Report

AEAT-1089
INDC(UK)053-LN

UK Nuclear Science Forum

Progress Report: Data Studies During 1996

Edited by A L Nichols

Magnox Electric Contract: NSF Support
Contract Numbers BL/G/44212/C - 1996/97
BL/G/52500/C - 1997/98
Reference Number: RPS/GNSR/5002
Milestone M5

May 1997

AEA Technology

The information which this report contains is accurate to the best knowledge and belief of AEA Technology, but neither AEA Technology nor any person acting on behalf of AEA Technology make any warranty or representation expressed or implied with respect to the accuracy, completeness or usefulness of this information, nor assume any liabilities with respect to the use of, or with respect to any damages which may result from the use of any information, apparatus, method or process disclosed in this report.

	Name	Signature	Position	Date
Lead Author	A L Nichols		Department Head	2 June 97
Checked	C J Dean		Project Manager	7 June 1997
Approved	A L Nichols		Department Head	11 June 97

CONTENTS

1. INTRODUCTION

The UK Nuclear Science Forum (UKNSF) is deemed to be the appropriate body within the UK for technical discussions on the measurement and evaluation of nuclear data (e.g., neutron cross sections, decay data and fission yields). The Forum also has the support of the UK Department of Trade and Industry and the nuclear-based Industry Management Committee (IMC) to act as the communications network for all matters relating to the NEA Data Bank/Nuclear Science Committee and the IAEA-Nuclear Data Section.

Two meetings of the UKNSF were held in 1996 on 16 May and 5 December (Chairman, A L Nichols (AEA Technology, Harwell) and Secretary, R W Mills (BNFL plc)). Membership covers approximately 20 different organisations, including nuclear plant operators, vendors, regulators, non-energy applications, academia, and various data measurers and evaluators. A comprehensive request list has been prepared for nuclear data needs within the UK, covering both measurement and evaluation requirements (1). This document represents the up-to-date situation within the UK nuclear industry, following a major review and the deletion of a significant number of requests for fast-reactor data.

2. MEASUREMENTS

2.1 Decay Scheme Data

(S I Kafala, T D MacMahon, D Sardari and K Usman (Centre for Analytical Research in the Environment, Imperial College at Silwood Park, Ascot))

(i) The half-life of ^{233}Pa is being determined by gamma-ray spectrometry. Gamma-ray spectra of ^{233}Pa sources produced in the Imperial College reactor are being measured for several half-lives.

(ii) International Decay Data Evaluation Project: Imperial College is participating with collaborators at Idaho Falls, Brookhaven and Lawrence Berkeley Laboratory, USA, LPRI, France, PTB, Germany, CIEMAT, Spain and Khlopin Radium Institute, Russia, in a project to provide evaluated decay scheme data for the following databases:

(a) ENSDF,
(b) new LPRI/PTB Table de Radionucleides,
(c) IAEA decay data database.

(iii) Studies have been completed on the decay of ^{239}U and ^{243}Am to the nuclear levels of ^{239}Np (2), and conversion-electron data have been assessed to determine the decay parameters of ^{104}Rh nuclear levels (3).

2.2 Nuclear Decay Data

(S A Woods (Radioactivity Measurement Group, National Physical Laboratory, Teddington))

Work within the field of radionuclide decay data has continued at NPL, predominantly associated with standards of importance to the UK measurement community. NPL has also continued to provide recommended radionuclide decay data upon demand.

(i) Further standardisations and measurements have been performed on selected decay scheme parameters of $^{237}Np/^{233}Pa$ equilibrium solutions. Whilst problems with the chemistry of such solutions have largely been reconciled, further complications have arisen due to the presence of plutonium radionuclides as contaminants. Purified solutions have been prepared and the work continues.

(ii) ^{153}Sm is a radionuclide of increasing importance in medical physics. Solutions of ^{153}Sm have been standardised and gamma-ray emission probabilities determined.

(iii) Participation in EUROMET Project no. 325, "Analysis of Plutonium Alpha-Particle Spectra", has been completed and the results published as part of a CEC-JRC, IRMM Report GE/R/RN/01/96, May 1996.

(iv) Samples of ^{133}Xe have been standardised under the auspices of a EUROMET intercomparison.

(v) An ICRM intercomparison of tritiated water standards is nearing completion. Initial results show agreement between the participating laboratories.

With the exception of item (iii) above, scientific papers on these work programmes have been submitted to a forthcoming meeting of the International Committee for Radionuclide Metrology to be held in Gaithersburg, USA, 19-23 May 1997. The financial support of the National Measurement System Policy Unit of the UK Department of Trade and Industry is acknowledged for the work listed above.

2.3 Epithermal Neutron Beam for Use in Boron Cancer Therapy

(D Tattam and D R Weaver (University of Birmingham))

Work is underway to produce a well-characterised epithermal neutron beam for use with Boron Cancer Therapy (BCT). Neutrons are produced by bombarding a thick lithium metal target with protons; these neutrons are partially moderated to epithermal energies in heavy water. The transport of neutrons through the moderator is calculated using the Monte Carlo code MCNP, which calls upon ENDF/B-V for neutron cross-section data. Current experimental work uses activation foils, boron trifluoride proportional counters, TLD and microdosimetric measurements in a water head-phantom. MCNP simulations have been favourably compared with the experimental work.

2.4 Fast Fission of ^{238}U: Delayed Neutron Yields

(M A Kellett and D R Weaver (University of Birmingham))

The experimental phase of the project has now been completed on the 3 MV Dynamitron facility, and work is concentrating on the analysis of these results.

A series of measurements were performed using three different samples (9.6, 24 and 48g) of depleted uranium with ^{238}U content of 99.7%. The same studies were also carried out for a sample of highly-enriched ^{235}U (99.3% and 40g). Various mono-energetic neutron beams over the ranges 1.4 to 2.0 MeV and 4.2 to 5.7 MeV were used, along with timing cycles involving 20 and 40 sec irradiations and count periods.

A paper has been submitted to the 5th International Conference on Nuclear Data to be held in Trieste, May 1997.

2.5 Site Characterisation to Determine the Extent of Land Contamination

(A Meehan (University of Birmingham) and M Phillips (Magnox Electric))

World-wide, thousands of sites have been used in the production, processing, use and storage of radioactive materials. In order to release such sites for public use, surveys must be carried out to facilitate remediation (where necessary), and build a technically defensible safety case to demonstrate with confidence that the site will be of minimal risk to future public health. Magnox Electric have developed a portable gamma-spectrometry system, linked with global positioning technology and modern surveying techniques, to enable rapid site characterisation. Spectral data obtained in such a manner have been used to produce semi-threedimensional maps of sites illustrating levels of contamination in terms of the gamma flux 1 meter above the ground. These maps expedite estimates of the volume of contaminated land above clearance levels, and have been used to provide an indication of the financial provision required to manage such waste streams.

3. DATA LIBRARIES: EVALUATIONS

3.1 Data Library Developments

The status of the UK Decay Data and Fission Yield Libraries is summarised in Table 1. Progress has been maintained in the evaluation of specific decay data (primarily activation products). These studies have been undertaken to assist in the further development of the Joint Evaluated Fission and Fusion Files (JEFF).

Table 1: *UKNSF Decay Data and Fission Yield Libraries - Status Table, December 1996.*

Data	Present status	File development
Fission product decay data	UKFPDD-2 evaluations (ENDF/B-V format) were submitted for JEF-1.1 and partially included. Some of these evaluations have been carried through to JEF-2.2.	None, but see UKPADD-3.
Activation product decay data	UKPADD-3 library (ENDF/B-VI format) has been completed: comprehensive decay-scheme data for 328 activation products (and some fission products) have been evaluated for this library, including the addition of 97 further radionuclides.	Decay data for further sets of radionuclides (including some fission products) are being evaluated, as agreed through the NEA Data Bank (see Section 3.1(a), below).
Heavy element and actinide decay data	UKHEDD-2 evaluations (ENDF/B-VI format) have been submitted and absorbed into JEF-2.2.	UKHEDD-2.1 includes newly recommended decay data for Pa-234g, Pa-234m and Th-234.
Fission yields	UKFY-2 has been submitted and accepted into JEF-2.2. A minor update to make the yields consistent with the JEF-2.2 decay data was completed in July 1993.	The evaluations for UKFY-3 have been completed, and a file produced for use with JEF-2.2 decay data. A further update is envisaged when JEFF-3 decay data become available.

(a) Activation and Fission Product Decay Data - Evaluations (A L Nichols (Harwell))

Discussions were initiated in mid-1995 to focus the limited amount of UK evaluation effort on improving the quality of the decay data for a specific number of radionuclides of particular interest to the nuclear industry. Lists of problematic nuclides were assembled that were initially based on discussions involving the JEF Working Group on Fission Yields and Radioactive Decay Data. Communications were also initiated with staff at CEN Cadarache (4) and BNF plc Sellafield (5), and a series of agreed tabulations were assembled.

A list of 37 radionuclides in priority order was formulated for which the decay-data files need to be assessed in order to judge whether a detailed re-evaluation needs to be undertaken (Table 2). Decay data for a further 35 radionuclides were defined as being important in decay heat and inventory calculations, although their measured data are known to be extremely sparse (Table 3). Detailed assessments have been made of the decay data to be

Table 2: Fission Product Nuclides That May Merit Further Evaluation of Decay Data

Nuclide	Importance	Priority	Request[a]	Re-evaluation?
45-Rh-106	Instrumentation for recycling	high	UK	Yes
44-Ru-106	Instrumentation for recycling	high	UK/FR	No
53-I-129	Radiotoxicity	high	UK/FR	No
54-Xe-135	Instrumentation for recycling	high	FR	No
56-Ba-140	Fission product standard	high	UK	No
57-La-140	Fission product standard	high	UK/FR	Yes
62-Sm-147	Instrumentation for recycling	high	FR	Yes
34-Se-79	Radiotoxicity	high	UK/FR	Yes
40-Zr-93	Radiotoxicity	high	FR	Yes
50-Sn-126	Radiotoxicity	high	FR	Yes
50-Sn-117m	Reprocessing	medium	UK	No
51-Sb-127	Reprocessing	medium	UK	(Yes?)
52-Te-127	Reprocessing	medium	UK	No
52-Te-127m	Reprocessing	medium	UK	No
53-I-131	Reprocessing	medium	UK	No
53-I-132	Reprocessing	medium	UK	Yes
52-Te-132	Reprocessing	medium	UK	(Yes?)
53-I-138	Reprocessing/Delayed neutron	medium	UK	Yes
58-Ce-141	Reprocessing	medium	UK	No
58-Ce-144	Reprocessing	medium	UK	No
59-Pr-143	Reprocessing	medium	UK	Yes
59-Pr-144	Reprocessing	medium	UK	Yes
65-Tb-161	Reprocessing	medium	UK	Yes
35-Br-88	Delayed neutron emission	medium	FR	Yes
35-Br-89	Delayed neutron emission	medium	FR	Yes
35-Br-90	Delayed neutron emission	medium	FR	Yes
37-Rb-94	Delayed neutron emission	medium	FR	Yes
39-Y-98m	Delayed neutron emission	medium	FR	Yes
53-I-137	Delayed neutron emission	medium	FR	Yes
39-Y-99	Delayed neutron emission	low	FR	Yes
51-Sb-135	Delayed neutron emission	low	FR	Yes
53-I-139	Delayed neutron emission	low	FR	Yes
35-Br-87	Delayed neutron emission	low	FR	Yes
35-Br-91	Delayed neutron emission	low	FR	(Yes?)
37-Rb-95	Delayed neutron emission	low	FR	Yes
37-Rb-93	Delayed neutron emission	low	FR	Yes
33-As-85	Delayed neutron emission	low	FR	Yes

a: UK = United Kingdom, FR = France

Table 3: Nuclides Missing from JEF-2.2 Decay Data Files that Represents >0.01 of the Fractional Cumulative Yield

Nuclide	JEF-2.2	ENDF/B-VI
39-Y-104	No	Yes
39-Y-105	No	Yes
40-Zr-105*	No	Yes
40-Zr-106*	No	Yes
40-Zr-107	No	Yes
41-Nb-109*	No	Yes
42-Mo-109*	No	Yes
42-Mo-111*	No	Yes
42-Mo-112	No	Yes
43-Tc-113*	No	Yes
43-Tc-114	No	Yes
43-Tc-115	No	Yes
43-Tc-116	No	Yes
44-Ru-115*	No	Yes
44-Ru-116	No	Yes
44-Ru-117	No	Yes
44-Ru-118	No	Yes
44-Ru-119	No	Yes
45-Rh-118*	No	Yes
45-Rh-120	No	Yes
45-Rh-121	No	Yes
46-Pd-121*	No	Yes
51-Sb-141	No	No
57-La-152	No	Yes
58-Ce-153*	No	Yes
58-Ce-154	No	Yes
58-Ce-158	No	No
59-Pr-156	No	Yes
59-Pr-157	No	Yes
60-Nd-157*	No	Yes
60-Nd-158*	No	Yes
60-Nd-159	No	Yes
60-Nd-160	No	Yes
61-Pm-159*	No	Yes
61-Pm-160*	No	Yes

* Nuclide that contributes > 0.1 of the fractional cumulative yield

found in JEF-2.2 (and ENDF/B-VI data library) for all of these radionuclides (see refs 6 and 7 for overall descriptions of JEF-22 and ENDF/B-V1, respectively). Using a combination of subjective judgement and statistical analysis, a series of clear directives can be produced to determine whether further labour-intensive efforts are required to improve the specific decay-data files (and hopefully generate more consistent decay schemes for these radionuclides).

Of the thirty-seven nuclides singled out for study (Table 2):

a) ten of these radionuclides were judged to be adequately quantified to the desired detail and consistency;

b) twenty-four radionuclides merit comprehensive re-evaluation of their decay data;

c) three radionuclides were found to be reasonably well defined, with the need for only minor modifications (denoted by (Yes?) in Table 2).

Studies were also undertaken of the US ENDF/B-VI decay-data files for a specific set of fission products that contribute >0.01 of the fractional cumulative yield (although not contained within the JEF-2.2 library). These nuclides are some considerable distance from the line of stability, and are very short-lived (Table 3). No decay-data files are included in the ENDF/B-VI library for two of the thirty-five nuclides, while the remaining radionuclides involve the adoption of average energies that originate from systematic considerations. These data have been used to generate continuum spectra for the gamma-ray and beta-particle components, while delayed neutron data have been derived from other sources. It was judged that further experimental studies of these short-lived nuclides are required before the ENDF/B-VI decay-data files can be modified with confidence; under such circumstances, the data in ENDF/B-VI should be adopted at the present time.

The decay datafiles of approximately 50 radionuclides within EAF (European Activation File) have also been identified as problematic or incomplete when used for fusion-reactor applications. Approximately 20 other radionuclides have been added to this list for completeness, as shown in Table 4. Some of the datafiles exhibit inconsistencies between the mean gamma energies and component radiations as listed in the files (gamma rays, x-rays, annihilation radiation and bremsstrahlung radiation), while others lack consistent gamma-ray transitions or do not exist in JEF-2.2. One aim is to generate the recommended decay datafiles in ENDF-B6 format for use in JEFF-3.

As outlined above, the decay data for a number of fission- and fusion-based radionuclides have been evaluated during 1996:

^{79}Se, ^{79m}Se, ^{96}Y, ^{96m}Y, ^{96n}Y(?), ^{93}Zr, ^{93m}Nb, ^{100}Nb, ^{100m}Nb, ^{97}Tc, ^{97m}Tc, ^{106}Rh, ^{106m}Rh, ^{107m}Ag, ^{107}Cd, ^{126}Sn, ^{126}Sb, ^{126m}Sb, ^{126n}Sb, ^{127}Sb, ^{127}Te, ^{127m}Te, ^{132}Te, ^{132}I, ^{132m}I, ^{129}Ba, ^{129m}Ba, ^{140}La, ^{147}Ce, ^{143}Pr, ^{144}Pr, ^{144m}Pr, ^{150}Pr, ^{147}Sm, ^{156}Tb, ^{156m}Tb, ^{156n}Tb, ^{161}Tb, ^{160}Ho, ^{160m}Ho, ^{160n}Ho, ^{161}Ho, ^{161m}Ho, ^{191}Re, ^{192}Re, ^{191m}Os, ^{195}Os, ^{193}Pt, ^{193m}Pt, ^{208}Bi and ^{208}Po.

All decay data for these radionuclides have been evaluated and will be incorporated in UKPADD as highly consistent data files. Evaluations will continue in 1997 and 1998 to

Table 4: Fusion Activation Products That Merit Evaluation of Decay Data

Nuclide	Nuclide	Nuclide
(25-Mn-58)	(49-In-112m)	75-Re-192*
25-Mn-58m*	56-Ba-129	76-Os-185
31-Ga-77	56-Ba-129m*	(76-Os-191m)
33-As-82	58-Ce-147	76-Os-195*
(33-As-82m)	59-Pr-143	77-Ir-187
34-Se-79*	59-Pr-144	(77-Ir-190)
34-Se-79m	(59-Pr-144m)	(77-Ir-190m)
38-Sr-87m	59-Pr-150	77-Ir-190n
39-Y-96*	(61-Pm-152)	(77-Ir-191m)
(39-Y-96m)	(61-Pm-152m)	77-Ir-191n**
(39-Y-96n)(?)	61-Pm-152n*	(77-Ir-192)
41-Nb-100	(65-Tb-156)	77-Ir-192m
(41-Nb-100m)	65-Tb-156m*	(77-Ir-192n)
43-Tc-97*	65-Tb-156n*	77-Ir-197
43-Tc-97m	67-Ho-160**	77-Ir-197m**
46-Pd-109	67-Ho-160m	78-Pt-193*
(46-Pd-109m)	67-Ho-160n**	(78-Pt-193m)
46-Pd-112	67-Ho-161	(79-Au-192)
(47-Ag-107m)	(67-Ho-161m)	79-Au-192m
(47-Ag-114)	(67-Ho-170)	80-Hg-199m
47-Ag-114m*	67-Ho-170m	(82-Pb-201)
(47-Ag-115)	72-Hf-178m	82-Pb-201m*
47-Ag-115m*	72-Hf-178n	83-Bi-208*
48-Cd-107	72-Hf-180m	84-Po-208*
49-In-112	75-Re-191*	

* No gamma lines in EAF/JEF library.

** No EAF/JEF data file.

Nuclides in parenthesis have not been requested, but are included for completeness.

complete both of these fission- and fusion-based programmes of work. These studies have been funded by British Nuclear Fuels plc and UK Atomic Energy Authority (Fusion Division).

(b) Heavy Element and Actinide Decay Data - Evaluations (A L Nichols (Harwell))

An improved version of the UK Heavy Element and Actinide Decay Data Library has been assembled. Minor corrections have been made to some of the spontaneous fission data, and the new data files for ^{234}Th, ^{234m}Pa and ^{234g}Pa have been incorporated into the database (8).

3.2 Neutron Cross-Section Evaluations

(S I Kafala, T D MacMahon, D Sardari and K Usman (Centre for Analytical Research in the Environment, Imperial College at Silwood Park, Ascot))

Experimental cross-section data for the following reactions have been evaluated: ^{10}B(n,α), ^{10}B(n,total), ^{14}N(n,p), ^{17}O(n,α), ^{56}Fe total, inelastic and capture, ^{237}Np(n,2n) and (n,3n) and ^{242}Pu fission and capture in the neutron energy range 10^{-5} eV to 20 MeV.

3.3 Compilation and Evaluation of $^{152, 154-158, 160}$Gd(n, γ) Experimental Cross Sections

(S P Fox and D L Watson (University of York))

The available experimental cross-section data for the (n,γ) reaction on the naturally-occurring Gd isotopes have been compiled and evaluated. These available data cover the neutron energy range from ~1keV to 3MeV, and were analysed using standard statistical techniques; the Modified Bayesian Technique was utilised in particular to ensure that underestimated errors on measurements did not have an undue weight in the analysis. The results have been compared to the standards available in the JEF-2.2, ENDF/B-VI and JENDL-3.2 data files.

A paper on this work will be presented at the 5th International Conference on Nuclear Data for Science and Technology to be held in Trieste, May 1997. The work was funded in part by the Nuclear Installations Inspectorate.

3.4 Resonance Neutron Cross-Section Evaluations

(C J Dean (Winfrith) and M C Moxon (Consultant (ex-Harwell))

British Nuclear Fuels plc has supported the evaluation of ^{153}Eu resonance cross-section data as an eventual contribution to JEFF-3.

A detailed assessment of ^{235}U data proposed by Derrien et al for JEFF-3 has resulted in a collaborative study based at ORNL, USA; the UK Nuclear Industry Management Committee (IMC) has supported the UK contribution to this work by M C Moxon. An initial file is being assessed, but further development is needed before the evaluation can be judged as suitable for JEFF-3. These efforts are part of the activity of Subgroup 18 (Epi-thermal Capture Cross Section of ^{235}U) of the NEANSC Working Party on International Evaluation Co-operation.

3.5 Nuclear Fission Yield Evaluation

(D J Hale (University of Birmingham), D R Weaver (University of Birmingham) and R W Mills (BNF plc))

The aim is to produce a new evaluation of nuclear fission yields using current and new theories of nuclear fission. Theories of the fission process are being examined to pursue the question of the likely variation of fission yields with neutron energy, which affects parameters such as the yields of burn-up monitors and nuclides of significance to decay heat and disposal. The Brosa model of nuclear scission is being studied to determine whether the parameters of the model can be extrapolated to other fissioning systems and inducing neutron energies.

The latest delayed neutron data (Rudstam et al) have been evaluated and extended to 272 delayed neutron precursors by means of the Kratz-Herrmann formula. Possible application of these data to the adjustment of the fission-yield data will be examined. These data have also been used in a summation calculation with the UKFY3 fission-yield file to generate a comparison between both the calculated and experimentally-determined delayed neutron nu-bar values.

An examination has been made of the potential effect of correlations in the experimental fission-yield input data on the evaluated results and their uncertainties. The overall effect was found to be small for the range of correlations likely to occur in the data sets.

Chain yields may be improved by modelling the fine structure that appears on the peaks and valley of the mass distribution. The A_p, model of Wahl will be applied to the isobaric yield data where possible to determine whether this model is an improvement over the Z_p model.

This work is being carried out with financial support from British Nuclear Fuels plc at Sellafield.

3.6 JEF-PC: A PC-computer Based Program to Display Data from JEF-2.2 Library

(D R Weaver (University of Birmingham), H Tagziria (Consultant) and M Konieczny (NEA Data Bank))

Work has principally concentrated on the component of the program which allows the visual display of cross sections. A module has been developed which allows data from the EXFOR database to be superimposed upon the evaluated cross sections. This display has required provision of the EXFOR data in CD-ROM format and reading of these data within JEF-PC. Development work was performed in parallel with other improvements, and the system was merged in late 1996.

Other activities during the year included:

(i) the completion of the task to implement a decay-path option in the decay-data option,
(ii) the implementation of a ratio plotting option for comparing data from external pointwise files,
(iii) improvements in the facilities for reading pointwise data from CD-ROM.

Since the number of options available within the code is now considerably more extensive than in the version released at the end of 1994, the possibility of providing subsets of the code is being developed so that users with lesser computer memory capabilities can still run portions of the code. It is anticipated that the code will shortly be released for beta testing prior to a launch of the new version.

3.7 JEF-X

(R F Evans (BNF plc))

JEF-X is a graphical interface to the JEF2.2 database for use on X-Windows based workstations, emulating the functionality of JEF-PC. This work began as an MSc project at the University of Birmingham under the supervision of D R Weaver, and is now being developed at BNF plc Sellafield.

Several new features have been added in 1996. Natural isotopic abundances have been included in the program. The code can now display JEF2.2, JENDL3.2 and ENF/B-VI point-wise cross-sections, that can be overlayed with up to five other cross sections from different libraries, nuclides or reaction types. The code can calculate average cross sections for four typical reactor types (AGR, PWR, BWR and CANDU), with a range of burnups and enrichments. Resulting flux spectra and cross sections can be tabulated or graphically displayed.

4. APPLICATIONS DEVELOPMENT

4.1 TSF, The Shielding Forum

(D N Simister (NII))

Various Nuclear Applications Groups have been established in recent years within the UK to ensure the development of good practices in specific technical areas (e.g. shielding and reactor physics) by the exchange of information between members. The Shielding Forum (TSF) was established in 1996 as a non-executive national committee to review developments in the area of shielding and radiation transport. Manual methods will be assessed, and feedback from code users will be encouraged to promote good practices. Two meetings of TSF were held in 1996 (Chairman: D N Simister (NII), Secretary: A J Cooper (BNF plc)). Links have also been forged with the UK Reactor Physics, Shielding and Criticality Industry Management Committee (IMC) and the UK Nuclear Science Forum.

4.2 Reactor Physics, Shielding and Criticality Applications

(C J Dean (Winfrith))

JEF-2.2 and other evaluated data have been reformed into group cross-section libraries using mainly the NJOY code. The resulting 1996 applications libraries have been subsequently adopted in benchmark studies. Reactor physics (WIMS) and shielding (DICE for MCBEND) libraries were issued to UK industry for assessment alongside the previous UK Nuclear Data Libraries (UKNDL). Benchmark studies showed K_{eff} values ~ 1% higher than experiment for Pu nitrate criticality assemblies when run with the MONK code. International comparison of the results within the on-going JEF programme tracked this problem to the use of a Maxwellian fission spectrum for ^{239}Pu instead of improved Madland-based work. When the DICE library was updated, satisfactory results were obtained; the criticality library will be released to industry in January 1997.

Reactor physics benchmark studies indicate that revised graphite thermal scattering data in JEF-2.2 had a significant effect on the moderator temperature coefficients. An assessment of the graphite data has been performed for the IMC. Butland phonon spectra, as used in previous UK studies, were processed with the latest NJOY LEAPR module and added to the 1996 WIMS library. Benchmark calculations indicated that the temperature coefficients remained similar to the JEF values. Further study is recommended.

4.3 Inventory Applications Libraries

(E B Webster (Winfrith))

A new multi-group cross-section database has been created for the TRAIL program, in both 69 and 172 energy groups. TRAIL is used in conjunction with the reactor physics program WIMS7, from which multi-group spectra and cross sections for the resonance self-shieldable actinides are taken and used to generate burnup-dependent cross-section libraries for the nuclide inventory code FISPIN. The cross sections were taken from the major evaluations JEF-2.2, ENDF/B-VI and JENDL-3.2 where available. Cross sections for the remaining

nuclides were estimated using N/Z systematics, augmented by expanding resonance integrals, 2200 m/s cross sections, fission spectrum averaged (n,2n) cross sections and (n,2n) threshold energies. The cross-section database will be further improved during 1997 by exploiting the use of cross sections from the European Activation File in place of those previously estimated by systematics.

4.4 Reactivity Worth of Fission Products

(N T Gulliford (Winfrith))

CERES is an Anglo-French collaborative programme to benchmark the most important fission-product absorption cross sections of JEF-2.2 against experiment. Phase 2 has demonstrated agreement within ~5% for both resonance and thermal spectra with three exceptions: ^{103}Rh results are 19% discrepant; ^{133}Cs results are ~12% discrepant; and ^{153}Eu results vary between 9% for resonance spectra and 17% for thermal spectra. Note that ^{153}Eu and ^{133}Cs studies of JEF-2.2 do not make use of the new evaluations by Moxon for inclusion in JEFF-3.

5. INTERNATIONAL COOPERATION

5.1 JEF Programme

(C J Dean (Winfrith), R W Mills (BNF plc) and A L Nichols (Harwell))

UK specialists contribute to several OECD/NEA and IAEA programmes involving nuclear data development. The main programme associated with neutron cross sections is the Joint Evaluated File (JEF). UK representatives raise items of importance at the relevant NEA Data Bank committees and report back to UKNSF members. The assembly of a new database called the Joint Evaluated Fission and Fusion (JEFF-3) file is now underway after incorporation of Quality Assurance procedures. The starter file (JEFF-3.T) will be based on data from the European Fusion File (EFF-3) for light and structural materials, with JEF-2.2 data used for fission products, heavy nuclides and actinides. However, a significant number of recommended files will come from later evaluations, e.g. ENDF/B-VI. There will be no further development of JEF-2.2, and any subsequent adjustments will only be made to the applications libraries.

At the suggestion of UK industry, a formal quality assurance programme has been introduced for the assembly of JEFF-3. A new database has been developed at the NEA Data Bank to store all evaluated libraries. The quality plan has been officially agreed, and was "signed off" at the July 1996 NEA Data Bank meeting after the incorporation of suitable changes to encompass the needs of the fusion programme. The main control in the preparation of JEFF-3 requires that all improvements to an evaluation be approved by a responsible evaluator as specified in the procedures.

5.2 European Activation File

(R A Forrest and J-Ch Sublet (Culham))

Staff at UKAEA Culham have the responsibility under the Nuclear Data Programme of the Euratom Fusion Technology Programme for the maintenance and development of the European Activation File (EAF). EAF covers the neutron-induced cross sections and decay data libraries that are required as input to the inventory code FISPACT.

The processing system for the production of activation libraries (SYMPAL) was transferred from ECN Petten to UKAEA during 1995. Over the last year, extensive work has been carried out to finish the SYMPAL development leading to a stable version, SYMPAL-96 (9,10). As a demonstration that the processing code was functional, the FENDL-2/A library was produced for the IAEA in March 1996. To simplify the continuing evaluation and processing of both the cross sections and other nuclear data in EAF and to ensure enhanced quality assurance, a Graphical User Interface (SAFEPAQ) has been developed, using the PV-WAVE data visualisation application (11).

It should be noted that about 25% of the EAF-97 library is substantially different from EAF-4.1. The improvements have led to a pointwise file which has a size of about 110 MB and is about twice as large as the previous version. In addition to cross-section improvements, new evaluations have been carried out by A L Nichols (AEA Technology) on the decay data for about twenty nuclides (see Section 3.1(a), above). The data for these nuclides had been found either not to contain any gamma-ray spectrum, or there was a large inconsistency between the mean gamma energy and the listed gamma spectrum; these new data are included in the EAF-97 decay data-library.

The EAF-97 cross-section library contains data for 12,469 cross sections on 766 targets, in a modified ENDF/B format (EAF format), and the decay data library contains data on 1917 nuclides in ENDF/B format. An extensive effort is underway to provide a comprehensive documentation set to accompany the release of the new version of the European Activation System (EASY) in 1997. EASY-97 consists of both EAF-97 (12-15) and FISPACT-97 (16).

ACKNOWLEDGEMENTS

This report was produced with the support of the IMC, and represents edited contributions from members of the UK Nuclear Science Forum.

REFERENCES

1. A.L. Nichols, UK Nuclear Science Forum: Request List - 1996, AEA Technology Report AEAT-0427, May 1996.

2. D. Sardari, T.D. MacMahon, S.P. Holloway, "U-239 and Am-243 Decay Data", Nucl. Instrum. Methods Phys. Res., A369 (1996) 486-490.

3. P.A. Sushkov, I.A. Kondurov, T.D. MacMahon, "Determination of the Gamma-ray Energies and Emission Probabilities in the Depopulation of ^{104}Rh Nuclear Levels Using Conversion Electron Data", Nucl. Instrum. Methods Phys. Res., A 369(1996) 491-493.

4. F. Storrer (CEN Cadarache) and A.L. Nichols, private communication, 10 August 1995.

5. R.W. Mills (BNF plc, Sellafield), C.J. Dean and A.L. Nichols, private communications, 12 September 1995 and 17 November 1995.

6. C. Nordborg, H. Gruppelaar and M. Salvatores, "Status of the JEF and EFF Projects", p782 in Proc. Nuclear Data for Science and Technology, Editor: S.M. Qaim, Springer-Verlag, Berlin 1992.

7. C.L. Dunford, "Evaluated Nuclear Data File ENDF/B-VI", p788 in Proc. Nuclear Data for Science and Technology, Editor: S.M. Qaim, Springer-Verlag, Berlin 1992.

8. I. Adsley, J.S. Kent, A.L. Nichols and J. Toole, "U-238 Decay Chain: Resolution of Observed Anomalies in the Measured Secular Equilibrium Between Th-234 and Daughter Pa-234m", to be published.

9. J.A. Simpson, J-Ch. Sublet and D. Nierop, "SYMPAL User Guide", UKAEA Report FUS 356, 1997.

10. J.A. Simpson and J-Ch. Sublet, "SYMPAL Utilities", UKAEA Report FUS 357, 1997.

11. R.A. Forrest and J.A. Simpson, "SAFEPAQ User Manual", UKAEA Report FUS 355, 1997.

12. J-Ch. Sublet, J. Kopecky and R.A. Forrest, "The European Activation File: EAF-97 Cross Section Library", UKAEA Report FUS 351, 1997.

13. J-Ch. Sublet, R.A. Forrest, J.A. Simpson, J. Kopecky and D. Nierop, "The European Activation File: EAF-97 Cross Section Library - (n,γ) Reactions", UKAEA Report FUS 352, 1997.

14. R.A. Forrest and J-Ch. Sublet, "The European Activation File: EAF-97 Decay Data Library", UKAEA Report FUS 353, 1997.

15. R.A. Forrest and J-Ch. Sublet, "The European Activation File: EAF-97 Biological and Transport Libraries", UKAEA Report FUS 354, 1997.

16. R.A. Forrest and J-Ch. Sublet, "FISPACT-97 User Manual", UKAEA Report FUS 358, 1997.

AEA Technology