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THE APPLICATION OF INTERACTIVE GRAPHICS
AND CONTINUOUS SLOWING DOWN THEORY TO
THE ASSESSMENT OF NUCLEAR DATA FILES +

by

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ABSTRACT

An interactive graphics analysis system was applied to the assessment and modification of the neutron cross section sets for depleted uranium (ENDF/B-II) and iron (1124). The system, RIGAS, allows one to: perform on-line flux calculations based on continuous slowing down theory; instantly compare the plotted results with experiment; and visually and interactively change the slowing down parameters to force agreement with experiment.

INTRODUCTION

Rensselaer Polytechnic Institute (RPI) has made extensive refinements to Continuous Slowing Down Theory (CSDT) to produce a theoretical flux which agrees nicely with more sophisticated calculations. Dunn and Becker (1,2) redefined the slowing down parameter XI to include inelastic scattering and formulated an analytical solution for both flux and importance spectra. These were sufficiently accurate to produce acceptable values for multigroup constants, capture and fission rates on isotopic basis and multiplication factors. Burns and Becker (3,4) extended this method to account for resonance absorption and extended it to finite media. They also devised a separable kernel technique to regenerate the cross sections from the slowing down parameters. These extensions facilitated evaluation of various cross section sets. An advantage of this method is that XI is a one dimensional variable which measures the effectiveness of the more complex, two dimensional inelastic scattering matrix.

For a point source, the equation for the neutron spectrum can be represented by Equation 1,

$$\phi(\vec{r}, u) = \frac{1}{\xi(u)\Sigma_s(u) + \gamma(u)\Sigma_a(u)} \int_0^u du' S(u') \frac{R(u)}{R(u')} \frac{e^{-r^2/4\tau(u, u')}}{(4\pi\tau(u, u'))^{3/2}} \quad (1)$$

where the flux is a function of the slowing down parameters XI and gamma. The Fermi Age, resonance escape probability and source are defined in Equations 2a-2c.

$$\tau(u) = \int_0^u \frac{D(u') du'}{\xi(u')\Sigma_s(u') + \gamma(u')\Sigma_a(u')} \quad (2a)$$

$$R(u) = \exp - \int_0^u \frac{\Sigma_a(u') du'}{\xi(u')\Sigma_s(u') + \gamma(u')\Sigma_a(u')} \quad (2b)$$

$$S(u) du = S(E) dE = \frac{2}{\sqrt{\pi}} \frac{\sqrt{E}}{T^{3/2}} e^{-(E/T)} dE \quad (2c)$$

Burns found that for uranium it was possible to vary the XI

in these equations to force a match of the theoretical flux with the experimental values. This resultant XI could then produce new cross sections, using the separable kernel technique. These iterations were done using remote batch processing and off-line plotting, which require an inordinate amount of time and perseverance. Each XI iteration had to be key punched, the data transmitted to a large remote computer for calculation, the results received and a plot made to determine the effects of the change. Assuming that all equipment was continually available, this process required at least one full day for each iteration. Although the method was feasible, only a few iterations were performed for the keV region of depleted uranium (4). To make this method practical requires an on-line calculation capability and an instant means of graphical representation.

To satisfy this requirement, we set out to couple a time-sharing system with interactive graphics to do in minutes what previously required days. We also recognized similar needs in other areas of nuclear work and designed the system as a general analysis tool, with the CSDT problem as the important test case. This resulted in the Rensselaer Interactive Graphics Analysis System (RIGAS), which allows the user to calculate, display, compare, manipulate and modify his data without requiring any programming on his part. The details of this system are described in a companion paper (5), which discusses the design considerations, flexibility and operation of RIGAS. Here we shall present a brief summary of the system and concentrate on its application to the assignment and modification of the neutron cross sections of depleted uranium and iron.

The entire control of RIGAS is effected through a man-machine dialogue which uses labeled pushbuttons, a CRT - lightpen and teletype for Input/Output (I/O). These pushbuttons comprise a device called the Hardware Dialogue Unit which serves as the operation initiator by merely pressing a button. The four major tasks, or functions, required are accessed through buttons labeled ENTER, TEXT, SELECT and DISPLA. These are augmented by a series of five options called from the buttons EXPAND/CONTRACT, SCROLL, EXACT VALUE, MODIFY DATA and USER ROUTINE.

ENTER is a function which inputs data, in CSISRS format (6), to the system and forms internal files for use throughout. TEXT is a means of selecting and viewing the bibliographic portions of each subfile entered. SELECT performs a similar operation for the numerical data and further allows the user to view all or part of a selected data set in either linear or logarithmic form. This specified data range may be scrolled left to right and expanded along either axis, using the first two options mentioned. Once satisfied with the selected

curve, the user saves it as a working file for the next function. DISPLA is the real analysis section of RIGAS and allows one to display two curves simultaneously as well as SCROLL, EXPAND, MODIFY and obtain the exact values of the displayed data. Modification may entail either normalizing, which shifts the entire curve, or changing the value of a single point.

THE RIGAS-INTERCOM ITERATION SCHEME

Iteration on the slowing down parameters is accomplished by utilizing the USER ROUTINE option of RIGAS. A preliminary calculation is done, through remote batch, to obtain an initial XI and age for each material, following the procedure of Burns. These, along with the experimental flux, form the basic input to RIGAS. The standard functions ENTER, TEXT and SELECT are used to enter this data and establish the working files necessary for the analysis function, DISPLA. The five options available in this function are then used to carry out the iteration process.

The five specialized user routines are given the names USR1 through USR5 and "plugged" into the system. The CSDT calculations are actually done on the CDC-6600 at the Courant Institute of Mathematical Sciences, New York University, using the CDC time-sharing system - INTERCOM. Although RIGAS has an asynchronous communications link with a maximum rate of 4800 baud, INTERCOM operates only at 110 or 300. USR1 determines the desired rate, automatically establishes the time-sharing mode, sets up and executes the necessary programs for flux calculation and receives and stores, on disk, the first flux resulting from the initial guess. USR2 takes a flux file from disk and creates a display file from that data. USR3 allows one to mathematically compare the theoretical and experimental fluxes and advises one of the energy regions where these differ by more than ten percent. USR4 extracts the parameter values, XI or age, from the iterated display file, transmits it to the CDC-6600 and receives and stores the new flux. USR5 terminates the entire time-sharing operation.

Figure 1 shows a typical RIGAS-INTERCOM sequence. The first guess values of XI and age, along with the experimental flux, are operated on by ENTER and SELECT to form the six working files shown in the first symbol. From the DISPLA function, USR1 is called to establish the communications link and retrieve and execute the flux calculation program, using basic input from a CDC-6600 disk file. Both this and the flux program files are established using remote batch. Although retrieving these files could also be automated, more flexibility is gained by allowing one to call up particular files for that calculation. The first calculated flux is then received and stored on the local disk. USR2 takes this, creates a display file from the information and does a crude normalization with the experimental flux to ensure both curves appear on the screen. Once complete, the

standard RIGAS option, MODIFY DATA, is used to finalize this normalization, according to the user's wishes. The two can then be compared and areas of discrepancy noted. This human decision is extremely important since age theory is not equally valid over the entire energy range. The analyst must decide where such divergences are expected and what action to take to rectify them. If the two spectra are so close that the eye cannot discern a difference, USR3 may be called to do a comparison and suggest energy regions where the fluxes diverge by more than the ten percent limit. Once these are noted, the parameter being iterated is displayed and the desired changes made, again using MODIFY DATA. This time, however, individual points are modified rather than the entire curve.

When this is done, USR4 is called and one specifies which parameter was modified. The system extracts the new values from the display file and transmits these to the CDC-6600 with instructions as to which parameter is being sent. If this is XI, new resonance escape and age values are computed prior to the flux calculation. If the parameter is age, the old values of XI and resonance escape are used, along with the new age, to compute the flux. This is again received and stored. The process continues until the analyst terminates the scheme with USR5, which logs him out of time-sharing and prints the amount of central and peripheral processing time used by the CDC-6600 for the iterations.

Thus, the entire iteration scheme can be accomplished by mixing standard RIGAS capabilities with those of the USER ROUTINE option. These operations allow one to easily change the displayed values of XI and age, calculate a new theoretical flux in real-time and make an instant comparison of the result with experimental values.

APPLICATION TO INTERPRETATION OF INTEGRAL EXPERIMENTS

The RIGAS-INTERCOM scheme was applied to the interpretation of calculation-experiment discrepancies associated with neutron spectrum measurements in depleted uranium and iron (7,8). The reference data file used for uranium was ENDF/B-II, while that for iron was MAT 1124 (which served as the basis for the ENDF/B-III iron file). The ENDF/B-II uranium data was used (rather than the more recent ENDF/B-III, which has also been used to analyze experiments at RPI (9)) to permit comparison with the brute force iteration performed earlier. The MAT 1124 iron file instituted the most recent file for which an analysis of iron measurements had been made at the time of this study (10).

In this study, iteration was performed on the continuous slowing down parameters XI and age. From the types of modifications required in these parameters, inferences about the types of data modifications required have been drawn. Since this type of interactive iteration has been carried out successfully, the effort at RPI has been extended to performance of specific data adjustments.

To indicate the type of problems to be resolved for uranium, consider the comparison between measured and calculated (via CSDT) spectra, shown in Figure 2, at a radius of 15.24cm (6 in.) (This and subsequent figures display what is seen on the screen). The types of discrepancies are typical of those observed in analyzing uranium spectra (7,9). (The calculated drop at the lowest energy group is associated with the group structure.) From 10 to above 50 keV, the curves have different shapes. The shape of the spectrum in this unresolved resonance range is sensitive to the capture cross-section. From about 50 keV to about 500 keV, there is a tendency to overpredict experimental results. In the vicinity of 1 MeV, there is a tendency for the calculation to dip below the experiment. The discrepancy in the high-MeV range is due to the limited validity of Age Theory at these energies, and is not characteristic of more elaborate transport calculations.

Uranium spectra are sensitive to inelastic scattering. The XI parameter was therefore varied in order to reduce calculation-measurement discrepancies. About three hours of RIGAS operation was required (though not all at one sitting). Figure 3 shows the final XI and displays the ENDF/B-II XI originally obtained by Burns for comparison. It may be observed that except above 3 MeV (where the results are questionable because of the already noted limitation

on model validity), a reduction in the effectiveness of the scattering process is called for. A substantial reduction of the peak effectiveness is indicated. Figure 4 shows a comparison of predicted and measured spectra using the final XI. Agreement is quite good. The principal remaining discrepancy is in the unresolved resonance region, which we shall discuss shortly in terms of the capture cross-section.

Table I also compares the XI values obtained by adjustment with the original values. Also shown for comparison are XI values derived from an early Argonne National Laboratory file (11). That file was not documented, but clearly had much weaker inelastic effectiveness than did the ENDF/B-II. The XI values obtained here are more similar to those of the ANL data set than from those of ENDF/B-II. It should be noted that transport calculations using the ANL data set have given the best prediction of measured results of any data file used to date (7).

The unresolved region occupies only a small portion of Figure 4. One flexible aspect of the RIGAS system is ability to expand scales by push-button. The lower energy portion of Figure 4 is thus expanded easily and displayed in Figure 5. (Further expansion is possible, and was indeed made during the analysis). The unresolved capture data of ENDF/B-III and the ANL file were substituted respectively for the ENDF/B-II capture data, yielding the results shown in Figures 6 and 7.

The three unresolved capture sets used are displayed in Table II. It may be seen that the ENDF/B-III and ANL sets are somewhat lower than the ENDF/B-II data, and provide better agreement with experiments.

The RIGAS-INTERCOM scheme also was applied to analysis of iron spectra. The iron case was considered in the demonstration of the scheme because of the more balanced relative roles of elastic and inelastic scattering in the slowing down process. Figure 8 shows calculated and measured spectra at a radius of six inches. The solid line is the experimental curve. The substantial discrepancy at very low (below 24 keV) energy is associated with the minimum in the major (25-30 keV) iron resonance. In the decade above that resonance, calculated and measured spectral shapes are in good general agreement. However, from several hundred kilovolts upward, there is some discrepancy between calculation and measurement. At high energies, there is substantial disagreement, but here again, the range of validity of continuous slowing down theory makes interpretation difficult.

Iteration with RIGAS-INTERCOM led to a combination of possible changes indicated in Figures 9 and 10. Both changes tend to increase the influence of inelastic scattering on the discrepant portion of the spectrum. Figure 9 indicates a sharper rise (solid curve) in the XI parameter in the vicinity of the inelastic threshold and an earlier peak. (The results at higher energies are uncertain because of the limitation on model validity cited earlier.) Figure 10 shows the age parameter, which reflects the XI change and additional direct increase between 439keV and 1.05MeV (implying reductions in elastic scattering). Figure 11 shows the improved agreement with the changes of Figures 9 and 10.

DISCUSSIONS AND RECOMMENDATIONS

The combined use of CSDT and RIGAS-INTERCOM shows substantial promise for utilizing the results of integral experiments to assess data. CSDT permits performing a space-dependent spectrum calculation inexpensively and frequently for a variety of data changes, and permits expressing data in terms of a small number of key parameters. The RIGAS-INTERCOM system permits capitalizing on the useful characteristics of CSDT by permitting frequent changes and tests of changes to be made.

We have estimated that use of the RIGAS-INTERCOM system reduces the amount of time required to perform the type of iterating on slowing down parameters discussed here by about two orders of magnitude relative to conventional procedures. The conventional approach would thus permit only a limited amount of iteration.

The total amount of RIGAS operation in the uranium problem was about three hours. Actual CDC-6600 time consumed was only about three central processing seconds and two hundred peripheral processing seconds. (The actual time associated with having these calculations performed turns out to be dominated by the telephone transmission time.) Thus, most of the time spent by the analyst is productively used in deciding on changes to make and on evaluating results of calculations.

The "output" of the analysis used in this paper is a modified set of CSDT parameters. The modifications called for are an indication of where more basic cross-section data should be modified. A logical extension of the work of this paper would be to iterate on specific cross-section changes. This type of extension currently is being pursued at RPI.

The uranium results obtained in this paper are basically a refinement of qualitatively similar conclusions reached before (7,9). The iron results suggest that further study be focused on both elastic and inelastic scattering in the vicinity of the inelastic threshold.

The principal limitations of the procedure used here are the limitations of CSDT itself. Except at high energies, it has been demonstrated that the CSDT spectra agree with more refined transport calculations (8.) When comparing CSDT scalar fluxes with measured time-of-flight spectra, the spectrum in the transverse direction is assumed to correspond to the scalar flux, since in that direction all forward-peaked flux components are zero. Experience

indicates that this is reasonable at moderate energies.

The principal limitation to CSDT is at high energies. It is possible that the domain of applicability of the theory could be extended by improved representation of first collision sources, uncollided fluxes, etc. These prospects for improvement shall be considered.

Portions of the work described in this paper are difficult to communicate. In particular, the interactive process is difficult to describe. For example, we indicated final iterated results for uranium and iron. These results were obtained after a number of iterations, several of which were "false starts". Results to date indicate that experience is a good teacher, that the analyst zeroes in on his answer rather quickly once he has gotten by the false starts. How quickly is a function of how good the judgement of the analyst is in regard to the types of changes that are physically reasonable and how quickly the analyst adaptively develops a feeling for the sensitivity of answers to changes he makes.

In summary, the utility of continuous slowing down theory in analyzing and interpreting measured spectra is greatly enhanced by the interactive graphics capability developed at RPI. More extensive and more detailed investigation is possible, and prospects for further useful extensions exist.

REFERENCES

- (1) Dunn, F. E. and Becker, M., "Improvements to Neutron Slowing Down Theory For Fast Reactors", Nucl. Sci. Eng., 47, 66 (1972)
- (2) Dunn, F. E. and Becker, M., "The Formulation and Application of Analytic Representations of Fast Reactor Flux and Importance Spectra", Nucl. Sci. Eng., 47, 83 (1972)
- (3) Becker, M. and Burns, E. T., "The Formulation of Continuous Slowing Down Theory for General Processes in Terms of Separable Kernels", Nucl. Sci. Eng., 42, 89 (1970)
- (4) Burns, E. T., "Fast Neutron Spectra From Space Dependent Continuous Slowing Down Theory", Ph.D. Thesis, Rensselaer Polytechnic Institute, Troy, New York (1971)
- (5) Danchak, M., Becker, M., and Moyer, W.R., "An Interactive Graphics Analysis System for Nuclear Engineering Applications", Nucl. Tech., to be published.
- (6) Goldberg, M. D. and May, V., Csisrs - an Experimentalist's Guide, NNCSC, Brookhaven National Laboratory, March 1, 1971.
- (7) Kaushal, N. N., Malaviya, B.K., Becker, M., Burns, E.T., Gaerttner, E. R., "Measurement and Analysis of Fast Neutron Spectra in Depleted Uranium-235 Isotope", Nucl. Sci. Eng., 49, 330 (1972)
- (8) Malaviya, B. K., Kaushal, N. N., Becker, M., Burns, E. T., Ginsberg, A. and Gaerttner, E. R., "Experimental and Analytical Studies of Fast Neutron Transport in Iron", Nucl. Sci. Eng., 47, 329 (1972)
- (9) Becker, M. and Kaushal, N. N., "An Assessment of ENDF/B-III Data For Uranium-238 Based on Integral Spectrum Measurements", Nucl. Sci. Eng., in press.
- (10) Malaviya, B. K., Kaushal, N.N., Becker, M., Ginsberg, A., Burns, E. T., and Gaerttner, E. R., "Evaluation of Nuclear Data and Computational Methods for Iron as a Shield Material", Proc. 4th Int. Conf., Reactor Shielding, Paris, France (1972)
- (11) Travelli, A., Private Communication (1967)

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TABLE I

Comparison of Slowing Down Parameter Values of U^{238}
For Various Cross Section Sets

<u>Energy</u>	<u>U^{238} ENDF/B II</u>	<u>U^{238} ANL</u>	<u>U^{238} RIGAS</u>
10.0000	0.0975	0.1264	0.1264
8.8240	0.0975	0.1264	0.1947
7.7880	0.1270	0.1599	0.1985
6.8728	0.1216	0.1715	0.2029
5.3526	0.1851	0.1925	0.2056
4.7236	0.1826	0.1896	0.2151
4.1686	0.2153	0.2340	0.2312
3.6787	0.2324	0.2624	0.2516
3.2465	0.2779	0.3043	0.2953
2.8650	0.3138	0.3466	0.3343
2.2313	0.4163	0.3465	0.3342
1.9691	0.4617	0.5411	0.3492
1.7377	0.5209	0.3743	0.3483
1.5335	0.5355	0.4304	0.3345
1.3533	0.5295	0.4021	0.2908
1.1943	0.3718	0.2299	0.2703
1.0539	0.3029	0.2404	0.1677
0.8208	0.1628	0.1354	0.1201
0.7243	0.1416	0.1192	0.1045
0.6392	0.1018	0.0977	0.0797
0.5641	0.0897	0.0736	0.0685
0.4978	0.0752	0.0687	0.0589
0.4393	0.0675	0.0589	0.0538
0.3877	0.0608	0.0531	0.0506
0.3019	0.0474	0.0469	0.0483
0.2664	0.0491	0.0398	0.0430
0.2351	0.0455	0.0399	0.0421
0.2075	0.0434	0.0399	0.0410
0.1831	0.0435	0.0361	0.0402
0.1616	0.0425	0.0372	0.0372
0.1258	0.0398	0.0352	0.0358
0.1110	0.0380	0.0346	0.0350
0.0980	0.0350	0.0343	0.0343
0.0865	0.0336	0.0335	0.0335
0.0763	0.0317	0.0322	0.0322
0.0673	0.0298	0.0318	0.0318
0.0594	0.0279	0.0307	0.0313
0.0463	0.0240	0.0266	0.0266
0.0408	0.0225	0.0231	0.0231
0.0360	0.0214	0.0221	0.0221
0.0318	0.0209	0.0214	0.0214
0.0280	0.0205	0.0210	0.0210
0.2047	0.0204	0.0203	0.0203

TABLE I
(continued)

<u>Energy</u>	<u>U²³⁸ ENDF/B II</u>	<u>U²³⁸ ANL</u>	<u>U²³⁸ RIGAS</u>
0.0193	0.0207	0.0200	0.0200
0.0170	0.0200	0.0200	0.0200
0.0150	0.0200	0.0200	0.0200
0.0132	0.0200	0.0200	0.0200
0.0117	0.0200	0.0200	0.0200
0.0103	0.0200	0.0200	0.0200

TABLE II
Self-Shielded Capture Cross Sections For U-238 In The
Unresolved Energy Region

<u>Lower Energy</u> <u>(Kev)</u>	<u>ENDF/B-II</u>	<u>ENDF/B-III</u>	<u>ANL</u>
46.31	0.3437	0.3388	0.3150
40.87	0.3774	0.3644	0.3373
36.07	0.3941	0.3749	0.3805
31.83	0.4114	0.3911	0.3994
28.09	0.4261*	0.4100	0.4193
24.78	0.4412	0.4308	0.4401
19.31	0.4863	0.4591	0.4691
17.04	0.5240	0.4900	0.4777
15.03	0.5492	0.5135	0.4933
13.27	0.5695	0.5312	0.5095
11.71	0.5836	0.5415	0.5259
10.33	0.5931	0.5479	0.5378

* Interpolated Value Due to Use of Different Group Structure for this Data File.

FIGURE CAPTIONS

- Figure 1. RIGAS INTERCOM Iteration Scheme.
- Figure 2. Comparison of Continuous Slowing Down Spectrum (FLUXED DAT) Using the ENDF/B-II XI parameter of Burns with Experimental Spectrum (EXPER DAT) in Depleted Uranium.
- Figure 3. Comparison of XI parameter for uranium obtained in this paper (PSIM1 DAT) with the ENDF/B-II XI of Burns (PSIED DAT).
- Figure 4. Comparison of Continuous Slowing Down Spectrum (FLXM1 DAT) for Uranium Based on the Modified XI of this paper with the Experimental Spectrum (EXPER DAT).
- Figure 5. Expansion of the Low Energy Portion of Figure 4.
- Figure 6. Comparison of Low Energy Calculation (FLXM2 DAT) Using New XI and ENDF/B-III Unresolved Capture Data with Experimental Spectrum (EXPER DAT).
- Figure 7. Comparison of Low Energy Calculation (FLXM3 DAT) Using New XI and ANL File Unresolved Capture Data with Experimental Uranium Spectrum (EXPER DAT).
- Figure 8. Comparison of Continuous Slowing Down Spectrum in Iron Based on MAT 1124 Data (FLX00 DAT) with Experimental Spectrum (EXPER DAT).
- Figure 9. Comparison of Final (PSISV DAT) and Initial (PSI00 DAT) XI Parameters for Iron.
- Figure 10. Comparison of Final (AGEPA DAT) and Initial (AGEAA DAT) Age Parameters for Iron.
- Figure 11. Comparison of Calculated Spectrum (FLXPA DAT) Using Final XI and Age Parameters with Experimental Spectrum in Iron (EXPER DAT).

RIGAS-INTERCOM ITERATION SCHEME

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11