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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

IAEA Advisory Group Meeting

on

Nuclear Data for Radiation Damage Assessment and Related Safety Aspects

Vienna, 12-16 October 1981

Summary Report

Edited by
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Nuclear Data Section
International Atomic Energy Agency

January 1982

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Summary Report

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Abstract

This Advisory Group Meeting on Nuclear Data for Radiation Damage Assessment and Related Safety Aspects was convened by the IAEA Nuclear Data Section, at IAEA Headquarters in Vienna, Austria, from 12-16 October 1981. The meeting was attended by 34 participants from 15 countries and 2 international organizations.

The main objective of the meeting was to review the requirements for and the status of nuclear data needed for radiation damage estimates in reactor structural materials and related reactor safety aspects, and to develop recommendations to the Nuclear Data Section of the IAEA for its future activities in this field.

Summary of the meeting

A. Introduction

The Advisory Group Meeting on Nuclear Data for Radiation Damage Assessment and Related Safety Aspects was convened by the IAEA Nuclear Data Section at IAEA Headquarters in Vienna, Austria, from 12-16 October 1981. The meeting was attended by 34 participants from 15 Member States and 2 international organizations. The list of participants is given in Appendix 1.

B. Objectives

The primary objective of this meeting was to review the requirements for and the status of nuclear data needed for radiation damage estimates in reactor structural materials and related reactor safety aspects, and to develop recommendations to the Nuclear Data Section of the IAEA for its future activities in this field.

The adopted agenda is given in Appendix 2 and the list of papers presented to the meeting by the participants is given in Appendix 3. The papers presented at this meeting are scheduled to be published as a separate technical document of the IAEA.

C. Conclusions and Recommendations

The conclusions and recommendations of the IAEA AGM on Nuclear Data for Radiation Damage Assessment and Safety Aspects consist of three separate reports developed by the participants of the three workshops which took place during the meeting on 15 and 16 October 1981.

1. Workshop on Nuclear Data for Environment Characterization.

2. Workshop on Status of Nuclear Data for Radiation Damage calculations (in terms of d.p.a.) and Damage Correlation Estimates.

3. Workshop on Evaluation of Preliminary Results of the REAL-80 (Reaction Rate Estimates, Evaluated by Adjustment Analysis in Leading Laboratories) International Exercise.

Conclusions and recommendations

Workshop 1. Nuclear Data for Environment Characterization

Chairman L.R. Greenwood

1. Requests for dosimetry cross section measurements have been made to the U.S. Cross-Section Evaluation Working Group (CSEWG) and to the World Request List for Nuclear Data of the IAEA (WRENDA). However, there are also discrepant reaction cross sections in ENDF/B-V, such as $^{47}Ti(n,p)$, $^{60}Ni(n,p)$, and $^{63}Cu(n,\alpha)$. It is recommended that IAEA prepare a file of all significant discrepancies in the ENDF/B-V Dosimetry and IRDF data files and stimulate reevaluation of these discrepant cross-sections.

2. The time interval between ENDF/B-V and IRDF data evaluations is too long and some files are already outdated. These dosimetry files should thus be reviewed more frequently with respect to the most discrepant reactions or significant new data, perhaps by IAEA; also this may be done with the new ENDF-A data file of integrally adjusted dosimetry cross-sections.

3. Integral cross section measurements for dosimetry reactions in well-known neutron fields should be considered during the evaluation of neutron cross sections. These data should then be included in the data files.

4. In order to insure the consistency of evaluated neutron cross sections and activity measurements, essential nuclear decay data, isotopic abundances, and fission yields should be included in evaluated dosimetry nuclear data files.

5. The particularly important Rh(n,n') and Nb(n,n') dosimetry reactions should be included in the ENDF/B-V and IRDF data files.

6. It is recommended that IAEA circulate a ^{93m}Nb(16 y) standard for calibration purposes, similar to the previous effort with Rhodium. Guidelines for self-absorption corrections should be included with the standard.

7. The critical reviews of nuclear data by IAEA-INDC are particularly useful to the international community and this work should be encouraged.

8. It is recommended that IAEA promote sensitivity studies of covariance matrices for neutron dosimetry cross sections and neutron input flux spectra. IAEA should also summarize and distribute available covariance information in an easily readable and condensed form, such as the recent work by D. Muir. The variances in this ENDF/B-V-based file should be adopted for unfolding; however, the covariance files must be

tested. It is also recommended that IAEA support the generation of computer codes designed to construct covariance matrices, especially for resonance parameter data contained in ENDF formated files, and to transform covariance matrices between different group structures.

9. At present it is often very difficult to construct covariance matrices from available documentation. The Nuclear Data Section of the IAEA should advertise the necessity of proper documentation of experimental nuclear data measurements so that covariance information can be obtained. It is especially important that the correlations between different sources of uncertainty are clearly stated.

10. Covariance uncertainty matrices should be generated for all benchmark, standard, reference, or controlled environment neutron fields to allow the proper propagation of uncertainties in nuclear data measured in these spectra.

11. The ^{252}Cf neutron spectrum should be remeasured above 7 MeV with a goal accuracy better than 10 %.

Workshop 2. Status of Nuclear Data for Radiation Damage Calculations and Damage Correlation Estimates

Chairman W. Schneider

The participants have discussed the quality and availability of displacement cross-section data. The following conclusions and recommendations were made.

1. It is recommended, for the time being, to use the following sets of displacement cross sections: ASTM and Euratom (for 640 neutron energy groups and for neutron energies up to 20 MeV). The data sets are based on ENDF/B-IV (ASTM) and ENDF/B-III (Euratom) libraries. These sets have been published in: ASTM Standard E 693-79 and included in EUR 5274 (in 50 energy groups); the Euratom set will be published in the DAMSIG-81 data library (in 640 groups) *). These recommended sets should be applied particularly for damage evaluation for pressure vessel steels in light-water reactors.

2. It is recommended to develop a new Reactor Radiation Damage Nuclear Data File of an international reference status within the next three years. This file should incorporate the file being prepared now in the U.S.A. which is based on ENDF data and which is expected to be issued in 1982 and made available internationally through the four nuclear data centers. It is understood that the released US-file will include data for Fe, Cr and Ni up to 20 Mev.

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*) available as report ECN-104 (Petten, November 1981)

It is recommended to supplement the future International Reactor Radiation Damage File, for Fe, Cr and Ni up to 40 MeV, and to include the data for Al up to 40 MeV with the first priority.
The data for Graphite, O, Ti, V, Mn, Cu, Zr, Mo, W up to 40 Mev and for Nb, Sn up to 20 Mev should be included in the file with second priority.

Few experimental data above 20 MeV exist. More experimental data are wanted, but in their absence one has to recur to theoretical calculations. Theoretical calculations of H and He production cross-sections show that at higher incident energies the contributions of reactions of the type (n,pp) and (n,pα) cannot be neglected for target nuclei with small neutron excess. Evaluations of needed changes in the energy dependence of the damage function should be considered in future theoretical and experimental research. For special purposes and environments (like e.g. D_2O reactors, strong γ-ray fields) the file should include the damage cross sections for (n,γ), (γ,n), and (γ,γ') reactions.

3. The Working Group recognizes the importance of neutron and gamma-ray kerma as a damage mechanism in organic materials such as fiberglass-reinforced epoxy. Some nuclear data for separate isotopes are required along with Q-values, nuclear decay data and spectra of emitted particles. The data for the following elements are essential in this context: Be, C, N, O, F, Na, Al, Si, Ca. The Working Group strongly supports the recommendations of the IAEA Advisory Group Meeting on Nuclear Data for Fusion Reactor Technology, Dec. 1978 (Ref. INDC(NDS)-101/LF, p. 14, 15) to create a kerma factor library with covariance information.

4. It is recommended to report uncertainties in the displacement or damage energy cross sections due to uncertainties in the nuclear data. The uncertainties should be reported in the form of a variance-covariance matrix. The uncertainty in the nuclear data should be based, if possible, on uncertainty information contained in the ENDF/B-V cross section library.

5. It is recommended that damage detectors are further developed and that the relationship between measured damage and displacement cross sections (as d.p.a.) is studied.

6. It is recommended to continue the study of competing damage processes (besides d.p.a.) in light water reactors, in fast breeder reactors and in fusion reactor investigations.

   For the calculations of gas production and solid transmutation accurate excitation functions would be necessary from threshold up to about 30 Mev for (n,γ); (n,xn); (n,tot.H) and (n, tot.He) mostly between 9 and 15 Mev. The list of important materials (e.g. Li, C, N, O, Al, Si, Ti, V, Cr, Mn, Fe, Ni, Cu, Zr, Nb, Mo, Pb) can be found in the IAEA biennial publication WRENDA.

The two-step process $^{58}Ni(n,\gamma)^{59}Ni(n,\alpha)^{56}Fe$ contributes considerably to the total helium production in stainless steels at high neutron fluences even in the fast neutron fields. It is recommended that in future work the contribution of this process should be duly accounted for.

It is further recommended that the Nuclear Data Section encourage measurements of total cross-sections up to 40 MeV for the above mentioned reactions. Such measurements are extremely useful for parametrization of nuclear model calculations.

7. The Advisory Group Meeting has noticed that the International Working Group for Reliability of Reactor Pressure Components has (in its Session in Vienna, 4-5 December 1980) agreed to the suggestion of preparing a Status Report of lifetime prediction and surveillance procedures for LWR pressure vessels, for studying the comparability and homogeneity of the procedures (and eventually for making recommendations for improving the homogeneity, by means of a Guidebook).

   This plan has found the support of the Advisory Group Meeting.

   It is recommended for this purpose to convene a small group of experts of reactor physicists, dosimetrists and metallurgists.

8. The Advisory Group Meeting urges the Nuclear Data Section to persuade the contributors of WRENDA to realistically redefine the accuracy requirements of their nuclear data needs pertinent to the scope of this meeting.

Workshop 3. Evaluation of Preliminary Results of the REAL-80 International Exercise

Chairman W.L. Zijp

The preliminary results obtained thus far were discussed in some detail, and some useful suggestions were made for the preparation of the final report on the REAL-80 project. Some particular problems mentioned in the preliminary REAL-80 report presented at this meeting received full attention.

1. It was felt that a separate and detailed study should be made on the effect of neutron self-shielding in activation detectors, and on the influence of cadmium, gadolinium and boron covers.

2. The occurrence of clearly different patterns of correlation matrices mentioned in the report was also discussed. It was noted that a study of this topic had already started in Budapest within the framework of REAL-80. Such a study is extremely useful for getting a better idea of the origin of different patterns of correlation matrices.

3. Also the problem of unlikely small values of the generalised chi-square parameter for the set of input data for the O.R.R. (Oak Ridge Research Reactor) received full attention. Often one might assume that the experimental values for reaction rates, cross sections and group flux densities are much better known than their uncertainties and correlation coefficients. One should always try to start the adjustment procedure with an input data set with a more likely value of chi-square. It is recognized that the consistency of all data used in an adjustment procedure plays an essential role. If the adjustment procedure leads to an unlikely value of chi-square, then the set of input data is inconsistent and the results of the adjustment algorithm are questionable. In this case the input data should be carefully examined in an attempt to improve their consistency. Any changes (which need not be equal for the different parameters) should be based on a good knowledge of the physics aspects of the adjustment problem.

   In general the internal consistency of the input data was considered to be more important than the particular algorithm of the adjustment code.

   With respect to actions in the future it was realised that one has a severe problem due to the fact that hardly any experimental correlation information is available for neutron spectra of interest. This may lead to a delay in any follow-up of the REAL-80 project.

   When a follow-up of REAL-80 is being organised, then one should include also a neutron spectrum representative for a reactor pressure vessel.

   It is expected that probably sufficient correlation data will be available within a short time for the benchmark fields of ISNF[1] and CFRMF[2] (based on sensitivity studies). With respect to the PCA[3] in the ORR poolside facility it was expected that in 1982 valuable covariance information on the neutron spectrum might become available. There was no strong support to include in a future exercise the ^{252}Cf fission neutron spectrum, since it was too well known by other techniques to expect improvement by adjustment procedures.

4. The following recommendations are based on the REAL-80 report, and the subsequent discussions in the workshop.

   a) The IAEA is advised to promote a detailed study of the problems of selfshielding and the influence of cadmium, gadolinium and boron covers.

   b) The IAEA is advised to organize an intercomparison of conversion procedures for processing of evaluated data to multigroup form.

   c) The IAEA should give support to studies for comparing the merits of several adjustment codes.

d) The IAEA should take into account the study of differences observed in the structure of correlation matrices, when preparing the final report on the REAL-80 exercise, and give the necessary support to the work already started at Budapest.

e) A possible follow-up of the REAL-80 project should be considered, when the final results of the present exercise have been communicated, and when more experimental information on correlation matrices for neutron spectra becomes available. The following spectra were in particular suggested for consideration in a future exercise: ISNF[1]; CFRMF[2] and PCA[3].

1) ISNF = Intermediate Spectrum Neutron Facility

2) CFRMF = Coupled Fast Reactivity Measurements Facility

3) PCA = Pool critical assembly

Appendix 1

List of participants

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Adopted Meeting Agenda

The titles of the sessions referred to in the Agenda are identified in the list of papers, Appendix 3.

12 October am	Introductory items
12 October am + pm	Presentation of Session 1 Papers Chairman L. Greenwood
13 October pm	Session 1 continued Chairman W. Schneider
13 October pm	Presentation of Session 2 papers Chairman W. Schneider
13 October pm	Presentation of Session 3 papers Chairman W. Schneider
14 October am + pm	Presentation of Session 4 and Session 5 papers Chairman D. Seeliger
15 October am	Presentation of Session 6 papers Chairman V. Sangiust
15 October pm	Parallel Workshops Workshop 1: Nuclear Data for Environment Characterization Chairman L. Greenwood Workshop 2: Status of Nuclear Data for Radiation Damage Calculations and Damage Correlation Estimates Chairman W. Schneider Workshop 3: Evaluation of Preliminary Results of the REAL-80 International Exercise Chairman W. Zijp
16 October am	Plenary Session. Discussion and Final Approval of Conclusions and Recommendations drafted by Workshops 1, 2 and 3. Chairman E.D. McGarry

Appendix 3

List of Presentations

Opening of the meeting
Opening Remarks, M. Zifferero, **Deputy Director General of the Department of Research and Isotopes, IAEA, Vienna**
Radiation Damage in Fission and Fusion Reactors; Related Safety, Design and Economic Aspects
R. Dierckx

Session 1:
Nuclear data required for the characterization of the radiation environment in fission and fusion reactors by means of activation and damage detector techniques. Uncertainties in the required data, status of covariance information.

ASTM Standard Recommended Guide on Application of ENDF/A Cross-Section and Uncertainty File: Establishment of the File
E.P. Lippincott and W.N. McElroy

Characterization of the Radiation Environment in Fission Reactors by the Activation Technique and Optimization of the Set of Nuclear Reactions of Possible Use
A. Cesana, G. Sandrelli, V. Sangiust, M. Terrani

Requirements for Referencing Reactor Pressure Vessel Surveillance Dosimetry to Benchmark Neutron Fields
E.D. McGarry

Status and Further Needs of Cross-Section Covariance Files
W. Mannhart

TASHI Results for Dosimetry Multigroup Cross-Sections and their Uncertainties
M. Petilli

Results of Neutron Fluence Monitors at the PSF Simulated Pressure Vessel Irradiation Facility
W. Mannhart

Sensitivity Coefficients of Neutron Fluence Detectors in the PCA/PSF Neutron Field
W. Mannhart

Relevance of Nonlinear Effects of Uncertainties in the Input Data on the Calculational Results
F. Carvalho Da Silva, A. D'Angelo, A. Gandini, V. Rado

Neutron Flux and Spectral Measurements for Materials Studies
L.R. Greenwood

Nuclear Data Needs and Standard Spectra for the Measurements and Analyses of d-Li Neutron Spectra
R. Dierckx, A. Cesana, M. Terrani, V. Sangiust

The Basic Principles of a Computerized Information System SAIPS
M.A. Berzonis, H.Y. Bondars

Neutron Dosimetry for Surveillance Test Purposes in the KFKI WWR-SM Research Reactor
J. Vegh, I. Vidovszky

Radiation Damage Experiment in a Spallation Neutron Spectrum
R. Dierckx

Pressure Vessel Surveillance Dosimetry Using Solid State Track Recorders
F.H. Ruddy, R. Gold, J.H. Roberts

Proton-Recoil Emulsion Observations for Integral Neutron Dosimetry
R. Gold, J.H. Roberts, F.H. Ruddy, C.C. Preston, C.A. Hendricks

A Simple Model for Calculation of Fast Neutron-Induced γ-Ray Spectra
B. Basarragtscha, D. Hermsdorf, D. Seeliger

Neutron Cross Section Calculations for ^{52}Cr, ^{55}Mn, ^{56}Fe and $^{58,60}Ni$ for Incident Energies up to 30 MeV
B. Strohmaier, M. Uhl, W. Reiter

Spectral Indices of some Threshold Reactions Measured in Uranium 235 Fission Spectrum
I.N. Acquah, B. Glumac, I. Remec, M. Najzer

Neutron Measurement with the $^{93}Nb(n,n')^{93m}Nb$ Reaction
K. Sakurai

Session 2:
Nuclear data required for the characterization of the radiation environment in fission and fusion reactors by means of theoretical neutron transport calculations. Uncertainties in the required data, status of covariance information.

Neutron Spectra Calculation in Material in Order to Compute Irradiation Damage
C. Dupont, J. Gonnord, A. le Dieu de Ville, J.C. Nimal, B. Totth

Session 3:
Status of displacment cross-sections, related nuclear data requirements, models for calculation of radiation damage in materials, sensitivity to uncertainties.

Status of Displacement Cross-Sections
P. Stiller

Displacement Cross Sections in Neutron-Irradiated Metals
T. Iwata, S. Takamura, H. Maeta, T. Aruga

Displacement Damage Calculations with ENDF/B-V
L.R. Greenwood, R.K. Smither

Effect of Uncertainties in Neutron Spectra and Fluences Determination on the WWER Pressure Vessel Lifetime Prediction
M. Brumovsky, B. Osmera, V. Valenta

Session 4:
Status of data required for calculations of gas production and transmutation. Uncertainties in the required data, status of covariance information.

Use of 14 MeV Generators for Radiation Damage Studies
J. Csikai

Status of Neutron Data Required for Calculations of Gas Production and Transmutation
J. Csikai

Session 5:
Correlations between the results of microscopic damage calculations and macroscopic property changes in irradiated materials. Uncertainties involved and their effect on life-time prediction of reactor structural components including pressure vessels.

Correlation of Macroscopic Material Properties with Microscopic Nuclear Data
R.L. Simons

Accuracy and Consistency in Irradiation Tests of LWR Pressure Vessel Steels
W. Schneider

G.A.M.I.N. and Tungsten Damage/Activation Ratio Correlations for Irradiation Effects Evaluation in Pressure Vessel Steels
A. Alberman, M. Thierry, P. Mas, R. Perdreau

Session 6:
Discussion of first results of the international project REAL-80 for the intercomparison of radiation damage (displacements per atom) estimates

First Results of the REAL-80 exercise
W.L. Zijp, C. Ertek, E.M. Zsolnay, E.J. Szondi, H.J. Nolthenius, D.E. Cullen

Results of HEDL Calculations on the REAL-80 Project
E.P. Lippincott, D.L. Oberg

Unfolding of REAL-80 Sample Data by ITER and STAYSL Codes
B. Glumac, M. Najzer

Conclusions and Recommendations of the IAEA Advisory Group Meeting on Nuclear Data for Radiation Damage Assessment and Safety Aspects