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INDC International Nuclear Data Committee

Summary Report of Consultants' Meeting

Review the Requirements to Improve and Extend the IRDF library (International Reactor Dosimetry File (IRDF-2002))

IAEA Headquarters, Vienna, Austria
25-26 January 2007

Prepared by

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January 2007

IAEA Nuclear Data Section, Wagramer Strasse 5, A-1400 Vienna, Austria

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Abstract

Presentations, recommendations and conclusions of a Consultants' Meeting to "Review the Requirements to Improve and Extend the IRDF library (International Reactor Dosimetry File (IRDF-2002))" are summarized is this report. The main aims of this meeting were to discuss scientific and technical matters related to reactor dosimetry and to consider the needs for improvements to the existing data in IRDF-2002 and possible extensions to other higher neutron energy applications. Specific tasks were assigned and deadlines agreed. The requirements for fusion studies are particularly challenging (up to 60 MeV) and should include adequate covariance data – the provision of these neutron cross sections will require additional effort and assessment prior to initiating any work programme, and specific participants agreed to undertake preliminary exercises.

January 2007

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1. OBJECTIVES

A Consultants' Meeting to "Review the Requirements to Improve and Extend the IRDF library (International Reactor Dosimetry File (IRDF-2002))" was held at IAEA Headquarters in Vienna, Austria, on 25 and 26 January 2007. The primary aims of this meeting were to assess and discuss the contents of the existing IRDF-2002 reactor dosimetry file with the aims of instigating improvements and corrections and exploring the feasibility of extended usage to other dosimetry applications (particularly with respect to fusion devices such as IFMIF (International Fusion Materials Interaction Facility)). L. R. Greenwood (PNL, USA) was elected Chairman of the meeting, and A.L. Nichols acted as Scientific Secretary and rapporteur in conjunction with the chairman. The approved agenda is attached (Appendix 1). Other experts attending the meeting were as follows: K.I. Zolotarev (IPPE, Obninsk, Russian Federation); E.M. Zsolnay (BUTE, Hungary); H.J. Nolthenius (Schagen, The Netherlands); U. Fischer (FZK, Karlsruhe, Germany); S.P. Simakov (FZK, Karlsruhe, Germany); and data specialists from within the IAEA Nuclear Data Section (D.H. Abriola, R. Capote Noy, A. Mengoni and V. Zerkin). A complete list of participants including affiliations and addresses is given in Appendix 2.

Mr. N. Ramamoorthy (Director of the Division of Physical and Chemical Sciences) welcomed the participants, and Nichols summarized the perceived objectives of the meeting, as encouraged by the International Nuclear Data Committee in May 2006. The primary objectives were to identify and seek corrections and other substantial improvements to the existing files (e.g. through known new evaluations), and in particular to consider dosimetry needs for fusion devices up to 60 MeV neutron energy. Whilst the primary aims were to identify and discuss future requirements, a number of presentations were made to substantiate findings and arguments, and these are outlined in Section 2 and their availability noted in Appendix 3.

2. SUMMARY OF DISCUSSIONS AND PRESENTATIONS

Discussions were initiated by e-mail prior to the meeting, and various correspondence had evolved with respect to the problems within the existing files, specific formatting issues, and proposals for extensions to embrace fusion and radiotherapy applications. Participants discussed these issues in some detail, led by Greenwood and Zsolnay.

2.1 Existing problems

Zsolnay and Nolthenius provided the meeting with a list of observed data issues to be addressed within IRDF-2002, and also drew the participants' attention to the footnotes of Table 3.1 of Ref. [1]. Taking their points of observation and concern in the order in which they were discussed:

(a) Au197G and U235F – adopt cross sections and covariances from the IAEA Neutron Cross Section Standards [2], or ENDF/B-VII nuclear applications library [3];

(b) Mn55G, Fe58G and Nb93G resonance integrals – ORNL/IRMM measurements on-going for MN55G; Moxon (IAEA/UK) has evaluated Fe58G; Nb93G needs to be re-assessed (JEFF-3.1 [4] and ENDF/B-VII [3]);

(c) cross sections and their uncertainties need to be improved for several reactions identified as Na23G, Nb93G, In115G (leading to In-116m), Ta181G and Th232G - assess the contents of JEFF-3.1 and ENDF/B-VII files; Th232G cross sections and comprehensive covariances are available from the IAEA CRP on “Nuclear data for the Th-U fuel cycle” [5];

(d) nuclear data properties (isotopic abundance, decay data of the reaction products, etc.) of IRDF-2002 are incomplete – this observation applies to the fission products of (n,f) reactions, and should come as no surprise; their appearance in IRDF was judged to be inappropriate, and file users should be referred to other suitable evaluated databases (e.g., JEFF-3.1 and ENDF/B-VII) in future documentation;

(e) CdNATX data are incorrect – studies are underway (measurements at IRMM, Geel, Belgium, and evaluation by Moxon (IAEA/UK));

(f) inconsistencies have been observed between recommended IRDF-90 cross sections and equivalent data adopted from IRDF-90 for IRDF-2002 (needs to be understood and resolved);

(g) no suitable neutron cross section data in IRDF-2002 for TiNATX, Cr50G, Mn552, Fe57NP and Eu151G reactions – assess contents of JEFF-3.1 [4] and ENDF/B-VII [3].

2.1.1 Recent and on-going evaluations

Zolotarev had undertaken an agreed series of new evaluations funded through an IAEA research contract, and guided by recognized inadequacies identified during the assessment and assembly of IRDF-2002 and subsequent validation using integral benchmarks [1]. The main features of this work and the resulting recommendations were presented:

^{47}Ti(n,p) – evaluated in late 2003 up to a neutron energy of 20 MeV, but too late for adoption in IRDF-2002;

^{63}Cu(n,2n), ^{65}Cu(n,2n), ^{64}Zn(n,p), and ^{199}Hg(n,2n) reactions are all comprehensive evaluations up to a neutron energy of 20 MeV;

^{197}Au(n,2n) reaction evaluated up to a neutron energy of 40 MeV;

^{27}Al(n.p) reaction evaluated over the 6 to 10 MeV neutron energy range only.

Several example cases were presented in which the scatter of some of the experimental data had been resolved by identifying the standards used by the experimenters and re-normalizing the data in terms of the current neutron cross section standards [2]. Cases were shown where the resulting re-normalization procedure reduced the spread in experimental data significantly.

Zolotarev noted some remaining problems in his newly recommended data, and advocated further integral measurements for the ^{63}Cu(n,2n) reaction. Other points of note included evidence that the ^{197}Au(n,2n) reaction data were in much better shape after re-normalization through the adoption of the new neutron cross section standards [2]. He had also found good agreement between the most recent ^{65}Cu(n,2n) measurements and much older data. Zolotarev was thanked for his significant contributions to the resolution of these difficulties, and participants encouraged him to extend his evaluation work to other problematic reactions (as planned). These future studies will include the following reactions: ^{24}Mg(n,p), ^{32}S(n,p), ^{60}Ni(n,p), ^{115}In(n,2n) and ^{127}I(n,2n).

2.1.2 Other issues

Consideration was given to the need for photofission data. The US ENDF/B-VII photofission files have been adopted and developed from an earlier IAEA coordinated research project that remains accessible on the Web. Precise needs and possible sources of photofission data for dosimetry applications will be assessed by Greenwood. There was no decision on the inclusion of photofission data in future versions of IRDF, which might only include a discussion and reference to other recommended files.

Nolthenius stated that all dosimetry applications files are derived for the pointwise database that can be maintained in ENDF-6 format without any difficulty or concern. However, groupwise and metrology databases would continue to involve format changes so that these files can be read by dosimetry codes. Some minor difficulties were listed: full documentation requires the addition of comments in the primary library; the T10T3 conversion code needs to be described in the open literature; decay data within the files require an improved utility code to facilitate readability. Participants agreed that the basic pointwise database be maintained in ENDF-6 format, and that users be left to choose their own group structure (reactor dosimetry and metrology files will continue to use 640 group structure).

Zerkin has developed an ENDF interface that plots cross section data and their uncertainties. User data can also be introduced to be plotted and compared directly with the available experimental cross sections. These studies can be carried out on the Web, and also include differential cross sections and angular distributions.

Table 1 lists a number of specific problems and issues identified by users since the formulation, assembly and release of IRDF-2002 in 2004. Furthermore, improved data are available to renormalize the various measurements [2], and new evaluations have been released along with their covariance matrices (see Refs. [3, 4, 5] and Section 2.1.1, above).

ACTION 1: New evaluated and re-evaluated data files will be made available directly or through the IAEA Web site by Nuclear Data Section staff (see column 3 of Table 1), and

ACTION 2: participants agreed to assess the contents of the new files and come forward with judgmental recommendations concerning their acceptance into IRDF (see column 4 of Table 1).

2.2 Extension to higher neutron energies

Greenwood introduced work he had undertaken to extend and perform integral testing of activation cross sections above 14 MeV [6], based on the available data at the time of this study. Foils had been irradiated with 40-MeV deuterons, and integral data obtained for 30 reactions, with an overall standard deviation of ± 11% for 25 recommended reactions. While introducing these data to the participants, Greenwood also posed various questions concerning any proposed extensions to the IRDF-2002 files: what would the extended data be used for? to what neutron energy should individual cross section data files be extended? Data for the study and design of IFMIF required cross sections up to neutron energies of 55-60 MeV, while much higher energies were needed for medical facilities and spallation devices (for the study of accelerator-driven systems). Choice and judgement would be severely limited by deficiencies and lack of uncertainty data and covariances. Nevertheless, specific data sets were known to exist that extended up to 150 MeV, and should be considered for inclusion in IRDF. Greenwood has already extended the IRDF-2002 somewhat, and would be interested in proposals to extend the library further through expert group activities. Integral testing of neutron cross sections can be done quite accurately using neutron time-of-flight techniques to measure the neutron spectra, as was done in Ref. 6. Capote agreed that there were significant gaps and inadequacies in various measured and evaluated cross section data above 20 MeV, but believed that recent developments in theoretical modelling could provide the means of generating suitable data to fill these substantial gaps (by means of EMPIRE and TALYS, for example).

Fischer provided information of direct relevance to the development of the multinational ITER programme, and the need for significant extensions to the dosimetry data files in order to carry out with confidence the design and construction of IFMIF (International Fusion Materials Interaction Facility) which will be used to assess and qualify a range of proposed materials for the DEMO fusion reactor (Demonstration Power Plant). Over a time span from 2007 to 2012, the EVEDA (Engineering Validation and Engineering Design Activities) phase of the project will require extensive testing of various proposed components of IFMIF. Deuterons up to energies of 40 MeV will be used in the IFMIF facility to generate neutron fields of ~ 10^{17} n s^{-1} by means of the (d + ^{6,7}Li) reactions. At such conditions, the resulting neutron spectrum extends up to 55 MeV, i.e. above the traditional energy cut-off of 20 MeV. Neutron and photon transport calculations are being carried out with the McDeLicious code (MCNP offspring). Neutronics studies in the foreseeable future will include the provision of data for the irradiation test modules in IFMIF and the layout of the test cell. Information is also required on flux distributions, and the quantification and facility responses to nuclear heating, accumulation of radiation damage and gas production.

Efforts will initially focus on the proposed structural materials of the first wall which will consist of Eurofer (primarily Fe, with about 9% Cr and much lesser quantities of Mn, W and Ta) in a target fluence of 150 dpa. Other materials of interest include SiC, V/V-alloy and tungsten (latter for the divertor). Adequate dosimetry files were one requirement, but Fischer also pointed out the need for a General Purpose fusion file up to 60 MeV (of which one possible route could be through an extensive programme of work to expand the FENDL database [7]). Mention was also made of the Intermediate Energy Activation File (IEAF-2001) and the European Activation File (EAF-2007) in this work. Neutron activation experiments are being conducted at the Nuclear Physics Institute (NPI), Řež, near Prague, Czech Republic, with respect to Eurofer-97 steel and tantalum to determine C/E cross section ratios (comparison of the measured data with the predictions of various computer models and evaluated libraries). Both measurements and evaluation efforts are required in the derivation of dosimetry reaction cross sections and their uncertainties above 20 MeV, while gas production measurements and theoretical calculations deviate considerably above ~ 30 MeV.

Simakov provided details of individual reactions for which neutron cross section files are required in the design and operation of IFMIF. The white neutron energy spectrum of this materials testing facility up to ~ 55 MeV will be created by two 40-MeV deuteron beams of 125 mA each. Various computational tools and neutronic predictions will need to be benchmarked by means of experimental studies within this facility. The IFMIF test cell spectra obtained from transport simulations are smooth functions of neutron energy without any prominent peaks at 14 MeV. These spectra differ considerably from the spectrum of a typical fusion device which peaks at 14 MeV, with a long low-energy tail and almost no flux above 15 MeV. Data needs were tabulated in terms of the location of the cross section maxima and relative to available evaluated and experimental data (Table 2). Specific reactions were reviewed in detail by Simakov:

^{nat}Al(n,x)^{24}Na from ^{27}Al(n,α) through ^{27}Al(n,3α) to ^{27}Al(n,npα);

^{nat}Fe(n,x)^{51}Cr from ^{54}Fe(n,α)^{51}Cr to ^{57}Fe(n,3nα)^{51}Cr;

^{59}Co(n,2n) ^{58}Co, ^{59}Co(n,3n)^{57}Co, and ^{59}Co(n,4n)^{56}Co;

^{169}Tm(n,3n)^{167}Tm;

^{197}Au(n,2n)^{196}Au, ^{197}Au(n,3n)^{195}Au, and ^{197}Au(n,4n)^{194}Au;

^{209}Bi(n,3n)^{207}Bi, ^{209}Bi(n,4n)^{206}Bi, ^{209}Bi(n,5n)^{205}Bi, and ^{209}Bi(n,6n)^{204}Bi.

The proposed NPI measurements of these and other reactions involve the irradiation of dosimetry foils for 10 to 12 hours. Calculations have also been carried out to assist in defining the dosimetry detectors and other experimental requirements for the IFMIF neutronics.

Measurements and evaluations of dosimetry reactions up to 60 MeV for the following:

(n,3-6n) reactions on Co, Tm, Bi and Au, and

(n,α) reaction on Al

have a high priority because their uncertainties are large (about 20-30%) and will be propagated directly into calculations of the final neutron spectrum.

ACTION 3: Participants agreed to consider the best means of formulating and assembling/ generating these particular cross section data files with uncertainty covariance matrices (by means of evaluation of experimental data and theoretical modelling).

3. CONCLUSIONS

Various actions were agreed as detailed in Table 1 to ensure improvements and corrections to IRDF-2002 [1]. These initial activities were agreed for completion by the end of 2007 if the re-evaluated data files can be made available by mid-2007 (^{58}Fe(n,γ), ^{63}Cu(n,2n), ^{32}S(n,p), ^{nat}Cd(n,x), etc.).

Proposed extensions for fusion applications will require considerably more effort and commitment (Table 2). Participants agreed to consider their possible involvement in such studies to extend and add new files to IRDF up to neutron energies of 60 MeV. This work would require evaluations of available experimental data in conjunction with evolving theoretical calculations with such codes as EMPIRE and TALYS that provide some fabric to sparse (and non-existent) data at neutron energies that can be modelled with emerging confidence. The situation needs to be reviewed on a case-by-case basis during the course and at the conclusion of the initial improvements of 2007.

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[1] O. Bersillon, L.R. Greenwood, P.J. Griffin. W. Mannhart, H.J. Nolthenius, R. Paviotti-Corcuera, K.I. Zolotarev, E.M. Zsolnay, P.K. McLaughlin, A. Trkov, *International Reactor Dosimetry File 2002 (IRDF-2002)*, IAEA Technical Reports Series No. 452, IAEA, Vienna, Austria, 2006, ISBN 92-0-105106-9; database archived at the International Atomic Energy Agency/Nuclear Data Section, Vienna, Austria - can be retrieved from: http://www-nds.iaea.org/irdf2002/ and also through: http://www-nds.iaea.org/exfor/endf00.htm.

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[6] L.R. Greenwood, R.R. Heinrich, M.J. Saltmarsh, C.B. Fulmer, *Integral Tests of Neutron Activation Cross Sections in a $^{9}Be(d,n)$ Field at $E_d = 40$ MeV*, Nucl. Sci. Eng. **72** (1979) 175-190.

[7] D. L. Aldama, A.Trkov, FENDL-2.1: *Evaluated Nuclear Data Library for Fusion Applications*, IAEA report INDC(NDS)-467, IAEA, Vienna, Austria, 2004.

Table 1: Existing IRDF-2002 Database: Specific Problems.

Reaction	Status/Comments	Actions	
		Communicate	Assess/Accept
IAEA Neutron Cross Section Standards: H(n,n) ^{3}He(n,p) ^{6}Li(n,t) ^{10}B(n,α) ^{10}B(n,$\alpha_1\gamma$) C(n,n) Au(n,γ) ^{235}U(n,f) ^{238}U(n,f)	Released in 2006 - adopt files and use in all future IRDF evaluations	IAEA Web	Zsolnay /Nolthenius
^{55}Mn(n,γ) ^{58}Fe(n,γ) ^{93}Nb(n,γ)	ORNL/IRMM collaboration IAEA/Moxon evaluation IRDF-2002 is incorrect; entry is total capture cross section, and not (n,γ) cross section for ^{94}Nb production – assess JEFF-3.1 and ENDF/B-VII files	IAEA IAEA IAEA Web	Zsolnay /Nolthenius Zsolnay /Nolthenius Zsolnay /Nolthenius
^{23}Na(n,γ) ^{93}Nb(n,γ) ^{115}In(n,γ)^{116m}In ^{181}Ta(n,γ) ^{232}Th(n,γ)	Assess JEFF-3.1 and ENDF/B-VII files Assess JEFF-3.1 and ENDF/B-VII files Assess JEFF-3.1 and ENDF/B-VII files New measurements have been carried out Assess/adopt data file(s) from Th-U CRP (includes extensive covariances)	IAEA Web IAEA Web IAEA Web IAEA IAEA	Zsolnay /Nolthenius Zsolnay /Nolthenius Zsolnay /Nolthenius Zsolnay /Nolthenius Zsolnay /Nolthenius
^{47}Ti(n,p)	New evaluation, 2003 (Zolotarev)	IAEA Web	Zsolnay /Nolthenius

$^{63}Cu(n,2n)$ $^{65}Cu(n,2n)$ $^{64}Zn(n,p)$ $^{197}Au(n,2n)$ $^{199}Hg(n,n')$ $^{27}Al(n,p)$	New evaluation, 2006 (Zolotarev) New evaluation, 2006 (Zolotarev) New evaluation, 2006 (Zolotarev) New evaluation, 2006 (Zolotarev) New evaluation, 2006 (Zolotarev) New evaluation over 6 to 10 MeV energy interval only, 2006 (Zolotarev)	IAEA Web IAEA Web IAEA Web IAEA Web IAEA Web IAEA Web	Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius
$^{24}Mg(n,p)$ $^{32}S(n,p)$ $^{60}Ni(n,p)$ $^{115}In(n,2n)^{114m}In(50d)$ $^{127}I(n,2n)$	Planned evaluation, 2007 (Zolotarev) Planned evaluation, 2007 (Zolotarev) Planned evaluation, 2007 (Zolotarev) Planned evaluation, 2007 (Zolotarev) Planned evaluation, 2007 (Zolotarev)	Zolotarev Zolotarev Zolotarev Zolotarev Zolotarev	Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius
$^{103}Rh(n,\gamma)$ $^{103}Rh(n,n')$	ORNL/IRMM collaboration	IAEA	Zsolnay/Nolthenius
$^{nat}Cd(n,x)$	IRMM/Moxon/IAEA measurements and evaluation underway	IAEA	Zsolnay/Nolthenius
$^{nat}Ti(n,x)^{47}Sc$ $^{50}Cr(n,\gamma)$ $^{55}Mn(n,2n)$ $^{57}Fe(n,np)$ $^{151}Eu(n,\gamma)$	Assess JEFF-3.1 and ENDF/B-VII files Assess JEFF-3.1 and ENDF/B-VII files Assess JEFF-3.1 and ENDF/B-VII files Assess JEFF-3.1 and ENDF/B-VII files Assess JEFF-3.1 and ENDF/B-VII files	IAEA Web IAEA Web IAEA Web IAEA Web IAEA Web	Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius Zsolnay/Nolthenius
photo fission cross sections	Consider for adoption in IRDF for dosimetry applications - list reactions of interest. Refer to ENDF/B-VII and IAEA-CRP.	IAEA Web	Greenwood
nuclear constants and decay parameters	Need to explain in the next release of IRDF that the recommended files do <u>not</u> contain nuclear decay data and fission yields for the significant numbers of fission products generated by (n,f) reactions – refer user to other appropriate database(s).		
covariances	Consider feasibility of replacing simple diagonal covariances in all IRDF files with comprehensive uncertainty matrices (on a case-by-case basis).		IAEA

Table 2: Proposed Extension to IRDF-2002 Database: Fusion Applications (up to 60 MeV).

Reaction	Upper energy limit (MeV)	
	IRDF-2002	**Experimental data**
Maximum cross section below 10 MeV		
^{93}Nb(n,n')^{93m}Nb	< 20	< 15
^{103}Rh(n,n')^{103m}Rh	< 20	< 17
^{115}In(n,n')^{115m}In	< 20	< 20
Maximum cross section between 10 and 20 MeV		
^{27}Al(n,α)^{24}Na	< 20	< 50
^{nat}Ti(n,x)^{48}Sc	< 20	< 20
^{55}Mn(n,2n)^{54}Mn	< 20	< 40
^{nat}Fe(n,x)^{56}Mn	< 20	< 15
^{59}Co(n,α)^{56}Mn	< 20	< 20
^{59}Co(n,p)^{59}Fe	–	< 55
^{59}Co(n,2n)^{58}Co	< 20	< 75
^{nat}Ni(n,x)^{57}Co	–	< 150
^{nat}Ni(n,x)^{58}Co	< 20	< 150
^{nat}Ni(n,x)^{60}Co	< 20	< 20
^{89}Y(n,p)^{89}Sr	–	< 20
^{89}Y(n,2n)^{88}Y	< 20	< 28
^{90}Zr(n,2n)^{89}Zr	< 20	< 28
^{93}Nb(n,2n)^{92m}Nb	< 20	< 24
^{197}Au(n,2n)^{196}Au	< 20	< 38
^{169}Tm(n,2n)^{168}Tm	< 20	< 28

Maximum cross section above 20 MeV		
$^{nat}Fe(n,x)^{51}Cr$	< 20	< 150
$^{nat}Fe(n,x)^{54}Mn$	< 20	< 150
$^{nat}Ti(n,x)^{46}Sc$	< 20	< 112
$^{nat}Ti(n,x)^{47}Sc$	< 20	< 20
$^{59}Co(n,3n)^{57}Co$	–	< 80
$^{59}Co(n,4n)^{56}Co$	–	< 80
$^{nat}Ni(n,x)^{57}Ni$	< 20	< 110
$^{169}Tm(n,3n)^{167}Tm$	–	< 30
$^{197}Au(n,3n)^{195}Au$	–	< 28
$^{197}Au(n,4n)^{194}Au$	–	< 38
$^{209}Bi(n,3n)^{207}Bi$	–	< 40
$^{209}Bi(n,4n)^{206}Bi$	–	< 90
$^{209}Bi(n,5n)^{205}Bi$	–	< 100
$^{209}Bi(n,6n)^{204}Bi$	–	< 147

APPENDIX 1

International Atomic Energy Agency

Consultants' Meeting (CM) on

Review of requirements to improve and extend the IRDF library

IAEA Headquarters, Vienna, Austria
25-26 January 2007

AGENDA

Thursday, 25 January 2007

09:00-09:15	Welcome and practical matters
09:15–09:30	Approval of the Agenda
09:30-10:30	IRDF-2002 recognised problems within the existing database, and cures
10:30-11:10	*Administrative matters/coffee break*
11:10-12:00	IRDF-2002 recognised problems within the existing database, and cures (cont'd.)
12:00-13:30	*Lunch*
13:30-16:30*	Extension of IRDF-2002 to higher energies: Fusion applications and requirements for dosimetry data Other issues with respect to extensions – theory, validation, covariance data
16:30-17:30	Discussion: future work on IRDF (e.g., for IFMIF, International Fusion Materials Interaction Facility)
19:00	*Social Event (Dinner Restaurant Pürstner)*

Friday 26 January 2007

09:30-10:30	Discussion: future work on IRDF (e.g., for IFMIF, International Fusion Materials Interaction Facility) (cont'd.)
10:30-10:50	*Coffee break*
10:50-12:00	Future plans
12:00-12:30	Any other business

**Coffee break as appropriate*

APPENDIX 2

International Atomic Energy Agency

Consultants' Meeting (CM) on

Review of requirements to improve and extend the IRDF library

IAEA Headquarters
Vienna, Austria

25-26 January 2007

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APPENDIX 3

Re-evaluation of Microscopic and Integral Cross Section Data for Important Dosimetry Reactions

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PAPER AVAILABLE ON WEB:

http://nds121.iaea.org/irdf2002ext/

Ideas and Problems to be Solved in Connection with IRDF-2002, and with the Preparation of a New Dosimetry File up to 40-MeV Neutron Energies

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1. Proposed extension of IRDF-2002 up to 40 MeV

1.1. Requirements for the reactor dosimetry library (energy region from thermal up to 20 MeV)

a) Availability of the cross section data (besides the pointwise format) in the special 640 (SAND) energy group structure together with uncertainty information in the form of covariance matrices.

b) The cross section data to be compared with experimental measurements in the following standard neutron fields [Wag03 , Sum02, Pro78]:

- Maxwellian thermal neutron spectrum;
- 1/E neutron field;
- ^{252}Cf spontaneous fission neutron spectrum;
- Monoenergetic 14-MeV neutron field from a D-T source.

c) Availability of typical dosimetry reactions used in the fission neutron energy region (from thermal to 20 MeV).

d) The dosimetry library should be assembled in a special format ("Metrology file format") so that the data can be processed by the neutron spectrum adjustment codes used by the Reactor Dosimetry Community (no MF= 10, and everything in MF=3; special MT numbers are used, see Appendix 1 of [TECR452]).

1.2. Problems in the preparation of the same cross section library to cover reactor dosimetry and other higher-energy neutron applications (above 20 MeV)

a) *Extending the cross section data up to 40 MeV in pointwise format is not a problem, but there are several problems related to the groupwise format for a high-energy neutron library*:

- E > 20 MeV neutron energy region - no uncertainty information (especially in the form of covariance matrices) is available for the majority of the reactions of interest. If we try to extend the group format of IRDF-2002 to high neutron energies (where the corresponding uncertainty information is missing), the new library would not be consistent. Better to make a separate group format library up to 40 MeV (if necessary) with no or limited uncertainty information for fusion applications. However, Larry Greenwood has experience with high neutron energy data, and his thoughts and opinions must be considered.
- The energy group structure needed for the "fusion cross section library" will differ from that used for fission dosimetry. Surely fewer energy groups are needed for the fusion library than 640 !

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- The MF=3 condition of the fission dosimetry library (as mentioned above) can not be used for fusion reactions because of the complexity of the possible neutron interactions.

b) Several reactions are used in the high neutron energy region that are not of interest in fission dosimetry; therefore, they are not present in IRDF-2002 (i.e. different dosimetry reactions are used in fission and fusion neutron fields).

c) Not enough standard (reference) neutron spectra data are experimentally available in the high neutron energy region to validate the evaluated cross section data. No comparison with experimental data will be possible for several reactions needed for dosimetry in this range. How can we determine the goodness of these data?

Due to all the above mentioned problems, I recommend the creation of two libraries, i.e. data of IRDF-2002 can be extended up to 40 MeV neutron energy for fusion purposes, but the fission and fusion dosimetry libraries should be handled separately.

2. Problems to be solved in connection with IRDF-2002

The shortcomings and problems to be solved in connection with IRDF-2002 can be found in the conclusion of chapters 3 and 6 of the technical report [TECR452]. Considering what has been said in these chapters and adding some newly-discovered shortcomings, the following problems should be solved in the first revision of IRDF-2002:

a) Reliable cross section uncertainty information should be derived for the reference reactions Au197G and U235F. While the corresponding data were withdrawn from ENDF/B-VI, and the ENDF/B-VII file has became available [ENVII].

b) The resonance integral should be improved for several important dosimetry reactions such as Mn55G, Fe58G (?) and Nb93G.

c) Only diagonal covariance matrices are available for a number of reactions: Na23G, Nb93G, In115G (leading to In116m), Ta181G and Th232G (latter only below 15 eV). New evaluations with complete covariance information are needed for as many of these reactions as possible.

d) The nuclear data properties (isotopic abundance, decay data of the reaction products, etc.) of IRDF-2002 are incomplete: decay data are missing for the fission reactions present in the cross section library, namely for the U235, Th232, U238, Np237, Pu239 and Am241 targets. These data should be made available in order to make the file consistent (O. Bersillon).

e) V. Pronyaev has stated that the total cross section of Cd (used as cover material in reactor dosimetry) was not correct. I do not know whether efforts are being made to improve these particular data (?) If not, this problem will have to be investigated and solved.

f) Checks have been made of the cross sections in IRDF-2002 that were originally taken from IRDF 90 by comparing them with the corresponding IRDF-90 data. There are some important deviations between the two sets of data that need to be investigated (including a study of the original conversion process).

g) No suitable cross section data have been found in the literature for several reactions needed for dosimetry (see footnotes to Table 3.1 and Chapter 3.2.2. of [TECR452]).

References

[Wag03] J. Wagemans, H. A. Abderrahim, P. J. D'Hondt, Reactor Dosimetry in the 21st Century, Proc. 11th Int. Symp. on Reactor Dosimetry, Brussels, Belgium, 18-23 August 2002, World Scientific Publ. Co. Ltd. (August 2003).

[Sum03] L. R. Greenwood, R. Paviotti-Corcuera, *Summary Report of the Technical Meeting on International Reactor Dosimetry File: IRDF-2002*, Vienna, 27-29 August 2002, IAEA Report INDC(NDS)-435, IAEA, Vienna, Austria, September 2002.

[Pro78] Neutron Cross Sections for Reactor Dosimetry, Proc. Consultants' Meeting, 25-20 September 1976, Vienna, IAEA TECDOC Series No. 208, Vol. 1 (1978), IAEA, Vienna, Austria.

[TECR452] O. Bersillon, L.R. Greenwood, P.J. Griffin. W. Mannhart, H.J. Nolthenius, R. Paviotti-Corcuera, K.I. Zolotarev, E.M. Zsolnay, P.K. McLaughlin, A. Trkov, *International Reactor Dosimetry File 2002 (IRDF-2002)*, IAEA Technical Reports Series No. 452, IAEA, Vienna, Austria, 2006.

[ENVII] for new file ENDF/B-VII see:
http://www.sciencedirect.com/science/journal/00903752
and on the homepage of NNDC, Brookhaven National Laboratory, USA:
http//www.nndc.bnl.gov/exfor7/endf00.htm

Relations Between the Various Files of IRDF-2002

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Relations of the various files of IRDF-2002 (H.J. Nolthenius)

A series of files are shown on the web page WWW-NDS.IAEA.ORG/IRDF2002:
i.e. Damage, Decay Data, Pointwise Data (in MS Windows and also in Linux format), Groupwise, Metrology, Plots, Document and Codes.

The Groupwise and Metrology files are converted and adapted versions of the Pointwise data. Conversion from Pointwise data to the **Groupwise** form was achieved through PREPRO 2002 (2002 ENDF/B Pre-Processing Codes, Nuclear Data Section, IAEA, Vienna, Austria) - LINEAR, RECENT, SIGMA1, FIXUP and GROUPIE programs were applied.
Mathematical precision was 1% for the programs applied in the conversion.
The neutron temperature for these data is 300 K (previous files such as the ENDF/B-V dosimetry file and IRDF-90 were for 0 K).

The Groupwise file has the extended SAND-II structure. Weighting was performed with a flat spectrum, and unshielded group cross sections were calculated. The format of the file is ENDF/B-6 (with MF=10 and the original MT numbers).

The Groupwise file was used to generate the Metrology file in the simplified ENDF/B-6 format - reactions leading to a metastable reaction product (that were originally stored in MF=10 of the ENDF/B-6 format) are written in MF=3 with special MT numbers. Details are given in Appendix 1 of IAEA Technical Reports Series No. 452 (2006). This conversion was carried out by means of the T10T3 utility program.
A requirement for the Metrology file is that the lower energy of the cross section and uncertainty information should be the same in the group structure applied. However, no software was available for this purpose, and therefore some editing was required. The Damage data for a few reactor materials as given in a separate file was merged in the Metrology file – the PREPRO 2002 program MERGE was used for this exercise.

Documentation

Not all modifications of the cross section files are documented in Technical Reports Series No. 452 (2006). For example, Q_i values were updated for a number of reactions, and the lower cross section value was corrected for several reactions.

Software

During the testing and preparation of the IRDF-2002, some difficulties with the software were experienced.

The requirement for an equal lower boundary for the cross section and uncertainty should be inserted in GROUPIE.
The T10T3 program should be made more official.
The decay data file is not particularly easy to read – a suitable utility program is required.

Nuclear Data Needs for IFMIF

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Activation Dosimeters for IFMIF-relevant Neutron Spectra

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