

## Present Status of JENDL Project

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### 1. JENDL-3 revision 3 (JENDL-3.3: General Purpose File )

The second revised version of JENDL-3 (JENDL-3.2) was released in June 1994. It contains the data for 340 nuclides in the energy range from  $10^{-5}$  eV to 20 MeV. The ENDF-6 format was adopted. The pointwise files were also constructed at 0 K and 300 K by using RESEND, RECENT, LINEAR and SIGMA1.

Though JENDL-3.2 gives much better evaluated data than JENDL-3.1, JENDL-3.2 has no covariance matrices. We recognize importance of the covariance matrices. A new working group has been set up in the Japanese Nuclear Data Committee (JNDC) for studying evaluation methodology of the covariance matrices. To meet the requests from FBR reactor projects, several materials have being compiled by this group.

The benchmark tests have shown that JENDL-3.2 gave much better prediction of various reactor characteristics than JENDL-3.1, though some problems have been pointed out from the users. Up to now a lot of experiences has been piled up. To reflect these feedback information to JENDL-3.3, a new task force was organized to summarize the problems of JENDL-3.2 at April 1996. A report indicating the direction of revision for JENDL-3.2 was submitted to JNDC by this group after one year survey. It was approved by the steering committee of JNDC at March 1997.

The data improvement of JENDL-3.2 has been started at April 1997. JENDL3.3 will be published as a consolidated new version of JENDL by JAERI NDC (Nuclear Data center) with the cooperation of JNDC (Japanese Nuclear Data Committee) in FY2001. It's main features are followings:

- 1) Covariance data supplemented for major elements such as major actinides, structural materials and main coolants for the applications of FBR, LWR and Fusion reactors, to enable the estimation of quantitative contribution of nuclear data uncertainty to design accuracy or safety margin. No covariance data were equipped in the JENDL-3.2.
- 2) New material evaluations such as Er for burnable poisons in LWR high burn-up applications.
- 3) Adoption of isotope evaluation policy rather than natural element evaluation policy. Up to

JENDL-3.2 version for natural elements data JENDL File was prepared by natural element evaluation policy, i.e., for the transport calculations in nuclear reactors, natural elements data are recommended to use and for the dosimetry or activation applications data file given by isotopic evaluations are recommended to use. We want to keep this isotope evaluation policy as far as possible, for some elements, however, we have to make natural element file due to maintaining the evaluation accuracy.

4) Among others, addition of gamma-ray production data for the materials needed in Fusion applications.

#### 5) Individual Evaluation

##### a. Heavy Nuclides (Modified Cross-sections)

A simultaneous evaluation of fission cross-section of U-233, U-235, U-238, Pu-239, Pu-240 and Pu-241 was made. A least squares method was applied to selected absolute and relative measurements on the fission cross sections. Covariance matrices of the experimental data were constructed from the uncertainty information reported in the original references.

U-233: URR(Un-Resolved Resonance), 2n (n,2n), 3n (n,3n) and nu.

U-235: RR(Resolved Resonance) (Leal's new evaluation), URR, 2n, 3n, 4n, nu and fission spectrum evaluated by multi-mode fission model.

U-238: 2n,3n,4n, capture in MeV range, partial level inela.

Pu-240:RR, URR, 2n,3n,4n and partial level inela

Pu-242:RR(fission width), 2n,3n and partial level inela

Problem of neutron emission spectrum is solved by GNASH+GAMFIL calculation.

Capture cross section in MeV range is calculated by newly developed code DSD calculating of Direct/Semi-Direct Capture cross-sections.

##### b. Medium Mass Nuclides

Na: Inela cross section (Geel + TNG code calculation)

Ti-46,47,48,49,50: threshold reaction, gamma production, elastic scattering angular distributions

V: RR, total cross section above 100keV by Geel data and gamma production data.

Cr-50,52,53,54: RR and gamma production data.

Fe-54,56,57,58: RR, total, capture in MeV range calculated by TNG including pre-equilibrium capture.

Co-59: RR, total, gamma-production.

Ni-58,60,61,62,64: Inela, threshold reaction, neutron emission spectra using SINCROS code.

Nb-93: capture gamma reflecting pre-equilibrium.

W-182,183,184,186: RR, threshold reaction, gamma production data.

Er-162,164,166,167,168,170: Complete new evaluation reflecting newly obtained capture measured data by TIT(Tokyo Institute of Technology).

The data will be released after the review including vast range benchmarks for all of the reevaluated nuclides.

Preliminary JENDL-3.3 file has been compiled and group constants or MCNP/MVP Monte Carlo libraries are generated. A vast benchmark tests are being made for shielding performances as well as reactor physics performances in LWR, FBR and Intermediate energy reactors. From criticality calculations, it shows very good performances and get superior results than JENDL 3.2 except for Iron/SUS reflector cores. For Iron/SUS reflector case, Keff

shows rather large increase compared with experiments. We believe this comes from Fe and Cr data that was newly revised by the latest high resolution data. The validity of this revision should be re-examined. Official distribution of the JENDL 3.3 is considered within this fiscal year, hopefully before ND2001 International Conference on Nuclear Data.

## 2. JENDL Special Purpose Files

The following special purpose files other than JENDL-3.3 general purpose file are being developed in Japan. Their status is given below.

### JENDL Fusion File

JENDL Fusion File(JFF) was released at March 1996 to provide precise double-differential neutron and charged particle emission data by using MF6 representation of the ENDF-6 format. The evaluation was made for the data of H, D, Li, Be, C, N, O, <sup>19</sup>F, <sup>27</sup>Al, Si, Ca, Ti, Cr, <sup>55</sup>Mn, Fe, <sup>59</sup>Co, Ni, Cu, <sup>75</sup>As, Zr, <sup>93</sup>Nb, Mo, Sn, Sb, W, Pb and <sup>209</sup>Bi. For H, D, Li, N and O, the data of JENDL-3.2 are directly adopted. The revision works for the nuclides excepting the light mass ones have been performed by the SINCROS-II code system which consists of GNASH, DWUCK, CASTHY and several auxiliary programs. Those results are examined by comparing with DDX measured at Tohoku and Osaka Universities. For the data of light mass nuclei, individual evaluation has been done. A lot of nuclides are adopted as FENDL-2 from this file. Complete version of JFF96 was released in the FY98.

### JENDL Actinide File

This file will provide the data of about 90 nuclei(Tl to Es) in the actinide region having more than 1 day half life from 10<sup>-5</sup> eV to 20 MeV in energy.. Data for about 60 nuclei will be taken from JENDL-3.2/3.3 with some modification. We need complete new evaluation work for about 30 nuclei. Up to now the evaluations have been completed for Th-232, U-233, 235, 236, 238, Pu-239, 240, 241, 242 (important major actinides evaluated JNDC group), Np-235, Pu-237, 238, 244, 246, Am-242, 242m, 243, Cm-240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, Bk-247. Among above we made reevaluation work for Pu-238, Am-242, 242m, Cm-243, 245, 246 based on the Maslov's evaluations.

Since 1994, International Science and Technology Center (ISTC) project for Measurements and Evaluation of minor actinide nuclei has been started at Institute of Physics and Power Engineering (IPPE, Obninsk Russia, #304.), V.I. Khlopin Radium Institute (KRI, StPetersburg Russia, #183.) and Radiation Physics and Chemistry Problem Institute (RPCPI, Minsk Belarus, #b-03). After that the forth project started to measure fission cross-sections of minor actinides in medium energy range, i.e., 1 to 200 MeV by .Petersburg Nuclear Physics Institute (PNPI St.Petersburg, #609.) A project of actinide nuclear data evaluation for Th cycle started April 2000 (RPCPI, Minsk Belarus, #B-404). And a new project succeeding #609 starts within this year. The results obtained by these projects are destined to be used in JENDL Actinide File. The file release will be envisaged in FY2001 material-by-material

bases after the release of JENDL-3.3. Summary record about ISTC is given in Appendix.A.

#### JENDL Dosimetry File

The working group on Dosimetry in JNDC which is working for JENDL Dosimetry File has been published a new file. The cross section data about 33 reactions was revised and their covariance matrices were replaced with new ones. Integral tests were also made. The file was released in FY99 as JENDL-D99 and the data are also released with a CD-ROM, which is freely available through NDC/JAERI. Contents are 67 reactions with point-wise and 671 group structures data. The working group of relevant data is decommissioned.

#### JENDL Activation Cross Section File

Evaluation and compilation work for JENDL Activation Cross Section File has been completed and released in March 1996 as JENDL-A96. This first version stores the data for 233 nuclei and 1246 reactions. Final report is under preparation. Revision of the files is foreseen near future for the feedback information from the ad hoc group for threshold reaction evaluation working group in JNDC considering comments from V. Manokhin.

#### JENDL Alpha-n Data File

Evaluation and compilation work for JENDL Alpha-n Data File has been progressed by Charged Particle Nuclear Data Working Group. This file is requested from Shielding Group or Nuclear Criticality Safety Group especially for the applications of spent fuel transportations and stockades or reprocessing plant design. Neutron behaviors are very important for the treatment of spent fuels due to the neutrons are born from alpha emitters of minor/major actinides converted from major actinides of fuels. Total of 32 nuclides for Li-6, 7, Be-9, B-10, 11, C-12, 13, N-14, 15, O-17, 18, F-19, Na-23, Al-27, Si-28, 29, 30, Cr-50, 52, 53, 54, Fe-54, 56, 57, 58, Ni-58, 60, 61,62,64, Cu-63, 65.will be stored. UP to now except Si the evaluation is nearly finished. File release is expected in FY2002.

#### JENDL FP Decay Data File

Evaluation and compilation work for JENDL FP Decay Data File has been completed by sub-group in Decay Heat Evaluation Working Group of JNDC. This file is a succession of former JNDC Decay Data Library compiled in private JNDC format. The new released file is compiled in ENDF-6 Format. The file contains decay data for 1229 FP nuclides consisting of 142 stable and 1087 unstable nuclides. For each nuclides following data are given, decay modes, their Q values and branching ratios, average decay energy values of beta-rays, gamma-rays and alpha-particles and their spectral data. This file is inevitable for the decay heat calculations for the power reactors. This file was released in FY2000 and named as JENDL FP Decay Data File 2000.

#### JENDL High Energy Files

The evaluation of data for high-energy neutrons and protons has been initiated in JNDC. They will make data files for neutrons and protons up to 50 MeV and about 3 GeV.

The former files will be used for the IFMIF project that JAERI participates. The evaluation of neutron data up to 50 MeV has been made for almost all necessary nuclides. The evaluation results for neutron are being reviewed. After review, the data will be combined with JENDL Fusion File or JENDL-3.2 below 20 MeV. The file release will be envisaged in FY2001.

The latter files will be used for design of accelerators, transmutation systems of high-level waste, medical applications and so on. Stored nuclides are listed in Table-1. Among the list, The evaluations for top and second categories were already finished for neutron and proton induced reactions up to 3 GeV. A test data file is compiled and benchmark test is in progress. The file release will be envisaged after the benchmark test, we expect starting within FY2001.

#### JENDL PKA/KERMA File

This file stores the spectra of primary knock-on atoms (PKA) and KERMA factors. The data to be stored are created from the data files(JENDL High Energy File) up to 50 MeV made for the IFMIF project. A couple of processing codes to create the file from evaluated nuclear data file, by using the effective single particle emission approximation, have been developed and tested. The test compilation has been performed from JENDL Fusion File for the 69 isotope data except light mass nuclei below 20 MeV. The file release will be made in FY2001.

#### JENDL Photonuclear Data File

The evaluation has been finished for 46 isotopes;  $^2\text{D}$ ,  $^{12}\text{C}$ ,  $^{14}\text{N}$ ,  $^{16}\text{O}$ ,  $^{23}\text{Na}$ ,  $^{24,25,26}\text{Mg}$ ,  $^{27}\text{Al}$ ,  $^{28,29,30}\text{Si}$ ,  $^{40,48}\text{Ca}$ ,  $^{46}\text{Ti}$ ,  $^{51}\text{V}$ ,  $^{52}\text{Cr}$ ,  $^{55}\text{Mn}$ ,  $^{54,56}\text{Fe}$ ,  $^{59}\text{Co}$ ,  $^{58,60}\text{Ni}$ ,  $^{63,65}\text{Cu}$ ,  $^{90}\text{Zr}$ ,  $^{93}\text{Nb}$ ,  $^{92,94,96,98,100}\text{Mo}$ ,  $^{133}\text{Cs}$ ,  $^{160}\text{Gd}$ ,  $^{182,183,184,186}\text{W}$ ,  $^{197}\text{Au}$ ,  $^{206,207,208}\text{Pb}$ ,  $^{209}\text{Bi}$  and  $^{235,238}\text{U}$  in the gamma-ray energy range up to 140 MeV. Their compilation in the ENDF-6 format and the critical review are in progress. The file will be released in FY2001 also.

### **3. Other Activity Relating to Nuclear Data**

#### **1) The 2000 Symposium on Nuclear Data**

The 2000 Symposium on Nuclear Data was held at Tokai Research Establishment, Japan Atomic Energy Research Institute (JAERI), on 16th and 17th of November 2000. Japanese Nuclear Data Committee and Nuclear Data Center, JAERI organized this symposium. In the oral sessions, presented were 18 papers on keynote address that was made by Dr. T.Fuketa,

status of nuclear data evaluation and its benchmark test for JENDL-3.3 General-purpose File and JENDL High Energy Files, international session and other topics. In the poster session, presented were 40 papers concerning experiments, evaluations, benchmark tests and software on nuclear data. Those presented papers are compiled in the proceedings and will be published as a JAERI-conf report having INDC (JPN)-188/U (2001) report number. Total of 155 attendees including 16 foreigners (of which 4 Asian researchers are invited by the organizing committee) and 101 outside JAERI were gathered. Every year more than 10 % attendees are foreigners.

## **2) Specialists meeting for Group Constants**

To enhance the use of JENDL-3.3 in the nuclear industries, it is inevitable to prepare and to distribute the group constants or application libraries for some specific use like Sn codes, Monte Carlo codes or burn up codes. Up to now many activities has been made to supply group constants in the users communities. To identify the problems in the processing and/or nuclear libraries itself, we held a specialists' meeting at Tokai Research Establishmen (JAERI), on 22nd and 23rd of February 2001. Overview for group constants generation, covariance data processing, and application data libraries in burn-up calculation or nuclear transmutation calculations are presented and discussed. In the final session, the necessity for common group cross section library was discussed in freely with floors and concluded that in spite of their selection of producing board or the processing code to be utilized we need common group library for the references of the processed data for JENDL-3.3. Total of 59 specialists were attended mostly from JAERI, industry and utilities. A proceedings will be published as a JAERI-Conf. report.

Table-1 Stored Nuclides in JENDL High Energy File

Priority	Nuclides
1 <sup>st</sup> Priority (42 nuclides)	H-1, C-12, N-14, O-16, Na-23, Al-27, Cr-50, 52, 53, 54, Fe-54, 56, 57, 58, Ni-58, 60, 61, 62, 64, Cu-63, 65, Ta-181, W-180, 182, 183, 184, 186, Au-197, Hg-196, 198, 199, 200, 201, 202, 204, Pb-204, 206, 207, 208, Bi-209, U-235, 238
2 <sup>nd</sup> Priority (41 nuclides)	Be-9, Mg-24, 25, 26, Si-28, 29, 30, K-39, 41, Ca-40, 42, 43, 44, 46, 48, Ti-46, 47, 48, 49, 50, V-51, Mn-55, Co-59, Zr-90, 91, 92, 94, 96, Nb-93, Mo-92, 94, 95, 96, 97, 98, 100, Pu-238, 239, 240, 241
3 <sup>rd</sup> Priority (40 nuclides)	H-2, Li-6, 7, B-10, 11, C-13, F-19, Cl-35, 37, Ar-35, 38, 40, V-50, Zn-64, 66, 67, 68, 70, Ga-69, 71, Ge-70, 72, 73, 74, 76, As-75, Y-89, Th-232, U-233, 234, 236, Np-237, Am-241, 242, 242m, 243, Cm-243, 244, 245, 246

NB. RED: Evaluation and File Compilation Finished.

. BLUE: Evaluation Finished.

BLACK: Evaluation not yet Finished.

## Appendix-A

Summary of ISTC project that JAERI participated with some funds, relating to the JENDL Actinide File

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Objective:

- Improvement of minor actinide data for transmutation projects using actinide burner reactors or accelerator driven spallation neutron sources.
- The data needed are for  $^{237, 238}\text{Np}$ ,  $^{238, 242}\text{Pu}$ ,  $^{241, 242g, 242m, 243}\text{Am}$  and  $^{242, 243, 244, 245, 246}\text{Cm}$ .
- The corresponding data for most important cross sections should be obtained on the basis of ISTC.

ISTC projects:

- “Measurements of the fission neutron spectra for minor actinides”  
V.I.Khlopin Radium Institute (KRI St.Petersburg Russia, # 183-p)  
1995-1997
- high precision measurements of the fission neutron spectra for spontaneous fission of Cm-244, -246, Pu-240 -242, and that for thermal induced fission of Cm-243, -245
- “Measurements and analysis of basic nuclear data for minor actinides”  
Institute of Physics and Power Engineering (IPPE Obninsk, #304-p)  
1995-1996
- precise measurements of the fission cross sections of  
Cm-243, -244, -245, -246, -247, -248m, Am-242m, Pu-238.
- measurements of fission product yields for Np-237
- measurements of inelastic scattering and prompt fission neutron spectra for Np-237
- measurements of delayed neutron yields and it's 6-group constants for Np-237 fast neutron fission
- critical comparison between evaluated data for BROND-2, JENDL-3 and ENDF/B-VI and deduction of recommended values
- “Evaluation of actinide nuclear data”  
Radiation Physics and Chemistry Problems Institute  
(RPCPIMinsk Belarus, # b-03)  
1995-1998

- complete new evaluations of neutron cross sections for Cm-243, -245 -246, Am-241, 242, 242m, 243, Np-238, Pu-238, -242.
- “Neutron induced fission cross-sections of some actinides heavy nuclei in energy region 1-200 MeV  
Petersburg Nuclear Physics Institute (PNPI St.Petersburg, #609)  
1996-1999
- measurements of neutron fission cross-section of U-233, U-238, Np-237, Th-232, Pu-239, Pb and Bi in the energy range up to 200 MeV.  
Relative measurements to U-235 fission with accuracy 3-10%.
- evaluation of above listed cross section for neutron and proton induced fissions in the energy range 20-200 MeV.
- “ Fission Cross section at Intermediate Energies“  
Petersburg Nuclear Physics Institute (PNPI St.Petersburg, #1971)  
2001-2002 (Extension of #609)
- measurements of neutron fission cross-section of Pu-240, Am-243 and W in the energy range up to 200 MeV.  
Relative measurements to U-235 fission with accuracy 3-10%.
- evaluation of above listed cross section for neutron and proton induced fissions in the energy range 20-200 MeV.

#### Other ISTC Project relating to Nuclear Data

- “Benchmark Data on Gamma-ray Production For Fusion Application”,  
Institute of Physics and Power Engineering (IPPE Obninsk, #731)  
1997-2000
- measurements and evaluations of the benchmark data on gamma-ray production cross section in the fast neutron induced reactions for materials that are most important for fusion power applications.  
Measurements anticipated are 32 structure materials at 14MeV.  
(For 1<sup>st</sup> year: Li-6,-7, B-10,-11, C, N, O, Al, Si, Fe, Cu, Mo,W, Pb were

measured.)

The data will be available in EXFOR Format.

Evaluations in ENDF/B-6 Format will be made for most important 20 nuclides.

- “Experimental and Theoretical Study of the Yields of Residual Product Nuclei Produced In thin Targets Irradiated by 100-2600 MeV protons”,  
Federal Scientific Center of Russia Institute for Theoretical and Experimental Physics (ITEP Moscow, #839)  
1997-2000
  - Residual product nuclei measurements from spallation by high energy proton beam for thin targets of  $^{182}\text{W}$ ,  $^{183}\text{W}$ ,  $^{184}\text{W}$ ,  $^{186}\text{W}$ ,  $^{232}\text{Th}$ ,  $^{\text{nat}}\text{U}$ ,  $^{99}\text{Tc}$ ,  $^{59}\text{Co}$ ,  $^{63}\text{Cu}$  and  $^{65}\text{Cu}$ .  
Measured proton energies are 100, 150, 200, 800, 1000, 1200, 1400, 1600 and 2600 MeV.  
To get the reference data to check the simulation code such as LAHET, ALICE, QMD, etc.
- “Nuclear Physics Investigation Aimed at the Solution of Weapon Plutonium Conversion and Long-lived Radioactive Wastes Transmutation Problems”,  
Russia Federal Nuclear Center All-Russia Scientific Research of Experimental Physics (VNIIEF Sarov, #1145)  
1998-2000
  - measurements of the cross sections necessary for the transmutation technologies and electro-nuclear energy production system on the basis of high-current proton accelerator.
  - Cross sections of a wide range of isotopes for minor actinides of Np, Pu, Am and Cm in the fast and intermediate neutron spectra; Thermal cross section for neutron induced fission and radiative capture of Np-238 ( $T_{1/2} = 2.12 \text{ d}$ ); Spectra of fast fission neutrons from Th, U, Np and Pu by 40-200 MeV protons.
- “Evaluation of actinide nuclear data”  
Radiation Physics and Chemistry Problems Institute  
(RPCPIMinsk Belarus, # B-404)  
2000-2002

- complete new evaluations of neutron cross sections for Th-232, Pa-231, Pa-233, U-232, U-233, U-234. up to 20MeV.
- new evaluations of neutron cross sections for U-238 and Pu-239 up to 150 MeV.