

A Review of Covariances for ENDF/B-VII (...Continuation...)

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OVERVIEW

A preliminary review of covariance information taken from ENDF/B-VI.8 and included in ENDF/B-VII.b1 was carried out by this author in January 2006, and the results were reported in an earlier communication (www.nndc.bnl.gov/csewg_members/). Consideration of quality factors such as the extent of detail provided on the errors and their correlations, the methods used to generate the covariances, and the manner in which various covariance formats were utilized, led to a significant reduction in the number of candidate covariance files to be considered for inclusion in ENDF/B-VII.b2 relative to the content of ENDF/B-VI.8. The present review continues this screening process by determining which of the preliminary candidate covariance files from ENDF/B-VII.b1 – as well as newly introduced files in ENDF/B-VII.b2 – could be processed for use in applications (in this case by code ERRORJ) and then examining plots of uncertainties and correlations generated by ERRORJ along with plots of the corresponding evaluated results and available experimental data for consistency. A comparison has also been made between the covariance file contents of ENDF/B-VI.8, -VII.b1, and -VII.b2 to insure that no potentially useful covariance information had been misplaced as a consequence of the transition from ENDF/B-VI.8 through ENDF/B-VII.b1 to ENDF/B-VII.b2. Based on conclusions drawn from these review steps, some recommendations are made in the present report as to which covariance files ought to be included in the official version of ENDF/B-VII to be released late in 2006 (hereafter referred to as “ENDF/B-VII”). The job of final selection of covariance files to be included in ENDF/B-VII is not yet complete as of this date (20 June 2006) for two main reasons: First, additional effort in the area of processing and visualization of covariance information will be necessary in order to arrive at recommendations for a number of those candidate files selected by the preliminary screening that to date either had not yet been processed – or could not be processed – by ERRORJ. Second, the situation concerning covariances for ENDF/B-VII remains fluid at this point in the sense that modifications continue to be introduced for covariance files that were submitted for consideration earlier (e.g., for Th-232). Therefore, it is anticipated that the present review process to select covariance files for ENDF/B-VII will be continued up to a cutoff date to be determined by CSEWG (most probably in the early Autumn of 2006).

INTRODUCTION

A covariance matrix specifies the errors and their correlations for a set of numerical values that represent a physical quantity. Here we are concerned with covariance matrices that correspond to evaluated nuclear reaction data, e.g., a set of cross sections at various energies.

The first covariance matrices for evaluations to appear in ENDF/B arrived more than 20 years ago with version ENDF/B-V. In recent years this area of evaluation activity has received only modest attention because of limited demand from data users. However, the situation has changed dramatically during the past few years because now there are strongly requested needs for covariance information emerging from several user communities. The evaluation community is currently striving to meet this challenge. Objective methods for producing evaluations of nuclear reaction data and concurrently generating the corresponding covariance matrices are well developed. They are now being implemented by many contemporary evaluators. Earlier, the situation was mixed. Some covariance matrices were generated as a consequence of rigorous evaluation procedures while others were produced in ad hoc fashion and introduced as “after-thoughts” into the evaluations. Unfortunately, in order to accommodate this questionable practice CSEWG over time adopted a plethora of “allowed” formats for representing covariances in the evaluated data libraries. This has led to a situation which, in the opinion of this author, is almost unmanageable. More recently, it was decided by CSEWG that a serious attempt should be made to improve the quality of the covariance content in ENDF/B-VII, even if it meant eliminating much of the earlier covariance material appearing in libraries as recent as ENDF/B-VI.8 and insisting that new evaluations – in principle – adhere to higher standards of quality in the area of covariances, as well as in other aspects of evaluation methodology, than has often been the case in the past. Also, there is a trend toward simplification of formats. A key problem is how to establish reasonably objective criteria for elimination or inclusion of covariance information in ENDF/B-VII that would be agreeable to both the nuclear data evaluator and user communities.

An earlier preliminary review of covariances was carried out by this author in January 2006. This review was based solely on material contained in ENDF/B-VII.b1. A report on this review (along with an accompanying spreadsheet) can be found at the CSEWG Members website (www.nndc.bnl.gov/csewg_members/). A fairly limited number of covariance files from ENDF/B-VII.b1 were identified as likely to be of sufficiently good quality to be included in ENDF/B-VII for its official release in late 2006. It was understood that even after surviving this preliminary screening process, these files would need to be subjected to further examination before final decisions concerning their inclusion in the officially released version of ENDF/B-VII could be made. Since the time of this earlier review a new version of ENDF/B, ENDF/B-VII.b2, has been made available to the nuclear data community for review and testing. The present review continues from the point where the earlier one left off by pursuing the following steps:

- *Determined whether the files recommended for migration from ENDF/B-VII.b1 to ENDF/B-VII final do indeed appear in ENDF/B-VII.b2.*
- *Examined ENDF/B-VI.8 to see if any covariance files were overlooked in the assembly of ENDF/B-VII.b1 (and hence escaped the earlier review).*
- *Generated an inventory of all the covariance files that appeared to be likely candidates for inclusion in ENDF/B-VII.*
- Processed all those files in ENDF/B-VI.b2 that could be processed with code ERRORJ and generated plots of corresponding error and correlation profiles.
- Plotted corresponding evaluated cross sections along with available experimental data from CSISRS (EXFOR).

- Examined the covariance plots along with the evaluation and experimental data plots in order to arrive at recommendations concerning inclusion or exclusion of the covariance information in ENDF/B-VII.

The present review (as did the earlier one) addresses covariance information from files in the categories MF = 31, 32, 33, 34, 35, and 40. Since no files exist in the MF = 34 category for any of the abovementioned libraries, attention has been given only to the other five MF categories. The only steps in the final review process that could be applied to MF = 31, 32, 35, and 40 covariances were those identified in italics above. No processing or visualization software has been available to date to enable the information in these categories to be analyzed. Thus it has not been possible yet to reach final conclusions concerning the appropriateness of their inclusion or exclusion in ENDF/B-VII. Furthermore, a number of covariance files in the category MF = 33 also could not be processed (at least in time for this review) since ERRORJ “crashed” for one reason or another when attempting analyzing these problematic files. The details are given in tables below.

It was anticipated earlier that ENDF/B-VI.b2 covariances would eventually become ENDF/B-VII covariances with only minor modifications applied in order to insure the best possible accuracy and completeness of the file before its finalization and formal release in late 2006. Whether this will be the case or not remains to be seen since much work will have to be done before such judgments can be rendered. The present document is a progress report which has been prepared explicitly to provide material for consideration by the CSEWG review panel at its 27 June 2006 ENDF/B-VII validation meeting where these issues will be discussed.

DETAILS AND RECOMMENDATIONS

The following discussion is organized according to MF category. Details related to those steps of the present review process that are identified by italics, as indicated above, occupy the major portion of this section. However, in the case of certain MF = 33 covariance files it has been possible to extend the screening process through the additional steps indicated above. For these case an explanation is provided of the reasoning exercised by this author in arriving at final recommendations for inclusion or exclusion of specific files in ENDF/B-VII.

MF = 31

Covariances for the Average Number of Fission Neutrons

Based on the review to date, only two files found in ENDF/B-VII.b1 are considered to be suitable candidates for ENDF/B-VII. Both of these files do indeed appear in ENDF/B-VII.b2. In addition, a new covariance file is found in ENDF/B-VII.b2 that does not appear in ENDF/B.b1. This file is for Th-232. Since this evaluation – including its determination of covariances - was carried out using modern methods, it was anticipated that the quality of these covariance files should satisfy ENDF/B-VII standards and therefore be included as candidates. An examination of ENDF/B-VI.8 revealed that only one MF = 31 file was dropped in assembling ENDF/B-VII.b1. That file was for Th-232 which has been substituted by the new evaluation mentioned

above. As of this date, it has not been possible to process or visualize any of these files. Thus, final recommendations on their inclusion in ENDF/B-VII cannot be made at this time.

MAT	Isotope	Candidate Covariance Files for ENDF/B-VII by MT Number
9040	Th-232	452
9228	U-235	452,456

- Files highlighted in yellow are from ENDF/B-VI.8. The other file is new.

MF = 32

Covariances for Resonance Parameters

Only one file contained in ENDF/B-VII.b1 was recommended as a candidate for inclusion in ENDF/B-VII. This file does indeed appear in ENDF/B-VII.b2 and all the other files from ENDF/B-VII.b1 were dropped during the earlier screening procedure. However, nine new files that were not included in ENDF/B-VII.b1 were added to ENDF/B-VII.b2. Eight of them correspond to the suite of Gd isotopes that were evaluated recently. It is appropriate that these files be considered for inclusion in ENDF/B-VII final since modern evaluation techniques were employed in generating this covariance information. The tenth file corresponds to the recent Th-232 evaluation mentioned above. An examination of ENDF/B-VI.8 revealed that there is a one-to-one correspondence of the MF = 32 files there with the content of ENDF/B-VII.b1. The Na-23 covariances for the resonance region could not be processed with ERRORJ. However, all the Gd and Th-232 files could be processed. The generation of cross section covariances from resonance parameter covariances is somewhat indirect. For the Gd and Th-232 results, plots were generated by ERRORJ. In the opinion of this author, some of the uncertainties in the resolved and unresolved resonance regions appear somewhat questionable, but final judgments on this matter will be deferred pending further examination and discussions with the authors. The comments indicated in the table of recommendations that appears below are based largely on consideration of the fast-neutron energy range.

MAT	Isotope	Candidate Covariance Files for ENDF/B-VII by MT Number
1125	Na-23	151
6425	Gd-152	151
6428	Gd-153	151
6431	Gd-154	151
6434	Gd-155	151
6437	Gd-156	151
6440	Gd-157	151
6443	Gd-158	151
6449	Gd-160	151
9040	Th-232	151

- Files highlighted in yellow are from ENDF/B-VI.8. All other files are new.
- Red font: File could not be processed with ERRORJ.
- Green font: Files have been processed with ERRORJ.

MF = 33

Covariances for Neutron Cross Sections

It should be noted that all of the covariance files from ENDF/B-VII.b1 that were deemed to be of good quality and selected to be considered further for inclusion in ENDF/B-VII do appear in ENDF/B-VII.b2. Also, there are a number of new (or revised) entries in ENDF/B-VII.b2 that require discussion. The Gd isotope and Th-232 evaluations are prominent among these. Several new covariance entries in ENDF/B-VII.b2 correspond to the new International Neutron Standards File that has been adopted for ENDF/B-VII {identified by NSUB = 19 (Std)}. Although carbon elastic scattering was not re-evaluated in the standards project, and the covariance matrix for this reaction from the general purpose file was rejected in the recent review of ENDF/B-VII.b1 covariances, a new covariance file has been prepared in the meantime for this process and it appears in ENDF/B-VII.b2. Also, a new (separate) evaluation of Li-6(n,t) – including a covariance matrix – has been provided recently. All but one of the covariance files for Li-7 found in ENDF/B-VII.b1 were rejected, but several new determinations of certain covariances have been made for this nucleus and these can be found in ENDF/B-VII.b2 (MT = 2, 4, 102, and 851). Referring to ENDF/B-VI.8, it is noted that a number of covariance files were eliminated in preparing ENDF/B-VII.b1. The files corresponding to an elemental Si evaluation were dropped because the entire elemental Si evaluation itself was dropped. The policy adopted by CSEWG in preparing ENDF/B-VII has been to drop all earlier elemental evaluations except for a few cases where no other information is available and the elements are dominated by a single isotope (carbon and vanadium are examples). One covariance file for Ti-46 and two for Ti-47 were dropped. Upon inspection, it was concluded that these files were of lower quality anyway and therefore did not merit consideration for inclusion in ENDF/B-VII. Eight covariance files for Y-89 appear in ENDF/B-VI.8 but they were dropped in ENDF/B-VII.b1. Upon inspection, it was decided that seven of these files are of lower quality and deserve to be dropped. However, the covariance matrix for Y-89 total cross section (MT = 1) was produced as the consequence of a rigorous statistical analysis that generated both variances and correlations. Therefore, this covariance matrix should be considered for migration from ENDF/B-VI.8 and inclusion in ENDF/B-VII. All covariance matrices for the natural In evaluation from ENDF/B-VI.8 were eliminated from ENDF/B-VII.b1 since the entire elemental In evaluation was eliminated. Two covariance files for In-115 are included in ENDF/B-VI.8 but were dropped in preparing ENDF/B-VII.b1. One file is for (n,n') to the first excited level and the second is for neutron capture. Upon inspection, it was concluded that both of these files are of lower quality and, indeed, should not appear in ENDF/B-VII. Covariance information for both Pb-206 and Pb-207 from ENDF/B-VI.8 were not included in ENDF/B-VII.b1. Upon inspection, this covariance information appears to be constructed from ad hoc estimates of uncertainty and would not pass the quality tests for inclusion in ENDF/B-VII. Finally, covariance information for Th-232 fission and capture that appears in ENDF/B-VI.8 was dropped in going to ENDF/B-VII.b1. However, as mentioned above, a new evaluation of Th-232 has recently been produced and it should be considered as a candidate for inclusion in ENDF/B-VII. These comments are summarized in the following table. It is noteworthy that to date it has not been possible to process a number of these files using ERRORJ or to produce plots that could be used in assessing their quality as candidates for ENDF/B-VII. More work needs to be done before finalizing the decisions on covariances for ENDF/B-VII, mainly in the area of file processing, visualization, and judgments on quality based on examination of the generated plots of uncertainties, correlations, evaluations, and experimental data.

MAT	Isotope	Candidate Covariance Files for ENDF/B-VII by MT Number
325	Li-6	105,105(Std)
328	Li-7	1,2,4,102,851
525	B-10	107,800,801
600	C-nat	2(Std)
925	F-19	4,16,22,28
2231	Ti-48	1,4,16,28,102,103,107
2300	V-nat	1
2725	Co-59	1,16,103,107
2825	Ni-58	16
3925	Y-89	1*
4125	Nb-93	1
6425	Gd-152	1,2,4,16,102,103
6428	Gd-153	1,2,4,16,102,103
6431	Gd-154	1,2,4,16,102,103,107
6434	Gd-155	1,2,4,16,102,103
6437	Gd-156	1,2,4,16,102,103,107
6440	Gd-157	1,2,4,16,102,103
6443	Gd-158	1,2,4,16,102,103,107
6449	Gd-160	1,2,4,16,102,103,107
7925	Au-197	1,102(Std)
8325	Bi-209	1
9040	Th-232	1,2,5,16,17,18,22,24,28,41,51,52-89(All),91,102,600,649,800,849,851,852,853,854,855
9228	U-235	18(Std)
9237	U-238	18(Std)

- Files highlighted in yellow are from ENDF/B-VI.8. All other files are new.
- Files marked with "*" do not appear in ENDF/B-VII.b2.
- (Std) indicates files taken from the ENDF/B-VII Standards File.
- (All) indicates that all files in the indicated MT number range are included.
- Black font: File not yet processed with ERRORJ.
- Green font: File was processed successfully with ERRORJ and readable plots are available.
- Red font: File could not be processed with ERRORJ.

Final decisions concerning inclusion or exclusion of individual candidate covariance files in ENDF/B-VII, based on processing with ERRORJ and examination of the generated plots, are indicated in the following table. In the opinion of this author, the most important factor in deciding whether or not a particular covariance file should be included in ENDF/B-VII was that the indicated uncertainties be consistent with the scatter of experimental about the final evaluation and that the error correlation patterns appear reasonable. In cases where no experimental data exist a common sense "reality check" was invoked. The uncertainties indicated by the covariance matrix ought to be consistent with what might be reasonably expected under existing circumstances for a particular reaction type, energy, range, and isotope mass range. In other words, experience served as the ultimate guiding principle in making recommendations for those cases where objective data are very limited or nonexistent.

MAT	Isotope	Abund	MT	Reaction	Cov Qual	Comments
925	F-19	100%	4	(n,inel)	Acceptable	Some expt'l data are available. Covariance values appear to be

						fairly reasonable.
			16	(n,2n)	Acceptable	Considerable expt'l data are available. Covariance values appear to be quite reasonable.
			22	(n,na)	Marginal	No expt'l data are available. Uncertainties appear to be rather low above 5 MeV. This reaction process is hard to calculate accurately with no data to guide the calculations.
			28	(n,np)	Marginal	No expt'l data are available. Uncertainties appear to be too low. This reaction process is difficult to calculate accurately without data to guide the calculations.
2231	Ti-48	73.7%	1	(n,tot)	Acceptable	No expt'l data are available. Broad-resolution total cross sections can be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			4	(n,inel)	Acceptable	No expt'l data are available. Uncertainties may be a bit low considering the lack of data, but the suggested error values are not totally unreasonable since broad-resolution inelastic scattering cross sections can generally be calculated from known discrete-level and level-density information to the indicated errors with reasonable confidence. Covariance values are plausible.
			16	(n,2n)	Acceptable	One questionable (and probably useless) expt'l data point is available. Uncertainties may be a bit low considering the lack meaningful guidance from the available data, but the given error values are not totally unreasonable since (n,2n) cross sections can be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			28	(n,np)	Acceptable	Considerable expt'l data are available. Covariance values appear to be quite reasonable.
			102	(n,g)	Acceptable	Some expt'l data are available. Covariance values are plausible.
			103	(n,p)	Acceptable	Extensive expt'l data are available. Covariance values appear to be quite reasonable.
			107	(n,a)	Marginal	Some expt'l data are available. Nevertheless, the given errors appear to be too low.
2300	V-nat	NA	1	(n,tot)	Acceptable	Extensive expt'l data are available. Covariance values appear to be quite reasonable.
2725	Co-59	100%	1	(n,tot)	Marginal	Extensive expt'l data are available. Nevertheless, the given errors appear to be too low.
			16	(n,2n)	Acceptable	Extensive expt'l data are available. Uncertainties may be a bit too low but are not totally unreasonable. Covariance values are plausible.
			103	(n,p)	Acceptable	Considerable expt'l data are available. Covariance values appear to be quite reasonable.
			107	(n,a)	Acceptable	Extensive expt'l data are available. Covariance values seem quite reasonable.
2825	Ni-58	68.1%	16	(n,2n)	Marginal	Extensive expt'l data are available. Nevertheless, the given uncertainties appear to be too low.
4125	Nb-93	100%	1	(n,tot)	Acceptable	Extensive expt'l data are available. The given uncertainties appear to be somewhat low although they are not totally unreasonable. Covariance values are plausible.
6425	Gd-152	0.2%	1	(n,tot)	Acceptable	Minor isotope. The only expt'l data available are below a few hundred keV. However, broad-resolution total cross sections can be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			2	(n,el)	Acceptable	Minor isotope. No expt'l data are available. Broad-resolution elastic scattering cross sections can generally be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			4	(n,inel)	Acceptable	Minor isotope. No expt'l data are available. Broad-resolution

						inelastic scattering cross sections can generally be calculated from known discrete-level and level-density information to the indicated errors with reasonable confidence. Covariance values are acceptable.
			16	(n,2n)	Acceptable	Minor isotope. One low-accuracy exp'tl data point is available to guide normalization. Indicated errors may be somewhat conservative in view of the available data and systematics, but they are not unreasonable. Covariance values are plausible.
			102	(n,g)	Acceptable	Minor isotope. The only exp'tl data available are below a few hundred keV. However, broad-resolution capture cross sections can be calculated with reasonable confidence to the indicated errors in view of the available normalization guidance. Covariance values are plausible.
			103	(n,p)	Acceptable	Minor isotope. No exp'tl data are available. The relatively large indicated uncertainties are probably realistic since this reaction process is difficult to calculate accurately in the absence of guidance from experimental data. Covariance values are plausible.
6428	Gd-153	RA	1	(n,tot)	Acceptable	Radioactive isotope. The only exp'tl data available are below one eV. However, broad-resolution total cross sections can be calculated from systematics to the errors indicated with reasonable confidence. Covariance values appear to be quite reasonable.
			2	(n,el)	Acceptable	Radioactive isotope. No exp'tl data are available. Broad-resolution elastic scattering cross sections can generally be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			4	(n,inel)	Acceptable	Radioactive isotope. No exp'tl data available. Broad-resolution inelastic scattering cross sections can generally be calculated from known discrete-level and level-density information to the indicated errors with reasonable confidence. Covariance values are plausible.
			16	(n,2n)	Acceptable	Radioactive isotope. No exp'tl data are available. This reaction cross section can generally be computed from systematics to the indicated uncertainties with reasonable confidence. Covariance values are plausible.
			102	(n,g)	Acceptable	Radioactive isotope. No exp'tl data are available. The relatively large indicated uncertainties are probably realistic since this reaction process is difficult to calculate accurately in the absence of guidance from experimental data. Covariance values are plausible.
			103	(n,p)	Acceptable	Radioactive isotope. No exp'tl data are available. The relatively large indicated uncertainties are probably realistic since this reaction process is difficult to calculate accurately in the absence of guidance from experimental data. Covariance values are plausible.
6431	Gd-154	2.2%	1	(n,tot)	Acceptable	Minor isotope. The only exp'tl data available are below about 100 keV. The indicated uncertainties appear to be a bit low, especially at the higher energies, but they are not totally unrealistic since the total cross section can generally be computed from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			2	(n,el)	Acceptable	Minor isotope. No exp'tl data are available. Broad-resolution elastic scattering cross sections can generally be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			4	(n,inel)	Acceptable	Minor isotope. No exp'tl data are available. Uncertainties may be a bit low, but they are not unreasonable because broad-resolution

						inelastic scattering cross sections can generally be calculated from known discrete-level and level-density information to the indicated error levels with reasonable confidence. Covariance values are plausible.
			16	(n,2n)	Marginal	Minor isotope. Three expt'l data points exist but the oldest one is discrepant with respect to the more recent two. Evaluation normalization is guided by the recent data. In view of this, the indicated errors appear to be too large (overly conservative).
			102	(n,g)	Acceptable	Minor isotope. Extensive expt'l data are available below 1 MeV. Broad-resolution capture cross sections can be calculated to the indicated errors with reasonable confidence in view of the expt'l normalization guidance. Covariance values appear to be quite reasonable.
			103	(n,p)	Acceptable	Minor isotope. No expt'l data available. The relatively large indicated uncertainties are probably realistic since this reaction process is difficult to calculate accurately in the absence of guidance from experimental data. Covariance values appear to be quite reasonable.
			107	(n,a)	Acceptable	Minor isotope. No expt'l data are available. The relatively large indicated uncertainties are probably realistic since this reaction process is difficult to calculate accurately in the absence of guidance from experimental data. Covariance values are plausible.
6434	Gd-155	14.8%	1	(n,tot)	Acceptable	Some expt'l data are available to guide the evaluation at both low and higher energies, and the total cross section can generally be computed from systematics to the indicated accuracies with reasonable confidence. Covariance values are plausible.
			2	(n,el)	Acceptable	No expt'l data are available. Broad-resolution elastic scattering cross sections can generally be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			4	(n,inel)	Acceptable	No expt'l data are available. Broad-resolution inelastic scattering cross sections can generally be calculated from known discrete-level and level-density information to the indicated errors with reasonable of confidence. Covariance values are plausible.
			16	(n,2n)	Acceptable	Some expt'l data are available. Covariance values appear to be quite reasonable.
			102	(n,g)	Acceptable	Considerable expt'l data are available. Covariance values appear to be quite reasonable.
			103	(n,p)	Acceptable	No expt'l data are available. The relatively large indicated uncertainties are probably realistic since this reaction process is difficult to calculate accurately in the absence of guidance from experimental data. Covariance values are plausible.
6437	Gd-156	20.5%	1	(n,tot)	Acceptable	Some expt'l data are available to guide the evaluation at both low and higher energies, and the total cross section can generally be computed from systematics to the indicated accuracies with reasonable confidence. Covariance values are plausible.
			2	(n,el)	Acceptable	No expt'l data are available. Broad-resolution elastic scattering cross sections can generally be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			4	(n,inel)	Acceptable	No expt'l data are available. Broad-resolution inelastic scattering cross sections can generally be calculated from known discrete-level and level-density information to the indicated errors with reasonable confidence. Covariance values are plausible.
			16	(n,2n)	Acceptable	Some expt'l data are available. Covariance values appear to be quite reasonable.

			102	(n,g)	Acceptable	Considerable expt'l data are available. Covariance values appear to be quite reasonable.
			103	(n,p)	Acceptable	One questionable (and probably useless) expt'l data point is available. The relatively large indicated uncertainties are probably realistic since this reaction process is difficult to calculate accurately in the absence of guidance from reliable data. Covariance values are plausible.
			107	(n,a)	Acceptable	Two discrepant data points are available. Evaluation follows the lower and more recent value. The indicated large uncertainties reflect this discrepancy, and although perhaps a bit too conservative they are not unrealistic since this reaction process is difficult to calculate accurately in the absence of guidance from reliable expt'l data. Covariance values are plausible.
6440	Gd-157	15.7%	1	(n,tot)	Acceptable	Some expt'l data are available to guide the evaluation at both low and higher energies, and the total cross section can generally be computed from systematics to the indicated accuracies with reasonable confidence. Covariance values appear to be quite reasonable.
			2	(n,el)	Acceptable	No expt'l data are available. Broad-resolution elastic scattering cross sections can generally be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			4	(n,inel)	Acceptable	No expt'l data are available. Broad-resolution inelastic scattering cross sections can generally be calculated from known discrete-level and level-density information to the indicated errors with reasonable confidence. Covariance values are plausible.
			16	(n,2n)	Acceptable	Some expt'l data are available. Covariance values appear to be quite reasonable.
			102	(n,g)	Acceptable	Considerable expt'l data are available. Covariance values appear to be quite reasonable.
			103	(n,p)	Acceptable	Two discrepant data points are available. Evaluation follows the lower and more recent value. The indicated large uncertainties reflect this discrepancy and are perhaps a bit too conservative but not unrealistic since this reaction process is difficult to calculate accurately in the absence of guidance from reliable expt'l data. Covariance values are plausible.
6443	Gd-158	24.8%	1	(n,tot)	Acceptable	Some expt'l data are available below about 100 keV to guide the evaluation, and the total cross section can generally be computed from systematics to the indicated accuracies with reasonable confidence. Covariance values appear to be quite reasonable.
			2	(n,el)	Acceptable	No expt'l data are available. Broad-resolution elastic scattering cross sections can generally be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			4	(n,inel)	Acceptable	No expt'l data are available. Broad-resolution inelastic scattering cross sections can generally be calculated from known discrete-level and level-density information to the indicated errors with reasonable confidence. Covariance values are plausible.
			16	(n,2n)	Acceptable	Some expt'l data are available. Covariance values appear to be quite reasonable.
			102	(n,g)	Acceptable	Extensive expt'l data are available. Covariance values appear to be quite reasonable.
			103	(n,p)	Acceptable	A single expt'l data point is available. The indicated uncertainties would appear to be somewhat large (overly conservative) given that there exist data to guide the cross section normalization. However, this reaction process is difficult to calculate accurately

						in the absence of guidance from reliable data and the available data point has a fairly large error bar. Covariance values are plausible.
			107	(n,a)	Marginal	There are four expt'l data points available, three of them in decent agreement with one another and one that is discrepant. This evaluation is guided by the three points that are in agreement. Consequently, the indicated errors appear to be excessively large (overly conservative).
6449	Gd-160	21.9%	1	(n,tot)	Acceptable	A single expt'l data point is available near 14 MeV to guide the evaluation, and the total cross section can generally be computed from systematics to the indicated accuracies with reasonable confidence. Covariance values are plausible.
			2	(n,el)	Acceptable	No expt'l data are available. Broad-resolution elastic scattering cross sections can generally be calculated from systematics to the indicated errors with reasonable confidence. Covariance values are plausible.
			4	(n,inel)	Acceptable	No expt'l data are available. Broad-resolution inelastic scattering cross sections can generally be calculated from known discrete-level and level-density information to the indicated errors with reasonable confidence. Covariance values are plausible.
			16	(n,2n)	Acceptable	Extensive expt'l data are available. Covariance values appear to be quite reasonable.
			102	(n,g)	Acceptable	Extensive expt'l data are available. Covariance values appear to be quite reasonable.
			103	(n,p)	Acceptable	No expt'l data are available. The relatively large indicated uncertainties are probably realistic since this reaction process is difficult to calculate accurately in the absence of guidance from experimental data. Covariance values are plausible.
			107	(n,a)	Acceptable	A single expt'l data point is available. The relatively large indicated uncertainties would appear to be justified since this reaction process is difficult to calculate accurately in the absence of guidance from accurate data, and the error bar of the existing point is quite large. Covariance values are plausible.
7925	Au-197	100%	1	(n,tot)	Acceptable	Extensive expt'l data are available. Covariance values seem quite reasonable.
8325	Bi-209	100%	1	(n,tot)	Acceptable	Extensive expt'l data are available. Covariance values seem quite reasonable.
9040	Th-232	RA	1	(n,tot)	Unacceptable	Extensive expt'l data are available. The indicated errors appear to be much too large in the MeV range since the total cross section can generally be computed from systematics to a much higher level of accuracy than indicated here with reasonable confidence, especially when supportive expt'l information is available.
			2	(n,el)	Marginal	Some expt'l data exist in the MeV range to guide nuclear modeling. Nevertheless, the indicated errors still appear to be on the small side even though broad-resolution elastic scattering cross sections can generally be calculated from systematics with reasonable confidence when guided by data.
			5	(n,X)	Unacceptable	There are no explicit expt'l data available in EXFOR for the category MT=5. It is not clear how the evaluators arrived at an evaluation and covariance matrix for this quantity, nor is it obvious what it represents physically in this instance. Therefore, it is not possible to judge the quality of this covariance information.
			17	(n,3n)	Marginal	A single expt'l data point with moderate uncertainty is available but the calculation has not been normalized to it and it differs from the data by more than the data error bar. It should be possible to calculate this physical quantity from systematics with

						uncertainties in the range 20-30%, and perhaps better, if guided by data. However, the given uncertainties appear to be quite low under the present circumstances.
			18	(n,f)	Unacceptable	Although extensive expt'l data are available, an uncertainty of about 1% across the entire energy range above 1 MeV given here appears to be unrealistically optimistic. This reaction process is not a standard but uncertainties worthy of a standard are indicated. It would seem that error values in the range of 3-5% on the plateau region (above 2 MeV), and considerably larger errors in the threshold region, would be more realistic.
			51	(n,n1)	Unacceptable	No expt'l data are available. Owing to competition from fission and inelastic scattering to other excited levels, it must be assumed that it is quite difficult to predict the scattering to any particular level – in this case the first excited state – to any degree of accuracy other than qualitative over the entire MeV energy range in the absence of expt'l guidance. Under these circumstances, the indicated uncertainties for this process seem to be unrealistically low and perhaps they should be considered as more representative of the total inelastic scattering cross section uncertainty rather than that of inelastic scattering to a single discrete level.

- Acceptable (green): Covariance file appears to be acceptable for inclusion in ENDF/B-VII with few if any qualifications
- Marginal (yellow): There are some minor issues associated with the covariance file (usually errors which appear to be somewhat small or large) but these issues do not appear to be sufficiently significant to warrant the file not being accepted for ENDF/B-VII.
- Unacceptable (red): The covariance file is sufficiently flawed to recommend that it not be included in ENDF/B-VII, at least not without revision.

As mentioned previously, final decisions have not been reached for a number of the files that passed the earlier screening. It is anticipated that many of these will be processed and visualized in one way or another in the weeks ahead. Perhaps it will be necessary to limit consideration to those energies in the fast region (avoiding the problematic resolved and unresolved resonance regions) and/or apply codes other than ERRORJ to process these files and generate covariance plots for visualization of the covariance information.

MT = 35

Covariances for Distributions of Secondary Particles

A covariance matrix for the emission of neutrons from spontaneous fission of Cf-252 appears in both ENDF/B-VI.8 and ENDF/B-VII.b1 {Mat = 9861, MF = 35, NSUB = 4, MT = 18} but not in ENDF/B-VII.b2. It was apparently misplaced somewhere along the line in the preparation of ENDF/B-VII.b2 and should be restored. This is a well determined neutron spectrum standard whose covariance matrix has been generated using extensive experimental data and rigorous statistical methods and is considered to be of the highest quality. Consequently, this author is inclined to recommend that it be included in ENDF/B-VII without further consideration. Of course it would be desirable to visualize this file to insure that there are no numerical errors. An attempt to do this will be made in the weeks ahead.

MAT	Isotope	Candidate Covariance Files for ENDF/B-VII by MT Number
9861	Cf-252	18*

- File highlighted in yellow is from ENDF/B-VI.8.

- File marked with “*” does not appear in ENDF/B-VII.b2.

$$\underline{MT = 40}$$

Covariances for Production of Radioactive Nuclei

The single covariance matrix in ENDF/B-VII.b2 should be considered as a candidate for inclusion in ENDF/B-VII, as recommended in the earlier review of ENDF/B-VII.b1. However, a survey of ENDF/B-VI.8 identified a second covariance matrix, for production of the isomer In-115m by neutron inelastic scattering from In-115 {MAT = 4931, MF = 40, NSUB = 10, MT = 4}, that should also be considered for inclusion in ENDF/B-VII final. It has not been possible to process these files to date so final decisions cannot be made concerning their destiny with regard to ENDF/B-VII. An attempt will be made to process and visualize these files in the weeks ahead.

MAT	Isotope	Candidate Covariance Files for ENDF/B-VII by MT Number
4125	Nb-93	4
4931	In-115	4*

- Files highlighted in yellow are from ENDF/B-VI.8. All other files are new.
- File marked with “*” does not appear in ENDF/B-VII.b2.

The detailed information in the preceding tables is summarized in the following table which indicates how many covariance files from ENDF/B-VI.8 survived the first screening for inclusion in ENDF/B-VII. The number of new files that have been introduced for consideration is also indicated. Not all of these files will ultimately be included in ENDF/B-VII for reasons mentioned above, but the table clearly suggests that ENDF/B-VII will contain fewer than one quarter of the number of covariance files found in ENDF/B-VI.8. Insistence on quality indeed will exact a relatively high price but, in the long run, the user community will be best served by these choices. Future modifications to ENDF/B-VII will likely introduce extensive high-quality covariance information as a consequence of the growing activity in this area.

MF	Description	ENDF/B-VI.8	ENDF/B-VII
31	Nu-bar	9 (2)	3 [1]
32	Resonance Parameters	4 (1)	10 [9]
33	Cross Sections	739 (26)	147 [121]
34	Angular Distributions	0	0
35	Secondary Particles	1 (1)	1 [0]
40	Radioactive Nuclei	2 (2)	2 [0]
Totals		755 (32)	163 [131]

(...) Candidate ENDF/B-VI.8 files to be migrated to ENDF/B-VII

[...] Candidate new files to be introduced in ENDF/B-VII