

CURRENT STATUS OF RUSSIAN EVALUATED NEUTRON DATA LIBRARIES

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ABSTRACT

The status of Russian Evaluated Data Libraries is discussed. The last modifications of the BROND-2 files and their relations to the additional files of the FOND library and the ABEN-90 group constants are considered. The main characteristics of new libraries for the photoneutron data, dosimetry and activation reaction cross sections and transmutation cross sections for intermediate energies are described briefly.

The problems of nuclear industry development in combination with economical questions and environmental aspects of nuclear wastes require a permanent improvement of nuclear data used in all projects of advanced nuclear technologies. In this report we want discuss main directions of modifications of Russian Nuclear Data Libraries recommended for practical applications.

In the elaboration process of the second version of the recommended general purpose files (the BROND-2 library) we tried to take into account all advanced nuclear reactor requirements for neutron data. The selection of evaluated data for the BROND-2 library, their analysis and handling were completed in 1990. The evaluated data for principal reactor materials developed by former soviet specialists have been included into the library. In the case of the materials used as neutron standards, the data recommended by the IAEA were accepted. As to the construction materials we paid much attention to the files of the natural mixture of isotopes. The files for separated

isotopes were constructed as it seems to be necessary. The evaluations included in BROND-2 are briefly described in Refs.^{1,2} All files were checked by the ENDF utility codes and BROND-2.2 version with some technical errors corrected was distributed at the end of 1992. In the following years some improvements of the BROND files recommended for the FENDL library³ were performed. New files for zinc and Pa-231, 233 isotopes were made and some corrections in the evaluated cross sections for the americium isotopes were included. The list of modern BROND-2.2 files is given in Table 1.

It should be noted that the full amount of the general purpose files used in practical applications exceeds the one included in Tab. 1. The additional files selected as a rule from ENDF/B-6 and JENDL-3 libraries are included in the FOND library. The list of such files is given in Table 2. These files were used in the working out ABBN-90 Russian group constant set.⁴

It is necessary to note that for some isotopes marked by asterisks in Tab. 2 foreign files were preferred to the BROND ones during the ABBN-90 constants preparation. It referred to the cases when the corresponding evaluations were performed much later and were based on updated experimental data (for example, oxygen and copper) or when the group constants have been calculated before the final processing of the BROND-2 files. In many cases the files included in the FOND were a little modified to improve the evaluated data important for nuclear reactor designs.

To transform the files into the group constants the GRUCON code was used as a rule. For the last years the

Table 2. Additional files included in the FOND

Elem	Eval/Rev	Origin	Comments
*H	1989/1993	ENDF/B-6	Capture data were modified.
Be	1983/1993	J-1	Thermal capture was corrected.
B	1989	J-1	B-10,11 files were used.
*N	1983-1990	J-1	N-14,15 files were used.
*O	1990	J-1	
*F	1990	J-1	
Mg	1987	JENDL-3	
Al	1988	JENDL-3	
*Si	1989	JENDL-3	
*S	1979/1993	ENDF/B-6	INT law for MT=103 was corrected.
*Cl	1979/1993	ENDF/B-6	INT law for MT=103-107 was corrected.
Ar	1979	JEF-1	
K	1987	JENDL-3	
Ca	1987/1993	JENDL-3	$\Gamma_{\text{comp}}^{\text{res}}$ were added for res.
Sc	1988	JENDL-3	
Ti	1988/1993	JENDL-3	Threshold for 1-st inelastic level was corrected.
V	1982	ENDL-83	
Mn	1988	ENDF/B-6	
Co	1989	ENDF/B-6	
*Ni	1989/1993	ENDF/B-6	Ni-58,60,61,62,64 files were used and missed p-res. were added.
*Cu	1987	JENDL-3	
Ga	1982	ENDL-83	
Ge	1974	ENDF/B-6	Ge-70,73,74,76 files were used, res. param. for Ge-70 were modified.
As	1982	ENDL-83	
Se	1974/1993	ENDF/B-6	Data in resonance and fast regions were revised.
Br	1974/1992	ENDF/B-6	Br-79 and Br-81 files were used and (n,2n) reactions were added.
Br	1974-1984	ENDF/B-6	Kr-78,80,82,83,84,86 files were used.
Rb	1984	JEF-1	Rb-85,87 files were used.
Sr	1984/1992	ENDF/B-6	Sr-84,86,87,88 were used, (n,2n) reactions were added.
*Zr	1977	JENDL-3	
Mo	1989	JENDL-3	Mo-nat,95,97,98,100 files were used.
Ru	1990	ENDF/B-6	Ru-96,98,99,100 files were used, others - from BROND-2.
Pd	1980-1991	ENDF/B-6	Pd-102,104 files were used, others - from BROND-2.
Ag	1977	JENDL-3	Ag-107 was used, Ag-109 - from BROND-2.
Cd	1975/1991	ENDF/B-6	Cd-nat and Cd-113 files were used. Energy spectra (n,2n) reaction were corrected.
In	1974-1979	ENDF/B-6	In-113,115 files were used.

Elem	Eval/Rev	Origin	Comments
Sb	1974-1979	ENDF/B-6	Sb-121,123,125 files were used.
Te	1974-1980	ENDF/B-6	Te-120,122,123,124,125,126,128,130 files were used.
I	1980	ENDF/B-6	
Xe	1978	ENDF/B-6	Xe-124,126,128,129,130,132,134,136 files were used.
Cs	1974-1978	ENDF/B-6	Cs-134,137 files were used.
Ba	1978	ENDF/B-6	Ba-134,135,136,137,138 files were used. Ba-130,132 were considered as Ba-134.
La	1977	JENDL-3	
Pr	1984/1991	ENDF/B-6	
Nd	1974/1980	ENDF/B-6	Nd-142,144,146,148,150 files were used. Nd-143,145 - from BROND-2.
Eu	1986	ENDF/B-6	Eu-151 was used, Eu-153 - from BROND-2.
Tb	1980	ENDF/B-6	
Dy	1974-1980	ENDF/B-6	Dy-160,161,162,163,164 files were used with res. param. modified. Dy-156,158 consider as Dy-160.
Ho	1974/1980	ENDF/B-6	
Lu	1967/1980	ENDF/B-6	Lu-175 and Lu-176 files were used.
Hf	1989	JENDL-3	Hf-nat,174,176,177,178,179 and Hf-180 files were used.
*Ta	1989	JENDL-3	
Pt	1982/1991	ENDL-83	Some errors were found and removed.
*Pb	1989	JENDL-3	Selection is based on integral experiments.
Th	1981	JENDL-3	Th-228,229 files were used.
	1982/1993	ENDF/B-6	Th-230 was used. Thermal cross sections were corrected.
*Pa	1977-1978	ENDF/B-6	Pa-231,233 were files used.
*U	1978-1989	ENDF/B-6	U-232,234,235 files were used.
Np	1978/1990	ENDF/B-5	Np-237 was used and (n,2n) cross sections were modified.
	1989	JENDL-3	Np-239 file was used.
*Pu	1987/1993	JENDL-3	Pu-239 was used; LIPAR-5 library was used below 100 ev.
Pu	1976-1978	ENDF/B-6	Pu-243 and Pu-244 files were used.
Cm	1976-1978	ENDF/B-6	Cm-243,245,246,247,248 files were used.
	1987	JENDL-3	Cm-249,250 files were used.
Bk	1986	ENDF/B-6	Bk-249 file was used.
Cf	1975-1986	ENDF/B-6	Cf-249,250,251,252,253 files were used.
Es	1975	ENDF/B-6	Es-253 file was used.

Table 1. The list of the original files in the BROND-2.

Isotopes	Eval./rev.	Authors
H-2,3	1988	Nikolaev M.N.
He-3,4	1988	Nikolaev M.N.
He-4	1976	Nikolaev M.N. et al.
Li-6	1989	Nikolaev M.N.
Li-7	1984	Bondarenko I.M.
N-14,15	1988/1993	Blokhin A.I. et al.
O-16	1977	Nikolaev M.N. et al.
F-19	1990	Blokhin A.I. et al.
Na-23	1978	Nikolaev M.N. et al.
Si-000	1985/1993	Hermesdorf D., Blokhin A.I. et al.
P-31	1989	Koscheev V.N.
Cl-000	1990	Nikolaev M.N. et al.
Cr-000	1984/1988	Pronyaev V.G. et al.
Cr-50,52, 53,54	1987	Blokhin A.I. et al.
Fe-000	1985/1994	Pronyaev V.G. et al.
Fe-54,56, 57,58	1985	Pronyaev V.G. et al.
Ni-000	1984	Blokhin A.I., Ignatyuk A.V. et al.
Ni-58,60,61, 62,64	1985	Blokhin A.I., Ignatyuk A.V. et al.
Cu-000	1981	Nikolaev M.N. et al.
Zn-000	1989	Nikolaev M.N., Zabrodskaya S.V.
Sr-90	1990	Grudzevich O.T., Zelenetsky A.V.
Zr-000	1988	Grudzevich O.T., Zelenetsky A.V.
Zr-90,91,92, 94,96	1988/1993	Grudzevich O.T. et al./Blokhin A.I.
Zr-93,95	1989	Grudzevich O.T., Zelenetsky A.V.
Nb-93	1988/1993	V.G.Pronyaev et al.
Nb-95	1990	Grudzevich O.T., Zelenetsky A.V.
Tc-99	1984	Ignatyuk A.V., Kravchenko I.V.
Ru-101,102, 104,106	1984	Ignatyuk A.V., Kravchenko I.V.
Rh-103	1985	Ignatyuk A.V., Kravchenko I.V.
Pd-105,107	1985	Ignatyuk A.V., Kravchenko I.V.
Pd-106,108	1987	Belanova T.S., Ignatyuk A.V.
Ag-109	1985	Ignatyuk A.V., Kravchenko I.V.
Sn-000	1990/1993	V.G.Pronyaev et al.
I-129	1985	Ignatyuk A.V., Kravchenko I.V.
Xe-131	1985	Ignatyuk A.V., Kravchenko I.V.

NJOY code has been applied intensively for such tasks too. The errors found during this processing have been corrected.

Now the ABBN-90 group constants are verified for the large number of critical assemblies and other integral experiments with different neutron spectra starting with hard spectra like the GODIVA assembly and finishing with thermalized spectra of critical plutonium and uranium aqueous solutions. No essential discrepancies which require group constant corrections for the main reactor materials were found.

Since 1990 the evaluated photoneutron data library (BOFOD) has been under development. Corresponding data include the single and double neutron emission cross sections, spectra of emitted neutrons and the photo-fission cross sections for transuranium isotopes.⁷

Isotopes	Eval./rev.	Authors
Cs-133,135	1985/1991	Ignatyuk A.V., Kravchenko I.V.
Ce-140,142, 144	1990	Ignatyuk A.V., Ulaeva M.V.
Nd-143,145	1985	Ignatyuk A.V., Kravchenko I.V.
Pm-147	1985	Ignatyuk A.V., Kravchenko I.V.
Sm-000, 144,154	1989	Belanova T.S. et al.
Sm-147,149, 151	1985	Ignatyuk A.V., Kravchenko I.V.
Sm-148,150, 152	1987	Zakharova S.M., Ignatyuk A.V.
Eu-153	1985	Ignatyuk A.V., Kravchenko I.V.
Gd-000,152, 154,155,156, 157,158,160	1989	Blokhin A.I.
Er-162,164, 166,167, 168,170	1976	Zakharova S.M. et al.
Ta-181	1988	Manturov G.N., Korchagina G.A.
W-182,183, 184,186	1983	Abagyan L.P., Manturov G.N.
Re-000	1988	Nikolaev M.N. et al.
Os-000	1990	Nikolaev M.N.
Ir-000	1990	Nikolaev M.N., Zabrodskaya S.V.
Pb-000	1984/1994	Hermesdorf D., Blokhin A.I.
Pb-204,206, 207,208	1990/1993	Blokhin A.I. et al.
Bi-209	1990/1993	Blokhin A.I. et al.
Th-232	1983	Nikolaev M.N. et al.
Pa-231,233	1994	Blokhin A.I. et al.
U-233	1990	Sukhovitsky E., Klepatsky A.
U-235,236	1986	Konshin V.A. et al.
U-238	1980	Nikolaev M.N. et al.
Pu-238	1987	Sukhovitsky E., Klepatsky A.
Pu-239,240, 241,242	1980	Konshin V.A. et al.
Am-241,242, 242m,243	1990/1994	Blokhin A.I., Maslov V.M.
Cm-242,244	1987	Sukhovitsky E., Klepatsky A.

The list of isotopes considered is given in Table 3. During 1993 the photoneutron cross section evaluations were also performed for the following fission products: Sr-90, Zr-93, Zr-96, Nb-94, Tc-99, Sn-121, Sn-126, Pd-107, Ag-108, Cs-135, Cs-137, I-129, Ho-166, Sm-147, Sm-148, Sm-151, Tb-158. The files of these isotopes in the ENDF-6 format are under preparation now.

Table 3. The list of isotopes included in the BOFOD-90

Be-9	Mo-92,94,96,98,100	Np-237
Na-23	W-182,184,186	Pu-239,241
Cr-52	Pb-000	Am-241,243
Mn-55	Bi-209	
Ni-000	Th-232	
Zr-000	U-233,234,235,236,238	

The Russian Dosimetry File (RDF-94) was formed last year. It contains 46 reactions, 36 of them are the new evaluations performed in the Nuclear Data Center (CJD). The list of reactions recommended both for the neutron spectra dosimetry and neutron measurement standards is given in Tab.4. The uncertainties for all reactions have been included and the covariance matrices have been prepared for the most of them. This file is being checked and tested nowadays.

Table 4. The list of reactions included in the RDF-94.

7-Li(n,t)*	52-Cr(n,2n)	93-Nb(n,n')m
10-B(n, α)	55-Mn(n,2n)	93-Nb(n,2n)m
19-F(n,2n)	55-Mn(n, γ)	115-In(n,2n)
23-Na(n, γ)	54-Fe(n,2n)	127-I(n,2n)
24-Mg(n,p)	54-Fe(n,p)	139-La(n, γ)
27-Al(n,p)	56-Fe(n,p)	141-Pr(n,2n)
27-Al(n, α)	59-Co(n,2n)	181-Ta(n, γ)
45-Sc(n,2n)	58-Ni(n,2n)	197-Au(n,2n)
45-Sc(n,2n)m	58-Ni(n,p)	197-Au(n, γ)*
45-Sc(n,2n)g	60-Ni(n,p)	232-Th(n, γ)*
46-Ti(n,p)	63-Cu(n,2n)	232-Th(n,f)*
46-Ti(n,2n)	63-Cu(n, γ)	235-U(n,f)*
47-Ti(n,x)	65-Cu(n,2n)	238-U(n, γ)*
48-Ti(n,x)	89-Y(n,2n)	238-U(n,f)*
48-Ti(n,p)	90-Zr(n,2n)	237-Np(n,f)*
51-V(n, α)		

* The reactions taken from IRDF-90

The new version of the Activation Data Library (ADL-3) has been prepared recently.⁸ It contains the evaluated cross sections for more than 20000 reactions on stable and radioactive nuclei including the nuclei in isomeric states. The cross sections for the threshold reactions were calculated on the basis of the optical-statistical approach taking into account the angular momentum conservation law as well as direct and preequilibrium processes contribution. The fitting of calculated excitation functions to experimental data or some cross section systematics for 14-MeV neutrons were used for the reactions where the corresponding data were available. Nowadays this library is tested intensively on the fusion neutron benchmarks.

The MENDL library of the evaluated transmutation cross sections for neutrons and protons with energies up to 100 MeV is under formation now.⁹ It contains the cross sections of the most important neutron and proton induced reactions for more than 500 stable and long-lived radioactive isotopes which could be important for different nuclear waste transmutation projects. Most of the data have been obtained on the basis of the geometry dependent hybrid model taking into account the preequilibrium processes.

A free access to modern versions of the libraries prepared in different laboratories creates favorable opportunities for international cooperation on testing and

analysis of the data recommended for various practical applications. The evaluated neutron data for principal reactor materials used in different countries have only minor discrepancies. So the task to select the best versions from the evaluations available is more important now than to prepare the new ones. Of course the search for cases where we can not come to an agreement of evaluations remains an important problem. New challenges for data intercomparison arise for the new nuclear technologies: fusion reactors, transmutation of nuclear wastes, various medical applications and so on. A search for new experiments and benchmarks for corresponding data tests is a necessary condition of successful development of these technologies.

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