A Compact ENDF (ACE) Format Specification

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1 Introduction

The ACE format consists of two *types* and many *classes* of data. The data are kept in an ACE Table. The term ACE Table and ACE file are often used interchangeably.

1.1 Types of ACE-Formatted Data

There are two types of ACE-formatted data; simply called Type 1 and Type 2.

Type 1 Standard formatted tables. These tables contain ASCII text and are machine independent; they are readable on every machine.

Type 2 Standard unformatted tables. These tables are binary and can be generated from the Type 1 files. They are more compact and faster to read than the Type 1 ACE Tables but are machine/platform dependent; they are not readable on every machine.

Traditionally Type 2 ACE files were more commonly used because they were smaller in size and faster to read. However due to the fact that they are not portable across machines and platforms they have fallen out of fashion.

1.2 Classes of ACE-Formatted Data

There are many classes of ACE-formatted data:

1. continuous-energy neutron (see Section 4),
2. discrete-reaction neutron,
3. neutron dosimetry (see Section 5),
4. $S(\alpha, \beta)$thermal (see Section 6),
5. continuous-energy photoatomic (see Section 7),
6. continuous-energy electron interaction,
7. continuous-energy photonuclear interaction,
8. multigroup-energy neutron, and
9. multigroup-energy photoatomic.

Each of these classes of data are described later in this document.

An ACE Table is an entity that contains evaluation-dependent data about one of the many classes of data for a specific material—an target isotope, isomer, or element. For a given ZAID, the data contained on a Type 1 and Type 2 tables are identical. Simulations run with one type of data should produce identical results as those run with the other type of data.

1.3 ACE Libraries

A collection of ACE data tables that derive from a single set of evaluation files are typically grouped together in a “library”—not to be confused from the evaluation library from which they derive. Multiple ACE data tables can concatenated into the same logical file on the computer, although this has fallen somewhat out of fashion due to the large amount of data on each ACE table derived from modern evaluation files. Applications that use ACE-formatted data should produce the same results regardless of whether the tables are contained in one logical file on the computer or spread across many.

2 ACE Tables

An ACE Table consists of a Header followed by an array (XSS) containing the actual data. The Header and XSS array are the same regardless of whether the ACE Table is Type 1 or Type 2. Each line in a Type 1 ACE Table is 80 characters or less.

2.1 ACE Header

The first section of an ACE Table is the Header. The ACE Header contains metadata[1] about the ACE Table. The Header consists of four parts:

1. Opening,
2. IZAW array,
3. NXS array, and
4. JXS array.

An example of an ACE Table Header (from ^{1}H in the ENDf71x library) is given in Figure 1 with each part highlighted a different color.

```
 1 1001.80c    0.999167  2.5301E-08   12/17/12
 2 H1 ENDF71x (jlconlin)  Ref. see jlconlin (ref 09/10/2012  10:00:53)      mat 125
 3       0         0.      0         0.      0         0.      0         0.
 4       0         0.      0         0.      0         0.      0         0.
 5       0         0.      0         0.      0         0.      0         0.
 6       0         0.      0         0.      0         0.      0         0.
 7    17969     1001      590        3        0        1        1        0
 8        0        1        1        0        0        0        0        0
 9        1        0     2951     2954     2957     2960     2963     4352
10     4353     5644     5644     5644     6234     6235     6236     6244
11     6245     6245     6246    16721        0    16722        0        0
12        0        0        0        0        0    16723    16724    16725
```

Figure 1: Header example. The (Legacy) Opening (lines 1–2) is in red, the IZAW array (lines 3–6) is in blue, the NXS array (lines 7–8) is in teal, and the JXS array (lines 9–12) is in violet.

Legacy Header Opening There are two slightly different formats for the Header Opening. The most common one found is called here the Legacy Opening and is the one demonstrated in the Header example in Figure 1.

The Legacy Opening consists of several variables given over two 80-character lines. The variables and the Fortran format for reading the variable is given in Table 1

2.0.1 Header Opening

Don't forget the 2.0.1 Header Opening

[1] data about the data

Line	Variable	Format	Description
1	HZ	A10	ZAID (see Section 3.1)
1	AW	E12.0	atomic weight ratio
1	TZ	E12.0	temperature
1	—	1X	(blank space)
1	HD	A10	processing date
2	HK	A70	descriptive string
2	HM	A10	10-character material identifier

Table 1: Variables in the Legacy Opening part of the ACE Header.

Line	Variable	Format	Description
1	VERS	A10	version format string
1	HZ	A24	SZAID (see Section 3.2)
1	SRC	???	evaluation source
2	AW	E12.0	atomic weight ratio
2	TZ	E12.0	temperature
2	—	1X	(blank space)
2	HD	A10	processing date
2	N	I10	number of comment lines to follow
3–(N+2)	—	A70	comment lines

Table 2: Variables in the 2.0.1 Opening part of the ACE Header.

There is a limitation to the number of unique ZA IDs for a given ZA; 100 different IDs, in fact, for each class of ACE Table. To overcome this limitation, a new Header Opening was developed in 2013and updated a few years later to correct some errors. check this

```
2.0.0      1001.710nc              ENDFB-VII.1
0.999167 2.5301E-08 12/17/12     3
The next two lines are the first two lines of 'old-style' ACE.
  1001.80c    0.999167  2.5301E-08   12/17/12
H1 ENDF71x (jlconlin)  Ref. see jlconlin (ref 09/10/2012  10:00:53)      mat 125
```

Figure 2: Header Opening example. The Legacy Opening is shown in blue while the 2.0.1 Opening consists of the red and the blue portions.

Note that a Legacy Header Opening can be contained in the comment section of the 2.0.1 Header Opening. This was designed explicitly to allow backwards compatibility while application codes were modified to be able to handle. An example of this is shown in Figure 1. Codes that cannot read the 2.0.1 Header can be told (typically via an verify correctness xsdirentry) to start reading the ACE Table several lines after the beginning of the 2.0.1 Header.

provide reference

Following the Opening of the Header are three arrays, IZAW, NXS, and JXS respectively. They are each described below. Immediately following the JXS array is the XSSarray.

2.1.1 IZAW Array

The IZAW array follows on the lines immediately following the Header. It consists of 16 pairs of ZA's (`IZ`) and atomic weight ratios (`AW`). The `IZ` entries are still needed for $S(\alpha, \beta)$ Tables to indicate for which isotope(s) the scattering data are appropriate.

The 16 pairs of numbers are spread over 4 lines. The Fortran format for reading/writing the numbers on one line is: `4(I7,F11.0)`.

2.1.2 NXS Array

The NXS array comes on the 2 lines after the IZAW array. The NXS array has 16 integer elements; 8 on each line. The Fortran format for reading/writing the numbers on each line is: `8I9`. The first element of the NXS array indicates how many numbers are in the XSS array. The remainder of the NXS array elements (usually) indicate how many of different pieces of data there is.

2.1.3 JXS Array

The JXS array comes on the 4 lines after the NXS array. The JXS array has 32 integer elements; 8 on each line. The Fortran format for reading/writing the numbers on each line is: `8I9`. The JXS array contains indices to the XSS array where difference pieces of data begins.

The specific definition of the elements of the NXS and JXS arrays are dependent on the class of data in the Table and are defined in the section of this document that describes each class of data.[2] Note that not all elements of the arrays are (currently) being used, allowing for future expansion.

2.2 The XSS Array

After the ACE Header comes the XSS array. It is typically *very* large with hundreds of thousands of elements. It is broken up into blocks with the blocks being dependent on the class of data that is contained in the table. The description and definition of each of these blocks can be found in the descriptions later in this document.

The data is written with 4 floating-point numbers on each 80-character line. All data in the XSS array can be read using the Fortran format: `4E20.0` for each line.

[2]See, for example, Table 3 and Table 4.

```
2.0.0      1001.710nc              ENDFB-VII.1
0.999167 2.5301E-08 12/17/12     3
The next two lines are the first two lines of 'old-style' ACE.
  1001.80c    0.999167  2.5301E-08   12/17/12
H1 ENDF71x (jlconlin)  Ref. see jlconlin (ref 09/10/2012  10:00:53)      mat 125
1.00000000000E-11   1.03125000000E-11   1.06250000000E-11   1.09375000000E-11
1.12500000000E-11   1.15625000000E-11   1.18750000000E-11   1.21875000000E-11
1.25000000000E-11   1.28125000000E-11   1.31250000000E-11   1.34375000000E-11
1.37500000000E-11   1.43750000000E-11   1.50000000000E-11   1.56250000000E-11
1.62500000000E-11   1.68750000000E-11   1.75000000000E-11   1.81250000000E-11
1.87500000000E-11   1.93750000000E-11   2.00000000000E-11   2.09375000000E-11
2.18750000000E-11   2.28125000000E-11   2.37500000000E-11   2.46875000000E-11
2.56250000000E-11   2.65625000000E-11   2.75000000000E-11   2.84375000000E-11
2.93750000000E-11   3.03125000000E-11   3.12500000000E-11   3.21875000000E-11
3.31250000000E-11   3.40625000000E-11   3.50000000000E-11   3.59375000000E-11
```

Figure 3: ACE Header with beginning of XSS array for ^{1}H from the ENDF71x library. Note this uses the 2.0.1 Header with backwards compatibility with the Legacy Header.

3 Unique ACE Table Identifier

This needs to be done.

Each ACE Table needs to have an identifier to uniquely distinguish the data that is contained in the Table.

3.1 ZAID

3.2 SZAID

With the introduction of the 2.0.1 ACE Header, the identifier was modified to better specify the metastable state of the material as well as expand the available space for identifiers.

The new identifier is referred to as a SZAID[3].

[3] pronounced "ess-ZAID"

4 Continuous-Energy and Discrete Neutron Transport Tables

The format of individual blocks found on neutron transport tables is identical for continuous-energy and discrete-reaction ACE Tables; the format for both are described in this section. The blocks of data are:

1. **ESZ Block**—contains the main energy gid for the Table and the total, absorption, and elastic cross sections as wella s the average heating numbers. The ESZ Block block always exists. See Section 4.3.1.
2. **NU Block**—contains prompt, delayed and/or total $\overline{\nu}$ as a function of incident neutron energy. The NU Block exists only for fissionable isotopes; that is, if `JXS(2)`$\neq 0$. See Section 4.3.2.
3. **MTR Block**—contains a list of ENDF MT numbers for all neutron reactions other than elastic scattering. The MTR Block exists for all isotopes that have reactions other than elastic scattering; that is, all isotopes with `NXS(4)`$\neq 0$. See Section 4.3.3.
4. **LQR Block**—contains a list of kinematic Q-values for all neutron reactions other than elastic scattering. The LTR Block exists if `NXS(4)`$\neq 0$. See Section 4.3.4.
5. **TYR Block**—contains information about the type of reaction for all neutron reactions other than elastic scattering. Information for each reaction includes the number of secondary neutrons and whether secondary neutron angular distributions are in the laboratory or center-of-masssystem. The TYR Block exists if `NXS(4)`$\neq 0$. See Section 4.3.5.
6. **LSIG Block**—contains a list of cross section locators for all neutron reacitons other than elastic scattering. The LSIG Block exists if `NXS(4)`$\neq 0$. See Section 4.3.6
7. **SIG Block**—contains cross sections for all reactions other than elastic scattering. The SIG Block exists if `NXS(4)`$\neq 0$. See Section 4.3.7.
8. **LAND Block**—contains a list of angular-distribution locators for all reactions producing secondary neutrons. The LAND Block always exists. See Section 4.3.8.
9. **AND Block**—contains list angular distributions for all reactions producing secondary neutrons. The AND Block always exists. See Section 4.3.9.
10. **LDLW Block**—contains a list of energy distributions for all reactions producing secondary neutrons except for elastic scattering. The LDLW Block exists if `NXS(5)`$\neq 0$. See Section 4.3.10.
11. **DLW Block**—contains energy distributions for all reactions producing secondary neutrons except for elastic scattering. The DLW Block exists if `NXS(5)`$\neq 0$. See Section 4.3.11.
12. **GPD Block**—contains the total photon production cross section tabulated on the ESZ energy grid and a 30× matrix of secondary photon energies. The GPD Block exists only for those older evaluations that provide coupled neutron/photon information; that is, if `JXS(12)`$\neq 0$. See Section 4.3.12.
13. **MTRP Block**—contains a list of MT numbers for all photon production reactions. The term "photon production reaction" is used for any information describing a specific neutron-in, photon-out reaction. The MTR Block exists if `NXS(6)`$\neq 6$. See

Section 4.3.3.

14. **LSIGP Block**—contains a list of cross section locators for all photon production reactions. The LSIGP Block exists if `NXS(6)`$\neq 0$. See Section 4.3.6.
15. **SIGP Block**—contains cross sections for all photon production reactions. The SIGP Block exists if `NXS(6)`$\neq 0$. See Section 4.3.13.
16. **LANDP Block**—contains a list of angular-distribution locators for all photon production reactions. The LANDP Block exist if `NXS(6)`$\neq 0$. See Section 4.3.14
17. **ANDP Block**—contains photon angular distributions for all photon production reactions. The ANDP Block exists if `NXS(6)`$\neq 0$. See Section 4.3.15.
18. **LDLWP Block**—contains a list of energy-distribution locators for all photon production reactions. The LDLWP Block exists if `NXS(6)`$\neq 0$. See Section 4.3.10.
19. **DLWP Block**—contains photon energy distributions for all photon production reactions. The DLWP Block exists if `NXS(6)`$\neq 0$. See Section 4.3.11.
20. **YP Block**—contains a list of MT identifiers of neutron reaction cross sections required as photon production yield multipliers. The YP Block exists if `NXS(6)`$\neq 0$. See Section 4.3.16.
21. **FIS Block**—contains the total fission cross section tabulated on the ESZ energy grid. The FIS Block exists if `JXS(21)`$\neq 0$. See Section 4.3.17.
22. **UNR Block**—contains the unresolved resonance range probability tables. The UNR Block exists if `JXS(23)`$\neq 0$. See Section 4.3.18.

4.1 NXS Array

Table 3: NXS array element definitions for NXS ACE Table.

Element	Name	Description
1	—	Length of second block of data (XSS array)
2	ZA	$1000 * Z + A$
3	NES	Number of energies
4	NTR	Number of reactions excluding elastic scattering
5	NR	Number of reactions having secondary neutrons excluding elastic scattering
6	NTRP	Number of photon production reactions
	...	
8	NPCR	Number of delayed neutron precurser families
	...	
15	NT	Number of PIKMT reaction
16	—	0=normal photon production
		-1=do not produce photons

Does NXS[15] apply to every type of data, or just fast tables?

4.2 JXS Array

Table 4: JXS array element definitions for JXS ACE Table.

Element	Name	Location Description
1	ESZ	Energy table
2	NU	Fission ν data
3	MTR	`MT` array
4	LQR	Q-value array
5	TYR	Reaction type array
6	LSIG	Table of cross section locators
7	SIG	Cross sections
8	LAND	Table of angular distribution locators
9	AND	Angular distributions
10	LDLW	Table of energy distribution locators
11	DLW	Energy distributions
12	GPD	Photon production data
13	MTRP	Photon production `MT` array
14	LSIGP	Table of photon production cross section locators
15	SIGP	Photon production cross sections
16	LANDP	Table of photon production angular distribution locators
17	ANDP	Photon production angular distributions
18	LDLWP	Table of photon production energy distribution locators
19	DLWP	Photon production energy distributions
20	YP	Table of yield multipliers
21	FIS	Total fission cross section
22	END	Last word of this table
23	LUNR	Probability tables
24	DNU	Delayed $\overline{\nu}$ data
25	BDD	Basic delayed data (λ's, probabilities)
26	DNEDL	Table of energy distribution locators
27	DNED	Energy distributions
	...	
32	—	

4.3 Format of Individual Data Blocks

4.3.1 ESZ Block

The format of the ESZ Block is given in Table 5.

Table 5: ESZ Block.

Location in XSS	Parameter	Description
S_{ESZ}	$E(l), l = 1, \ldots, N_E$	Energies
$S_{\mathsf{ESZ}} + N_E$	$\sigma_t(l), l = 1, \ldots, N_E$	Total cross section
$S_{\mathsf{ESZ}} + 2N_E$	$\sigma_s(l), l = 1, \ldots, N_E$	Total absorption cross section
$S_{\mathsf{ESZ}} + 3N_E$	$\sigma_{el}(l), l = 1, \ldots, N_E$	Elastic cross section
$S_{\mathsf{ESZ}} + 4N_E$	$H_{el}(l), l = 1, \ldots, N_E$	Average Heating numbers

Note: S_{ESZ} is index of the XSS array where the ESZ Block starts, `JXS(1)`, and N_E is the number of energy energy points, `NXS(3)`.

4.3.2 NU Block

There are four possibilities for the NU Block:

1. No NU Block. This happens when `JXS(2)`=0.
2. Either prompt or total $\overline{\nu}$ is given (but not both). The NU array begins at location `XSS(KNU)` where KNU=`JXS(2)`.
3. Both prompt and total $\overline{\nu}$ are given. The prompt NU array begins at `XSS(KNU)` where KNU=`JXS(2)`; the total NU array begins at `XSS(KNU)` where KNU = `JXS(2)` + ABS(`XSS(JXS(2))`)+1
4. Delayed $\overline{\nu}$ is given. The delayed $\overline{\nu}$ array begins at `XSS(KNU)` where KNU=`JXS(24)`. Delayed $\overline{\nu}$ must be given in form b described below.

The format of the NU Block has two forms (if it exists); polynomial (see Table 6) and tabulated (see Table 7). The format is specified by the LNU flag located in the XSS array at index KNU where KNU is defined above.

Table 6: NU Block—Polynomial function form.

Location in XSS	Parameter	Description
KNU	LNU=1	Polynomial function flag
KNU+1	N_C	Number of coefficients
KNU+2	$C(l), l = 1, \ldots, N_C$	Coefficients

When using the polynomial function form of the NU array, $\overline{\nu}$ is reconstructed as

$$\overline{\nu}(E) = \sum_{l=1}^{N_C} C(l) E^{l-1}, \tag{1}$$

where the energy, E, is given in MeV.

Table 7: NU Block—Tabulated form.

Location in XSS	Parameter	Description
KNU	LNU=2	Tabulated data flag
KNU+1	N_R	Number of interpolation regions
KNU+2	NBT$(l), l = 1, \ldots, N_R$	ENDF interpolation parameters
KNU+2+N_R	INT$(l), l = 1, \ldots, N_R$	ENDF interpolation scheme†
KNU+2+2N_R	N_E	Number of energies
KNU+3+2N_R	$E(l), l = 1, \ldots, N_E$	Tabulated energy points
KNU+3+2$N_R + N_E$	$\overline{\nu}(l), l = 1, \ldots, N_E$	Tabulated $\overline{\nu}$ values

† If $N_R = 0$, NBT and INT are omitted and linear-linear interpolation is assumed.

If delayed neutron data exist (when `JXS(24)`>0), the precursor distribution format is given as in Table 8. The decay constant for the first group DEC_1 is given at `XSS(JXS(25))`. The precursor distribution immediately follows as described in Table 8. The indices (locators) of the XSS array where each precursor distribution begins (S_{DNU}) can found using the format described in Section 4.3.10 and Section 4.3.11, where LED=`JXS(26)` and NMT=`NXS(8)`.

Table 8: Delayed $\overline{\nu}$ precursor distribution..

Location in XSS	Parameter	Description
S_{DNU}	DEC_i	Decay constant for the i-th group
S_{DNU}+1	N_R	Number of interpolation regions
S_{KNU}+2	NBT$(l), l = 1, \ldots, N_R$	ENDF interpolation parameters†
S_{KNU}+2+N_R	INT$(l), l = 1, \ldots, N_R$	ENDF interpolation scheme
S_{DNU}+2+2N_R	N_E	Number of energies
S_{DNU}+3+2N_R	$E(l), l = 1, \ldots, N_E$	Tabulated energy points
S_{DNU}+3+2$N_R + N_E$	$P(l), l = 1, \ldots, N_E$	Corresponding probabilities

† If $N_R = 0$, NBT and INT are omitted and linear-linear interpolation is assumed.

Note: S_{DNU} is the index of the XSS array where the delayed $\overline{\nu}$ precursor distribution begins; the first one is at S_{DNU}=`JXS(25)`.

4.3.3 MTR & MTRP Blocks

The format of the MTR Block (for incident neutron reactions) and MTRP Block (for photon production reactions) is given in Table 10. The starting index depends on whether it is the MTR Block or MTRP Block and are given in Table 9.

Block	LMT	NMT
MTR	JXS(3)	NXS(4)
MTRP	JXS(13)	NXS(6)

Table 9: LMT and NMT values for the MTR Block and MTR Block.

Table 10: MTR & MTRP Block.

Location in XSS	Parameter	Description
LMT	MT_1	First ENDF Reaction available
LMT+1	MT_2	Second sENDF Reaction available
...		
LMT+NMT+1	$\mathsf{MT}_{\mathsf{NMT}}$	Last ENDF reaction available

For the MTR Block, $\mathsf{MT}_1, \ldots, \mathsf{MT}_{\mathsf{NMT}}$ are standard ENDF MTnumbers; that is, MT$=16=(n, 2n)$; MT$=17=(n, 3n)$; etc. For a complete listing of MT numbers, see [1, Appendix B].

For the MTRP Block, the MT numbers are somewhat arbitrary. To understand the scheme used for numbering the photon production MTs, it is necessary to realize that in the ENDF format, more than one photon can be produced by a particular neutron reaction that is itself specified by a single MT. Each of these photons is produced with an individual energy-dependent cross section. For example, MT102 (radiatiive capture) might be responsible for 40 photons, each with its own cross section, angular distribution, and energy distribution. We need 40 photon MTs to represent the data; the MTs are numbered 1002001, 1002002, ..., 1002040. Therefore, if ENDF MT N is responsible for M photons, we shall number the photon MTs 1000*N+1, 1000*N+2, ..., 1000*N+M.

4.3.4 LQR Block

The format of the LQR Block, containing the reaction-specific Q-values, is given in Table 11. The index at the start of the LQR Block, S_{LQR}=JXS(4). The number of reactions, NMT, is the same through the ACE Table, NMT=NXS(4).

Table 11: LQR Block.

Location in XSS	Parameter	Description
S_{LQR}	Q_1	Q-value for reaction MT_1
$S_{\mathsf{LQR}}+1$	Q_2	Q-value for reaction MT_2
...		
S_{LQR}+NMT-1	Q_{NMT}	Q-value for reaction $\mathsf{MT}_{\mathsf{NMT}}$

4.3.5 TYR Block

The format of the TYR Block is given in Table 12. The index at the start of the TYR Block, S_{TYR}=JXS(5). The number of reactions, NMT, is the same through the ACE Table, NMT=NXS(4).

Table 12: TYR Block.

Location in XSS	Parameter	Description
S_{TYR}	TY_1	Neutron release for reaction MT_1
S_{TYR}+1	TY_2	Neutron release for reaction MT_2
...		
S_{TYR}+NMT-1	$\mathsf{TY}_{\mathsf{NMT}}$	Neutron release for reaction $\mathsf{MT}_{\mathsf{NMT}}$

The possible values of TY are ±1, ±2, ±3, ±4, ±19, 0, and integers greater than 100 in absolute value; the sign indicates the system for scattering: negative=center-of-mass, positive=Lab. Thus if TY_i=+3, three neutrons are released for reaction MT_i and the data on the cross section tables used to determine the exiting neutrons' angles are given in the Lab frame of reference. TY=19 indicates fission. The number of secondary neutrons released is determined from the fission $\overline{\nu}$ data found in the NU Block. TY_i=0 indicates absorption (ENDF reactions MT>100); no neutrons are released. $\|\mathsf{TY}_i\| > 100$ signifies reactions other than fission that have energy-dependent neutron multiplicities. The number of secondary neutrons released is determined from the yield data found in the DLW Block. The MT_is are given in the MTR Block.

4.3.6 LSIG & LSIGP Block

The LSIG Block and LSIGP Block give the locators for cross section array for each reaction MT. A locator is a *relative* index in the XSS array where some piece of data. In this case, the data is the cross section values. The format of the LSIG Block (for incident neutron cross sections) and LSIGP Block (for photon production cross sections) is given in Table 13. The format for the incident neutron cross section arrays is given in Section 4.3.7. The format for the photon production cross sections is given in Section 4.3.13.

All locators are relative to `JXS(7)` for the LSIG Block or `JXS(15)` for the LSIGP Block. That is, LXS=`JXS(7)` for the LSIG Block and LXS=`JXS(15)` for the LSIGP Block. So the actual cross section data begins at the index $\mathsf{LOCA}_{\text{-NoValue-}}$+LXS. The MTs are given in the MTR Block and the MTRP Block for the LSIG Block and the LSIGP Block respectively. $\mathsf{LOCA}_{\mathrm{i}}$ must be monotonically increasing.

Table 13: LSIG & LSIGP Block.

Location in XSS	Parameter	Description
LXS	LOCA_1=1	Location of cross sections for reaction MT_1
LXS+1	LOCA_2	Location of cross sections for reaction MT_2
...		
LXS+NMT-1	$\mathsf{LOCA}_{\mathsf{NMT}}$	Location of cross sections for reaction $\mathsf{MT}_{\mathsf{NMT}}$

4.3.7 SIG Block

The SIG Block contains the incident neutron cross section data. (The photon production cross section is in the SIGP Block.) The format of the SIG Block is given in Table 14. The cross section data begins at the index specified by the locator from the LSIG Block; the format for which is given in Table 15.

Table 14: SIG Block.

Location in XSS	Description
LXS+LOCA_1-1	Cross section array for reaction MT_1
LXS+LOCA_2-1	Cross section array for reaction MT_2
...	
LXS+LOCA_{NMT}-1	Cross section array for reaction MT_{NMT}

Note: The number of cross section arrays NMT=`NXS(4)`.

The LOCA_i values are given in the LSIG Block and are all relative to `JXS(7)`. The energy grid, $E(K)$ is given in the ESZ Block. The energy grid index IE_i corresponds to the first energy in the grid at which a cross section is given. The MT_is are defined in the MTR Block.

Table 15: Cross section array for the i-th reaction..

Location in XSS	Parameter	Description
LXS + LOCA_i-1	IE_i	Energy grid index for reaction MT_i
LXS + LOCA_i	NE_i	Number of consecutive entries for MT_i
LXS + LOCA_i+1	$\sigma_i[E(K)]$ for $K = IE_i, \ldots, IE_i + NE_i - 1$	Cross section for reaction MT_i

4.3.8 LAND Block

The LAND Block contains locators for the angular distributions for all reactions producing secondary neutrons. The LAND Block always exists and begins at S_{LAND}=`JXS(8)`. All locators ($\text{LOCB}_{\text{-NoValue-}}$) are relative `JXS(9)`; that is, the angular distribution begins at `JXS(9)`+$\text{LOCB}_{\text{-NoValue-}i}$. The LOCB_i locators must be monotonically increasing. The format of the LAND Block is given in Table 16.

Table 16: LAND Block.

Location in XSS	Parameter	Description
S_{LAND}	LOCB_1=1	Location of angular distribution data for elastic scattering reaction
$S_{\mathsf{LAND}}+1$	LOCB_2	Location of angular distribution data for reaction MT_1
...		
$S_{\mathsf{LAND}}+\mathsf{NMT}$	$\mathsf{LOCB}_{\mathsf{NMT}}$	Location of angular distribution data for reaction $\mathsf{MT}_{\mathsf{NMT}}$

Note: S_{LAND}=`JXS(8)` and NMT=`NXS(5)` is the number of reactions (excluding elastic scattering).

4.3.9 AND Block

The AND Block contains angular distribution data for all reactions that produce secondary neutrons. The format of the AND Block is given in Table 17. The angular distribution data begins at the index specified by the locator $\mathsf{LOCB}_{\text{-NoValue-}}$ from the LAND Block. If LOCB_i=0 (given in the LAND Block), no angular distribution data are given for reaction i and isotropic scattering is assumed in either the Lab or center-of-mass system. The choice of Lab or center-of-mass system depends upon the value for reaction i in the TYR Block. If LOCB_i=-1 no angular distribution data are given for reaction i in the AND Block. The angular distribution data are specified through law=44 in the DLW Block.

Table 17: AND Block.

Location in XSS	Description
`JXS(9)`+LOCB_1-1	Angular distribution array for elastic scattering
`JXS(9)`+LOCB_2-1	Angular distribution array for reaction MT_1
`JXS(9)`+$\mathsf{LOCB}_{\mathsf{NMT}}$-1	Angular distribution array for reaction $\mathsf{MT}_{\mathsf{NMT}}$

Note: The format for the angular distribution of the i-th array is given in Table 18.

Table 18: Angular distribution array for the i-th reaction..

Location in XSS	Parameter	Description
`JXS(9)`+LOCB_i-1	N_E	Number of energies at which angular distributions are tabulated.

Continued on next page

Table 18: Angular distribution array for the i-th reaction. (continued)

Location in XSS	Parameter	Description
JXS(9)+LOCB$_\mathrm{i}$	$E(l), l = 1, \ldots, N_E$	Energy grid
JXS(9)+LOCB$_\mathrm{i}$+N_E	$L_C(l), l = 1, \ldots, N_E$	Location of tables associated with $E(l)$

The angular distribution arrays (Table 18) contains additional locators, L_C; the sign of these locators is a flag:

- if $L_C(l) > 0$, then $L_C(l)$ points to a 32 equiprobable bin distribution (see Table 19);
- if $L_C(l) < 0$, then $L_C(l)$ points to a tabulated angular distribution (see Table 20);
- if $L_C(l) = 0$, then distribution is isotropic and no further data is needed.

Table 19: Format for the 32 equiprobable bin distribution.

Location in XSS	Parameter	Description
JXS(9)+$\lvert L_C(l)\rvert - 1$	$P(1, K)$ $K = 1, \ldots, 33$	32 equiprobable cosine bins for scattering at energy $E(1)$.

Table 20: Format for the tabulated angular distribution..

Location in XSS	Parameter	Description
LDAT$_l + 1$	JJ	Interpolation flag†
LDAT$_l + 2$	N_P	Number of points in the distribution
LDAT$_l + 3$	$CS_{\mathrm{out}}(j), j = 1, \ldots, N_P$	Cosine scattering angular grid
LDAT$_l + 4$	$\mathrm{PDF}(j), j = 1, \ldots, N_P$	Probability density function
LDAT$_l + 5$	$\mathrm{CDF}(j), j = 1, \ldots, N_P$	Cumulative density function

† 0 histogram interpolation
1 linear-linear interpolation

Note: LDAT$_l$ = JXS(9) + $\lvert L_C(l)\rvert - 1$

4.3.10 LDLW & LDLWP Block

The LDLW Block and LDLW Block give the locators for the energy distribution for every reaction that produces secondary neutrons or secondary photons (respectively). The format of the LDLW Block (for secondary neutrons) and LDLW Block (for secondary photons) is given in Table 22. The locators for the delayed neutron precursors (see Section 4.3.2) also use the same format. The format for the distribution arrays is given in Section 4.3.11.

The LDLW Block exists if NXS(5)$\neq$ 0 while the LDLWP Block exists if NXS(6)$\neq$ 0. The starting index, LED, depends on what data is being read; the starting values and the number of locators, NMT, are given in Table 21.

Block	LED	NMT
LDLW	JXS(10)	NXS(5)
LDLWP	JXS(18)	NXS(5)
delayed neutrons	JXS(26)	NXS(8)

Table 21: LED and NMT values for the LDLW Block and LDLWP Block.

Table 22: LDLW Block.

Location in XSS	Parameter	Description
LED	LOCC_1	Location of energy distribution data for reaction MT_1 or group 1 (if delayed neutron)
LED+1	LOCC_2	Location of energy distribution data for reaction MT_2 or group 2 (if delayed neutron)
...		
LED+NMT-1	$\mathsf{LOCC}_{\mathsf{NMT}}$	Location of energy distribution data for reaction $\mathsf{MT}_{\mathsf{NMT}}$ or group NMT (if delayed neutron)

Note: The LOCC_i must be monotonically increasing.

All locators point to data *relative* to JED (see Section 4.3.11) in the XSS array. The MT values are given in the MTR Block for LDLW Block or MTRP Block for LDLWP Block.

4.3.11 DLW Block

The format of the DLW Block is given in Table 23.

Table 23: DLW Block.

Location in XSS	Parameter	Description

4.3.12 GPD Block

The GPD Block contains the *total* photon production cross section, tabulated on the energy grid given in the ESZ Block, the size of which is given by NXS(3). The GPD Block only exists if `JXS(12)`$\neq 0$.

There are 30 groups for the incident neutron energies, the boundaries of which are shown in Table 24. For each incident neutron energy group, the outgoing photon energies are discretized into 20 equiprobable energy groups, thus creating a 30×20 matrix. The outgoing energies are given in the GPD Block as shown in Table 25. Note that this matrix is only used for older tables that do not provide expanded photon production data.

Table 24: Discrete neutron energy boundaries.

Group #	Upper Boundary (MeV)	Group #	Upper Boundary (MeV)
1	1.39×10^{-10}	16	0.184
2	1.52×10^{-7}	17	0.303
3	4.14×10^{-7}	18	0.500
4	1.13×10^{-6}	19	0.823
5	3.06×10^{-6}	20	1.353
6	8.32×10^{-6}	21	1.738
7	2.26×10^{-5}	22	2.232
8	6.14×10^{-5}	23	2.865
9	1.67×10^{-4}	24	3.68
10	4.54×10^{-4}	25	6.07
11	1.235×10^{-3}	26	7.79
12	3.35×10^{-3}	27	10.0
13	9.23×10^{-3}	28	12.0
14	2.48×10^{-2}	29	13.5
15	6.76×10^{-2}	30	15.0

The format of the this Block is given in Table 25. The XSS array index at the start of the GPD Block, S_{GPD}=`JXS(12)`.

Table 25: GPD Block.

Location in XSS	Parameter	Description
S_{GPD}	$\sigma_\gamma(l), l = 1, \ldots, \mathsf{NES}$	Total photon production cross section
S_{GPD}+NES	$E_1(K), K = 1, 20$	20 equiprobable outgoing photon energies for incident neutron $E < E_N(2)$
S_{GPD}+NES+20	$E_2(K), K = 1, 20$	20 equiprobable outgoing photon energies for incident neutron $E_N(2) \leq E < E_N(3)$
...		
S_{GPD}+NES+(i-1)*20	$E_i(K), K = 1, 20$	20 equiprobable outgoing photon energies for incident neutron $E_N(i) \leq E < E_N(i+1)$
...		

Continued on next page

Table 25: GPD Block (continued)

Location in XSS	Parameter	Description
S_{GPD}+NES+(30-1)*20	$E_2(K), K = 1, 20$	20 equiprobable outgoing photon energies for incident neutron $E \geq E_N(30)$

4.3.13 SIGP Block

The SIGP Block contains the photon production cross section data. The format of the SIGP Block is given in Table 26. The cross section data begins at the index specified by the locator, $\mathsf{LOCA_i}$, given in the LSIG Block (see Section 4.3.6). All indices to the XSS array are *relative* to `JXS(15)`.

Table 26: SIGP Block.

Location in XSS	Parameter	Description
`JXS(15)`+$\mathsf{LOCA_1}$-1	$\mathsf{MFTYPE_1}$	Cross section array for reaction $\mathsf{MT_1}$
`JXS(15)`+$\mathsf{LOCA_2}$-1	$\mathsf{MFTYPE_2}$	Cross section array for reaction $\mathsf{MT_2}$
...		
`JXS(15)`+$\mathsf{LOCA_{NMT}}$-1	$\mathsf{MFTYPE_{NMT}}$	Cross section array for reaction $\mathsf{MT_{NMT}}$

Note: The number of photon production cross section arrays NMT=`NXS(6)`.

The format of the i-th cross section array has two possible forms depending on the first number in the array, MFTYPE.

1. If MFTYPE=12 or MFTYPE=16, yield data taken from ENDF File 12 or 6, respectively (see Table 27). With this format, the photon production cross section can be constructed using Equation 2;

$$\sigma_{\gamma,i}(E) = Y(E) * \sigma_{\mathsf{MTMULT}}(E). \tag{2}$$

2. If MFTYPE=13, cross section data from ENDF File 13 (see Table 28).

Table 27: Photon production array if MFTYPE=12 or 16.

Location in XSS	Parameter	Description
`JXS(15)`+$\mathsf{LOCA_i}$-1	MFTYPE	12 or 16
`JXS(15)`+$\mathsf{LOCA_i}$	MTMULT	Neutron MT whose cross section should multiply the yield
`JXS(15)`+$\mathsf{LOCA_i}$+1	N_R	Number of interpolation regions
`JXS(15)`+$\mathsf{LOCA_i}$+2	$\mathsf{NBT}(l), l = 1, \ldots, N_R$	ENDF interpolation parameters

Continued on next page

Table 27: Photon production array if MFTYPE=12 or 16 (continued)

Location in XSS	Parameter	Description
JXS(15)+LOCA$_i$+2 $+N_R$	INT$(l), l = 1, \ldots, N_R$	ENDF interpolation scheme
JXS(15)+LOCA$_i$+2 $+2*N_R$	N_E	Number of energies at which the yield is tabulated
JXS(15)+LOCA$_i$+3 $+2*N_R$	$E(l), l = 1, \ldots, N_E$	Energies
JXS(15)+LOCA$_i$+3 $+2*N_R+N_E$	$Y(l), l = 1, \ldots, N_E$	Yields

† If $N_R = 0$, NBT and INT are omitted and linear-linear interpolation is used.

Table 28: Photon production cross section array if MFTYPE=13.

Location in XSS	Parameter	Description
JXS(15)+LOCA$_i$-1	MFTYPE	13
JXS(15)+LOCA$_i$	IE	Energy grid index
JXS(15)+LOCA$_i$+1	N_E	Number of consecutive entries
JXS(15)+LOCA$_i$+2	$\sigma_{\gamma,i}[E(K)]$, $K = \mathrm{IE}, \ldots, \mathrm{IE} + N_E - 1$	Photon production cross sections for reaction MT$_i$

4.3.14 LANDP Block

The format of the LANDP Block is given in Table 29.

Table 29: LANDP Block.

Location in XSS	Parameter	Description

4.3.15 ANDP Block

The format of the ANDP Block is given in Table 30.

Continued on next page

Table 30: ANDP Block (continued)

Location in XSS	Parameter	Description

Table 30: ANDP Block.

Location in XSS	Parameter	Description

4.3.16 YP Block

The format of the YP Block is given in Table 31.

Table 31: YP Block.

Location in XSS	Parameter	Description

4.3.17 FIS Block

The format of the FIS Block is given in Table 32.

Table 32: FIS Block.

Location in XSS	Parameter	Description

4.3.18 UNR Block

The format of the UNR Block is given in Table 33.

Table 33: UNR Block.

Location in XSS	Parameter	Description

Element	Name	Description
1	—	Length of second block of data (XSS array)
2	ZA	$1000 * Z + A$
3	—	
4	NTR	Number of reactions
	...	
16	—	

Table 34: NXS array element definitions for neutron dosimetry ACE Table.

Element	Name	Location Description
1	LONE	First word of table
2	—	
3	MTR	`MT` array
	...	
6	LSIG	Table of cross section locators
7	SIGD	Cross sections
	...	
22	END	Last word of this table
	...	
32	—	

Table 35: JXS array element definitions for neutron dosimtry ACE Table.

5 Neutron Dosimetry

5.1 NXS Array

5.2 JXS Array

Element	Name	Description
1	—	Length of second block of data (XSS array)
2	IDPNI	Inelastic scattering mode
3	NIL	Inelastic dimensioning parameter
4	NIEB	Number of inelastic exiting energies
5	IDPNC	Elastic scattering mode
6	NCL	Elastic dimensioning parameter
7	IFENG	Secondary energy mode
	...	
16	—	

Table 36: NXS array element definitions for thermal scattering ACE Table.

Element	Name	Location Description
1	ITIE	Inelastic energy table
2	ITIX	Inelastic cross sections
3	ITXE	Inelastic energy/angle distributions
4	ITCX	Elastic cross sections
5	ITCA	Elastic angular distributions
	...	
32	—	

Table 37: JXS array element definitions for thermal scattering ACE Table.

6 Thermal Scattering $S(\alpha, \beta)$

6.1 NXS Array

6.2 JXS Array

7 Continuous-Energy Photon

7.1 NXS Array

Table 38: NXS array element definitions for NXS ACE Table.

Element	Name	Description
1	—	Length of second block of data (XSS array)
2	Z	Atomic number
3	NES	Number of energies
4	NFLC	Length of the flourescence data divided by 4
5	NSH	Number of electron shells
	...	
16	—	

7.2 JXS Array

Table 39: JXS array element definitions for JXS ACE Table.

Element	Name	Location Description
1	ESZG	Energy table
2	JINC	Incoherent form factors
3	JCOH	Coherent form factors
4	JFLO	Fluorescence data
5	LHNM	Heating numbers
6	LNEPS	Number of electrons per shell
7	LBEPS	Binding energy per shell
8	LPIPS	Probability of interaction per shell
9	LSWD	Array of offsets to the shell-wise data
10	SWD	Shell-wise data in PDF and CDF form
	...	
32	—	

References

[1] A. Trkov, M. Herman, and D. A. Brown. *ENDF-6 Formats Manual: Data Formats and Procedures for the Evaluated Nuclear Data Files.* Tech. rep. BNL-90365-2009 Rev.2. National Nuclear Data Center, Brookhaven National Laboratory, Dec. 2011.