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ABSTRACT

Most current adjustment procedures, including LSL (1), can adjust only one spectrum with dosimetry located at the point of the input spectrum. Many radiation experiments have dosimetry at more than one location, and fluence or damage exposure values are desired for locations other than those covered by dosimetry. Thus, the use of single-spectrum dosimetry to these experiments causes considerable loss of information and introduces large uncertainties. Two extensions of the LSL code to cover multiple-spectra adjustment are discussed. Each extension has different restrictions and covers a different range of applications.

INTRODUCTION

For an accurate determination of neutron fluences in test and power reactors, both transport calculations and dosimetry measurements are needed. Adjustment methods provide the analytical tool for combining the two. As a result, best estimates for fluences and damage parameter values with improved uncertainties can be obtained. The output shows also whether the input data are consistent within the bounds of the input uncertainties. The majority of the currently available adjustment methods (2) allow adjustment of only one spectrum at a time, which is restricted to the location of a dosimeter set. However, the fluence spectra of interest, for instance in metallurgical test specimen or inside the pressure vessel wall of power reactors, are at locations without dosimeters and some form of extrapolation is necessary. Also, sensors with different response functions are often placed at different locations, so that different parts of the spectrum are adjusted in different adjustment runs depending on the monitor set used. These problems can be solved by processing simultaneously several spectra making use of the high correlation between the calculated spectra within the same transport calculation. Since a larger amount of input information is used, uncertainties are decreased at the same time.

The benefits of multiple spectrum adjustment come at a price. Each calculated group fluence and each dosimetry measurement adds an entry to the covariance matrix, with the consequence that the storage requirement goes up roughly with the square of the entries and the computing time with the third power of the dosimetry data. Thus, some restrictions are necessary to keep the computing requirement reasonable. For the LSL-M2 version, the number of spectra is restricted to $N_s \times N_g \leq 400$, where N_s is the number of spectra and N_g is the number of energy groups, that is roughly 10-20 spectra with 20-40 energy groups. The number of dosimeters is restricted to 100. The energy group structure must be the same for each spectrum and the largest number of energy groups, N_g, should not exceed $N_g = 50$. These are reasonable restrictions which will suffice for most applications.

A larger number of spectra can be processed without substantial increase in computations if the correlations between any two spectra at different locations are essentially the same, not dependent on the space coordinates. This is not an unreasonable assumption, since the errors in transport calculations will affect equally all fluence spectra, which are not too far apart in space, say, all spectra within a metallurgical irradiation capsule or a pressure vessel surveillance capsule. A "super matrix" is then created having as elements the covariance matrices from each individual spectrum. This super matrix can be inverted explicitly provided the assumption about spectrum correlations holds. Only the covariance matrices for the individual spectra need to be inverted; their size is the number of different dosimetry sensors at a given location which may differ from one location to the other. This method is named LSL-M1, since it was the first extension of the original LSL method (1). The mathematical details are discussed in Ref. 3. In both extensions of the LSL method calculated fluxes may be introduced either by absolute magnitude or as relative spectra, allowing for a free scale factor, which fits the calculated spectrum to the dosimetry measurements in the least squares sense. There is also a choice of reaction rates or equivalent fission fluxes or any mixture thereof as input for dosimetry measurements.

Output consists of integral parameters, such as fluence > 1.0 MeV or dpa with uncertainties in the form of relative standard deviation and correlation. These can be obtained at any location, whether there are dosimeters at this location or not. Unlike the original, single-spectrum, LSL method, no iterations are performed in the multiple spectra LSL methods in order to keep the computation effort down. This means that the adjusted values are only approximately consistent if adjustments are large. This is of little consequence, however, since large adjustments are always connected with large uncertainties, which exceed potential inconsistencies.

PROGRAMMING CONSIDERATIONS

The two multiple spectrum adjustment methods, LSL-M1 and LSL-M2, are intended primarily for application to test and research reactors. That means that the program can accept a large variety of configurations with few restrictions to the input and output data. However, the user has to provide not only the input spectra and input dosimetry measurements but must also supply variances and covariances for these data. While this does not exclude application to pressure vessel surveillance and extrapolation procedures, the much more comprehensive LEPRICON (7) methodology is preferable in this case.

The programs are written in standard FORTRAN for interactive use on the DEC-10 system. Separate files are needed for the reaction rate, spectrum, and cross section data and for the corresponding variance-covariance information. An additional file is needed to contain the response functions for the damage parameter values. Data sets are identified by names for reactions and locations, so that the information need not be given in any specific order, and the same cross-section files can be used for several adjustment problems. Auxiliary programs have been written to create LSL files from more basic information. The primary ones are:

- FPROC - a general purpose program which interpolates, extrapolates, and converts group fluences in a given energy group structure to any other structure using a 620-group auxiliary spectrum for interpolation and/or extrapolation.
- PUFF (4) - which has been developed earlier to read ENDF cross-section and covariance files (5) and convert them to a specified energy group structure.
- ACT - converts count rates to reaction rates for any given irradiation history including possible spectrum changes during irradiation.

Both LSL-M1 and LSL-M2 have been thoroughly tested and successfully applied (3,6). Documentation and release is expected to be completed by the end of 1985.

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