MACK: A Program to Calculate Neutron Energy Release Parameters and Multigroup Neutron Reactions Cross Sections from ENDF/B

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February 1973

UWFDM-39
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MACK: A Program to Calculate Neutron Energy Release Parameters and Multigroup Neutron Reactions Cross Sections from ENDF/B

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February 1973

University of Wisconsin

FDN 39

Summary of a paper to be presented at the American Nuclear Society Meeting, June 1973
NACK: A Program to Calculate Neutron Energy Release Parameters and Multigroup Neutron Reactions Cross Sections from ENDF/B.

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Calculation of the heat-generation and dose rates due to interaction of nuclear radiation with matter is of prime importance in practically any nuclear system. A theoretical model and computational techniques were developed\(^1\) for calculation of the neutron fluence-to-kerma factors\(^2\) from nuclear data in ENDF/B\(^3\) format.

For the purposes of the calculation, the heating rate due to neutron reactions is conveniently divided into two types of contribution. The first type is heat generated by charged particles (and recoil nuclei) emitted in neutron reactions, and the second is heat generated by the secondary gamma radiation produced by these reactions. The heating rate by the first type of contribution can be expressed as

\[
H(r) = \int \phi_n(r,E) \sum_j N_j k_j(E) dE
\]  
(1)

where

\[
k_j(E) = \sum_i k_{ij}(E) = \sum_i \sigma_{ij}(E) E_{ij}(E)
\]  
(2)

and \(\phi_n(E)\) is the neutron flux for neutrons of energy \(E\), \(N_j\) is the nuclide density for element \(j\), \(\sigma_{ij}\) is the microscopic cross section for reaction \(i\) in element \(j\), \(E_{ij}\) is the energy release per reaction, and \(k\) denotes the microscopic fluence-to-kerma factor. The analytic expressions for \(E_{ij}\) for all possible nuclear reactions for \(E\) less
than 20 MeV were obtained from a solution of the kinematics
equations for the nuclear reactions. The anisotropy of elastic
and inelastic scattering is included and the competition between
gamma and charged particles emission is adequately treated. The
MACK program was written to calculate pointwise neutron kerma
factors at an arbitrary energy mesh from nuclear data in ENDF format. The program processes all reactions significant to heat
deposition and recognizes all of the multiplicity of data formats
currently allowed by ENDF/B. The limit on the accuracy of kerma
factors calculations is set only be the adequacy and availability
of the required nuclear data.

In addition, the MACK program calculates energy group kerma
factors and group cross sections by reactions averaged over an
arbitrary input weighting function or any of several "built-in"
functions for any desired energy group structure. An efficient
treatment of the resonance region was built into the code to
calculate the contribution to cross sections from the resolved
and unresolved resonance parameters including the Doppler effect.
A calculational flow chart of the MACK program is given in figure 1
from which the general features and algorithm of the program follow.

The contribution to energy deposition from radioactive decay
of the residual nucleus is also calculated. Fermi Theory of
\( \beta^- \)-decay was used to calculate the average kinetic energy of a
\( \beta^- \) or \( \beta^+ \) particle for a given endpoint energy, \( E_o \), of the \( \beta \)-spectrum.
and atomic number, \( Z \), of the residual nucleus. The results are in
excellent agreement with the experiment and show that the ratio,
\( R \), of the average to maximum kinetic energy for \( \beta^- \) varies from
about 37\% to 48\% for \( E_\circ \) from 1 MeV to 10 MeV. For \( \beta^+ \), \( R \) is about
90\% for low \( E_\circ \), decreases to a minimum of about 44\% at \( \sim 1 \) MeV,
and then increases again. \( R \) depends strongly on \( E_\circ \) and \( Z \) for
small \( E_\circ \). The results are quite different from that commonly used
in literature\(^4\), namely \( R \approx 30\% \) for \( \beta^- \) and 40\% for \( \beta^+ \). Although
the effect may be small on the total heating rate in the nuclear
system, it is very important in decay heating calculations.

The pointwise cross sections, pointwise kerma factors, energy
group cross sections and kerma factors can be printed, punched,
and saved on tape for individual reactions and the sum as selected
by input. The pointwise kerma factors by reaction and sum can
be used for inclusion in the ENDF/B evaluation for the nuclide with
MT numbers in the 300's series.\(^4\) The output group kerma factors
and partial cross sections are in a form suitable for use as "activity
cross section tables" in the present transport codes\(^5,6,7\) (one-, two-, or three-dimensional) for calculation of heating rates and
reaction rates of interest (e.g. helium and hydrogen production).

The program has proven to be extremely useful in providing the
basic input for heat transfer and radiation damage analysis of
fusion reactor blankets and magnet shields at the University of
Wisconsin\(^8\).
REFERENCES


Figure 1 - Calculational Flow Chart for HACC