35. FILE 35. COVARIANCES FOR ENERGY DISTRIBUTIONS OF SECONDARY PARTICLES

35.1. Introduction

File 35 contains covariance matrices for the energy distribution of secondary neutrons given in File 5. The data in File 5 are given in the Laboratory system, and are expressed as normalized probability distributions.

Since there is usually very fragmentary information with which to construct the data given in File 5, the uncertainties in the secondary distributions are highly correlated as a function of incident neutron energy. It is therefore proposed that only a few (at most 4 or 5) covariance matrices be used in each MT value in file 35 to cover the complete incident energy range. Each covariance matrix applies to the complete secondary energy distributions for the broad incident energy range specified, regardless of how these secondary energy distributions are specified, or broken down into various components, in File 5. In this first attempt at dealing with covariance matrices of secondary energy distributions, no covariances between the different incident energy ranges will be allowed. Also, no covariances linking different materials or reaction types are allowed. Furthermore, no covariances with information in other files, for instance File 3 and v_(E) in File 1 are allowed in File 35.

35.2. Formats

Each subsection covers a covariance matrix for an incident neutron energy range, and the complete incident energy range is covered by the NK subsections.

A new type of LB subsection is defined (LB=7), since in File 35 it is natural to specify the covariance matrices as absolute covariances rather than relative covariances. The LB=7 subsection is similar to an LB=5 subsection, but with entries that are absolute rather than relative.

The following quantities are defined:

NK	Number of subsections
E_1	Lowest incident neutron energy to which the covariance matrix in the subsection applies.
E_2	Highest incident neutron energy to which the covariance matrix in the subsection applies. The value of E_2 in a subsection becomes the value of E_1 in the next subsection.
LS=1	Flag indicating that the covariance data matrix $F_{k,k'}$, is symmetric.
LB=7	Flag indicating that the elements of the covariance matrix $F_{k,k'}$ are absolute.
NT	Total number of entries in the list. NT=[NE∗(NE+1)]/2.
NE	Number of entries in the array $\{E'_k\}$
$\{E'_k\}$	Array containing outgoing neutron energies, and defining NE-1 energy intervals for outgoing neutrons. The value of E'_1 in the array must be the lowest outgoing neutron energy possible at E_1; E'_{NE} in the array must be the highest outgoing neutron energy possible at E_2 and represented in File 5.
$\{F_{k,k'}\}$	covariance matrix. The $F_{k,k'}$'s are ordered by rows, starting from the diagonal term $\{F_{k,k'}\} \equiv F_{1,1}, F_{1,2}; F_{2,2}, F_{2,3}, ..., ...; F_{NE-1,NE-1}$.

The structure of a section of File 35 is as follows:

```
[MAT,35,MT/  ZA, AWR,   0,   0,  NK,   0] HEAD
             <subsection for k=1>
             <subsection for k=NK>
[MAT,35, 0/ 0.0, 0.0,   0,   0,   0,   0] SEND
```

The structure of a subsection is:

$[MAT,35,MT/ \quad E_1, \quad E_2, \; LS, \; LB, \; NT, \; NE/\{E'_k\},\{F_{k,k'}\}]$ LIST (LS=1,LB=7)

In terms of the dimensionless operators defined in Section 33.2, the covariance between two points on the unity-normalized probability distribution is:

$$Cov\left(p\left(E \to E'_i\right), p\left(E \to E'_j\right)\right) = \sum_{k,k'} P^{i,k}_{j,k'} F_{k,k'}$$

where $E_1 \le E \le E_2$, and the P values are defined so that only the term in the sum for $E'_k \le E'_I \le E'_{k+1}$ and $E'_k \le E'_I \le E'_{K'+1}$ is non-zero.

35.3. Procedures

Because probability distributions must remain normalized to unity, covariance matrices in File 35 must satisfy a constraint in addition to being symmetric. This constraint is that the sums of the elements in any row of the matrix, therefore also of any column, must be zero. Therefore, if one were to divide the outgoing energy of a distribution into n energy ranges, it would only be necessary to give the covariance matrix of the probabilities in n-1 energy ranges. The remainder of the full covariance matrix could be obtained from the above constraint.

There is a procedural objection to the above suggestion. It is that, for the covariance file, if no information is provided in the file, this does not imply anything as far as the uncertainties in the data are concerned. Therefore, it is necessary to provide redundant information in File 35 for each covariance matrix of a secondary energy distribution and to require that each covariance matrix in File 35 meets the above constraint. The sum of each row or column should be $<10^{-5}$ on the evaluator's energy grid. [Note that this condition must also be met with processed data on the user's energy grid].

If $F_{k,k'}$ are the covariance elements defined above for the normalized spectral yields Y_k on the evaluator's grid $\{E'_k\}$, but the above constraint has not been applied, corrected values $\hat{F}_{k,k'}$ may be obtained from the following relation.

$$\hat{F}_{k,k'} = F_{k,k'} - S_k Y'_k - S'_k Y_k + Y_k Y'_k \sum_j S_j$$

where $S_k = \sum_i F_{i,k}$

The secondary energy distribution uncertainty analysis using the "hot-cold" technique of Gerstl, et al., (see References) can be based on spectral uncertainty data stored in this form. In this case the covariance matrix is a 2×2 matrix for each incident energy range.

REFERENCES

1. S. A. W. Gerstl, "Uncertainty Analyses for Secondary Energy Distributions", *A Review of the Theory and Application of Sensitivity and Uncertainty Analysis: Proceedings of a Seminar-Workshop, August 22-24, 1978*, C. R. Weisbin, et al., Eds, Radiation Shielding Information Center report, Oak Ridge National Laboratory **ORNL/RSIC-42** (1978) p. 219.
2. S. A. W. Gerstl, R. J. LaBauve, and P. G. Young, *A Comprehensive Neutron Cross-Section and Secondary Energy Distribution Uncertainty Analysis for a Fusion Reactor*, Los Alamos Scientific Laboratory report **LA-8333-MS** (1980).