

Designation: E722 –  $09^{\epsilon 1}$ 

# StandardPractice for Characterizing Neutron Fluence Spectra in Terms of an Equivalent Monoenergetic Neutron Fluence for Radiation-Hardness Testing of Electronics<sup>1</sup>

This standard is issued under the fixed designation E722; 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  $(\varepsilon)$  indicates an editorial change since the last revision or reapproval.

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

 $\epsilon^1$  NOTE—Editorial changes were made throughout in October 2009

#### 1. Scope

1.1 This practice covers procedures for characterizing 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 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.standards.iteh.ai/catalog/standards/sist/1b906d9d

- 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)<sup>2</sup> 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 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 fluence 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 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 a251a/astm-e722-09e1

2.1 ASTM Standards:<sup>3</sup>

E170 Terminology Relating to Radiation Measurements and Dosimetry

E265 Test Method for Measuring Reaction Rates and Fast-Neutron Fluences by Radioactivation of Sulfur-32

E693 Practice for Characterizing Neutron Exposures in Iron and Low Alloy Steels in Terms of Displacements Per Atom (DPA), E 706(ID)

E720 Guide for Selection and Use of Neutron Sensors for Determining Neutron Spectra Employed in Radiation-Hardness Testing of Electronics

E721 Guide for Determining Neutron Energy Spectra from Neutron Sensors for Radiation-Hardness Testing of Electronics

<sup>&</sup>lt;sup>1</sup> This practice is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applicationsand is the direct responsibility of Subcommittee E10.07 on Radiation Dosimetry for Radiation Effects on Materials and Devices.

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<sup>&</sup>lt;sup>2</sup> The boldface numbers in parentheses refer to a list of references at the end of this practice.

<sup>&</sup>lt;sup>3</sup> 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.

E844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance, E 706 (IIC)

E944 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 Kerma<sup>4</sup>

ICRU Report 26—Neutron Dosimetry for Biology and Medicine<sup>4</sup>

ICRU Report 33—Radiation Quantities and Units<sup>4</sup>

#### 3. Terminology

- 3.1 Definitions of Terms Specific to This Standard:
- 3.1.1 displacement damage function— $(F_{D,mat})$  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  $F_{D,mat}(E)/d\Phi$  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 microscopic displacement kerma factor— $(\kappa_{D,mat}(E))$  the energy-dependent quotient of the displacement kerma per target atom and the neutron fluence.  $\kappa_{D,mat}(E)$  is proportional to  $K_{D,mat}\bar{A}/\Phi$ , where  $K_{D,mat}$  is the displacement kerma,  $\bar{A}$  is the mean atomic mass of the material and  $\Phi$  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. 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 E170.

- 3.1.3 fluence spectrum hardness parameter— $(H_{mat} = \Phi_{eq}, E_{ref,mat}/\Phi)$  this parameter is defined as the ratio of the equivalent monoenergetic neutron fluence to the total fluence,  $\Phi_{eq}, E_{ref,mat}/\Phi$ . 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 neutron spectrum  $\Phi(E)$ .
- 3.1.3.1 *Discussion*—For damage correlation, a convenient method of characterizing the shape of an incident neutron fluence spectrum  $\Phi(E)$ , is in terms of a 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 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 fluence and fluence spectrum—see neutron fluence and neutron fluence spectrum.
- 3.1.6 *kerma factor*— $(\kappa_{mat}(E))$  the **kerma** per unit fluence of particles of energy E present in a specified material, mat. See Terminology E170 for the definition of **kerma**, and a formula for calculating the kerma factor.
- 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 kerma. The 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 E170.
- 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,  $\Phi_{\rm eq,Eref,mat}$ , 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 fluence spectrum,

<sup>&</sup>lt;sup>4</sup> Available from International Commission on Radiation Units and Measurements, 7910 Woodmont Avenue Suite 400 Bethesda, MD 20841-3095, http://www.icru.org/



 $F_{\mathrm{D,mat}}$ 

 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 incident neutron fluence spectrum and by the material being irradiated.

4.2 The neutron spectrum hardness parameter,  $H_{\rm mat}$ , is given as follows:

$$H_{\text{mat}} = \frac{\int_0^\infty \Phi(E) F_{\text{D,mat}}(E) dE}{F_{\text{D,Eref,mat}} \int_0^\infty \Phi(E) dE}$$
 (2)

4.3 Once the neutron fluence spectrum has been determined (for example, in accordance with Test Method E721) 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,  $\Phi_{\text{eq.Eref,mat}}/M_{\text{r}}$ . Use of a monitor foil to predict  $\Phi_{\text{eq.Eref,mat}}$  is valid only if the neutron 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 fluence 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 $\Phi_{eq, Eref, mat}$

- 6.1 To evaluate Eq 1 and 2, determine the energy limits  $E_{\rm min}$  and  $E_{\rm max}$  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  $F_{\rm D,mat}(E)$  for the irradiated material and perform the indicated integrations.
- 6.1.1 Choose the upper limit  $E_{\text{max}}$  to be at an energy above which the integral damage falls to an insignificant level. For Godiva- or TRIGA-type spectra, this limit is about 12 MeV.
- 6.1.2 Choose the lower-energy limit  $E_{\rm min}$  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  $F_{\mathrm{D,Eref,mat}}$  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  $F_{\rm D,mat}({\rm E})$  term is normalized by dividing by  $F_{\rm D,Eref,mat}$  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  $\Phi_{\text{eq,Eref,mat}}$  and  $H_{\text{mat}}$ .

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

- 7.1 At the same time that the fluence spectrum,  $\Phi(E)$ , of the source is determined (for example, with an activation foil set in accordance with Guides E720 or E844, or both, and Test Method E721 or Practice E944, or both, place a fast-neutron monitor foil in the neutron field at an appropriate location. After  $\Phi_{eq,Eref,mat}$  is determined and the monitor foil counted, calculate the ratio of the equivalent monoenergetic fluence to the unit monitor response,  $\Phi_{eq,Eref,mat}/M_r$ .
- 7.2 Use the response of the fast-neutron monitor foil,  $M_{\rm r}$ , to predict  $\Phi_{\rm eq,Eref,mat}$  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 fluence

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 <sup>54</sup>Fe or <sup>58</sup>Ni foils utilized as monitors. However, if a beta particle detector system is available, then <sup>32</sup>S foils are suitable. Details of the use of sulfur foils are given in Test Method E265.

#### 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 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  $F_{\rm D,Eref,mat}$  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  $\Phi_{\text{eq,Eref,mat}}$ ,  $H_{\text{mat}}$ , and  $\Phi_{\text{eq,Eref,mat}}/M_{\text{r}}$ .

#### 9. Precision and Bias

- 9.1 The precision in calculating  $\Phi_{\rm eq,Eref,mat}$  and  $H_{\rm mat}$  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 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

A1.1.1 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.
- A1.1.3 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 $\Phi_{eq,1MeV,Si}$

A1.2.1 The displacement damage function,  $F_{\rm D,mat}(E)$ , 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 E720 and Test Method E721 for details).

A1.2.4 Results of calculations of silicon microscopic displacement kerma factors (displacement kerma per target atom per unit neutron fluence),  $\kappa_{D.Si}(E)$ , 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 microscopic kerma factor is megaelectron volt times millibarns (MeV·mbarn). Each factor can be multiplied by  $3.435 \times 10^{-13}$  to convert to rad(Si)·cm<sup>2</sup>, or by  $3.435 \times 10^{-19}$  to convert to J·m<sup>2</sup>/kg or Gy(Si)·m<sup>2</sup>. 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:  $F_{D,Si}(E) = \kappa_{D,Si}(E)$ . This microscopic displacement kerma was computed by using the ENDF/B-VI<sup>28</sup>Si cross section evaluation (18), a displacement threshold energy of 25 eV, the Robinson fit to the Lindhard energy partition function (19), and the NJOY97 processing code (20). Fig. A1.1 shows the energy dependence of the silicon 1-MeV damage function.

A1.2.5 An average value of neutron microscopic displacement kerma factor near 1 MeV is difficult to determine because of sharp neutron cross-section resonances in that energy region. To avoid these difficulties, Namenson, Wolicki, and Messenger (13) fitted the function  $AE(1 - \exp(-B/E))$  to

various tabulations of  $\kappa_D(E)$  versus energy. The values of A and B obtained by a least squares fit yielded an average value at 1 MeV of 95  $\pm$  4 MeV·mbarn. A similar procedure applied to the data given in Table A1.1 also gives a value close to 95 MeV·mbarn. Accordingly, the designated value of  $F_{D,1\text{MeV},\text{Si}}$  to be used in Eq 1 and 2 to calculate a 1-MeV equivalent fluence is 95 MeV·mbarn.

A1.2.6 For purposes of intercomparison of hardness testing results from various laboratories, the value of  $F_{\rm D,1MeV,Si}$  used in obtaining such results is very important; therefore, reporting of results should include confirmation that the value of  $F_{\rm D,1MeV,Si}$  designated in A1.2.5 was used in any calculation.

A1.2.7 Once the neutron fluence spectrum  $\Phi(E)$  has been determined for the energy range of interest, then use numerical integration to evaluate Eq 1 and 2, using values for  $F_D(E)$  from Table A1.1 and  $F_{D,1\text{MeV},\text{Si}} = 95 \text{ MeV} \cdot \text{mbarn}$ .

Note A1.1—The damage function provided here differs from that in versions of this practice earlier than E722 – 93, and will result in a different value for  $\Phi_{\rm eq.1MeV,Si}$ . For fast-burst and TRIGA reactors, the value calculated for  $\Phi_{\rm eq.1MeV,Si}$  will typically be 5 to 10 % lower than that calculated using E722 – 85.

#### A1.3 Precision and Bias

A1.3.1 The values for  $\kappa_{D,Si}(E)$  given in Table A1.1 are determined by calculating the total kerma and then partitioning it into ionization and displacement fractions. Because of the lack of adequate theory to partition the kerma and uncertainties in cross sections, the estimated uncertainty in the microscopic displacement kerma factor is about 10 % up to 3 MeV. Correlation of displacement kerma with measured damage in many neutron fields has been confirmed with uncertainties no larger than 10 % (14).

A1.3.2 Uncertainties in the neutron fluence spectrum,  $\Phi(E)$ , will vary based on the method used to obtain it. If neutron sensors such as activation foils were used, see Standard Guide E721.

A1.3.3 Since this mandatory annex requires the use of Table A1.1 and  $F_{D,1MeV,Si} = 95$  MeV·mbarn, no uncertainty in the calculation of 1-MeV equivalent fluence is attributable to the consistent use of these data. Therefore only the uncertainty in the determination of  $\Phi(E)$  need be considered in assigning an uncertainty to the 1-MeV equivalent fluence. An uncertainty in the spectrum in the range  $\pm 20$  %, would most often lead to uncertainties no more than  $\pm 10\%$  in the integral quantity  $\Phi_{\text{eq.1MeV.Si}}$ . While no specific group structure for representing the neutron fluence spectrum is recommended, the choice of energy bin boundaries will affect the uncertainty in the 1-MeV equivalent fluence. The energy bin boundaries should be chosen with due consideration for the shape of both the neutron spectrum and the 1-MeV equivalent damage function. A poor choice of the energy group structure used to evaluate the integral in Eq 2 could increase this uncertainty (see 8.1.7).

TABLE A1.1 Silicon Microscopic Displacement Kerma Factor

Bin	Mid-Point Energy	Displacement Damage Function	
#	(MeV)	(MeV⋅mbarn)	
1	19.9500	182.8700	
2	19.8500	183.0000	
3	19.7500	183.1200	
4	19.6500	183.2500	
5 6	19.5500 19.4500	183.3800 183.5100	
7	19.4500	183.6300	
8	19.2500	183.7500	
9	19.1500	183.8800	
10	19.0500	184.0000	
11	18.9500	184.1100	
12	18.8500	184.2000	
13	18.7500	184.2800	
14 15	18.6500 18.5500	184.3700 184.4500	
16	18.4500	184.3100	
17	18.3500	183.9700	
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 25	17.6500 17.5500	181.5800 181.2400	
26	17.4500	180.6700	
27	17.3500	179.8800	
28	17.2500	179.0800	
29	17.1500	178.2800	
30	17.0500	177.4900	
31	16.9500	177.2400	
32 33	16.8500 16.7500	177.5000 177.7600	
34	16.6500	178.0100	
35	16.5500	178.2700	
36	16.4500	178.3200	
37	16.3500	178.1800	
38	16.2500	178.0300	
39	16.1500	177.8900	
40	16.0500	177.7400	
41	15.9500	176.3000 A / 1460 173.6300 10075 275 1 a / actor 2700	
0g/sta420	15.7500	e-4bb2-9173.6300 171.3200 20075a251a/astm-e722	
44	15.6500	170.8600	
45	15.5500	170.7200	
46	15.4500	170.5600	
47	15.3500	170.4000	
48	15.2500	170.2500	
49 50	15.1500 15.0500	170.0900 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 57	14.4500	168.7300	
57 58	14.3500 14.2500	167.9400 167.1400	
59	14.1500	166.3400	
60	14.0500	165.5400	
61	13.9500	165.4000	
62	13.8500	165.8600	
63	13.7500	166.2900	
64	13.6500	166.7300	
65	13.5500	167.1600	
66 67	13.4500 13.3500	167.5300 167.8300	
68	13.2500	168.1100	
69	13.1500	168.3900	
70	13.0500	168.6600	
71	12.9500	168.6200	
72	12.8500	168.2800	
73	12.7500	167.9400	



 TABLE A1.1
 Continued

Bin   Mid-Point Energy		TABLE A1.1	Continued
# (MeV) (MeV-mbam)  74	Rin	Mid-Point Energy	
74		who i out Ellergy	
75	#	(MeV)	(MeV·mbarn)
76	74	12.6500	167.6000
77			
78			
79 12.1500 167.9500 80 12.0500 168.1700 81 11.9500 165.6800 82 11.8500 165.6800 83 11.7500 166.6200 84 11.6500 165.7900 85 11.5500 168.6200 86 11.4500 165.3800 87 11.3500 166.0300 88 11.2500 159.5200 89 11.1500 159.5200 90 11.0500 159.5200 91 10.9500 160.0500 92 10.8500 159.5100 93 10.7500 159.0000 94 10.6500 155.5100 95 10.5500 154.6000 96 10.4500 154.7600 97 10.3500 164.6700 98 10.2500 163.3600 99 10.1500 168.6300 100 10.0500 168.6300 101 9.9500 164.4900 102 9.9500 164.4900 103 9.9500 164.4900 104 9.9500 164.4900 105 9.9500 164.4900 106 9.9500 164.4110 107 9.9500 164.4110 108 9.2500 169.8200 109 9.1500 159.8200 101 9.9500 164.4300 102 9.8500 164.4300 103 104 9.7500 166.2100 105 9.5500 164.4300 106 9.7500 166.2100 107 9.9500 164.4300 108 9.2500 166.2100 109 9.1500 156.83800 110 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0			
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84	82	11.8500	165.4600
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97 10.3500 164.6700 98 10.2500 163.3600 199 10.1500 168.6300 100 10.0500 166.2100 101 9.9500 164.4900 102 9.8500 164.0600 103 9.7500 161.9600 104 9.6500 156.1000 105 9.5500 166.2100 106 9.4500 166.2100 107 9.3500 166.2100 108 9.2500 150.6900 109 9.1500 174.5800 111 8.9500 177.5700 112 8.8500 160.2200 113 8.7500 166.6100 114 8.6500 163.8600 115 8.5500 166.6100 117 8.3500 165.8300 118 8.2500 155.4300 119 8.1500 154.4300 120 8.0500 165.0000 121 7.9500 165.0000 122 7.8500 175.3400 124 7.6500 175.3400 125 7.5500 162.9100 126 7.4500 170.3100 127 7.3500 168.4300 128 7.2500 169.2700 129 7.1500 169.2700 120 8.0500 165.0000 121 7.9500 165.0000 122 7.8500 175.3400 124 7.6500 170.3100 125 7.5500 162.9100 126 7.4500 167.0500 127 7.3500 168.4300 128 7.2500 169.2700 130 7.0500 161.1000 131 6.9500 141.7700 132 6.8500 150.9200 133 6.7500 162.2500 134 6.6500 150.9200 135 6.5500 175.3800 137 6.3500 150.9200 138 6.2500 175.3800 139 6.1500 175.3800 140 6.0500 155.0000 141 5.9500 175.3800 139 6.1500 175.3800 140 6.0500 155.0000 141 5.9500 175.3800 142 5.8500 175.3800 143 5.7500 180.0500 144 5.8500 175.3800 145 5.5500 180.0500			
98	96	10.4500	154.7600
99 10.1500 168.6300 100 10.0500 166.2100 101 9.9500 164.4900 102 9.8500 164.0600 103 9.7500 164.0600 104 9.6500 165.0000 105 9.5500 164.4100 106 9.4500 166.2100 107 9.3500 166.2100 108 9.2500 150.6900 109 9.1500 174.5800 111 8.9500 177.5700 112 8.8500 160.2200 113 8.7500 166.2100 114 8.6500 722-091 163.8600 115 8.5500 166.6100 116 8.3500 166.6100 117 8.3500 166.6100 118 8.2500 155.8300 119 8.1500 166.6100 110 17 8.3500 166.2000 111 8.5500 177.5700 112 8.6500 170.3100 114 8.6500 722-091 168.4200 115 8.5500 166.6000 116.0000 117 8.3500 162.0200 118 8.2500 154.4300 120 8.0500 165.0000 121 7.9500 186.4000 122 7.8500 175.3400 123 7.7500 174.8000 124 7.6500 170.3100 125 7.5500 162.9100 126 7.4500 167.0500 127 7.3500 168.4300 128 7.2500 169.2700 129 7.1500 139.1600 130 7.0500 161.1000 131 6.9500 141.7700 132 6.8500 169.2700 133 6.7500 162.2500 134 6.6500 150.9200 135 6.5500 119.2700 136 6.4500 139.2700 137 6.3500 150.0000 141 5.9500 175.3800 139 6.1500 175.3800 139 6.1500 127.7100 140 6.0500 153.0000 141 5.9500 175.3800 143 5.7500 180.0500 144 5.8500 164.7000 144 5.8500 164.7000 145 5.5500 180.0500			
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105	103	9.7500	161.9600
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107 9.3500 166.2100 108 9.2500 150.6900 109 9.1500 153.8800 110 9.0500 177.5700 111 8.9500 177.5700 112 8.8500 160.2200 113 8.7500 146.7500 114 8.6500 165.8300 115 8.4500 166.6100 117 8.3500 162.0200 118 8.2500 158.4200 119 8.1500 158.4200 119 8.1500 165.0000 120 8.0500 165.0000 121 7.9500 186.4000 122 7.8500 175.3400 123 7.7500 174.8000 124 7.6500 170.3100 125 7.5500 162.9100 126 7.4500 167.0500 127 7.3500 168.4300 128 7.2500 169.2700 129 7.1500 139.1600 130 7.0500 161.1000 131 6.9500 141.7700 132 6.8500 162.2500 133 6.7500 162.2500 134 6.6500 150.9200 135 6.5500 119.2700 136 6.4500 139.2700 137 6.3500 150.9200 138 6.2500 175.3800 139 6.1500 177.3800 131 6.9500 175.3800 133 6.7500 162.2500 134 6.6500 150.9200 135 6.5500 119.2700 136 6.4500 139.2700 137 6.3500 150.9200 138 6.2500 175.3800 139 6.1500 177.3800 141 5.9500 137.1000 141 5.9500 137.1000 142 5.8500 164.7000 143 5.7500 180.0500 144 5.6500 155.20700 144 5.6500 155.20700 144 5.6500 155.20700 144 5.6500 155.20700 144 5.6500 155.20700 144 5.6500 155.20700 145 5.5500 145.6000			
108			
109 110 9.0500 174.5800 174.5800 1111 8.9500 177.5700 112 8.8500 160.2200 113 8.7500 146.7500 146.7500 114 8.6500 172.091 163.8600 165.8300 166.6100 177 8.3500 166.6100 177 8.3500 166.6000 177 8.3500 166.6000 177 8.3500 166.6000 177 8.3500 166.6000 177 178 8.3500 167 188 8.2500 188.4200 188.4200 188.4200 199 188.4200 190 190 188.4200 191 190 191 191 191 191 191 191 191 1			
111       8.9500       177.5700         112       8.8500       160.2200         113       8.7500       146.7500         114       8.6500       722-0901       163.8600         115       8.5500       165.8300       165.8300         116       8.4500       166.6100       166.6100         117       8.3500       162.0200         118       8.2500       158.4200         119       8.1500       154.4300         120       8.0500       165.0000         121       7.9500       186.4000         122       7.8500       175.3400         123       7.7500       174.8000         124       7.6500       170.3100         125       7.5500       162.9100         126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         134       6.6500       150.9200         135		9.1500	
112       8.8500       160.2200         113       8.7500       146.7500         114       8.6500       722-09el       163.8600         115       8.5500       165.8300       20075a2         116       8.4500       166.6100       20075a2         117       8.3500       162.0200         118       8.2500       158.4200         119       8.1500       154.4300         120       8.0500       165.0000         121       7.9500       186.4000         122       7.8500       175.3400         123       7.7500       174.8000         124       7.6500       170.3100         125       7.5500       162.9100         126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         138			
113			
114			
115			
117         8.3500         162.0200           118         8.2500         158.4200           119         8.1500         154.4300           120         8.0500         165.0000           121         7.9500         186.4000           122         7.8500         175.3400           123         7.7500         174.8000           124         7.6500         170.3100           125         7.5500         162.9100           126         7.4500         167.0500           127         7.3500         168.4300           128         7.2500         169.2700           129         7.1500         139.1600           130         7.0500         161.1000           131         6.9500         141.7700           132         6.8500         146.8900           133         6.7500         162.2500           134         6.6500         150.9200           135         6.5500         119.2700           136         6.4500         139.2700           137         6.3500         150.0900           138         6.2500         175.3800           139         6.1500 <t< td=""><td>/ 115 1 1 / •</td><td>8 5500</td><td>105.0000</td></t<>	/ 115 1 1 / •	8 5500	105.0000
118       8.2500       158.4200         119       8.1500       154.4300         120       8.0500       165.0000         121       7.9500       186.4000         122       7.8500       175.3400         123       7.7500       174.8000         124       7.6500       170.3100         125       7.5500       162.9100         126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       164.7000 <td< td=""><td></td><td>8.4500</td><td>100.0100</td></td<>		8.4500	100.0100
119       8.1500       154.4300         120       8.0500       165.0000         121       7.9500       186.4000         122       7.8500       175.3400         123       7.7500       174.8000         124       7.6500       170.3100         125       7.5500       162.9100         126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       137.1000         142       5.8500       164.7000 <td< td=""><td></td><td></td><td></td></td<>			
120       8.0500       165.0000         121       7.9500       186.4000         122       7.8500       175.3400         123       7.7500       174.8000         124       7.6500       170.3100         125       7.5500       162.9100         126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       164.7000         143       5.7500       180.0500         144       5.6500       152.0700 <td< td=""><td></td><td></td><td></td></td<>			
121       7.9500       186.4000         122       7.8500       175.3400         123       7.7500       174.8000         124       7.6500       170.3100         125       7.5500       162.9100         126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       137.1000         142       5.8500       164.7000         143       5.7500       180.0500         144       5.6500       152.0700 <td< td=""><td></td><td></td><td></td></td<>			
122       7.8500       175.3400         123       7.7500       174.8000         124       7.6500       170.3100         125       7.5500       162.9100         126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       137.1000         142       5.8500       164.7000         143       5.7500       180.0500         144       5.6500       152.0700         145       5.5500       145.6000 <td></td> <td></td> <td></td>			
123       7.7500       174.8000         124       7.6500       170.3100         125       7.5500       162.9100         126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       137.1000         142       5.8500       164.7000         143       5.7500       180.0500         144       5.6500       152.0700         145       5.5500       145.6000			
125       7.5500       162.9100         126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       137.1000         142       5.8500       164.7000         143       5.7500       180.0500         144       5.6500       152.0700         145       5.5500       145.6000	123	7.7500	174.8000
126       7.4500       167.0500         127       7.3500       168.4300         128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       137.1000         142       5.8500       164.7000         143       5.7500       180.0500         144       5.6500       152.0700         145       5.5500       145.6000			
127     7.3500     168.4300       128     7.2500     169.2700       129     7.1500     139.1600       130     7.0500     161.1000       131     6.9500     141.7700       132     6.8500     146.8900       133     6.7500     162.2500       134     6.6500     150.9200       135     6.5500     119.2700       136     6.4500     139.2700       137     6.3500     150.0900       138     6.2500     175.3800       139     6.1500     127.7100       140     6.0500     153.0000       141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000			
128       7.2500       169.2700         129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       137.1000         142       5.8500       164.7000         143       5.7500       180.0500         144       5.6500       152.0700         145       5.5500       145.6000			
129       7.1500       139.1600         130       7.0500       161.1000         131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       137.1000         142       5.8500       164.7000         143       5.7500       180.0500         144       5.6500       152.0700         145       5.5500       145.6000			
131       6.9500       141.7700         132       6.8500       146.8900         133       6.7500       162.2500         134       6.6500       150.9200         135       6.5500       119.2700         136       6.4500       139.2700         137       6.3500       150.0900         138       6.2500       175.3800         139       6.1500       127.7100         140       6.0500       153.0000         141       5.9500       137.1000         142       5.8500       164.7000         143       5.7500       180.0500         144       5.6500       152.0700         145       5.5500       145.6000			
132     6.8500     146.8900       133     6.7500     162.2500       134     6.6500     150.9200       135     6.5500     119.2700       136     6.4500     139.2700       137     6.3500     150.0900       138     6.2500     175.3800       139     6.1500     127.7100       140     6.0500     153.0000       141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000	130	7.0500	161.1000
133     6.7500     162.2500       134     6.6500     150.9200       135     6.5500     119.2700       136     6.4500     139.2700       137     6.3500     150.0900       138     6.2500     175.3800       139     6.1500     127.7100       140     6.0500     153.0000       141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000			
134     6.6500     150.9200       135     6.5500     119.2700       136     6.4500     139.2700       137     6.3500     150.0900       138     6.2500     175.3800       139     6.1500     127.7100       140     6.0500     153.0000       141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000			
135     6.5500     119.2700       136     6.4500     139.2700       137     6.3500     150.0900       138     6.2500     175.3800       139     6.1500     127.7100       140     6.0500     153.0000       141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000			
136     6.4500     139.2700       137     6.3500     150.0900       138     6.2500     175.3800       139     6.1500     127.7100       140     6.0500     153.0000       141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000			
138     6.2500     175.3800       139     6.1500     127.7100       140     6.0500     153.0000       141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000			
139     6.1500     127.7100       140     6.0500     153.0000       141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000	137	6.3500	150.0900
140     6.0500     153.0000       141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000			
141     5.9500     137.1000       142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000			
142     5.8500     164.7000       143     5.7500     180.0500       144     5.6500     152.0700       145     5.5500     145.6000			
143       5.7500       180.0500         144       5.6500       152.0700         145       5.5500       145.6000			
144       5.6500       152.0700         145       5.5500       145.6000			
	144		152.0700
146 5.4500 116.9800			
	146	5.4500	116.9800



TABLE A1.1 Continued

	TABLE A1.1	Continued
Din	Mid Doint Frage:	Displacement Damage
Bin	Mid-Point Energy	Function
#	(MeV)	(MeV⋅mbarn)
147 148	5.3500 5.2500	120.1500 145.7000
149	5.1500	170.3100
150	5.0500	149.1600
151	4.9500	145.5000
152	4.8500	160.6700
153	4.7500	185.6100
154	4.6500	158.6400
155	4.5500	138.3800
156	4.4500	140.9200
157	4.3500	134.8600
158	4.2500	164.4100
159	4.1500	108.7100
160	4.0500	131.6400
161	3.9500	134.3400
162	3.8500	108.8400
163	3.7500	115.1300
164	3.6500	69.52400
165	3.5500	111.2700
166	3.4500	119.0600
167	3.3500	113.8700
168	3.2500	118.0200
169	3.1500	131.5000
170	3.0500	120.2000
171	2.9500	98.84500
172	2.8500	135.0400
173	2.7500	106.9100
173	2.6500	115.6700
175	2.5500	131.1900
176	2.4500	118.9200
177	2.3500	102.8200
178	2.2500	105.4900
179	2.1500	106.9200
180	2.0500	95.21800
181	1.9500	129.4000
182	1.8500	129.2100
183	1.7500	78.34200
184	1.6500	163.0200
185	1.5500	105.9800
186	1.4500	98.97900
187	AS 1.3500 722	- <u>09e1</u> 88.76000
188	1 2500	00.00400
0g/St <sub>189</sub>	lards/sist/161.1500 9c-c	d0e-4bb2-968.99400 62.67300
190	1.0500	75.69200
191	0.98000	111.7900
192	0.94000	111.4900
193	0.90000	87.78100
194	0.86000	78.33600
195	0.82000	136.8000
196	0.78000	87.94400
197	0.74000	64.57500
198	0.70500	59.30200
199	0.67500	56.76700
200	0.64500	55.29000
201	0.61500	52.61800
202	0.58750	58.33400
203	0.56250	124.5500
204	0.53750	77.95800
205	0.51250	57.41600
206	0.48750	55.40500
207	0.46250	53.50800
208	0.43750	52.65400
209	0.41250	51.89700
210	0.39000	52.10700
211	0.37000	49.72200
212	0.35000	50.09500
213	0.33000	49.28000
214	0.31000	50.23700
214	0.29000	51.32600
216	0.27500	52.55800
217	0.26250	54.95900
218	0.24750	58.46000
219	0.23500	64.07300
	0.23300	04.07300



TABLE A1.1 Continued

Bin   Mid-Point Energy   Displacement Damage Function   # (MeV)	TABLE A1.1	Continued
# (MeV) (MeV-mbam)  220	Rin Mid Boint Engran	Displacement Damage
220 0.22500 69.75000 221 0.21500 78.66700 222 0.20500 91.83600 223 0.19500 111.2800 224 0.18500 114.1000 225 0.17500 64.49300 226 0.16500 19.04800 227 0.15500 4.323200 228 0.14625 13.50900 229 0.13875 18.70700 230 0.13125 2.552600 231 0.12375 3.352800 232 0.11750 3.982800 233 0.11250 4.431900 234 0.10750 4.876000 235 0.10250 5.197800 236 0.98000E-01 5.197800 237 0.94000E-01 5.814300 238 0.98000E-01 5.814300 239 0.86000E-01 6.040100 240 0.82000E-01 6.185300 241 0.7500E-01 6.972900 242 0.74000E-01 7.178200 243 0.75050E-01 7.992000 244 0.67500E-01 7.178200 245 0.64500E-01 1.45300 246 0.61500E-01 1.45300 247 0.58750E-01 1.458700 258 0.36000E-01 1.454700 259 0.5125E-01 1.45800 250 0.5125E-01 1.45800 251 0.48750E-01 2.2470200 252 0.46250E-01 1.299200 253 0.39000E-01 1.45800 254 0.6250E-01 1.45800 255 0.05750E-01 1.45800 256 0.5125E-01 1.45800 257 0.35000E-01 1.45800 258 0.35000E-01 1.45800 259 0.31000E-01 1.45800 250 0.5125E-01 1.45800 250 0.5125E-01 1.45800 250 0.5125E-01 1.45800 251 0.48750E-01 2.2470200 252 0.46250E-01 1.299200 253 0.43750E-01 2.2470200 254 0.2500E-01 1.45800 255 0.39000E-01 1.45800 257 0.3500E-01 1.45800 258 0.33000E-01 2.256800 259 0.31000E-01 2.256800 270 0.5125E-01 1.45800 271 0.1550E-01 1.45800 272 0.1550E-01 1.45800 273 0.14625E-01 1.45800 274 0.58750E-01 1.26800 275 0.3500E-01 1.299500 276 0.1525E-01 1.165500 277 0.1550E-01 1.165500 278 0.1150E-01 1.778200 288 0.1950C-01 1.900700 289 0.11500E-01 1.900700 280 0.1250E-01 1.165500 277 0.1550E-01 1.165500 278 0.1150E-01 1.165500 279 0.1150E-01 1.165500 270 0.1750E-01 1.165500 270 0.1750E-01 1.165500 271 0.1750E-01 1.165500 272 0.1550E-01 1.165500 273 0.14625E-01 1.165500 274 0.1350E-01 1.165500 275 0.1550E-01 1.165500 277 0.1550E-01 1.165500 278 0.1150E-01 1.165500 279 0.1150E-01 1.165500 270 0.1750E-01 1.165500 27	iviid-Foliit Energy	Function
221 0.21500 78.66700 222 0.20500 91.83600 223 0.19500 111.2800 224 0.18500 114.1000 225 0.17500 64.49300 226 0.16500 19.04800 227 0.15500 4.323200 228 0.14625 1.350900 229 0.13875 1.870700 230 0.13125 2.552600 231 0.12375 3.352800 232 0.11750 3.982800 233 0.11250 4.876000 234 0.10750 4.876000 235 0.10250 5.197800 236 0.98000E-01 5.417300 237 0.94000E-01 5.417300 239 0.86000E-01 5.417300 239 0.86000E-01 6.040100 240 0.82000E-01 6.185300 241 0.78500E-01 6.310600 242 0.74000E-01 6.310600 244 0.67500E-01 6.310600 245 0.64500E-01 7.992000 246 0.61500E-01 7.992000 247 0.58750E-01 4.98700 248 0.53750E-01 4.98700 259 0.3000E-01 4.98700 260 0.29000E-01 2.470200 270 0.51250E-01 4.98700 288 0.3000E-01 2.470200 290 0.53750E-01 2.470200 249 0.53750E-01 2.470200 250 0.51250E-01 2.470200 251 0.48750E-01 2.261300 252 0.46250E-01 2.261300 253 0.3000E-01 1.884700 254 0.12550E-01 2.270200 255 0.39000E-01 1.884700 256 0.29500E-01 2.261300 257 0.35000E-01 1.89200 257 0.35000E-01 1.89200 257 0.35000E-01 1.89200 257 0.35000E-01 1.283100 259 0.31000E-01 2.261300 260 0.29000E-01 1.283100 270 0.17500E-01 1.283100 271 0.18750E-01 1.283100 272 0.15500E-01 1.283100 273 0.14025E-01 1.283000 274 0.13750E-01 1.283100 275 0.35000E-01 1.283100 277 0.17500E-01 1.283100 277 0.17500E-01 1.283100 277 0.17500E-01 1.283100 277 0.17500E-01 1.283000 277 0.17500E-01 1.283000 277 0.17500E-01 1.365500 273 0.14625E-01 1.365500 273 0.14625E-01 1.365500 274 0.1750E-01 1.268000 275 0.31325E-01 1.365500 288 0.19500E-01 1.1900700 288 0.19500E-01 1.1900700 288 0.19500E-01 1.1900700 289 0.18500E-01 1.1900700 280 0.18500E-01 1.1900700 280 0.18500E-01 1.1900000 270 0.17500E-01 1.121000 277 0.17500E-01 1.268000000000000000000000000000000000000	# (MeV)	(MeV⋅mbarn)
221 0.21500 78.66700 222 0.20500 91.83600 223 0.19500 111.2800 224 0.18500 114.1000 225 0.17500 64.49300 226 0.16500 19.04800 227 0.15500 4.323200 228 0.14625 1.350900 229 0.13875 1.870700 230 0.13125 2.552600 231 0.12375 3.352800 232 0.11750 3.982800 233 0.11250 4.876000 234 0.10750 4.876000 235 0.10250 5.197800 236 0.98000E-01 5.417300 237 0.94000E-01 5.417300 239 0.86000E-01 5.417300 239 0.86000E-01 6.040100 240 0.82000E-01 6.185300 241 0.78500E-01 6.310600 242 0.74000E-01 6.310600 244 0.67500E-01 6.310600 245 0.64500E-01 7.992000 246 0.61500E-01 7.992000 247 0.58750E-01 4.98700 248 0.53750E-01 4.98700 259 0.3000E-01 4.98700 260 0.29000E-01 2.470200 270 0.51250E-01 4.98700 288 0.3000E-01 2.470200 290 0.53750E-01 2.470200 249 0.53750E-01 2.470200 250 0.51250E-01 2.470200 251 0.48750E-01 2.261300 252 0.46250E-01 2.261300 253 0.3000E-01 1.884700 254 0.12550E-01 2.270200 255 0.39000E-01 1.884700 256 0.29500E-01 2.261300 257 0.35000E-01 1.89200 257 0.35000E-01 1.89200 257 0.35000E-01 1.89200 257 0.35000E-01 1.283100 259 0.31000E-01 2.261300 260 0.29000E-01 1.283100 270 0.17500E-01 1.283100 271 0.18750E-01 1.283100 272 0.15500E-01 1.283100 273 0.14025E-01 1.283000 274 0.13750E-01 1.283100 275 0.35000E-01 1.283100 277 0.17500E-01 1.283100 277 0.17500E-01 1.283100 277 0.17500E-01 1.283100 277 0.17500E-01 1.283000 277 0.17500E-01 1.283000 277 0.17500E-01 1.365500 273 0.14625E-01 1.365500 273 0.14625E-01 1.365500 274 0.1750E-01 1.268000 275 0.31325E-01 1.365500 288 0.19500E-01 1.1900700 288 0.19500E-01 1.1900700 288 0.19500E-01 1.1900700 289 0.18500E-01 1.1900700 280 0.18500E-01 1.1900700 280 0.18500E-01 1.1900000 270 0.17500E-01 1.121000 277 0.17500E-01 1.268000000000000000000000000000000000000	220 0.22500	69.75000
223		
224 0.18500 114.1000 225 0.17500 64.49300 226 0.16500 19.04800 227 0.15500 4.323200 228 0.14625 1.35090 229 0.13875 1.870700 230 0.13125 2.552600 231 0.12375 3.352800 232 0.11750 3.982800 233 0.11250 4.431900 234 0.10750 4.876000 235 0.10250 5.197800 236 0.98000E-01 5.417300 237 0.94000E-01 5.611900 238 0.98000E-01 5.611900 239 0.86000E-01 5.611900 239 0.86000E-01 6.040100 240 0.82000E-01 6.040100 241 0.78000E-01 6.310600 242 0.74000E-01 6.310600 243 0.70500E-01 6.310600 244 0.67500E-01 7.178200 245 0.64500E-01 7.992000 246 0.61500E-01 7.992000 247 0.58750E-01 11.45300 248 0.56250E-01 11.45800 249 0.53750E-01 1.498700 250 0.51250E-01 1.498700 250 0.51250E-01 1.498700 251 0.48750E-01 2.820300 252 0.46250E-01 2.9995800 253 0.33000E-01 2.9995800 254 0.41250E-01 2.9995800 255 0.33000E-01 2.9995800 256 0.39000E-01 1.999100 257 0.35000E-01 2.9995800 258 0.33000E-01 2.9995800 259 0.31000E-01 1.999100 260 0.29000E-01 1.999100 260 0.29000E-01 1.999100 260 0.2500E-01 1.999200 260 0.2500E-01 1.999200 260 0.2500E-01 1.999300 277 0.1750E-01 1.99000 278 0.18500E-01 1.999200 279 0.18500E-01 1.999200 288 0.19500E-01 1.999200 270 0.1750E-01 1.99000 277 0.1750E-01 1.99000 277 0.1750E-01 1.99000 277 0.1750E-01 1.990000 277 0.1750E-01 1.990000 278 0.18500E-01 1.99000000000000000000000000000000000	222 0.20500	91.83600
225 0.17500 64.49300 226 0.16500 19.04800 227 0.15500 4.323200 228 0.14625 1.350900 229 0.13875 1.870700 230 0.13125 2.552600 231 0.12375 3.352800 232 0.11750 3.962800 233 0.11250 4.431900 234 0.10750 4.876000 235 0.10250 5.197800 236 0.98000E-01 5.417300 237 0.94000E-01 5.417300 239 0.86000E-01 5.417300 239 0.86000E-01 5.844300 239 0.86000E-01 6.040100 240 0.82000E-01 6.310600 241 0.78000E-01 6.310600 242 0.74000E-01 6.310600 244 0.67500E-01 6.310600 244 0.67500E-01 6.31900 245 0.64500E-01 7.178200 246 0.64500E-01 7.992000 247 0.58750E-01 4.795000 249 0.53750E-01 4.795000 255 0.43750E-01 2.470200 256 0.51250E-01 2.470200 257 0.35000E-01 2.2823100 259 0.31000E-01 2.295800 250 0.4750E-01 2.270200 251 0.48750E-01 2.270200 252 0.46250E-01 2.270200 253 0.30000E-01 1.89700 256 0.37000E-01 1.992000 257 0.35000E-01 2.295800 258 0.33000E-01 2.295800 259 0.31000E-01 1.99200 250 0.51250E-01 2.470200 264 0.4750E-01 2.270200 265 0.22500E-01 2.295800 266 0.27500E-01 1.99200 277 0.35000E-01 1.99200 279 0.151250E-01 2.270200 268 0.1950E-01 2.2823100 269 0.18150E-01 1.90700 270 0.1750E-01 1.90000 271 0.16500E-01 1.90000 272 0.15500E-01 1.90000 273 0.14625E-01 1.900700 274 0.15500E-01 1.90000 275 0.35000E-01 1.900000 277 0.15500E-01 1.90000000000000000000000000000000000	223 0.19500	111.2800
226 0.16500 19.04800   227 0.15500 4.323200   228 0.14625 1.350900   230 0.13125 2.552600   231 0.12375 3.352800   232 0.11750 3.982800   233 0.11250 4.431900   234 0.10750 4.876000   235 0.10250 5.197800   236 0.98000E-01 5.417300   237 0.94000E-01 5.611900   238 0.9000E-01 5.611900   239 0.86000E-01 6.040100   240 0.82000E-01 6.310600   241 0.78000E-01 6.310600   242 0.74000E-01 6.310600   244 0.67500E-01 6.310600   244 0.67500E-01 7.178200   245 0.64500E-01 7.178200   246 0.61500E-01 7.992000   247 0.58750E-01 7.992000   248 0.56250E-01 4.98700   250 0.51250E-01 1.488700   251 0.48750E-01 2.820300   252 0.43750E-01 3.234200   253 0.43750E-01 3.234200   253 0.43750E-01 3.234200   254 0.43500E-01 3.234200   255 0.39000E-01 3.695600   257 0.35000E-01 3.234200   258 0.33000E-01 3.234200   259 0.31000E-01 3.234200   250 0.51250E-01 3.234200   251 0.48750E-01 3.234200   252 0.43750E-01 3.234200   253 0.43750E-01 3.234200   256 0.37000E-01 1.88700   257 0.35000E-01 3.234200   258 0.33000E-01 2.995800   257 0.35000E-01 3.234200   258 0.33000E-01 3.234200   259 0.31000E-01 3.234200   250 0.27500E-01 1.999100   250 0.27500E-01 1.999100   251 0.48750E-01 1.999200   252 0.43750E-01 1.999300   253 0.43750E-01 1.999300   254 0.1250E-01 1.999300   255 0.39000E-01 2.995800   257 0.35000E-01 3.234200   258 0.33000E-01 2.995800   259 0.31000E-01 3.234200   260 0.29000E-01 3.699700   260 0.29000E-01 3.699700   260 0.29000E-01 3.699700   260 0.29000E-01 3.699700   260 0.29500E-01 1.999200   277 0.17500E-01 1.999200   288 0.19500E-01 1.999200   277 0.17500E-01 1.999200   289 0.18500E-01 1.999200   277 0.17500E-01 1.999200   289 0.18500E-01 1.999200   289 0.18500E-01 1.999200   280 0.19500E-01 1.999200   280 0.19500E-01 1.999200   281 0.99000E-02 0.9998900   282 0.99000E-02 0.9998900   283 0.9000E-02 0.9998900   284 0.9000E-02 0.9998900   285 0.99000E-02 0.9998900   286 0.78000E-02 0.9998900   288 0.76500E-02 0.7765000   290 0.64500E-02 0.7765000   290 0.64500E-02 0.7765000   290 0.64500E-02 0.7765000   290 0.64500E-02 0.7765000		
227 0.15500 4.323200 228 0.14625 1.350900 229 0.13875 1.870700 230 0.13125 2.552600 231 0.12375 3.352800 232 0.11750 3.982800 233 0.11250 4.431900 234 0.10750 4.876000 235 0.10250 5.197800 236 0.98000E-01 5.417300 237 0.94000E-01 5.611900 238 0.90000E-01 5.644300 239 0.86000E-01 6.185300 241 0.78000E-01 6.315600 242 0.74000E-01 6.315600 243 0.70500E-01 6.391900 244 0.67500E-01 6.831900 245 0.64500E-01 6.972900 246 0.61500E-01 7.992000 247 0.58750E-01 4.95000 248 0.53750E-01 4.95000 250 0.51250E-01 4.95000 251 0.48750E-01 2.470200 252 0.46250E-01 2.470200 253 0.43750E-01 2.470200 254 0.41250E-01 2.470200 255 0.39000E-01 2.995800 256 0.39000E-01 2.995800 257 0.35000E-01 2.823100 259 0.31000E-01 2.295800 250 0.27500E-01 2.295800 250 0.27500E-01 1.847000 251 0.48750E-01 2.470200 252 0.46250E-01 2.280300 253 0.43750E-01 2.280300 254 0.41250E-01 2.280300 257 0.35000E-01 2.995800 259 0.31000E-01 2.995800 250 0.27500E-01 2.363700 250 0.27500E-01 1.847000 250 0.27500E-01 1.995800 257 0.35000E-01 2.995800 259 0.31500E-01 2.995800 259 0.31500E-01 2.995800 250 0.27500E-01 1.847000 260 0.29000E-01 1.900700 260 0.29000E-01 1.900700 260 0.29000E-01 1.85500 274 0.1350E-01 1.16500E-01 1.900700 269 0.18500E-01 1.178000 277 0.17500E-01 1.185000 277 0.17500E-01 1.200000 277 0.17500E-01 1.200000 278 0.11250E-01 1.121000 279 0.11750E-01 1.121000 270 0.17500E-01 1.200000 271 0.17500E-01 1.200000 272 0.15500E-01 1.200000 273 0.14625E-01 1.121000 274 0.13375E-01 1.121000 275 0.13500E-01 1.200000 288 0.19500E-01 1.200000 288 0.19500E-01 1.200000 288 0.19500E-01 1.20000000000000000000000000000000000		
228 0.14625 1.350900 229 0.13875 1.870700 230 0.13125 2.552600 231 0.12375 3.352800 232 0.11750 3.982800 233 0.11250 4.431900 234 0.10750 4.876000 235 0.10250 5.197800 236 0.98000E-01 5.417300 237 0.94000E-01 5.417300 238 0.9000E-01 5.417300 239 0.86000E-01 6.040100 240 0.82000E-01 6.040100 241 0.78000E-01 6.310600 241 0.78000E-01 6.310600 242 0.74000E-01 6.355600 243 0.70500E-01 7.178200 244 0.67500E-01 7.178200 245 0.64500E-01 7.992000 246 0.61500E-01 7.992000 247 0.58750E-01 7.478200 248 0.56250E-01 7.478200 249 0.53750E-01 7.478200 249 0.53750E-01 7.478200 250 0.51250E-01 7.847000 251 0.48750E-01 7.892000 252 0.46250E-01 7.892000 253 0.43750E-01 7.892000 254 0.41250E-01 7.892000 255 0.37000E-01 7.992000 256 0.37000E-01 7.992000 257 0.35000E-01 7.892000 258 0.33000E-01 7.892000 259 0.31000E-01 7.992000 250 0.51250E-01 7.892000 251 0.48750E-01 7.892000 252 0.46250E-01 7.892000 253 0.43750E-01 7.892000 254 0.41250E-01 7.892000 255 0.35000E-01 7.892000 256 0.37000E-01 7.992000 257 0.35000E-01 7.992000 258 0.35000E-01 7.992000 259 0.31000E-01 7.992000 260 0.29000E-01 7.2823100 250 0.51250E-01 7.892000 251 0.48750E-01 7.892000 252 0.46250E-01 7.892000 253 0.43750E-01 7.892000 254 0.41250E-01 7.892000 255 0.35000E-01 7.892000 256 0.37000E-01 7.992000 257 0.35000E-01 7.992000 258 0.31000E-01 7.99200 259 0.31000E-01 7.99200 260 0.29000E-01 7.99200 260 0.29000E-01 7.99200 270 0.17500E-01 7.99200 270 0.17500E-01 7.99200 271 0.16500E-01 7.99200 272 0.15500E-01 7.16500E-01 7.99200 273 0.14625E-01 7.16500E-01 7.99200 274 0.13750E-01 7.178000 275 0.13125E-01 7.16500E-01 7.99200 276 0.12500E-01 7.178000 277 0.17500E-01 7.178000 278 0.11250E-01 7.178000 279 0.10750E-01 7.121000 270 0.17500E-01 7.121000 271 0.16500E-01 7.99200 282 0.994000E-02 0.998900 283 0.90000E-02 0.998900 284 0.86000E-02 0.998900 285 0.8000E-02 0.998900 286 0.76500E-02 0.77454000		
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231		
232		
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235	233 0.11250	4.431900
236	234 0.10750	4.876000
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242		
243		
245		
246	244 0.67500E-01	7.178200
247	245 0.64500E-01	6.972900
248		
249		
250		
251		
252		
253		
255		
256	254 0.41250E-01	3.234200
257 0.35000E-01 2.949100 258 0.33000E-01 2.823100 259 0.31000E-01 2.689600 260 0.29000E-01 209e1 2.556800 261 0.27500E-01 2.2500E-01 262 0.24750E-01 2.263300 263 0.24750E-01 2.261300 264 0.23500E-01 2.180800 265 0.22500E-01 2.116100 266 0.21500E-01 2.050100 267 0.20500E-01 1.979200 268 0.19500E-01 1.999200 268 0.19500E-01 1.990700 269 0.18500E-01 1.820900 270 0.17500E-01 1.738500 271 0.16500E-01 1.565500 272 0.15500E-01 1.565500 273 0.14625E-01 1.485300 274 0.13875E-01 1.485300 274 0.13875E-01 1.414100 275 0.13125E-01 1.270100 277 0.11750E-01 1.210800 278 0.11250E-01 1.166800 279 0.10750E-01 1.166800 279 0.10750E-01 1.166800 279 0.10750E-01 1.1076200 281 0.98000E-02 0.9989800 282 0.94000E-02 0.9989800 284 0.86000E-02 0.9232700 285 0.82000E-02 0.8854100 286 0.78000E-02 0.8096600 287 0.74500E-02 0.7451400 290 0.64500E-02 0.7451400 290 0.64500E-02 0.7451400 290 0.64500E-02 0.7451400		
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         264       0.23500E-01       2.180800         265       0.22500E-01       2.116100         266       0.21500E-01       2.050100         267       0.20500E-01       1.979200         268       0.19500E-01       1.979200         269       0.18500E-01       1.820900         270       0.17500E-01       1.738500         271       0.16500E-01       1.565500         273       0.14625E-01       1.485300         274       0.13875E-01       1.445300         274       0.13875E-01       1.270100         275       0.13125E-01       1.270100         276       0.12375E-01       1.270100         277       0.11750E-01       1.165800         279       0.10750E-01       1.165800         279       0.10750E-01       1.121000         280       0.10250E-01       1.036000 <td></td> <td></td>		
259		
260		
261 262 263 264 265 265 266 266 267 266 268 269 269 268 269 269 269 269 269 269 270 289 270 271 271 271 272 273 274 274 275 275 275 277 277 277 277 277 277 277		
262         0.26250E-01         2.363100           263         0.24750E-01         2.261300           264         0.23500E-01         2.180800           265         0.22500E-01         2.116100           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         1.565500           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           278         0.11250E-01         1.165800           279         0.10750E-01         1.121000           280         0.10250E-01         1.076200           281         0.98000E-02         0.9989800           283         0.9000E-02         0.9611300           284         0.8600		0.450700
263         0.24750E-01         2.261300           264         0.23500E-01         2.180800           265         0.22500E-01         2.116100           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         1.655100           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           278         0.11250E-01         1.165800           279         0.10750E-01         1.121000           280         0.10250E-01         1.076200           281         0.98000E-02         0.9989800           283         0.9000E-02         0.9981300           284         0.86000E-02         0.8854100           286         0.780		
265       0.22500E-01       2.116100         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       1.655100         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         278       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       0.9000E-02       0.9611300         284       0.86000E-02       0.8854100         285       0.82000E-02       0.8854100         286       0.78000E-02       0.8475500         287       0.74000E-02       0.89960		
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         1.655100           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           278         0.11250E-01         1.165800           279         0.10750E-01         1.121000           280         0.10250E-01         1.076200           281         0.98000E-02         0.9989800           282         0.94000E-02         0.9989800           283         0.9000E-02         0.9611300           284         0.86000E-02         0.8854100           285         0.82000E-02         0.8854100           286         0.78000E-02         0.8475500           287         0.	264 0.23500E-01	2.180800
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       1.5655100         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         278       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       0.9000E-02       0.9611300         284       0.86000E-02       0.9232700         285       0.8200E-02       0.8854100         286       0.7800E-02       0.8996600         287       0.74000E-02       0.8996600         288       0.70500E-02       0.77451400         290       0.64500E-02       0.714	265 0.22500E-01	2.116100
268       0.19500E-01       1.900700         269       0.18500E-01       1.820900         270       0.17500E-01       1.738500         271       0.16500E-01       1.655100         272       0.15500E-01       1.566500         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         278       0.11250E-01       1.165800         279       0.10750E-01       1.121000         280       0.10250E-01       1.076200         281       0.9800E-02       1.036000         282       0.94000E-02       0.9989800         283       0.9000E-02       0.9611300         284       0.86000E-02       0.9232700         285       0.82000E-02       0.8854100         286       0.78000E-02       0.8996600         287       0.74000E-02       0.8096600         288       0.70500E-02       0.7451400         290       0.64500E-02       0.7451400         290       0.64500E-02       0.745		
269       0.18500E-01       1.820900         270       0.17500E-01       1.738500         271       0.16500E-01       1.655100         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         278       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       0.77451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
270       0.17500E-01       1.738500         271       0.16500E-01       1.655100         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         278       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       0.9000E-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       0.896600         288       0.77500E-02       0.7753600         289       0.67500E-02       0.77451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
271       0.16500E-01       1.655100         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         278       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       0.9000E-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       0.899600         288       0.70500E-02       0.77451400         289       0.67500E-02       0.74451400         290       0.64500E-02       0.6847000		
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         278       0.11250E-01       1.165800         279       0.10750E-01       1.076200         281       0.98000E-02       1.036000         282       0.9400E-02       0.998980         283       0.9000E-02       0.9611300         284       0.86000E-02       0.9232700         285       0.8200E-02       0.8854100         286       0.78000E-02       0.8475500         287       0.74000E-02       0.8096600         288       0.70500E-02       0.77451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
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         278       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         289       0.67500E-02       0.7451400         290       0.64500E-02       0.7451400         291       0.61500E-02       0.6847000		
274       0.13875E-01       1.414100         275       0.13125E-01       1.342200         276       0.12375E-01       1.270100         277       0.11750E-01       1.210800         278       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         289       0.67500E-02       0.7451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
275       0.13125E-01       1.342200         276       0.12375E-01       1.270100         277       0.11750E-01       1.210800         278       0.11250E-01       1.165800         279       0.10750E-01       1.076200         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       0.8996600         288       0.70500E-02       0.7753600         289       0.67500E-02       0.7451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
276       0.12375E-01       1.270100         277       0.11750E-01       1.210800         278       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         289       0.67500E-02       0.7451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
278       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       0.9000E-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         289       0.67500E-02       0.74451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
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         289       0.67500E-02       0.7451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
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         289       0.67500E-02       0.7451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
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       289     0.67500E-02     0.7451400       290     0.64500E-02     0.7149200       291     0.61500E-02     0.6847000		
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         289       0.67500E-02       0.7451400         290       0.64500E-02       0.7149200         291       0.61500E-02       0.6847000		
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       289     0.67500E-02     0.7451400       290     0.64500E-02     0.7149200       291     0.61500E-02     0.6847000		
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       289     0.67500E-02     0.7451400       290     0.64500E-02     0.7149200       291     0.61500E-02     0.6847000		
285     0.82000E-02     0.8854100       286     0.78000E-02     0.8475500       287     0.74000E-02     0.8096600       288     0.70500E-02     0.7753600       289     0.67500E-02     0.7451400       290     0.64500E-02     0.7149200       291     0.61500E-02     0.6847000		
286     0.78000E-02     0.8475500       287     0.74000E-02     0.8096600       288     0.70500E-02     0.7753600       289     0.67500E-02     0.7451400       290     0.64500E-02     0.7149200       291     0.61500E-02     0.6847000		
288     0.70500E-02     0.7753600       289     0.67500E-02     0.7451400       290     0.64500E-02     0.7149200       291     0.61500E-02     0.6847000		
289     0.67500E-02     0.7451400       290     0.64500E-02     0.7149200       291     0.61500E-02     0.6847000		
290     0.64500E-02     0.7149200       291     0.61500E-02     0.6847000		
291 0.61500E-02 0.6847000		
202 U.00700E-02 U.0070400		
	232 U.30/3UE-U2	0.0070400



TABLE A1.1 Continued

TABLE	A1.1	Continued
Bin Mid-Point En	ergy	Displacement Damage
# (MeV)	- 37	Function (MeV·mbarn)
# (MeV) 293 0.56250E-0	02	0.6318600
294 0.53700E-0		0.6066800
295 0.51250E-(		0.5821900
296 0.48750E-		0.6085100
297 0.46250E-		0.5211400
298 0.43750E-0		0.4872300
299 0.41250E-0 300 0.39000E-0		0.4598900
301 0.37000E-0		0.4361800 0.4151300
302 0.35000E-		0.3939900
303 0.33000E-0	02	0.3727900
304 0.31000E-0		0.3514300
305 0.29000E-0 306 0.27500E-0		0.3298500 0.3137700
307 0.26250E-0		0.3002000
308 0.24750E-(		0.2834300
309 0.23500E-0	02	0.2693700
310 0.22500E-		0.2580800
311 0.21500E-0		0.2467900
312 0.20500E-0 313 0.19500E-0		0.2355000 0.2243300
314 0.18500E-		0.2132400
315 0.17500E-		0.2021500
316 0.16500E-0	02	0.1910600
317 0.15500E-		0.1799600
318 0.14625E-0		0.1697200
319 0.13875E-0 320 0.13125E-0		0.1606400 0.1515600
321 0.12375E-(		0.1424900
322 0.11750E-0	02	0.1349500
323 0.11250E-0		0.1289000
324 0.10750E-0		0.1228500
325 326 0.10250E-0 0.98000E-0		0.1168000 0.1115900
327 0.94000E-		0.1071900
328 0.90000E-	03	0.1028000
329 0.86000E-0		0.98406E-01
330 0.82000E-0 331 0.78000E-0		0.94013E-01 0.89045E-01
332 0.74000E-0		0.83513E-01
333 0.70500E-		0.78736E-01
334 0.67500E-0		$d0e-4bb2 = 0.75315E-01_{-0.72097E-01}2007$
0.64500E-0		0.72037L-01
336 0.61500E-0 337 0.58750E-0		0.68880E-01 0.65583E-01
338 0.56250E-0		0.62205E-01
339 0.53750E-(		0.58827E-01
340 0.51250E-		0.55449E-01
341 0.48750E-0		0.51682E-01
342 0.46250E-0		0.47534E-01
343 0.43750E-0 344 0.41250E-0		0.43386E-01 0.39238E-01
345 0.39000E-		0.36301E-01
346 0.37000E-		0.34546E-01
347 0.35000E-0		0.32464E-01
348 0.33000E-0		0.28456E-01
349 0.31000E-0		0.24134E-01
350 0.29000E-0 351 0.27500E-0		0.20712E-01 0.18816E-01
352 0.26250E-(		0.17222E-01
353 0.24750E-		0.14956E-01
354 0.23500E-0		0.12137E-01
355 0.22500E-0		0.98052E-02
356 0.21500E-0		0.74733E-02
357 0.20500E-0 358 0.19500E-0		0.51414E-02 0.34199E-02
359 0.18500E-0		0.34199E-02 0.22979E-02
360 0.17500E-		0.13235E-02
361 0.16500E-0		0.12182E-02
362 0.15500E-		0.12548E-02
363 0.14625E-0 364 0.13875E-0		0.12918E-02 0.13292E-02
365 0.13125E-0		0.13292E-02 0.13666E-02
0.10125		0.10000L-02