Present Status of JENDL Project and Activities of JNDC

Akira Hasegawa
Nuclear Data Center
Japan Atomic Energy Research Institute
Hasegawa@ndc.tokai.jaeri.go.jp

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

The data improvement of JENDL-3.2 started in April 1997. Then after 5 years endurable work, JENDL-3.3 has been completed by March 2002 and released in May 2002 officially as a consolidated new version of JENDL. This is a cooperative work done by JAERI NDC (Nuclear Data Center) and JNDC (Japanese Nuclear Data Committee).

The main features of JENDL-3.3 are summarized as follows:

1) Enrichment of covariance data

Covariance data are supplied for major reactor constituents, such as major actinides, structural materials and main coolants, to be used for the applications of FBR, LWR and Fusion reactors. This was done so as to be able to make estimation of quantitative contribution of nuclear data uncertainty to design accuracy or safety margin. Only one nuclide (Mn-55) covariance data was supplied in the JENDL-3.2.

2) New material evaluation important for high burn-up application

Evaluations of new material not available in JENDL-3.2 are made. For example, Er isotopes are important as burnable poisons in LWR in high burn-up applications.

3) Adoption of isotope evaluation policy

From this version isotope evaluation policy is introduced against the natural element evaluation policy taken in the JENDL-3.2. Up to the JENDL-3.2, natural element data was prepared usually for a natural element material (i.e., isotopes data are aggregated in one material) data. At the same time, there exist isotope data. In some cases, inconsistency between natural and isotope data were alive. So as to solve the inconsistency we have claimed that for transport calculations in nuclear reactors, natural elements data are recommended to use and for dosimetry or activation applications, data given by isotopic evaluations are recommended. But there happened miss use so much. Therefore we changed the policy.

4) Enrichment of secondary gamma-ray production data

Secondary gamma-ray production data are newly incorporated for many nuclides needed in Fusion applications. The number of nuclides with gamma-ray production data was increased from 66 to 114.

5) Individual Evaluation

a. Heavy Nuclides (Modified Cross-sections)

A simultaneous evaluation of fission cross-sections for 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 of each measurements.

U-233: URR(Un-resolved Resonance), 2n (n,2n), 3n (n,3n) and nu (neutrons per fission).

U-235: RR(Resolved Resonance) (Leal's 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; calculation code 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 data measured by TIT(Tokyo Institute of Technology).

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

The latest version of JENDL Fusion File (JFF) was released in 1999 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, ^{6,7}Li, ^{9}Be, ^{12}C, ^{14}N, ^{16}O, ^{19}F, ^{27}Al, Si, Ca, Ti, ^{51}V, Cr, ^{55}Mn, Fe, ^{59}Co, Ni, Cu, Ga, ^{75}As, Zr, ^{93}Nb, Mo, Sn, Sb, W, Pb and ^{209}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 were 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 were adopted as FENDL-2 from this file. Formal evaluation paper was published as “Chiba S., Fukahori T., Shibata K. et.al: JENDL Fusion File 99,J. Nucl. Sci.Technol., 39,187 (2002)”.

JENDL Actinide File

This file will provide the data of main and minor actinides about 90 nuclei(Tl to ES) more than 1 day half life from 10-5 eV to 20 MeV in energy. The revision work of major and minor actinides has been made and their results were adopted in JENDL-3.3. The revision work for minor actinides not available in JENDL-3.3 will be continued in the coming several years. The results of the reevaluation will be stored in JENDL Actinide File.

Since 1994, International Science and Technology Center (ISTC) project for Measurements and Evaluation of miner 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 Russia, #609.) A project of actinide nuclear data evaluation for Th cycle started April 2000 (RPCPI, Minsk Belarus, #B-404). The last one is currently underway.

JENDL Dosimetry File

The working group on Dosimetry cross sections in JNDC has been published a new file JENDL Dosimetry File 99 and dissolved the WG. The cross section data of old version, JENDL Dosimetry File 91, were revised for 33 materials and their covariance matrices were replaced with new ones. Integral tests were also made. The file was released in FY99.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. An official evaluation report was published as "Kobayashi K., Iguchi T., Iwasaki S., at. al.:JENDL Dosimetry File 99 (JENDL/D-99), JAERI-1344 (2001)".

JENDL Activation Cross Section File

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

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 and/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 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 the former JNDC Decay Data Library compiled in private JNDC format. The newly 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. The official evaluation report was published as "Katakura J., et al. :JENDL FP Decay Data File 2000, JAERI-1343 (2001)".

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 up to 50 MeV and for neutrons and protons up to 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-3.3 below 20 MeV. The file release will be envisaged in FY2002.

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, evaluations for first 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 distribution starts within FY2002.

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 FY2002.

JENDL Photonuclear Data File

The evaluation has been finished for 46 isotopes; ^{2}D, ^{12}C, ^{14}N, ^{16}O, ^{23}Na, ^{24,25,26}Mg, ^{27}Al, ^{28,29,30}Si, ^{40,48}Ca, ^{46}Ti, ^{51}V, ^{52}Cr, ^{55}Mn, ^{54,56}Fe, ^{59}Co, ^{58,60}Ni, ^{63,65}Cu, ^{90}Zr, ^{93}Nb, ^{92,94,96,98,100}Mo, ^{133}Cs, ^{160}Gd, ^{182,183,184,186}W, ^{197}Au, ^{206,207,208}Pb, ^{209}Bi and ^{235,238}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 FY2002 also.

3. Other Activity Relating to Nuclear Data

1) ND2001: International Conference on Nuclear Data for Science and Technology

The International Conference on Nuclear Data for Science and Technology (ND2001) was held 7-12th October 2001 at the EPOCHAL Tsukuba International Congress Center in Tsukuba, Ibaraki, Japan. The Japan Atomic Energy Research Institute (JAERI) sponsored and organized in collaboration with OECD Nuclear Energy Agency – Nuclear Science Committee (NEA/NSC) and Atomic Energy Society of Japan (AESJ) as the co-sponsors. Total of 375 scientists from 41countries and 4 international organizations participated in the conference, of which 207 persons come from abroad. Total of 375 papers were presented including 4 keynotes and 3 summary talks in the 40 sessions; i.e., 50 invited talks, 116 oral and 202 poster contributed papers. One third of the presented papers are in the topics of Nuclear Reaction Data and Evaluated data Libraries. The other one third is devoted to the applications in energy production including ADS applications and Industry or Medical applications. The rest one third is devoted for forefront of Nuclear Reaction Theory, Astrophysics, Facilities for new century and steady progress in International Collaborations. An emphasis was laid down on the application of the Nuclear Data to ADS due to the increased interests in the world-wide environmental concern on nuclear high level waste. And data applications in the Astrophysics are also enthusiastically debated in connection with nuclear synthesis of the universe.

The proceedings will be published by July 2002 as a supplement to Journal of Nuclear Science and Technology of Japan Atomic Energy Society, including all the reviewed invited and contributed papers.

2) The 2001 Symposium on Nuclear Data and a specialists' meeting

As the side effect of the ND2001, both of the Symposium on Nuclear Data, which is held every year in November, and a specialists' meeting on some special topics, which is a topical meeting held every year on the selected hottest topics in that period, were cancelled in 2001.

Table 1. Stored Nuclides in JENDL High Energy File

Priority	Nuclides
1st 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*
2nd 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, 241,242*
3rd Priority (39 nuclides)	H-2, Li-6, 7, B-10, 11, C-13, F-19, Cl-35, 37, Ar-35, 38, 40, 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 bold font**: Evaluation and File Compilation Finished.
. *BLUE italic font*: Evaluation Finished.
BLACK: Evaluation not yet Finished.

Appendix Activities of Japanese Nuclear Data Committee (Fiscal year 2001)

The Japanese Nuclear Data Committee (JNDC) consists of three subcommittees, six standing groups and a steering committee. Each subcommittee consists of several working groups (WG). The Committee Meeting of JNDC was held in July 2001 to discuss the nuclear data activity in the previous fiscal year and plans for the fiscal year 2001. Discussions were made on several topics including the final preparation status of ND2001: International Conference on Nuclear Data for Science and Technology to be held in TSUKUBA as well as domestic and international collaboration on nuclear data.

The ND2001 was held in 7-12th October 2001 at the EPOCHAL Tsukuba International Congress Center in Tsukuba, Ibaraki, Japan. As the side effect, both of the 2001 Symposium on Nuclear Data, which is held every year in November, and a specialists' meeting on some special topics, which is a topical meeting held every year on the selected hottest topics in that period, were cancelled.

The activities of subcommittees and standing groups are briefly summarized below.

Subcommittee on Nuclear Data

1) High Energy Nuclear Data Evaluation WG :

The evaluation is progressing parallel in two phases. In the phase-I, the data up to 50 MeV for IFMIF(International Fusion Material Irradiation Facility) project are targeted for neutron and proton induced reactions. In the phase-II, evaluations for high-energy neutron/proton induced reactions up to 3GeV are ongoing. Data requests are very keen by the joint projects for High Intensity Proton Accelerator of Center for Neutron Research in JAERI and KEK (High Energy Accelerator Research Organizations). Following is the status of each SWG.

- IFMIF Neutron File Compilation SWG: Neutron file compilation is the main task of this SWG. Up to now, evaluation of 43 nuclides has been finished. The files are in the final reviewing stage after the FORMAT check.
- MeV and GeV File compilation SWG: Compilation and evaluation of phase-II data is a main mission. Evaluations for the priority 2 nuclides (about 40 nuclides) has been performed together with the code preparation inevitable for the fundamental evaluation tools in this energy range(Quick-Gnash, QMD, JAM). Evaluation started for the priority 3 nuclides.
- Other Sub-Groups like Photonuclear Data, PKA/KERMA, High Energy Activation Cross-sections, and Guideline discussion group for differential data checking also have been progressed.

2)Evaluation and Calculation System WG :

Recommended parameters required in the nuclear model calculations such as OMP, level density, gamma strength functions, as well as advanced methodologies like multi-modal fission, essence from the latest frontiers of theoretical calculations are discussed. The results will be reflected to RIPL-2(Reference Input Parameter Library Version 2).

3) Charged Particle Nuclear Data WG : This WG is responsible for the JENDL (alpha,n) Reaction File. Evaluation has been finished and a file will be produced within a year. This group was dissolved at the end of March 2002 due to the completion of the missions..

4) Delayed Neutron Data Evaluation WG: This group was set up due to the follow up work of OECD/NEA/WPEC(Working Party on Evaluation Cooperation) subgroup 13 to investigate the delayed neutron data related problems. Evaluations of delayed neutron yields and spectra for main actinides of JENDL 3.3(U-235,-238, Pu-239) are also the mission of this group. Data evaluation in 6 group time dependent scheme has been made.

5) Evaluation WG on Intermediate Mass Nuclides: This WG was set up due to the revision fork for JENDL-3.3. Re-evaluation work and relevant checking has been finished for Na-23, V-51, Co-59, Cr, Ti, Ni, W, Nb and Er (total of 32 nuclides). Some follow up from the results of benchmark tests were made. This group has been dissolved by the end of March 2002 due to the completion of JENDL-3.3.

6) Evaluation WG on Heavy Mass Nuclides: This WG was set up due to the revision work for JENDL-3.3. Re-evaluation work has been made for U-233, -235,-236,-238, and Pu-236,-239,-240,-241,-242. Working group has been watching the feedback information from benchmark tests made by subcommittee of reactor constants. This group has been dissolved by the end of March 2002 due to the completion of the mission.

Subcommittee of Reactor Constants

1) Reactor Integral Test WG : Benchmark test of JENDL-3.3 tentative version for fast and thermal reactors has been made. Although over all agreements (C/E values) in Keff for thermal system as well as fast system revealed superior than JENDL 3.2 data. Problems for over estimation on Keff for SUS reflected cores are dissolved by the reevaluation of Cr data. No major problems are found.

2) Shielding Integral Test WG :

For the tentative version of JENDL-3.3, benchmark test were made for main shielding materials such as Al, Si, Na, Ti, V, Cr, Fe, Co, Ni, Cu, Nb, W. All the results were fed back to the evaluation WG on intermediate mass nuclides. Much effort has been given to Na, Fe, Cr and Ni data reevaluation.

3) Standard Group Constants WG : Revision work for JSSTDL library has been progressed. Report of the JSSTDL-300 are being prepared. Direction of group constants preparation for JENDL-3.3 has been discussed.

Subcommittee on Nuclear Fuel Cycle

The subcommittee on nuclear fuel cycle consists of three WGs, i.e., Decay Heat Evaluation WG, WG on Evaluation of Nuclide Generation and Depletion, and FP Mass Yield Evaluation WG.

For the first WG, FP Decay Data File has been completed and released as JENDL FP Decay Data File 2000. A plan for new measurement of strength function of beta decay at Valencia University(TAGS) was presented and discussions were made how to contribute the project by JNDC. For the second WG, new entry for PWR and BWR-MOX has been added to ORIGEN-2 Library and published a report. Methodology for the evaluation of sensitivity in one group cross section is discussed. To pole for questionnaire of ORIGEN Calculation Needs has been decided and preparation work has been made. For the last WG, this group was organized so as to work with IAEA CRP. To give precise mass yields data for minor actinides as well as major actinides covering the wide range of incident neutron/proton energies is the main mission. Collection of mass yields data evaluated/measured in Japan was made. The systematic made by Moriyama and Ohnishi was applied and analyzed and found that for Cm-248(p,f) case typical two peak cannot produced. A possibility for updating of recent Benllinure's semi-empirical model was investigated. Measurements of mass yields for Np-237, Am-241 and 243, Cm-248 by proton bombardment at 25 and 30Mev were made.

Standing Groups

1) CINDA Group : Papers on neutron induced reaction data published in Japanese journals and reports are surveyed. Total of 289 entries (without ND2001 presentations) were sent to the NEA Data Bank in the last one year to update the CINDA master database.

2) ENSDF Group : The evaluation of nuclear structure data is the duty of this group for nuclei with mass numbers from 118 to 129. Re-evaluation work has been made for A= 118 and 124.
3) Group on Atomic, Molecular and Nuclear Data for Medical Use : Survey work has been made for the radiopharmaceutical data needed in the field of nuclear medicine. Home page of this group was opened to promote and encourage WG missions.
4) JENDL Compilation Group : File compilation and editing were made for the JENDL-3.3.
5) Editorial Group of "Nuclear Data News" : Three issues of "Nuclear Data News" (No.69-71) which is a periodic informal journal circulated in nuclear data communities of Japan (written in Japanese) were published. Some 450 copies were distributed in the nuclear data communities without fee.
6) High Priority Request List Group: A revision was made(new entry:3, remove/merge:35, others:71) for the latest version of HPRL, this is mainly from ADS (Accelerator Driven System) application's requests. This group is a coordination group to set up a Japanese Requests Lists from domestic data users and a world-wide request list HPRL that is maintained at OECD/NEA/WPEC (Working Party on Evaluation Cooperation).