning track system was designed and installed by Hopewell Designs, Inc. in 2011. The neutron field from the new, stronger ^{252}Cf source in the modified calibration environment needed to be characterized as well as the modified neutron fields produced by the new source and seven different neutron moderators. Comprehensive information about our ^{252}Cf source, its origin, production, and isotopic content and decay characteristics needed to be compiled as well. This technical report is intended to address these issues.

Summary

A neutron spectrometer and dose rate meter (Rospec) was used to measure the neutron fluence spectral distribution and ambient dose rates at RCL's Low Scatter Facility from bare and moderated ^{252}Cf sources. The moderators were spheres of heavy water (D_2O) and high density polyethylene with thicknesses of 15, 10 and 5 cm for D_2O and 15, 10, 5 and 2 cm for the high density polyethylene. The measurements were conducted at 2.0 to 4.5 meters at 50 cm intervals. Additionally, a neutron survey meter (aka remball), calibrated by National Institute of Standards and Technology (NIST), was used to measure the neutron ambient dose rates from the same sources and at the same locations. An ion chamber was used to measure the gamma exposure rates from all neutron sources and locations.

A short summary of the applicable dosimetric quantities and the neutron fluence-to-dose conversion coefficients are provided in Section 2 and Appendix A. The strength and the isotopic composition of the used ^{252}Cf source and its encapsulation, as well as information about the production, decay, emission rate, conversion units, total activity and suppliers are given in Section 3 and Appendix B. Section 4 provides information, pictures and the parameters of the neutron spectrometer Rospec, the neutron survey meter model NRD and its moderating sphere and manufacturer provided response curve, the neutron moderating spheres, the ion chamber and the experimental set up. The composition and dimensions of all moderating spheres are provided in Appendix C. The pneumatic transport system for moving the californium source from its storage location to its exposure position as well as the californium source transport container (rabbit) are described in Appendix D. A summary of the measurement results is given in Section 5: tables of Rospec measured neutron fluence rates and neutron ambient dose equivalent rates, NRD neutron survey meter measured ambient dose

equivalent rates, ion chamber measured gamma exposure rates and the ratio of the gamma and neutron dose rates. In Section 6, discussion and graphical and table representations are provided on:

- Dependence of the neutron spectra on the distance from the source
- Comparison of bare and moderated ^{252}Cf spectra at various distances from the source
- Comparison of the neutron fluence and dose rates from bare and moderated ^{252}Cf with various moderator thicknesses
- Dependence of the neutron fluence and dose rates from bare and moderated ^{252}Cf with various moderator thicknesses on the source distance
- Comparison between two sets of NRD survey meter measured neutron dose rates
- Comparison between Rospec and NRD measured neutron dose rates

The neutron spectra, fluence and dose rates measured by Rospec for each location are presented in Appendices E to L in a detailed table and graphical forms.

Rospec measurements successfully characterized RCL's new ^{252}Cf calibration source in various geometries in terms of neutron energy and and fluence rate, and provided the most accurate measurement of the neutron ambient dose rate equivalent of RCL reference neutron fields. They can be used for evaluation of the contribution of the scattered neutrons, and to correlate neutron environments encountered in the field against standard or reference neutron environments. The characterized RCL neutron fields will be used for calibration of LLNL neutron radiation protection survey instruments and LLNL personal and neutron accident dosimeters.

Section 2

Dosimetric Quantities and Abbreviations

Dosimetric quantities

The quoted measured dosimetric quantities in this report are the operational quantities ambient dose equivalent dose, ambient dose equivalent dose rate, kerma and kerma rate. A short summary of the relevant dosimetric quantities is given in Appendix A.

Abbreviations

BTI	Bubble Technologies Industries
CFR	Code of Federal Regulations
DOE	Department of Energy
HD	High Density
HFIR	High Flux Isotope Reactor
ICRP	International Council on Radiation Protection
ICRU	International Council on Radiation Units
ISO	International Standards Organization
LLNL	Lawrence Livermore National Laboratory
NIST	National Institute for Standards and Technology
NRD	Neutron dose rate meter from Thermo Scientific
ORNL	Oak Ridge National Laboratory
RCL	Radiation Calibration Lab
RIAR	Research Institute for Atomic Reactors
ROSPEC	ROtating SPECtrometer; Neutron spectrometer and dose rate meter from Bubble Technology Industries

Section 3

RCL ^{252}Cf Source

RCL's ^{252}Cf source number SR-CF-3050-OR was purchased in 2014 from a pool of older californium sources from Oak Ridge National Laboratory (ORNL). This SR-Cf-3000 series source (NRC Registry No. NR-277-S-106-S0 was fabricated at ORNL using the procedures described in reference [16]. Figure 1 shows schematically the SR-Cf-3000 series source design. The californium in these sources is in the form of Cf_2O_3 which results from the thermal decomposition of californium oxalate which is formed by precipitation with oxalic acid. The isotopic composition of the californium production material (batch) from which this source was made and other source fabrication data are listed in Table 1. After leak-testing, smear testing and confirmatory assay at ORNL, the source was inserted into Hopewell Designs, Inc. supplied aluminum rabbit (Figure D-2 in Appendix D). More information on production of californium sources, suppliers, decay, determination of neutron emission rate, conversion units and total activity is provided in Appendix B and in reference [19].

Table 1. Initial isotopic composition of ^{252}Cf source SR-CF-3050-OR

Neutron source	SR-CF-3050-OR
Batch identification	CX-CF598
Date of analysis	January 13,1999
Isotope	**Isotopic Composition (atom %)**
^{249}Cf	4.32
^{250}Cf	10.82
^{251}Cf	3.31
^{252}Cf	81.50
^{253}Cf	0.04
^{254}Cf	0.01
Date of final purification	March 16, 1999

The isotopic composition of our ^{252}Cf (SR-CF-3050-OR) on 8/30/2013 was provided by ORNL and it is listed in Table 2.

Table 2. Isotopic composition of ^{252}Cf source SR-CF-3050-OR as of 8/30/2013

Source ID	**Batch ID**	**Cf-249 µg**	**Cf-250 µg**	**Cf-251 µg**	**Cf-252 µg**	**Cm-245 µg**	**Cm-246 µg**	**Cm-247 µg**	**Cm-248 µg**
SR-CF-3050OR	CXCF598	1713.53	2042.972	1346.968	728.84	49.52	2345.77	15.09	31262.97

The estimated neutron emission of ^{252}Cf (SR-CF-3050-OR) was 1.4099×10^9 neutrons per second (n/s) on 5/6/2014.

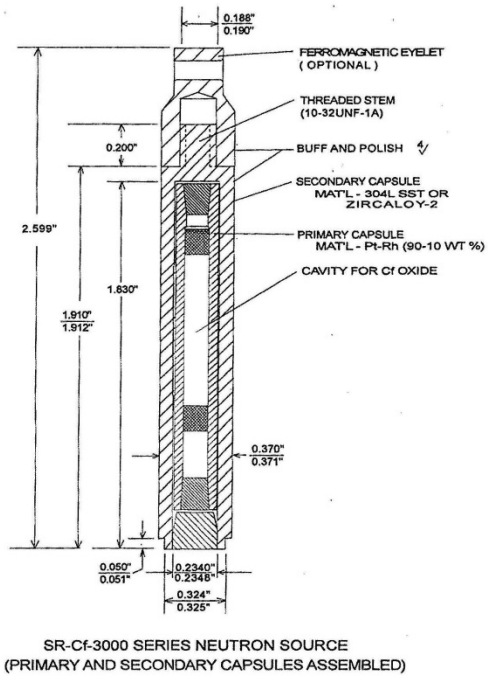


Figure 1. ^{252}Cf (SR-CF-3050-OR) double encapsulated source

Section 4

Equipment and Experimental Set-up

Rospec spectrometer and dose (rate) meter

Rospec is a neutron spectrometer and dose rate meter designed to measure neutron energy spectra, neutron fluence and neutron dose rate data. The instrument is manufactured by Bubble Technologies Industries (BTI) of Chalk River, Canada [4]. Rospec is a fairly compact (16" in diameter and 23.75" high) device weighing about 50 lbs.; however, it is not a field instrument for everyday use. Rospec consists of six gas-filled proportional counters as shown in Figure 2.

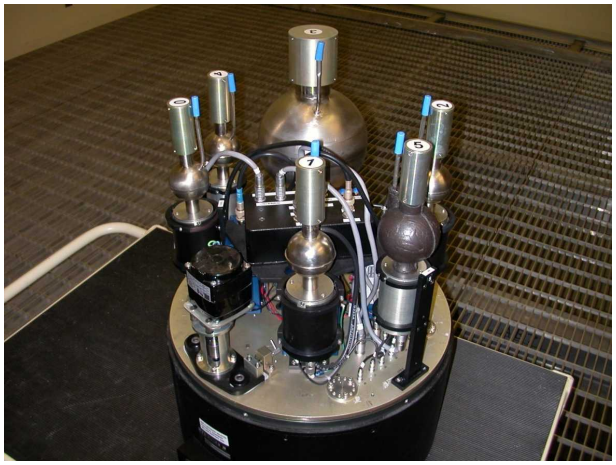


Figure 2. Rospec

Four of the Rospec counters measure the neutron energy from recoiling protons in the gas (H_2 or P10). The other two counters are filled with ^{3}He and use the (n,p) reaction to measure the neutron energy. Each counter is dedicated to a particular neutron energy range. The six counters cover the range from thermal to 4.5 MeV. Table 3 details the parameters for the Rospec counters. The 5-10 MeV region is covered by a generic fission spectra supplied with Rospec. The six neutron counters are mounted on a 30 cm diameter circular rotating platform which constrains each of the counters to follow the same circular orbit. This allows each of the counters to sample the same average neutron field so that spatial variation of the field is averaged. National Institute for Standards and Technology (NIST) tested Rospec and determined that the spectrometer gives a good approximation of the neutron spectrum, and excellent values for neutron fluence for all NIST calibration fields [8]. Other measurements with Rospec are provided in reference [6]. The Laboratory of Neutron Metrology and Dosimetry (Institute of Radiation Protection and Nuclear Safety, IRSN, France) performed energy and fluence calibration measurements with accelerator monoenergetic neutron radiation fields for metrology and neutron applications in external dosimetry. Results showed that the Rospec device was in agreement with the absolute neutron fluences within 10%. Moreover, the new energy calibration factors are in good agreement with those derived by Rospec's manufacturer [2].

Table 3. Rospec counter parameters

Counter #	Name	Diameter (inches)	Gas	Pressure (atm)	Range (MeV)
0	SP2-1	2	H_2	0.75	0.05-0.25
1	SP2-4	2	H_2	4.0	0.15-0.70
2	SP2-10	2	H_2	10.0	0.40-1.50
3	SP6	6	P10	5.0	1.20-4.50
4		2	^{3}He	0.08	$<1\times10^{-6}$
5		2	^{3}He	0.5	1×10^{-6}-1×10^{-2}

More information about Rospec and the measurement methodology is provided in reference [21].

NRD neutron rem meter

The neutron rem meter (aka remball) is a standard commercial instrument from Thermo Scientific, model NRD consisting of a BF_3 detector in a 9" diameter cadmium loaded high density (HD) polyethylene sphere connected to an ASP-2 meter (see Figures 3 and 4) also from Thermo Scientific [24]. The weight of the detector only (with the 9" moderating sphere) is 6.2 kg (13.75 lbs.). The NRD neutron rem meter was calibrated by NIST with bare (free-in air) ^{252}Cf and ^{252}Cf moderated by 15 cm of D_2O [17]. NIST calibration includes correction for the wall scattering in the NIST facility, i.e., the NRD instrument is calibrated for a "free-in-air" environment that is free of any neutron scattering. The BF_3 detector is mounted into a cutoff in the polyethylene sphere at 45 degrees to the vertical axis of the instrument. Note that the response of the NRD instrument is not isotropic and depends on the orientation of the BF_3 detector. NIST calibrated our NRD with the BF_3 detector pointing toward the calibration source in the vertical plane.

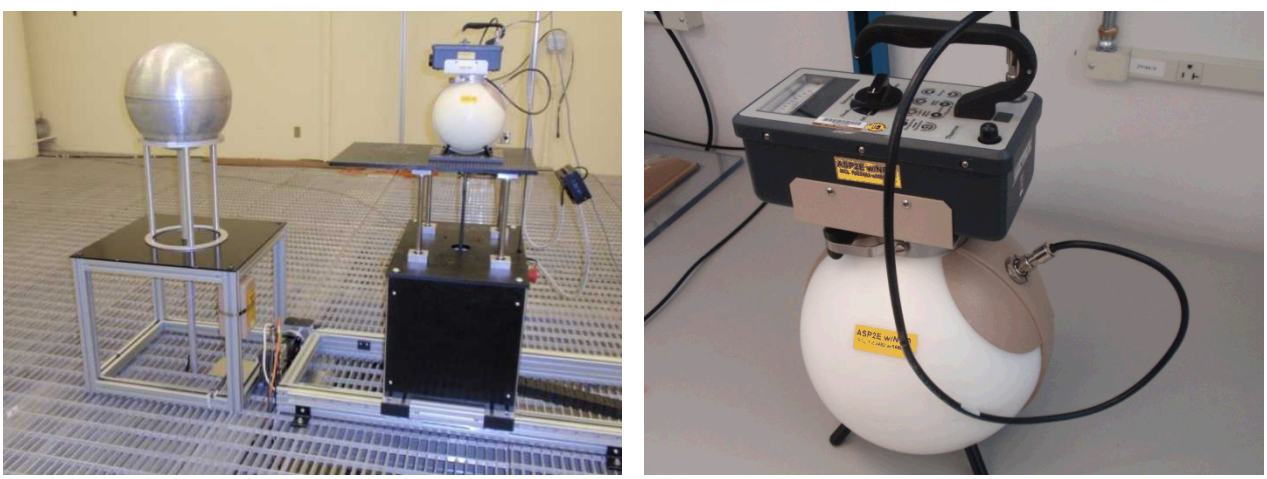


Figure 3. Thermo NRD neutron rem meter mounted on the positioning track in front of the 15 cm thick D_2O moderating sphere (left) and NRD remball and ASP-2 meter (right)

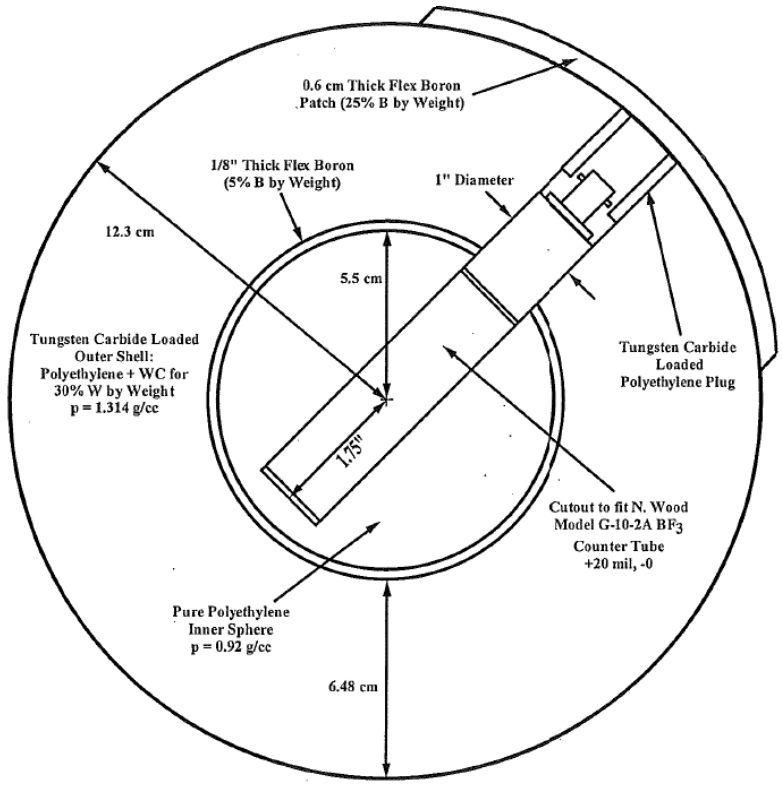


Figure 4. Sketch of Thermo Scientific NRD remball HD polyethylene sphere

The NRD meter is not a spectroscopic instrument. NRD's BF_3 detector counts the thermal neutrons moderated by the polyethylene sphere. The manufacturer claims that the NRD meter response follows the theoretical dose curve for neutrons in the energy range from 0.025 eV (thermal neutrons) to about 10 MeV. Figure 5 shows the NRD response curve provided in the manufacturer's instrument manual. The scale in the neutron energy response curve graph in the NRD manual is not sufficient to determine the uncertainly in the NRD response. While the NRD response seems to agree with the theoretical dose curve at energies below 0.1 eV and between 0.3 - 3 MeV, in the 0.1 eV – 300 keV it over-responds almost 10 times and in energies above 3 MeV it under-responds.

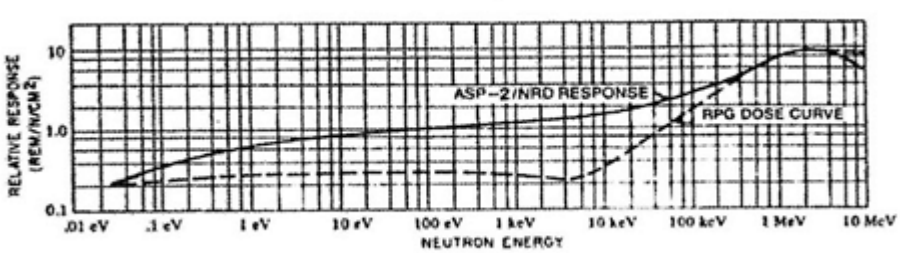


Figure 5. Response curve of Thermo Scientific NRD rem meter (provided by manufacturer)

Neutron spectra moderators

Seven different spherical moderators were used to change the neutron spectrum from bare ^{252}Cf (Figure 6). The neutron moderators used at LLNL were originally designed with a 64 mm diameter opening to fit the source tube of the old pneumatic source transport system. The source tube of the current pneumatic source transport system has a 39 mm outside diameter. Three of the moderating spheres are filled with high purity heavy water (99.98% of D_2O). The thickness of the moderating heavy water (D_2O) media is 15 cm, 10 cm and 5 cm. The remaining four moderators consist of high density polyethylene (poly) with thickness of the moderating media 15 cm, 10 cm, 5 cm and 2 cm. LLNL's 15 cm thick D_2O sphere is covered by thin 1mm cadmium (Cd) layer and a 1mm aluminum (Al) shell over the cadmium. More information about LLNL's moderating spheres is provided in Appendix C.

Figure 6. LLNL's D2O and polyethylene moderating spheres sets

Ion chamber

The gamma and X-ray exposure rates from the bare and moderated californium sources were measured with Exradin, model A6 spherical ion chamber manufactured by Standard Imaging Inc. [23]. The Exradin ion chamber used is shown in Figure 7. The electrometer was a Supermax model also by Standard Imaging Inc. The Exradin, model A6 spherical ion chamber has a 57.2 mm radius with a 3 mm shell wall thickness. The material of the shell wall, the collector and the guard is Shonka air equivalent plastic C552. The collecting volume is 800 cc. The atmospheric pressure was measured with a Setra Datum 2000 barometer.

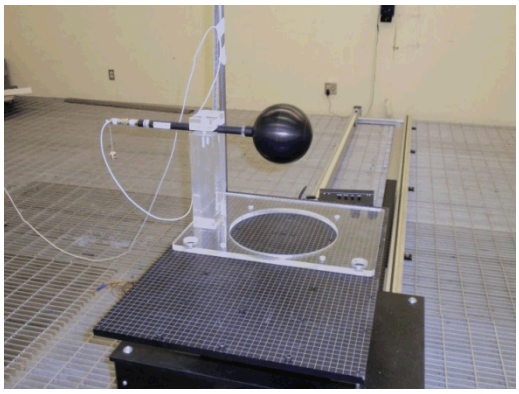


Figure 7. LLNL's calibrated ion chamber

Experimental set up

RCL's Low Scatter Calibration Facility (Building 255, Room 183A) has 61 cm (2 ft.) thick concrete walls and measures 12.2 m x 9.1 m and 6 m height (Figure 8). A suspended aluminum grating floor at 2.7 m above the concrete floor serves as the main surface for positioning the detection equipment and the objects to be irradiated by the radiation field. The calibration sources (three ^{252}Cf, two ^{60}Co and two ^{137}Cs) are stored in a shielded housing on the bottom concrete floor below the aluminum grid when not in use. The Hopewell Designs, Inc. N40 irradiation system positions one ^{252}Cf source at a given time for exposure in the center of Room 183A at a height of 1 m above the aluminum grating floor and at 3.7 m above the concrete floor. Detectors under test or objects to be irradiated are placed on a movable table on tracks. A linear positioning system moves and positions the table along the tracks pointing toward the north from the source with ± 0.1 cm accuracy. More information about the Hopewell Designs, Inc. N40 irradiation system and the linear positioning system can be found in Appendix D. The ion chamber, Rospec and NRD detector centers were positioned on the movable table at the same height above the aluminum grating floor as the ^{252}Cf source. See the Figures in Appendices E through L. The source-to-detector distance was measured from the source (or center of the moderating spheres) to the center of the detector (or center of the rotating disc with the 6 detectors for Rospec). The measurements were conducted at 50 cm intervals from 2.0 meters to 4.5 meters. Measurements at distances larger than 4.5 m from the source have limited practical value because the room's north wall is very close (~ 1 m or less) and the neutron scatter from the concrete wall at these points exceeds the direct neutron flux from the ^{252}Cf source. Only bare and moderated by 15 cm thick D_2O ^{252}Cf source measurements were conducted at 5 m from the source. At distances less than 2 meters, the high count rates from the strong californium source were overwhelming Rospec's communication channels and the obtained data were not reliable. The major difference from the experimental set up in reference [21] was the introduction of the linear positioning system with movable table on tracks and a new, stronger ^{252}Cf source.

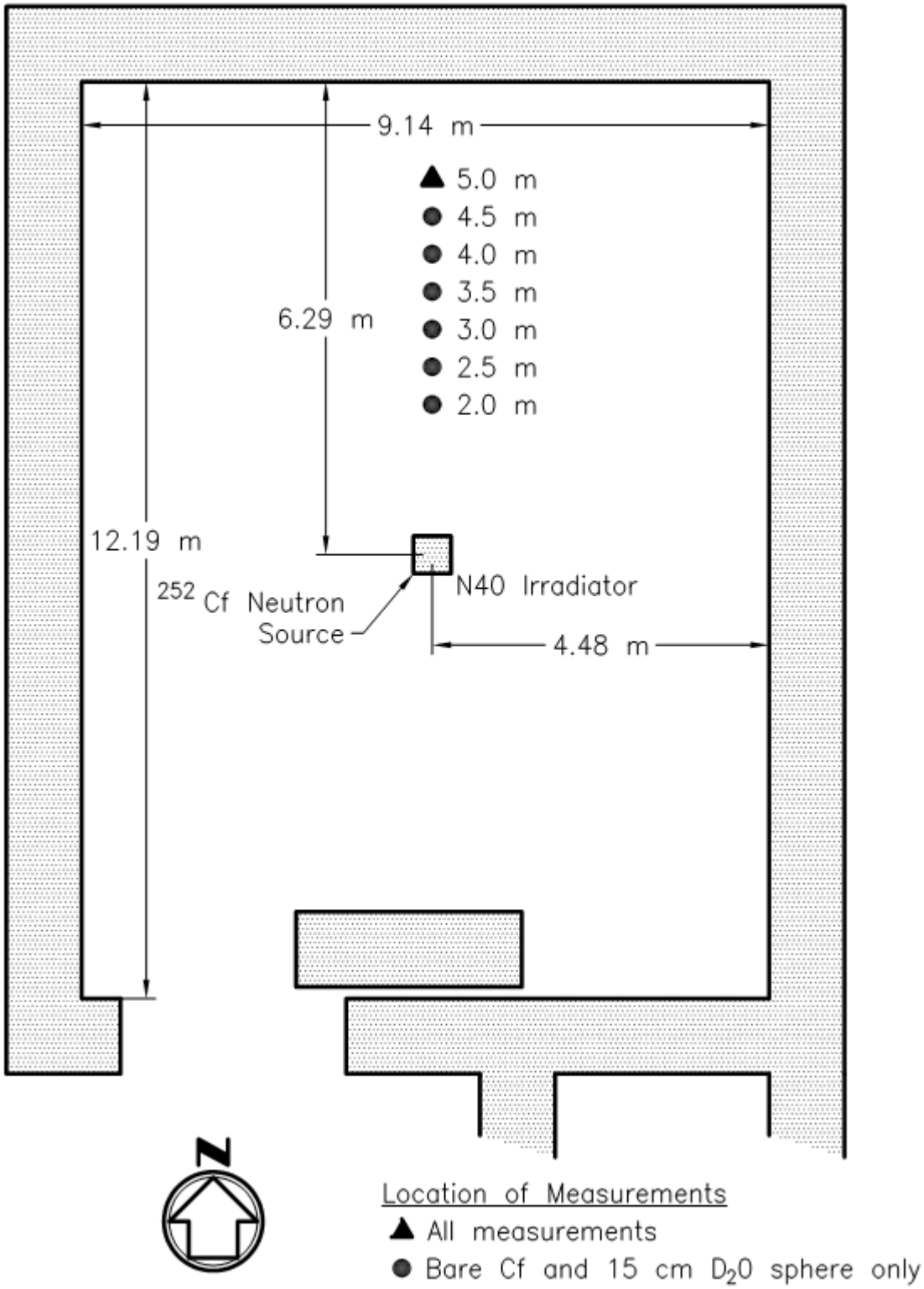


Figure 8. Diagram of RCL Low Scatter Calibration Facility (Rm 183A)

Section 5

Measurement Results

Background

The californium sources were stored in the shielded compartment 2.7 m below the grating floor when not in use. These sources produced negligible neutron background (less than 0.04 mrem/hr at the measurement locations); therefore, the background was not subtracted from the neutron measurement results. The measurement methodology was similar to that described in reference [21].

Measurements of the neutron spectra, fluence and dose rates with Rospec

The neutron fluence, dose rate and spectra measurements with Rospec were taken in May and June 2014. A summary of the measured neutron fluence rates is presented in Table 4. A summary of the measured neutron ambient dose rates is presented in Table 5. The dates for each measurement are provided in Table 6 and in Appendices E through L.

Detailed neutron fluence, spectroscopic and dosimetric data measured with Rospec are presented in Appendices E through L for bare ^{252}Cf field and for ^{252}Cf moderated by 7 different moderators. For each measurement the first table lists the neutron fluence and neutron fluence rate for broad energy regions [thermal, epi-thermal and fast neutrons (50 keV-4.5 MeV)]. The dosimetric quantities kerma, ambient dose, kerma rate and ambient dose rate are also presented for the same broad energy regions. The kerma, ambient dose equivalent H*(10) and personal dose equivalent Hp(10,0) and the respective rates are provided also for the entire neutron energy region (thermal – 10 MeV). The dosimetric data are calculated from the measured neutron fluence spectral distribution and ICRP-74 fluence-to-dose conversion coefficients [13]. The ICRP-74 neutron fluence-to-dose conversion coefficients are provided in Appendix A. The second table for each measurement provides detailed energy distribution (in 52 energy bins spanning from thermal energies to 10 MeV) of the neutron fluence, neutron fluence per 1 MeV, and neutron fluence per unit lethargy. The spectral distribution of the neutron fluence for each measurement is presented in graphical form after the two tables in 2 plots. The neutron energy range in the upper plot is from thermal to 10 MeV and in the lower plot the neutron energy range is form 100 keV to 4.5 MeV. The second plot provides better spectral details in the fast neutron energy region. Watts fission spectrum is added to extend the measured spectrum to 10 MeV. The added neutron spectrum accounts only for a few percent of the total neutron spectrum. Neutron energy E, times the neutron fluence rate $d\Phi/dE$ is plotted on the vertical axis in logarithmic scale against the neutron energy E on the horizontal axis. Energy E is in MeV units and is plotted on a logarithmic scale. On all Rospec neutron energy plots the vertical axis is in lethargy units. The lethargy = $\Phi(E)/\ln(E1/E2)$, where

- $\Phi(E)$ is the neutron fluence in a given energy bin (in neutrons per cm^2) and
- E1 and E2 are the upper and lower boundaries of the energy bin (group).

E PHI E on the plots is a shorthand for lethargy because lethargy is often approximated with E $\Phi(E)$/delta E (i.e., E $d\Phi/dE$). The data in the upper plots are normalized per one neutron reaching the detector in order to facilitate visual comparison of measurements with different duration.

No reliable data were obtained for distances less than 2 meters from the ^{252}Cf source because the high count rate from the ^{252}Cf source was overwhelming the throughput of the Rospec communication channel. Rospec's buffer that stores and transfers the counts from the six detectors contributes to excessive dead time for count rates greater than 1,000 counts per second. We were able to partially circumvent this problem by conducting high count rate measurements in a multi-step process. The first measurement was conducted with some of the detectors disconnected (e.g., any combination from 2 to 5 detectors), followed by measurement with some of the previously disconnected detectors, and so on until measurements from all six detectors are collected. In each of these measurements the count rate was kept below 1,000 counts per second. Then the pulse height spectra (recoil proton spectra) are combined and normalized by the counting time. The combined pulse height spectrum is then unfolded with the Rospec software code to obtain the neutron spectrum.

Table 4. Rospec measured neutron fluence rates

Distance (m)	Neutron fluence rate in n.cm^{-2}.s^{-1}							
	Bare Cf	15 cm D_2O	10 cm D_2O	5 cm D_2O	15 cm POLY	10 cm POLY	5 cm POLY	2 cm POLY
2.0	5.3084E+03	3.7517E+03	4.7395E+03	4.7223E+03	1.3301E+03	2.6463E+03	4.4148E+03	5.4866E+03
2.5	4.1716E+03	3.0102E+03	3.7542E+03	3.7757E+03	1.0961E+03	1.9509E+03	3.4795E+03	4.2741E+03
3.0	3.5361E+03	2.6438E+03	3.1833E+03	3.2643E+03	9.3047E+02	1.8238E+03	2.9954E+03	3.2886E+03
3.5	3.1144E+03	2.3956E+03	2.8339E+03	2.9123E+03	8.3372E+02	1.6156E+03	2.6781E+03	3.1120E+03
4.0	2.8389E+03	2.1623E+03	2.6008E+03	2.6345E+03	7.6850E+02	1.4855E+03	2.4243E+03	2.8336E+03
4.5	2.6459E+03	2.0469E+03	2.4108E+03	2.4849E+03	7.0901E+02	1.3907E+03	2.2912E+03	2.6430E+03
5.0	2.5098E+03	1.5127E+03						

Table 5. Rospec measured neutron ambient dose equivalent rates

Distance	Dose rate, H*(10) in μSv/h							
	Bare Cf	15 cm D_2O	10 cm D_2O	5 cm D_2O	15 cm POLY	10 cm POLY	5 cm POLY	2 cm POLY
2.0	5.0445E+03	1.3188E+03	2.2155E+03	3.4533E+03	6.1550E+02	1.3650E+03	3.2961E+03	5.0158E+03
2.5	3.6094E+03	9.6824E+02	1.5961E+03	2.5115E+03	4.5358E+02	9.8180E+02	2.3747E+03	3.5530E+03
3.0	2.7856E+03	7.5737E+02	1.2405E+03	1.9746E+03	3.5406E+02	7.8134E+02	1.8473E+03	2.5278E+03
3.5	2.2550E+03	6.2891E+02	1.0200E+03	1.6109E+03	2.9333E+02	6.3972E+02	1.5209E+03	2.1829E+03
4.0	1.9133E+03	5.3472E+02	8.6327E+02	1.3598E+03	2.5099E+02	5.4563E+02	1.2835E+03	1.8493E+03
4.5	1.6715E+03	4.7154E+02	7.6130E+02	1.2022E+03	2.1858E+02	4.8288E+02	1.1433E+03	1.6012E+03
5.0	1.4977E+03	3.3319E+02						

Table 6. Dates of Rospec measured neutron fluence and ambient dose rates

Distance	Dates of Rospec measurements in 2014							
	Bare Cf	15 cm D_2O	10 cm D_2O	5 cm D_2O	15 cm POLY	10 cm POLY	5 cm POLY	2 cm POLY
2.0	8-May	15-May	22-May	4-Jun	9-Jun	12-Jun	17-Jun	25-Jun
2.5	7-May	15-May	22-May	29-May	10-Jun	13-Jun	18-Jun	24-Jun
3.0	7-May	15-May	27-May	29-May	10-Jun	13-Jun	19-Jun	24-Jun
3.5	6-May	15-May	27-May	29-May	10-Jun	13-Jun	19-Jun	24-Jun
4.0	6-May	16-May	23-May	30-May	10-Jun	16-Jun	19-Jun	25-Jun
4.5	7-May	16-May	27-May	30-May	11-Jun	16-Jun	19-Jun	25-Jun
5.0	7-May	19-May						

Measurements of the neutron dose rates with NRD neutron rem meter

The ambient neutron dose equivalent rates were measured with a NIST-calibrated NRD neutron rem meter at the same locations and with the same moderators as the Rospec measurements. The measurement time was 10 minutes for each measurement. Calibration factors of 1.015 for bare ^{252}Cf and 0.748 for D_2O (15 cm thickness) moderated ^{252}Cf were applied in accordance with the NIST Calibration Report [17]. NIST calibrated our NRD rem meter with four ^{252}Cf sources with different emission rates at several distances. The above two calibration factors are the weighted means of the calibration factors obtained from each ^{252}Cf source and distance. The combined standard expanded uncertainties (k=2) in the calibration factors are 5.8% for bare ^{252}Cf and 8.7% for D_2O moderated (15 cm) ^{252}Cf. These uncertainties include both Type A uncertainties and Type B uncertainties (i.e., uncertainties determined by other than strictly statistical means).

The Type A uncertainties for NIST provided calibration factors ranging from <1 % to 7.0 % (moderated sources) and <1 % to 5.6 % (bare sources). The Type A uncertainties are from the uncertainties, for each measurement condition, in the least-squares linear fit values of the slope of integrated dose vs. time, expressed as a fraction of the fitted slopes. The Type B uncertainties include: the uncertainty in the source strength (2.4 % moderated, 5.1 % bare), the uncertainty in the neutron scatter correction (1.7 % to 2.9 % [moderated sources] and <1 % to 3.3 % [bare sources], depending on the distance from the source), and the uncertainty in the location of the effective center of the instrument (1.2 % to 3.3 % [moderated sources] and 1.4 % to 7.0 % [bare sources], depending on the distance from the source). Fluctuations in the instrument readings (Type A) are the dominant uncertainty at the lowest dose equivalent rates. The main Type B uncertainties are in the source calibration, the neutron scatter correction, and the distance from the source to the instrument for the highest dose equivalent rates. The value listed for the mean is the weighted mean of the listed calibration factors.

The measurement results for the other moderated neutron fields (10 cm and 5 cm D_2O and 15-, 10-, 5-, and 2 cm Polyethylene) were not corrected because NIST does not calibrate for neutron fields other than for bare and D_2O (15 cm thickness) moderated ^{252}Cf. The NRD measurements were conducted on July 17-18, 2014 and repeated on September 18-19, 2014. The NRD measurement results are presented in Table 7 (July 2014) and Table 8 (September 2014).

Table 7. NRD measured neutron ambient dose equivalent rates (July 18, 2014)

Distance	Dose rate, H*(10) in μSv/h							
	Bare Cf	15 cm D_2O	10 cm D_2O	5 cm D_2O	15 cm POLY	10 cm POLY	5 cm POLY	2 cm POLY
2.0	4.829E+03	1.185E+03	2.454E+03	3.510E+03	6.180E+02	1.368E+03	3.624E+03	4.908E+03
2.5	3.410E+03	8.671E+02	1.776E+03	0.000E+00	4.518E+02	9.948E+02	2.592E+03	3.468E+03
3.0	2.643E+03	6.710E+02	1.404E+03	1.992E+03	3.480E+02	8.094E+02	2.004E+03	2.646E+03
3.5	2.162E+03	5.673E+02	1.153E+03	1.644E+03	3.006E+02	6.516E+02	1.644E+03	2.148E+03
4.0	1.864E+03	4.878E+02	9.972E+02	1.416E+03	2.604E+02	5.694E+02	1.410E+03	1.818E+03
4.5	1.632E+03	4.407E+02	8.838E+02	1.254E+03	2.280E+02	5.058E+02	1.224E+03	1.614E+03
5.0	1.480E+03	3.985E+02						

Table 8. NRD measured neutron ambient dose equivalent rates (September 18, 2014)

Distance	Dose rate, H*(10) in μSv/h							
	Bare Cf	15 cm D_2O	10 cm D_2O	5 cm D_2O	15 cm POLY	10 cm POLY	5 cm POLY	2 cm POLY
2.0	4.750E+03	1.167E+03	2.280E+03	3.546E+03	5.856E+02	1.332E+03	3.204E+03	4.860E+03
2.5	3.374E+03	8.500E+02	1.662E+03	2.550E+03	4.362E+02	9.702E+02	2.280E+03	3.438E+03
3.0	2.619E+03	6.741E+02	1.320E+03	1.986E+03	3.456E+02	7.668E+02	1.770E+03	2.634E+03
3.5	2.144E+03	5.588E+02	1.076E+03	1.650E+03	2.838E+02	6.318E+02	1.470E+03	2.142E+03
4.0	1.833E+03	4.807E+02	9.426E+02	1.422E+03	2.472E+02	5.604E+02	1.266E+03	1.824E+03
4.5	1.614E+03	4.286E+02	8.352E+02	1.266E+03	2.250E+02	5.010E+02	1.128E+03	1.602E+03
5.0	1.480E+03	3.887E+02						

Discussion and comparison of July and September NRD measured dose rates as well as comparison with Rospec measured dose rates are provided in Section 6.

Measurements of gamma exposure rates from the ^{252}Cf source with ion chamber

Gamma exposure rates were measured on January 16-18, 2015 to get experimental data of the contribution of the X-ray and gamma radiation from ^{252}Cf sources to the total ambient dose rate. X-rays and gammas originate from the fission products of ^{252}Cf spontaneous decay (~3%) and ^{252}Cf alpha decay (~97%). Older ^{252}Cf sources contain significant amounts of other Cf isotopes (^{249}Cf, ^{250}Cf, ^{251}Cf and ^{253}Cf) whose decay products also contribute to the X-ray and gamma radiation. The measured gamma exposure rates were not decay-corrected to the time of the corresponding Rospec or NRD measured neutron dose rates because of the small overall contribution and the complexity of accounting for the contribution of multiple decay schemes and Cf source isotopic composition. The measured exposure rates from bare and moderated ^{252}Cf sources are presented in Table 9. Each data point is the average of 5 measurements of 120 seconds each with a ratio of the standard deviation to the average value less than 1%.

Table 9. Exposure rates from bare and moderated ^{252}Cf measured with NIST-traceable ion chamber (January 18, 2015)

Distance	Gamma Exposure Rate, in mR/h							
	Bare Cf	15 cm D_2O	10 cm D_2O	5 cm D_2O	15 cm POLY	10 cm POLY	5 cm POLY	2 cm POLY
2.0	20.79	14.27	14.23	16.90	13.77	15.69	18.34	21.56
2.5	14.40	10.14	10.24	12.00	9.13	10.94	12.96	14.98
3.0	10.87	7.77	8.03	9.27	6.70	8.28	9.95	11.37
3.5	8.77	6.40	6.70	7.58	5.26	6.67	8.11	9.12
4.0	7.51	5.49	5.81	6.52	4.27	5.64	6.92	7.71
4.5	6.56	4.87	5.22	5.77	3.63	4.93	6.09	6.74
5.0	5.87	4.42			3.16			

The gamma exposure rates from the moderated ^{252}Cf sources are lower than those from the bare ^{252}Cf due primarily to attenuation in the moderation media. As expected, gamma exposure rates steadily increase with the decrease of the moderator thickness for both D_2O and polyethylene. Note that exposure rates for 15 cm and 10 cm thick D_2O at 2.0 m and 2.5 m are practically the same within their uncertainties. Higher exposure rates are observed from the same size polyethylene moderated ^{252}Cf than D_2O moderated ^{252}Cf due to the density of polyethylene (0.92 g/cm^3) being lower than the density of heavy water (1.105 g/cm^3). There is no obvious explanation why this observation does not hold true for the 15 cm thick spheres.

To evaluate the contribution of X-ray and gamma radiation to the total dose rate from the californium sources the gamma exposure rates were converted to gamma dose equivalent rates taking into account that in air 1 R = 0.87 rad=0.87 rem=0.0087 Sv. The ratios of the gamma and neutron ambient equivalent dose rates are presented in Table 10.

Table 10. Ratio of the measured gamma and neutron ambient dose equivalent rates (Rospec) from bare and moderated ^{252}Cf sources

Distance (m)	Ratio of the gamma and neutron ambient dose equivalent rates from Cf sources (%) Rospec values decay corrected to the date of gamma measurement (1/18/2015)							
	Bare Cf	15 cm D_2O	10 cm D_2O	5 cm D_2O	15 cm POLY	10 cm POLY	5 cm POLY	2 cm POLY
2.0	4.3%	11.2%	6.6%	5.0%	22.8%	11.7%	5.6%	4.3%
2.5	4.2%	10.9%	6.6%	4.9%	20.5%	11.3%	5.5%	4.3%
3.0	4.1%	10.7%	6.7%	4.8%	19.3%	10.8%	5.5%	4.5%
3.5	4.1%	10.6%	6.8%	4.8%	18.3%	10.6%	5.4%	4.2%
4.0	4.1%	10.7%	7.0%	4.9%	17.4%	10.5%	5.5%	4.2%
4.5	4.1%	10.7%	7.1%	4.9%	16.9%	10.4%	5.4%	4.2%
5.0	4.1%	13.8%						

The gamma dose rate is about 4% of the neutron dose rate for bare ^{252}Cf. The contributions of the gamma dose rates from the moderated ^{252}Cf sources to the total dose are higher than those for a bare ^{252}Cf. Also gamma dose contribution to total dose is higher for polyethylene moderated sources than for D_2O moderated sources for the same thickness and distance from the source.

Section 6

Discussion

The representation of the neutron spectra in Figures 9-19 of Section 6 is standard in the field of neutron physics and radiation protection from neutrons. Neutron energy E, times the neutron fluence rate dΦ/dE is plotted on the vertical axis against the neutron energy E on the horizontal axis. Energy E is in MeV units and is plotted on a logarithmic scale. It is conceptually simpler to plot just the neutron fluence rate dΦ/dE on the vertical axis, however, that would require a log-log plot for neutrons covering many orders of magnitude on both axes, making details difficult to see. On all Rospec neutron energy plots the vertical axis is in lethargy units.

The lethargy = Φ(E)/ln(E1/E2), where

Φ(E) is the neutron fluence in a given energy bin (in neutrons per cm^2) and
E1 and E2 are the upper and lower boundaries of the energy bin (group).

E PHI E on the plots is a shorthand for lethargy because lethargy is often approximated with E Φ(E)/delta E (i.e., E dΦ/dE). All neutron spectra in Section 6 are normalized to one neutron reaching the detector for ease of visual comparison.

Dependence of the neutron spectra from bare and moderated ^{252}Cf sources on the distance from the source

Figures 9 to 13 show how the neutron spectra from bare and moderated ^{252}Cf sources change with the distance from the source. Figures 9 to 13 indicate that for every given neutron source the energy spectrum is different at different distances from the source. This means that the neutron dose rate at various points would differ from the inverse square law because the neutron dose is dependent on the neutron energy. With increasing the distance from the source and getting closer to the north wall, the number of neutrons that are elastically scattered from the north wall back to the detector is increasing (Figure 8). The process of neutron scattering also results in some energy loss and neutrons move from the fast energy region down to the intermediate and thermal energy regions.

The relative contribution of the scattered neutrons into the intermediate and thermal regions is more pronounced for bare ^{252}Cf (Figure 9) than for highly moderated ^{252}Cf sources (e.g., Figures 10 and 11). The neutron spectrum does not change much with the distance for highly moderated sources (15 cm of D_2O or 15 cm of polyethylene). The plots in the figures provide information on the relative magnitude of the contribution of the scattered neutrons from concrete walls to the energy distribution of the neutron fluence and hence to the neutron dose rate.

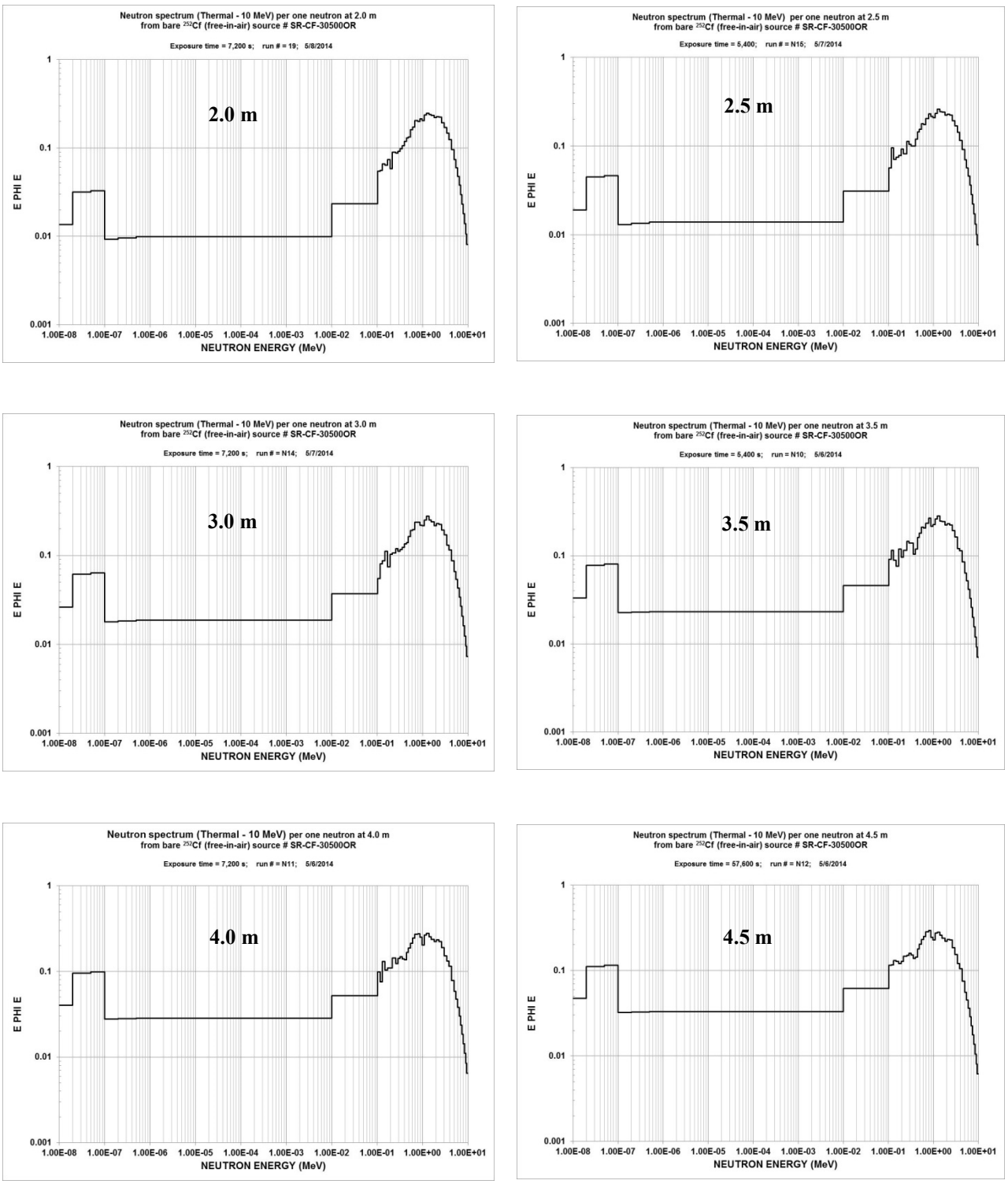


Figure 9. Neutron spectra at various distances from bare ^{252}Cf source

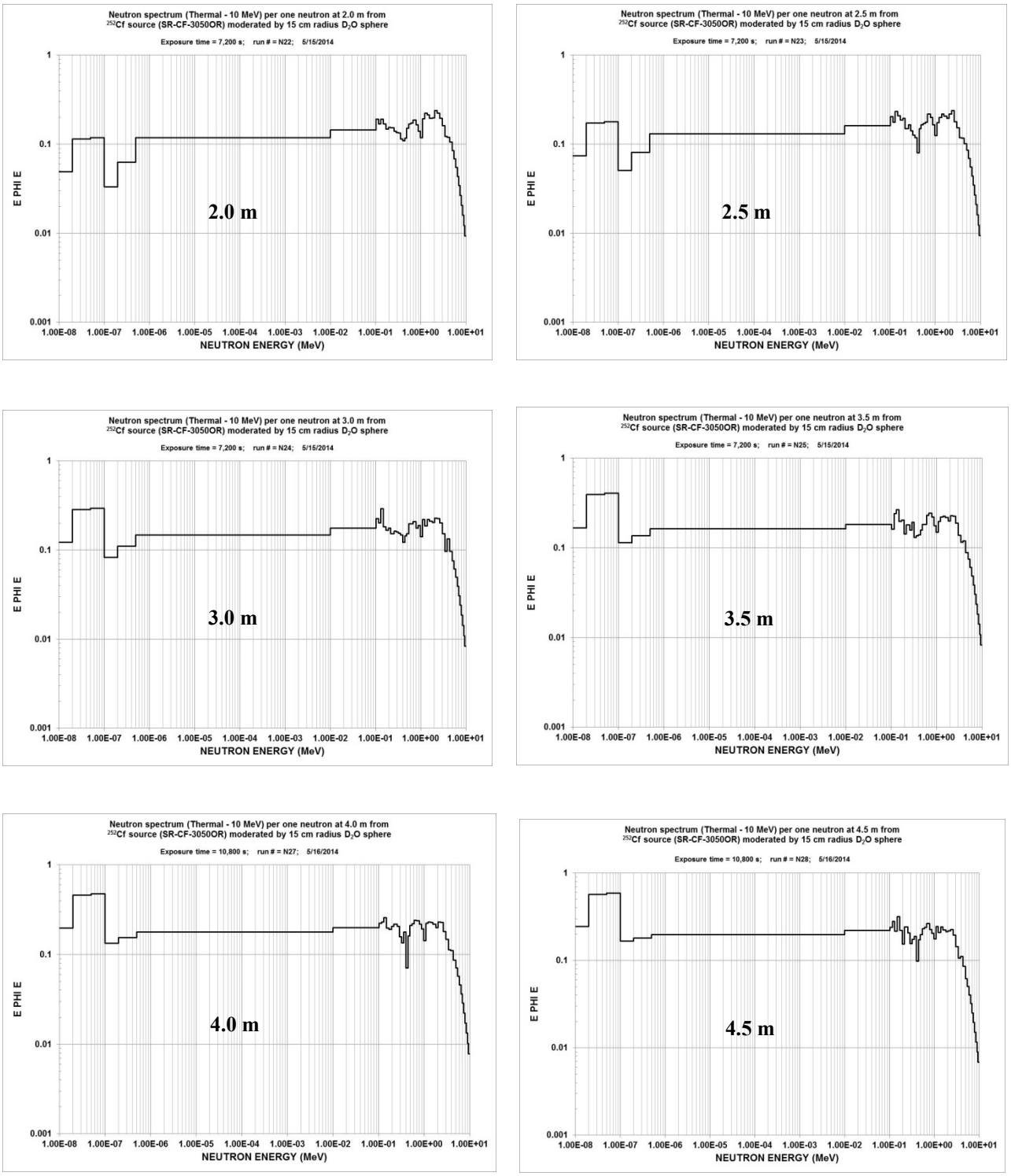


Figure 10. Neutron spectra at various distances from ^{252}Cf source moderated by 15 cm D_2O

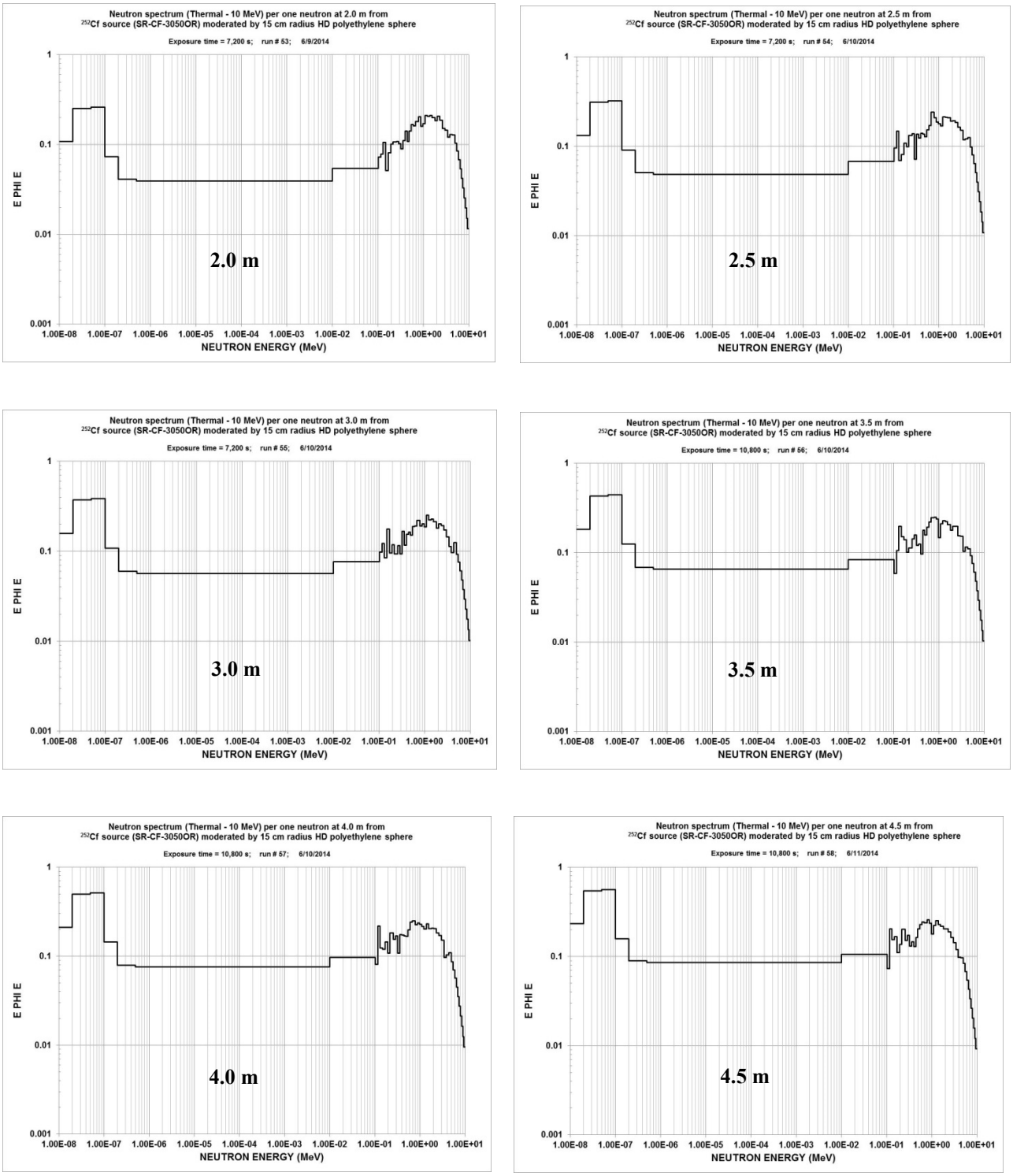


Figure 11. Neutron spectra at various distances from ^{252}Cf source moderated by 15 cm polyethylene

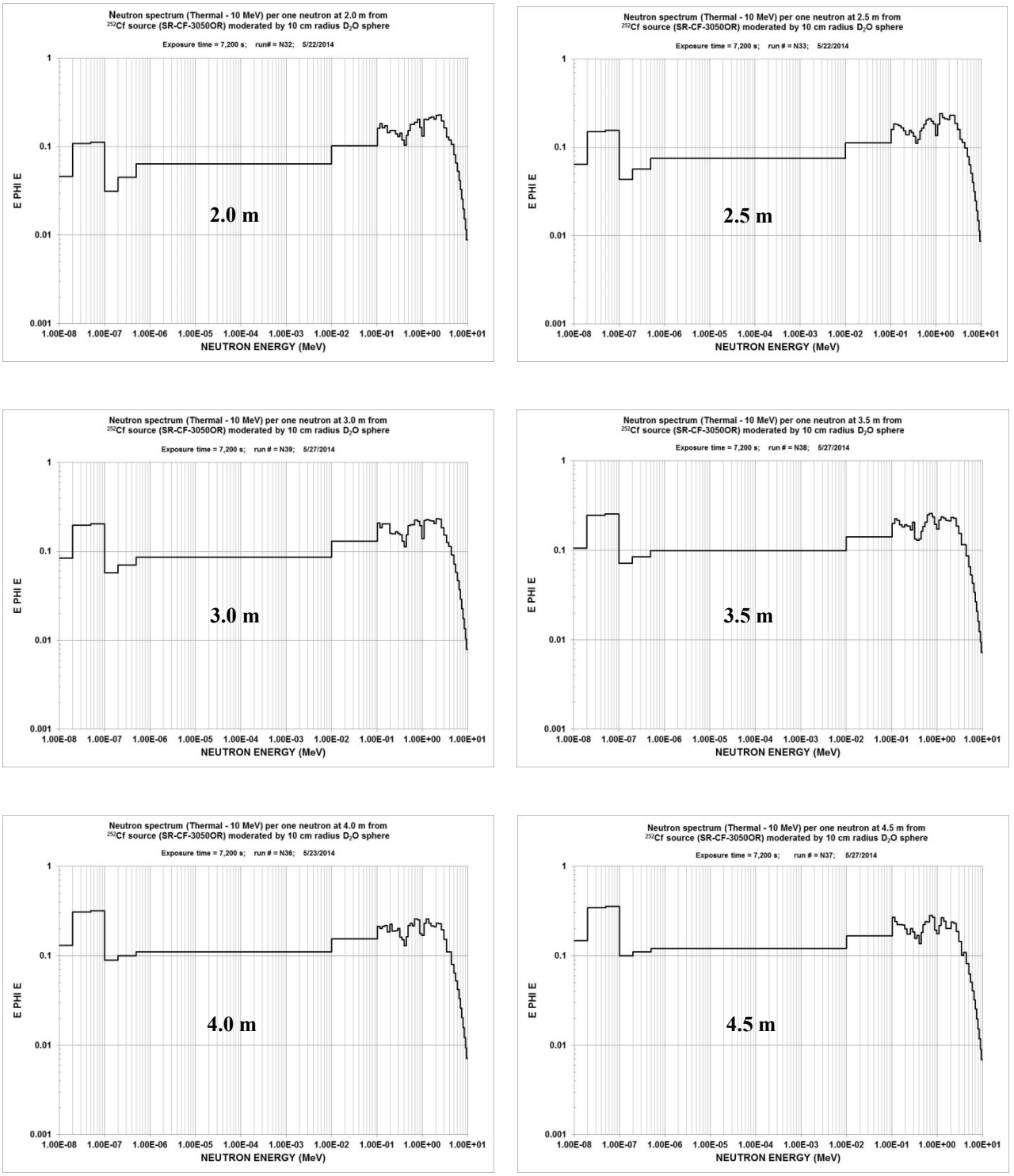


Figure 12. Neutron spectra at various distances from ^{252}Cf source moderated by 10 cm D_2O

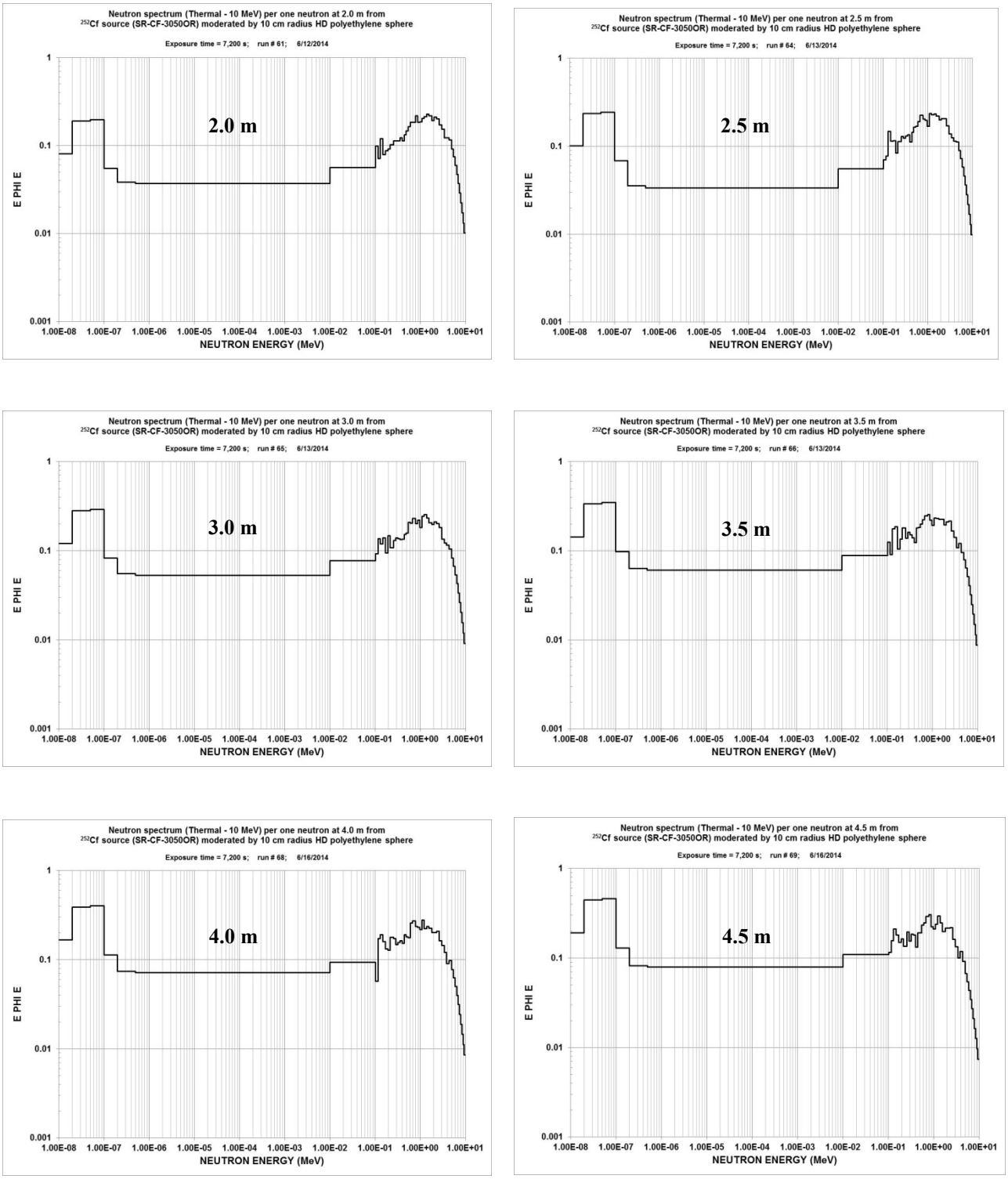


Figure 13. Neutron spectra at various distances from ^{252}Cf source moderated by 10 cm polyethylene

Comparison of bare ^{252}Cf neutron spectrum with neutron spectra from moderated ^{252}Cf sources at various distances from the source

Figures 14-19 provide side-by-side visual comparison of the spectra from bare ^{252}Cf and ^{252}Cf moderated by 15 cm, 10 cm and 5 cm of D_2O and polyethylene at 2.0, 3.0 and 4.0 meters from the source. Comparing Figures 14 (15 cm D_2O) and 15 (15 cm polyethylene) one can easily see that heavy water (D_2O) is a better moderator than polyethylene. The spectral difference between the bare ^{252}Cf and moderated ^{252}Cf sources is less pronounced at larger distances from the wall than at closer distances. This is due to the larger portion of intermediate and thermal neutrons in the bare Cf spectrum that result from wall scattering at closer to the wall distances.

Bare ^{252}Cf source | **^{252}Cf moderated by 15 cm D_2O**

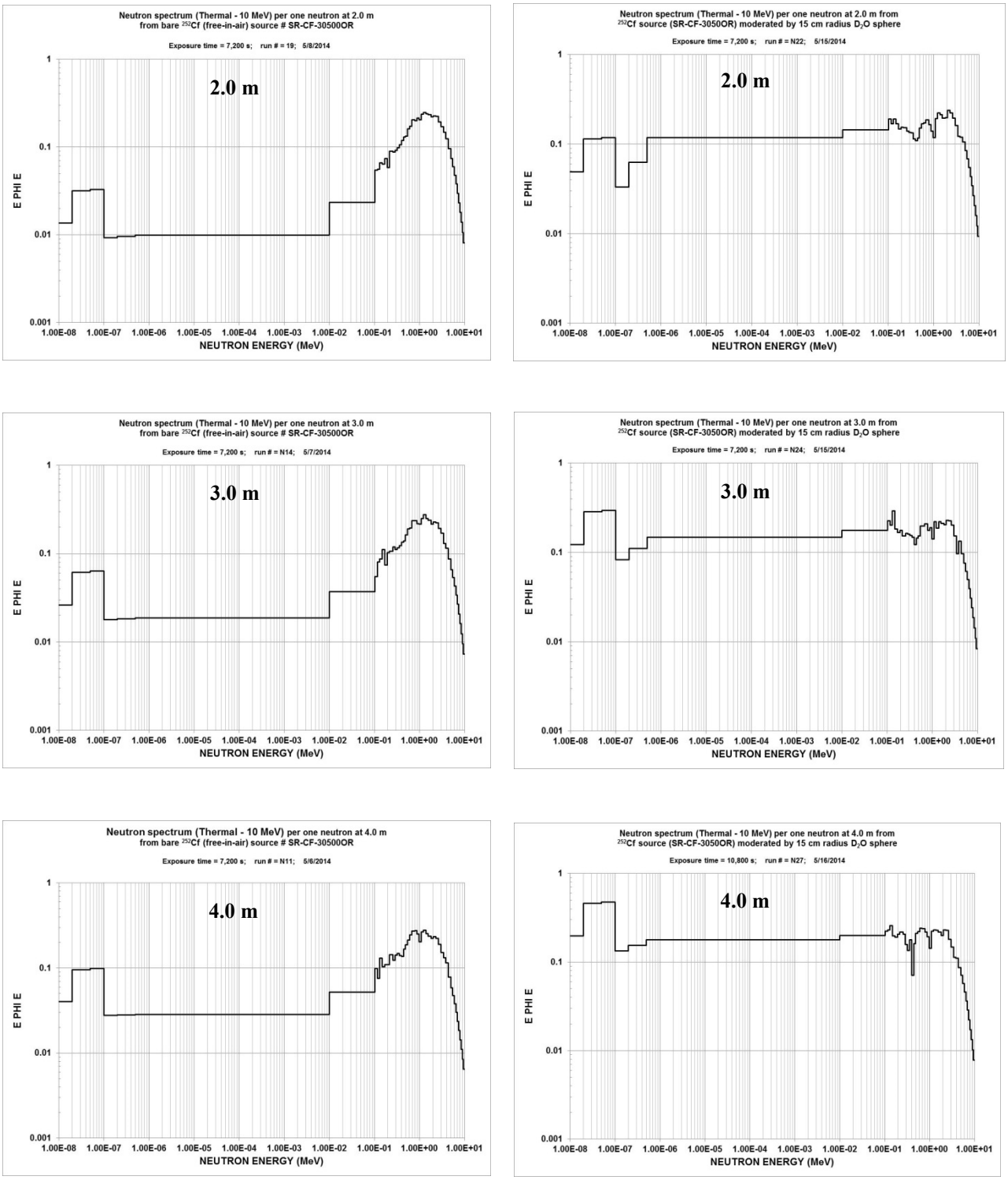


Figure 14. Neutron spectra from bare ^{252}Cf (left column) and ^{252}Cf moderated by 15 cm D_2O (right column)

Bare ^{252}Cf source | **^{252}Cf moderated by 15 cm polyethylene**

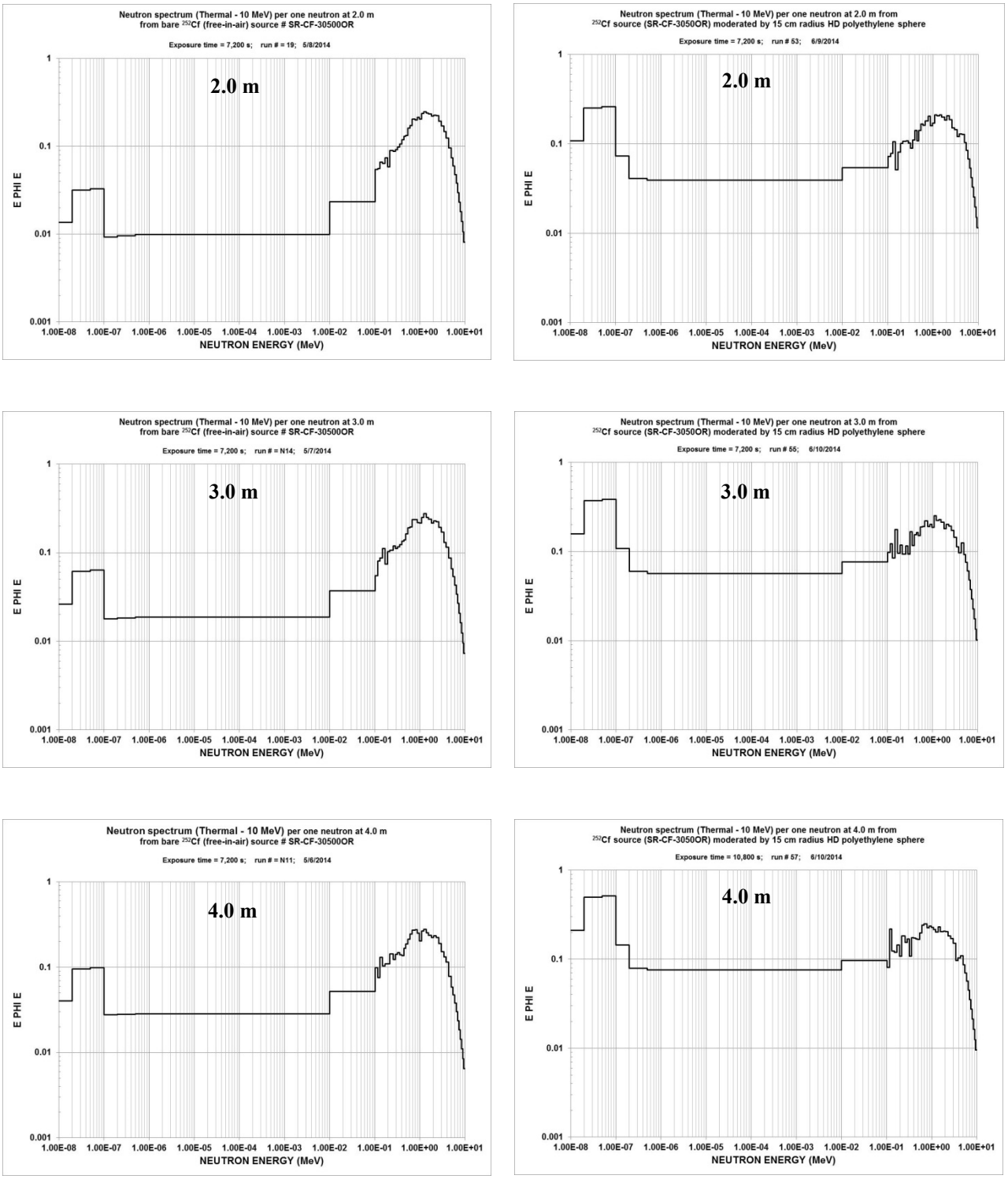
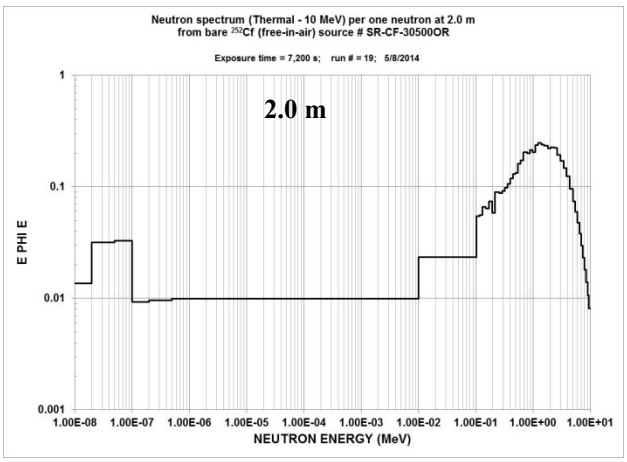
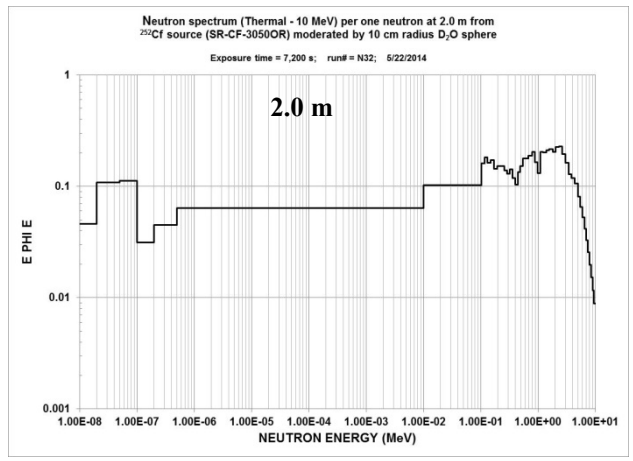
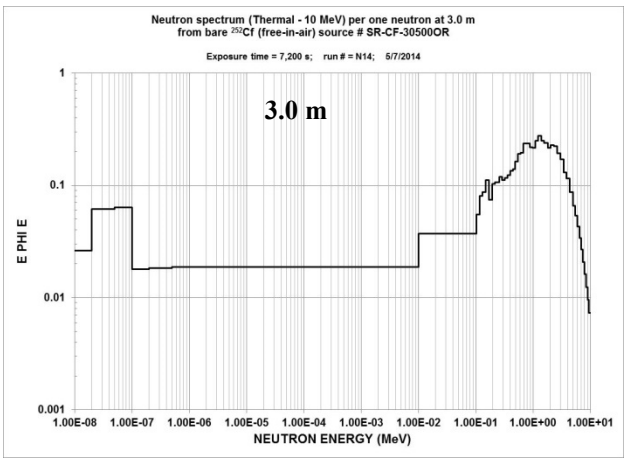


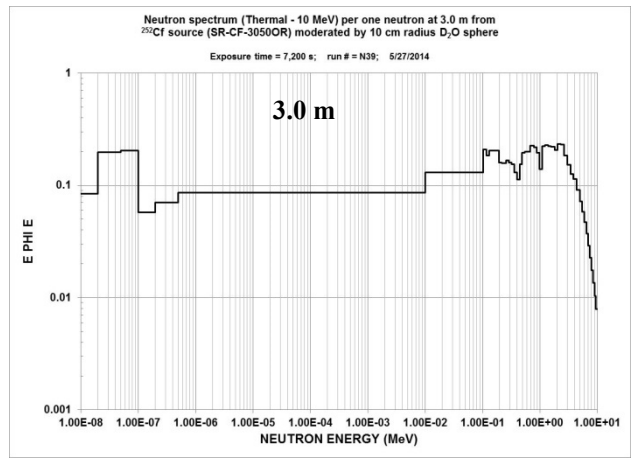
Figure 15. Neutron spectra from bare ^{252}Cf (left column) and ^{252}Cf moderated by 15 cm polyethylene (right column)

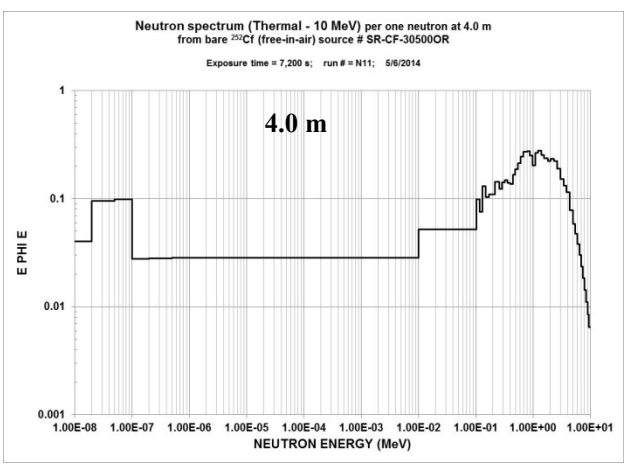
Bare ^{252}Cf source | **^{252}Cf moderated by 10 cm D_2O**











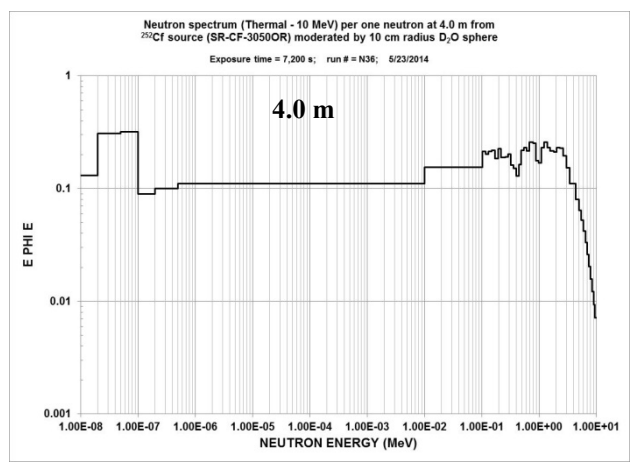


Figure 16. Neutron spectra from bare ^{252}Cf (left column) and ^{252}Cf moderated by 10 cm D_2O (right column)

Bare ^{252}Cf source | **^{252}Cf moderated by 10 cm polyethylene**

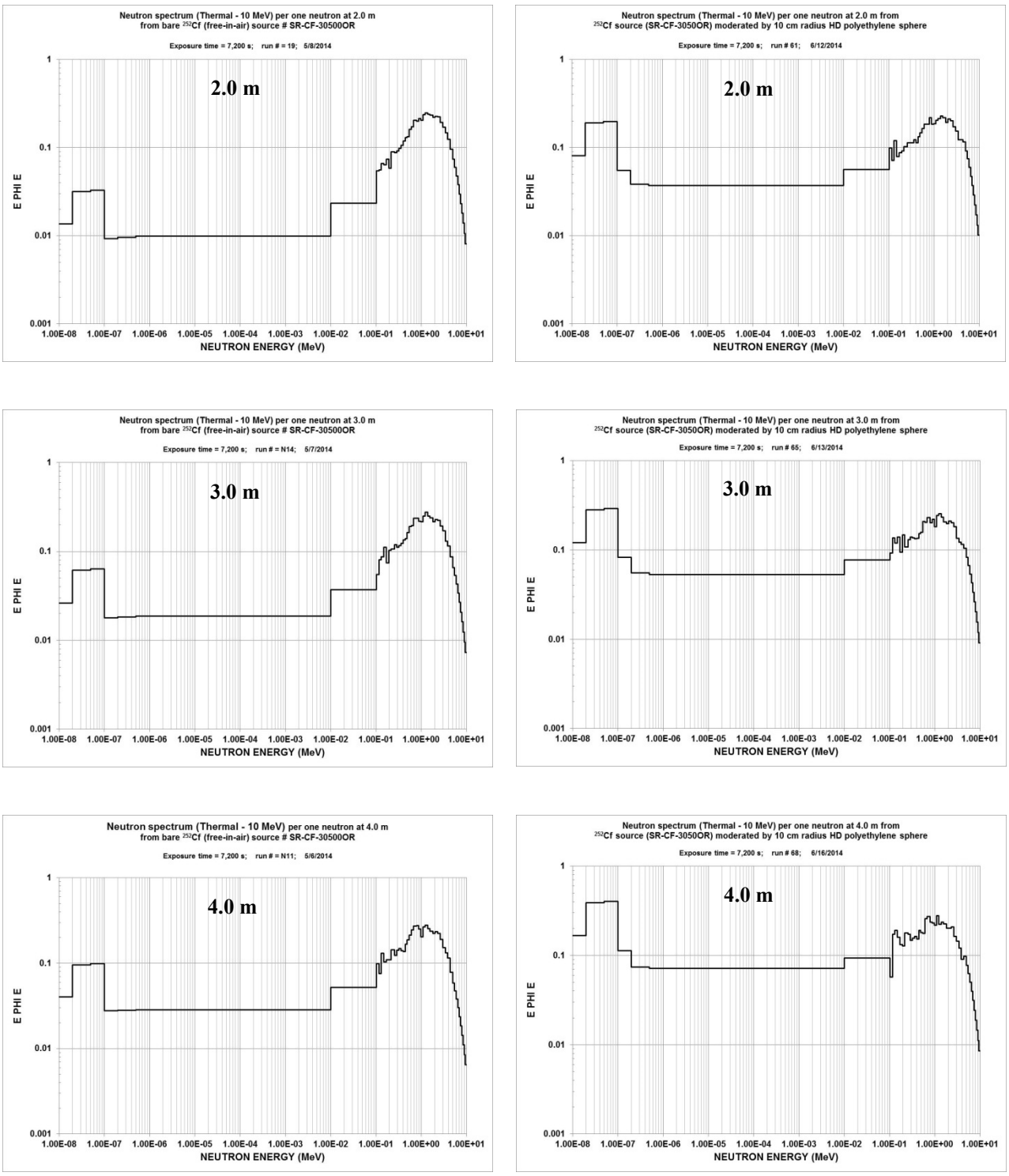
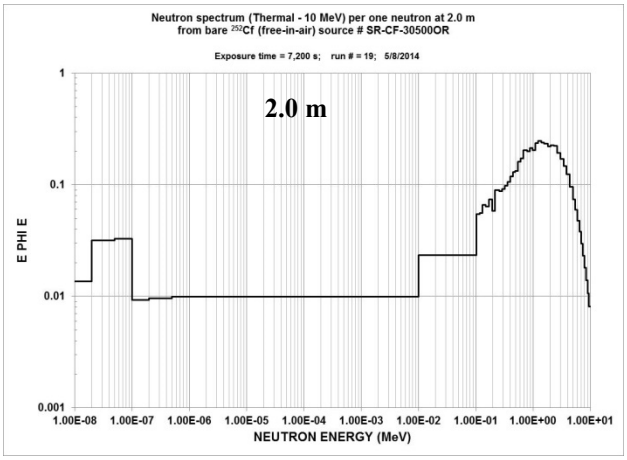
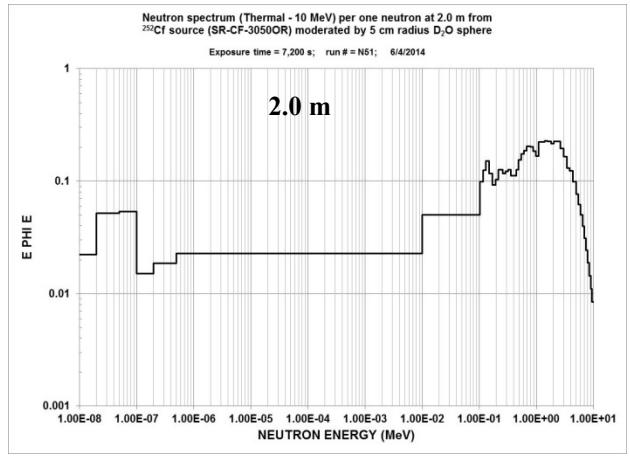
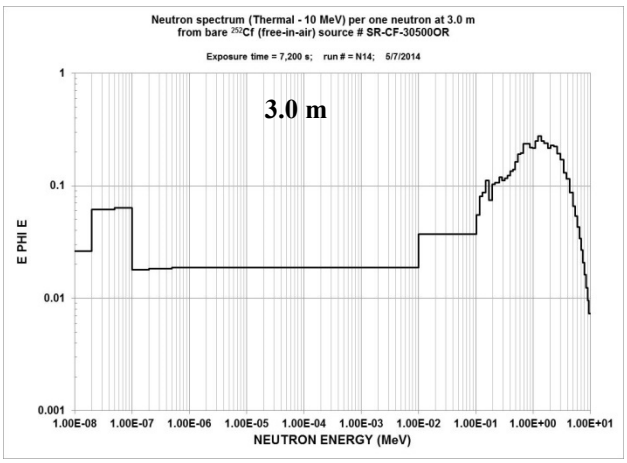


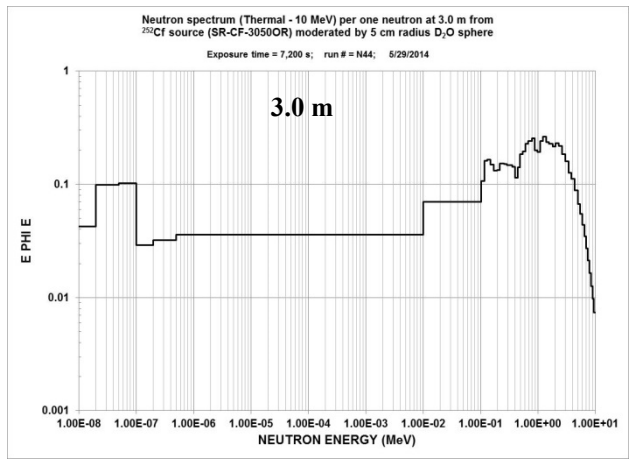
Figure 17. Neutron spectra from bare ^{252}Cf (left column) and ^{252}Cf moderated by 10 cm polyethylene (right column)

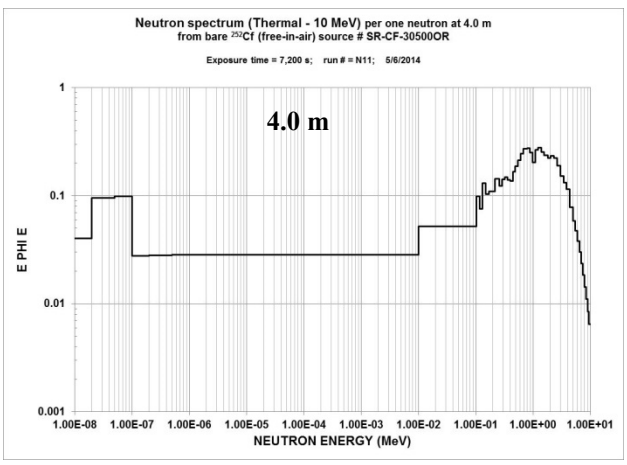
Bare ^{252}Cf source | **^{252}Cf moderated by 5 cm D_2O**











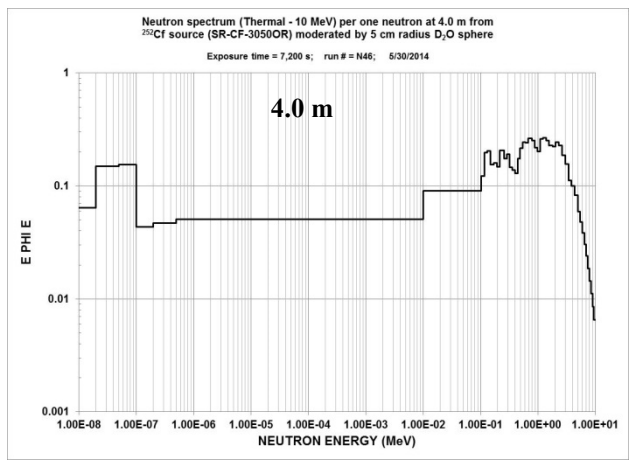


Figure 18. Neutron spectra from bare ^{252}Cf (left column) and ^{252}Cf moderated by 5 cm D_2O (right column)

Bare ^{252}Cf source | **^{252}Cf moderated by 5 cm polyethylene**

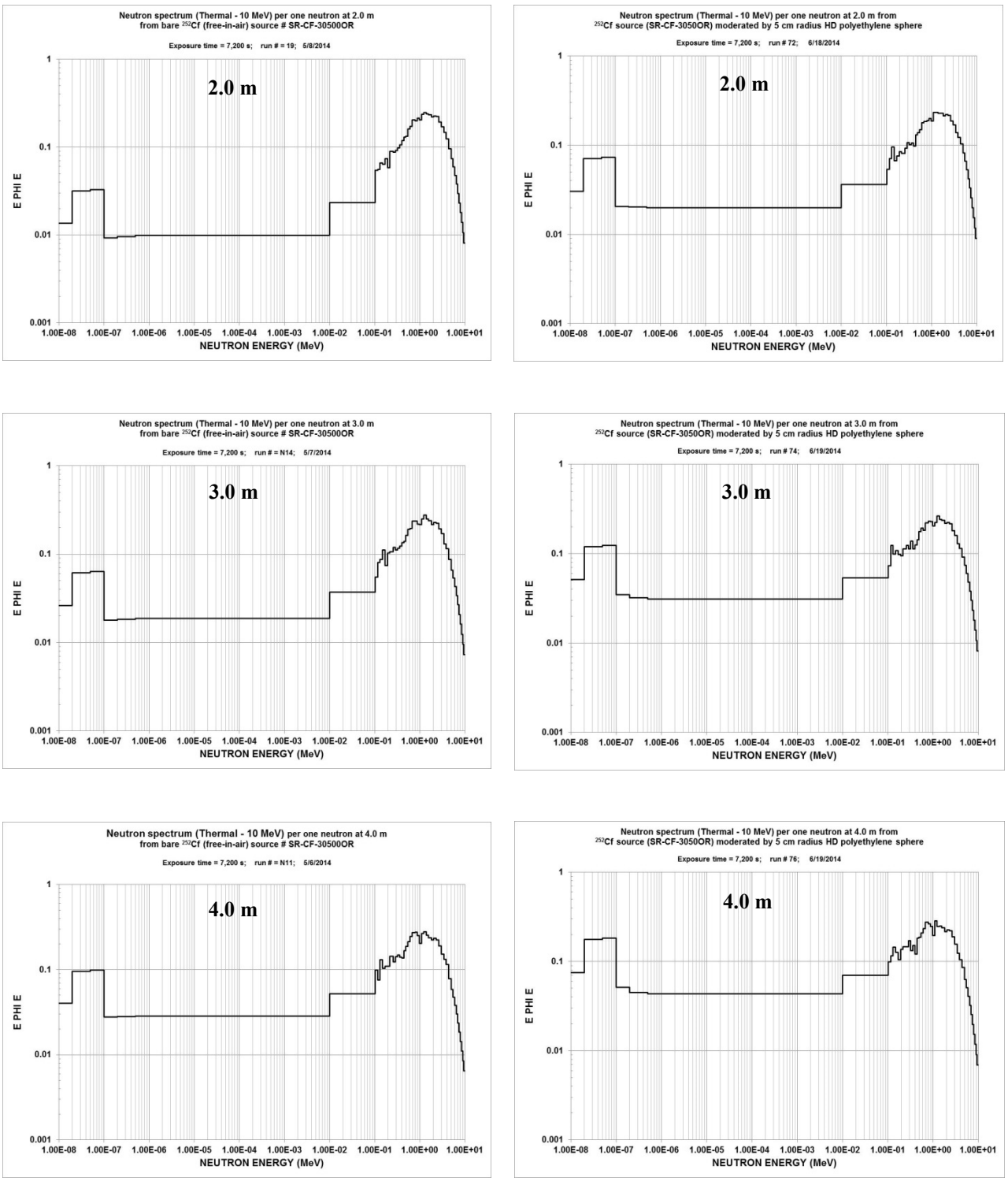


Figure 19. Neutron spectra from bare ^{252}Cf (left column) and ^{252}Cf moderated by 5 cm polyethylene (right column)

Comparison of the neutron fluence and dose rates from bare and moderated ^{252}Cf source with various moderator thicknesses and at various distances from the source

Figure 20 depicts the neutron fluence rates at different distances from bare ^{252}Cf and ^{252}Cf moderated by D_2O and HD polyethylene. Neutron fluence rates were measured by Rospec on different dates. In Figure 20 the neutron fluence rates are decay-corrected to a single date: July 18, 2014. The charts indicate that high density (HD) polyethylene shield (moderator) reduces neutron fluence much more than the same thickness of heavy water. Neutron fluence rates from bare ^{252}Cf and ^{252}Cf moderated by 2 cm HD polyethylene are practically the same.

Figure 21 shows the neutron ambient dose equivalent rates at different distances from bare ^{252}Cf and ^{252}Cf moderated by D_2O and HD polyethylene. Neutron ambient dose equivalent rates were measured by Rospec on different dates; however, in Figure 21 they are decay-corrected to a single date: July 18, 2014. The neutron ambient dose equivalent rate depends more strongly on the thickness of both moderators at distances closer to the source (e.g., 2.0 meters) than at distances further away from the source and closer to the wall (e.g., 4.5 meters). This is due to the increased number of scattered neutrons and hence the spectral change at distances (locations) closer to the north wall.

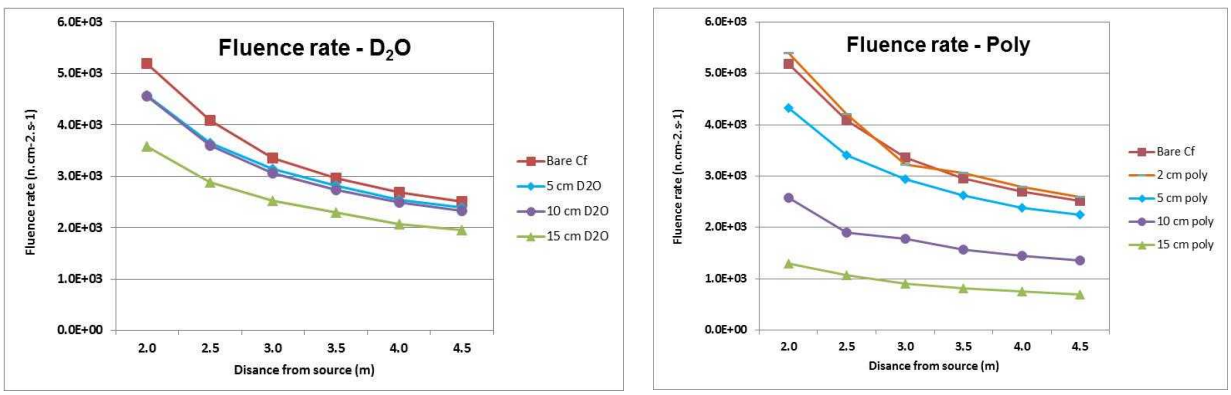


Figure 20. Neutron fluence rates from ^{252}Cf moderated by D_2O (left column) and by polyethylene (right column) at various distances from the source

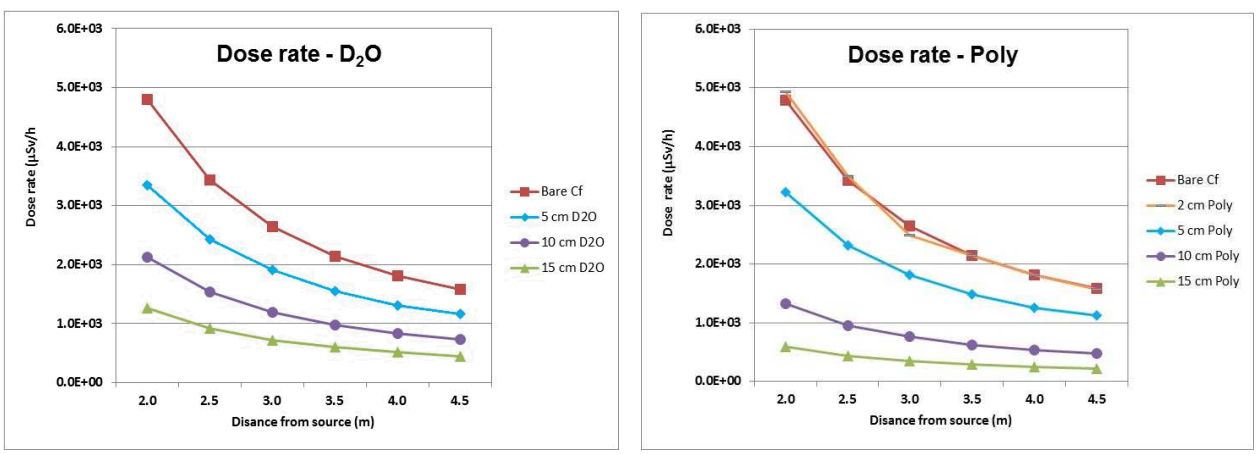


Figure 21. Neutron dose rates from ^{252}Cf moderated by D_2O (left column) and by polyethylene (right column) at various distances from the source

Dependence of the neutron fluence and dose rates from bare and moderated ^{252}Cf sources with various moderator thicknesses on the source distance

The neutron fluence rates and neutron ambient dose equivalent rates dependence on the thickness of the moderator are shown in Figures 22 and 23 respectively. Both neutron fluence and ambient dose equivalent rates presented in Figures 22 and 23 were measured with Rospec and decay-corrected to a single date: July 18, 2014. The thickness of the moderator is plotted on the horizontal axis. The neutron fluence rate (in neutrons per cm^2 per second) and the neutron ambient dose equivalent rate (in µSv/h) are plotted on the vertical axes correspondingly. Figure 22 suggests that the neutron fluence rate is more dependent on the thickness of the HD polyethylene than on the thickness of D_2O. Figure 23 indicates that the dose rate from bare ^{252}Cf and moderated by 2 cm polyethylene are very close; in other words 2 cm of polyethylene is not an adequate shield against ^{252}Cf neutrons. The neutron dose rates from ^{252}Cf moderated by 5 cm of D_2O or 5 cm of polyethylene are pretty close; however, the neutron dose rates from ^{252}Cf moderated by 10 cm of polyethylene are much lower than the neutron dose rates from ^{252}Cf moderated by 10 cm of D_2O. Detailed numerical data of the neutron fluence and neutron ambient dose equivalent rates from bare and moderated ^{252}Cf can be found in Appendices E through L.

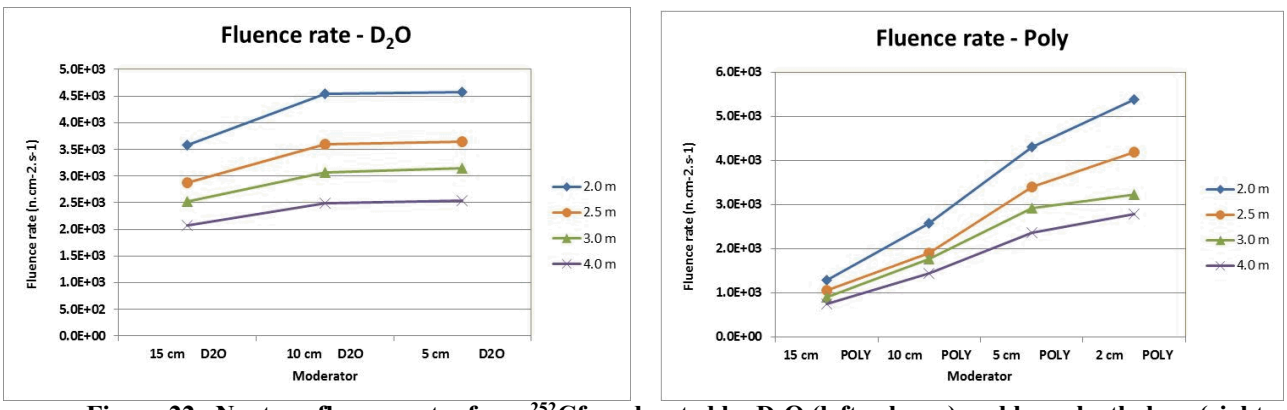


Figure 22. Neutron fluence rates from ^{252}Cf moderated by D_2O (left column) and by polyethylene (right column) with various thicknesses

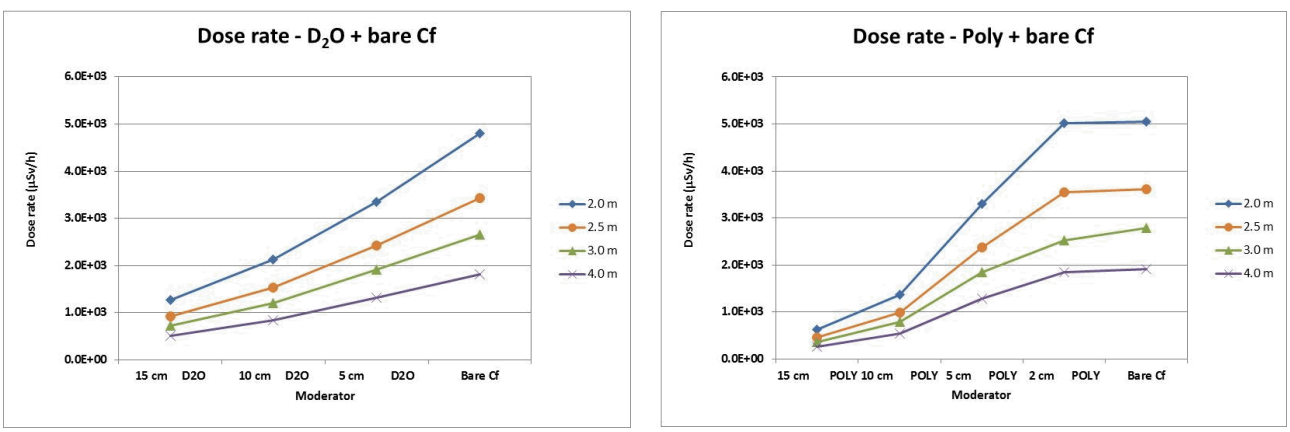


Figure 23. Neutron dose rates from ^{252}Cf moderated by D_2O (left column) and by polyethylene (right column) with various thicknesses

Comparison between NRD measured neutron dose rates

Two complete measurements of the neutron ambient dose equivalent rates were conducted on July 17-18, 2014 and on September 18-19, 2014 with the NIST calibrated NRD neutron rem meter. The relative difference between these two measurements is given in Table 11. July NRD measured data were decay-corrected to September 18, 2014 for this comparison.

Table 11. Difference between NRD measured neutron ambient dose equivalent rates (September and July, 2014)

Distance	Relative difference between July and September NRD measured neutron dose rates							
	Bare Cf	15 cm D_2O	10 cm D_2O	5 cm D_2O	15 cm POLY	10 cm POLY	5 cm POLY	2 cm POLY
2.0	-2.8%	-3.0%	2.9%	-5.6%	0.9%	-1.8%	7.6%	-3.5%
2.5	-3.4%	-2.5%	2.2%	-4.3%	-0.9%	-2.0%	8.0%	-3.6%
3.0	-3.6%	-5.0%	1.7%	-4.2%	-3.8%	1.0%	7.7%	-4.1%
3.5	-3.7%	-3.0%	2.4%	-4.9%	1.3%	-1.4%	6.5%	-4.3%
4.0	-2.8%	-3.0%	1.2%	-5.0%	0.8%	-2.9%	6.1%	-4.9%
4.5	-3.4%	-1.7%	1.2%	-5.5%	-3.2%	-3.6%	3.7%	-3.8%
5.0	-4.5%	-2.0%						
Average difference	**-3.5%**	**-2.9%**	**1.9%**	**-4.9%**	**-0.8%**	**-1.8%**	**6.6%**	**-4.0%**

- 1.015 NIST calibration factor applied to NRD dose rates only for bare ^{252}Cf measurements
- 0.748 NIST calibration factor applied to NRD dose rates only for 15 cm D_2O measurements

The statistical uncertainty for the neutron dose rate measurements with the NRD rem meter (the relative or fractional standard deviation = σ/x) was less than 1%. The statistical fluctuations of the measurement cannot alone explain the observed difference between the two measurements. Possible explanations for these differences may include the orientation of BF_3 detector in July measurements was not monitored and the positioning of the moderating spheres on the source tube (source tube was centered in the larger diameter of the spheres' opening by visual judgement). The BF_3 detector is mounted into a cutoff in the polyethylene sphere at 45 degrees to the vertical axis of the instrument. The cylindrical BF_3 detector that is inside the 9" polyethylene sphere of the NRD was oriented in the vertical plane along the neutron beam (the source-detector line) in the September measurements, while in July measurements the BF_3 detector orientation was not monitored. The visual verification of the centering of moderating spheres on the source tube was not precise and sometimes was not even possible because of the obstruction of the source tube support table and the spheres themselves. In future measurements this source of uncertainty will be addressed by adding specially designed positioning shims that may reduce this uncertainty. See Figure C-1 in Appendix C.

Comparison between Rospec and NRD measured neutron dose rates

The relative difference between Rospec measured neutron dose rates and NRD measured neutron dose rates in September is presented in Table 12. The difference is relative to the Rospec data. Rospec measured dose rates were decay-corrected to the date of September measurement.

Table 12. Difference between Rospec and NRD (September 2014) measured neutron ambient dose equivalent rates; Difference is relative to Rospec data

Distance	Relative difference between Rospec and NRD (September) measured dose rates							
	Bare Cf	15 cm D_2O	10 cm D_2O	5 cm D_2O	15 cm POLY	10 cm POLY	5 cm POLY	2 cm POLY
2.0	-3.6%	3.1%	-12.1%	-10.8%	-2.3%	-4.7%	-3.8%	-3.0%
2.5	-2.9%	3.9%	-13.4%	-10.0%	-3.3%	-5.9%	-2.6%	-2.9%
3.0	-3.5%	2.6%	-15.5%	-9.0%	-4.9%	-5.2%	-2.3%	-10.8%
3.5	-4.7%	2.7%	-14.5%	-11.0%	-3.9%	-5.9%	-3.2%	-4.4%
4.0	-5.6%	1.7%	-18.8%	-13.2%	-5.8%	-9.9%	-5.3%	-4.8%
4.5	-6.4%	0.6%	-19.1%	-14.0%	-10.5%	-11.0%	-5.3%	-6.3%
Average difference	**-4.4%**	**2.4%**	**-15.6%**	**-11.3%**	**-5.1%**	**-7.1%**	**-3.7%**	**-5.4%**

It is expected that the Rospec and NRD dose rate measurement results be in close agreement for bare ^{252}Cf and for ^{252}Cf moderated by 15 cm thick D_2O because the NRD was calibrated by NIST for these two fields. The noticed differences can be explained by the contribution of scattered neutrons from the walls. At larger distances from the ^{252}Cf source (i.e., closer to the walls) there are more scattered neutrons. These scattered neutrons have somewhat lower energy than the direct neutrons from the ^{252}Cf source. Rospec being a spectroscopic instrument properly measures the neutrons with different energy and applies correctly the energy dependent neutron fluence-to-dose conversion coefficients. For example the neutron fluence-to-dose conversion coefficients for 0.5 – 1.2 MeV are ~ 300-400 pSv/n/cm^2 while for the lower energies of 1 – 10 keV the coefficients are ~ 10 pSv/n/cm^2, a difference of 30 times or more. NRD is not a spectroscopic instrument and applies a single calibration coefficient for all neutron energies. Rospec will assign a lower dose rate for the scattered neutrons with the lower energies while NRD will determine a higher dose rate for the same scattered neutrons. This is confirmed by the measurements of bare ^{252}Cf: NRD gives progressively higher dose rates than Rospec when measurements are done closer to the wall. The difference between Rospec and NRD for 15 cm thick D_2O also progressively changes with the distance from the wall. However, here the NRD dose rate at 2.0 m is higher than Rospec dose rate possibly due to the larger uncertainty of the NIST calibration factor (8.7%) for the D_2O sphere. In the tables NRD results for moderating spheres other than 15 cm thick D_2O sphere were not corrected by calibration coefficients because such coefficients were not provided by NIST. Contribution to the differences between Rospec and NRD measurements may also come from the positioning of the moderating spheres on the ^{252}Cf source tube which were discussed previously. The differences between Rospec and NRD measured dose rates for HD polyethylene moderated ^{252}Cf fields do not exceed 12% which is quite remarkable. For D_2O moderated ^{252}Cf neutron fields (with higher moderation than by HD polyethylene) the differences do not exceed 19% which is acceptable for health physics purposes considering the overall uncertainty in neutron dose determination.

Scattered neutrons from the concrete walls, floor and ceiling

Evaluation of the contribution from scattered neutrons to the neutron fluence and dose rates and the neutron spectra is subject to further investigation. A model of RCL Low Scatter Facility (Rm 183A) and the ^{252}Cf source including its encapsulation and transport rabbit need to be developed using a Monte Carlo radiation transport code (e.g., MCNP). In the next step the validity of the model needs to be verified by comparison with the measured data from this report. Using the validated model calculations of the neutron spectra, fluence and dose rates need to be performed for a bare ^{252}Cf source free-in-air without any scattering surfaces and/or objects. Comparing the calculated data for free-in air with the measured data will provide information on the contribution of the scattered neutrons to the neutron fluence and dose rates. Previous estimates for Rm 183A with a smaller ^{252}Cf source [21] indicated that contribution of the scatted neutrons to the neutron dose rate is equal to the direct beam from the ^{252}Cf source at 4.5 and above for bare ^{252}Cf, and at 4.0 and above for D_2O moderated (15cm) ^{252}Cf source. ISO 8529-2 [14] recommends that the calibration room should be such that scatter contributions are as low as possible, but in any case they should not cause an increase in instrument reading of more than 40% at the calibration point. Annex B in ISO 8529-2 provides the room size

which will give 40% room return for each of the ISO-recommended radioactive neutron sources for a 75 cm source-detector distance for two types of neutron detectors.

Section 7

Conclusion

The ambient neutron dose rates determined from the measured neutron spectral distribution are the best estimates of the true neutron dose rates from the bare and moderated californium sources. The measured neutron dose rates can be used to establish RCL neutron reference fields for calibrating LLNL radiation protection instruments in various environments. These reference neutron fields can also be used to calibrate LLNL neutron personal dosimeters (both TLDs and CR-39) and neutron accident dosimeters. The measured neutron spectral fluence distribution can also be used for benchmarking future modeling of RCL Low Scatter Facility for radiation transport calculations for various applications.

It is challenging to estimate the accuracy of the Rospec neutron fluence and dose rate measurements. The accuracy of the Rospec dose rate measurements is determined only by the accuracy of the spectral and fluence measurement because the neutron dose rates are obtained from the spectral fluence distribution by multiplying with constants (ICRP-74 fluence-to-dose conversion coefficients). Rospec neutron spectrum accuracy is verified by periodic measurements of a ^{252}Cf spectrum and looking for any spectrum changes as well as with comparing with MCNP calculations of a standard ISO spectrum. No spectral changes or shifts have been observed. Others [8] estimated Rospec neutron spectral accuracy to 10%. The neutron fluence rate accuracy in principle can be estimated from measurements of a NIST calibrated source in “free-in-air” environment, i.e., with no walls and other surrounding materials that can contribute to neutron scattering. However, such facilities practically do not exist. The contribution of the scattered neutrons from the walls can be estimated by comparing Monte Carlo (e.g., MCNP) calculations of the neutron fluence and dose rates with the measured data. We are planning in the near future to model and perform MCNP calculations of the RCL Low Scatter facility (Room 183A).

NRD measurements were conducted to evaluate how close are measured neutron dose rates by a survey instrument to a more precise spectroscopic measurement of the neutron ambient dose equivalent rates by Ropsec. NRD measurements had good statistical accuracy (standard deviation less than 1%); however, the observed difference between the two NRD measurements is larger than the only statistical uncertainty. Further investigation of this difference is warranted. The difference between Rospec and NRD dose rates was only a few percent for bare ^{252}Cf and ^{252}Cf moderated by 15 cm thick D_2O. This is due to the specific NIST calibration factors for these neutron fields. The difference between Rospec and NRD measured neutron dose rates for most of the other moderated environments does not exceed 10%. Only two of the fields, the 10 cm and 5 cm D_2O moderated, have differences higher than 10%, but not exceeding 20%.

Rospec measurements did verify the neutron spectrum for RCL’s new ^{252}Cf calibration source in various geometries, provided the most accurate measurement of the neutron ambient dose rate equivalent of RCL reference neutron fields, can be used for evaluation of the contribution of the scattered neutrons, and can be used to correlate neutron environments encountered in the field against standard or reference neutron environments. The characterized RCL neutron fields will be used for calibration of LLNL neutron radiation protection survey instruments and LLNL personal and neutron accident dosimeters. The well characterized RCL neutron fields will help to establish LLNL’s low-scatter Radiation Calibration Lab as a reference ^{252}Cf radiation field for neutron, photon and nuclear accident dosimetry.

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Appendix A

Dosimetric quantities and neutron-to-fluence conversion coefficients

Dosimetric quantities

The following summarizes some dosimetric quantities used as defined by the International Council on Radiation Protection (ICRP) and International Council on Radiation Units (ICRU). Details of the definitions of these quantities, including their relationship to the
physical quantities can be found in the appropriate references [11-13].

Protection quantities
Dosimetric quantities specified in the human body by the ICRP. Examples of protection quantities are equivalent dose and effective dose.

Equivalent dose:
Denoted as $H_{T,R}$ is the absorbed dose in an organ or tissue multiplied by the relevant radiation weighting factor

$$H_{T,R} = w_R.D_{T,R}$$

where w_R is the radiation weighting factor and $D_{T,R}$ is the absorbed dose averaged over the tissue or organ, *T*, due to radiation *R*.

Effective dose:
A summation of the equivalent doses in tissue or organs, each multiplied by the appropriate tissue weighting factor

$$E = \Sigma w_T.H_T$$

where w_T is the tissue weighting factor, H_T is the equivalent dose in tissue or organ, T.

Operational quantities
Quantities with which, by means of their measurement, compliance with the system of protection may be demonstrated. Examples of operational quantities are ambient dose equivalent, directional dose equivalent and personal dose equivalent.

Ambient dose equivalent, H(d)*
H(d)*, at a point in a radiation field, is the dose equivalent that would be produced by the corresponding aligned and expanded field in the ICRU sphere at a depth *d* on the radius opposing the direction of the aligned field. A depth *d* = 10 mm is recommended for strongly penetrating radiation (e.g., neutrons). The unit of ambient dose equivalent is joule per kilogram ($J.kg^{-1}$) and its special name is Sievert (Sv). Unit still in use in the U.S. is rem (1Sv=100 rem).

Kerma, K
The quotient of dE by dm, where dE is the sum of the initial kinetic energies of all the charged ionizing particles liberated by uncharged particles in a volume element of mass dm

$$K = \frac{dE}{dm}$$

Directional dose equivalent, H'(d, W*)*
H'(d, W*)*, at a point in a radiation field, is the dose equivalent that would be produced by the corresponding expanded field in the ICRU sphere at depth *d* on a radius in a specified direction, W. A depth *d* = 0.07 mm is recommended for weakly penetrating radiation. Not used for neutrons.

Individual monitoring

Personal dose equivalent, Hp(d)
Hp(d) is defined for both strongly and weakly penetrating radiations. *Hp(d)* is the dose equivalent in soft tissue below a specified point on the body at an appropriate depth *d*. Depths of *d* = 10 mm for strongly penetrating radiation and *d* =0.07 mm for weakly penetrating radiation are recommended.

Neutron fluence-to-dose conversion coefficients

Table A-1 contains the fluence-to-dose conversion factors used by Rospec software code to calculate the dosimetric quantities from the measured neutron fluence and spectra by Rospec. The neutron fluence in neutrons per square centimeter should be multiplied by the coefficient in order to obtain the ambient dose equivalent and personal dose equivalent in pSv (= 100 picorem) and kerma in nanorads).

Table notations:

H*(10) is the ambient dose equivalent as defined in ICRP-74 [13]

Hp(10,0) is the personal dose equivalent as defined in ICRP-74 in soft tissue at 10 mm below a specified point on the body at 0 degree between the incident unidirectional neutron field and the direction normal to the surface (in atero-posterior geometry).

Table A-1. Neutron fluence-to-dose conversion coefficients (ICRP-74)

En (MeV)	KERMA (nrad/n/cm^2)	H*(10) ICRP-74 (pSv/n/cm^2)	Hp(10,0) ICRP-74 (pSv/n/cm^2)
2.50E-08	0.02	10.6	11.4
1.00E-07	0.01	12.9	12.6
1.00E-06	0.003	13.3	14.4
1.00E-05	0.001	11.3	13.2
1.00E-04	0.001	9.4	10.3
0.001	0.011	7.9	8.78
0.002	0.02	7.7	8.72
0.005	0.05	8.0	9.36
0.01	0.10	10.5	11.2
0.02	0.18	16.6	17.1
0.03	0.29	23.7	24.9
0.05	0.41	41.1	39.0
0.07	0.51	60.0	59.0
0.10	0.64	88.0	90.6
0.15	0.82	132.0	139.0
0.20	0.97	170.0	180.0
0.25	1.10	210.0	213.0
0.30	1.22	233.0	246.0
0.35	1.33	270.0	268.3
0.40	1.49	280.0	290.5
0.45	1.65	310.0	312.8
0.50	1.61	322.0	335.0
0.55	1.68	340.0	347.8
0.60	1.76	350.0	360.5
0.65	1.83	365.0	373.3
0.70	1.90	375.0	386.0
0.75	1.97	385.0	393.0
0.80	2.03	390.0	400.0
0.85	2.09	395.0	407.0
0.90	2.16	400.0	414.0
0.95	2.33	400.0	418.0
1.00	2.51	416.0	422.0
1.20	2.46	425.0	433.0
1.40	2.64	425.0	435.3
1.60	2.80	420.0	437.5
1.80	2.95	420.0	439.8

En (MeV)	KERMA (nrad/n/cm^2)	H*(10) ICRP-74 (pSv/n/cm^2)	Hp(10,0) ICRP-74 (pSv/n/cm^2)
2.00	3.09	420.0	442.0
2.20	3.22	418.0	439.8
2.40	3.34	416.0	437.6
2.60	3.45	415.0	435.4
2.80	3.56	412.0	433.2
3.00	3.69	412.0	431.0
3.20	3.86	410.0	429.2
3.40	4.07	410.0	427.4
3.60	4.23	410.0	425.6
3.80	4.24	408.0	423.8
4.00	4.20	408.0	422.0
4.20	4.20	408.0	421.6
4.40	4.25	408.0	421.2
4.60	4.31	408.0	420.8
4.80	4.38	405.0	420.4
5.00	4.45	405.0	420.0
5.50	4.60	402.0	421.5
6.00	4.75	400.0	423.0
6.50	4.89	402.0	427.5
7.00	5.01	405.0	432.0
8.00	5.25	409.0	445.0
9.00	5.46	420.0	461.0
10.00	5.65	440.0	480.0
11.00	5.82	460.0	498.5
12.00	5.99	480.0	517.0
13.00	6.14	500.0	533.5
14.00	6.29	520.0	550.0
15.00	6.36	540.0	564.0
16.00	6.41	540.0	576.0
17.00	6.47	562.0	585.5
18.00	6.52	570.0	595.0
19.00	6.57	585.0	597.5
20.00	6.62	600.0	600.0

Appendix B

Cf source: production, isotopic content, neutron emission, decay characteristics

Californium source serial number SR-CF-3050-OR

The historical information in this subsection was provided by the Radiochemical Engineering Development Center at ORNL, the manufacturer of this source.

The californium used to prepare this neutron source is identified by batch code CX-CF598. The isotopic mass distribution of this lot of material is listed in Table 1 in Section 3. The ^{248}Cm decay product was last separated from this lot on 3/16/1999. The californium in the source is the chemical form of Cf_2O_3 which was prepared by heating the oxalate in air to 700 °C.

The SR-Cf-3050-OR source is double encapsulated. The primary capsule was closed on 3/24/1999; the secondary capsule was closed on 4/20/1999. Schematic diagram of the double encapsulated ^{252}Cf source is provided in Figure 1 in Section 3.

The initial neutron emission rate of the encapsulated source was determined by comparing its strength to that of SR-Cf-3022, a reference ORNL ^{252}Cf source traceable to the national reference radium-beryllium source, NS-1 at NIST. The comparison was made by inserting each capsule into a moderator containing an array of fission counters and measuring the subsequent induced electric current by a picometer. The total neutron emission rate of this source was found to be 7.444×10^{10} neutrons per second with a relative standard error of ±0.17% as of 4/20/1999.

The ^{252}Cf content has been inferred from the measured neutron emission rate by correcting the gross emission rate by a factor of 0.97662, the fraction of the spontaneous fission neutrons emanating from the isotope ^{252}Cf and by dividing by 2.31434×10^6 neutrons per second per microgram. These values may be calculated from the isotopic composition listed in Table 1 (Section 2) and from the nuclear data listed in Table B-1. The equivalent ^{252}Cf content on the assay date, 4/20/1999, was computed to be 31,412.5 µg with relative standard error of ±0.17%. Due to propagation of errors along the chain of traceability and also to non-random errors, the overall accuracy of the assay is estimated to be ±3%.

General properties

^{252}Cf is an intense neutron emitter that is routinely doubly encapsulated in compact, cylindrical source capsules. ^{252}Cf decays by alpha emission (96.91% probability) and spontaneous fission (3.09% probability) which results in an overall half-life of 2.645 years (see Table B-1, Figure B-3 and reference [1]). The average neutron energy is 2.13 MeV and the most probable energy is 0.70 MeV. Californium source activity may be seen quoted in three different ways:

a) in µCi (or Bq),

b) in micrograms (µg) or

c) in neutron flux units (n/s in 4π).

When californium source activity is quoted in µCi (or Bq) it includes all disintegrations that produce alpha particles or neutrons. The relationship between ^{252}Cf activity units is as follows:

- ^{252}Cf emits 2.314×10^6 neutrons per second per microgram,
- its specific activity is 536 µCi/µg and

- 1 μCi of ^{252}Cf yields 4,316 n/s.

The H*(10) neutron dose rate from 1 μg of ^{252}Cf at one meter without any shielding is 2.55 mrem/h. The gamma rays contribute another 0.140 mrem/h. The dose rates (and emission rates) may slightly vary among different ^{252}Cf sources depending on their age, isotopic composition and encapsulation (these are discussed later). The basic nuclear data for californium isotopes is provided in Table B-1.

Table B-1. Basic nuclear data for Cf isotopes

Nuclide	Half-Life ($T_{1/2}$)	a-Decay Branching Fraction	Spontaneous Fission (SF) Branching Fraction	Average Neutron Yield per Fission (SF)	Total Neutron Emission Rate [n/(g.s)]
^{249}Cf	351 y	≈ 1.0	5.2×10^{-9}	3.4	2.676×10^{3}
^{250}Cf	13.20 y	0.99921	0.00079	3.53	1.117×10^{10}
^{251}Cf	898 y	≈ 1.0	9.0×10^{-6}	3.7	1.954×10^{6}
^{252}Cf	2.645 y	0.96904	0.03096	3.768	2.314×10^{12}
^{253}Cf	17.81 d	0.0031	Unknown	Unknown	8.406×10^{4}
^{254}Cf	60.5 d	0.00299	0.99701	3.93	1.232×10^{15}

The energy spectrum of ^{252}Cf can be described by the Watt equation:

$$N(E) = e^{-E/a}\sinh(\sqrt{bE}),$$

where E is the neutron energy in MeV and for ^{252}Cf, a=1.18 MeV and b = 1.03419 MeV^{-1}. The average neutron energy is 2.13 MeV and the most probable energy is 0.70 MeV.

More information about californium sources may be found in references [1, 5, 9, 10, 15, 20, 22].

Production

Californium properties, production, supply and applications are reviewed in several reports and presentations [3, 7, 16, 18, 21]. Californium is produced in two facilities world-wide: at the High Flux Isotope Reactor (HFIR) located at the Oak Ridge National Laboratory (ORNL) in Tennessee, United States and at the Research Institute for Atomic Reactors (RIAR) in Dimitrovgrad, Russia (Figure B-1).

Figure B-1. Oak Ridge National Laboratory facility in USA and Research Institute for Atomic Reactors in Dimitrovgrad, Russia

Californium produced at ORNL supplies approximately 70% of the demand for the material. ^{252}Cf is produced in HFIR and then processed in the adjacent Radiochemical Engineering Development Center (REDC) located also at ORNL. The HFIR produces californium by transmutation from curium oxide targets. The transmutation involves two processes: a) neutron absorption, which increases the nuclear mass by 1 and b) beta decay, which increases the atomic number by 1. For example, ^{244}Cm absorbs a neutron to become ^{245}Cm, and then ^{245}Cm absorbs a neutron to become ^{246}Cm and so on up to ^{249}Cm. At this point the beta decay replaces the neutron absorption by ^{249}Cm because the half-life of ^{249}Cm (64.2 min) is too short to allow further capture of a neutron before ejecting a beta particle and becoming ^{249}Bk. Then the ^{249}Bk either captures a neutron and becomes ^{250}Bk which decays to ^{250}Cf or ^{249}Bk absorbs a neutron to become ^{250}Bk which beta decays into ^{250}Cf. From this point consecutive neutron absorptions produce californium isotopes up to ^{255}Cf (Figure B-2).

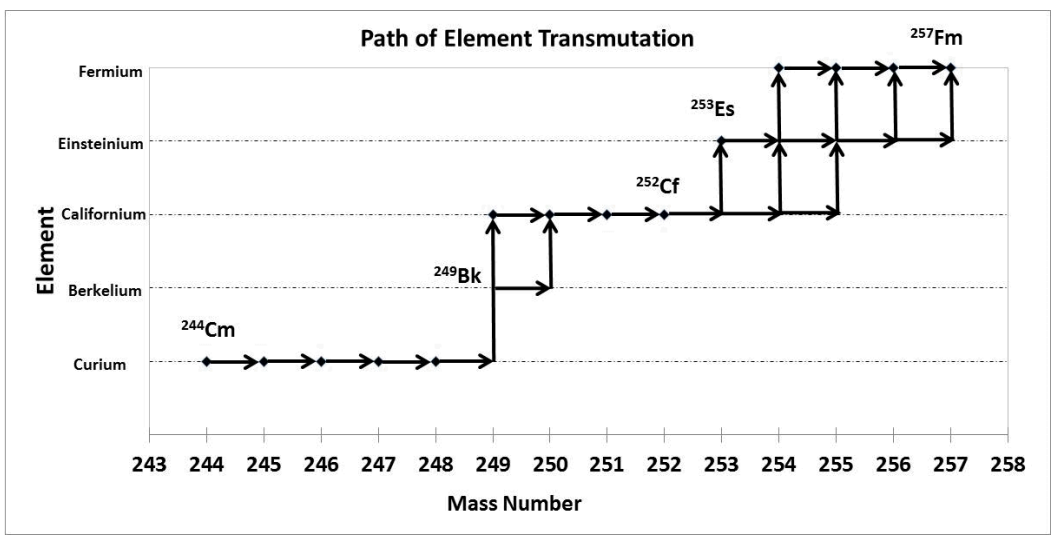


Figure B-2. Path of element transmutation in the High Flux Isotope Reactor (ORNL)

The transplutonium elements produced at HFIR are chemically separated and purified in a highly sophisticated, remotely operated process. As a result of the californium production technology each irradiated batch has a mixture of californium isotopes. The isotopic composition of the californium sources is usually given in mass units (e.g., μg).

After the chemical separation from curium the californium mixture is plated onto a palladium alloy wire. An appropriate amount of this wire, dependent on the neutron activity desired, is cut and then doubly encapsulated into small zirconium alloy or stainless steel containers.

Neutron emission

The basic nuclear data used by the Radiological Engineering Development Center at ORNL for Cf isotopes are provided in Table 1. The emission rates given in Table B-1 can be calculated by the following expression:

$$\text{Emission rate} = \nu*(\text{SF Branching Fraction})*[(\ln 2)/T_{1/2}]*[6.02214\text{x}10^{23}/(\text{At. Wt.})] \qquad (1)$$

To get the neutron emission rate in [n/(g.s)], the half-life must be in seconds. ν is the average neutron yield per fission, "At.Wt." is the atomic weight of the isotope.

Since the amount of californium isotopes is usually given in mass units (e.g. μg, grams,) the masses of the isotopes present in the californium source mixture need to be decay-corrected to get the current amounts. To obtain the activity of each isotope the following formula can be used:

$$A(\text{Bq}) = [\ln(2)/(t_{1/2}(\text{s}))] * \text{mass(g)} * 6.02\text{E}23 / \text{atomic number}, \qquad (2)$$

where the half-life is in seconds, mass is in grams, and the resulting activity A (the number of disintegrations per unit time) is in Becquerels. The atomic number is an approximation to the atomic mass term used in Eq. (1). If needed the activity may be easily converted from Bq into Ci by dividing by 3.7E10.

With time, californium isotopes in the source decay by alpha emission to curium isotopes. The isotopic composition of some older (>15 years) ^{252}Cf sources provided by ORNL is shown in Table B-2. The ^{245}Cm, ^{246}Cm, ^{247}Cm and ^{248}Cm isotopes in Table B-2 come from the alpha decay of the ^{249}Cf, ^{250}Cf, ^{251}Cf and ^{252}Cf isotopes.

Table B-2. Isotopic composition of several old ^{252}Cf sources from ORNL assayed after 15 or more years after production

Source ID	Batch ID	Cf-249 µg	Cf-250 µg	Cf-251 µg	Cf-252 µg	Cm-245 µg	Cm-246 µg	Cm-247 µg	Cm-248, µg
SR-CF-3050OR	CXCF598	1713.53	2042.972	1346.968	728.84	49.52	2345.77	15.09	31262.97
SR-CF-3048OR	CXCF579	2991.615	1819.724	1364.31	445.657	93.12	2322.96	16.45	25621.12
SR-CF-3046OR	CXCF561	2358.67	1379.51	1050.985	338.088	79.42	1975.77	13.7	27092.87
SR-CF-3040OR	CXCF537	2320.446	1956.731	1540.457	331.765	79.78	2890.96	20.49	29154.7
SR-CF-3039OR	CXCF537	1593.869	1344.041	1058.11	227.883	57.7	2146.49	14.81	25345.68
SR-CF-3047OR	CXCF561	1554.705	909.297	692.752	222.849	52.35	1302.32	9.03	17858.13
SR-CF-3037OR	CXCF537	1462.013	1232.852	970.576	209.031	53.24	1986.61	13.67	23897.37
SR-CF-3036OR	CXCF537	1432.616	1208.063	951.06	204.828	52.17	1946.67	13.39	23416.86
SR-CF-3038OR	CXCF537	1419.588	1197.076	942.411	202.965	51.39	1911.78	13.19	22574.26
SR-CF-3041OR	CXCF537	1195.11	1007.784	793.389	170.871	40.95	1481.35	10.52	14788.53
SR-CF-3042OR	CXCF537	1105.295	932.047	733.764	158.029	38.02	1378.05	9.77	13917.49
SR-CF-3034OR	C68EST	2776.956	1442.62	1419.684	126.897	116.85	2917.81	23.06	30037.88
SR-CF-3035OR	CXCF537	769.917	649.238	511.119	110.079	27.55	1018.86	7.07	11604.34

If the californium source has known mixtures of curium isotopes expressed in mass units (e.g., µg), their activity can also be calculated using equation (2). The overall activity (disintegrations/unit time) of the californium source is the sum of the activities of all isotopes present in the mixture.

According to ISO 8529-1 [14] the relative standard uncertainty in the ^{252}Cf half-life is 0.5% to 0.7%. After about two half-lives (~ 5 y), the uncertainty in the half-life will result in a relative standard uncertainty in the source strength of about 1%. The uncertainties in the half-lives of other Cf isotopes may be even larger. Given the limited supplies of pure isotopes of californium as well as other experimental limitations it may not be possible to carry out the desired measurements to the degree of perfection that may be desired. It is therefore recommended that ^{252}Cf sources be recalibrated every 5 years. ISO 8529-1 [14] requires that the source strength of a ^{252}Cf source shall be corrected for radioactive decay on a day-to-day basis.

In practice, only ^{250}Cf needs to be considered as a competing neutron source as the other californium isotopes are either too short or long-lived in comparison to ^{252}Cf. A detailed diagram of californium isotopes decay is given in Figure B-3. Eventually all Cf isotopes will decay to stable isotopes.

However, the contribution of ^{250}Cf to the overall neutron emission rate is negligible for Cf sources less than about 15 years old. The alpha decay daughter of ^{252}Cf, ^{248}Cm has a long half-life (3.48×10^5 y) but a relatively high spontaneous fission probability (8.4%) and so contributes to the overall neutron emission rate. But even after 25 years this contribution is only about 1% of the total neutron yield. Note that the above time scales are comparable to the typical recommended working lifetime of 15 years for Cf sources. But if old (>15y) Cf sources are to be used, an initial neutron emission calibration will be required (due to the propagation of the uncertainty in the ^{252}Cf half-life and the generally unknown contribution from ^{250}Cf). Thereafter, increasingly frequent recalibration will be required as the relative ^{248}Cm contribution increases and the overall neutron yield no longer follows a predictable exponential decrease. Figure B-4 shows the neutron yield with time of a Cf source with the initial composition shown in Table 1 of Section 3. The absolute emission rate shown in Figure B-4 is based on an initial ^{252}Cf content of 10 µg.

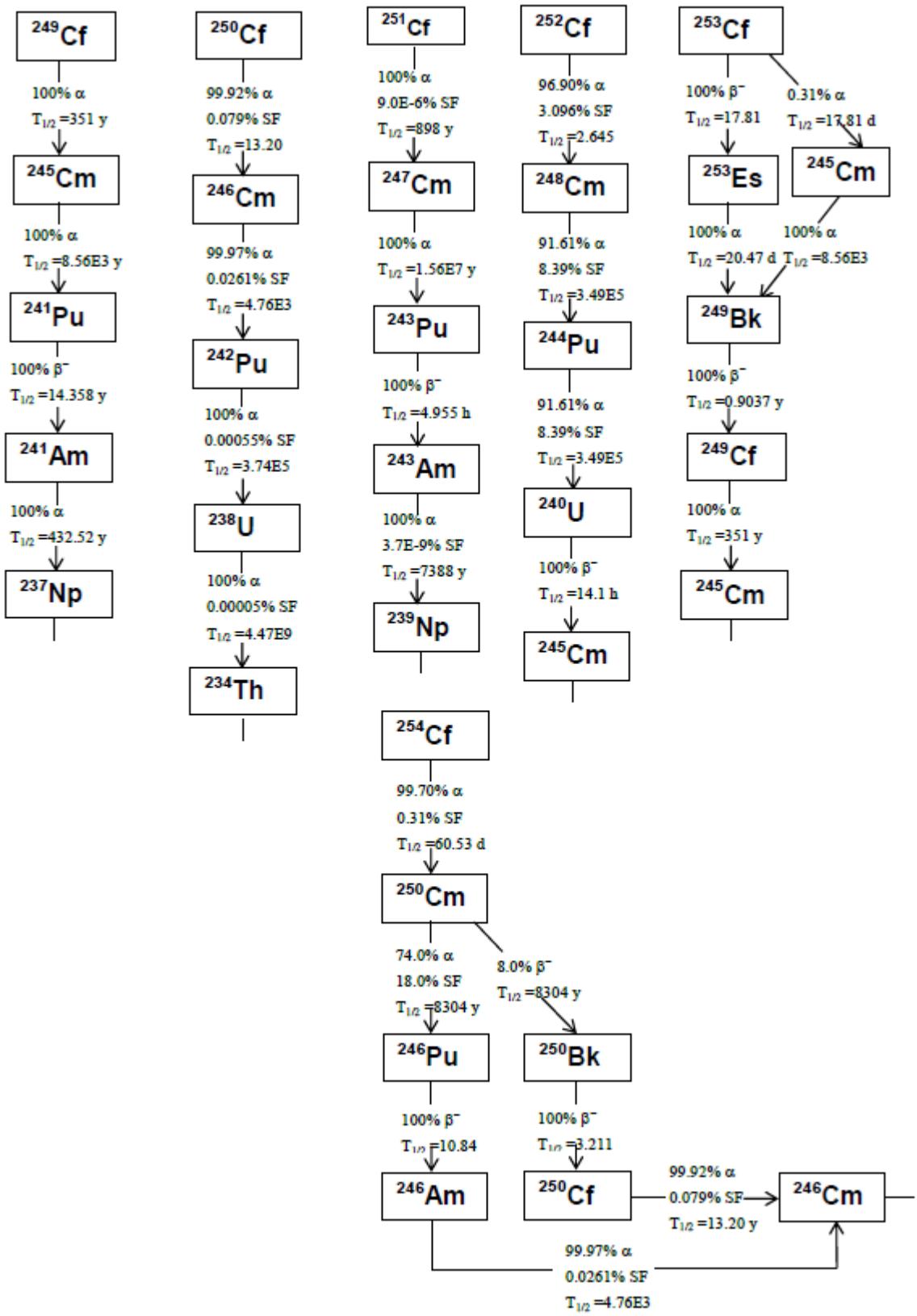


Figure B-3. Decay schemes of some Cf isotopes

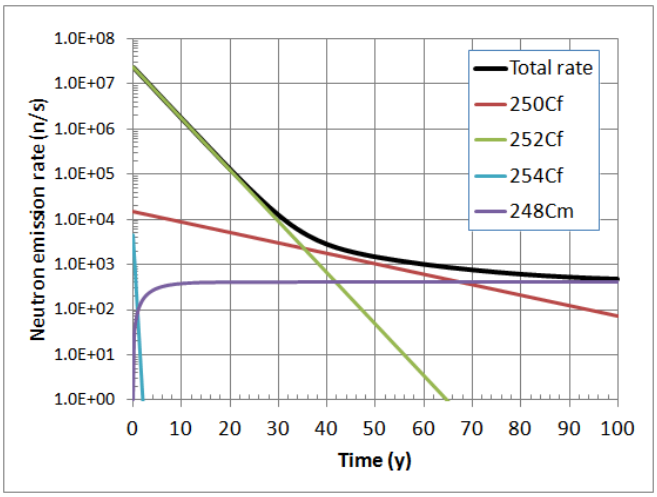


Figure B-4. Neutron emission rate of Cf source with time

Neutron emission rate is best established using the manganese bath technique at a neutron metrology facility such as NIST. For a new ^{252}Cf source, a simple exponential decay correction (λ=0.2621 y^{-1}) will give an accurate neutron emission rate for many years. An older source (>15 y), will require frequent recalibration as the neutron emission rate increasingly deviates from a single exponential decay.

NIST usually calibrates neutron sources in the range of 10^5 to 10^{10} n/s with an expanded uncertainty from 2-3.5% (k=2) by the manganese bath method. Weaker sources (10^4-10^5) n/s may be calibrated but the uncertainties will be larger. Commercial suppliers calibrate the emission rate of ^{252}Cf neutron sources to 5-8% using cross calibration or a transfer-standard calibration source.

Nuclear decay data

There is a spread among the nuclear decay data measured by different researchers and there are multiple evaluations of the "best" values. In 2002 DOE standardized all nuclear data for inventory reporting to one source – the sixth edition of Nuclear Wallet Cards (2000) in PDF version is maintained by the Nuclear Data Center of Brookhaven National Laboratory. This version will be "frozen" in time and will be the official, DOE reference source for nuclear decay information until replaced by a new DOE Standard. The data in the Nuclear Wallet Cards (2000) of interest to ^{252}Cf neutron sources includes the half-lives and branching ratios of californium and curium isotopes.

Photon emissions

Photons are produced within the source during spontaneous fission and following alpha decay. The low energy fluence is attenuated by the stainless encapsulation but there is an appreciable fluence of higher energy photons and overall the photon fluence is about 50% of the neutron fluence. However, from a dose perspective, the photon dose is about 5% of the neutron component. Secondary photons will also be produced through neutron-induced inelastic collisions and capture gamma reactions with material comprising and within the test facility. The measured gamma (photon) exposure rates from our Cf sources are provided in Section 5 "Measurements of gamma exposure rates from the ^{252}Cf source with ion chamber."

Appendix C

LLNL's neutron moderators

Seven different spherical moderators were used to change the neutron spectrum from bare ^{252}Cf. Three of the moderating spheres consisted of stainless steel filled with high purity heavy water (99.8% D_2O). Each sphere has a cylindrical cutout for inserting the source tube with the source The physical dimensions of the D_2O filled spheres are listed in Table C-1.

Table C-1. Dimension of LLNL D_2O moderating spheres

D_2O (heavy water) filled spheres				
Sphere ID	**d_1** Overall outside ø (mm)	**d_2** Tube cutout ø (mm)	**d_3** Tube cutout depth (mm)	D_2O thickness (mm)
15 cm D_2O	370[a]	64	205	150
10 cm D_2O	268[b]	64	153	100
5 cm D_2O	168[b]	64	96	50

[a] - includes 1 mm thick Cd cover and 1 mm thick stainless steel walls

[b] - includes 1 mm thick stainless steel walls

The 15 cm D_2O sphere is covered by a thin 1 mm aluminum shell with a 1 mm thick cadmium (Cd) layer on the inside surface. The Cd layer consists of small cadmium sheet sectors which are glued to the inside of the aluminum shell. The cadmium/aluminum shell tightly wraps the 15 cm D_2O sphere. Figure C-1 shows the schematic diagram of the 15 cm D_2O sphere.

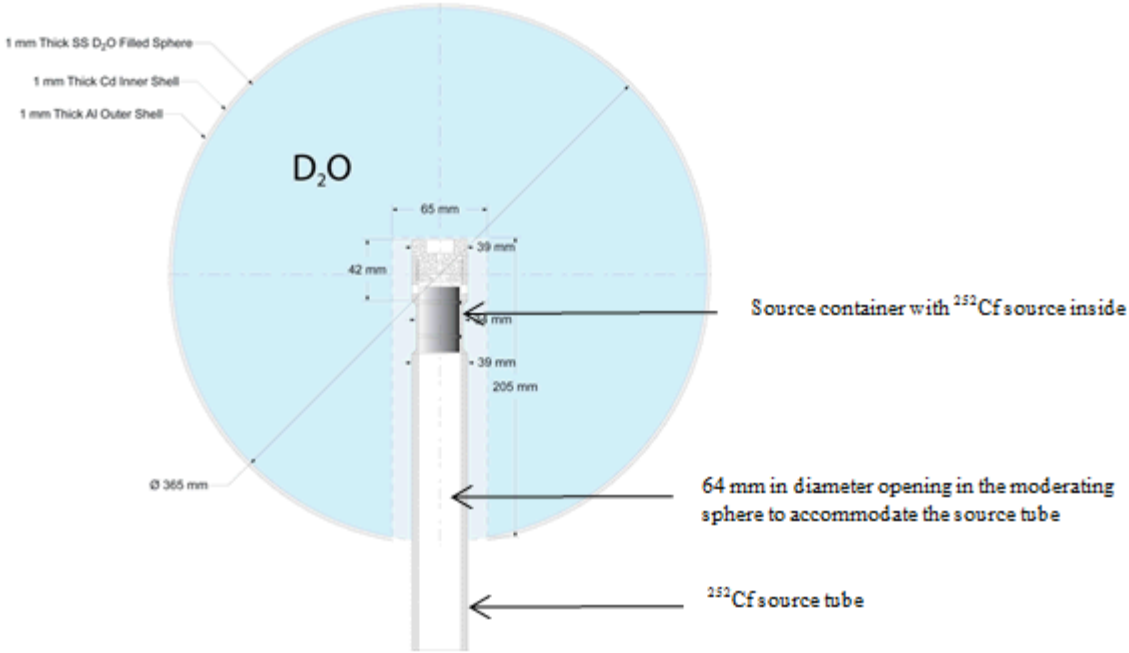


Figure C-1. Schematic of LLNL's 15 cm thick D_2O sphere mounted on the source tube with the ^{252}Cf source

The polyethylene moderating spheres were machined from high density (0.93 to 0.97 g/cm^3) polyethylene. Each of the polyethylene spheres has a cylindrical cutout for inserting the source tube with the source (Figure C-2). The physical dimensions of the polyethylene spheres are listed in Table C-2.

Table C-2. Dimension of LLNL polyethylene (Poly) moderating spheres

Polyethylene spheres				
Sphere ID	d_1 Overall outside ø (mm)	d_2 Tube cutout Ø (mm)	d_3 Tube cutout depth (mm)	Polyethylene thickness (mm)
15 cm Poly	365	64	206	150.5
10 cm Poly	267	65	153	101
5 cm Poly	165	64	94	50.5
2 cm Poly	105	64	65	20.5

During measurements with the moderated sources the central axis of the source tube (with the ^{252}Cf source inside) was positioned in the center of the cylindrical cutout of the sphere.

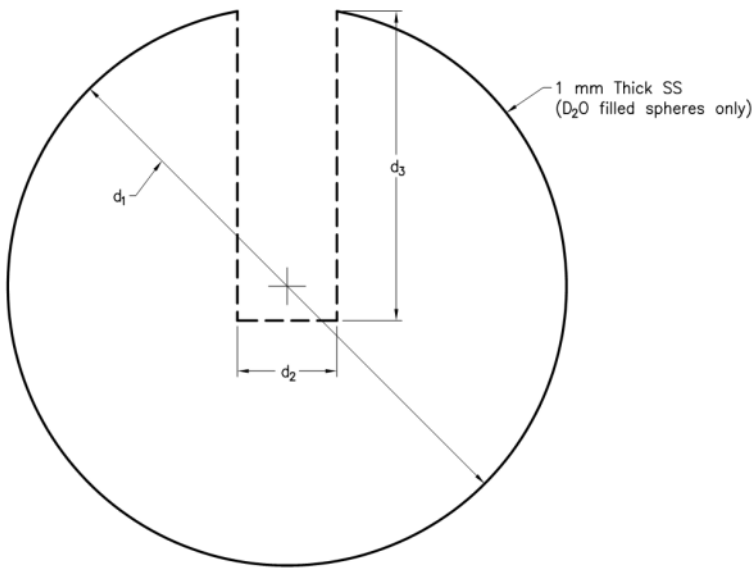


Figure C-2. Schematic of LLNL's neutron moderating spheres

Appendix D

Irradiator and pneumatic transport source container (rabbit)

Hopewell Designs Inc. irradiator model N40 consists of a carousel that holds up to 8 sources, shielding around the carousel, an aluminum transport tube, and an exposure position where a suction cup holds the source. N40 irradiator incorporates:

1. A carousel with eight positions for radioactive sources.
2. A pneumatic transport system for moving the source from the shielded storage position to the calibration position.
3. A calibration receiver and a storage receiver.
4. Shielding for the source in the storage position.
5. A computer controlled system that controls the N40 irradiator.

The sources are stored in a rectangular shield consisting of lead, water extended polyester (WEP) that consists of borated polyethylene in a polyester matrix, and a steel skin. This shield is 24” square and 48” tall and weighs 1800 lbs. The rectangular shield is surrounded by 3 layers of solid concrete blocks so that the overall shield is approximately 6’ square by 48” tall. The source carousel which holds the sources is located at the bottom of this shield. See Figure D-1 B.

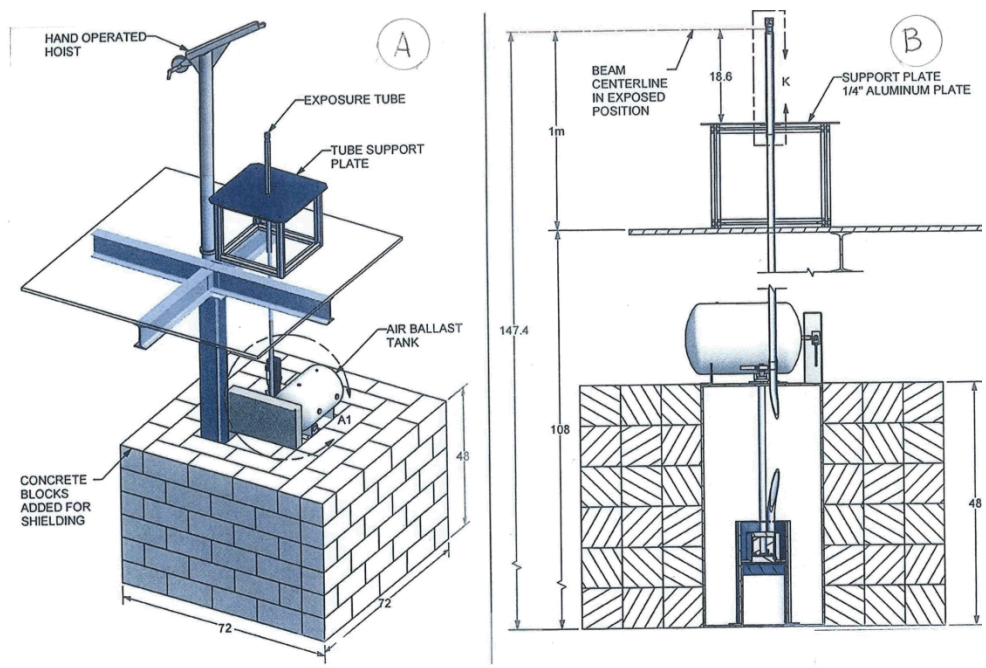


Figure D-1. Schematic of Hopewell Designs N40 irradiation system

The source is moved from the shielded storage receiver to the calibration receiver and back by air pressure. Airflow is controlled by two solenoid valves, one to blow the sources from the carousel to the calibration receiver, and one to cushion the sources upon return to the storage receiver. The source travels through an aluminum tube approximately 12’ long. All tubing and support structure above the shield is aluminum material to reduce neutron scatter. The carousel has 8 positions to hold the 7 sources plus a dummy. The transport tube has a slight “Z” bend to prevent direct radiation shine coming from the carousel. The calibration receiver is constructed from a thin-walled aluminum cylinder to minimize overall size and amount

of material. Compressed air pushes the source holder from the storage position to the calibration receiver. A suction cup at the top of the receiver holds the source carrier in position by vacuum. The centerline of the exposure position is 1 meter above the aluminum grate floor. The N40 irradiator without the computer control system is shown in Figure D-1 A. The moderation sphere hoist for hoisting and positioning the heavy spheres on top of the source tube is depicted in Figure D-1 A; however, it was never used. N-40 irradiator's computer control panel is shown in Figure D-2.

Figure D-2. N-40 irradiator's computer control panel

The double encapsulated ^{252}Cf source (SR-CF-3050-OR) is enclosed in a rabbit that can move inside the N40 source tube. The dimensions and the material of the rabbit are given in Figure D-3.

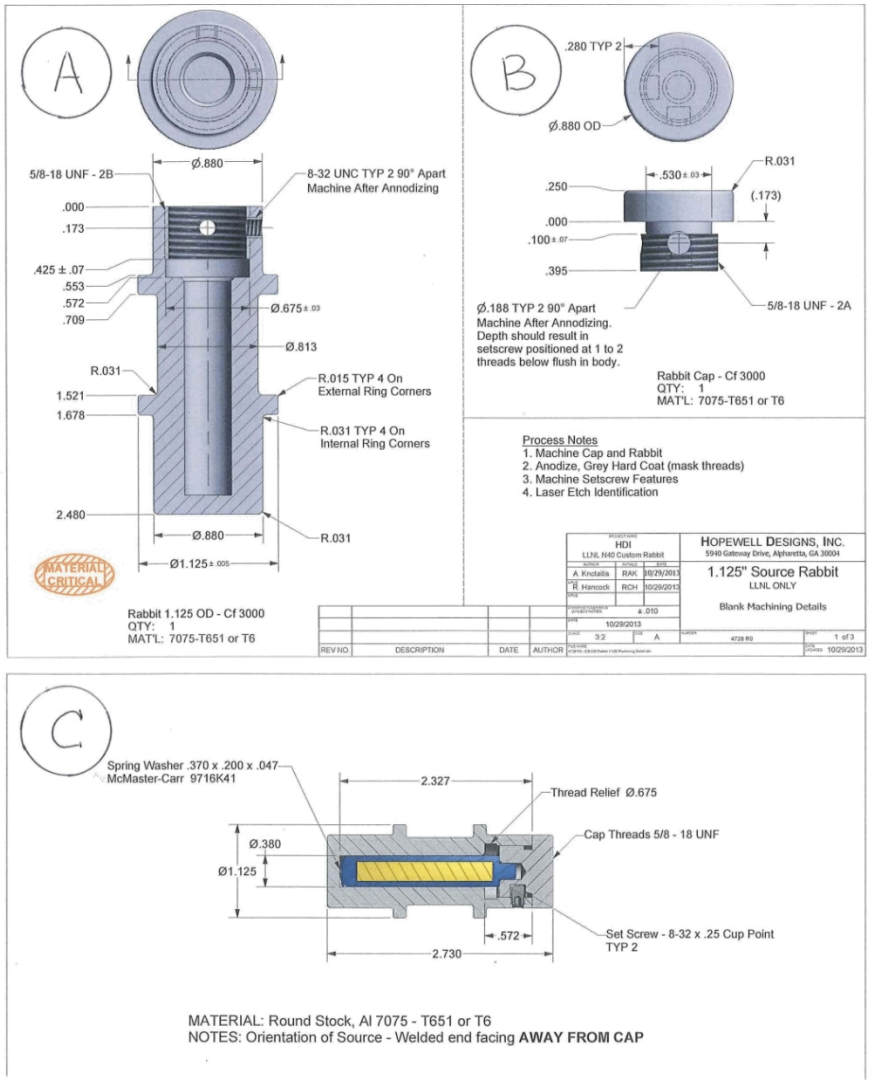
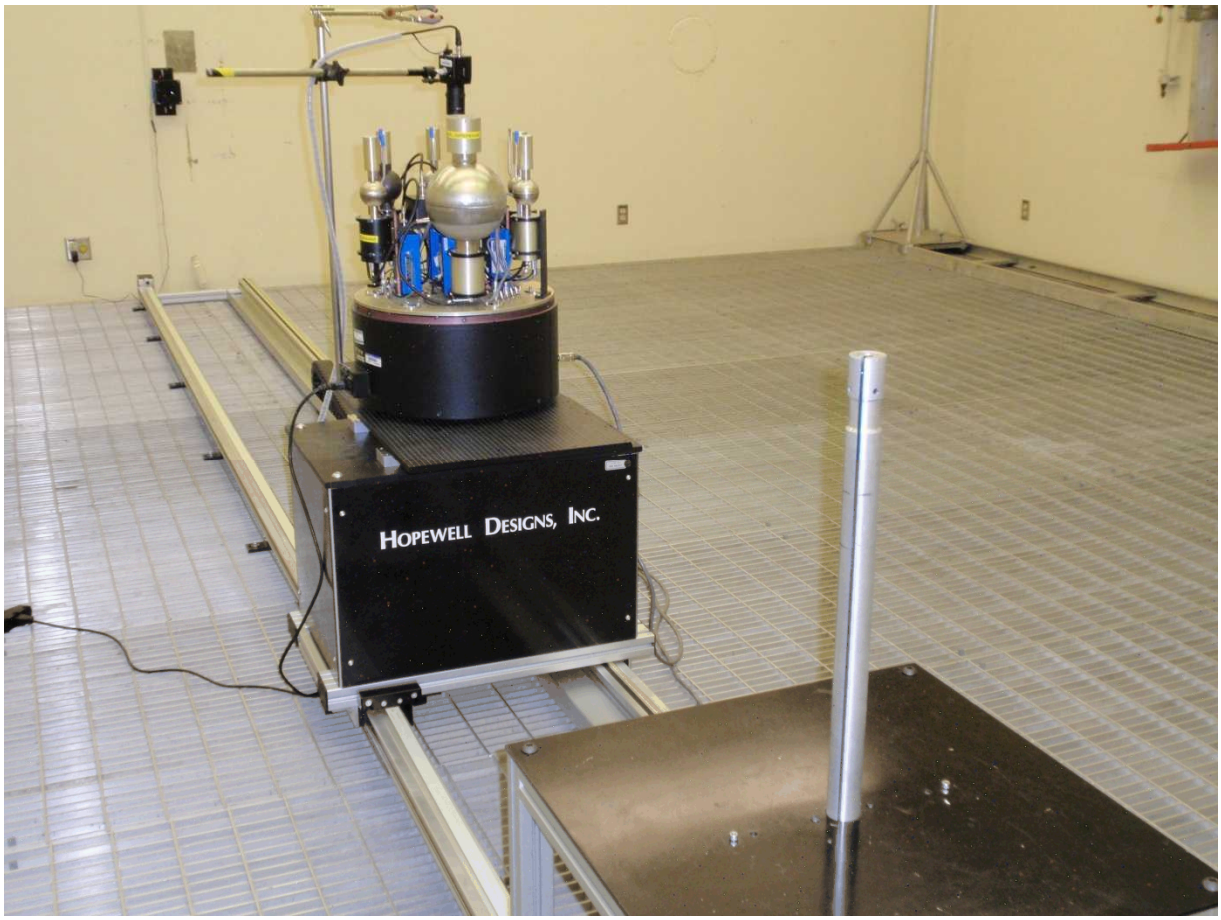


Figure D-3. ^{252}Cf source rabbit

Appendix E

Neutron fluence, spectra and dose rates from bare (free-in-air) ^{252}Cf



Fluence, spectral and dosimetric data at 2.0 meters from bare ^{252}Cf

Table E-1. Neutron fluence and dosimetric data at 2.0 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date:	5/8/2014
Exposure time:	7,200 s
Run number:	N19

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	2.64E+07	3.66E+03
Epi-thermal region	:	7.42E+06	1.03E+03
Thermal region	:	3.31E+06	4.60E+02
Thermal – 4.5 MeV	:	3.71E+07	5.15E+03
Thermal – 10.0 MeV	:	3.8220E+07	5.3084E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	6.48E-02	9.54E-03	3.24E+01	4.77E+03
Epi-thermal region	:	9.52E-04	1.47E-04	4.76E-01	7.34E+01
Thermal region	:	6.62E-05	3.51E-05	3.31E-02	1.75E+01
Thermal – 4.5 MeV	:	6.58E-02	9.73E-03	3.29E+01	4.86E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	6.9399E-02 rads	3.4699E+01 mrads/hr
H*(10) ICRP-74	=	1.0089E-02 Sv	5.0445E+03 uSv/hr
Hp(10,0) ICRP-74	=	1.0445E-02 Sv	5.2227E+03 uSv/hr

Table E-2. Neutron fluence at 2.0 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date: 5/8/2014
Exposure time: 7,200 s
Run number: N19

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg (MeV)
.1000E-08	.2000E-08	7.479E+03	7.479E+12	1.079E+04	.1500E-08
.2000E-08	.5000E-08	4.798E+04	1.599E+13	5.237E+04	.3500E-08
.5000E-08	.1000E-07	1.459E+05	2.919E+13	2.105E+05	.7500E-08
.1000E-07	.2000E-07	4.302E+05	4.302E+13	6.207E+05	.1500E-07
.2000E-07	.5000E-07	1.334E+06	4.445E+13	1.455E+06	.3500E-07
.5000E-07	.1000E-06	1.042E+06	2.085E+13	1.504E+06	.7500E-07
.1000E-06	.2000E-06	2.932E+05	2.932E+12	4.230E+05	.1500E-06
.2000E-06	.5000E-06	4.026E+05	1.342E+12	4.394E+05	.3500E-06
.5000E-06	.1000E-01	4.521E+06	4.521E+08	4.565E+05	.5000E-02
.1000E-01	.1027E+00	2.497E+06	2.694E+07	1.072E+06	.5635E-01
.1027E+00	.1166E+00	3.152E+05	2.274E+07	2.489E+06	.1096E+00
.1166E+00	.1317E+00	3.103E+05	2.052E+07	2.544E+06	.1241E+00
.1317E+00	.1493E+00	3.820E+05	2.166E+07	3.039E+06	.1405E+00
.1493E+00	.1707E+00	3.912E+05	1.826E+07	2.918E+06	.1600E+00
.1707E+00	.1934E+00	4.203E+05	1.853E+07	3.370E+06	.1821E+00
.1934E+00	.2199E+00	3.413E+05	1.290E+07	2.662E+06	.2066E+00
.2199E+00	.2606E+00	6.957E+05	1.707E+07	4.091E+06	.2402E+00
.2606E+00	.2906E+00	4.352E+05	1.451E+07	3.995E+06	.2756E+00
.2906E+00	.3244E+00	4.593E+05	1.361E+07	4.180E+06	.3075E+00
.3244E+00	.3581E+00	4.423E+05	1.311E+07	4.469E+06	.3413E+00
.3581E+00	.3994E+00	5.319E+05	1.289E+07	4.879E+06	.3787E+00
.3994E+00	.4444E+00	5.831E+05	1.296E+07	5.461E+06	.4219E+00
.4444E+00	.4931E+00	6.211E+05	1.274E+07	5.967E+06	.4688E+00
.4931E+00	.5456E+00	6.177E+05	1.177E+07	6.105E+06	.5194E+00
.5456E+00	.6094E+00	8.149E+05	1.278E+07	7.374E+06	.5775E+00
.6094E+00	.6769E+00	8.317E+05	1.232E+07	7.917E+06	.6431E+00
.6769E+00	.7946E+00	1.495E+06	1.269E+07	9.319E+06	.7358E+00
.7946E+00	.8870E+00	1.003E+06	1.085E+07	9.115E+06	.8408E+00
.8870E+00	.9871E+00	1.043E+06	1.042E+07	9.757E+06	.9371E+00
.9871E+00	.1095E+01	9.695E+05	8.993E+06	9.354E+06	.1041E+01
.1095E+01	.1218E+01	1.159E+06	9.405E+06	1.087E+07	.1157E+01
.1218E+01	.1391E+01	1.504E+06	8.701E+06	1.133E+07	.1305E+01
.1391E+01	.1573E+01	1.341E+06	7.367E+06	1.090E+07	.1482E+01
.1573E+01	.1807E+01	1.477E+06	6.312E+06	1.065E+07	.1690E+01
.1807E+01	.2041E+01	1.231E+06	5.259E+06	1.011E+07	.1924E+01
.2041E+01	.2327E+01	1.364E+06	4.770E+06	1.040E+07	.2184E+01
.2327E+01	.2639E+01	1.286E+06	4.122E+06	1.022E+07	.2483E+01
.2639E+01	.3003E+01	1.138E+06	3.126E+06	8.806E+06	.2821E+01
.3003E+01	.3419E+01	1.015E+06	2.439E+06	7.822E+06	.3211E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg (MeV)
.3419E+01	.3861E+01	8.156E+05	1.845E+06	6.708E+06	.3640E+01
.3861E+01	.4407E+01	7.560E+05	1.385E+06	5.716E+06	.4134E+01
.4407E+01	.5000E+01	5.528E+05	9.322E+05	4.379E+06	.4703E+01
.5000E+01	.5500E+01	3.212E+05	6.425E+05	3.370E+06	.5250E+01
.5500E+01	.6000E+01	2.379E+05	4.758E+05	2.734E+06	.5750E+01
.6000E+01	.6500E+01	1.754E+05	3.508E+05	2.191E+06	.6250E+01
.6500E+01	.7000E+01	1.287E+05	2.575E+05	1.737E+06	.6750E+01
.7000E+01	.7500E+01	9.422E+04	1.884E+05	1.366E+06	.7250E+01
.7500E+01	.8000E+01	6.869E+04	1.374E+05	1.064E+06	.7750E+01
.8000E+01	.8500E+01	4.997E+04	9.994E+04	8.243E+05	.8250E+01
.8500E+01	.9000E+01	3.627E+04	7.255E+04	6.346E+05	.8750E+01
.9000E+01	.9500E+01	2.629E+04	5.259E+04	4.863E+05	.9250E+01
.9500E+01	.1000E+02	1.906E+04	3.812E+04	3.716E+05	.9750E+01

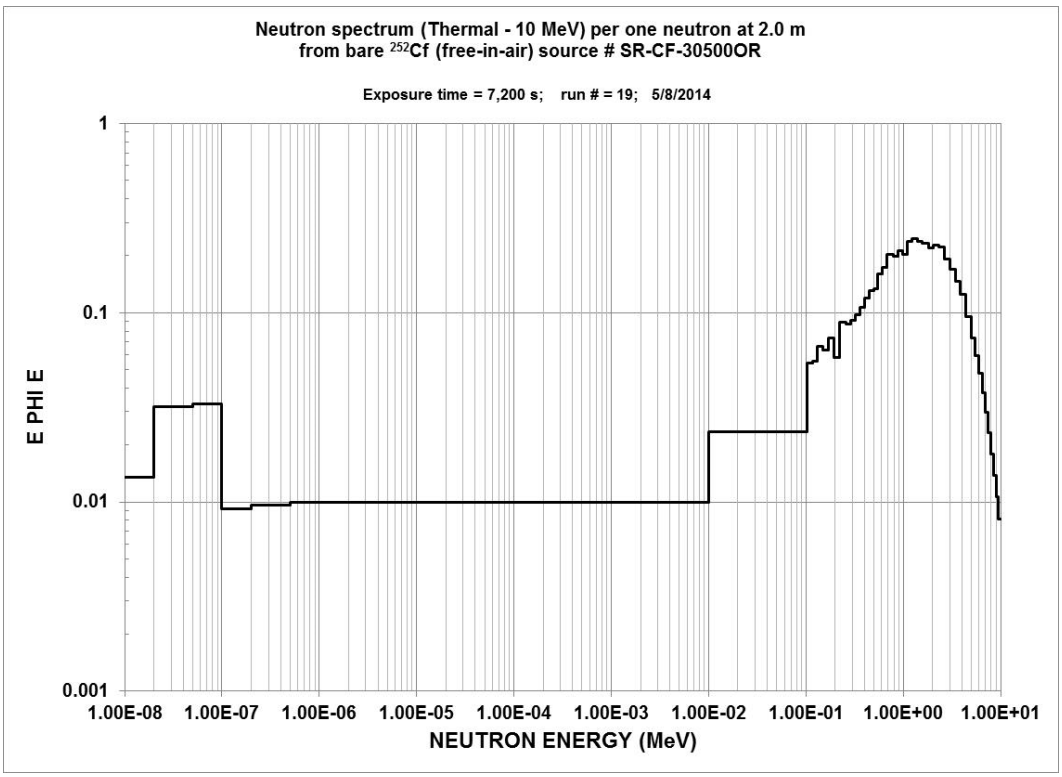
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



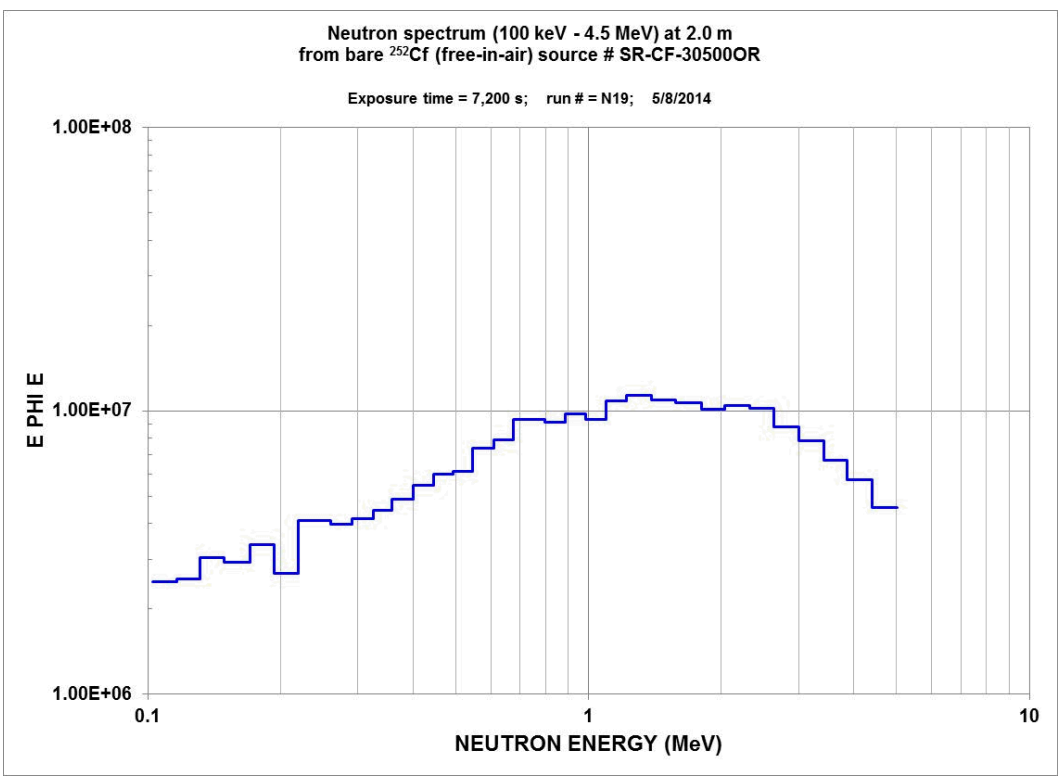


Figure E-1. Neutron spectra at 2.0 m from bare ^{252}Cf

Fluence, spectral and dosimetric data at 2.5 meters from bare ^{252}Cf

Table E-3. Neutron fluence and dosimetric data at 2.5 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date:	5/7/2014
Exposure time:	5,400 s
Run #	N15

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.43E+07	2.65E+03
Epi-thermal region	:	5.27E+06	9.75E+02
Thermal region	:	2.42E+06	4.47E+02
Thermal – 4.5 MeV	:	2.20E+07	4.07E+03
Thermal – 10.0 MeV	:	2.2526E+07	4.1716E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	3.43E-02	5.10E-03	2.29E+01	3.40E+03
Epi-thermal region	:	6.54E-04	1.02E-04	4.36E-01	6.83E+01
Thermal region	:	4.83E-05	2.56E-05	3.22E-02	1.71E+01
Thermal – 4.5 MeV	:	3.50E-02	5.23E-03	2.34E+01	3.49E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	3.6752E-02 rads	2.4501E+01 mrads/hr
H*(10) ICRP-74	=	5.4022E-03 Sv	3.6015E+03 uSv/hr
Hp(10,0) ICRP-74	=	5.5927E-03 Sv	3.7285E+03 uSv/hr

Table E-4. Neutron fluence at 2.5 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date: 5/7/2014
Exposure time: 5,400 s
Run number: N15

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	5.460E+03	5.460E+12	7.877E+03	.1500E-08
.2000E-08	.5000E-08	3.503E+04	1.168E+13	3.823E+04	.3500E-08
.5000E-08	.1000E-07	1.065E+05	2.131E+13	1.537E+05	.7500E-08
.1000E-07	.2000E-07	3.141E+05	3.141E+13	4.531E+05	.1500E-07
.2000E-07	.5000E-07	9.736E+05	3.245E+13	1.063E+06	.3500E-07
.5000E-07	.1000E-06	7.610E+05	1.522E+13	1.098E+06	.7500E-07
.1000E-06	.2000E-06	2.140E+05	2.140E+12	3.088E+05	.1500E-06
.2000E-06	.5000E-06	2.925E+05	9.748E+11	3.192E+05	.3500E-06
.5000E-06	.1000E-01	3.267E+06	3.267E+08	3.299E+05	.5000E-02
.1000E-01	.1027E+00	1.707E+06	1.842E+07	7.331E+05	.5635E-01
.1027E+00	.1166E+00	1.699E+05	1.226E+07	1.342E+06	.1096E+00
.1166E+00	.1317E+00	2.770E+05	1.832E+07	2.271E+06	.1241E+00
.1317E+00	.1493E+00	2.117E+05	1.200E+07	1.684E+06	.1405E+00
.1493E+00	.1707E+00	2.377E+05	1.110E+07	1.773E+06	.1600E+00
.1707E+00	.1934E+00	2.319E+05	1.023E+07	1.860E+06	.1821E+00
.1934E+00	.2199E+00	2.830E+05	1.069E+07	2.207E+06	.2066E+00
.2199E+00	.2606E+00	3.318E+05	8.141E+06	1.951E+06	.2402E+00
.2606E+00	.2906E+00	2.921E+05	9.738E+06	2.681E+06	.2756E+00
.2906E+00	.3244E+00	2.739E+05	8.117E+06	2.493E+06	.3075E+00
.3244E+00	.3581E+00	2.360E+05	6.992E+06	2.384E+06	.3413E+00
.3581E+00	.3994E+00	2.589E+05	6.277E+06	2.375E+06	.3787E+00
.3994E+00	.4444E+00	3.023E+05	6.719E+06	2.832E+06	.4219E+00
.4444E+00	.4931E+00	3.559E+05	7.301E+06	3.419E+06	.4688E+00
.4931E+00	.5456E+00	3.723E+05	7.092E+06	3.680E+06	.5194E+00
.5456E+00	.6094E+00	4.687E+05	7.352E+06	4.241E+06	.5775E+00
.6094E+00	.6769E+00	4.335E+05	6.423E+06	4.127E+06	.6431E+00
.6769E+00	.7946E+00	7.782E+05	6.608E+06	4.852E+06	.7358E+00
.7946E+00	.8870E+00	6.033E+05	6.529E+06	5.484E+06	.8408E+00
.8870E+00	.9871E+00	5.479E+05	5.474E+06	5.124E+06	.9371E+00
.9871E+00	.1095E+01	5.153E+05	4.780E+06	4.972E+06	.1041E+01
.1095E+01	.1218E+01	5.926E+05	4.810E+06	5.558E+06	.1157E+01
.1218E+01	.1391E+01	8.191E+05	4.739E+06	6.173E+06	.1305E+01
.1391E+01	.1573E+01	7.151E+05	3.929E+06	5.815E+06	.1482E+01
.1573E+01	.1807E+01	7.913E+05	3.382E+06	5.706E+06	.1690E+01
.1807E+01	.2041E+01	6.461E+05	2.761E+06	5.306E+06	.1924E+01
.2041E+01	.2327E+01	7.093E+05	2.480E+06	5.409E+06	.2184E+01
.2327E+01	.2639E+01	6.643E+05	2.129E+06	5.279E+06	.2483E+01
.2639E+01	.3003E+01	5.898E+05	1.620E+06	4.565E+06	.2821E+01
.3003E+01	.3419E+01	5.193E+05	1.248E+06	4.003E+06	.3211E+01
.3419E+01	.3861E+01	4.114E+05	9.307E+05	3.384E+06	.3640E+01
.3861E+01	.4407E+01	3.642E+05	6.670E+05	2.753E+06	.4134E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.4407E+01	.5000E+01	2.734E+05	4.610E+05	2.165E+06	.4703E+01
.5000E+01	.5500E+01	1.588E+05	3.177E+05	1.666E+06	.5250E+01
.5500E+01	.6000E+01	1.176E+05	2.353E+05	1.352E+06	.5750E+01
.6000E+01	.6500E+01	8.673E+04	1.735E+05	1.083E+06	.6250E+01
.6500E+01	.7000E+01	6.365E+04	1.273E+05	8.589E+05	.6750E+01
.7000E+01	.7500E+01	4.658E+04	9.317E+04	6.752E+05	.7250E+01
.7500E+01	.8000E+01	3.396E+04	6.793E+04	5.262E+05	.7750E+01
.8000E+01	.8500E+01	2.471E+04	4.941E+04	4.075E+05	.8250E+01
.8500E+01	.9000E+01	1.794E+04	3.587E+04	3.138E+05	.8750E+01
.9000E+01	.9500E+01	1.300E+04	2.600E+04	2.404E+05	.9250E+01
.9500E+01	.1000E+02	9.424E+03	1.885E+04	1.837E+05	.9750E+01

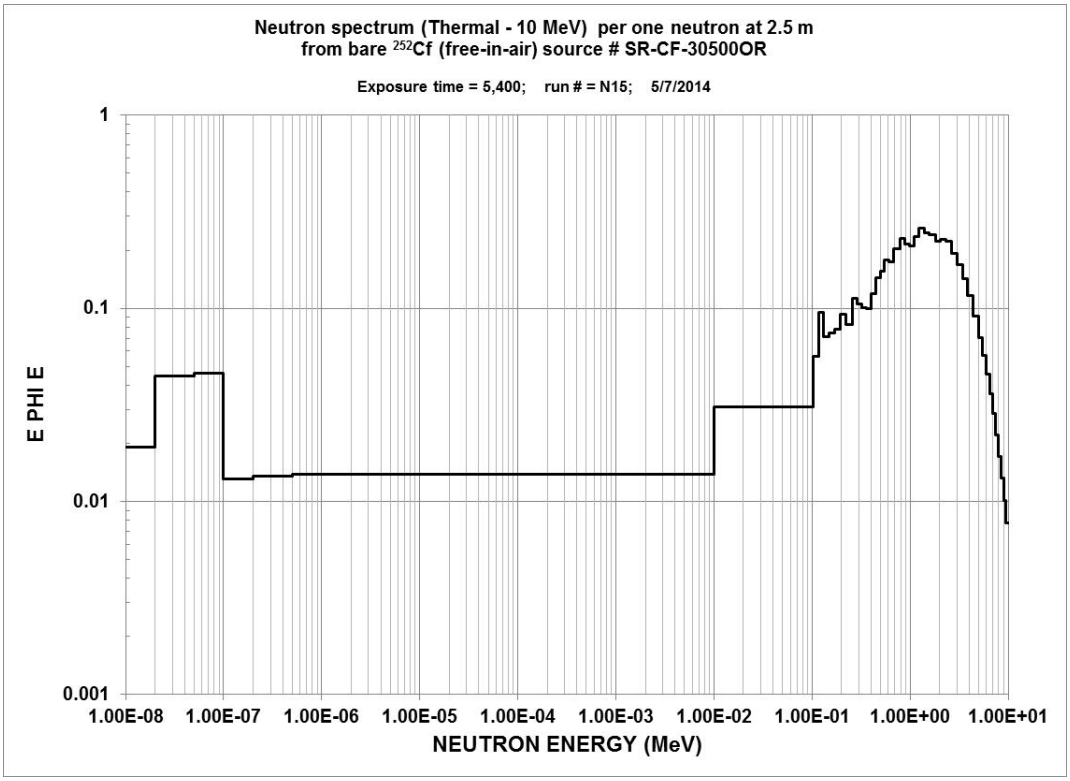
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



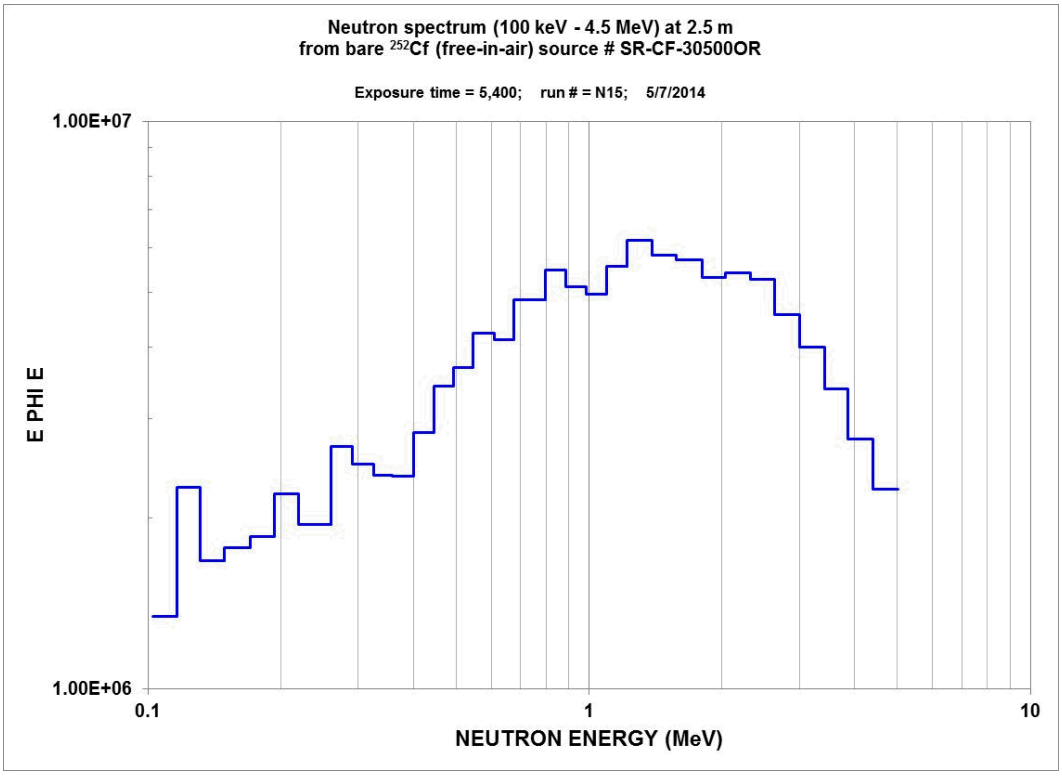


Figure E-2. Neutron spectra at 2.5 m from bare ^{252}Cf

Fluence, spectral and dosimetric data at 3.0 meters from bare ^{252}Cf

Table E-5. Neutron fluence and dosimetric data at 3.0 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date:	5/7/2014
Exposure time:	7,200 s
Run #	N14

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.49E+07	2.07E+03
Epi-thermal region	:	6.79E+06	9.43E+02
Thermal region	:	3.29E+06	4.57E+02
Thermal – 4.5 MeV	:	2.50E+07	3.47E+03
Thermal – 10.0 MeV	:	2.5460E+07	3.5361E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	3.51E-02	5.26E-03	1.75E+01	2.63E+03
Epi-thermal region	:	7.84E-04	1.27E-04	3.92E-01	6.35E+01
Thermal region	:	6.58E-05	3.49E-05	3.29E-02	1.74E+01
Thermal – 4.5 MeV	:	3.59E-02	5.42-03	1.80E+01	2.71E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	3.7385E-02 rads	1.8693E+01 mrads/hr
H*(10) ICRP-74	=	5.5712E-03 Sv	2.7856E+03 uSv/hr
Hp(10,0) ICRP-74	=	5.7664E-03 Sv	2.8832E+03 uSv/hr

Table E-6. Neutron fluence at 3.0 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date: 5/7/2014
Exposure time: 7,200 s
Run number: N14

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	7.434E+03	7.434E+12	1.072E+04	.1500E-08
.2000E-08	.5000E-08	4.770E+04	1.590E+13	5.205E+04	.3500E-08
.5000E-08	.1000E-07	1.451E+05	2.901E+13	2.093E+05	.7500E-08
.1000E-07	.2000E-07	4.276E+05	4.276E+13	6.169E+05	.1500E-07
.2000E-07	.5000E-07	1.326E+06	4.419E+13	1.447E+06	.3500E-07
.5000E-07	.1000E-06	1.036E+06	2.072E+13	1.495E+06	.7500E-07
.1000E-06	.2000E-06	2.914E+05	2.914E+12	4.205E+05	.1500E-06
.2000E-06	.5000E-06	3.946E+05	1.315E+12	4.307E+05	.3500E-06
.5000E-06	.1000E-01	4.369E+06	4.369E+08	4.412E+05	.5000E-02
.1000E-01	.1027E+00	2.027E+06	2.187E+07	8.702E+05	.5635E-01
.1027E+00	.1166E+00	1.648E+05	1.189E+07	1.301E+06	.1096E+00
.1166E+00	.1317E+00	2.314E+05	1.531E+07	1.897E+06	.1241E+00
.1317E+00	.1493E+00	2.574E+05	1.459E+07	2.047E+06	.1405E+00
.1493E+00	.1707E+00	3.517E+05	1.642E+07	2.624E+06	.1600E+00
.1707E+00	.1934E+00	2.184E+05	9.630E+06	1.751E+06	.1821E+00
.1934E+00	.2199E+00	3.103E+05	1.173E+07	2.420E+06	.2066E+00
.2199E+00	.2606E+00	4.256E+05	1.044E+07	2.503E+06	.2402E+00
.2606E+00	.2906E+00	3.047E+05	1.016E+07	2.797E+06	.2756E+00
.2906E+00	.3244E+00	2.872E+05	8.510E+06	2.614E+06	.3075E+00
.3244E+00	.3581E+00	2.701E+05	8.002E+06	2.728E+06	.3413E+00
.3581E+00	.3994E+00	3.154E+05	7.647E+06	2.893E+06	.3787E+00
.3994E+00	.4444E+00	3.403E+05	7.563E+06	3.188E+06	.4219E+00
.4444E+00	.4931E+00	3.434E+05	7.044E+06	3.299E+06	.4688E+00
.4931E+00	.5456E+00	3.887E+05	7.403E+06	3.842E+06	.5194E+00
.5456E+00	.6094E+00	4.989E+05	7.826E+06	4.515E+06	.5775E+00
.6094E+00	.6769E+00	4.807E+05	7.122E+06	4.576E+06	.6431E+00
.6769E+00	.7946E+00	8.957E+05	7.606E+06	5.584E+06	.7358E+00
.7946E+00	.8870E+00	6.138E+05	6.643E+06	5.580E+06	.8408E+00
.8870E+00	.9871E+00	5.502E+05	5.496E+06	5.145E+06	.9371E+00
.9871E+00	.1095E+01	5.267E+05	4.886E+06	5.082E+06	.1041E+01
.1095E+01	.1218E+01	6.255E+05	5.077E+06	5.867E+06	.1157E+01
.1218E+01	.1391E+01	8.609E+05	4.981E+06	6.488E+06	.1305E+01
.1391E+01	.1573E+01	7.197E+05	3.954E+06	5.853E+06	.1482E+01
.1573E+01	.1807E+01	7.820E+05	3.342E+06	5.638E+06	.1690E+01
.1807E+01	.2041E+01	6.209E+05	2.654E+06	5.099E+06	.1924E+01
.2041E+01	.2327E+01	7.082E+05	2.476E+06	5.400E+06	.2184E+01
.2327E+01	.2639E+01	6.615E+05	2.120E+06	5.257E+06	.2483E+01
.2639E+01	.3003E+01	5.854E+05	1.608E+06	4.531E+06	.2821E+01
.3003E+01	.3419E+01	5.225E+05	1.256E+06	4.028E+06	.3211E+01
.3419E+01	.3861E+01	3.749E+05	8.482E+05	3.084E+06	.3640E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.3861E+01	.4407E+01	3.588E+05	6.571E+05	2.712E+06	.4134E+01
.4407E+01	.5000E+01	2.593E+05	4.372E+05	2.054E+06	.4703E+01
.5000E+01	.5500E+01	1.480E+05	2.960E+05	1.553E+06	.5250E+01
.5500E+01	.6000E+01	1.096E+05	2.193E+05	1.260E+06	.5750E+01
.6000E+01	.6500E+01	8.082E+04	1.616E+05	1.010E+06	.6250E+01
.6500E+01	.7000E+01	5.932E+04	1.186E+05	8.005E+05	.6750E+01
.7000E+01	.7500E+01	4.341E+04	8.683E+04	6.292E+05	.7250E+01
.7500E+01	.8000E+01	3.165E+04	6.330E+04	4.904E+05	.7750E+01
.8000E+01	.8500E+01	2.303E+04	4.605E+04	3.798E+05	.8250E+01
.8500E+01	.9000E+01	1.671E+04	3.343E+04	2.924E+05	.8750E+01
.9000E+01	.9500E+01	1.212E+04	2.423E+04	2.241E+05	.9250E+01
.9500E+01	.1000E+02	8.783E+03	1.757E+04	1.712E+05	.9750E+01

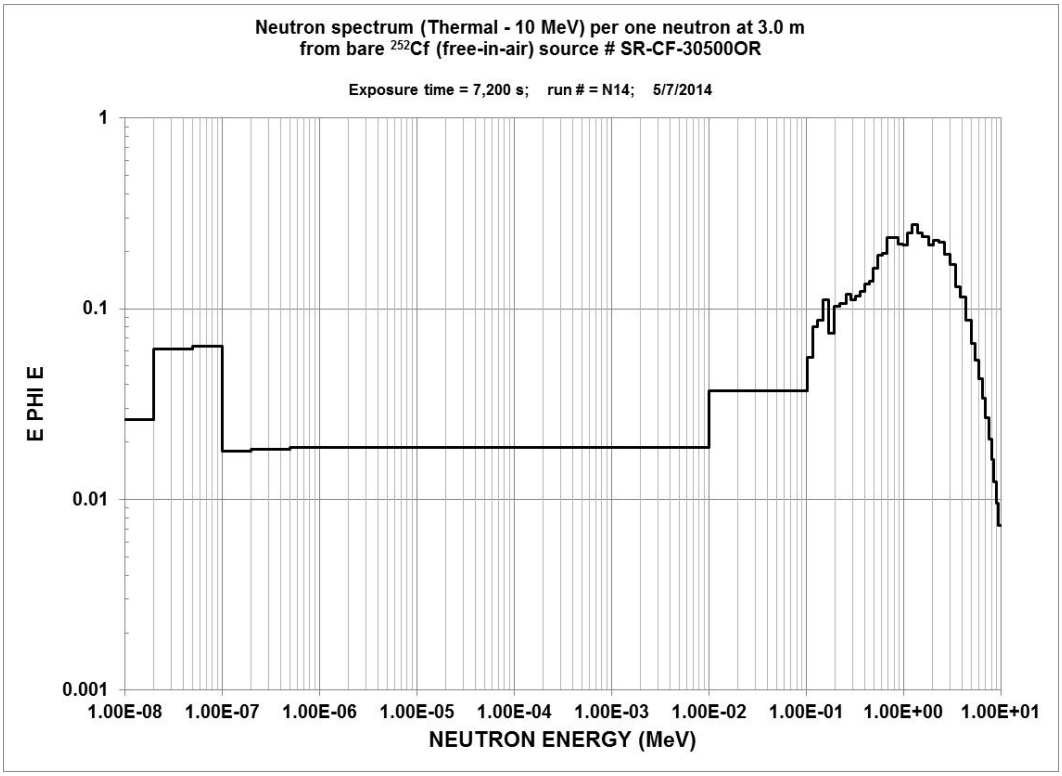
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



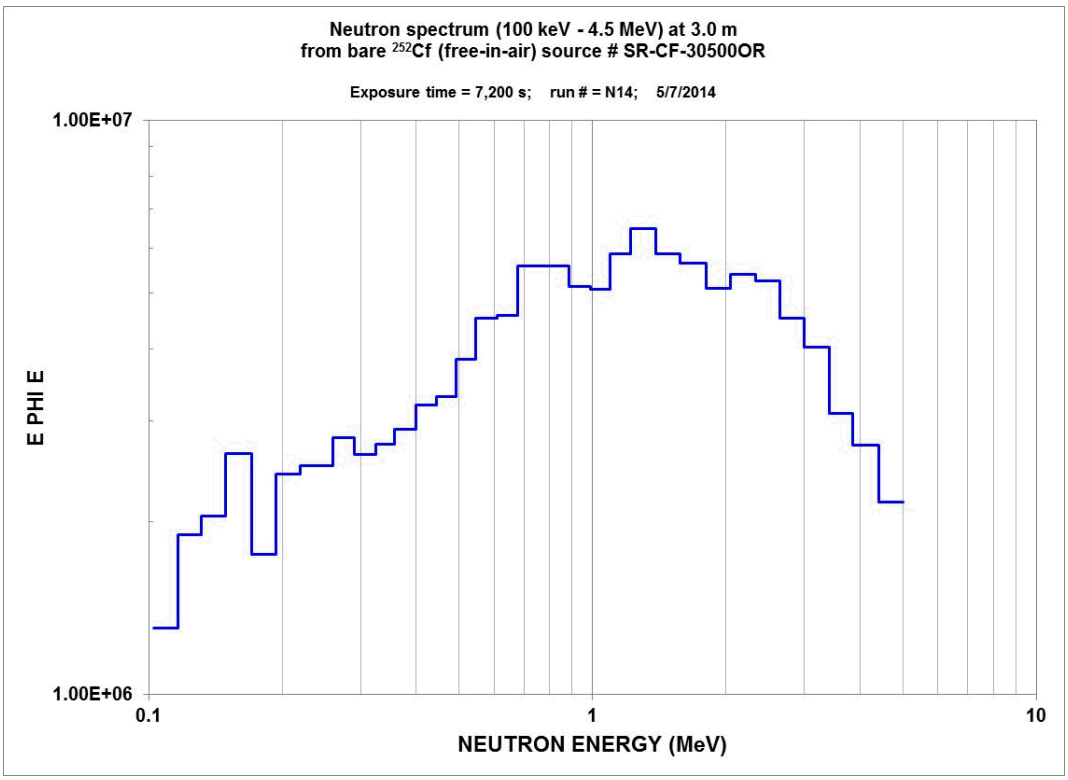


Figure E-3. Neutron spectra at 3.0 m from bare ^{252}Cf

Fluence, spectral and dosimetric data at 3.5 meters from bare ^{252}Cf

Table E-7. Neutron fluence and dosimetric data at 3.5 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date:	5/6/2014
Exposure time:	5,400 s
Run #	N10

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	9.12E+06	1.69E+03
Epi-thermal region	:	4.96E+06	9.19E+02
Thermal region	:	2.45E+06	4.54E+02
Thermal – 4.5 MeV	:	1.65E+07	3.06E+03
Thermal – 10 MeV	:	1.6818E+07	3.1144E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	2.11E-02	3.18E-03	1.40E+01	2.12E+03
Epi-thermal region	:	5.75E-04	9.30E-05	3.83E-01	6.20E+01
Thermal region	:	4.90E-05	2.60E-05	3.27E-02	1.73E+01
Thermal – 4.5 MeV	:	2.17E-02	3.30E-03	1.45E+01	2.20E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.2488E-02 rads	1.4992E+01 mrads/hr
H*(10) ICRP-74	=	3.3825E-03 Sv	2.2550E+03 uSv/hr
Hp(10,0) ICRP-74	=	3.5006E-03 Sv	2.3337E+03 uSv/hr

Table E-8. Neutron fluence at 3.5 m from bare ^{252}Cf (free in air) source # SR-CF-30500-OR

Date: 5/6/2014
Exposure time: 5,400 s
Run number: N10

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	5.537E+03	5.537E+12	7.988E+03	.1500E-08
.2000E-08	.5000E-08	3.552E+04	1.184E+13	3.877E+04	.3500E-08
.5000E-08	.1000E-07	1.080E+05	2.161E+13	1.559E+05	.7500E-08
.1000E-07	.2000E-07	3.185E+05	3.185E+13	4.595E+05	.1500E-07
.2000E-07	.5000E-07	9.873E+05	3.291E+13	1.077E+06	.3500E-07
.5000E-07	.1000E-06	7.717E+05	1.543E+13	1.113E+06	.7500E-07
.1000E-06	.2000E-06	2.171E+05	2.171E+12	3.131E+05	.1500E-06
.2000E-06	.5000E-06	2.907E+05	9.691E+11	3.173E+05	.3500E-06
.5000E-06	.1000E-01	3.184E+06	3.184E+08	3.215E+05	.5000E-02
.1000E-01	.1027E+00	1.487E+06	1.605E+07	6.386E+05	.5635E-01
.1027E+00	.1166E+00	1.589E+05	1.147E+07	1.255E+06	.1096E+00
.1166E+00	.1317E+00	1.958E+05	1.295E+07	1.605E+06	.1241E+00
.1317E+00	.1493E+00	1.560E+05	8.844E+06	1.241E+06	.1405E+00
.1493E+00	.1707E+00	1.420E+05	6.630E+06	1.059E+06	.1600E+00
.1707E+00	.1934E+00	2.049E+05	9.036E+06	1.643E+06	.1821E+00
.1934E+00	.2199E+00	1.718E+05	6.493E+06	1.340E+06	.2066E+00
.2199E+00	.2606E+00	2.710E+05	6.650E+06	1.594E+06	.2402E+00
.2606E+00	.2906E+00	2.210E+05	7.366E+06	2.028E+06	.2756E+00
.2906E+00	.3244E+00	2.115E+05	6.268E+06	1.925E+06	.3075E+00
.3244E+00	.3581E+00	1.913E+05	5.667E+06	1.932E+06	.3413E+00
.3581E+00	.3994E+00	1.569E+05	3.804E+06	1.439E+06	.3787E+00
.3994E+00	.4444E+00	1.762E+05	3.916E+06	1.651E+06	.4219E+00
.4444E+00	.4931E+00	2.332E+05	4.785E+06	2.241E+06	.4688E+00
.4931E+00	.5456E+00	2.538E+05	4.835E+06	2.509E+06	.5194E+00
.5456E+00	.6094E+00	3.247E+05	5.094E+06	2.939E+06	.5775E+00
.6094E+00	.6769E+00	2.992E+05	4.432E+06	2.848E+06	.6431E+00
.6769E+00	.7946E+00	5.163E+05	4.384E+06	3.219E+06	.7358E+00
.7946E+00	.8870E+00	4.051E+05	4.385E+06	3.683E+06	.8408E+00
.8870E+00	.9871E+00	3.194E+05	3.191E+06	2.987E+06	.9371E+00
.9871E+00	.1095E+01	3.247E+05	3.012E+06	3.133E+06	.1041E+01
.1095E+01	.1218E+01	3.842E+05	3.119E+06	3.603E+06	.1157E+01
.1218E+01	.1391E+01	5.174E+05	2.993E+06	3.899E+06	.1305E+01
.1391E+01	.1573E+01	4.225E+05	2.321E+06	3.436E+06	.1482E+01
.1573E+01	.1807E+01	4.709E+05	2.012E+06	3.395E+06	.1690E+01
.1807E+01	.2041E+01	3.762E+05	1.608E+06	3.090E+06	.1924E+01
.2041E+01	.2327E+01	4.180E+05	1.462E+06	3.188E+06	.2184E+01
.2327E+01	.2639E+01	3.873E+05	1.241E+06	3.078E+06	.2483E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2639E+01	.3003E+01	3.452E+05	9.484E+05	2.672E+06	.2821E+01
.3003E+01	.3419E+01	2.924E+05	7.030E+05	2.254E+06	.3211E+01
.3419E+01	.3861E+01	2.025E+05	4.581E+05	1.665E+06	.3640E+01
.3861E+01	.4407E+01	2.083E+05	3.814E+05	1.574E+06	.4134E+01
.4407E+01	.5000E+01	1.490E+05	2.512E+05	1.180E+06	.4703E+01
.5000E+01	.5500E+01	8.435E+04	1.687E+05	8.850E+05	.5250E+01
.5500E+01	.6000E+01	6.247E+04	1.249E+05	7.180E+05	.5750E+01
.6000E+01	.6500E+01	4.606E+04	9.212E+04	5.754E+05	.6250E+01
.6500E+01	.7000E+01	3.381E+04	6.761E+04	4.562E+05	.6750E+01
.7000E+01	.7500E+01	2.474E+04	4.948E+04	3.586E+05	.7250E+01
.7500E+01	.8000E+01	1.804E+04	3.607E+04	2.795E+05	.7750E+01
.8000E+01	.8500E+01	1.312E+04	2.624E+04	2.164E+05	.8250E+01
.8500E+01	.9000E+01	9.525E+03	1.905E+04	1.666E+05	.8750E+01
.9000E+01	.9500E+01	6.904E+03	1.381E+04	1.277E+05	.9250E+01
.9500E+01	.1000E+02	5.005E+03	1.001E+04	9.758E+04	.9750E+01

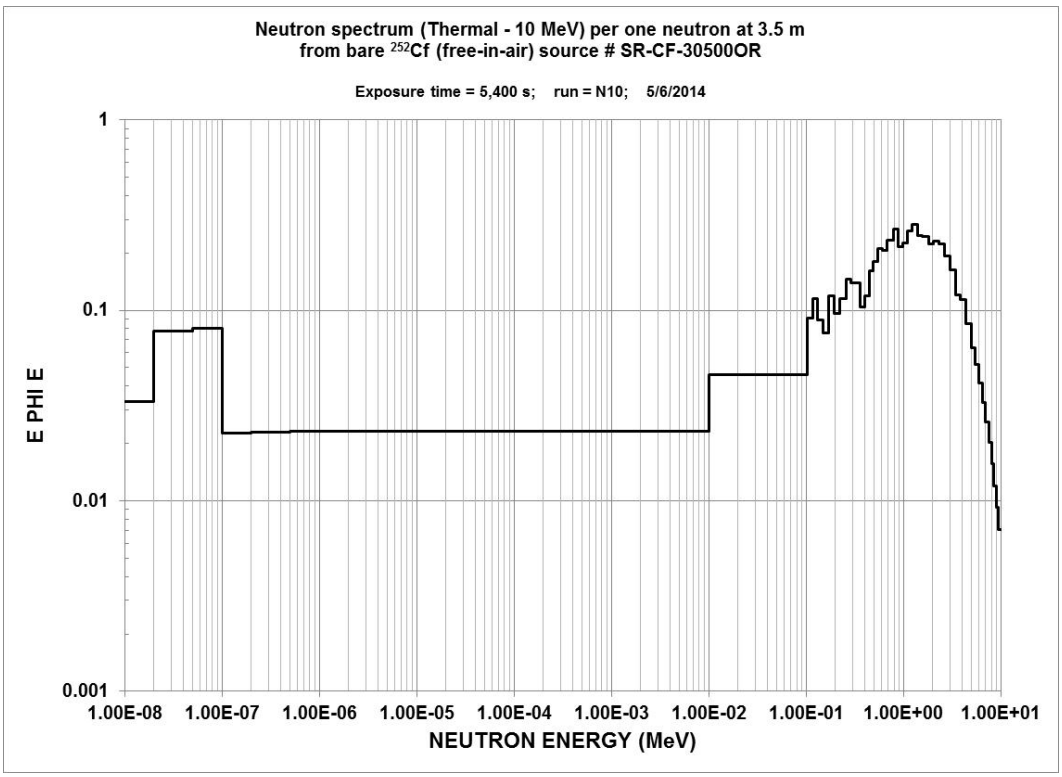
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



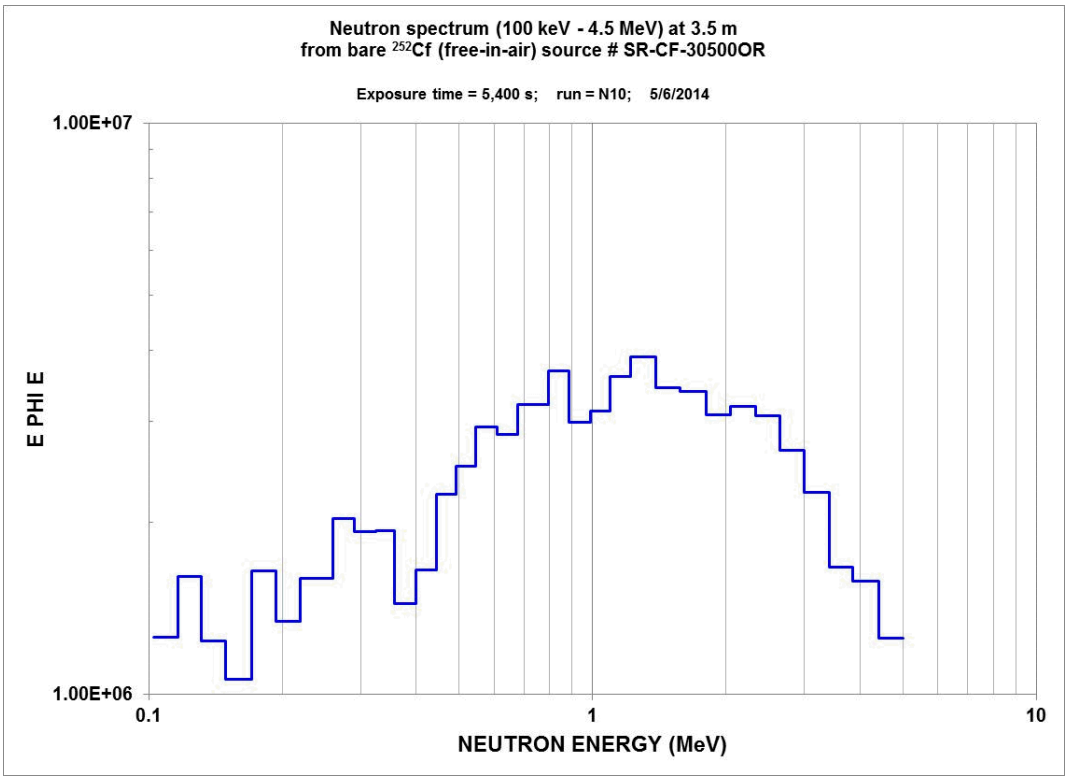


Figure E-4. Neutron spectra at 3.5 m from bare ^{252}Cf

Fluence, spectral and dosimetric data at 4.0 meters from bare ^{252}Cf

Table E-9. Neutron fluence and dosimetric data at 4.0 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date:	5/6/2014
Exposure time:	7,200 s
Run #	N11

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.04E+07	1.44E+03
Epi-thermal region	:	6.50E+06	9.02E+02
Thermal region	:	3.27E+06	4.54E+02
Thermal – 4.5 MeV	:	2.02E+07	2.80E+03
Thermal – 10 MeV	:	2.0440E+07	2.8389E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	2.36E-02	3.60E-03	1.18E+01	1.80E+03
Epi-thermal region	:	7.13E-04	1.18E-04	3.57E-01	5.92E+01
Thermal region	:	6.54E-05	3.47E-05	3.27E-02	1.73E+01
Thermal – 4.5 MeV	:	2.44E-02	3.75E-03	1.22E+01	1.88E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.5125E-02 rads	1.2563E+01 mrads/hr
H*(10) ICRP-74	=	3.8265E-03 Sv	1.9133E+03 uSv/hr
Hp(10,0) ICRP-74	=	3.9597E-03 Sv	1.9799E+03 uSv/hr

Table E-10. Neutron fluence at 4.0 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date: 5/6/2014
Exposure time: 7,200 s
Run number: N11

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	7.394E+03	7.394E+12	1.067E+04	.1500E-08
.2000E-08	.5000E-08	4.744E+04	1.581E+13	5.177E+04	.3500E-08
.5000E-08	.1000E-07	1.443E+05	2.886E+13	2.082E+05	.7500E-08
.1000E-07	.2000E-07	4.253E+05	4.253E+13	6.136E+05	.1500E-07
.2000E-07	.5000E-07	1.319E+06	4.395E+13	1.439E+06	.3500E-07
.5000E-07	.1000E-06	1.031E+06	2.061E+13	1.487E+06	.7500E-07
.1000E-06	.2000E-06	2.899E+05	2.899E+12	4.182E+05	.1500E-06
.2000E-06	.5000E-06	3.894E+05	1.298E+12	4.249E+05	.3500E-06
.5000E-06	.1000E-01	4.276E+06	4.277E+08	4.318E+05	.5000E-02
.1000E-01	.1027E+00	1.831E+06	1.976E+07	7.862E+05	.5635E-01
.1027E+00	.1166E+00	1.884E+05	1.359E+07	1.488E+06	.1096E+00
.1166E+00	.1317E+00	1.396E+05	9.231E+06	1.144E+06	.1241E+00
.1317E+00	.1493E+00	2.476E+05	1.403E+07	1.969E+06	.1405E+00
.1493E+00	.1707E+00	2.095E+05	9.782E+06	1.563E+06	.1600E+00
.1707E+00	.1934E+00	2.073E+05	9.138E+06	1.662E+06	.1821E+00
.1934E+00	.2199E+00	2.117E+05	8.001E+06	1.651E+06	.2066E+00
.2199E+00	.2606E+00	3.676E+05	9.019E+06	2.161E+06	.2402E+00
.2606E+00	.2906E+00	2.025E+05	6.750E+06	1.859E+06	.2756E+00
.2906E+00	.3244E+00	2.364E+05	7.005E+06	2.152E+06	.3075E+00
.3244E+00	.3581E+00	2.224E+05	6.591E+06	2.247E+06	.3413E+00
.3581E+00	.3994E+00	2.320E+05	5.624E+06	2.128E+06	.3787E+00
.3994E+00	.4444E+00	2.224E+05	4.942E+06	2.083E+06	.4219E+00
.4444E+00	.4931E+00	2.620E+05	5.375E+06	2.517E+06	.4688E+00
.4931E+00	.5456E+00	2.867E+05	5.461E+06	2.834E+06	.5194E+00
.5456E+00	.6094E+00	3.548E+05	5.566E+06	3.211E+06	.5775E+00
.6094E+00	.6769E+00	3.914E+05	5.798E+06	3.726E+06	.6431E+00
.6769E+00	.7946E+00	6.581E+05	5.588E+06	4.103E+06	.7358E+00
.7946E+00	.8870E+00	4.607E+05	4.986E+06	4.188E+06	.8408E+00
.8870E+00	.9871E+00	4.062E+05	4.058E+06	3.799E+06	.9371E+00
.9871E+00	.1095E+01	3.188E+05	2.957E+06	3.076E+06	.1041E+01
.1095E+01	.1218E+01	4.275E+05	3.470E+06	4.010E+06	.1157E+01
.1218E+01	.1391E+01	5.617E+05	3.250E+06	4.233E+06	.1305E+01
.1391E+01	.1573E+01	4.749E+05	2.609E+06	3.862E+06	.1482E+01
.1573E+01	.1807E+01	4.979E+05	2.128E+06	3.590E+06	.1690E+01
.1807E+01	.2041E+01	4.103E+05	1.753E+06	3.369E+06	.1924E+01
.2041E+01	.2327E+01	4.631E+05	1.619E+06	3.531E+06	.2184E+01
.2327E+01	.2639E+01	4.255E+05	1.364E+06	3.382E+06	.2483E+01
.2639E+01	.3003E+01	3.687E+05	1.013E+06	2.854E+06	.2821E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.3003E+01	.3419E+01	2.977E+05	7.156E+05	2.295E+06	.3211E+01
.3419E+01	.3861E+01	2.439E+05	5.518E+05	2.006E+06	.3640E+01
.3861E+01	.4407E+01	2.289E+05	4.192E+05	1.731E+06	.4134E+01
.4407E+01	.5000E+01	1.496E+05	2.522E+05	1.185E+06	.4703E+01
.5000E+01	.5500E+01	8.436E+04	1.687E+05	8.851E+05	.5250E+01
.5500E+01	.6000E+01	6.248E+04	1.250E+05	7.180E+05	.5750E+01
.6000E+01	.6500E+01	4.606E+04	9.212E+04	5.755E+05	.6250E+01
.6500E+01	.7000E+01	3.381E+04	6.762E+04	4.562E+05	.6750E+01
.7000E+01	.7500E+01	2.474E+04	4.948E+04	3.586E+05	.7250E+01
.7500E+01	.8000E+01	1.804E+04	3.608E+04	2.795E+05	.7750E+01
.8000E+01	.8500E+01	1.312E+04	2.624E+04	2.165E+05	.8250E+01
.8500E+01	.9000E+01	9.526E+03	1.905E+04	1.667E+05	.8750E+01
.9000E+01	.9500E+01	6.904E+03	1.381E+04	1.277E+05	.9250E+01
.9500E+01	.1000E+02	5.005E+03	1.001E+04	9.758E+04	.9750E+01

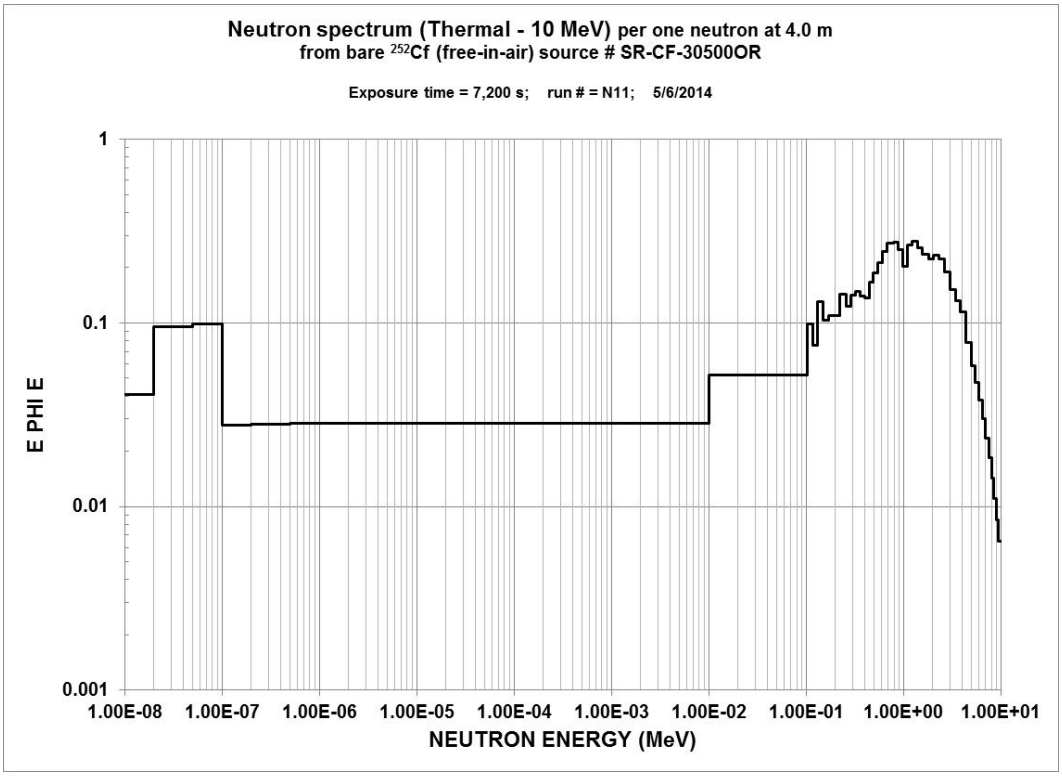
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



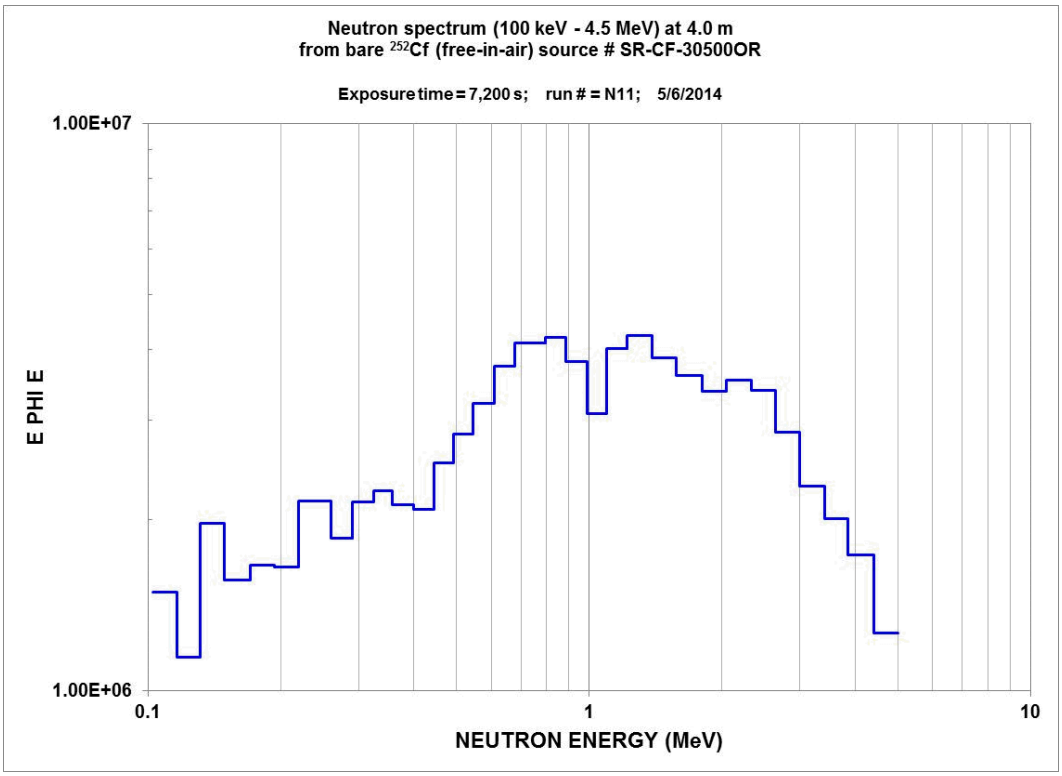


Figure E-5. Neutron spectra at 4.0 m from bare ^{252}Cf

Fluence, spectral and dosimetric data at 4.5 meters from bare ^{252}Cf

Table E-11. Neutron fluence and dosimetric data at 4.5 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date:	5/7/2014
Exposure time:	57,600 s
Run #	N12

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	7.35E+07	1.28E+03
Epi-thermal region	:	5.12E+07	8.88E+02
Thermal region	:	2.59E+07	4.50E+02
Thermal – 4.5 MeV	:	1.51E+08	2.61E+03
Thermal - 10 MeV	:	1.5240E+08	2.6459E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr))	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.63E-01	2.51E-02	1.02E+01	1.57E+03
Epi-thermal region	:	5.72E-03	9.41E-04	3.57E-01	5.88E+01
Thermal region	:	5.19E-04	2.75E-04	3.24E-02	1.72E+01
Thermal – 4.5 MeV	:	1.70E-01	2.63E-02	1.06E+01	1.65E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.7395E-01 rads	1.0872E+01 mrads/hr
H*(10) ICRP-74	=	2.6744E-02 Sv	1.6715E+03 uSv/hr
Hp(10,0) ICRP-74	=	2.7672E-02 Sv	1.7295E+03 uSv/hr

Table E-12. Neutron fluence at 4.5 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date: 5/6/2014
Exposure time: 57,600 s
Run number: N12

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	5.862E+04	5.862E+13	8.457E+04	.1500E-08
.2000E-08	.5000E-08	3.761E+05	1.254E+14	4.105E+05	.3500E-08
.5000E-08	.1000E-07	1.144E+06	2.288E+14	1.650E+06	.7500E-08
.1000E-07	.2000E-07	3.372E+06	3.372E+14	4.865E+06	.1500E-07
.2000E-07	.5000E-07	1.045E+07	3.484E+14	1.141E+07	.3500E-07
.5000E-07	.1000E-06	8.170E+06	1.634E+14	1.179E+07	.7500E-07
.1000E-06	.2000E-06	2.298E+06	2.298E+13	3.315E+06	.1500E-06
.2000E-06	.5000E-06	3.063E+06	1.021E+13	3.343E+06	.3500E-06
.5000E-06	.1000E-01	3.338E+07	3.339E+09	3.371E+06	.5000E-02
.1000E-01	.1027E+00	1.472E+07	1.588E+08	6.319E+06	.5635E-01
.1027E+00	.1166E+00	1.490E+06	1.075E+08	1.177E+07	.1096E+00
.1166E+00	.1317E+00	1.451E+06	9.595E+07	1.189E+07	.1241E+00
.1317E+00	.1493E+00	1.689E+06	9.573E+07	1.343E+07	.1405E+00
.1493E+00	.1707E+00	1.754E+06	8.188E+07	1.308E+07	.1600E+00
.1707E+00	.1934E+00	1.549E+06	6.831E+07	1.242E+07	.1821E+00
.1934E+00	.2199E+00	1.674E+06	6.327E+07	1.306E+07	.2066E+00
.2199E+00	.2606E+00	2.567E+06	6.298E+07	1.509E+07	.2402E+00
.2606E+00	.2906E+00	1.670E+06	5.568E+07	1.533E+07	.2756E+00
.2906E+00	.3244E+00	1.786E+06	5.292E+07	1.626E+07	.3075E+00
.3244E+00	.3581E+00	1.547E+06	4.582E+07	1.562E+07	.3413E+00
.3581E+00	.3994E+00	1.551E+06	3.761E+07	1.423E+07	.3787E+00
.3994E+00	.4444E+00	1.569E+06	3.486E+07	1.469E+07	.4219E+00
.4444E+00	.4931E+00	1.914E+06	3.925E+07	1.838E+07	.4688E+00
.4931E+00	.5456E+00	2.102E+06	4.004E+07	2.078E+07	.5194E+00
.5456E+00	.6094E+00	2.624E+06	4.116E+07	2.374E+07	.5775E+00
.6094E+00	.6769E+00	2.697E+06	3.996E+07	2.568E+07	.6431E+00
.6769E+00	.7946E+00	4.682E+06	3.976E+07	2.919E+07	.7358E+00
.7946E+00	.8870E+00	3.301E+06	3.573E+07	3.001E+07	.8408E+00
.8870E+00	.9871E+00	2.688E+06	2.685E+07	2.514E+07	.9371E+00
.9871E+00	.1095E+01	2.420E+06	2.245E+07	2.335E+07	.1041E+01
.1095E+01	.1218E+01	2.992E+06	2.428E+07	2.806E+07	.1157E+01
.1218E+01	.1391E+01	3.822E+06	2.211E+07	2.880E+07	.1305E+01
.1391E+01	.1573E+01	3.276E+06	1.800E+07	2.664E+07	.1482E+01
.1573E+01	.1807E+01	3.400E+06	1.453E+07	2.452E+07	.1690E+01
.1807E+01	.2041E+01	2.737E+06	1.170E+07	2.248E+07	.1924E+01
.2041E+01	.2327E+01	3.088E+06	1.080E+07	2.354E+07	.2184E+01
.2327E+01	.2639E+01	2.951E+06	9.458E+06	2.345E+07	.2483E+01
.2639E+01	.3003E+01	2.460E+06	6.759E+06	1.904E+07	.2821E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.3003E+01	.3419E+01	2.042E+06	4.908E+06	1.574E+07	.3211E+01
.3419E+01	.3861E+01	1.512E+06	3.420E+06	1.243E+07	.3640E+01
.3861E+01	.4407E+01	1.426E+06	2.613E+06	1.078E+07	.4134E+01
.4407E+01	.5000E+01	9.725E+05	1.640E+06	7.703E+06	.4703E+01
.5000E+01	.5500E+01	5.444E+05	1.089E+06	5.712E+06	.5250E+01
.5500E+01	.6000E+01	4.032E+05	8.065E+05	4.634E+06	.5750E+01
.6000E+01	.6500E+01	2.973E+05	5.946E+05	3.714E+06	.6250E+01
.6500E+01	.7000E+01	2.182E+05	4.364E+05	2.944E+06	.6750E+01
.7000E+01	.7500E+01	1.597E+05	3.194E+05	2.315E+06	.7250E+01
.7500E+01	.8000E+01	1.164E+05	2.328E+05	1.804E+06	.7750E+01
.8000E+01	.8500E+01	8.469E+04	1.694E+05	1.397E+06	.8250E+01
.8500E+01	.9000E+01	6.148E+04	1.230E+05	1.076E+06	.8750E+01
.9000E+01	.9500E+01	4.456E+04	8.912E+04	8.242E+05	.9250E+01
.9500E+01	.1000E+02	3.231E+04	6.461E+04	6.298E+05	.9750E+01

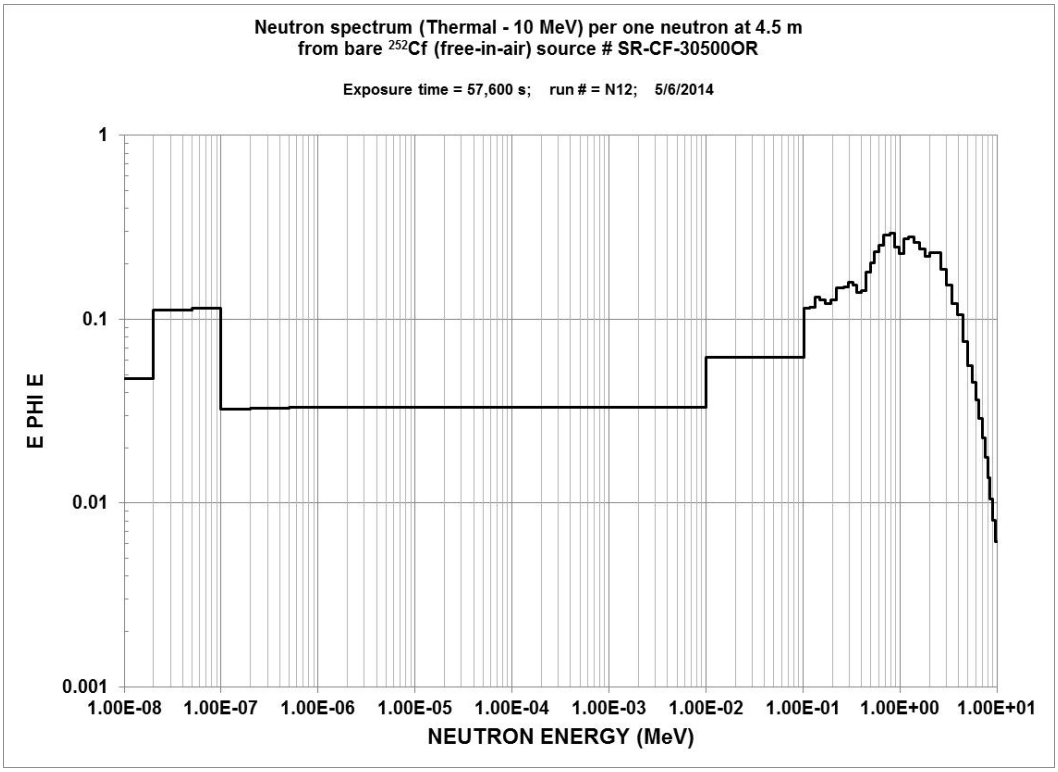
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



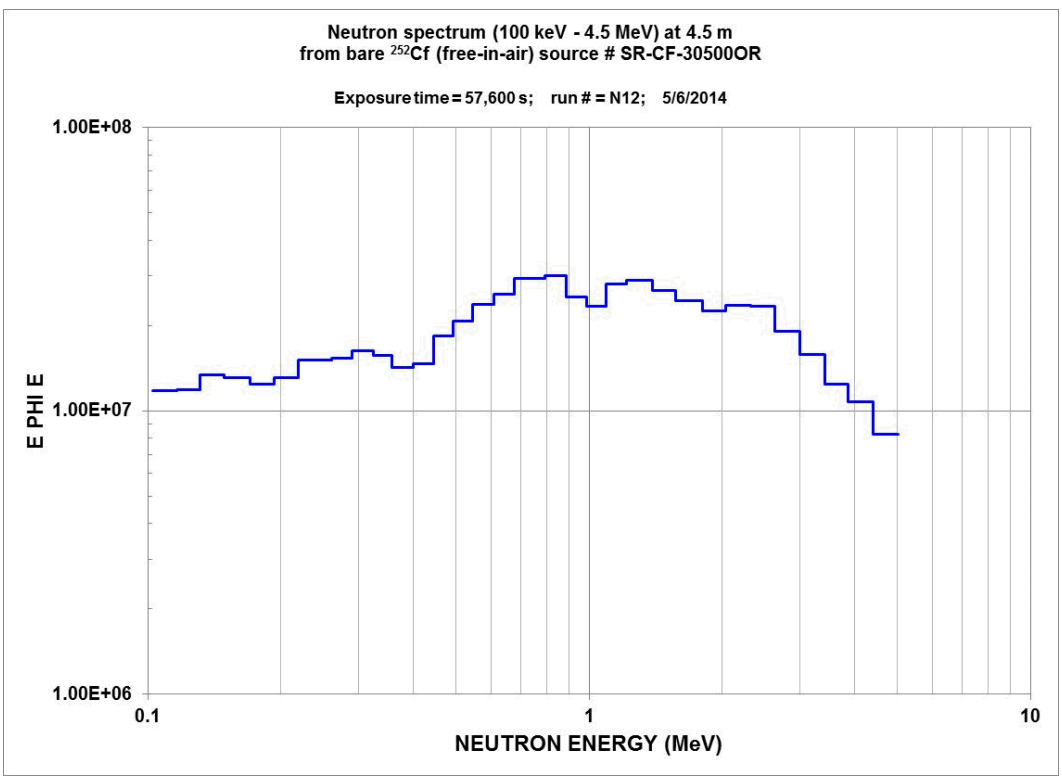


Figure E-6. Neutron spectra at 4.5 m from bare ^{252}Cf

Fluence, spectral and dosimetric data at 5.0 meters from bare ^{252}Cf

Table E-13. Neutron fluence and dosimetric data at 5.0 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date:	5/7/2014
Exposure time:	10,800 s
Run #	N13

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.24E+07	1.15E+03
Epi-thermal region	:	9.48E+06	8.78E+02
Thermal region	:	4.91E+06	4.55E+02
Thermal – 4.5 MeV	:	2.68E+07	2.48E+03
Thermal – 10.0 MeV	:	2.7106E+07	2.5098E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV- 4.5 MeV	:	2.73E-02	4.22E-03	9.09E+00	1.41E+03
Epi-thermal region	:	1.03E-03	1.72E-04	3.42E-01	5.72E+01
Thermal region	:	9.82E-05	5.21E-05	3.27E-02	1.74E+01
Thermal – 4.5 MeV	:	2.84E-02	4.44E-03	9.46E+00	1.48E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.8948E-02 rads	9.6492E+00 mrads/hr
H*(10) ICRP-74	=	4.4930E-03 Sv	1.4977E+03 uSv/hr
Hp(10,0) ICRP-74	=	4.6486E-03 Sv	1.5495E+03 uSv/hr

Table E-14. Neutron fluence at 5.0 m from bare ^{252}Cf (free in air) source # SR-CF-3050-OR

Date: 5/7/2014
Exposure time: 10,800 s
Run number: N13

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	1.110E+04	1.110E+13	1.602E+04	.1500E-08
.2000E-08	.5000E-08	7.122E+04	2.374E+13	7.773E+04	.3500E-08
.5000E-08	.1000E-07	2.166E+05	4.332E+13	3.125E+05	.7500E-08
.1000E-07	.2000E-07	6.386E+05	6.386E+13	9.213E+05	.1500E-07
.2000E-07	.5000E-07	1.980E+06	6.599E+13	2.160E+06	.3500E-07
.5000E-07	.1000E-06	1.547E+06	3.095E+13	2.232E+06	.7500E-07
.1000E-06	.2000E-06	4.352E+05	4.352E+12	6.279E+05	.1500E-06
.2000E-06	.5000E-06	5.778E+05	1.926E+12	6.306E+05	.3500E-06
.5000E-06	.1000E-01	6.273E+06	6.273E+08	6.334E+05	.5000E-02
.1000E-01	.1027E+00	2.627E+06	2.835E+07	1.128E+06	.5635E-01
.1027E+00	.1166E+00	2.120E+05	1.530E+07	1.675E+06	.1096E+00
.1166E+00	.1317E+00	2.159E+05	1.428E+07	1.770E+06	.1241E+00
.1317E+00	.1493E+00	3.922E+05	2.223E+07	3.120E+06	.1405E+00
.1493E+00	.1707E+00	3.121E+05	1.457E+07	2.328E+06	.1600E+00
.1707E+00	.1934E+00	2.720E+05	1.199E+07	2.181E+06	.1821E+00
.1934E+00	.2199E+00	2.485E+05	9.390E+06	1.938E+06	.2066E+00
.2199E+00	.2606E+00	5.228E+05	1.283E+07	3.074E+06	.2402E+00
.2606E+00	.2906E+00	3.023E+05	1.008E+07	2.775E+06	.2756E+00
.2906E+00	.3244E+00	3.206E+05	9.498E+06	2.918E+06	.3075E+00
.3244E+00	.3581E+00	2.646E+05	7.839E+06	2.673E+06	.3413E+00
.3581E+00	.3994E+00	2.803E+05	6.795E+06	2.571E+06	.3787E+00
.3994E+00	.4444E+00	2.599E+05	5.775E+06	2.434E+06	.4219E+00
.4444E+00	.4931E+00	3.228E+05	6.621E+06	3.101E+06	.4688E+00
.4931E+00	.5456E+00	3.625E+05	6.905E+06	3.583E+06	.5194E+00
.5456E+00	.6094E+00	4.778E+05	7.494E+06	4.324E+06	.5775E+00
.6094E+00	.6769E+00	4.555E+05	6.748E+06	4.336E+06	.6431E+00
.6769E+00	.7946E+00	7.793E+05	6.618E+06	4.859E+06	.7358E+00
.7946E+00	.8870E+00	5.504E+05	5.957E+06	5.004E+06	.8408E+00
.8870E+00	.9871E+00	4.714E+05	4.710E+06	4.409E+06	.9371E+00
.9871E+00	.1095E+01	3.891E+05	3.610E+06	3.754E+06	.1041E+01
.1095E+01	.1218E+01	5.010E+05	4.067E+06	4.699E+06	.1157E+01
.1218E+01	.1391E+01	6.343E+05	3.669E+06	4.780E+06	.1305E+01
.1391E+01	.1573E+01	5.360E+05	2.945E+06	4.359E+06	.1482E+01
.1573E+01	.1807E+01	5.754E+05	2.459E+06	4.149E+06	.1690E+01
.1807E+01	.2041E+01	4.443E+05	1.899E+06	3.648E+06	.1924E+01
.2041E+01	.2327E+01	5.066E+05	1.771E+06	3.863E+06	.2184E+01
.2327E+01	.2639E+01	4.729E+05	1.516E+06	3.758E+06	.2483E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2639E+01	.3003E+01	3.934E+05	1.081E+06	3.045E+06	.2821E+01
.3003E+01	.3419E+01	3.330E+05	8.004E+05	2.566E+06	.3211E+01
.3419E+01	.3861E+01	2.453E+05	5.549E+05	2.017E+06	.3640E+01
.3861E+01	.4407E+01	2.161E+05	3.957E+05	1.633E+06	.4134E+01
.4407E+01	.5000E+01	1.571E+05	2.649E+05	1.244E+06	.4703E+01
.5000E+01	.5500E+01	8.349E+04	1.670E+05	8.760E+05	.5250E+01
.5500E+01	.6000E+01	6.183E+04	1.237E+05	7.106E+05	.5750E+01
.6000E+01	.6500E+01	4.559E+04	9.117E+04	5.695E+05	.6250E+01
.6500E+01	.7000E+01	3.346E+04	6.692E+04	4.515E+05	.6750E+01
.7000E+01	.7500E+01	2.449E+04	4.897E+04	3.549E+05	.7250E+01
.7500E+01	.8000E+01	1.785E+04	3.570E+04	2.766E+05	.7750E+01
.8000E+01	.8500E+01	1.299E+04	2.597E+04	2.142E+05	.8250E+01
.8500E+01	.9000E+01	9.428E+03	1.886E+04	1.649E+05	.8750E+01
.9000E+01	.9500E+01	6.833E+03	1.367E+04	1.264E+05	.9250E+01
.9500E+01	.1000E+02	4.954E+03	9.908E+03	9.658E+04	.9750E+01

* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

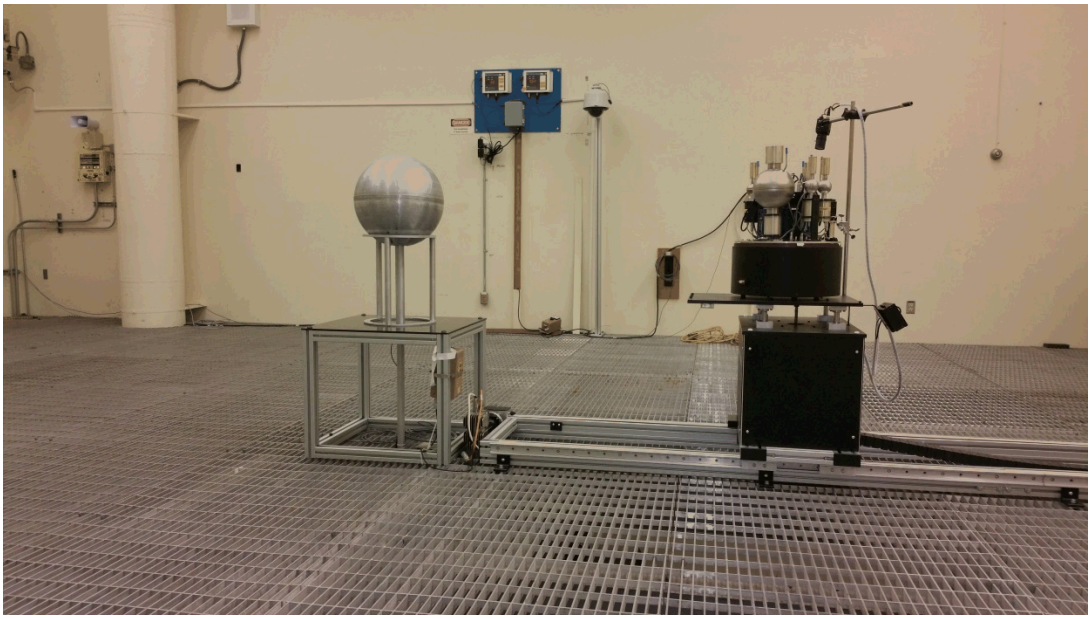
where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2

Appendix F

Neutron fluence, spectra and dose rates from ^{252}Cf moderated by 15 cm of D_2O



Fluence, spectral and dosimetric data at 2.0 m from ^{252}Cf moderated by 15 cm of D_2O

Table F-1. Neutron fluence and dosimetric data at 2.0 m from 15 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/15/2014
Exposure time:	7,200 s
Run #	N22

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	6.92E+06	9.62E+02
Epi-thermal region	:	1.70E+07	2.36E+03
Thermal region	:	2.82E+06	3.92E+02
Thermal – 4.5 MeV	:	2.67E+07	3.71E+03
Thermal – 10.0 MeV	:	2.7012E+07	3.7517E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.51E-02	2.24E-03	7.56E+00	1.12E+03
Epi-thermal region	:	1.48E-03	2.75E-04	7.39E-01	1.37E+02
Thermal region	:	5.65E-05	2.99E-05	2.82E-02	1.50E+01
Thermal – 4.5 MeV	:	1.66E-02	2.54E-03	8.32E+00	1.27E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.7709E-02 rads	8.8543E+00 mrads/hr
H*(10) ICRP-74	=	2.6377E-03 Sv	1.3188E+03 uSv/hr
Hp(10,0) ICRP-74	=	2.7395E-03 Sv	1.3697E+03 uSv/hr

Table F-2. Neutron fluence at 2.0 m from 15 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/15/2014
Exposure time: 7,200 s
Run number: N22

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.1000E-08	.2000E-08	6.381E+03	6.381E+12	9.205E+03	.1500E-08
.2000E-08	.5000E-08	4.094E+04	1.365E+13	4.468E+04	.3500E-08
.5000E-08	.1000E-07	1.245E+05	2.490E+13	1.796E+05	.7500E-08
.1000E-07	.2000E-07	3.670E+05	3.670E+13	5.295E+05	.1500E-07
.2000E-07	.5000E-07	1.138E+06	3.793E+13	1.242E+06	.3500E-07
.5000E-07	.1000E-06	8.893E+05	1.779E+13	1.283E+06	.7500E-07
.1000E-06	.2000E-06	2.501E+05	2.501E+12	3.609E+05	.1500E-06
.2000E-06	.5000E-06	6.233E+05	2.078E+12	6.803E+05	.3500E-06
.5000E-06	.1000E-01	1.270E+07	1.270E+09	1.282E+06	.5000E-02
.1000E-01	.1027E+00	3.636E+06	3.923E+07	1.561E+06	.5635E-01
.1027E+00	.1166E+00	2.602E+05	1.877E+07	2.055E+06	.1096E+00
.1166E+00	.1317E+00	2.237E+05	1.479E+07	1.834E+06	.1241E+00
.1317E+00	.1493E+00	2.604E+05	1.476E+07	2.071E+06	.1405E+00
.1493E+00	.1707E+00	2.451E+05	1.144E+07	1.828E+06	.1600E+00
.1707E+00	.1934E+00	1.984E+05	8.749E+06	1.591E+06	.1821E+00
.1934E+00	.2199E+00	2.144E+05	8.104E+06	1.672E+06	.2066E+00
.2199E+00	.2606E+00	2.796E+05	6.860E+06	1.644E+06	.2402E+00
.2606E+00	.2906E+00	1.650E+05	5.499E+06	1.514E+06	.2756E+00
.2906E+00	.3244E+00	1.612E+05	4.777E+06	1.468E+06	.3075E+00
.3244E+00	.3581E+00	1.429E+05	4.235E+06	1.444E+06	.3413E+00
.3581E+00	.3994E+00	1.348E+05	3.268E+06	1.237E+06	.3787E+00
.3994E+00	.4444E+00	1.267E+05	2.815E+06	1.187E+06	.4219E+00
.4444E+00	.4931E+00	1.316E+05	2.700E+06	1.265E+06	.4688E+00
.4931E+00	.5456E+00	1.661E+05	3.163E+06	1.641E+06	.5194E+00
.5456E+00	.6094E+00	2.030E+05	3.184E+06	1.837E+06	.5775E+00
.6094E+00	.6769E+00	1.969E+05	2.917E+06	1.874E+06	.6431E+00
.6769E+00	.7946E+00	3.249E+05	2.759E+06	2.026E+06	.7358E+00
.7946E+00	.8870E+00	1.974E+05	2.136E+06	1.794E+06	.8408E+00
.8870E+00	.9871E+00	1.623E+05	1.621E+06	1.518E+06	.9371E+00
.9871E+00	.1095E+01	1.330E+05	1.234E+06	1.283E+06	.1041E+01
.1095E+01	.1218E+01	2.216E+05	1.799E+06	2.079E+06	.1157E+01
.1218E+01	.1391E+01	3.198E+05	1.850E+06	2.410E+06	.1305E+01
.1391E+01	.1573E+01	2.824E+05	1.552E+06	2.297E+06	.1482E+01
.1573E+01	.1807E+01	2.920E+05	1.248E+06	2.106E+06	.1690E+01
.1807E+01	.2041E+01	2.611E+05	1.116E+06	2.144E+06	.1924E+01
.2041E+01	.2327E+01	3.376E+05	1.181E+06	2.575E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	3.042E+05	9.751E+05	2.418E+06	.2483E+01
.2639E+01	.3003E+01	2.728E+05	7.495E+05	2.111E+06	.2821E+01
.3003E+01	.3419E+01	2.279E+05	5.479E+05	1.757E+06	.3211E+01
.3419E+01	.3861E+01	1.603E+05	3.626E+05	1.318E+06	.3640E+01
.3861E+01	.4407E+01	1.720E+05	3.151E+05	1.301E+06	.4134E+01
.4407E+01	.5000E+01	1.438E+05	2.425E+05	1.139E+06	.4703E+01
.5000E+01	.5500E+01	8.713E+04	1.743E+05	9.141E+05	.5250E+01
.5500E+01	.6000E+01	6.453E+04	1.291E+05	7.416E+05	.5750E+01
.6000E+01	.6500E+01	4.757E+04	9.515E+04	5.943E+05	.6250E+01
.6500E+01	.7000E+01	3.492E+04	6.983E+04	4.712E+05	.6750E+01
.7000E+01	.7500E+01	2.555E+04	5.111E+04	3.704E+05	.7250E+01
.7500E+01	.8000E+01	1.863E+04	3.726E+04	2.887E+05	.7750E+01
.8000E+01	.8500E+01	1.355E+04	2.711E+04	2.236E+05	.8250E+01
.8500E+01	.9000E+01	9.838E+03	1.968E+04	1.721E+05	.8750E+01
.9000E+01	.9500E+01	7.131E+03	1.426E+04	1.319E+05	.9250E+01
.9500E+01	.1000E+02	5.170E+03	1.034E+04	1.008E+05	.9750E+01

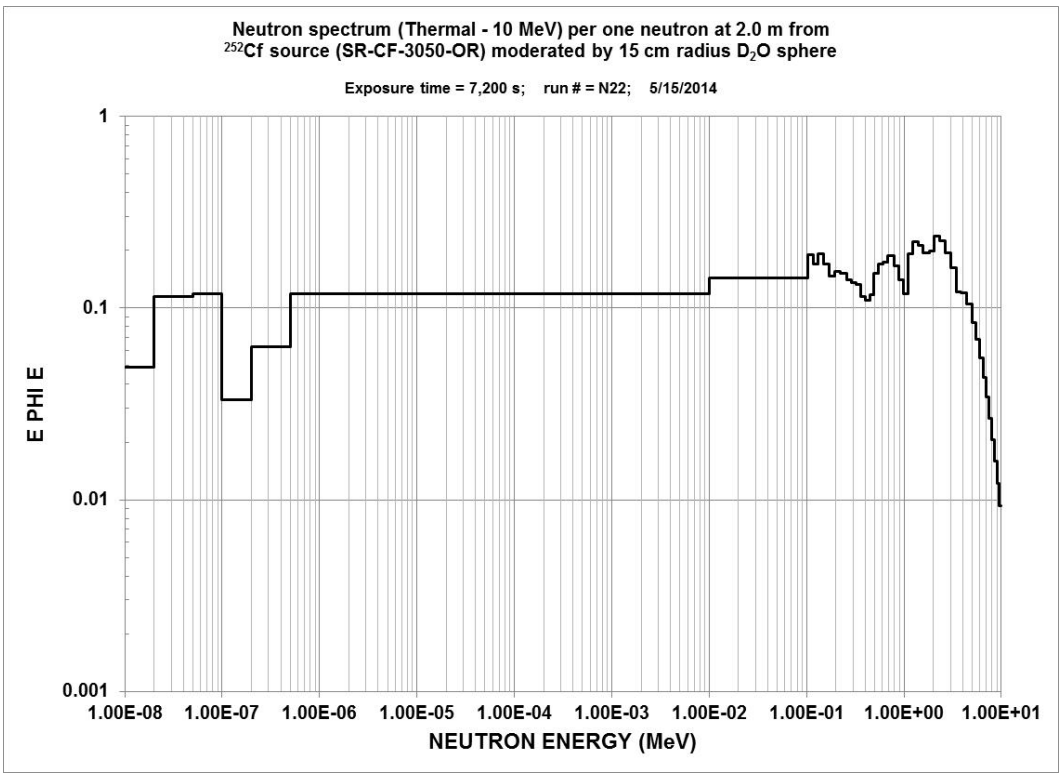
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



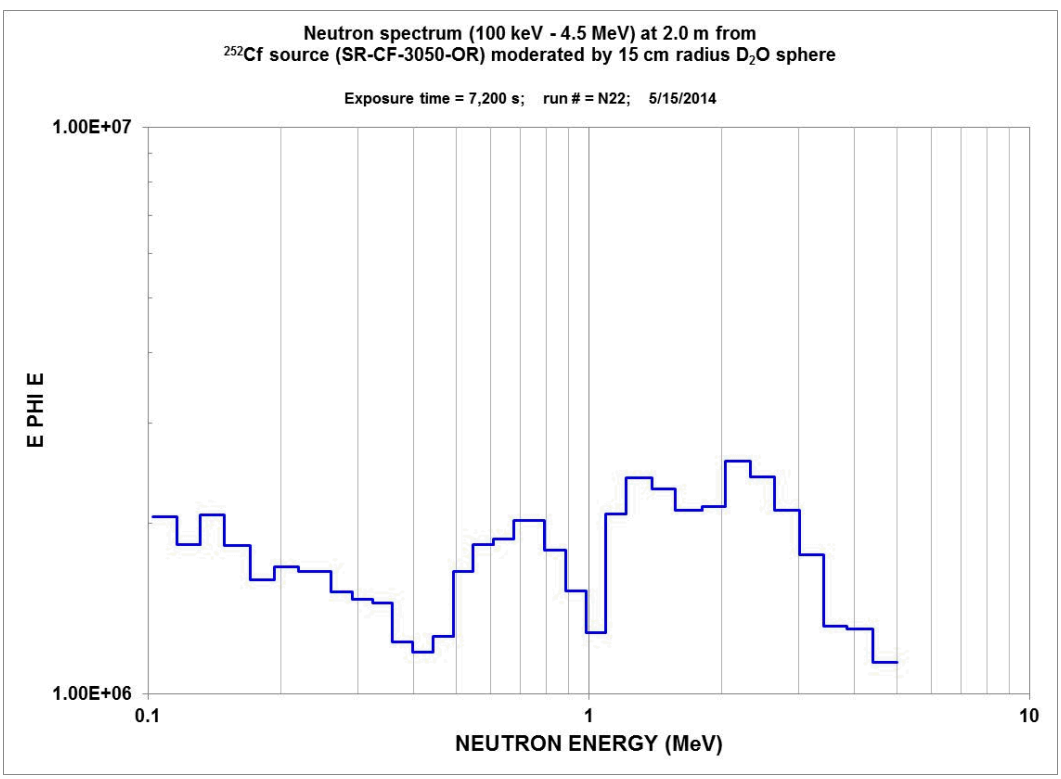


Figure F-1. Neutron spectra at 2.0 m from ^{252}Cf moderated by 15 cm of D_2O

Fluence, spectral and dosimetric data at 2.5 m from ^{252}Cf moderated by 15 cm of D_2O

Table F-3. Neutron fluence and dosimetric data at 2.5 m from 15 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/15/2014
Exposure time:	7,200 s
Run #	N23

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	5.11E+06	7.10E+02
Epi-thermal region	:	1.33E+07	1.85E+03
Thermal region	:	3.01E+06	4.18E+02
Thermal – 4.5 MeV	:	2.15E+07	2.98E+03
Thermal – 10.0 MeV	:	2.1673E+07	3.0102E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.08E-02	1.62E-03	5.41E+00	8.10E+02
Epi-thermal region	:	1.17E-03	2.17E-04	5.84E-01	1.08E+02
Thermal region	:	6.02E-05	3.19E-05	3.01E-02	1.60E+01
Thermal – 4.5 MeV	:	1.20E-02	1.87E-03	6.02E+00	9.34E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.2823E-02 rads	6.4113E+00 mrads/hr
H*(10) ICRP-74	=	1.9365E-03 Sv	9.6824E+02 uSv/hr
Hp(10,0) ICRP-74	=	2.0116E-03 Sv	1.0058E+03 uSv/hr

Table F-4. Neutron fluence at 2.5 m from 15 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050-OR)

Date: 5/15/2014
Exposure time: 7,200 s
Run number: N23

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	6.803E+03	6.803E+12	9.815E+03	.1500E-08
.2000E-08	.5000E-08	4.365E+04	1.455E+13	4.763E+04	.3500E-08
.5000E-08	.1000E-07	1.327E+05	2.655E+13	1.915E+05	.7500E-08
.1000E-07	.2000E-07	3.913E+05	3.913E+13	5.646E+05	.1500E-07
.2000E-07	.5000E-07	1.213E+06	4.044E+13	1.324E+06	.3500E-07
.5000E-07	.1000E-06	9.482E+05	1.896E+13	1.368E+06	.7500E-07
.1000E-06	.2000E-06	2.667E+05	2.667E+12	3.848E+05	.1500E-06
.2000E-06	.5000E-06	5.677E+05	1.892E+12	6.195E+05	.3500E-06
.5000E-06	.1000E-01	9.879E+06	9.880E+08	9.976E+05	.5000E-02
.1000E-01	.1027E+00	2.880E+06	3.107E+07	1.237E+06	.5635E-01
.1027E+00	.1166E+00	1.970E+05	1.421E+07	1.556E+06	.1096E+00
.1166E+00	.1317E+00	1.641E+05	1.086E+07	1.346E+06	.1241E+00
.1317E+00	.1493E+00	2.236E+05	1.268E+07	1.778E+06	.1405E+00
.1493E+00	.1707E+00	2.125E+05	9.921E+06	1.585E+06	.1600E+00
.1707E+00	.1934E+00	1.781E+05	7.855E+06	1.428E+06	.1821E+00
.1934E+00	.2199E+00	1.900E+05	7.182E+06	1.482E+06	.2066E+00
.2199E+00	.2606E+00	1.930E+05	4.736E+06	1.135E+06	.2402E+00
.2606E+00	.2906E+00	1.380E+05	4.600E+06	1.266E+06	.2756E+00
.2906E+00	.3244E+00	1.183E+05	3.506E+06	1.077E+06	.3075E+00
.3244E+00	.3581E+00	9.553E+04	2.831E+06	9.652E+05	.3413E+00
.3581E+00	.3994E+00	9.851E+04	2.388E+06	9.036E+05	.3787E+00
.3994E+00	.4444E+00	6.515E+04	1.448E+06	6.102E+05	.4219E+00
.4444E+00	.4931E+00	1.192E+05	2.445E+06	1.145E+06	.4688E+00
.4931E+00	.5456E+00	1.273E+05	2.425E+06	1.258E+06	.5194E+00
.5456E+00	.6094E+00	1.447E+05	2.269E+06	1.309E+06	.5775E+00
.6094E+00	.6769E+00	1.411E+05	2.090E+06	1.343E+06	.6431E+00
.6769E+00	.7946E+00	2.662E+05	2.261E+06	1.660E+06	.7358E+00
.7946E+00	.8870E+00	1.667E+05	1.804E+06	1.515E+06	.8408E+00
.8870E+00	.9871E+00	1.344E+05	1.343E+06	1.257E+06	.9371E+00
.9871E+00	.1095E+01	9.916E+04	9.199E+05	9.567E+05	.1041E+01
.1095E+01	.1218E+01	1.414E+05	1.147E+06	1.326E+06	.1157E+01
.1218E+01	.1391E+01	2.021E+05	1.169E+06	1.523E+06	.1305E+01
.1391E+01	.1573E+01	2.040E+05	1.121E+06	1.659E+06	.1482E+01
.1573E+01	.1807E+01	2.180E+05	9.318E+05	1.572E+06	.1690E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1807E+01	.2041E+01	1.819E+05	7.774E+05	1.494E+06	.1924E+01
.2041E+01	.2327E+01	2.181E+05	7.626E+05	1.663E+06	.2184E+01
.2327E+01	.2639E+01	2.286E+05	7.326E+05	1.817E+06	.2483E+01
.2639E+01	.3003E+01	1.769E+05	4.859E+05	1.369E+06	.2821E+01
.3003E+01	.3419E+01	1.508E+05	3.624E+05	1.162E+06	.3211E+01
.3419E+01	.3861E+01	1.092E+05	2.470E+05	8.979E+05	.3640E+01
.3861E+01	.4407E+01	1.186E+05	2.171E+05	8.963E+05	.4134E+01
.4407E+01	.5000E+01	9.741E+04	1.643E+05	7.716E+05	.4703E+01
.5000E+01	.5500E+01	6.220E+04	1.244E+05	6.526E+05	.5250E+01
.5500E+01	.6000E+01	4.607E+04	9.213E+04	5.294E+05	.5750E+01
.6000E+01	.6500E+01	3.396E+04	6.793E+04	4.243E+05	.6250E+01
.6500E+01	.7000E+01	2.493E+04	4.986E+04	3.364E+05	.6750E+01
.7000E+01	.7500E+01	1.824E+04	3.649E+04	2.644E+05	.7250E+01
.7500E+01	.8000E+01	1.330E+04	2.660E+04	2.061E+05	.7750E+01
.8000E+01	.8500E+01	9.676E+03	1.935E+04	1.596E+05	.8250E+01
.8500E+01	.9000E+01	7.024E+03	1.405E+04	1.229E+05	.8750E+01
.9000E+01	.9500E+01	5.091E+03	1.018E+04	9.416E+04	.9250E+01
.9500E+01	.1000E+02	3.691E+03	7.381E+03	7.195E+04	.9750E+01

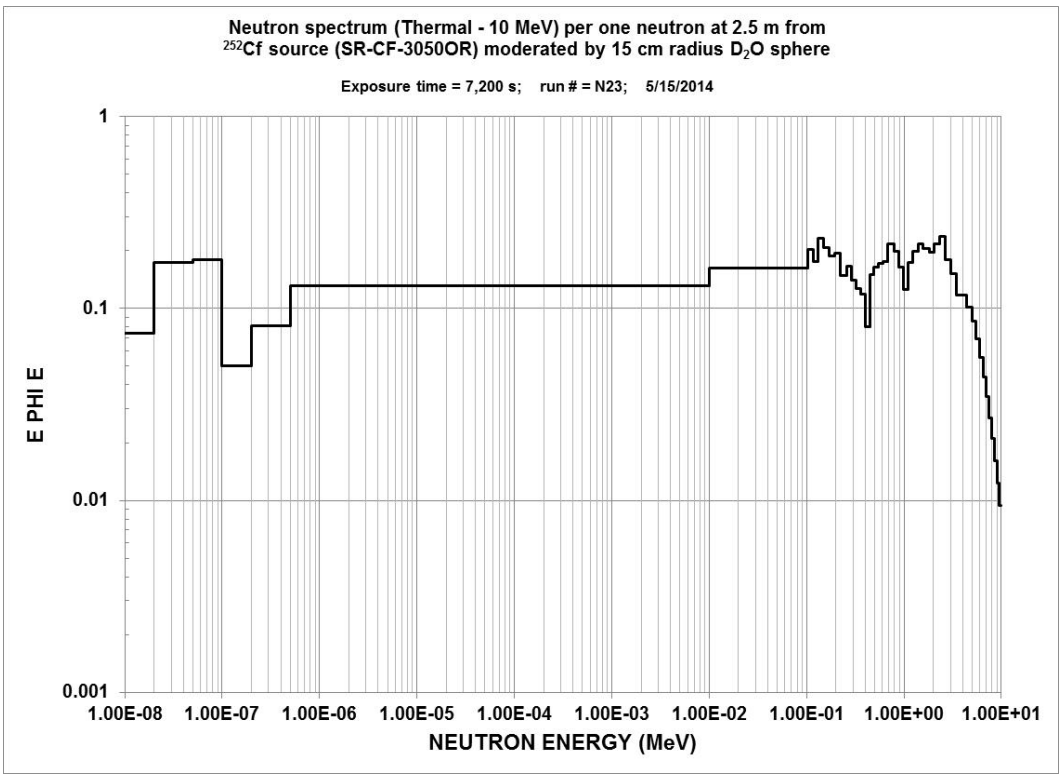
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



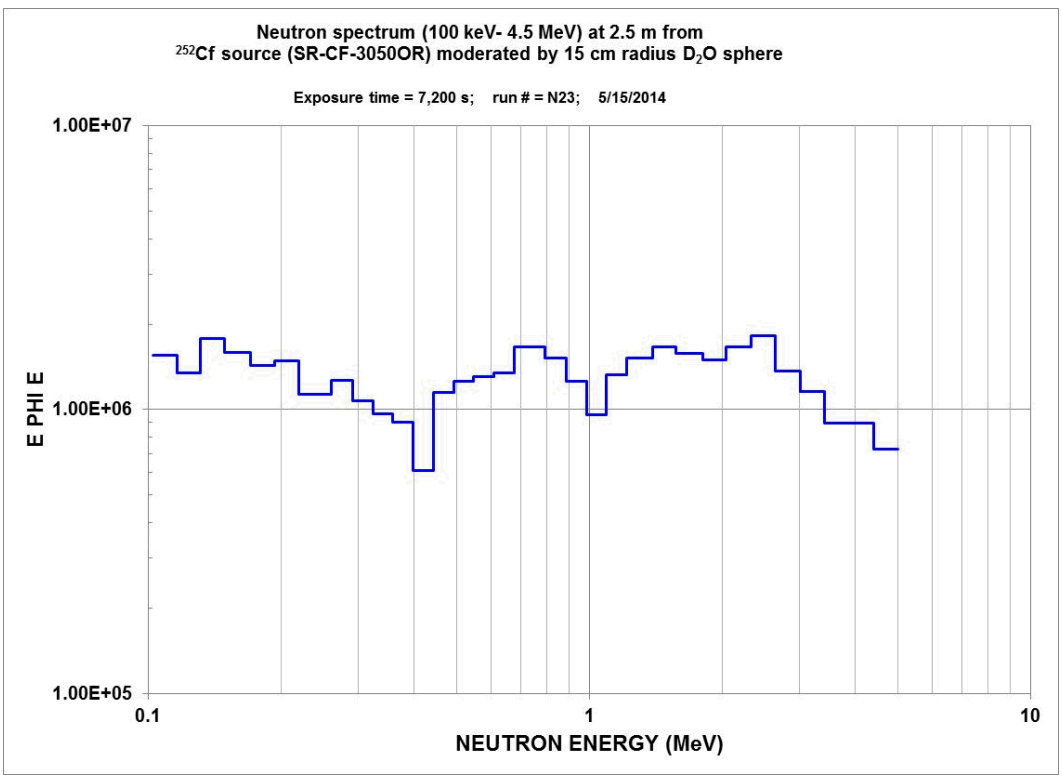


Figure F-2. Neutron spectra at 2.5 m from ^{252}Cf moderated by 15 cm of D_2O

Fluence, spectral and dosimetric data at 3.0 m from ^{252}Cf moderated by 15 cm of D_2O

Table F-5. Neutron fluence and dosimetric data at 3.0 m from 15 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/15/2014
Exposure time:	7,200 s
Run #	N24

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	3.98E+06	5.52E+02
Epi-thermal region	:	1.12E+07	1.56E+03
Thermal region	:	3.70E+06	5.14E+02
Thermal – 4.5 MeV	:	1.89E+07	2.62E+03
Thermal – 10.0 MeV	:	1.9035E+07	2.6438E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	8.36E-03	1.26E-03	4.18E+00	6.28E+02
Epi-thermal region	:	9.53E-04	1.80E-04	4.76E-01	9.02E+01
Thermal region	:	7.40E-05	3.92E-05	3.70E-02	1.96E+01
Thermal – 4.5 MeV	:	9.38E-03	1.47E-03	4.69E+00	7.37E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	9.8445E-03 rads	4.9222E+00 mrads/hr
H*(10) ICRP-74	=	1.5147E-03 Sv	7.5737E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.5738E-03 Sv	7.8690E+02 uSv/hr

Table F-6. Neutron fluence at 3.0 m from 15 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050-OR)

Date: 5/15/2014
Exposure time: 7,200 s
Run number: N24

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	8.366E+03	8.366E+12	1.207E+04	.1500E-08
.2000E-08	.5000E-08	5.367E+04	1.789E+13	5.858E+04	.3500E-08
.5000E-08	.1000E-07	1.632E+05	3.265E+13	2.355E+05	.7500E-08
.1000E-07	.2000E-07	4.812E+05	4.812E+13	6.942E+05	.1500E-07
.2000E-07	.5000E-07	1.492E+06	4.973E+13	1.628E+06	.3500E-07
.5000E-07	.1000E-06	1.166E+06	2.332E+13	1.682E+06	.7500E-07
.1000E-06	.2000E-06	3.280E+05	3.280E+12	4.732E+05	.1500E-06
.2000E-06	.5000E-06	5.772E+05	1.924E+12	6.299E+05	.3500E-06
.5000E-06	.1000E-01	8.304E+06	8.305E+08	8.385E+05	.5000E-02
.1000E-01	.1027E+00	2.337E+06	2.521E+07	1.003E+06	.5635E-01
.1027E+00	.1166E+00	1.616E+05	1.166E+07	1.276E+06	.1096E+00
.1166E+00	.1317E+00	1.393E+05	9.211E+06	1.142E+06	.1241E+00
.1317E+00	.1493E+00	2.076E+05	1.177E+07	1.652E+06	.1405E+00
.1493E+00	.1707E+00	1.386E+05	6.472E+06	1.034E+06	.1600E+00
.1707E+00	.1934E+00	1.187E+05	5.232E+06	9.513E+05	.1821E+00
.1934E+00	.2199E+00	1.289E+05	4.873E+06	1.006E+06	.2066E+00
.2199E+00	.2606E+00	1.482E+05	3.637E+06	8.717E+05	.2402E+00
.2606E+00	.2906E+00	1.013E+05	3.377E+06	9.300E+05	.2756E+00
.2906E+00	.3244E+00	9.995E+04	2.962E+06	9.098E+05	.3075E+00
.3244E+00	.3581E+00	8.665E+04	2.567E+06	8.754E+05	.3413E+00
.3581E+00	.3994E+00	9.126E+04	2.212E+06	8.371E+05	.3787E+00
.3994E+00	.4444E+00	7.396E+04	1.643E+06	6.927E+05	.4219E+00
.4444E+00	.4931E+00	8.507E+04	1.745E+06	8.172E+05	.4688E+00
.4931E+00	.5456E+00	8.750E+04	1.667E+06	8.649E+05	.5194E+00
.5456E+00	.6094E+00	1.238E+05	1.943E+06	1.121E+06	.5775E+00
.6094E+00	.6769E+00	1.182E+05	1.751E+06	1.125E+06	.6431E+00
.6769E+00	.7946E+00	1.910E+05	1.622E+06	1.191E+06	.7358E+00
.7946E+00	.8870E+00	1.110E+05	1.201E+06	1.009E+06	.8408E+00
.8870E+00	.9871E+00	1.142E+05	1.141E+06	1.068E+06	.9371E+00
.9871E+00	.1095E+01	8.345E+04	7.741E+05	8.052E+05	.1041E+01
.1095E+01	.1218E+01	1.331E+05	1.081E+06	1.249E+06	.1157E+01
.1218E+01	.1391E+01	1.403E+05	8.119E+05	1.058E+06	.1305E+01
.1391E+01	.1573E+01	1.542E+05	8.474E+05	1.254E+06	.1482E+01
.1573E+01	.1807E+01	1.669E+05	7.132E+05	1.203E+06	.1690E+01
.1807E+01	.2041E+01	1.419E+05	6.062E+05	1.165E+06	.1924E+01
.2041E+01	.2327E+01	1.701E+05	5.949E+05	1.297E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	1.609E+05	5.156E+05	1.279E+06	.2483E+01
.2639E+01	.3003E+01	1.484E+05	4.076E+05	1.148E+06	.2821E+01
.3003E+01	.3419E+01	1.124E+05	2.702E+05	8.663E+05	.3211E+01
.3419E+01	.3861E+01	6.710E+04	1.518E+05	5.519E+05	.3640E+01
.3861E+01	.4407E+01	1.009E+05	1.848E+05	7.629E+05	.4134E+01
.4407E+01	.5000E+01	6.939E+04	1.170E+05	5.496E+05	.4703E+01
.5000E+01	.5500E+01	4.113E+04	8.227E+04	4.316E+05	.5250E+01
.5500E+01	.6000E+01	3.046E+04	6.093E+04	3.501E+05	.5750E+01
.6000E+01	.6500E+01	2.246E+04	4.492E+04	2.806E+05	.6250E+01
.6500E+01	.7000E+01	1.648E+04	3.297E+04	2.224E+05	.6750E+01
.7000E+01	.7500E+01	1.206E+04	2.413E+04	1.749E+05	.7250E+01
.7500E+01	.8000E+01	8.796E+03	1.759E+04	1.363E+05	.7750E+01
.8000E+01	.8500E+01	6.398E+03	1.280E+04	1.055E+05	.8250E+01
.8500E+01	.9000E+01	4.645E+03	9.290E+03	8.126E+04	.8750E+01
.9000E+01	.9500E+01	3.367E+03	6.733E+03	6.227E+04	.9250E+01
.9500E+01	.1000E+02	2.441E+03	4.881E+03	4.758E+04	.9750E+01

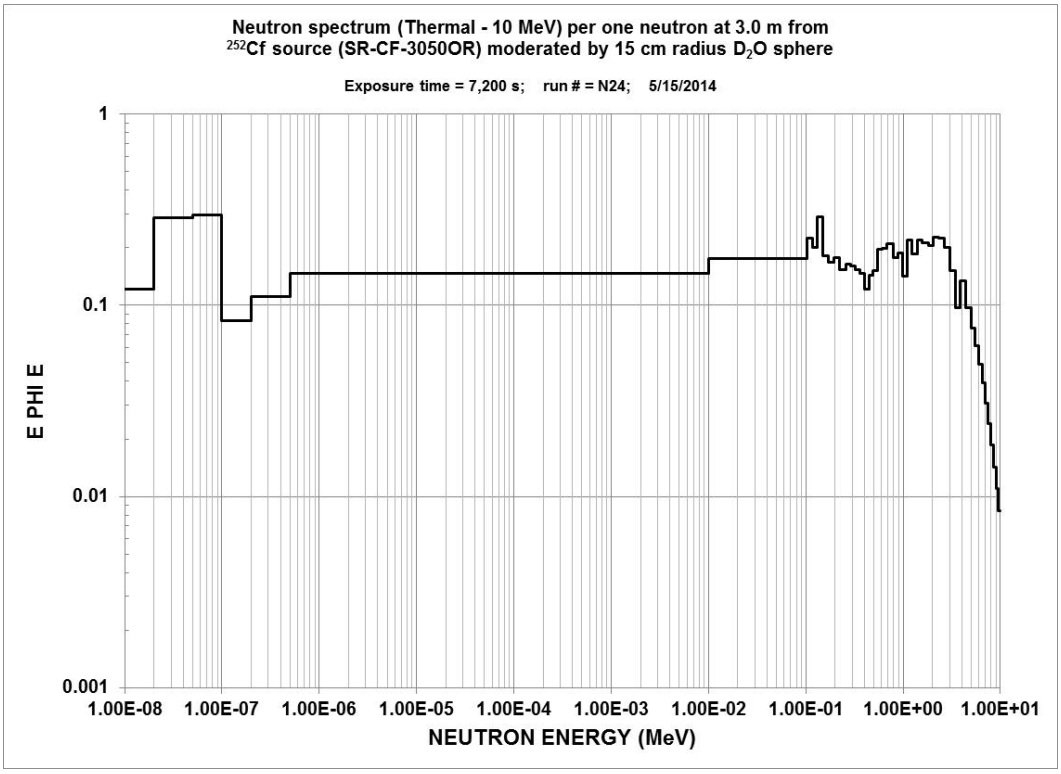
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



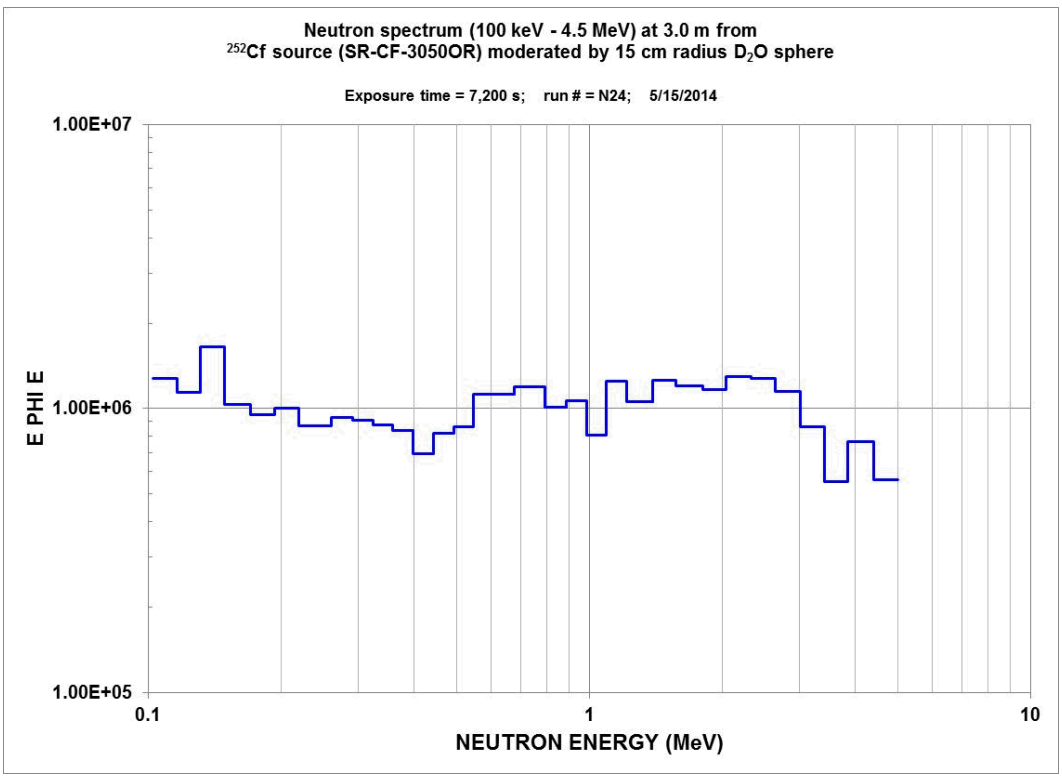


Figure F-3. Neutron spectra at 3.0 m from ^{252}Cf moderated by 15 cm of D_2O

Fluence, spectral and dosimetric data at 3.5 m from ^{252}Cf moderated by 15 cm of D_2O

Table F-7. Neutron fluence and dosimetric data at 3.5 m from 15 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/15/2014
Exposure time:	10,800 s
Run #	N25

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	4.87E+06	4.51E+02
Epi-thermal region	:	1.48E+07	1.37E+03
Thermal region	:	6.08E+06	5.63E+02
Thermal – 4.5 MeV	:	2.57E+07	2.38E+03
Thermal – 10.0 MeV	:	2.5873E+07	2.3956E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.02E-02	1.54E-03	3.38E+00	5.14E+02
Epi-thermal region	:	1.19E-03	2.32E-04	3.96E-01	7.73E+01
Thermal region	:	1.22E-04	6.45E-05	4.05E-02	2.15E+01
Thermal – 4.5 MeV	:	1.15E-02	1.84E-03	3.82E+00	6.13E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.2017E-02 rads	4.0055E+00 mrads/hr
H*(10) ICRP-74	=	1.8867E-03 Sv	6.2891E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.9612E-03 Sv	6.5372E+02 uSv/hr

Table F-8. Neutron fluence at 3.5 m from 15 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050-OR)

Date: 5/15/2014
Exposure time: 7,200 s
Run number: N25

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	1.375E+04	1.375E+13	1.983E+04	.1500E-08
.2000E-08	.5000E-08	8.820E+04	2.940E+13	9.625E+04	.3500E-08
.5000E-08	.1000E-07	2.682E+05	5.365E+13	3.870E+05	.7500E-08
.1000E-07	.2000E-07	7.907E+05	7.907E+13	1.141E+06	.1500E-07
.2000E-07	.5000E-07	2.451E+06	8.171E+13	2.675E+06	.3500E-07
.5000E-07	.1000E-06	1.916E+06	3.832E+13	2.764E+06	.7500E-07
.1000E-06	.2000E-06	5.389E+05	5.389E+12	7.775E+05	.1500E-06
.2000E-06	.5000E-06	8.525E+05	2.842E+12	9.304E+05	.3500E-06
.5000E-06	.1000E-01	1.103E+07	1.103E+09	1.113E+06	.5000E-02
.1000E-01	.1027E+00	2.880E+06	3.107E+07	1.236E+06	.5635E-01
.1027E+00	.1166E+00	1.389E+05	1.002E+07	1.097E+06	.1096E+00
.1166E+00	.1317E+00	1.996E+05	1.320E+07	1.636E+06	.1241E+00
.1317E+00	.1493E+00	2.289E+05	1.298E+07	1.821E+06	.1405E+00
.1493E+00	.1707E+00	1.800E+05	8.405E+06	1.343E+06	.1600E+00
.1707E+00	.1934E+00	1.733E+05	7.642E+06	1.390E+06	.1821E+00
.1934E+00	.2199E+00	1.240E+05	4.686E+06	9.671E+05	.2066E+00
.2199E+00	.2606E+00	2.090E+05	5.128E+06	1.229E+06	.2402E+00
.2606E+00	.2906E+00	1.164E+05	3.881E+06	1.069E+06	.2756E+00
.2906E+00	.3244E+00	1.434E+05	4.248E+06	1.305E+06	.3075E+00
.3244E+00	.3581E+00	8.776E+04	2.600E+06	8.866E+05	.3413E+00
.3581E+00	.3994E+00	1.008E+05	2.444E+06	9.248E+05	.3787E+00
.3994E+00	.4444E+00	1.009E+05	2.243E+06	9.455E+05	.4219E+00
.4444E+00	.4931E+00	1.113E+05	2.283E+06	1.069E+06	.4688E+00
.4931E+00	.5456E+00	1.261E+05	2.402E+06	1.246E+06	.5194E+00
.5456E+00	.6094E+00	1.369E+05	2.148E+06	1.239E+06	.5775E+00
.6094E+00	.6769E+00	1.638E+05	2.427E+06	1.560E+06	.6431E+00
.6769E+00	.7946E+00	2.672E+05	2.269E+06	1.666E+06	.7358E+00
.7946E+00	.8870E+00	1.642E+05	1.777E+06	1.493E+06	.8408E+00
.8870E+00	.9871E+00	1.282E+05	1.281E+06	1.199E+06	.9371E+00
.9871E+00	.1095E+01	1.054E+05	9.776E+05	1.017E+06	.1041E+01
.1095E+01	.1218E+01	1.437E+05	1.166E+06	1.347E+06	.1157E+01
.1218E+01	.1391E+01	1.994E+05	1.154E+06	1.503E+06	.1305E+01
.1391E+01	.1573E+01	1.880E+05	1.033E+06	1.529E+06	.1482E+01
.1573E+01	.1807E+01	2.060E+05	8.803E+05	1.485E+06	.1690E+01
.1807E+01	.2041E+01	1.660E+05	7.092E+05	1.363E+06	.1924E+01
.2041E+01	.2327E+01	2.026E+05	7.083E+05	1.545E+06	.2184E+01

E2	E1	FLUENCE/	FLUENCE/	FLUENCE/	E avg.

(MeV)	(MeV)	(E1-E2) (n/cm²)	MeV (n/cm².MeV)	LETHARGY* (n/cm².u)	(MeV)
.2327E+01	.2639E+01	1.936E+05	6.204E+05	1.538E+06	.2483E+01
.2639E+01	.3003E+01	1.661E+05	4.562E+05	1.285E+06	.2821E+01
.3003E+01	.3419E+01	1.217E+05	2.925E+05	9.378E+05	.3211E+01
.3419E+01	.3861E+01	9.579E+04	2.167E+05	7.879E+05	.3640E+01
.3861E+01	.4407E+01	1.078E+05	1.975E+05	8.151E+05	.4134E+01
.4407E+01	.5000E+01	7.554E+04	1.274E+05	5.984E+05	.4703E+01
.5000E+01	.5500E+01	4.832E+04	9.664E+04	5.070E+05	.5250E+01
.5500E+01	.6000E+01	3.579E+04	7.157E+04	4.113E+05	.5750E+01
.6000E+01	.6500E+01	2.638E+04	5.277E+04	3.296E+05	.6250E+01
.6500E+01	.7000E+01	1.937E+04	3.873E+04	2.613E+05	.6750E+01
.7000E+01	.7500E+01	1.417E+04	2.834E+04	2.054E+05	.7250E+01
.7500E+01	.8000E+01	1.033E+04	2.067E+04	1.601E+05	.7750E+01
.8000E+01	.8500E+01	7.517E+03	1.503E+04	1.240E+05	.8250E+01
.8500E+01	.9000E+01	5.457E+03	1.091E+04	9.546E+04	.8750E+01
.9000E+01	.9500E+01	3.955E+03	7.910E+03	7.315E+04	.9250E+01
.9500E+01	.1000E+02	2.867E+03	5.734E+03	5.590E+04	.9750E+01

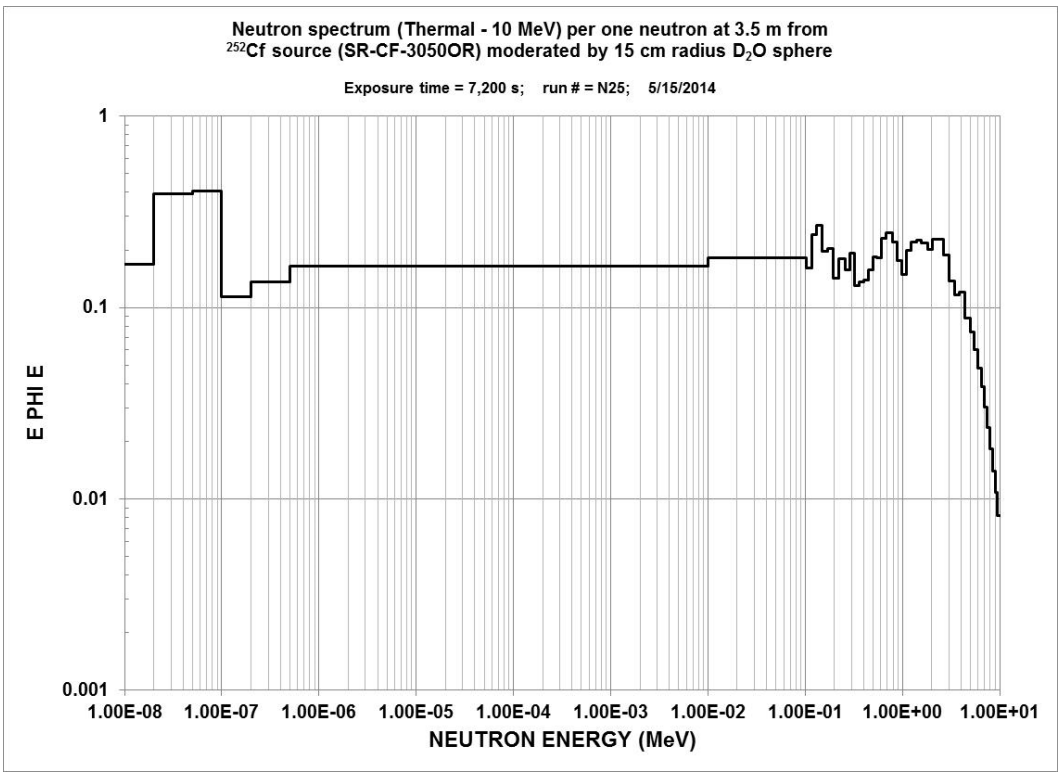
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



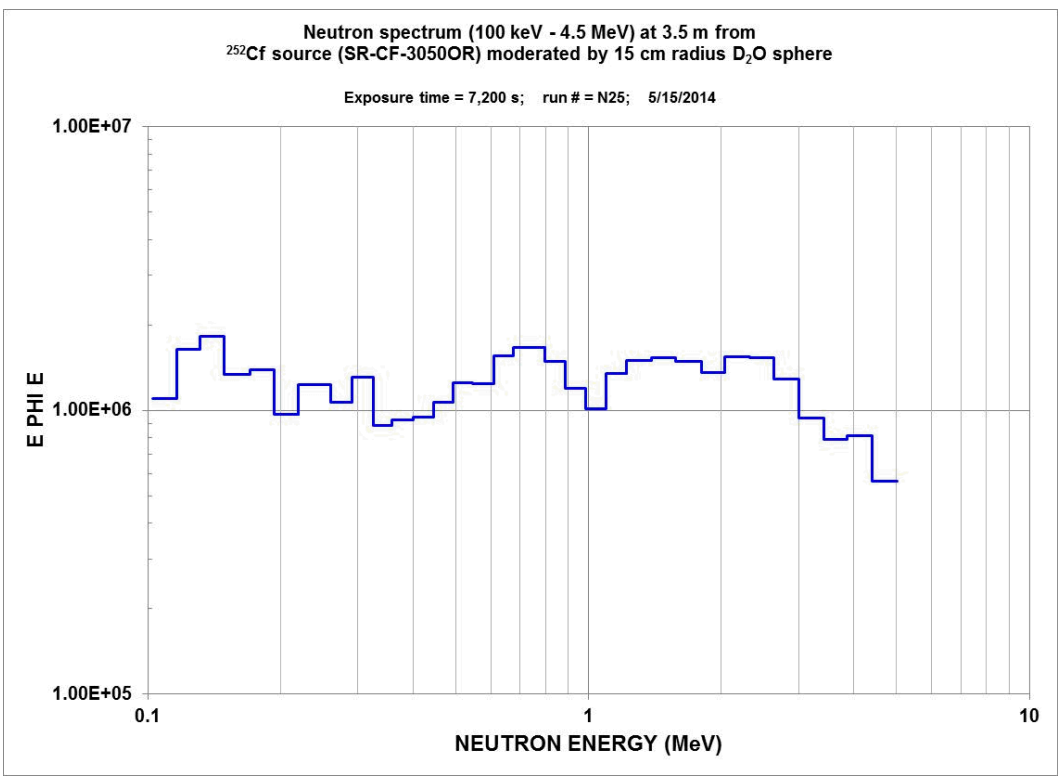


Figure F-4. Neutron spectra at 3.5 m from ^{252}Cf moderated by 15 cm of D_2O

Fluence, spectral and dosimetric data at 4.0 m from ^{252}Cf moderated by 15 cm of D_2O

Table F-9. Neutron fluence and dosimetric data at 4.0 m from 15 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/16/2014
Exposure time:	10,800 s
Run #	N27

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	4.15E+06	3.84E+02
Epi-thermal region	:	1.33E+07	1.23E+03
Thermal region	:	5.83E+06	5.40E+02
Thermal – 4.5 MeV	:	2.32E+07	2.15E+03
Thermal – 10.0 MeV	:	2.3353E+07	2.1623E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	8.51E-03	1.30E-03	2.84E+00	4.33E+02
Epi-thermal region	:	1.07E-03	2.09E-04	3.56E-01	6.95E+01
Thermal region	:	1.17E-04	6.18E-05	3.89E-02	2.06E+01
Thermal – 4.5 MeV	:	9.69E-03	1.57E-03	3.23E+00	5.23E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.0092E-02 rads	3.3638E+00 mrads/hr
H*(10) ICRP-74	=	1.6042E-03 Sv	5.3472E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.6673E-03 Sv	5.5577E+02 uSv/hr

Table F-10. Neutron fluence at 4.0 m from 15 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050-OR)

Date: 5/16/2014
Exposure time: 10,800 s
Run number: N27

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	1.318E+04	1.318E+13	1.902E+04	.1500E-08
.2000E-08	.5000E-08	8.459E+04	2.820E+13	9.232E+04	.3500E-08
.5000E-08	.1000E-07	2.573E+05	5.145E+13	3.712E+05	.7500E-08
.1000E-07	.2000E-07	7.584E+05	7.584E+13	1.094E+06	.1500E-07
.2000E-07	.5000E-07	2.351E+06	7.837E+13	2.566E+06	.3500E-07
.5000E-07	.1000E-06	1.838E+06	3.675E+13	2.651E+06	.7500E-07
.1000E-06	.2000E-06	5.169E+05	5.169E+12	7.457E+05	.1500E-06
.2000E-06	.5000E-06	7.898E+05	2.633E+12	8.620E+05	.3500E-06
.5000E-06	.1000E-01	9.868E+06	9.869E+08	9.964E+05	.5000E-02
.1000E-01	.1027E+00	2.594E+06	2.799E+07	1.114E+06	.5635E-01
.1027E+00	.1166E+00	1.571E+05	1.134E+07	1.241E+06	.1096E+00
.1166E+00	.1317E+00	1.568E+05	1.037E+07	1.286E+06	.1241E+00
.1317E+00	.1493E+00	1.795E+05	1.018E+07	1.428E+06	.1405E+00
.1493E+00	.1707E+00	1.465E+05	6.839E+06	1.093E+06	.1600E+00
.1707E+00	.1934E+00	1.329E+05	5.860E+06	1.066E+06	.1821E+00
.1934E+00	.2199E+00	1.464E+05	5.534E+06	1.142E+06	.2066E+00
.2199E+00	.2606E+00	2.070E+05	5.078E+06	1.217E+06	.2402E+00
.2606E+00	.2906E+00	1.252E+05	4.172E+06	1.149E+06	.2756E+00
.2906E+00	.3244E+00	9.682E+04	2.869E+06	8.813E+05	.3075E+00
.3244E+00	.3581E+00	7.440E+04	2.205E+06	7.517E+05	.3413E+00
.3581E+00	.3994E+00	1.078E+05	2.612E+06	9.885E+05	.3787E+00
.3994E+00	.4444E+00	4.187E+04	9.305E+05	3.922E+05	.4219E+00
.4444E+00	.4931E+00	9.346E+04	1.917E+06	8.979E+05	.4688E+00
.4931E+00	.5456E+00	1.192E+05	2.270E+06	1.178E+06	.5194E+00
.5456E+00	.6094E+00	1.352E+05	2.121E+06	1.224E+06	.5775E+00
.6094E+00	.6769E+00	1.405E+05	2.082E+06	1.338E+06	.6431E+00
.6769E+00	.7946E+00	2.121E+05	1.801E+06	1.323E+06	.7358E+00
.7946E+00	.8870E+00	1.331E+05	1.441E+06	1.210E+06	.8408E+00
.8870E+00	.9871E+00	1.151E+05	1.150E+06	1.077E+06	.9371E+00
.9871E+00	.1095E+01	8.235E+04	7.639E+05	7.945E+05	.1041E+01
.1095E+01	.1218E+01	1.316E+05	1.068E+06	1.234E+06	.1157E+01
.1218E+01	.1391E+01	1.712E+05	9.901E+05	1.290E+06	.1305E+01
.1391E+01	.1573E+01	1.553E+05	8.533E+05	1.263E+06	.1482E+01
.1573E+01	.1807E+01	1.684E+05	7.197E+05	1.214E+06	.1690E+01
.1807E+01	.2041E+01	1.350E+05	5.771E+05	1.109E+06	.1924E+01
.2041E+01	.2327E+01	1.682E+05	5.883E+05	1.283E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	1.597E+05	5.120E+05	1.270E+06	.2483E+01
.2639E+01	.3003E+01	1.292E+05	3.551E+05	1.000E+06	.2821E+01
.3003E+01	.3419E+01	1.063E+05	2.556E+05	8.196E+05	.3211E+01
.3419E+01	.3861E+01	7.620E+04	1.724E+05	6.267E+05	.3640E+01
.3861E+01	.4407E+01	8.125E+04	1.488E+05	6.143E+05	.4134E+01
.4407E+01	.5000E+01	6.083E+04	1.026E+05	4.818E+05	.4703E+01
.5000E+01	.5500E+01	3.748E+04	7.496E+04	3.932E+05	.5250E+01
.5500E+01	.6000E+01	2.776E+04	5.551E+04	3.190E+05	.5750E+01
.6000E+01	.6500E+01	2.046E+04	4.093E+04	2.557E+05	.6250E+01
.6500E+01	.7000E+01	1.502E+04	3.004E+04	2.027E+05	.6750E+01
.7000E+01	.7500E+01	1.099E+04	2.198E+04	1.593E+05	.7250E+01
.7500E+01	.8000E+01	8.014E+03	1.603E+04	1.242E+05	.7750E+01
.8000E+01	.8500E+01	5.830E+03	1.166E+04	9.616E+04	.8250E+01
.8500E+01	.9000E+01	4.232E+03	8.464E+03	7.404E+04	.8750E+01
.9000E+01	.9500E+01	3.068E+03	6.135E+03	5.673E+04	.9250E+01
.9500E+01	.1000E+02	2.224E+03	4.448E+03	4.335E+04	.9750E+01

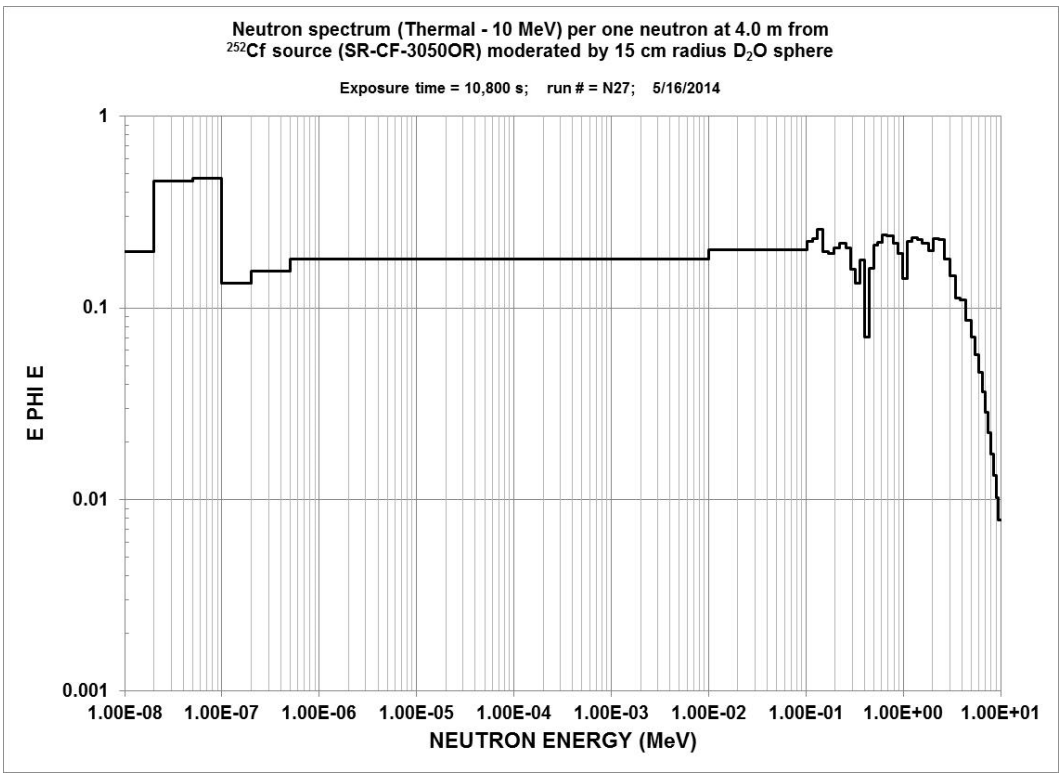
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



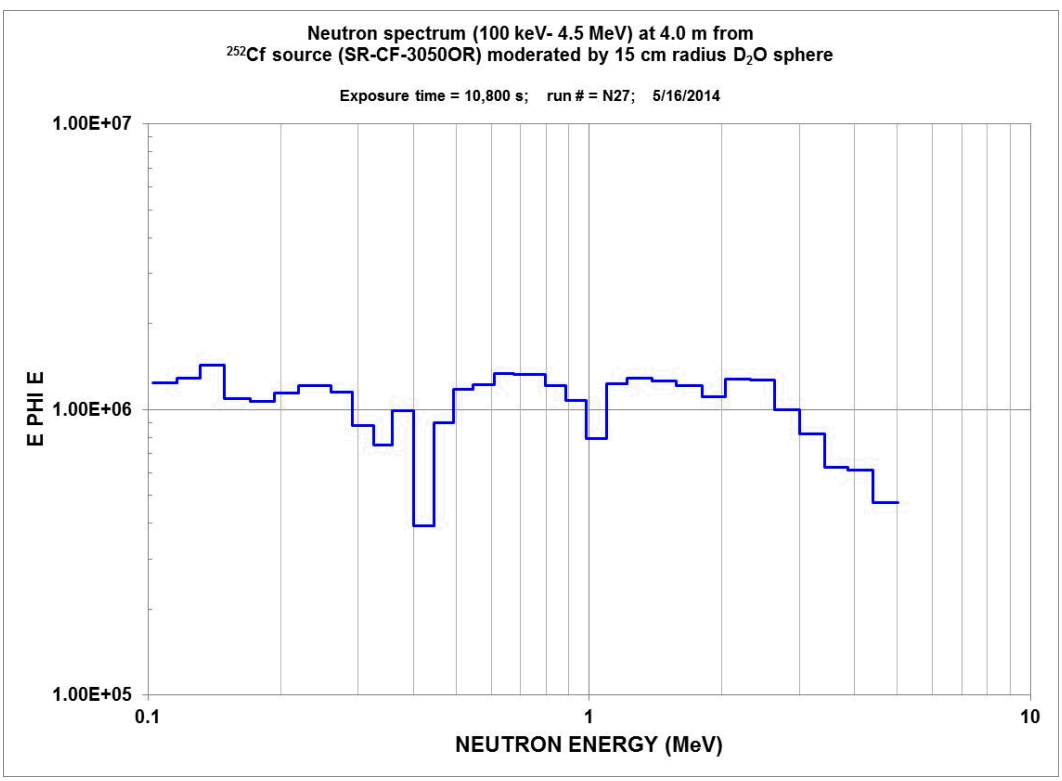


Figure F-5. Neutron spectra at 4.0 m from ^{252}Cf moderated by 15 cm of D_2O

Fluence, spectral and dosimetric data at 4.5 m from ^{252}Cf moderated by 15 cm of D_2O

Table F-11. Neutron fluence and dosimetric data at 4.5 m from 15 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/16/2014
Exposure time:	10,800 s
Run #	N28

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	3.67E+06	3.40E+02
Epi-thermal region	:	1.23E+07	1.14E+03
Thermal region	:	6.04E+06	5.59E+02
Thermal – 4.5 MeV	:	2.20E+07	2.04E+03
Thermal – 10.0 MeV	:	2.2106E+07	2.0469E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	7.42E-03	1.14E-03	2.47E+00	3.79E+02
Epi-thermal region	:	9.86E-04	1.93E-04	3.29E-01	6.45E+01
Thermal region	:	1.21E-04	6.40E-05	4.03E-02	2.13E+01
Thermal – 4.5 MeV	:	8.52E-03	1.40E-03	2.84E+00	4.65E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	8.7592E-03 rads	2.9197E+00 mrads/hr
H*(10) ICRP-74	=	1.4146E-03 Sv	4.7154E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.4705E-03 Sv	4.9016E+02 uSv/hr

Table F-12. Neutron fluence at 4.5 m from 15 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050-OR)

Date: 5/16/2014
Exposure time: 10,800 s
Run number: N28

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	1.365E+04	1.365E+13	1.970E+04	.1500E-08
.2000E-08	.5000E-08	8.759E+04	2.920E+13	9.560E+04	.3500E-08
.5000E-08	.1000E-07	2.664E+05	5.328E+13	3.843E+05	.7500E-08
.1000E-07	.2000E-07	7.853E+05	7.853E+13	1.133E+06	.1500E-07
.2000E-07	.5000E-07	2.434E+06	8.115E+13	2.657E+06	.3500E-07
.5000E-07	.1000E-06	1.903E+06	3.806E+13	2.745E+06	.7500E-07
.1000E-06	.2000E-06	5.352E+05	5.352E+12	7.722E+05	.1500E-06
.2000E-06	.5000E-06	7.740E+05	2.580E+12	8.447E+05	.3500E-06
.5000E-06	.1000E-01	9.151E+06	9.151E+08	9.240E+05	.5000E-02
.1000E-01	.1027E+00	2.390E+06	2.579E+07	1.026E+06	.5635E-01
.1027E+00	.1166E+00	1.416E+05	1.021E+07	1.118E+06	.1096E+00
.1166E+00	.1317E+00	1.593E+05	1.054E+07	1.306E+06	.1241E+00
.1317E+00	.1493E+00	1.266E+05	7.176E+06	1.007E+06	.1405E+00
.1493E+00	.1707E+00	1.985E+05	9.266E+06	1.480E+06	.1600E+00
.1707E+00	.1934E+00	1.287E+05	5.674E+06	1.032E+06	.1821E+00
.1934E+00	.2199E+00	9.154E+04	3.460E+06	7.139E+05	.2066E+00
.2199E+00	.2606E+00	1.922E+05	4.717E+06	1.130E+06	.2402E+00
.2606E+00	.2906E+00	1.047E+05	3.490E+06	9.610E+05	.2756E+00
.2906E+00	.3244E+00	7.959E+04	2.358E+06	7.244E+05	.3075E+00
.3244E+00	.3581E+00	8.014E+04	2.375E+06	8.097E+05	.3413E+00
.3581E+00	.3994E+00	9.609E+04	2.329E+06	8.814E+05	.3787E+00
.3994E+00	.4444E+00	4.882E+04	1.085E+06	4.573E+05	.4219E+00
.4444E+00	.4931E+00	8.317E+04	1.706E+06	7.990E+05	.4688E+00
.4931E+00	.5456E+00	9.317E+04	1.775E+06	9.209E+05	.5194E+00
.5456E+00	.6094E+00	1.185E+05	1.859E+06	1.073E+06	.5775E+00
.6094E+00	.6769E+00	1.174E+05	1.739E+06	1.118E+06	.6431E+00
.6769E+00	.7946E+00	1.986E+05	1.686E+06	1.238E+06	.7358E+00
.7946E+00	.8870E+00	1.163E+05	1.259E+06	1.058E+06	.8408E+00
.8870E+00	.9871E+00	1.019E+05	1.018E+06	9.532E+05	.9371E+00
.9871E+00	.1095E+01	8.503E+04	7.888E+05	8.204E+05	.1041E+01
.1095E+01	.1218E+01	1.213E+05	9.842E+05	1.137E+06	.1157E+01
.1218E+01	.1391E+01	1.293E+05	7.480E+05	9.744E+05	.1305E+01
.1391E+01	.1573E+01	1.379E+05	7.575E+05	1.121E+06	.1482E+01
.1573E+01	.1807E+01	1.446E+05	6.180E+05	1.043E+06	.1690E+01
.1807E+01	.2041E+01	1.216E+05	5.195E+05	9.983E+05	.1924E+01
.2041E+01	.2327E+01	1.335E+05	4.669E+05	1.018E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	1.328E+05	4.257E+05	1.056E+06	.2483E+01
.2639E+01	.3003E+01	1.178E+05	3.237E+05	9.119E+05	.2821E+01
.3003E+01	.3419E+01	8.669E+04	2.084E+05	6.682E+05	.3211E+01
.3419E+01	.3861E+01	5.993E+04	1.356E+05	4.929E+05	.3640E+01
.3861E+01	.4407E+01	6.839E+04	1.253E+05	5.171E+05	.4134E+01
.4407E+01	.5000E+01	5.033E+04	8.488E+04	3.987E+05	.4703E+01
.5000E+01	.5500E+01	2.753E+04	5.506E+04	2.888E+05	.5250E+01
.5500E+01	.6000E+01	2.039E+04	4.077E+04	2.343E+05	.5750E+01
.6000E+01	.6500E+01	1.503E+04	3.006E+04	1.878E+05	.6250E+01
.6500E+01	.7000E+01	1.103E+04	2.206E+04	1.489E+05	.6750E+01
.7000E+01	.7500E+01	8.074E+03	1.615E+04	1.170E+05	.7250E+01
.7500E+01	.8000E+01	5.886E+03	1.177E+04	9.121E+04	.7750E+01
.8000E+01	.8500E+01	4.282E+03	8.564E+03	7.063E+04	.8250E+01
.8500E+01	.9000E+01	3.108E+03	6.217E+03	5.438E+04	.8750E+01
.9000E+01	.9500E+01	2.253E+03	4.506E+03	4.167E+04	.9250E+01
.9500E+01	.1000E+02	1.633E+03	3.267E+03	3.184E+04	.9750E+01

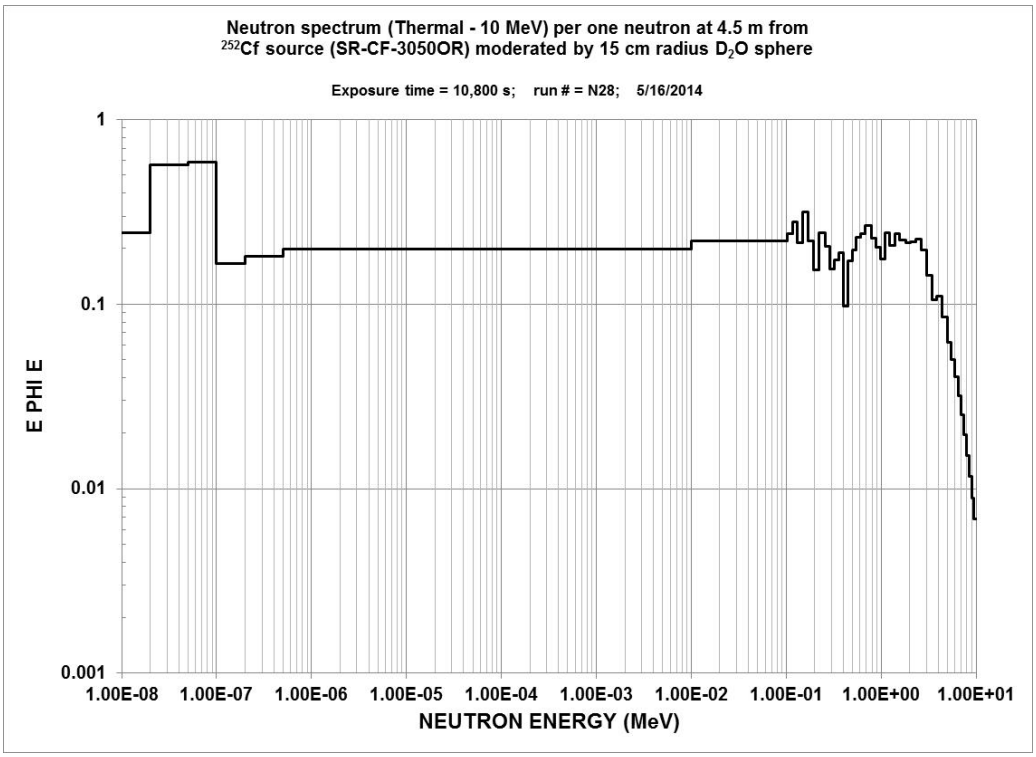
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



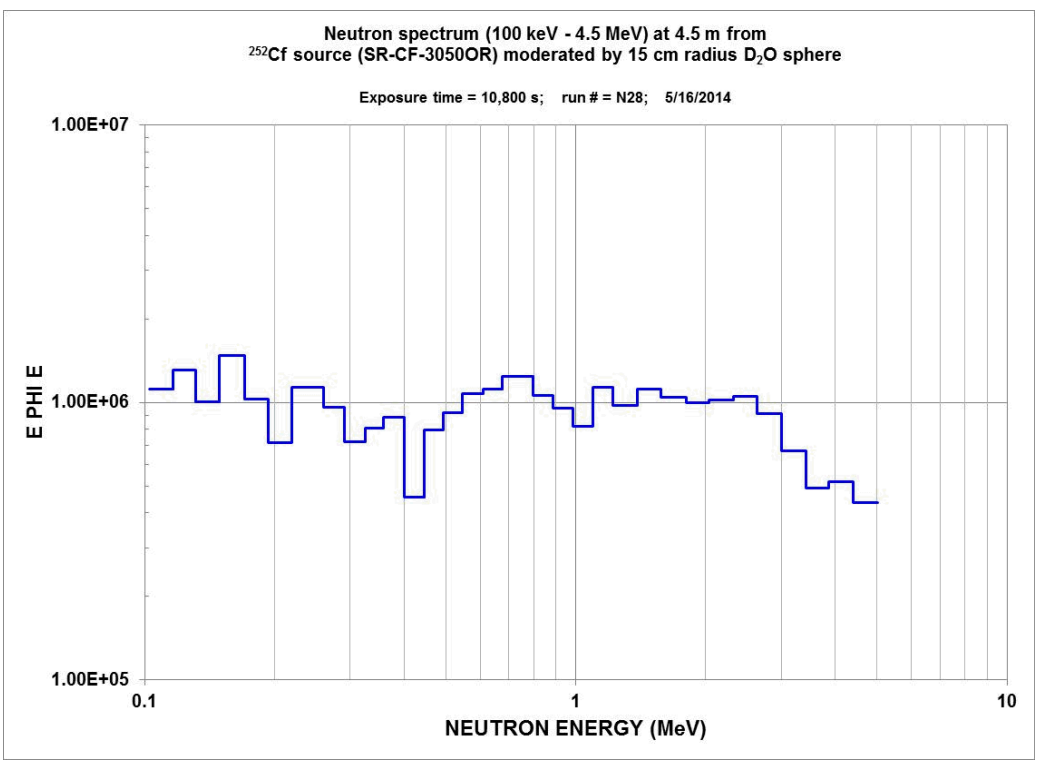


Figure F-6. Neutron spectra at 4.5 m from ^{252}Cf moderated by 15 cm of D_2O

Fluence, spectral and dosimetric data at 5.0 m from ^{252}Cf moderated by 15 cm of D_2O

Table F-13. Neutron fluence and dosimetric data at 5.0 m from 15 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/19/2014
Exposure time:	10,800 s
Run #	N29

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	2.57E+06	2.38E+02
Epi-thermal region	:	9.03E+06	8.37E+02
Thermal region	:	4.68E+06	4.33E+02
Thermal – 4.5 MeV	:	1.63E+07	1.51E+03
Thermal – 10.0 MeV	:	1.6337E+07	1.5127E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	5.15E-03	7.94E-04	1.72E+00	2.65E+02
Epi-thermal region	:	7.14E-04	1.41E-04	2.38E-01	4.70E+01
Thermal region	:	9.35E-05	4.96E-05	3.12E-02	1.65E+01
Thermal – 4.5 MeV	:	5.96E-03	9.85E-04	1.99E+00	3.28E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	6.1461E-03 rads	2.0487E+00 mrads/hr
H*(10) ICRP-74	=	9.9957E-04 Sv	3.3319E+02
Hp(10,0) ICRP-74	=	1.0397E-03 Sv	3.4656E+02 uSv/hr

Table F-14. Neutron fluence at 5.0 m from 15 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050-OR)

Date: 5/19/2014
Exposure time: 10,800 s
Run number: N29

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	1.057E+04	1.057E+13	1.525E+04	.1500E-08
.2000E-08	.5000E-08	6.780E+04	2.260E+13	7.399E+04	.3500E-08
.5000E-08	.1000E-07	2.062E+05	4.124E+13	2.975E+05	.7500E-08
.1000E-07	.2000E-07	6.079E+05	6.079E+13	8.770E+05	.1500E-07
.2000E-07	.5000E-07	1.884E+06	6.281E+13	2.057E+06	.3500E-07
.5000E-07	.1000E-06	1.473E+06	2.946E+13	2.125E+06	.7500E-07
.1000E-06	.2000E-06	4.143E+05	4.143E+12	5.977E+05	.1500E-06
.2000E-06	.5000E-06	5.837E+05	1.946E+12	6.370E+05	.3500E-06
.5000E-06	.1000E-01	6.724E+06	6.724E+08	6.790E+05	.5000E-02
.1000E-01	.1027E+00	1.727E+06	1.863E+07	7.413E+05	.5635E-01
.1027E+00	.1166E+00	1.114E+05	8.039E+06	8.801E+05	.1096E+00
.1166E+00	.1317E+00	1.256E+05	8.309E+06	1.030E+06	.1241E+00
.1317E+00	.1493E+00	7.393E+04	4.191E+06	5.880E+05	.1405E+00
.1493E+00	.1707E+00	1.064E+05	4.967E+06	7.936E+05	.1600E+00
.1707E+00	.1934E+00	9.886E+04	4.359E+06	7.926E+05	.1821E+00
.1934E+00	.2199E+00	9.288E+04	3.510E+06	7.244E+05	.2066E+00
.2199E+00	.2606E+00	1.128E+05	2.768E+06	6.634E+05	.2402E+00
.2606E+00	.2906E+00	7.485E+04	2.495E+06	6.870E+05	.2756E+00
.2906E+00	.3244E+00	6.219E+04	1.843E+06	5.661E+05	.3075E+00
.3244E+00	.3581E+00	6.011E+04	1.781E+06	6.073E+05	.3413E+00
.3581E+00	.3994E+00	4.212E+04	1.021E+06	3.864E+05	.3787E+00
.3994E+00	.4444E+00	5.466E+04	1.215E+06	5.120E+05	.4219E+00
.4444E+00	.4931E+00	6.269E+04	1.286E+06	6.023E+05	.4688E+00
.4931E+00	.5456E+00	8.084E+04	1.540E+06	7.991E+05	.5194E+00
.5456E+00	.6094E+00	8.196E+04	1.286E+06	7.417E+05	.5775E+00
.6094E+00	.6769E+00	7.781E+04	1.153E+06	7.407E+05	.6431E+00
.6769E+00	.7946E+00	1.363E+05	1.157E+06	8.495E+05	.7358E+00
.7946E+00	.8870E+00	8.687E+04	9.401E+05	7.897E+05	.8408E+00
.8870E+00	.9871E+00	6.431E+04	6.424E+05	6.014E+05	.9371E+00
.9871E+00	.1095E+01	6.652E+04	6.171E+05	6.418E+05	.1041E+01
.1095E+01	.1218E+01	8.105E+04	6.578E+05	7.601E+05	.1157E+01
.1218E+01	.1391E+01	8.494E+04	4.914E+05	6.401E+05	.1305E+01
.1391E+01	.1573E+01	9.476E+04	5.206E+05	7.706E+05	.1482E+01
.1573E+01	.1807E+01	9.903E+04	4.232E+05	7.141E+05	.1690E+01
.1807E+01	.2041E+01	8.719E+04	3.726E+05	7.160E+05	.1924E+01
.2041E+01	.2327E+01	1.003E+05	3.507E+05	7.648E+05	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	9.613E+04	3.081E+05	7.640E+05	.2483E+01
.2639E+01	.3003E+01	7.114E+04	1.954E+05	5.506E+05	.2821E+01
.3003E+01	.3419E+01	5.897E+04	1.417E+05	4.545E+05	.3211E+01
.3419E+01	.3861E+01	4.226E+04	9.561E+04	3.476E+05	.3640E+01
.3861E+01	.4407E+01	4.565E+04	8.361E+04	3.452E+05	.4134E+01
.4407E+01	.5000E+01	3.311E+04	5.584E+04	2.623E+05	.4703E+01
.5000E+01	.5500E+01	1.960E+04	3.920E+04	2.056E+05	.5250E+01
.5500E+01	.6000E+01	1.452E+04	2.903E+04	1.668E+05	.5750E+01
.6000E+01	.6500E+01	1.070E+04	2.140E+04	1.337E+05	.6250E+01
.6500E+01	.7000E+01	7.855E+03	1.571E+04	1.060E+05	.6750E+01
.7000E+01	.7500E+01	5.749E+03	1.150E+04	8.332E+04	.7250E+01
.7500E+01	.8000E+01	4.191E+03	8.382E+03	6.494E+04	.7750E+01
.8000E+01	.8500E+01	3.049E+03	6.098E+03	5.029E+04	.8250E+01
.8500E+01	.9000E+01	2.213E+03	4.427E+03	3.872E+04	.8750E+01
.9000E+01	.9500E+01	1.604E+03	3.208E+03	2.967E+04	.9250E+01
.9500E+01	.1000E+02	1.163E+03	2.326E+03	2.267E+04	.9750E+01

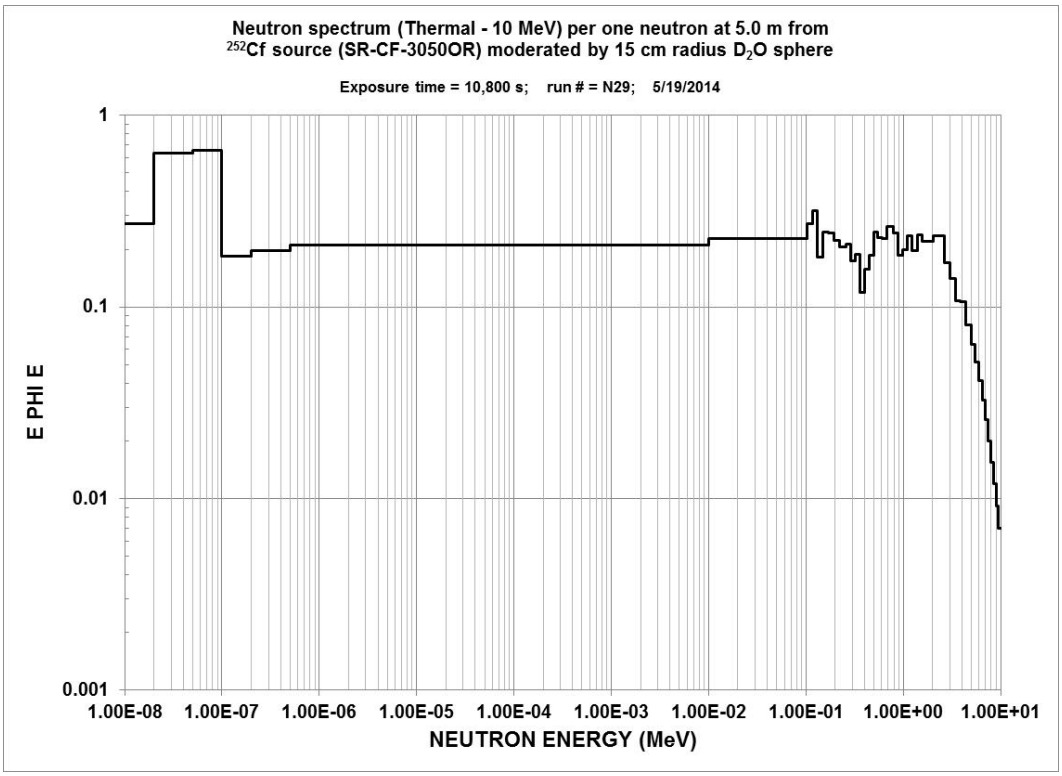
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



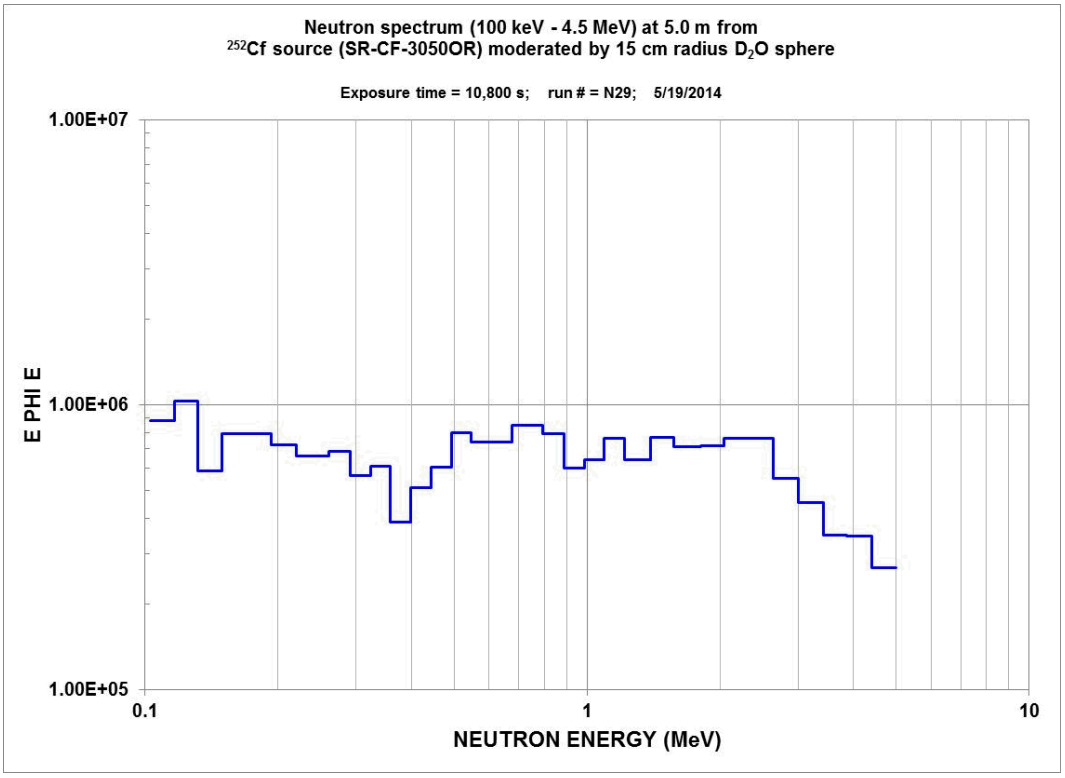
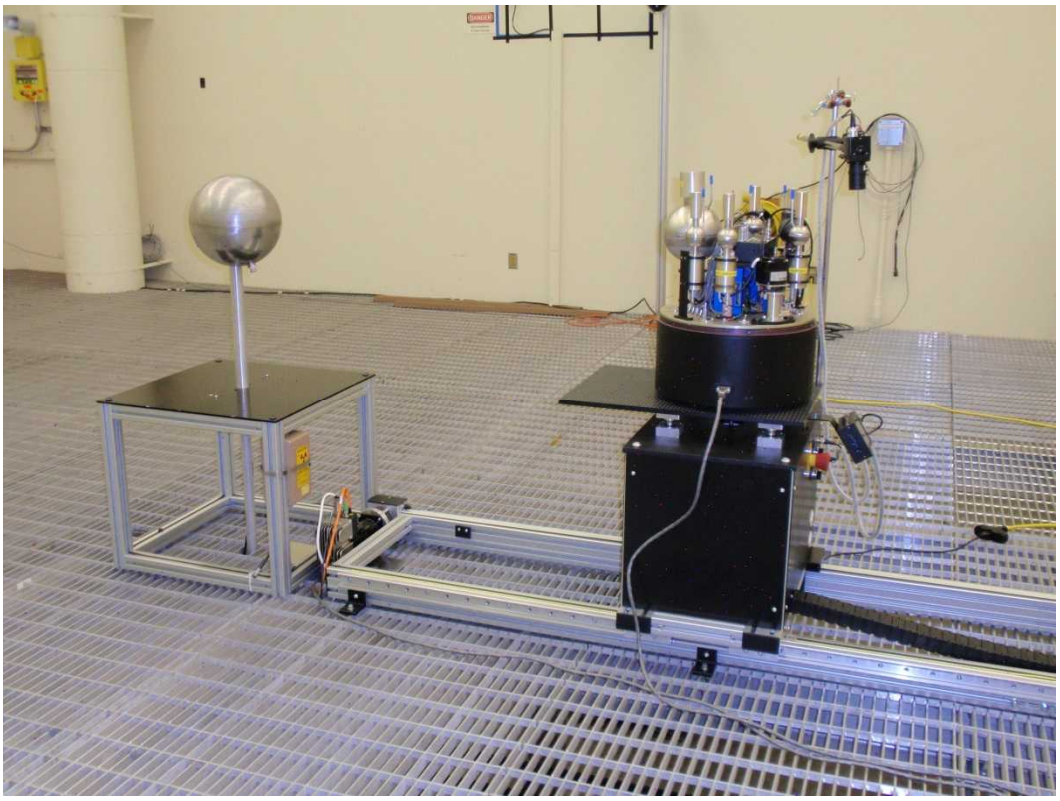


Figure F-7. Neutron spectra at 5.0 m from ^{252}Cf moderated by 15 cm of D_2O

Appendix G

Neutron fluence, spectra and dose rates from ^{252}Cf moderated by 10 cm of D_2O



Fluence, spectral and dosimetric data at 2.0 m from ^{252}Cf moderated by 10 cm of D_2O

Table G-1. Neutron fluence and dosimetric data at 2.0 m from 10 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/22/2014
Exposure time:	7,200 s
Run #	N32

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.21E+07	1.67E+03
Epi-thermal region	:	1.70E+07	2.36E+03
Thermal region	:	4.58E+06	6.37E+02
Thermal – 4.5 MeV	:	3.36E+07	4.67E+03
Thermal – 10.0 MeV	:	3.4124E+07	4.7395E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	2.65E-02	3.93E-03	1.33E+01	1.97E+03
Epi-thermal region	:	1.76E-03	3.00E-04	8.78E-01	1.50E+02
Thermal region	:	9.17E-05	4.86E-05	4.58E-02	2.43E+01
Thermal – 4.5 MeV	:	2.84E-02	4.28E-03	1.42E+01	2.14E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	3.0006E-02 rads	1.5003E+01 mrads/hr
H*(10) ICRP-74	=	4.4310E-03 Sv	2.2155E+03 uSv/hr
Hp(10,0) ICRP-74	=	4.5955E-03 Sv	2.2977E+03 uSv/hr

Table G-2. Neutron fluence at 2.0 m from 10 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/22/2014
Exposure time: 7,200 s
Run number: N32

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	1.036E+04	1.036E+13	1.494E+04	.1500E-08
.2000E-08	.5000E-08	6.645E+04	2.215E+13	7.252E+04	.3500E-08
.5000E-08	.1000E-07	2.021E+05	4.042E+13	2.916E+05	.7500E-08
.1000E-07	.2000E-07	5.958E+05	5.958E+13	8.595E+05	.1500E-07
.2000E-07	.5000E-07	1.847E+06	6.156E+13	2.016E+06	.3500E-07
.5000E-07	.1000E-06	1.444E+06	2.887E+13	2.083E+06	.7500E-07
.1000E-06	.2000E-06	4.060E+05	4.060E+12	5.858E+05	.1500E-06
.2000E-06	.5000E-06	7.647E+05	2.549E+12	8.345E+05	.3500E-06
.5000E-06	.1000E-01	1.177E+07	1.178E+09	1.189E+06	.5000E-02
.1000E-01	.1027E+00	4.460E+06	4.812E+07	1.915E+06	.5635E-01
.1027E+00	.1166E+00	3.785E+05	2.731E+07	2.989E+06	.1096E+00
.1166E+00	.1317E+00	4.121E+05	2.726E+07	3.379E+06	.1241E+00
.1317E+00	.1493E+00	3.810E+05	2.160E+07	3.031E+06	.1405E+00
.1493E+00	.1707E+00	4.303E+05	2.009E+07	3.210E+06	.1600E+00
.1707E+00	.1934E+00	3.319E+05	1.463E+07	2.661E+06	.1821E+00
.1934E+00	.2199E+00	3.620E+05	1.368E+07	2.824E+06	.2066E+00
.2199E+00	.2606E+00	4.829E+05	1.185E+07	2.840E+06	.2402E+00
.2606E+00	.2906E+00	2.824E+05	9.414E+06	2.592E+06	.2756E+00
.2906E+00	.3244E+00	2.654E+05	7.864E+06	2.416E+06	.3075E+00
.3244E+00	.3581E+00	2.613E+05	7.743E+06	2.640E+06	.3413E+00
.3581E+00	.3994E+00	2.406E+05	5.834E+06	2.207E+06	.3787E+00
.3994E+00	.4444E+00	2.070E+05	4.599E+06	1.938E+06	.4219E+00
.4444E+00	.4931E+00	2.605E+05	5.343E+06	2.502E+06	.4688E+00
.4931E+00	.5456E+00	2.869E+05	5.464E+06	2.835E+06	.5194E+00
.5456E+00	.6094E+00	3.650E+05	5.725E+06	3.303E+06	.5775E+00
.6094E+00	.6769E+00	3.493E+05	5.174E+06	3.325E+06	.6431E+00
.6769E+00	.7946E+00	5.605E+05	4.760E+06	3.495E+06	.7358E+00
.7946E+00	.8870E+00	4.174E+05	4.517E+06	3.794E+06	.8408E+00
.8870E+00	.9871E+00	3.278E+05	3.275E+06	3.066E+06	.9371E+00
.9871E+00	.1095E+01	2.521E+05	2.339E+06	2.433E+06	.1041E+01
.1095E+01	.1218E+01	4.041E+05	3.280E+06	3.790E+06	.1157E+01
.1218E+01	.1391E+01	4.967E+05	2.873E+06	3.743E+06	.1305E+01
.1391E+01	.1573E+01	4.815E+05	2.646E+06	3.916E+06	.1482E+01
.1573E+01	.1807E+01	5.553E+05	2.373E+06	4.004E+06	.1690E+01
.1807E+01	.2041E+01	4.637E+05	1.982E+06	3.808E+06	.1924E+01
.2041E+01	.2327E+01	5.510E+05	1.927E+06	4.202E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)

.2327E+01	.2639E+01	5.370E+05	1.721E+06	4.268E+06	.2483E+01
.2639E+01	.3003E+01	4.695E+05	1.290E+06	3.634E+06	.2821E+01
.3003E+01	.3419E+01	3.919E+05	9.422E+05	3.021E+06	.3211E+01
.3419E+01	.3861E+01	2.905E+05	6.573E+05	2.390E+06	.3640E+01
.3861E+01	.4407E+01	2.931E+05	5.368E+05	2.216E+06	.4134E+01
.4407E+01	.5000E+01	2.489E+05	4.198E+05	1.972E+06	.4703E+01
.5000E+01	.5500E+01	1.429E+05	2.859E+05	1.500E+06	.5250E+01
.5500E+01	.6000E+01	1.059E+05	2.117E+05	1.217E+06	.5750E+01
.6000E+01	.6500E+01	7.805E+04	1.561E+05	9.751E+05	.6250E+01
.6500E+01	.7000E+01	5.728E+04	1.146E+05	7.730E+05	.6750E+01
.7000E+01	.7500E+01	4.192E+04	8.385E+04	6.076E+05	.7250E+01
.7500E+01	.8000E+01	3.056E+04	6.113E+04	4.736E+05	.7750E+01
.8000E+01	.8500E+01	2.223E+04	4.447E+04	3.668E+05	.8250E+01
.8500E+01	.9000E+01	1.614E+04	3.228E+04	2.824E+05	.8750E+01
.9000E+01	.9500E+01	1.170E+04	2.340E+04	2.164E+05	.9250E+01
.9500E+01	.1000E+02	8.481E+03	1.696E+04	1.653E+05	.9750E+01

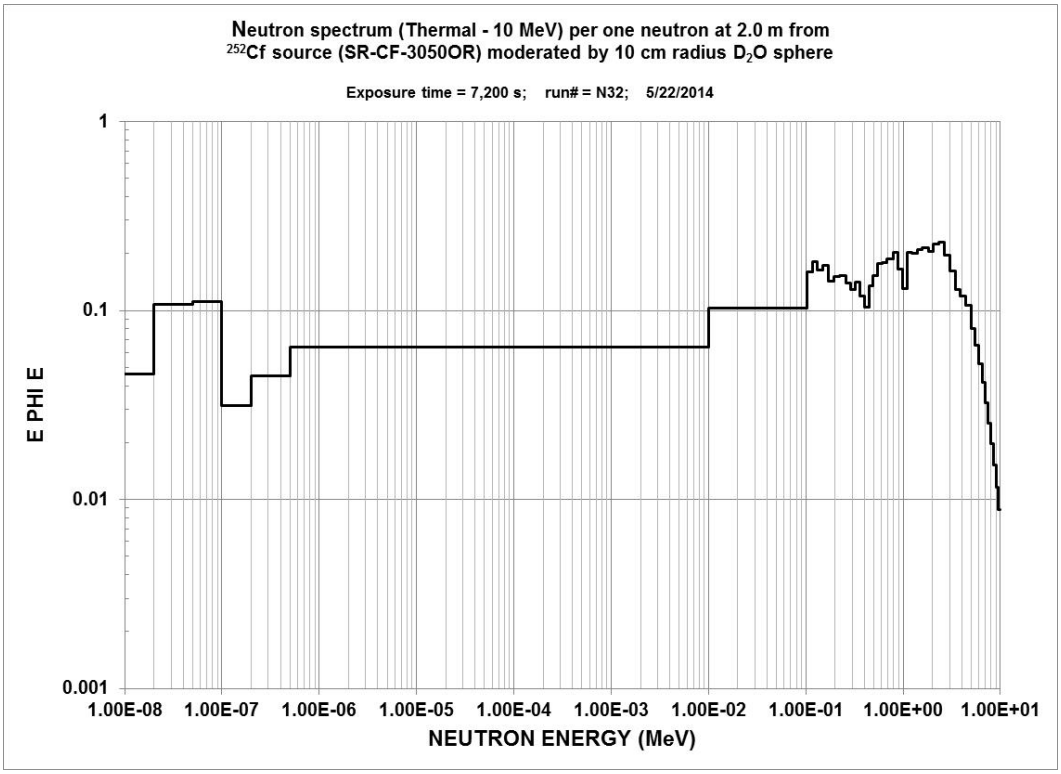
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



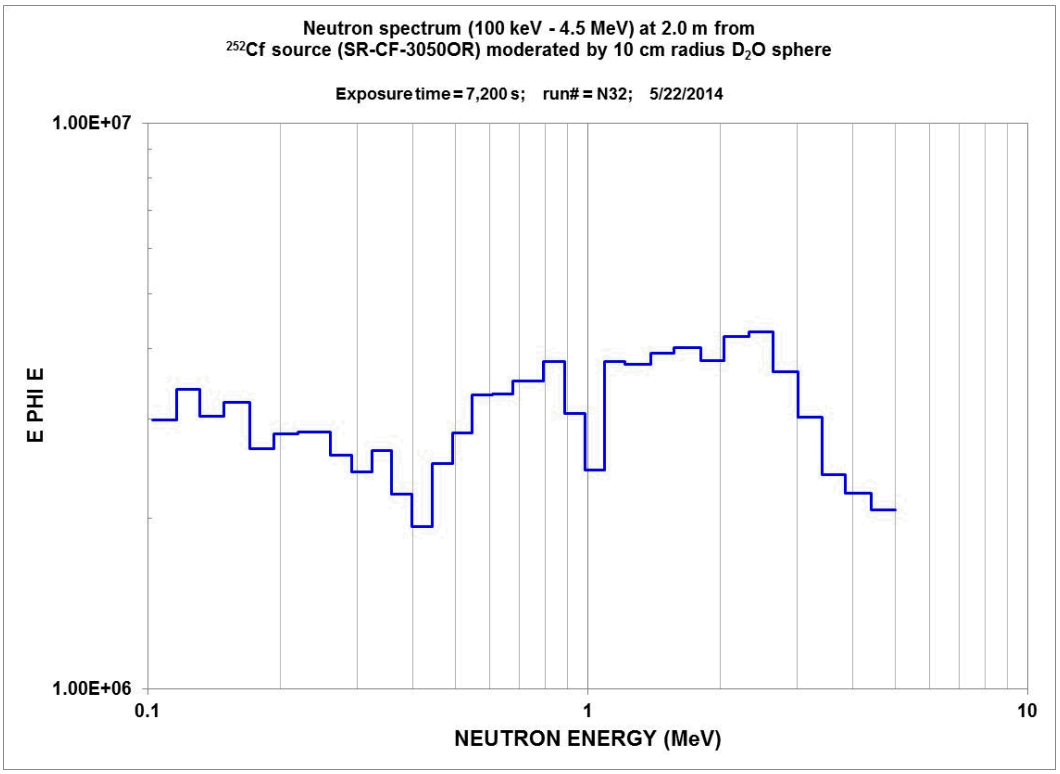


Figure G-1. Neutron spectra at 2.0 m from ^{252}Cf moderated by 10 cm of D_2O

Fluence, spectral and dosimetric data at 2.5 m from ^{252}Cf moderated by 10 cm of D_2O

Table G-3. Neutron fluence and dosimetric data at 2.5 m from 10 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/22/2014
Exposure time:	7,200 s
Run #	N33

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	8.64E+06	1.20E+03
Epi-thermal region	:	1.36E+07	1.90E+03
Thermal region	:	4.41E+06	6.13E+02
Thermal – 4.5 MeV	:	2.67E+07	3.71E+03
Thermal – 10.0 MeV	:	2.7031E+07	3.7542E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.88E-02	2.81E-03	9.38E+00	1.41E+03
Epi-thermal region	:	1.35E-03	2.35E-04	6.73E-01	1.18E+02
Thermal region	:	8.83E-05	4.68E-05	4.41E-02	2.34E+01
Thermal – 4.5 MeV	:	2.02E-02	3.09E-03	1.01E+01	1.55E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.1302E-02 rads	1.0651E+01 mrads/hr
H*(10) ICRP-74	=	3.1923E-03 Sv	1.5961E+03 uSv/hr
Hp(10,0) ICRP-74	=	3.3113E-03 Sv	1.6556E+03 uSv/hr

Table G-4. Neutron fluence at 2.5 m from 10 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/22/2014
Exposure time: 7,200 s
Run number: N33

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	9.977E+03	9.977E+12	1.439E+04	.1500E-08
.2000E-08	.5000E-08	6.401E+04	2.134E+13	6.986E+04	.3500E-08
.5000E-08	.1000E-07	1.947E+05	3.894E+13	2.809E+05	.7500E-08
.1000E-07	.2000E-07	5.739E+05	5.739E+13	8.280E+05	.1500E-07
.2000E-07	.5000E-07	1.779E+06	5.930E+13	1.942E+06	.3500E-07
.5000E-07	.1000E-06	1.391E+06	2.781E+13	2.006E+06	.7500E-07
.1000E-06	.2000E-06	3.911E+05	3.911E+12	5.643E+05	.1500E-06
.2000E-06	.5000E-06	6.768E+05	2.256E+12	7.386E+05	.3500E-06
.5000E-06	.1000E-01	9.574E+06	9.574E+08	9.667E+05	.5000E-02
.1000E-01	.1027E+00	3.395E+06	3.663E+07	1.458E+06	.5635E-01
.1027E+00	.1166E+00	2.608E+05	1.882E+07	2.060E+06	.1096E+00
.1166E+00	.1317E+00	2.921E+05	1.932E+07	2.394E+06	.1241E+00
.1317E+00	.1493E+00	2.975E+05	1.686E+07	2.366E+06	.1405E+00
.1493E+00	.1707E+00	3.054E+05	1.426E+07	2.278E+06	.1600E+00
.1707E+00	.1934E+00	2.677E+05	1.180E+07	2.147E+06	.1821E+00
.1934E+00	.2199E+00	2.541E+05	9.602E+06	1.981E+06	.2066E+00
.2199E+00	.2606E+00	3.053E+05	7.492E+06	1.796E+06	.2402E+00
.2606E+00	.2906E+00	2.196E+05	7.320E+06	2.016E+06	.2756E+00
.2906E+00	.3244E+00	2.088E+05	6.186E+06	1.900E+06	.3075E+00
.3244E+00	.3581E+00	1.699E+05	5.033E+06	1.716E+06	.3413E+00
.3581E+00	.3994E+00	1.570E+05	3.805E+06	1.440E+06	.3787E+00
.3994E+00	.4444E+00	1.705E+05	3.788E+06	1.597E+06	.4219E+00
.4444E+00	.4931E+00	2.078E+05	4.262E+06	1.996E+06	.4688E+00
.4931E+00	.5456E+00	2.148E+05	4.091E+06	2.123E+06	.5194E+00
.5456E+00	.6094E+00	2.590E+05	4.063E+06	2.344E+06	.5775E+00
.6094E+00	.6769E+00	2.765E+05	4.096E+06	2.632E+06	.6431E+00
.6769E+00	.7946E+00	4.364E+05	3.706E+06	2.721E+06	.7358E+00
.7946E+00	.8870E+00	2.810E+05	3.041E+06	2.555E+06	.8408E+00
.8870E+00	.9871E+00	2.555E+05	2.553E+06	2.390E+06	.9371E+00
.9871E+00	.1095E+01	1.817E+05	1.685E+06	1.753E+06	.1041E+01
.1095E+01	.1218E+01	2.506E+05	2.034E+06	2.350E+06	.1157E+01
.1218E+01	.1391E+01	4.125E+05	2.386E+06	3.108E+06	.1305E+01
.1391E+01	.1573E+01	3.463E+05	1.903E+06	2.817E+06	.1482E+01
.1573E+01	.1807E+01	3.799E+05	1.623E+06	2.739E+06	.1690E+01
.1807E+01	.2041E+01	3.254E+05	1.391E+06	2.672E+06	.1924E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2041E+01	.2327E+01	3.923E+05	1.372E+06	2.991E+06	.2184E+01
.2327E+01	.2639E+01	3.768E+05	1.208E+06	2.995E+06	.2483E+01
.2639E+01	.3003E+01	3.125E+05	8.586E+05	2.419E+06	.2821E+01
.3003E+01	.3419E+01	2.674E+05	6.427E+05	2.061E+06	.3211E+01
.3419E+01	.3861E+01	1.931E+05	4.368E+05	1.588E+06	.3640E+01
.3861E+01	.4407E+01	1.954E+05	3.579E+05	1.477E+06	.4134E+01
.4407E+01	.5000E+01	1.603E+05	2.704E+05	1.270E+06	.4703E+01
.5000E+01	.5500E+01	9.637E+04	1.927E+05	1.011E+06	.5250E+01
.5500E+01	.6000E+01	7.138E+04	1.428E+05	8.203E+05	.5750E+01
.6000E+01	.6500E+01	5.262E+04	1.052E+05	6.574E+05	.6250E+01
.6500E+01	.7000E+01	3.862E+04	7.725E+04	5.212E+05	.6750E+01
.7000E+01	.7500E+01	2.827E+04	5.653E+04	4.097E+05	.7250E+01
.7500E+01	.8000E+01	2.061E+04	4.122E+04	3.193E+05	.7750E+01
.8000E+01	.8500E+01	1.499E+04	2.998E+04	2.473E+05	.8250E+01
.8500E+01	.9000E+01	1.088E+04	2.177E+04	1.904E+05	.8750E+01
.9000E+01	.9500E+01	7.888E+03	1.578E+04	1.459E+05	.9250E+01
.9500E+01	.1000E+02	5.718E+03	1.144E+04	1.115E+05	.9750E+01

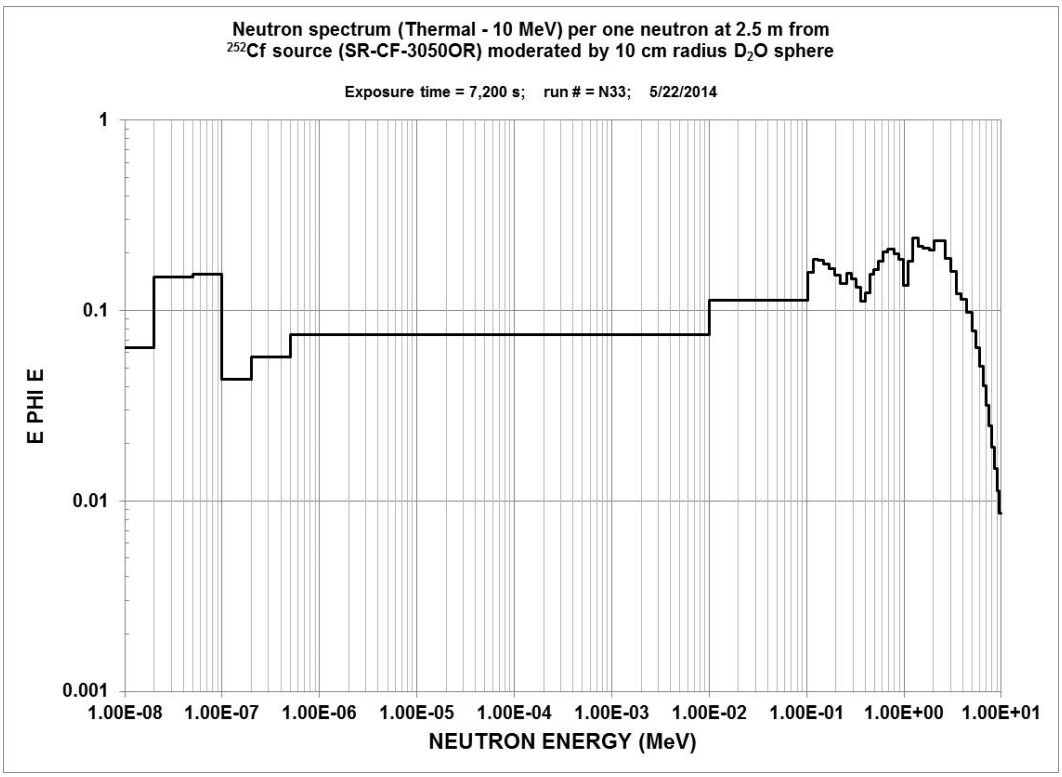
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



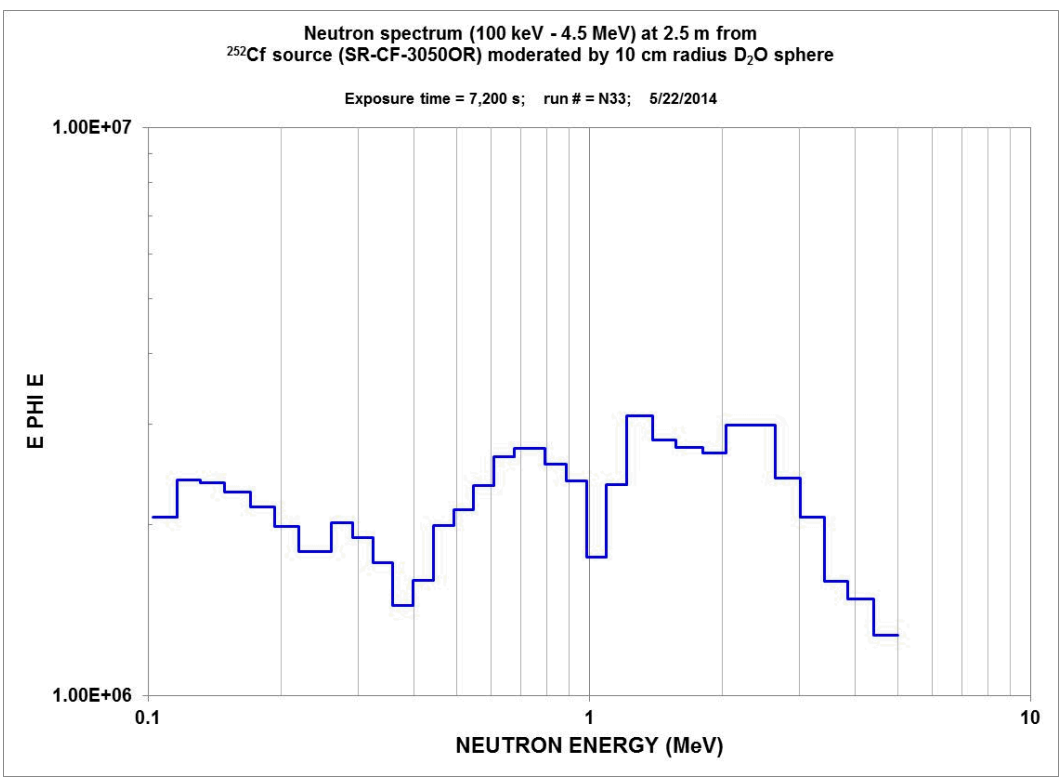


Figure G-2. Neutron spectra at 2.5 m from ^{252}Cf moderated by 10 cm of D_2O

Fluence, spectral and dosimetric data at 3.0 m from ^{252}Cf moderated by 10 cm of D_2O

Table G-5. Neutron fluence and dosimetric data at 3.0 m from 10 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/27/2014
Exposure time:	7,200 s
Run #	N39

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	6.78E+06	9.42E+02
Epi-thermal region	:	1.16E+07	1.61E+03
Thermal region	:	4.29E+06	5.96E+02
Thermal – 4.5 MeV	:	2.27E+07	3.15E+03
Thermal – 10.0 MeV	:	2.2920E+07	3.1833E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.44E-02	2.17E-03	7.19E+00	1.09E+03
Epi-thermal region	:	1.15E-03	2.00E-04	5.73E-01	1.00E+02
Thermal region	:	8.58E-05	4.55E-05	4.29E-02	2.27E+01
Thermal – 4.5 MeV	:	1.56E-02	2.42E-03	7.81E+00	1.21E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.6319E-02 rads	8.1596E+00 mrads/hr
H*(10) ICRP-74	=	2.4811E-03 Sv	1.2405E+03 uSv/hr
Hp(10,0) ICRP-74	=	2.5733E-03 Sv	1.2866E+03 uSv/hr

Table G-6. Neutron fluence at 3.0 m from 10 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/27/2014
Exposure time: 7,200 s
Run number: N39

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	9.700E+03	9.700E+12	1.399E+04	.1500E-08
.2000E-08	.5000E-08	6.224E+04	2.075E+13	6.792E+04	.3500E-08
.5000E-08	.1000E-07	1.893E+05	3.786E+13	2.731E+05	.7500E-08
.1000E-07	.2000E-07	5.580E+05	5.580E+13	8.050E+05	.1500E-07
.2000E-07	.5000E-07	1.730E+06	5.766E+13	1.888E+06	.3500E-07
.5000E-07	.1000E-06	1.352E+06	2.704E+13	1.951E+06	.7500E-07
.1000E-06	.2000E-06	3.803E+05	3.803E+12	5.486E+05	.1500E-06
.2000E-06	.5000E-06	6.144E+05	2.048E+12	6.706E+05	.3500E-06
.5000E-06	.1000E-01	8.117E+06	8.117E+08	8.196E+05	.5000E-02
.1000E-01	.1027E+00	2.890E+06	3.117E+07	1.241E+06	.5635E-01
.1027E+00	.1166E+00	2.524E+05	1.821E+07	1.994E+06	.1096E+00
.1166E+00	.1317E+00	2.158E+05	1.427E+07	1.769E+06	.1241E+00
.1317E+00	.1493E+00	2.459E+05	1.394E+07	1.956E+06	.1405E+00
.1493E+00	.1707E+00	2.617E+05	1.222E+07	1.952E+06	.1600E+00
.1707E+00	.1934E+00	2.425E+05	1.069E+07	1.944E+06	.1821E+00
.1934E+00	.2199E+00	1.960E+05	7.407E+06	1.529E+06	.2066E+00
.2199E+00	.2606E+00	2.555E+05	6.270E+06	1.503E+06	.2402E+00
.2606E+00	.2906E+00	1.747E+05	5.822E+06	1.603E+06	.2756E+00
.2906E+00	.3244E+00	1.679E+05	4.976E+06	1.529E+06	.3075E+00
.3244E+00	.3581E+00	1.463E+05	4.336E+06	1.478E+06	.3413E+00
.3581E+00	.3994E+00	1.367E+05	3.314E+06	1.254E+06	.3787E+00
.3994E+00	.4444E+00	1.150E+05	2.555E+06	1.077E+06	.4219E+00
.4444E+00	.4931E+00	1.543E+05	3.165E+06	1.482E+06	.4688E+00
.4931E+00	.5456E+00	1.883E+05	3.586E+06	1.861E+06	.5194E+00
.5456E+00	.6094E+00	2.119E+05	3.324E+06	1.918E+06	.5775E+00
.6094E+00	.6769E+00	1.996E+05	2.956E+06	1.900E+06	.6431E+00
.6769E+00	.7946E+00	3.470E+05	2.947E+06	2.163E+06	.7358E+00
.7946E+00	.8870E+00	2.285E+05	2.473E+06	2.077E+06	.8408E+00
.8870E+00	.9871E+00	2.004E+05	2.002E+06	1.874E+06	.9371E+00
.9871E+00	.1095E+01	1.376E+05	1.277E+06	1.328E+06	.1041E+01
.1095E+01	.1218E+01	2.277E+05	1.848E+06	2.136E+06	.1157E+01
.1218E+01	.1391E+01	2.889E+05	1.671E+06	2.177E+06	.1305E+01
.1391E+01	.1573E+01	2.624E+05	1.442E+06	2.134E+06	.1482E+01
.1573E+01	.1807E+01	2.914E+05	1.245E+06	2.101E+06	.1690E+01
.1807E+01	.2041E+01	2.400E+05	1.026E+06	1.971E+06	.1924E+01
.2041E+01	.2327E+01	2.946E+05	1.030E+06	2.247E+06	.2184E+01
.2327E+01	.2639E+01	2.788E+05	8.936E+05	2.216E+06	.2483E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2639E+01	.3003E+01	2.286E+05	6.281E+05	1.770E+06	.2821E+01
.3003E+01	.3419E+01	1.887E+05	4.535E+05	1.454E+06	.3211E+01
.3419E+01	.3861E+01	1.474E+05	3.335E+05	1.213E+06	.3640E+01
.3861E+01	.4407E+01	1.445E+05	2.646E+05	1.092E+06	.4134E+01
.4407E+01	.5000E+01	1.101E+05	1.857E+05	8.724E+05	.4703E+01
.5000E+01	.5500E+01	6.570E+04	1.314E+05	6.893E+05	.5250E+01
.5500E+01	.6000E+01	4.866E+04	9.732E+04	5.592E+05	.5750E+01
.6000E+01	.6500E+01	3.587E+04	7.175E+04	4.482E+05	.6250E+01
.6500E+01	.7000E+01	2.633E+04	5.266E+04	3.553E+05	.6750E+01
.7000E+01	.7500E+01	1.927E+04	3.854E+04	2.793E+05	.7250E+01
.7500E+01	.8000E+01	1.405E+04	2.810E+04	2.177E+05	.7750E+01
.8000E+01	.8500E+01	1.022E+04	2.044E+04	1.686E+05	.8250E+01
.8500E+01	.9000E+01	7.419E+03	1.484E+04	1.298E+05	.8750E+01
.9000E+01	.9500E+01	5.377E+03	1.075E+04	9.946E+04	.9250E+01
.9500E+01	.1000E+02	3.898E+03	7.797E+03	7.600E+04	.9750E+01

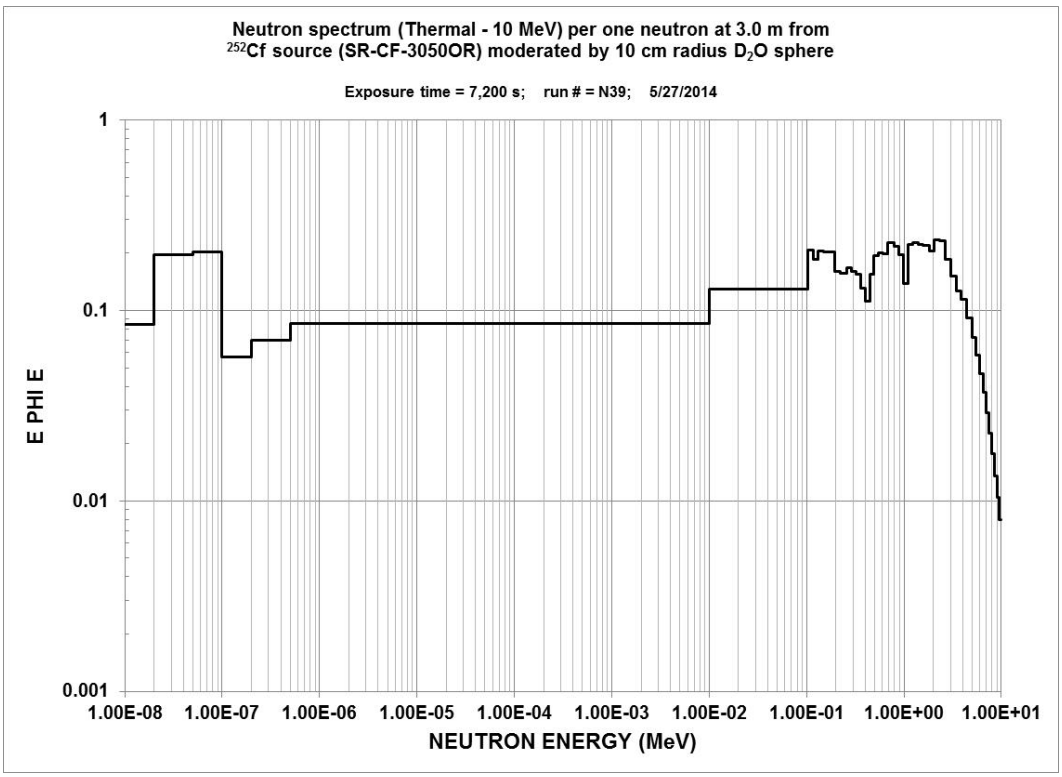
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



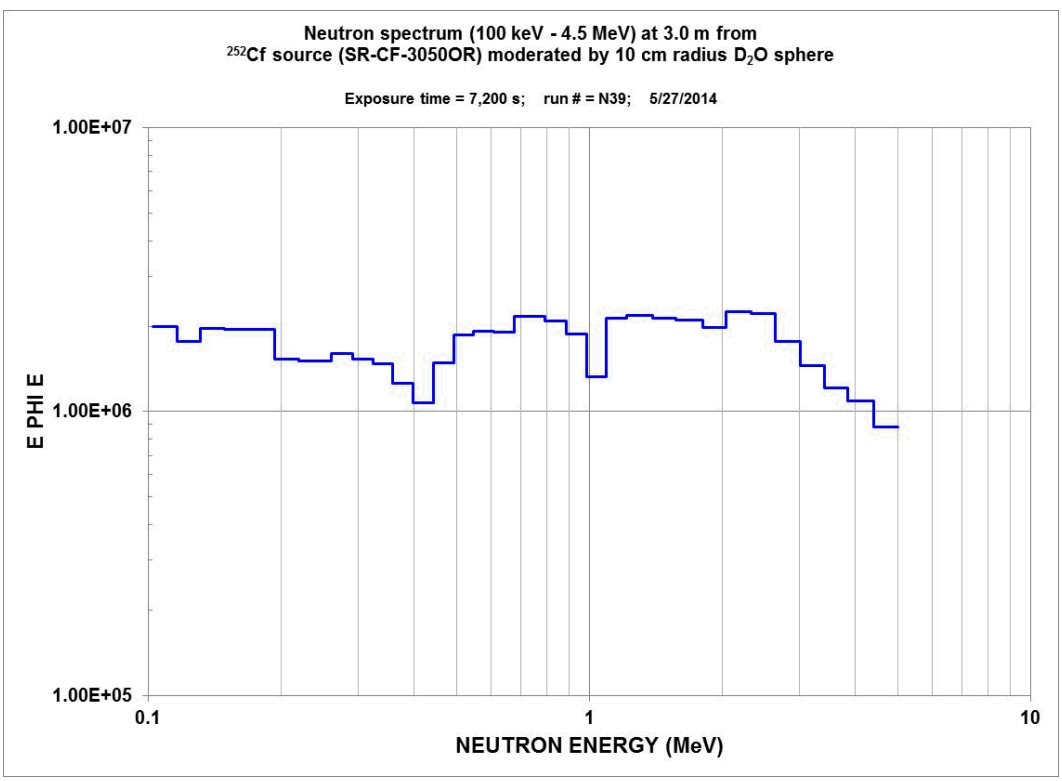


Figure G-3. Neutron spectra at 3.0 m from ^{252}Cf moderated by 10 cm of D_2O

Fluence, spectral and dosimetric data at 3.5 m from ^{252}Cf moderated by 10 cm of D_2O

Table G-7. Neutron fluence and dosimetric data at 3.5 m from 10 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/27/2014
Exposure time:	7,200 s
Run #	N38

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	5.58E+06	7.75E+02
Epi-thermal region	:	1.04E+07	1.45E+03
Thermal region	:	4.23E+06	5.88E+02
Thermal – 4.5 MeV	:	2.03E+07	2.81E+03
Thermal – 10.0 MeV	:	2.0404E+07	2.8339E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.17E-02	1.78E-03	5.84E+00	8.90E+02
Epi-thermal region	:	9.93E-04	1.77E-04	4.96E-01	8.85E+01
Thermal region	:	8.46E-05	4.49E-05	4.23E-02	2.24E+01
Thermal – 4.5 MeV	:	1.28E-02	2.00E-03	6.38E+00	1.00E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.3206E-02 rads	6.6029E+00 mrads/hr
H*(10) ICRP-74	=	2.0401E-03 Sv	1.0200E+03 uSv/hr
Hp(10,0) ICRP-74	=	2.1162E-03 Sv	1.0581E+03 uSv/hr

Table G-8. Neutron fluence at 3.5 m from 10 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/27/2014
Exposure time: 7,200 s
Run number: N38

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	9.563E+03	9.563E+12	1.380E+04	.1500E-08
.2000E-08	.5000E-08	6.136E+04	2.045E+13	6.696E+04	.3500E-08
.5000E-08	.1000E-07	1.866E+05	3.732E+13	2.692E+05	.7500E-08
.1000E-07	.2000E-07	5.501E+05	5.501E+13	7.936E+05	.1500E-07
.2000E-07	.5000E-07	1.705E+06	5.684E+13	1.861E+06	.3500E-07
.5000E-07	.1000E-06	1.333E+06	2.666E+13	1.923E+06	.7500E-07
.1000E-06	.2000E-06	3.749E+05	3.749E+12	5.409E+05	.1500E-06
.2000E-06	.5000E-06	5.813E+05	1.938E+12	6.344E+05	.3500E-06
.5000E-06	.1000E-01	7.370E+06	7.370E+08	7.441E+05	.5000E-02
.1000E-01	.1027E+00	2.489E+06	2.685E+07	1.069E+06	.5635E-01
.1027E+00	.1166E+00	1.901E+05	1.372E+07	1.502E+06	.1096E+00
.1166E+00	.1317E+00	2.082E+05	1.377E+07	1.707E+06	.1241E+00
.1317E+00	.1493E+00	2.047E+05	1.160E+07	1.628E+06	.1405E+00
.1493E+00	.1707E+00	1.952E+05	9.114E+06	1.456E+06	.1600E+00
.1707E+00	.1934E+00	1.715E+05	7.560E+06	1.375E+06	.1821E+00
.1934E+00	.2199E+00	1.863E+05	7.040E+06	1.453E+06	.2066E+00
.2199E+00	.2606E+00	2.395E+05	5.877E+06	1.409E+06	.2402E+00
.2606E+00	.2906E+00	1.384E+05	4.614E+06	1.270E+06	.2756E+00
.2906E+00	.3244E+00	1.709E+05	5.065E+06	1.556E+06	.3075E+00
.3244E+00	.3581E+00	9.925E+04	2.941E+06	1.003E+06	.3413E+00
.3581E+00	.3994E+00	1.055E+05	2.558E+06	9.678E+05	.3787E+00
.3994E+00	.4444E+00	1.074E+05	2.386E+06	1.006E+06	.4219E+00
.4444E+00	.4931E+00	1.283E+05	2.631E+06	1.232E+06	.4688E+00
.4931E+00	.5456E+00	1.399E+05	2.665E+06	1.383E+06	.5194E+00
.5456E+00	.6094E+00	1.712E+05	2.685E+06	1.549E+06	.5775E+00
.6094E+00	.6769E+00	1.961E+05	2.906E+06	1.867E+06	.6431E+00
.6769E+00	.7946E+00	3.100E+05	2.633E+06	1.933E+06	.7358E+00
.7946E+00	.8870E+00	1.951E+05	2.111E+06	1.774E+06	.8408E+00
.8870E+00	.9871E+00	1.577E+05	1.575E+06	1.474E+06	.9371E+00
.9871E+00	.1095E+01	1.342E+05	1.244E+06	1.294E+06	.1041E+01
.1095E+01	.1218E+01	1.743E+05	1.415E+06	1.634E+06	.1157E+01
.1218E+01	.1391E+01	2.364E+05	1.367E+06	1.781E+06	.1305E+01
.1391E+01	.1573E+01	2.106E+05	1.157E+06	1.712E+06	.1482E+01
.1573E+01	.1807E+01	2.259E+05	9.654E+05	1.629E+06	.1690E+01
.1807E+01	.2041E+01	1.965E+05	8.398E+05	1.614E+06	.1924E+01
.2041E+01	.2327E+01	2.312E+05	8.085E+05	1.763E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	2.163E+05	6.932E+05	1.719E+06	.2483E+01
.2639E+01	.3003E+01	1.811E+05	4.976E+05	1.402E+06	.2821E+01
.3003E+01	.3419E+01	1.503E+05	3.612E+05	1.158E+06	.3211E+01
.3419E+01	.3861E+01	1.054E+05	2.384E+05	8.667E+05	.3640E+01
.3861E+01	.4407E+01	1.147E+05	2.101E+05	8.672E+05	.4134E+01
.4407E+01	.5000E+01	8.199E+04	1.383E+05	6.495E+05	.4703E+01
.5000E+01	.5500E+01	4.706E+04	9.413E+04	4.938E+05	.5250E+01
.5500E+01	.6000E+01	3.486E+04	6.971E+04	4.006E+05	.5750E+01
.6000E+01	.6500E+01	2.570E+04	5.140E+04	3.211E+05	.6250E+01
.6500E+01	.7000E+01	1.886E+04	3.772E+04	2.545E+05	.6750E+01
.7000E+01	.7500E+01	1.380E+04	2.761E+04	2.001E+05	.7250E+01
.7500E+01	.8000E+01	1.006E+04	2.013E+04	1.559E+05	.7750E+01
.8000E+01	.8500E+01	7.321E+03	1.464E+04	1.208E+05	.8250E+01
.8500E+01	.9000E+01	5.315E+03	1.063E+04	9.298E+04	.8750E+01
.9000E+01	.9500E+01	3.852E+03	7.704E+03	7.125E+04	.9250E+01
.9500E+01	.1000E+02	2.793E+03	5.585E+03	5.444E+04	.9750E+01

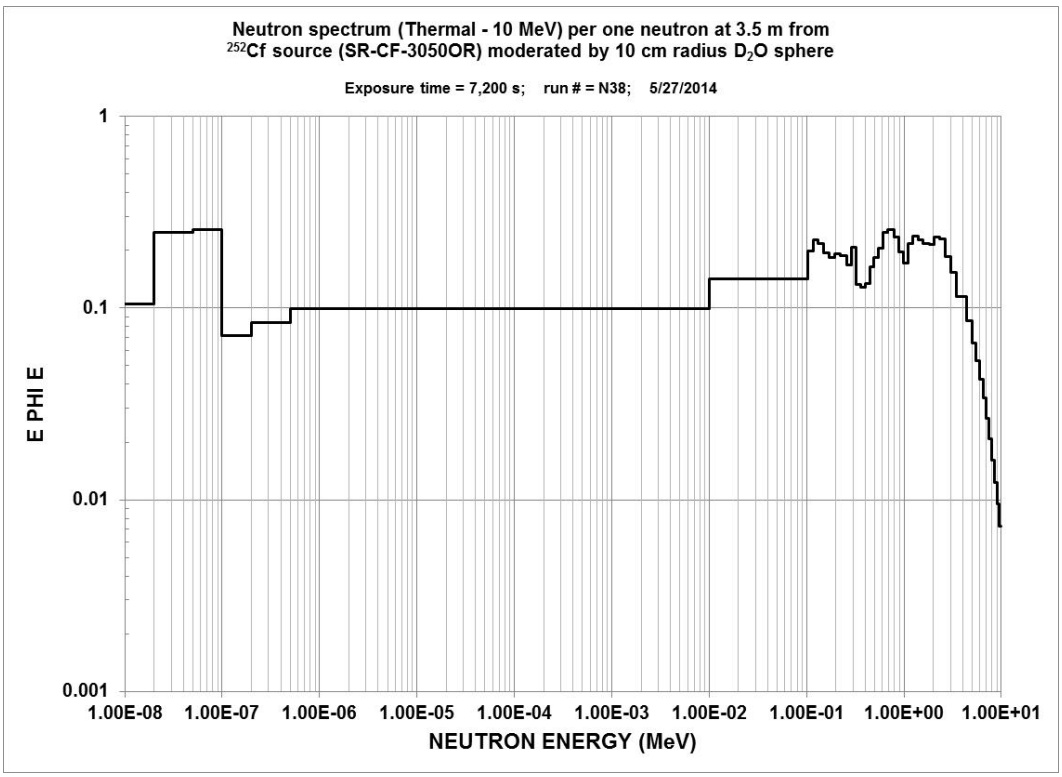
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



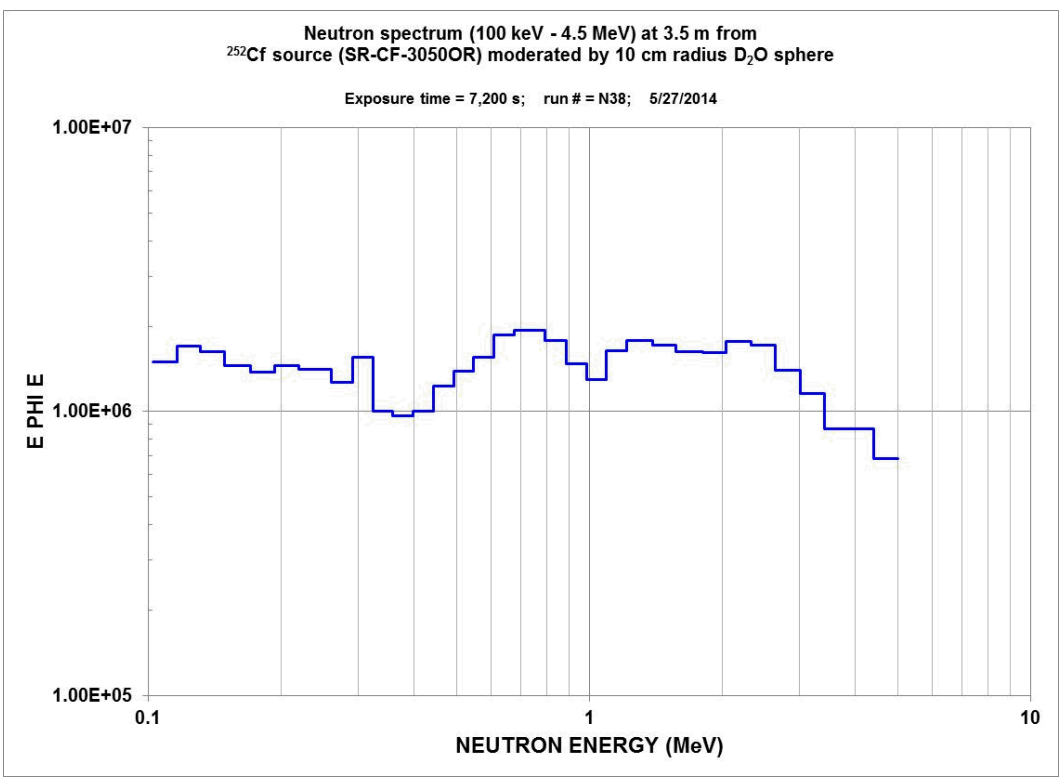


Figure G-4. Neutron spectra at 3.5 m from ^{252}Cf moderated by 10 cm of D_2O

Fluence, spectral and dosimetric data at 4.0 m from ^{252}Cf moderated by 10 cm of D_2O

Table G-9. Neutron fluence and dosimetric data at 4.0 m from 10 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/23/2014
Exposure time:	7,200 s
Run #	N36

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	4.69E+06	6.52E+02
Epi-thermal region	:	9.59E+06	1.33E+03
Thermal region	:	4.32E+06	6.00E+02
Thermal – 4.5 MeV	:	1.86E+07	2.58E+03
Thermal – 10.0 MeV	:	1.8726E+07	2.6008E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	9.71E-03	1.49E-03	4.85E+00	7.44E+02
Epi-thermal region	:	8.88E-04	1.61E-04	4.44E-01	8.03E+01
Thermal region	:	8.64E-05	4.58E-05	4.32E-02	2.29E+01
Thermal – 4.5 MeV	:	1.07E-02	1.70E-03	5.34E+00	8.48E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.1054E-02 rads	5.5269E+00 mrads/hr
H*(10) ICRP-74	=	1.7265E-03 Sv	8.6327E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.7912E-03 Sv	8.9559E+02 uSv/hr

Table G-10. Neutron fluence at 4.0 m from 10 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/23/2014
Exposure time: 7,200 s
Run number: N36

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	9.766E+03	9.766E+12	1.409E+04	.1500E-08
.2000E-08	.5000E-08	6.266E+04	2.089E+13	6.838E+04	.3500E-08
.5000E-08	.1000E-07	1.906E+05	3.811E+13	2.749E+05	.7500E-08
.1000E-07	.2000E-07	5.617E+05	5.617E+13	8.104E+05	.1500E-07
.2000E-07	.5000E-07	1.741E+06	5.805E+13	1.900E+06	.3500E-07
.5000E-07	.1000E-06	1.361E+06	2.722E+13	1.964E+06	.7500E-07
.1000E-06	.2000E-06	3.828E+05	3.828E+12	5.523E+05	.1500E-06
.2000E-06	.5000E-06	5.646E+05	1.882E+12	6.162E+05	.3500E-06
.5000E-06	.1000E-01	6.808E+06	6.808E+08	6.874E+05	.5000E-02
.1000E-01	.1027E+00	2.216E+06	2.390E+07	9.513E+05	.5635E-01
.1027E+00	.1166E+00	1.663E+05	1.200E+07	1.314E+06	.1096E+00
.1166E+00	.1317E+00	1.529E+05	1.012E+07	1.254E+06	.1241E+00
.1317E+00	.1493E+00	1.666E+05	9.447E+06	1.325E+06	.1405E+00
.1493E+00	.1707E+00	1.802E+05	8.412E+06	1.344E+06	.1600E+00
.1707E+00	.1934E+00	1.432E+05	6.312E+06	1.148E+06	.1821E+00
.1934E+00	.2199E+00	1.793E+05	6.778E+06	1.399E+06	.2066E+00
.2199E+00	.2606E+00	1.981E+05	4.861E+06	1.165E+06	.2402E+00
.2606E+00	.2906E+00	1.283E+05	4.276E+06	1.177E+06	.2756E+00
.2906E+00	.3244E+00	1.368E+05	4.052E+06	1.245E+06	.3075E+00
.3244E+00	.3581E+00	9.850E+04	2.918E+06	9.951E+05	.3413E+00
.3581E+00	.3994E+00	1.023E+05	2.480E+06	9.385E+05	.3787E+00
.3994E+00	.4444E+00	8.533E+04	1.896E+06	7.992E+05	.4219E+00
.4444E+00	.4931E+00	1.048E+05	2.149E+06	1.006E+06	.4688E+00
.4931E+00	.5456E+00	1.358E+05	2.587E+06	1.343E+06	.5194E+00
.5456E+00	.6094E+00	1.583E+05	2.484E+06	1.433E+06	.5775E+00
.6094E+00	.6769E+00	1.408E+05	2.087E+06	1.341E+06	.6431E+00
.6769E+00	.7946E+00	2.550E+05	2.165E+06	1.590E+06	.7358E+00
.7946E+00	.8870E+00	1.717E+05	1.858E+06	1.561E+06	.8408E+00
.8870E+00	.9871E+00	1.174E+05	1.173E+06	1.098E+06	.9371E+00
.9871E+00	.1095E+01	1.081E+05	1.002E+06	1.043E+06	.1041E+01
.1095E+01	.1218E+01	1.524E+05	1.237E+06	1.430E+06	.1157E+01
.1218E+01	.1391E+01	2.106E+05	1.218E+06	1.587E+06	.1305E+01
.1391E+01	.1573E+01	1.753E+05	9.631E+05	1.426E+06	.1482E+01
.1573E+01	.1807E+01	1.856E+05	7.931E+05	1.338E+06	.1690E+01
.1807E+01	.2041E+01	1.581E+05	6.758E+05	1.299E+06	.1924E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2041E+01	.2327E+01	1.875E+05	6.555E+05	1.430E+06	.2184E+01
.2327E+01	.2639E+01	1.777E+05	5.695E+05	1.412E+06	.2483E+01
.2639E+01	.3003E+01	1.557E+05	4.276E+05	1.205E+06	.2821E+01
.3003E+01	.3419E+01	1.224E+05	2.942E+05	9.434E+05	.3211E+01
.3419E+01	.3861E+01	8.296E+04	1.877E+05	6.824E+05	.3640E+01
.3861E+01	.4407E+01	9.071E+04	1.661E+05	6.858E+05	.4134E+01
.4407E+01	.5000E+01	6.228E+04	1.050E+05	4.933E+05	.4703E+01
.5000E+01	.5500E+01	3.798E+04	7.596E+04	3.985E+05	.5250E+01
.5500E+01	.6000E+01	2.813E+04	5.626E+04	3.233E+05	.5750E+01
.6000E+01	.6500E+01	2.074E+04	4.148E+04	2.591E+05	.6250E+01
.6500E+01	.7000E+01	1.522E+04	3.044E+04	2.054E+05	.6750E+01
.7000E+01	.7500E+01	1.114E+04	2.228E+04	1.615E+05	.7250E+01
.7500E+01	.8000E+01	8.122E+03	1.624E+04	1.258E+05	.7750E+01
.8000E+01	.8500E+01	5.908E+03	1.182E+04	9.746E+04	.8250E+01
.8500E+01	.9000E+01	4.289E+03	8.578E+03	7.504E+04	.8750E+01
.9000E+01	.9500E+01	3.109E+03	6.218E+03	5.750E+04	.9250E+01
.9500E+01	.1000E+02	2.254E+03	4.507E+03	4.394E+04	.9750E+01

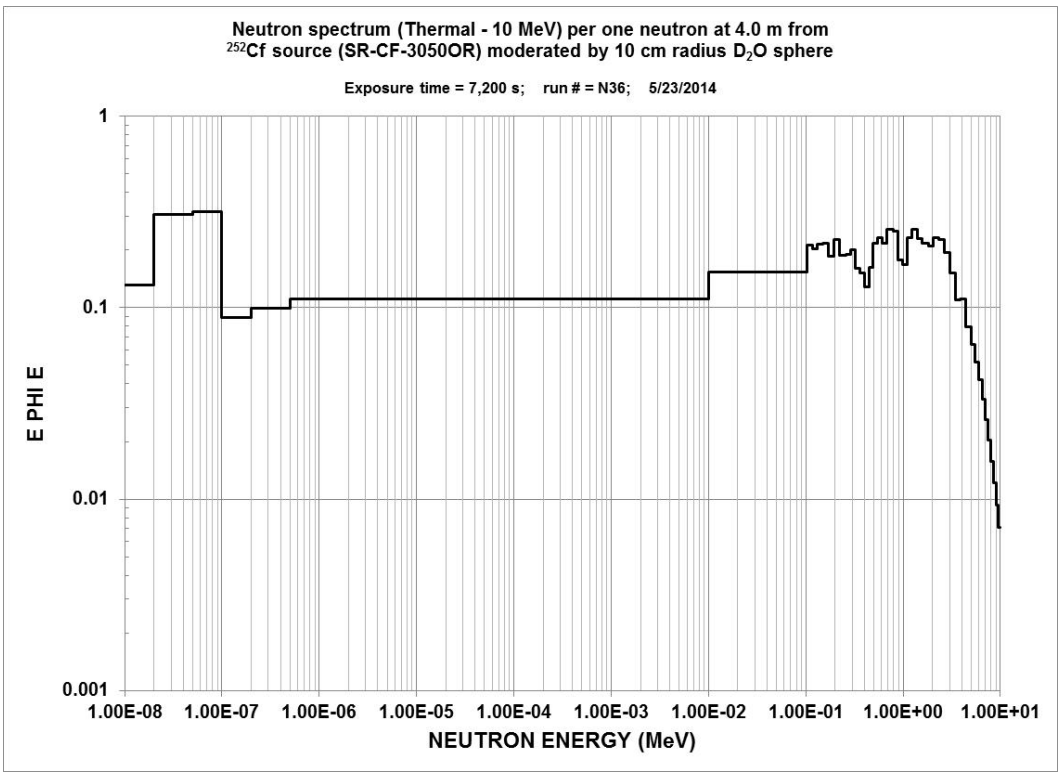
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



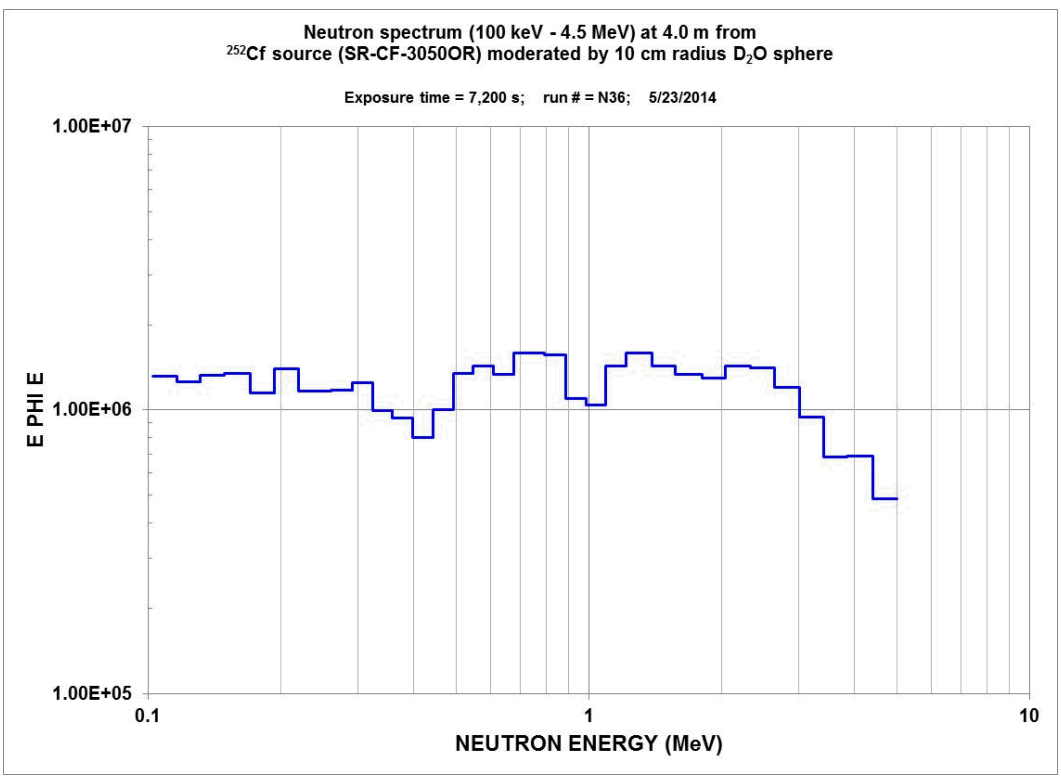


Figure G-5. Neutron spectra at 4.0 m from ^{252}Cf moderated by 10 cm of D_2O

Fluence, spectral and dosimetric data at 4.5 m from ^{252}Cf moderated by 10 cm of D_2O

Table G-11. Neutron fluence and dosimetric data at 4.5 m from 10 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/27/2014
Exposure time:	7,200 s
Run #	N37

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	4.15E+06	5.77E+02
Epi-thermal region	:	8.94E+06	1.24E+03
Thermal region	:	4.17E+06	5.79E+02
Thermal – 4.5 MeV	:	1.73E+07	2.40E+03
Thermal – 10.0 MeV	:	1.7358E+07	2.4108E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	8.46E-03	1.31E-03	4.23E+00	6.53E+02
Epi-thermal region	:	8.25E-04	1.50E-04	4.13E-01	7.48E+01
Thermal region	:	8.33E-05	4.42E-05	4.17E-02	2.21E+01
Thermal – 4.5 MeV	:	9.37E-03	1.50E-03	4.69E+00	7.50E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	9.6561E-03 rads	4.8281E+00 mrads/hr
H*(10) ICRP-74	=	1.5226E-03 Sv	7.6130E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.5793E-03 Sv	7.8966E+02 uSv/hr

Table G-12. Neutron fluence at 4.0 m from 10 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/27/2014
Exposure time: 7,200 s
Run number: N37

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	9.416E+03	9.416E+12	1.358E+04	.1500E-08
.2000E-08	.5000E-08	6.041E+04	2.014E+13	6.593E+04	.3500E-08
.5000E-08	.1000E-07	1.837E+05	3.675E+13	2.651E+05	.7500E-08
.1000E-07	.2000E-07	5.416E+05	5.416E+13	7.814E+05	.1500E-07
.2000E-07	.5000E-07	1.679E+06	5.597E+13	1.832E+06	.3500E-07
.5000E-07	.1000E-06	1.312E+06	2.625E+13	1.893E+06	.7500E-07
.1000E-06	.2000E-06	3.691E+05	3.691E+12	5.326E+05	.1500E-06
.2000E-06	.5000E-06	5.351E+05	1.784E+12	5.840E+05	.3500E-06
.5000E-06	.1000E-01	6.343E+06	6.343E+08	6.405E+05	.5000E-02
.1000E-01	.1027E+00	2.058E+06	2.221E+07	8.838E+05	.5635E-01
.1027E+00	.1166E+00	1.811E+05	1.306E+07	1.430E+06	.1096E+00
.1166E+00	.1317E+00	1.557E+05	1.030E+07	1.277E+06	.1241E+00
.1317E+00	.1493E+00	1.491E+05	8.453E+06	1.186E+06	.1405E+00
.1493E+00	.1707E+00	1.591E+05	7.426E+06	1.186E+06	.1600E+00
.1707E+00	.1934E+00	1.455E+05	6.414E+06	1.166E+06	.1821E+00
.1934E+00	.2199E+00	1.349E+05	5.098E+06	1.052E+06	.2066E+00
.2199E+00	.2606E+00	1.573E+05	3.861E+06	9.253E+05	.2402E+00
.2606E+00	.2906E+00	1.170E+05	3.900E+06	1.074E+06	.2756E+00
.2906E+00	.3244E+00	1.069E+05	3.169E+06	9.734E+05	.3075E+00
.3244E+00	.3581E+00	8.222E+04	2.436E+06	8.306E+05	.3413E+00
.3581E+00	.3994E+00	9.708E+04	2.354E+06	8.905E+05	.3787E+00
.3994E+00	.4444E+00	7.683E+04	1.707E+06	7.196E+05	.4219E+00
.4444E+00	.4931E+00	1.010E+05	2.072E+06	9.704E+05	.4688E+00
.4931E+00	.5456E+00	1.198E+05	2.282E+06	1.184E+06	.5194E+00
.5456E+00	.6094E+00	1.417E+05	2.223E+06	1.282E+06	.5775E+00
.6094E+00	.6769E+00	1.330E+05	1.970E+06	1.266E+06	.6431E+00
.6769E+00	.7946E+00	2.398E+05	2.036E+06	1.495E+06	.7358E+00
.7946E+00	.8870E+00	1.564E+05	1.693E+06	1.422E+06	.8408E+00
.8870E+00	.9871E+00	1.098E+05	1.097E+06	1.027E+06	.9371E+00
.9871E+00	.1095E+01	9.646E+04	8.948E+05	9.307E+05	.1041E+01
.1095E+01	.1218E+01	1.234E+05	1.001E+06	1.157E+06	.1157E+01
.1218E+01	.1391E+01	1.880E+05	1.088E+06	1.417E+06	.1305E+01
.1391E+01	.1573E+01	1.587E+05	8.719E+05	1.290E+06	.1482E+01
.1573E+01	.1807E+01	1.481E+05	6.329E+05	1.068E+06	.1690E+01
.1807E+01	.2041E+01	1.298E+05	5.548E+05	1.066E+06	.1924E+01
.2041E+01	.2327E+01	1.664E+05	5.818E+05	1.269E+06	.2184E+01
.2327E+01	.2639E+01	1.530E+05	4.905E+05	1.216E+06	.2483E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2639E+01	.3003E+01	1.283E+05	3.525E+05	9.931E+05	.2821E+01
.3003E+01	.3419E+01	9.881E+04	2.375E+05	7.616E+05	.3211E+01
.3419E+01	.3861E+01	6.476E+04	1.465E+05	5.327E+05	.3640E+01
.3861E+01	.4407E+01	7.687E+04	1.408E+05	5.812E+05	.4134E+01
.4407E+01	.5000E+01	5.463E+04	9.213E+04	4.327E+05	.4703E+01
.5000E+01	.5500E+01	3.155E+04	6.309E+04	3.310E+05	.5250E+01
.5500E+01	.6000E+01	2.336E+04	4.673E+04	2.685E+05	.5750E+01
.6000E+01	.6500E+01	1.722E+04	3.445E+04	2.152E+05	.6250E+01
.6500E+01	.7000E+01	1.264E+04	2.528E+04	1.706E+05	.6750E+01
.7000E+01	.7500E+01	9.252E+03	1.850E+04	1.341E+05	.7250E+01
.7500E+01	.8000E+01	6.746E+03	1.349E+04	1.045E+05	.7750E+01
.8000E+01	.8500E+01	4.907E+03	9.814E+03	8.094E+04	.8250E+01
.8500E+01	.9000E+01	3.562E+03	7.124E+03	6.232E+04	.8750E+01
.9000E+01	.9500E+01	2.582E+03	5.164E+03	4.775E+04	.9250E+01
.9500E+01	.1000E+02	1.872E+03	3.744E+03	3.649E+04	.9750E+01

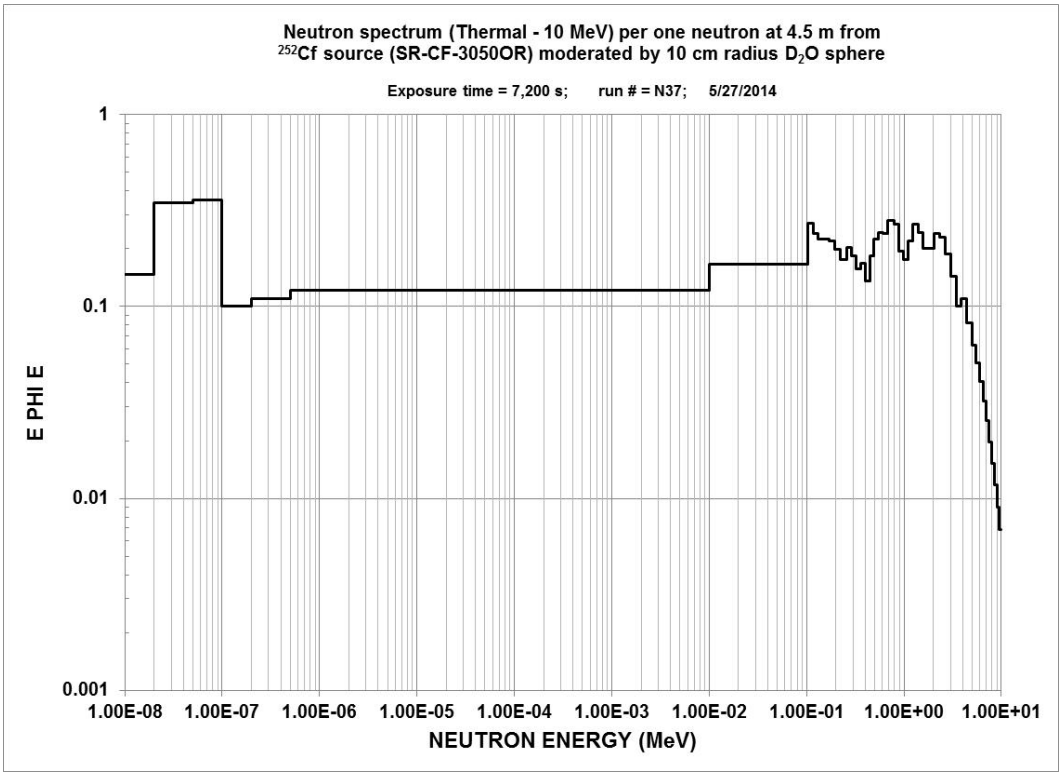
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



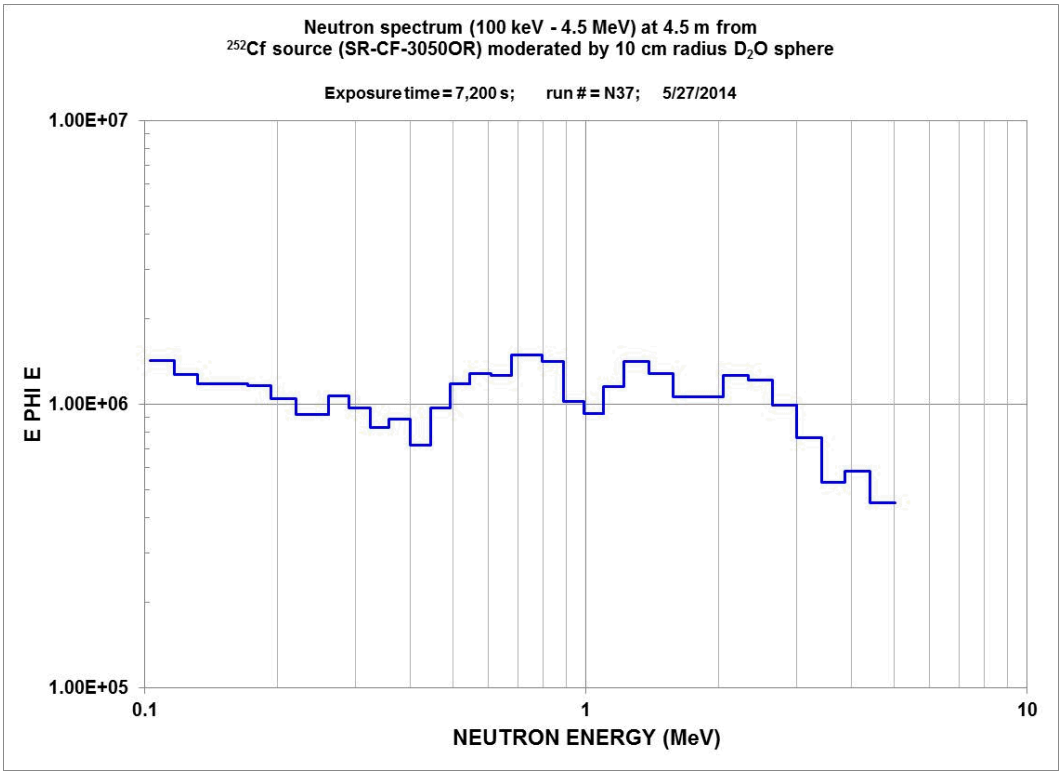


Figure G-6. Neutron spectra at 4.5 m from ^{252}Cf moderated by 10 cm of D_2O

Appendix H

Neutron fluence, spectra and dose rates from ^{252}Cf moderated by 5 cm of D_2O

Fluence, spectral and dosimetric data at 2.0 m from ^{252}Cf moderated by 5 cm of D_2O

Table H-1. Neutron fluence and dosimetric data at 2.0 m from 5 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	6/4/2014
Exposure time:	7,200 s
Run #	N51

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.88E+07	2.61E+03
Epi-thermal region	:	1.09E+07	1.51E+03
Thermal region	:	3.58E+06	4.97E+02
Thermal – 4.5 MeV	:	3.32E+07	4.62E+03
Thermal – 10.0 MeV	:	3.4000E+07	4.7223E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	4.33E-02	6.42E-03	2.16E+01	3.21E+03
Epi-thermal region	:	1.36E-03	2.12E-04	6.80E-01	1.06E+02
Thermal region	:	7.15E-05	3.79E-05	3.58E-02	1.90E+01
Thermal – 4.5 MeV	:	4.47E-02	6.67E-03	2.24E+01	3.33E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	4.7217E-02 rads	2.3609E+01 mrads/hr
H*(10) ICRP-74	=	6.9067E-03 Sv	3.4533E+03 uSv/hr
Hp(10,0) ICRP-74	=	7.1544E-03 Sv	3.5772E+03 uSv/hr

Table H-2. Neutron fluence at 2.0 m from 5 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 6/4/2014
Exposure time: 7,200 s
Run number: N51

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	8.083E+03	8.083E+12	1.166E+04	.1500E-08
.2000E-08	.5000E-08	5.186E+04	1.729E+13	5.660E+04	.3500E-08
.5000E-08	.1000E-07	1.577E+05	3.155E+13	2.276E+05	.7500E-08
.1000E-07	.2000E-07	4.650E+05	4.650E+13	6.708E+05	.1500E-07
.2000E-07	.5000E-07	1.441E+06	4.805E+13	1.573E+06	.3500E-07
.5000E-07	.1000E-06	1.127E+06	2.253E+13	1.625E+06	.7500E-07
.1000E-06	.2000E-06	3.169E+05	3.169E+12	4.572E+05	.1500E-06
.2000E-06	.5000E-06	5.139E+05	1.713E+12	5.608E+05	.3500E-06
.5000E-06	.1000E-01	6.814E+06	6.814E+08	6.880E+05	.5000E-02
.1000E-01	.1027E+00	3.550E+06	3.829E+07	1.524E+06	.5635E-01
.1027E+00	.1166E+00	3.797E+05	2.740E+07	2.999E+06	.1096E+00
.1166E+00	.1317E+00	4.595E+05	3.039E+07	3.767E+06	.1241E+00
.1317E+00	.1493E+00	5.771E+05	3.271E+07	4.590E+06	.1405E+00
.1493E+00	.1707E+00	4.727E+05	2.207E+07	3.526E+06	.1600E+00
.1707E+00	.1934E+00	3.514E+05	1.549E+07	2.817E+06	.1821E+00
.1934E+00	.2199E+00	4.031E+05	1.524E+07	3.144E+06	.2066E+00
.2199E+00	.2606E+00	6.523E+05	1.600E+07	3.836E+06	.2402E+00
.2606E+00	.2906E+00	3.843E+05	1.281E+07	3.527E+06	.2756E+00
.2906E+00	.3244E+00	4.081E+05	1.209E+07	3.715E+06	.3075E+00
.3244E+00	.3581E+00	3.768E+05	1.116E+07	3.807E+06	.3413E+00
.3581E+00	.3994E+00	3.680E+05	8.920E+06	3.375E+06	.3787E+00
.3994E+00	.4444E+00	3.601E+05	8.002E+06	3.373E+06	.4219E+00
.4444E+00	.4931E+00	3.975E+05	8.155E+06	3.819E+06	.4688E+00
.4931E+00	.5456E+00	4.722E+05	8.994E+06	4.667E+06	.5194E+00
.5456E+00	.6094E+00	5.823E+05	9.135E+06	5.270E+06	.5775E+00
.6094E+00	.6769E+00	5.929E+05	8.783E+06	5.643E+06	.6431E+00
.6769E+00	.7946E+00	9.887E+05	8.395E+06	6.164E+06	.7358E+00
.7946E+00	.8870E+00	6.742E+05	7.297E+06	6.129E+06	.8408E+00
.8870E+00	.9871E+00	5.949E+05	5.943E+06	5.564E+06	.9371E+00
.9871E+00	.1095E+01	5.268E+05	4.887E+06	5.083E+06	.1041E+01
.1095E+01	.1218E+01	7.226E+05	5.865E+06	6.777E+06	.1157E+01
.1218E+01	.1391E+01	9.002E+05	5.207E+06	6.784E+06	.1305E+01
.1391E+01	.1573E+01	8.455E+05	4.646E+06	6.876E+06	.1482E+01
.1573E+01	.1807E+01	9.426E+05	4.028E+06	6.797E+06	.1690E+01
.1807E+01	.2041E+01	7.983E+05	3.412E+06	6.556E+06	.1924E+01
.2041E+01	.2327E+01	8.972E+05	3.137E+06	6.842E+06	.2184E+01

E2	E1	FLUENCE/	FLUENCE/	FLUENCE/	E avg.

(MeV)	(MeV)	(E1-E2) (n/cm²)	MeV (n/cm².MeV)	LETHARGY* (n/cm².u)	(MeV)
.2327E+01	.2639E+01	8.615E+05	2.761E+06	6.847E+06	.2483E+01
.2639E+01	.3003E+01	7.649E+05	2.101E+06	5.920E+06	.2821E+01
.3003E+01	.3419E+01	6.505E+05	1.564E+06	5.014E+06	.3211E+01
.3419E+01	.3861E+01	4.792E+05	1.084E+06	3.942E+06	.3640E+01
.3861E+01	.4407E+01	4.930E+05	9.030E+05	3.728E+06	.4134E+01
.4407E+01	.5000E+01	3.798E+05	6.404E+05	3.008E+06	.4703E+01
.5000E+01	.5500E+01	2.214E+05	4.427E+05	2.322E+06	.5250E+01
.5500E+01	.6000E+01	1.639E+05	3.279E+05	1.884E+06	.5750E+01
.6000E+01	.6500E+01	1.209E+05	2.417E+05	1.510E+06	.6250E+01
.6500E+01	.7000E+01	8.871E+04	1.774E+05	1.197E+06	.6750E+01
.7000E+01	.7500E+01	6.492E+04	1.298E+05	9.410E+05	.7250E+01
.7500E+01	.8000E+01	4.733E+04	9.466E+04	7.334E+05	.7750E+01
.8000E+01	.8500E+01	3.443E+04	6.886E+04	5.680E+05	.8250E+01
.8500E+01	.9000E+01	2.500E+04	4.999E+04	4.373E+05	.8750E+01
.9000E+01	.9500E+01	1.812E+04	3.623E+04	3.351E+05	.9250E+01
.9500E+01	.1000E+02	1.313E+04	2.627E+04	2.561E+05	.9750E+01

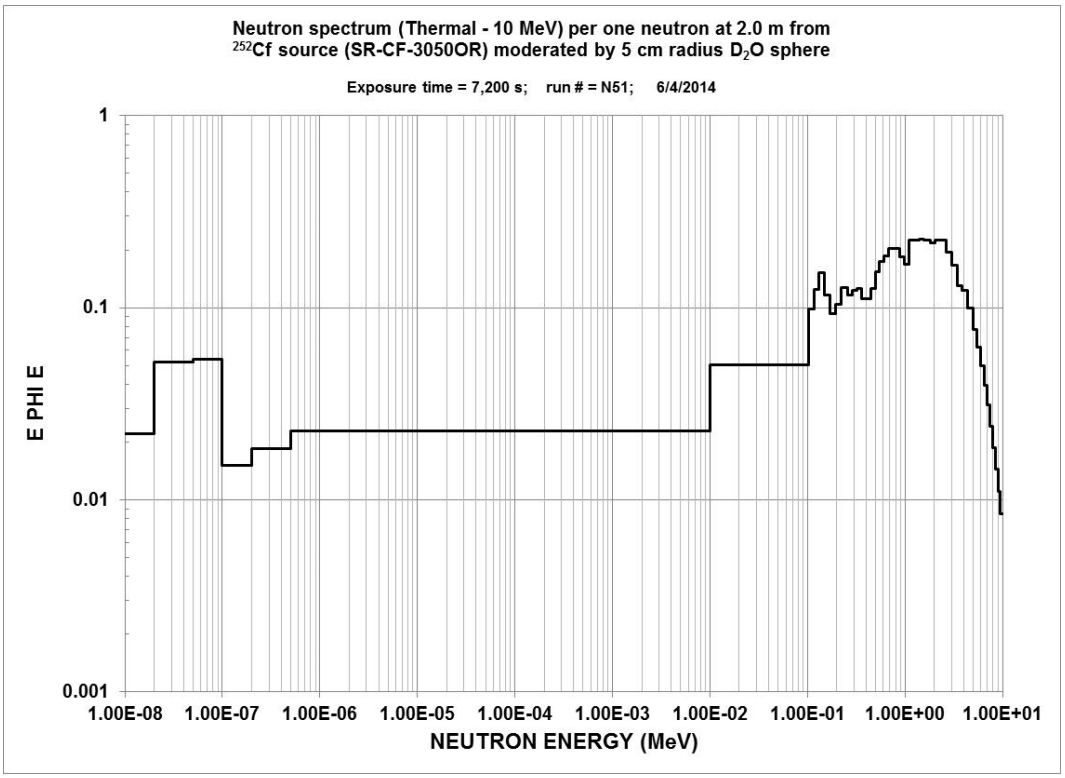
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



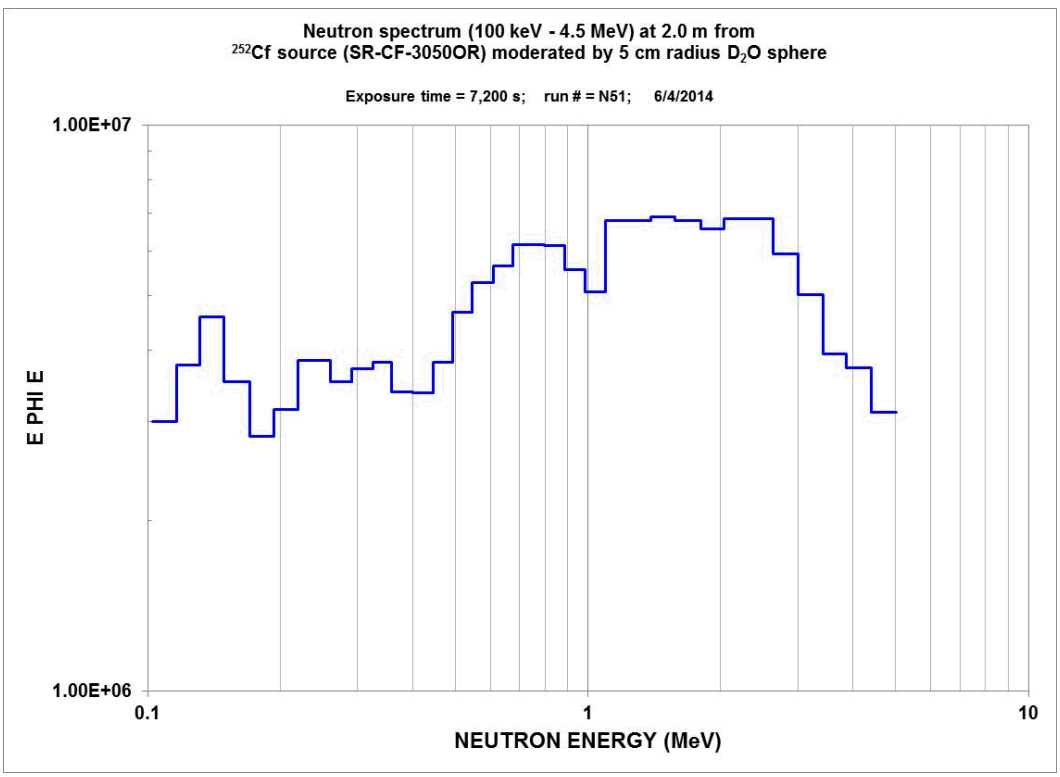


Figure H-1. Neutron spectra at 2.0 m from ^{252}Cf moderated by 5 cm of D_2O

Fluence, spectral and dosimetric data at 2.5 m from ^{252}Cf moderated by 5 cm of D_2O

Table H-3. Neutron fluence and dosimetric data at 2.5 m from 5 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/29/2014
Exposure time:	7,200 s
Run #	N43

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.37E+07	1.91E+03
Epi-thermal region	:	9.34E+06	1.30E+03
Thermal region	:	3.60E+06	5.00E+02
Thermal – 4.5 MeV	:	2.67E+07	3.70E+03
Thermal – 10.0 MeV	:	2.7185E+07	3.7757E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	3.10E-02	4.65E-03	1.55E+01	2.33E+03
Epi-thermal region	:	1.12E-03	1.78E-04	5.62E-01	8.92E+01
Thermal region	:	7.20E-05	3.81E-05	3.60E-02	1.91E+01
Thermal – 4.5 MeV	:	3.22E-02	4.87E-03	1.61E+01	2.44E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	3.3829E-02 rads	1.6914E+01 mrads/hr
H*(10) ICRP-74	=	5.0231E-03 Sv	2.5115E+03 uSv/hr
Hp(10,0) ICRP-74	=	5.2018E-03 Sv	2.6009E+03 uSv/hr

Table H-4. Neutron fluence at 2.5 m from 5 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/29/2014
Exposure time: 7,200 s
Run number: N43

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	8.133E+03	8.133E+12	1.173E+04	.1500E-08
.2000E-08	.5000E-08	5.218E+04	1.739E+13	5.695E+04	.3500E-08
.5000E-08	.1000E-07	1.587E+05	3.174E+13	2.290E+05	.7500E-08
.1000E-07	.2000E-07	4.678E+05	4.678E+13	6.749E+05	.1500E-07
.2000E-07	.5000E-07	1.450E+06	4.834E+13	1.583E+06	.3500E-07
.5000E-07	.1000E-06	1.134E+06	2.267E+13	1.635E+06	.7500E-07
.1000E-06	.2000E-06	3.188E+05	3.188E+12	4.600E+05	.1500E-06
.2000E-06	.5000E-06	4.813E+05	1.604E+12	5.253E+05	.3500E-06
.5000E-06	.1000E-01	5.940E+06	5.941E+08	5.998E+05	.5000E-02
.1000E-01	.1027E+00	2.922E+06	3.153E+07	1.255E+06	.5635E-01
.1027E+00	.1166E+00	3.442E+05	2.484E+07	2.719E+06	.1096E+00
.1166E+00	.1317E+00	3.672E+05	2.428E+07	3.010E+06	.1241E+00
.1317E+00	.1493E+00	3.149E+05	1.785E+07	2.504E+06	.1405E+00
.1493E+00	.1707E+00	3.552E+05	1.658E+07	2.649E+06	.1600E+00
.1707E+00	.1934E+00	3.285E+05	1.448E+07	2.633E+06	.1821E+00
.1934E+00	.2199E+00	3.493E+05	1.320E+07	2.724E+06	.2066E+00
.2199E+00	.2606E+00	4.228E+05	1.037E+07	2.486E+06	.2402E+00
.2606E+00	.2906E+00	3.465E+05	1.155E+07	3.181E+06	.2756E+00
.2906E+00	.3244E+00	3.124E+05	9.256E+06	2.843E+06	.3075E+00
.3244E+00	.3581E+00	2.387E+05	7.072E+06	2.411E+06	.3413E+00
.3581E+00	.3994E+00	2.936E+05	7.117E+06	2.693E+06	.3787E+00
.3994E+00	.4444E+00	2.439E+05	5.421E+06	2.285E+06	.4219E+00
.4444E+00	.4931E+00	3.231E+05	6.629E+06	3.104E+06	.4688E+00
.4931E+00	.5456E+00	3.555E+05	6.772E+06	3.514E+06	.5194E+00
.5456E+00	.6094E+00	4.369E+05	6.854E+06	3.954E+06	.5775E+00
.6094E+00	.6769E+00	4.588E+05	6.798E+06	4.368E+06	.6431E+00
.6769E+00	.7946E+00	7.604E+05	6.457E+06	4.741E+06	.7358E+00
.7946E+00	.8870E+00	5.187E+05	5.613E+06	4.715E+06	.8408E+00
.8870E+00	.9871E+00	4.516E+05	4.512E+06	4.224E+06	.9371E+00
.9871E+00	.1095E+01	3.668E+05	3.403E+06	3.539E+06	.1041E+01
.1095E+01	.1218E+01	5.193E+05	4.215E+06	4.870E+06	.1157E+01
.1218E+01	.1391E+01	6.837E+05	3.955E+06	5.153E+06	.1305E+01
.1391E+01	.1573E+01	6.113E+05	3.359E+06	4.972E+06	.1482E+01
.1573E+01	.1807E+01	6.790E+05	2.902E+06	4.896E+06	.1690E+01
.1807E+01	.2041E+01	5.493E+05	2.347E+06	4.511E+06	.1924E+01
.2041E+01	.2327E+01	6.342E+05	2.218E+06	4.836E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.2327E+01	.2639E+01	5.945E+05	1.906E+06	4.725E+06	.2483E+01
.2639E+01	.3003E+01	5.309E+05	1.459E+06	4.109E+06	.2821E+01
.3003E+01	.3419E+01	4.396E+05	1.057E+06	3.389E+06	.3211E+01
.3419E+01	.3861E+01	3.263E+05	7.383E+05	2.684E+06	.3640E+01
.3861E+01	.4407E+01	3.235E+05	5.925E+05	2.446E+06	.4134E+01
.4407E+01	.5000E+01	2.443E+05	4.121E+05	1.936E+06	.4703E+01
.5000E+01	.5500E+01	1.461E+05	2.921E+05	1.532E+06	.5250E+01
.5500E+01	.6000E+01	1.082E+05	2.163E+05	1.243E+06	.5750E+01
.6000E+01	.6500E+01	7.975E+04	1.595E+05	9.963E+05	.6250E+01
.6500E+01	.7000E+01	5.853E+04	1.171E+05	7.898E+05	.6750E+01
.7000E+01	.7500E+01	4.284E+04	8.567E+04	6.209E+05	.7250E+01
.7500E+01	.8000E+01	3.123E+04	6.246E+04	4.839E+05	.7750E+01
.8000E+01	.8500E+01	2.272E+04	4.544E+04	3.748E+05	.8250E+01
.8500E+01	.9000E+01	1.649E+04	3.298E+04	2.885E+05	.8750E+01
.9000E+01	.9500E+01	1.195E+04	2.391E+04	2.211E+05	.9250E+01
.9500E+01	.1000E+02	8.666E+03	1.733E+04	1.690E+05	.9750E+01

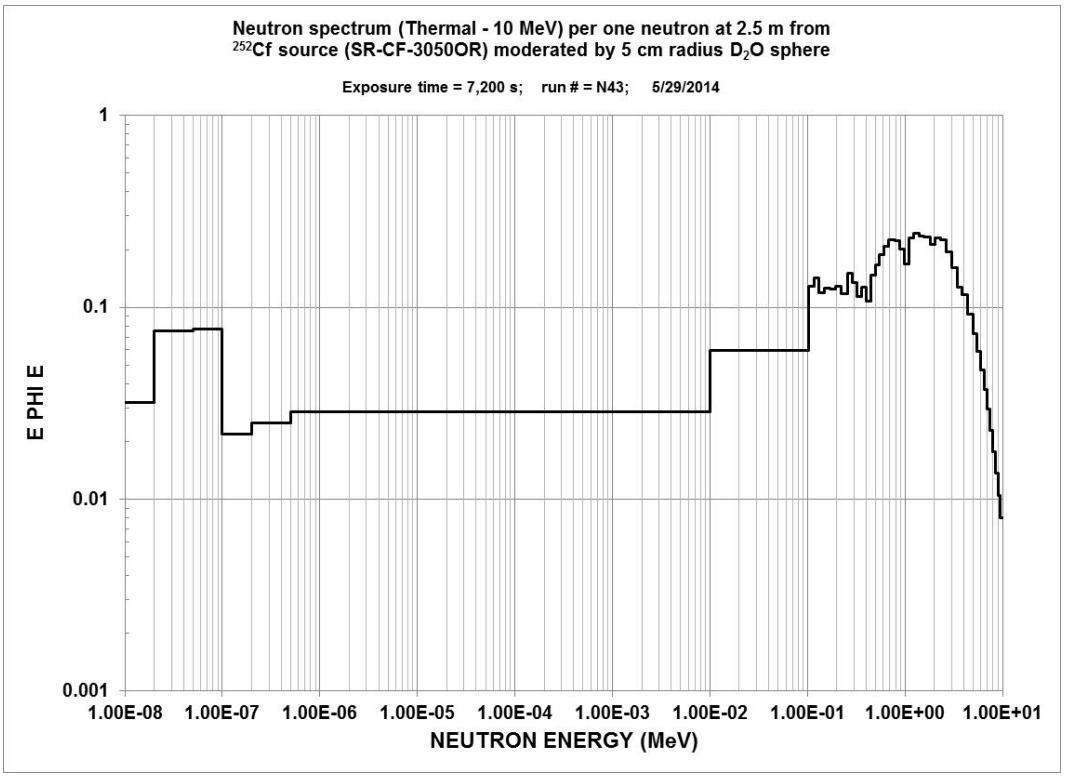
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



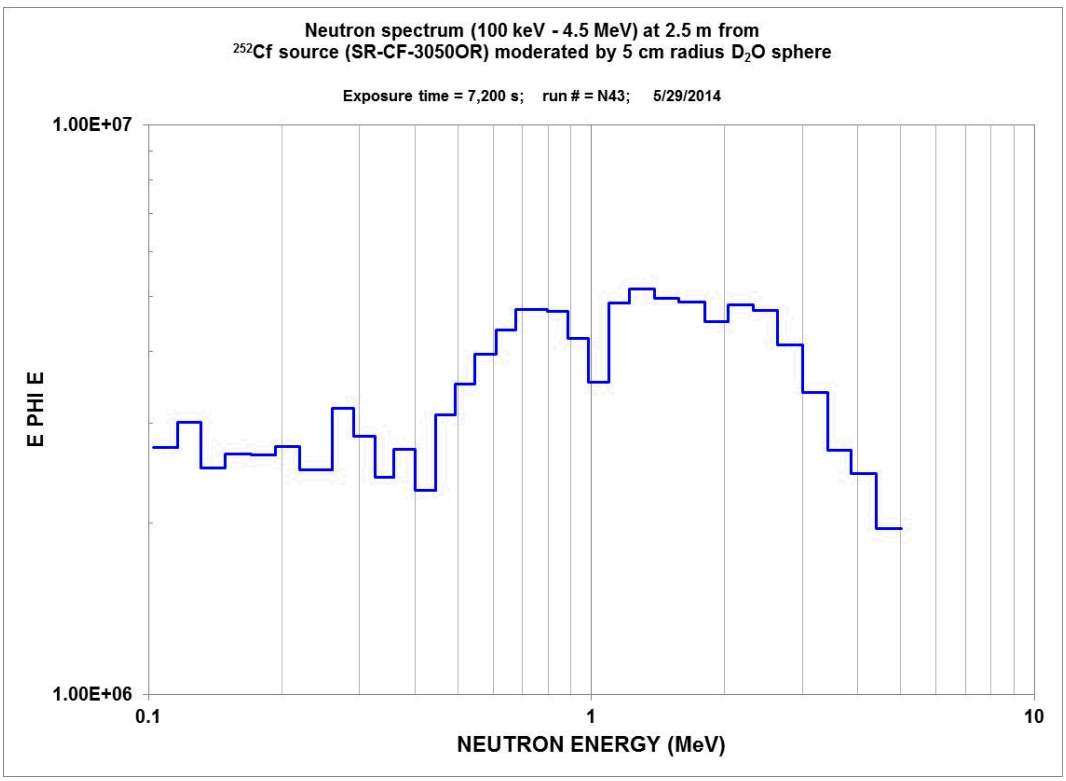


Figure H-2. Neutron spectra at 2.5 m from ^{252}Cf moderated by 5 cm of D_2O

Fluence, spectral and dosimetric data at 3.0 m from ^{252}Cf moderated by 5 cm of D_2O

Table H-5. Neutron fluence and dosimetric data at 3.0 m from 5 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/29/2014
Exposure time:	7,200 s
Run #	N44

FLUENCE RATE

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.09E+07	1.52E+03
Epi-thermal region	:	8.66E+06	1.20E+03
Thermal region	:	3.59E+06	4.98E+02
Thermal – 4.5 MeV	:	2.32E+07	3.22E+03
Thermal – 10.0 MeV	:	2.3503E+07	3.2643E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	2.41E-02	3.66E-03	1.21E+01	1.83E+03
Epi-thermal region	:	1.00E-03	1.62E-04	5.00E-01	8.10E+01
Thermal region	:	7.17E-05	3.80E-05	3.59E-02	1.90E+01
Thermal – 4.5 MeV	:	2.52E-02	3.86E-03	1.26E+01	1.93E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.6206E-02 rads	1.3103E+01 mrads/hr
H*(10) ICRP-74	=	3.9491E-03 Sv	1.9746E+03 uSv/hr
Hp(10,0) ICRP-74	=	4.0889E-03 Sv	2.0444E+03 uSv/hr

Table H-6. Neutron fluence at 3.0 m from 5 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/29/2014
Exposure time: 7,200 s
Run number: N44

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	8.103E+03	8.103E+12	1.169E+04	.1500E-08
.2000E-08	.5000E-08	5.199E+04	1.733E+13	5.674E+04	.3500E-08
.5000E-08	.1000E-07	1.581E+05	3.162E+13	2.281E+05	.7500E-08
.1000E-07	.2000E-07	4.661E+05	4.661E+13	6.724E+05	.1500E-07
.2000E-07	.5000E-07	1.445E+06	4.816E+13	1.577E+06	.3500E-07
.5000E-07	.1000E-06	1.129E+06	2.259E+13	1.629E+06	.7500E-07
.1000E-06	.2000E-06	3.177E+05	3.177E+12	4.583E+05	.1500E-06
.2000E-06	.5000E-06	4.668E+05	1.556E+12	5.095E+05	.3500E-06
.5000E-06	.1000E-01	5.609E+06	5.610E+08	5.664E+05	.5000E-02
.1000E-01	.1027E+00	2.585E+06	2.789E+07	1.110E+06	.5635E-01
.1027E+00	.1166E+00	2.141E+05	1.545E+07	1.691E+06	.1096E+00
.1166E+00	.1317E+00	3.138E+05	2.075E+07	2.572E+06	.1241E+00
.1317E+00	.1493E+00	3.301E+05	1.872E+07	2.626E+06	.1405E+00
.1493E+00	.1707E+00	3.161E+05	1.476E+07	2.358E+06	.1600E+00
.1707E+00	.1934E+00	2.628E+05	1.159E+07	2.107E+06	.1821E+00
.1934E+00	.2199E+00	2.714E+05	1.026E+07	2.117E+06	.2066E+00
.2199E+00	.2606E+00	4.140E+05	1.016E+07	2.434E+06	.2402E+00
.2606E+00	.2906E+00	2.611E+05	8.703E+06	2.396E+06	.2756E+00
.2906E+00	.3244E+00	2.579E+05	7.640E+06	2.347E+06	.3075E+00
.3244E+00	.3581E+00	2.327E+05	6.896E+06	2.351E+06	.3413E+00
.3581E+00	.3994E+00	2.464E+05	5.973E+06	2.260E+06	.3787E+00
.3994E+00	.4444E+00	1.932E+05	4.294E+06	1.810E+06	.4219E+00
.4444E+00	.4931E+00	2.326E+05	4.772E+06	2.235E+06	.4688E+00
.4931E+00	.5456E+00	2.952E+05	5.623E+06	2.918E+06	.5194E+00
.5456E+00	.6094E+00	3.406E+05	5.342E+06	3.082E+06	.5775E+00
.6094E+00	.6769E+00	3.813E+05	5.649E+06	3.630E+06	.6431E+00
.6769E+00	.7946E+00	6.132E+05	5.207E+06	3.823E+06	.7358E+00
.7946E+00	.8870E+00	4.426E+05	4.791E+06	4.024E+06	.8408E+00
.8870E+00	.9871E+00	3.383E+05	3.380E+06	3.164E+06	.9371E+00
.9871E+00	.1095E+01	3.176E+05	2.946E+06	3.065E+06	.1041E+01
.1095E+01	.1218E+01	4.072E+05	3.306E+06	3.819E+06	.1157E+01
.1218E+01	.1391E+01	5.531E+05	3.200E+06	4.168E+06	.1305E+01
.1391E+01	.1573E+01	4.616E+05	2.536E+06	3.754E+06	.1482E+01
.1573E+01	.1807E+01	5.042E+05	2.155E+06	3.636E+06	.1690E+01
.1807E+01	.2041E+01	4.185E+05	1.788E+06	3.437E+06	.1924E+01

E2	E1	FLUENCE/	FLUENCE/	FLUENCE/	E avg.

(MeV)	(MeV)	(E1-E2) (n/cm²)	MeV (n/cm².MeV)	LETHARGY* (n/cm².u)	(MeV)
.2041E+01	.2327E+01	4.783E+05	1.672E+06	3.647E+06	.2184E+01
.2327E+01	.2639E+01	4.354E+05	1.395E+06	3.460E+06	.2483E+01
.2639E+01	.3003E+01	3.800E+05	1.044E+06	2.941E+06	.2821E+01
.3003E+01	.3419E+01	3.294E+05	7.919E+05	2.539E+06	.3211E+01
.3419E+01	.3861E+01	2.434E+05	5.507E+05	2.002E+06	.3640E+01
.3861E+01	.4407E+01	2.342E+05	4.289E+05	1.770E+06	.4134E+01
.4407E+01	.5000E+01	1.781E+05	3.003E+05	1.410E+06	.4703E+01
.5000E+01	.5500E+01	1.017E+05	2.034E+05	1.067E+06	.5250E+01
.5500E+01	.6000E+01	7.532E+04	1.506E+05	8.656E+05	.5750E+01
.6000E+01	.6500E+01	5.553E+04	1.111E+05	6.937E+05	.6250E+01
.6500E+01	.7000E+01	4.076E+04	8.151E+04	5.499E+05	.6750E+01
.7000E+01	.7500E+01	2.983E+04	5.965E+04	4.323E+05	.7250E+01
.7500E+01	.8000E+01	2.175E+04	4.349E+04	3.369E+05	.7750E+01
.8000E+01	.8500E+01	1.582E+04	3.164E+04	2.609E+05	.8250E+01
.8500E+01	.9000E+01	1.148E+04	2.297E+04	2.009E+05	.8750E+01
.9000E+01	.9500E+01	8.323E+03	1.665E+04	1.539E+05	.9250E+01
.9500E+01	.1000E+02	6.034E+03	1.207E+04	1.176E+05	.9750E+01

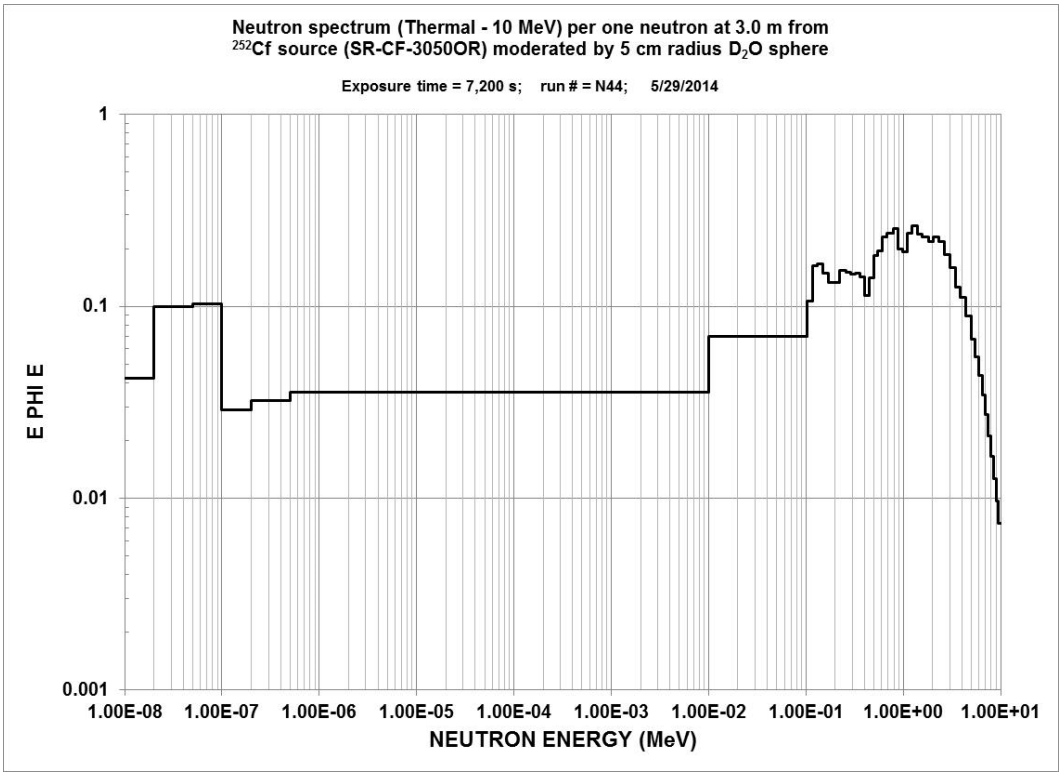
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



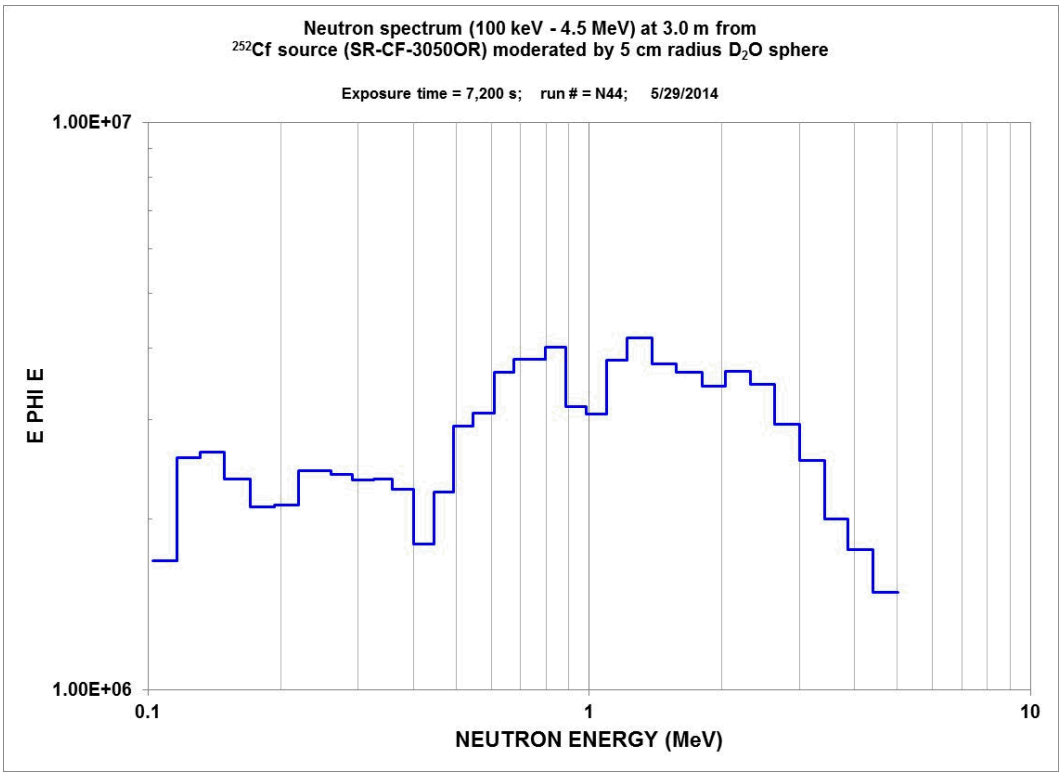


Figure H-3. Neutron spectra at 3.0 m from ^{252}Cf moderated by 5 cm of D_2O

Fluence, spectral and dosimetric data at 3.5 m from ^{252}Cf moderated by 5 cm of D_2O

Table H-7. Neutron fluence and dosimetric data at 3.5 m from 5 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/29/2014
Exposure time:	7,200 s
Run #	N45

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	8.97E+06	1.25E+03
Epi-thermal region	:	8.17E+06	1.14E+03
Thermal region	:	3.58E+06	4.97E+02
Thermal – 4.5 MeV	:	2.07E+07	2.88E+03
Thermal – 10.0 MeV	:	2.0969E+07	2.9123E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.95E-02	2.97E-03	9.75E+00	1.49E+03
Epi-thermal region	:	9.22E-04	1.51E-04	4.61E-01	7.55E+01
Thermal region	:	7.15E-05	3.79E-05	3.58E-02	1.89E+01
Thermal – 4.5 MeV	:	2.05E-02	3.16E-03	1.02E+01	1.58E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.1132E-02 rads	1.0566E+01 mrads/hr
H*(10) ICRP-74	=	3.2218E-03 Sv	1.6109E+03 uSv/hr
Hp(10,0) ICRP-74	=	3.3359E-03 Sv	1.6679E+03 uSv/hr

Table H-8. Neutron fluence at 3.5 m from 5 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/29/2014
Exposure time: 7,200 s
Run number: N45

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	8.080E+03	8.080E+12	1.166E+04	.1500E-08
.2000E-08	.5000E-08	5.184E+04	1.728E+13	5.658E+04	.3500E-08
.5000E-08	.1000E-07	1.577E+05	3.153E+13	2.275E+05	.7500E-08
.1000E-07	.2000E-07	4.648E+05	4.648E+13	6.706E+05	.1500E-07
.2000E-07	.5000E-07	1.441E+06	4.803E+13	1.572E+06	.3500E-07
.5000E-07	.1000E-06	1.126E+06	2.252E+13	1.625E+06	.7500E-07
.1000E-06	.2000E-06	3.168E+05	3.168E+12	4.570E+05	.1500E-06
.2000E-06	.5000E-06	4.550E+05	1.517E+12	4.966E+05	.3500E-06
.5000E-06	.1000E-01	5.343E+06	5.344E+08	5.396E+05	.5000E-02
.1000E-01	.1027E+00	2.376E+06	2.564E+07	1.020E+06	.5635E-01
.1027E+00	.1166E+00	2.512E+05	1.813E+07	1.984E+06	.1096E+00
.1166E+00	.1317E+00	2.385E+05	1.578E+07	1.955E+06	.1241E+00
.1317E+00	.1493E+00	2.341E+05	1.327E+07	1.862E+06	.1405E+00
.1493E+00	.1707E+00	3.197E+05	1.493E+07	2.385E+06	.1600E+00
.1707E+00	.1934E+00	2.013E+05	8.874E+06	1.614E+06	.1821E+00
.1934E+00	.2199E+00	2.837E+05	1.072E+07	2.212E+06	.2066E+00
.2199E+00	.2606E+00	3.109E+05	7.630E+06	1.829E+06	.2402E+00
.2606E+00	.2906E+00	2.482E+05	8.273E+06	2.278E+06	.2756E+00
.2906E+00	.3244E+00	2.076E+05	6.151E+06	1.890E+06	.3075E+00
.3244E+00	.3581E+00	1.665E+05	4.934E+06	1.682E+06	.3413E+00
.3581E+00	.3994E+00	1.853E+05	4.492E+06	1.700E+06	.3787E+00
.3994E+00	.4444E+00	1.779E+05	3.953E+06	1.666E+06	.4219E+00
.4444E+00	.4931E+00	2.123E+05	4.354E+06	2.039E+06	.4688E+00
.4931E+00	.5456E+00	2.582E+05	4.918E+06	2.552E+06	.5194E+00
.5456E+00	.6094E+00	2.978E+05	4.671E+06	2.695E+06	.5775E+00
.6094E+00	.6769E+00	3.144E+05	4.658E+06	2.993E+06	.6431E+00
.6769E+00	.7946E+00	5.115E+05	4.343E+06	3.189E+06	.7358E+00
.7946E+00	.8870E+00	3.425E+05	3.706E+06	3.113E+06	.8408E+00
.8870E+00	.9871E+00	2.991E+05	2.988E+06	2.797E+06	.9371E+00
.9871E+00	.1095E+01	2.433E+05	2.257E+06	2.347E+06	.1041E+01
.1095E+01	.1218E+01	3.149E+05	2.556E+06	2.953E+06	.1157E+01
.1218E+01	.1391E+01	4.695E+05	2.716E+06	3.538E+06	.1305E+01
.1391E+01	.1573E+01	3.707E+05	2.037E+06	3.015E+06	.1482E+01
.1573E+01	.1807E+01	3.972E+05	1.698E+06	2.864E+06	.1690E+01
.1807E+01	.2041E+01	3.297E+05	1.409E+06	2.707E+06	.1924E+01
.2041E+01	.2327E+01	3.707E+05	1.296E+06	2.827E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.2327E+01	.2639E+01	3.597E+05	1.153E+06	2.859E+06	.2483E+01
.2639E+01	.3003E+01	3.006E+05	8.257E+05	2.326E+06	.2821E+01
.3003E+01	.3419E+01	2.448E+05	5.885E+05	1.887E+06	.3211E+01
.3419E+01	.3861E+01	1.907E+05	4.315E+05	1.569E+06	.3640E+01
.3861E+01	.4407E+01	1.853E+05	3.394E+05	1.401E+06	.4134E+01
.4407E+01	.5000E+01	1.282E+05	2.162E+05	1.015E+06	.4703E+01
.5000E+01	.5500E+01	7.257E+04	1.451E+05	7.614E+05	.5250E+01
.5500E+01	.6000E+01	5.374E+04	1.075E+05	6.177E+05	.5750E+01
.6000E+01	.6500E+01	3.962E+04	7.925E+04	4.950E+05	.6250E+01
.6500E+01	.7000E+01	2.908E+04	5.816E+04	3.924E+05	.6750E+01
.7000E+01	.7500E+01	2.128E+04	4.257E+04	3.085E+05	.7250E+01
.7500E+01	.8000E+01	1.552E+04	3.103E+04	2.404E+05	.7750E+01
.8000E+01	.8500E+01	1.129E+04	2.258E+04	1.862E+05	.8250E+01
.8500E+01	.9000E+01	8.194E+03	1.639E+04	1.434E+05	.8750E+01
.9000E+01	.9500E+01	5.939E+03	1.188E+04	1.099E+05	.9250E+01
.9500E+01	.1000E+02	4.306E+03	8.612E+03	8.394E+04	.9750E+01

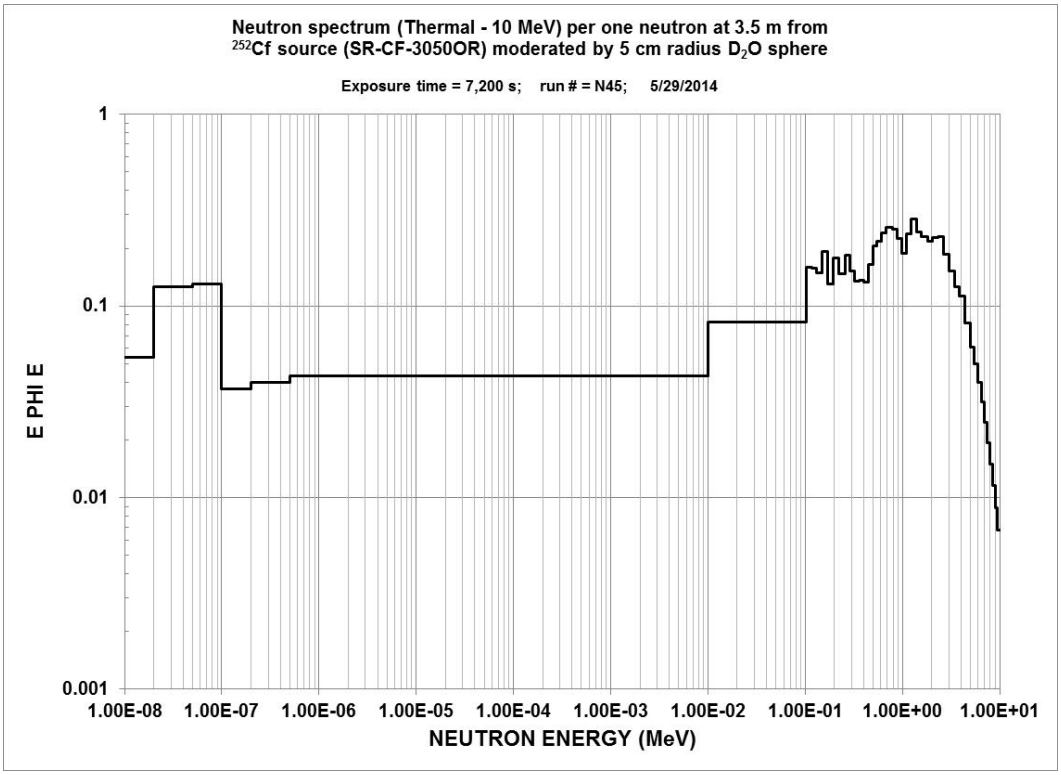
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



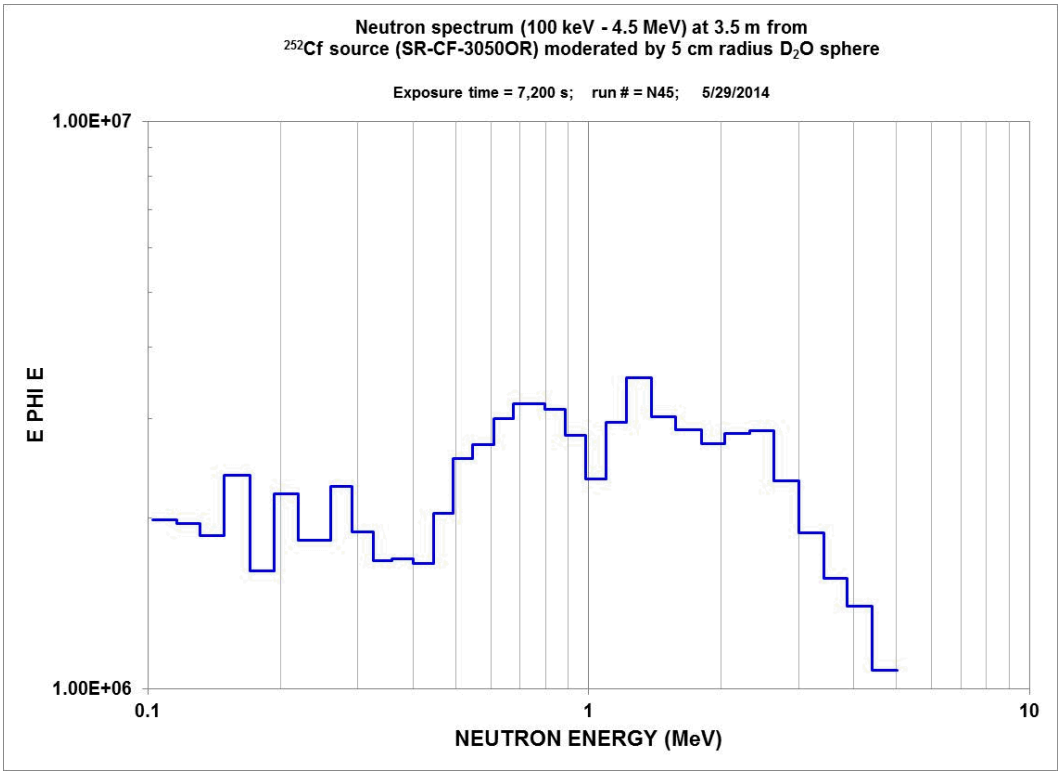


Figure H-4. Neutron spectra at 3.5 m from ^{252}Cf moderated by 5 cm of D_2O

Fluence, spectral and dosimetric data at 4.0 m from ^{252}Cf moderated by 5 cm of D_2O

Table H-9. Neutron fluence and dosimetric data at 4.0 m from 5 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/30/2014
Exposure time:	7,200 s
Run #	N46

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	7.61E+06	1.06E+03
Epi-thermal region	:	7.70E+06	1.07E+03
Thermal region	:	3.47E+06	4.82E+02
Thermal – 4.5 MeV	:	1.88E+07	2.61E+03
Thermal – 10.0 MeV	:	1.8969E+07	2.6345E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.63E-02	2.50E-03	8.15E+00	1.25E+03
Epi-thermal region	:	8.38E-04	1.40E-04	4.19E-01	6.99E+01
Thermal region	:	6.94E-05	3.68E-05	3.47E-02	1.84E+01
Thermal – 4.5 MeV	:	1.72E-02	2.68E-03	8.60E+00	1.34E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.7668E-02 rads	8.8338E+00 mrads/hr
H*(10) ICRP-74	=	2.7196E-03 Sv	1.3598E+03 uSv/hr
Hp(10,0) ICRP-74	=	2.8161E-03 Sv	1.4081E+03 uSv/hr

Table H-10. Neutron fluence at 4.0 m from 5 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/30/2014
Exposure time: 7,200 s
Run number: N46

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	7.842E+03	7.842E+12	1.131E+04	.1500E-08
.2000E-08	.5000E-08	5.031E+04	1.677E+13	5.491E+04	.3500E-08
.5000E-08	.1000E-07	1.530E+05	3.060E+13	2.208E+05	.7500E-08
.1000E-07	.2000E-07	4.511E+05	4.511E+13	6.508E+05	.1500E-07
.2000E-07	.5000E-07	1.398E+06	4.661E+13	1.526E+06	.3500E-07
.5000E-07	.1000E-06	1.093E+06	2.186E+13	1.577E+06	.7500E-07
.1000E-06	.2000E-06	3.074E+05	3.074E+12	4.435E+05	.1500E-06
.2000E-06	.5000E-06	4.386E+05	1.462E+12	4.787E+05	.3500E-06
.5000E-06	.1000E-01	5.117E+06	5.117E+08	5.167E+05	.5000E-02
.1000E-01	.1027E+00	2.149E+06	2.318E+07	9.225E+05	.5635E-01
.1027E+00	.1166E+00	1.586E+05	1.144E+07	1.253E+06	.1096E+00
.1166E+00	.1317E+00	2.453E+05	1.622E+07	2.011E+06	.1241E+00
.1317E+00	.1493E+00	2.605E+05	1.477E+07	2.072E+06	.1405E+00
.1493E+00	.1707E+00	2.102E+05	9.815E+06	1.568E+06	.1600E+00
.1707E+00	.1934E+00	2.021E+05	8.910E+06	1.620E+06	.1821E+00
.1934E+00	.2199E+00	1.939E+05	7.329E+06	1.512E+06	.2066E+00
.2199E+00	.2606E+00	3.569E+05	8.757E+06	2.099E+06	.2402E+00
.2606E+00	.2906E+00	1.947E+05	6.488E+06	1.787E+06	.2756E+00
.2906E+00	.3244E+00	2.147E+05	6.363E+06	1.955E+06	.3075E+00
.3244E+00	.3581E+00	1.480E+05	4.385E+06	1.495E+06	.3413E+00
.3581E+00	.3994E+00	1.539E+05	3.730E+06	1.411E+06	.3787E+00
.3994E+00	.4444E+00	1.406E+05	3.124E+06	1.317E+06	.4219E+00
.4444E+00	.4931E+00	1.852E+05	3.800E+06	1.780E+06	.4688E+00
.4931E+00	.5456E+00	2.223E+05	4.235E+06	2.198E+06	.5194E+00
.5456E+00	.6094E+00	2.751E+05	4.315E+06	2.490E+06	.5775E+00
.6094E+00	.6769E+00	2.576E+05	3.817E+06	2.453E+06	.6431E+00
.6769E+00	.7946E+00	4.331E+05	3.678E+06	2.700E+06	.7358E+00
.7946E+00	.8870E+00	2.837E+05	3.070E+06	2.579E+06	.8408E+00
.8870E+00	.9871E+00	2.377E+05	2.375E+06	2.223E+06	.9371E+00
.9871E+00	.1095E+01	2.129E+05	1.975E+06	2.054E+06	.1041E+01
.1095E+01	.1218E+01	2.827E+05	2.295E+06	2.651E+06	.1157E+01
.1218E+01	.1391E+01	3.617E+05	2.092E+06	2.726E+06	.1305E+01
.1391E+01	.1573E+01	3.167E+05	1.740E+06	2.576E+06	.1482E+01
.1573E+01	.1807E+01	3.227E+05	1.379E+06	2.327E+06	.1690E+01
.1807E+01	.2041E+01	2.759E+05	1.179E+06	2.266E+06	.1924E+01
.2041E+01	.2327E+01	3.250E+05	1.136E+06	2.479E+06	.2184E+01
.2327E+01	.2639E+01	2.921E+05	9.363E+05	2.322E+06	.2483E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2639E+01	.3003E+01	2.465E+05	6.773E+05	1.908E+06	.2821E+01
.3003E+01	.3419E+01	2.059E+05	4.951E+05	1.587E+06	.3211E+01
.3419E+01	.3861E+01	1.387E+05	3.138E+05	1.141E+06	.3640E+01
.3861E+01	.4407E+01	1.348E+05	2.468E+05	1.019E+06	.4134E+01
.4407E+01	.5000E+01	1.066E+05	1.797E+05	8.443E+05	.4703E+01
.5000E+01	.5500E+01	5.739E+04	1.148E+05	6.021E+05	.5250E+01
.5500E+01	.6000E+01	4.250E+04	8.500E+04	4.885E+05	.5750E+01
.6000E+01	.6500E+01	3.134E+04	6.267E+04	3.915E+05	.6250E+01
.6500E+01	.7000E+01	2.300E+04	4.600E+04	3.103E+05	.6750E+01
.7000E+01	.7500E+01	1.683E+04	3.366E+04	2.440E+05	.7250E+01
.7500E+01	.8000E+01	1.227E+04	2.454E+04	1.901E+05	.7750E+01
.8000E+01	.8500E+01	8.927E+03	1.785E+04	1.473E+05	.8250E+01
.8500E+01	.9000E+01	6.480E+03	1.296E+04	1.134E+05	.8750E+01
.9000E+01	.9500E+01	4.697E+03	9.394E+03	8.687E+04	.9250E+01
.9500E+01	.1000E+02	3.405E+03	6.810E+03	6.639E+04	.9750E+01

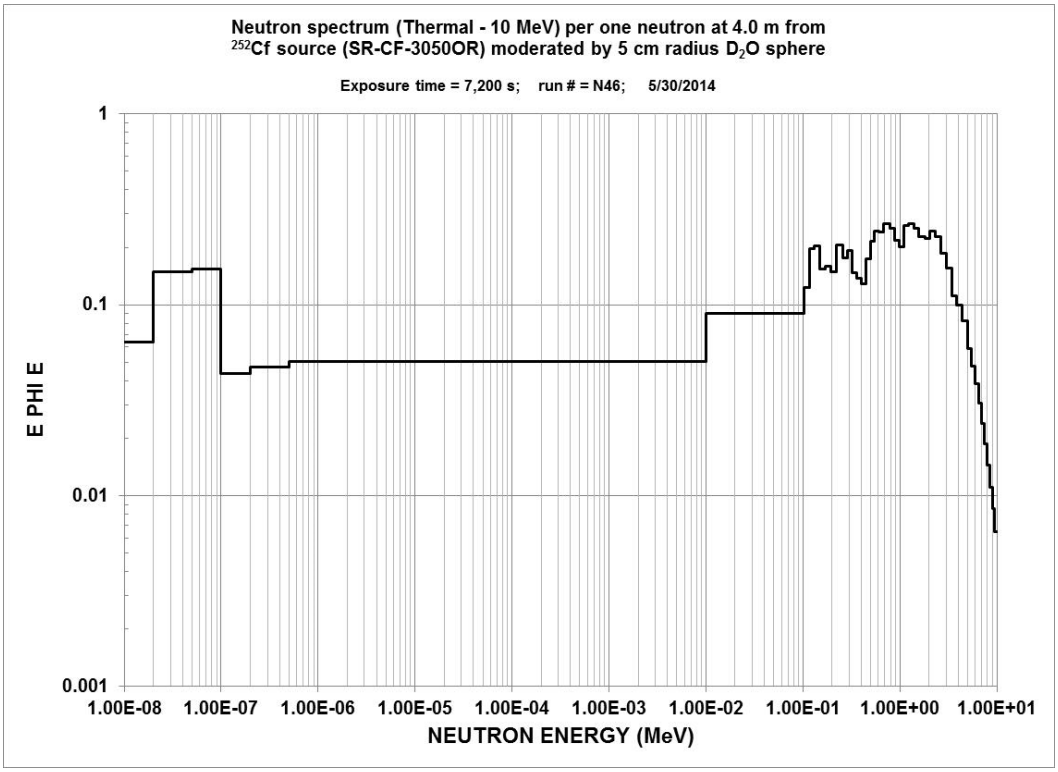
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



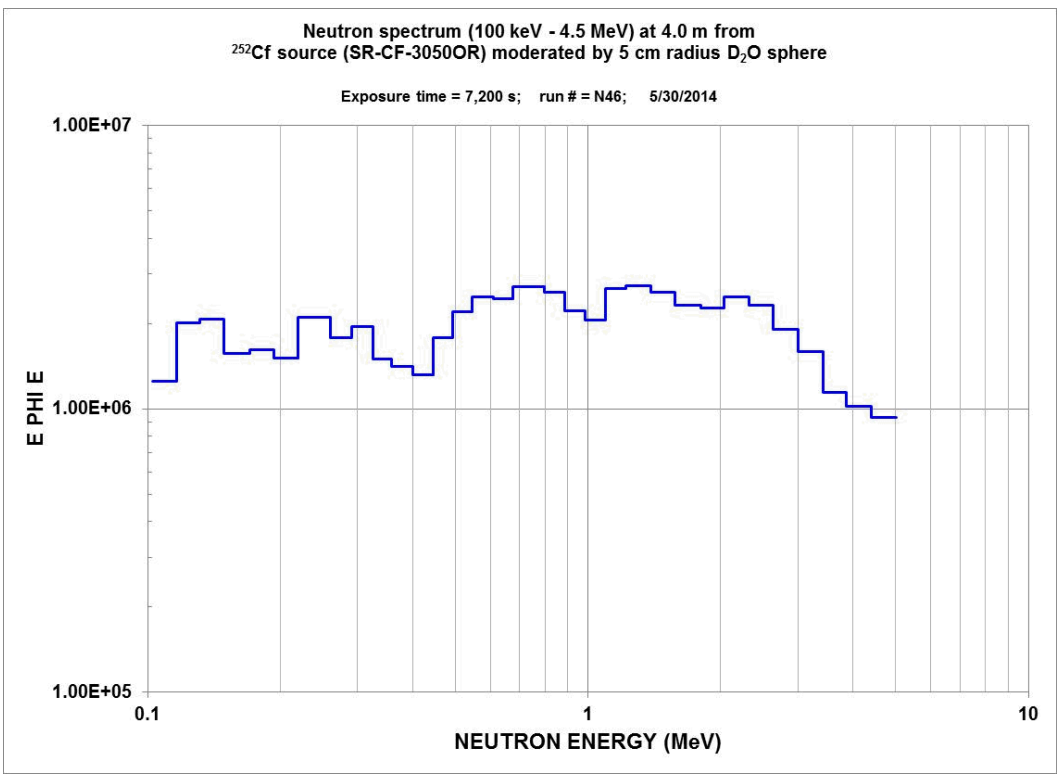


Figure H-5. Neutron spectra at 4.0 m from ^{252}Cf moderated by 5 cm of D_2O

Fluence, spectral and dosimetric data at 4.5 m from ^{252}Cf moderated by 5 cm of D_2O

Table H-11. Neutron fluence and dosimetric data at 4.5 m from 5 cm thick D_2O moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	5/30/2014
Exposure time:	7,200 s
Run #	N47

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	6.76E+06	9.39E+02
Epi-thermal region	:	7.51E+06	1.04E+03
Thermal region	:	3.47E+06	4.81E+02
Thermal – 4.5 MeV	:	1.77E+07	2.46E+03
Thermal – 10.0 MeV	:	1.7891E+07	2.4849E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.42E-02	2.20E-03	7.12E+00	1.10E+03
Epi-thermal region	:	8.07E-04	1.35E-04	4.04E-01	6.77E+01
Thermal region	:	6.93E-05	3.67E-05	3.47E-02	1.84E+01
Thermal – 4.5 MeV	:	1.51E-02	2.37E-03	7.55E+00	1.19E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.5469E-02 rads	7.7346E+00 mrads/hr
H*(10) ICRP-74	=	2.4044E-03 Sv	1.2022E+03 uSv/hr
Hp(10,0) ICRP-74	=	2.4897E-03 Sv	1.2448E+03 uSv/hr

Table H-12. Neutron fluence at 4.5 m from 5 cm thick D_2O moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 5/30/2014
Exposure time: 7,200 s
Run number: N47

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	7.834E+03	7.834E+12	1.130E+04	.1500E-08
.2000E-08	.5000E-08	5.026E+04	1.675E+13	5.485E+04	.3500E-08
.5000E-08	.1000E-07	1.529E+05	3.057E+13	2.205E+05	.7500E-08
.1000E-07	.2000E-07	4.506E+05	4.506E+13	6.501E+05	.1500E-07
.2000E-07	.5000E-07	1.397E+06	4.656E+13	1.525E+06	.3500E-07
.5000E-07	.1000E-06	1.092E+06	2.184E+13	1.575E+06	.7500E-07
.1000E-06	.2000E-06	3.071E+05	3.071E+12	4.431E+05	.1500E-06
.2000E-06	.5000E-06	4.339E+05	1.446E+12	4.735E+05	.3500E-06
.5000E-06	.1000E-01	5.012E+06	5.012E+08	5.061E+05	.5000E-02
.1000E-01	.1027E+00	2.065E+06	2.228E+07	8.867E+05	.5635E-01
.1027E+00	.1166E+00	1.648E+05	1.189E+07	1.301E+06	.1096E+00
.1166E+00	.1317E+00	2.519E+05	1.666E+07	2.065E+06	.1241E+00
.1317E+00	.1493E+00	1.830E+05	1.037E+07	1.456E+06	.1405E+00
.1493E+00	.1707E+00	2.131E+05	9.947E+06	1.589E+06	.1600E+00
.1707E+00	.1934E+00	1.947E+05	8.585E+06	1.561E+06	.1821E+00
.1934E+00	.2199E+00	1.992E+05	7.527E+06	1.553E+06	.2066E+00
.2199E+00	.2606E+00	2.890E+05	7.092E+06	1.700E+06	.2402E+00
.2606E+00	.2906E+00	1.580E+05	5.265E+06	1.450E+06	.2756E+00
.2906E+00	.3244E+00	2.089E+05	6.190E+06	1.902E+06	.3075E+00
.3244E+00	.3581E+00	1.585E+05	4.696E+06	1.601E+06	.3413E+00
.3581E+00	.3994E+00	1.300E+05	3.151E+06	1.192E+06	.3787E+00
.3994E+00	.4444E+00	1.270E+05	2.822E+06	1.189E+06	.4219E+00
.4444E+00	.4931E+00	1.805E+05	3.702E+06	1.734E+06	.4688E+00
.4931E+00	.5456E+00	1.987E+05	3.786E+06	1.965E+06	.5194E+00
.5456E+00	.6094E+00	2.240E+05	3.513E+06	2.027E+06	.5775E+00
.6094E+00	.6769E+00	2.444E+05	3.621E+06	2.327E+06	.6431E+00
.6769E+00	.7946E+00	4.063E+05	3.450E+06	2.533E+06	.7358E+00
.7946E+00	.8870E+00	2.718E+05	2.942E+06	2.471E+06	.8408E+00
.8870E+00	.9871E+00	2.158E+05	2.156E+06	2.018E+06	.9371E+00
.9871E+00	.1095E+01	1.806E+05	1.675E+06	1.742E+06	.1041E+01
.1095E+01	.1218E+01	2.404E+05	1.952E+06	2.255E+06	.1157E+01
.1218E+01	.1391E+01	3.106E+05	1.797E+06	2.341E+06	.1305E+01
.1391E+01	.1573E+01	2.704E+05	1.485E+06	2.199E+06	.1482E+01
.1573E+01	.1807E+01	2.822E+05	1.206E+06	2.035E+06	.1690E+01
.1807E+01	.2041E+01	2.368E+05	1.012E+06	1.944E+06	.1924E+01
.2041E+01	.2327E+01	2.618E+05	9.152E+05	1.996E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	2.577E+05	8.260E+05	2.048E+06	.2483E+01
.2639E+01	.3003E+01	1.974E+05	5.423E+05	1.528E+06	.2821E+01
.3003E+01	.3419E+01	1.764E+05	4.239E+05	1.359E+06	.3211E+01
.3419E+01	.3861E+01	1.148E+05	2.597E+05	9.442E+05	.3640E+01
.3861E+01	.4407E+01	1.198E+05	2.194E+05	9.056E+05	.4134E+01
.4407E+01	.5000E+01	8.491E+04	1.432E+05	6.726E+05	.4703E+01
.5000E+01	.5500E+01	4.689E+04	9.379E+04	4.920E+05	.5250E+01
.5500E+01	.6000E+01	3.473E+04	6.946E+04	3.991E+05	.5750E+01
.6000E+01	.6500E+01	2.560E+04	5.121E+04	3.199E+05	.6250E+01
.6500E+01	.7000E+01	1.879E+04	3.759E+04	2.536E+05	.6750E+01
.7000E+01	.7500E+01	1.375E+04	2.751E+04	1.993E+05	.7250E+01
.7500E+01	.8000E+01	1.003E+04	2.005E+04	1.554E+05	.7750E+01
.8000E+01	.8500E+01	7.294E+03	1.459E+04	1.203E+05	.8250E+01
.8500E+01	.9000E+01	5.295E+03	1.059E+04	9.264E+04	.8750E+01
.9000E+01	.9500E+01	3.838E+03	7.676E+03	7.099E+04	.9250E+01
.9500E+01	.1000E+02	2.782E+03	5.565E+03	5.425E+04	.9750E+01

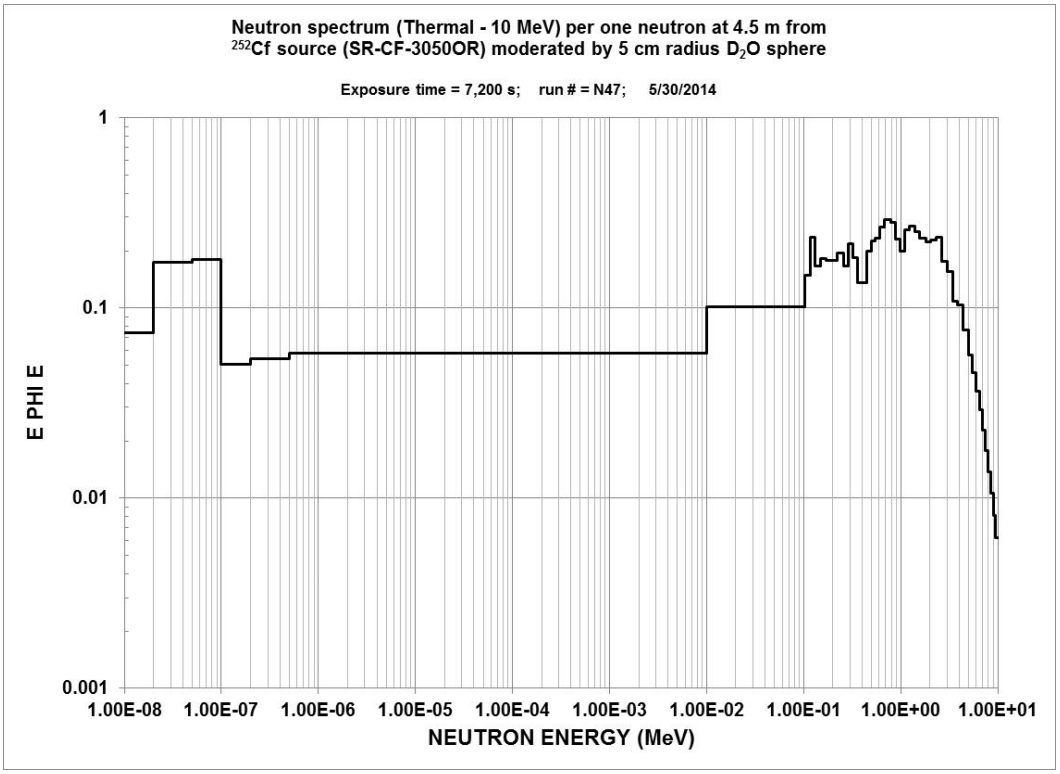
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



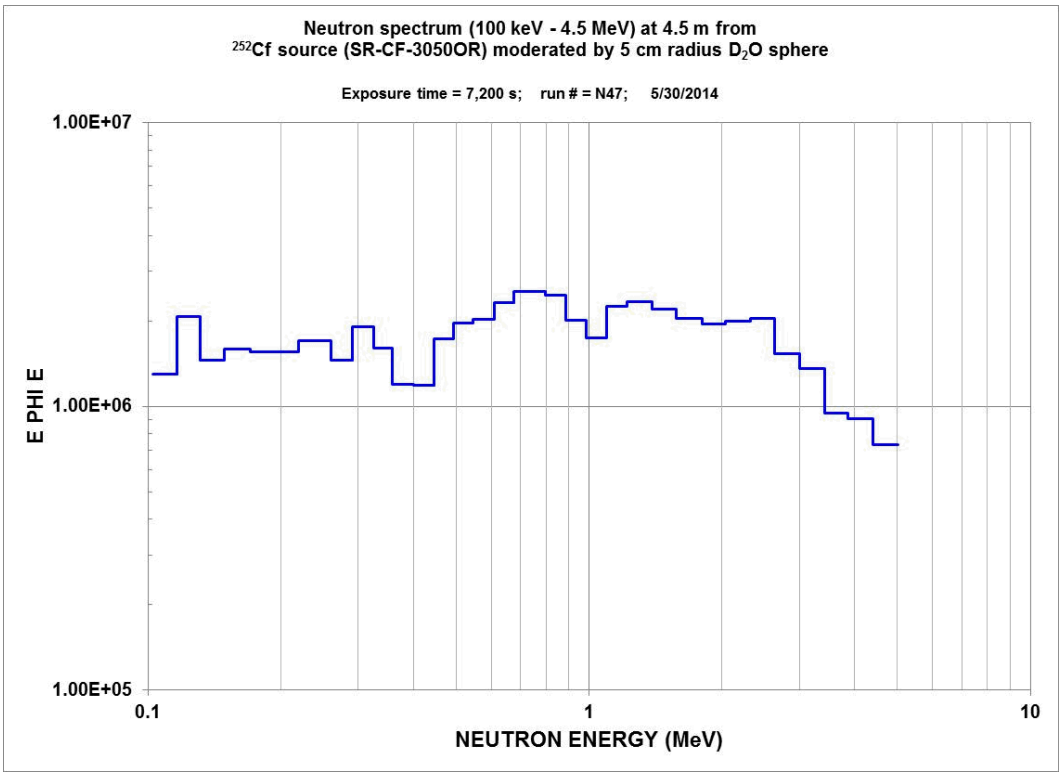
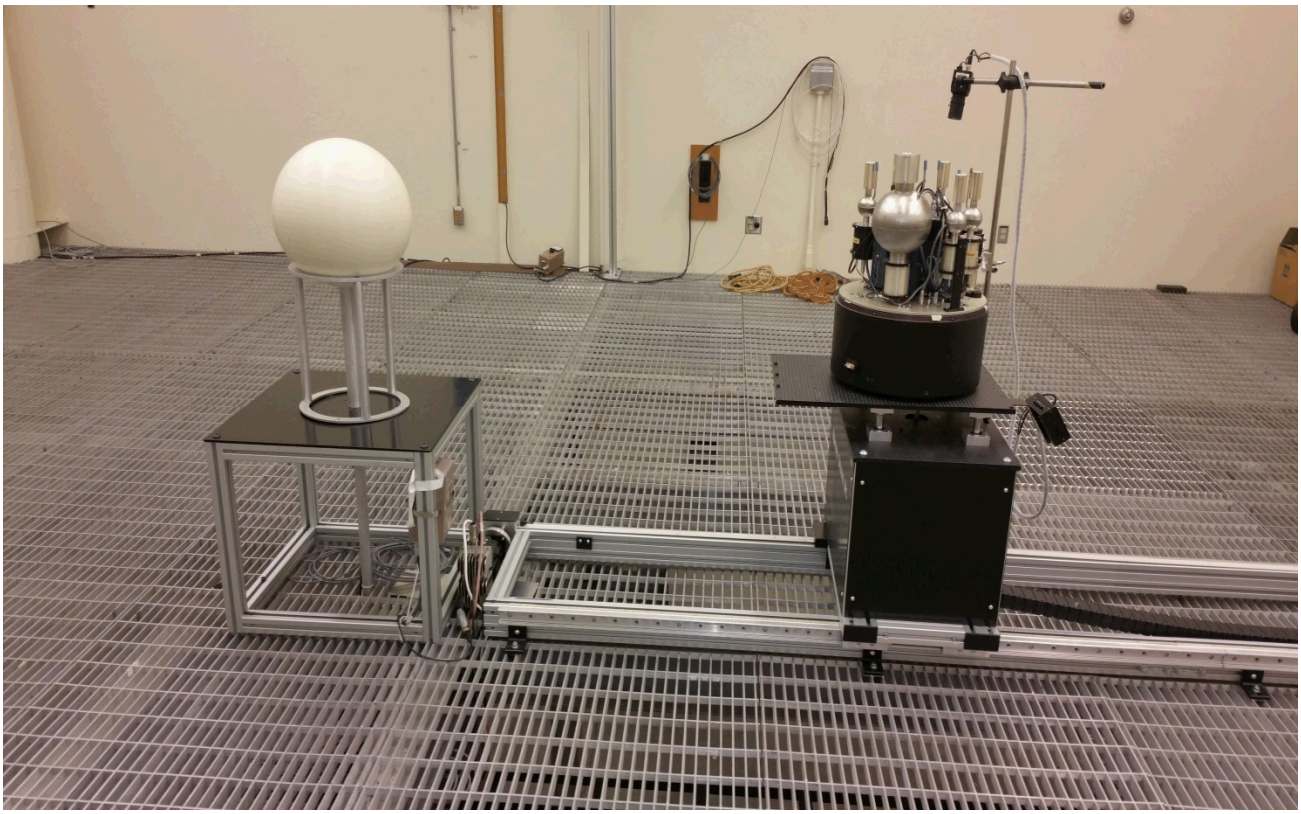


Figure H-6. Neutron spectra at 4.5 m from ^{252}Cf moderated by 5 cm of D_2O

Appendix I

Neutron fluence, spectra and dose rates from ^{252}Cf moderated by 15 cm high density polyethylene



Fluence, spectral and dosimetric data at 2.0 m from ^{252}Cf moderated by 15 cm of polyethylene

Table I-1. Neutron fluence and dosimetric data at 2.0 m from 15 cm thick polyethylene moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	6/9/2014
Exposure time:	7,200 s
Run #	N53

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	3.08E+06	4.28E+02
Epi-thermal region	:	3.08E+06	4.27E+02
Thermal region	:	3.22E+06	4.47E+02
Thermal – 4.5 MeV	:	9.37E+06	1.30E+03
Thermal – 10.0 MeV	:	9.5768E+06	1.3301E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	7.28E-03	1.08E-03	3.64E+00	5.38E+02
Epi-thermal region	:	2.83E-04	5.15E-05	1.42E-01	2.57E+01
Thermal region	:	6.44E-05	3.41E-05	3.22E-02	1.71E+01
Thermal – 4.5 MeV	:	7.63E-03	1.16E-03	3.81E+00	5.81E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	8.3850E-03 rads	4.1925E+00 mrads/hr
H*(10) ICRP-74	=	1.2310E-03 Sv	6.1550E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.2769E-03 Sv	6.3845E+02 uSv/hr

Table I-2. Neutron fluence at 2.0 m from 15 cm thick polyethylene moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 6/9/2014
Exposure time: 7,200 s
Run number: N53

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	7.273E+03	7.273E+12	1.049E+04	.1500E-08
.2000E-08	.5000E-08	4.666E+04	1.555E+13	5.093E+04	.3500E-08
.5000E-08	.1000E-07	1.419E+05	2.838E+13	2.048E+05	.7500E-08
.1000E-07	.2000E-07	4.184E+05	4.184E+13	6.036E+05	.1500E-07
.2000E-07	.5000E-07	1.297E+06	4.323E+13	1.415E+06	.3500E-07
.5000E-07	.1000E-06	1.014E+06	2.027E+13	1.463E+06	.7500E-07
.1000E-06	.2000E-06	2.851E+05	2.851E+12	4.114E+05	.1500E-06
.2000E-06	.5000E-06	2.105E+05	7.016E+11	2.297E+05	.3500E-06
.5000E-06	.1000E-01	2.170E+06	2.170E+08	2.191E+05	.5000E-02
.1000E-01	.1027E+00	7.056E+05	7.613E+06	3.030E+05	.5635E-01
.1027E+00	.1166E+00	5.157E+04	3.721E+06	4.073E+05	.1096E+00
.1166E+00	.1317E+00	5.356E+04	3.542E+06	4.391E+05	.1241E+00
.1317E+00	.1493E+00	7.440E+04	4.218E+06	5.918E+05	.1405E+00
.1493E+00	.1707E+00	3.862E+04	1.803E+06	2.881E+05	.1600E+00
.1707E+00	.1934E+00	5.675E+04	2.502E+06	4.550E+05	.1821E+00
.1934E+00	.2199E+00	7.236E+04	2.735E+06	5.643E+05	.2066E+00
.2199E+00	.2606E+00	1.015E+05	2.491E+06	5.970E+05	.2402E+00
.2606E+00	.2906E+00	6.636E+04	2.212E+06	6.091E+05	.2756E+00
.2906E+00	.3244E+00	6.305E+04	1.868E+06	5.738E+05	.3075E+00
.3244E+00	.3581E+00	4.948E+04	1.466E+06	4.999E+05	.3413E+00
.3581E+00	.3994E+00	6.739E+04	1.634E+06	6.181E+05	.3787E+00
.3994E+00	.4444E+00	8.464E+04	1.881E+06	7.927E+05	.4219E+00
.4444E+00	.4931E+00	6.292E+04	1.291E+06	6.045E+05	.4688E+00
.4931E+00	.5456E+00	8.049E+04	1.533E+06	7.956E+05	.5194E+00
.5456E+00	.6094E+00	1.032E+05	1.618E+06	9.337E+05	.5775E+00
.6094E+00	.6769E+00	9.528E+04	1.412E+06	9.070E+05	.6431E+00
.6769E+00	.7946E+00	1.626E+05	1.381E+06	1.014E+06	.7358E+00
.7946E+00	.8870E+00	1.264E+05	1.368E+06	1.149E+06	.8408E+00
.8870E+00	.9871E+00	9.589E+04	9.580E+05	8.968E+05	.9371E+00
.9871E+00	.1095E+01	9.960E+04	9.239E+05	9.610E+05	.1041E+01
.1095E+01	.1218E+01	1.261E+05	1.023E+06	1.182E+06	.1157E+01
.1218E+01	.1391E+01	1.539E+05	8.902E+05	1.160E+06	.1305E+01
.1391E+01	.1573E+01	1.463E+05	8.037E+05	1.190E+06	.1482E+01
.1573E+01	.1807E+01	1.546E+05	6.606E+05	1.115E+06	.1690E+01
.1807E+01	.2041E+01	1.263E+05	5.399E+05	1.038E+06	.1924E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2041E+01	.2327E+01	1.517E+05	5.303E+05	1.157E+06	.2184E+01
.2327E+01	.2639E+01	1.315E+05	4.215E+05	1.045E+06	.2483E+01
.2639E+01	.3003E+01	1.095E+05	3.008E+05	8.474E+05	.2821E+01
.3003E+01	.3419E+01	1.050E+05	2.523E+05	8.091E+05	.3211E+01
.3419E+01	.3861E+01	8.254E+04	1.867E+05	6.789E+05	.3640E+01
.3861E+01	.4407E+01	9.639E+04	1.765E+05	7.287E+05	.4134E+01
.4407E+01	.5000E+01	9.073E+04	1.530E+05	7.187E+05	.4703E+01
.5000E+01	.5500E+01	5.559E+04	1.112E+05	5.832E+05	.5250E+01
.5500E+01	.6000E+01	4.117E+04	8.234E+04	4.732E+05	.5750E+01
.6000E+01	.6500E+01	3.035E+04	6.071E+04	3.792E+05	.6250E+01
.6500E+01	.7000E+01	2.228E+04	4.456E+04	3.006E+05	.6750E+01
.7000E+01	.7500E+01	1.630E+04	3.261E+04	2.363E+05	.7250E+01
.7500E+01	.8000E+01	1.189E+04	2.377E+04	1.842E+05	.7750E+01
.8000E+01	.8500E+01	8.647E+03	1.729E+04	1.426E+05	.8250E+01
.8500E+01	.9000E+01	6.277E+03	1.255E+04	1.098E+05	.8750E+01
.9000E+01	.9500E+01	4.550E+03	9.100E+03	8.415E+04	.9250E+01
.9500E+01	.1000E+02	3.298E+03	6.597E+03	6.430E+04	.9750E+01

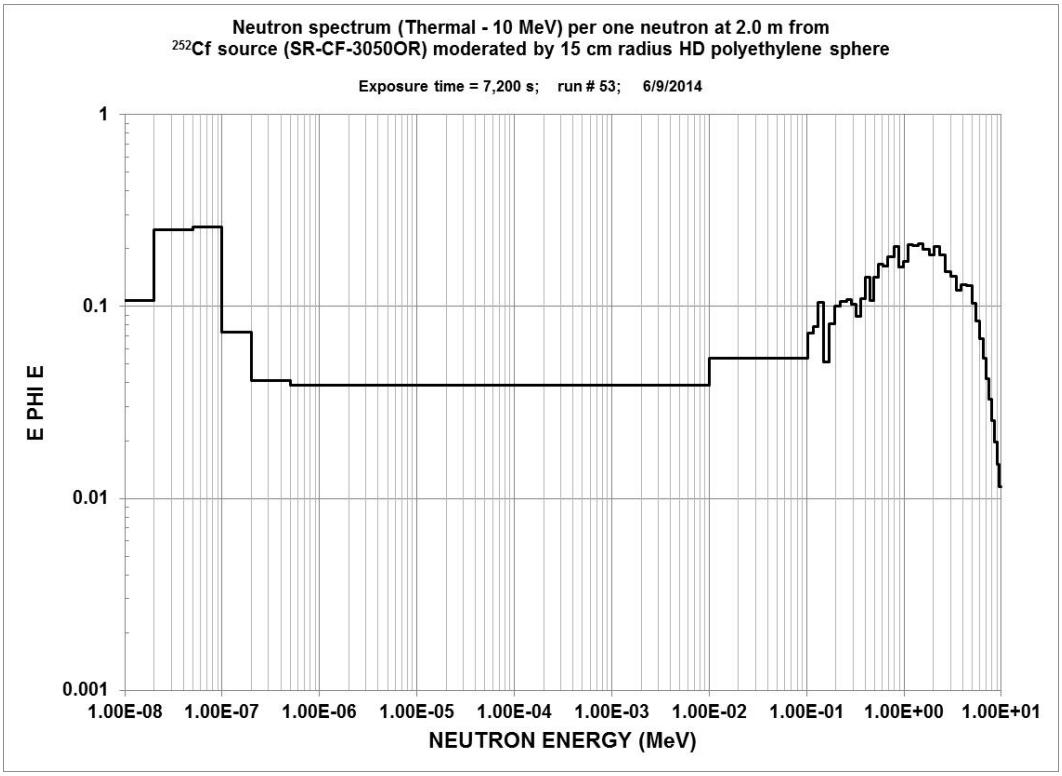
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



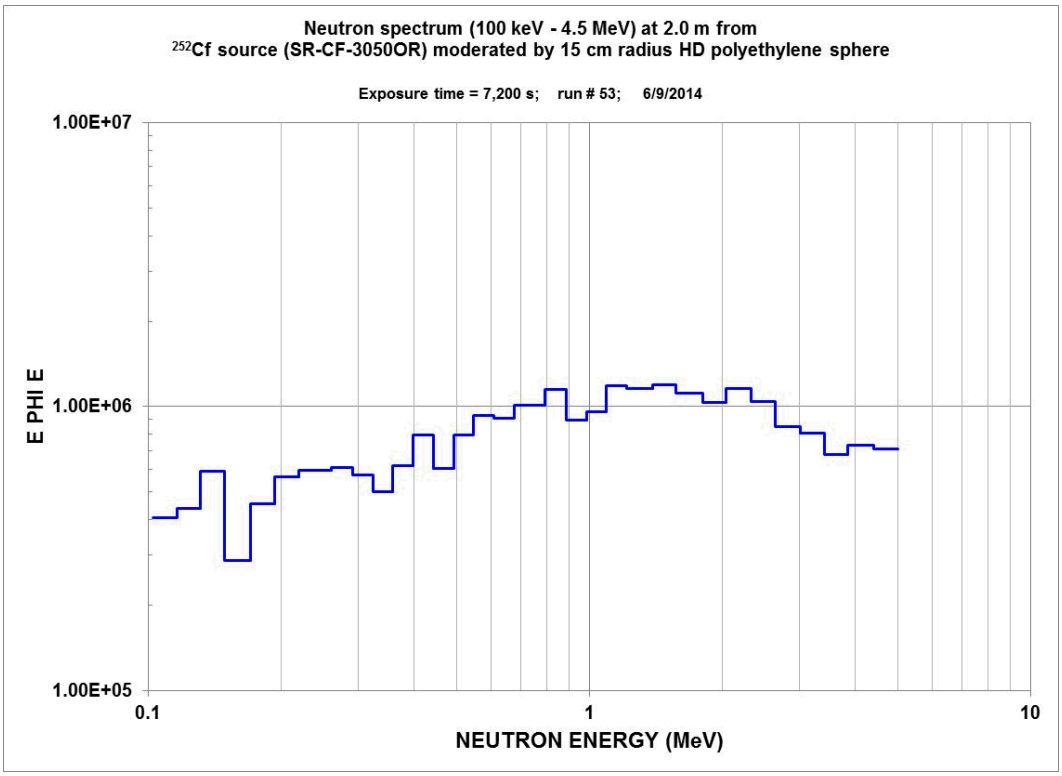


Figure I-1. Neutron spectra at 2.0 m from ^{252}Cf moderated by 15 cm of polyethylene

Fluence, spectral and dosimetric data at 2.5 m from ^{252}Cf moderated by 15 cm of polyethylene

Table I-3. Neutron fluence and dosimetric data at 2.5 m from 15 cm thick polyethylene moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	6/10/2014
Exposure time:	7,200 s
Run #	N54

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	2.30E+06	3.20E+02
Epi-thermal region	:	2.68E+06	3.72E+02
Thermal region	:	2.78E+06	3.86E+02
Thermal – 4.5 MeV	:	7.76E+06	1.08E+03
Thermal – 10.0 MeV	:	7.8922E+06	1.0961E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	5.30E-03	7.90E-04	2.65E+00	3.95E+02
Epi-thermal region	:	2.49E-04	4.50E-05	1.24E-01	2.25E+01
Thermal region	:	5.56E-05	2.95E-05	2.78E-02	1.47E+01
Thermal – 4.5 MeV	:	5.60E-03	8.64E-04	2.80E+00	4.32E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	6.0757E-03 rads	3.0379E+00 mrads/hr
H*(10) ICRP-74	=	9.0716E-04 Sv	4.5358E+02 uSv/hr
Hp(10,0) ICRP-74	=	9.4093E-04 Sv	4.7046E+02 uSv/hr

Table I-4. Neutron fluence at 2.5 m from 15 cm thick polyethylene moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 6/10/2014
Exposure time: 7,200 s
Run number: N54

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	6.281E+03	6.281E+12	9.062E+03	.1500E-08
.2000E-08	.5000E-08	4.030E+04	1.343E+13	4.398E+04	.3500E-08
.5000E-08	.1000E-07	1.226E+05	2.451E+13	1.768E+05	.7500E-08
.1000E-07	.2000E-07	3.613E+05	3.613E+13	5.212E+05	.1500E-07
.2000E-07	.5000E-07	1.120E+06	3.733E+13	1.222E+06	.3500E-07
.5000E-07	.1000E-06	8.755E+05	1.751E+13	1.263E+06	.7500E-07
.1000E-06	.2000E-06	2.462E+05	2.462E+12	3.552E+05	.1500E-06
.2000E-06	.5000E-06	1.824E+05	6.079E+11	1.990E+05	.3500E-06
.5000E-06	.1000E-01	1.880E+06	1.880E+08	1.899E+05	.5000E-02
.1000E-01	.1027E+00	6.209E+05	6.698E+06	2.666E+05	.5635E-01
.1027E+00	.1166E+00	4.765E+04	3.438E+06	3.764E+05	.1096E+00
.1166E+00	.1317E+00	7.079E+04	4.682E+06	5.803E+05	.1241E+00
.1317E+00	.1493E+00	3.431E+04	1.945E+06	2.729E+05	.1405E+00
.1493E+00	.1707E+00	4.293E+04	2.004E+06	3.202E+05	.1600E+00
.1707E+00	.1934E+00	5.298E+04	2.336E+06	4.248E+05	.1821E+00
.1934E+00	.2199E+00	4.996E+04	1.888E+06	3.897E+05	.2066E+00
.2199E+00	.2606E+00	8.871E+04	2.177E+06	5.217E+05	.2402E+00
.2606E+00	.2906E+00	5.929E+04	1.976E+06	5.442E+05	.2756E+00
.2906E+00	.3244E+00	3.087E+04	9.147E+05	2.810E+05	.3075E+00
.3244E+00	.3581E+00	5.307E+04	1.572E+06	5.361E+05	.3413E+00
.3581E+00	.3994E+00	5.315E+04	1.289E+06	4.875E+05	.3787E+00
.3994E+00	.4444E+00	5.894E+04	1.310E+06	5.520E+05	.4219E+00
.4444E+00	.4931E+00	5.599E+04	1.149E+06	5.379E+05	.4688E+00
.4931E+00	.5456E+00	5.077E+04	9.671E+05	5.019E+05	.5194E+00
.5456E+00	.6094E+00	6.621E+04	1.039E+06	5.992E+05	.5775E+00
.6094E+00	.6769E+00	7.084E+04	1.050E+06	6.744E+05	.6431E+00
.6769E+00	.7946E+00	1.516E+05	1.287E+06	9.450E+05	.7358E+00
.7946E+00	.8870E+00	9.010E+04	9.751E+05	8.191E+05	.8408E+00
.8870E+00	.9871E+00	7.827E+04	7.819E+05	7.321E+05	.9371E+00
.9871E+00	.1095E+01	7.302E+04	6.773E+05	7.045E+05	.1041E+01
.1095E+01	.1218E+01	7.096E+04	5.760E+05	6.655E+05	.1157E+01
.1218E+01	.1391E+01	1.117E+05	6.463E+05	8.419E+05	.1305E+01
.1391E+01	.1573E+01	1.025E+05	5.632E+05	8.337E+05	.1482E+01
.1573E+01	.1807E+01	1.144E+05	4.888E+05	8.247E+05	.1690E+01
.1807E+01	.2041E+01	9.103E+04	3.890E+05	7.475E+05	.1924E+01
.2041E+01	.2327E+01	9.994E+04	3.495E+05	7.621E+05	.2184E+01
.2327E+01	.2639E+01	9.126E+04	2.925E+05	7.253E+05	.2483E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.2639E+01	.3003E+01	8.329E+04	2.288E+05	6.446E+05	.2821E+01
.3003E+01	.3419E+01	7.751E+04	1.863E+05	5.974E+05	.3211E+01
.3419E+01	.3861E+01	5.678E+04	1.285E+05	4.670E+05	.3640E+01
.3861E+01	.4407E+01	6.300E+04	1.154E+05	4.763E+05	.4134E+01
.4407E+01	.5000E+01	6.186E+04	1.043E+05	4.900E+05	.4703E+01
.5000E+01	.5500E+01	3.685E+04	7.369E+04	3.866E+05	.5250E+01
.5500E+01	.6000E+01	2.729E+04	5.458E+04	3.136E+05	.5750E+01
.6000E+01	.6500E+01	2.012E+04	4.024E+04	2.514E+05	.6250E+01
.6500E+01	.7000E+01	1.477E+04	2.953E+04	1.993E+05	.6750E+01
.7000E+01	.7500E+01	1.081E+04	2.161E+04	1.566E+05	.7250E+01
.7500E+01	.8000E+01	7.879E+03	1.576E+04	1.221E+05	.7750E+01
.8000E+01	.8500E+01	5.732E+03	1.146E+04	9.454E+04	.8250E+01
.8500E+01	.9000E+01	4.161E+03	8.322E+03	7.279E+04	.8750E+01
.9000E+01	.9500E+01	3.016E+03	6.032E+03	5.578E+04	.9250E+01
.9500E+01	.1000E+02	2.186E+03	4.373E+03	4.262E+04	.9750E+01

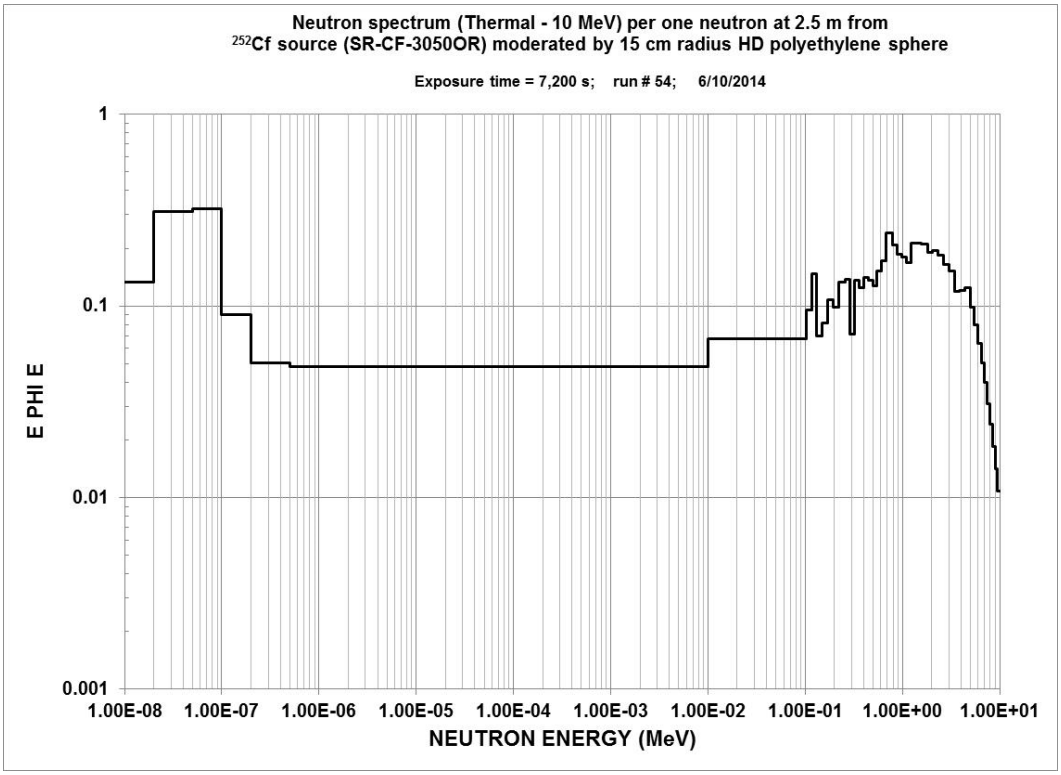
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



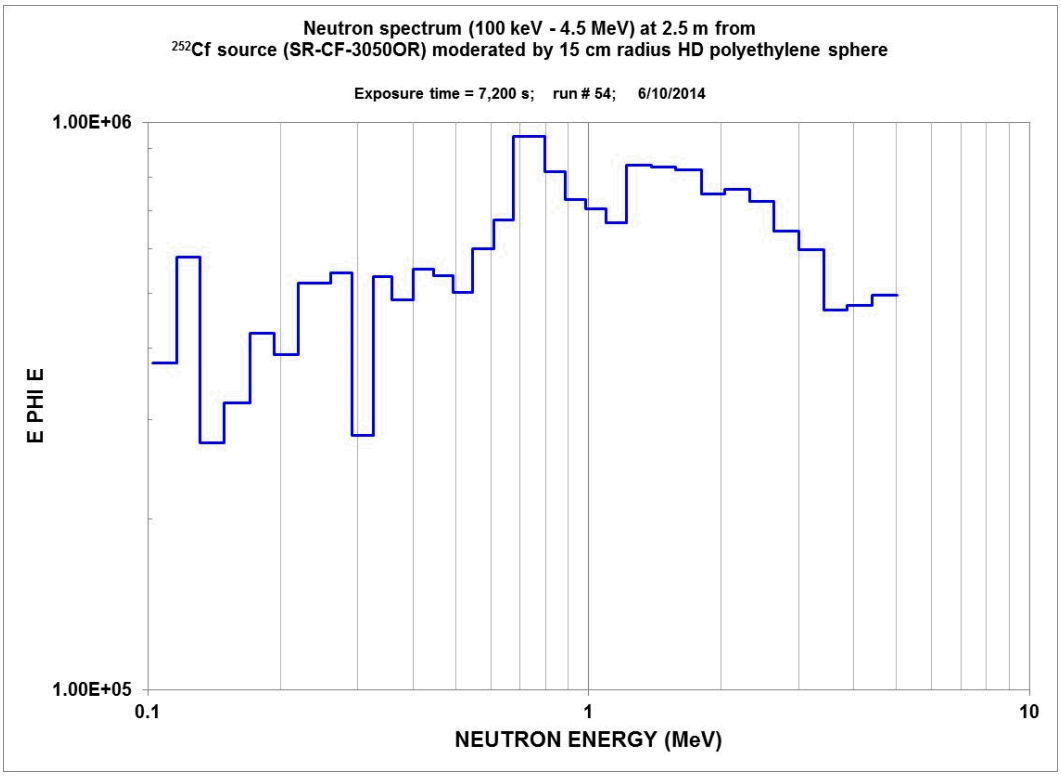


Figure I-2. Neutron spectra at 2.5 m from ^{252}Cf moderated by 15 cm of polyethylene

Fluence, spectral and dosimetric data at 3.0 m from ^{252}Cf moderated by 15 cm of polyethylene

Table I-5. Neutron fluence and dosimetric data at 3.0 m from 15 cm thick polyethylene moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	6/10/2014
Exposure time:	7,200 s
Run #	N55

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.80E+06	2.50E+02
Epi-thermal region	:	2.33E+06	3.23E+02
Thermal region	:	2.48E+06	3.44E+02
Thermal – 4.5 MeV	:	6.61E+06	9.18E+02
Thermal – 10.0 MeV	:	6.6994E+06	9.3047E+02

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	4.09E-03	6.15E-04	2.04E+00	3.07E+02
Epi-thermal region	:	2.10E-04	3.86E-05	1.05E-01	1.93E+01
Thermal region	:	4.96E-05	2.63E-05	2.48E-02	1.31E+01
Thermal – 4.5 MeV	:	4.35E-03	6.80E-04	2.17E+00	3.40E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	4.6612E-03 rads	2.3306E+00 mrads/hr
H*(10) ICRP-74	=	7.0812E-04 Sv	3.5406E+02 uSv/hr
Hp(10,0) ICRP-74	=	7.3447E-04 Sv	3.6723E+02 uSv/hr

Table I-6. Neutron fluence at 3.0 m from 15 cm thick polyethylene moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 6/10/2014
Exposure time: 7,200 s
Run number: N55

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	5.605E+03	5.605E+12	8.087E+03	.1500E-08
.2000E-08	.5000E-08	3.596E+04	1.199E+13	3.925E+04	.3500E-08
.5000E-08	.1000E-07	1.094E+05	2.188E+13	1.578E+05	.7500E-08
.1000E-07	.2000E-07	3.224E+05	3.224E+13	4.652E+05	.1500E-07
.2000E-07	.5000E-07	9.995E+05	3.332E+13	1.091E+06	.3500E-07
.5000E-07	.1000E-06	7.813E+05	1.563E+13	1.127E+06	.7500E-07
.1000E-06	.2000E-06	2.197E+05	2.197E+12	3.170E+05	.1500E-06
.2000E-06	.5000E-06	1.601E+05	5.337E+11	1.747E+05	.3500E-06
.5000E-06	.1000E-01	1.649E+06	1.649E+08	1.665E+05	.5000E-02
.1000E-01	.1027E+00	5.231E+05	5.644E+06	2.246E+05	.5635E-01
.1027E+00	.1166E+00	3.623E+04	2.614E+06	2.862E+05	.1096E+00
.1166E+00	.1317E+00	4.349E+04	2.876E+06	3.565E+05	.1241E+00
.1317E+00	.1493E+00	3.121E+04	1.769E+06	2.482E+05	.1405E+00
.1493E+00	.1707E+00	6.972E+04	3.255E+06	5.200E+05	.1600E+00
.1707E+00	.1934E+00	3.486E+04	1.537E+06	2.795E+05	.1821E+00
.1934E+00	.2199E+00	4.463E+04	1.687E+06	3.480E+05	.2066E+00
.2199E+00	.2606E+00	4.680E+04	1.148E+06	2.752E+05	.2402E+00
.2606E+00	.2906E+00	3.681E+04	1.227E+06	3.379E+05	.2756E+00
.2906E+00	.3244E+00	3.002E+04	8.893E+05	2.732E+05	.3075E+00
.3244E+00	.3581E+00	4.832E+04	1.432E+06	4.881E+05	.3413E+00
.3581E+00	.3994E+00	3.731E+04	9.046E+05	3.423E+05	.3787E+00
.3994E+00	.4444E+00	4.805E+04	1.068E+06	4.501E+05	.4219E+00
.4444E+00	.4931E+00	4.974E+04	1.020E+06	4.779E+05	.4688E+00
.4931E+00	.5456E+00	4.479E+04	8.531E+05	4.427E+05	.5194E+00
.5456E+00	.6094E+00	6.133E+04	9.620E+05	5.550E+05	.5775E+00
.6094E+00	.6769E+00	5.842E+04	8.655E+05	5.561E+05	.6431E+00
.6769E+00	.7946E+00	1.038E+05	8.815E+05	6.472E+05	.7358E+00
.7946E+00	.8870E+00	6.128E+04	6.632E+05	5.571E+05	.8408E+00
.8870E+00	.9871E+00	6.317E+04	6.310E+05	5.908E+05	.9371E+00
.9871E+00	.1095E+01	5.656E+04	5.246E+05	5.457E+05	.1041E+01
.1095E+01	.1218E+01	7.873E+04	6.390E+05	7.384E+05	.1157E+01
.1218E+01	.1391E+01	8.701E+04	5.034E+05	6.557E+05	.1305E+01
.1391E+01	.1573E+01	8.256E+04	4.536E+05	6.714E+05	.1482E+01
.1573E+01	.1807E+01	8.640E+04	3.692E+05	6.230E+05	.1690E+01

E2	E1	FLUENCE/	FLUENCE/	FLUENCE/	E avg.

(MeV)	(MeV)	(E1-E2) (n/cm²)	MeV (n/cm².MeV)	LETHARGY* (n/cm².u)	(MeV)
.1807E+01	.2041E+01	6.434E+04	2.750E+05	5.284E+05	.1924E+01
.2041E+01	.2327E+01	7.790E+04	2.724E+05	5.940E+05	.2184E+01
.2327E+01	.2639E+01	7.138E+04	2.288E+05	5.673E+05	.2483E+01
.2639E+01	.3003E+01	6.529E+04	1.794E+05	5.053E+05	.2821E+01
.3003E+01	.3419E+01	5.493E+04	1.321E+05	4.234E+05	.3211E+01
.3419E+01	.3861E+01	4.016E+04	9.087E+04	3.304E+05	.3640E+01
.3861E+01	.4407E+01	3.768E+04	6.901E+04	2.849E+05	.4134E+01
.4407E+01	.5000E+01	4.636E+04	7.818E+04	3.672E+05	.4703E+01
.5000E+01	.5500E+01	2.595E+04	5.191E+04	2.723E+05	.5250E+01
.5500E+01	.6000E+01	1.922E+04	3.844E+04	2.209E+05	.5750E+01
.6000E+01	.6500E+01	1.417E+04	2.834E+04	1.770E+05	.6250E+01
.6500E+01	.7000E+01	1.040E+04	2.080E+04	1.404E+05	.6750E+01
.7000E+01	.7500E+01	7.612E+03	1.522E+04	1.103E+05	.7250E+01
.7500E+01	.8000E+01	5.550E+03	1.110E+04	8.599E+04	.7750E+01
.8000E+01	.8500E+01	4.037E+03	8.074E+03	6.659E+04	.8250E+01
.8500E+01	.9000E+01	2.931E+03	5.861E+03	5.127E+04	.8750E+01
.9000E+01	.9500E+01	2.124E+03	4.248E+03	3.929E+04	.9250E+01
.9500E+01	.1000E+02	1.540E+03	3.080E+03	3.002E+04	.9750E+01

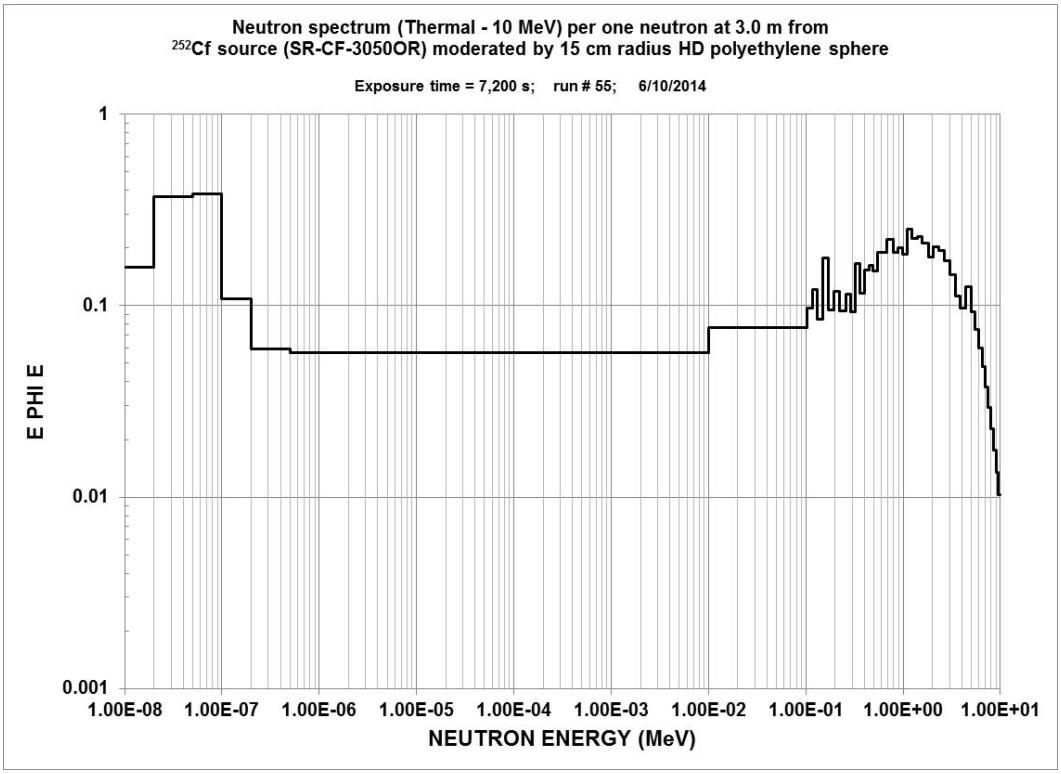
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



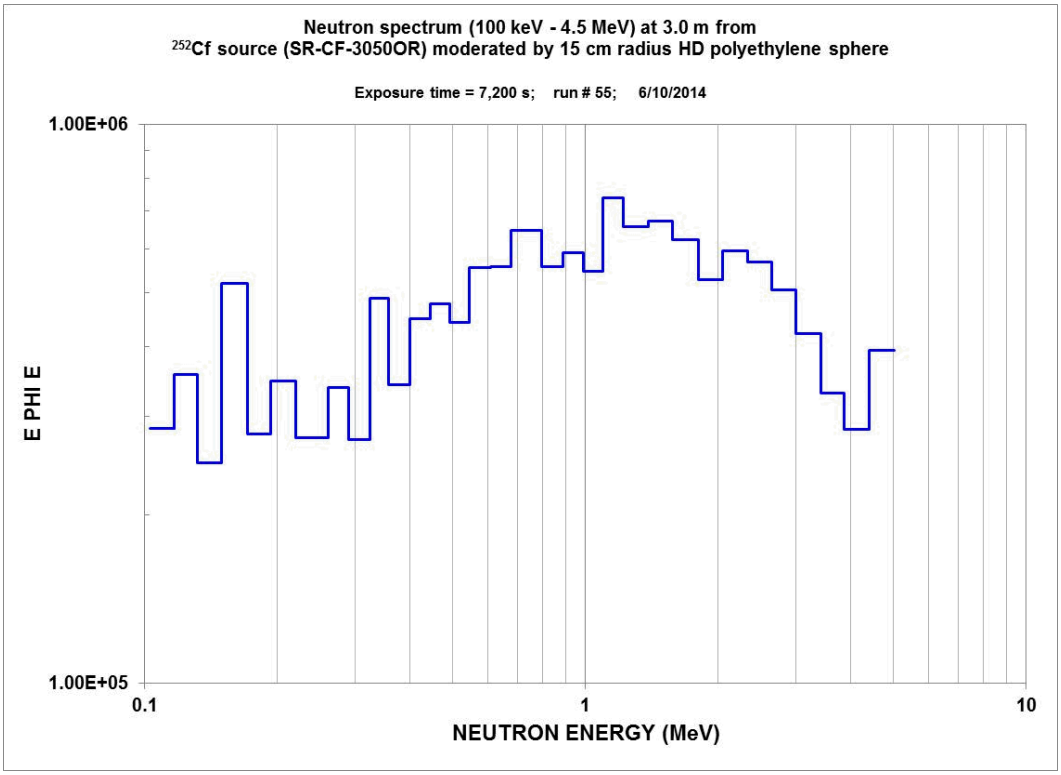


Figure I-3. Neutron spectra at 3.0 m from ^{252}Cf moderated by 15 cm of polyethylene

Fluence, spectral and dosimetric data at 3.5 m from ^{252}Cf moderated by 15 cm of polyethylene

Table I-7. Neutron fluence and dosimetric data at 3.5 m from 15 cm thick polyethylene moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	6/10/2014
Exposure time:	10,800 s
Run #	N56

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	2.24E+06	2.07E+02
Epi-thermal region	:	3.19E+06	2.96E+02
Thermal region	:	3.45E+06	3.20E+02
Thermal – 4.5 MeV	:	8.89E+06	8.23E+02
Thermal – 10.0 MeV	:	9.0041E+06	8.3372E+02

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	4.97E-03	7.55E-04	1.66E+00	2.52E+02
Epi-thermal region	:	2.79E-04	5.22E-05	9.28E-02	1.74E+01
Thermal region	:	6.91E-05	3.66E-05	2.30E-02	1.22E+01
Thermal – 4.5 MeV	:	5.32E-03	8.44E-04	1.77E+00	2.81E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	5.7219E-03 rads	1.9073E+00 mrads/hr
H*(10) ICRP-74	=	8.8000E-04 Sv	2.9333E+02 uSv/hr
Hp(10,0) ICRP-74	=	9.1313E-04 Sv	3.0438E+02 uSv/hr

Table I-8. Neutron fluence at 3.5 m from 15 cm thick polyethylene moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 6/10/2014
Exposure time: 10,800 s
Run number: N56

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	7.803E+03	7.803E+12	1.126E+04	.1500E-08
.2000E-08	.5000E-08	5.006E+04	1.669E+13	5.464E+04	.3500E-08
.5000E-08	.1000E-07	1.523E+05	3.045E+13	2.197E+05	.7500E-08
.1000E-07	.2000E-07	4.488E+05	4.488E+13	6.475E+05	.1500E-07
.2000E-07	.5000E-07	1.391E+06	4.638E+13	1.519E+06	.3500E-07
.5000E-07	.1000E-06	1.088E+06	2.175E+13	1.569E+06	.7500E-07
.1000E-06	.2000E-06	3.059E+05	3.059E+12	4.413E+05	.1500E-06
.2000E-06	.5000E-06	2.228E+05	7.426E+11	2.431E+05	.3500E-06
.5000E-06	.1000E-01	2.295E+06	2.295E+08	2.318E+05	.5000E-02
.1000E-01	.1027E+00	6.875E+05	7.417E+06	2.952E+05	.5635E-01
.1027E+00	.1166E+00	2.632E+04	1.899E+06	2.079E+05	.1096E+00
.1166E+00	.1317E+00	4.586E+04	3.033E+06	3.759E+05	.1241E+00
.1317E+00	.1493E+00	8.778E+04	4.976E+06	6.982E+05	.1405E+00
.1493E+00	.1707E+00	7.143E+04	3.335E+06	5.328E+05	.1600E+00
.1707E+00	.1934E+00	6.152E+04	2.713E+06	4.932E+05	.1821E+00
.1934E+00	.2199E+00	4.573E+04	1.728E+06	3.566E+05	.2066E+00
.2199E+00	.2606E+00	6.776E+04	1.663E+06	3.985E+05	.2402E+00
.2606E+00	.2906E+00	5.484E+04	1.828E+06	5.034E+05	.2756E+00
.2906E+00	.3244E+00	6.121E+04	1.814E+06	5.571E+05	.3075E+00
.3244E+00	.3581E+00	4.219E+04	1.250E+06	4.262E+05	.3413E+00
.3581E+00	.3994E+00	4.839E+04	1.173E+06	4.438E+05	.3787E+00
.3994E+00	.4444E+00	3.656E+04	8.124E+05	3.424E+05	.4219E+00
.4444E+00	.4931E+00	6.554E+04	1.344E+06	6.296E+05	.4688E+00
.4931E+00	.5456E+00	5.676E+04	1.081E+06	5.610E+05	.5194E+00
.5456E+00	.6094E+00	7.547E+04	1.184E+06	6.830E+05	.5775E+00
.6094E+00	.6769E+00	8.177E+04	1.211E+06	7.783E+05	.6431E+00
.6769E+00	.7946E+00	1.394E+05	1.184E+06	8.690E+05	.7358E+00
.7946E+00	.8870E+00	9.763E+04	1.057E+06	8.876E+05	.8408E+00
.8870E+00	.9871E+00	9.032E+04	9.023E+05	8.448E+05	.9371E+00
.9871E+00	.1095E+01	5.418E+04	5.026E+05	5.228E+05	.1041E+01
.1095E+01	.1218E+01	7.969E+04	6.469E+05	7.474E+05	.1157E+01
.1218E+01	.1391E+01	1.075E+05	6.219E+05	8.101E+05	.1305E+01
.1391E+01	.1573E+01	9.676E+04	5.316E+05	7.869E+05	.1482E+01
.1573E+01	.1807E+01	1.009E+05	4.311E+05	7.274E+05	.1690E+01
.1807E+01	.2041E+01	7.740E+04	3.308E+05	6.356E+05	.1924E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2041E+01	.2327E+01	9.126E+04	3.191E+05	6.959E+05	.2184E+01
.2327E+01	.2639E+01	8.755E+04	2.806E+05	6.958E+05	.2483E+01
.2639E+01	.3003E+01	7.093E+04	1.949E+05	5.489E+05	.2821E+01
.3003E+01	.3419E+01	7.053E+04	1.695E+05	5.437E+05	.3211E+01
.3419E+01	.3861E+01	4.476E+04	1.013E+05	3.682E+05	.3640E+01
.3861E+01	.4407E+01	5.438E+04	9.959E+04	4.111E+05	.4134E+01
.4407E+01	.5000E+01	4.948E+04	8.344E+04	3.919E+05	.4703E+01
.5000E+01	.5500E+01	3.140E+04	6.279E+04	3.294E+05	.5250E+01
.5500E+01	.6000E+01	2.325E+04	4.651E+04	2.672E+05	.5750E+01
.6000E+01	.6500E+01	1.714E+04	3.429E+04	2.142E+05	.6250E+01
.6500E+01	.7000E+01	1.258E+04	2.517E+04	1.698E+05	.6750E+01
.7000E+01	.7500E+01	9.209E+03	1.842E+04	1.335E+05	.7250E+01
.7500E+01	.8000E+01	6.714E+03	1.343E+04	1.040E+05	.7750E+01
.8000E+01	.8500E+01	4.884E+03	9.768E+03	8.056E+04	.8250E+01
.8500E+01	.9000E+01	3.545E+03	7.091E+03	6.203E+04	.8750E+01
.9000E+01	.9500E+01	2.570E+03	5.140E+03	4.753E+04	.9250E+01
.9500E+01	.1000E+02	1.863E+03	3.726E+03	3.632E+04	.9750E+01

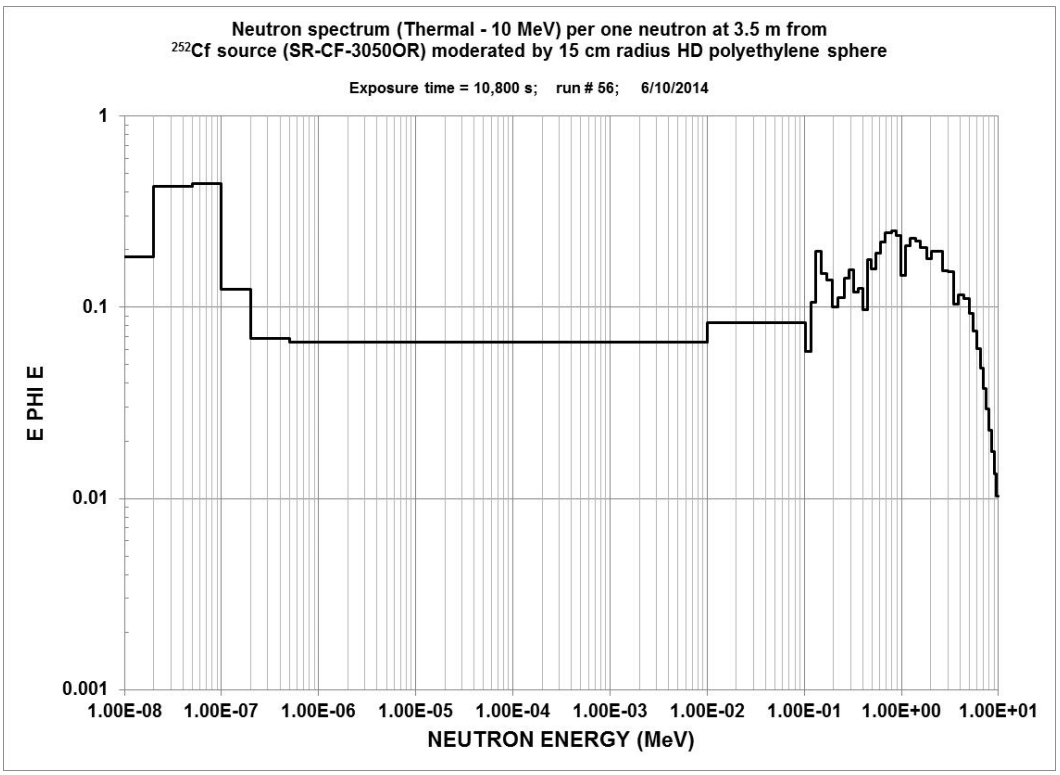
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



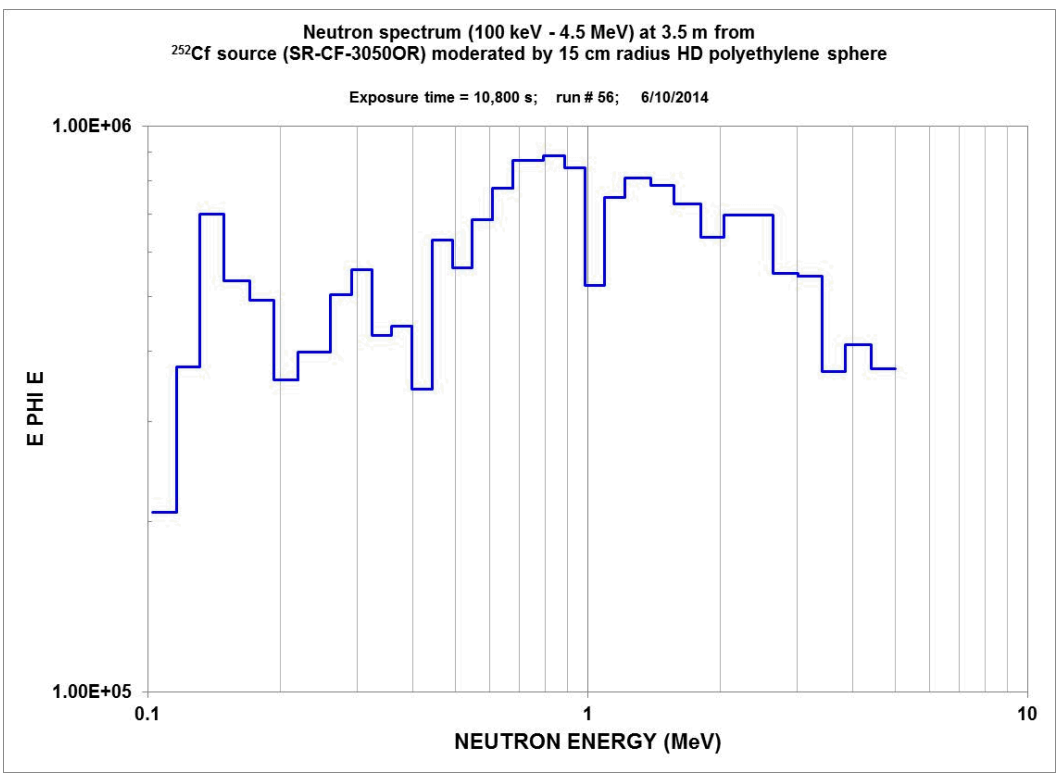


Figure I-4. Neutron spectra at 3.5 m from ^{252}Cf moderated by 15 cm of polyethylene

Fluence, spectral and dosimetric data at 4.0 m from ^{252}Cf moderated by 15 cm of polyethylene

Table I-9. Neutron fluence and dosimetric data at 4.0 m from 15 cm thick polyethylene moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	6/10/2014
Exposure time:	10,800 s
Run #	N57

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.94E+06	1.79E+02
Epi-thermal region	:	3.02E+06	2.79E+02
Thermal region	:	3.26E+06	3.02E+02
Thermal – 4.5 MeV	:	8.21E+06	7.60E+02
Thermal – 10.0 MeV	:	8.2998E+06	7.6850E+02

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	4.21E-03	6.44E-04	1.40E+00	2.15E+02
Epi-thermal region	:	2.64E-04	4.93E-05	8.79E-02	1.64E+01
Thermal region	:	6.52E-05	3.46E-05	2.17E-02	1.15E+01
Thermal – 4.5 MeV	:	4.54E-03	7.28E-04	1.51E+00	2.43E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	4.8213E-03 rads	1.6071E+00 mrads/hr
H*(10) ICRP-74	=	7.5296E-04 Sv	2.5099E+02 uSv/hr
Hp(10,0) ICRP-74	=	7.8131E-04 Sv	2.6044E+02 uSv/hr

Table I-10. Neutron fluence at 4.0 m from 15 cm thick polyethylene moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 6/10/2014
Exposure time: 10,800 s
Run number: N57

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	7.367E+03	7.367E+12	1.063E+04	.1500E-08
.2000E-08	.5000E-08	4.727E+04	1.576E+13	5.158E+04	.3500E-08
.5000E-08	.1000E-07	1.438E+05	2.875E+13	2.074E+05	.7500E-08
.1000E-07	.2000E-07	4.238E+05	4.238E+13	6.114E+05	.1500E-07
.2000E-07	.5000E-07	1.314E+06	4.379E+13	1.434E+06	.3500E-07
.5000E-07	.1000E-06	1.027E+06	2.054E+13	1.481E+06	.7500E-07
.1000E-06	.2000E-06	2.888E+05	2.888E+12	4.167E+05	.1500E-06
.2000E-06	.5000E-06	2.101E+05	7.002E+11	2.293E+05	.3500E-06
.5000E-06	.1000E-01	2.164E+06	2.164E+08	2.185E+05	.5000E-02
.1000E-01	.1027E+00	6.509E+05	7.022E+06	2.795E+05	.5635E-01
.1027E+00	.1166E+00	2.940E+04	2.121E+06	2.322E+05	.1096E+00
.1166E+00	.1317E+00	7.657E+04	5.064E+06	6.278E+05	.1241E+00
.1317E+00	.1493E+00	4.479E+04	2.539E+06	3.562E+05	.1405E+00
.1493E+00	.1707E+00	4.624E+04	2.159E+06	3.449E+05	.1600E+00
.1707E+00	.1934E+00	5.198E+04	2.292E+06	4.167E+05	.1821E+00
.1934E+00	.2199E+00	3.981E+04	1.504E+06	3.104E+05	.2066E+00
.2199E+00	.2606E+00	8.973E+04	2.202E+06	5.277E+05	.2402E+00
.2606E+00	.2906E+00	4.863E+04	1.621E+06	4.464E+05	.2756E+00
.2906E+00	.3244E+00	5.346E+04	1.584E+06	4.866E+05	.3075E+00
.3244E+00	.3581E+00	3.068E+04	9.089E+05	3.099E+05	.3413E+00
.3581E+00	.3994E+00	5.483E+04	1.329E+06	5.030E+05	.3787E+00
.3994E+00	.4444E+00	5.283E+04	1.174E+06	4.948E+05	.4219E+00
.4444E+00	.4931E+00	5.066E+04	1.039E+06	4.867E+05	.4688E+00
.4931E+00	.5456E+00	4.876E+04	9.287E+05	4.819E+05	.5194E+00
.5456E+00	.6094E+00	6.256E+04	9.814E+05	5.662E+05	.5775E+00
.6094E+00	.6769E+00	7.332E+04	1.086E+06	6.979E+05	.6431E+00
.6769E+00	.7946E+00	1.155E+05	9.806E+05	7.199E+05	.7358E+00
.7946E+00	.8870E+00	7.118E+04	7.704E+05	6.471E+05	.8408E+00
.8870E+00	.9871E+00	7.290E+04	7.283E+05	6.818E+05	.9371E+00
.9871E+00	.1095E+01	6.829E+04	6.335E+05	6.589E+05	.1041E+01
.1095E+01	.1218E+01	6.595E+04	5.353E+05	6.186E+05	.1157E+01
.1218E+01	.1391E+01	7.689E+04	4.448E+05	5.794E+05	.1305E+01
.1391E+01	.1573E+01	8.201E+04	4.506E+05	6.670E+05	.1482E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.1573E+01	.1807E+01	8.135E+04	3.477E+05	5.866E+05	.1690E+01
.1807E+01	.2041E+01	7.248E+04	3.098E+05	5.952E+05	.1924E+01
.2041E+01	.2327E+01	7.728E+04	2.702E+05	5.893E+05	.2184E+01
.2327E+01	.2639E+01	6.654E+04	2.133E+05	5.288E+05	.2483E+01
.2639E+01	.3003E+01	6.363E+04	1.748E+05	4.924E+05	.2821E+01
.3003E+01	.3419E+01	5.617E+04	1.350E+05	4.329E+05	.3211E+01
.3419E+01	.3861E+01	3.393E+04	7.676E+04	2.791E+05	.3640E+01
.3861E+01	.4407E+01	3.923E+04	7.185E+04	2.966E+05	.4134E+01
.4407E+01	.5000E+01	3.983E+04	6.717E+04	3.155E+05	.4703E+01
.5000E+01	.5500E+01	2.382E+04	4.764E+04	2.499E+05	.5250E+01
.5500E+01	.6000E+01	1.764E+04	3.529E+04	2.028E+05	.5750E+01
.6000E+01	.6500E+01	1.301E+04	2.601E+04	1.625E+05	.6250E+01
.6500E+01	.7000E+01	9.547E+03	1.909E+04	1.288E+05	.6750E+01
.7000E+01	.7500E+01	6.987E+03	1.397E+04	1.013E+05	.7250E+01
.7500E+01	.8000E+01	5.094E+03	1.019E+04	7.893E+04	.7750E+01
.8000E+01	.8500E+01	3.706E+03	7.411E+03	6.112E+04	.8250E+01
.8500E+01	.9000E+01	2.690E+03	5.380E+03	4.706E+04	.8750E+01
.9000E+01	.9500E+01	1.950E+03	3.900E+03	3.606E+04	.9250E+01
.9500E+01	.1000E+02	1.413E+03	2.827E+03	2.756E+04	.9750E+01

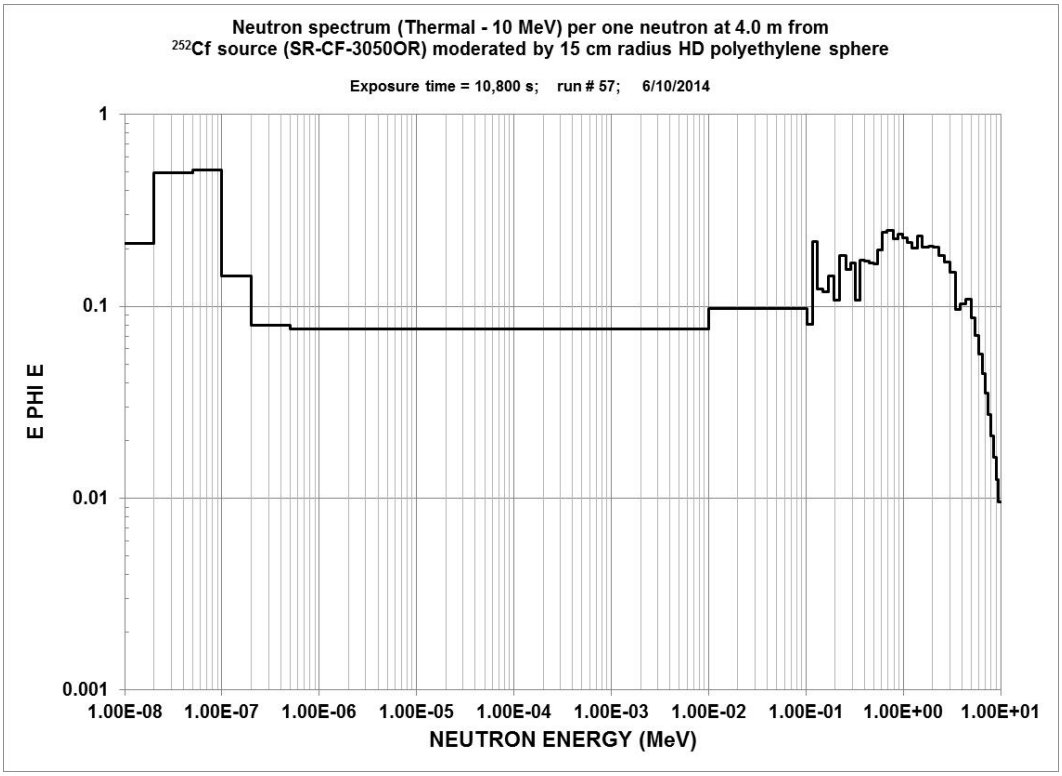
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



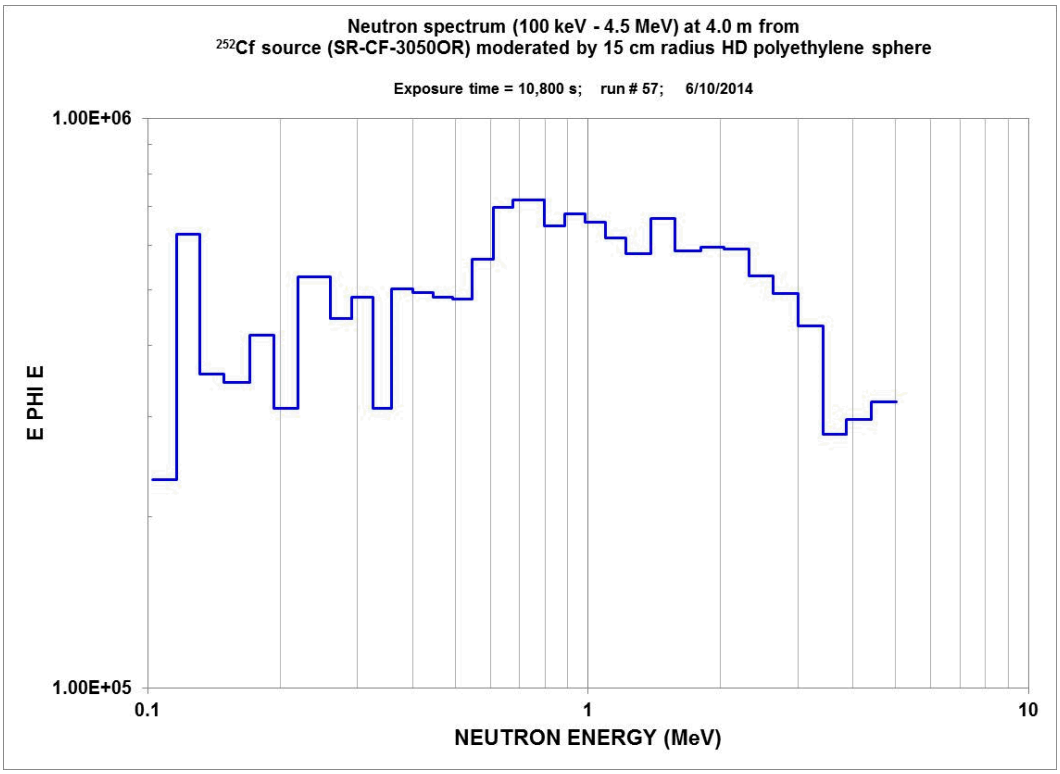


Figure I-5. Neutron spectra at 4.0 m from ^{252}Cf moderated by 15 cm of polyethylene

Fluence, spectral and dosimetric data at 4.5 m from ^{252}Cf moderated by 15 cm of polyethylene

Table I-11. Neutron fluence and dosimetric data at 4.5 m from 15 cm thick polyethylene moderated ^{252}Cf source (s# SR-CF-3050OR)

Date:	6/11/2014
Exposure time:	10,800 s
Run #	N58

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.68E+06	1.56E+02
Epi-thermal region	:	2.87E+06	2.66E+02
Thermal region	:	3.03E+06	2.81E+02
Thermal – 4.5 MeV	:	7.58E+06	7.02E+02
Thermal – 10.0 MeV	:	7.6573E+06	7.0901E+02

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	3.62E-03	5.56E-04	1.21E+00	1.85E+02
Epi-thermal region	:	2.45E-04	4.64E-05	8.17E-02	1.55E+01
Thermal region	:	6.06E-05	3.21E-05	2.02E-02	1.07E+01
Thermal – 4.5 MeV	:	3.92E-03	6.35E-04	1.31E+00	2.12E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	4.1592E-03 rads	1.3864E+00 mrads/hr
H*(10) ICRP-74	=	6.5574E-04 Sv	2.1858E+02 uSv/hr
Hp(10,0) ICRP-74	=	6.8062E-04 Sv	2.2687E+02 uSv/hr

Table I-12. Neutron fluence at 4.5 m from 15 cm thick polyethylene moderated ^{252}Cf source (# SR-CF-3050OR)

Date: 6/11/2014
Exposure time: 10,800 s
Run number: N58

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	6.851E+03	6.851E+12	9.884E+03	.1500E-08
.2000E-08	.5000E-08	4.396E+04	1.465E+13	4.797E+04	.3500E-08
.5000E-08	.1000E-07	1.337E+05	2.674E+13	1.929E+05	.7500E-08
.1000E-07	.2000E-07	3.941E+05	3.941E+13	5.686E+05	.1500E-07
.2000E-07	.5000E-07	1.222E+06	4.072E+13	1.333E+06	.3500E-07
.5000E-07	.1000E-06	9.549E+05	1.910E+13	1.378E+06	.7500E-07
.1000E-06	.2000E-06	2.686E+05	2.686E+12	3.875E+05	.1500E-06
.2000E-06	.5000E-06	2.012E+05	6.707E+11	2.196E+05	.3500E-06
.5000E-06	.1000E-01	2.076E+06	2.076E+08	2.096E+05	.5000E-02
.1000E-01	.1027E+00	6.023E+05	6.498E+06	2.586E+05	.5635E-01
.1027E+00	.1166E+00	2.278E+04	1.643E+06	1.799E+05	.1096E+00
.1166E+00	.1317E+00	6.097E+04	4.032E+06	4.998E+05	.1241E+00
.1317E+00	.1493E+00	4.737E+04	2.685E+06	3.768E+05	.1405E+00
.1493E+00	.1707E+00	5.465E+04	2.551E+06	4.076E+05	.1600E+00
.1707E+00	.1934E+00	3.362E+04	1.482E+06	2.695E+05	.1821E+00
.1934E+00	.2199E+00	4.301E+04	1.625E+06	3.354E+05	.2066E+00
.2199E+00	.2606E+00	8.435E+04	2.070E+06	4.961E+05	.2402E+00
.2606E+00	.2906E+00	4.032E+04	1.344E+06	3.701E+05	.2756E+00
.2906E+00	.3244E+00	4.656E+04	1.379E+06	4.237E+05	.3075E+00
.3244E+00	.3581E+00	3.157E+04	9.354E+05	3.189E+05	.3413E+00
.3581E+00	.3994E+00	3.882E+04	9.410E+05	3.561E+05	.3787E+00
.3994E+00	.4444E+00	3.370E+04	7.489E+05	3.156E+05	.4219E+00
.4444E+00	.4931E+00	4.136E+04	8.484E+05	3.973E+05	.4688E+00
.4931E+00	.5456E+00	5.041E+04	9.602E+05	4.983E+05	.5194E+00
.5456E+00	.6094E+00	6.180E+04	9.694E+05	5.593E+05	.5775E+00
.6094E+00	.6769E+00	6.246E+04	9.253E+05	5.945E+05	.6431E+00
.6769E+00	.7946E+00	9.308E+04	7.904E+05	5.803E+05	.7358E+00
.7946E+00	.8870E+00	6.944E+04	7.515E+05	6.313E+05	.8408E+00
.8870E+00	.9871E+00	6.163E+04	6.157E+05	5.764E+05	.9371E+00
.9871E+00	.1095E+01	4.529E+04	4.201E+05	4.370E+05	.1041E+01
.1095E+01	.1218E+01	5.827E+04	4.730E+05	5.465E+05	.1157E+01
.1218E+01	.1391E+01	8.218E+04	4.754E+05	6.193E+05	.1305E+01
.1391E+01	.1573E+01	6.851E+04	3.765E+05	5.572E+05	.1482E+01
.1573E+01	.1807E+01	7.373E+04	3.151E+05	5.317E+05	.1690E+01
.1807E+01	.2041E+01	6.089E+04	2.602E+05	5.000E+05	.1924E+01
.2041E+01	.2327E+01	6.572E+04	2.298E+05	5.011E+05	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	5.797E+04	1.858E+05	4.608E+05	.2483E+01
.2639E+01	.3003E+01	5.141E+04	1.412E+05	3.979E+05	.2821E+01
.3003E+01	.3419E+01	4.513E+04	1.085E+05	3.479E+05	.3211E+01
.3419E+01	.3861E+01	3.555E+04	8.043E+04	2.924E+05	.3640E+01
.3861E+01	.4407E+01	3.173E+04	5.811E+04	2.399E+05	.4134E+01
.4407E+01	.5000E+01	2.980E+04	5.025E+04	2.360E+05	.4703E+01
.5000E+01	.5500E+01	1.941E+04	3.881E+04	2.036E+05	.5250E+01
.5500E+01	.6000E+01	1.437E+04	2.874E+04	1.652E+05	.5750E+01
.6000E+01	.6500E+01	1.060E+04	2.119E+04	1.324E+05	.6250E+01
.6500E+01	.7000E+01	7.777E+03	1.555E+04	1.049E+05	.6750E+01
.7000E+01	.7500E+01	5.691E+03	1.138E+04	8.249E+04	.7250E+01
.7500E+01	.8000E+01	4.150E+03	8.299E+03	6.430E+04	.7750E+01
.8000E+01	.8500E+01	3.019E+03	6.037E+03	4.979E+04	.8250E+01
.8500E+01	.9000E+01	2.191E+03	4.383E+03	3.834E+04	.8750E+01
.9000E+01	.9500E+01	1.588E+03	3.177E+03	2.938E+04	.9250E+01
.9500E+01	.1000E+02	1.151E+03	2.303E+03	2.245E+04	.9750E+01

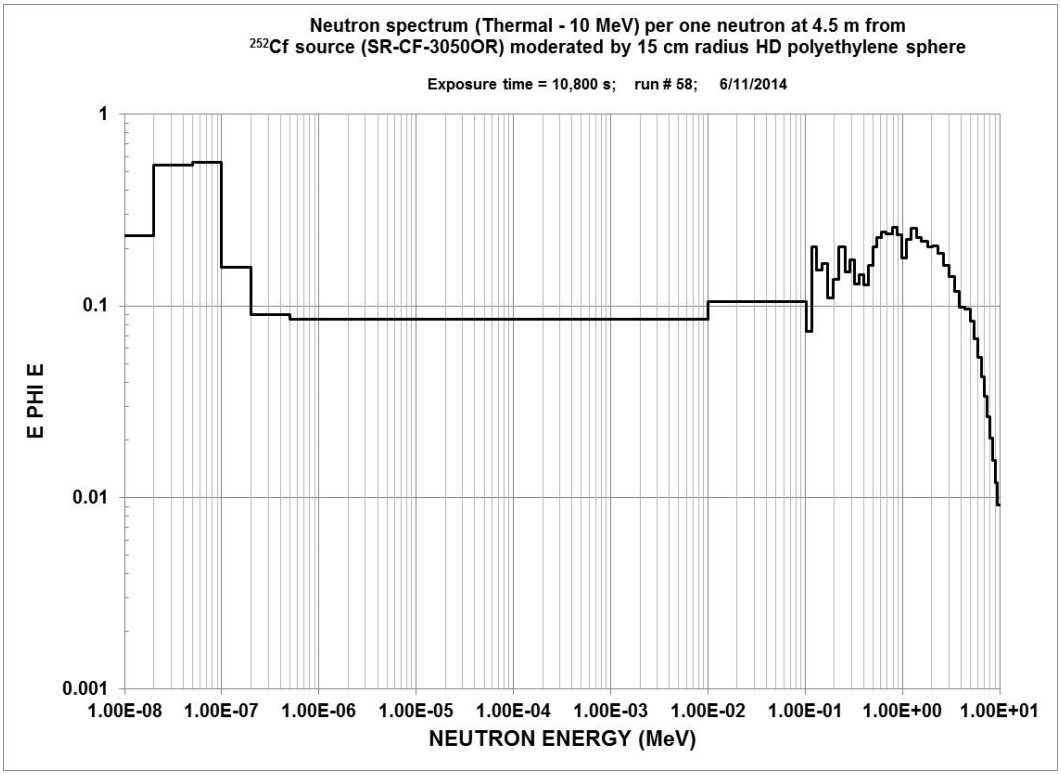
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



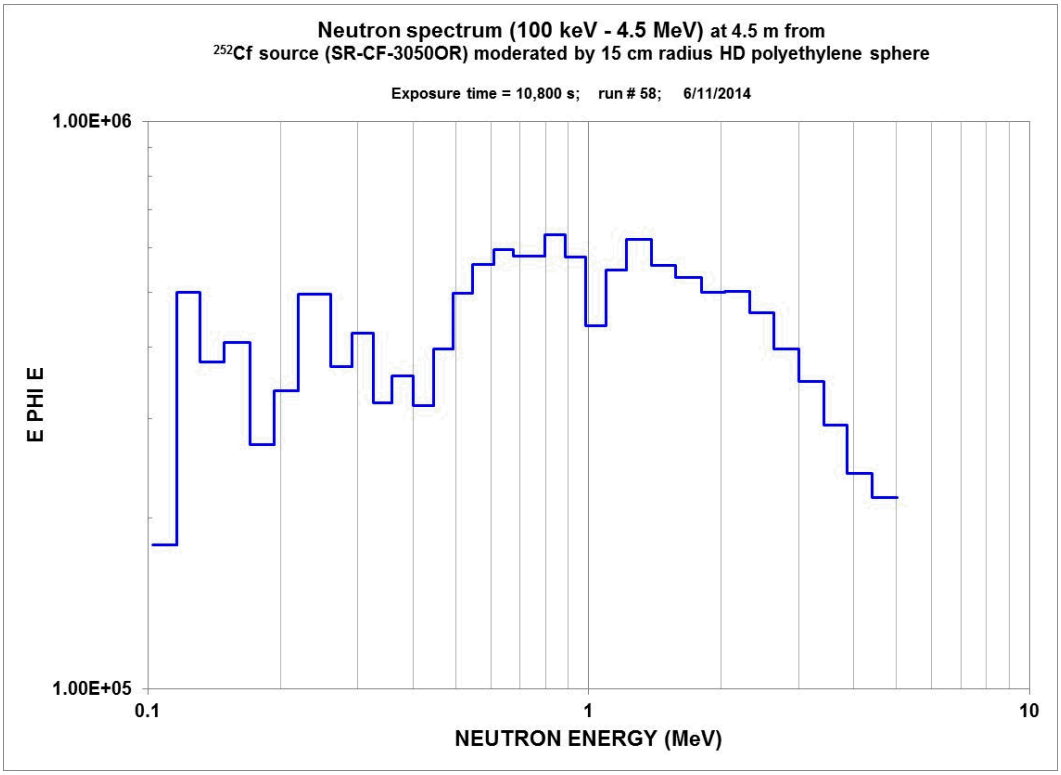
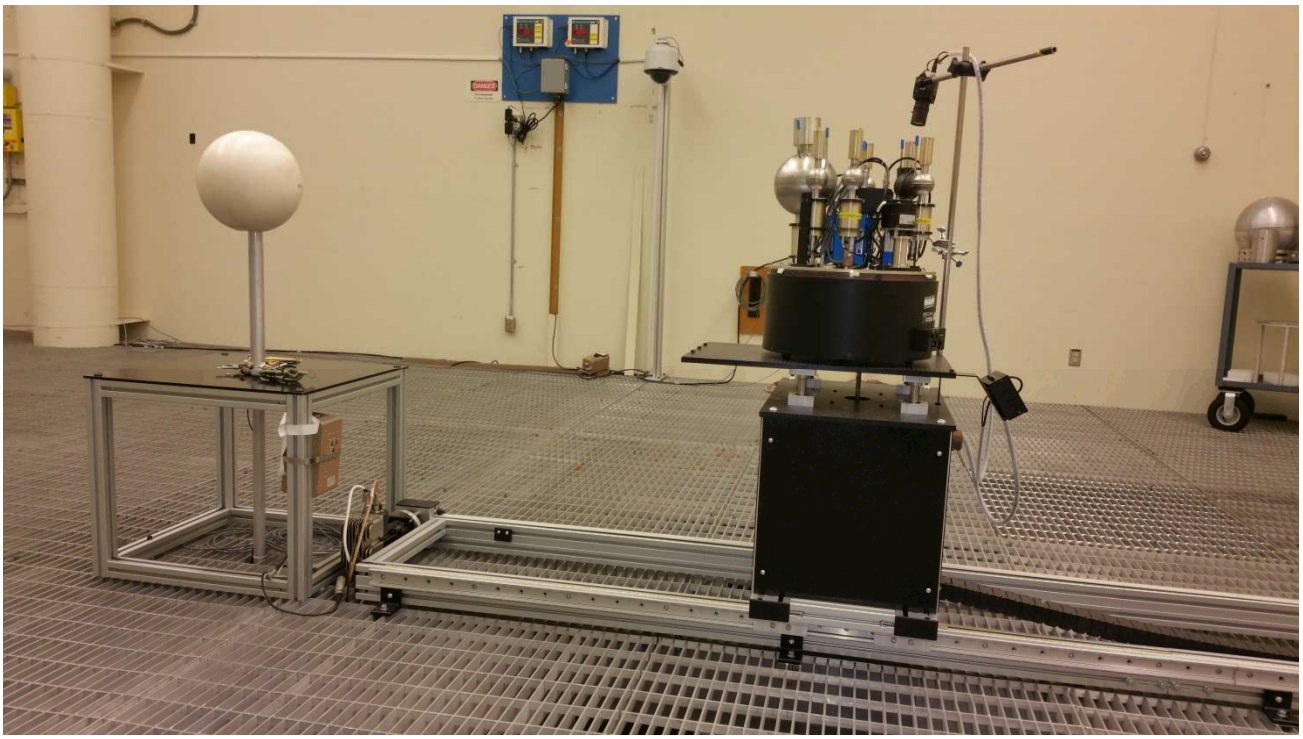


Figure I-6. Neutron spectra at 4.5 m from ^{252}Cf moderated by 15 cm of polyethylene

Appendix J

Neutron fluence, spectra and dose rates from ^{252}Cf moderated by 10 cm high density polyethylene



Fluence, spectral and dosimetric data at 2.0 m from ^{252}Cf moderated by 10 cm of polyethylene

Table J-1. Neutron fluence and dosimetric data at 2.0 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date:	6/12/2014
Exposure time:	7,200 s
Run #	N61

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	7.01E+06	9.74E+02
Epi-thermal region	:	6.42E+06	8.92E+02
Thermal region	:	5.24E+06	7.27E+02
Thermal – 4.5 MeV	:	1.87E+07	2.59E+03
Thermal – 10.0 MeV	:	1.9053E+07	2.6463E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.64E-02	2.44E-03	8.22E+00	1.22E+03
Epi-thermal region	:	6.31E-04	1.11E-04	3.15E-01	5.54E+01
Thermal region	:	1.05E-04	5.55E-05	5.24E-02	2.78E+01
Thermal – 4.5 MeV	:	1.72E-02	2.61E-03	8.59E+00	1.30E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.8513E-02 rads	9.2563E+00 mrads/hr
H*(10) ICRP-74	=	2.7300E-03 Sv	1.3650E+03 uSv/hr
Hp(10,0) ICRP-74	=	2.8299E-03 Sv	1.4150E+03 uSv/hr

Table J-2. Neutron fluence at 2.0 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date: 6/12/2014
Exposure time: 7,200 s
Run number: N61

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	1.184E+04	1.184E+13	1.708E+04	.1500E-08
.2000E-08	.5000E-08	7.594E+04	2.531E+13	8.288E+04	.3500E-08
.5000E-08	.1000E-07	2.310E+05	4.619E+13	3.332E+05	.7500E-08
.1000E-07	.2000E-07	6.809E+05	6.809E+13	9.823E+05	.1500E-07
.2000E-07	.5000E-07	2.111E+06	7.036E+13	2.304E+06	.3500E-07
.5000E-07	.1000E-06	1.650E+06	3.300E+13	2.380E+06	.7500E-07
.1000E-06	.2000E-06	4.640E+05	4.640E+12	6.695E+05	.1500E-06
.2000E-06	.5000E-06	4.249E+05	1.416E+12	4.638E+05	.3500E-06
.5000E-06	.1000E-01	4.422E+06	4.422E+08	4.465E+05	.5000E-02
.1000E-01	.1027E+00	1.591E+06	1.716E+07	6.829E+05	.5635E-01
.1027E+00	.1166E+00	1.514E+05	1.092E+07	1.196E+06	.1096E+00
.1166E+00	.1317E+00	1.056E+05	6.985E+06	8.658E+05	.1241E+00
.1317E+00	.1493E+00	1.824E+05	1.034E+07	1.450E+06	.1405E+00
.1493E+00	.1707E+00	1.280E+05	5.975E+06	9.547E+05	.1600E+00
.1707E+00	.1934E+00	1.311E+05	5.782E+06	1.051E+06	.1821E+00
.1934E+00	.2199E+00	1.421E+05	5.369E+06	1.108E+06	.2066E+00
.2199E+00	.2606E+00	2.101E+05	5.156E+06	1.236E+06	.2402E+00
.2606E+00	.2906E+00	1.486E+05	4.954E+06	1.364E+06	.2756E+00
.2906E+00	.3244E+00	1.510E+05	4.473E+06	1.374E+06	.3075E+00
.3244E+00	.3581E+00	1.363E+05	4.038E+06	1.377E+06	.3413E+00
.3581E+00	.3994E+00	1.616E+05	3.918E+06	1.482E+06	.3787E+00
.3994E+00	.4444E+00	1.468E+05	3.262E+06	1.375E+06	.4219E+00
.4444E+00	.4931E+00	1.666E+05	3.417E+06	1.600E+06	.4688E+00
.4931E+00	.5456E+00	1.805E+05	3.439E+06	1.785E+06	.5194E+00
.5456E+00	.6094E+00	2.192E+05	3.439E+06	1.984E+06	.5775E+00
.6094E+00	.6769E+00	2.347E+05	3.477E+06	2.234E+06	.6431E+00
.6769E+00	.7946E+00	3.581E+05	3.041E+06	2.232E+06	.7358E+00
.7946E+00	.8870E+00	2.903E+05	3.142E+06	2.639E+06	.8408E+00
.8870E+00	.9871E+00	2.371E+05	2.369E+06	2.217E+06	.9371E+00
.9871E+00	.1095E+01	2.326E+05	2.158E+06	2.245E+06	.1041E+01
.1095E+01	.1218E+01	2.627E+05	2.132E+06	2.464E+06	.1157E+01
.1218E+01	.1391E+01	3.430E+05	1.984E+06	2.585E+06	.1305E+01
.1391E+01	.1573E+01	3.381E+05	1.858E+06	2.750E+06	.1482E+01
.1573E+01	.1807E+01	3.639E+05	1.555E+06	2.624E+06	.1690E+01
.1807E+01	.2041E+01	2.845E+05	1.216E+06	2.336E+06	.1924E+01
.2041E+01	.2327E+01	3.348E+05	1.171E+06	2.553E+06	.2184E+01
.2327E+01	.2639E+01	3.054E+05	9.788E+05	2.427E+06	.2483E+01
.2639E+01	.3003E+01	2.695E+05	7.403E+05	2.085E+06	.2821E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.3003E+01	.3419E+01	2.422E+05	5.821E+05	1.867E+06	.3211E+01
.3419E+01	.3861E+01	1.807E+05	4.089E+05	1.487E+06	.3640E+01
.3861E+01	.4407E+01	1.969E+05	3.606E+05	1.489E+06	.4134E+01
.4407E+01	.5000E+01	1.760E+05	2.968E+05	1.394E+06	.4703E+01
.5000E+01	.5500E+01	1.055E+05	2.109E+05	1.107E+06	.5250E+01
.5500E+01	.6000E+01	7.811E+04	1.562E+05	8.977E+05	.5750E+01
.6000E+01	.6500E+01	5.759E+04	1.152E+05	7.195E+05	.6250E+01
.6500E+01	.7000E+01	4.227E+04	8.454E+04	5.704E+05	.6750E+01
.7000E+01	.7500E+01	3.093E+04	6.187E+04	4.484E+05	.7250E+01
.7500E+01	.8000E+01	2.255E+04	4.511E+04	3.494E+05	.7750E+01
.8000E+01	.8500E+01	1.641E+04	3.281E+04	2.706E+05	.8250E+01
.8500E+01	.9000E+01	1.191E+04	2.382E+04	2.084E+05	.8750E+01
.9000E+01	.9500E+01	8.632E+03	1.726E+04	1.597E+05	.9250E+01
.9500E+01	.1000E+02	6.258E+03	1.252E+04	1.220E+05	.9750E+01

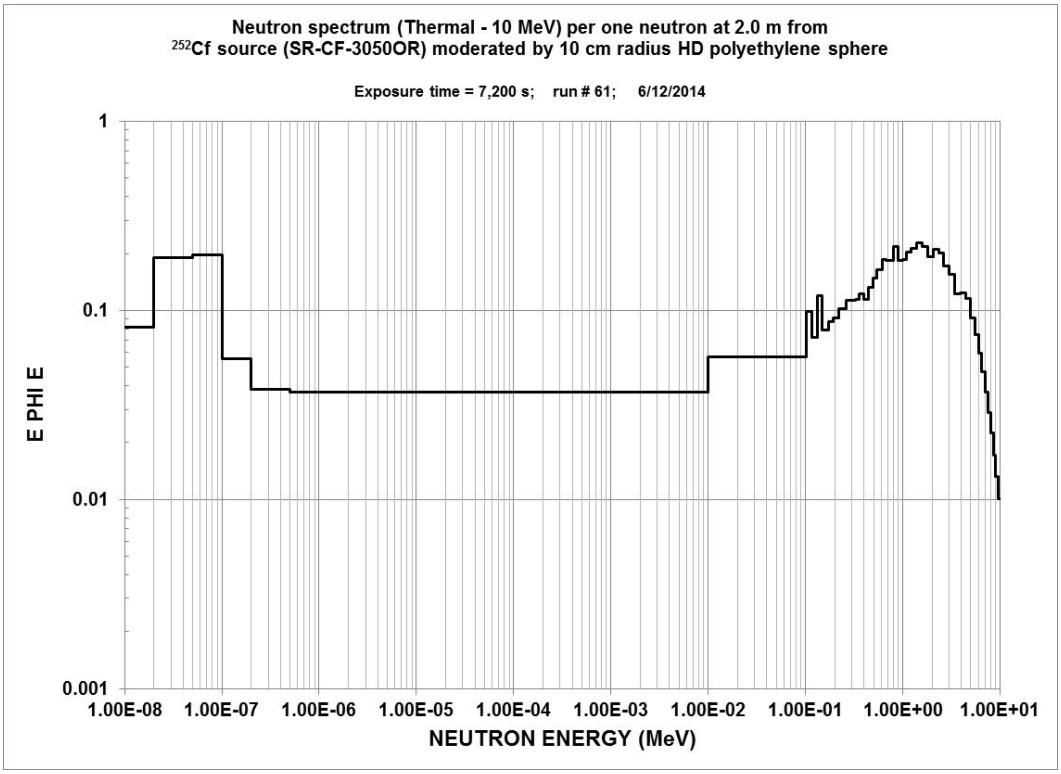
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



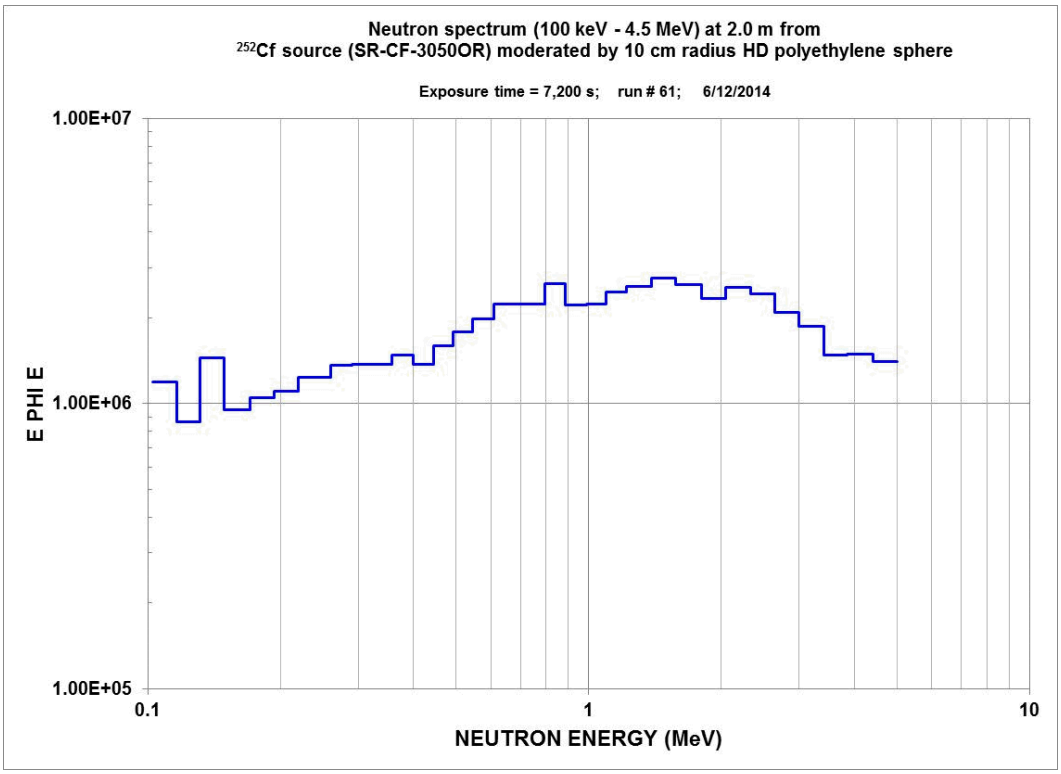


Figure J-1. Neutron spectra at 2.0 m from ^{252}Cf moderated by 10 cm of polyethylene

Fluence, spectral and dosimetric data at 2.5 m from ^{252}Cf moderated by 10 cm of polyethylene

Table J-3. Neutron fluence and dosimetric data at 2.5 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date:	6/13/2014
Exposure time:	7,200 s
Run #	N64

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	5.11E+06	7.10E+02
Epi-thermal region	:	4.15E+06	5.77E+02
Thermal region	:	4.53E+06	6.29E+02
Thermal – 4.5 MeV	:	1.38E+07	1.92E+03
Thermal – 10.0 MeV	:	1.4046E+07	1.9509E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.17E-02	1.76E-03	5.87E+00	8.80E+02
Epi-thermal region	:	4.26E-04	7.32E-05	2.13E-01	3.66E+01
Thermal region	:	9.05E-05	4.80E-05	4.53E-02	2.40E+01
Thermal – 4.5 MeV	:	1.22E-02	1.88E-03	6.12E+00	9.41E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.3139E-02 rads	6.5697E+00 mrads/hr
H*(10) ICRP-74	=	1.9636E-03 Sv	9.8180E+02 uSv/hr
Hp(10,0) ICRP-74	=	2.0351E-03 Sv	1.0175E+03 uSv/hr

Table J-4. Neutron fluence at 2.5 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date: 6/13/2014
Exposure time: 7,200 s
Run number: N64

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	1.023E+04	1.023E+13	1.476E+04	.1500E-08
.2000E-08	.5000E-08	6.564E+04	2.188E+13	7.164E+04	.3500E-08
.5000E-08	.1000E-07	1.997E+05	3.993E+13	2.880E+05	.7500E-08
.1000E-07	.2000E-07	5.885E+05	5.885E+13	8.491E+05	.1500E-07
.2000E-07	.5000E-07	1.824E+06	6.082E+13	1.991E+06	.3500E-07
.5000E-07	.1000E-06	1.426E+06	2.852E+13	2.057E+06	.7500E-07
.1000E-06	.2000E-06	4.011E+05	4.011E+12	5.787E+05	.1500E-06
.2000E-06	.5000E-06	2.735E+05	9.118E+11	2.985E+05	.3500E-06
.5000E-06	.1000E-01	2.809E+06	2.809E+08	2.836E+05	.5000E-02
.1000E-01	.1027E+00	1.082E+06	1.168E+07	4.647E+05	.5635E-01
.1027E+00	.1166E+00	7.442E+04	5.370E+06	5.878E+05	.1096E+00
.1166E+00	.1317E+00	7.945E+04	5.255E+06	6.513E+05	.1241E+00
.1317E+00	.1493E+00	1.553E+05	8.806E+06	1.236E+06	.1405E+00
.1493E+00	.1707E+00	1.282E+05	5.984E+06	9.562E+05	.1600E+00
.1707E+00	.1934E+00	1.207E+05	5.321E+06	9.675E+05	.1821E+00
.1934E+00	.2199E+00	9.009E+04	3.405E+06	7.026E+05	.2066E+00
.2199E+00	.2606E+00	1.615E+05	3.963E+06	9.499E+05	.2402E+00
.2606E+00	.2906E+00	1.185E+05	3.950E+06	1.088E+06	.2756E+00
.2906E+00	.3244E+00	1.136E+05	3.367E+06	1.034E+06	.3075E+00
.3244E+00	.3581E+00	1.083E+05	3.208E+06	1.094E+06	.3413E+00
.3581E+00	.3994E+00	1.242E+05	3.010E+06	1.139E+06	.3787E+00
.3994E+00	.4444E+00	1.007E+05	2.239E+06	9.435E+05	.4219E+00
.4444E+00	.4931E+00	1.260E+05	2.584E+06	1.210E+06	.4688E+00
.4931E+00	.5456E+00	1.412E+05	2.689E+06	1.395E+06	.5194E+00
.5456E+00	.6094E+00	1.566E+05	2.457E+06	1.418E+06	.5775E+00
.6094E+00	.6769E+00	1.691E+05	2.506E+06	1.610E+06	.6431E+00
.6769E+00	.7946E+00	3.043E+05	2.584E+06	1.897E+06	.7358E+00
.7946E+00	.8870E+00	1.884E+05	2.039E+06	1.713E+06	.8408E+00
.8870E+00	.9871E+00	1.775E+05	1.773E+06	1.660E+06	.9371E+00
.9871E+00	.1095E+01	1.467E+05	1.361E+06	1.416E+06	.1041E+01
.1095E+01	.1218E+01	2.113E+05	1.715E+06	1.982E+06	.1157E+01
.1218E+01	.1391E+01	2.545E+05	1.472E+06	1.918E+06	.1305E+01
.1391E+01	.1573E+01	2.405E+05	1.321E+06	1.956E+06	.1482E+01
.1573E+01	.1807E+01	2.580E+05	1.103E+06	1.861E+06	.1690E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.1807E+01	.2041E+01	2.035E+05	8.695E+05	1.671E+06	.1924E+01
.2041E+01	.2327E+01	2.285E+05	7.989E+05	1.742E+06	.2184E+01
.2327E+01	.2639E+01	2.190E+05	7.019E+05	1.741E+06	.2483E+01
.2639E+01	.3003E+01	1.851E+05	5.085E+05	1.433E+06	.2821E+01
.3003E+01	.3419E+01	1.505E+05	3.618E+05	1.160E+06	.3211E+01
.3419E+01	.3861E+01	1.273E+05	2.881E+05	1.047E+06	.3640E+01
.3861E+01	.4407E+01	1.275E+05	2.335E+05	9.639E+05	.4134E+01
.4407E+01	.5000E+01	1.184E+05	1.997E+05	9.380E+05	.4703E+01
.5000E+01	.5500E+01	7.136E+04	1.427E+05	7.488E+05	.5250E+01
.5500E+01	.6000E+01	5.285E+04	1.057E+05	6.074E+05	.5750E+01
.6000E+01	.6500E+01	3.897E+04	7.793E+04	4.868E+05	.6250E+01
.6500E+01	.7000E+01	2.860E+04	5.720E+04	3.859E+05	.6750E+01
.7000E+01	.7500E+01	2.093E+04	4.186E+04	3.034E+05	.7250E+01
.7500E+01	.8000E+01	1.526E+04	3.052E+04	2.365E+05	.7750E+01
.8000E+01	.8500E+01	1.110E+04	2.220E+04	1.831E+05	.8250E+01
.8500E+01	.9000E+01	8.059E+03	1.612E+04	1.410E+05	.8750E+01
.9000E+01	.9500E+01	5.841E+03	1.168E+04	1.080E+05	.9250E+01
.9500E+01	.1000E+02	4.234E+03	8.469E+03	8.255E+04	.9750E+01

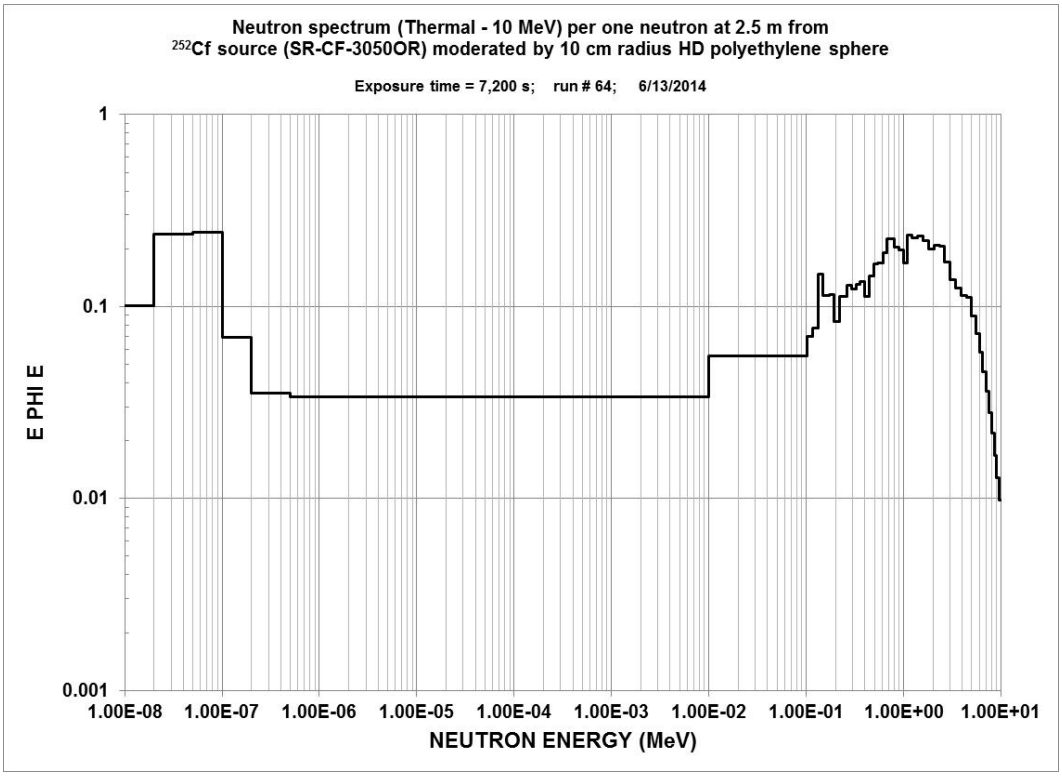
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



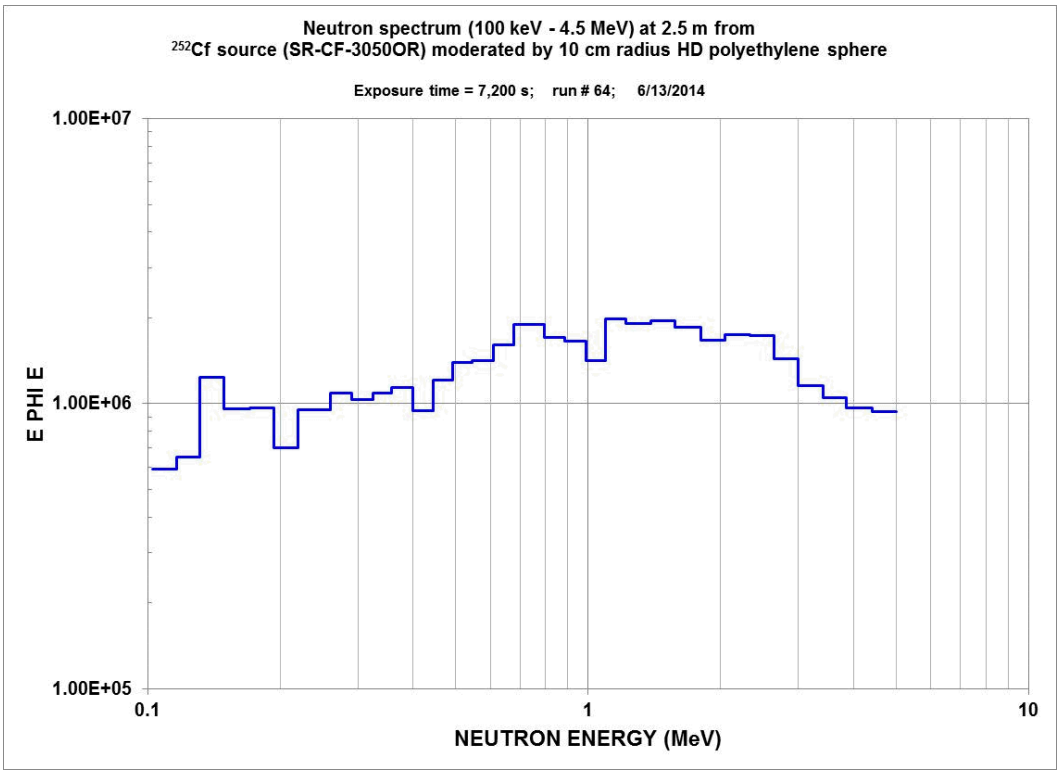


Figure J-2. Neutron spectra at 2.5 m from ^{252}Cf moderated by 10 cm of polyethylene

Fluence, spectral and dosimetric data at 3.0 m from ^{252}Cf moderated by 10 cm of polyethylene

Table J-5. Neutron fluence and dosimetric data at 3.0 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date:	6/13/2014
Exposure time:	7,200 s
Run #	N65

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	4.07E+06	5.66E+02
Epi-thermal region	:	4.79E+06	6.65E+02
Thermal region	:	4.09E+06	5.68E+02
Thermal – 4.5 MeV	:	1.30E+07	1.80E+03
Thermal – 10.0 MeV	:	1.3131E+07	1.8238E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	9.15E-03	1.38E-03	4.58E+00	6.92E+02
Epi-thermal region	:	4.54E-04	8.13E-05	2.27E-01	4.06E+01
Thermal region	:	8.18E-05	4.34E-05	4.09E-02	2.17E+01
Thermal – 4.5 MeV	:	9.69E-03	1.51E-03	4.84E+00	7.54E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.0285E-02 rads	5.1425E+00 mrads/hr
H*(10) ICRP-74	=	1.5627E-03 Sv	7.8134E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.6199E-03 Sv	8.0994E+02 uSv/hr

Table J-6. Neutron fluence at 3.0 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date: 6/13/2014
Exposure time: 7,200 s
Run number: N65

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	9.248E+03	9.248E+12	1.334E+04	.1500E-08
.2000E-08	.5000E-08	5.934E+04	1.978E+13	6.476E+04	.3500E-08
.5000E-08	.1000E-07	1.805E+05	3.609E+13	2.604E+05	.7500E-08
.1000E-07	.2000E-07	5.320E+05	5.320E+13	7.675E+05	.1500E-07
.2000E-07	.5000E-07	1.649E+06	5.497E+13	1.800E+06	.3500E-07
.5000E-07	.1000E-06	1.289E+06	2.578E+13	1.860E+06	.7500E-07
.1000E-06	.2000E-06	3.626E+05	3.626E+12	5.231E+05	.1500E-06
.2000E-06	.5000E-06	3.211E+05	1.070E+12	3.504E+05	.3500E-06
.5000E-06	.1000E-01	3.337E+06	3.337E+08	3.370E+05	.5000E-02
.1000E-01	.1027E+00	1.140E+06	1.230E+07	4.893E+05	.5635E-01
.1027E+00	.1166E+00	7.457E+04	5.381E+06	5.890E+05	.1096E+00
.1166E+00	.1317E+00	1.062E+05	7.026E+06	8.709E+05	.1241E+00
.1317E+00	.1493E+00	9.562E+04	5.421E+06	7.605E+05	.1405E+00
.1493E+00	.1707E+00	1.189E+05	5.552E+06	8.870E+05	.1600E+00
.1707E+00	.1934E+00	7.507E+04	3.310E+06	6.019E+05	.1821E+00
.1934E+00	.2199E+00	1.200E+05	4.537E+06	9.363E+05	.2066E+00
.2199E+00	.2606E+00	1.169E+05	2.869E+06	6.876E+05	.2402E+00
.2606E+00	.2906E+00	9.087E+04	3.029E+06	8.340E+05	.2756E+00
.2906E+00	.3244E+00	9.786E+04	2.899E+06	8.907E+05	.3075E+00
.3244E+00	.3581E+00	8.619E+04	2.554E+06	8.708E+05	.3413E+00
.3581E+00	.3994E+00	9.207E+04	2.232E+06	8.446E+05	.3787E+00
.3994E+00	.4444E+00	9.152E+04	2.034E+06	8.572E+05	.4219E+00
.4444E+00	.4931E+00	1.015E+05	2.082E+06	9.751E+05	.4688E+00
.4931E+00	.5456E+00	1.018E+05	1.940E+06	1.007E+06	.5194E+00
.5456E+00	.6094E+00	1.472E+05	2.309E+06	1.332E+06	.5775E+00
.6094E+00	.6769E+00	1.364E+05	2.021E+06	1.299E+06	.6431E+00
.6769E+00	.7946E+00	2.358E+05	2.002E+06	1.470E+06	.7358E+00
.7946E+00	.8870E+00	1.406E+05	1.521E+06	1.278E+06	.8408E+00
.8870E+00	.9871E+00	1.498E+05	1.497E+06	1.401E+06	.9371E+00
.9871E+00	.1095E+01	1.207E+05	1.119E+06	1.164E+06	.1041E+01
.1095E+01	.1218E+01	1.654E+05	1.342E+06	1.551E+06	.1157E+01
.1218E+01	.1391E+01	2.143E+05	1.240E+06	1.615E+06	.1305E+01
.1391E+01	.1573E+01	1.830E+05	1.006E+06	1.488E+06	.1482E+01
.1573E+01	.1807E+01	1.819E+05	7.774E+05	1.312E+06	.1690E+01
.1807E+01	.2041E+01	1.531E+05	6.543E+05	1.257E+06	.1924E+01
.2041E+01	.2327E+01	1.754E+05	6.134E+05	1.338E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	1.618E+05	5.187E+05	1.286E+06	.2483E+01
.2639E+01	.3003E+01	1.496E+05	4.111E+05	1.158E+06	.2821E+01
.3003E+01	.3419E+01	1.112E+05	2.674E+05	8.573E+05	.3211E+01
.3419E+01	.3861E+01	9.442E+04	2.136E+05	7.766E+05	.3640E+01
.3861E+01	.4407E+01	9.683E+04	1.774E+05	7.321E+05	.4134E+01
.4407E+01	.5000E+01	8.399E+04	1.416E+05	6.653E+05	.4703E+01
.5000E+01	.5500E+01	5.014E+04	1.003E+05	5.260E+05	.5250E+01
.5500E+01	.6000E+01	3.713E+04	7.426E+04	4.267E+05	.5750E+01
.6000E+01	.6500E+01	2.738E+04	5.475E+04	3.420E+05	.6250E+01
.6500E+01	.7000E+01	2.009E+04	4.019E+04	2.711E+05	.6750E+01
.7000E+01	.7500E+01	1.470E+04	2.941E+04	2.131E+05	.7250E+01
.7500E+01	.8000E+01	1.072E+04	2.144E+04	1.661E+05	.7750E+01
.8000E+01	.8500E+01	7.799E+03	1.560E+04	1.286E+05	.8250E+01
.8500E+01	.9000E+01	5.661E+03	1.132E+04	9.905E+04	.8750E+01
.9000E+01	.9500E+01	4.104E+03	8.207E+03	7.590E+04	.9250E+01
.9500E+01	.1000E+02	2.975E+03	5.950E+03	5.800E+04	.9750E+01

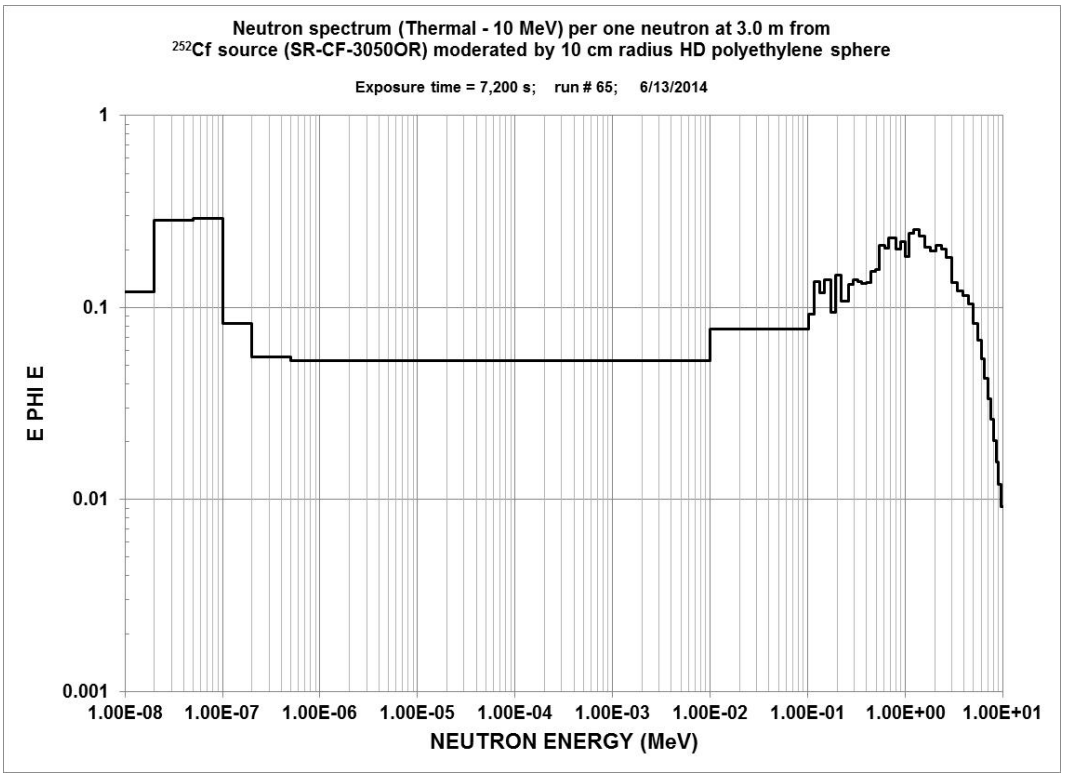
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



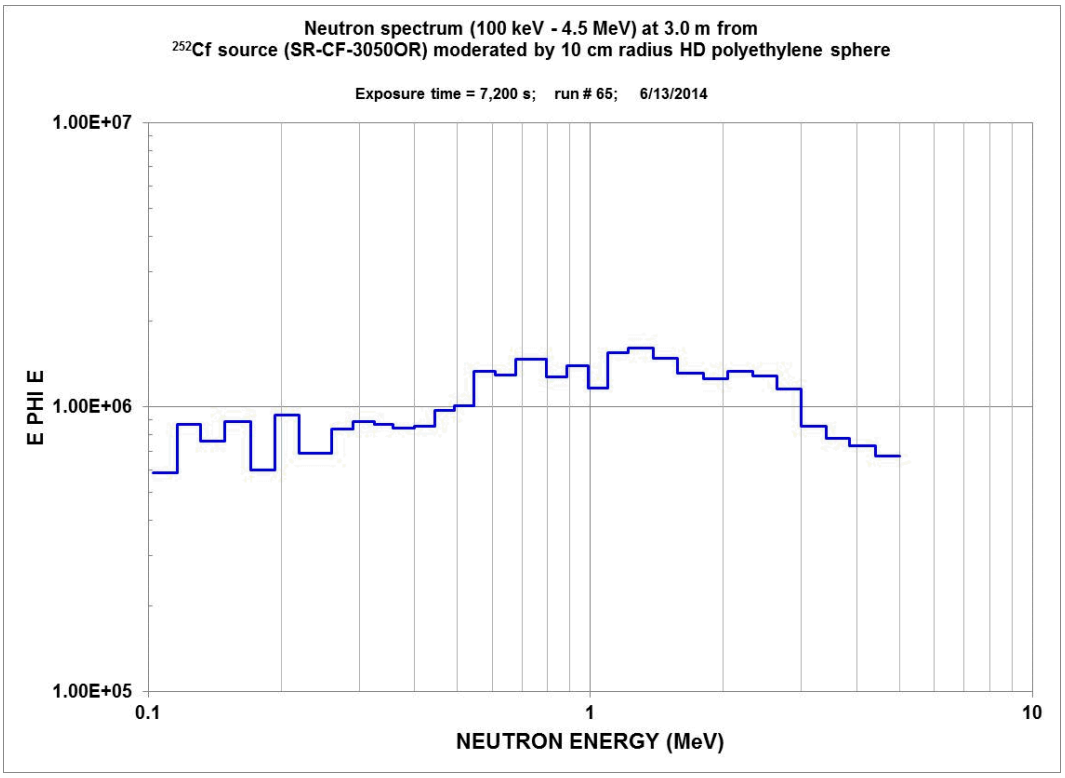


Figure J-3. Neutron spectra at 3.0 m from ^{252}Cf moderated by 10 cm of polyethylene

Fluence, spectral and dosimetric data at 3.5 m from ^{252}Cf moderated by 10 cm of polyethylene

Table J-7. Neutron fluence and dosimetric data at 3.5 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date:	6/13/2014
Exposure time:	7,200 s
Run #	N66

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	3.38E+06	4.70E+02
Epi-thermal region	:	4.30E+06	5.97E+02
Thermal region	:	3.81E+06	5.29E+02
Thermal – 4.5 MeV	:	1.15E+07	1.60E+03
Thermal – 10.0 MeV	:	1.1632E+07	1.6156E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	7.38E-03	1.13E-03	3.69E+00	5.64E+02
Epi-thermal region	:	4.09E-04	7.31E-05	2.05E-01	3.65E+01
Thermal region	:	7.62E-05	4.04E-05	3.81E-02	2.02E+01
Thermal – 4.5 MeV	:	7.86E-03	1.24E-03	3.93E+00	6.20E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	8.3046E-03 rads	4.1523E+00 mrads/hr
H*(10) ICRP-74	=	1.2794E-03 Sv	6.3972E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.3265E-03 Sv	6.6324E+02 uSv/hr

Table J-8. Neutron fluence at 3.5 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date: 6/13/2014
Exposure time: 7,200 s
Run number: N66

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	8.615E+03	8.615E+12	1.243E+04	.1500E-08
.2000E-08	.5000E-08	5.527E+04	1.842E+13	6.032E+04	.3500E-08
.5000E-08	.1000E-07	1.681E+05	3.362E+13	2.425E+05	.7500E-08
.1000E-07	.2000E-07	4.956E+05	4.956E+13	7.149E+05	.1500E-07
.2000E-07	.5000E-07	1.536E+06	5.121E+13	1.677E+06	.3500E-07
.5000E-07	.1000E-06	1.201E+06	2.402E+13	1.732E+06	.7500E-07
.1000E-06	.2000E-06	3.377E+05	3.377E+12	4.873E+05	.1500E-06
.2000E-06	.5000E-06	2.887E+05	9.622E+11	3.150E+05	.3500E-06
.5000E-06	.1000E-01	2.996E+06	2.996E+08	3.025E+05	.5000E-02
.1000E-01	.1027E+00	1.026E+06	1.107E+07	4.405E+05	.5635E-01
.1027E+00	.1166E+00	7.916E+04	5.711E+06	6.252E+05	.1096E+00
.1166E+00	.1317E+00	5.485E+04	3.627E+06	4.496E+05	.1241E+00
.1317E+00	.1493E+00	1.102E+05	6.249E+06	8.768E+05	.1405E+00
.1493E+00	.1707E+00	1.250E+05	5.834E+06	9.321E+05	.1600E+00
.1707E+00	.1934E+00	6.515E+04	2.872E+06	5.223E+05	.1821E+00
.1934E+00	.2199E+00	8.663E+04	3.274E+06	6.756E+05	.2066E+00
.2199E+00	.2606E+00	1.523E+05	3.737E+06	8.957E+05	.2402E+00
.2606E+00	.2906E+00	7.491E+04	2.497E+06	6.875E+05	.2756E+00
.2906E+00	.3244E+00	8.787E+04	2.603E+06	7.998E+05	.3075E+00
.3244E+00	.3581E+00	7.408E+04	2.195E+06	7.484E+05	.3413E+00
.3581E+00	.3994E+00	7.595E+04	1.841E+06	6.967E+05	.3787E+00
.3994E+00	.4444E+00	6.577E+04	1.461E+06	6.160E+05	.4219E+00
.4444E+00	.4931E+00	9.322E+04	1.912E+06	8.956E+05	.4688E+00
.4931E+00	.5456E+00	9.182E+04	1.749E+06	9.076E+05	.5194E+00
.5456E+00	.6094E+00	1.094E+05	1.717E+06	9.903E+05	.5775E+00
.6094E+00	.6769E+00	1.171E+05	1.734E+06	1.114E+06	.6431E+00
.6769E+00	.7946E+00	1.968E+05	1.671E+06	1.227E+06	.7358E+00
.7946E+00	.8870E+00	1.403E+05	1.518E+06	1.275E+06	.8408E+00
.8870E+00	.9871E+00	1.174E+05	1.173E+06	1.098E+06	.9371E+00
.9871E+00	.1095E+01	9.991E+04	9.268E+05	9.640E+05	.1041E+01
.1095E+01	.1218E+01	1.243E+05	1.009E+06	1.166E+06	.1157E+01
.1218E+01	.1391E+01	1.520E+05	8.791E+05	1.145E+06	.1305E+01
.1391E+01	.1573E+01	1.389E+05	7.630E+05	1.129E+06	.1482E+01
.1573E+01	.1807E+01	1.565E+05	6.686E+05	1.128E+06	.1690E+01

E2	E1	FLUENCE/	FLUENCE/	FLUENCE/	E avg.

(MeV)	(MeV)	(E1-E2) (n/cm²)	MeV (n/cm².MeV)	LETHARGY* (n/cm².u)	(MeV)
.1807E+01	.2041E+01	1.184E+05	5.058E+05	9.720E+05	.1924E+01
.2041E+01	.2327E+01	1.374E+05	4.805E+05	1.048E+06	.2184E+01
.2327E+01	.2639E+01	1.346E+05	4.314E+05	1.070E+06	.2483E+01
.2639E+01	.3003E+01	1.077E+05	2.960E+05	8.337E+05	.2821E+01
.3003E+01	.3419E+01	9.170E+04	2.204E+05	7.069E+05	.3211E+01
.3419E+01	.3861E+01	6.522E+04	1.475E+05	5.364E+05	.3640E+01
.3861E+01	.4407E+01	7.939E+04	1.454E+05	6.003E+05	.4134E+01
.4407E+01	.5000E+01	6.043E+04	1.019E+05	4.787E+05	.4703E+01
.5000E+01	.5500E+01	3.755E+04	7.509E+04	3.939E+05	.5250E+01
.5500E+01	.6000E+01	2.781E+04	5.562E+04	3.196E+05	.5750E+01
.6000E+01	.6500E+01	2.050E+04	4.100E+04	2.561E+05	.6250E+01
.6500E+01	.7000E+01	1.505E+04	3.010E+04	2.030E+05	.6750E+01
.7000E+01	.7500E+01	1.101E+04	2.202E+04	1.596E+05	.7250E+01
.7500E+01	.8000E+01	8.029E+03	1.606E+04	1.244E+05	.7750E+01
.8000E+01	.8500E+01	5.841E+03	1.168E+04	9.634E+04	.8250E+01
.8500E+01	.9000E+01	4.240E+03	8.480E+03	7.418E+04	.8750E+01
.9000E+01	.9500E+01	3.073E+03	6.146E+03	5.684E+04	.9250E+01
.9500E+01	.1000E+02	2.228E+03	4.456E+03	4.343E+04	.9750E+01

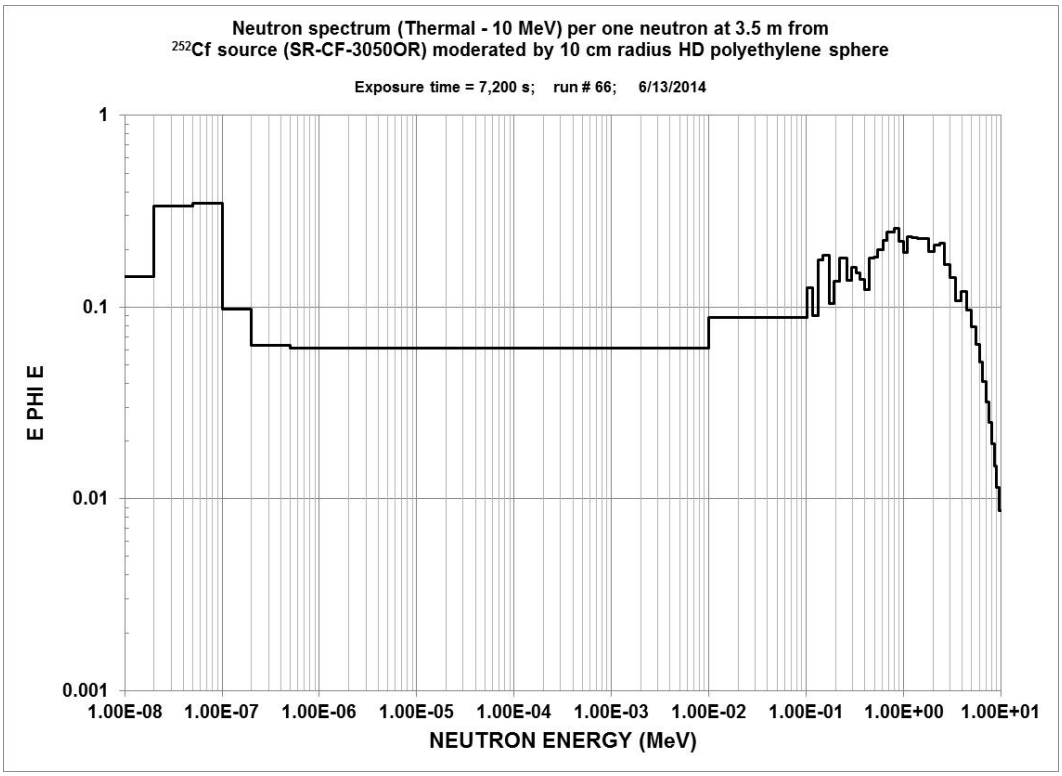
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



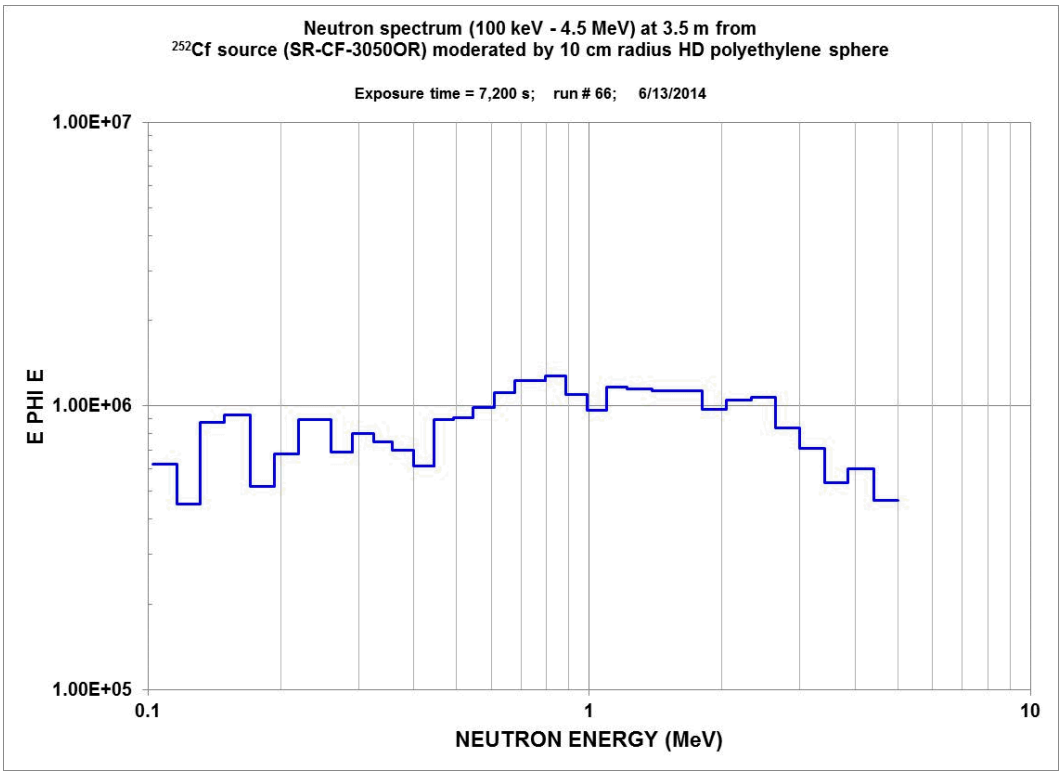


Figure J-4. Neutron spectra at 3.5 m from ^{252}Cf moderated by 10 cm of polyethylene

Fluence, spectral and dosimetric data at 4.0 m from ^{252}Cf moderated by 10 cm of polyethylene

Table J-9. Neutron fluence and dosimetric data at 4.0 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date:	6/16/2014
Exposure time:	7,200 s
Run #	N68

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	2.87E+06	3.99E+02
Epi-thermal region	:	4.07E+06	5.65E+02
Thermal region	:	3.65E+06	5.07E+02
Thermal – 4.5 MeV	:	1.06E+07	1.47E+03
Thermal – 10.0 MeV	:	1.0695E+07	1.4855E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	6.22E-03	9.56E-04	3.11E+00	4.78E+02
Epi-thermal region	:	3.61E-04	6.69E-05	1.81E-01	3.35E+01
Thermal region	:	7.29E-05	3.87E-05	3.65E-02	1.93E+01
Thermal – 4.5 MeV	:	6.65E-03	1.06E-03	3.32E+00	5.31E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	6.9856E-03 rads	3.4928E+00 mrads/hr
H*(10) ICRP-74	=	1.0913E-03 Sv	5.4563E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.1314E-03 Sv	5.6570E+02 uSv/hr

Table J-10. Neutron fluence at 4.0 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date: 6/16/2014
Exposure time: 7,200 s
Run number: N68

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	8.243E+03	8.243E+12	1.189E+04	.1500E-08
.2000E-08	.5000E-08	5.289E+04	1.763E+13	5.772E+04	.3500E-08
.5000E-08	.1000E-07	1.608E+05	3.217E+13	2.321E+05	.7500E-08
.1000E-07	.2000E-07	4.741E+05	4.741E+13	6.841E+05	.1500E-07
.2000E-07	.5000E-07	1.470E+06	4.900E+13	1.604E+06	.3500E-07
.5000E-07	.1000E-06	1.149E+06	2.298E+13	1.658E+06	.7500E-07
.1000E-06	.2000E-06	3.232E+05	3.232E+12	4.662E+05	.1500E-06
.2000E-06	.5000E-06	2.795E+05	9.316E+11	3.050E+05	.3500E-06
.5000E-06	.1000E-01	2.902E+06	2.902E+08	2.930E+05	.5000E-02
.1000E-01	.1027E+00	8.951E+05	9.656E+06	3.843E+05	.5635E-01
.1027E+00	.1166E+00	2.967E+04	2.140E+06	2.343E+05	.1096E+00
.1166E+00	.1317E+00	8.678E+04	5.740E+06	7.115E+05	.1241E+00
.1317E+00	.1493E+00	9.807E+04	5.560E+06	7.800E+05	.1405E+00
.1493E+00	.1707E+00	8.819E+04	4.117E+06	6.578E+05	.1600E+00
.1707E+00	.1934E+00	6.799E+04	2.998E+06	5.451E+05	.1821E+00
.1934E+00	.2199E+00	6.689E+04	2.528E+06	5.217E+05	.2066E+00
.2199E+00	.2606E+00	1.251E+05	3.069E+06	7.355E+05	.2402E+00
.2606E+00	.2906E+00	7.682E+04	2.561E+06	7.051E+05	.2756E+00
.2906E+00	.3244E+00	6.649E+04	1.970E+06	6.052E+05	.3075E+00
.3244E+00	.3581E+00	6.375E+04	1.889E+06	6.441E+05	.3413E+00
.3581E+00	.3994E+00	7.279E+04	1.765E+06	6.677E+05	.3787E+00
.3994E+00	.4444E+00	6.725E+04	1.494E+06	6.298E+05	.4219E+00
.4444E+00	.4931E+00	8.179E+04	1.678E+06	7.857E+05	.4688E+00
.4931E+00	.5456E+00	7.504E+04	1.429E+06	7.418E+05	.5194E+00
.5456E+00	.6094E+00	8.021E+04	1.258E+06	7.259E+05	.5775E+00
.6094E+00	.6769E+00	1.115E+05	1.652E+06	1.062E+06	.6431E+00
.6769E+00	.7946E+00	1.803E+05	1.531E+06	1.124E+06	.7358E+00
.7946E+00	.8870E+00	1.070E+05	1.158E+06	9.728E+05	.8408E+00
.8870E+00	.9871E+00	1.008E+05	1.007E+06	9.431E+05	.9371E+00
.9871E+00	.1095E+01	9.327E+04	8.652E+05	8.999E+05	.1041E+01
.1095E+01	.1218E+01	1.218E+05	9.890E+05	1.143E+06	.1157E+01
.1218E+01	.1391E+01	1.212E+05	7.013E+05	9.136E+05	.1305E+01
.1391E+01	.1573E+01	1.191E+05	6.546E+05	9.689E+05	.1482E+01
.1573E+01	.1807E+01	1.285E+05	5.493E+05	9.268E+05	.1690E+01
.1807E+01	.2041E+01	1.013E+05	4.329E+05	8.320E+05	.1924E+01

E2	E1	FLUENCE/	FLUENCE/	FLUENCE/	E avg.

(MeV)	(MeV)	(E1-E2) (n/cm²)	MeV (n/cm².MeV)	LETHARGY* (n/cm².u)	(MeV)
.2041E+01	.2327E+01	1.089E+05	3.808E+05	8.305E+05	.2184E+01
.2327E+01	.2639E+01	1.072E+05	3.437E+05	8.523E+05	.2483E+01
.2639E+01	.3003E+01	8.704E+04	2.391E+05	6.736E+05	.2821E+01
.3003E+01	.3419E+01	7.731E+04	1.859E+05	5.959E+05	.3211E+01
.3419E+01	.3861E+01	6.036E+04	1.366E+05	4.965E+05	.3640E+01
.3861E+01	.4407E+01	4.911E+04	8.995E+04	3.713E+05	.4134E+01
.4407E+01	.5000E+01	5.064E+04	8.539E+04	4.011E+05	.4703E+01
.5000E+01	.5500E+01	3.022E+04	6.044E+04	3.171E+05	.5250E+01
.5500E+01	.6000E+01	2.238E+04	4.476E+04	2.572E+05	.5750E+01
.6000E+01	.6500E+01	1.650E+04	3.300E+04	2.061E+05	.6250E+01
.6500E+01	.7000E+01	1.211E+04	2.422E+04	1.634E+05	.6750E+01
.7000E+01	.7500E+01	8.863E+03	1.773E+04	1.285E+05	.7250E+01
.7500E+01	.8000E+01	6.462E+03	1.292E+04	1.001E+05	.7750E+01
.8000E+01	.8500E+01	4.701E+03	9.401E+03	7.754E+04	.8250E+01
.8500E+01	.9000E+01	3.412E+03	6.825E+03	5.970E+04	.8750E+01
.9000E+01	.9500E+01	2.473E+03	4.947E+03	4.575E+04	.9250E+01
.9500E+01	.1000E+02	1.793E+03	3.586E+03	3.496E+04	.9750E+01

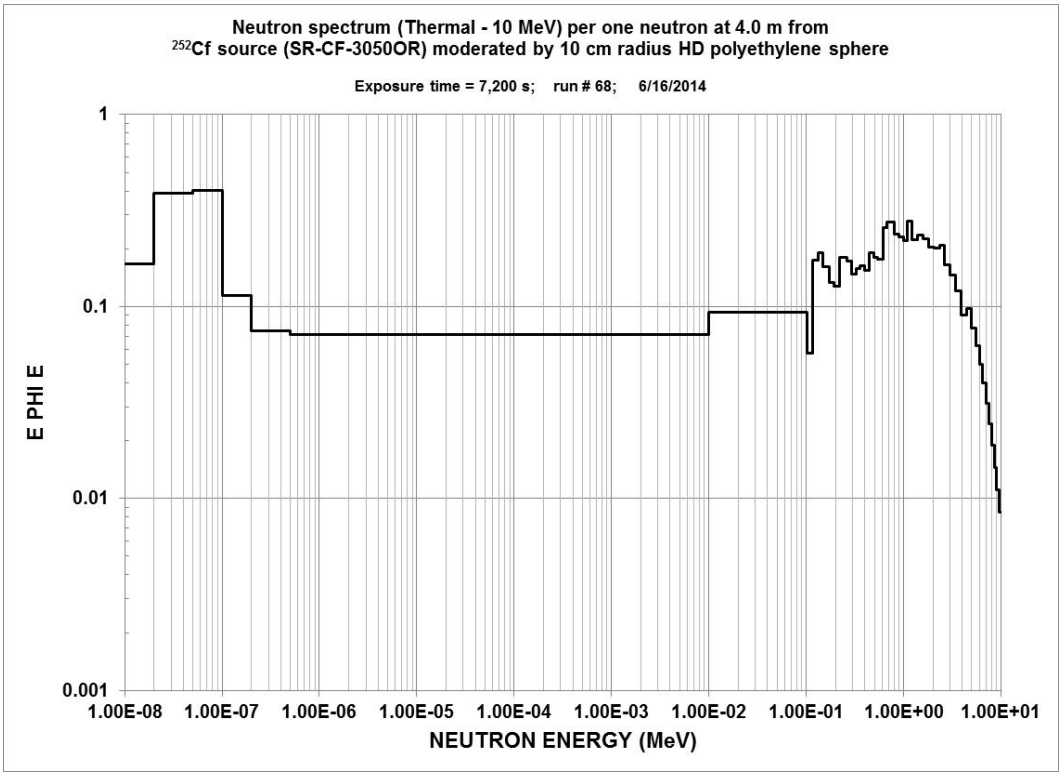
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



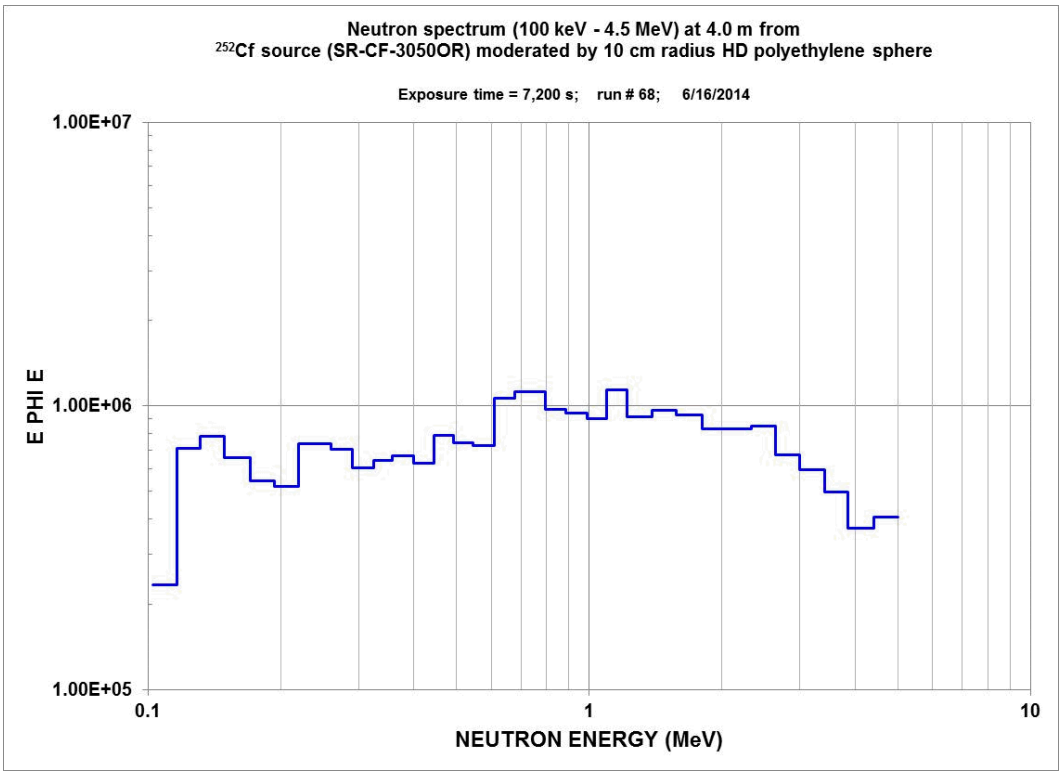


Figure J-5. Neutron spectra at 4.0 m from ^{252}Cf moderated by 10 cm of polyethylene

Fluence, spectral and dosimetric data at 4.5 m from ^{252}Cf moderated by 10 cm of polyethylene

Table J-11. Neutron fluence and dosimetric data at 4.5 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date:	6/16/2014
Exposure time:	7,200 s
Run #	N69

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	2.56E+06	3.56E+02
Epi-thermal region	:	3.85E+06	5.35E+02
Thermal region	:	3.52E+06	4.89E+02
Thermal – 4.5 MeV	:	9.94E+06	1.38E+03
Thermal – 10.0 MeV	:	1.0013E+07	1.3907E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	5.47E-03	8.46E-04	2.73E+00	4.23E+02
Epi-thermal region	:	3.56E-04	6.46E-05	1.78E-01	3.23E+01
Thermal region	:	7.04E-05	3.73E-05	3.52E-02	1.86E+01
Thermal – 4.5 MeV	:	5.89E-03	9.48E-04	2.95E+00	4.74E+02

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	6.1020E-03 rads	3.0510E+00 mrads/hr
H*(10) ICRP-74	=	9.6575E-04 Sv	4.8288E+02 uSv/hr
Hp(10,0) ICRP-74	=	1.0010E-03 Sv	5.0048E+02 uSv/hr

Table J-12. Neutron fluence at 4.5 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 10 cm of polyethylene

Date: 6/16/2014
Exposure time: 7,200 s
Run number: N69

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	7.952E+03	7.952E+12	1.147E+04	.1500E-08
.2000E-08	.5000E-08	5.102E+04	1.701E+13	5.568E+04	.3500E-08
.5000E-08	.1000E-07	1.552E+05	3.104E+13	2.239E+05	.7500E-08
.1000E-07	.2000E-07	4.574E+05	4.574E+13	6.599E+05	.1500E-07
.2000E-07	.5000E-07	1.418E+06	4.727E+13	1.548E+06	.3500E-07
.5000E-07	.1000E-06	1.108E+06	2.217E+13	1.599E+06	.7500E-07
.1000E-06	.2000E-06	3.118E+05	3.118E+12	4.498E+05	.1500E-06
.2000E-06	.5000E-06	2.619E+05	8.730E+11	2.858E+05	.3500E-06
.5000E-06	.1000E-01	2.716E+06	2.716E+08	2.742E+05	.5000E-02
.1000E-01	.1027E+00	8.872E+05	9.572E+06	3.809E+05	.5635E-01
.1027E+00	.1166E+00	5.112E+04	3.688E+06	4.038E+05	.1096E+00
.1166E+00	.1317E+00	6.612E+04	4.373E+06	5.421E+05	.1241E+00
.1317E+00	.1493E+00	9.227E+04	5.231E+06	7.339E+05	.1405E+00
.1493E+00	.1707E+00	8.451E+04	3.945E+06	6.304E+05	.1600E+00
.1707E+00	.1934E+00	6.510E+04	2.871E+06	5.220E+05	.1821E+00
.1934E+00	.2199E+00	7.285E+04	2.753E+06	5.681E+05	.2066E+00
.2199E+00	.2606E+00	8.024E+04	1.969E+06	4.719E+05	.2402E+00
.2606E+00	.2906E+00	7.384E+04	2.461E+06	6.777E+05	.2756E+00
.2906E+00	.3244E+00	5.879E+04	1.742E+06	5.351E+05	.3075E+00
.3244E+00	.3581E+00	6.380E+04	1.890E+06	6.445E+05	.3413E+00
.3581E+00	.3994E+00	6.860E+04	1.663E+06	6.293E+05	.3787E+00
.3994E+00	.4444E+00	4.898E+04	1.088E+06	4.587E+05	.4219E+00
.4444E+00	.4931E+00	6.937E+04	1.423E+06	6.664E+05	.4688E+00
.4931E+00	.5456E+00	6.680E+04	1.272E+06	6.603E+05	.5194E+00
.5456E+00	.6094E+00	8.915E+04	1.398E+06	8.068E+05	.5775E+00
.6094E+00	.6769E+00	9.052E+04	1.341E+06	8.616E+05	.6431E+00
.6769E+00	.7946E+00	1.627E+05	1.381E+06	1.014E+06	.7358E+00
.7946E+00	.8870E+00	1.162E+05	1.258E+06	1.057E+06	.8408E+00
.8870E+00	.9871E+00	8.288E+04	8.280E+05	7.752E+05	.9371E+00
.9871E+00	.1095E+01	7.591E+04	7.042E+05	7.324E+05	.1041E+01
.1095E+01	.1218E+01	8.803E+04	7.146E+05	8.256E+05	.1157E+01
.1218E+01	.1391E+01	1.356E+05	7.845E+05	1.022E+06	.1305E+01
.1391E+01	.1573E+01	1.054E+05	5.790E+05	8.570E+05	.1482E+01
.1573E+01	.1807E+01	9.508E+04	4.063E+05	6.856E+05	.1690E+01
.1807E+01	.2041E+01	9.143E+04	3.907E+05	7.508E+05	.1924E+01
.2041E+01	.2327E+01	9.880E+04	3.455E+05	7.534E+05	.2184E+01

E2	E1	FLUENCE/	FLUENCE/	FLUENCE/	E avg.

(MeV)	(MeV)	(E1-E2) (n/cm²)	MeV (n/cm².MeV)	LETHARGY* (n/cm².u)	(MeV)
.2327E+01	.2639E+01	9.496E+04	3.044E+05	7.547E+05	.2483E+01
.2639E+01	.3003E+01	7.283E+04	2.001E+05	5.637E+05	.2821E+01
.3003E+01	.3419E+01	6.041E+04	1.452E+05	4.657E+05	.3211E+01
.3419E+01	.3861E+01	4.206E+04	9.516E+04	3.459E+05	.3640E+01
.3861E+01	.4407E+01	5.408E+04	9.906E+04	4.089E+05	.4134E+01
.4407E+01	.5000E+01	4.015E+04	6.770E+04	3.180E+05	.4703E+01
.5000E+01	.5500E+01	2.211E+04	4.422E+04	2.320E+05	.5250E+01
.5500E+01	.6000E+01	1.638E+04	3.275E+04	1.882E+05	.5750E+01
.6000E+01	.6500E+01	1.207E+04	2.415E+04	1.508E+05	.6250E+01
.6500E+01	.7000E+01	8.862E+03	1.772E+04	1.196E+05	.6750E+01
.7000E+01	.7500E+01	6.485E+03	1.297E+04	9.400E+04	.7250E+01
.7500E+01	.8000E+01	4.728E+03	9.456E+03	7.326E+04	.7750E+01
.8000E+01	.8500E+01	3.440E+03	6.879E+03	5.674E+04	.8250E+01
.8500E+01	.9000E+01	2.497E+03	4.994E+03	4.368E+04	.8750E+01
.9000E+01	.9500E+01	1.810E+03	3.620E+03	3.347E+04	.9250E+01
.9500E+01	.1000E+02	1.312E+03	2.624E+03	2.558E+04	.9750E+01

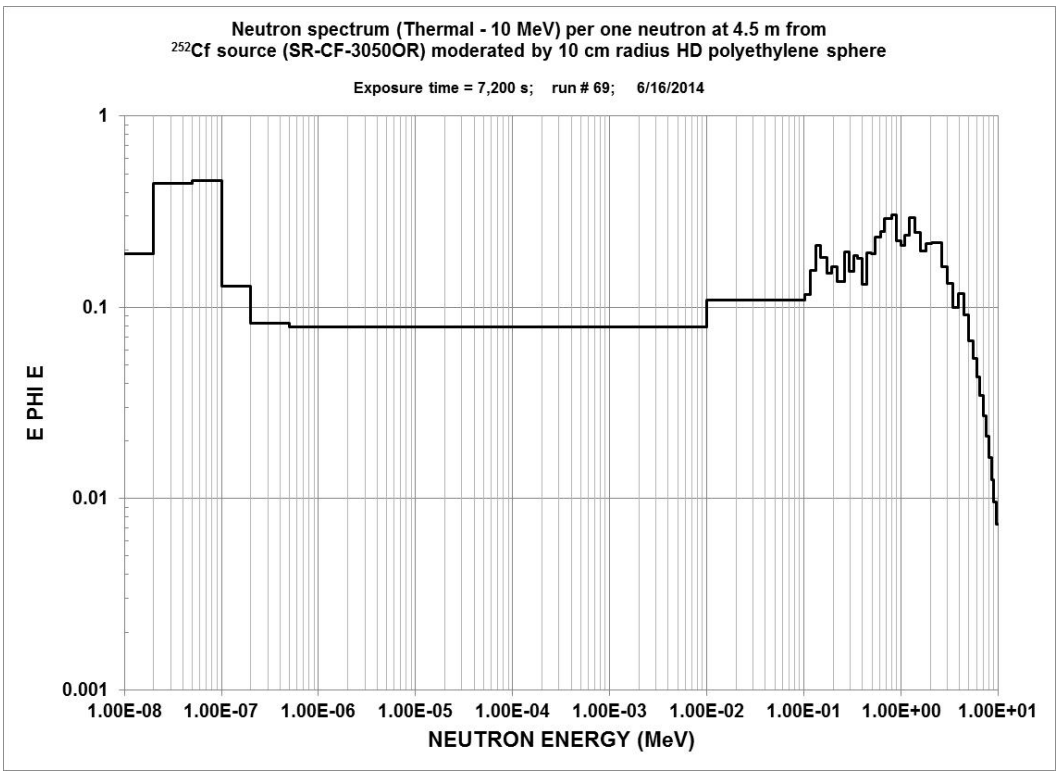
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



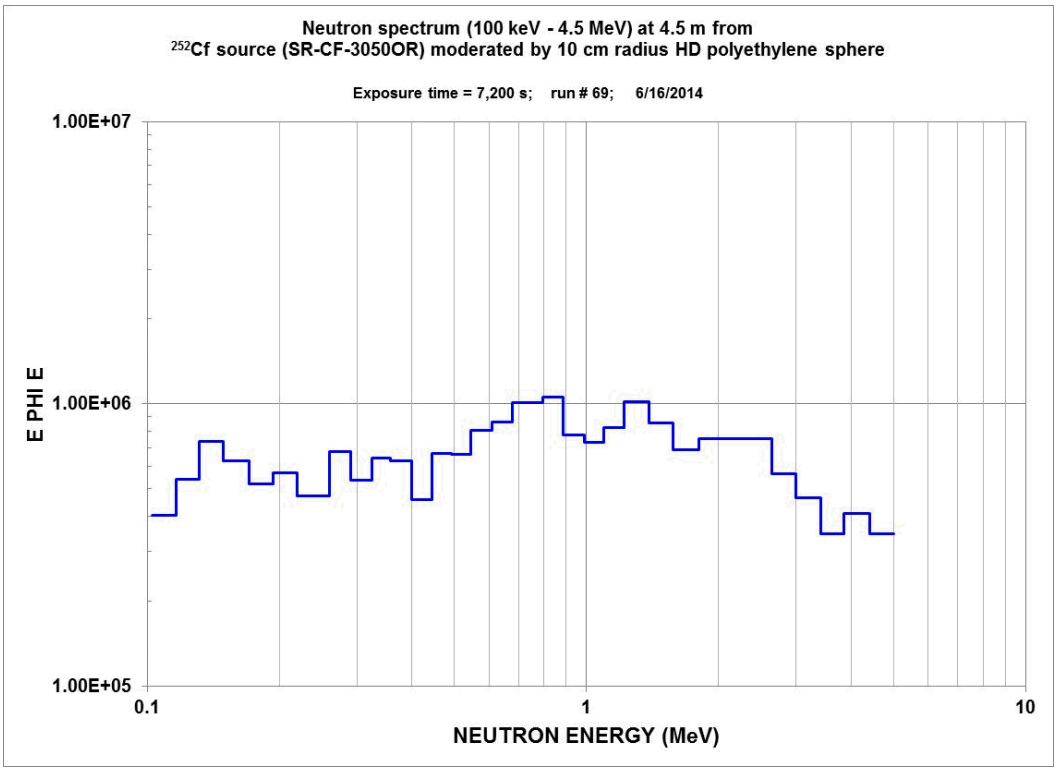
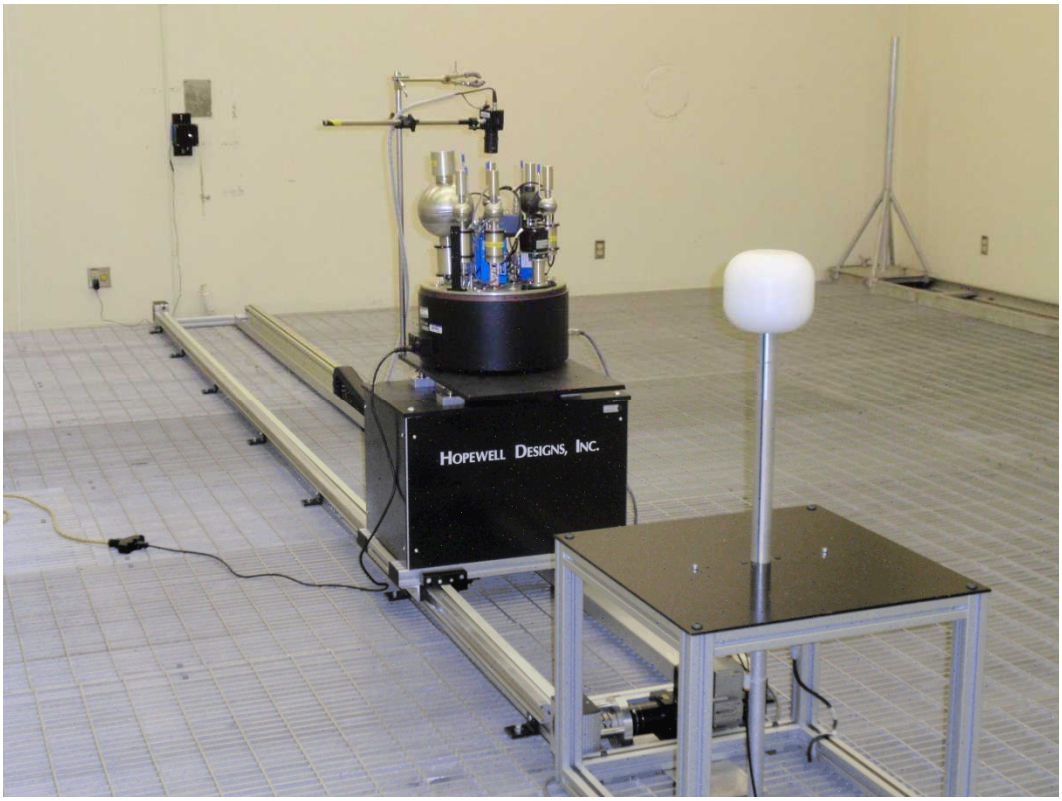


Figure J-6. Neutron spectra at 4.5 m from ^{252}Cf moderated by 10 cm of polyethylene

Appendix K

Neutron fluence, spectra and dose rates from ^{252}Cf moderated by 5 cm high density polyethylene



Fluence, spectral and dosimetric data at 2.0 m from ^{252}Cf moderated by 5 cm of polyethylene

Table K-1. Neutron fluence and dosimetric data at 2.0 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date:	6/18/2014
Exposure time:	7,200 s
Run #	N72

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.71E+07	2.37E+03
Epi-thermal region	:	9.00E+06	1.25E+03
Thermal region	:	4.86E+06	6.75E+02
Thermal – 4.5 MeV	:	3.09E+07	4.30E+03
Thermal – 10.0 MeV	:	3.1787E+07	4.4148E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	4.15E-02	6.10E-03	2.07E+01	3.05E+03
Epi-thermal region	:	9.86E-04	1.64E-04	4.93E-01	8.19E+01
Thermal region	:	9.73E-05	5.15E-05	4.86E-02	2.58E+01
Thermal – 4.5 MeV	:	4.25E-02	6.32E-03	2.13E+01	3.16E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	4.5384E-02 rads	2.2692E+01 mrads/hr
H*(10) ICRP-74	=	6.5921E-03 Sv	3.2961E+03 uSv/hr
Hp(10,0) ICRP-74	=	6.8292E-03 Sv	3.4146E+03 uSv/hr

Table K-2. Neutron fluence at 2.0 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date: 6/18/2014
Exposure time: 7,200 s
Run number: N72

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	1.099E+04	1.099E+13	1.586E+04	.1500E-08
.2000E-08	.5000E-08	7.051E+04	2.350E+13	7.696E+04	.3500E-08
.5000E-08	.1000E-07	2.145E+05	4.289E+13	3.094E+05	.7500E-08
.1000E-07	.2000E-07	6.322E+05	6.322E+13	9.121E+05	.1500E-07
.2000E-07	.5000E-07	1.960E+06	6.533E+13	2.139E+06	.3500E-07
.5000E-07	.1000E-06	1.532E+06	3.064E+13	2.210E+06	.7500E-07
.1000E-06	.2000E-06	4.309E+05	4.309E+12	6.216E+05	.1500E-06
.2000E-06	.5000E-06	5.625E+05	1.875E+12	6.139E+05	.3500E-06
.5000E-06	.1000E-01	5.921E+06	5.921E+08	5.979E+05	.5000E-02
.1000E-01	.1027E+00	2.530E+06	2.729E+07	1.086E+06	.5635E-01
.1027E+00	.1166E+00	2.053E+05	1.481E+07	1.622E+06	.1096E+00
.1166E+00	.1317E+00	2.586E+05	1.710E+07	2.120E+06	.1241E+00
.1317E+00	.1493E+00	3.605E+05	2.044E+07	2.867E+06	.1405E+00
.1493E+00	.1707E+00	2.706E+05	1.263E+07	2.019E+06	.1600E+00
.1707E+00	.1934E+00	2.836E+05	1.251E+07	2.274E+06	.1821E+00
.1934E+00	.2199E+00	3.271E+05	1.236E+07	2.551E+06	.2066E+00
.2199E+00	.2606E+00	4.125E+05	1.012E+07	2.426E+06	.2402E+00
.2606E+00	.2906E+00	3.047E+05	1.016E+07	2.797E+06	.2756E+00
.2906E+00	.3244E+00	3.542E+05	1.049E+07	3.224E+06	.3075E+00
.3244E+00	.3581E+00	3.027E+05	8.969E+06	3.058E+06	.3413E+00
.3581E+00	.3994E+00	3.471E+05	8.415E+06	3.184E+06	.3787E+00
.3994E+00	.4444E+00	3.127E+05	6.950E+06	2.929E+06	.4219E+00
.4444E+00	.4931E+00	4.072E+05	8.353E+06	3.912E+06	.4688E+00
.4931E+00	.5456E+00	4.200E+05	8.001E+06	4.152E+06	.5194E+00
.5456E+00	.6094E+00	4.951E+05	7.766E+06	4.480E+06	.5775E+00
.6094E+00	.6769E+00	5.622E+05	8.329E+06	5.352E+06	.6431E+00
.6769E+00	.7946E+00	8.956E+05	7.605E+06	5.584E+06	.7358E+00
.7946E+00	.8870E+00	6.236E+05	6.749E+06	5.669E+06	.8408E+00
.8870E+00	.9871E+00	6.409E+05	6.403E+06	5.994E+06	.9371E+00
.9871E+00	.1095E+01	5.791E+05	5.372E+06	5.588E+06	.1041E+01
.1095E+01	.1218E+01	7.475E+05	6.067E+06	7.010E+06	.1157E+01
.1218E+01	.1391E+01	9.309E+05	5.385E+06	7.015E+06	.1305E+01
.1391E+01	.1573E+01	8.474E+05	4.656E+06	6.891E+06	.1482E+01
.1573E+01	.1807E+01	9.490E+05	4.055E+06	6.843E+06	.1690E+01
.1807E+01	.2041E+01	7.850E+05	3.355E+06	6.447E+06	.1924E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2041E+01	.2327E+01	8.661E+05	3.028E+06	6.604E+06	.2184E+01
.2327E+01	.2639E+01	8.170E+05	2.619E+06	6.493E+06	.2483E+01
.2639E+01	.3003E+01	7.287E+05	2.002E+06	5.639E+06	.2821E+01
.3003E+01	.3419E+01	6.558E+05	1.576E+06	5.055E+06	.3211E+01
.3419E+01	.3861E+01	5.048E+05	1.142E+06	4.152E+06	.3640E+01
.3861E+01	.4407E+01	4.890E+05	8.957E+05	3.697E+06	.4134E+01
.4407E+01	.5000E+01	3.929E+05	6.625E+05	3.112E+06	.4703E+01
.5000E+01	.5500E+01	2.344E+05	4.688E+05	2.459E+06	.5250E+01
.5500E+01	.6000E+01	1.736E+05	3.472E+05	1.995E+06	.5750E+01
.6000E+01	.6500E+01	1.280E+05	2.560E+05	1.599E+06	.6250E+01
.6500E+01	.7000E+01	9.394E+04	1.879E+05	1.268E+06	.6750E+01
.7000E+01	.7500E+01	6.875E+04	1.375E+05	9.965E+05	.7250E+01
.7500E+01	.8000E+01	5.012E+04	1.002E+05	7.767E+05	.7750E+01
.8000E+01	.8500E+01	3.646E+04	7.293E+04	6.015E+05	.8250E+01
.8500E+01	.9000E+01	2.647E+04	5.294E+04	4.631E+05	.8750E+01
.9000E+01	.9500E+01	1.919E+04	3.837E+04	3.549E+05	.9250E+01
.9500E+01	.1000E+02	1.391E+04	2.782E+04	2.712E+05	.9750E+01

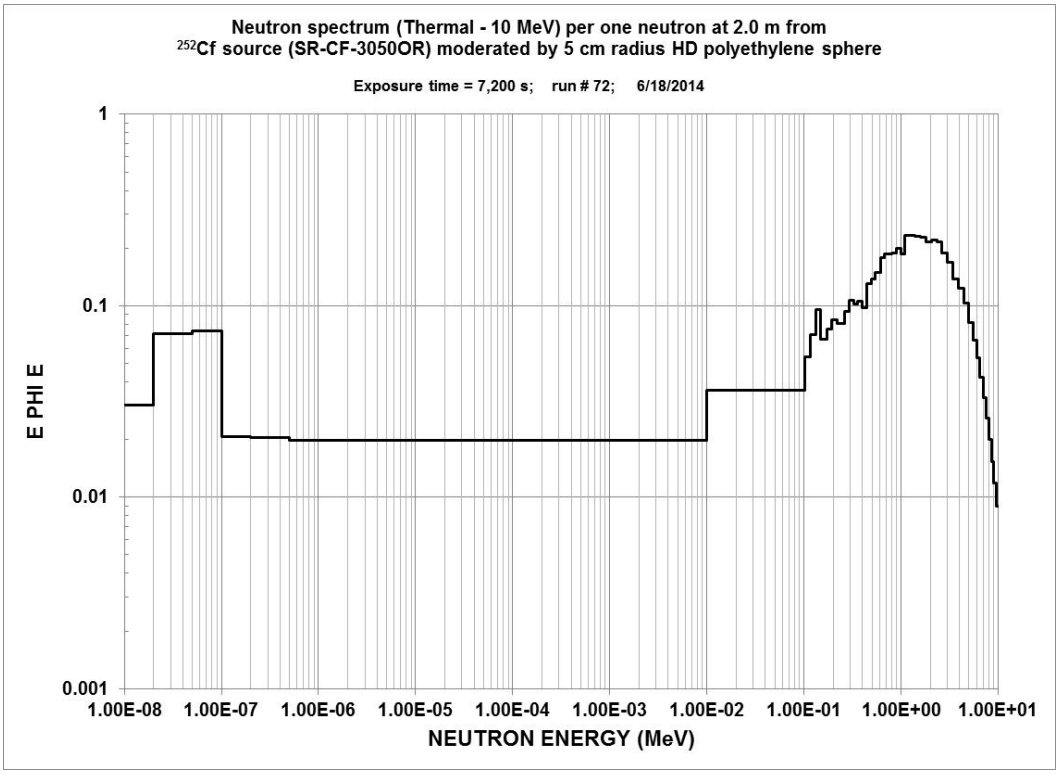
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



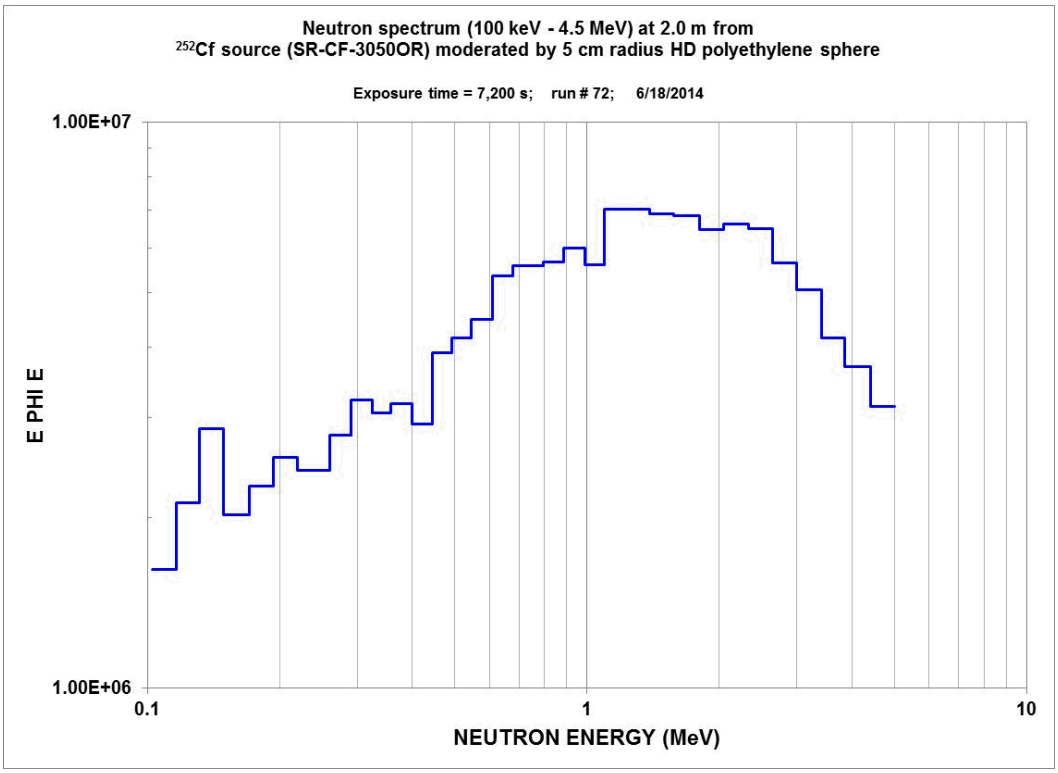


Figure K-1. Neutron spectra at 2.0 m from ^{252}Cf moderated by 5 cm of polyethylene

Fluence, spectral and dosimetric data at 2.5 m from ^{252}Cf moderated by 5 cm of polyethylene

Table K-3. Neutron fluence and dosimetric data at 2.5 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date:	6/18/2014
Exposure time:	7,200 s
Run #	N73

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.25E+07	1.74E+03
Epi-thermal region	:	7.54E+06	1.05E+03
Thermal region	:	4.47E+06	6.21E+02
Thermal – 4.5 MeV	:	2.45E+07	3.41E+03
Thermal – 10.0 MeV	:	2.5053E+07	3.4795E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	2.96E-02	4.40E-03	1.48E+01	2.20E+03
Epi-thermal region	:	8.30E-04	1.38E-04	4.15E-01	6.88E+01
Thermal region	:	8.95E-05	4.74E-05	4.47E-02	2.37E+01
Thermal – 4.5 MeV	:	3.05E-02	4.58E-03	1.53E+01	2.29E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	3.2200E-02 rads	1.6100E+01 mrads/hr
H*(10) ICRP-74	=	6.5921E-03 Sv	2.3747E+03 uSv/hr
Hp(10,0) ICRP-74	=	6.8292E-03 Sv	3.4146E+03 uSv/hr

Table K-4. Neutron fluence at 2.5 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date: 6/18/2014
Exposure time: 7,200 s
Run number: N73

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	1.099E+04	1.099E+13	1.586E+04	.1500E-08
.2000E-08	.5000E-08	7.051E+04	2.350E+13	7.696E+04	.3500E-08
.5000E-08	.1000E-07	2.145E+05	4.289E+13	3.094E+05	.7500E-08
.1000E-07	.2000E-07	6.322E+05	6.322E+13	9.121E+05	.1500E-07
.2000E-07	.5000E-07	1.960E+06	6.533E+13	2.139E+06	.3500E-07
.5000E-07	.1000E-06	1.532E+06	3.064E+13	2.210E+06	.7500E-07
.1000E-06	.2000E-06	4.309E+05	4.309E+12	6.216E+05	.1500E-06
.2000E-06	.5000E-06	5.625E+05	1.875E+12	6.139E+05	.3500E-06
.5000E-06	.1000E-01	5.921E+06	5.921E+08	5.979E+05	.5000E-02
.1000E-01	.1027E+00	2.530E+06	2.729E+07	1.086E+06	.5635E-01
.1027E+00	.1166E+00	2.053E+05	1.481E+07	1.622E+06	.1096E+00
.1166E+00	.1317E+00	2.586E+05	1.710E+07	2.120E+06	.1241E+00
.1317E+00	.1493E+00	3.605E+05	2.044E+07	2.867E+06	.1405E+00
.1493E+00	.1707E+00	2.706E+05	1.263E+07	2.019E+06	.1600E+00
.1707E+00	.1934E+00	2.836E+05	1.251E+07	2.274E+06	.1821E+00
.1934E+00	.2199E+00	3.271E+05	1.236E+07	2.551E+06	.2066E+00
.2199E+00	.2606E+00	4.125E+05	1.012E+07	2.426E+06	.2402E+00
.2606E+00	.2906E+00	3.047E+05	1.016E+07	2.797E+06	.2756E+00
.2906E+00	.3244E+00	3.542E+05	1.049E+07	3.224E+06	.3075E+00
.3244E+00	.3581E+00	3.027E+05	8.969E+06	3.058E+06	.3413E+00
.3581E+00	.3994E+00	3.471E+05	8.415E+06	3.184E+06	.3787E+00
.3994E+00	.4444E+00	3.127E+05	6.950E+06	2.929E+06	.4219E+00
.4444E+00	.4931E+00	4.072E+05	8.353E+06	3.912E+06	.4688E+00
.4931E+00	.5456E+00	4.200E+05	8.001E+06	4.152E+06	.5194E+00
.5456E+00	.6094E+00	4.951E+05	7.766E+06	4.480E+06	.5775E+00
.6094E+00	.6769E+00	5.622E+05	8.329E+06	5.352E+06	.6431E+00
.6769E+00	.7946E+00	8.956E+05	7.605E+06	5.584E+06	.7358E+00
.7946E+00	.8870E+00	6.236E+05	6.749E+06	5.669E+06	.8408E+00
.8870E+00	.9871E+00	6.409E+05	6.403E+06	5.994E+06	.9371E+00
.9871E+00	.1095E+01	5.791E+05	5.372E+06	5.588E+06	.1041E+01
.1095E+01	.1218E+01	7.475E+05	6.067E+06	7.010E+06	.1157E+01
.1218E+01	.1391E+01	9.309E+05	5.385E+06	7.015E+06	.1305E+01
.1391E+01	.1573E+01	8.474E+05	4.656E+06	6.891E+06	.1482E+01
.1573E+01	.1807E+01	9.490E+05	4.055E+06	6.843E+06	.1690E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.1807E+01	.2041E+01	7.850E+05	3.355E+06	6.447E+06	.1924E+01
.2041E+01	.2327E+01	8.661E+05	3.028E+06	6.604E+06	.2184E+01
.2327E+01	.2639E+01	8.170E+05	2.619E+06	6.493E+06	.2483E+01
.2639E+01	.3003E+01	7.287E+05	2.002E+06	5.639E+06	.2821E+01
.3003E+01	.3419E+01	6.558E+05	1.576E+06	5.055E+06	.3211E+01
.3419E+01	.3861E+01	5.048E+05	1.142E+06	4.152E+06	.3640E+01
.3861E+01	.4407E+01	4.890E+05	8.957E+05	3.697E+06	.4134E+01
.4407E+01	.5000E+01	3.929E+05	6.625E+05	3.112E+06	.4703E+01
.5000E+01	.5500E+01	2.344E+05	4.688E+05	2.459E+06	.5250E+01
.5500E+01	.6000E+01	1.736E+05	3.472E+05	1.995E+06	.5750E+01
.6000E+01	.6500E+01	1.280E+05	2.560E+05	1.599E+06	.6250E+01
.6500E+01	.7000E+01	9.394E+04	1.879E+05	1.268E+06	.6750E+01
.7000E+01	.7500E+01	6.875E+04	1.375E+05	9.965E+05	.7250E+01
.7500E+01	.8000E+01	5.012E+04	1.002E+05	7.767E+05	.7750E+01
.8000E+01	.8500E+01	3.646E+04	7.293E+04	6.015E+05	.8250E+01
.8500E+01	.9000E+01	2.647E+04	5.294E+04	4.631E+05	.8750E+01
.9000E+01	.9500E+01	1.919E+04	3.837E+04	3.549E+05	.9250E+01
.9500E+01	.1000E+02	1.391E+04	2.782E+04	2.712E+05	.9750E+01

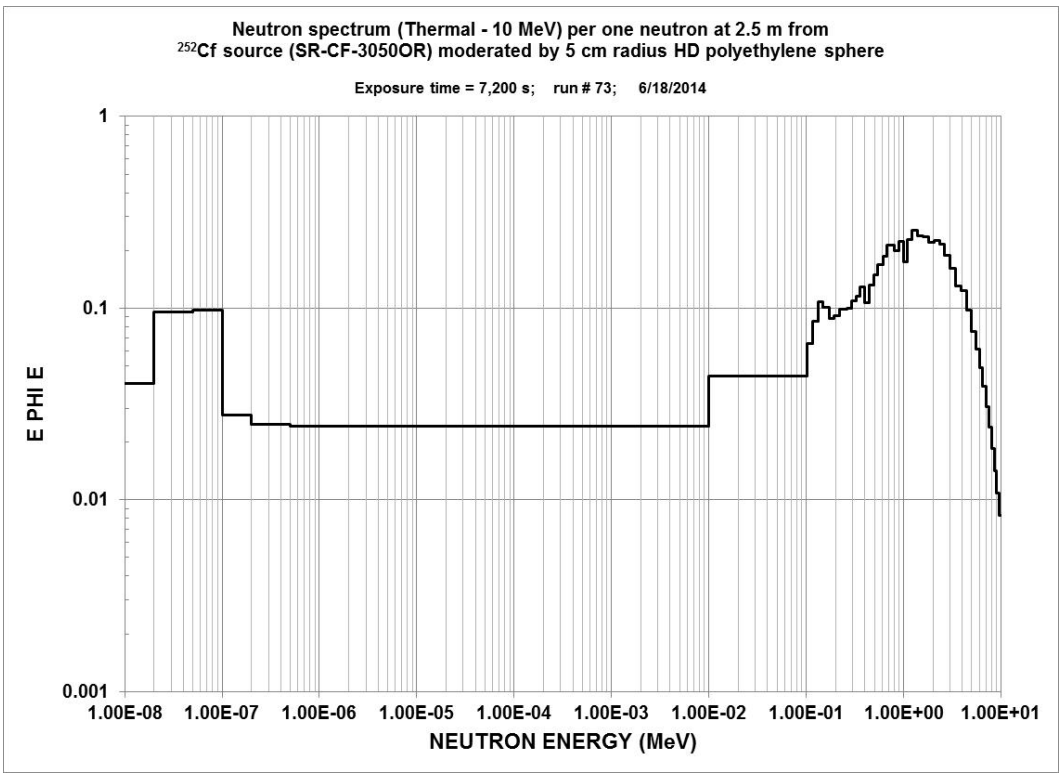
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



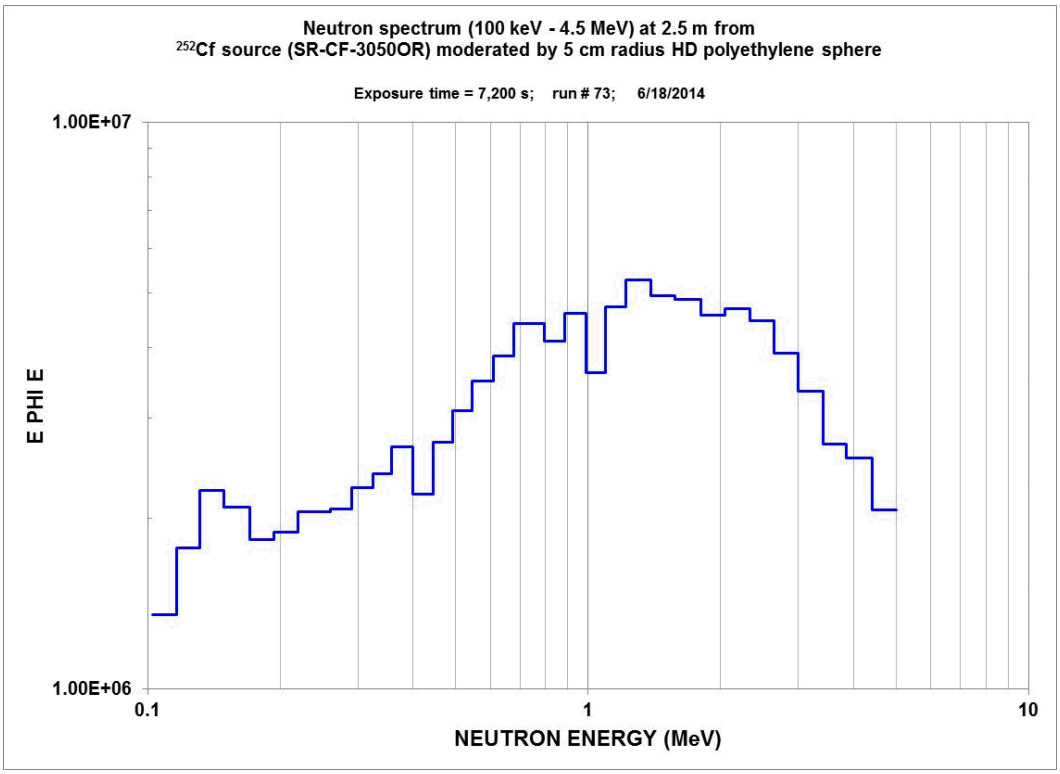


Figure K-2. Neutron spectra at 2.5 m from ^{252}Cf moderated by 5 cm of polyethylene

Fluence, spectral and dosimetric data at 3.0 m from ^{252}Cf moderated by 5 cm of polyethylene

Table K-5. Neutron fluence and dosimetric data at 3.0 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date:	6/19/2014
Exposure time:	7,200 s
Run #	N74

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	9.78E+06	1.36E+03
Epi-thermal region	:	7.15E+06	9.93E+02
Thermal region	:	4.23E+06	5.88E+02
Thermal – 4.5 MeV	:	2.12E+07	2.94E+03
Thermal – 10.0 MeV	:	2.1567E+07	2.9954E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	2.26E-02	3.40E-03	1.13E+01	1.70E+03
Epi-thermal region	:	7.57E-04	1.28E-04	3.79E-01	6.40E+01
Thermal region	:	8.47E-05	4.49E-05	4.23E-02	2.24E+01
Thermal – 4.5 MeV	:	2.35E-02	3.58E-03	1.17E+01	1.79E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.4714E-02 rads	1.2357E+01 mrads/hr
H*(10) ICRP-74	=	3.6946E-03 Sv	1.8473E+03 uSv/hr
Hp(10,0) ICRP-74	=	3.8264E-03 Sv	1.9132E+03 uSv/hr

Table K-6. Neutron fluence at 3.0 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date: 6/19/2014
Exposure time: 7,200 s
Run number: N74

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	9.569E+03	9.569E+12	1.381E+04	.1500E-08
.2000E-08	.5000E-08	6.139E+04	2.046E+13	6.700E+04	.3500E-08
.5000E-08	.1000E-07	1.867E+05	3.734E+13	2.694E+05	.7500E-08
.1000E-07	.2000E-07	5.504E+05	5.504E+13	7.941E+05	.1500E-07
.2000E-07	.5000E-07	1.706E+06	5.688E+13	1.862E+06	.3500E-07
.5000E-07	.1000E-06	1.334E+06	2.667E+13	1.924E+06	.7500E-07
.1000E-06	.2000E-06	3.751E+05	3.751E+12	5.412E+05	.1500E-06
.2000E-06	.5000E-06	4.548E+05	1.516E+12	4.964E+05	.3500E-06
.5000E-06	.1000E-01	4.778E+06	4.778E+08	4.824E+05	.5000E-02
.1000E-01	.1027E+00	1.933E+06	2.085E+07	8.298E+05	.5635E-01
.1027E+00	.1166E+00	1.442E+05	1.040E+07	1.139E+06	.1096E+00
.1166E+00	.1317E+00	2.325E+05	1.538E+07	1.906E+06	.1241E+00
.1317E+00	.1493E+00	1.920E+05	1.089E+07	1.527E+06	.1405E+00
.1493E+00	.1707E+00	2.253E+05	1.052E+07	1.681E+06	.1600E+00
.1707E+00	.1934E+00	1.901E+05	8.383E+06	1.524E+06	.1821E+00
.1934E+00	.2199E+00	1.888E+05	7.136E+06	1.473E+06	.2066E+00
.2199E+00	.2606E+00	2.974E+05	7.298E+06	1.749E+06	.2402E+00
.2606E+00	.2906E+00	2.096E+05	6.987E+06	1.924E+06	.2756E+00
.2906E+00	.3244E+00	1.932E+05	5.726E+06	1.759E+06	.3075E+00
.3244E+00	.3581E+00	2.132E+05	6.318E+06	2.154E+06	.3413E+00
.3581E+00	.3994E+00	1.916E+05	4.645E+06	1.758E+06	.3787E+00
.3994E+00	.4444E+00	2.080E+05	4.623E+06	1.949E+06	.4219E+00
.4444E+00	.4931E+00	2.319E+05	4.756E+06	2.228E+06	.4688E+00
.4931E+00	.5456E+00	2.769E+05	5.274E+06	2.737E+06	.5194E+00
.5456E+00	.6094E+00	3.322E+05	5.210E+06	3.006E+06	.5775E+00
.6094E+00	.6769E+00	2.975E+05	4.407E+06	2.832E+06	.6431E+00
.6769E+00	.7946E+00	5.501E+05	4.671E+06	3.429E+06	.7358E+00
.7946E+00	.8870E+00	3.945E+05	4.269E+06	3.586E+06	.8408E+00
.8870E+00	.9871E+00	3.783E+05	3.779E+06	3.538E+06	.9371E+00
.9871E+00	.1095E+01	3.271E+05	3.035E+06	3.156E+06	.1041E+01
.1095E+01	.1218E+01	3.693E+05	2.998E+06	3.464E+06	.1157E+01
.1218E+01	.1391E+01	5.426E+05	3.139E+06	4.089E+06	.1305E+01
.1391E+01	.1573E+01	4.609E+05	2.532E+06	3.748E+06	.1482E+01
.1573E+01	.1807E+01	5.094E+05	2.177E+06	3.673E+06	.1690E+01
.1807E+01	.2041E+01	4.121E+05	1.761E+06	3.384E+06	.1924E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2041E+01	.2327E+01	4.555E+05	1.593E+06	3.474E+06	.2184E+01
.2327E+01	.2639E+01	4.208E+05	1.349E+06	3.344E+06	.2483E+01
.2639E+01	.3003E+01	3.603E+05	9.898E+05	2.788E+06	.2821E+01
.3003E+01	.3419E+01	3.226E+05	7.754E+05	2.486E+06	.3211E+01
.3419E+01	.3861E+01	2.429E+05	5.496E+05	1.998E+06	.3640E+01
.3861E+01	.4407E+01	2.357E+05	4.317E+05	1.782E+06	.4134E+01
.4407E+01	.5000E+01	1.785E+05	3.011E+05	1.414E+06	.4703E+01
.5000E+01	.5500E+01	1.090E+05	2.180E+05	1.144E+06	.5250E+01
.5500E+01	.6000E+01	8.072E+04	1.614E+05	9.277E+05	.5750E+01
.6000E+01	.6500E+01	5.951E+04	1.190E+05	7.435E+05	.6250E+01
.6500E+01	.7000E+01	4.368E+04	8.736E+04	5.894E+05	.6750E+01
.7000E+01	.7500E+01	3.197E+04	6.393E+04	4.633E+05	.7250E+01
.7500E+01	.8000E+01	2.331E+04	4.661E+04	3.611E+05	.7750E+01
.8000E+01	.8500E+01	1.695E+04	3.391E+04	2.797E+05	.8250E+01
.8500E+01	.9000E+01	1.231E+04	2.461E+04	2.153E+05	.8750E+01
.9000E+01	.9500E+01	8.921E+03	1.784E+04	1.650E+05	.9250E+01
.9500E+01	.1000E+02	6.467E+03	1.293E+04	1.261E+05	.9750E+01

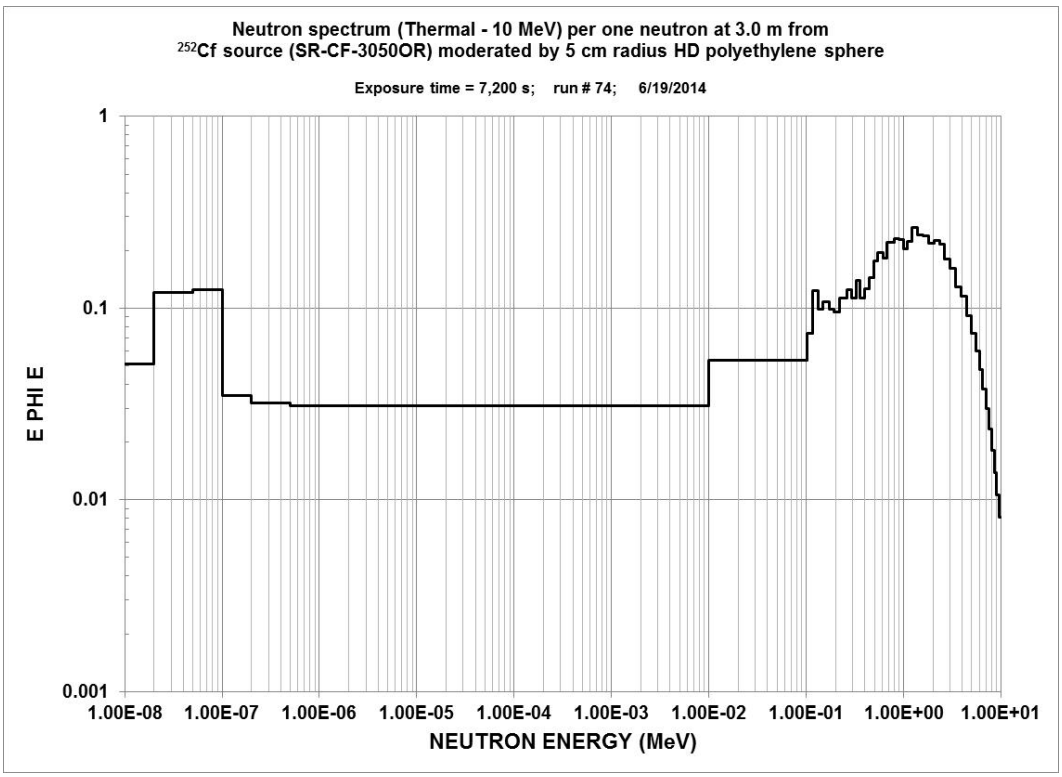
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



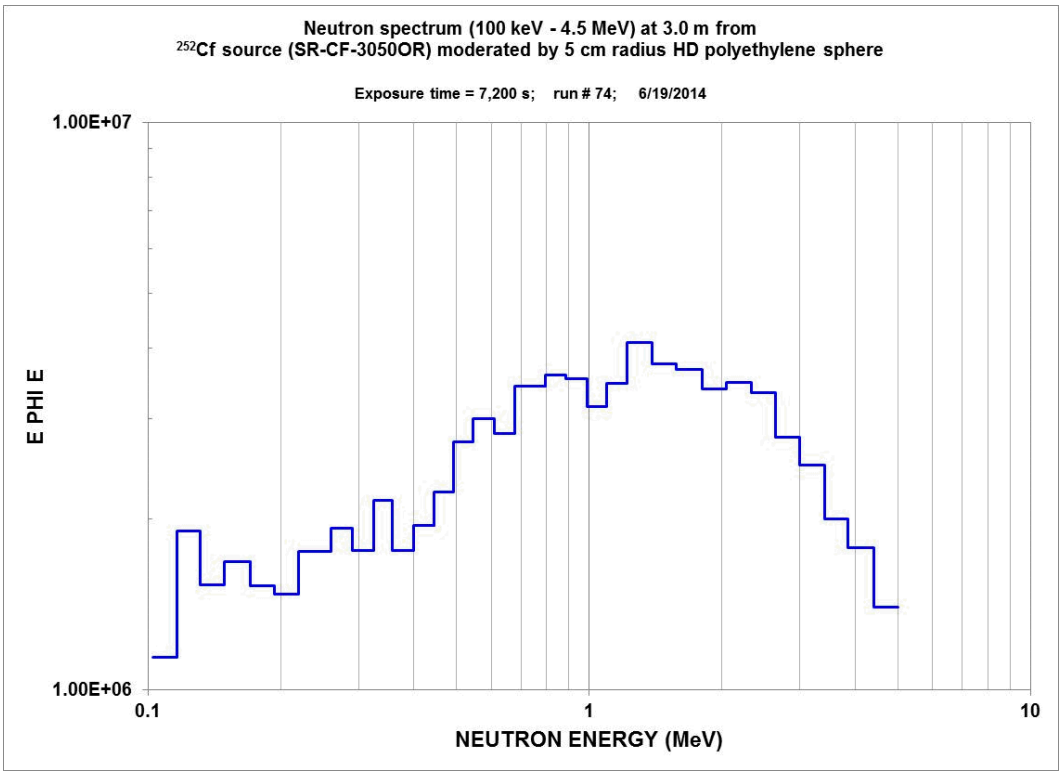


Figure K-3. Neutron spectra at 3.0 m from ^{252}Cf moderated by 5 cm of polyethylene

Fluence, spectral and dosimetric data at 3.5 m from ^{252}Cf moderated by 5 cm of polyethylene

Table K-7. Neutron fluence and dosimetric data at 3.5 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date:	6/19/2014
Exposure time:	7,200 s
Run #	N75

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	8.16E+06	1.13E+03
Epi-thermal region	:	6.77E+06	9.40E+02
Thermal region	:	4.08E+06	5.66E+02
Thermal – 4.5 MeV	:	1.90E+07	2.64E+03
Thermal – 10.0 MeV	:	1.9282E+07	2.6781E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.85E-02	2.81E-03	9.24E+00	1.40E+03
Epi-thermal region	:	7.01E-04	1.20E-04	3.51E-01	5.99E+01
Thermal region	:	8.16E-05	4.32E-05	4.08E-02	2.16E+01
Thermal – 4.5 MeV	:	1.93E-02	2.97E-03	9.63E+00	1.48E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.0028E-02 rads	1.0014E+01 mrads/hr
H*(10) ICRP-74	=	3.0418E-03 Sv	1.5209E+03 uSv/hr
Hp(10,0) ICRP-74	=	3.1493E-03 Sv	1.5746E+03 uSv/hr

Table K-8. Neutron fluence at 3.5 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date: 6/19/2014
Exposure time: 7,200 s
Run number: N75

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	9.218E+03	9.218E+12	1.330E+04	.1500E-08
.2000E-08	.5000E-08	5.914E+04	1.971E+13	6.454E+04	.3500E-08
.5000E-08	.1000E-07	1.799E+05	3.597E+13	2.595E+05	.7500E-08
.1000E-07	.2000E-07	5.302E+05	5.302E+13	7.650E+05	.1500E-07
.2000E-07	.5000E-07	1.644E+06	5.479E+13	1.794E+06	.3500E-07
.5000E-07	.1000E-06	1.285E+06	2.570E+13	1.854E+06	.7500E-07
.1000E-06	.2000E-06	3.614E+05	3.614E+12	5.214E+05	.1500E-06
.2000E-06	.5000E-06	4.344E+05	1.448E+12	4.741E+05	.3500E-06
.5000E-06	.1000E-01	4.562E+06	4.562E+08	4.606E+05	.5000E-02
.1000E-01	.1027E+00	1.784E+06	1.924E+07	7.658E+05	.5635E-01
.1027E+00	.1166E+00	1.702E+05	1.228E+07	1.344E+06	.1096E+00
.1166E+00	.1317E+00	1.198E+05	7.926E+06	9.824E+05	.1241E+00
.1317E+00	.1493E+00	2.108E+05	1.195E+07	1.677E+06	.1405E+00
.1493E+00	.1707E+00	2.477E+05	1.156E+07	1.848E+06	.1600E+00
.1707E+00	.1934E+00	1.368E+05	6.031E+06	1.097E+06	.1821E+00
.1934E+00	.2199E+00	1.633E+05	6.173E+06	1.274E+06	.2066E+00
.2199E+00	.2606E+00	2.810E+05	6.895E+06	1.653E+06	.2402E+00
.2606E+00	.2906E+00	1.827E+05	6.090E+06	1.677E+06	.2756E+00
.2906E+00	.3244E+00	1.621E+05	4.803E+06	1.476E+06	.3075E+00
.3244E+00	.3581E+00	1.891E+05	5.603E+06	1.911E+06	.3413E+00
.3581E+00	.3994E+00	1.732E+05	4.199E+06	1.589E+06	.3787E+00
.3994E+00	.4444E+00	1.810E+05	4.022E+06	1.695E+06	.4219E+00
.4444E+00	.4931E+00	2.045E+05	4.194E+06	1.964E+06	.4688E+00
.4931E+00	.5456E+00	1.948E+05	3.711E+06	1.926E+06	.5194E+00
.5456E+00	.6094E+00	2.776E+05	4.355E+06	2.513E+06	.5775E+00
.6094E+00	.6769E+00	3.059E+05	4.532E+06	2.912E+06	.6431E+00
.6769E+00	.7946E+00	4.623E+05	3.926E+06	2.882E+06	.7358E+00
.7946E+00	.8870E+00	3.413E+05	3.693E+06	3.102E+06	.8408E+00
.8870E+00	.9871E+00	2.893E+05	2.890E+06	2.706E+06	.9371E+00
.9871E+00	.1095E+01	2.745E+05	2.546E+06	2.649E+06	.1041E+01
.1095E+01	.1218E+01	3.080E+05	2.500E+06	2.889E+06	.1157E+01
.1218E+01	.1391E+01	4.693E+05	2.715E+06	3.537E+06	.1305E+01
.1391E+01	.1573E+01	3.692E+05	2.028E+06	3.002E+06	.1482E+01
.1573E+01	.1807E+01	4.011E+05	1.714E+06	2.892E+06	.1690E+01
.1807E+01	.2041E+01	3.240E+05	1.385E+06	2.661E+06	.1924E+01
.2041E+01	.2327E+01	3.532E+05	1.235E+06	2.693E+06	.2184E+01
.2327E+01	.2639E+01	3.424E+05	1.098E+06	2.722E+06	.2483E+01
.2639E+01	.3003E+01	2.738E+05	7.522E+05	2.119E+06	.2821E+01
.3003E+01	.3419E+01	2.487E+05	5.978E+05	1.917E+06	.3211E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.3419E+01	.3861E+01	1.969E+05	4.455E+05	1.620E+06	.3640E+01
.3861E+01	.4407E+01	1.686E+05	3.087E+05	1.275E+06	.4134E+01
.4407E+01	.5000E+01	1.335E+05	2.251E+05	1.057E+06	.4703E+01
.5000E+01	.5500E+01	7.696E+04	1.539E+05	8.074E+05	.5250E+01
.5500E+01	.6000E+01	5.699E+04	1.140E+05	6.550E+05	.5750E+01
.6000E+01	.6500E+01	4.202E+04	8.404E+04	5.250E+05	.6250E+01
.6500E+01	.7000E+01	3.084E+04	6.168E+04	4.162E+05	.6750E+01
.7000E+01	.7500E+01	2.257E+04	4.514E+04	3.271E+05	.7250E+01
.7500E+01	.8000E+01	1.646E+04	3.291E+04	2.550E+05	.7750E+01
.8000E+01	.8500E+01	1.197E+04	2.394E+04	1.975E+05	.8250E+01
.8500E+01	.9000E+01	8.690E+03	1.738E+04	1.520E+05	.8750E+01
.9000E+01	.9500E+01	6.299E+03	1.260E+04	1.165E+05	.9250E+01
.9500E+01	.1000E+02	4.566E+03	9.132E+03	8.902E+04	.9750E+01

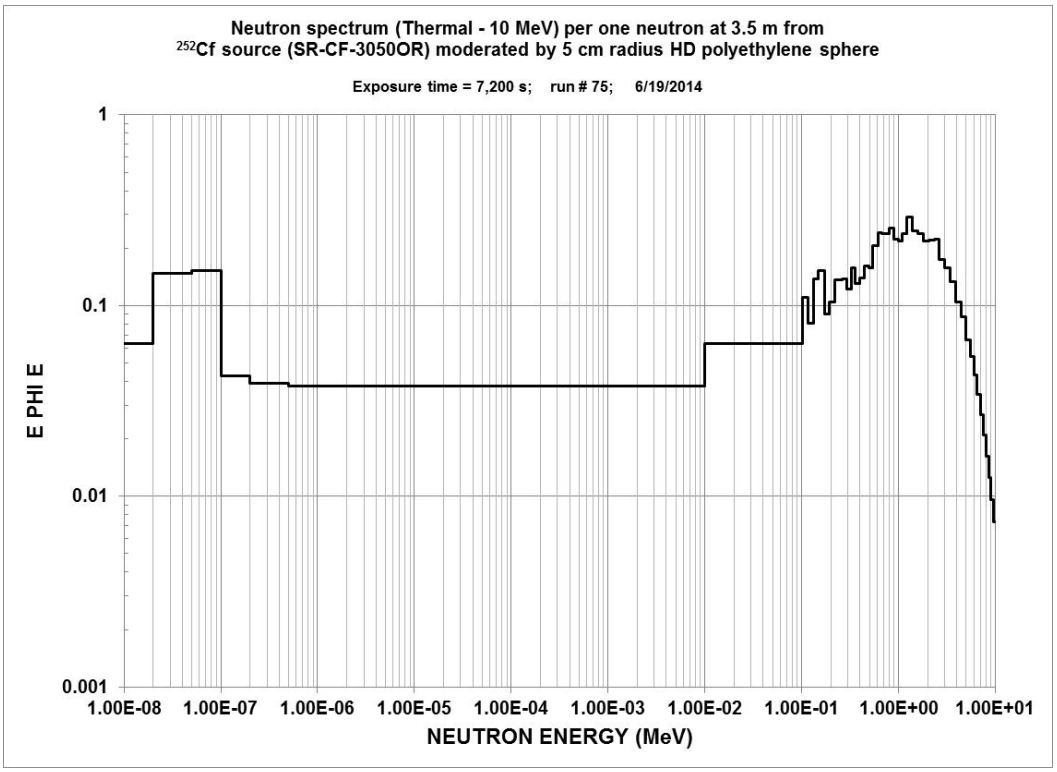
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



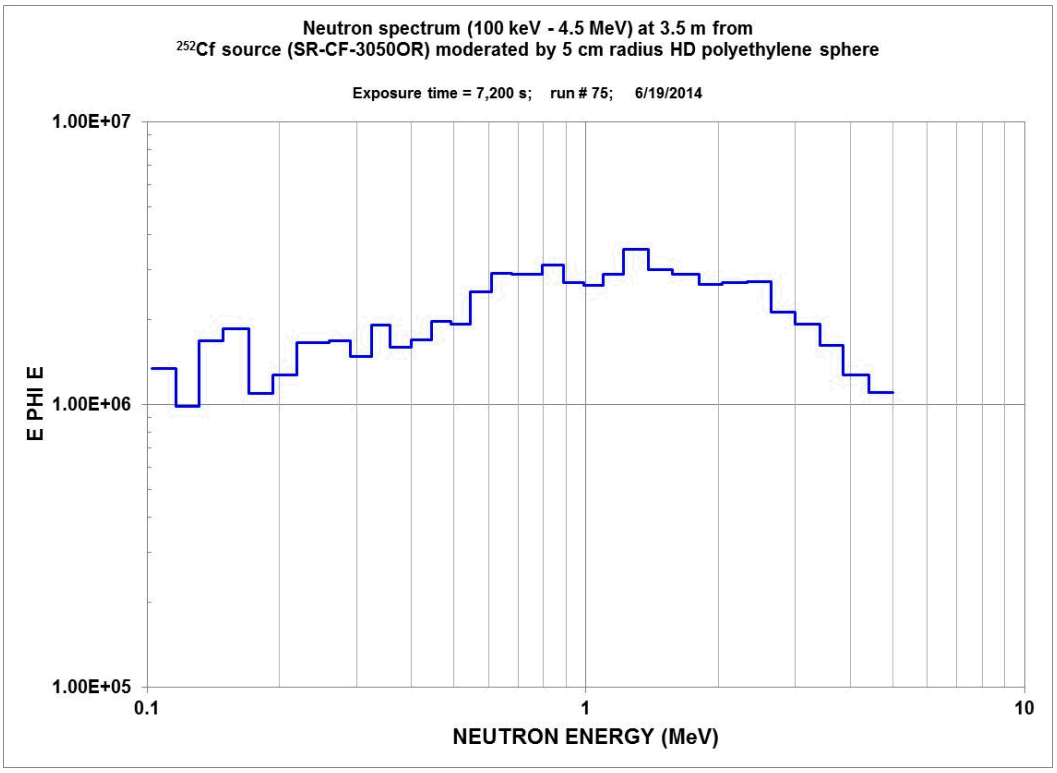


Figure K-4. Neutron spectra at 3.5 m from ^{252}Cf moderated by 5 cm of polyethylene

Fluence, spectral and dosimetric data at 4.0 m from ^{252}Cf moderated by 5 cm of polyethylene

Table K-9. Neutron fluence and dosimetric data at 4.0 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date:	6/19/2014
Exposure time:	7,200 s
Run #	N76

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	6.93E+06	9.62E+02
Epi-thermal region	:	6.33E+06	8.80E+02
Thermal region	:	3.99E+06	5.54E+02
Thermal – 4.5 MeV	:	1.72E+07	2.40E+03
Thermal – 10.0 MeV	:	1.7455E+07	2.4243E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.55E-02	2.36E-03	7.74E+00	1.18E+03
Epi-thermal region	:	6.43E-04	1.11E-04	3.22E-01	5.55E+01
Thermal region	:	7.97E-05	4.23E-05	3.99E-02	2.11E+01
Thermal – 4.5 MeV	:	1.62E-02	2.52E-03	8.10E+00	1.26E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.6733E-02 rads	8.3667E+00 mrads/hr
H*(10) ICRP-74	=	2.5670E-03 Sv	1.2835E+03 uSv/hr
Hp(10,0) ICRP-74	=	2.6580E-03 Sv	1.3290E+03 uSv/hr

Table K-10. Neutron fluence at 4.0 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date: 6/19/2014
Exposure time: 7,200 s
Run number: N76

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	9.012E+03	9.012E+12	1.300E+04	.1500E-08
.2000E-08	.5000E-08	5.782E+04	1.927E+13	6.310E+04	.3500E-08
.5000E-08	.1000E-07	1.758E+05	3.517E+13	2.537E+05	.7500E-08
.1000E-07	.2000E-07	5.184E+05	5.184E+13	7.478E+05	.1500E-07
.2000E-07	.5000E-07	1.607E+06	5.356E+13	1.754E+06	.3500E-07
.5000E-07	.1000E-06	1.256E+06	2.512E+13	1.812E+06	.7500E-07
.1000E-06	.2000E-06	3.533E+05	3.533E+12	5.097E+05	.1500E-06
.2000E-06	.5000E-06	4.102E+05	1.367E+12	4.476E+05	.3500E-06
.5000E-06	.1000E-01	4.303E+06	4.303E+08	4.345E+05	.5000E-02
.1000E-01	.1027E+00	1.632E+06	1.761E+07	7.006E+05	.5635E-01
.1027E+00	.1166E+00	1.246E+05	8.992E+06	9.844E+05	.1096E+00
.1166E+00	.1317E+00	1.410E+05	9.328E+06	1.156E+06	.1241E+00
.1317E+00	.1493E+00	1.817E+05	1.030E+07	1.445E+06	.1405E+00
.1493E+00	.1707E+00	1.693E+05	7.902E+06	1.263E+06	.1600E+00
.1707E+00	.1934E+00	1.306E+05	5.758E+06	1.047E+06	.1821E+00
.1934E+00	.2199E+00	1.753E+05	6.626E+06	1.367E+06	.2066E+00
.2199E+00	.2606E+00	2.465E+05	6.049E+06	1.450E+06	.2402E+00
.2606E+00	.2906E+00	1.584E+05	5.279E+06	1.454E+06	.2756E+00
.2906E+00	.3244E+00	1.863E+05	5.519E+06	1.695E+06	.3075E+00
.3244E+00	.3581E+00	1.297E+05	3.844E+06	1.311E+06	.3413E+00
.3581E+00	.3994E+00	1.642E+05	3.981E+06	1.506E+06	.3787E+00
.3994E+00	.4444E+00	1.291E+05	2.870E+06	1.210E+06	.4219E+00
.4444E+00	.4931E+00	1.892E+05	3.881E+06	1.818E+06	.4688E+00
.4931E+00	.5456E+00	1.886E+05	3.593E+06	1.864E+06	.5194E+00
.5456E+00	.6094E+00	2.300E+05	3.608E+06	2.081E+06	.5775E+00
.6094E+00	.6769E+00	2.436E+05	3.609E+06	2.319E+06	.6431E+00
.6769E+00	.7946E+00	4.409E+05	3.744E+06	2.749E+06	.7358E+00
.7946E+00	.8870E+00	2.887E+05	3.124E+06	2.625E+06	.8408E+00
.8870E+00	.9871E+00	2.625E+05	2.623E+06	2.455E+06	.9371E+00
.9871E+00	.1095E+01	2.017E+05	1.871E+06	1.946E+06	.1041E+01
.1095E+01	.1218E+01	3.021E+05	2.452E+06	2.833E+06	.1157E+01
.1218E+01	.1391E+01	3.258E+05	1.885E+06	2.455E+06	.1305E+01
.1391E+01	.1573E+01	3.071E+05	1.687E+06	2.498E+06	.1482E+01
.1573E+01	.1807E+01	3.308E+05	1.414E+06	2.385E+06	.1690E+01
.1807E+01	.2041E+01	2.608E+05	1.115E+06	2.142E+06	.1924E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2041E+01	.2327E+01	2.934E+05	1.026E+06	2.237E+06	.2184E+01
.2327E+01	.2639E+01	2.757E+05	8.835E+05	2.191E+06	.2483E+01
.2639E+01	.3003E+01	2.432E+05	6.682E+05	1.882E+06	.2821E+01
.3003E+01	.3419E+01	2.018E+05	4.852E+05	1.556E+06	.3211E+01
.3419E+01	.3861E+01	1.502E+05	3.397E+05	1.235E+06	.3640E+01
.3861E+01	.4407E+01	1.384E+05	2.535E+05	1.047E+06	.4134E+01
.4407E+01	.5000E+01	1.074E+05	1.811E+05	8.509E+05	.4703E+01
.5000E+01	.5500E+01	5.933E+04	1.187E+05	6.225E+05	.5250E+01
.5500E+01	.6000E+01	4.394E+04	8.788E+04	5.050E+05	.5750E+01
.6000E+01	.6500E+01	3.239E+04	6.479E+04	4.047E+05	.6250E+01
.6500E+01	.7000E+01	2.378E+04	4.755E+04	3.208E+05	.6750E+01
.7000E+01	.7500E+01	1.740E+04	3.480E+04	2.522E+05	.7250E+01
.7500E+01	.8000E+01	1.269E+04	2.537E+04	1.966E+05	.7750E+01
.8000E+01	.8500E+01	9.229E+03	1.846E+04	1.522E+05	.8250E+01
.8500E+01	.9000E+01	6.699E+03	1.340E+04	1.172E+05	.8750E+01
.9000E+01	.9500E+01	4.856E+03	9.712E+03	8.981E+04	.9250E+01
.9500E+01	.1000E+02	3.520E+03	7.041E+03	6.863E+04	.9750E+01

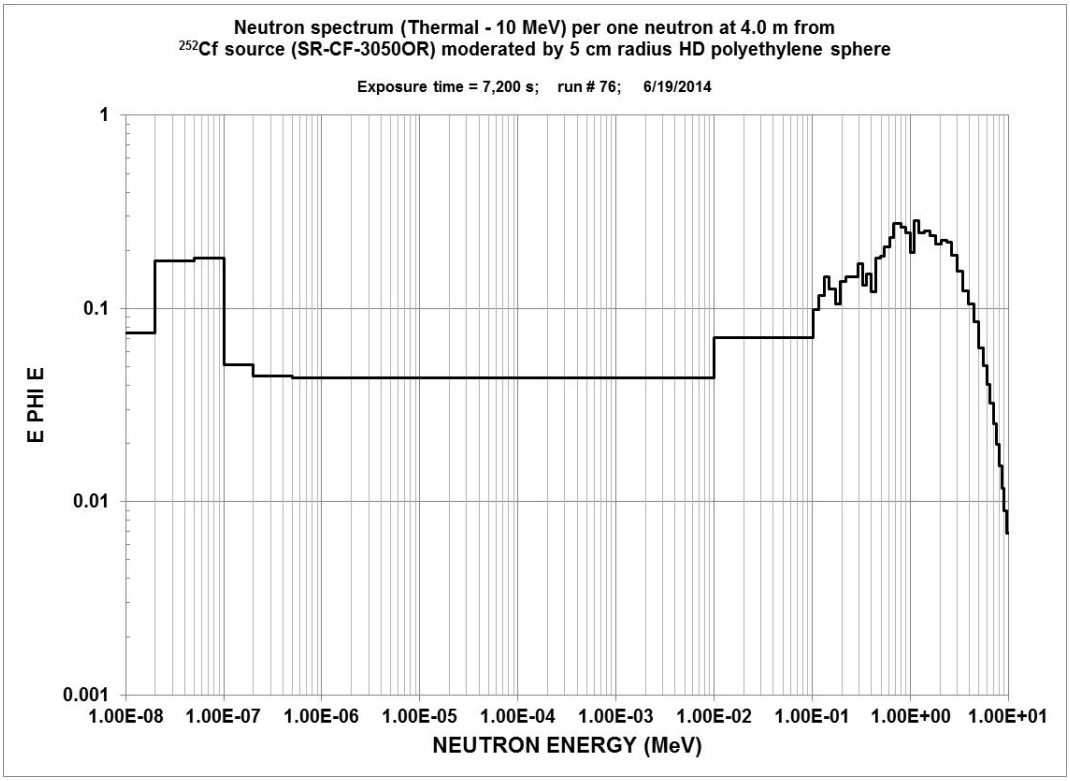
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



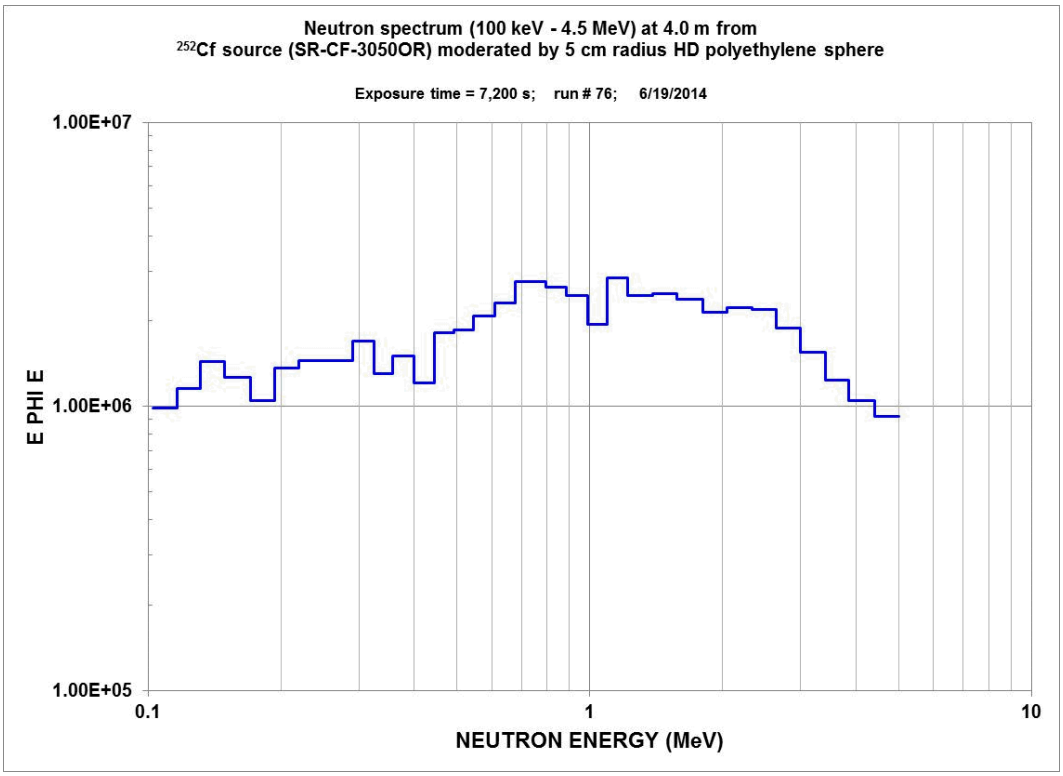


Figure K-5. Neutron spectra at 4.0 m from ^{252}Cf moderated by 5 cm of polyethylene

Fluence, spectral and dosimetric data at 4.5 m from ^{252}Cf moderated by 5 cm of polyethylene

Table K-11. Neutron fluence and dosimetric data at 4.5 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date:	6/19/2014
Exposure time:	7,200 s
Run #	N77

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	6.24E+06	8.67E+02
Epi-thermal region	:	6.18E+06	8.59E+02
Thermal region	:	3.90E+06	5.42E+02
Thermal – 4.5 MeV	:	1.63E+07	2.27E+03
Thermal – 10.0 MeV	:	1.6497E+07	2.2912E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.36E-02	2.10E-03	6.82E+00	1.05E+03
Epi-thermal region	:	6.38E-04	1.09E-04	3.19E-01	5.46E+01
Thermal region	:	7.81E-05	4.14E-05	3.90E-02	2.07E+01
Thermal – 4.5 MeV	:	1.43E-02	2.25E-03	7.17E+00	1.12E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	1.4761E-02 rads	7.3803E+00 mrads/hr
H*(10) ICRP-74	=	2.2866E-03 Sv	1.1433E+03 uSv/hr
Hp(10,0) ICRP-74	=	2.3675E-03 Sv	1.1837E+03 uSv/hr

Table K-12. Neutron fluence at 4.5 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 5 cm of polyethylene

Date: 6/19/2014
Exposure time: 7,200 s
Run number: N77

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	8.824E+03	8.824E+12	1.273E+04	.1500E-08
.2000E-08	.5000E-08	5.662E+04	1.887E+13	6.179E+04	.3500E-08
.5000E-08	.1000E-07	1.722E+05	3.444E+13	2.484E+05	.7500E-08
.1000E-07	.2000E-07	5.076E+05	5.076E+13	7.323E+05	.1500E-07
.2000E-07	.5000E-07	1.574E+06	5.245E+13	1.717E+06	.3500E-07
.5000E-07	.1000E-06	1.230E+06	2.460E+13	1.774E+06	.7500E-07
.1000E-06	.2000E-06	3.459E+05	3.459E+12	4.991E+05	.1500E-06
.2000E-06	.5000E-06	3.978E+05	1.326E+12	4.342E+05	.3500E-06
.5000E-06	.1000E-01	4.172E+06	4.173E+08	4.213E+05	.5000E-02
.1000E-01	.1027E+00	1.623E+06	1.751E+07	6.968E+05	.5635E-01
.1027E+00	.1166E+00	1.164E+05	8.400E+06	9.196E+05	.1096E+00
.1166E+00	.1317E+00	1.955E+05	1.293E+07	1.603E+06	.1241E+00
.1317E+00	.1493E+00	1.550E+05	8.789E+06	1.233E+06	.1405E+00
.1493E+00	.1707E+00	1.557E+05	7.268E+06	1.161E+06	.1600E+00
.1707E+00	.1934E+00	1.515E+05	6.680E+06	1.215E+06	.1821E+00
.1934E+00	.2199E+00	1.434E+05	5.418E+06	1.118E+06	.2066E+00
.2199E+00	.2606E+00	2.542E+05	6.237E+06	1.495E+06	.2402E+00
.2606E+00	.2906E+00	1.484E+05	4.946E+06	1.362E+06	.2756E+00
.2906E+00	.3244E+00	1.416E+05	4.196E+06	1.289E+06	.3075E+00
.3244E+00	.3581E+00	1.170E+05	3.467E+06	1.182E+06	.3413E+00
.3581E+00	.3994E+00	1.376E+05	3.337E+06	1.263E+06	.3787E+00
.3994E+00	.4444E+00	1.502E+05	3.337E+06	1.406E+06	.4219E+00
.4444E+00	.4931E+00	1.562E+05	3.203E+06	1.500E+06	.4688E+00
.4931E+00	.5456E+00	1.886E+05	3.592E+06	1.864E+06	.5194E+00
.5456E+00	.6094E+00	2.012E+05	3.156E+06	1.821E+06	.5775E+00
.6094E+00	.6769E+00	2.051E+05	3.039E+06	1.953E+06	.6431E+00
.6769E+00	.7946E+00	4.018E+05	3.412E+06	2.505E+06	.7358E+00
.7946E+00	.8870E+00	2.554E+05	2.764E+06	2.322E+06	.8408E+00
.8870E+00	.9871E+00	2.282E+05	2.280E+06	2.134E+06	.9371E+00
.9871E+00	.1095E+01	1.961E+05	1.819E+06	1.892E+06	.1041E+01
.1095E+01	.1218E+01	2.207E+05	1.792E+06	2.070E+06	.1157E+01
.1218E+01	.1391E+01	3.533E+05	2.044E+06	2.663E+06	.1305E+01
.1391E+01	.1573E+01	2.657E+05	1.460E+06	2.160E+06	.1482E+01
.1573E+01	.1807E+01	2.852E+05	1.219E+06	2.057E+06	.1690E+01
.1807E+01	.2041E+01	2.196E+05	9.386E+05	1.804E+06	.1924E+01
.2041E+01	.2327E+01	2.613E+05	9.137E+05	1.993E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	2.359E+05	7.560E+05	1.875E+06	.2483E+01
.2639E+01	.3003E+01	2.036E+05	5.593E+05	1.575E+06	.2821E+01
.3003E+01	.3419E+01	1.669E+05	4.011E+05	1.286E+06	.3211E+01
.3419E+01	.3861E+01	1.160E+05	2.623E+05	9.538E+05	.3640E+01
.3861E+01	.4407E+01	1.181E+05	2.162E+05	8.926E+05	.4134E+01
.4407E+01	.5000E+01	8.775E+04	1.480E+05	6.951E+05	.4703E+01
.5000E+01	.5500E+01	4.880E+04	9.760E+04	5.120E+05	.5250E+01
.5500E+01	.6000E+01	3.614E+04	7.228E+04	4.154E+05	.5750E+01
.6000E+01	.6500E+01	2.664E+04	5.329E+04	3.329E+05	.6250E+01
.6500E+01	.7000E+01	1.956E+04	3.911E+04	2.639E+05	.6750E+01
.7000E+01	.7500E+01	1.431E+04	2.862E+04	2.074E+05	.7250E+01
.7500E+01	.8000E+01	1.043E+04	2.087E+04	1.617E+05	.7750E+01
.8000E+01	.8500E+01	7.591E+03	1.518E+04	1.252E+05	.8250E+01
.8500E+01	.9000E+01	5.510E+03	1.102E+04	9.640E+04	.8750E+01
.9000E+01	.9500E+01	3.994E+03	7.988E+03	7.387E+04	.9250E+01
.9500E+01	.1000E+02	2.895E+03	5.791E+03	5.645E+04	.9750E+01

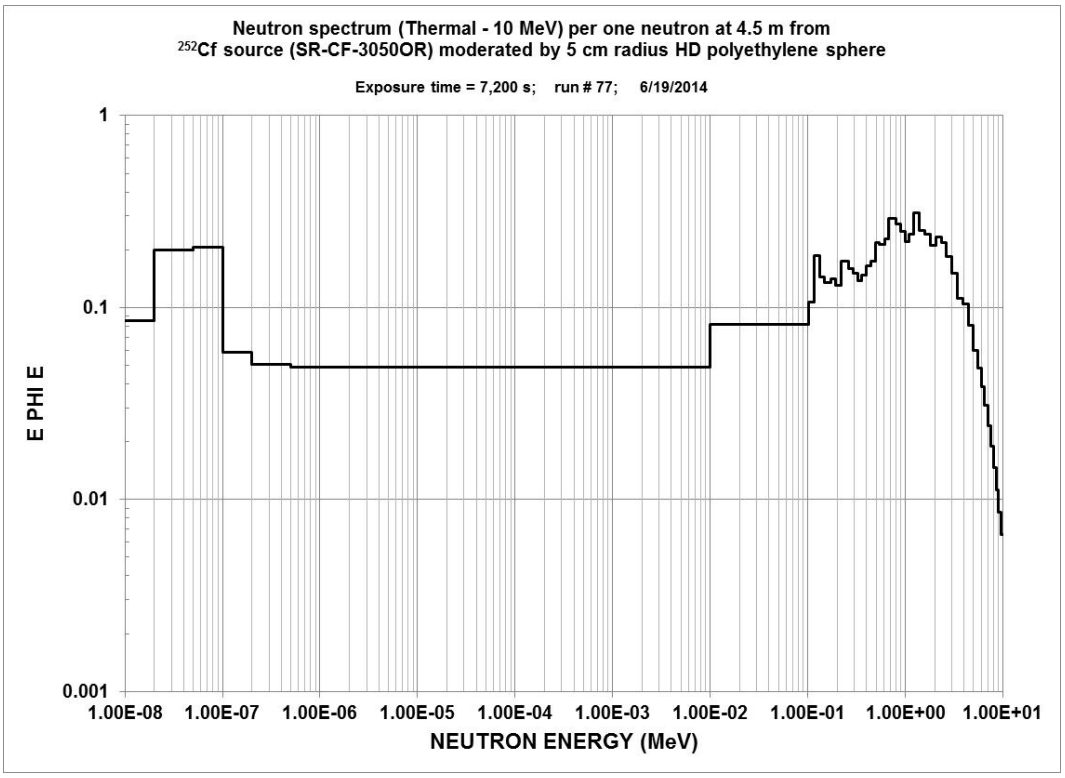
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



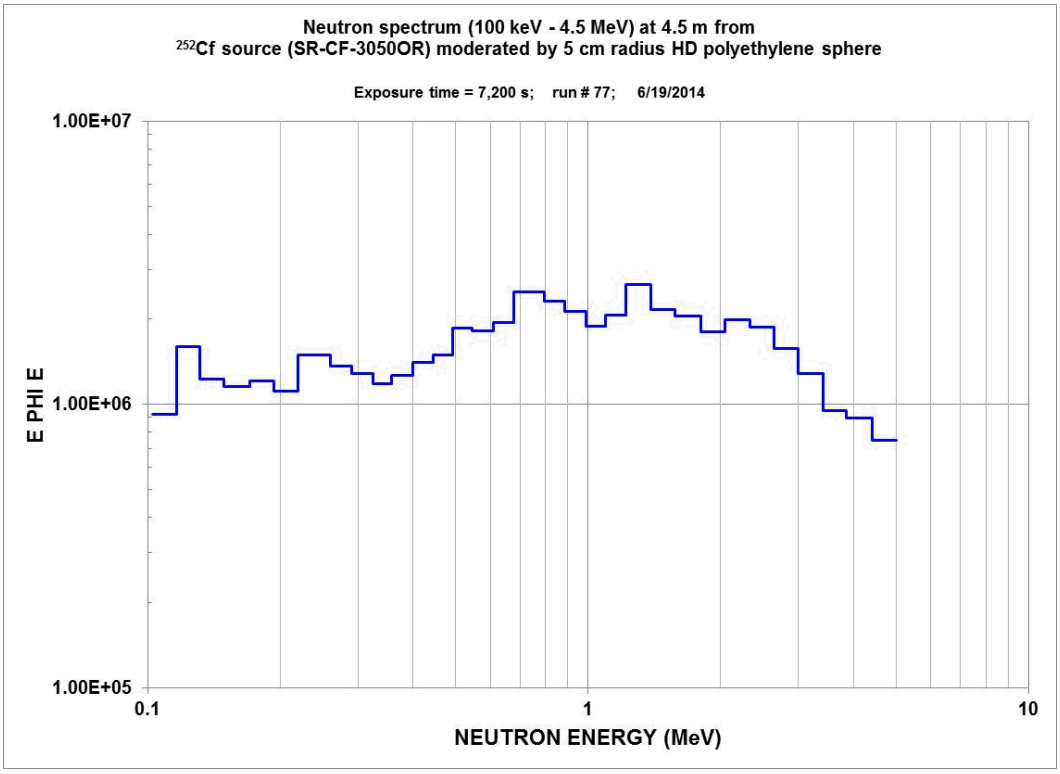


Figure K-6. Neutron spectra at 4.5 m from ^{252}Cf moderated by 5 cm of polyethylene

Appendix L

Neutron fluence, spectra and dose rates from ^{252}Cf moderated by 2 cm high density polyethylene

Fluence, spectral and dosimetric data at 2.0 m from ^{252}Cf moderated by 2 cm of polyethylene

Table L-1. Neutron fluence and dosimetric data at 2.0 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date:	6/25/2014
Exposure time:	7,200 s
Run #	N86

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	2.64E+07	3.67E+03
Epi-thermal region	:	8.51E+06	1.18E+03
Thermal region	:	3.53E+06	4.91E+02
Thermal – 4.5 MeV	:	3.84E+07	5.34E+03
Thermal – 10.0 MeV	:	3.9503E+07	5.4866E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	6.42E-02	9.49E-03	3.21E+01	4.75E+03
Epi-thermal region	:	1.06E-03	1.66E-04	5.31E-01	8.29E+01
Thermal region	:	7.07E-05	3.75E-05	3.53E-02	1.87E+01
Thermal – 4.5 MeV	:	6.53E-02	9.70E-03	3.27E+01	4.85E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	6.8676E-02 rads	3.4338E+01 mrads/hr
H*(10) ICRP-74	=	1.0032E-02 Sv	5.0158E+03 uSv/hr
Hp(10,0) ICRP-74	=	1.0385E-02 Sv	5.1926E+03 uSv/hr

Table L-2. Neutron fluence at 2.0 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date: 6/25/2014
Exposure time: 7,200 s
Run number: N86

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	7.986E+03	7.986E+12	1.152E+04	.1500E-08
.2000E-08	.5000E-08	5.124E+04	1.708E+13	5.592E+04	.3500E-08
.5000E-08	.1000E-07	1.558E+05	3.117E+13	2.248E+05	.7500E-08
.1000E-07	.2000E-07	4.594E+05	4.594E+13	6.628E+05	.1500E-07
.2000E-07	.5000E-07	1.424E+06	4.747E+13	1.554E+06	.3500E-07
.5000E-07	.1000E-06	1.113E+06	2.226E+13	1.606E+06	.7500E-07
.1000E-06	.2000E-06	3.131E+05	3.131E+12	4.517E+05	.1500E-06
.2000E-06	.5000E-06	4.498E+05	1.499E+12	4.909E+05	.3500E-06
.5000E-06	.1000E-01	5.283E+06	5.283E+08	5.334E+05	.5000E-02
.1000E-01	.1027E+00	2.773E+06	2.992E+07	1.191E+06	.5635E-01
.1027E+00	.1166E+00	2.829E+05	2.041E+07	2.234E+06	.1096E+00
.1166E+00	.1317E+00	3.781E+05	2.501E+07	3.100E+06	.1241E+00
.1317E+00	.1493E+00	3.957E+05	2.243E+07	3.147E+06	.1405E+00
.1493E+00	.1707E+00	4.205E+05	1.963E+07	3.137E+06	.1600E+00
.1707E+00	.1934E+00	3.679E+05	1.622E+07	2.950E+06	.1821E+00
.1934E+00	.2199E+00	4.925E+05	1.861E+07	3.841E+06	.2066E+00
.2199E+00	.2606E+00	7.144E+05	1.753E+07	4.201E+06	.2402E+00
.2606E+00	.2906E+00	4.765E+05	1.588E+07	4.373E+06	.2756E+00
.2906E+00	.3244E+00	4.566E+05	1.353E+07	4.156E+06	.3075E+00
.3244E+00	.3581E+00	4.789E+05	1.419E+07	4.839E+06	.3413E+00
.3581E+00	.3994E+00	5.281E+05	1.280E+07	4.844E+06	.3787E+00
.3994E+00	.4444E+00	5.784E+05	1.285E+07	5.417E+06	.4219E+00
.4444E+00	.4931E+00	6.068E+05	1.245E+07	5.829E+06	.4688E+00
.4931E+00	.5456E+00	6.607E+05	1.259E+07	6.531E+06	.5194E+00
.5456E+00	.6094E+00	8.661E+05	1.359E+07	7.838E+06	.5775E+00
.6094E+00	.6769E+00	8.282E+05	1.227E+07	7.884E+06	.6431E+00
.6769E+00	.7946E+00	1.458E+06	1.238E+07	9.090E+06	.7358E+00
.7946E+00	.8870E+00	1.044E+06	1.130E+07	9.495E+06	.8408E+00
.8870E+00	.9871E+00	9.608E+05	9.598E+06	8.986E+06	.9371E+00
.9871E+00	.1095E+01	9.640E+05	8.942E+06	9.301E+06	.1041E+01
.1095E+01	.1218E+01	1.136E+06	9.217E+06	1.065E+07	.1157E+01
.1218E+01	.1391E+01	1.517E+06	8.775E+06	1.143E+07	.1305E+01
.1391E+01	.1573E+01	1.326E+06	7.286E+06	1.078E+07	.1482E+01
.1573E+01	.1807E+01	1.473E+06	6.295E+06	1.062E+07	.1690E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.1807E+01	.2041E+01	1.217E+06	5.200E+06	9.992E+06	.1924E+01
.2041E+01	.2327E+01	1.316E+06	4.601E+06	1.003E+07	.2184E+01
.2327E+01	.2639E+01	1.246E+06	3.993E+06	9.903E+06	.2483E+01
.2639E+01	.3003E+01	1.113E+06	3.059E+06	8.617E+06	.2821E+01
.3003E+01	.3419E+01	1.016E+06	2.443E+06	7.835E+06	.3211E+01
.3419E+01	.3861E+01	7.596E+05	1.719E+06	6.248E+06	.3640E+01
.3861E+01	.4407E+01	7.504E+05	1.374E+06	5.673E+06	.4134E+01
.4407E+01	.5000E+01	5.373E+05	9.060E+05	4.256E+06	.4703E+01
.5000E+01	.5500E+01	3.069E+05	6.138E+05	3.220E+06	.5250E+01
.5500E+01	.6000E+01	2.273E+05	4.546E+05	2.612E+06	.5750E+01
.6000E+01	.6500E+01	1.676E+05	3.352E+05	2.094E+06	.6250E+01
.6500E+01	.7000E+01	1.230E+05	2.460E+05	1.660E+06	.6750E+01
.7000E+01	.7500E+01	9.002E+04	1.800E+05	1.305E+06	.7250E+01
.7500E+01	.8000E+01	6.563E+04	1.313E+05	1.017E+06	.7750E+01
.8000E+01	.8500E+01	4.774E+04	9.549E+04	7.875E+05	.8250E+01
.8500E+01	.9000E+01	3.466E+04	6.931E+04	6.063E+05	.8750E+01
.9000E+01	.9500E+01	2.512E+04	5.024E+04	4.646E+05	.9250E+01
.9500E+01	.1000E+02	1.821E+04	3.642E+04	3.550E+05	.9750E+01

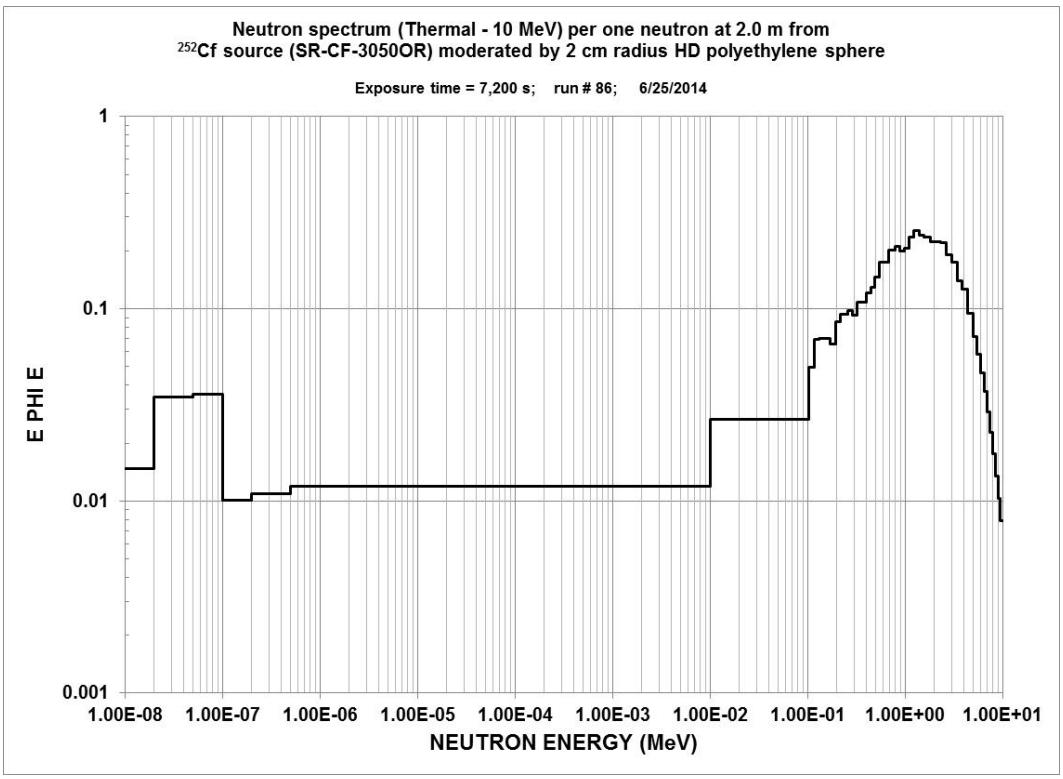
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



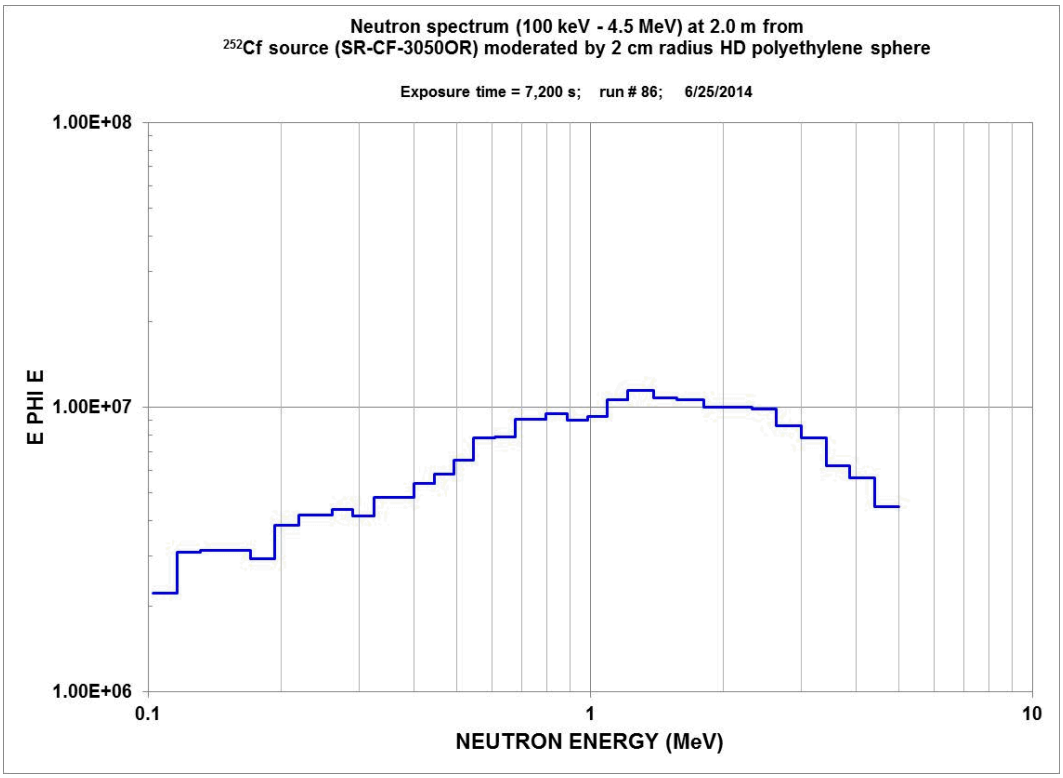


Figure L-1. Neutron spectra at 2.0 m from ^{252}Cf moderated by 2 cm of polyethylene

Fluence, spectral and dosimetric data at 2.5 m from ^{252}Cf moderated by 5 cm of polyethylene

Table L-3. Neutron fluence and dosimetric data at 2.5 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date:	6/24/2014
Exposure time:	7,200 s
Run #	N81

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.89E+07	2.62E+03
Epi-thermal region	:	7.69E+06	1.07E+03
Thermal region	:	3.48E+06	4.83E+02
Thermal – 4.5 MeV	:	3.01E+07	4.18E+03
Thermal – 10.0 MeV	:	3.0774E+07	4.2741E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	4.50E-02	6.71E-03	2.25E+01	3.35E+03
Epi-thermal region	:	9.34E-04	1.48E-04	4.67E-01	7.39E+01
Thermal region	:	6.96E-05	3.69E-05	3.48E-02	1.84E+01
Thermal – 4.5 MeV	:	4.60E-02	6.89E-03	2.30E+01	3.45E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	4.8170E-02 rads	2.4085E+01 mrads/hr
H*(10) ICRP-74	=	7.1059E-03 Sv	3.5530E+03 uSv/hr
Hp(10,0) ICRP-74	=	7.3563E-03 Sv	3.6782E+03 uSv/hr

Table L-4. Neutron fluence at 2.5 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date: 6/24/2014
Exposure time: 7,200 s
Run number: N81

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	7.865E+03	7.865E+12	1.135E+04	.1500E-08
.2000E-08	.5000E-08	5.046E+04	1.682E+13	5.507E+04	.3500E-08
.5000E-08	.1000E-07	1.535E+05	3.069E+13	2.214E+05	.7500E-08
.1000E-07	.2000E-07	4.524E+05	4.524E+13	6.527E+05	.1500E-07
.2000E-07	.5000E-07	1.402E+06	4.675E+13	1.531E+06	.3500E-07
.5000E-07	.1000E-06	1.096E+06	2.192E+13	1.581E+06	.7500E-07
.1000E-06	.2000E-06	3.083E+05	3.083E+12	4.448E+05	.1500E-06
.2000E-06	.5000E-06	4.268E+05	1.423E+12	4.658E+05	.3500E-06
.5000E-06	.1000E-01	4.831E+06	4.832E+08	4.878E+05	.5000E-02
.1000E-01	.1027E+00	2.431E+06	2.623E+07	1.044E+06	.5635E-01
.1027E+00	.1166E+00	2.464E+05	1.778E+07	1.946E+06	.1096E+00
.1166E+00	.1317E+00	2.792E+05	1.847E+07	2.289E+06	.1241E+00
.1317E+00	.1493E+00	3.974E+05	2.253E+07	3.161E+06	.1405E+00
.1493E+00	.1707E+00	3.627E+05	1.693E+07	2.705E+06	.1600E+00
.1707E+00	.1934E+00	2.576E+05	1.136E+07	2.065E+06	.1821E+00
.1934E+00	.2199E+00	3.935E+05	1.487E+07	3.068E+06	.2066E+00
.2199E+00	.2606E+00	5.066E+05	1.243E+07	2.979E+06	.2402E+00
.2606E+00	.2906E+00	3.336E+05	1.112E+07	3.062E+06	.2756E+00
.2906E+00	.3244E+00	3.652E+05	1.082E+07	3.324E+06	.3075E+00
.3244E+00	.3581E+00	3.567E+05	1.057E+07	3.603E+06	.3413E+00
.3581E+00	.3994E+00	3.672E+05	8.903E+06	3.369E+06	.3787E+00
.3994E+00	.4444E+00	4.521E+05	1.005E+07	4.234E+06	.4219E+00
.4444E+00	.4931E+00	4.645E+05	9.528E+06	4.462E+06	.4688E+00
.4931E+00	.5456E+00	4.899E+05	9.332E+06	4.843E+06	.5194E+00
.5456E+00	.6094E+00	5.459E+05	8.564E+06	4.941E+06	.5775E+00
.6094E+00	.6769E+00	6.772E+05	1.003E+07	6.447E+06	.6431E+00
.6769E+00	.7946E+00	1.029E+06	8.741E+06	6.418E+06	.7358E+00
.7946E+00	.8870E+00	7.508E+05	8.125E+06	6.825E+06	.8408E+00
.8870E+00	.9871E+00	7.110E+05	7.103E+06	6.650E+06	.9371E+00
.9871E+00	.1095E+01	7.111E+05	6.596E+06	6.861E+06	.1041E+01
.1095E+01	.1218E+01	8.111E+05	6.584E+06	7.607E+06	.1157E+01
.1218E+01	.1391E+01	1.011E+06	5.850E+06	7.621E+06	.1305E+01
.1391E+01	.1573E+01	9.293E+05	5.106E+06	7.558E+06	.1482E+01
.1573E+01	.1807E+01	1.016E+06	4.341E+06	7.325E+06	.1690E+01
.1807E+01	.2041E+01	8.385E+05	3.583E+06	6.886E+06	.1924E+01
.2041E+01	.2327E+01	9.148E+05	3.198E+06	6.975E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	8.642E+05	2.770E+06	6.868E+06	.2483E+01
.2639E+01	.3003E+01	7.628E+05	2.096E+06	5.903E+06	.2821E+01
.3003E+01	.3419E+01	6.798E+05	1.634E+06	5.240E+06	.3211E+01
.3419E+01	.3861E+01	5.069E+05	1.147E+06	4.169E+06	.3640E+01
.3861E+01	.4407E+01	5.011E+05	9.177E+05	3.788E+06	.4134E+01
.4407E+01	.5000E+01	3.491E+05	5.887E+05	2.765E+06	.4703E+01
.5000E+01	.5500E+01	2.026E+05	4.052E+05	2.126E+06	.5250E+01
.5500E+01	.6000E+01	1.501E+05	3.001E+05	1.725E+06	.5750E+01
.6000E+01	.6500E+01	1.106E+05	2.213E+05	1.382E+06	.6250E+01
.6500E+01	.7000E+01	8.120E+04	1.624E+05	1.096E+06	.6750E+01
.7000E+01	.7500E+01	5.943E+04	1.189E+05	8.614E+05	.7250E+01
.7500E+01	.8000E+01	4.333E+04	8.666E+04	6.713E+05	.7750E+01
.8000E+01	.8500E+01	3.152E+04	6.304E+04	5.199E+05	.8250E+01
.8500E+01	.9000E+01	2.288E+04	4.576E+04	4.003E+05	.8750E+01
.9000E+01	.9500E+01	1.658E+04	3.317E+04	3.067E+05	.9250E+01
.9500E+01	.1000E+02	1.202E+04	2.405E+04	2.344E+05	.9750E+01

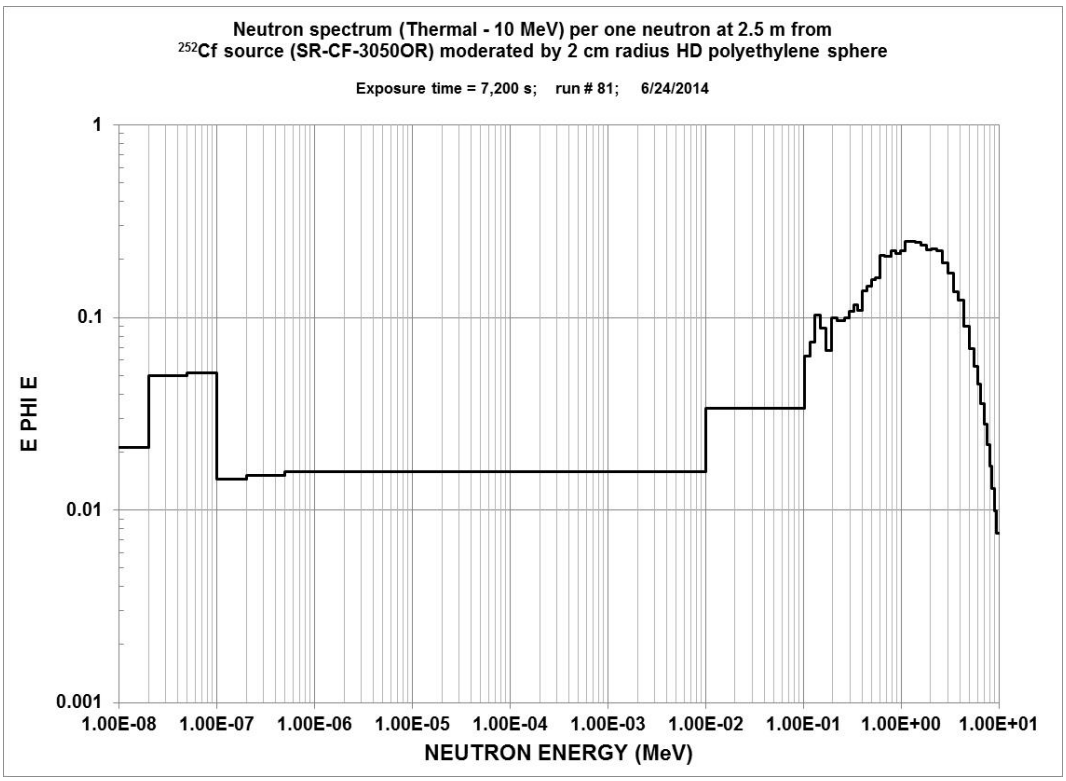
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



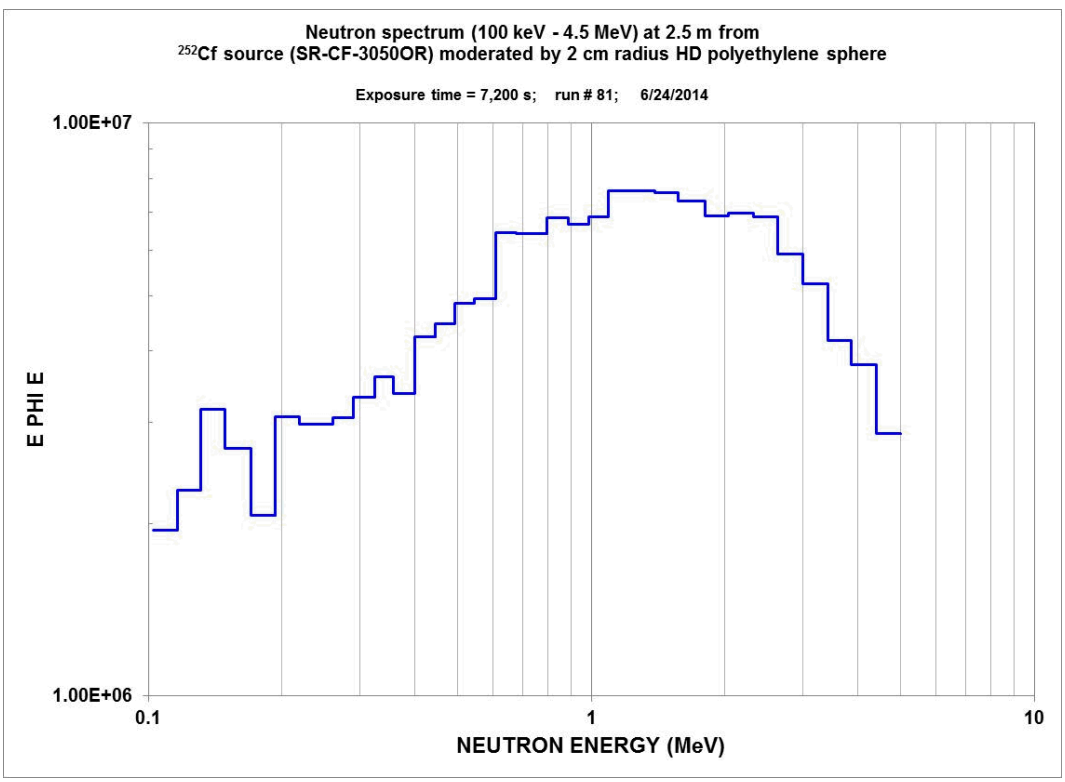


Figure L-2. Neutron spectra at 2.5 m from ^{252}Cf moderated by 2 cm of polyethylene

Fluence, spectral and dosimetric data at 3.0 m from ^{252}Cf moderated by 2 cm of polyethylene

Table L-5. Neutron fluence and dosimetric data at 3.0 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date:	6/24/2014
Exposure time:	7,200 s
Run #	N82

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.36E+07	1.88E+03
Epi-thermal region	:	6.46E+06	8.97E+02
Thermal region	:	3.20E+06	4.44E+02
Thermal – 4.5 MeV	:	2.32E+07	3.22E+03
Thermal – 10.0 MeV	:	2.3678E+07	3.2886E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	3.17E-02	4.77E-03	1.59E+01	2.38E+03
Epi-thermal region	:	7.63E-04	1.22E-04	3.82E-01	6.12E+01
Thermal region	:	6.39E-05	3.39E-05	3.20E-02	1.69E+01
Thermal – 4.5 MeV	:	3.25E-02	4.92E-03	1.63E+01	2.46E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	3.3897E-02 rads	1.6948E+01 mrads/hr
H*(10) ICRP-74	=	5.0557E-03 Sv	2.5278E+03 uSv/hr
Hp(10,0) ICRP-74	=	5.2327E-03 Sv	2.6163E+03 uSv/hr

Table L-6. Neutron fluence at 3.0 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date: 6/24/2014
Exposure time: 7,200 s
Run number: N82

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm²)	FLUENCE/ MeV (n/cm².MeV)	FLUENCE/ LETHARGY* (n/cm².u)	E avg. (MeV)
.1000E-08	.2000E-08	7.223E+03	7.223E+12	1.042E+04	.1500E-08
.2000E-08	.5000E-08	4.634E+04	1.545E+13	5.057E+04	.3500E-08
.5000E-08	.1000E-07	1.409E+05	2.819E+13	2.033E+05	.7500E-08
.1000E-07	.2000E-07	4.155E+05	4.155E+13	5.994E+05	.1500E-07
.2000E-07	.5000E-07	1.288E+06	4.293E+13	1.406E+06	.3500E-07
.5000E-07	.1000E-06	1.007E+06	2.013E+13	1.452E+06	.7500E-07
.1000E-06	.2000E-06	2.832E+05	2.832E+12	4.085E+05	.1500E-06
.2000E-06	.5000E-06	3.770E+05	1.257E+12	4.114E+05	.3500E-06
.5000E-06	.1000E-01	4.104E+06	4.104E+08	4.144E+05	.5000E-02
.1000E-01	.1027E+00	1.980E+06	2.136E+07	8.501E+05	.5635E-01
.1027E+00	.1166E+00	2.277E+05	1.643E+07	1.798E+06	.1096E+00
.1166E+00	.1317E+00	2.088E+05	1.381E+07	1.712E+06	.1241E+00
.1317E+00	.1493E+00	2.425E+05	1.375E+07	1.929E+06	.1405E+00
.1493E+00	.1707E+00	2.447E+05	1.143E+07	1.826E+06	.1600E+00
.1707E+00	.1934E+00	2.634E+05	1.161E+07	2.112E+06	.1821E+00
.1934E+00	.2199E+00	2.485E+05	9.393E+06	1.938E+06	.2066E+00
.2199E+00	.2606E+00	4.367E+05	1.072E+07	2.568E+06	.2402E+00
.2606E+00	.2906E+00	2.623E+05	8.745E+06	2.408E+06	.2756E+00
.2906E+00	.3244E+00	3.107E+05	9.205E+06	2.828E+06	.3075E+00
.3244E+00	.3581E+00	2.526E+05	7.484E+06	2.552E+06	.3413E+00
.3581E+00	.3994E+00	2.995E+05	7.260E+06	2.747E+06	.3787E+00
.3994E+00	.4444E+00	2.945E+05	6.545E+06	2.758E+06	.4219E+00
.4444E+00	.4931E+00	3.273E+05	6.713E+06	3.144E+06	.4688E+00
.4931E+00	.5456E+00	3.481E+05	6.631E+06	3.441E+06	.5194E+00
.5456E+00	.6094E+00	4.437E+05	6.959E+06	4.015E+06	.5775E+00
.6094E+00	.6769E+00	4.619E+05	6.843E+06	4.397E+06	.6431E+00
.6769E+00	.7946E+00	7.946E+05	6.748E+06	4.954E+06	.7358E+00
.7946E+00	.8870E+00	5.383E+05	5.826E+06	4.893E+06	.8408E+00
.8870E+00	.9871E+00	4.991E+05	4.986E+06	4.668E+06	.9371E+00
.9871E+00	.1095E+01	4.769E+05	4.424E+06	4.602E+06	.1041E+01
.1095E+01	.1218E+01	5.932E+05	4.815E+06	5.563E+06	.1157E+01
.1218E+01	.1391E+01	7.328E+05	4.239E+06	5.522E+06	.1305E+01
.1391E+01	.1573E+01	6.526E+05	3.586E+06	5.307E+06	.1482E+01
.1573E+01	.1807E+01	7.017E+05	2.999E+06	5.060E+06	.1690E+01
.1807E+01	.2041E+01	5.662E+05	2.420E+06	4.650E+06	.1924E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2041E+01	.2327E+01	6.351E+05	2.220E+06	4.843E+06	.2184E+01
.2327E+01	.2639E+01	6.072E+05	1.946E+06	4.826E+06	.2483E+01
.2639E+01	.3003E+01	5.208E+05	1.431E+06	4.030E+06	.2821E+01
.3003E+01	.3419E+01	4.398E+05	1.057E+06	3.390E+06	.3211E+01
.3419E+01	.3861E+01	3.593E+05	8.130E+05	2.956E+06	.3640E+01
.3861E+01	.4407E+01	3.160E+05	5.788E+05	2.389E+06	.4134E+01
.4407E+01	.5000E+01	2.367E+05	3.992E+05	1.875E+06	.4703E+01
.5000E+01	.5500E+01	1.348E+05	2.697E+05	1.415E+06	.5250E+01
.5500E+01	.6000E+01	9.987E+04	1.997E+05	1.148E+06	.5750E+01
.6000E+01	.6500E+01	7.363E+04	1.473E+05	9.199E+05	.6250E+01
.6500E+01	.7000E+01	5.404E+04	1.081E+05	7.292E+05	.6750E+01
.7000E+01	.7500E+01	3.955E+04	7.910E+04	5.732E+05	.7250E+01
.7500E+01	.8000E+01	2.883E+04	5.767E+04	4.468E+05	.7750E+01
.8000E+01	.8500E+01	2.098E+04	4.195E+04	3.460E+05	.8250E+01
.8500E+01	.9000E+01	1.523E+04	3.045E+04	2.664E+05	.8750E+01
.9000E+01	.9500E+01	1.104E+04	2.207E+04	2.041E+05	.9250E+01
.9500E+01	.1000E+02	8.001E+03	1.600E+04	1.560E+05	.9750E+01

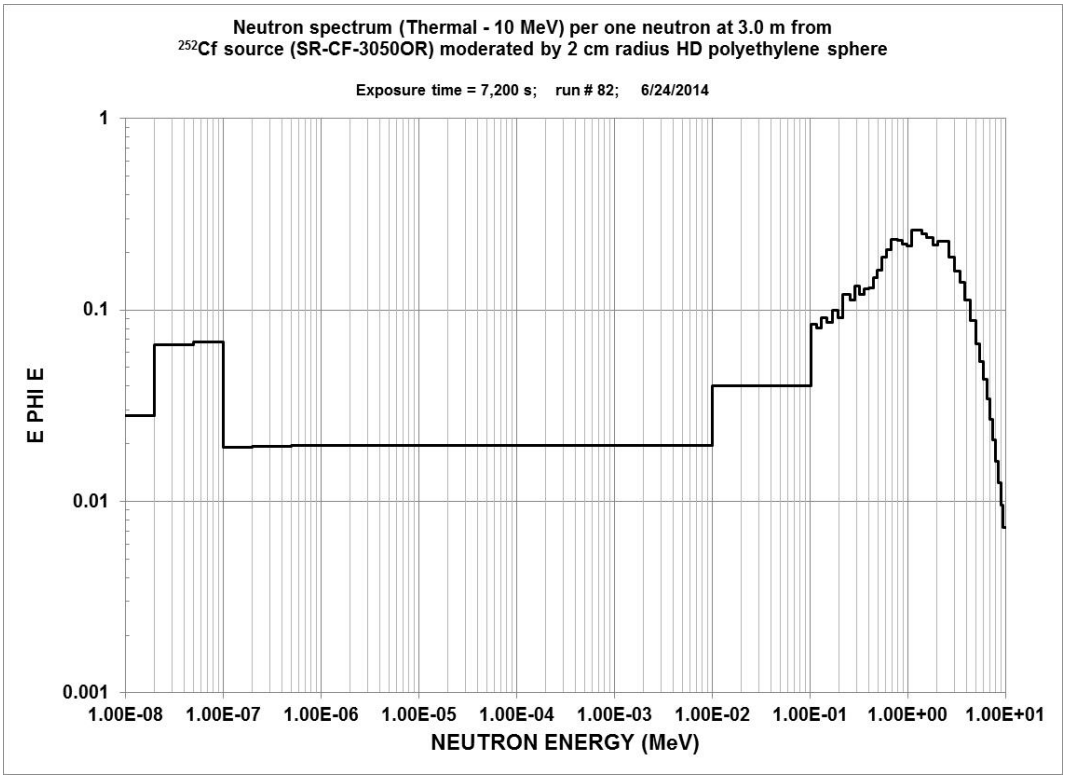
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



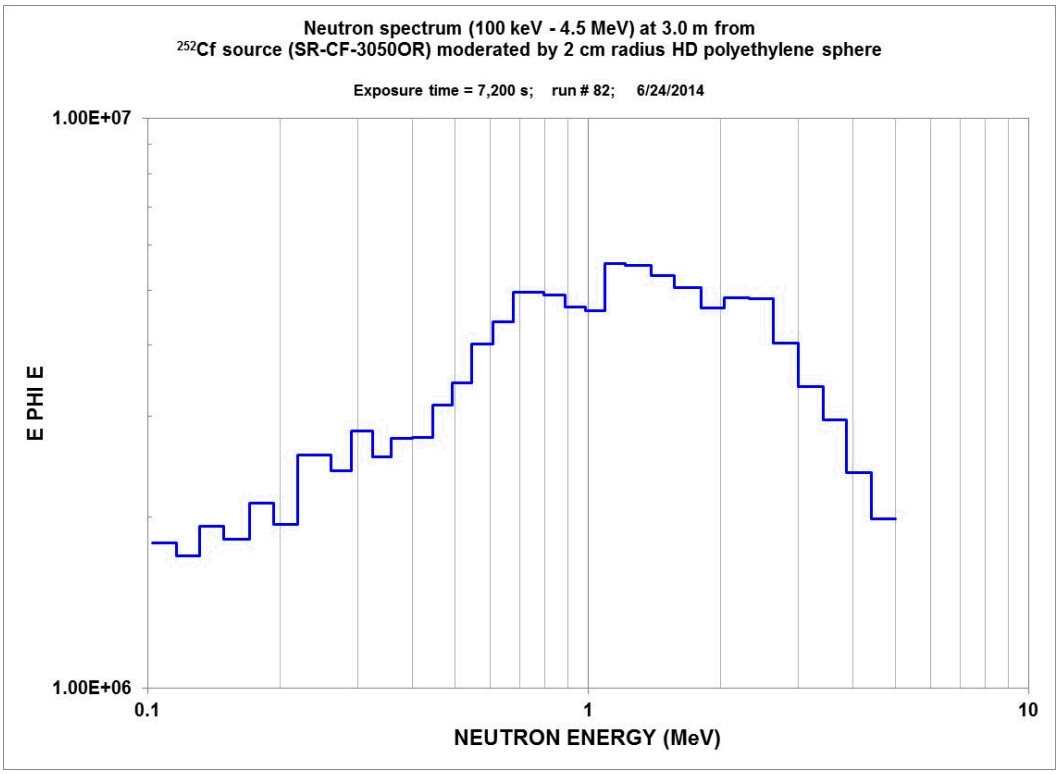


Figure L-3. Neutron spectra at 3.0 m from ^{252}Cf moderated by 2 cm of polyethylene

Fluence, spectral and dosimetric data at 3.5 m from ^{252}Cf moderated by 2 cm of polyethylene

Table L-7. Neutron fluence and dosimetric data at 3.5 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date:	6/24/2014
Exposure time:	7,200 s
Run #	N83

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.18E+07	1.64E+03
Epi-thermal region	:	6.85E+06	9.51E+02
Thermal region	:	3.40E+06	4.72E+02
Thermal – 4.5 MeV	:	2.20E+07	3.06E+03
Thermal – 10.0 MeV	:	2.2406E+07	3.1120E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	2.71E-02	4.10E-03	1.35E+01	2.05E+03
Epi-thermal region	:	7.81E-04	1.27E-04	3.90E-01	6.36E+01
Thermal region	:	6.79E-05	3.60E-05	3.40E-02	1.80E+01
Thermal – 4.5 MeV	:	2.79E-02	4.26E-03	1.40E+01	2.13E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.8975E-02 rads	1.4488E+01 mrads/hr
H*(10) ICRP-74	=	4.3657E-03 Sv	2.1829E+03 uSv/hr
Hp(10,0) ICRP-74	=	4.5183E-03 Sv	2.2592E+03 uSv/hr

Table L-8. Neutron fluence at 3.5 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date: 6/24/2014
Exposure time: 7,200 s
Run number: N83

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	7.675E+03	7.675E+12	1.107E+04	.1500E-08
.2000E-08	.5000E-08	4.924E+04	1.641E+13	5.374E+04	.3500E-08
.5000E-08	.1000E-07	1.498E+05	2.995E+13	2.161E+05	.7500E-08
.1000E-07	.2000E-07	4.415E+05	4.415E+13	6.369E+05	.1500E-07
.2000E-07	.5000E-07	1.369E+06	4.562E+13	1.494E+06	.3500E-07
.5000E-07	.1000E-06	1.070E+06	2.139E+13	1.543E+06	.7500E-07
.1000E-06	.2000E-06	3.009E+05	3.009E+12	4.341E+05	.1500E-06
.2000E-06	.5000E-06	4.038E+05	1.346E+12	4.407E+05	.3500E-06
.5000E-06	.1000E-01	4.432E+06	4.432E+08	4.475E+05	.5000E-02
.1000E-01	.1027E+00	2.014E+06	2.173E+07	8.648E+05	.5635E-01
.1027E+00	.1166E+00	2.080E+05	1.501E+07	1.643E+06	.1096E+00
.1166E+00	.1317E+00	2.059E+05	1.362E+07	1.688E+06	.1241E+00
.1317E+00	.1493E+00	2.842E+05	1.611E+07	2.261E+06	.1405E+00
.1493E+00	.1707E+00	2.004E+05	9.357E+06	1.495E+06	.1600E+00
.1707E+00	.1934E+00	2.545E+05	1.122E+07	2.040E+06	.1821E+00
.1934E+00	.2199E+00	2.271E+05	8.583E+06	1.771E+06	.2066E+00
.2199E+00	.2606E+00	3.676E+05	9.019E+06	2.162E+06	.2402E+00
.2606E+00	.2906E+00	2.262E+05	7.542E+06	2.077E+06	.2756E+00
.2906E+00	.3244E+00	2.532E+05	7.503E+06	2.305E+06	.3075E+00
.3244E+00	.3581E+00	2.535E+05	7.511E+06	2.561E+06	.3413E+00
.3581E+00	.3994E+00	2.766E+05	6.705E+06	2.537E+06	.3787E+00
.3994E+00	.4444E+00	2.509E+05	5.575E+06	2.350E+06	.4219E+00
.4444E+00	.4931E+00	2.912E+05	5.974E+06	2.798E+06	.4688E+00
.4931E+00	.5456E+00	3.155E+05	6.010E+06	3.119E+06	.5194E+00
.5456E+00	.6094E+00	4.134E+05	6.485E+06	3.741E+06	.5775E+00
.6094E+00	.6769E+00	3.995E+05	5.919E+06	3.803E+06	.6431E+00
.6769E+00	.7946E+00	7.211E+05	6.123E+06	4.496E+06	.7358E+00
.7946E+00	.8870E+00	4.759E+05	5.150E+06	4.326E+06	.8408E+00
.8870E+00	.9871E+00	4.591E+05	4.586E+06	4.293E+06	.9371E+00
.9871E+00	.1095E+01	3.970E+05	3.683E+06	3.831E+06	.1041E+01
.1095E+01	.1218E+01	4.535E+05	3.681E+06	4.253E+06	.1157E+01
.1218E+01	.1391E+01	6.457E+05	3.735E+06	4.866E+06	.1305E+01
.1391E+01	.1573E+01	5.539E+05	3.044E+06	4.505E+06	.1482E+01
.1573E+01	.1807E+01	5.904E+05	2.523E+06	4.257E+06	.1690E+01
.1807E+01	.2041E+01	4.683E+05	2.001E+06	3.845E+06	.1924E+01
.2041E+01	.2327E+01	5.407E+05	1.891E+06	4.123E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	5.025E+05	1.611E+06	3.994E+06	.2483E+01
.2639E+01	.3003E+01	4.341E+05	1.192E+06	3.359E+06	.2821E+01
.3003E+01	.3419E+01	3.760E+05	9.039E+05	2.898E+06	.3211E+01
.3419E+01	.3861E+01	2.808E+05	6.354E+05	2.310E+06	.3640E+01
.3861E+01	.4407E+01	2.714E+05	4.970E+05	2.052E+06	.4134E+01
.4407E+01	.5000E+01	1.826E+05	3.080E+05	1.447E+06	.4703E+01
.5000E+01	.5500E+01	1.078E+05	2.156E+05	1.131E+06	.5250E+01
.5500E+01	.6000E+01	7.983E+04	1.597E+05	9.175E+05	.5750E+01
.6000E+01	.6500E+01	5.886E+04	1.177E+05	7.353E+05	.6250E+01
.6500E+01	.7000E+01	4.320E+04	8.640E+04	5.829E+05	.6750E+01
.7000E+01	.7500E+01	3.162E+04	6.323E+04	4.582E+05	.7250E+01
.7500E+01	.8000E+01	2.305E+04	4.610E+04	3.571E+05	.7750E+01
.8000E+01	.8500E+01	1.677E+04	3.354E+04	2.766E+05	.8250E+01
.8500E+01	.9000E+01	1.217E+04	2.434E+04	2.130E+05	.8750E+01
.9000E+01	.9500E+01	8.823E+03	1.765E+04	1.632E+05	.9250E+01
.9500E+01	.1000E+02	6.396E+03	1.279E+04	1.247E+05	.9750E+01

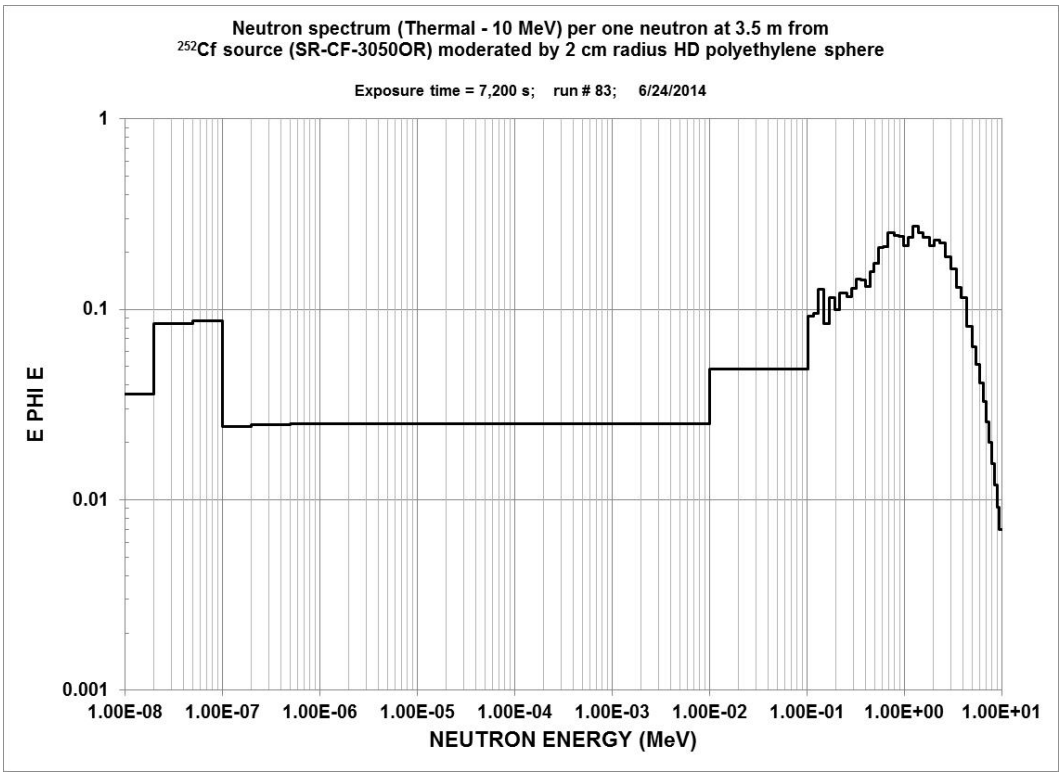
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



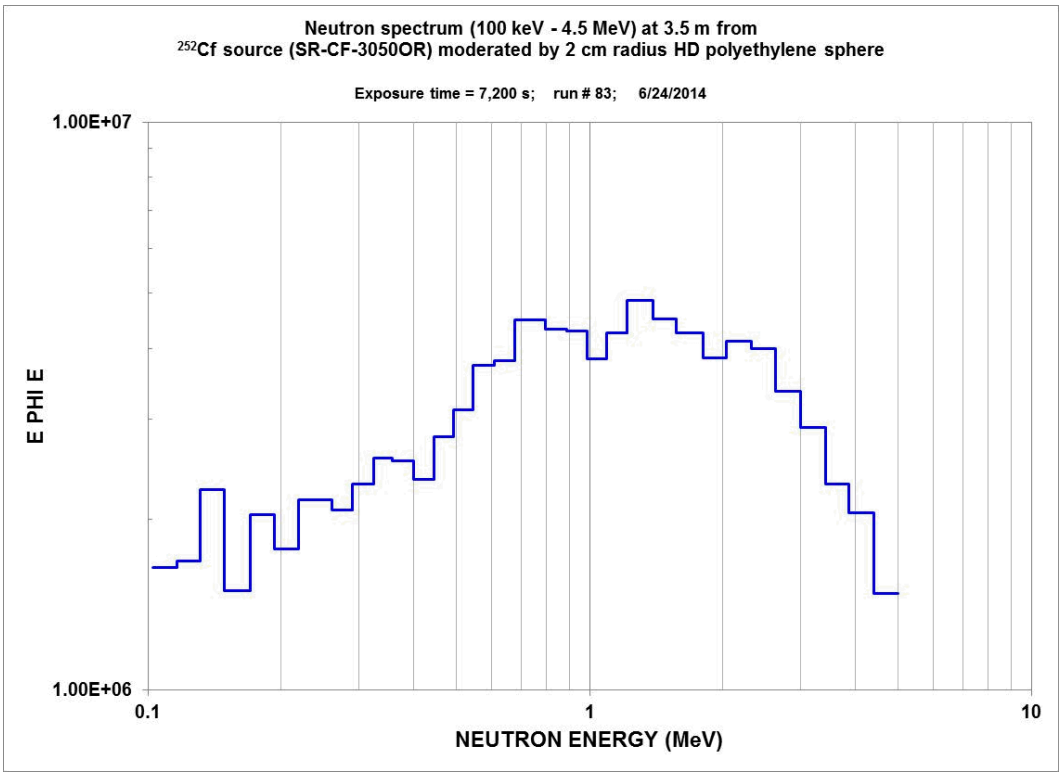


Figure L-4. Neutron spectra at 3.5 m from ^{252}Cf moderated by 2 cm of polyethylene

Fluence, spectral and dosimetric data at 4.0 m from ^{252}Cf moderated by 2 cm of polyethylene

Table L-9. Neutron fluence and dosimetric data at 4.0 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date:	6/25/2014
Exposure time:	7,200 s
Run #	N84

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	1.01E+07	1.41E+03
Epi-thermal region	:	6.59E+06	9.15E+02
Thermal region	:	3.41E+06	4.74E+02
Thermal – 4.5 MeV	:	2.01E+07	2.80E+03
Thermal – 10.0 MeV	:	2.0402E+07	2.8336E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	2.29E-02	3.48E-03	1.14E+01	1.74E+03
Epi-thermal region	:	7.51E-04	1.22E-04	3.75E-01	6.12E+01
Thermal region	:	6.83E-05	3.62E-05	3.41E-02	1.81E+01
Thermal – 4.5 MeV	:	2.37E-02	3.64E-03	1.18E+01	1.82E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.4243E-02 rads	1.2122E+01 mrads/hr
H*(10) ICRP-74	=	3.6987E-03 Sv	1.8493E+03 uSv/hr
Hp(10,0) ICRP-74	=	3.8275E-03 Sv	1.9138E+03 uSv/hr

Table L-10. Neutron fluence at 4.0 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date: 6/25/2014
Exposure time: 7,200 s
Run number: N84

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	7.714E+03	7.714E+12	1.113E+04	.1500E-08
.2000E-08	.5000E-08	4.949E+04	1.650E+13	5.402E+04	.3500E-08
.5000E-08	.1000E-07	1.505E+05	3.011E+13	2.172E+05	.7500E-08
.1000E-07	.2000E-07	4.437E+05	4.437E+13	6.402E+05	.1500E-07
.2000E-07	.5000E-07	1.376E+06	4.585E+13	1.501E+06	.3500E-07
.5000E-07	.1000E-06	1.075E+06	2.150E+13	1.551E+06	.7500E-07
.1000E-06	.2000E-06	3.024E+05	3.024E+12	4.363E+05	.1500E-06
.2000E-06	.5000E-06	4.041E+05	1.347E+12	4.411E+05	.3500E-06
.5000E-06	.1000E-01	4.257E+06	4.257E+08	4.298E+05	.5000E-02
.1000E-01	.1027E+00	1.937E+06	2.090E+07	8.316E+05	.5635E-01
.1027E+00	.1166E+00	2.103E+05	1.517E+07	1.661E+06	.1096E+00
.1166E+00	.1317E+00	1.753E+05	1.160E+07	1.437E+06	.1241E+00
.1317E+00	.1493E+00	2.080E+05	1.179E+07	1.654E+06	.1405E+00
.1493E+00	.1707E+00	2.793E+05	1.304E+07	2.084E+06	.1600E+00
.1707E+00	.1934E+00	2.334E+05	1.029E+07	1.871E+06	.1821E+00
.1934E+00	.2199E+00	2.354E+05	8.897E+06	1.836E+06	.2066E+00
.2199E+00	.2606E+00	2.927E+05	7.182E+06	1.721E+06	.2402E+00
.2606E+00	.2906E+00	2.046E+05	6.821E+06	1.878E+06	.2756E+00
.2906E+00	.3244E+00	2.572E+05	7.621E+06	2.341E+06	.3075E+00
.3244E+00	.3581E+00	2.474E+05	7.331E+06	2.500E+06	.3413E+00
.3581E+00	.3994E+00	1.916E+05	4.645E+06	1.757E+06	.3787E+00
.3994E+00	.4444E+00	2.195E+05	4.877E+06	2.056E+06	.4219E+00
.4444E+00	.4931E+00	2.431E+05	4.986E+06	2.335E+06	.4688E+00
.4931E+00	.5456E+00	2.938E+05	5.596E+06	2.904E+06	.5194E+00
.5456E+00	.6094E+00	3.737E+05	5.862E+06	3.382E+06	.5775E+00
.6094E+00	.6769E+00	3.422E+05	5.070E+06	3.258E+06	.6431E+00
.6769E+00	.7946E+00	5.919E+05	5.026E+06	3.690E+06	.7358E+00
.7946E+00	.8870E+00	4.149E+05	4.490E+06	3.772E+06	.8408E+00
.8870E+00	.9871E+00	3.918E+05	3.914E+06	3.664E+06	.9371E+00
.9871E+00	.1095E+01	3.196E+05	2.964E+06	3.083E+06	.1041E+01
.1095E+01	.1218E+01	4.260E+05	3.458E+06	3.996E+06	.1157E+01
.1218E+01	.1391E+01	5.591E+05	3.234E+06	4.213E+06	.1305E+01
.1391E+01	.1573E+01	4.622E+05	2.539E+06	3.759E+06	.1482E+01
.1573E+01	.1807E+01	4.946E+05	2.114E+06	3.566E+06	.1690E+01
.1807E+01	.2041E+01	3.880E+05	1.658E+06	3.186E+06	.1924E+01
.2041E+01	.2327E+01	4.238E+05	1.482E+06	3.231E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	4.148E+05	1.330E+06	3.297E+06	.2483E+01
.2639E+01	.3003E+01	3.395E+05	9.328E+05	2.628E+06	.2821E+01
.3003E+01	.3419E+01	2.996E+05	7.203E+05	2.310E+06	.3211E+01
.3419E+01	.3861E+01	2.218E+05	5.017E+05	1.824E+06	.3640E+01
.3861E+01	.4407E+01	2.123E+05	3.888E+05	1.605E+06	.4134E+01
.4407E+01	.5000E+01	1.536E+05	2.591E+05	1.217E+06	.4703E+01
.5000E+01	.5500E+01	7.722E+04	1.544E+05	8.102E+05	.5250E+01
.5500E+01	.6000E+01	5.719E+04	1.144E+05	6.573E+05	.5750E+01
.6000E+01	.6500E+01	4.217E+04	8.433E+04	5.268E+05	.6250E+01
.6500E+01	.7000E+01	3.095E+04	6.190E+04	4.176E+05	.6750E+01
.7000E+01	.7500E+01	2.265E+04	4.530E+04	3.283E+05	.7250E+01
.7500E+01	.8000E+01	1.651E+04	3.303E+04	2.559E+05	.7750E+01
.8000E+01	.8500E+01	1.201E+04	2.402E+04	1.981E+05	.8250E+01
.8500E+01	.9000E+01	8.720E+03	1.744E+04	1.526E+05	.8750E+01
.9000E+01	.9500E+01	6.320E+03	1.264E+04	1.169E+05	.9250E+01
.9500E+01	.1000E+02	4.582E+03	9.164E+03	8.933E+04	.9750E+01

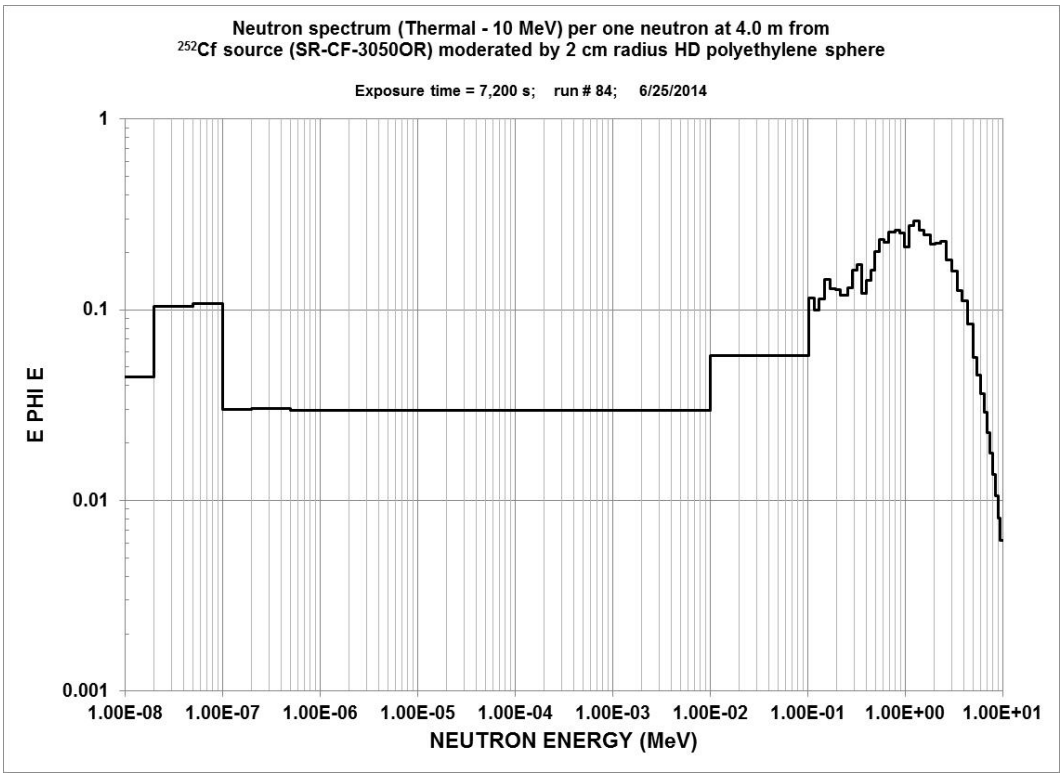
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



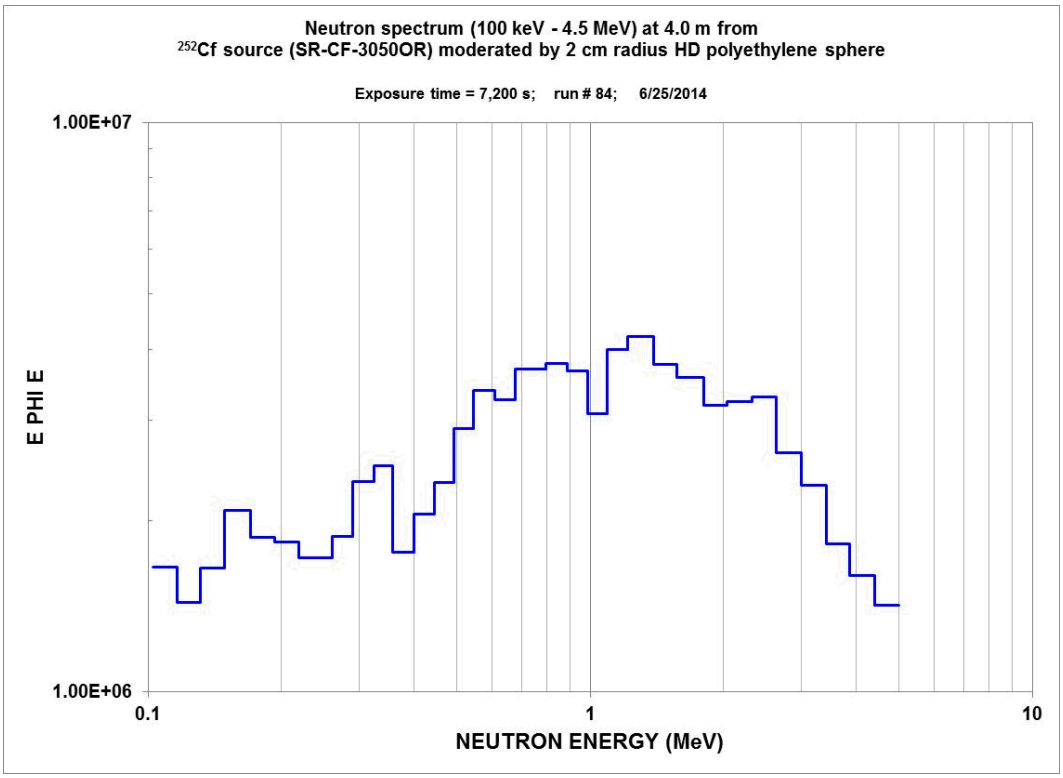


Figure L-5. Neutron spectra at 4.0 m from ^{252}Cf moderated by 2 cm of polyethylene

Fluence, spectral and dosimetric data at 4.5 m from ^{252}Cf moderated by 2 cm of polyethylene

Table L-11. Neutron fluence and dosimetric data at 4.5 m from ^{252}Cf source (s# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date:	6/25/2014
Exposure time:	7,200 s
Run #	N85

FLUENCE DATA

		FLUENCE (n cm-2)	FLUENCE RATE (n cm-2 s-1)
50 keV - 4.5 MeV	:	8.76E+06	1.22E+03
Epi-thermal region	:	6.63E+06	9.21E+02
Thermal region	:	3.40E+06	4.72E+02
Thermal – 4.5 MeV	:	1.88E+07	2.61E+03
Thermal – 10.0 MeV	:	1.9029E+07	2.6430E+03

DOSIMETRIC DATA

		DOSE		DOSE RATE	
		KERMA (rads)	H*(10) (Sv)	KERMA (mrads/hr)	H*(10) (uSv/hr)
50 keV - 4.5 MeV	:	1.95E-02	2.99E-03	9.74E+00	1.49E+03
Epi-thermal region	:	7.16E-04	1.20E-04	3.58E-01	6.00E+01
Thermal region	:	6.80E-05	3.60E-05	3.40E-02	1.80E+01
Thermal – 4.5 MeV	:	2.03E-02	3.14E-03	1.01E+01	1.57E+03

		DOSE Thermal - 10 MeV	DOSE RATE Thermal - 10 MeV
KERMA	=	2.0868E-02 rads	1.0434E+01 mrads/hr
H*(10) ICRP-74	=	3.2024E-03 Sv	1.6012E+03 uSv/hr
Hp(10,0) ICRP-74	=	3.3141E-03 Sv	1.6570E+03 uSv/hr

Table L-12. Neutron fluence at 4.5 m from ^{252}Cf source (# SR-CF-3050OR) moderated by 2 cm of polyethylene

Date: 6/25/2014
Exposure time: 7,200 s
Run number: N85

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV (n/cm^2.MeV)	FLUENCE/ LETHARGY* (n/cm^2.u)	E avg. (MeV)
.1000E-08	.2000E-08	7.684E+03	7.684E+12	1.109E+04	.1500E-08
.2000E-08	.5000E-08	4.930E+04	1.643E+13	5.380E+04	.3500E-08
.5000E-08	.1000E-07	1.499E+05	2.999E+13	2.163E+05	.7500E-08
.1000E-07	.2000E-07	4.420E+05	4.420E+13	6.377E+05	.1500E-07
.2000E-07	.5000E-07	1.370E+06	4.567E+13	1.495E+06	.3500E-07
.5000E-07	.1000E-06	1.071E+06	2.142E+13	1.545E+06	.7500E-07
.1000E-06	.2000E-06	3.012E+05	3.012E+12	4.346E+05	.1500E-06
.2000E-06	.5000E-06	4.024E+05	1.341E+12	4.392E+05	.3500E-06
.5000E-06	.1000E-01	4.396E+06	4.396E+08	4.439E+05	.5000E-02
.1000E-01	.1027E+00	1.834E+06	1.979E+07	7.876E+05	.5635E-01
.1027E+00	.1166E+00	1.723E+05	1.243E+07	1.361E+06	.1096E+00
.1166E+00	.1317E+00	1.788E+05	1.183E+07	1.466E+06	.1241E+00
.1317E+00	.1493E+00	1.450E+05	8.219E+06	1.153E+06	.1405E+00
.1493E+00	.1707E+00	2.742E+05	1.280E+07	2.045E+06	.1600E+00
.1707E+00	.1934E+00	1.967E+05	8.673E+06	1.577E+06	.1821E+00
.1934E+00	.2199E+00	2.056E+05	7.771E+06	1.604E+06	.2066E+00
.2199E+00	.2606E+00	2.922E+05	7.170E+06	1.719E+06	.2402E+00
.2606E+00	.2906E+00	2.067E+05	6.889E+06	1.897E+06	.2756E+00
.2906E+00	.3244E+00	1.983E+05	5.877E+06	1.805E+06	.3075E+00
.3244E+00	.3581E+00	1.818E+05	5.386E+06	1.836E+06	.3413E+00
.3581E+00	.3994E+00	2.036E+05	4.935E+06	1.867E+06	.3787E+00
.3994E+00	.4444E+00	2.147E+05	4.771E+06	2.011E+06	.4219E+00
.4444E+00	.4931E+00	2.272E+05	4.661E+06	2.183E+06	.4688E+00
.4931E+00	.5456E+00	2.452E+05	4.670E+06	2.423E+06	.5194E+00
.5456E+00	.6094E+00	3.218E+05	5.047E+06	2.912E+06	.5775E+00
.6094E+00	.6769E+00	3.254E+05	4.820E+06	3.097E+06	.6431E+00
.6769E+00	.7946E+00	5.201E+05	4.417E+06	3.243E+06	.7358E+00
.7946E+00	.8870E+00	3.458E+05	3.743E+06	3.144E+06	.8408E+00
.8870E+00	.9871E+00	3.273E+05	3.270E+06	3.062E+06	.9371E+00
.9871E+00	.1095E+01	2.802E+05	2.599E+06	2.704E+06	.1041E+01
.1095E+01	.1218E+01	3.587E+05	2.911E+06	3.364E+06	.1157E+01
.1218E+01	.1391E+01	4.625E+05	2.676E+06	3.485E+06	.1305E+01
.1391E+01	.1573E+01	3.978E+05	2.186E+06	3.235E+06	.1482E+01
.1573E+01	.1807E+01	4.089E+05	1.747E+06	2.948E+06	.1690E+01
.1807E+01	.2041E+01	3.312E+05	1.415E+06	2.720E+06	.1924E+01
.2041E+01	.2327E+01	3.660E+05	1.280E+06	2.791E+06	.2184E+01

E2 (MeV)	E1 (MeV)	FLUENCE/ (E1-E2) (n/cm^2)	FLUENCE/ MeV ($n/cm^2.MeV$)	FLUENCE/ LETHARGY* ($n/cm^2.u$)	E avg. (MeV)
.2327E+01	.2639E+01	3.538E+05	1.134E+06	2.812E+06	.2483E+01
.2639E+01	.3003E+01	2.965E+05	8.145E+05	2.295E+06	.2821E+01
.3003E+01	.3419E+01	2.393E+05	5.753E+05	1.845E+06	.3211E+01
.3419E+01	.3861E+01	1.847E+05	4.179E+05	1.519E+06	.3640E+01
.3861E+01	.4407E+01	1.836E+05	3.363E+05	1.388E+06	.4134E+01
.4407E+01	.5000E+01	1.138E+05	1.919E+05	9.015E+05	.4703E+01
.5000E+01	.5500E+01	6.816E+04	1.363E+05	7.152E+05	.5250E+01
.5500E+01	.6000E+01	5.048E+04	1.010E+05	5.802E+05	.5750E+01
.6000E+01	.6500E+01	3.722E+04	7.444E+04	4.650E+05	.6250E+01
.6500E+01	.7000E+01	2.732E+04	5.464E+04	3.686E+05	.6750E+01
.7000E+01	.7500E+01	1.999E+04	3.998E+04	2.898E+05	.7250E+01
.7500E+01	.8000E+01	1.458E+04	2.915E+04	2.258E+05	.7750E+01
.8000E+01	.8500E+01	1.060E+04	2.121E+04	1.749E+05	.8250E+01
.8500E+01	.9000E+01	7.697E+03	1.539E+04	1.347E+05	.8750E+01
.9000E+01	.9500E+01	5.579E+03	1.116E+04	1.032E+05	.9250E+01
.9500E+01	.1000E+02	4.045E+03	8.089E+03	7.885E+04	.9750E+01

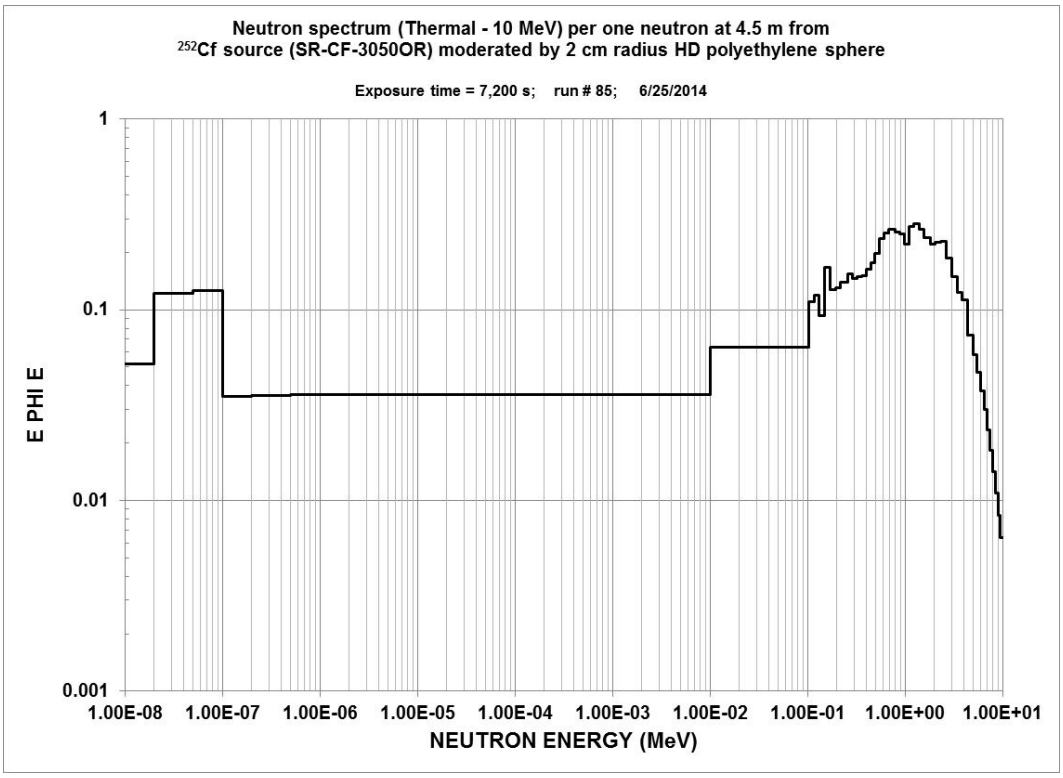
* **u** is neutron lethargy. Neutron lethargy **u** is the logarithmic energy decrement (loss).

Neutron lethargy **u** = ln(E1/E2)

where E1 is the upper boundary of the energy group (bin) and E2 is the lower boundary of the energy bin.

Neutron flux per unit lethargy is usually used in the discussion of neutron moderation (i.e., slow down) instead of neutron flux per unit energy. Neutron flux per unit lethargy is used in neutron energy distribution plots when the energy ranges several orders of magnitude.

- First column, E2, is the lower boundary of the energy bin
- Second column, E1, is the upper boundary of the energy bin
- Third column, FLUENCE/(E1-E2), is the neutron fluence in the energy bin E1-E2
- Fourth column, FLUENCE/MeV, is the neutron fluence per 1 MeV
- Fifth column, FLUENCE/LETHARGY, is the neutron fluence per unit lethargy
- Six column, E avg., is the average energy in the bin = (E1-E2)/2



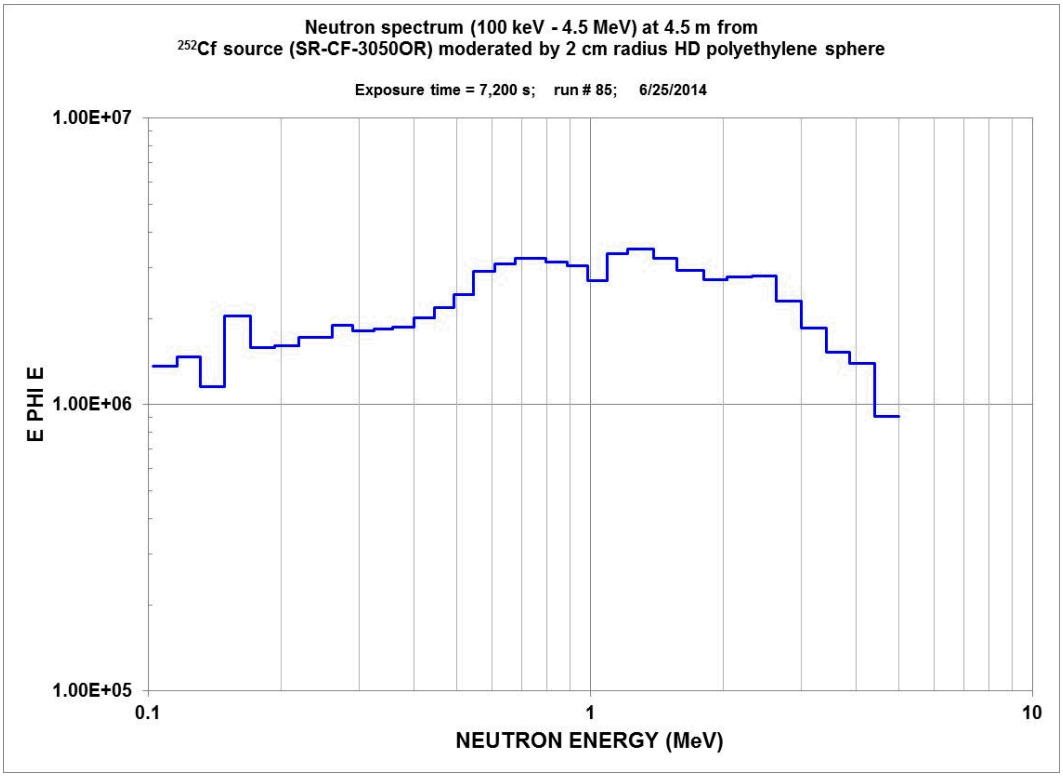


Figure L-6. Neutron spectra at 4.5 m from ^{252}Cf moderated by 2 cm of polyethylene