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Standard Practice for Characterizing Neutron Energy Fluence Spectra in Terms of an Equivalent Monoenergetic Neutron Fluence for Radiation-Hardness Testing of Electronics¹

This standard is issued under the fixed designation E 722; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ε¹Note—Table A1.1 and A2.1 were corrected editorially in February 2005. ε^2 Note—An = sign was added in Eq 1 in April 2007.

1. Scope

- 1.1 This practice covers procedures for characterizing a-neutron fluence from a source in terms of an equivalent monoenergetic neutron fluence. It is applicable to neutron effects testing, to the development of test specifications, and to the characterization of neutron test environments. The sources may have a broad neutron-energy spectrum, range, or may be mono-energetic neutron sources with energies up to 20 MeV. This practice is not applicable in cases where the predominant source of displacement damage is from neutrons of energy less than 10 keV. The relevant equivalence is in terms of a specified effect on certain physical properties of materials upon which the source spectrum is incident. In order to achieve this, knowledge of the effects of neutrons as a function of energy on the specific property of the material of interest is required. Sharp variations in the effects with neutron energy may limit the usefulness of this practice in the case of mono-energetic sources.
- 1.2 This practice is presented in a manner to be of general application to a variety of materials and sources. Correlation between displacements (1-3)² caused by different particles (electrons, neutrons, protons, and heavy ions) is beyond the scope of this practice. In radiation-hardness testing of electronic semiconductor devices, specific materials of interest include silicon and gallium arsenide, and the neutron sources generally are test and research reactors and californium-252 irradiators.
- 1.3 The technique involved relies on the following factors: (1) a detailed determination of the energy fluence spectrum of the neutron source, and (2) a knowledge of the degradation (damage) effects of neutrons as a function of energy on specific material properties.
- 1.4 The detailed determination of the neutron energyfluence spectrum referred to in 1.3 need not be performed afresh for each test exposure, provided the exposure conditions are repeatable. When the spectrum determination is not repeated, a neutron fluence monitor shall be used for each test exposure.

1.5

- 1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.
- 1.6 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

- 2.1 ASTM Standards:³
- E 170 Terminology Relating to Radiation Measurements and Dosimetry
- E 265 Test Method for Measuring Reaction Rates and Fast-Neutron Fluences by Radioactivation of Sulfur-32
- E 693 Practice for Characterizing Neutron Exposures in Iron and Low Alloy Steels in Terms of Displacements Per Atom (DPA), E 706(ID)
- E 720 Guide for Selection and Use of Neutron Sensors for Determining Neutron Spectra Employed in Radiation-Hardness Testing of Electronics

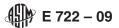
¹ This practice is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.07 on Radiation Dosimetry for Radiation Effects on Materials and Devices.

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The boldface numbers in parentheses refer to a list of references at the end of this practice.

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.



- E 721 Guide for Determining Neutron Energy Spectra from Neutron Sensors for Radiation-Hardness Testing of Electronics
- E 844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance, E 706(IIC)
- E 944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance, E 706 (IIA)
- 2.2 International Commission on Radiation Units and Measurements (ICRU) Reports:
- ICRU Report 13—Neutron Fluence, Neutron Spectra, and Kerma⁴
- ICRU Report 26—Neutron Dosimetry for Biology and Medicine⁴ ICRU Report 33—RadiationQuantities and Units⁴
- ICRU Report 33—Radiation Quantities and Units⁴

3. Terminology

- 3.1 Definitions of Terms Specific to This Standard:
- 3.1.1 displacement damage function—(F_{D,mat}) an energydependent parameter proportional to the quotient of the observable displacement damage per target atom and the neutron fluence.) an energy-dependent parameter proportional to the quotient of the observable displacement damage per target atom and the neutron fluence. Different displacement-related damage functions may exist, so the damage mode of interest and the observation procedure shall be identified when the specific damage function is defined. See, for example, Annexes A1.2.2 and A2.2.2.
- 3.1.1.1 Discussion—Observable changes in a material's properties attributable to the atomic displacement process are useful indices of displacement damage in that material. In cases where the observed displacement damage is not in linear proportion to the applied fluence, the displacement damage function represents the quotient $F_{D,mat}$ (E)/d Φ , in the limiting case of zero fluence. Examples of suitable representations of displacement damage functions are given in the annexes. In the case of silicon, it has been shown that the displacement damage function may be successfully equated with the displacement kerma factor. This question is discussed further in the annexes. (E)/d Φ , in the limiting case of zero fluence. Examples of suitable representations of displacement damage functions are given in the annexes. In the case of silicon, damage mode of interest is the change in minority-carrier recombination lifetime in the bulk semiconductor material. While several procedures exist to directly measure the minority carrier lifetime in bulk material, since this lifetime is related to the gain of a bipolar junction transistor (BJT), one observable damage metric is the BJT gain degradation. For this damage mode, it has been shown that the displacement damage function may be successfully equated with the microscopic displacement kerma factor. This question is discussed further in the annexes.
- 3.1.2 displacement kerma factor—(K_{microscopic displacement kerma factor—(K_{D,mat} (E)) the energy dependent quotient of the displacement kerma per target atom and the neutron fluence. (E)) the energy-dependent quotient of the displacement kerma per target atom} and the neutron fluence. $K_{D,mat}$ (E) is proportional to $K_{D,mat}$. \bar{A}/Φ , where $K_{D,mat}$ is the displacement kerma, \bar{A} is the mean atomic mass of the material and Φ is the neutron fluence from a monoenergetic source of energy E.
- 3.1.2.1 Discussion—This quantity may be calculated from the microscopic neutron interaction cross sections, the kinematic relations for each reaction and from a suitable partition function which divides the total kerma into ionization and displacement kerma.—This quantity may be calculated from the microscopic neutron interaction cross sections, the kinematic relations for each reaction and from a suitable partition function which divides the total kerma into ionization and displacement kerma. The use of the term *microscopic* kerma factor in this standard is to indicate that energy times area per atom is used, instead of per unit mass, as in the term kerma factor defined in E 170.
- 3.1.3 <u>energy-spectrum hardness parameter</u> fluence spectrum hardness parameter (H $_{mat} = \Phi_{eq,Eref,mat}/\Phi$) this parameter is defined as the ratio of the equivalent monoenergetic neutron fluence to the true-total fluence, $\Phi_{eq,Eref,mat}/\Phi$. The numerical value of the hardness parameter is also equal to the fluence of monoenergetic neutrons at the specific energy, Eref, required to produce the same displacement damage in the specified material, mat, per unit fluence of neutrons of spectral distribution neutron spectrum $\Phi(E)$.
- 3.1.3.1 Discussion—For damage correlation, a convenient method of characterizing the shape of an incident neutron energy-fluence fluence spectrum $\Phi(E)$, is in terms of an energy fluence spectrum hardness parameter. The hardness parameter in a particular neutron field depends on the displacement damage function used to compute the damage (see annexes) and is therefore different for different semiconductor materials.
- 3.1.4 equivalent monoenergetic neutron fluence— ($\Phi_{eq,Eref,mat}$) an equivalent monoenergetic neutron fluence, $\Phi_{eq,Eref,mat}$, characterizes an incident energy-fluence fluence spectrum, $\Phi(E)$, in terms of the fluence of monoenergetic neutrons at a specific energy Eref required to produce the same displacement damage in a specified irradiated material, mat, as $\Phi(E)$.
- 3.1.4.1 Discussion—Note that $\Phi_{eq,Eref,mat}$ is equivalent to $\Phi(E)$ if, and only if, the specific device effect (for example, current gain degradation in silicon) being correlated is described by the displacement damage function used in the calculation.
- 3.1.5 kerma—(K_{fluence} and fluence spectrum—see neutron fluence and neutron fluence spectrum.

 3.1.6 kerma factor—(K_{mat} (E)) the sum of the initial kinetic energies of all the charged particles liberated by indirectly ionizing particles (for example, neutrons) in a volume element containing a unit mass of the specified material (see ICRU reports 13 and 33).
- 3.1.5.1(E)) the kerma per unit fluence of particles of energy E present in a specified material, mat. See Terminology E 170 for the definition of kerma, and a formula for calculating the kerma factor.

⁴ Available from International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Avenue Suite 400 Bethesda, MD 20814:20841-3095, http://www.icru.org/



- 3.1.6.1 Discussion—When a material is irradiated by a neutron field, the energy imparted to charged particles in the material may be described by the quantity kerma. The total kerma may be divided into two parts, ionization kerma and displacement kerma. See 3.1.2.1 for the distinction between kerma factor and microscopic kerma factor. Calculations of ionization and microscopic displacement kerma in silicon and gallium arsenide as a result of irradiation by neutrons with energies up to 20 MeV are described in Refs 5-8 and in the annexes.
- 3.1.7 neutron fluence and neutron fluence spectrum are used in this standard, and are special cases of **particle fluence** and **particle fluence spectrum** as defined in E 170.
- 3.1.7.1 *Discussion*—In cases where the context makes clear that neutrons are referred to, the terms *fluence* and *fluence spectrum* are sometimes used.

4. Summary of Practice

4.1 The equivalent monoenergetic neutron fluence,

 Φ $_{\rm eq,Eref,mat}\!,$ is given as follows:

$$\Phi_{\text{eq,Eref,mat}} = \frac{\int_{0}^{\infty} \Phi(E) F_{\text{D,mat}}(E) dE}{F_{\text{D,Eref,mat}}}$$
(1)

where:

 $\Phi(E)$ = incident neutron energy-fluence spectral distribution, incident neutron fluence spectrum,

F_{D,mat} = neutron displacement damage function for the irradiated material (displacement damage per unit fluence) as a function of energy, and

 $F_{D,Eref,mat}$ = displacement damage reference value designated for the irradiated material and for the specified equivalent energy, Eref, as given in the annexes.

The energy limits on the integral are determined in practice by the <u>incident-energy incident neutron fluence</u> spectrum and by the material being irradiated.

4.2 The neutron-energy spectrum hardness parameter, H_{mat}, is given as follows:

$$\left(\frac{\text{https:}}{H_{\text{mat}}} = \frac{\int_{0}^{\infty} \Phi(E) F_{D,\text{mat}}(E) dE}{F_{D,Eref,mat}} \right)$$

$$= \frac{1}{F_{D,Eref,mat}} \int_{0}^{\infty} \Phi(E) dE$$
(2)

4.3 Once the neutron energy-fluence spectrum has been determined (for example, in accordance with Test Method E 721) and the equivalent monoenergetic fluence calculated, then a monitor (such as an activation foil) can be used in subsequent irradiations at the same location to determine the fluence; that is, the neutron fluence is then described in terms of the equivalent monoenergetic neutron fluence per unit monitor response, $\Phi_{eq,Eref,mat}$ /M_r. Use of a monitor foil to predict $\Phi_{eq,Eref,mat}$ is valid only if the energyneutron spectrum remains constant.

5. Significance and Use

- 5.1 This practice is important in characterizing the radiation hardness of electronic devices irradiated by neutrons. This characterization makes it feasible to predict some changes in operational properties of irradiated semiconductor devices or electronic systems. To facilitate uniformity of the interpretation and evaluation of results of irradiations by sources of different energyfluence spectra, it is convenient to reduce the incident neutron fluence from a source to a single parameter—an equivalent monoenergetic neutron fluence—applicable to a particular semiconductor material.
- 5.2 In order to determine an equivalent monoenergetic neutron fluence, it is necessary to evaluate the displacement damage of the particular semiconductor material. Ideally, this quantity is correlated to the degradation of a specific functional performance parameter (such as current gain) of the semiconductor device or system being tested. However, this correlation has not been established unequivocally for all device types and performance parameters since, in many instances, other effects also can be important. Ionization effects produced by the incident neutron fluence or by gamma rays in a mixed neutron fluence, short-term and long-term annealing, and other factors can contribute to observed performance degradation (damage). Thus, caution should be exercised in making a correlation between calculated displacement damage and performance degradation of a given electronic device. The types of devices for which this correlation is applicable, and numerical evaluation of displacement damage are discussed in the annexes.
- 5.3 The concept of 1-MeV equivalent fluence is widely used in the radiation-hardness testing community. It has merits and disadvantages that have been debated widely (9-12). For these reasons, specifics of a standard application of the 1-MeV equivalent fluence are presented in the annexes.

6. Procedure for Calculating $\Phi_{\rm eq,Eref,mat}$

6.1 To evaluate Eq 1 and 2, determine the energy limits E_{min} and E_{max} to be used in place of zero and infinity in the integrals of (Eq 1) and (Eq 2) and the values of the displacement damage function $F_{D,mat}$ (E) for the irradiated material and perform the indicated integrations.



- 6.1.1 Choose the upper limit E_{max} to be at an energy above which the integral damage falls to an insignificant level. For Godivaor TRIGA-type spectra, this limit is about 12 MeV.
- 6.1.2 Choose the lower-energy limit E_{min} to be at an energy below which the integral damage falls to an insignificant level. For silicon irradiated by Godiva-type spectra, this energy has been historically chosen to be about 0.01 MeV. More highly moderated spectra may require lower thresholds or specialized filtering requirements such as a boron shield, or both.
- 6.1.3 The values of the neutron displacement damage function used in Eq 1 and 2 obviously depend on the material and the equivalent energy chosen. For silicon, resonance effects cause large variations (by a factor of 20 or more) in the displacement damage function as a function of energy over the range from about 0.1 to 8 MeV (4,5). Therefore, monoenergetic neutron sources with these energies may not be useful for effects testing. Also, for a selected equivalent energy, the value of $F_{D,Eref,mat}$ at that specific energy may not be representative of the displacement damage function at nearby energies. In such cases, a method of averaging the damage function over a range of energies around the chosen equivalent energy can be used. Such averaging is discussed in the annexes. Because the $F_{D,mat}$ (E) term is normalized by dividing by $F_{D,Eref,mat}$ in Eq 1 and 2, only the shape of the $F_{D,mat}$ (E) function versus energy is of primary importance. In such a case, precise knowledge of the absolute values of $F_{D,mat}$ (E) is not required in evaluating $\Phi_{eq,Eref,mat}$ and H_{mat} .

7. Determining $\Phi_{eq,Eref,mat}$ with a Monitor Foil

- 7.1 At the same time that the energyfluence spectrum, $\Phi(E)$, of the source is determined (for example, with an activation foil set in accordance with Guides E 720 or E 844, or both, and Test Method E 721 or Practice E 944, or both, place a fast-neutron monitor foil in the neutron field at an appropriate location. After $\Phi_{\text{eq,Eref,mat}}$ is determined and the monitor foil counted, calculate the ratio of the equivalent monoenergetic fluence to the unit monitor response, $\Phi_{\text{eq,Eref,mat}}/M_r$.
- 7.2 Use the response of the fast-neutron monitor foil, M_r , to predict $\Phi_{eq,Eref,mat}$ in subsequent routine device test irradiations. For this method to be valid, it is important to keep the source-foil geometry essentially identical to that used for calibrating the monitor foil. Moderate changes in source-to-foil distance are allowable. In addition, make sure the source location (of a Godiva-type reactor) with respect to scattering materials (walls, floor, etc.) is the same. Do not change or move nearby scattering materials or moderators.
- 7.3 Precautions in maintaining original calibration conditions are necessary to avoid altering the neutron energyfluence spectrum significantly in subsequent irradiations. An appreciable change in the spectrum will invalidate the calibration of the monitor foil and, therefore, would necessitate a new measurement of $\Phi(E)$ and recalibration of the monitor foil. Whenever the neutron source configuration is changed, as for example, if the core fuel elements are replaced or rearranged in a nuclear reactor, the activation foil spectrum measurements and all quantities derived from them may need to be remeasured.
 - 7.4 The choice of a monitor foil material depends on several factors:
 - 7.4.1 The activation threshold should be high enough so as to make it insensitive to neutrons below the E_{min} value used in Eq 1 and 2. However, the threshold energy should be low enough to sample a significant fraction of the total fluence.
 - 7.4.2 The monitor foil should have a high neutron sensitivity and a convenient half-life.
 - 7.4.3 The detector system available for counting the monitor foil may dictate the choice of foil material. A germanium gamma-ray detector system can be used, and ⁵⁴Fe or ⁵⁸Ni foils utilized as monitors. However, if a beta particle detector system is available, then ³²S foils are suitable. Details of the use of sulfur foils are given in Test Method E 265.

8. Report

- 8.1 In the report of the results of radiation-hardness tests in which an equivalent monoenergetic neutron fluence is calculated, the report should include at least the following information:
- 8.1.1 Semiconductor material and device performance parameter (for example, current gain in silicon bipolar transistors) degradation being correlated to displacement damage should be specified.
 - 8.1.2 Neutron source as to type and mode of operation during tests (fast-pulse or steady state).
- 8.1.3 Neutron energy-fluence fluence spectrum and how it was determined.
- 8.1.4 Monitor foil employed and the detector system used for counting the foil. If an effective fission cross section for the monitor foil is used, its value should be stated.
- 8.1.5 The neutron displacement damage function should be given, or referenced. The specific material (for example, silicon) whose applicable damage function was used must be specified. The values cited in Annex A1 and Annex A2 shall be used for silicon and GaAs, respectively.
- 8.1.6 Methods used for determining the average value of $F_{D,Eref,mat}$ and the value of Eref selected. The values cited in Annex A1 and Annex A2 shall be used for silicon and GaAs, respectively.
- 8.1.7 Method used for evaluating the integrals of Eq 1 and 2 (for example, the energy bin width and number of bins in a numerical integration).
 - 8.1.8 Values of $\Phi_{eq,Eref,mat}$, H $_{mat}$, and $\Phi_{eq,Eref,mat}/M_{r}$.

9. Precision and Bias

9.1 The precision in calculating $\Phi_{eq,Eref,mat}$ and H_{mat} will depend on the method of evaluation of the integrals in Eq 1 and 2 (for example, the width of the energy bins used in a numerical integration).



- 9.2 The uncertainty of the calculated results depends on (1) knowledge of the neutron source energy-fluence fluence spectrum, (2) knowledge of the displacement damage functions over that energy spectrum, and (3) knowledge of the value of the average displacement damage function at the specified equivalent energy.
- 9.3 A specific example of the uncertainty associated with the calculation of a 1-MeV equivalent fluence for silicon is given in Annex A1.

10. Keywords

10.1 displacement damage; electronic hardness; gallium arsenide; hardness parameter; silicon; silicon damage; silicon equivalent damage (SED); 1–MeV equivalent fluence

ANNEXES

(Mandatory Information)

A1. CALCULATION OF 1-MeV EQUIVALENT NEUTRON FLUENCE FOR SILICON

A1.1 Background

A1.1.1The choice of the specific energy for determining an equivalent fluence has been the subject of some controversy within the electronics hardness-testing community

A1.1.1 The observable damage metric of interest in this annex is the change in gain of a silicon bipolar junction transistor (BJT) due to bulk displacement damage effects. The damage mechanism is the change in minority-carrier recombination lifetime in the bulk semiconductor material. While a BJT gain may also be degraded by oxide traps and interface states introduced by the ionizing dose to the oxide, this is a surface effect and is not within the scope of this standard. In interpreting measurements of this 1-MeV(Si) damage, efforts must be made to eliminate any interference from ionization-related surface effects.

A1.1.2 The choice of the specific energy for determining an equivalent fluence has been the subject of some controversy within the electronics hardness-testing community (9). Some workers (10) have proposed that 1 MeV be used while others (11 12) have suggested 14 MeV to be more appropriate. The concept of 1-MeV equivalent fluence has gained broad acceptance in practice, and procedures for applying it to silicon are described in this annex in some detail.

A1.1.2AnA1.1.3 An important basis of the practice is the correlation of radiation damage effects in a semiconductor device with the displacement kerma produced in bulk silicon by neutron irradiation. This correlation assumes that volume (versus surface) effects are the dominant radiation damage mechanism. Experimental evidence indicates that displacement kerma is a valid measure of device performance degradation (for example, reduction in current gain) in bipolar transistors whose operation basically depends on volume mechanisms (13, 14). However, for device types governed by surface phenomena (such as MOSFET devices), it is clear that this correlation is not valid. Surface-effect devices are more sensitive than are volume-effect devices to ionization radiation effects produced either by a neutron field or a mixed neutron-gamma field. Therefore, the basic mechanism associated with device performance and the effect being correlated (for example, gain degradation) should be kept in mind before applying this practice at any equivalent energy.

A1.2 Calculation of $\Phi_{eq,1MeV,Si}$

A1.2.1A 1-MeV equivalent fluence in a given material can be defined for an irradiation by neutrons of any neutron spectrum. The neutron energy fluence, $\Phi(E)$, may be that determined from a neutron transport calculation, that determined from measurements, or that given in an environment specification document.

A1.2.2The neutron energy-fluence spectrum, $\Phi(E)$, may be determined experimentally by measuring a set of activation foils and then by application of a spectral adjustment computer code (see Guide E720

A1.2.1 The displacement damage function, $F_{D,mat}$ (E), defined for silicon in this annex is the silicon microscopic displacement kerma factor, as tabulated in Table A1.1.

A1.2.2 A 1-MeV equivalent fluence in silicon is defined for an irradiation by neutrons of any neutron spectrum for which the predominant source of displacement damage is from neutrons of energy between 10 keV and 20 MeV. The neutron fluence spectrum, $\Phi(E)$, may be that determined from a neutron transport calculation, that determined from measurements, or that given in an environment specification document.

A1.2.3 The neutron fluence spectrum, $\Phi(E)$, may be determined experimentally by measuring a set of activation foils and then by application of a spectral adjustment computer code (see Guide E 720 and Test Method E 721 for details).

A1.2.34 Results of calculations of silicon <u>microscopic</u> displacement kerma factors (displacement kerma <u>per target atom</u> per unit neutron fluence), $K_{D,Si}$ (E), are given in Table A1.1 as a function of neutron energy over the range from 10^{-10} to 20 MeV (11, 15). The unit of the <u>microscopic</u> kerma factor is megaelectron volt times millibarns (MeV-:mbarn). Each factor can be multiplied by 3.435×10^{-13} to convert to rad(Si)=:cm², or by 3.435×10^{-19} to convert to $J-m^2$ /kg or Gy(Si)=m/kg or Gy(Si)=m/kg or Gy(Si):m². The silicon microscopic displacement kerma factor as given in Table A1.1 is the accepted silicon damage function to be used in the application of this standard: $F_{D,Si}$ (E) = $K_{D,Si}$ (E). This microscopic displacement kerma was computed by using the ENDF/B-VI²⁸Si cross section evaluation (18), a displacement threshold energy of 25 eV, the Robinson fit to the Lindhard energy partition function (19),



Bin Mid-Point Energy Displacement Damage Function
(MeV) (MeV•mbarn)
$\begin{array}{cccc} & & & & & & & & & & & & & & & & & $
<u>3</u> <u>19.7500</u> <u>183.1200</u>
$\begin{array}{c cccc} & & & & & & & & & \\ \hline 4 & & & & & & & \\ \hline 5 & & & & & & & \\ \hline 5 & & & & & & \\ \hline \end{array}$
<u>6</u> 19.4500 183.5100
7 19.3500 183.6300 10.3500 189.7500
8
10 19.0500 184.0000 10.0500 184.0000
11 18.9500 184.1100 184.2000 184.2000
13 18.7500 184.2800
14 18.6500 184.3700 15 18.5500 184.4500
16 18.4500 184.3100
17 18.3500 183.9700 18.0500 180.0000
18 18.2500 183.6200 19 18.1500 183.2800
20 18.0500 182.9400
21 17.9500 182.5900 22 17.8500 182.2400
23 17.7500 181.9100
24 17.6500 181.5800 25 17.5500 181.2400
25 17.5500 161.2400 26 17.4500 180.6700
<u>27</u> <u>17.3500</u> <u>179.8800</u>
28 11 0 17.2500 12 11 0 179.0800 178.2800
30 17.0500 177.4900
$\begin{array}{c c} \hline 31 \\ \hline 32 \\ \hline 32 \\ \hline \end{array}$
33 16.7500 177.7600
34 35 16.6500 16.5500 178.2700
35 16.5500 178.2700 178.3200 178.3200
37 16.3500 178.1800 40.0500 470.0000
38 16.2500 178.0300 39 16.1500 F722-()9 177.8900
https://standards.iteh.ai/eata41 g/standards/15.9500/3404c3-9164-4176.3000 28-f9e3b2b
https://standards.iteh.ai/cat <u>41</u>
43 15.7500 171.3200
46 15.4500 170.5600
47 15.3500 170.4000 48 15.3500 170.4000
48 15.2500 170.2500 49 15.1500 170.0900
50 15.0500 169.9300
51 14.9500 169.7900 52 14.8500 169.6600
53 14.7500 169.5200
54 14.6500 169.3700 55 14.5500 169.2100
56 14.4500 168.7300 168.7300
57 14.3500 167.9400
58 14.2500 167.1400 59 14.1500 166.3400
60 14.0500 165.5400
$\begin{array}{c cccc} \underline{61} & \underline{13.9500} & \underline{165.4000} \\ \hline 62 & \underline{13.8500} & \underline{165.8600} \end{array}$
63 13.7500 166.2900
64 13.6500 166.7300
65 13.5500 167.1600 66 13.4500 167.5300
67 <u>13.3500</u> 167.8300
68 13.2500 168.1100 69 13.1500 168.3900
70 13.0500 168.6600
47 15.3500 170.4000 48 15.2500 170.2500 49 15.1500 170.0900 50 15.0500 169.9300 51 14.9500 169.7900 52 14.8500 169.6600 53 14.7500 169.3700 54 14.6500 169.3700 55 14.5500 169.2100 56 14.4500 168.7300 57 14.3500 167.9400 58 14.2500 167.1400 59 14.1500 166.3400 60 14.0500 165.400 61 13.9500 165.400 62 13.8500 166.800 63 13.7500 166.2900 64 13.6500 167.1600 65 13.3500 167.8300 67 13.3500 167.8300 68 13.2500 168.1100 69 13.1500 168.600 70 13.0500 16
<u>72</u> <u>12.8500</u> <u>168.2800</u>



-		IABLE	Continued	
	Bin	Mid-Point Energy	Displacement Damage Func-	
-		<u></u>	<u>tion</u>	
-	<u>#</u>	(MeV)	(MeV•mbarn)	
	_73	12.7500	167.9400	
	74	12.6500	167.6000 167.2700	
	<u></u>	<u>12.5500</u> 12.4500	167.2700 167.2200	
	77	12.3500	167.4700	
	78	12.2500	167.7100	
	73 74 75 76 77 78 79 80	12.1500	167.9500	
	<u>80</u> <u>81</u>	12.0500 11.9500	168.1700 165.6600	
	82	11.8500	165.4600	
	83	11.7500	166.6200	
	84	11.6500	165.7900 168.6000	
	85 86	11.5500 11.4500	168.6200 165.3800	
	87	11.3500	166.0300	
	88	11.2500	159.5200	
	89 90	11.1500 11.0500	155.6100 158.7500	
	91	10.9500	160.0500	
	92	10.8500	162.9100	
	93	10.7500	159.0000	
	94 95	10.6500 10.5500	155.5100 154.6000	
	96	10.4500	154.7600	
	97	10.3500	164.6700	
	98	10.2500 10.1500	163.3600 168.6300	
	100	10.0500	166.2100	
	101	9.9500	164.4900	
	102	9.8500	164.0600	
	103	9.7500 9.6500	161.9600 156.1000	
	105	9.5500	164.4100	
	106	9.4500	169.8200	
	107 108	9.3500 9.2500	166.2100 150.6900	
	109	9.1500	153.8800	
	110	9.0500	174.5800	
	111 112	8.9500 8.8500	177.5700 160.2200	
		andards/\$18.7500 404	4C3-9164-410146.75008-19e3b.	
	114	8.6500	163.8600	
	115 116	<u>8.5500</u> <u>8.4500</u>	165.8300 166.6100	
	117	8.3500	162.0200	
	118	8.2500	158.4200	
	119 120	8.1500 8.0500	154.4300 165.0000	
	121	<u>7.9500</u>	186.4000	
	122	7.8500	175.3400	
	123 124	7.7500 7.6500	174.8000 170.3100	
	125	7.5500	162.9100	
	126	7.4500	167.0500	
	127	7.3500	168.4300	
	128 129	7.2500 7.1500	169.2700 139.1600	
	130	7.0500	161.1000	
	131	6.9500	141.7700	
	132	6.8500 6.7500	146.8900 162.2500	
	133 134	6.6500	150.9200	
	135	6.5500	119.2700	
	136	6.4500	139.2700	
	137 138	6.3500 6.2500	150.0900 175.3800	
	139	6.1500	127.7100	
	140	6.0500	153.0000	
	141 142	5.9500 5.8500	137.1000 164.7000	
	142	5.8500 5.7500	180.0500	
	144	5.6500	152.0700	



Bin	Mid-Point Energy	Displacement Damage Func- tion	
<u>#</u>	(MeV)	(MeV•mbarn)	
	5.5500	145.6000	
145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 167 168 169 170 171 172 173 174 175 176 177	5.4500	116.9800	
147	<u>5.3500</u> <u>5.2500</u>	120.1500 145.7000	
149	<u>5.1500</u>	170.3100	
151	<u>5.0500</u> <u>4.9500</u>	149.1600 145.5000	
152	<u>4.8500</u> <u>4.7500</u>	160.6700 185.6100	
154	4.6500	158.6400	
155 156	4.5500 4.4500	138.3800 140.9200	
157	4.3500	134.8600	
<u>158</u> 159	<u>4.2500</u> <u>4.1500</u>	164.4100 108.7100	
160	4.0500	131.6400	
161 162	3.9500 3.8500	134.3400 108.8400	
163	<u>3.7500</u>	115.1300	
164 165	3.6500 3.5500	69.52400 111.2700	
166	3.4500	119.0600	
168	3.3500 3.2500	113.8700 118.0200	
169	3.1500	131.5000	
170 171	3.0500 2.9500	120.2000 98.84500	
$\frac{172}{173}$	2.8500 2.7500	135.0400 106.9100	
173	2.6500	115.6700	
175 176	2.5500 2.4500	131.1900 118.9200	
177	2.5500 2.4500 2.3500	102.8200	
178 179	2.2500 2.1500	105.4900 106.9200	
180	2.0500	95.21800	
180 181 182 183 184 (Ca) 185	1.9500 1.8500	129.4000 129.2100	
183	1.7500 TM E7	78.34200 163.0200	
cat 185 g	/standards/ <u>1.5500</u> /3404c	3-9164-4 <u>105.9800</u> 28-19e3	
186	1.4500 1.3500	98.97900 88.76000	
187 188 189 190 191	1.2500	88.99400	
189 190	1.1500 1.0500	62.67300 75.69200	
191	0.98000	111.7900	
192 193	<u>0.94000</u> 0.90000	<u>111.4900</u> 87.78100	
194 195	0.86000 0.82000	78.33600 136.8000	
196 197	0.78000	87.94400	
197 198	0.74000 0.70500	64.57500 59.30200	
199 200	0.67500	56.76700	
200 201	0.64500 0.61500	55.29000 52.61800	
202	0.58750	58.33400	
202 203 204	0.56250 0.53750	124.5500 77.95800	
205	0.51250	57.41600	
206 207	0.48750 0.46250	55.40500 53.50800	
208 209	0.43750 0.41250	52.65400 51.89700	
210	0.39000	52.10700	
211 212	0.37000 0.35000	49.72200 50.09500	
213	0.33000	49.28000	
214 215	0.31000 0.29000	50.23700 51.32600	
216	0.27500	52.55800	



	IABLE COI	ninueu	_
		Displacement Damage Func-	_
<u>Bin</u>	Mid-Point Energy	tion	
		<u>uon</u>	_
<u>#</u>	<u>(MeV)</u>	(MeV•mbarn)	
	0.06050	E4.0E000	-
217	0.26250	54.95900	
218	0.24750	58.46000	
219	<u>0.23500</u>	64.07300	
220	0.22500	69.75000	
221	0.21500	<u>78.66700</u>	
222	0.20500	91.83600	
222 223 224	0.19500	111.2800	
224	0.18500	114.1000	
225	0.17500	64.49300	
225 226	0.16500	19.04800	
227	0.15500	4.323200	
227			
228	0.14625	1.350900	
229	0.13875	1.870700	
230	<u>0.13125</u>	2.552600	
<u>231</u>	0.12375	3.352800	
230 231 232 233	<u>0.11750</u>	3.982800	
233	0.11250	4.431900	
234	0.10750	4.876000	
235	0.10250	5.197800	
236	0.98000E-01	5.417300	
236 237	0.94000E-01	5.611900	
238	0.90000E-01	5.844300	
239			
239	0.86000E-01	6.040100	
240	0.82000E-01	6.185300	
241	0.78000E-01	6.310600	
242	0.74000E-01	<u>6.595600</u>	
243	0.70500E-01	6.831900	
244	0.67500E-01	7.178200	
245	0.64500E-01	6.972900	
246	0.61500E-01	7.992000	
247	0.58750E-01	11.45300	
248	0.56250E-01	47.95000	
249	0.53750E-01	1.498700	
	0.51250E-01	1.847000	
250			
251	0.48750E-01	2.470200	
252	0.46250E-01	2.820300	
253	0.43750E-01	3.026800	
254	0.41250E-01	3.234200	
255		2-()9 <u>3.697700</u>	
256 257 Sta	0.37000E-01	2.995800	
257	and and S 0.35000E-01 4 C 5	-9164-41(2.949100)-19636	
258	0.33000E-01	2.823100	
259	0.31000E-01	2.689600	
260	0.29000E-01	2.556800	
261	0.27500E-01	2.452700	
262	0.26250E-01	2.363100	
263	0.24750E-01	2.261300	
<u>264</u>	0.23500E-01	2.180800	
		2.116100	
<u>265</u>	0.22500E-01		
266	0.21500E-01	2.050100	
267	0.20500E-01	1.979200	
268	0.19500E-01	1.900700	
269	0.18500E-01	1.820900	
270	0.17500E-01	1.738500	
271	0.16500E-01	<u>1.655100</u>	
272	0.15500E-01	1.565500	
273	0.14625E-01	1.485300	
274	0.13875E-01	1.414100	
275	0.13125E-01	1.342200	
276	0.12375E-01	1.270100	
277	0.11750E-01	1.210800	
277 278	0.11750E-01 0.11250E-01	1.165800	
279	0.10750E-01	1.121000	
280	0.10250E-01	1.076200	
281	0.98000E-02	1.036000	
282	0.94000E-02	0.9989800	
283	0.90000E-02	0.9611300	
284	0.86000E-02	0.9232700	
285	0.82000E-02	0.8854100	
286	0.78000E-02	0.8475500	
287	0.74000E-02	0.8096600	
288	0.70500E-02	0.7753600	
	<u>5.75500L 02</u>	0100000	-



Bin Mos-Point Energy	_		IABLE	<u> </u>	
289		Bin	Mid-Point Energy		
200	-	<u>#</u>	(MeV)	(MeV•mbarn)	
291 0.51500E-02 0.8847000 282 0.55750E-02 0.68570400 283 0.558750E-02 0.68570400 284 0.55750E-02 0.6858000 285 0.55750E-02 0.6858000 285 0.685750E-02 0.6868000 285 0.045750E-02 0.6868000 285 0.045750E-02 0.6868000 285 0.045750E-02 0.487530E-02 289 0.41550E-02 0.487530E-02 299 0.41550E-02 0.487530E-02 300 0.359000E-02 0.45851800 301 0.357000E-02 0.45851800 302 0.359000E-02 0.45851800 303 0.359000E-02 0.45851800 303 0.359000E-02 0.35851800 304 0.359000E-02 0.35851800 305 0.25750E-02 0.35851800 306 0.25500E-02 0.35851800 307 0.26250E-02 0.35851800 308 0.24750E-02 0.35851800 309 0.245750E-02 0.35851800 300 0.258500E-02 0.35851800 301 0.25500E-02 0.35851800 302 0.245500E-02 0.35851800 303 0.245750E-02 0.35851800 304 0.245750E-02 0.35851800 305 0.245750E-02 0.35851800 307 0.26250E-02 0.35851800 308 0.245750E-02 0.35851800 309 0.245750E-02 0.35851800 301 0.25500E-02 0.2855000 301 0.25500E-02 0.285500E-02 0.2855000 301 0.25500E-02 0.285500E-02 0.285500E-02 0.285500E-02 0.28	_		0.67500E-02	0.7451400	
292 0.58750E-0.2 0.6570400 283 0.56250E-0.2 0.6518600 284 0.55700E-0.2 0.6606800 285 0.55250E-0.2 0.6606800 286 0.55250E-0.2 0.65251000 287 0.46250E-0.2 0.55251000 287 0.46250E-0.2 0.55251000 289 0.41250E-0.2 0.452500 289 0.41250E-0.2 0.4581600 300 0.39000E-0.2 0.4581600 301 0.37000E-0.2 0.4151300 302 0.55000E-0.2 0.4515100 303 0.39000E-0.2 0.4515100 303 0.39000E-0.2 0.4551600 303 0.39000E-0.2 0.35999900 303 0.33000E-0.2 0.35999900 303 0.33000E-0.2 0.35999900 303 0.33000E-0.2 0.35999900 304 0.27500E-0.2 0.35999900 305 0.27500E-0.2 0.35999900 306 0.24500E-0.2 0.35999900 307 0.26550E-0.2 0.35999900 308 0.24500E-0.2 0.2859900 309 0.35900E-0.2 0.2859900 310 0.25500E-0.2 0.2859900 311 0.22500E-0.2 0.2859900 311 0.22500E-0.2 0.2859900 311 0.21500E-0.2 0.2859000 311 0.15500E-0.2 0.2819000 311 0.15500E-0.2 0.21515000 311 0.15500E-0.2 0.11515000 312 0.15500E-0.2 0.11515000 313 0.15500E-0.2 0.11515000 314 0.15500E-0.2 0.11515000 315 0.15500E-0.2 0.11515000 316 0.15500E-0.2 0.11515000 317 0.15500E-0.2 0.15500E-0.2 0.11515000 318 0.1450E-0.2 0.15500E-0.2 0.11515000 319 0.13577E-0.2 0.15500E-0.2 0.15500E-0.2 0.15500000 310 0.13577E-0.2 0.15500E-0.2 0.1550000000000000000000000000000000000					
293		291			
284 0.53700E-02 0.6066800 285 0.51250E-02 0.5691900 286 0.48750E-02 0.66951900 287 0.48250E-02 0.66951900 287 0.48250E-02 0.669511000 288 0.43750E-02 0.4672500 289 0.43750E-02 0.4672500 280 0.43750E-02 0.4513000 280 0.43750E-02 0.4513000 280 0.43750E-02 0.4513000 280 0.43750E-02 0.3398000 280 0.24000E-02 0.3398500 280 0.24500E-02 0.3398500 280 0.24550E-02 0.30825000 280 0.24550E-02 0.30825000 280 0.24550E-02 0.30825000 280 0.24550E-02 0.28455000 280 0.24550E-02 0.28455000 281 0.24550E-02 0.28455000 281 112 0.21500E-02 0.28455000 281 112 0.21500E-02 0.28455000 281 113 0.18500E-02 0.28455000 281 114 0.18500E-02 0.28455000 281 115 0.18500E-02 0.28455000 281 116 0.18500E-02 0.28455000 281 117 0.18500E-02 0.28455000 281 118 0.18500E-02 0.28455000 281 119 0.18500E-02 0.28455000 281 119 0.18500E-02 0.28455000 281 119 0.18500E-02 0.28455000 281 119 0.18500E-02 0.18505000 281 119 0.18500E-02 0.18505000 281 119 0.18500E-02 0.18505000 281 119 0.18500E-02 0.18505000 281 119 0.18500E-02 0.18505000000000000000000000000000000000		293			
296		294	0.53700E-02		
297		<u>295</u>			
298		296 297			
900 0.39000E-02 0.451800 901 0.37000E-02 0.4151300 902 0.55000E-02 0.33939900 903 0.35000E-02 0.3727900 305 0.29000E-02 0.33939900 305 0.29000E-02 0.33939500 306 0.27500E-02 0.33939500 307 0.28250E-02 0.33939500 308 0.27500E-02 0.33939500 309 0.28250E-02 0.300000 309 0.28250E-02 0.2825700 310 0.28250E-02 0.2825700 311 0.21500E-02 0.2457900 311 0.21500E-02 0.2457900 312 0.0500E-02 0.2457900 313 0.19500E-02 0.2457900 314 0.18500E-02 0.2255000 315 0.17500E-02 0.245300 316 0.16500E-02 0.213400 317 0.15500E-02 0.1916000 318 0.14625E-02 0.1916000 319 0.13875E-02 0.1916000 320 0.1315E-02 0.15500E-02 0.155000 321 0.12575E-02 0.15500E-02 0.155000 321 0.12575E-02 0.15500E-02 0.155000 322 0.11590E-02 0.15500E-02 0.155000 323 0.13575E-02 0.15500E-02 0.155000 324 0.13575E-02 0.15500E-02 0.155000 327 0.45000E-03 0.15500E-03 0.155000 328 0.15500E-02 0.15500E-03 0.155000 329 0.15500E-03 0.15500E-03 0.155000 320 0.15500E-03 0.15500E-03 0.155000 321 0.12575E-02 0.15500E-03 0.155000 322 0.11590E-02 0.15500E-03 0.155000 323 0.15500E-03 0.15500E-03 0.155000 324 0.10500E-03 0.15500E-03 0.155000 325 0.15500E-03 0.15500E-03 0.155000 326 0.88000E-03 0.15500E-03 0.155000 327 0.44000E-03 0.88515E-01 0.155000 328 0.88000E-03 0.88515E-01 0.155000-03 0.155000 0.15		298			
301 0.37000E-02 0.4151300 302 0.3800E-02 0.3939900 303 0.33000E-02 0.35727900 304 0.31000E-02 0.3574300 305 0.2900CE-02 0.35298500 306 0.27500E-02 0.3137700 307 0.26250E-02 0.30022000 308 0.24750E-02 0.2834300 309 0.23500E-02 0.2853500 310 0.2550E-02 0.2858300 311 0.2250E-02 0.2858300 311 0.2250E-02 0.2858000 311 0.21500E-02 0.2858000 311 0.21500E-02 0.2858000 311 0.21500E-02 0.2858000 311 0.18500E-02 0.2813000 311 0.18500E-02 0.2813200 311 0.18500E-02 0.2813200 311 0.18500E-02 0.21500E-03 0.2					
302 0.35000E-02 0.3939900 304 0.31000E-02 0.3727900 305 0.2900E-02 0.32514300 305 0.2900E-02 0.3298500 306 0.27500E-02 0.3137700 307 0.26250E-02 0.3002000 308 0.24750E-02 0.2834300 309 0.23500E-02 0.2834300 310 0.2500E-02 0.2850900 311 0.21500E-02 0.2859000 311 0.21500E-02 0.2457900 312 0.25500E-02 0.2550000 313 0.18500E-02 0.2457900 313 0.18500E-02 0.2457900 314 0.18500E-02 0.24132400 315 0.18500E-02 0.24132400 316 0.18500E-02 0.24132400 317 0.15500E-02 0.24132400 317 0.15500E-02 0.24132400 318 0.13750E-02 0.24132400 319 0.1375E-02 0.197500E-02 0.1975000 319 0.1375E-02 0.19750E-02 0.1975000 320 0.112375E-02 0.19750E-02 0.198500 321 0.112375E-02 0.198500 322 0.112375E-02 0.198500 323 0.11250E-02 0.1285000 324 0.1750E-02 0.1285000 325 0.10250E-02 0.1285000 326 0.98000E-03 0.1945900 327 0.94000E-03 0.9401SE-01 0.98400E-01 0.					
303 0.38000E-02 0.3727900 304 0.3100E-02 0.3514300 305 0.2900E-02 0.3298500 306 0.2750E-02 0.3137700 307 0.26250E-02 0.3002000 308 0.24750E-02 0.2834300 309 0.23500E-02 0.2663700 311 0.22500E-02 0.2663700 311 0.25500E-02 0.2663700 311 0.21500E-02 0.2565000 311 0.21500E-02 0.2555000 311 0.15500E-02 0.2555000 313 0.18500E-02 0.2243300 314 0.18500E-02 0.2243300 315 0.15500E-02 0.2243300 316 0.15500E-02 0.2243300 317 0.15500E-02 0.2015000 318 0.1625E-02 0.1995000 317 0.15500E-02 0.1995000 318 0.1462E-02 0.1995000 319 0.13875E-02 0.1097200 320 0.13875E-02 0.155500E 321 0.12375E-02 0.155500E 322 0.1750E-02 0.1228500 323 0.1750E-02 0.1228500 324 0.1750E-02 0.1228500 325 0.10230E-02 0.1228500 326 0.8000E-03 0.17199000 327 0.8000E-03 0.17199000 328 0.8000E-03 0.17199000 329 0.8000E-03 0.17199000 320 0.8000E-03 0.17199000 321 0.8000E-03 0.17199000 322 0.8000E-03 0.17199000 323 0.8000E-03 0.17199000 324 0.1750E-02 0.1288500 325 0.10230E-02 0.1288500 326 0.8000E-03 0.17199000 327 0.8000E-03 0.9001SE-01 0.9004SE-01 0.9004SE					
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355 0.22500E-03 0.98052E-02 356 0.21500E-03 0.74733E-02 357 0.20500E-03 0.51414E-02 358 0.19500E-03 0.34199E-02 359 0.18500E-03 0.22979E-02		353			
356 0.21500E-03 0.74733E-02 357 0.20500E-03 0.51414E-02 358 0.19500E-03 0.34199E-02 359 0.18500E-03 0.22979E-02					
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359 0.18500E-03 0.22979E-02					



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Bin	Mid-Point Energy	Displacement Damage Func-	
	inia i onii ziioigy	<u>tion</u>	
<u>#</u>	(MeV)	(MeV•mbarn)	
361	0.16500E-03	0.12182E-02	
362	0.15500E-03	0.12548E-02	
363 364	0.14625E-03	0.12918E-02	
365	0.13875E-03 0.13125E-03	0.13292E-02 0.13666E-02	
366	0.12375E-03	0.14070E-02	
367	0.11750E-03	0.14484E-02	
368	0.11250E-03	0.14822E-02	
369 370	0.10750E-03 0.10250E-03	<u>0.15161E-02</u> 0.15499E-02	
371	0.98000E-04	0.15839E-02	
372	0.94000E-04	0.16182E-02	
373	0.90000E-04	0.16525E-02	
374 375	0.86000E-04 0.82000E-04	0.16895E-02 0.17301E-02	
37 <u>5</u> 37 <u>6</u>	0.78000E-04	0.17750E-02	
377	0.74000E-04	0.18242E-02	
378	0.70500E-04	0.18676E-02	
379 380	0.67500E-04 0.64500E-04	0.19115E-02 0.19572E-02	
381	0.61500E-04	0.20030E-02	
382	0.58750E-04	0.20493E-02	
383	0.56250E-04	0.20963E-02	
384 385	0.53750E-04	0.21432E-02 0.21902E-02	
386	0.51250E-04 0.48750E-04	0.21902E-02 0.22454E-02	
387	0.46250E-04	0.23088E-02	
388	0.43750E-04	0.23721E-02	
389 390	0.41250E-04 0.39000E-04	0.24355E-02 0.25026E-02	
390	0.37000E-04 0.37000E-04	0.25026E-02 0.25734E-02	
392	0.35000E-04	0.26464E-02	
393	0.33000E-04	0.27325E-02	
394	0.31000E-04	0.28207E-02	
395 396	0.29000E-04 0.27500E-04	0.29183E-02 0.29980E-02	
397	0.26250E-04	0.30649E-02	
398	0.24750E-04	0.31573E-02	
399 400	0.23500E-04 0.22500E-04	0.32438E-02 0.33133E-02	
atal 401 star	ndards 0.22500E-04 04c3-	9164-4 0.33827E-02 19e3b2	
402	0.20500E-04	0.34596E-02	
403	0.19500E-04	0.35523E-02	
404 405	0.18500E-04 0.17500E-04	0.36539E-02 0.37586E-02	
406	0.16500E-04	0.38817E-02	
407	0.15500E-04	0.40078E-02	
408	0.14625E-04	0.41264E-02	
409 410	0.13875E-04 0.13125E-04	0.42379E-02 0.43494E-02	
411	0.12375E-04	0.44697E-02	
412	0.11750E-04	0.45924E-02	
413 414	0.11250E-04 0.10750E-04	0.46927E-02	
414	0.10750E-04 0.10250E-04	0.47929E-02 0.48931E-02	
416	0.98000E-05	0.50030E-02	
417	0.94000E-05	0.51225E-02	
418 419	0.90000E-05 0.86000E-05	0.52420E-02 0.53615E-02	
420	0.82000E-05	0.54810E-02	
421	0.78000E-05	0.56148E-02	
422	0.74000E-05	0.57627E-02	
423 424	0.70500E-05 0.67500E-05	0.58933E-02 0.60251E-02	
425	0.64500E-05	0.61627E-02	
426	0.61500E-05	0.63003E-02	
427	0.58750E-05	0.64441E-02	
428 429	0.56250E-05 0.53750E-05	0.65942E-02 0.67442E-02	
430	0.51250E-05	0.68942E-02	
431	0.48750E-05	0.70711E-02	
432	0.46250E-05	0.72741E-02	



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	Bin	Mid-Point Energy	Displacement Damage Function	
-	#	(MeV)	(MeV•mbarn)	
-	433	0.43750E-05	0.74772E-02	
	434	0.41250E-05	0.76803E-02	
	435	0.39000E-05	0.78956E-02	
	$\frac{436}{437}$	0.37000E-05	0.81233E-02 0.83582E-02	
	437	0.35000E-05 0.33000E-05	0.86361E-02	
	439	0.31000E-05	0.89211E-02	
	440	0.29000E-05	0.92370E-02	
	441	0.27500E-05	0.94950E-02	
	$\frac{442}{443}$	0.26250E-05 0.24750E-05	0.97120E-02 0.99916E-02	
	444	0.23500E-05	0.10276E-01	
	445	0.22500E-05	0.10508E-01	
	446	0.21500E-05	0.10740E-01	
	447 448	0.20500E-05 0.19500E-05	<u>0.10972E-01</u> 0.1123500E-01	
	449	0.18500E-05	0.1153100E-01	
	450	0.17500E-05	0.1183500E-01	
	451	0.16500E-05	0.12196E-01	
	452	0.15500E-05	0.12566E-01	
	453 454	0.14625E-05 0.13875E-05	0.12938E-01 0.13313E-01	
	455	0.13125E-05	0.13688E-01	
	456	0.12375E-05	0.14093E-01	
	457	<u>0.11750E-05</u>	0.14508E-01	
	458 459	<u>0.11250E-05</u> 0.10750E-05	0.14847E-01 0.15187E-01	
	460	0.10750E-05 0.10250E-05	0.15767E-01 0.15526E-01	
	461	0.98000E-06	0.15879E-01	
	462	0.94000E-06	0.16247E-01	
	463	0.9000E-06	0.16615E-01	
	464 465	0.86000E-06 0.82000E-06	0.16982E-01 0.17350E-01	
	466	0.78000E-06	0.17778E-01	
	467	0.74000E-06	0.18266E-01	
	468	0.70500E-06	0.18696E-01	
	469 470	<u>0.67500E-06</u> 0.64500E-06	0.19134E-01 0.19591E-01	
	471	0.61500E-06	722-09 0.20049E-01	
	472	0.58750E-06	0.20501E-01	
		2/Standard <u>0.56250E-06</u> 4U4		
	474 475	<u>0.53750E-06</u> 0.51250E-06	0.21425E-01 0.21927E-01	
	476	0.48750E-06	0.22476E-01	
	477	0.46250E-06	0.23071E-01	
	478	0.43750E-06	0.23710E-01	
	479 480	0.41250E-06 0.39000E-06	0.24392E-01 0.25056E-01	
	481	0.37000E-06	0.25732E-01	
	482	0.35000E-06	0.26488E-01	
	483	0.33000E-06	0.27350E-01	
	484 485	0.31000E-06 0.29000E-06	0.28229E-01 0.29186E-01	
	486	0.27500E-06	0.29964E-01	
	487	0.26250E-06	0.30690E-01	
	488	0.24750E-06	0.31600E-01	
	489 490	0.23500E-06 0.22500E-06	0.32440E-01 0.33135E-01	
	491	0.21500E-06	0.33919E-01	
	492	0.20500E-06	0.34716E-01	
	493	0.19500E-06	0.35582E-01	
	494 495	0.18500E-06 0.17500E-06	0.36547E-01 0.37608E-01	
	495	0.16500E-06	0.38770E-01	
	497	0.15500E-06	0.40035E-01	
	498	0.14625E-06	0.41221E-01	
	<u>499</u> 500	0.13875E-06 0.13125E-06	0.42307E-01 0.43491E-01	
	500 501	0.13125E-06 0.12375E-06	0.44747E-01	
	502	0.11750E-06	0.45901E-01	
	503	0.11250E-06	0.46859E-01	
_	<u>504</u>	0.10750E-06	0.47951E-01	