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TITLE: FISSION-PRODUCT CHAIN YIELDS AND DELAYED NEUTRONS: ANS 5.2 AND ANS 5.8

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YIELDS (ANS 5.2)

Chain yields are the addition of the direct values along constant (Z+N) paths (see Fig. 1). The addition must also account for decay branching, especially for delayed neutrons that couple the mass chains. The result is the familiar double-humped plot of yield per fission vs A (also evident in Fig. 1). The lines of stable nuclides and most probable yield are shown in the (Z,N) plane. Some modern measurements provide direct yields; others provide cumulative values for long-lived or stable products. Yield evaluations must account for each type of measurement and the degree of decay coupling, beginning with direct yields.

For some fissioning nuclides at thermal or fast neutron incident energies, the amount of data is enormous; and for other nuclide-energy combinations, the data must be developed from systematics.[1,2,3] Many applications of chain yields can use the same systematics to estimate independent values. Reference 3 will include all measurements (1939-1990) and recommended yields (that include measurements as well) for sixty yield sets, each containing approximately 1200 fission products. However, the document will contain over 9000 pages: its equivalent in ENDF/B-VI will contain over 250 000 card images. Many users will prefer to refer to the ANS 5.2 chain yield standard, depending upon each application.

The ANS 5.2 standard is currently in rough draft form for comment from Working Group members. It includes 107 mass chain yields and uncertainties for ^{233,235,238}U, ^{239,240,241}Pu, ^{232}Th, and ^{252}Cf. Only fast fission yields are included for ^{232}Th, ^{238}U, and ^{240}Pu, and spontaneous yields for ^{252}Cf. The final chain yields in it will be developed from (but not included in) the individual nuclide yields and branchings in ENDF/B-VI. A relatively small ANS document can be generated due to the existence of ENDF/B-VI and inclusion of measurements and references (through April 1990), as seen in Ref. 3.

Some applications of this standard and problems, *e.g.*, with energy dependence, will be discussed.

DELAYED NEUTRONS (ANS 5.8)

The first meeting of this Working Group occurred on 10 June 1990. A related international working group was formed by NEACRP/NEANDC in April 1990 to provide delayed neutron benchmarks. Several individuals have joint membership with the ANS 5.8 group and a good level of cooperation is expected. The international group is concerned primarily with β_{eff}, $\bar{\nu}_d$, six-group data, and the energy dependence of these, but this will almost certainly expand to include precursor data.

We decided to keep precursor data (Pn and spectra), $\bar{\nu}_d(E)$, and six-group data (spectra, abundance and halflives) within the scope of the ANS 5.8 standard, unless it later proves impossible to achieve an acceptable consistency with benchmarks when using precursor data.

The reader should be aware that, while ANS 5.8 is very new, the effort to improve delayed neutron precursor data has been progressing nearly continuously since the mid-70's, with a particularly large effort expending during 1984-87. Such data are necessary for ENDF decay files as well as yield files. However, except for Pn data in ENDF/B-V, individual precursor data were not included in this version. We found the aggregate six-group spectra to be inadequate and decided to improve these spectra with precursor calculations. F. Mann *et al.*[6] evaluated measured Pn values and T. England *et al.*[7] updated spectra with available measurements. Later (> 1984) we decided that the measured precursor spectra were still inadequate in energy range and in the number of precursors having measured spectra. Simple models were used to expand the spectra where measurements exist and to provide spectra for precursors having no measurements.[8] Pn values were estimated from systematics for unmeasured values. A consistent set of six-group abundances, halflives, and spectra were developed from the resulting 271 precursor data base. Brady *et al.*[8] provide a particularly good description of this work, including comparisons with very recent measurements.[9]

The six-group data will be incorporated into ENDF/B-VI, thereby extending the number of fissioning systems from 7 to 28 and expanding the spectra from ~ 79 keV - 1.2 MeV to 0 - 3 MeV. Individual precursor spectra and Pn values for 271 nuclides will also be incorporated into the ENDF/ -VI decay files. Some current Pn values may be altered as a result of recent Studsvik measurements (reported in Ref. 10). $\bar{\nu}_d$ data remain as the values determined by Cox[4] and Tuttle,[5] or those calculated where $\bar{\nu}_d$ had not been measured, with a few exceptions.[8]

We were not aware of the European concern with inconsistent β_{eff} measurements until the ENDF/B-VI data were completed. The primary reason for this concern is based on ^{238}U fast fission. Unfortunately, this is also the most inconsistent case of precursor calculations and measurements. Perhaps a reason and solution of the problem will be determined by the time of this meeting.

In summary, ANS 5.2 is near completion and ANS 5.8 is starting from existing, extensive work, with the cooperation of the international community involved.

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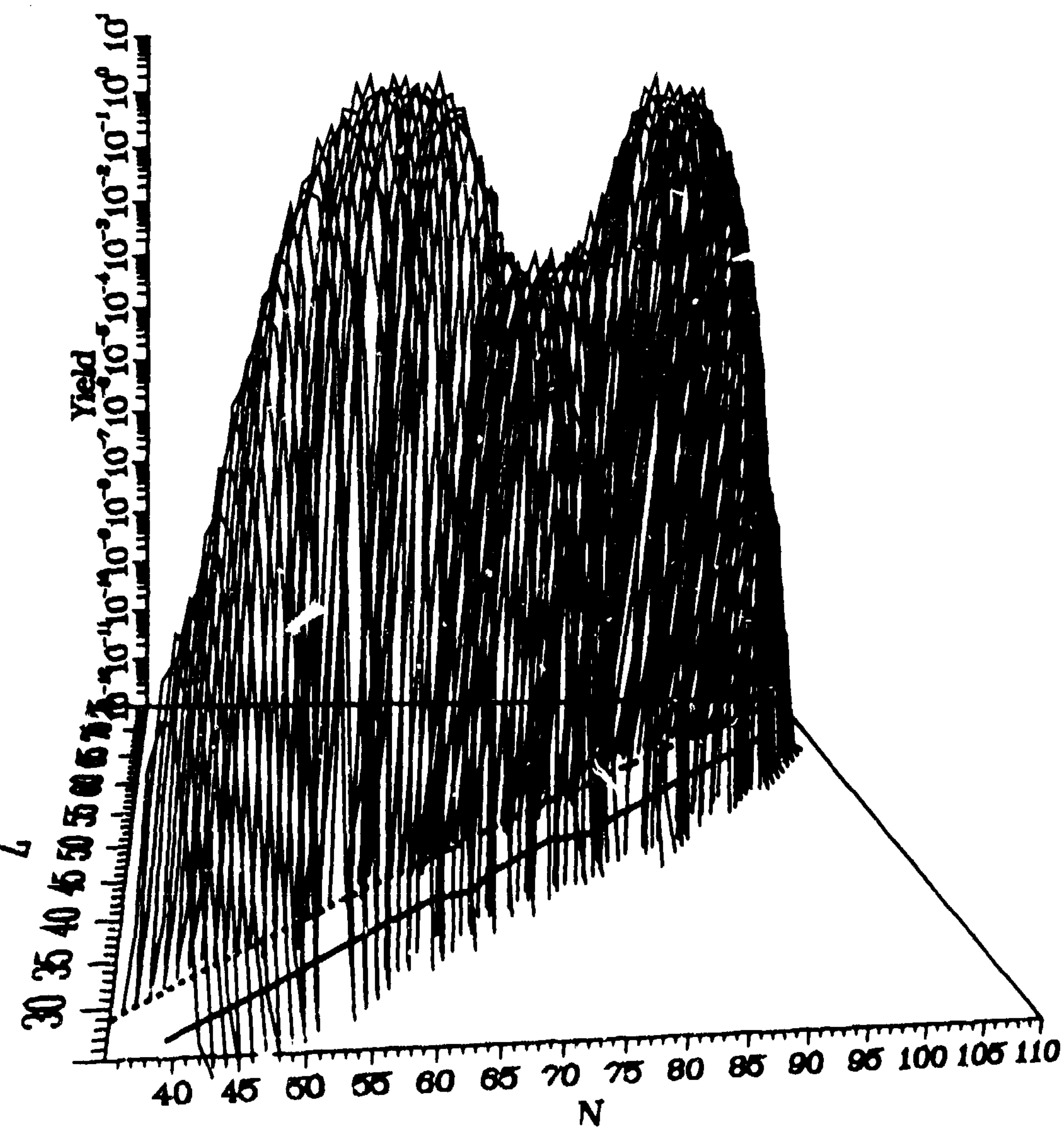

Fig. 1. ^{235}U independent yields (Los Alamos National Laboratory 1989).