Detailed Description of the Derivation of the Silicon Damage Response Function

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Detailed Description of the Derivation of the Silicon Damage Response Function

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Abstract

This report provides a set of consistent definitions for radiation damage metrics relevant to the modeling of displacement damage in materials. The limitations/approximations built into the various metrics are discussed, as are the intended applications that gave rise to community use of the damage metrics. Numerical tabulations are provided, based on the latest nuclear data, for recommended values of the neutron displacement kerma factor and various NRT-based damage energy metrics in silicon.

ACKNOWLEDGMENTS

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NOMENCLATURE

arc	athermal recombination-corrected
BCA	binary collision approximation
cema	Converted Energy per unit MAss
CPE	charged particle equilibrium
CSEWG	Cross Section Evaluation Working Group
DFT	density functional theory
dpa	displacement per atom
ENDF	Evaluated Nuclear Data File
ENEA	Ente per le Nuove Tecnologie l'Energia e l'Ambiente (Italian National Board for New Technologies, Energy and the Environment)
GGA	generalized gradient approximation
HF	Hartree-Fock
IAEA	International Atomic Energy Agency
ICRU	International Commission on Radiation Units
IV	interstitial-vacancy
kerma	<u>K</u>inetic <u>E</u>nergy <u>R</u>eleased per unit <u>MA</u>ss
KP	Kinchin-Pease
LDA	local density approximation
LET	linear energy transfer
LI	lower integration (limit/bound)
LSS	Lindhard, Scharff, Schiott
MCNP	Monte Carlo N-Particle
MD	molecular dynamics
NIEL	non-ionizing energy loss
NRT	Norgett-Robinson-Torrens
PKA	primary knock-on atom
rpa	replacement per atom
SIA	self-interstitial atom
ZBL	Zeigler, Biersack, Littmark

1. PURPOSE

There has been a request from the standards organization, ASTM International, Subcommittee E10.07 on Radiation Dosimetry for Radiation Effects on Materials and Devices, to provide the details used in the derivation of the silicon damage response function. This response function formed the basis of ASTM E722, Standard Practice for Characterizing Neutron Fluence Spectra in Terms of an Equivalent Monoenergetic Neutron Fluence for Radiation-Hardness Testing of Electronics. Several parties have tried to reproduce the details of the damage response function and they have not been able to replicate some features in the 100 - 300 eV energy region – the region where the maximum recoil ion energy from neutron elastic reactions falls below the displacement threshold energy. The reason for the difficulty in replicating the damage response functions stems from a failure to fully document the assumptions applied to the threshold function used within the derivation of the response within the body of the standard. This report is designed to provide sufficient detail to permit another party to exactly duplicate the calculations used in the derivation of the recommended silicon damage response function – and to permit future calculations to modify or update the methodology as improved nuclear data becomes available.

2. DEFINITIONS

The derivation of the appropriate silicon displacement damage metric requires that one starts by establishing the definitions for the basic quantities being referenced. The best source for the definition of fundamental quantities comes from international standards, such as the ICRU [ICRU60, ICRU85]. The use of internationally accepted sources should support the establishment of clear and accepted definitions for the basic quantities that will underpin the later discussion of displacement kerma and non-ionizing energy loss (NIEL). This base of fundamental definitions will then be extended to address additional quantities, such as damage energy and Frenkel pair creation, which are used within the formalism adopted here to support the characterization of the neutron energy-dependence of various observed physical degradation metrics in silicon when used in semiconductor applications.

2.1 Kerma

Kerma, K, (for ionizing uncharged particles) is, in accordance with the ICRU 85 definitions, the quotient of dE_{tr} by dm, where dE_{tr} is the mean sum of the initial kinetic energies of all charged particles liberated in a mass dm of a material by the uncharged particle incident on a mass dm of a material, thus:

$$K = dE_{tr} \Big/ dm \qquad \text{Eqn. 1}$$

The term dE_{tr} includes the kinetic energy of the charged particles emitted in the decay of excited atoms/molecules or in nuclear de-excitation or disintegrations.

Kerma is an acronym for "<u>k</u>inetic <u>e</u>nergy <u>r</u>eleased per unit <u>ma</u>ss".

For a fluence, Φ, of uncharged particles of energy E, the kerma, K, in a specific material is given by:

$$K = \Phi \cdot E \cdot \frac{\mu_{tr}}{\rho} \qquad \text{Eqn. 2}$$

The kerma per fluence, K/Φ, is termed the kerma coefficient for uncharged particles of energy E in a specified material. μ_{tr}/ρ is the mass energy transfer coefficient, defined in ICRU 85, and ρ is the material density.

In dosimetry applications, the kerma, K, is often expressed in terms of the distribution, Φ_E, of the uncharged particle fluence with respect to energy. Thus:

$$K = \int \Phi_E \cdot E \cdot \frac{\mu_{tr}}{\rho} dE \qquad \text{Eqn. 3}$$

There are some apparent ambiguities in the above Equations 2 and 3 in that:
- it uses μ_{tr} rather than μ_{en}, i.e. energy transfer rather than energy absorption, thus it includes the energy radiated as uncharged particles from charged particle emission, e.g. bremsstrahlung from liberated electrons,
- yet the definition addresses energy liberated as a sum "over all charged particles" emitted, and hence should not include photons emitted from primary neutron interactions – this distinction being tied in with the observation that bremsstrahlung is not a "direct" neutron interaction product;

and
- it includes kinetic energy of secondary charged particle emission from the decay of excited atoms,
- yet the definition addresses only including the sum of "initial" kinetic energies from all charged particles.

While the above facts can be properly taken into account in calculating the kerma, one has to be very careful to reconcile the definitions for these terms.

Although kerma is a quantity that addresses the initial transfer of energy to matter, it is sometimes used as an approximation to absorbed dose. The numerical value of the kerma approaches the absorbed dose to the degree that 1) charged particle equilibrium exists; 2) radiative losses are negligible; and 3) the kinetic energy of the uncharged particles is large compared with the binding energy of the liberated particles. When radiative losses are not negligible, a quantity termed the collision kerma is a better approximation to the absorbed dose. The definition of the collision kerma, K_{col}, is similar to that for kerma but has μ_{tr} replaced by μ_{en} in Equations 2 and 3.

2.2 DPA
Displacements per atom, dpa, in accordance with ASTM E170-15a, Standard Terminology Relating to Radiation Measurements and Dosimetry [A170], is the mean number of times each atom of a solid is displaced from its lattice site during an exposure to displacing radiation.

2.3 Lattice Energy Transfer Cross Section
Lattice energy transfer cross section, $\sigma_{en}^{lattice}(E \rightarrow T)$, characterizes the energy imparted to the lattice by neutron-nucleus reactions [He93] and can be defined as:

$$\sigma_{en}^{lattice}(E \rightarrow T) = \sum_i \sigma_i(E) \cdot K_i^{recoil}(E \rightarrow T) \qquad \text{Eqn. 4}$$

where:

$\sigma_i(E)$ is the neutron energy-dependent cross section for the ith reaction channel;

$K_i^{recoil}(E \rightarrow T)$ is the probability density that a reacting neutron with energy E will produce a recoil of energy T in the laboratory system;

$\sigma_{en}^{lattice}(E \rightarrow T)$ is a microscopic differential cross section for a neutron with energy E producing a recoil ion with energy T.

2.4 Displacement Dose

Displacements dose, D_d, in accordance with ASTM E170-15a, is the quotient of $d\varepsilon_d$ by dm, where $d\varepsilon_d$ is the mean energy imparted by radiation to matter which produces displacements (that is, excluding the part that produces ionization and excitation of electrons) in a volume element dm, thus,

$$D_d = d\varepsilon_d \Big/ dm \qquad\qquad \text{Eqn. 5}$$

2.5 Damage Energy

The definition of damage energy, T_{dam}, is not entirely consistent throughout the range of applications in the radiation damage community. To clarify the issue, we distinguish, in this report, two separate types of damage energy, one for neutrons and one for ions.

The complexity that requires the use of two terms is that, while the concept of neutron damage energy only includes the energy imparted by a single neutron interaction (including neutron elastic scattering events), it does includes the energy imparted by the charged particles integrated over their complete slowing down process. There may be different ways to define this "damage energy" term without forcing a definition of the two separate types of this quantities, such as by defining the energy deposition to take place within the "local" region, but it is felt that this two-term definition is clearer than other approaches.

When the symbol T_{dam} is used in this document, it is assumed that it can apply equally to either the neutron-induced damage energy, $^nT_{dam,}$ or the charged particle-induced damage energy, $^{ion}T_{dam}$. Thus the T_{dam} notation is used in conjunction with an energy argument that refers to the energy of either an incident neutron or charged particle.

2.5.1 Charged Particle Damage Energy

The damage energy for a charged particle, $^{ion}T_{dam}(T)$, is the total energy imparted to the lattice by an incident ion of energy T as it slows down in a lattice of infinite homogeneous extent. Note that the ion slowing down process involves many different ion-atom interactions and that the energy imparted to the lattice over this total slowing down process is summed over the infinite volume. When an ion-atom collision displaces a lattice atom, the subsequent energy imparted by this displaced lattice atom is also included in the sum.

The damage energy for a charged particle can be divided into two components, that due to the stopping or radiation of the principal ion, $^{ion}T_{dam}^{rad}(T)$, and that due to any subsequent transmutation and spallation reactions induced by the principal ion, $^{ion}T_{dam}^{trans}(T)$. Thus:

$$^{ion}T_{dam}(T) = {}^{ion}T_{dam}^{rad}(T) + {}^{ion}T_{dam}^{trans}(T) \qquad\qquad \text{Eqn. 6}$$

The first term on the right-hand side of this expression relates back to the definition of the stopping power of an ion which, by definition, includes only Coulombic interactions – even though it includes a term that has traditionally been referred to as a "nuclear stopping power" but actually refers to ion-lattice atom Coulombic interactions. The second term on the right-hand

side of the expression above represents the true "nuclear" component. The WinNIEL code, is an example of one of the few codes that address the kinetic energy transfer (in the rest frame) from any actual ion-atom nuclear transmutation reaction, that is, ion-induced transmutation reactions and spallation reactions, and it addresses this term in the context of the non-ionizing energy loss (NIEL), rather than from the perspective of a damage energy.

Note that the ion damage energy was defined to apply to "a lattice of infinite homogeneous extent", and thus is a good metric for the local energy deposition imparted to the lattice only if there is a local equilibrium for the induced charged particles. It should be noted that, due to attenuation of the incident source particles, local charged particle equilibrium may not be attainable in a physically meaning scenario if the extent of the range of the induced charged particles is not small with respect to the mean free path for interactions of the source particle.

Figure 1, taken from Reference [La08], shows the displacement energy as a function of the incident ion energy for carbon ions in carbon; silicon ions in silicon; and germanium ions in germanium. The energy going into displacements first increases with increasing ion energy and then saturates. The saturation reflects the behavior of the stopping power and its partition between nuclear and ionization contributions.
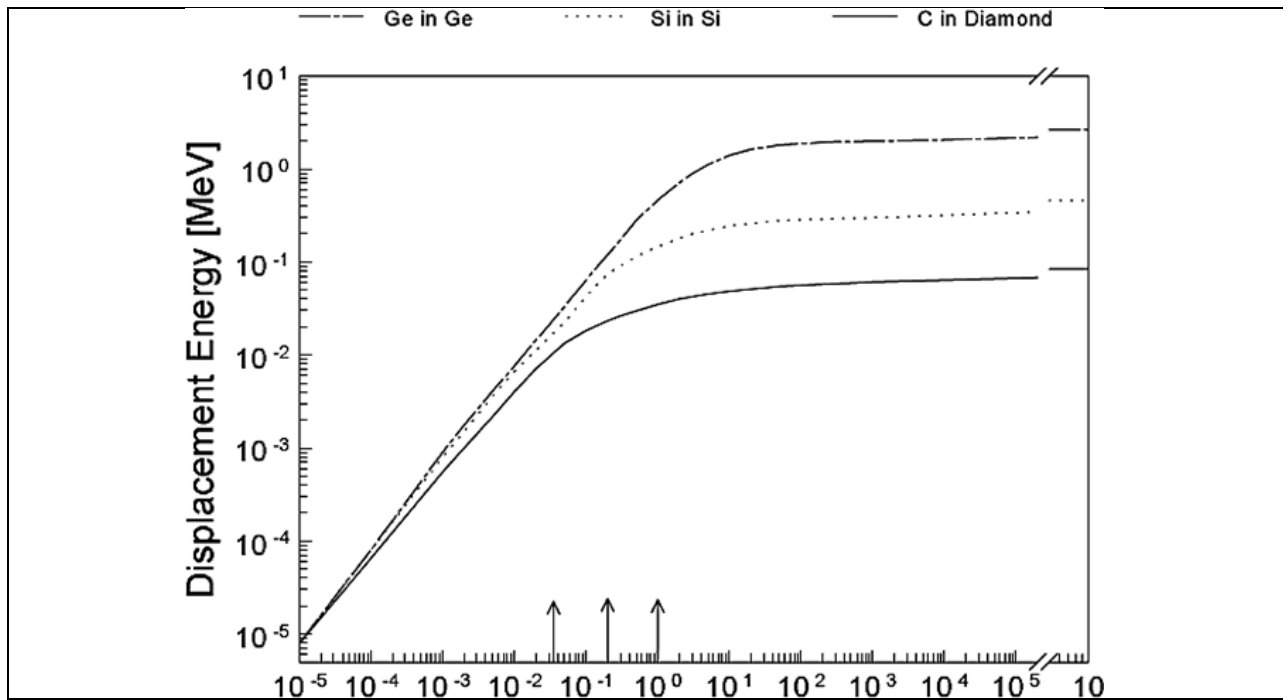
Figure 1: Displacement Energy as a Function of Energy for an Incident Germanium, Silicon, and Carbon Ions in Like Materials

2.5.2 Neutron Particle Damage Energy

The damage energy, $^nT_{dam}(E)$, is the reaction probability multiplied by the total energy imparted to the lattice by an incident neutron of energy E in a single neutron-nucleus reaction, including the imparted energy to the lattice that comes from subsequent collisions by any of the secondary charged particles that are generated, but not including the effects from any secondary gammas

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emitted. Secondary gammas are not included here because they have a long range, i.e. they do not deposit their energy locally in the lattice. Photons can cause various modes of damage, even inducing lattice displacements through their generation of high energy electrons. Any locally generated gamma radiation needs to be treated separately, i.e. the photon field needs to be quantified with respect to fluence and spectrum and the deposited lattice energy due to gamma interactions needs to be addressed as a separate contributor to the damage metric, e.g. see Reference [Re93].

Various types of damage energy can be defined based on the treatment of the damage efficiency for subsequently displaced lattice atoms near the displacement threshold energy for the lattice material. These damage energy models are discussed in detail in Section 5 along with a discussion of the various defect creation models.

For small feature sizes, especially in semiconductors, the condition of local charged particle equilibrium may not exist, even for neutron as the source particles, due to differing neutron interaction probabilities and the variation of materials within the range of the secondary charged particles. While the ion damage energy, and by implication the neutron damage energy, is still a well-defined quantity in the absence of this local secondary charged particle equilibrium, this lack of correlation with the "local" energy imparted to the lattice may impact the correlation of some damage metrics with experimentally observed damage effects.

2.6 Neutron Damage Energy Cross Section

The neutron damage energy cross section, $^{n}\sigma_{dam}$, is another name for the neutron damage energy, $^{n}T_{dam}$, and, as discussed above, has units of energy multiplied by a microscopic cross section. It can be expressed as the sum, over all open neutron-induced reaction channels indexed with the subscript "i", and all emitted particles within a channel "i" as indexed with the subscript "j_i", of the cross section for that channel multiplied by the energy transfer distribution for that channel and the damage energy for the resulting charged particles and can be written as:

$$^{n}\sigma_{dam}(E) = {}^{n}T_{dam}(E) = \sum_{i,j_i} \int \sigma_{i,j_i}(E) \cdot K_{i,j_i}^{recoil}\left(E \to T_{j_i}\right) \cdot {}^{ion}T_{dam}(T_{j_i}) \cdot dT_{j_i} \qquad \text{Eqn. 7}$$

The effective damage energy, with units of energy, is given by:

$$^{n}E_{dam}(E) = \frac{{}^{n}\sigma_{dam}(E)}{\sigma(E)} \qquad \text{Eqn. 8}$$

where $\sigma(E)$ is the total neutron cross section.

Note that in Equation 7 we do not, at this time, make explicit the lower integration bound to be used in computing the neutron damage cross section. This issue will be addressed later in Section 5 along with a discussion of the displacement cross section and the treatment of the threshold energy region.

The notation adopted here for a neutron-induced reaction is:

$$_0^1 n + {}_Z^A T \rightarrow {}_{Z-z}^{A-a+1} R + {}_z^a r$$
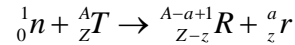
This notation captures both the atomic weight and atomic number of the various nuclei in the entrance and exit channels. In this notation: "n" is the incident neutron, "T" is the target element with atomic weight "A" and atomic number "Z"; "R" is the primary residual nucleus; and "r" is the light isotope in the residual channel. In this notation, "$A-a+1$" is greater than "a". The attribute "primary" for the "R" nucleus in the outgoing reaction channel denotes that it is the heavy particle in this exit channel. This residual nucleus is often referred to as the primary "knock-on" atom (PKA).

The community is not consistent in the treatment of the lower bound for the integration used to define the damage energy, as seen in Equations 7. In Robinsons initial work [Ro71, Ro75, Ro77] he notes that, for electrons, it is customary to set the damage energy to zero below a certain energy (his equation 3), but, in defining the damage energy for neutrons, he uses a lower integration bound of zero for the recoil atom energy while employing an integrand containing his analytic formulation for the energy partition function (his equation 17) that goes down to zero energy.

With respect to the implementation of "damage energy" in the MARLOWE binary collision approximation (BCA) code, Robinson notes [Ro83]:

"The damage energy appears in MARLOWE as the sum of three terms.

a) The kinetic energy transferred in quasielastic collisions to target atoms which are not displaced (each contribution $< E_d$).

b) The energy expended by displaced particles in overcoming binding (each contribution $= E_b$).

c) The final kinetic energy of each recoil which stops within the target (each contribution $< E_c$)."

Thus MARLOWE includes the energy less than E_d in its definition of the "damage energy". In the above quote, E_b is the binding energy and E_c is the cut-off energy below which the ion is not tracked in the calculation [Ro92]. Since this lower integration (LI) bound will affect the values for damage metrics discussed later in this report, we will adopt a notation for the "damage energy" that includes a clear statement about the LI used. Thus, when this distinction may be important, the notation used will be $_{LI}T_{dam}(E)$. Since the two values of the lower integration limit that appear in the literature are zero and E_d, the notation becomes: $_0T_{dam}(E)$ or $_{E_d}T_{dam}(E)$. This modified notation applies to the neutron damage energy, $^nT_{dam}(E)$. While this notation is not needed for the charged particle damage energy, $^{ion}T_{dam}(T)$, since, for a charged particle, this value is derived directly from the partition function and is not derived through an integration, but a notation indicating the applicable energy partition model is needed for ions. The options and notation for the energy partition model are discussed in Section 3.

It should be noted that, while some analysis/codes only treat the damage energy from the primary residual atom, the formal definition of damage energy requires that the damage from all emitted particles be considered. Thus the definition requires that the damage energy from the light isotope in the outgoing channel also be considered. This underscores the warning above that the "definition of damage energy … is not entirely consistent throughout the range of applications."

In cases where a neutron-induced residual reaction product is emitted in an excited state that subsequently decays with the emission of a different ion, the damage energy from the subsequent decay products should also be included in the neutron damage energy. The SPECTER code [Gr85] includes this consideration for some cases of interest to the pressure vessel embrittlement community, e.g. beta decay of ^{28}Al.

2.7 Neutron DPA Cross Section

Neutron dpa cross section, $^{n}\sigma_{dpa}(E)$, characterizes the production of Frenkel pairs, i.e. lattice vacancy-interstitial combinations, produced in the lattice by neutron-nucleus reactions [He93] and can be defined as:

$$^{n}\sigma_{dpa}(E) = \int \sigma(E \rightarrow T) \cdot v_d \left[^{ion}T_{dam}(T) \right] \cdot dT \qquad \text{Eqn. 9}$$

where $v_d(T)$ is defined as the number of Frenkel pairs created by an ion with damage energy T. There is an implied summation/integration in Equation 9 over all of the open cross section channels and all emitted particles in each open channel. There are various possible formulations for the term $v_d(T)$, these formulations are discussed in detail in Section 5.

2.8 Microscopic Displacement Kerma Factor

Microscopic displacement kerma factor, κ^{dpa}, can be written as:

$$\kappa^{dpa}(E) = \sum_{i,j_i} \sigma_{i,j_i}(E) \int_0^{\infty} dT_{R,j_i} \int_{-1}^{1} d\mu \cdot f_{i,j_i}\left(E, \mu, T_{R,j_i}\right) \cdot {}^{ion}T_{dam}\left(T_{R,j_i}\right) \qquad \text{Eqn. 10}$$

where:
- the summation is over all open neutron-induced reaction channels, i
- the summation is over all emitted particles in the ith channel, j_i
- $\sigma_{i,ji}(E)$ is the cross section for the j_i particle in the ith reaction channel
- $f_{i,ji}(E,\mu,T_{R,ji})$ is the energy distribution for resulting charged particles which are emitted with:
  - an energy $T_{R,ji}$
  - at an angle characterized by $\mu = cos(\theta)$
  - that result from the j_i particle in the ith reaction channel
  - and are induced by the incident neutron energy with energy E.
- $^{ion}T_{dam}(T_{R,ji})$ is the displacement partition function for the emitted ion j_i in the ith open channel with energy $T_{R,ji}$.

Note that the lower energy limit for the integration in Equation 10 is 0 eV. This is the appropriate lower bound for a displacement kerma. The earlier discussion on the different

approaches within the radiation effects community for the lower bound only applies to the determination of the neutron damage energy, not to the displacement kerma (or microscopic displacement kerma factor).

This term is sometimes also referred to as the "displacement kerma factor".

For neutrons, a code such as NJOY-2012 can be used in conjunction with a nuclear data evaluation to find the displacement kerma factor, κ^{dpa}. NJOY first calculates the reaction-specific total kerma induced by neutron interactions and then identifies the recoil energy distribution for all of the reaction products. The recoil atom energy distribution for each reaction is then partitioned into a displacement component using the Robinson fit to the LSS theory. This energy partition is discussed in Section 3 and the calculation of the displacement kerma is discussed in Section 5.

2.9 Displacement Kerma
Displacement kerma, K^{dpa}, is equal to the microscopic kerma factor multiplied by number of atoms per unit mass in the target material and the incident particle fluence. One has to be careful in interpreting the literature because the microscopic displacement kerma factor is often, incorrectly, referred to as the displacement kerma.

2.10 Ionization Kerma
Ionization kerma, K^{ion}, is obtained by subtracting the displacement kerma. K^{dpa}, from the total kerma, K.

2.11 NIEL – Non-Ionizing Energy Loss
Non-ionizing energy loss, *NIEL(E)*, is given by:

$$NIEL^{T_{\min}}(E) = \frac{N_A}{A_L'} \cdot \sum_i \sigma_i(E) \cdot \int_{T_{min}}^{\infty} dT_R \int_{-1}^{1} d\mu \cdot f_i(E, \mu, T_R) \cdot {}^{ion}T_{dam}(T_R) \qquad \text{Eqn. 11}$$

where N_A is Avogadro's number of particles per mole and A_L' is the molar mass of the lattice atoms, i.e. a quantity with units of kg/mole and equal to the mass of Avogadro's number of particles.

The lower bound for the integral, T_{min}, is defined differently by various authors. In this document, the *NIEL* notation uses this value as a superscript in order to uniquely capture what was used by an author. Some authors set T_{min} to zero, others/most [Ak01, Bo09, Xap] use the displacement threshold energy, E_d. Based on the physics of the collision, for cases where the energy transfer is less that E_d, the lattice atom stays in its lattice position but energy does go into phonons – and, hence, is part of the non-ionizing component. The importance of this difference is obscured somewhat by the fact that some models for the damage energy partition define the ion damage energy to be zero below the displacement threshold energy – which makes the lower integration bound irrelevant, or at least it becomes a coupled consideration.

Reference [La08] provides some analytical approximations for *NIEL* and observes that *NIEL* is the "rate at which energy of the incoming particle is lost per unit length in the material, in non-ionizing processes. It is the analogue of the linear energy transfer (LET) or stopping power for ionizing events."

NIEL is defined for both charged and uncharged particles. For uncharged particles, NIEL is equal to the microscopic displacement kerma factor multiplied by the factor N_A/A'_L. For silicon, this conversion between microscopic displacement kerma factor (given in units of MeV·barn) and the *NIEL* (in units of keV·cm^2/g) is 0.02144 [keV·cm^2/g]/[MeV·barn]. For charged particles it is equal to the displacement augmented cema multiplied by the factor N_A/A'_L.

2.12 1-MeV(Si) Equivalent Neutron Fluence

Per the guidance in ASTM E722-14, Standard Practice for Characterizing Neutron Energy Fluence Spectra in terms of an Equivalent Monoenergetic Neutron Fluence for Radiation-Hardness Testing of Electronics, the reference 1-MeV(Si) microscopic displacement kerma factor (or damage energy) is defined to be a community standard value of 95 MeV·mbarn. ASTM E722 also provides a detailed 640-group tabulation of the neutron-induced damage factor. In the case of silicon, this damage factor is identical to the microscopic displacement damage energy for silicon. Thus, the 1-MeV(Si) neutron damage equivalent fluence is obtained by dividing the appropriate spectrum-averaged microscopic displacement damage energy, obtained by folding the response from E722 with the given neutron energy spectrum, by the reference 1-MeV(Si) value of 95 MeV·mbarn. The selection of the damage energy model is addressed with the discussion of the displacement models in Section 5.

The determination of a reference 1-MeV(Si) microscopic displacement kerma factor, or damage energy [Da98, Gr03], is difficult since this energy is in the middle of a resonance in the cross section. The reference value was determined to be 95 MeV·mbarn ± 4 MeV·mbarn [A722] by fitting, over the energy region from 0.01 MeV to 15 MeV, the microscopic displacement kerma factor data to a simple smooth functional form [Na72, Me66, Me65, Me86] given by:

$$\kappa_{Si}^{dpa}(E) = A \cdot E \left(1 - e^{-B/E} \right) \qquad\qquad \text{Eqn. 12}$$

This fit yielded the parameters $A = 1.02$ MeV^{-1} and $B = 3.1$ MeV [Me86].

3. ENERGY PARTITION FUNCTION

The definition of the mass stopping power means that, in addition to energy being lost due to radiative processes, energy deposited from a particle interaction can come about due to electronic process or nuclear processes. The word "nuclear", in the context of a stopping power, does not apply to a "true nuclear process" but rather refers energy deposited in lattice atoms by elastic Coulomb collisions, including the screened Coulombic interactions. A "true nuclear process" refers to any interaction due to the strong or weak nuclear forces, and thus, for an incident proton or light ion, would include true nuclear elastic scattering, e.g. of the proton (or light ion) from the individual nucleons in the lattice atoms. "True nuclear processes" also includes spallation reactions induced by the incident particle. When there is a danger of confusion in the usage of the term "nuclear" in this report we will use the words "radiative nuclear" and "transmutation nuclear" to distinguish the processes. When the term "nuclear" is used without qualification, it should be considered to include both the radiative and transmutation nuclear components.

In the context of a stopping power, the "radiative nuclear" or (lattice) displacement component of the deposited energy can go into overcoming the binding energy of displaced lattice atoms, or into phonons within the crystal structure that eventually are reflected in bulk material heating. The non-nuclear energy deposition represents energy imparted to electrons by ionization or excitation. The concept of an energy partition function is used to divide the energy imparted by an ion, i.e. the lattice recoil atom from a neutron-induced reaction, into its ionization and "nuclear" (including both radiative and transmutation) energy deposition components. This allows the damage energy, $^{n}T_{dam}$, within a material to be determined from the initial ion/recoil-atom energy and a definition of the lattice material (atomic mass, atomic number, and, in some energy partition models, even the crystal structure) where it originates.

In general, the deposited energy can be "partitioned" into any set of processes and this need not be a binary division. In practice, the most important partition is into two categories that are referred to as "ionization" and "displacement" processes. In this nomenclature, the word "displacement" is more properly termed "non-ionizing" since many types of energy deposition, such as energy going into lattice phonons, are typically binned in the "displacement" category. Properly, only the lattice atom binding energy would go into a pure "displacement" partition.

Note that the energy partition function, as defined in this document, yields the amount of energy that goes into the lattice and does not represent the fraction of this energy, i.e. it corresponds to $^{n}T_{dam}$. When most sources plot the energy partition function, they are plotting the ratio of (what is defined here as) the energy partition function, $^{n}T_{dam}$, and the recoil ion/particle energy, T_R. The fractional energy partition function is notated here as: $P^{type}(T_R) = {}^{n}T_{dam}(T_R)/T_R$, where "type" is the representation or source of the defined partition function and T_R is the kinetic energy of the recoiling ion/particle.

Various representations of the displacement energy partition function are addressed in the following subsections. There is considerable ambiguity/variation in the treatment of the energy partition function for energies below the displacement threshold energy, E_d. While the conventional analytical representations, as addressed in the widely used Robinson and Akkerman models, produce a numerical value for ion energies less than E_d, by definition no lattice atom

displacements can take place for ion energies less than E_d. However, for energies less than E_d, the energy imparted to a lattice atom does go into phonons – and hence should be accounted as part of the non-ionizing portion of the damage even if it does not result in any lattice atom displacements. Many implementations of these analytical functions, such as the implementation of the Robinson energy partition in the NJOY-2012.50 code, assume that the contribution from an ion to the damage energy is zero for energies below E_d.

3.1 LSS

The classical treatment of the energy partition for ions into ionization and displacement components comes from the work by Lindhard, Scharff, and Schiott [Li63] in 1963 and is referred to as the LSS energy partition [Do72]. The LSS partition of energy into the lattice from an ion with energy T_R is notated as ${}^{ion}T_{dam}^{LSS}(T_R)$. This approach is based upon the continuous slowing down treatment of the primary and secondary recoil atoms. The LSS approach used a Thomas-Fermi screening function over the Coulomb potential to model the elastic interactions and a non-local free uniform electron gas model for the inelastic electronic scattering.

The LSS model assumes the local density approximation (LDA); that is, material can be represented as a "structureless" solid, referred to as a "lattice gas". Thus the LSS theory does not account for any crystal effects upon the lattice displacement nor does it account for any complications due to the cascade development [He93].

The Lindhard model is limited to energies, T_R, less than about *24.8*Z$^{4/3}$*A* (in keV) [No75, Ro71] where *A* is the atomic mass of the incident ion and *Z* is the atomic number of the incident ion. In iron this limitation translates to a maximum permissible ion energy of 107 MeV. In silicon, the limitation translates to a maximum permissible ion energy of 23 MeV. These limitations are relevant when considering the equivalence of charged particle induced damage and neutron-induced damage. This energy limitation is related to the LSS assumption that the stopping power is related to the ion velocity and, for collisions that impart more than the Bohr velocity to the lattice recoils, $e^2/\bar{h}$ = ~25 keV/amu, this assumption is violated [Mo12, Zi99].

It must be noted that, while the above energy limitation applies to the Lindhard LSS model, codes such as MARLOWE that incorporate the LSS model often are augmented to also use the semi-empirical Ziegler potential to address "the transition from the Lindhard to the Bethe regime governed by Rutherford scattering" [Hou10] through the use of this "heavy ion scaling rule" to capture the stopping power of atoms with energies greater than 25 keV per amu. In MARLOWE, this has been implemented by several different people and is typically accomplished by augmenting the MARLOWE code with new interaction potentials based on the ZBL potential [ZBL85, Hou10].

3.2 Robinson

Robinson and Torrens [Ro74, Ro96] have compared the LSS approach with a detailed simulation using the Firsov theory for inelastic energy loss. Robinson [Ro71] showed that the LSS energy partition function can be approximated by a displacement damage energy, $^{ion}T_{dam}^{Robinson}(T_R)$, given by:

$$^{ion}T_{dam}^{Robinson}(T_R) = \frac{T_R}{\left[1 + k_L \cdot g\left(T_R/E_L\right)\right]}$$

Eqn. 13

where:

- $^{ion}T_{dam}^{Robinson}(T_R)$ is the energy that is imparted to the lattice, i.e. the non-ionizing component of the deposited energy, from an ion with energy T_R
- T_R is the initial energy of the incident ion, in the case of a neutron interaction this is the neutron-induced primary recoil atom
- Z_R is the atomic number of the recoil atom
- Z_L is the atomic number of the lattice atom
- A_R is the atomic weight of the recoil atom
- A_L is the atomic weight of the lattice atom

k_L, $g(\varepsilon)$, and E_L are defined as:

$$k_L = \frac{0.0793 \cdot Z_R^{2/3} \cdot Z_L^{1/2} \cdot \left(A_R + A_L\right)^{3/2}}{\left(Z_R^{2/3} + Z_L^{2/3}\right)^{3/4} \cdot A_R^{3/2} \cdot A_L^{1/2}}$$

Eqn. 14

$$g(\varepsilon) = 3.4008 \cdot \varepsilon^{1/6} + 0.40244 \cdot \varepsilon^{3/4} + \varepsilon$$

Eqn. 15

$$E_L = 30.724 \cdot Z_R \cdot Z_L \cdot \left(Z_R^{2/3} + Z_L^{2/3}\right)^{1/2} \cdot \frac{\left(A_R + A_L\right)}{A_L}$$

Eqn. 16

Note, with respect to the above equations, while the NJOY-2012 code properly implements the above formula, the NJOY-2012 code manual [NJ2012] Equation 198 incorrectly reported the exponent of the combined mass term in the numerator of the quantity k_L, in Equation 33 above, as 2/3 rather than the correct value of 3/2. In the NJOY manual this term is labeled as F_L. Recent updates to NJOY-2012.50, incorporated into up43m, correct this typographical issue in the manual.

For cases where the recoil atom is the same as the lattice atoms, i.e. $A_R = A_L$ and $Z_R = Z_L$, the k_L and E_L terms correspond to parameters in the original Lindhard theory:

$$k_L = \frac{0.133745 \cdot Z^{2/3}}{A^{1/2}}$$

<div align="right">Eqn. 17</div>

$$E_L = 86.931 \cdot Z^{7/3} \quad (eV)$$

<div align="right">Eqn. 18</div>

Note that the Robinson fit to the LSS energy partition is limited, by the nature of its empirical derivation, to cases where the recoil atom is close in atomic number and atomic weight to the lattice atoms. To quote from Section 5 of Reference [No75]:

> "Some limitations of this model must be pointed out. The Lindhard formulation of eqs (5)-(9) applies strictly only to monatomic systems (i.e. Z1=Z2) and to energies less (perhaps much less) than about 25*Z1^4/3*A1 (keV). The former limitation should not be too serious as long as the ratio Z1/Z2 does not differ too much from unity. If necessary, it could be relaxed by repeating the Lindhard calculation for other cases"

This means that the Robinson fit to the LSS partition function should not be used to capture the displacement energy from low mass secondary particles, e.g. protons and alpha, that result from neutron-induced reactions. The damage from the low mass secondary particles should still be considered and is modeled in the general LSS approach; it is only that the Robinson fit to the energy partition may not be accurate to address these cases where the mass of the residual ion is much less than that of the lattice atoms. Analysis tools such as the HEATR module of the NJOY-2012 code use the Robinson fit to the energy partition to address the displacement kerma factor due to both the primary residual particle and the lighter secondary particles, such as protons and alpha particles. This is usually an adequate approximation because the displacement kerma from these light secondary particles is typically very small relative to that from the heavy primary recoil ion.

When the damage partition is being used to establish a correlation with an observed level of damage, the energy from all secondary particles should be taken into consideration, as should any relevant deposited energy from the time-dependent decay of any emitted metastable secondary particles. The adequacy of the modeling of the displacement kerma from the light recoil ions and from emitted metastable particles should be considered on an application-by-application basis. For neutrons up to 20 MeV on silicon, the displacement kerma from emitted metastable particles can generally be dismissed. Figure 2 shows that, for neutron energies less than 20 MeV, the contribution from particles with low atomic weight (less than 4 amu) using the Robinson damage partition function, makes only a ~3% contribution to the silicon damage energy.

For scattering in a silicon-28 lattice, Figure 3 shows the fraction of energy imparted to recoil atoms (phonons and displacements, i.e. the non-ionizing energy fraction). Figure 3 shows that, for low energy recoils, most of the energy goes into the lattice as opposed to ionization. As the lattice atom recoil energy increases, more and more of the energy goes into ionization. For a low recoil energy of 20 eV for a silicon atom in a silicon lattice, 91% of the energy, or 18.2 eV, goes into the lattice.
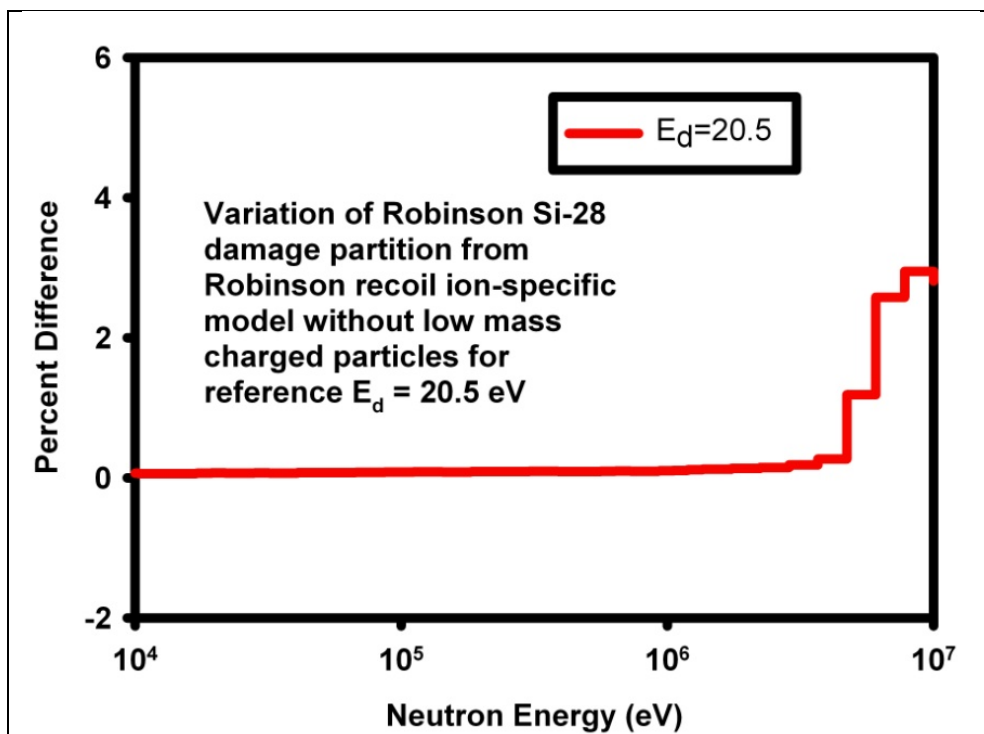
Figure 2: Difference in Damage Energy in Silicon when Low Mass Recoils are Ignored
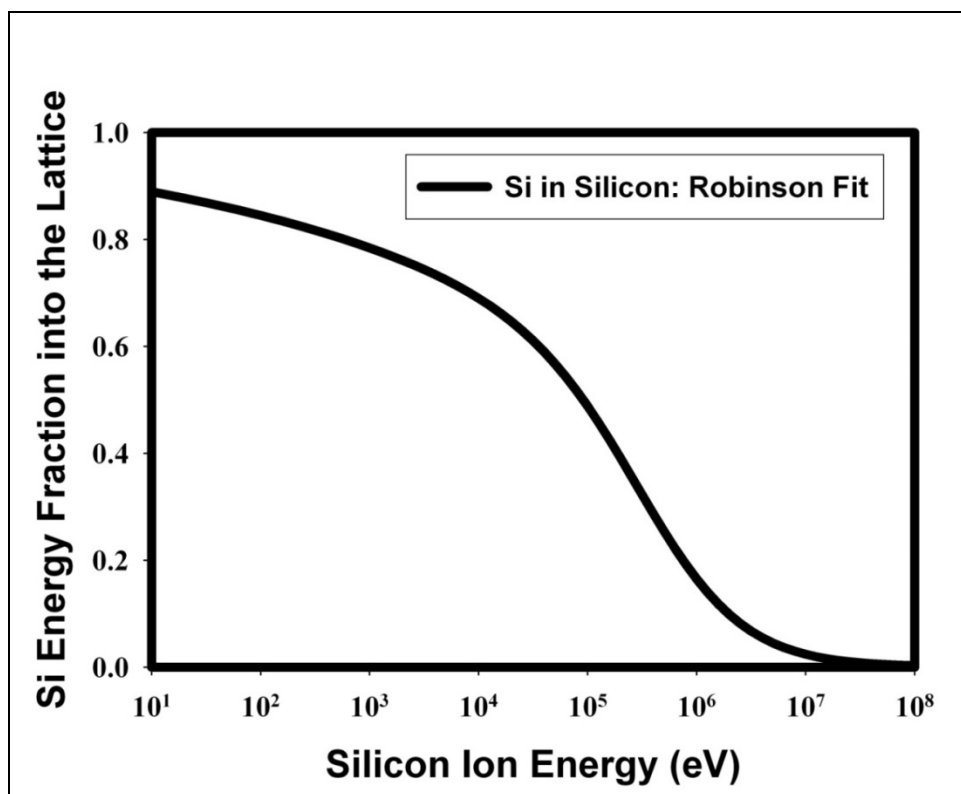
Figure 3: Fraction of Recoil Energy from a Si Ion Imparted to the Lattice in a Silicon Crystal

3.3   Akkerman

Recent work by Akkerman [Ak06], has used updated potentials for silicon to derive a new energy partition in silicon valid for ion energies < 500 keV. Akkerman used the Ziegler, Biersack, and Littmark (ZBL) [ZBL85] potential for the elastic Coulomb scattering and used a combination of a local (impact parameter dependent) model and a non-local model for the inelastic ion-atom scattering. Their results used a displacement threshold energy of 21 eV for silicon.

The Akkerman damage partition model, $^{ion}T_{dam}^{Akkerman-Si}$, uses the same functional representation as was adopted by the Robinson methodology, but they defined a different g-function. We label the Akkerman g-function as $g_{Akkerman}(\varepsilon)$. Its functional form is:

$$g_{Akkerman}(\varepsilon) = 0.74422 \cdot \varepsilon + 1.6812 \cdot \varepsilon^{3/4} + 0.90565 \cdot \varepsilon^{1/6} \qquad \text{Eqn. 19}$$

The Akkerman damage partition is then given by:

$$^{ion}T_{dam}^{Akkerman}(T_R) = \frac{T_R}{\left[1 + k_L \cdot g_{Akkerman}\left(T_R/E_L\right)\right]} \qquad \text{Eqn. 20}$$

In Reference [Ak06] the authors report that, for protons on the silicon lattice, "the presence of a significant part of low energy particles in the recoil spectrum where the new partition function is significantly larger than Lindhard's result". In the conclusion to Reference [Ak06] the authors note that:

> "for protons ... the new partition factor increases significantly the calculated NIEL, up to 15% relative to those calculated with Lindhard's factor. However, this difference decreases with increasing proton energy and becomes negligible when approaching 10 MeV."

and

> "The use of the new partition factor increases NIEL for electrons with energy from 0.3 MeV to 100 MeV by 12% to 15% compared to the data calculated with Lindhard's partition factor."

It is not clear if the author comments above regarding the energy partition comparisons for protons and alpha particles were made using the LSS methodology or if they used the Robinson fit to the LSS work. It must be noted that the original Robinson work clearly stated that their fit to the LSS work is only valid when the incident particle was similar in *Z* and *A* to the lattice. Clearly use of the Robinson damage partition for protons in a silicon lattice violates this caution concerning the fit.

Figure 4 compares the Akkerman and Robinson energy partition functions for a silicon ion incident on a silicon lattice atom. The agreement is seen to be consistent with the above comments from the authors regarding the observed differences for incident protons and alpha particles in the silicon lattice, i.e. the agreement is within about 15% for low energy incident silicon ions and decreases to a negligible difference for high energy incident ions. As was noted for protons and alpha particles, the Akkerman partition function results in about a 15% high lattice displacement damage component for low energy incident particles. At high energy the difference between the Akkerman and Robinson energy partition functions is not clearly depicted in Figure 4 due to the small values of the damage energy. To clarify the comparison, Figure 5 shows the ratio between the two damage partition functions. The figure shows that the Akkerman partition results tend to smaller damage energies, with an 8% lower value for 2 MeV incident silicon ions, and then tend higher again with the damage energy being about 8% higher for 100 MeV incident silicon ions.

3.4   BCA

 Some investigators have used binary collision approximation (BCA) codes, such as MARLOWE, to determine the partition of energy into ionization and lattice deposition components, $^{ion}T_{dam}^{BCA-code/potential}$. The use of a BCA model permits the user to specify the electronic (elastic and inelastic ion-electron) and nuclear (ion-atom) potentials used in the Monte Carlo simulation of the ion slowing down process and while tracking the various sources of energy deposition. Since there are a wide variety of BCA codes, this damage energy term is notated in the format (with superscripts) in order to clearly identify both the "code" and "potential" that were used in defining the energy partition.

The MARLOWE code supports dividing the energy loss into:
- Inelastic energy loss
- Binding loss (displacements)
- Binding loss (replacement)
- Binding loss (non-lattice)
- Sub-threshold loss (lattice)
- Sub-threshold Loss (non-lattice)
- Remaining kinetic energy
- Available for damage
- In replacement sequences
- Carried by focusons
- Replacement threshold
- Focuson threshold
- Carried through front surface
- Binding loss (front surface)
- Remaining kinetic (front adatoms)
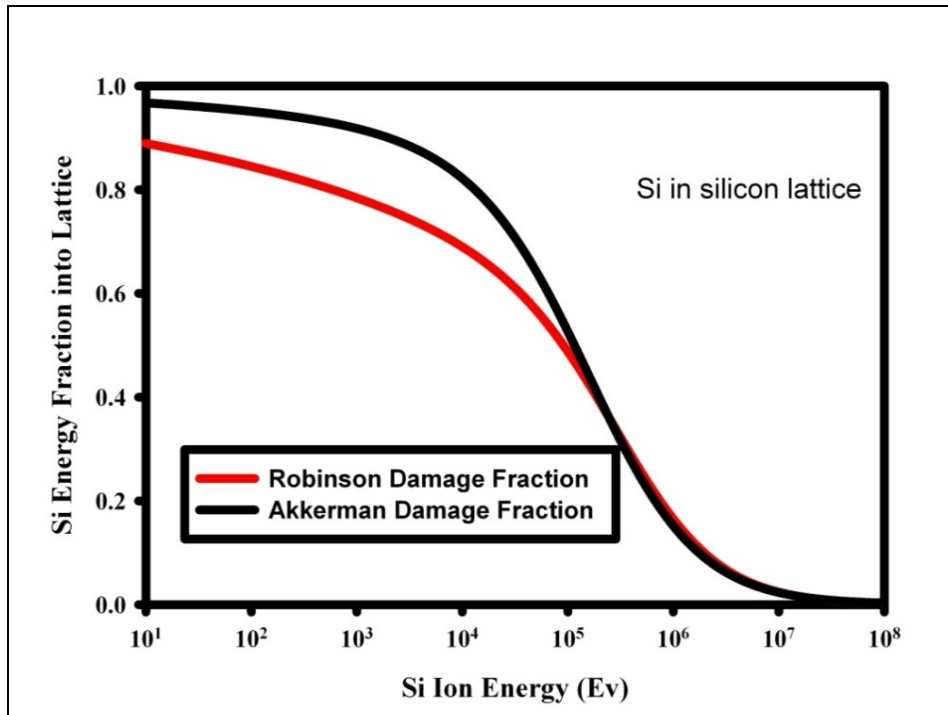
Figure 4: Comparison of the Robinson and Akkerman Damage Partition Functions for a Si Ion in a Silicon Crystal
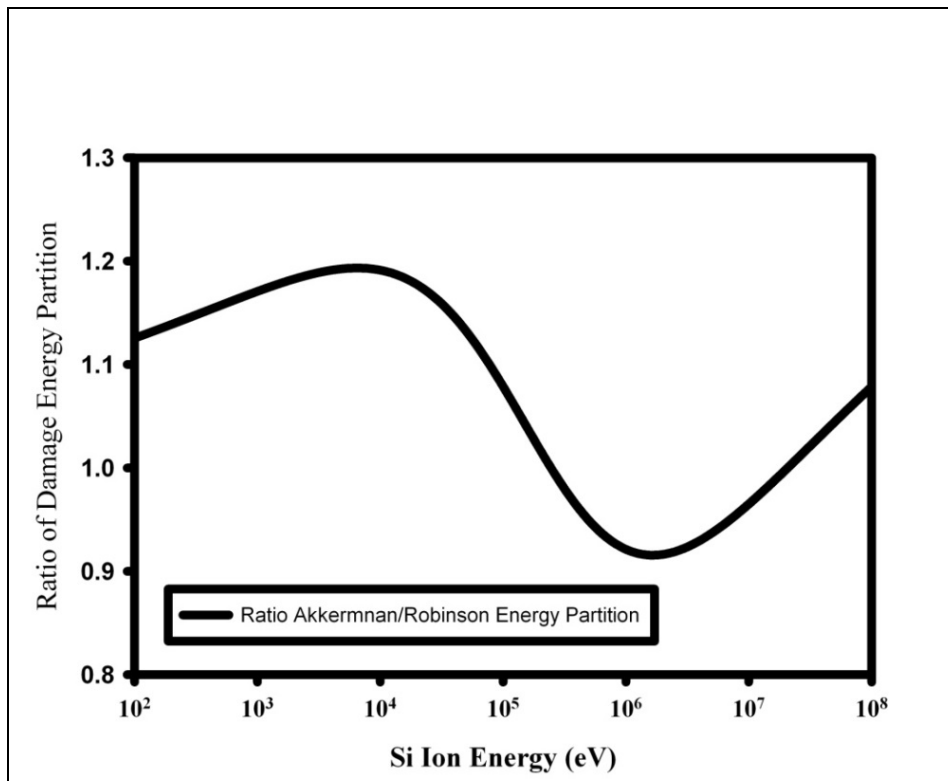
Figure 5: Ratio of Akkerman-to-Robinson Damage Energy Partition Function

The SRIM code divides the energy into
- Electronic/ionization
  - from source ions
  - from recoil ions
- Phonons (includes all energies less than the displacement threshold energy)
  - from source ion
  - from recoil ions
- Vacancies, i.e. binding energy (loss to the target through creation of vacancies or replacement collisions)
  - from source ions
  - from recoil ions

Table 1 shows the energy partition for a 50 keV silicon ion in a silicon matrix as computed with the SRIM code. The energy into ionization is 56.17% while the energy into non-ionizing damage is 43.82%. The important observation here is that 70.22% of the non-ionizing damage energy goes into phonons rather than the broken lattice bonds that represent the vacancy energy loss.

Table 1: Partition of 50 keV Silicon Ion Damage

Energy Loss Mechanism: (50 keV Si ion in Si lattice, range = 736 A, straggle = 290 A)	Percent of Energy Deposition	
	Primary Ion	**Recoil Atoms**
Ionization	30.50	25.67
Vacancies	0.23	3.38
Phonons	0.77	39.44

3.5   Influence of the Interaction Potential on the Energy Partition

Table 2 compares the percent of the kerma that is ionizing for a Si recoil atom in a silicon lattice as computed by various potentials in the MARLOWE BCA code. This is compared to an LSS entry that utilizes the Robinson fit to the LSS methodologies. While the form of the potential can affect the energy partition, this is not seen to be a large effect for the variations investigated here.

Table 2: Comparison of Various Damage Partition Methodologies into Ionization for Silicon

Si Ion Energy (keV)	MARLOWE BCA Code Using:		LSS
	Moliere Potential	**ZBL Potential**	
30 keV	29.1	32.9	38.5
50 keV	35.1	38.9	43.3
100 keV	44.0	47.8	52.
500 keV	72.0	72.9	74.5
1 MeV	82.7	82.7	83.5
10 MeV	94.7	95.0	97.6

4. DISPLACEMENT THRESHOLD ENERGY IN CRYSTALLINE SILICON

Displacement threshold energy, E_d, is the minimum energy imparted to the primary recoil atom as a result of a neutron-induced reaction that will result in a displacement of the resulting lattice atom (identical to the target lattice atom in the case of an elastic or inelastic event).

For silicon, the traditional displacement threshold energy for silicon is 25 eV. This is the default values used in some codes such as NJOY [NJ2012] and reported in previous computations of the silicon displacement kerma factor. The ASTM E722-94 standard [A722] (a previous version of this standard) also used a recommended value of 25 eV. Other codes, such as SRIM [Zi10], use a value of 15 eV. The value of 15 eV is supported by circa 1995 molecular dynamics simulation results discussed in Section 4.2 below. Other work, such as the results of Akkerman [Ak06] and the WinNIEL code [Xap, Xa04] use a value of 21 eV.

4.1 Experimental Data

The status of experimental data is succinctly captured in Reference [Ho08]:

> "E_d is poorly known in the material (Silicon). Experimental methods show a widely varying scale of results for E_d in the range of 10 – 30 eV."

The range of the experiment data can be seen in References [Bo76, Lof58, Co65, He69, Ma94, Smit]. The minimum displacement threshold energy in the <111> direction in silicon has been measured as 13 eV [Lof58, Co66]. This value has been matched by density functional theory (DFT) molecular dynamics (MD) calculations [Ho08]. The Reference [Co65] value is an indirect measure of the average measured over all crystal directions. A good baseline experimental value of 20.5 ± 1 eV comes from the Reference [Bo76] and was derived from capacitance-voltage measurements on gold-silicon Schottky diodes using electron irradiation.

4.2 Molecular Dynamics Circa 1995

Molecular dynamics calculations by L. Miller et al. [Mi94] indicate that the silicon displacement threshold energy varies from 10 - 15 eV. Their conclusion was:

> "For our computational cell size of 576 atoms, a PKA kinetic energy of 15 eV results in a temperature of approximately 100-150 K (the lower value corresponds to a displaced atom with a formation energy of approximately 6 eV; the higher energy corresponds to no displacement."

An important consideration is the working definition of a displacement. The authors of the above work [Mi94] provide some insight to this:

> "A simple working definition ... (is) ... that the primary knock-on atom (PKA) in the silicon lattice is considered displaced when it exits the tetrahedron formed by the nearest neighbor atoms and comes into quasithermal equilibrium with the surrounding lattice before recombination can occur. (By quasithermal equilibrium we mean that the total available kinetic energy is more or less randomly distributed over all atoms in the computational cell.). ...

> The definition of a displacement event was also found to be dependent upon the time scale over which the Frenkel pair exerts it influence over the property being measured."

The authors [Mi94] present molecular dynamics calculations that show that the displacement threshold energy is dependent upon the direction of the recoil and upon the distance from the original lattice location that is set as the criteria for declaring the existence of a displacement. For closely separated Frenkel pairs, there is a strong probability for recombination. For displacements only outside the nearest-neighbor tetrahedron, the displacement threshold energies range from 10.1 to 18.3 eV. For displacements beyond three quarters of a cubic unit-cell width (with a lattice spacing constant of 5.4 Angstroms), the displacement threshold energies range from 11.5 to 22 eV.

If one uses a definition of a displacement that corresponds to a lattice displacement that is only just outside the nearest neighbor tetrahedron, the result is a displacement threshold energy that is about half that seen from radiation damage experimental studies using electrons [Bo76, He68]. This difference is attributed to the most probable separation distance between the members of the Frenkel pair and the fact that only widely separated Frenkel pairs persist for sufficient time to contribute to the observed electron damage. At temperatures of 80K, close Frenkel pairs, as defined here, may only exist for about 0.2 μs [Mi94. He70]. More stable defects are introduced when the vacancy-interstitial separations are at least 4.5 Angstroms (or greater than about 3/4 of a lattice constant).

Miller et al. [Mi94] give analytic expressions for the angle dependent displacement threshold energy. Fits to the equations in the <111> direction give:

$$E_d = 10.6 + 64.1 \cdot (\sin\theta)^2 - 4.54 \cdot (\sin\theta)^3 \cdot (\cos 3\theta) - 126.9 \cdot (\sin\theta)^4 \qquad \text{Eqn. 21}$$

and, in the <100> direction,

$$E_d = 17.4 + 20.9 \cdot (\sin\theta)^2 - 15.6 \cdot (\sin\theta)^2 \cdot (\cos 2\theta) \qquad \text{Eqn. 22}$$

These expressions give an average bulk displacement energy of 17.5 eV in the <111> direction and 12.2 eV in the <100> unit cell direction. The formalism typically implemented in processing codes such as NJOY is not capable of handling an angle-dependent displacement threshold energy - so one must select a single average displacement threshold energy. Based on the molecular dynamics calculations and the comparisons to experimental observations, this MD modeling effort would suggest an energy of 15 eV. This corresponds to the value of the displacement threshold energy implemented by Zeigler in the SRIM code.

Different values could be selected for particular applications of the resulting displacement kerma factor reflecting different assumptions on the relevant time for observation of a phenomenon, and hence on the time at which the Frenkel pair exists. For an application with electronic lifetime degradation, where the late-time recombination is expected to be important, kinetic Monte Carlo or other defect annealing treatments should be used to transform this early-time displacement metric into a relevant late-time metric. Other treatments have been used by the material damage community to address the difference between close and distant Frenkel pairs.

4.3 DFT Calculations Circa 2008

Work in 2008 [Ho08] studied the displacement threshold energy in silicon using density functional theory (DFT) and molecular dynamics simulations. Consistent results were found using both the local density approximation (LDA) and the generalized gradient approximation (GGA). The DFT and Hartree-Fock (HF) methods "provided repulsive potentials which are significantly improved compared to the standard universal ZBL potential" [No97]. The average threshold energy, over all lattice directions, for the creation of stable Frenkel pairs was found to be 36 ± 2 eV; in the <100> direction it was 20 ± 2 eV; in the <111> direction it was found to be 12.5 ± 1.5 eV. This work also found that there was a bond defect complex with a lower threshold than a Frenkel pair [La09]. The average threshold energy for producing this bond defect or a Frenkel pair was found to be 24 eV $\pm$ 2 eV. Reference [Ho08] notes that:

> "The common usage of 13 and 15 eV for the value of the parameter (displacement threshold energy) is highly inappropriate, as from our calculations it is clear that the actual value is over a factor of two higher."

4.4 Displacement Modeling Considerations for BCA Modeling in Silicon

The application of the E_d in binary collision approximation codes was studied in Reference [Bu13]. They observed:

> "The displacement threshold energy is the energy that a target atom needs to leave its lattice site and form a stable interstitial. Its values given in the literature range from ~9 to 35 eV for silicon … A 13 eV displacement threshold energy was adopted in our simulations for amorphous Si, 20 eV for crystalline Si ... In our BCA simulations we assumed the surface binding energy to be … 4.7 eV for Si. … In our simulations we chose the bulk cut-off energy and the cut-off energy in the surface layer to be 3 and 1 eV, respectively, for all three target materials."

In this work [Bu13], MD and BCA simulation results for crystalline silicon were found to have some differences at small displacements, less than 5 Å, "due to displacements in amorphous pockets". They concluded, for silicon, that "the discrepancy between BCA and MD results is reduced but still significant for impacts on crystalline Si, which becomes partly amorphous during irradiations."

It should be noted that in BCA codes, such as MARLOWE, the relevant parameter in modeling the physics of the interactions may not be the displacement threshold energy, E_d, but the surface binding energies (one for a lattice site and one for atoms near the surface) and the model cut-off energy below which a recoil atom is not tracked. Section 2.6 of this report defines some of the energy terms used in the MARLOWE code. Reference [Ro92] notes that:

> "It must be emphasized that the only explicit displacement threshold energy (in) MARLOWE is $E_c + E_b$."

This reference notes an example of this for Cu where the E_d is ~58 eV while the relevant MARLOWE input parameter $E_c + E_b$ is 7.02 eV. Thus there is a big difference between the displacement threshold energy and the relevant input parameters in MARLOWE BCA code models.

4.5 Recommended E$_d$ Value in Silicon

For comparison of 1-MeV(Si) displacement damage, the recommendation, at this time, is for the value of E_d is 20.5 eV. This selection is based upon consideration of the best experimental values [Bo76], 20.5 $\pm$ 1 eV, and the latest high fidelity DFT-MD modeling [Ho08] value, 24 $\pm$2 eV, and recent comparisons between BCA and MD modeling, which recommend using 20 eV.

5. DISPLACEMENT MODEL

The displacement model relates the number of displaced atoms, ν_d, to the ion damage energy, $^{ion}T_{dam}$. Several models are used by the community. In order to differentiate these models we will adopt the notation of $^{type}\nu_d$ to distinguish the various Frenkel pair production models.

Models for displaced atoms, which are addressed in the following subsections, do not cover the total range of ways that "defects" can be introduced into materials through irradiation. All "defects" introduced into materials cannot necessarily be attributed to displaced lattice ions. As noted for silicon, broken bond pairs, not just vacancy-interstitial pairs, can result in electrically active defects in silicon. Traps in TLDs are an example of ionization-related defect introduction in materials. Defect production from ionization has also been observed in insulating materials such as SiO_2 [De92, To12]. This observation complicates attempts to correlate observed defect production metrics with calculated quantities using non-ionizing energy deposition. In silicon semiconductors, trapped charge in the insulating SiO_2 can result in electric fields that affect the gain in bipolar semiconductors and complicate the interpretation of minority carrier lifetime changes due to the introduction of defects from displaced atoms, for example divacancies (V_2) and vacancy-phosphorus (VP) defects that evolve from the primary Frenkel pair damage.

In order to support the later discussion of a damage response function and, in particular, to provide a clear consistent definition of the damage energy, we elect to break up the displacement model into:

- a threshold function, $^{type\text{-}A}\Lambda(E_d, \,^{ion}T_{dam})$;
- a Frenkel pair generation efficiency component, $^{type\text{-}B}\zeta_d(E_d, \,^{ion}T_{dam})$; and
- a residual defect efficiency survival term, $^{type\text{-}C}\xi(^{ion}T_{dam})$.

Thus,

$$^{type}\nu_d\left(E_d, \,^{ion}T_{dam}\right) = {}^{type-A}\Lambda(E_d, \,^{ion}T_{dam}) \bullet {}^{type-B}\varsigma_d(E_d, \,^{ion}T_{dam}) \bullet {}^{type-C}\xi(^{ion}T_{dam}) \qquad \text{Eqn. 23}$$

The "*type*" descriptor/superscript on these $^{type\text{-}A}\Lambda(E_d)$, $^{type\text{-}B}\zeta_d(E_d, \,^{ion}T_{dam})$, and $^{type\text{-}C}\xi(^{ion}T_{dam})$ quantities will not necessarily be the same as the "*type*" descriptor/superscript used on the root damage model, $^{type}\nu(E_d, \,^{ion}T_{dam})$, but the definition of the "*type*" for the damage model will be coupled to a clear selection of "*type-A*", "*type-B*" and "*type-C*" component selections.

5.1 Kinchin-Pease

The material damage community has long recognized that closely spaced Frenkel pairs have a high probability for recombining. The community-standard approach has been to apply a weighting function for very closely spaced Frenkel pairs. For a displacement energy less than that required to displace a stable Frenkel pair, there are no displaced atoms created. For an energy up to the energy required to produce two defect pairs, only one defect pair is created.

5.1.1 Original Kinchin-Pease

The original Kinchin-Pease model [Ro68, Ki55, Si69, Od76] relates the number of defects, $^{orig\_K\&P}v_d(E_d, E_I, T_R)$, to the primary recoil atom energy:

$$^{orig\_K\&P}v_d\left(E_d, E_I, T_R\right) = \begin{pmatrix} 0 & 0 \leq T_R < E_d \\ 1 & E_d \leq T_R < 2 \cdot E_d \\ T_R/(2 \cdot E_d) & 2 \cdot E_d \leq T_R < E_I \\ E_I/(2 \cdot E_d) & E_I \leq T_R < \infty \end{pmatrix} \qquad \text{Eqn. 24}$$

where E_I is the energy is the energy above which ions lose their energy only through ionization and below which energy loose could be modeled with an elastic hard sphere scattering model. When this was coupled with the LSS model for the energy partition function, then there was no longer a need to introduce the E_I energy and the equation could be rewritten as a function of the non-ionizing portion of the ion energy, $^{ion}T_{dam}$.

The commonly seen version of the Kinchin-Pease model uses this LSS energy partition function and has the number of defects, $^{K\&P}v_d(E_d, {}^{ion}T_{dam})$, given by the expression:

$$^{K\&P}v_d\left(E_d, {}^{ion}T_{dam}\right) = \begin{pmatrix} 0 & 0 \leq {}^{ion}T_{dam} < E_d \\ 1 & E_d \leq {}^{ion}T_{dam} < 2 \cdot E_d \\ {}^{ion}T_{dam}\Big/(2 \cdot E_d) & 2 \cdot E_d \leq {}^{ion}T_{dam} < \infty \end{pmatrix} \qquad \text{Eqn. 25}$$

This equation can be re-written as:

$$^{K\&P}v_d\left(E_d, {}^{ion}T_{dam}\right) = {}^{K\&P}\Lambda(E_d, {}^{ion}T_{dam}) \cdot {}^{defect}\varsigma[{}^{ion}T_{dam}/(2 \cdot E_d)] \cdot {}^{null}\xi({}^{ion}T_{dam}) \qquad \text{Eqn. 26}$$

where,

$$^{K\&P}\Lambda_d\left(E_d, {}^{ion}T_{dam}\right) = \begin{pmatrix} 0 & 0 \leq {}^{ion}T_{dam} < E_d \\ (2 \cdot E_d)\Big/{}^{ion}T_{dam} & E_d \leq {}^{ion}T_{dam} < 2 \cdot E_d \\ & 2 \cdot E_d \leq {}^{ion}T_{dam} < \infty \\ 1 & \end{pmatrix} \qquad \text{Eqn. 27}$$

$$^{defect}\varsigma\left(X\right) = X \qquad \text{Eqn. 28}$$

$$^{null}\xi_d\left(^{ion}T_{dam}\right)=1$$ Eqn. 29

In order to support a later discussion of damage energy, we also define the term:

$$^{K\&P}\varsigma_d\left(E_d,{}^{ion}T_{dam}\right)= {}^{defect}\varsigma[^{ion}T_{dam}/(2\bullet E_d)]$$ Eqn. 30

5.1.2 Sharp-transition Kinchin-Pease

The Kinchin-Pease model is sometimes quoted as using a sharp transition, the transition being modeled as occurring at E_d.

$$^{sp-K\&P}v_d\left(E_d,{}^{ion}T_{dam}\right)=\begin{pmatrix} 0 & 0\le{}^{ion}T_{dam}<E_d \\ \\ {}^{ion}T_{dam}\Big/\left(2\cdot E_d\right) & E_d\le{}^{ion}T_{dam}<\infty \end{pmatrix}$$ Eqn. 31

This equation can be re-written as:

$$^{sp-K\&P}v_d\left(E_d,{}^{ion}T_{dam}\right)={}^{sp-K\&P}\Lambda(E_d,{}^{ion}T_{dam})\bullet{}^{defect}\varsigma[^{ion}T_{dam}/(2\bullet E_d)]\bullet{}^{null}\xi(^{ion}T_{dam})$$ Eqn. 32

where,

$$^{sp-K\&P}\Lambda_d\left(E_d,{}^{ion}T_{dam}\right)=\begin{pmatrix} 0 & 0\le{}^{ion}T_{dam}<E_d \\ \\ 1 & E_d\le{}^{ion}T_{dam}<\infty \end{pmatrix}$$ Eqn. 33

In order to support a later discussion of damage energy, we also define the term:

$$^{sp-K\&P}\varsigma_d\left(E_d,{}^{ion}T_{dam}\right)= {}^{defect}\varsigma[^{ion}T_{dam}/(2\bullet E_d)]= {}^{K\&P}\varsigma_d\left(E_d,{}^{ion}T_{dam}\right)$$ Eqn. 34

Above the threshold region, the slope of the defect creation with respect to energy, $^{sp-K\&P}\eta$, is, from Equation 31,

$$^{sp-K\&P}\eta = dv[^{ion}T_{dam}]/d[^{ion}T_{dam}]=[1/(2\bullet E_d)]$$ Eqn. 35

The reference energy required to create a defect, $^{sp-K\&P}\alpha$, is then given by:

$$^{sp-K\&P}\alpha =(2\bullet E_d)$$ Eqn. 36

The sharp threshold Kinchin-Pease form of the equation described above is what is built into codes such as NJOY [NJ2012] and used to compute the quantity identified in their code output as the "damage energy".

5.2 Robinson-Sigmund Modification

The community has examined various forms for the number of Frenkel pairs resulting from different analytic forms of the differential elastic scattering cross section between atoms, $K(E,T)$, represented by a screened Coulomb interaction with the form:

$$K(E,T) = E^{-m} * T^{(-1-m)} \text{ where } -1 \leq m \leq 1.$$

Here $K(E,T)$ is the probability that a particle of initial kinetic energy E will transfer energy T to another particle in a single collision.

While imposing a consistency condition on the average number of Frenkel pairs produced in a random collision cascade, Robinson calculated an asymptotic solution for $E > 2E_d$ of:

$$N(E) = \zeta(m) * E/(2 * E_d)$$

For $m = -1$ the equation represents hard sphere scattering and $\zeta(m=-1) = 1$, the Kinchin-Pease initial expression. When $m = 1$, the Rutherford collision region, the expression became

$$\zeta(m=1) = (12/pi^2)/ln(2) \approx 0.84$$

While Robinson derived these initial results, Sigmund showed that, if "m" is permitted to vary with energy, a nonlinearity was introduced into the Frenkel pair production term.

5.3 Norgett-Robinson-Torrens (NRT)

After the original Kinchin-Pease formulation, the radiation damage community did additional theoretical work and computer simulations. A group of experts at an IAEA Specialist's meeting on radiation damage units adopted a modified formulation for the number of displacements. This approach used the Robinson-Sigmund modification of the hard-sphere scattering energy loss model. This model is called the Norgett, Robinson, and Torrens (NRT) Frenkel pair model, or the modified Kinchin-Pease, and is given by:

$$^{NRT}v_d\left(E_d, {}^{ion}T_{dam}\right) = \begin{pmatrix} 0 & 0 \leq {}^{ion}T_{dam} < E_d \\ 1 & E_d \leq {}^{ion}T_{dam} < 2 \cdot E_d/\beta \\ \beta \cdot {}^{ion}T_{dam}/(2 \cdot E_d) & 2 \cdot E_d/\beta \leq {}^{ion}T_{dam} < \infty \end{pmatrix} \qquad \text{Eqn. 37}$$

where β is an atomic scattering correction and is taken to be 0.8. This adopted value of 0.8 is close to the $\zeta(m=1)$ value used in the Robinson-Sigmund analysis.

Figure 6 shows the defect creation rate as a function of the non-ionizing damage delivered.
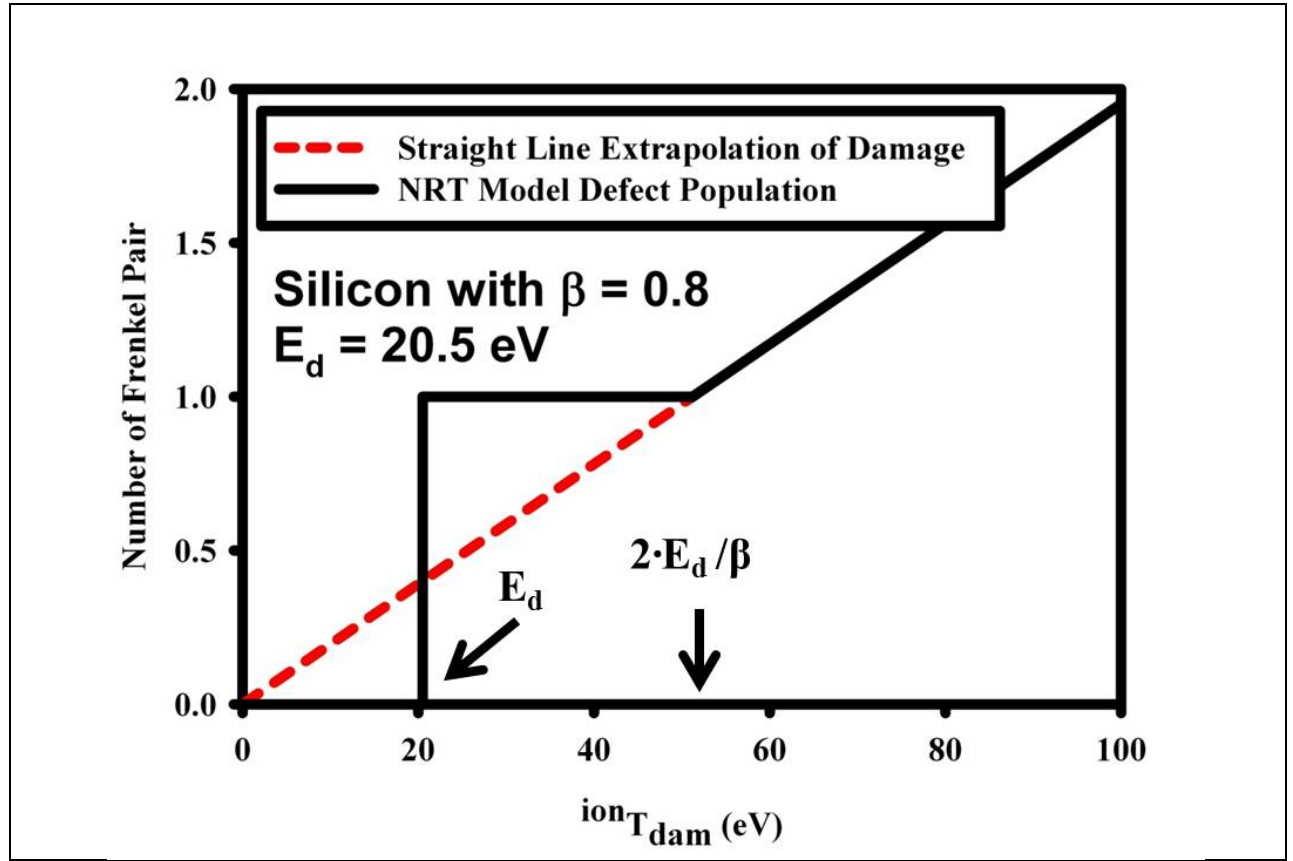
Figure 6: Non-ionizing Ion Energy Dependence of NRT Frenkel Pair Creation in Silicon

This equation can be re-written as:

$$^{NRT}v_d\left(E_d, {}^{ion}T_{dam}\right) = {}^{NRT}\Lambda(E_d, {}^{ion}T_{dam}) \bullet {}^{defect}\varsigma[(\beta \bullet {}^{ion}T_{dam})/(2 \bullet E_d)] \bullet {}^{null}\xi({}^{ion}T_{dam}) \qquad \text{Eqn. 38}$$

where,

$$^{NRT}\Lambda_d\left(E_d, {}^{ion}T_{dam}\right) = \begin{pmatrix} 0 & 0 \le {}^{ion}T_{dam} < E_d \\ \dfrac{(2 \cdot E_d)}{(\beta \bullet {}^{ion}T_{dam})} & E_d \le {}^{ion}T_{dam} < (2 \bullet E_d / \beta) \\ 1 & (2 \bullet E_d / \beta) \le {}^{ion}T_{dam} < \infty \end{pmatrix} \qquad \text{Eqn. 39}$$

In order to support a later discussion of damage energy, we also define the term:

$$^{NRT}\varsigma_d\left(E_d, {}^{ion}T_{dam}\right) = {}^{defect}\varsigma[(\beta \bullet {}^{ion}T_{dam})/(2 \bullet E_d)] \qquad \text{Eqn. 40}$$

The reference energy required to create a defect, $^{NRT}\alpha$, is then given by:

$$^{NRT}\alpha = (2 \bullet E_d) / \beta \qquad \text{Eqn. 41}$$

Note from Equation 37 that the energy required to create the first defect is only E_d, whereas at high recoil energies the non-ionizing energy required to create each defect is $^{NRT}\alpha$, more than twice value at the displacement threshold. Figure 7 shows that, because of this treatment of displacements near the threshold energy, the NRT threshold function, $^{NRT}\Lambda_d\left(E_d,{}^{ion}T_{dam}\right)$, shows an enhancement for energies between E_d and $^{NRT}\alpha$. As seen in Figure 7, the sharp transition Kinchin-Pease threshold function does not exhibit this enhancement.
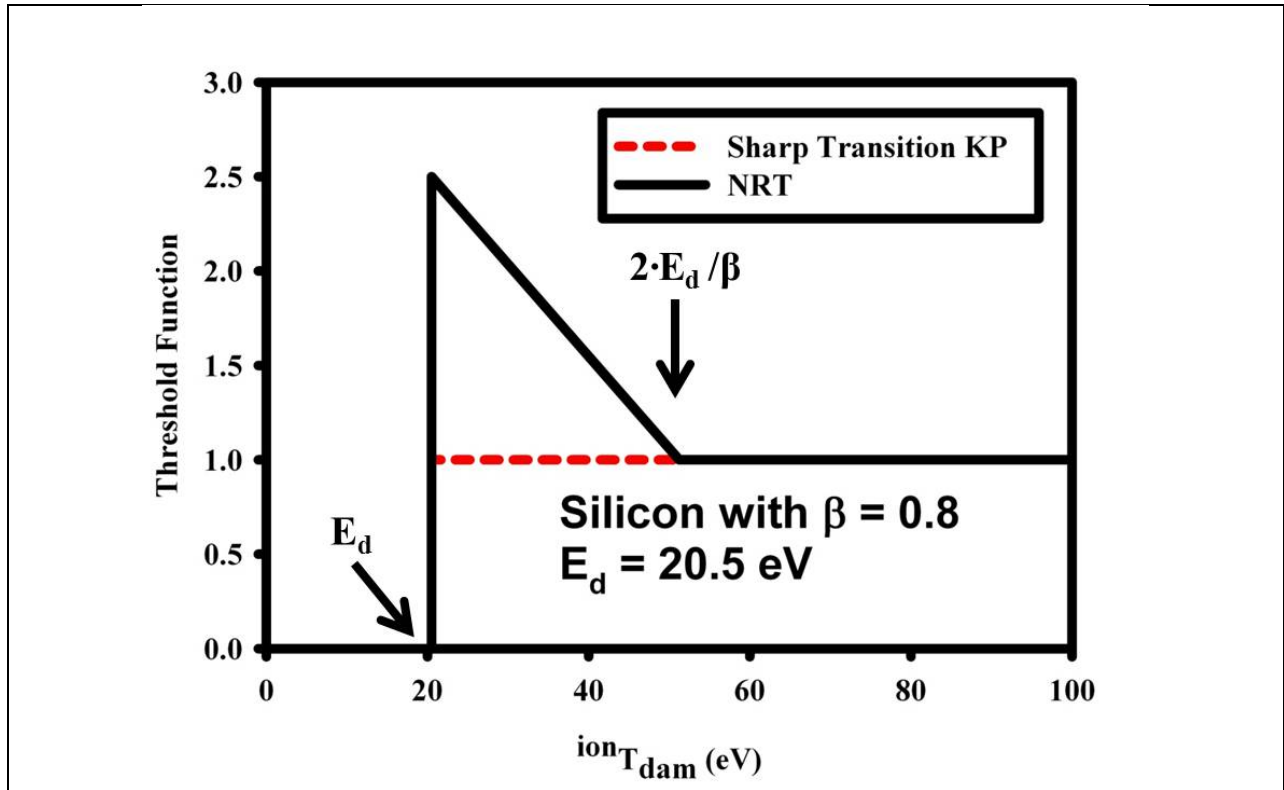
Figure 7: Energy-dependence of the Sharp-transition Kinchin-Pease and NRT Threshold Functions

5.4 Snyder-Neufeld

Snyder-Neufeld introduced a model using a slightly different formulation for the Frenkel pair generation efficiency term. Their formulation is described by:

$$^{SN}v_d\left(E_d,{}^{ion}T_{dam}\right) = {}^{K\&P}\Lambda(E_d,{}^{ion}T_{dam})\bullet{}^{SN}\varsigma_d[E_d,{}^{ion}T_{dam}]\bullet{}^{null}\xi({}^{ion}T_{dam}) \qquad \text{Eqn. 42}$$

$$^{SN}\varsigma_d\left(E_d,{}^{ion}T_{dam}\right) = {}^{defect}\varsigma[({}^{ion}T_{dam}+E_d)/(2\bullet E_d)] \qquad \text{Eqn. 43}$$

5.5 Neufeld-Snyder

Another variation in the Frenkel pair generation efficiency term is found in the Neufeld-Snyder formulation given by:

$$^{NS}v_d\left(E_d,{}^{ion}T_{dam}\right)={}^{K\&P}\Lambda(E_d,{}^{ion}T_{dam})\bullet{}^{NS}\varsigma_d[E_d,{}^{ion}T_{dam}]\bullet{}^{null}\xi({}^{ion}T_{dam}) \qquad \text{Eqn. 44}$$

$$^{NS}\varsigma_d\left(E_d,{}^{ion}T_{dam}\right)={}^{defect}\varsigma[({}^{ion}T_{dam}+E_d)/(3\bullet E_d)] \qquad \text{Eqn. 45}$$

5.6 Bacon

Work by Bacon [Ba95, Ga01] used MD calculations that modeled the many-body effects of the thermal spike phase in the cascade development and found that the results could be fit with an equation of the form:

$$^{Bacon}v_d\left(E_d,{}^{ion}T_{dam},m\right)={}^{K\&P}\Lambda(E_d,{}^{ion}T_{dam})\bullet{}^{Bacon}\varsigma_d(E_d,{}^{ion}T_{dam},m)\bullet{}^{null}\xi({}^{ion}T_{dam}) \qquad \text{Eqn. 46}$$

$$^{Bacon}\varsigma_d\left(E_d,{}^{ion}T_{dam},m\right)={}^{defect}\varsigma[A\bullet(T_{dam})^m] \qquad \text{Eqn. 47}$$

This form corresponds to the NRT model (for $\beta = 0.8$) when $m = 1$ and $A = 0.8/(2*E_d)$. Bacon fit the MD results for various metals and observed a trend of decreased Frenkel pair production with increasing recoil ion energy. The fit for the coefficient "m" yielded a value of 0.76 for Titanium and as 0.787 for Zirconium.

5.7 Athermal Recombination-corrected Displacement (arc-dpa)

The NRT-dpa model has the number of defects being, essentially, proportional to the radiation energy deposited per volume. This model is known to over-estimate the production of Frenkel pairs in metals under energetic ion displacement cascade conditions [OECD14].

To address short-comings in the NRT-dpa model, an athermal recombination-corrected (arc) dpa equation was developed [OECD14]. The arc-dpa model is given by

$$^{arc-dpa}v_d\left(E_d,{}^{ion}T_{dam}\right)=\begin{pmatrix}0 & 0\leq {}^{ion}T_{dam}<E_d\\1 & E_d\leq {}^{ion}T_{dam}<{}^{2\cdot E_d}/_\beta\\\beta\cdot {}^{ion}T_{dam}\cdot{}^{arc-dpa}\xi\left({}^{ion}T_{dam}\right)/_{\left(2\cdot E_d\right)} & {}^{2\cdot E_d}/_\beta\leq {}^{ion}T_{dam}<\infty\end{pmatrix} \quad \text{Eqn. 48}$$

Where $^{arc-dpa}\xi\left({}^{ion}T_{dam}\right)$ is an efficiency factor intended to represent the ratio of the number of true defects divided by the number of defects as defined by the NRT formalism in Equation 37.

This equation can also be written as:

$$^{arc-dpa}v_d\left(E_d, {}^{ion}T_{dam}\right) = {}^{NRT}\Lambda(E_d, {}^{ion}T_{dam}) \bullet {}^{defect}\varsigma[\beta \bullet {}^{ion}T_{dam} \bullet {}^{arc-dpa}\xi({}^{ion}T_{dam})/(2\bullet E_d)] \bullet {}^{arc-dpa}\xi({}^{ion}T_{dam})$$

<div align="right">Eqn. 49</div>

In order to support a later discussion of damage energy, we also define the term:

$$^{arc-dpa}\varsigma_d\left(E_d, {}^{ion}T_{dam}\right) = {}^{defect}\varsigma[\beta \bullet {}^{ion}T_{dam} \bullet {}^{arc-dpa}\xi({}^{ion}T_{dam})/(2\bullet E_d)] \qquad \text{Eqn. 50}$$

The efficiency factor should, based on experimental evidence and molecular dynamic modeling, be close to the NRT value at the threshold displacement energy, have a power law form at low displacement energies, and saturate at a high displacement energy. This efficiency factor has the form:

$$^{arc-dpa}\xi\left({}^{ion}T_{dam}\right) = \frac{1-c_{arc-dpa}}{\left(2\cdot E_d\Big/0.8\right)^b} \cdot {}^{ion}T_{dam}^{b_{arc-dpa}} + c_{arc-dpa} \qquad \text{Eqn. 51}$$

where T_R is the damage energy, E_d is the displacement threshold energy, and b and $c_{arc-dpa}$ are two unitless fitting parameters designed to match experimentally derived data with a physical meaning that is discussed in Reference [OECD14]. In this formulation, a fitting constraint is applied so that:

$$\xi(2\cdot E_d/0.8) = a_{arc-dpa}\cdot(2\cdot E_d/0.8)^b + c_{arc-dpa} = 1$$

and continuity is maintained at the boundaries of the functional description. The parameter "b" has the physical interpretation that it gives the point where there is a transition from a power law behavior, E^c, into a linear behavior that corresponds to where cascades split into sub-cascades. $c_{arc-dpa}$ can be physically interpreted as related to how efficiently interstitials are transported to the outer periphery of the displacement cascade, and it corresponds to the saturation level at high energy, and hence is ~ 0.3.

5.8   Replacement-per-atom (rpa)

In many materials, atom mixing is an important phenomenon and damage metrics can depend upon the number of atom replacements in a collision cascade. A major component in atom mixing comes from the heat spike in a collisional cascade [Gad95, Nor98a, Nor98b]. In this replacement model, the actual number of atoms that are displaced from the initial lattice site and end up in another site can significantly exceed the number of residual Frenkel pairs predicted in BCA models. This rpa model is presented in reference [OECD14]. The rpa model is given by:

$$
{}^{rpa}v_d\left(E_d, {}^{ion}T_{dam}\right) = \begin{pmatrix} 0 & 0 \le {}^{ion}T_{dam} < E_d \\ 1 & E_d \le {}^{ion}T_{dam} < 2 \cdot E_d \big/ \beta \\ \beta \cdot {}^{ion}T_{dam} \cdot {}^{rpa}\xi\left({}^{ion}T_{dam}\right) \Big/ (2 \cdot E_d) & 2 \cdot E_d \big/ \beta \le {}^{ion}T_{dam} < \infty \end{pmatrix} \qquad \text{Eqn. 52}
$$

where $\xi_{rpa}\left({}^{ion}T_{dam}\right)$ is an efficiency factor given by the functional form:

$$
{}^{rpa}\xi({}^{ion}T_{dam}) = \left[\frac{b_{rpa}^{c_{rpa}}}{\left(2 \cdot E_d \big/ 0.8\right)^{c_{rpa}}} + 1 \right] \cdot \frac{{}^{ion}T_{dam}^{c_{rpa}}}{b_{rpa}^{c_{rpa}} + {}^{ion}T_{dam}^{c_{rpa}}} \qquad \text{Eqn. 53}
$$

${}^{ion}T_{dam}$ is the damage energy, and b_{rpa} and c_{rpa} are two unitless fitting parameters designed to match experimentally derived data with a physical meaning that is discussed in Reference [OECD14].

This equation can be written as:

$$
{}^{rpa}v_d\left(E_d, {}^{ion}T_{dam}\right) = {}^{NRT}\Lambda(E_d, {}^{ion}T_{dam}) \bullet {}^{defect}\varsigma[\beta \bullet {}^{ion}T_{dam} \bullet {}^{rpa}\xi({}^{ion}T_{dam})/(2 \bullet E_d)] \bullet {}^{rpa}\xi({}^{ion}T_{dam}) \qquad \text{Eqn. 54}
$$

In order to support a later discussion of damage energy, we also define the term:

$$
{}^{rpa}\varsigma_d\left(E_d, {}^{ion}T_{dam}\right) = {}^{defect}\varsigma[\beta \bullet {}^{ion}T_{dam} \bullet {}^{rpa}\xi({}^{ion}T_{dam})/(2 \bullet E_d)] \qquad \text{Eqn. 55}
$$

Figure 8, taken from Reference [OECD14], shows the results of the replacement-per-atom efficiency factors that result from MD calculations and the results of fitting the data to the function form used in Equation 53. Unlike for the arc-dpa efficiency factors from Equation 51, the rpa efficiency factors can be much greater than unity.

5.9   Treatment of the Threshold Function in the Damage Energy

In Equation 7 of Section 2.6 the lower integration bound to be used in determining the neutron damage energy was deferred until after this Section 5 discussion of the defect production metrics. The previous discussion makes it clear that the various neutron displacement models have a very specific treatment for the threshold region, the region near the displacement threshold energy. The definition of the energy partition function for ions in Section 3 does not have any threshold condition/limitation – it is rigorously defined for all ion energies such that all of the energy - either going into ionization or what is called "displacement" but actually corresponds to a "non-ionizing" energy. It is also clear from Section 3 that the displacement kerma involves a lower integration bound of zero. The definition of NIEL, in this document and as reflected in Equation 11 and the Section 2.11 discussion, requires the specification of a lower

integration bound. The following subsection address three alternative definitions of the neutron damage energy.
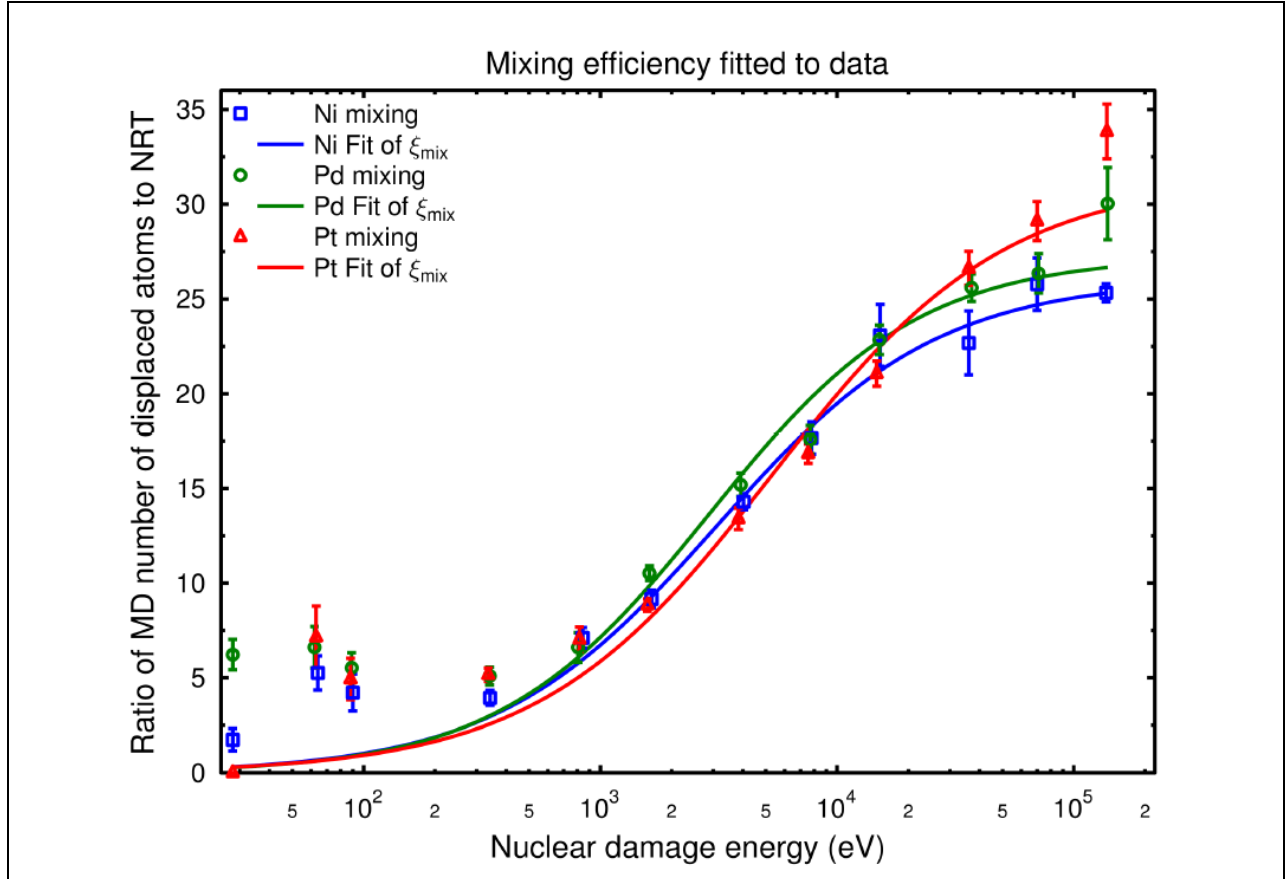
Figure 8: Calculated rpa Efficiency Factors and Fits in Ion Beam Mixing for Metals

5.9.1 Damage Energy with a No-threshold Kinchin-Pease Model

If there is no lower integration bound in Equation 7, then the damage energy is exactly the same as the definition of the microscopic displacement kerma factor in Equation 10. We will notate this damage energy as ${}^n_0 T_{dam}(E)$ and it is given by:

$$
{}^n_0 \sigma_{dam}(E) = {}^n_0 T_{dam}(E) = \sum_{i,j_i} \int_0^\infty \sigma_{i,j_i}(E) \cdot K_{i,j_i}^{recoil}\left(E \to T_{j_i}\right) \cdot {}^{ion}T_{dam}(T_{j_i}) \cdot dT_{j_i} \qquad \text{Eqn. 56}
$$

and the effective damage energy, with units of energy, is given by:

$$
{}^n_0 E_{dam}(E) = \frac{{}^n_{sp}\sigma_{dam}(E)}{\sigma(E)} \qquad \text{Eqn. 57}
$$

5.9.2 Damage Energy with a Sharp-threshold Kinchin-Pease Model

A sharp threshold model corresponds to damage that goes into Frenkel pair production, or the displacement cross section, for a sharp threshold Kinchin-Pease model.

$$_{sp=E_d}^{n}\sigma_{dam}(E) =_{sp=E_d}^{n} T_{dam}(E) = \sum_{i,j_i} \int_{E_d}^{\infty} \sigma_{i,j_i}(E) \cdot K_{i,j_i}^{recoil}\left(E \to T_{j_i}\right) \cdot {}^{ion}T_{dam}(T_{j_i}) \cdot dT_{j_i} \quad \text{Eqn. 58}$$

This notation captures the lower integration bound, E_d, for the sharp threshold.

Using the notation incorporated into the threshold treatment of the displacement cross section rather than the explicit integration bound, this can also be written as:

$$_{sp=E_d}^{n} T_{dam}(E) = \sum_{i,j_i} \int_{0}^{\infty} \sigma_{i,j_i}(E) \bullet K_{i,j_i}^{recoil}\left(E \to T_{j_i}\right) \bullet {}^{sp\_K\&P}\Lambda_d[E_d, {}^{ion}T_{dam}(T_{j_i})] \bullet {}^{ion}T_{dam}(T_{j_i}) \cdot dT_{j_i} \quad \text{Eqn. 59}$$

5.9.3 Damage Energy Based on the NRT Model

The spirit of including a lower integration bound for neutron damage energy in Equation 7, but not for the definition of the ion damage energy, is based on a desire for the "damage energy" metric to be proportional to experimentally observed damage metrics related to Frenkel pair creation. Consistent with this theme of considering the Frenkel pair production to be the primary metric of interest, the damage energy should treat the threshold in the same way that it is treated in the NRT displacement cross section metric.

Using the notation incorporated into the threshold treatment of the NRT displacement cross section, this can be written as:

$$_{NRT=E_d}^{n} T_{dam}(E) = \sum_{i,j_i} \int_{0}^{\infty} \sigma_{i,j_i}(E) \bullet K_{i,j_i}^{recoil}\left(E \to T_{j_i}\right) \bullet {}^{NRT}\Lambda_d[E_d, {}^{ion}T_{dam}(T_{j_i})] \bullet {}^{ion}T_{dam}(T_{j_i}) \cdot dT_{j_i} \quad \text{Eqn. 60}$$

The fact that the NRT threshold function can exhibit an enhancement in the energy region between E_d and ${}^{NRT}\alpha$, as discussed in Section 5.3, makes the physical interpretation of $_{NRT=E_d}^{n} T_{dam}(E)$ a challenge. What needs to be kept in mind is that, just as the non-ionizing energy delivered for low energy recoils below the displacement threshold energy results in no displaced atoms and, hence, no "damage energy", the non-ionizing energy, within the NRT formalism, is more effective just above the displacement threshold energy - and this is reflected in this "damage energy enhancement" seen in the threshold function. It is only the treatment of the non-ionizing energy below and near the displacement threshold energy that differentiates this quantity, termed damage energy in the literature, from the displacement kerma factor.

6. CODE-SPECIFIC TREATMENT

6.1 NJOY

The HEATR module of the NJOY-2012 code provides outputs for the "total kerma" and for the "damage energy" – as well as various reaction-specific components of these quantities, e.g. the elastic (MT=445), inelastic (MT=446), and disappearance (MT=447) damage energies. The NJOY-reported "damage energy" corresponds to the quantity ${}^{n}_{sp=E_d}T_{dam}(E)$ discussed in Section 5.9.2. No combination of these normally output NJOY quantities can be used to obtain the displacement kerma factor, the non-ionizing kerma factor, or the NIEL. To obtain the displacement kerma factor, the user must invoke the NJOY-2012 option to input a value for the displacement threshold energy and select a value of zero for this quantity. If this is done, then the user can subtract the displacement kerma from the total kerma to obtain the ionizing kerma. If a user wants to extract the NRT damage energy, ${}^{n}_{NRT=E_d}T_{dam}(E)$, from NJOY-2012, code modification have to be made in the HEATR/DF function to modify the treatment of the damage partition near the displacement threshold energy.

6.2 MARLOWE

The MARLOWE code does not call for explicit user input of what is termed here the displacement threshold energy. As was discussed in Section 4.4 on BCA code modeling, the relevant parameters in modeling the physics of the interactions in MARLOWE do not include the displacement threshold energy, E_d, but are the surface binding energies (one for an internal lattice site and one for atoms near the surface) and the model cut-off energy below which a recoil atom is not tracked. In Reference [Ro92] Robinson notes that:

> "It must be emphasized that the only explicit displacement threshold energy (in) MARLOWE is $E_c + E_b$."

This reference notes an example of this for Cu where the E_d is ~58 eV while the relevant MARLOWE input parameter $E_c + E_b$ is 7.02 eV. Thus there is a big difference between the displacement threshold energy and the relevant input parameters in MARLOWE BCA code models. This definition affects the division of ion energy that is reported in the MARLOWE code and addressed in Section 3.

7. COMPARISON OF DAMAGE METRICS

Section 5 provided detailed definitions for several damage metrics. This section considers neutrons incident on a silicon lattice and examines the variation in the energy-dependent response function that results from a selection between the various damage models.

This comparison uses the recommended baseline silicon displacement threshold energy of 20.5 eV and the latest ENDF/B-VII.1 ^{28}Si cross section. The target material is characterized as elemental silicon with an atomic number of 14 and an atomic weight of 28.08550 amu, which is equal to 0.9913793103*28.08550 = 27.84338362 neutron masses[1]. This analysis uses a 770-group SAND-IV group structure. This energy structure is augmented version of the widely used 640-group SAND-II energy structure that extends the energy structure to 150 MeV, an upper energy limit that is supported in many recent nuclear data evaluations.

The baseline code used in this analysis is the NJOY-2012 code, updated to reflect the up50m updates, a version called NJOY-2012.50. This code has been further modified at Sandia National Laboratories to include the following features:

- Provide a set of control parameters that permits the user to select a damage metric of interest in the calculation.
- Provides direct user control of the atomic number and atomic weight of the target lattice. This permits the user to consider a damage partition function based on the Robinson formalism where the incident particle is different from the target material.
- Provides user control of the displacement threshold energy. This recent version of NJOY provides this option through the modified inputs tot the HEATR module, but, to be consistent with prior local code modifications, this control at the main module level is retained.
- Provides an option for the user to modify the treatment of the threshold function of the damage model.
- Provides an option for user specification and direct tabular input of an energy-dependent damage partition function.
- Provides an option to turn off contributions to the damage energy from light ions in the outgoing reaction channel.
- Adds the option for a user to select the SAND-IV 770 group structure rather than requiring one to input this as a user-specified energy group structure.
- Contains modifications designed to ease the user interface with cross section correlation matrices and recoil atom spectra.

---

[1] The ENDF-6 format [see Section 2.2.1 of reference E6] and the NJOY-2012 code require that masses be entered in units of the neutron mass rather than the more standard atomic mass units. From reference [Tu11], 1 amu = 931.5 MeV/c^2 and 1 neutron mass = 939.6 MeV/c^2.

7.1 Difference between Damage Energy and Displacement Kerma Factor

This section will address the difference between the various options for the "damage energy" and the "displacement kerma factor" in ^{28}Si.

Figure 9 shows that the difference between the various damage metrics is negligible except in a narrow neutron energy range between 100 eV and 1 keV. Due to the range of values for the displacement kerma factor, the logarithmic y-axis in Figure 9 makes the difference between the curves hard to discern. Figure 10 shows an expanded view of this region where there are differences. To better highlight this difference, Figure 11 shows the difference between the various quantities, expressed as a percent variation, [displacement kerma factor – damage energy]/[displacement kerma factor]*100.

Figure 11 shows a significant variation, greater than 50%, between the displacement kerma factor and the damage energy near 170 eV and a noticeable difference in the general neutron energy region between ~150 eV and ~400 eV. The difference between these quantities in this neutron energy region is due to the fact that the elastic interaction channel is the dominant reaction in this region and conservation of momentum and energy for each elastic interaction results in a maximum energy transfer to a lattice atom given by:

$$E_{recoil} = \frac{4 \cdot A \cdot E_n}{(A+1)^2}$$

Eqn. 61

where E_n is the energy of the incident neutron and A is the atomic weight of the lattice atom. For a lattice recoil energy in silicon equal to the displacement threshold energy of 20.5 eV, this corresponds to a neutron energy of ~153 eV. For lower neutron energies the deviations seen in Figure 10 are very small since the displacement kerma factor is dominated by the contributions from the (n,γ) reaction, which kinematically permits a larger recoil energy for the residual ion, so that the lower integration bound for the displacement threshold energy no longer plays an important role in the damage energy calculation.

The analysis above used the Sandia modifications to the NJOY-2012 code, which included a modification to treat the atomic weight of the lattice material, i.e. to use the elemental atomic weight rather than the isotopic weight of the selected isotope. Figure 12 compares the effect of changing the atomic weight of the lattice atoms on the results for the Sandia-modified version of NJOY-2012 for Silicon-28. This effect is seen to be negligible.
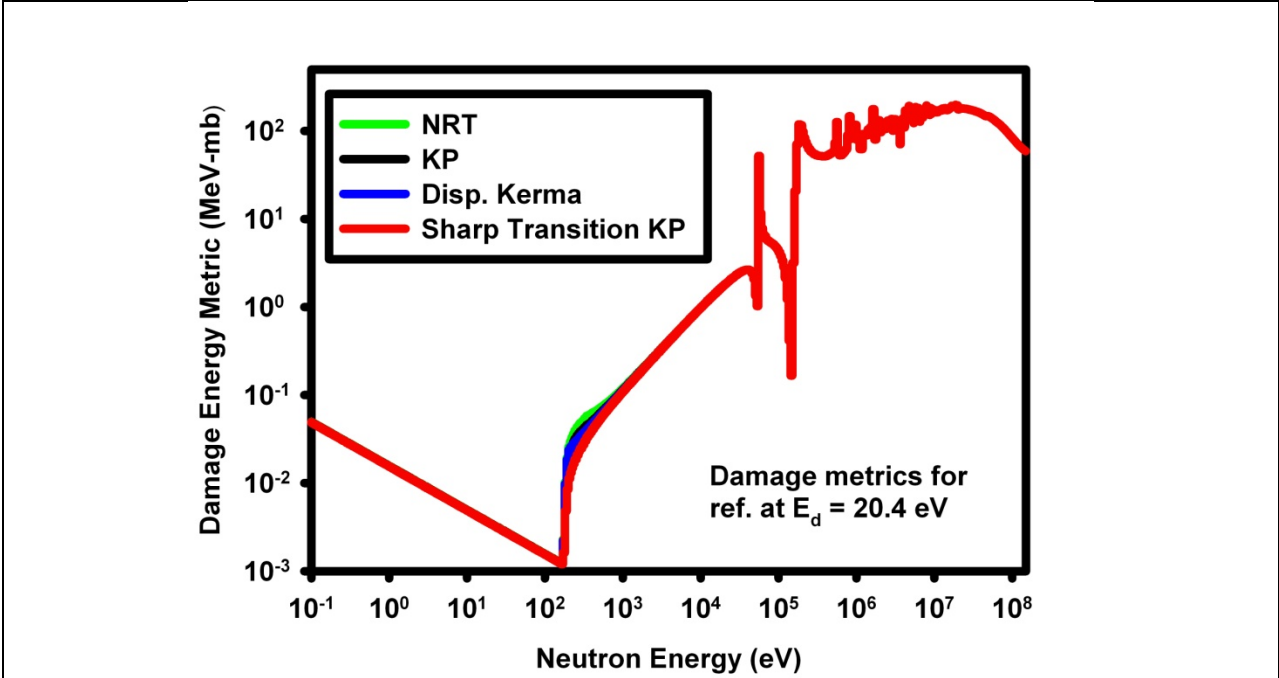
Figure 9: **Comparison of Variations of the Damage Energy Metrics**
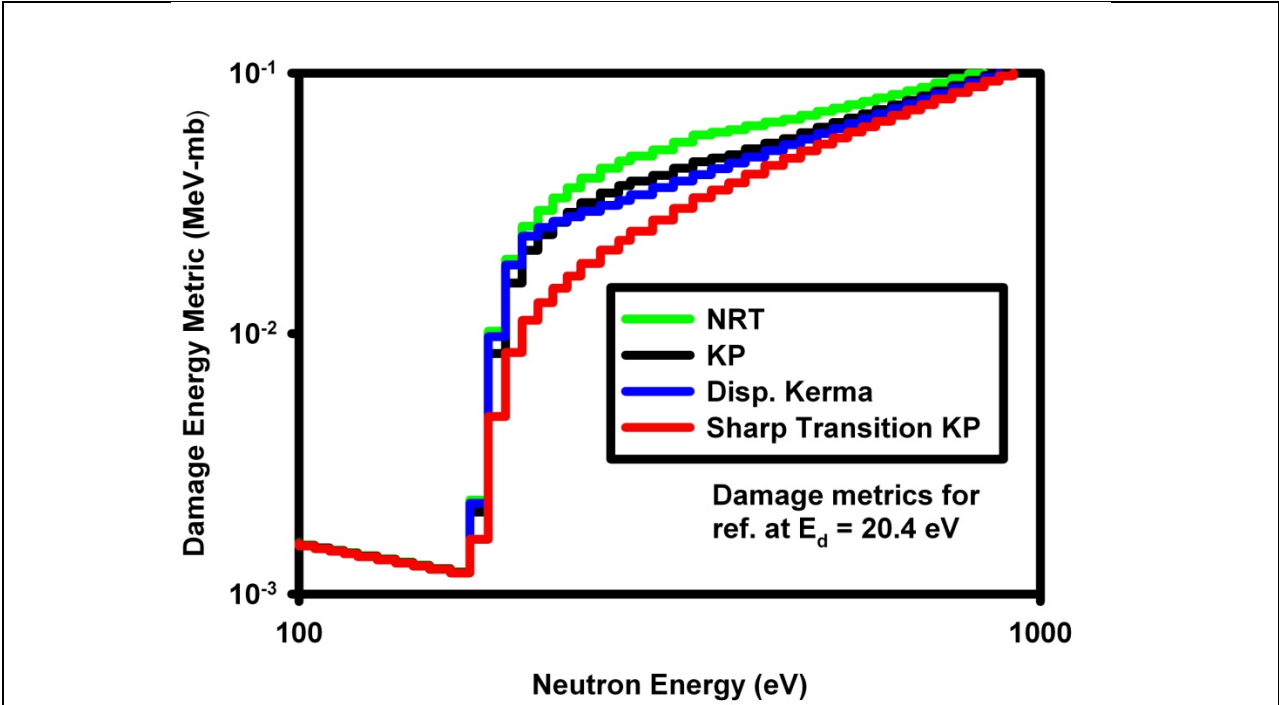
Figure 10: Expanded View of the Comparison of Variations of the Damage Energy Metrics
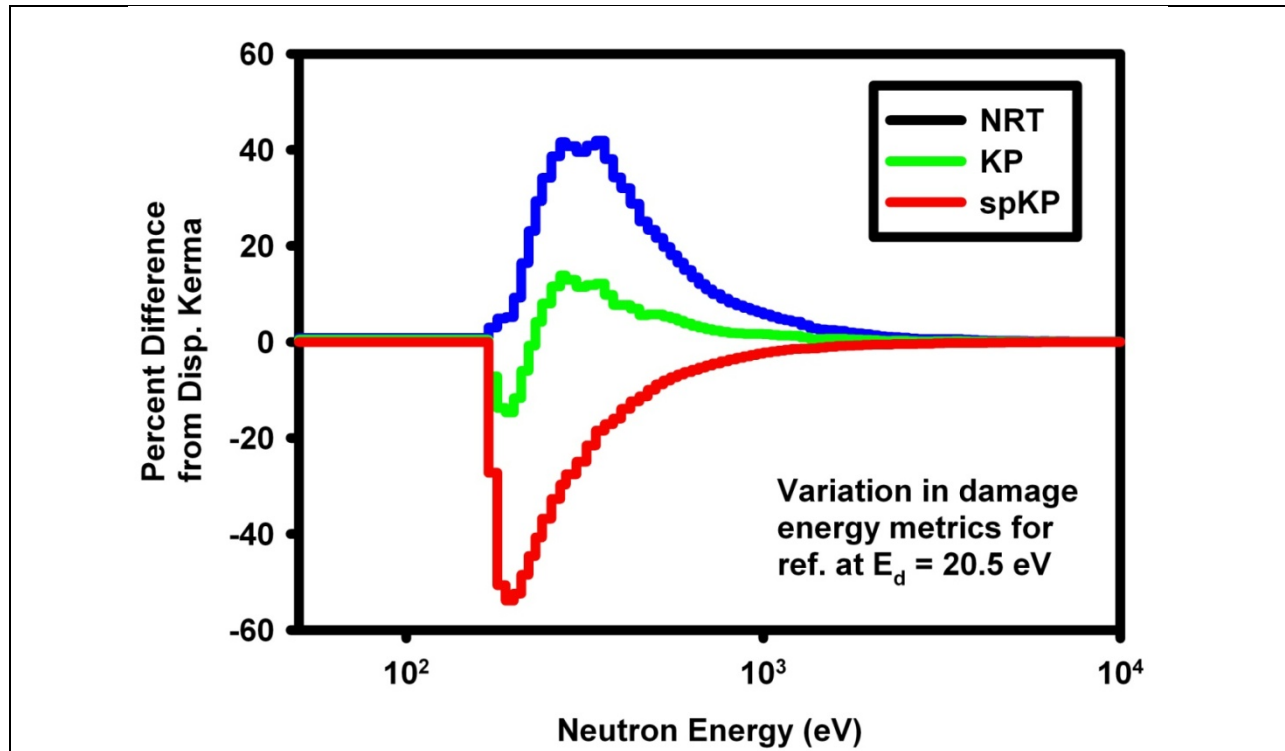
Figure 11: Percent Difference between Displacement Kerma Factor and Damage Energy

The default NJOY-2012 treatment of the damage energy is equivalent to the results labeled as the sharp transition Kinchin-Pease model in the previous discussion. In order to verify the implementation of the Sandia modifications on the analysis, Figure 12 shows the energy-dependent difference between the default NJOY version 2012.50 and the Sandia modified NJOY-2012.50 version when one selects the use of the sharp transition Kinchin-Pease model. Small differences, differences in the range between [+0.017% | +0.207%], are seen in this comparison, but the differences can be attributed to the fact that the Figure 12 curves are not comparing the same exact same quantity. The default NJOY calculation is performed for the case where the lattice material is Silicon-28, i.e. has an atomic weight of 27.737 neutron mass, which is equal to 27.9781913 amu. The Sandia calculation has been performed for the case where the lattice atom is treated as elemental silicon, i.e. it uses for the atomic weight for the lattice atom, the elemental silicon atomic weight of 28.08550 amu, which is equal to 27.84338362 neutron masses. Figure 13 shows the comparison where the Sandia version uses the input specification options to designate Silicon-28 as the lattice material. This figure shows a nearly exact agreement – differing from zero at only one energy bin, the energy bin between 1.3 and 1.4 MeV, and there the difference was only +0.0001%, essentially a round-off error in specifying the atomic weight of the lattice atom. This one discrepant data point also corresponds to an energy region where, as seen in Figure 14, resonance structure still plays a role in the energy-dependent representation of the cross section. This comparison verifies that the Sandia modified version of NJOY-2012.50 does not introduce any meaningful non-physical distortion into the normal NJOY calculations.
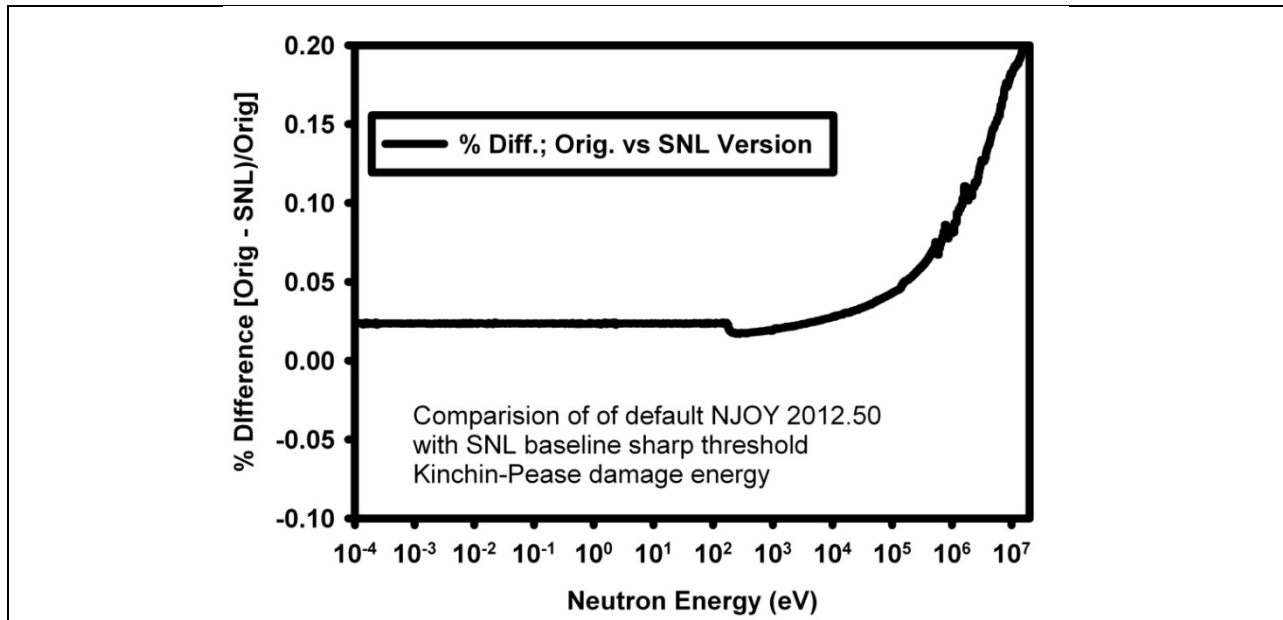
Figure 12: Effect of Lattice Atom Atomic Weight on the Sharp-transition Kinchin-Pease Damage Energy
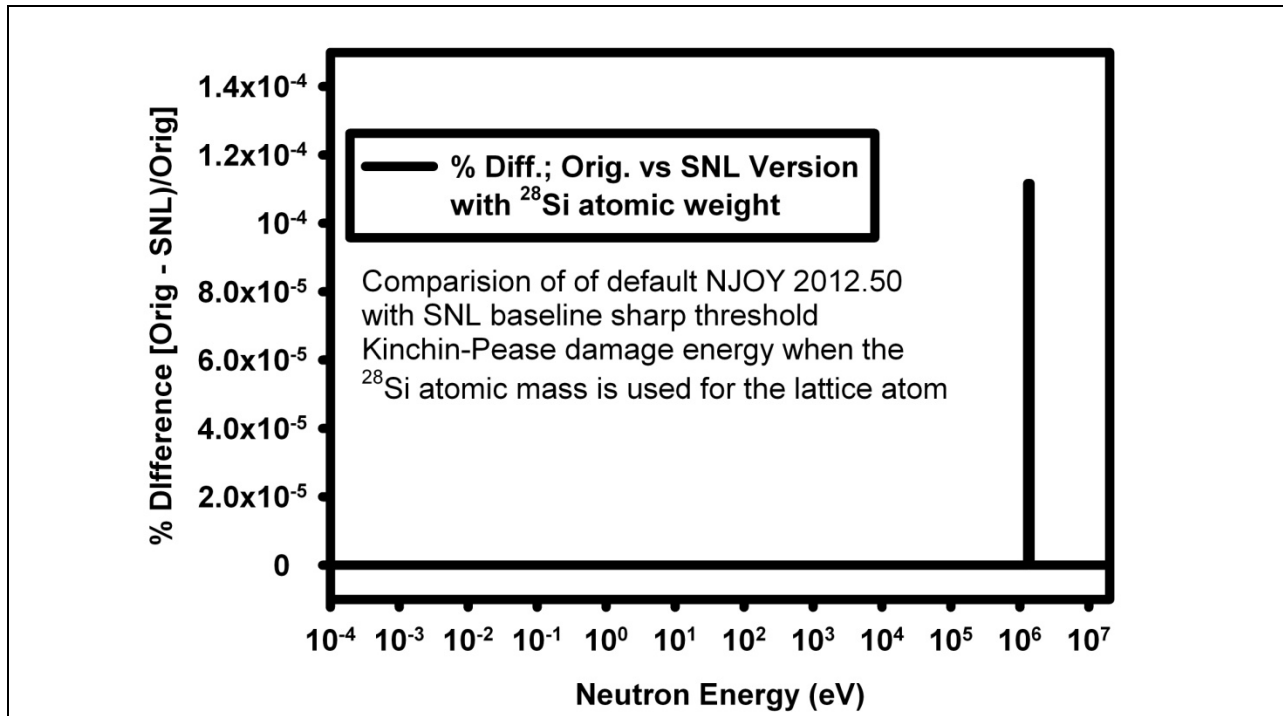
Figure 13: Comparison of Default NJOY Version 2012.50 and Sandia Modified NJOY-2012 Version for the Silicon-28 Sharp-threshold Kinchin-Pease Damage Energy Metric
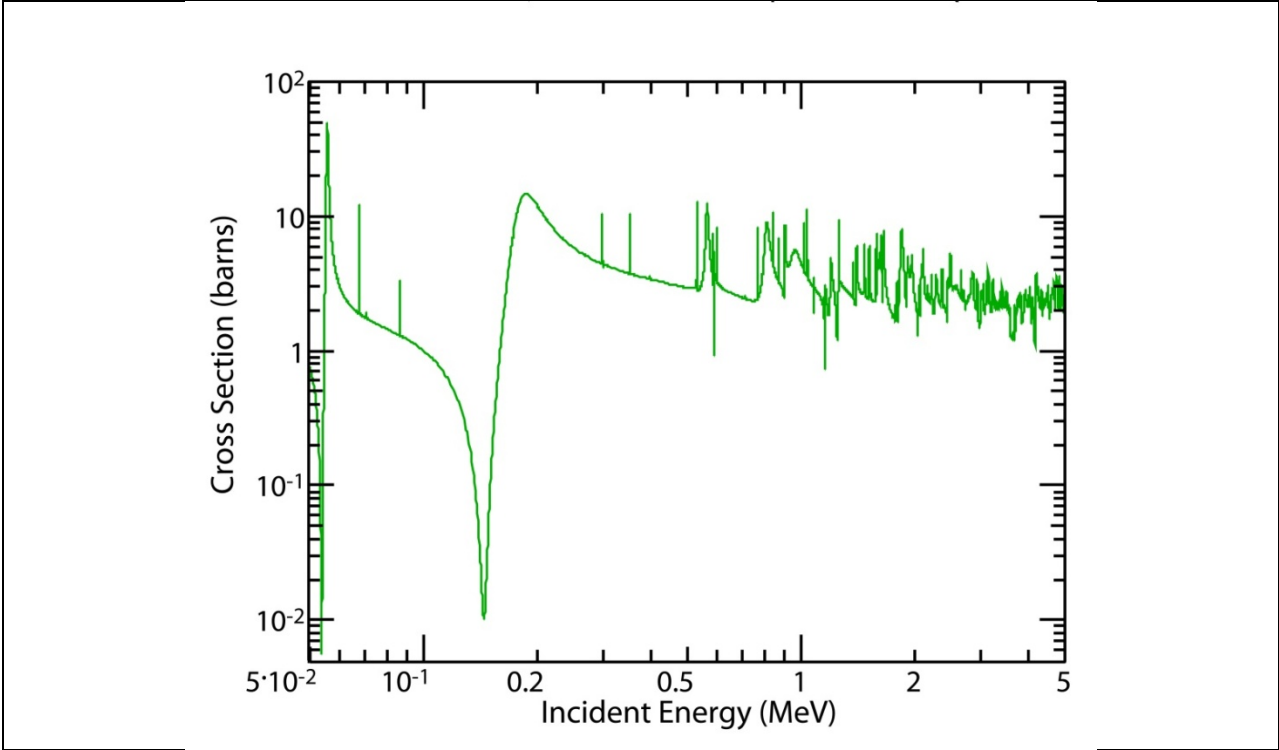
Figure 14: Total Cross Section Near the 1-MeV Energy Region

8. ^{28}SI NRT DAMAGE ENERGY

The ^{28}Si NRT damage energy in the clearly defined 770 SAND-IV energy group structure is presented in Table 3. Table 4 provides an energy-dependent tabular comparison of various damage metrics discussed in the previous section.

Table 3: ^{28}Si Neutron NRT Damage Energy

Bin #	Lower Energy Bound (MeV)	Upper Energy Bound (MeV)	Energy Mid-point (MeV)	NRT Damage Energy (MeV-mb)
1	1.4900E+02	1.5000E+02	1.4950E+02	5.910600E+01
2	1.4800E+02	1.4900E+02	1.4850E+02	5.937300E+01
3	1.4700E+02	1.4800E+02	1.4750E+02	5.964800E+01
4	1.4600E+02	1.4700E+02	1.4650E+02	5.992600E+01
5	1.4500E+02	1.4600E+02	1.4550E+02	6.021400E+01
6	1.4400E+02	1.4500E+02	1.4450E+02	6.050500E+01
7	1.4300E+02	1.4400E+02	1.4350E+02	6.080800E+01
8	1.4200E+02	1.4300E+02	1.4250E+02	6.111500E+01
9	1.4100E+02	1.4200E+02	1.4150E+02	6.143500E+01
10	1.4000E+02	1.4100E+02	1.4050E+02	6.176000E+01
11	1.3900E+02	1.4000E+02	1.3950E+02	6.208100E+01
12	1.3800E+02	1.3900E+02	1.3850E+02	6.239800E+01
13	1.3700E+02	1.3800E+02	1.3750E+02	6.272500E+01
14	1.3600E+02	1.3700E+02	1.3650E+02	6.305600E+01
15	1.3500E+02	1.3600E+02	1.3550E+02	6.339600E+01
16	1.3400E+02	1.3500E+02	1.3450E+02	6.374100E+01
17	1.3300E+02	1.3400E+02	1.3350E+02	6.409700E+01
18	1.3200E+02	1.3300E+02	1.3250E+02	6.445700E+01
19	1.3100E+02	1.3200E+02	1.3150E+02	6.482900E+01
20	1.3000E+02	1.3100E+02	1.3050E+02	6.520600E+01
21	1.2900E+02	1.3000E+02	1.2950E+02	6.560900E+01
22	1.2800E+02	1.2900E+02	1.2850E+02	6.602500E+01
23	1.2700E+02	1.2800E+02	1.2750E+02	6.644901E+01
24	1.2600E+02	1.2700E+02	1.2650E+02	6.687801E+01
25	1.2500E+02	1.2600E+02	1.2550E+02	6.731800E+01
26	1.2400E+02	1.2500E+02	1.2450E+02	6.776300E+01
27	1.2300E+02	1.2400E+02	1.2350E+02	6.822100E+01
28	1.2200E+02	1.2300E+02	1.2250E+02	6.868501E+01
29	1.2100E+02	1.2200E+02	1.2150E+02	6.916500E+01
30	1.2000E+02	1.2100E+02	1.2050E+02	6.965200E+01
31	1.1900E+02	1.2000E+02	1.1950E+02	7.023200E+01
32	1.1800E+02	1.1900E+02	1.1850E+02	7.085800E+01
33	1.1700E+02	1.1800E+02	1.1750E+02	7.149700E+01
34	1.1600E+02	1.1700E+02	1.1650E+02	7.214400E+01

35	1.1500E+02	1.1600E+02	1.1550E+02	7.280500E+01
36	1.1400E+02	1.1500E+02	1.1450E+02	7.347200E+01
37	1.1300E+02	1.1400E+02	1.1350E+02	7.415601E+01
38	1.1200E+02	1.1300E+02	1.1250E+02	7.484700E+01
39	1.1100E+02	1.1200E+02	1.1150E+02	7.555300E+01
40	1.1000E+02	1.1100E+02	1.1050E+02	7.626801E+01
41	1.0900E+02	1.1000E+02	1.0950E+02	7.697501E+01
42	1.0800E+02	1.0900E+02	1.0850E+02	7.767900E+01
43	1.0700E+02	1.0800E+02	1.0750E+02	7.839500E+01
44	1.0600E+02	1.0700E+02	1.0650E+02	7.911900E+01
45	1.0500E+02	1.0600E+02	1.0550E+02	7.985900E+01
46	1.0400E+02	1.0500E+02	1.0450E+02	8.060600E+01
47	1.0300E+02	1.0400E+02	1.0350E+02	8.137400E+01
48	1.0200E+02	1.0300E+02	1.0250E+02	8.215000E+01
49	1.0100E+02	1.0200E+02	1.0150E+02	8.295000E+01
50	1.0000E+02	1.0100E+02	1.0050E+02	8.376200E+01
51	9.9000E+01	1.0000E+02	9.9500E+01	8.459801E+01
52	9.8000E+01	9.9000E+01	9.8500E+01	8.546001E+01
53	9.7000E+01	9.8000E+01	9.7500E+01	8.634000E+01
54	9.6000E+01	9.7000E+01	9.6500E+01	8.723901E+01
55	9.5000E+01	9.6000E+01	9.5500E+01	8.815601E+01
56	9.4000E+01	9.5000E+01	9.4500E+01	8.909200E+01
57	9.3000E+01	9.4000E+01	9.3500E+01	9.004700E+01
58	9.2000E+01	9.3000E+01	9.2500E+01	9.102100E+01
59	9.1000E+01	9.2000E+01	9.1500E+01	9.201200E+01
60	9.0000E+01	9.1000E+01	9.0500E+01	9.302100E+01
61	8.9000E+01	9.0000E+01	8.9500E+01	9.407301E+01
62	8.8000E+01	8.9000E+01	8.8500E+01	9.513700E+01
63	8.7000E+01	8.8000E+01	8.7500E+01	9.619901E+01
64	8.6000E+01	8.7000E+01	8.6500E+01	9.727701E+01
65	8.5000E+01	8.6000E+01	8.5500E+01	9.839201E+01
66	8.4000E+01	8.5000E+01	8.4500E+01	9.954700E+01
67	8.3000E+01	8.4000E+01	8.3500E+01	1.007400E+02
68	8.2000E+01	8.3000E+01	8.2500E+01	1.019800E+02
69	8.1000E+01	8.2000E+01	8.1500E+01	1.032300E+02
70	8.0000E+01	8.1000E+01	8.0500E+01	1.044800E+02
71	7.9000E+01	8.0000E+01	7.9500E+01	1.057000E+02
72	7.8000E+01	7.9000E+01	7.8500E+01	1.069000E+02
73	7.7000E+01	7.8000E+01	7.7500E+01	1.081200E+02
74	7.6000E+01	7.7000E+01	7.6500E+01	1.093600E+02
75	7.5000E+01	7.6000E+01	7.5500E+01	1.106200E+02
76	7.4000E+01	7.5000E+01	7.4500E+01	1.119300E+02
77	7.3000E+01	7.4000E+01	7.3500E+01	1.132700E+02
78	7.2000E+01	7.3000E+01	7.2500E+01	1.146400E+02
79	7.1000E+01	7.2000E+01	7.1500E+01	1.160000E+02

80	7.0000E+01	7.1000E+01	7.0500E+01	1.174000E+02
81	6.9000E+01	7.0000E+01	6.9500E+01	1.187500E+02
82	6.8000E+01	6.9000E+01	6.8500E+01	1.200600E+02
83	6.7000E+01	6.8000E+01	6.7500E+01	1.213600E+02
84	6.6000E+01	6.7000E+01	6.6500E+01	1.226700E+02
85	6.5000E+01	6.6000E+01	6.5500E+01	1.239800E+02
86	6.4000E+01	6.5000E+01	6.4500E+01	1.253800E+02
87	6.3000E+01	6.4000E+01	6.3500E+01	1.268000E+02
88	6.2000E+01	6.3000E+01	6.2500E+01	1.282300E+02
89	6.1000E+01	6.2000E+01	6.1500E+01	1.297200E+02
90	6.0000E+01	6.1000E+01	6.0500E+01	1.312200E+02
91	5.9000E+01	6.0000E+01	5.9500E+01	1.327700E+02
92	5.8000E+01	5.9000E+01	5.8500E+01	1.343400E+02
93	5.7000E+01	5.8000E+01	5.7500E+01	1.359300E+02
94	5.6000E+01	5.7000E+01	5.6500E+01	1.375200E+02
95	5.5000E+01	5.6000E+01	5.5500E+01	1.391200E+02
96	5.4000E+01	5.5000E+01	5.4500E+01	1.407200E+02
97	5.3000E+01	5.4000E+01	5.3500E+01	1.422800E+02
98	5.2000E+01	5.3000E+01	5.2500E+01	1.438000E+02
99	5.1000E+01	5.2000E+01	5.1500E+01	1.452900E+02
100	5.0000E+01	5.1000E+01	5.0500E+01	1.468000E+02
101	4.9000E+01	5.0000E+01	4.9500E+01	1.475300E+02
102	4.8000E+01	4.9000E+01	4.8500E+01	1.477100E+02
103	4.7000E+01	4.8000E+01	4.7500E+01	1.479200E+02
104	4.6000E+01	4.7000E+01	4.6500E+01	1.481700E+02
105	4.5000E+01	4.6000E+01	4.5500E+01	1.484700E+02
106	4.4000E+01	4.5000E+01	4.4500E+01	1.497000E+02
107	4.3000E+01	4.4000E+01	4.3500E+01	1.516600E+02
108	4.2000E+01	4.3000E+01	4.2500E+01	1.536600E+02
109	4.1000E+01	4.2000E+01	4.1500E+01	1.556600E+02
110	4.0000E+01	4.1000E+01	4.0500E+01	1.575700E+02
111	3.9000E+01	4.0000E+01	3.9500E+01	1.593500E+02
112	3.8000E+01	3.9000E+01	3.8500E+01	1.610700E+02
113	3.7000E+01	3.8000E+01	3.7500E+01	1.627000E+02
114	3.6000E+01	3.7000E+01	3.6500E+01	1.642700E+02
115	3.5000E+01	3.6000E+01	3.5500E+01	1.657600E+02
116	3.4000E+01	3.5000E+01	3.4500E+01	1.672200E+02
117	3.3000E+01	3.4000E+01	3.3500E+01	1.686700E+02
118	3.2000E+01	3.3000E+01	3.2500E+01	1.700600E+02
119	3.1000E+01	3.2000E+01	3.1500E+01	1.713900E+02
120	3.0000E+01	3.1000E+01	3.0500E+01	1.726900E+02
121	2.9000E+01	3.0000E+01	2.9500E+01	1.740500E+02
122	2.8000E+01	2.9000E+01	2.8500E+01	1.754600E+02
123	2.7000E+01	2.8000E+01	2.7500E+01	1.767800E+02
124	2.6000E+01	2.7000E+01	2.6500E+01	1.779900E+02

125	2.5000E+01	2.6000E+01	2.5500E+01	1.791500E+02
126	2.4000E+01	2.5000E+01	2.4500E+01	1.802400E+02
127	2.3000E+01	2.4000E+01	2.3500E+01	1.809500E+02
128	2.2000E+01	2.3000E+01	2.2500E+01	1.813800E+02
129	2.1000E+01	2.2000E+01	2.1500E+01	1.799500E+02
130	2.0000E+01	2.1000E+01	2.0500E+01	1.768500E+02
131	1.9900E+01	2.0000E+01	1.9950E+01	1.966100E+02
132	1.9800E+01	1.9900E+01	1.9850E+01	1.959800E+02
133	1.9700E+01	1.9800E+01	1.9750E+01	1.953400E+02
134	1.9600E+01	1.9700E+01	1.9650E+01	1.947500E+02
135	1.9500E+01	1.9600E+01	1.9550E+01	1.944400E+02
136	1.9400E+01	1.9500E+01	1.9450E+01	1.941800E+02
137	1.9300E+01	1.9400E+01	1.9350E+01	1.941400E+02
138	1.9200E+01	1.9300E+01	1.9250E+01	1.942500E+02
139	1.9100E+01	1.9200E+01	1.9150E+01	1.947000E+02
140	1.9000E+01	1.9100E+01	1.9050E+01	1.960000E+02
141	1.8900E+01	1.9000E+01	1.8950E+01	1.972800E+02
142	1.8800E+01	1.8900E+01	1.8850E+01	1.982200E+02
143	1.8700E+01	1.8800E+01	1.8750E+01	1.990200E+02
144	1.8600E+01	1.8700E+01	1.8650E+01	1.968500E+02
145	1.8500E+01	1.8600E+01	1.8550E+01	1.929500E+02
146	1.8400E+01	1.8500E+01	1.8450E+01	1.910900E+02
147	1.8300E+01	1.8400E+01	1.8350E+01	1.921000E+02
148	1.8200E+01	1.8300E+01	1.8250E+01	1.932100E+02
149	1.8100E+01	1.8200E+01	1.8150E+01	1.946200E+02
150	1.8000E+01	1.8100E+01	1.8050E+01	1.954200E+02
151	1.7900E+01	1.8000E+01	1.7950E+01	1.931700E+02
152	1.7800E+01	1.7900E+01	1.7850E+01	1.907000E+02
153	1.7700E+01	1.7800E+01	1.7750E+01	1.895000E+02
154	1.7600E+01	1.7700E+01	1.7650E+01	1.887200E+02
155	1.7500E+01	1.7600E+01	1.7550E+01	1.897400E+02
156	1.7400E+01	1.7500E+01	1.7450E+01	1.911100E+02
157	1.7300E+01	1.7400E+01	1.7350E+01	1.912900E+02
158	1.7200E+01	1.7300E+01	1.7250E+01	1.911300E+02
159	1.7100E+01	1.7200E+01	1.7150E+01	1.913100E+02
160	1.7000E+01	1.7100E+01	1.7050E+01	1.915400E+02
161	1.6900E+01	1.7000E+01	1.6950E+01	1.909500E+02
162	1.6800E+01	1.6900E+01	1.6850E+01	1.903800E+02
163	1.6700E+01	1.6800E+01	1.6750E+01	1.924600E+02
164	1.6600E+01	1.6700E+01	1.6650E+01	1.941100E+02
165	1.6500E+01	1.6600E+01	1.6550E+01	1.890500E+02
166	1.6400E+01	1.6500E+01	1.6450E+01	1.843900E+02
167	1.6300E+01	1.6400E+01	1.6350E+01	1.852800E+02
168	1.6200E+01	1.6300E+01	1.6250E+01	1.864500E+02
169	1.6100E+01	1.6200E+01	1.6150E+01	1.870100E+02

170	1.6000E+01	1.6100E+01	1.6050E+01	1.869400E+02
171	1.5900E+01	1.6000E+01	1.5950E+01	1.861100E+02
172	1.5800E+01	1.5900E+01	1.5850E+01	1.828600E+02
173	1.5700E+01	1.5800E+01	1.5750E+01	1.788500E+02
174	1.5600E+01	1.5700E+01	1.5650E+01	1.777400E+02
175	1.5500E+01	1.5600E+01	1.5550E+01	1.778700E+02
176	1.5400E+01	1.5500E+01	1.5450E+01	1.796900E+02
177	1.5300E+01	1.5400E+01	1.5350E+01	1.808200E+02
178	1.5200E+01	1.5300E+01	1.5250E+01	1.808900E+02
179	1.5100E+01	1.5200E+01	1.5150E+01	1.768800E+02
180	1.5000E+01	1.5100E+01	1.5050E+01	1.741600E+02
181	1.4900E+01	1.5000E+01	1.4950E+01	1.778700E+02
182	1.4800E+01	1.4900E+01	1.4850E+01	1.772400E+02
183	1.4700E+01	1.4800E+01	1.4750E+01	1.739600E+02
184	1.4600E+01	1.4700E+01	1.4650E+01	1.730600E+02
185	1.4500E+01	1.4600E+01	1.4550E+01	1.753600E+02
186	1.4400E+01	1.4500E+01	1.4450E+01	1.804700E+02
187	1.4300E+01	1.4400E+01	1.4350E+01	1.802900E+02
188	1.4200E+01	1.4300E+01	1.4250E+01	1.790600E+02
189	1.4100E+01	1.4200E+01	1.4150E+01	1.778200E+02
190	1.4000E+01	1.4100E+01	1.4050E+01	1.749000E+02
191	1.3900E+01	1.4000E+01	1.3950E+01	1.769100E+02
192	1.3800E+01	1.3900E+01	1.3850E+01	1.827700E+02
193	1.3700E+01	1.3800E+01	1.3750E+01	1.764700E+02
194	1.3600E+01	1.3700E+01	1.3650E+01	1.740800E+02
195	1.3500E+01	1.3600E+01	1.3550E+01	1.762200E+02
196	1.3400E+01	1.3500E+01	1.3450E+01	1.796700E+02
197	1.3300E+01	1.3400E+01	1.3350E+01	1.764900E+02
198	1.3200E+01	1.3300E+01	1.3250E+01	1.752400E+02
199	1.3100E+01	1.3200E+01	1.3150E+01	1.784700E+02
200	1.3000E+01	1.3100E+01	1.3050E+01	1.816300E+02
201	1.2900E+01	1.3000E+01	1.2950E+01	1.807700E+02
202	1.2800E+01	1.2900E+01	1.2850E+01	1.804300E+02
203	1.2700E+01	1.2800E+01	1.2750E+01	1.810300E+02
204	1.2600E+01	1.2700E+01	1.2650E+01	1.791600E+02
205	1.2500E+01	1.2600E+01	1.2550E+01	1.715700E+02
206	1.2400E+01	1.2500E+01	1.2450E+01	1.747000E+02
207	1.2300E+01	1.2400E+01	1.2350E+01	1.776800E+02
208	1.2200E+01	1.2300E+01	1.2250E+01	1.770100E+02
209	1.2100E+01	1.2200E+01	1.2150E+01	1.766900E+02
210	1.2000E+01	1.2100E+01	1.2050E+01	1.739900E+02
211	1.1900E+01	1.2000E+01	1.1950E+01	1.723500E+02
212	1.1800E+01	1.1900E+01	1.1850E+01	1.710700E+02
213	1.1700E+01	1.1800E+01	1.1750E+01	1.707600E+02
214	1.1600E+01	1.1700E+01	1.1650E+01	1.722600E+02

215	1.1500E+01	1.1600E+01	1.1550E+01	1.732600E+02
216	1.1400E+01	1.1500E+01	1.1450E+01	1.720500E+02
217	1.1300E+01	1.1400E+01	1.1350E+01	1.691200E+02
218	1.1200E+01	1.1300E+01	1.1250E+01	1.649900E+02
219	1.1100E+01	1.1200E+01	1.1150E+01	1.638300E+02
220	1.1000E+01	1.1100E+01	1.1050E+01	1.691000E+02
221	1.0900E+01	1.1000E+01	1.0950E+01	1.718000E+02
222	1.0800E+01	1.0900E+01	1.0850E+01	1.719200E+02
223	1.0700E+01	1.0800E+01	1.0750E+01	1.681800E+02
224	1.0600E+01	1.0700E+01	1.0650E+01	1.633500E+02
225	1.0500E+01	1.0600E+01	1.0550E+01	1.654800E+02
226	1.0400E+01	1.0500E+01	1.0450E+01	1.667000E+02
227	1.0300E+01	1.0400E+01	1.0350E+01	1.727600E+02
228	1.0200E+01	1.0300E+01	1.0250E+01	1.720300E+02
229	1.0100E+01	1.0200E+01	1.0150E+01	1.737100E+02
230	1.0000E+01	1.0100E+01	1.0050E+01	1.716700E+02
231	9.9000E+00	1.0000E+01	9.9500E+00	1.735200E+02
232	9.8000E+00	9.9000E+00	9.8500E+00	1.711300E+02
233	9.7000E+00	9.8000E+00	9.7500E+00	1.667200E+02
234	9.6000E+00	9.7000E+00	9.6500E+00	1.631700E+02
235	9.5000E+00	9.6000E+00	9.5500E+00	1.725700E+02
236	9.4000E+00	9.5000E+00	9.4500E+00	1.778800E+02
237	9.3000E+00	9.4000E+00	9.3500E+00	1.708100E+02
238	9.2000E+00	9.3000E+00	9.2500E+00	1.573000E+02
239	9.1000E+00	9.2000E+00	9.1500E+00	1.627900E+02
240	9.0000E+00	9.1000E+00	9.0500E+00	1.830800E+02
241	8.9000E+00	9.0000E+00	8.9500E+00	1.837600E+02
242	8.8000E+00	8.9000E+00	8.8500E+00	1.637800E+02
243	8.7000E+00	8.8000E+00	8.7500E+00	1.529000E+02
244	8.6000E+00	8.7000E+00	8.6500E+00	1.708400E+02
245	8.5000E+00	8.6000E+00	8.5500E+00	1.716100E+02
246	8.4000E+00	8.5000E+00	8.4500E+00	1.728000E+02
247	8.3000E+00	8.4000E+00	8.3500E+00	1.715700E+02
248	8.2000E+00	8.3000E+00	8.2500E+00	1.692600E+02
249	8.1000E+00	8.2000E+00	8.1500E+00	1.624500E+02
250	8.0000E+00	8.1000E+00	8.0500E+00	1.776700E+02
251	7.9000E+00	8.0000E+00	7.9500E+00	1.952800E+02
252	7.8000E+00	7.9000E+00	7.8500E+00	1.815800E+02
253	7.7000E+00	7.8000E+00	7.7500E+00	1.814900E+02
254	7.6000E+00	7.7000E+00	7.6500E+00	1.747600E+02
255	7.5000E+00	7.6000E+00	7.5500E+00	1.719400E+02
256	7.4000E+00	7.5000E+00	7.4500E+00	1.746300E+02
257	7.3000E+00	7.4000E+00	7.3500E+00	1.764700E+02
258	7.2000E+00	7.3000E+00	7.2500E+00	1.759700E+02
259	7.1000E+00	7.2000E+00	7.1500E+00	1.427900E+02

260	7.0000E+00	7.1000E+00	7.0500E+00	1.735500E+02
261	6.9000E+00	7.0000E+00	6.9500E+00	1.474500E+02
262	6.8000E+00	6.9000E+00	6.8500E+00	1.527900E+02
263	6.7000E+00	6.8000E+00	6.7500E+00	1.731500E+02
264	6.6000E+00	6.7000E+00	6.6500E+00	1.568100E+02
265	6.5000E+00	6.6000E+00	6.5500E+00	1.281800E+02
266	6.4000E+00	6.5000E+00	6.4500E+00	1.470700E+02
267	6.3000E+00	6.4000E+00	6.3500E+00	1.590500E+02
268	6.2000E+00	6.3000E+00	6.2500E+00	1.834200E+02
269	6.1000E+00	6.2000E+00	6.1500E+00	1.317700E+02
270	6.0000E+00	6.1000E+00	6.0500E+00	1.610800E+02
271	5.9000E+00	6.0000E+00	5.9500E+00	1.419100E+02
272	5.8000E+00	5.9000E+00	5.8500E+00	1.734500E+02
273	5.7000E+00	5.8000E+00	5.7500E+00	1.875300E+02
274	5.6000E+00	5.7000E+00	5.6500E+00	1.557100E+02
275	5.5000E+00	5.6000E+00	5.5500E+00	1.514500E+02
276	5.4000E+00	5.5000E+00	5.4500E+00	1.231100E+02
277	5.3000E+00	5.4000E+00	5.3500E+00	1.288900E+02
278	5.2000E+00	5.3000E+00	5.2500E+00	1.554000E+02
279	5.1000E+00	5.2000E+00	5.1500E+00	1.767400E+02
280	5.0000E+00	5.1000E+00	5.0500E+00	1.548900E+02
281	4.9000E+00	5.0000E+00	4.9500E+00	1.511000E+02
282	4.8000E+00	4.9000E+00	4.8500E+00	1.650100E+02
283	4.7000E+00	4.8000E+00	4.7500E+00	1.930600E+02
284	4.6000E+00	4.7000E+00	4.6500E+00	1.607700E+02
285	4.5000E+00	4.6000E+00	4.5500E+00	1.436400E+02
286	4.4000E+00	4.5000E+00	4.4500E+00	1.443900E+02
287	4.3000E+00	4.4000E+00	4.3500E+00	1.383700E+02
288	4.2000E+00	4.3000E+00	4.2500E+00	1.710800E+02
289	4.1000E+00	4.2000E+00	4.1500E+00	1.099100E+02
290	4.0000E+00	4.1000E+00	4.0500E+00	1.367500E+02
291	3.9000E+00	4.0000E+00	3.9500E+00	1.391500E+02
292	3.8000E+00	3.9000E+00	3.8500E+00	1.138100E+02
293	3.7000E+00	3.8000E+00	3.7500E+00	1.184000E+02
294	3.6000E+00	3.7000E+00	3.6500E+00	7.105200E+01
295	3.5000E+00	3.6000E+00	3.5500E+00	1.158500E+02
296	3.4000E+00	3.5000E+00	3.4500E+00	1.201200E+02
297	3.3000E+00	3.4000E+00	3.3500E+00	1.165700E+02
298	3.2000E+00	3.3000E+00	3.2500E+00	1.229500E+02
299	3.1000E+00	3.2000E+00	3.1500E+00	1.365000E+02
300	3.0000E+00	3.1000E+00	3.0500E+00	1.218800E+02
301	2.9000E+00	3.0000E+00	2.9500E+00	1.011100E+02
302	2.8000E+00	2.9000E+00	2.8500E+00	1.375200E+02
303	2.7000E+00	2.8000E+00	2.7500E+00	1.098000E+02
304	2.6000E+00	2.7000E+00	2.6500E+00	1.177600E+02

305	2.5000E+00	2.6000E+00	2.5500E+00	1.316600E+02
306	2.4000E+00	2.5000E+00	2.4500E+00	1.208400E+02
307	2.3000E+00	2.4000E+00	2.3500E+00	1.054000E+02
308	2.2000E+00	2.3000E+00	2.2500E+00	1.072500E+02
309	2.1000E+00	2.2000E+00	2.1500E+00	1.101500E+02
310	2.0000E+00	2.1000E+00	2.0500E+00	9.711001E+01
311	1.9000E+00	2.0000E+00	1.9500E+00	1.321300E+02
312	1.8000E+00	1.9000E+00	1.8500E+00	1.338200E+02
313	1.7000E+00	1.8000E+00	1.7500E+00	8.041901E+01
314	1.6000E+00	1.7000E+00	1.6500E+00	1.769400E+02
315	1.5000E+00	1.6000E+00	1.5500E+00	1.106600E+02
316	1.4000E+00	1.5000E+00	1.4500E+00	1.045300E+02
317	1.3000E+00	1.4000E+00	1.3500E+00	8.950600E+01
318	1.2000E+00	1.3000E+00	1.2500E+00	9.237300E+01
319	1.1000E+00	1.2000E+00	1.1500E+00	6.245200E+01
320	1.0000E+00	1.1000E+00	1.0500E+00	7.969000E+01
321	9.6000E-01	1.0000E+00	9.8000E-01	1.178100E+02
322	9.2000E-01	9.6000E-01	9.4000E-01	1.170700E+02
323	8.8000E-01	9.2000E-01	9.0000E-01	9.282900E+01
324	8.4000E-01	8.8000E-01	8.6000E-01	8.163800E+01
325	8.0000E-01	8.4000E-01	8.2000E-01	1.470400E+02
326	7.6000E-01	8.0000E-01	7.8000E-01	8.975101E+01
327	7.2000E-01	7.6000E-01	7.4000E-01	6.226100E+01
328	6.9000E-01	7.2000E-01	7.0500E-01	5.809400E+01
329	6.6000E-01	6.9000E-01	6.7500E-01	5.549300E+01
330	6.3000E-01	6.6000E-01	6.4500E-01	5.324600E+01
331	6.0000E-01	6.3000E-01	6.1500E-01	5.306000E+01
332	5.7500E-01	6.0000E-01	5.8750E-01	5.817100E+01
333	5.5000E-01	5.7500E-01	5.6250E-01	1.264900E+02
334	5.2500E-01	5.5000E-01	5.3750E-01	7.358701E+01
335	5.0000E-01	5.2500E-01	5.1250E-01	5.870500E+01
336	4.7500E-01	5.0000E-01	4.8750E-01	5.655800E+01
337	4.5000E-01	4.7500E-01	4.6250E-01	5.505000E+01
338	4.2500E-01	4.5000E-01	4.3750E-01	5.359100E+01
339	4.0000E-01	4.2500E-01	4.1250E-01	5.217800E+01
340	3.8000E-01	4.0000E-01	3.9000E-01	5.148400E+01
341	3.6000E-01	3.8000E-01	3.7000E-01	5.152200E+01
342	3.4000E-01	3.6000E-01	3.5000E-01	5.208400E+01
343	3.2000E-01	3.4000E-01	3.3000E-01	5.221600E+01
344	3.0000E-01	3.2000E-01	3.1000E-01	5.302100E+01
345	2.8000E-01	3.0000E-01	2.9000E-01	5.473700E+01
346	2.7000E-01	2.8000E-01	2.7500E-01	5.627900E+01
347	2.5500E-01	2.7000E-01	2.6250E-01	5.856400E+01
348	2.4000E-01	2.5500E-01	2.4750E-01	6.264700E+01
349	2.3000E-01	2.4000E-01	2.3500E-01	6.793301E+01

350	2.2000E-01	2.3000E-01	2.2500E-01	7.441500E+01
351	2.1000E-01	2.2000E-01	2.1500E-01	8.400101E+01
352	2.0000E-01	2.1000E-01	2.0500E-01	9.818800E+01
353	1.9000E-01	2.0000E-01	1.9500E-01	1.166800E+02
354	1.8000E-01	1.9000E-01	1.8500E-01	1.190000E+02
355	1.7000E-01	1.8000E-01	1.7500E-01	7.073701E+01
356	1.6000E-01	1.7000E-01	1.6500E-01	2.080900E+01
357	1.5000E-01	1.6000E-01	1.5500E-01	3.180600E+00
358	1.4250E-01	1.5000E-01	1.4625E-01	1.668700E-01
359	1.3500E-01	1.4250E-01	1.3875E-01	4.166700E-01
360	1.2750E-01	1.3500E-01	1.3125E-01	1.236200E+00
361	1.2000E-01	1.2750E-01	1.2375E-01	2.144100E+00
362	1.1500E-01	1.2000E-01	1.1750E-01	2.857300E+00
363	1.1000E-01	1.1500E-01	1.1250E-01	3.365700E+00
364	1.0500E-01	1.1000E-01	1.0750E-01	3.804500E+00
365	1.0000E-01	1.0500E-01	1.0250E-01	4.190900E+00
366	9.6000E-02	1.0000E-01	9.8000E-02	4.508201E+00
367	9.2000E-02	9.6000E-02	9.4000E-02	4.743200E+00
368	8.8000E-02	9.2000E-02	9.0000E-02	4.950201E+00
369	8.4000E-02	8.8000E-02	8.6000E-02	5.157800E+00
370	8.0000E-02	8.4000E-02	8.2000E-02	5.300500E+00
371	7.6000E-02	8.0000E-02	7.8000E-02	5.467600E+00
372	7.2000E-02	7.6000E-02	7.4000E-02	5.656701E+00
373	6.9000E-02	7.2000E-02	7.0500E-02	5.870500E+00
374	6.6000E-02	6.9000E-02	6.7500E-02	6.370400E+00
375	6.3000E-02	6.6000E-02	6.4500E-02	6.658300E+00
376	6.0000E-02	6.3000E-02	6.150001E-02	7.812500E+00
377	5.7500E-02	6.0000E-02	5.8750E-02	1.165300E+01
378	5.5000E-02	5.7500E-02	5.6250E-02	5.202200E+01
379	5.2500E-02	5.5000E-02	5.3750E-02	1.029000E+00
380	5.0000E-02	5.2500E-02	5.1250E-02	1.346600E+00
381	4.7500E-02	5.0000E-02	4.8750E-02	2.076500E+00
382	4.5000E-02	4.7500E-02	4.6250E-02	2.419100E+00
383	4.2500E-02	4.5000E-02	4.3750E-02	2.584500E+00
384	4.0000E-02	4.2500E-02	4.1250E-02	2.652200E+00
385	3.8000E-02	4.0000E-02	3.9000E-02	2.657000E+00
386	3.6000E-02	3.8000E-02	3.7000E-02	2.626700E+00
387	3.4000E-02	3.6000E-02	3.5000E-02	2.574100E+00
388	3.2000E-02	3.4000E-02	3.3000E-02	2.505400E+00
389	3.0000E-02	3.2000E-02	3.1000E-02	2.423800E+00
390	2.8000E-02	3.0000E-02	2.9000E-02	2.324600E+00
391	2.7000E-02	2.8000E-02	2.7500E-02	2.242300E+00
392	2.5500E-02	2.7000E-02	2.6250E-02	2.170800E+00
393	2.4000E-02	2.5500E-02	2.4750E-02	2.084800E+00
394	2.3000E-02	2.4000E-02	2.3500E-02	2.005900E+00

395	2.2000E-02	2.3000E-02	2.2500E-02	1.939600E+00
396	2.1000E-02	2.2000E-02	2.1500E-02	1.873300E+00
397	2.0000E-02	2.1000E-02	2.0500E-02	1.807100E+00
398	1.9000E-02	2.0000E-02	1.9500E-02	1.737400E+00
399	1.8000E-02	1.9000E-02	1.8500E-02	1.664300E+00
400	1.7000E-02	1.8000E-02	1.7500E-02	1.590700E+00
401	1.6000E-02	1.7000E-02	1.6500E-02	1.513900E+00
402	1.5000E-02	1.6000E-02	1.5500E-02	1.436500E+00
403	1.4250E-02	1.5000E-02	1.4625E-02	1.367400E+00
404	1.3500E-02	1.4250E-02	1.3875E-02	1.306300E+00
405	1.2750E-02	1.3500E-02	1.3125E-02	1.245100E+00
406	1.2000E-02	1.2750E-02	1.2375E-02	1.183300E+00
407	1.1500E-02	1.2000E-02	1.1750E-02	1.130400E+00
408	1.1000E-02	1.1500E-02	1.1250E-02	1.087700E+00
409	1.0500E-02	1.1000E-02	1.0750E-02	1.044500E+00
410	1.0000E-02	1.0500E-02	1.0250E-02	1.001100E+00
411	9.6000E-03	1.0000E-02	9.8000E-03	9.617500E-01
412	9.2000E-03	9.6000E-03	9.4000E-03	9.261900E-01
413	8.8000E-03	9.2000E-03	9.0000E-03	8.906301E-01
414	8.4000E-03	8.8000E-03	8.6000E-03	8.546900E-01
415	8.0000E-03	8.4000E-03	8.2000E-03	8.181400E-01
416	7.6000E-03	8.0000E-03	7.8000E-03	7.815800E-01
417	7.2000E-03	7.6000E-03	7.4000E-03	7.448401E-01
418	6.9000E-03	7.2000E-03	7.0500E-03	7.123901E-01
419	6.6000E-03	6.9000E-03	6.7500E-03	6.845000E-01
420	6.3000E-03	6.6000E-03	6.4500E-03	6.566000E-01
421	6.0000E-03	6.3000E-03	6.1500E-03	6.284200E-01
422	5.7500E-03	6.0000E-03	5.8750E-03	6.021501E-01
423	5.5000E-03	5.7500E-03	5.6250E-03	5.782200E-01
424	5.2500E-03	5.5000E-03	5.3750E-03	5.542800E-01
425	5.0000E-03	5.2500E-03	5.1250E-03	5.303401E-01
426	4.7500E-03	5.0000E-03	4.8750E-03	5.061300E-01
427	4.5000E-03	4.7500E-03	4.6250E-03	4.816500E-01
428	4.2500E-03	4.5000E-03	4.3750E-03	4.571800E-01
429	4.0000E-03	4.2500E-03	4.1250E-03	4.327700E-01
430	3.8000E-03	4.0000E-03	3.9000E-03	4.109000E-01
431	3.6000E-03	3.8000E-03	3.7000E-03	3.913200E-01
432	3.4000E-03	3.6000E-03	3.5000E-03	3.716300E-01
433	3.2000E-03	3.4000E-03	3.3000E-03	3.513800E-01
434	3.0000E-03	3.2000E-03	3.1000E-03	3.310300E-01
435	2.8000E-03	3.0000E-03	2.9000E-03	3.106500E-01
436	2.7000E-03	2.8000E-03	2.7500E-03	2.954900E-01
437	2.5500E-03	2.7000E-03	2.6250E-03	2.829300E-01
438	2.4000E-03	2.5500E-03	2.4750E-03	2.679500E-01
439	2.3000E-03	2.4000E-03	2.3500E-03	2.554000E-01

440	2.2000E-03	2.3000E-03	2.2500E-03	2.450600E-01
441	2.1000E-03	2.2000E-03	2.1500E-03	2.348900E-01
442	2.0000E-03	2.1000E-03	2.0500E-03	2.249800E-01
443	1.9000E-03	2.0000E-03	1.9500E-03	2.148800E-01
444	1.8000E-03	1.9000E-03	1.8500E-03	2.045900E-01
445	1.7000E-03	1.8000E-03	1.7500E-03	1.943400E-01
446	1.6000E-03	1.7000E-03	1.6500E-03	1.842600E-01
447	1.5000E-03	1.6000E-03	1.5500E-03	1.738300E-01
448	1.4250E-03	1.5000E-03	1.4625E-03	1.646400E-01
449	1.3500E-03	1.4250E-03	1.3875E-03	1.568500E-01
450	1.2750E-03	1.3500E-03	1.3125E-03	1.496300E-01
451	1.2000E-03	1.2750E-03	1.2375E-03	1.424000E-01
452	1.1500E-03	1.2000E-03	1.1750E-03	1.358900E-01
453	1.1000E-03	1.1500E-03	1.1250E-03	1.306500E-01
454	1.0500E-03	1.1000E-03	1.0750E-03	1.255600E-01
455	1.0000E-03	1.0500E-03	1.0250E-03	1.205000E-01
456	9.6000E-04	1.0000E-03	9.8000E-04	1.159200E-01
457	9.2000E-04	9.6000E-04	9.4000E-04	1.118100E-01
458	8.8000E-04	9.2000E-04	9.0000E-04	1.077000E-01
459	8.4000E-04	8.8000E-04	8.6000E-04	1.035900E-01
460	8.0000E-04	8.4000E-04	8.2000E-04	9.949300E-02
461	7.6000E-04	8.0000E-04	7.8000E-04	9.551600E-02
462	7.2000E-04	7.6000E-04	7.4000E-04	9.160300E-02
463	6.9000E-04	7.2000E-04	7.0500E-04	8.823800E-02
464	6.6000E-04	6.9000E-04	6.7500E-04	8.545700E-02
465	6.3000E-04	6.6000E-04	6.4500E-04	8.282300E-02
466	6.0000E-04	6.3000E-04	6.1500E-04	8.018900E-02
467	5.7500E-04	6.0000E-04	5.8750E-04	7.777900E-02
468	5.5000E-04	5.7500E-04	5.6250E-04	7.558800E-02
469	5.2500E-04	5.5000E-04	5.3750E-04	7.341101E-02
470	5.0000E-04	5.2500E-04	5.1250E-04	7.123701E-02
471	4.7500E-04	5.0000E-04	4.8750E-04	6.884700E-02
472	4.5000E-04	4.7500E-04	4.6250E-04	6.639700E-02
473	4.2500E-04	4.5000E-04	4.3750E-04	6.483700E-02
474	4.0000E-04	4.2500E-04	4.1250E-04	6.283600E-02
475	3.8000E-04	4.0000E-04	3.9000E-04	6.058900E-02
476	3.6000E-04	3.8000E-04	3.7000E-04	5.927501E-02
477	3.4000E-04	3.6000E-04	3.5000E-04	5.779200E-02
478	3.2000E-04	3.4000E-04	3.3000E-04	5.426900E-02
479	3.0000E-04	3.2000E-04	3.1000E-04	5.067100E-02
480	2.8000E-04	3.0000E-04	2.9000E-04	4.802200E-02
481	2.7000E-04	2.8000E-04	2.7500E-04	4.596901E-02
482	2.5500E-04	2.7000E-04	2.6250E-04	4.308800E-02
483	2.4000E-04	2.5500E-04	2.4750E-04	3.947400E-02
484	2.3000E-04	2.4000E-04	2.3500E-04	3.626800E-02

485	2.2000E-04	2.3000E-04	2.2500E-04	3.316200E-02
486	2.1000E-04	2.2000E-04	2.1500E-04	2.972200E-02
487	2.0000E-04	2.1000E-04	2.0500E-04	2.579600E-02
488	1.9000E-04	2.0000E-04	1.9500E-04	1.927200E-02
489	1.8000E-04	1.9000E-04	1.8500E-04	1.020300E-02
490	1.7000E-04	1.8000E-04	1.7500E-04	2.294900E-03
491	1.6000E-04	1.7000E-04	1.6500E-04	1.215600E-03
492	1.5000E-04	1.6000E-04	1.5500E-04	1.254300E-03
493	1.4250E-04	1.5000E-04	1.4625E-04	1.291200E-03
494	1.3500E-04	1.4250E-04	1.3875E-04	1.325400E-03
495	1.2750E-04	1.3500E-04	1.3125E-04	1.363200E-03
496	1.2000E-04	1.2750E-04	1.2375E-04	1.403600E-03
497	1.1500E-04	1.2000E-04	1.1750E-04	1.440900E-03
498	1.1000E-04	1.1500E-04	1.1250E-04	1.471700E-03
499	1.0500E-04	1.1000E-04	1.0750E-04	1.506700E-03
500	1.0000E-04	1.0500E-04	1.0250E-04	1.542400E-03
501	9.6000E-05	1.0000E-04	9.8000E-05	1.577400E-03
502	9.2000E-05	9.6000E-05	9.4000E-05	1.611800E-03
503	8.8000E-05	9.2000E-05	9.0000E-05	1.646300E-03
504	8.4000E-05	8.8000E-05	8.6000E-05	1.682900E-03
505	8.0000E-05	8.4000E-05	8.2000E-05	1.723400E-03
506	7.6000E-05	8.0000E-05	7.8000E-05	1.767400E-03
507	7.2000E-05	7.6000E-05	7.4000E-05	1.814400E-03
508	6.9000E-05	7.2000E-05	7.0500E-05	1.858900E-03
509	6.6000E-05	6.9000E-05	6.7500E-05	1.899700E-03
510	6.3000E-05	6.6000E-05	6.4500E-05	1.943800E-03
511	6.0000E-05	6.3000E-05	6.1500E-05	1.990400E-03
512	5.7500E-05	6.0000E-05	5.8750E-05	2.037200E-03
513	5.5000E-05	5.7500E-05	5.6250E-05	2.080800E-03
514	5.2500E-05	5.5000E-05	5.3750E-05	2.130300E-03
515	5.0000E-05	5.2500E-05	5.1250E-05	2.180700E-03
516	4.7500E-05	5.0000E-05	4.8750E-05	2.235200E-03
517	4.5000E-05	4.7500E-05	4.6250E-05	2.294600E-03
518	4.2500E-05	4.5000E-05	4.3750E-05	2.359700E-03
519	4.0000E-05	4.2500E-05	4.1250E-05	2.430400E-03
520	3.8000E-05	4.0000E-05	3.9000E-05	2.498900E-03
521	3.6000E-05	3.8000E-05	3.7000E-05	2.566800E-03
522	3.4000E-05	3.6000E-05	3.5000E-05	2.638200E-03
523	3.2000E-05	3.4000E-05	3.3000E-05	2.718700E-03
524	3.0000E-05	3.2000E-05	3.1000E-05	2.804000E-03
525	2.8000E-05	3.0000E-05	2.9000E-05	2.901200E-03
526	2.7000E-05	2.8000E-05	2.7500E-05	2.975900E-03
527	2.5500E-05	2.7000E-05	2.6250E-05	3.050100E-03
528	2.4000E-05	2.5500E-05	2.4750E-05	3.140500E-03
529	2.3000E-05	2.4000E-05	2.3500E-05	3.218800E-03

530	2.2000E-05	2.3000E-05	2.2500E-05	3.290000E-03
531	2.1000E-05	2.2000E-05	2.1500E-05	3.365400E-03
532	2.0000E-05	2.1000E-05	2.0500E-05	3.447000E-03
533	1.9000E-05	2.0000E-05	1.9500E-05	3.536100E-03
534	1.8000E-05	1.9000E-05	1.8500E-05	3.632300E-03
535	1.7000E-05	1.8000E-05	1.7500E-05	3.730700E-03
536	1.6000E-05	1.7000E-05	1.6500E-05	3.841600E-03
537	1.5000E-05	1.6000E-05	1.5500E-05	3.964100E-03
538	1.4250E-05	1.5000E-05	1.4625E-05	4.080900E-03
539	1.3500E-05	1.4250E-05	1.3875E-05	4.189300E-03
540	1.2750E-05	1.3500E-05	1.3125E-05	4.309200E-03
541	1.2000E-05	1.2750E-05	1.2375E-05	4.437000E-03
542	1.1500E-05	1.2000E-05	1.1750E-05	4.555000E-03
543	1.1000E-05	1.1500E-05	1.1250E-05	4.652700E-03
544	1.0500E-05	1.1000E-05	1.0750E-05	4.763600E-03
545	1.0000E-05	1.0500E-05	1.0250E-05	4.876600E-03
546	9.6000E-06	1.0000E-05	9.8000E-06	4.987400E-03
547	9.2000E-06	9.6000E-06	9.4000E-06	5.096200E-03
548	8.8000E-06	9.2000E-06	9.0000E-06	5.205100E-03
549	8.4000E-06	8.8000E-06	8.6000E-06	5.321000E-03
550	8.0000E-06	8.4000E-06	8.2000E-06	5.448700E-03
551	7.6000E-06	8.0000E-06	7.8000E-06	5.588000E-03
552	7.2000E-06	7.6000E-06	7.4000E-06	5.736600E-03
553	6.9000E-06	7.2000E-06	7.0500E-06	5.877700E-03
554	6.6000E-06	6.9000E-06	6.7500E-06	6.006900E-03
555	6.3000E-06	6.6000E-06	6.4500E-06	6.146400E-03
556	6.0000E-06	6.3000E-06	6.1500E-06	6.294000E-03
557	5.7500E-06	6.0000E-06	5.8750E-06	6.442200E-03
558	5.5000E-06	5.7500E-06	5.6250E-06	6.580500E-03
559	5.2500E-06	5.5000E-06	5.3750E-06	6.736900E-03
560	5.0000E-06	5.2500E-06	5.1250E-06	6.896300E-03
561	4.7500E-06	5.0000E-06	4.8750E-06	7.068400E-03
562	4.5000E-06	4.7500E-06	4.6250E-06	7.256000E-03
563	4.2500E-06	4.5000E-06	4.3750E-06	7.462101E-03
564	4.0000E-06	4.2500E-06	4.1250E-06	7.686201E-03
565	3.8000E-06	4.0000E-06	3.9000E-06	7.902800E-03
566	3.6000E-06	3.8000E-06	3.7000E-06	8.118100E-03
567	3.4000E-06	3.6000E-06	3.5000E-06	8.344101E-03
568	3.2000E-06	3.4000E-06	3.3000E-06	8.599200E-03
569	3.0000E-06	3.2000E-06	3.1000E-06	8.869400E-03
570	2.8000E-06	3.0000E-06	2.9000E-06	9.177400E-03
571	2.7000E-06	2.8000E-06	2.7500E-06	9.414100E-03
572	2.5500E-06	2.7000E-06	2.6250E-06	9.648600E-03
573	2.4000E-06	2.5500E-06	2.4750E-06	9.934201E-03
574	2.3000E-06	2.4000E-06	2.3500E-06	1.018100E-02

575	2.2000E-06	2.3000E-06	2.2500E-06	1.040600E-02
576	2.1000E-06	2.2000E-06	2.1500E-06	1.064400E-02
577	2.0000E-06	2.1000E-06	2.0500E-06	1.090300E-02
578	1.9000E-06	2.0000E-06	1.9500E-06	1.118500E-02
579	1.8000E-06	1.9000E-06	1.8500E-06	1.149000E-02
580	1.7000E-06	1.8000E-06	1.7500E-06	1.180000E-02
581	1.6000E-06	1.7000E-06	1.6500E-06	1.215000E-02
582	1.5000E-06	1.6000E-06	1.5500E-06	1.253700E-02
583	1.4250E-06	1.5000E-06	1.4625E-06	1.290700E-02
584	1.3500E-06	1.4250E-06	1.3875E-06	1.325000E-02
585	1.2750E-06	1.3500E-06	1.3125E-06	1.363000E-02
586	1.2000E-06	1.2750E-06	1.2375E-06	1.403500E-02
587	1.1500E-06	1.2000E-06	1.1750E-06	1.440800E-02
588	1.1000E-06	1.1500E-06	1.1250E-06	1.471800E-02
589	1.0500E-06	1.1000E-06	1.0750E-06	1.506900E-02
590	1.0000E-06	1.0500E-06	1.0250E-06	1.542700E-02
591	9.6000E-07	1.0000E-06	9.8000E-07	1.577800E-02
592	9.2000E-07	9.6000E-07	9.4000E-07	1.612200E-02
593	8.8000E-07	9.2000E-07	9.0000E-07	1.646500E-02
594	8.4000E-07	8.8000E-07	8.6000E-07	1.683000E-02
595	8.0000E-07	8.4000E-07	8.2000E-07	1.723200E-02
596	7.6000E-07	8.0000E-07	7.8000E-07	1.767300E-02
597	7.2000E-07	7.6000E-07	7.4000E-07	1.814300E-02
598	6.9000E-07	7.2000E-07	7.0500E-07	1.858900E-02
599	6.6000E-07	6.9000E-07	6.7500E-07	1.899900E-02
600	6.3000E-07	6.6000E-07	6.4500E-07	1.944000E-02
601	6.0000E-07	6.3000E-07	6.1500E-07	1.990700E-02
602	5.7500E-07	6.0000E-07	5.8750E-07	2.037700E-02
603	5.5000E-07	5.7500E-07	5.6250E-07	2.081400E-02
604	5.2500E-07	5.5000E-07	5.3750E-07	2.130900E-02
605	5.0000E-07	5.2500E-07	5.1250E-07	2.181200E-02
606	4.7500E-07	5.0000E-07	4.8750E-07	2.235600E-02
607	4.5000E-07	4.7500E-07	4.6250E-07	2.294500E-02
608	4.2500E-07	4.5000E-07	4.3750E-07	2.359000E-02
609	4.0000E-07	4.2500E-07	4.1250E-07	2.429600E-02
610	3.8000E-07	4.0000E-07	3.9000E-07	2.498700E-02
611	3.6000E-07	3.8000E-07	3.7000E-07	2.565400E-02
612	3.4000E-07	3.6000E-07	3.5000E-07	2.637500E-02
613	3.2000E-07	3.4000E-07	3.3000E-07	2.716100E-02
614	3.0000E-07	3.2000E-07	3.1000E-07	2.802400E-02
615	2.8000E-07	3.0000E-07	2.9000E-07	2.897200E-02
616	2.7000E-07	2.8000E-07	2.7500E-07	2.974400E-02
617	2.5500E-07	2.7000E-07	2.6250E-07	3.044900E-02
618	2.4000E-07	2.5500E-07	2.4750E-07	3.136100E-02
619	2.3000E-07	2.4000E-07	2.3500E-07	3.218100E-02

620	2.2000E-07	2.3000E-07	2.2500E-07	3.288900E-02
621	2.1000E-07	2.2000E-07	2.1500E-07	3.364600E-02
622	2.0000E-07	2.1000E-07	2.0500E-07	3.445700E-02
623	1.9000E-07	2.0000E-07	1.9500E-07	3.533600E-02
624	1.8000E-07	1.9000E-07	1.8500E-07	3.627100E-02
625	1.7000E-07	1.8000E-07	1.7500E-07	3.729400E-02
626	1.6000E-07	1.7000E-07	1.6500E-07	3.840900E-02
627	1.5000E-07	1.6000E-07	1.5500E-07	3.963200E-02
628	1.4250E-07	1.5000E-07	1.4625E-07	4.079600E-02
629	1.3500E-07	1.4250E-07	1.3875E-07	4.188700E-02
630	1.2750E-07	1.3500E-07	1.3125E-07	4.306800E-02
631	1.2000E-07	1.2750E-07	1.2375E-07	4.435400E-02
632	1.1500E-07	1.2000E-07	1.1750E-07	4.551000E-02
633	1.1000E-07	1.1500E-07	1.1250E-07	4.651000E-02
634	1.0500E-07	1.1000E-07	1.0750E-07	4.758000E-02
635	1.0000E-07	1.0500E-07	1.0250E-07	4.873000E-02
636	9.6000E-08	1.0000E-07	9.8000E-08	4.984400E-02
637	9.2000E-08	9.6000E-08	9.4000E-08	5.088700E-02
638	8.8000E-08	9.2000E-08	9.0000E-08	5.200300E-02
639	8.4000E-08	8.8000E-08	8.6000E-08	5.320000E-02
640	8.0000E-08	8.4000E-08	8.2000E-08	5.448500E-02
641	7.6000E-08	8.0000E-08	7.8000E-08	5.586800E-02
642	7.2000E-08	7.6000E-08	7.4000E-08	5.735900E-02
643	6.9000E-08	7.2000E-08	7.0500E-08	5.875900E-02
644	6.6000E-08	6.9000E-08	6.7500E-08	6.005100E-02
645	6.3000E-08	6.6000E-08	6.4500E-08	6.143200E-02
646	6.0000E-08	6.3000E-08	6.1500E-08	6.291300E-02
647	5.7500E-08	6.0000E-08	5.8750E-08	6.436400E-02
648	5.5000E-08	5.7500E-08	5.6250E-08	6.577800E-02
649	5.2500E-08	5.5000E-08	5.3750E-08	6.729200E-02
650	5.0000E-08	5.2500E-08	5.1250E-08	6.891800E-02
651	4.7500E-08	5.0000E-08	4.8750E-08	7.066600E-02
652	4.5000E-08	4.7500E-08	4.6250E-08	7.253700E-02
653	4.2500E-08	4.5000E-08	4.3750E-08	7.458300E-02
654	4.0000E-08	4.2500E-08	4.1250E-08	7.681200E-02
655	3.8000E-08	4.0000E-08	3.9000E-08	7.899401E-02
656	3.6000E-08	3.8000E-08	3.7000E-08	8.110200E-02
657	3.4000E-08	3.6000E-08	3.5000E-08	8.339000E-02
658	3.2000E-08	3.4000E-08	3.3000E-08	8.588400E-02
659	3.0000E-08	3.2000E-08	3.1000E-08	8.861101E-02
660	2.8000E-08	3.0000E-08	2.9000E-08	9.161600E-02
661	2.7000E-08	2.8000E-08	2.7500E-08	9.407600E-02
662	2.5500E-08	2.7000E-08	2.6250E-08	9.629300E-02
663	2.4000E-08	2.5500E-08	2.4750E-08	9.916200E-02
664	2.3000E-08	2.4000E-08	2.3500E-08	1.017600E-01

665	2.2000E-08	2.3000E-08	2.2500E-08	1.040000E-01
666	2.1000E-08	2.2000E-08	2.1500E-08	1.063900E-01
667	2.0000E-08	2.1000E-08	2.0500E-08	1.089600E-01
668	1.9000E-08	2.0000E-08	1.9500E-08	1.117200E-01
669	1.8000E-08	1.9000E-08	1.8500E-08	1.146800E-01
670	1.7000E-08	1.8000E-08	1.7500E-08	1.179100E-01
671	1.6000E-08	1.7000E-08	1.6500E-08	1.214300E-01
672	1.5000E-08	1.6000E-08	1.5500E-08	1.252900E-01
673	1.4250E-08	1.5000E-08	1.4625E-08	1.289800E-01
674	1.3500E-08	1.4250E-08	1.3875E-08	1.324200E-01
675	1.2750E-08	1.3500E-08	1.3125E-08	1.361500E-01
676	1.2000E-08	1.2750E-08	1.2375E-08	1.402200E-01
677	1.1500E-08	1.2000E-08	1.1750E-08	1.439000E-01
678	1.1000E-08	1.1500E-08	1.1250E-08	1.470600E-01
679	1.0500E-08	1.1000E-08	1.0750E-08	1.504500E-01
680	1.0000E-08	1.0500E-08	1.0250E-08	1.540800E-01
681	9.6000E-09	1.0000E-08	9.8000E-09	1.575900E-01
682	9.2000E-09	9.6000E-09	9.4000E-09	1.608800E-01
683	8.8000E-09	9.2000E-09	9.0000E-09	1.644100E-01
684	8.4000E-09	8.8000E-09	8.6000E-09	1.681900E-01
685	8.0000E-09	8.4000E-09	8.2000E-09	1.722400E-01
686	7.6000E-09	8.0000E-09	7.8000E-09	1.766100E-01
687	7.2000E-09	7.6000E-09	7.400002E-09	1.813200E-01
688	6.9000E-09	7.2000E-09	7.0500E-09	1.857700E-01
689	6.6000E-09	6.9000E-09	6.7500E-09	1.898500E-01
690	6.3000E-09	6.6000E-09	6.4500E-09	1.942200E-01
691	6.0000E-09	6.3000E-09	6.1500E-09	1.989000E-01
692	5.7500E-09	6.0000E-09	5.8750E-09	2.035100E-01
693	5.5000E-09	5.7500E-09	5.6250E-09	2.079800E-01
694	5.2500E-09	5.5000E-09	5.3750E-09	2.127700E-01
695	5.0000E-09	5.2500E-09	5.1250E-09	2.179100E-01
696	4.7500E-09	5.0000E-09	4.8750E-09	2.233900E-01
697	4.5000E-09	4.7500E-09	4.6250E-09	2.293500E-01
698	4.2500E-09	4.5000E-09	4.3750E-09	2.358100E-01
699	4.0000E-09	4.2500E-09	4.1250E-09	2.428500E-01
700	3.8000E-09	4.0000E-09	3.9000E-09	2.497700E-01
701	3.6000E-09	3.8000E-09	3.7000E-09	2.564300E-01
702	3.4000E-09	3.6000E-09	3.5000E-09	2.636600E-01
703	3.2000E-09	3.4000E-09	3.3000E-09	2.715400E-01
704	3.0000E-09	3.2000E-09	3.1000E-09	2.801700E-01
705	2.8000E-09	3.0000E-09	2.9000E-09	2.896300E-01
706	2.7000E-09	2.8000E-09	2.7500E-09	2.974200E-01
707	2.5500E-09	2.7000E-09	2.6250E-09	3.044200E-01
708	2.4000E-09	2.5500E-09	2.4750E-09	3.135100E-01
709	2.3000E-09	2.4000E-09	2.3500E-09	3.217500E-01

710	2.2000E-09	2.3000E-09	2.2500E-09	3.288200E-01
711	2.1000E-09	2.2000E-09	2.1500E-09	3.363800E-01
712	2.0000E-09	2.1000E-09	2.0500E-09	3.444900E-01
713	1.9000E-09	2.0000E-09	1.9500E-09	3.532700E-01
714	1.8000E-09	1.9000E-09	1.8500E-09	3.626200E-01
715	1.7000E-09	1.8000E-09	1.7500E-09	3.728400E-01
716	1.6000E-09	1.7000E-09	1.6500E-09	3.839700E-01
717	1.5000E-09	1.6000E-09	1.5500E-09	3.961700E-01
718	1.4250E-09	1.5000E-09	1.4625E-09	4.078500E-01
719	1.3500E-09	1.4250E-09	1.3875E-09	4.187400E-01
720	1.2750E-09	1.3500E-09	1.3125E-09	4.305400E-01
721	1.2000E-09	1.2750E-09	1.2375E-09	4.434000E-01
722	1.1500E-09	1.2000E-09	1.1750E-09	4.550500E-01
723	1.1000E-09	1.1500E-09	1.1250E-09	4.650500E-01
724	1.0500E-09	1.1000E-09	1.0750E-09	4.757600E-01
725	1.0000E-09	1.0500E-09	1.0250E-09	4.872500E-01
726	9.6000E-10	1.0000E-09	9.8000E-10	4.983300E-01
727	9.2000E-10	9.6000E-10	9.4000E-10	5.087500E-01
728	8.8000E-10	9.2000E-10	9.0000E-10	5.199000E-01
729	8.4000E-10	8.8000E-10	8.6000E-10	5.318400E-01
730	8.0000E-10	8.4000E-10	8.2000E-10	5.446700E-01
731	7.6000E-10	8.0000E-10	7.8000E-10	5.584700E-01
732	7.2000E-10	7.6000E-10	7.4000E-10	5.733600E-01
733	6.9000E-10	7.2000E-10	7.0500E-10	5.874400E-01
734	6.6000E-10	6.9000E-10	6.7500E-10	6.003600E-01
735	6.3000E-10	6.6000E-10	6.4500E-10	6.141700E-01
736	6.0000E-10	6.3000E-10	6.1500E-10	6.289800E-01
737	5.7500E-10	6.0000E-10	5.8750E-10	6.435301E-01
738	5.5000E-10	5.7500E-10	5.6250E-10	6.576800E-01
739	5.2500E-10	5.5000E-10	5.3750E-10	6.728200E-01
740	5.0000E-10	5.2500E-10	5.1250E-10	6.890700E-01
741	4.7500E-10	5.0000E-10	4.8750E-10	7.064000E-01
742	4.5000E-10	4.7500E-10	4.6250E-10	7.252600E-01
743	4.2500E-10	4.5000E-10	4.3750E-10	7.456800E-01
744	4.0000E-10	4.2500E-10	4.1250E-10	7.679501E-01
745	3.8000E-10	4.0000E-10	3.9000E-10	7.898200E-01
746	3.6000E-10	3.8000E-10	3.7000E-10	8.109001E-01
747	3.4000E-10	3.6000E-10	3.5000E-10	8.337600E-01
748	3.2000E-10	3.4000E-10	3.3000E-10	8.586700E-01
749	3.0000E-10	3.2000E-10	3.1000E-10	8.859600E-01
750	2.8000E-10	3.0000E-10	2.9000E-10	9.158700E-01
751	2.7000E-10	2.8000E-10	2.7500E-10	9.405200E-01
752	2.5500E-10	2.7000E-10	2.6250E-10	9.626400E-01
753	2.4000E-10	2.5500E-10	2.4750E-10	9.914001E-01
754	2.3000E-10	2.4000E-10	2.3500E-10	1.017400E+00

755	2.2000E-10	2.3000E-10	2.2500E-10	1.039800E+00
756	2.1000E-10	2.2000E-10	2.1500E-10	1.063700E+00
757	2.0000E-10	2.1000E-10	2.0500E-10	1.089400E+00
758	1.9000E-10	2.0000E-10	1.9500E-10	1.117100E+00
759	1.8000E-10	1.9000E-10	1.8500E-10	1.146700E+00
760	1.7000E-10	1.8000E-10	1.7500E-10	1.179000E+00
761	1.6000E-10	1.7000E-10	1.6500E-10	1.214200E+00
762	1.5000E-10	1.6000E-10	1.5500E-10	1.252800E+00
763	1.4250E-10	1.5000E-10	1.4625E-10	1.289700E+00
764	1.3500E-10	1.4250E-10	1.3875E-10	1.324100E+00
765	1.2750E-10	1.3500E-10	1.3125E-10	1.361500E+00
766	1.2000E-10	1.2750E-10	1.2375E-10	1.402100E+00
767	1.1500E-10	1.2000E-10	1.1750E-10	1.439000E+00
768	1.1000E-10	1.1500E-10	1.1250E-10	1.470600E+00
769	1.0500E-10	1.1000E-10	1.0750E-10	1.504500E+00
770	1.0000E-10	1.0500E-10	1.0250E-10	1.540800E+00

Table 4: Tabular Comparison of ^{28}Si Neutron Damage Metrics

Bin #	Microscopic Displacement Kerma Factor (MeV-mbarn)	Kinchin-Pease (MeV-mbarn)	Sharp-threshold Kinchin-Pease (MeV-mbarn)	NRT (MeV-mbarn)
1	5.910600E+01	5.910600E+01	5.879000E+01	5.910600E+01
2	5.937300E+01	5.937300E+01	5.905600E+01	5.937300E+01
3	5.964800E+01	5.964800E+01	5.933000E+01	5.964800E+01
4	5.992600E+01	5.992600E+01	5.960800E+01	5.992600E+01
5	6.021400E+01	6.021400E+01	5.989500E+01	6.021400E+01
6	6.050500E+01	6.050500E+01	6.018600E+01	6.050500E+01
7	6.080800E+01	6.080800E+01	6.048700E+01	6.080800E+01
8	6.111500E+01	6.111500E+01	6.079300E+01	6.111500E+01
9	6.143500E+01	6.143500E+01	6.111200E+01	6.143500E+01
10	6.176000E+01	6.176000E+01	6.143600E+01	6.176000E+01
11	6.208100E+01	6.208100E+01	6.175600E+01	6.208100E+01
12	6.239800E+01	6.239800E+01	6.207200E+01	6.239800E+01
13	6.272500E+01	6.272500E+01	6.239800E+01	6.272500E+01
14	6.305600E+01	6.305600E+01	6.272800E+01	6.305600E+01
15	6.339600E+01	6.339600E+01	6.306700E+01	6.339600E+01
16	6.374100E+01	6.374100E+01	6.341100E+01	6.374100E+01
17	6.409700E+01	6.409700E+01	6.376500E+01	6.409700E+01
18	6.445700E+01	6.445700E+01	6.412500E+01	6.445700E+01
19	6.482900E+01	6.482900E+01	6.449500E+01	6.482900E+01
20	6.520600E+01	6.520600E+01	6.487100E+01	6.520600E+01
21	6.560900E+01	6.560900E+01	6.527200E+01	6.560900E+01
22	6.602500E+01	6.602500E+01	6.568700E+01	6.602500E+01
23	6.644901E+01	6.644901E+01	6.611000E+01	6.644901E+01
24	6.687801E+01	6.687801E+01	6.653700E+01	6.687801E+01
25	6.731800E+01	6.731800E+01	6.697501E+01	6.731800E+01
26	6.776300E+01	6.776300E+01	6.741901E+01	6.776300E+01
27	6.822100E+01	6.822100E+01	6.787500E+01	6.822100E+01
28	6.868501E+01	6.868501E+01	6.833801E+01	6.868501E+01
29	6.916500E+01	6.916500E+01	6.881500E+01	6.916500E+01
30	6.965200E+01	6.965200E+01	6.930100E+01	6.965200E+01
31	7.023200E+01	7.023200E+01	6.987801E+01	7.023200E+01
32	7.085800E+01	7.085800E+01	7.050201E+01	7.085800E+01
33	7.149700E+01	7.149700E+01	7.113900E+01	7.149700E+01
34	7.214400E+01	7.214400E+01	7.178300E+01	7.214400E+01
35	7.280500E+01	7.280500E+01	7.244100E+01	7.280500E+01
36	7.347200E+01	7.347200E+01	7.310600E+01	7.347200E+01
37	7.415601E+01	7.415601E+01	7.378600E+01	7.415601E+01
38	7.484700E+01	7.484700E+01	7.447401E+01	7.484700E+01
39	7.555300E+01	7.555300E+01	7.517800E+01	7.555300E+01

40	7.626801E+01	7.626801E+01	7.589001E+01	7.626801E+01
41	7.697501E+01	7.697501E+01	7.659400E+01	7.697501E+01
42	7.767900E+01	7.767900E+01	7.729401E+01	7.767900E+01
43	7.839500E+01	7.839500E+01	7.800800E+01	7.839500E+01
44	7.911900E+01	7.911900E+01	7.872900E+01	7.911900E+01
45	7.985900E+01	7.985900E+01	7.946600E+01	7.985900E+01
46	8.060600E+01	8.060600E+01	8.021001E+01	8.060600E+01
47	8.137400E+01	8.137400E+01	8.097401E+01	8.137400E+01
48	8.215000E+01	8.215000E+01	8.174800E+01	8.215000E+01
49	8.295000E+01	8.295000E+01	8.254501E+01	8.295000E+01
50	8.376200E+01	8.376200E+01	8.335300E+01	8.376200E+01
51	8.459801E+01	8.459801E+01	8.418501E+01	8.459801E+01
52	8.546001E+01	8.546001E+01	8.504401E+01	8.546001E+01
53	8.634000E+01	8.634000E+01	8.592101E+01	8.634000E+01
54	8.723901E+01	8.723901E+01	8.681600E+01	8.723901E+01
55	8.815601E+01	8.815601E+01	8.772900E+01	8.815601E+01
56	8.909200E+01	8.909200E+01	8.866200E+01	8.909200E+01
57	9.004700E+01	9.004700E+01	8.961301E+01	9.004700E+01
58	9.102100E+01	9.102100E+01	9.058200E+01	9.102100E+01
59	9.201200E+01	9.201200E+01	9.157001E+01	9.201200E+01
60	9.302100E+01	9.302100E+01	9.257401E+01	9.302100E+01
61	9.407301E+01	9.407301E+01	9.362200E+01	9.407301E+01
62	9.513700E+01	9.513700E+01	9.468201E+01	9.513700E+01
63	9.619901E+01	9.619901E+01	9.573901E+01	9.619901E+01
64	9.727701E+01	9.727701E+01	9.681300E+01	9.727701E+01
65	9.839201E+01	9.839201E+01	9.792300E+01	9.839201E+01
66	9.954700E+01	9.954700E+01	9.907301E+01	9.954700E+01
67	1.007400E+02	1.007400E+02	1.002700E+02	1.007400E+02
68	1.019800E+02	1.019800E+02	1.015000E+02	1.019800E+02
69	1.032300E+02	1.032300E+02	1.027400E+02	1.032300E+02
70	1.044800E+02	1.044800E+02	1.039900E+02	1.044800E+02
71	1.057000E+02	1.057000E+02	1.052000E+02	1.057000E+02
72	1.069000E+02	1.069000E+02	1.064000E+02	1.069000E+02
73	1.081200E+02	1.081200E+02	1.076100E+02	1.081200E+02
74	1.093600E+02	1.093600E+02	1.088500E+02	1.093600E+02
75	1.106200E+02	1.106200E+02	1.101100E+02	1.106200E+02
76	1.119300E+02	1.119300E+02	1.114100E+02	1.119300E+02
77	1.132700E+02	1.132700E+02	1.127400E+02	1.132700E+02
78	1.146400E+02	1.146400E+02	1.141000E+02	1.146400E+02
79	1.160000E+02	1.160000E+02	1.154600E+02	1.160000E+02
80	1.174000E+02	1.174000E+02	1.168600E+02	1.174000E+02
81	1.187500E+02	1.187500E+02	1.182000E+02	1.187500E+02
82	1.200600E+02	1.200600E+02	1.195000E+02	1.200600E+02
83	1.213600E+02	1.213600E+02	1.208000E+02	1.213600E+02
84	1.226700E+02	1.226700E+02	1.221000E+02	1.226700E+02

85	1.239800E+02	1.239800E+02	1.234100E+02	1.239800E+02
86	1.253800E+02	1.253800E+02	1.248000E+02	1.253800E+02
87	1.268000E+02	1.268000E+02	1.262200E+02	1.268000E+02
88	1.282300E+02	1.282300E+02	1.276500E+02	1.282300E+02
89	1.297200E+02	1.297200E+02	1.291300E+02	1.297200E+02
90	1.312200E+02	1.312200E+02	1.306300E+02	1.312200E+02
91	1.327700E+02	1.327700E+02	1.321700E+02	1.327700E+02
92	1.343400E+02	1.343400E+02	1.337300E+02	1.343400E+02
93	1.359300E+02	1.359300E+02	1.353100E+02	1.359300E+02
94	1.375200E+02	1.375200E+02	1.368900E+02	1.375200E+02
95	1.391200E+02	1.391200E+02	1.384900E+02	1.391200E+02
96	1.407200E+02	1.407200E+02	1.400800E+02	1.407200E+02
97	1.422800E+02	1.422800E+02	1.416400E+02	1.422800E+02
98	1.438000E+02	1.438000E+02	1.431500E+02	1.438000E+02
99	1.452900E+02	1.452900E+02	1.446400E+02	1.452900E+02
100	1.468000E+02	1.468000E+02	1.461400E+02	1.468000E+02
101	1.475300E+02	1.475300E+02	1.468700E+02	1.475300E+02
102	1.477100E+02	1.477100E+02	1.470500E+02	1.477100E+02
103	1.479200E+02	1.479200E+02	1.472600E+02	1.479200E+02
104	1.481700E+02	1.481700E+02	1.475100E+02	1.481700E+02
105	1.484700E+02	1.484700E+02	1.478100E+02	1.484700E+02
106	1.497000E+02	1.497000E+02	1.490400E+02	1.497000E+02
107	1.516600E+02	1.516600E+02	1.509900E+02	1.516600E+02
108	1.536600E+02	1.536600E+02	1.529800E+02	1.536600E+02
109	1.556600E+02	1.556600E+02	1.549700E+02	1.556600E+02
110	1.575700E+02	1.575700E+02	1.568700E+02	1.575700E+02
111	1.593500E+02	1.593500E+02	1.586400E+02	1.593500E+02
112	1.610700E+02	1.610700E+02	1.603600E+02	1.610700E+02
113	1.627000E+02	1.627000E+02	1.619800E+02	1.627000E+02
114	1.642700E+02	1.642700E+02	1.635400E+02	1.642700E+02
115	1.657600E+02	1.657600E+02	1.650300E+02	1.657600E+02
116	1.672200E+02	1.672200E+02	1.664700E+02	1.672200E+02
117	1.686700E+02	1.686700E+02	1.679200E+02	1.686700E+02
118	1.700600E+02	1.700600E+02	1.693000E+02	1.700600E+02
119	1.713900E+02	1.713900E+02	1.706200E+02	1.713900E+02
120	1.726900E+02	1.726900E+02	1.719300E+02	1.726900E+02
121	1.740500E+02	1.740500E+02	1.732800E+02	1.740500E+02
122	1.754600E+02	1.754600E+02	1.746800E+02	1.754600E+02
123	1.767800E+02	1.767800E+02	1.759900E+02	1.767800E+02
124	1.779900E+02	1.779900E+02	1.772000E+02	1.779900E+02
125	1.791500E+02	1.791500E+02	1.783500E+02	1.791500E+02
126	1.802400E+02	1.802400E+02	1.794300E+02	1.802400E+02
127	1.809500E+02	1.809500E+02	1.801400E+02	1.809500E+02
128	1.813800E+02	1.813800E+02	1.805700E+02	1.813800E+02
129	1.799500E+02	1.799500E+02	1.791500E+02	1.799500E+02

130	1.768500E+02	1.768500E+02	1.760600E+02	1.768500E+02
131	1.966100E+02	1.966100E+02	1.956900E+02	1.966100E+02
132	1.959800E+02	1.959800E+02	1.950600E+02	1.959800E+02
133	1.953400E+02	1.953400E+02	1.944200E+02	1.953400E+02
134	1.947500E+02	1.947500E+02	1.938400E+02	1.947500E+02
135	1.944400E+02	1.944400E+02	1.935300E+02	1.944400E+02
136	1.941800E+02	1.941800E+02	1.932700E+02	1.941800E+02
137	1.941400E+02	1.941400E+02	1.932300E+02	1.941400E+02
138	1.942500E+02	1.942500E+02	1.933500E+02	1.942500E+02
139	1.947000E+02	1.947000E+02	1.937900E+02	1.947000E+02
140	1.960000E+02	1.960000E+02	1.950900E+02	1.960000E+02
141	1.972800E+02	1.972800E+02	1.963700E+02	1.972800E+02
142	1.982200E+02	1.982200E+02	1.973000E+02	1.982200E+02
143	1.990200E+02	1.990200E+02	1.981000E+02	1.990200E+02
144	1.968500E+02	1.968500E+02	1.959400E+02	1.968500E+02
145	1.929500E+02	1.929500E+02	1.920500E+02	1.929500E+02
146	1.910900E+02	1.910900E+02	1.902000E+02	1.910900E+02
147	1.921000E+02	1.921000E+02	1.912000E+02	1.921000E+02
148	1.932100E+02	1.932100E+02	1.923200E+02	1.932100E+02
149	1.946200E+02	1.946200E+02	1.937200E+02	1.946200E+02
150	1.954200E+02	1.954200E+02	1.945200E+02	1.954200E+02
151	1.931700E+02	1.931700E+02	1.922700E+02	1.931700E+02
152	1.907000E+02	1.907000E+02	1.898200E+02	1.907000E+02
153	1.895000E+02	1.895000E+02	1.886200E+02	1.895000E+02
154	1.887200E+02	1.887200E+02	1.878400E+02	1.887200E+02
155	1.897400E+02	1.897400E+02	1.888600E+02	1.897400E+02
156	1.911100E+02	1.911100E+02	1.902300E+02	1.911100E+02
157	1.912900E+02	1.912900E+02	1.904100E+02	1.912900E+02
158	1.911300E+02	1.911300E+02	1.902600E+02	1.911300E+02
159	1.913100E+02	1.913100E+02	1.904400E+02	1.913100E+02
160	1.915400E+02	1.915400E+02	1.906700E+02	1.915400E+02
161	1.909500E+02	1.909500E+02	1.900800E+02	1.909500E+02
162	1.903800E+02	1.903800E+02	1.895100E+02	1.903800E+02
163	1.924600E+02	1.924600E+02	1.915900E+02	1.924600E+02
164	1.941100E+02	1.941100E+02	1.932300E+02	1.941100E+02
165	1.890500E+02	1.890500E+02	1.882000E+02	1.890500E+02
166	1.843900E+02	1.843900E+02	1.835500E+02	1.843900E+02
167	1.852800E+02	1.852800E+02	1.844400E+02	1.852800E+02
168	1.864500E+02	1.864500E+02	1.856100E+02	1.864500E+02
169	1.870100E+02	1.870100E+02	1.861700E+02	1.870100E+02
170	1.869400E+02	1.869400E+02	1.861000E+02	1.869400E+02
171	1.861100E+02	1.861100E+02	1.852800E+02	1.861100E+02
172	1.828600E+02	1.828600E+02	1.820400E+02	1.828600E+02
173	1.788500E+02	1.788500E+02	1.780400E+02	1.788500E+02
174	1.777400E+02	1.777400E+02	1.769400E+02	1.777400E+02

175	1.778700E+02	1.778700E+02	1.770700E+02	1.778700E+02
176	1.796900E+02	1.796900E+02	1.788900E+02	1.796900E+02
177	1.808200E+02	1.808200E+02	1.800100E+02	1.808200E+02
178	1.808900E+02	1.808900E+02	1.800900E+02	1.808900E+02
179	1.768800E+02	1.768800E+02	1.760900E+02	1.768800E+02
180	1.741600E+02	1.741600E+02	1.733800E+02	1.741600E+02
181	1.778700E+02	1.778700E+02	1.770800E+02	1.778700E+02
182	1.772400E+02	1.772400E+02	1.764600E+02	1.772400E+02
183	1.739600E+02	1.739600E+02	1.731900E+02	1.739600E+02
184	1.730600E+02	1.730600E+02	1.722900E+02	1.730600E+02
185	1.753600E+02	1.753600E+02	1.745900E+02	1.753600E+02
186	1.804700E+02	1.804700E+02	1.796800E+02	1.804700E+02
187	1.802900E+02	1.802900E+02	1.795100E+02	1.802900E+02
188	1.790600E+02	1.790600E+02	1.782800E+02	1.790600E+02
189	1.778200E+02	1.778200E+02	1.770500E+02	1.778200E+02
190	1.749000E+02	1.749000E+02	1.741300E+02	1.749000E+02
191	1.769100E+02	1.769100E+02	1.761300E+02	1.769100E+02
192	1.827700E+02	1.827700E+02	1.819800E+02	1.827700E+02
193	1.764700E+02	1.764700E+02	1.757000E+02	1.764700E+02
194	1.740800E+02	1.740800E+02	1.733200E+02	1.740800E+02
195	1.762200E+02	1.762200E+02	1.754600E+02	1.762200E+02
196	1.796700E+02	1.796700E+02	1.788900E+02	1.796700E+02
197	1.764900E+02	1.764900E+02	1.757300E+02	1.764900E+02
198	1.752400E+02	1.752400E+02	1.744800E+02	1.752400E+02
199	1.784700E+02	1.784700E+02	1.777000E+02	1.784700E+02
200	1.816300E+02	1.816300E+02	1.808600E+02	1.816300E+02
201	1.807700E+02	1.807700E+02	1.800000E+02	1.807700E+02
202	1.804300E+02	1.804300E+02	1.796600E+02	1.804300E+02
203	1.810300E+02	1.810300E+02	1.802600E+02	1.810300E+02
204	1.791600E+02	1.791600E+02	1.783900E+02	1.791600E+02
205	1.715700E+02	1.715700E+02	1.708300E+02	1.715700E+02
206	1.747000E+02	1.747000E+02	1.739500E+02	1.747000E+02
207	1.776800E+02	1.776800E+02	1.769200E+02	1.776800E+02
208	1.770100E+02	1.770100E+02	1.762600E+02	1.770100E+02
209	1.766900E+02	1.766900E+02	1.759400E+02	1.766900E+02
210	1.739900E+02	1.739900E+02	1.732500E+02	1.739900E+02
211	1.723500E+02	1.723500E+02	1.716200E+02	1.723500E+02
212	1.710700E+02	1.710700E+02	1.703400E+02	1.710700E+02
213	1.707600E+02	1.707600E+02	1.700400E+02	1.707600E+02
214	1.722600E+02	1.722600E+02	1.715300E+02	1.722600E+02
215	1.732600E+02	1.732600E+02	1.725300E+02	1.732600E+02
216	1.720500E+02	1.720500E+02	1.713200E+02	1.720500E+02
217	1.691200E+02	1.691200E+02	1.684100E+02	1.691200E+02
218	1.649900E+02	1.649900E+02	1.642900E+02	1.649900E+02
219	1.638300E+02	1.638300E+02	1.631400E+02	1.638300E+02

220	1.691000E+02	1.691000E+02	1.683900E+02	1.691000E+02
221	1.718000E+02	1.718000E+02	1.710800E+02	1.718000E+02
222	1.719200E+02	1.719200E+02	1.712000E+02	1.719200E+02
223	1.681800E+02	1.681800E+02	1.674700E+02	1.681800E+02
224	1.633500E+02	1.633500E+02	1.626600E+02	1.633500E+02
225	1.654800E+02	1.654800E+02	1.647900E+02	1.654800E+02
226	1.667000E+02	1.667000E+02	1.660100E+02	1.667000E+02
227	1.727600E+02	1.727600E+02	1.720400E+02	1.727600E+02
228	1.720300E+02	1.720300E+02	1.713200E+02	1.720300E+02
229	1.737100E+02	1.737100E+02	1.730000E+02	1.737100E+02
230	1.716700E+02	1.716700E+02	1.709700E+02	1.716700E+02
231	1.735200E+02	1.735200E+02	1.728000E+02	1.735200E+02
232	1.711300E+02	1.711300E+02	1.704300E+02	1.711300E+02
233	1.667200E+02	1.667200E+02	1.660300E+02	1.667200E+02
234	1.631700E+02	1.631700E+02	1.625000E+02	1.631700E+02
235	1.725700E+02	1.725700E+02	1.718700E+02	1.725700E+02
236	1.778800E+02	1.778800E+02	1.771600E+02	1.778800E+02
237	1.708100E+02	1.708100E+02	1.701200E+02	1.708100E+02
238	1.573000E+02	1.573000E+02	1.566600E+02	1.573000E+02
239	1.627900E+02	1.627900E+02	1.621400E+02	1.627900E+02
240	1.830800E+02	1.830800E+02	1.823400E+02	1.830800E+02
241	1.837600E+02	1.837600E+02	1.830200E+02	1.837600E+02
242	1.637800E+02	1.637800E+02	1.631200E+02	1.637800E+02
243	1.529000E+02	1.529000E+02	1.522900E+02	1.529000E+02
244	1.708400E+02	1.708400E+02	1.701600E+02	1.708400E+02
245	1.716100E+02	1.716100E+02	1.709300E+02	1.716100E+02
246	1.728000E+02	1.728000E+02	1.721200E+02	1.728000E+02
247	1.715700E+02	1.715700E+02	1.709000E+02	1.715700E+02
248	1.692600E+02	1.692600E+02	1.685900E+02	1.692600E+02
249	1.624500E+02	1.624500E+02	1.618000E+02	1.624500E+02
250	1.776700E+02	1.776700E+02	1.769600E+02	1.776700E+02
251	1.952800E+02	1.952800E+02	1.945100E+02	1.952800E+02
252	1.815800E+02	1.815800E+02	1.808700E+02	1.815800E+02
253	1.814900E+02	1.814900E+02	1.807900E+02	1.814900E+02
254	1.747600E+02	1.747600E+02	1.740800E+02	1.747600E+02
255	1.719400E+02	1.719400E+02	1.712700E+02	1.719400E+02
256	1.746300E+02	1.746300E+02	1.739600E+02	1.746300E+02
257	1.764700E+02	1.764700E+02	1.758000E+02	1.764700E+02
258	1.759700E+02	1.759700E+02	1.753100E+02	1.759700E+02
259	1.427900E+02	1.427900E+02	1.422500E+02	1.427900E+02
260	1.735500E+02	1.735500E+02	1.729000E+02	1.735500E+02
261	1.474500E+02	1.474500E+02	1.469000E+02	1.474500E+02
262	1.527900E+02	1.527900E+02	1.522200E+02	1.527900E+02
263	1.731500E+02	1.731500E+02	1.725200E+02	1.731500E+02
264	1.568100E+02	1.568100E+02	1.562400E+02	1.568100E+02

265	1.281800E+02	1.281800E+02	1.277100E+02	1.281800E+02
266	1.470700E+02	1.470700E+02	1.465400E+02	1.470700E+02
267	1.590500E+02	1.590500E+02	1.584900E+02	1.590500E+02
268	1.834200E+02	1.834200E+02	1.827800E+02	1.834200E+02
269	1.317700E+02	1.317700E+02	1.313000E+02	1.317700E+02
270	1.610800E+02	1.610800E+02	1.605100E+02	1.610800E+02
271	1.419100E+02	1.419100E+02	1.414100E+02	1.419100E+02
272	1.734500E+02	1.734500E+02	1.728500E+02	1.734500E+02
273	1.875300E+02	1.875300E+02	1.868800E+02	1.875300E+02
274	1.557100E+02	1.557100E+02	1.551700E+02	1.557100E+02
275	1.514500E+02	1.514500E+02	1.509300E+02	1.514500E+02
276	1.231100E+02	1.231100E+02	1.226900E+02	1.231100E+02
277	1.288900E+02	1.288900E+02	1.284500E+02	1.288900E+02
278	1.554000E+02	1.554000E+02	1.548700E+02	1.554000E+02
279	1.767400E+02	1.767400E+02	1.761400E+02	1.767400E+02
280	1.548900E+02	1.548900E+02	1.543700E+02	1.548900E+02
281	1.511000E+02	1.511000E+02	1.505900E+02	1.511000E+02
282	1.650100E+02	1.650100E+02	1.644600E+02	1.650100E+02
283	1.930600E+02	1.930600E+02	1.924200E+02	1.930600E+02
284	1.607700E+02	1.607700E+02	1.602400E+02	1.607700E+02
285	1.436400E+02	1.436400E+02	1.431800E+02	1.436400E+02
286	1.443900E+02	1.443900E+02	1.439300E+02	1.443900E+02
287	1.383700E+02	1.383700E+02	1.379400E+02	1.383700E+02
288	1.710800E+02	1.710800E+02	1.705400E+02	1.710800E+02
289	1.099100E+02	1.099100E+02	1.095700E+02	1.099100E+02
290	1.367500E+02	1.367500E+02	1.363300E+02	1.367500E+02
291	1.391500E+02	1.391500E+02	1.387200E+02	1.391500E+02
292	1.138100E+02	1.138100E+02	1.134700E+02	1.138100E+02
293	1.184000E+02	1.184000E+02	1.180500E+02	1.184000E+02
294	7.105200E+01	7.105200E+01	7.084400E+01	7.105200E+01
295	1.158500E+02	1.158500E+02	1.155100E+02	1.158500E+02
296	1.201200E+02	1.201200E+02	1.197800E+02	1.201200E+02
297	1.165700E+02	1.165700E+02	1.162300E+02	1.165700E+02
298	1.229500E+02	1.229500E+02	1.225900E+02	1.229500E+02
299	1.365000E+02	1.365000E+02	1.361100E+02	1.365000E+02
300	1.218800E+02	1.218800E+02	1.215300E+02	1.218800E+02
301	1.011100E+02	1.011100E+02	1.008300E+02	1.011100E+02
302	1.375200E+02	1.375200E+02	1.371500E+02	1.375200E+02
303	1.098000E+02	1.098000E+02	1.095100E+02	1.098000E+02
304	1.177600E+02	1.177600E+02	1.174500E+02	1.177600E+02
305	1.316600E+02	1.316600E+02	1.313300E+02	1.316600E+02
306	1.208400E+02	1.208400E+02	1.205300E+02	1.208400E+02
307	1.054000E+02	1.054000E+02	1.051400E+02	1.054000E+02
308	1.072500E+02	1.072500E+02	1.069900E+02	1.072500E+02
309	1.101500E+02	1.101500E+02	1.098900E+02	1.101500E+02

310	9.711001E+01	9.711001E+01	9.687200E+01	9.711001E+01
311	1.321300E+02	1.321300E+02	1.318100E+02	1.321300E+02
312	1.338200E+02	1.338200E+02	1.335100E+02	1.338200E+02
313	8.041901E+01	8.041901E+01	8.022200E+01	8.041901E+01
314	1.769400E+02	1.769400E+02	1.764900E+02	1.769400E+02
315	1.106600E+02	1.106600E+02	1.104100E+02	1.106600E+02
316	1.045300E+02	1.045300E+02	1.042900E+02	1.045300E+02
317	8.950600E+01	8.950600E+01	8.931001E+01	8.950600E+01
318	9.237300E+01	9.237300E+01	9.217600E+01	9.237300E+01
319	6.245200E+01	6.245200E+01	6.232800E+01	6.245200E+01
320	7.969000E+01	7.969000E+01	7.954201E+01	7.969000E+01
321	1.178100E+02	1.178100E+02	1.176000E+02	1.178100E+02
322	1.170700E+02	1.170700E+02	1.168500E+02	1.170700E+02
323	9.282900E+01	9.282900E+01	9.265401E+01	9.282900E+01
324	8.163800E+01	8.163800E+01	8.149400E+01	8.163800E+01
325	1.470400E+02	1.470400E+02	1.467800E+02	1.470400E+02
326	8.975101E+01	8.975101E+01	8.957500E+01	8.975101E+01
327	6.226100E+01	6.226100E+01	6.214600E+01	6.226100E+01
328	5.809400E+01	5.809400E+01	5.799000E+01	5.809400E+01
329	5.549300E+01	5.549300E+01	5.539600E+01	5.549300E+01
330	5.324500E+01	5.324600E+01	5.315600E+01	5.324600E+01
331	5.306000E+01	5.306000E+01	5.297400E+01	5.306000E+01
332	5.817100E+01	5.817100E+01	5.808200E+01	5.817100E+01
333	1.264900E+02	1.264900E+02	1.262900E+02	1.264900E+02
334	7.358701E+01	7.358701E+01	7.346101E+01	7.358701E+01
335	5.870500E+01	5.870500E+01	5.861000E+01	5.870500E+01
336	5.655800E+01	5.655800E+01	5.646800E+01	5.655800E+01
337	5.505000E+01	5.505000E+01	5.496400E+01	5.505000E+01
338	5.359100E+01	5.359100E+01	5.351000E+01	5.359100E+01
339	5.217800E+01	5.217800E+01	5.210000E+01	5.217800E+01
340	5.148400E+01	5.148400E+01	5.140900E+01	5.148400E+01
341	5.152200E+01	5.152200E+01	5.144800E+01	5.152200E+01
342	5.208400E+01	5.208400E+01	5.201100E+01	5.208400E+01
343	5.221600E+01	5.221600E+01	5.214400E+01	5.221600E+01
344	5.302100E+01	5.302100E+01	5.294900E+01	5.302100E+01
345	5.473700E+01	5.473700E+01	5.466400E+01	5.473700E+01
346	5.627900E+01	5.627900E+01	5.620500E+01	5.627900E+01
347	5.856400E+01	5.856400E+01	5.848800E+01	5.856400E+01
348	6.264700E+01	6.264700E+01	6.256700E+01	6.264700E+01
349	6.793301E+01	6.793301E+01	6.784800E+01	6.793301E+01
350	7.441500E+01	7.441500E+01	7.432301E+01	7.441500E+01
351	8.400101E+01	8.400101E+01	8.389900E+01	8.400101E+01
352	9.818800E+01	9.818800E+01	9.807001E+01	9.818800E+01
353	1.166800E+02	1.166800E+02	1.165400E+02	1.166800E+02
354	1.190000E+02	1.190000E+02	1.188600E+02	1.190000E+02

355	7.073701E+01	7.073600E+01	7.065401E+01	7.073701E+01
356	2.080900E+01	2.080900E+01	2.078500E+01	2.080900E+01
357	3.180600E+00	3.180600E+00	3.177000E+00	3.180600E+00
358	1.668700E-01	1.668700E-01	1.666900E-01	1.668700E-01
359	4.166600E-01	4.166700E-01	4.162200E-01	4.166700E-01
360	1.236200E+00	1.236200E+00	1.234900E+00	1.236200E+00
361	2.144100E+00	2.144100E+00	2.141900E+00	2.144100E+00
362	2.857300E+00	2.857300E+00	2.854400E+00	2.857300E+00
363	3.365600E+00	3.365600E+00	3.362200E+00	3.365700E+00
364	3.804400E+00	3.804500E+00	3.800600E+00	3.804500E+00
365	4.190800E+00	4.190800E+00	4.186700E+00	4.190900E+00
366	4.508201E+00	4.508201E+00	4.503800E+00	4.508201E+00
367	4.743100E+00	4.743100E+00	4.738500E+00	4.743200E+00
368	4.950100E+00	4.950100E+00	4.945300E+00	4.950201E+00
369	5.157701E+00	5.157800E+00	5.152800E+00	5.157800E+00
370	5.300500E+00	5.300500E+00	5.295500E+00	5.300500E+00
371	5.467600E+00	5.467500E+00	5.462400E+00	5.467600E+00
372	5.656701E+00	5.656600E+00	5.651400E+00	5.656701E+00
373	5.870400E+00	5.870400E+00	5.865100E+00	5.870500E+00
374	6.370100E+00	6.370201E+00	6.364300E+00	6.370400E+00
375	6.658300E+00	6.658300E+00	6.652300E+00	6.658300E+00
376	7.812400E+00	7.812400E+00	7.805400E+00	7.812500E+00
377	1.165300E+01	1.165300E+01	1.164300E+01	1.165300E+01
378	5.202000E+01	5.202100E+01	5.197500E+01	5.202200E+01
379	1.028900E+00	1.028900E+00	1.028000E+00	1.029000E+00
380	1.346500E+00	1.346500E+00	1.345400E+00	1.346600E+00
381	2.076500E+00	2.076500E+00	2.074700E+00	2.076500E+00
382	2.419000E+00	2.419000E+00	2.416900E+00	2.419100E+00
383	2.584300E+00	2.584400E+00	2.582200E+00	2.584500E+00
384	2.652000E+00	2.652100E+00	2.649800E+00	2.652200E+00
385	2.656800E+00	2.656900E+00	2.654700E+00	2.657000E+00
386	2.626400E+00	2.626500E+00	2.624300E+00	2.626700E+00
387	2.573800E+00	2.574000E+00	2.571800E+00	2.574100E+00
388	2.505300E+00	2.505300E+00	2.503200E+00	2.505400E+00
389	2.423800E+00	2.423700E+00	2.421800E+00	2.423800E+00
390	2.324500E+00	2.324500E+00	2.322700E+00	2.324600E+00
391	2.242100E+00	2.242100E+00	2.240300E+00	2.242300E+00
392	2.170600E+00	2.170600E+00	2.168900E+00	2.170800E+00
393	2.084500E+00	2.084600E+00	2.082900E+00	2.084800E+00
394	2.005600E+00	2.005700E+00	2.004000E+00	2.005900E+00
395	1.939300E+00	1.939400E+00	1.937800E+00	1.939600E+00
396	1.873000E+00	1.873100E+00	1.871600E+00	1.873300E+00
397	1.806700E+00	1.806900E+00	1.805300E+00	1.807100E+00
398	1.737000E+00	1.737200E+00	1.735700E+00	1.737400E+00
399	1.664100E+00	1.664100E+00	1.662700E+00	1.664300E+00

400	1.590500E+00	1.590500E+00	1.589200E+00	1.590700E+00
401	1.513600E+00	1.513600E+00	1.512400E+00	1.513900E+00
402	1.436200E+00	1.436300E+00	1.435100E+00	1.436500E+00
403	1.367100E+00	1.367200E+00	1.366000E+00	1.367400E+00
404	1.305800E+00	1.306000E+00	1.304800E+00	1.306300E+00
405	1.244500E+00	1.244700E+00	1.243600E+00	1.245100E+00
406	1.182700E+00	1.182900E+00	1.181800E+00	1.183300E+00
407	1.130000E+00	1.130100E+00	1.129000E+00	1.130400E+00
408	1.087500E+00	1.087400E+00	1.086500E+00	1.087700E+00
409	1.044100E+00	1.044100E+00	1.043100E+00	1.044500E+00
410	1.000700E+00	1.000700E+00	9.997200E-01	1.001100E+00
411	9.611600E-01	9.612701E-01	9.602700E-01	9.617500E-01
412	9.255301E-01	9.256800E-01	9.246801E-01	9.261900E-01
413	8.899100E-01	8.901000E-01	8.890901E-01	8.906301E-01
414	8.539500E-01	8.541300E-01	8.531401E-01	8.546900E-01
415	8.174601E-01	8.175800E-01	8.166201E-01	8.181400E-01
416	7.809700E-01	7.810100E-01	7.800901E-01	7.815800E-01
417	7.442200E-01	7.442501E-01	7.433401E-01	7.448401E-01
418	7.116100E-01	7.117500E-01	7.107701E-01	7.123901E-01
419	6.835800E-01	6.838101E-01	6.827701E-01	6.845000E-01
420	6.555500E-01	6.558600E-01	6.547801E-01	6.566000E-01
421	6.273301E-01	6.276301E-01	6.265500E-01	6.284200E-01
422	6.012000E-01	6.013100E-01	6.003401E-01	6.021501E-01
423	5.773700E-01	5.773401E-01	5.764500E-01	5.782200E-01
424	5.533201E-01	5.533900E-01	5.524200E-01	5.542800E-01
425	5.292300E-01	5.294501E-01	5.283800E-01	5.303401E-01
426	5.049700E-01	5.052200E-01	5.041000E-01	5.061300E-01
427	4.805400E-01	4.807200E-01	4.796100E-01	4.816500E-01
428	4.561000E-01	4.562200E-01	4.551200E-01	4.571800E-01
429	4.315300E-01	4.316800E-01	4.305400E-01	4.327700E-01
430	4.093100E-01	4.096100E-01	4.083800E-01	4.109000E-01
431	3.894100E-01	3.899100E-01	3.885300E-01	3.913200E-01
432	3.694500E-01	3.701400E-01	3.685900E-01	3.716300E-01
433	3.493600E-01	3.499500E-01	3.484000E-01	3.513800E-01
434	3.292200E-01	3.296500E-01	3.281300E-01	3.310300E-01
435	3.089500E-01	3.092300E-01	3.077200E-01	3.106500E-01
436	2.938100E-01	2.940200E-01	2.925000E-01	2.954900E-01
437	2.809900E-01	2.813400E-01	2.796900E-01	2.829300E-01
438	2.656400E-01	2.661900E-01	2.643600E-01	2.679500E-01
439	2.528700E-01	2.535000E-01	2.515800E-01	2.554000E-01
440	2.425700E-01	2.430500E-01	2.411700E-01	2.450600E-01
441	2.322400E-01	2.327400E-01	2.308000E-01	2.348900E-01
442	2.218900E-01	2.226700E-01	2.204900E-01	2.249800E-01
443	2.115000E-01	2.124400E-01	2.100800E-01	2.148800E-01
444	2.010700E-01	2.020300E-01	1.995600E-01	2.045900E-01

445	1.906400E-01	1.916600E-01	1.890500E-01	1.943400E-01
446	1.801700E-01	1.814000E-01	1.785600E-01	1.842600E-01
447	1.696700E-01	1.708200E-01	1.679000E-01	1.738300E-01
448	1.604700E-01	1.614500E-01	1.585000E-01	1.646400E-01
449	1.525600E-01	1.534100E-01	1.504100E-01	1.568500E-01
450	1.446100E-01	1.458900E-01	1.425100E-01	1.496300E-01
451	1.366500E-01	1.383700E-01	1.346000E-01	1.424000E-01
452	1.300200E-01	1.317200E-01	1.278300E-01	1.358900E-01
453	1.247000E-01	1.263600E-01	1.223800E-01	1.306500E-01
454	1.193500E-01	1.210800E-01	1.169000E-01	1.255600E-01
455	1.140000E-01	1.158200E-01	1.114200E-01	1.205000E-01
456	1.091900E-01	1.110200E-01	1.064600E-01	1.159200E-01
457	1.048900E-01	1.066600E-01	1.020000E-01	1.118100E-01
458	1.005900E-01	1.023100E-01	9.754401E-02	1.077000E-01
459	9.628901E-02	9.797700E-02	9.307400E-02	1.035900E-01
460	9.197500E-02	9.367601E-02	8.858401E-02	9.949300E-02
461	8.765400E-02	8.945701E-02	8.407701E-02	9.551600E-02
462	8.332600E-02	8.527400E-02	7.955700E-02	9.160300E-02
463	7.954200E-02	8.164200E-02	7.559600E-02	8.823800E-02
464	7.628601E-02	7.854300E-02	7.218500E-02	8.545700E-02
465	7.302500E-02	7.547001E-02	6.876400E-02	8.282300E-02
466	6.976101E-02	7.242800E-02	6.533800E-02	8.018900E-02
467	6.676700E-02	6.969201E-02	6.219500E-02	7.777900E-02
468	6.404100E-02	6.718300E-02	5.931800E-02	7.558800E-02
469	6.130900E-02	6.455301E-02	5.634900E-02	7.341101E-02
470	5.857600E-02	6.190400E-02	5.336400E-02	7.123701E-02
471	5.584000E-02	5.902800E-02	5.025400E-02	6.884700E-02
472	5.310000E-02	5.605400E-02	4.706300E-02	6.639700E-02
473	5.035700E-02	5.381700E-02	4.411900E-02	6.483700E-02
474	4.761100E-02	5.124300E-02	4.095500E-02	6.283600E-02
475	4.514300E-02	4.861300E-02	3.791900E-02	6.058900E-02
476	4.294100E-02	4.712700E-02	3.556800E-02	5.927501E-02
477	4.073800E-02	4.567100E-02	3.320400E-02	5.779200E-02
478	3.853300E-02	4.308400E-02	3.022100E-02	5.426900E-02
479	3.632700E-02	4.048200E-02	2.725400E-02	5.067100E-02
480	3.411900E-02	3.850500E-02	2.471500E-02	4.802200E-02
481	3.247300E-02	3.695300E-02	2.281400E-02	4.596901E-02
482	3.108800E-02	3.466000E-02	2.091300E-02	4.308800E-02
483	2.943000E-02	3.177500E-02	1.859600E-02	3.947400E-02
484	2.805400E-02	2.921500E-02	1.662700E-02	3.626800E-02
485	2.695000E-02	2.673400E-02	1.492900E-02	3.316200E-02
486	2.553200E-02	2.398700E-02	1.314600E-02	2.972200E-02
487	2.362400E-02	2.085100E-02	1.123800E-02	2.579600E-02
488	1.833500E-02	1.563700E-02	8.450401E-03	1.927200E-02
489	9.730901E-03	8.388400E-03	4.800800E-03	1.020300E-02

490	2.228400E-03	2.067900E-03	1.621000E-03	2.294900E-03
491	1.205800E-03	1.211400E-03	1.205100E-03	1.215600E-03
492	1.244200E-03	1.250000E-03	1.243500E-03	1.254300E-03
493	1.280800E-03	1.286700E-03	1.280000E-03	1.291200E-03
494	1.314800E-03	1.320800E-03	1.314000E-03	1.325400E-03
495	1.352300E-03	1.358500E-03	1.351500E-03	1.363200E-03
496	1.392400E-03	1.398800E-03	1.391500E-03	1.403600E-03
497	1.429300E-03	1.435900E-03	1.428400E-03	1.440900E-03
498	1.459900E-03	1.466700E-03	1.459000E-03	1.471700E-03
499	1.494600E-03	1.501500E-03	1.493700E-03	1.506700E-03
500	1.530000E-03	1.537100E-03	1.529100E-03	1.542400E-03
501	1.564800E-03	1.572000E-03	1.563800E-03	1.577400E-03
502	1.598900E-03	1.606300E-03	1.597900E-03	1.611800E-03
503	1.633100E-03	1.640600E-03	1.632100E-03	1.646300E-03
504	1.669400E-03	1.677100E-03	1.668400E-03	1.682900E-03
505	1.709500E-03	1.717400E-03	1.708500E-03	1.723400E-03
506	1.753200E-03	1.761300E-03	1.752200E-03	1.767400E-03
507	1.799800E-03	1.808100E-03	1.798700E-03	1.814400E-03
508	1.844000E-03	1.852500E-03	1.842900E-03	1.858900E-03
509	1.884500E-03	1.893200E-03	1.883300E-03	1.899700E-03
510	1.928200E-03	1.937100E-03	1.927000E-03	1.943800E-03
511	1.974400E-03	1.983500E-03	1.973200E-03	1.990400E-03
512	2.020800E-03	2.030100E-03	2.019600E-03	2.037200E-03
513	2.064100E-03	2.073700E-03	2.062900E-03	2.080800E-03
514	2.113200E-03	2.123000E-03	2.111900E-03	2.130300E-03
515	2.163200E-03	2.173200E-03	2.161900E-03	2.180700E-03
516	2.217300E-03	2.227500E-03	2.215900E-03	2.235200E-03
517	2.276200E-03	2.286600E-03	2.274800E-03	2.294600E-03
518	2.340700E-03	2.351500E-03	2.339300E-03	2.359700E-03
519	2.411000E-03	2.422100E-03	2.409500E-03	2.430400E-03
520	2.478800E-03	2.490200E-03	2.477300E-03	2.498900E-03
521	2.546200E-03	2.558000E-03	2.544700E-03	2.566800E-03
522	2.617000E-03	2.629100E-03	2.615400E-03	2.638200E-03
523	2.696900E-03	2.709300E-03	2.695300E-03	2.718700E-03
524	2.781500E-03	2.794300E-03	2.779800E-03	2.804000E-03
525	2.877900E-03	2.891200E-03	2.876200E-03	2.901200E-03
526	2.952000E-03	2.965600E-03	2.950200E-03	2.975900E-03
527	3.025600E-03	3.039600E-03	3.023800E-03	3.050100E-03
528	3.115300E-03	3.129700E-03	3.113400E-03	3.140500E-03
529	3.193000E-03	3.207700E-03	3.191100E-03	3.218800E-03
530	3.263600E-03	3.278600E-03	3.261600E-03	3.290000E-03
531	3.338400E-03	3.353800E-03	3.336400E-03	3.365400E-03
532	3.419400E-03	3.435100E-03	3.417300E-03	3.447000E-03
533	3.507700E-03	3.523900E-03	3.505600E-03	3.536100E-03
534	3.603200E-03	3.619800E-03	3.601000E-03	3.632300E-03

535	3.700800E-03	3.717800E-03	3.698500E-03	3.730700E-03
536	3.810700E-03	3.828300E-03	3.808400E-03	3.841600E-03
537	3.932300E-03	3.950500E-03	3.930000E-03	3.964100E-03
538	4.048200E-03	4.066800E-03	4.045700E-03	4.080900E-03
539	4.155701E-03	4.174900E-03	4.153200E-03	4.189300E-03
540	4.274600E-03	4.294300E-03	4.272000E-03	4.309200E-03
541	4.401400E-03	4.421700E-03	4.398700E-03	4.437000E-03
542	4.518400E-03	4.539200E-03	4.515700E-03	4.555000E-03
543	4.615400E-03	4.636700E-03	4.612600E-03	4.652700E-03
544	4.725300E-03	4.747100E-03	4.722500E-03	4.763600E-03
545	4.837400E-03	4.859700E-03	4.834500E-03	4.876600E-03
546	4.947400E-03	4.970200E-03	4.944400E-03	4.987400E-03
547	5.055300E-03	5.078600E-03	5.052300E-03	5.096200E-03
548	5.163300E-03	5.187100E-03	5.160200E-03	5.205100E-03
549	5.278300E-03	5.302600E-03	5.275100E-03	5.321000E-03
550	5.404900E-03	5.429900E-03	5.401700E-03	5.448700E-03
551	5.543200E-03	5.568800E-03	5.539900E-03	5.588000E-03
552	5.690600E-03	5.716801E-03	5.687200E-03	5.736600E-03
553	5.830500E-03	5.857400E-03	5.827000E-03	5.877700E-03
554	5.958800E-03	5.986200E-03	5.955101E-03	6.006900E-03
555	6.097100E-03	6.125200E-03	6.093400E-03	6.146400E-03
556	6.243500E-03	6.272200E-03	6.239700E-03	6.294000E-03
557	6.390500E-03	6.419900E-03	6.386600E-03	6.442200E-03
558	6.527700E-03	6.557701E-03	6.523700E-03	6.580500E-03
559	6.682900E-03	6.713700E-03	6.678801E-03	6.736900E-03
560	6.841001E-03	6.872500E-03	6.836900E-03	6.896300E-03
561	7.011700E-03	7.044001E-03	7.007401E-03	7.068400E-03
562	7.197801E-03	7.230900E-03	7.193400E-03	7.256000E-03
563	7.402201E-03	7.436300E-03	7.397700E-03	7.462101E-03
564	7.624500E-03	7.659700E-03	7.619901E-03	7.686201E-03
565	7.839400E-03	7.875500E-03	7.834701E-03	7.902800E-03
566	8.053001E-03	8.090100E-03	8.048100E-03	8.118100E-03
567	8.277200E-03	8.315301E-03	8.272200E-03	8.344101E-03
568	8.530300E-03	8.569600E-03	8.525101E-03	8.599200E-03
569	8.798200E-03	8.838801E-03	8.792900E-03	8.869400E-03
570	9.103800E-03	9.145800E-03	9.098301E-03	9.177400E-03
571	9.338501E-03	9.381601E-03	9.332901E-03	9.414100E-03
572	9.571201E-03	9.615300E-03	9.565401E-03	9.648600E-03
573	9.854500E-03	9.900000E-03	9.848601E-03	9.934201E-03
574	1.010000E-02	1.014600E-02	1.009400E-02	1.018100E-02
575	1.032200E-02	1.037000E-02	1.031600E-02	1.040600E-02
576	1.055900E-02	1.060700E-02	1.055200E-02	1.064400E-02
577	1.081600E-02	1.086600E-02	1.080900E-02	1.090300E-02
578	1.109500E-02	1.114700E-02	1.108900E-02	1.118500E-02
579	1.139700E-02	1.145000E-02	1.139100E-02	1.149000E-02

580	1.170600E-02	1.176000E-02	1.169900E-02	1.180000E-02
581	1.205200E-02	1.210800E-02	1.204500E-02	1.215000E-02
582	1.243700E-02	1.249400E-02	1.242900E-02	1.253700E-02
583	1.280300E-02	1.286200E-02	1.279500E-02	1.290700E-02
584	1.314400E-02	1.320400E-02	1.313600E-02	1.325000E-02
585	1.352000E-02	1.358300E-02	1.351200E-02	1.363000E-02
586	1.392200E-02	1.398600E-02	1.391300E-02	1.403500E-02
587	1.429300E-02	1.435800E-02	1.428400E-02	1.440800E-02
588	1.460000E-02	1.466700E-02	1.459100E-02	1.471800E-02
589	1.494800E-02	1.501700E-02	1.493900E-02	1.506900E-02
590	1.530400E-02	1.537400E-02	1.529400E-02	1.542700E-02
591	1.565100E-02	1.572400E-02	1.564200E-02	1.577800E-02
592	1.599200E-02	1.606600E-02	1.598300E-02	1.612200E-02
593	1.633300E-02	1.640800E-02	1.632300E-02	1.646500E-02
594	1.669500E-02	1.677200E-02	1.668500E-02	1.683000E-02
595	1.709400E-02	1.717300E-02	1.708400E-02	1.723200E-02
596	1.753100E-02	1.761200E-02	1.752000E-02	1.767300E-02
597	1.799700E-02	1.808000E-02	1.798600E-02	1.814300E-02
598	1.844000E-02	1.852500E-02	1.842900E-02	1.858900E-02
599	1.884600E-02	1.893300E-02	1.883500E-02	1.899900E-02
600	1.928400E-02	1.937300E-02	1.927300E-02	1.944000E-02
601	1.974800E-02	1.983900E-02	1.973600E-02	1.990700E-02
602	2.021300E-02	2.030600E-02	2.020100E-02	2.037700E-02
603	2.064700E-02	2.074300E-02	2.063500E-02	2.081400E-02
604	2.113800E-02	2.123500E-02	2.112500E-02	2.130900E-02
605	2.163700E-02	2.173700E-02	2.162400E-02	2.181200E-02
606	2.217600E-02	2.227900E-02	2.216300E-02	2.235600E-02
607	2.276100E-02	2.286600E-02	2.274700E-02	2.294500E-02
608	2.340100E-02	2.350800E-02	2.338600E-02	2.359000E-02
609	2.410100E-02	2.421300E-02	2.408700E-02	2.429600E-02
610	2.478600E-02	2.490100E-02	2.477100E-02	2.498700E-02
611	2.544800E-02	2.556500E-02	2.543200E-02	2.565400E-02
612	2.616300E-02	2.628400E-02	2.614800E-02	2.637500E-02
613	2.694300E-02	2.706700E-02	2.692700E-02	2.716100E-02
614	2.779900E-02	2.792700E-02	2.778200E-02	2.802400E-02
615	2.873900E-02	2.887200E-02	2.872200E-02	2.897200E-02
616	2.950500E-02	2.964100E-02	2.948700E-02	2.974400E-02
617	3.020500E-02	3.034400E-02	3.018600E-02	3.044900E-02
618	3.110900E-02	3.125300E-02	3.109000E-02	3.136100E-02
619	3.192300E-02	3.207000E-02	3.190300E-02	3.218100E-02
620	3.262500E-02	3.277600E-02	3.260600E-02	3.288900E-02
621	3.337600E-02	3.353000E-02	3.335600E-02	3.364600E-02
622	3.418100E-02	3.433800E-02	3.416000E-02	3.445700E-02
623	3.505200E-02	3.521400E-02	3.503100E-02	3.533600E-02
624	3.598000E-02	3.614500E-02	3.595800E-02	3.627100E-02

625	3.699400E-02	3.716500E-02	3.697200E-02	3.729400E-02
626	3.810100E-02	3.827600E-02	3.807700E-02	3.840900E-02
627	3.931400E-02	3.949500E-02	3.929000E-02	3.963200E-02
628	4.046900E-02	4.065600E-02	4.044500E-02	4.079600E-02
629	4.155100E-02	4.174200E-02	4.152500E-02	4.188700E-02
630	4.272200E-02	4.291900E-02	4.269600E-02	4.306800E-02
631	4.399800E-02	4.420100E-02	4.397100E-02	4.435400E-02
632	4.514500E-02	4.535300E-02	4.511800E-02	4.551000E-02
633	4.613701E-02	4.634900E-02	4.610900E-02	4.651000E-02
634	4.719801E-02	4.741600E-02	4.717000E-02	4.758000E-02
635	4.834000E-02	4.856200E-02	4.831000E-02	4.873000E-02
636	4.944400E-02	4.967200E-02	4.941401E-02	4.984400E-02
637	5.047900E-02	5.071100E-02	5.044800E-02	5.088700E-02
638	5.158600E-02	5.182400E-02	5.155500E-02	5.200300E-02
639	5.277300E-02	5.301700E-02	5.274100E-02	5.320000E-02
640	5.404800E-02	5.429700E-02	5.401600E-02	5.448500E-02
641	5.542000E-02	5.567500E-02	5.538600E-02	5.586800E-02
642	5.689900E-02	5.716100E-02	5.686500E-02	5.735900E-02
643	5.828800E-02	5.855600E-02	5.825200E-02	5.875900E-02
644	5.956900E-02	5.984401E-02	5.953300E-02	6.005100E-02
645	6.093900E-02	6.122001E-02	6.090300E-02	6.143200E-02
646	6.240800E-02	6.269600E-02	6.237100E-02	6.291300E-02
647	6.384800E-02	6.414200E-02	6.380900E-02	6.436400E-02
648	6.525000E-02	6.555101E-02	6.521100E-02	6.577800E-02
649	6.675200E-02	6.706000E-02	6.671100E-02	6.729200E-02
650	6.836500E-02	6.868000E-02	6.832400E-02	6.891800E-02
651	7.009900E-02	7.042200E-02	7.005601E-02	7.066600E-02
652	7.195500E-02	7.228601E-02	7.191101E-02	7.253700E-02
653	7.398500E-02	7.432600E-02	7.394001E-02	7.458300E-02
654	7.619600E-02	7.654700E-02	7.614901E-02	7.681200E-02
655	7.836001E-02	7.872201E-02	7.831301E-02	7.899401E-02
656	8.045100E-02	8.082201E-02	8.040300E-02	8.110200E-02
657	8.272100E-02	8.310300E-02	8.267100E-02	8.339000E-02
658	8.519500E-02	8.558700E-02	8.514300E-02	8.588400E-02
659	8.790001E-02	8.830600E-02	8.784700E-02	8.861101E-02
660	9.088201E-02	9.130001E-02	9.082600E-02	9.161600E-02
661	9.332200E-02	9.375200E-02	9.326500E-02	9.407600E-02
662	9.552000E-02	9.596001E-02	9.546200E-02	9.629300E-02
663	9.836600E-02	9.881900E-02	9.830601E-02	9.916200E-02
664	1.009500E-01	1.014100E-01	1.008900E-01	1.017600E-01
665	1.031600E-01	1.036400E-01	1.031000E-01	1.040000E-01
666	1.055300E-01	1.060200E-01	1.054700E-01	1.063900E-01
667	1.080900E-01	1.085800E-01	1.080200E-01	1.089600E-01
668	1.108200E-01	1.113300E-01	1.107600E-01	1.117200E-01
669	1.137600E-01	1.142800E-01	1.136900E-01	1.146800E-01

670	1.169600E-01	1.175000E-01	1.168900E-01	1.179100E-01
671	1.204500E-01	1.210100E-01	1.203800E-01	1.214300E-01
672	1.242800E-01	1.248500E-01	1.242100E-01	1.252900E-01
673	1.279400E-01	1.285300E-01	1.278600E-01	1.289800E-01
674	1.313600E-01	1.319600E-01	1.312800E-01	1.324200E-01
675	1.350600E-01	1.356800E-01	1.349800E-01	1.361500E-01
676	1.391000E-01	1.397400E-01	1.390100E-01	1.402200E-01
677	1.427500E-01	1.434000E-01	1.426600E-01	1.439000E-01
678	1.458800E-01	1.465600E-01	1.458000E-01	1.470600E-01
679	1.492400E-01	1.499300E-01	1.491500E-01	1.504500E-01
680	1.528500E-01	1.535500E-01	1.527600E-01	1.540800E-01
681	1.563200E-01	1.570400E-01	1.562300E-01	1.575900E-01
682	1.595900E-01	1.603300E-01	1.595000E-01	1.608800E-01
683	1.630900E-01	1.638400E-01	1.629900E-01	1.644100E-01
684	1.668400E-01	1.676100E-01	1.667400E-01	1.681900E-01
685	1.708600E-01	1.716500E-01	1.707600E-01	1.722400E-01
686	1.751900E-01	1.760000E-01	1.750800E-01	1.766100E-01
687	1.798600E-01	1.806900E-01	1.797500E-01	1.813200E-01
688	1.842800E-01	1.851200E-01	1.841600E-01	1.857700E-01
689	1.883300E-01	1.892000E-01	1.882100E-01	1.898500E-01
690	1.926600E-01	1.935500E-01	1.925400E-01	1.942200E-01
691	1.973100E-01	1.982200E-01	1.971900E-01	1.989000E-01
692	2.018700E-01	2.028000E-01	2.017500E-01	2.035100E-01
693	2.063100E-01	2.072600E-01	2.061900E-01	2.079800E-01
694	2.110600E-01	2.120300E-01	2.109300E-01	2.127700E-01
695	2.161600E-01	2.171600E-01	2.160300E-01	2.179100E-01
696	2.215900E-01	2.226200E-01	2.214600E-01	2.233900E-01
697	2.275100E-01	2.285600E-01	2.273700E-01	2.293500E-01
698	2.339200E-01	2.350000E-01	2.337800E-01	2.358100E-01
699	2.409100E-01	2.420200E-01	2.407600E-01	2.428500E-01
700	2.477600E-01	2.489100E-01	2.476100E-01	2.497700E-01
701	2.543800E-01	2.555500E-01	2.542200E-01	2.564300E-01
702	2.615500E-01	2.627500E-01	2.613900E-01	2.636600E-01
703	2.693600E-01	2.706100E-01	2.692000E-01	2.715400E-01
704	2.779200E-01	2.792000E-01	2.777600E-01	2.801700E-01
705	2.873100E-01	2.886300E-01	2.871300E-01	2.896300E-01
706	2.950400E-01	2.964000E-01	2.948600E-01	2.974200E-01
707	3.019800E-01	3.033700E-01	3.017900E-01	3.044200E-01
708	3.110000E-01	3.124300E-01	3.108100E-01	3.135100E-01
709	3.191700E-01	3.206400E-01	3.189700E-01	3.217500E-01
710	3.261800E-01	3.276900E-01	3.259900E-01	3.288200E-01
711	3.336900E-01	3.352200E-01	3.334800E-01	3.363800E-01
712	3.417300E-01	3.433100E-01	3.415200E-01	3.444900E-01
713	3.504400E-01	3.520600E-01	3.502300E-01	3.532700E-01
714	3.597100E-01	3.613700E-01	3.594900E-01	3.626200E-01

715	3.698500E-01	3.715500E-01	3.696200E-01	3.728400E-01
716	3.808900E-01	3.826400E-01	3.806500E-01	3.839700E-01
717	3.929900E-01	3.948000E-01	3.927500E-01	3.961700E-01
718	4.045800E-01	4.064400E-01	4.043300E-01	4.078500E-01
719	4.153800E-01	4.172900E-01	4.151300E-01	4.187400E-01
720	4.270900E-01	4.290600E-01	4.268300E-01	4.305400E-01
721	4.398400E-01	4.418700E-01	4.395800E-01	4.434000E-01
722	4.514000E-01	4.534800E-01	4.511200E-01	4.550500E-01
723	4.613200E-01	4.634500E-01	4.610400E-01	4.650500E-01
724	4.719400E-01	4.741100E-01	4.716500E-01	4.757600E-01
725	4.833400E-01	4.855700E-01	4.830500E-01	4.872500E-01
726	4.943300E-01	4.966100E-01	4.940300E-01	4.983300E-01
727	5.046700E-01	5.070000E-01	5.043700E-01	5.087500E-01
728	5.157200E-01	5.181000E-01	5.154100E-01	5.199000E-01
729	5.275800E-01	5.300100E-01	5.272600E-01	5.318400E-01
730	5.403000E-01	5.427900E-01	5.399700E-01	5.446700E-01
731	5.539900E-01	5.565400E-01	5.536500E-01	5.584700E-01
732	5.687600E-01	5.713800E-01	5.684200E-01	5.733600E-01
733	5.827300E-01	5.854100E-01	5.823700E-01	5.874400E-01
734	5.955400E-01	5.982900E-01	5.951800E-01	6.003600E-01
735	6.092400E-01	6.120500E-01	6.088700E-01	6.141700E-01
736	6.239300E-01	6.268000E-01	6.235500E-01	6.289800E-01
737	6.383700E-01	6.413100E-01	6.379800E-01	6.435301E-01
738	6.524001E-01	6.554100E-01	6.520100E-01	6.576800E-01
739	6.674200E-01	6.704900E-01	6.670101E-01	6.728200E-01
740	6.835400E-01	6.866900E-01	6.831300E-01	6.890700E-01
741	7.007300E-01	7.039601E-01	7.003101E-01	7.064000E-01
742	7.194400E-01	7.227500E-01	7.190000E-01	7.252600E-01
743	7.397000E-01	7.431100E-01	7.392501E-01	7.456800E-01
744	7.617900E-01	7.653000E-01	7.613301E-01	7.679501E-01
745	7.834900E-01	7.871000E-01	7.830101E-01	7.898200E-01
746	8.044001E-01	8.081000E-01	8.039100E-01	8.109001E-01
747	8.270701E-01	8.308800E-01	8.265700E-01	8.337600E-01
748	8.517801E-01	8.557101E-01	8.512701E-01	8.586700E-01
749	8.788500E-01	8.829001E-01	8.783200E-01	8.859600E-01
750	9.085301E-01	9.127101E-01	9.079700E-01	9.158700E-01
751	9.329800E-01	9.372801E-01	9.324100E-01	9.405200E-01
752	9.549201E-01	9.593201E-01	9.543401E-01	9.626400E-01
753	9.834501E-01	9.879800E-01	9.828500E-01	9.914001E-01
754	1.009300E+00	1.013900E+00	1.008700E+00	1.017400E+00
755	1.031500E+00	1.036200E+00	1.030800E+00	1.039800E+00
756	1.055200E+00	1.060100E+00	1.054600E+00	1.063700E+00
757	1.080600E+00	1.085600E+00	1.080000E+00	1.089400E+00
758	1.108200E+00	1.113300E+00	1.107500E+00	1.117100E+00
759	1.137500E+00	1.142700E+00	1.136800E+00	1.146700E+00

760	1.169500E+00	1.174900E+00	1.168800E+00	1.179000E+00
761	1.204400E+00	1.210000E+00	1.203700E+00	1.214200E+00
762	1.242700E+00	1.248400E+00	1.242000E+00	1.252800E+00
763	1.279400E+00	1.285300E+00	1.278600E+00	1.289700E+00
764	1.313500E+00	1.319600E+00	1.312700E+00	1.324100E+00
765	1.350600E+00	1.356800E+00	1.349700E+00	1.361500E+00
766	1.390900E+00	1.397300E+00	1.390100E+00	1.402100E+00
767	1.427400E+00	1.434000E+00	1.426600E+00	1.439000E+00
768	1.458800E+00	1.465500E+00	1.457900E+00	1.470600E+00
769	1.492400E+00	1.499300E+00	1.491500E+00	1.504500E+00
770	1.528400E+00	1.535500E+00	1.527500E+00	1.540800E+00

9. ^{nat}SI DAMAGE ENERGY

The latest U.S. Evaluated Nuclear Data File cross sections are found in the ENDF/B-VII.1 library [Ch11] and in the latest natural abundance data is found in Reference [Tu11].

Table 5: Nuclear Data Used in the Determination of the ^{nat}Si Displacement Kerma Factor

Isotope	ENDF/B-VII.1 MAT Designator	Natural Abundance (mole %)	Mass Excess (MeV)
^{28}Si	1425	92.223 (19)	-21.4927
^{29}Si	1428	4.685 (8)	-21.8950
^{30}Si	1431	3.092 (11)	-24.4329
Mass excess correction applied using 1 amu = 931.494013 MeV Data from Reference [Tu11]			

Figure 15 shows the ENDF/B-VII.1 NRT-based damage energy for ^{28}Si, ^{29}Si, and ^{30}Si in units of MeV·mbarn and based on an E_d = 20.5 eV. The NRT-based damage energy for ^{nat}Si is formed by using the natural abundance data from Table 5 to weight and sum the damage energy from the individual silicon isotopes. Unlike in the case of a true kerma where the weight/mass fractions are the appropriate weighting factors to use when combining contributions, atom/mole number fractions are used to combine contributors to the microscopic displacement kerma factor and to the damage energy. Figure 16 shows the fractional contribution to the ^{nat}Si NRT-based damage energy from the various naturally occurring isotopes. The curves in this plot represent the natural abundance of the given silicon isotope multiplied by the NRT-based damage energy and divided by the ^{nat}Si NRT-based damage energy. The deviations of the fractional contribution from the values for the natural isotopic abundance values, shown in the legend of the figure, indicate the influence of the energy-dependent shape differences in the cross sections between the various silicon isotopes. Figure 17 shows the percentage difference in the NRT-based silicon damage metric if one treats silicon as pure ^{28}Si as opposed to a treatment that includes the difference in response between the various silicon isotopes. In order to show the energy-dependence of the difference, the vertical scale in the plot has been reduced from the full range. When one considers the difference in any of the 770-group energy bins due to the resonance structure, the maximum variation is in the range [+83.7% | -7.4%].

Table 6 also provides the final recommended NRT-based damage energy for ^{28}Si, ^{29}Si, ^{30}Si and ^{nat}Si. The number of digits presented in the table for the damage energy does not intended to indicate accuracy, but, rather, they are include to support traceability of the calculation with the nuclear data and processing code.

This most recent analysis uses:

- NJOY-2012.50 code with the previously indicated SNL modifications
- ENDF/B-VII.1 cross sections
- Robinson fit to the LSS damage partition function for the primary recoil atom and for any emitted light atoms (protons, alpha particles, etc.) in the outgoing reaction channel
- E_d = 20.5 eV

- Silicon isotopes combined using their natural abundances, as shown in Table 2.
- The NRT damage energy as defined in Equations 39 and 60

.
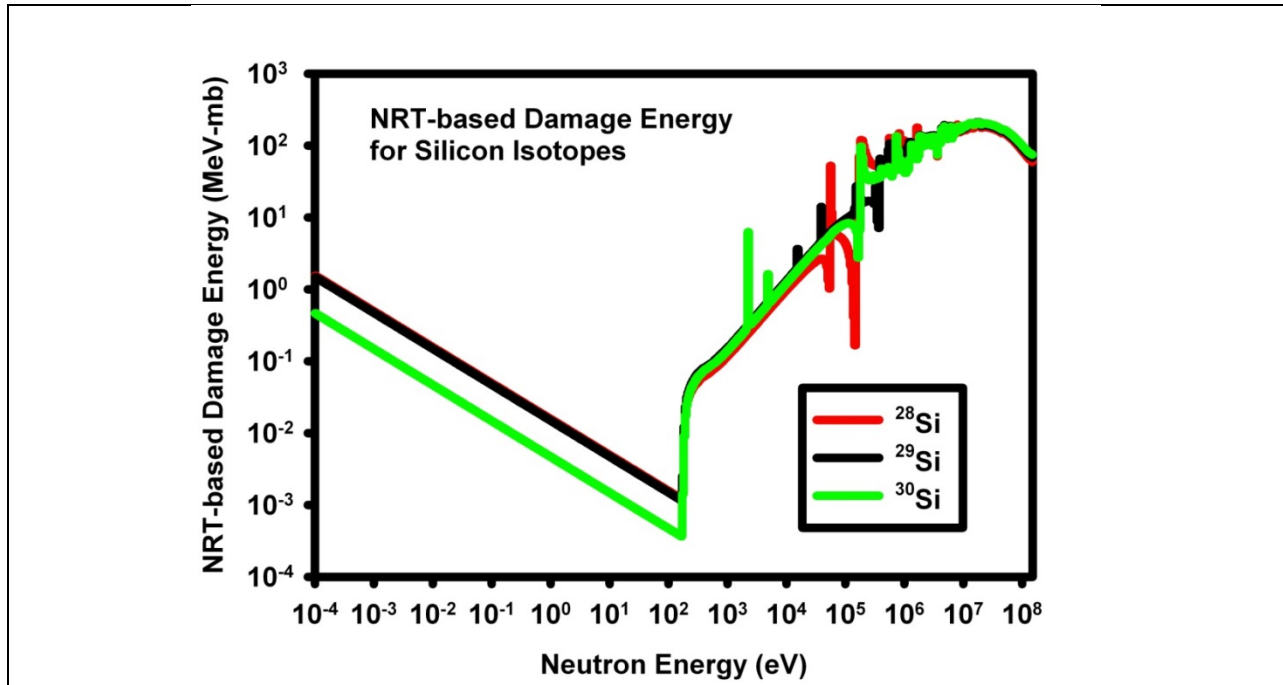
Figure 15: Comparison of NRT-based Damage Energy for Silicon Isotopes
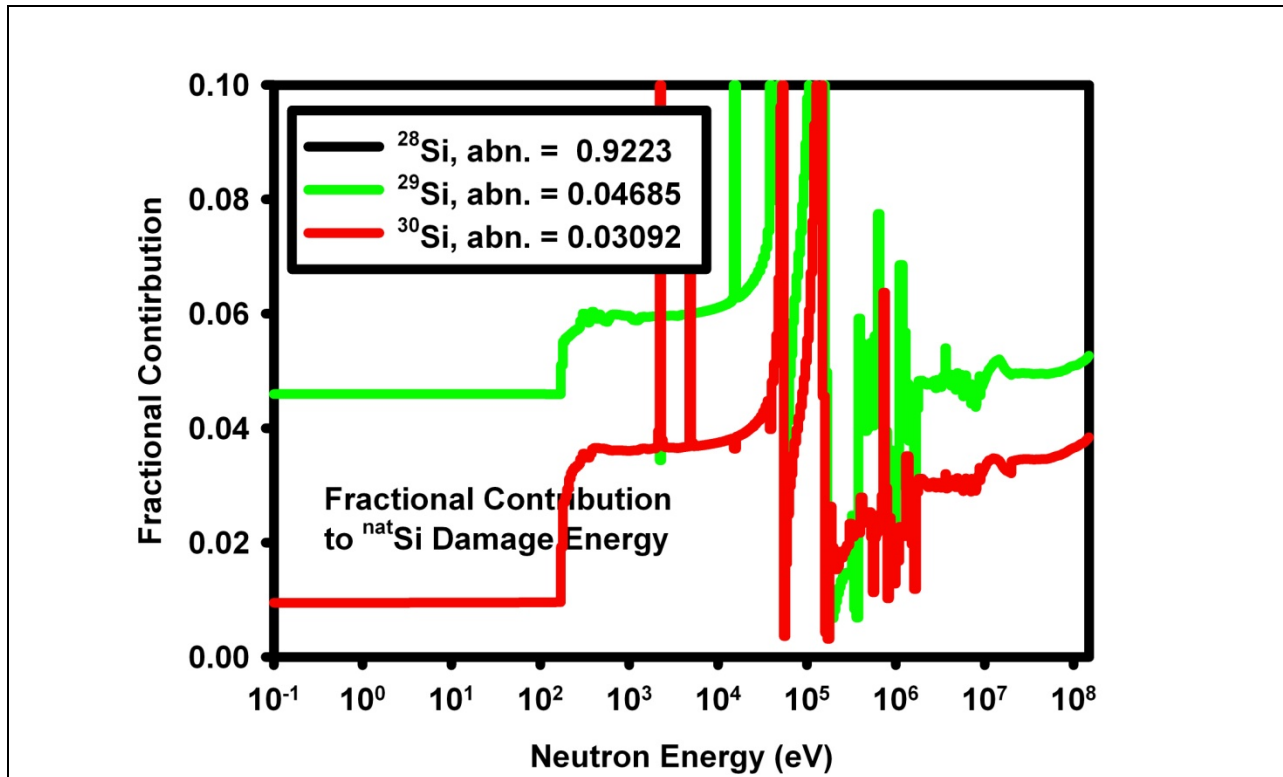
Figure 16: Fractional Contribution of the Various Silicon Isotopes to the NRT-based Damage Energy for Elemental Silicon
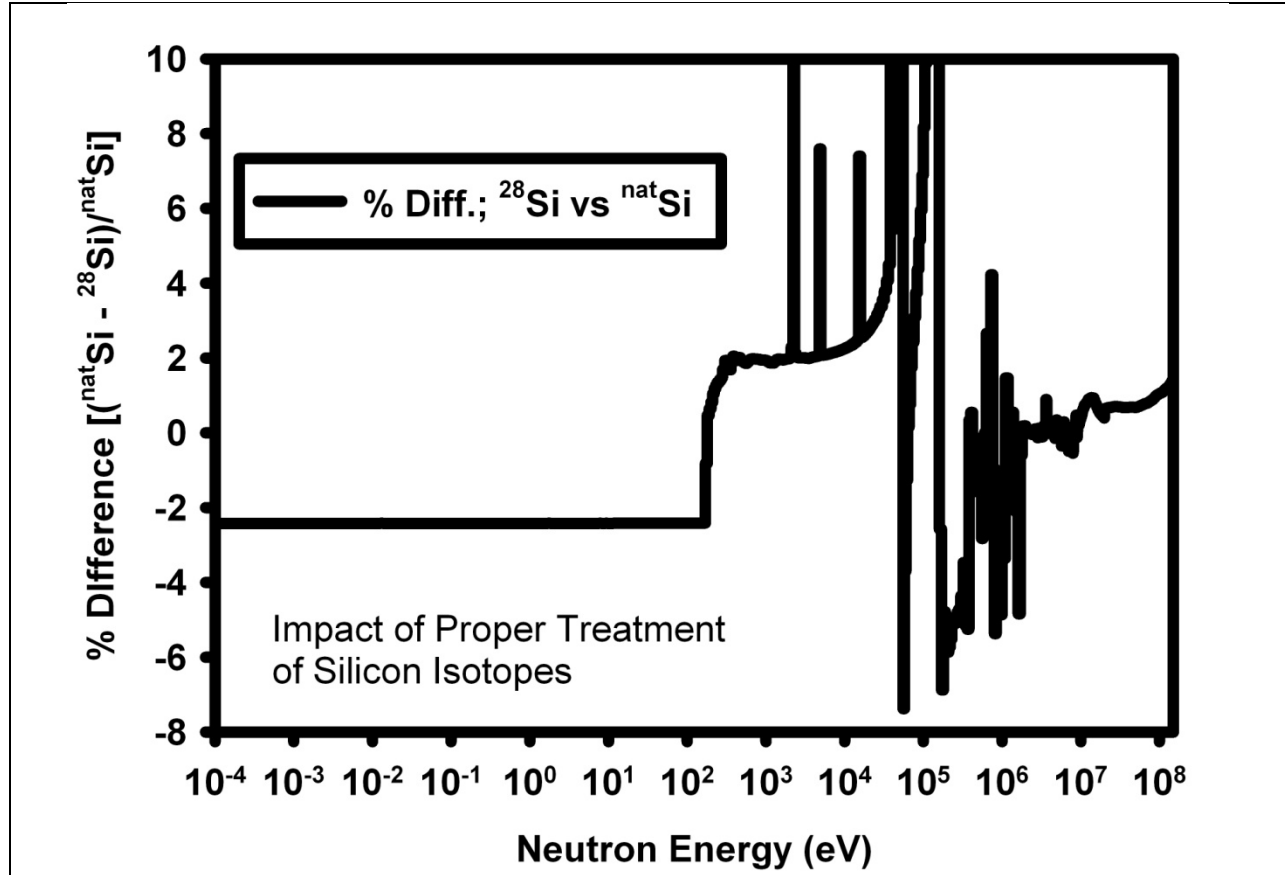
Figure 17: Difference between ^{28}Si and ^{nat}Si NRT-based Damage Metric

Table 6: NRT Damage Energy in Isotopic and Elemental Silicon

Bin #	Lower Energy Bound (MeV)	^{28}Si NRT Damage Energy (MeV-mbarn)	^{29}Si NRT Damage Energy (MeV-mbarn)	^{30}Si NRT Damage Energy (MeV-mbarn)	^{nat}Si NRT Damage Energy (MeV-mbarn)
1	1.4900E+02	5.910600E+01	6.743401E+01	7.451000E+01	5.997246E+01
2	1.4800E+02	5.937300E+01	6.765100E+01	7.472800E+01	6.023560E+01
3	1.4700E+02	5.964800E+01	6.787701E+01	7.495600E+01	6.050685E+01
4	1.4600E+02	5.992600E+01	6.810700E+01	7.518800E+01	6.078118E+01
5	1.4500E+02	6.021400E+01	6.834600E+01	7.543000E+01	6.106546E+01
6	1.4400E+02	6.050500E+01	6.859100E+01	7.567700E+01	6.135295E+01
7	1.4300E+02	6.080800E+01	6.884600E+01	7.593600E+01	6.165234E+01
8	1.4200E+02	6.111500E+01	6.910700E+01	7.620200E+01	6.195592E+01
9	1.4100E+02	6.143500E+01	6.938100E+01	7.648100E+01	6.227249E+01
10	1.4000E+02	6.176000E+01	6.966200E+01	7.676701E+01	6.259422E+01
11	1.3900E+02	6.208100E+01	6.995100E+01	7.705300E+01	6.291265E+01
12	1.3800E+02	6.239800E+01	7.024400E+01	7.733900E+01	6.322756E+01
13	1.3700E+02	6.272500E+01	7.054800E+01	7.763600E+01	6.355255E+01
14	1.3600E+02	6.305600E+01	7.085600E+01	7.793800E+01	6.388158E+01
15	1.3500E+02	6.339600E+01	7.117400E+01	7.825101E+01	6.421972E+01
16	1.3400E+02	6.374100E+01	7.149800E+01	7.857001E+01	6.456293E+01
17	1.3300E+02	6.409700E+01	7.183200E+01	7.890000E+01	6.491709E+01
18	1.3200E+02	6.445700E+01	7.217200E+01	7.923600E+01	6.527541E+01
19	1.3100E+02	6.482900E+01	7.252400E+01	7.958501E+01	6.564577E+01
20	1.3000E+02	6.520600E+01	7.288100E+01	7.994000E+01	6.602115E+01
21	1.2900E+02	6.560900E+01	7.328201E+01	8.036501E+01	6.642474E+01
22	1.2800E+02	6.602500E+01	7.370500E+01	8.082600E+01	6.684245E+01
23	1.2700E+02	6.644901E+01	7.413600E+01	8.129601E+01	6.726822E+01
24	1.2600E+02	6.687801E+01	7.457301E+01	8.177100E+01	6.769901E+01
25	1.2500E+02	6.731800E+01	7.502100E+01	8.225800E+01	6.814083E+01
26	1.2400E+02	6.776300E+01	7.547501E+01	8.275201E+01	6.858777E+01
27	1.2300E+02	6.822100E+01	7.594200E+01	8.326000E+01	6.904774E+01
28	1.2200E+02	6.868501E+01	7.641600E+01	8.377500E+01	6.951379E+01
29	1.2100E+02	6.916500E+01	7.690701E+01	8.430801E+01	6.999593E+01
30	1.2000E+02	6.965200E+01	7.740601E+01	8.485001E+01	7.048521E+01
31	1.1900E+02	7.023200E+01	7.798701E+01	8.546900E+01	7.106645E+01
32	1.1800E+02	7.085800E+01	7.860800E+01	8.612601E+01	7.169318E+01
33	1.1700E+02	7.149700E+01	7.924300E+01	8.679700E+01	7.233298E+01
34	1.1600E+02	7.214400E+01	7.988500E+01	8.747501E+01	7.298070E+01
35	1.1500E+02	7.280500E+01	8.054201E+01	8.817001E+01	7.364257E+01
36	1.1400E+02	7.347200E+01	8.120700E+01	8.887200E+01	7.431055E+01
37	1.1300E+02	7.415601E+01	8.188700E+01	8.959000E+01	7.499543E+01
38	1.1200E+02	7.484700E+01	8.257500E+01	9.031700E+01	7.568739E+01

39	1.1100E+02	7.555300E+01	8.328001E+01	9.106200E+01	7.639455E+01
40	1.1000E+02	7.626801E+01	8.399300E+01	9.181500E+01	7.711064E+01
41	1.0900E+02	7.697501E+01	8.473200E+01	9.258301E+01	7.782103E+01
42	1.0800E+02	7.767900E+01	8.548500E+01	9.335900E+01	7.852954E+01
43	1.0700E+02	7.839500E+01	8.625101E+01	9.414900E+01	7.925017E+01
44	1.0600E+02	7.911900E+01	8.702500E+01	9.494701E+01	7.997880E+01
45	1.0500E+02	7.985900E+01	8.781500E+01	9.576200E+01	8.072346E+01
46	1.0400E+02	8.060600E+01	8.861401E+01	9.658701E+01	8.147531E+01
47	1.0300E+02	8.137400E+01	8.943301E+01	9.743201E+01	8.224808E+01
48	1.0200E+02	8.215000E+01	9.026200E+01	9.828800E+01	8.302904E+01
49	1.0100E+02	8.295000E+01	9.111501E+01	9.916901E+01	8.383402E+01
50	1.0000E+02	8.376200E+01	9.197900E+01	1.000600E+02	8.465091E+01
51	9.9000E+01	8.459801E+01	9.286501E+01	1.009800E+02	8.549184E+01
52	9.8000E+01	8.546001E+01	9.377400E+01	1.019100E+02	8.635815E+01
53	9.7000E+01	8.634000E+01	9.470200E+01	1.028700E+02	8.724287E+01
54	9.6000E+01	8.723901E+01	9.564900E+01	1.038500E+02	8.814664E+01
55	9.5000E+01	8.815601E+01	9.661501E+01	1.048400E+02	8.906818E+01
56	9.4000E+01	8.909200E+01	9.758000E+01	1.058500E+02	9.000782E+01
57	9.3000E+01	9.004700E+01	9.855401E+01	1.068600E+02	9.096541E+01
58	9.2000E+01	9.102100E+01	9.954800E+01	1.079000E+02	9.194239E+01
59	9.1000E+01	9.201200E+01	1.005600E+02	1.089500E+02	9.293620E+01
60	9.0000E+01	9.302100E+01	1.015900E+02	1.100200E+02	9.394807E+01
61	8.9000E+01	9.407301E+01	1.026200E+02	1.111000E+02	9.499992E+01
62	8.8000E+01	9.513700E+01	1.036500E+02	1.121700E+02	9.606250E+01
63	8.7000E+01	9.619901E+01	1.046600E+02	1.132400E+02	9.712231E+01
64	8.6000E+01	9.727701E+01	1.056900E+02	1.143200E+02	9.819813E+01
65	8.5000E+01	9.839201E+01	1.067600E+02	1.154400E+02	9.931118E+01
66	8.4000E+01	9.954700E+01	1.079100E+02	1.166100E+02	1.004664E+02
67	8.3000E+01	1.007400E+02	1.091100E+02	1.178300E+02	1.016606E+02
68	8.2000E+01	1.019800E+02	1.103600E+02	1.191000E+02	1.029020E+02
69	8.1000E+01	1.032300E+02	1.116200E+02	1.203800E+02	1.041534E+02
70	8.0000E+01	1.044800E+02	1.128800E+02	1.216600E+02	1.054047E+02
71	7.9000E+01	1.057000E+02	1.141200E+02	1.229200E+02	1.066269E+02
72	7.8000E+01	1.069000E+02	1.153500E+02	1.241800E+02	1.078302E+02
73	7.7000E+01	1.081200E+02	1.166000E+02	1.254600E+02	1.090534E+02
74	7.6000E+01	1.093600E+02	1.178700E+02	1.267500E+02	1.102964E+02
75	7.5000E+01	1.106200E+02	1.191600E+02	1.280500E+02	1.115590E+02
76	7.4000E+01	1.119300E+02	1.204700E+02	1.293900E+02	1.128700E+02
77	7.3000E+01	1.132700E+02	1.218000E+02	1.308000E+02	1.142117E+02
78	7.2000E+01	1.146400E+02	1.231500E+02	1.322000E+02	1.155816E+02
79	7.1000E+01	1.160000E+02	1.245200E+02	1.335700E+02	1.169424E+02
80	7.0000E+01	1.174000E+02	1.258900E+02	1.350100E+02	1.183423E+02
81	6.9000E+01	1.187500E+02	1.272500E+02	1.364600E+02	1.196958E+02
82	6.8000E+01	1.200600E+02	1.286600E+02	1.378700E+02	1.210136E+02
83	6.7000E+01	1.213600E+02	1.300300E+02	1.392700E+02	1.223200E+02

84	6.6000E+01	1.226700E+02	1.314100E+02	1.406800E+02	1.236363E+02
85	6.5000E+01	1.239800E+02	1.328200E+02	1.421100E+02	1.249547E+02
86	6.4000E+01	1.253800E+02	1.342200E+02	1.435300E+02	1.263554E+02
87	6.3000E+01	1.268000E+02	1.356600E+02	1.450100E+02	1.277781E+02
88	6.2000E+01	1.282300E+02	1.371400E+02	1.464900E+02	1.292120E+02
89	6.1000E+01	1.297200E+02	1.386400E+02	1.480000E+02	1.307031E+02
90	6.0000E+01	1.312200E+02	1.401300E+02	1.495400E+02	1.322039E+02
91	5.9000E+01	1.327700E+02	1.417300E+02	1.511100E+02	1.337569E+02
92	5.8000E+01	1.343400E+02	1.433100E+02	1.527300E+02	1.353289E+02
93	5.7000E+01	1.359300E+02	1.449400E+02	1.543300E+02	1.369210E+02
94	5.6000E+01	1.375200E+02	1.465600E+02	1.559600E+02	1.385137E+02
95	5.5000E+01	1.391200E+02	1.481900E+02	1.576100E+02	1.401166E+02
96	5.4000E+01	1.407200E+02	1.498100E+02	1.592400E+02	1.417185E+02
97	5.3000E+01	1.422800E+02	1.513800E+02	1.608200E+02	1.432796E+02
98	5.2000E+01	1.438000E+02	1.529400E+02	1.623600E+02	1.448021E+02
99	5.1000E+01	1.452900E+02	1.544600E+02	1.638600E+02	1.462938E+02
100	5.0000E+01	1.468000E+02	1.559900E+02	1.654000E+02	1.478057E+02
101	4.9000E+01	1.475300E+02	1.567500E+02	1.661500E+02	1.485377E+02
102	4.8000E+01	1.477100E+02	1.570000E+02	1.663600E+02	1.487219E+02
103	4.7000E+01	1.479200E+02	1.572900E+02	1.666300E+02	1.489375E+02
104	4.6000E+01	1.481700E+02	1.576200E+02	1.669500E+02	1.491934E+02
105	4.5000E+01	1.484700E+02	1.580200E+02	1.673500E+02	1.495012E+02
106	4.4000E+01	1.497000E+02	1.593600E+02	1.686900E+02	1.507397E+02
107	4.3000E+01	1.516600E+02	1.614100E+02	1.708000E+02	1.527086E+02
108	4.2000E+01	1.536600E+02	1.635300E+02	1.729700E+02	1.547195E+02
109	4.1000E+01	1.556600E+02	1.656500E+02	1.751400E+02	1.567303E+02
110	4.0000E+01	1.575700E+02	1.676700E+02	1.771900E+02	1.586499E+02
111	3.9000E+01	1.593500E+02	1.695500E+02	1.791400E+02	1.604398E+02
112	3.8000E+01	1.610700E+02	1.713400E+02	1.810600E+02	1.621693E+02
113	3.7000E+01	1.627000E+02	1.730300E+02	1.828500E+02	1.638070E+02
114	3.6000E+01	1.642700E+02	1.746600E+02	1.846000E+02	1.653854E+02
115	3.5000E+01	1.657600E+02	1.762100E+02	1.862600E+02	1.668834E+02
116	3.4000E+01	1.672200E+02	1.778200E+02	1.879500E+02	1.683576E+02
117	3.3000E+01	1.686700E+02	1.795000E+02	1.897100E+02	1.698279E+02
118	3.2000E+01	1.700600E+02	1.811000E+02	1.913900E+02	1.712368E+02
119	3.1000E+01	1.713900E+02	1.826200E+02	1.929900E+02	1.725840E+02
120	3.0000E+01	1.726900E+02	1.841000E+02	1.945700E+02	1.739011E+02
121	2.9000E+01	1.740500E+02	1.856200E+02	1.961300E+02	1.752748E+02
122	2.8000E+01	1.754600E+02	1.871600E+02	1.976600E+02	1.766946E+02
123	2.7000E+01	1.767800E+02	1.886000E+02	1.990700E+02	1.780230E+02
124	2.6000E+01	1.779900E+02	1.899400E+02	2.003200E+02	1.792403E+02
125	2.5000E+01	1.791500E+02	1.910600E+02	2.014500E+02	1.803975E+02
126	2.4000E+01	1.802400E+02	1.919800E+02	2.024300E+02	1.814762E+02
127	2.3000E+01	1.809500E+02	1.926900E+02	2.029400E+02	1.821799E+02
128	2.2000E+01	1.813800E+02	1.932300E+02	2.030800E+02	1.826061E+02

129	2.1000E+01	1.799500E+02	1.916300E+02	2.009500E+02	1.811465E+02
130	2.0000E+01	1.768500E+02	1.882200E+02	1.969100E+02	1.780029E+02
131	1.9900E+01	1.966100E+02	2.076700E+02	2.049700E+02	1.973867E+02
132	1.9800E+01	1.959800E+02	2.071600E+02	2.044700E+02	1.967663E+02
133	1.9700E+01	1.953400E+02	2.066500E+02	2.039700E+02	1.961367E+02
134	1.9600E+01	1.947500E+02	2.061900E+02	2.035100E+02	1.955568E+02
135	1.9500E+01	1.944400E+02	2.060100E+02	2.033400E+02	1.952572E+02
136	1.9400E+01	1.941800E+02	2.058700E+02	2.032100E+02	1.950069E+02
137	1.9300E+01	1.941400E+02	2.059700E+02	2.033200E+02	1.949781E+02
138	1.9200E+01	1.942500E+02	2.062300E+02	2.035800E+02	1.950997E+02
139	1.9100E+01	1.947000E+02	2.068100E+02	2.041600E+02	1.955598E+02
140	1.9000E+01	1.960000E+02	2.082600E+02	2.056200E+02	1.968718E+02
141	1.8900E+01	1.972800E+02	2.096900E+02	2.070600E+02	1.981638E+02
142	1.8800E+01	1.982200E+02	2.107700E+02	2.081400E+02	1.991147E+02
143	1.8700E+01	1.990200E+02	2.117200E+02	2.090800E+02	1.999261E+02
144	1.8600E+01	1.968500E+02	2.096600E+02	2.069900E+02	1.977637E+02
145	1.8500E+01	1.929500E+02	2.058600E+02	2.031500E+02	1.938702E+02
146	1.8400E+01	1.910900E+02	2.041200E+02	2.013700E+02	1.920183E+02
147	1.8300E+01	1.921000E+02	2.052800E+02	2.025100E+02	1.930394E+02
148	1.8200E+01	1.932100E+02	2.065400E+02	2.037700E+02	1.941610E+02
149	1.8100E+01	1.946200E+02	2.081100E+02	2.053200E+02	1.955829E+02
150	1.8000E+01	1.954200E+02	2.090400E+02	2.062400E+02	1.963926E+02
151	1.7900E+01	1.931700E+02	2.069000E+02	2.040500E+02	1.941497E+02
152	1.7800E+01	1.907000E+02	2.045500E+02	2.016400E+02	1.916871E+02
153	1.7700E+01	1.895000E+02	2.034600E+02	2.005000E+02	1.904942E+02
154	1.7600E+01	1.887200E+02	2.028000E+02	1.998000E+02	1.897222E+02
155	1.7500E+01	1.897400E+02	2.039600E+02	2.009300E+02	1.907522E+02
156	1.7400E+01	1.911100E+02	2.055100E+02	2.025100E+02	1.921371E+02
157	1.7300E+01	1.912900E+02	2.059100E+02	2.029900E+02	1.923367E+02
158	1.7200E+01	1.911300E+02	2.059600E+02	2.031100E+02	1.921952E+02
159	1.7100E+01	1.913100E+02	2.063600E+02	2.035800E+02	1.923945E+02
160	1.7000E+01	1.915400E+02	2.068100E+02	2.040900E+02	1.926434E+02
161	1.6900E+01	1.909500E+02	2.064400E+02	2.037700E+02	1.920721E+02
162	1.6800E+01	1.903800E+02	2.061000E+02	2.034800E+02	1.915215E+02
163	1.6700E+01	1.924600E+02	2.084500E+02	2.059000E+02	1.936247E+02
164	1.6600E+01	1.941100E+02	2.103500E+02	2.078600E+02	1.952960E+02
165	1.6500E+01	1.890500E+02	2.055100E+02	2.030100E+02	1.902528E+02
166	1.6400E+01	1.843900E+02	2.010500E+02	1.985500E+02	1.856083E+02
167	1.6300E+01	1.852800E+02	2.022300E+02	1.997600E+02	1.865218E+02
168	1.6200E+01	1.864500E+02	2.036700E+02	2.012400E+02	1.877141E+02
169	1.6100E+01	1.870100E+02	2.045200E+02	2.021200E+02	1.882975E+02
170	1.6000E+01	1.869400E+02	2.047200E+02	2.023300E+02	1.882488E+02
171	1.5900E+01	1.861100E+02	2.041100E+02	2.018400E+02	1.874397E+02
172	1.5800E+01	1.828600E+02	2.010400E+02	1.989600E+02	1.842095E+02
173	1.5700E+01	1.788500E+02	1.972000E+02	1.952900E+02	1.802180E+02

174	1.5600E+01	1.777400E+02	1.963000E+02	1.945800E+02	1.791302E+02
175	1.5500E+01	1.778700E+02	1.966600E+02	1.951400E+02	1.792843E+02
176	1.5400E+01	1.796900E+02	1.987300E+02	1.974100E+02	1.811299E+02
177	1.5300E+01	1.808200E+02	2.001000E+02	1.989700E+02	1.822845E+02
178	1.5200E+01	1.808900E+02	2.004100E+02	1.994500E+02	1.823784E+02
179	1.5100E+01	1.768800E+02	1.966000E+02	1.957700E+02	1.783880E+02
180	1.5000E+01	1.741600E+02	1.941000E+02	1.934100E+02	1.756894E+02
181	1.4900E+01	1.778700E+02	1.981000E+02	1.975800E+02	1.794272E+02
182	1.4800E+01	1.772400E+02	1.977100E+02	1.973200E+02	1.788199E+02
183	1.4700E+01	1.739600E+02	1.946400E+02	1.943600E+02	1.755596E+02
184	1.4600E+01	1.730600E+02	1.939900E+02	1.938200E+02	1.746825E+02
185	1.4500E+01	1.753600E+02	1.966100E+02	1.965800E+02	1.770117E+02
186	1.4400E+01	1.804700E+02	2.017800E+02	2.020200E+02	1.821347E+02
187	1.4300E+01	1.802900E+02	2.014600E+02	2.020300E+02	1.819540E+02
188	1.4200E+01	1.790600E+02	2.000700E+02	2.009600E+02	1.807215E+02
189	1.4100E+01	1.778200E+02	1.986800E+02	1.998700E+02	1.794791E+02
190	1.4000E+01	1.749000E+02	1.955800E+02	1.970600E+02	1.765540E+02
191	1.3900E+01	1.769100E+02	1.974700E+02	1.992000E+02	1.785625E+02
192	1.3800E+01	1.827700E+02	2.032700E+02	2.053800E+02	1.844295E+02
193	1.3700E+01	1.764700E+02	1.967900E+02	1.991200E+02	1.781223E+02
194	1.3600E+01	1.740800E+02	1.942600E+02	1.968300E+02	1.757289E+02
195	1.3500E+01	1.762200E+02	1.963100E+02	1.991500E+02	1.778702E+02
196	1.3400E+01	1.796700E+02	1.997000E+02	2.028100E+02	1.813239E+02
197	1.3300E+01	1.764900E+02	1.963900E+02	1.997000E+02	1.781400E+02
198	1.3200E+01	1.752400E+02	1.950500E+02	1.985600E+02	1.768892E+02
199	1.3100E+01	1.784700E+02	1.982300E+02	2.019700E+02	1.801224E+02
200	1.3000E+01	1.816300E+02	2.013500E+02	2.053000E+02	1.832858E+02
201	1.2900E+01	1.807700E+02	2.002700E+02	2.044300E+02	1.824151E+02
202	1.2800E+01	1.804300E+02	1.996100E+02	2.039700E+02	1.820564E+02
203	1.2700E+01	1.810300E+02	1.999000E+02	2.044700E+02	1.826388E+02
204	1.2600E+01	1.791600E+02	1.976900E+02	2.024400E+02	1.807480E+02
205	1.2500E+01	1.715700E+02	1.897200E+02	1.945900E+02	1.731321E+02
206	1.2400E+01	1.747000E+02	1.926300E+02	1.976900E+02	1.762509E+02
207	1.2300E+01	1.776800E+02	1.952300E+02	2.004800E+02	1.792072E+02
208	1.2200E+01	1.770100E+02	1.942000E+02	1.996000E+02	1.785138E+02
209	1.2100E+01	1.766900E+02	1.935300E+02	1.990600E+02	1.781706E+02
210	1.2000E+01	1.739900E+02	1.904600E+02	1.961000E+02	1.754453E+02
211	1.1900E+01	1.723500E+02	1.884500E+02	1.942000E+02	1.737799E+02
212	1.1800E+01	1.710700E+02	1.867900E+02	1.926600E+02	1.724741E+02
213	1.1700E+01	1.707600E+02	1.861200E+02	1.921000E+02	1.721395E+02
214	1.1600E+01	1.722600E+02	1.872500E+02	1.933600E+02	1.736147E+02
215	1.1500E+01	1.732600E+02	1.879000E+02	1.941300E+02	1.745912E+02
216	1.1400E+01	1.720500E+02	1.863100E+02	1.926400E+02	1.733547E+02
217	1.1300E+01	1.691200E+02	1.830100E+02	1.894300E+02	1.703987E+02
218	1.1200E+01	1.649900E+02	1.784500E+02	1.849400E+02	1.662375E+02

219	1.1100E+01	1.638300E+02	1.768800E+02	1.834700E+02	1.650487E+02
220	1.1000E+01	1.691000E+02	1.817700E+02	1.885000E+02	1.702934E+02
221	1.0900E+01	1.718000E+02	1.840900E+02	1.908700E+02	1.729654E+02
222	1.0800E+01	1.719200E+02	1.836300E+02	1.903800E+02	1.730394E+02
223	1.0700E+01	1.681800E+02	1.792400E+02	1.859300E+02	1.692470E+02
224	1.0600E+01	1.633500E+02	1.737600E+02	1.803600E+02	1.643637E+02
225	1.0500E+01	1.654800E+02	1.752500E+02	1.818200E+02	1.664429E+02
226	1.0400E+01	1.667000E+02	1.758600E+02	1.823800E+02	1.676140E+02
227	1.0300E+01	1.727600E+02	1.812700E+02	1.877700E+02	1.736228E+02
228	1.0200E+01	1.720300E+02	1.799000E+02	1.863200E+02	1.728406E+02
229	1.0100E+01	1.737100E+02	1.809200E+02	1.872600E+02	1.744668E+02
230	1.0000E+01	1.716700E+02	1.781600E+02	1.844000E+02	1.723677E+02
231	9.9000E+00	1.735200E+02	1.794200E+02	1.855300E+02	1.741678E+02
232	9.8000E+00	1.711300E+02	1.764900E+02	1.823800E+02	1.717290E+02
233	9.7000E+00	1.667200E+02	1.712700E+02	1.769200E+02	1.672486E+02
234	9.6000E+00	1.631700E+02	1.667500E+02	1.721600E+02	1.636157E+02
235	9.5000E+00	1.725700E+02	1.754300E+02	1.806900E+02	1.729551E+02
236	9.4000E+00	1.778800E+02	1.804300E+02	1.855300E+02	1.782360E+02
237	9.3000E+00	1.708100E+02	1.733000E+02	1.781600E+02	1.711539E+02
238	9.2000E+00	1.573000E+02	1.622600E+02	1.668500E+02	1.578277E+02
239	9.1000E+00	1.627900E+02	1.702900E+02	1.747300E+02	1.635106E+02
240	9.0000E+00	1.830800E+02	1.824900E+02	1.868000E+02	1.831674E+02
241	8.9000E+00	1.837600E+02	1.791900E+02	1.832200E+02	1.835292E+02
242	8.8000E+00	1.637800E+02	1.669700E+02	1.706100E+02	1.641406E+02
243	8.7000E+00	1.529000E+02	1.609700E+02	1.642500E+02	1.536290E+02
244	8.6000E+00	1.708400E+02	1.735000E+02	1.765600E+02	1.711415E+02
245	8.5000E+00	1.716100E+02	1.735400E+02	1.762800E+02	1.718448E+02
246	8.4000E+00	1.728000E+02	1.738000E+02	1.761300E+02	1.729498E+02
247	8.3000E+00	1.715700E+02	1.732700E+02	1.751600E+02	1.717607E+02
248	8.2000E+00	1.692600E+02	1.703800E+02	1.719400E+02	1.693953E+02
249	8.1000E+00	1.624500E+02	1.587400E+02	1.600200E+02	1.622010E+02
250	8.0000E+00	1.776700E+02	1.662600E+02	1.675100E+02	1.768213E+02
251	7.9000E+00	1.952800E+02	1.812100E+02	1.824600E+02	1.942244E+02
252	7.8000E+00	1.815800E+02	1.736300E+02	1.746300E+02	1.809927E+02
253	7.7000E+00	1.814900E+02	1.756500E+02	1.764300E+02	1.810600E+02
254	7.6000E+00	1.747600E+02	1.671600E+02	1.676200E+02	1.741832E+02
255	7.5000E+00	1.719400E+02	1.643400E+02	1.645100E+02	1.713542E+02
256	7.4000E+00	1.746300E+02	1.695400E+02	1.694000E+02	1.742298E+02
257	7.3000E+00	1.764700E+02	1.753600E+02	1.748700E+02	1.763685E+02
258	7.2000E+00	1.759700E+02	1.697500E+02	1.688200E+02	1.754575E+02
259	7.1000E+00	1.427900E+02	1.454800E+02	1.439900E+02	1.429531E+02
260	7.0000E+00	1.735500E+02	1.632700E+02	1.614400E+02	1.726940E+02
261	6.9000E+00	1.474500E+02	1.496200E+02	1.472600E+02	1.475458E+02
262	6.8000E+00	1.527900E+02	1.540700E+02	1.512600E+02	1.528027E+02
263	6.7000E+00	1.731500E+02	1.690800E+02	1.658600E+02	1.727339E+02

264	6.6000E+00	1.568100E+02	1.560100E+02	1.522500E+02	1.566315E+02
265	6.5000E+00	1.281800E+02	1.297700E+02	1.254100E+02	1.281688E+02
266	6.4000E+00	1.470700E+02	1.479300E+02	1.434500E+02	1.469984E+02
267	6.3000E+00	1.590500E+02	1.610400E+02	1.565300E+02	1.590653E+02
268	6.2000E+00	1.834200E+02	1.867100E+02	1.820300E+02	1.835312E+02
269	6.1000E+00	1.317700E+02	1.388900E+02	1.334700E+02	1.321561E+02
270	6.0000E+00	1.610800E+02	1.644300E+02	1.584800E+02	1.611566E+02
271	5.9000E+00	1.419100E+02	1.469700E+02	1.406200E+02	1.421072E+02
272	5.8000E+00	1.734500E+02	1.749000E+02	1.685000E+02	1.733649E+02
273	5.7000E+00	1.875300E+02	1.816600E+02	1.751200E+02	1.868713E+02
274	5.6000E+00	1.557100E+02	1.612400E+02	1.544900E+02	1.559314E+02
275	5.5000E+00	1.514500E+02	1.546200E+02	1.478100E+02	1.514860E+02
276	5.4000E+00	1.231100E+02	1.300400E+02	1.235100E+02	1.234470E+02
277	5.3000E+00	1.288900E+02	1.340000E+02	1.277500E+02	1.290942E+02
278	5.2000E+00	1.554000E+02	1.547300E+02	1.485400E+02	1.551565E+02
279	5.1000E+00	1.767400E+02	1.770600E+02	1.705600E+02	1.765639E+02
280	5.0000E+00	1.548900E+02	1.607000E+02	1.537300E+02	1.551263E+02
281	4.9000E+00	1.511000E+02	1.606900E+02	1.533600E+02	1.516192E+02
282	4.8000E+00	1.650100E+02	1.698500E+02	1.626200E+02	1.651629E+02
283	4.7000E+00	1.930600E+02	1.921600E+02	1.850700E+02	1.927708E+02
284	4.6000E+00	1.607700E+02	1.645600E+02	1.573900E+02	1.608431E+02
285	4.5000E+00	1.436400E+02	1.504700E+02	1.432800E+02	1.439489E+02
286	4.4000E+00	1.443900E+02	1.518900E+02	1.450700E+02	1.447624E+02
287	4.3000E+00	1.383700E+02	1.430200E+02	1.364000E+02	1.385269E+02
288	4.2000E+00	1.710800E+02	1.731300E+02	1.661500E+02	1.710236E+02
289	4.1000E+00	1.099100E+02	1.161100E+02	1.088700E+02	1.101683E+02
290	4.0000E+00	1.367500E+02	1.432000E+02	1.361600E+02	1.370339E+02
291	3.9000E+00	1.391500E+02	1.430200E+02	1.350600E+02	1.392048E+02
292	3.8000E+00	1.138100E+02	1.180700E+02	1.087200E+02	1.138522E+02
293	3.7000E+00	1.184000E+02	1.225200E+02	1.127400E+02	1.184180E+02
294	3.6000E+00	7.105200E+01	8.261501E+01	7.417400E+01	7.169026E+01
295	3.5000E+00	1.158500E+02	1.218700E+02	1.144000E+02	1.160872E+02
296	3.4000E+00	1.201200E+02	1.260400E+02	1.189700E+02	1.203618E+02
297	3.3000E+00	1.165700E+02	1.196200E+02	1.130600E+02	1.166044E+02
298	3.2000E+00	1.229500E+02	1.236900E+02	1.175500E+02	1.228177E+02
299	3.1000E+00	1.365000E+02	1.387000E+02	1.329100E+02	1.364921E+02
300	3.0000E+00	1.218800E+02	1.249200E+02	1.201500E+02	1.219689E+02
301	2.9000E+00	1.011100E+02	1.047100E+02	9.976801E+01	1.012372E+02
302	2.8000E+00	1.375200E+02	1.377600E+02	1.315400E+02	1.373463E+02
303	2.7000E+00	1.098000E+02	1.134000E+02	1.082200E+02	1.099198E+02
304	2.6000E+00	1.177600E+02	1.211800E+02	1.164100E+02	1.178785E+02
305	2.5000E+00	1.316600E+02	1.346900E+02	1.294100E+02	1.317324E+02
306	2.4000E+00	1.208400E+02	1.227100E+02	1.162600E+02	1.207860E+02
307	2.3000E+00	1.054000E+02	1.076100E+02	1.011100E+02	1.053709E+02
308	2.2000E+00	1.072500E+02	1.090000E+02	1.054500E+02	1.072763E+02

309	2.1000E+00	1.101500E+02	1.129200E+02	1.079300E+02	1.102111E+02
310	2.0000E+00	9.711001E+01	9.901701E+01	9.691100E+01	9.719320E+01
311	1.9000E+00	1.321300E+02	1.365500E+02	1.333800E+02	1.323757E+02
312	1.8000E+00	1.338200E+02	1.381000E+02	1.350700E+02	1.340592E+02
313	1.7000E+00	8.041901E+01	7.408501E+01	7.455300E+01	7.994087E+01
314	1.6000E+00	1.769400E+02	7.664001E+01	6.479200E+01	1.687733E+02
315	1.5000E+00	1.106600E+02	8.917500E+01	6.910101E+01	1.083684E+02
316	1.4000E+00	1.045300E+02	8.297701E+01	8.488400E+01	1.029128E+02
317	1.3000E+00	8.950600E+01	9.171400E+01	1.021500E+02	9.000039E+01
318	1.2000E+00	9.237300E+01	1.118900E+02	6.308200E+01	9.238169E+01
319	1.1000E+00	6.245200E+01	9.269401E+01	4.667200E+01	6.338092E+01
320	1.0000E+00	7.969000E+01	4.939000E+01	4.187100E+01	7.710108E+01
321	9.6000E-01	1.178100E+02	4.824800E+01	4.651600E+01	1.123466E+02
322	9.2000E-01	1.170700E+02	5.880500E+01	5.107300E+01	1.122997E+02
323	8.8000E-01	9.282900E+01	6.978700E+01	5.530000E+01	9.058909E+01
324	8.4000E-01	8.163800E+01	5.961000E+01	6.297600E+01	8.002896E+01
325	8.0000E-01	1.470400E+02	5.364600E+01	4.627000E+01	1.395487E+02
326	7.6000E-01	8.975101E+01	7.495300E+01	8.501000E+01	8.891113E+01
327	7.2000E-01	6.226100E+01	7.363300E+01	1.339300E+02	6.500979E+01
328	6.9000E-01	5.809400E+01	6.545100E+01	5.302600E+01	5.828197E+01
329	6.6000E-01	5.549300E+01	7.396400E+01	4.395800E+01	5.600171E+01
330	6.3000E-01	5.324600E+01	9.045600E+01	4.389300E+01	5.470009E+01
331	6.0000E-01	5.306000E+01	6.361300E+01	3.719400E+01	5.306384E+01
332	5.7500E-01	5.817100E+01	6.964500E+01	3.913200E+01	5.811987E+01
333	5.5000E-01	1.264900E+02	1.061700E+02	4.494600E+01	1.230167E+02
334	5.2500E-01	7.358701E+01	8.618800E+01	4.976200E+01	7.344070E+01
335	5.0000E-01	5.870500E+01	5.658600E+01	4.774900E+01	5.826697E+01
336	4.7500E-01	5.655800E+01	4.765800E+01	4.444500E+01	5.576650E+01
337	4.5000E-01	5.505000E+01	4.570100E+01	4.172700E+01	5.420005E+01
338	4.2500E-01	5.359100E+01	4.861100E+01	4.015100E+01	5.294212E+01
339	4.0000E-01	5.217800E+01	6.146600E+01	4.734700E+01	5.246377E+01
340	3.8000E-01	5.148400E+01	6.524500E+01	3.623500E+01	5.165721E+01
341	3.6000E-01	5.152200E+01	7.173300E+00	3.557200E+01	4.895109E+01
342	3.4000E-01	5.208400E+01	8.890901E+00	3.490900E+01	4.952935E+01
343	3.2000E-01	5.221600E+01	2.667500E+01	3.427600E+01	5.046470E+01
344	3.0000E-01	5.302100E+01	1.546200E+01	3.826800E+01	5.080520E+01
345	2.8000E-01	5.473700E+01	1.642200E+01	3.299400E+01	5.226965E+01
346	2.7000E-01	5.627900E+01	1.680700E+01	3.286000E+01	5.370562E+01
347	2.5500E-01	5.856400E+01	1.696200E+01	3.292900E+01	5.582231E+01
348	2.4000E-01	6.264700E+01	1.695400E+01	3.340300E+01	5.960206E+01
349	2.3000E-01	6.793301E+01	1.682900E+01	3.844200E+01	6.462692E+01
350	2.2000E-01	7.441500E+01	1.665300E+01	3.608900E+01	7.052381E+01
351	2.1000E-01	8.400101E+01	1.640900E+01	3.934800E+01	7.945364E+01
352	2.0000E-01	9.818800E+01	1.615600E+01	4.658000E+01	9.274909E+01
353	1.9000E-01	1.166800E+02	1.599000E+01	6.851200E+01	1.104733E+02

354	1.8000E-01	1.190000E+02	1.786600E+01	9.660900E+01	1.135695E+02
355	1.7000E-01	7.073701E+01	1.584700E+01	6.732600E+00	6.618640E+01
356	1.6000E-01	2.080900E+01	2.155600E+01	2.778400E+00	2.028649E+01
357	1.5000E-01	3.180600E+00	2.695000E+01	6.480500E+00	4.396229E+00
358	1.4250E-01	1.668700E-01	1.342800E+01	7.709001E+00	1.021357E+00
359	1.3500E-01	4.166700E-01	1.153300E+01	7.633400E+00	1.160611E+00
360	1.2750E-01	1.236200E+00	1.088900E+01	7.949900E+00	1.896021E+00
361	1.2000E-01	2.144100E+00	1.054200E+01	8.197701E+00	2.724719E+00
362	1.1500E-01	2.857300E+00	1.024400E+01	8.302200E+00	3.371723E+00
363	1.1000E-01	3.365700E+00	1.000100E+01	8.318201E+00	3.829695E+00
364	1.0500E-01	3.804500E+00	9.757200E+00	8.266100E+00	4.221336E+00
365	1.0000E-01	4.190900E+00	9.513801E+00	8.187901E+00	4.563865E+00
366	9.6000E-02	4.508201E+00	9.272901E+00	8.080400E+00	4.841880E+00
367	9.2000E-02	4.743200E+00	9.037401E+00	7.945000E+00	5.043383E+00
368	8.8000E-02	4.950201E+00	8.801800E+00	7.809600E+00	5.219061E+00
369	8.4000E-02	5.157800E+00	8.553600E+00	7.650100E+00	5.393956E+00
370	8.0000E-02	5.300500E+00	8.285701E+00	7.452800E+00	5.506906E+00
371	7.6000E-02	5.467600E+00	8.017401E+00	7.255000E+00	5.642324E+00
372	7.2000E-02	5.656701E+00	7.739000E+00	7.041700E+00	5.797081E+00
373	6.9000E-02	5.870500E+00	7.474900E+00	6.823400E+00	5.975130E+00
374	6.6000E-02	6.370400E+00	7.247000E+00	6.634400E+00	6.419631E+00
375	6.3000E-02	6.658300E+00	7.019101E+00	6.445300E+00	6.668618E+00
376	6.0000E-02	7.812500E+00	6.784201E+00	6.216300E+00	7.714969E+00
377	5.7500E-02	1.165300E+01	6.557400E+00	5.940300E+00	1.123763E+01
378	5.5000E-02	5.202200E+01	6.333800E+00	5.687700E+00	4.844885E+01
379	5.2500E-02	1.029000E+00	6.008500E+00	5.435101E+00	1.398526E+00
380	5.0000E-02	1.346600E+00	5.645500E+00	5.182500E+00	1.666610E+00
381	4.7500E-02	2.076500E+00	5.357800E+00	4.959400E+00	2.319368E+00
382	4.5000E-02	2.419100E+00	5.150600E+00	4.765500E+00	2.619622E+00
383	4.2500E-02	2.584500E+00	4.944100E+00	4.571500E+00	2.756485E+00
384	4.0000E-02	2.652200E+00	4.777700E+00	4.362900E+00	2.804674E+00
385	3.8000E-02	2.657000E+00	1.396000E+01	4.162601E+00	3.233099E+00
386	3.6000E-02	2.626700E+00	4.370900E+00	3.984200E+00	2.750390E+00
387	3.4000E-02	2.574100E+00	4.096500E+00	3.803800E+00	2.683447E+00
388	3.2000E-02	2.505400E+00	3.884700E+00	3.611800E+00	2.604230E+00
389	3.0000E-02	2.423800E+00	3.675500E+00	3.417900E+00	2.513180E+00
390	2.8000E-02	2.324600E+00	3.464500E+00	3.224000E+00	2.405814E+00
391	2.7000E-02	2.242300E+00	3.305400E+00	3.078900E+00	2.317974E+00
392	2.5500E-02	2.170800E+00	3.170700E+00	2.952700E+00	2.241822E+00
393	2.4000E-02	2.084800E+00	3.007300E+00	2.801000E+00	2.150164E+00
394	2.3000E-02	2.005900E+00	2.871000E+00	2.674300E+00	2.067097E+00
395	2.2000E-02	1.939600E+00	2.760800E+00	2.570400E+00	1.997578E+00
396	2.1000E-02	1.873300E+00	2.649600E+00	2.466500E+00	1.928011E+00
397	2.0000E-02	1.807100E+00	2.537400E+00	2.362600E+00	1.858491E+00
398	1.9000E-02	1.737400E+00	2.424600E+00	2.257200E+00	1.785668E+00

399	1.8000E-02	1.664300E+00	2.310700E+00	2.150600E+00	1.709620E+00
400	1.7000E-02	1.590700E+00	2.196200E+00	2.043700E+00	1.633074E+00
401	1.6000E-02	1.513900E+00	2.082600E+00	1.935500E+00	1.553580E+00
402	1.5000E-02	1.436500E+00	3.627700E+00	1.827000E+00	1.551232E+00
403	1.4250E-02	1.367400E+00	1.871200E+00	1.731500E+00	1.402261E+00
404	1.3500E-02	1.306300E+00	1.774000E+00	1.648600E+00	1.338796E+00
405	1.2750E-02	1.245100E+00	1.684000E+00	1.565600E+00	1.275572E+00
406	1.2000E-02	1.183300E+00	1.594000E+00	1.482200E+00	1.211783E+00
407	1.1500E-02	1.130400E+00	1.518800E+00	1.412100E+00	1.157307E+00
408	1.1000E-02	1.087700E+00	1.458100E+00	1.355600E+00	1.113337E+00
409	1.0500E-02	1.044500E+00	1.397200E+00	1.298900E+00	1.068890E+00
410	1.0000E-02	1.001100E+00	1.336300E+00	1.242100E+00	1.024256E+00
411	9.6000E-03	9.617500E-01	1.281300E+00	1.190900E+00	9.838062E-01
412	9.2000E-03	9.261900E-01	1.232100E+00	1.145000E+00	9.472876E-01
413	8.8000E-03	8.906301E-01	1.182900E+00	1.099200E+00	9.107720E-01
414	8.4000E-03	8.546900E-01	1.133300E+00	1.053100E+00	8.738777E-01
415	8.0000E-03	8.181400E-01	1.083200E+00	1.006700E+00	8.363883E-01
416	7.6000E-03	7.815800E-01	1.033100E+00	9.599401E-01	7.988786E-01
417	7.2000E-03	7.448401E-01	9.829201E-01	9.131501E-01	7.611983E-01
418	6.9000E-03	7.123901E-01	9.389700E-01	8.724000E-01	7.279529E-01
419	6.6000E-03	6.845000E-01	9.012101E-01	8.373000E-01	6.993775E-01
420	6.3000E-03	6.566000E-01	8.634501E-01	8.019900E-01	6.707864E-01
421	6.0000E-03	6.284200E-01	8.254100E-01	7.664500E-01	6.419169E-01
422	5.7500E-03	6.021501E-01	7.901200E-01	7.336700E-01	6.150230E-01
423	5.5000E-03	5.782200E-01	7.580100E-01	7.039700E-01	5.905313E-01
424	5.2500E-03	5.542800E-01	7.259900E-01	6.746401E-01	5.660461E-01
425	5.0000E-03	5.303401E-01	6.939901E-01	6.564900E-01	5.419076E-01
426	4.7500E-03	5.061300E-01	6.617200E-01	1.615400E+00	5.477180E-01
427	4.5000E-03	4.816500E-01	6.291900E-01	5.850500E-01	4.917594E-01
428	4.2500E-03	4.571800E-01	5.966700E-01	5.541900E-01	4.667147E-01
429	4.0000E-03	4.327700E-01	5.643100E-01	5.239300E-01	4.417513E-01
430	3.8000E-03	4.109000E-01	5.353301E-01	4.967700E-01	4.193846E-01
431	3.6000E-03	3.913200E-01	5.089300E-01	4.721700E-01	3.993299E-01
432	3.4000E-03	3.716300E-01	4.824600E-01	4.477600E-01	3.791763E-01
433	3.2000E-03	3.513800E-01	4.564800E-01	4.237500E-01	3.585416E-01
434	3.0000E-03	3.310300E-01	4.304100E-01	3.996900E-01	3.378089E-01
435	2.8000E-03	3.106500E-01	4.037400E-01	3.753900E-01	3.170130E-01
436	2.7000E-03	2.954900E-01	3.838700E-01	3.569800E-01	3.015319E-01
437	2.5500E-03	2.829300E-01	3.675600E-01	3.420400E-01	2.887226E-01
438	2.4000E-03	2.679500E-01	3.481200E-01	3.257600E-01	2.734934E-01
439	2.3000E-03	2.554000E-01	3.318800E-01	3.200800E-01	2.609830E-01
440	2.2000E-03	2.450600E-01	3.186200E-01	6.242800E+00	4.339564E-01
441	2.1000E-03	2.348900E-01	3.053500E-01	3.067900E-01	2.404142E-01
442	2.0000E-03	2.249800E-01	2.920800E-01	2.727300E-01	2.296001E-01
443	1.9000E-03	2.148800E-01	2.787000E-01	2.584700E-01	2.192178E-01

444	1.8000E-03	2.045900E-01	2.652100E-01	2.459800E-01	2.087098E-01
445	1.7000E-03	1.943400E-01	2.517500E-01	2.331900E-01	1.982309E-01
446	1.6000E-03	1.842600E-01	2.384200E-01	2.205800E-01	1.879204E-01
447	1.5000E-03	1.738300E-01	2.251100E-01	2.087500E-01	1.773122E-01
448	1.4250E-03	1.646400E-01	2.133200E-01	1.980500E-01	1.679537E-01
449	1.3500E-03	1.568500E-01	2.029600E-01	1.884400E-01	1.599870E-01
450	1.2750E-03	1.496300E-01	1.925900E-01	1.790100E-01	1.525511E-01
451	1.2000E-03	1.424000E-01	1.822900E-01	1.696000E-01	1.451099E-01
452	1.1500E-03	1.358900E-01	1.739600E-01	1.617200E-01	1.384722E-01
453	1.1000E-03	1.306500E-01	1.674200E-01	1.554300E-01	1.331389E-01
454	1.0500E-03	1.255600E-01	1.616400E-01	1.493300E-01	1.279853E-01
455	1.0000E-03	1.205000E-01	1.560000E-01	1.432600E-01	1.228669E-01
456	9.6000E-04	1.159200E-01	1.505100E-01	1.378100E-01	1.182174E-01
457	9.2000E-04	1.118100E-01	1.451700E-01	1.329600E-01	1.140269E-01
458	8.8000E-04	1.077000E-01	1.398400E-01	1.281100E-01	1.098368E-01
459	8.4000E-04	1.035900E-01	1.345800E-01	1.233000E-01	1.056513E-01
460	8.0000E-04	9.949300E-02	1.294500E-01	1.185400E-01	1.014854E-01
461	7.6000E-04	9.551600E-02	1.243900E-01	1.138400E-01	9.743533E-02
462	7.2000E-04	9.160300E-02	1.193800E-01	1.092000E-01	9.344845E-02
463	6.9000E-04	8.823800E-02	1.150900E-01	1.052200E-01	9.002110E-02
464	6.6000E-04	8.545700E-02	1.114500E-01	1.018700E-01	8.718226E-02
465	6.3000E-04	8.282300E-02	1.079000E-01	9.858301E-02	8.448516E-02
466	6.0000E-04	8.018900E-02	1.040000E-01	9.544700E-02	8.177631E-02
467	5.7500E-04	7.777900E-02	9.988100E-02	9.282000E-02	7.927955E-02
468	5.5000E-04	7.558800E-02	9.629400E-02	9.042901E-02	7.701696E-02
469	5.2500E-04	7.341101E-02	9.374300E-02	8.801001E-02	7.481497E-02
470	5.0000E-04	7.123701E-02	9.136301E-02	8.558600E-02	7.262359E-02
471	4.7500E-04	6.884700E-02	8.902301E-02	8.281700E-02	7.022420E-02
472	4.5000E-04	6.639700E-02	8.659501E-02	7.990800E-02	6.776103E-02
473	4.2500E-04	6.483700E-02	8.340400E-02	7.817800E-02	6.611937E-02
474	4.0000E-04	6.283600E-02	8.107600E-02	7.570000E-02	6.408830E-02
475	3.8000E-04	6.058900E-02	7.969001E-02	7.261001E-02	6.185557E-02
476	3.6000E-04	5.927501E-02	7.675301E-02	6.946601E-02	6.040896E-02
477	3.4000E-04	5.779200E-02	7.337201E-02	6.621900E-02	5.878248E-02
478	3.2000E-04	5.426900E-02	6.997000E-02	6.296100E-02	5.527335E-02
479	3.0000E-04	5.067100E-02	6.622500E-02	5.938400E-02	5.166911E-02
480	2.8000E-04	4.802200E-02	6.123301E-02	5.463900E-02	4.884553E-02
481	2.7000E-04	4.596901E-02	5.734800E-02	5.095100E-02	4.665616E-02
482	2.5500E-04	4.308800E-02	5.346300E-02	4.729000E-02	4.370399E-02
483	2.4000E-04	3.947400E-02	4.872600E-02	4.282900E-02	4.001119E-02
484	2.3000E-04	3.626800E-02	4.453300E-02	3.884000E-02	3.673474E-02
485	2.2000E-04	3.316200E-02	4.049200E-02	3.489500E-02	3.355899E-02
486	2.1000E-04	2.972200E-02	3.606200E-02	3.029200E-02	3.003665E-02
487	2.0000E-04	2.579600E-02	3.106600E-02	2.470400E-02	2.600914E-02
488	1.9000E-04	1.927200E-02	2.304500E-02	1.757500E-02	1.939629E-02

489	1.8000E-04	1.020300E-02	1.206000E-02	8.944700E-03	1.025109E-02
490	1.7000E-04	2.294900E-03	2.479000E-03	1.415500E-03	2.276334E-03
491	1.6000E-04	1.215600E-03	1.163700E-03	3.677000E-04	1.186951E-03
492	1.5000E-04	1.254300E-03	1.200800E-03	3.791500E-04	1.224734E-03
493	1.4250E-04	1.291200E-03	1.236100E-03	3.900600E-04	1.260755E-03
494	1.3500E-04	1.325400E-03	1.268900E-03	4.002000E-04	1.294146E-03
495	1.2750E-04	1.363200E-03	1.305200E-03	4.114200E-04	1.331054E-03
496	1.2000E-04	1.403600E-03	1.343900E-03	4.234000E-04	1.370495E-03
497	1.1500E-04	1.440900E-03	1.379600E-03	4.344600E-04	1.406909E-03
498	1.1000E-04	1.471700E-03	1.409200E-03	4.436200E-04	1.436984E-03
499	1.0500E-04	1.506700E-03	1.442700E-03	4.540300E-04	1.471153E-03
500	1.0000E-04	1.542400E-03	1.476900E-03	4.646300E-04	1.506007E-03
501	9.6000E-05	1.577400E-03	1.510500E-03	4.750500E-04	1.540181E-03
502	9.2000E-05	1.611800E-03	1.543500E-03	4.852900E-04	1.573768E-03
503	8.8000E-05	1.646300E-03	1.576400E-03	4.955400E-04	1.607444E-03
504	8.4000E-05	1.682900E-03	1.611600E-03	5.064500E-04	1.643184E-03
505	8.0000E-05	1.723400E-03	1.650300E-03	5.185000E-04	1.682720E-03
506	7.6000E-05	1.767400E-03	1.692500E-03	5.316201E-04	1.725681E-03
507	7.2000E-05	1.814400E-03	1.737500E-03	5.456100E-04	1.771566E-03
508	6.9000E-05	1.858900E-03	1.780200E-03	5.588900E-04	1.815017E-03
509	6.6000E-05	1.899700E-03	1.819300E-03	5.710601E-04	1.854852E-03
510	6.3000E-05	1.943800E-03	1.861500E-03	5.842000E-04	1.897905E-03
511	6.0000E-05	1.990400E-03	1.906200E-03	5.981000E-04	1.943405E-03
512	5.7500E-05	2.037200E-03	1.951000E-03	6.120600E-04	1.989096E-03
513	5.5000E-05	2.080800E-03	1.992800E-03	6.250900E-04	2.031667E-03
514	5.2500E-05	2.130300E-03	2.040300E-03	6.398600E-04	2.079999E-03
515	5.0000E-05	2.180700E-03	2.088600E-03	6.549200E-04	2.129208E-03
516	4.7500E-05	2.235200E-03	2.140700E-03	6.711700E-04	2.182413E-03
517	4.5000E-05	2.294600E-03	2.197600E-03	6.889000E-04	2.240407E-03
518	4.2500E-05	2.359700E-03	2.260000E-03	7.083500E-04	2.303969E-03
519	4.0000E-05	2.430400E-03	2.327800E-03	7.295000E-04	2.373002E-03
520	3.8000E-05	2.498900E-03	2.393400E-03	7.499400E-04	2.439879E-03
521	3.6000E-05	2.566800E-03	2.458500E-03	7.702500E-04	2.506177E-03
522	3.4000E-05	2.638200E-03	2.526800E-03	7.915801E-04	2.575884E-03
523	3.2000E-05	2.718700E-03	2.604000E-03	8.156500E-04	2.654484E-03
524	3.0000E-05	2.804000E-03	2.685700E-03	8.411400E-04	2.737766E-03
525	2.8000E-05	2.901200E-03	2.778800E-03	8.701900E-04	2.832667E-03
526	2.7000E-05	2.975900E-03	2.850400E-03	8.925301E-04	2.905602E-03
527	2.5500E-05	3.050100E-03	2.921500E-03	9.147201E-04	2.978049E-03
528	2.4000E-05	3.140500E-03	3.008100E-03	9.417600E-04	3.066312E-03
529	2.3000E-05	3.218800E-03	3.083100E-03	9.651801E-04	3.142761E-03
530	2.2000E-05	3.290000E-03	3.151300E-03	9.864700E-04	3.212277E-03
531	2.1000E-05	3.365400E-03	3.223600E-03	1.009000E-03	3.285897E-03
532	2.0000E-05	3.447000E-03	3.301700E-03	1.033400E-03	3.365564E-03
533	1.9000E-05	3.536100E-03	3.387000E-03	1.060100E-03	3.452557E-03

534	1.8000E-05	3.632300E-03	3.479300E-03	1.088900E-03	3.546490E-03
535	1.7000E-05	3.730700E-03	3.573500E-03	1.118300E-03	3.642560E-03
536	1.6000E-05	3.841600E-03	3.679700E-03	1.151500E-03	3.750837E-03
537	1.5000E-05	3.964100E-03	3.797100E-03	1.188200E-03	3.870445E-03
538	1.4250E-05	4.080900E-03	3.909000E-03	1.223100E-03	3.984483E-03
539	1.3500E-05	4.189300E-03	4.012800E-03	1.255500E-03	4.090318E-03
540	1.2750E-05	4.309200E-03	4.127600E-03	1.291400E-03	4.207382E-03
541	1.2000E-05	4.437000E-03	4.250100E-03	1.329700E-03	4.332166E-03
542	1.1500E-05	4.555000E-03	4.363100E-03	1.365000E-03	4.447374E-03
543	1.1000E-05	4.652700E-03	4.456700E-03	1.394200E-03	4.542765E-03
544	1.0500E-05	4.763600E-03	4.562900E-03	1.427400E-03	4.651042E-03
545	1.0000E-05	4.876600E-03	4.671200E-03	1.461200E-03	4.761373E-03
546	9.6000E-06	4.987400E-03	4.777300E-03	1.494400E-03	4.869553E-03
547	9.2000E-06	5.096200E-03	4.881600E-03	1.527000E-03	4.975786E-03
548	8.8000E-06	5.205100E-03	4.985900E-03	1.559600E-03	5.082111E-03
549	8.4000E-06	5.321000E-03	5.096900E-03	1.594200E-03	5.195268E-03
550	8.0000E-06	5.448700E-03	5.219200E-03	1.632500E-03	5.319951E-03
551	7.6000E-06	5.588000E-03	5.352800E-03	1.674200E-03	5.455966E-03
552	7.2000E-06	5.736600E-03	5.495100E-03	1.718700E-03	5.601053E-03
553	6.9000E-06	5.877700E-03	5.630200E-03	1.760900E-03	5.738813E-03
554	6.6000E-06	6.006900E-03	5.754001E-03	1.799600E-03	5.864962E-03
555	6.3000E-06	6.146400E-03	5.887700E-03	1.841400E-03	6.001169E-03
556	6.0000E-06	6.294000E-03	6.029000E-03	1.885500E-03	6.145274E-03
557	5.7500E-06	6.442200E-03	6.171000E-03	1.929900E-03	6.289974E-03
558	5.5000E-06	6.580500E-03	6.303400E-03	1.971300E-03	6.425002E-03
559	5.2500E-06	6.736900E-03	6.453300E-03	2.018100E-03	6.577708E-03
560	5.0000E-06	6.896300E-03	6.606000E-03	2.065900E-03	6.733343E-03
561	4.7500E-06	7.068400E-03	6.770800E-03	2.117400E-03	6.901372E-03
562	4.5000E-06	7.256000E-03	6.950601E-03	2.173600E-03	7.084544E-03
563	4.2500E-06	7.462101E-03	7.148000E-03	2.235300E-03	7.285773E-03
564	4.0000E-06	7.686201E-03	7.362600E-03	2.302400E-03	7.504573E-03
565	3.8000E-06	7.902800E-03	7.570200E-03	2.367200E-03	7.716057E-03
566	3.6000E-06	8.118100E-03	7.776401E-03	2.431700E-03	7.926269E-03
567	3.4000E-06	8.344101E-03	7.992900E-03	2.499400E-03	8.146929E-03
568	3.2000E-06	8.599200E-03	8.237300E-03	2.575700E-03	8.395999E-03
569	3.0000E-06	8.869400E-03	8.496101E-03	2.656600E-03	8.659812E-03
570	2.8000E-06	9.177400E-03	8.791100E-03	2.748900E-03	8.960533E-03
571	2.7000E-06	9.414100E-03	9.017801E-03	2.819700E-03	9.191635E-03
572	2.5500E-06	9.648600E-03	9.242401E-03	2.889900E-03	9.420590E-03
573	2.4000E-06	9.934201E-03	9.516100E-03	2.975500E-03	9.699451E-03
574	2.3000E-06	1.018100E-02	9.7752900E-03	3.049500E-03	9.940439E-03
575	2.2000E-06	1.040600E-02	9.967800E-03	3.116700E-03	1.016008E-02
576	2.1000E-06	1.064400E-02	1.019600E-02	3.188100E-03	1.039247E-02
577	2.0000E-06	1.090300E-02	1.044400E-02	3.265600E-03	1.064535E-02
578	1.9000E-06	1.118500E-02	1.071400E-02	3.350100E-03	1.092068E-02

579	1.8000E-06	1.149000E-02	1.100600E-02	3.441300E-03	1.121846E-02
580	1.7000E-06	1.180000E-02	1.130400E-02	3.534300E-03	1.152119E-02
581	1.6000E-06	1.215000E-02	1.163800E-02	3.638900E-03	1.186285E-02
582	1.5000E-06	1.253700E-02	1.201000E-02	3.755000E-03	1.224077E-02
583	1.4250E-06	1.290700E-02	1.236400E-02	3.865600E-03	1.260200E-02
584	1.3500E-06	1.325000E-02	1.269200E-02	3.968500E-03	1.293687E-02
585	1.2750E-06	1.363000E-02	1.305600E-02	4.082100E-03	1.330789E-02
586	1.2000E-06	1.403500E-02	1.344400E-02	4.203400E-03	1.370332E-02
587	1.1500E-06	1.440800E-02	1.380200E-02	4.315300E-03	1.406754E-02
588	1.1000E-06	1.471800E-02	1.409900E-02	4.408000E-03	1.437021E-02
589	1.0500E-06	1.506900E-02	1.443500E-02	4.513200E-03	1.471291E-02
590	1.0000E-06	1.542700E-02	1.477800E-02	4.620500E-03	1.506246E-02
591	9.6000E-07	1.577800E-02	1.511400E-02	4.725400E-03	1.540515E-02
592	9.2000E-07	1.612200E-02	1.544300E-02	4.828400E-03	1.574099E-02
593	8.8000E-07	1.646500E-02	1.577200E-02	4.931300E-03	1.607591E-02
594	8.4000E-07	1.683000E-02	1.612200E-02	5.040700E-03	1.643231E-02
595	8.0000E-07	1.723200E-02	1.650700E-02	5.161000E-03	1.682480E-02
596	7.6000E-07	1.767300E-02	1.692900E-02	5.292900E-03	1.725535E-02
597	7.2000E-07	1.814300E-02	1.737900E-02	5.433701E-03	1.771424E-02
598	6.9000E-07	1.858900E-02	1.780700E-02	5.567400E-03	1.814974E-02
599	6.6000E-07	1.899900E-02	1.819900E-02	5.689900E-03	1.855000E-02
600	6.3000E-07	1.944000E-02	1.862200E-02	5.822200E-03	1.898061E-02
601	6.0000E-07	1.990700E-02	1.907000E-02	5.962100E-03	1.943661E-02
602	5.7500E-07	2.037700E-02	1.951900E-02	6.102701E-03	1.989544E-02
603	5.5000E-07	2.081400E-02	1.993900E-02	6.233800E-03	2.032219E-02
604	5.2500E-07	2.130900E-02	2.041200E-02	6.381800E-03	2.080543E-02
605	5.0000E-07	2.181200E-02	2.089500E-02	6.532600E-03	2.129660E-02
606	4.7500E-07	2.235600E-02	2.141500E-02	6.695300E-03	2.182768E-02
607	4.5000E-07	2.294500E-02	2.198000E-02	6.871800E-03	2.240281E-02
608	4.2500E-07	2.359000E-02	2.259700E-02	7.064900E-03	2.303252E-02
609	4.0000E-07	2.429600E-02	2.327400E-02	7.276501E-03	2.372188E-02
610	3.8000E-07	2.498700E-02	2.393600E-02	7.483301E-03	2.439655E-02
611	3.6000E-07	2.565400E-02	2.457400E-02	7.683001E-03	2.504774E-02
612	3.4000E-07	2.637500E-02	2.526500E-02	7.899000E-03	2.575172E-02
613	3.2000E-07	2.716100E-02	2.601800E-02	8.134400E-03	2.651915E-02
614	3.0000E-07	2.802400E-02	2.684500E-02	8.392801E-03	2.736177E-02
615	2.8000E-07	2.897200E-02	2.775300E-02	8.676601E-03	2.828736E-02
616	2.7000E-07	2.974400E-02	2.849200E-02	8.907900E-03	2.904109E-02
617	2.5500E-07	3.044900E-02	2.916800E-02	9.119001E-03	2.972946E-02
618	2.4000E-07	3.136100E-02	3.004100E-02	9.392201E-03	3.061988E-02
619	2.3000E-07	3.218100E-02	3.082700E-02	9.637700E-03	3.142053E-02
620	2.2000E-07	3.288900E-02	3.150600E-02	9.849900E-03	3.211184E-02
621	2.1000E-07	3.364600E-02	3.223100E-02	1.007700E-02	3.285095E-02
622	2.0000E-07	3.445700E-02	3.300800E-02	1.032000E-02	3.364280E-02
623	1.9000E-07	3.533600E-02	3.384900E-02	1.058300E-02	3.450097E-02

624	1.8000E-07	3.627100E-02	3.474400E-02	1.086300E-02	3.541384E-02
625	1.7000E-07	3.729400E-02	3.572400E-02	1.116900E-02	3.641266E-02
626	1.6000E-07	3.840900E-02	3.679300E-02	1.150300E-02	3.750135E-02
627	1.5000E-07	3.963200E-02	3.796400E-02	1.186900E-02	3.869542E-02
628	1.4250E-07	4.079600E-02	3.908001E-02	1.221800E-02	3.983198E-02
629	1.3500E-07	4.188700E-02	4.012400E-02	1.254500E-02	4.089715E-02
630	1.2750E-07	4.306800E-02	4.125600E-02	1.289800E-02	4.205025E-02
631	1.2000E-07	4.435400E-02	4.248700E-02	1.328300E-02	4.330581E-02
632	1.1500E-07	4.551000E-02	4.359500E-02	1.363000E-02	4.443455E-02
633	1.1000E-07	4.651000E-02	4.455300E-02	1.392900E-02	4.541091E-02
634	1.0500E-07	4.758000E-02	4.557800E-02	1.424900E-02	4.645561E-02
635	1.0000E-07	4.873000E-02	4.668000E-02	1.459400E-02	4.757848E-02
636	9.6000E-08	4.984400E-02	4.774600E-02	1.492700E-02	4.866607E-02
637	9.2000E-08	5.088700E-02	4.874600E-02	1.524000E-02	4.968449E-02
638	8.8000E-08	5.200300E-02	4.981500E-02	1.557400E-02	5.077411E-02
639	8.4000E-08	5.320000E-02	5.096200E-02	1.593300E-02	5.194285E-02
640	8.0000E-08	5.448500E-02	5.219300E-02	1.631800E-02	5.319750E-02
641	7.6000E-08	5.586800E-02	5.351700E-02	1.673200E-02	5.454777E-02
642	7.2000E-08	5.735900E-02	5.494600E-02	1.717800E-02	5.600356E-02
643	6.9000E-08	5.875900E-02	5.628700E-02	1.759800E-02	5.737049E-02
644	6.6000E-08	6.005100E-02	5.752501E-02	1.798500E-02	5.863198E-02
645	6.3000E-08	6.143200E-02	5.884800E-02	1.839800E-02	5.998033E-02
646	6.0000E-08	6.291300E-02	6.026600E-02	1.884200E-02	6.142631E-02
647	5.7500E-08	6.436400E-02	6.165600E-02	1.927600E-02	6.284301E-02
648	5.5000E-08	6.577800E-02	6.301101E-02	1.969900E-02	6.422361E-02
649	5.2500E-08	6.729200E-02	6.446000E-02	2.015300E-02	6.570178E-02
650	5.0000E-08	6.891800E-02	6.601800E-02	2.064000E-02	6.728937E-02
651	4.7500E-08	7.066600E-02	6.769300E-02	2.116300E-02	6.899608E-02
652	4.5000E-08	7.253700E-02	6.948500E-02	2.172400E-02	7.082288E-02
653	4.2500E-08	7.458300E-02	7.144500E-02	2.233600E-02	7.282051E-02
654	4.0000E-08	7.681200E-02	7.358000E-02	2.300400E-02	7.499684E-02
655	3.8000E-08	7.899401E-02	7.567100E-02	2.365800E-02	7.712734E-02
656	3.6000E-08	8.110200E-02	7.769001E-02	2.428900E-02	7.918549E-02
657	3.4000E-08	8.339000E-02	7.988201E-02	2.497400E-02	8.141942E-02
658	3.2000E-08	8.588400E-02	8.227101E-02	2.572100E-02	8.385448E-02
659	3.0000E-08	8.861101E-02	8.488300E-02	2.653800E-02	8.651705E-02
660	2.8000E-08	9.161600E-02	8.776201E-02	2.743800E-02	8.945105E-02
661	2.7000E-08	9.407600E-02	9.011800E-02	2.817400E-02	9.185287E-02
662	2.5500E-08	9.629300E-02	9.224100E-02	2.883800E-02	9.401746E-02
663	2.4000E-08	9.916200E-02	9.498900E-02	2.969700E-02	9.681863E-02
664	2.3000E-08	1.017600E-01	9.748100E-02	3.047600E-02	9.935543E-02
665	2.2000E-08	1.040000E-01	9.962001E-02	3.114500E-02	1.015421E-01
666	2.1000E-08	1.063900E-01	1.019100E-01	3.186100E-02	1.038757E-01
667	2.0000E-08	1.089600E-01	1.043800E-01	3.263200E-02	1.063854E-01
668	1.9000E-08	1.117200E-01	1.070200E-01	3.345800E-02	1.090799E-01

669	1.8000E-08	1.146800E-01	1.098500E-01	3.434300E-02	1.119697E-01
670	1.7000E-08	1.179100E-01	1.129500E-01	3.531100E-02	1.151237E-01
671	1.6000E-08	1.214300E-01	1.163200E-01	3.636600E-02	1.185604E-01
672	1.5000E-08	1.252900E-01	1.200200E-01	3.752100E-02	1.223293E-01
673	1.4250E-08	1.289800E-01	1.235500E-01	3.862700E-02	1.259319E-01
674	1.3500E-08	1.324200E-01	1.268500E-01	3.965800E-02	1.292908E-01
675	1.2750E-08	1.361500E-01	1.304300E-01	4.077600E-02	1.329331E-01
676	1.2000E-08	1.402200E-01	1.343200E-01	4.199400E-02	1.369064E-01
677	1.1500E-08	1.439000E-01	1.378500E-01	4.309600E-02	1.404997E-01
678	1.1000E-08	1.470600E-01	1.408800E-01	4.404300E-02	1.435852E-01
679	1.0500E-08	1.504500E-01	1.441200E-01	4.505700E-02	1.468947E-01
680	1.0000E-08	1.540800E-01	1.476000E-01	4.614600E-02	1.504391E-01
681	9.6000E-09	1.575900E-01	1.509600E-01	4.719400E-02	1.538659E-01
682	9.2000E-09	1.608800E-01	1.541100E-01	4.818200E-02	1.570782E-01
683	8.8000E-09	1.644100E-01	1.574900E-01	4.923700E-02	1.605246E-01
684	8.4000E-09	1.681900E-01	1.611100E-01	5.036900E-02	1.642153E-01
685	8.0000E-09	1.722400E-01	1.650000E-01	5.158400E-02	1.681701E-01
686	7.6000E-09	1.766100E-01	1.691800E-01	5.289100E-02	1.724365E-01
687	7.2000E-09	1.813200E-01	1.736900E-01	5.430100E-02	1.770351E-01
688	6.9000E-09	1.857700E-01	1.779500E-01	5.563400E-02	1.813798E-01
689	6.6000E-09	1.898500E-01	1.818600E-01	5.685700E-02	1.853635E-01
690	6.3000E-09	1.942200E-01	1.860500E-01	5.816500E-02	1.896304E-01
691	6.0000E-09	1.989000E-01	1.905300E-01	5.956800E-02	1.941997E-01
692	5.7500E-09	2.035100E-01	1.949400E-01	6.094700E-02	1.987004E-01
693	5.5000E-09	2.079800E-01	1.992300E-01	6.228600E-02	2.030652E-01
694	5.2500E-09	2.127700E-01	2.038100E-01	6.372000E-02	2.077416E-01
695	5.0000E-09	2.179100E-01	2.087400E-01	6.526001E-02	2.127604E-01
696	4.7500E-09	2.233900E-01	2.139900E-01	6.690101E-02	2.181110E-01
697	4.5000E-09	2.293500E-01	2.197000E-01	6.868700E-02	2.239302E-01
698	4.2500E-09	2.358100E-01	2.258900E-01	7.062200E-02	2.302376E-01
699	4.0000E-09	2.428500E-01	2.326400E-01	7.273100E-02	2.371116E-01
700	3.8000E-09	2.497700E-01	2.392600E-01	7.480200E-02	2.438676E-01
701	3.6000E-09	2.564300E-01	2.456500E-01	7.679800E-02	2.503707E-01
702	3.4000E-09	2.636600E-01	2.525700E-01	7.896300E-02	2.574296E-01
703	3.2000E-09	2.715400E-01	2.601200E-01	8.132301E-02	2.651235E-01
704	3.0000E-09	2.801700E-01	2.683800E-01	8.390700E-02	2.735492E-01
705	2.8000E-09	2.896300E-01	2.774500E-01	8.674000E-02	2.827860E-01
706	2.7000E-09	2.974200E-01	2.849100E-01	8.907400E-02	2.903919E-01
707	2.5500E-09	3.044200E-01	2.916100E-01	9.116900E-02	2.972261E-01
708	2.4000E-09	3.135100E-01	3.003200E-01	9.389300E-02	3.061015E-01
709	2.3000E-09	3.217500E-01	3.082100E-01	9.635901E-02	3.141465E-01
710	2.2000E-09	3.288200E-01	3.149900E-01	9.847700E-02	3.210498E-01
711	2.1000E-09	3.363800E-01	3.222300E-01	1.007400E-01	3.284311E-01
712	2.0000E-09	3.444900E-01	3.300000E-01	1.031700E-01	3.363495E-01
713	1.9000E-09	3.532700E-01	3.384100E-01	1.058000E-01	3.449220E-01

714	1.8000E-09	3.626200E-01	3.473600E-01	1.086000E-01	3.540508E-01
715	1.7000E-09	3.728400E-01	3.571500E-01	1.116600E-01	3.640293E-01
716	1.6000E-09	3.839700E-01	3.678100E-01	1.149900E-01	3.748960E-01
717	1.5000E-09	3.961700E-01	3.795000E-01	1.186500E-01	3.868081E-01
718	1.4250E-09	4.078500E-01	3.906900E-01	1.221400E-01	3.982119E-01
719	1.3500E-09	4.187400E-01	4.011200E-01	1.254100E-01	4.088447E-01
720	1.2750E-09	4.305400E-01	4.124300E-01	1.289400E-01	4.203661E-01
721	1.2000E-09	4.434000E-01	4.247500E-01	1.327900E-01	4.329222E-01
722	1.1500E-09	4.550500E-01	4.359000E-01	1.362800E-01	4.442964E-01
723	1.1000E-09	4.650500E-01	4.454900E-01	1.392800E-01	4.540608E-01
724	1.0500E-09	4.757600E-01	4.557400E-01	1.424800E-01	4.645171E-01
725	1.0000E-09	4.872500E-01	4.667500E-01	1.459200E-01	4.757356E-01
726	9.6000E-10	4.983300E-01	4.773600E-01	1.492400E-01	4.865537E-01
727	9.2000E-10	5.087500E-01	4.873500E-01	1.523600E-01	4.967279E-01
728	8.8000E-10	5.199000E-01	4.980200E-01	1.557000E-01	5.076139E-01
729	8.4000E-10	5.318400E-01	5.094700E-01	1.592800E-01	5.192724E-01
730	8.0000E-10	5.446700E-01	5.217600E-01	1.631200E-01	5.317991E-01
731	7.6000E-10	5.584700E-01	5.349700E-01	1.672500E-01	5.452725E-01
732	7.2000E-10	5.733600E-01	5.492400E-01	1.717100E-01	5.598110E-01
733	6.9000E-10	5.874400E-01	5.627200E-01	1.759300E-01	5.735580E-01
734	6.6000E-10	6.003600E-01	5.751000E-01	1.798000E-01	5.861729E-01
735	6.3000E-10	6.141700E-01	5.883300E-01	1.839300E-01	5.996564E-01
736	6.0000E-10	6.289800E-01	6.025100E-01	1.883700E-01	6.141162E-01
737	5.7500E-10	6.435301E-01	6.164600E-01	1.927300E-01	6.283231E-01
738	5.5000E-10	6.576800E-01	6.300101E-01	1.969600E-01	6.421382E-01
739	5.2500E-10	6.728200E-01	6.445100E-01	2.015000E-01	6.569204E-01
740	5.0000E-10	6.890700E-01	6.600801E-01	2.063700E-01	6.727867E-01
741	4.7500E-10	7.064000E-01	6.766800E-01	2.115500E-01	6.897069E-01
742	4.5000E-10	7.252600E-01	6.947400E-01	2.172000E-01	7.081209E-01
743	4.2500E-10	7.456800E-01	7.143101E-01	2.233200E-01	7.280590E-01
744	4.0000E-10	7.679501E-01	7.356400E-01	2.299900E-01	7.498026E-01
745	3.8000E-10	7.898200E-01	7.565901E-01	2.365400E-01	7.711557E-01
746	3.6000E-10	8.109001E-01	7.767801E-01	2.428500E-01	7.917375E-01
747	3.4000E-10	8.337600E-01	7.986800E-01	2.497000E-01	8.140574E-01
748	3.2000E-10	8.586700E-01	8.225400E-01	2.571600E-01	8.383786E-01
749	3.0000E-10	8.859600E-01	8.486800E-01	2.653300E-01	8.650235E-01
750	2.8000E-10	9.158700E-01	8.773401E-01	2.742900E-01	8.942272E-01
751	2.7000E-10	9.405200E-01	9.009501E-01	2.816700E-01	9.182945E-01
752	2.5500E-10	9.626400E-01	9.221401E-01	2.882900E-01	9.398917E-01
753	2.4000E-10	9.914001E-01	9.496900E-01	2.969100E-01	9.679724E-01
754	2.3000E-10	1.017400E+00	9.746401E-01	3.047100E-01	9.933603E-01
755	2.2000E-10	1.039800E+00	9.960700E-01	3.114100E-01	1.015229E+00
756	2.1000E-10	1.063700E+00	1.019000E+00	3.185700E-01	1.038566E+00
757	2.0000E-10	1.089400E+00	1.043500E+00	3.262500E-01	1.063653E+00
758	1.9000E-10	1.117100E+00	1.070100E+00	3.345600E-01	1.090702E+00

759	1.8000E-10	1.146700E+00	1.098400E+00	3.434200E-01	1.119600E+00
760	1.7000E-10	1.179000E+00	1.129400E+00	3.530900E-01	1.151139E+00
761	1.6000E-10	1.214200E+00	1.163100E+00	3.636300E-01	1.185506E+00
762	1.5000E-10	1.252800E+00	1.200100E+00	3.751800E-01	1.223195E+00
763	1.4250E-10	1.289700E+00	1.235500E+00	3.862500E-01	1.259226E+00
764	1.3500E-10	1.324100E+00	1.268400E+00	3.965600E-01	1.292811E+00
765	1.2750E-10	1.361500E+00	1.304200E+00	4.077400E-01	1.329325E+00
766	1.2000E-10	1.402100E+00	1.343100E+00	4.199200E-01	1.368967E+00
767	1.1500E-10	1.439000E+00	1.378400E+00	4.309500E-01	1.404992E+00
768	1.1000E-10	1.470600E+00	1.408700E+00	4.404200E-01	1.435847E+00
769	1.0500E-10	1.504500E+00	1.441200E+00	4.505600E-01	1.468947E+00
770	1.0000E-10	1.540800E+00	1.476000E+00	4.614500E-01	1.504391E+00

10. SUMMARY

This report has provided a detailed description of how various displacement damage metrics are defined. It examines the energy-dependent difference seen between the various neutron damage metrics when they are applied to silicon. The atomic and nuclear data used to develop these damage metrics in silicon are clearly defined, e.g. silicon displacement threshold energy, damage partition function, and values for the natural abundance of the silicon isotopes. The NRT-based damage energy in ^{nat}Si is recommended as the best metric to be used to assess the displacement damage equivalence for the gain degradation of silicon semiconductors when they are exposed in neutron fields with difference energy spectra.

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