Report

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Report

UK Nuclear Science Forum

Progress Report: Data Studies During 1999

A report produced for the IMC

Milestone M1.3
Contract TE/G/01913/Z
IMC: NP/GNSR/5022E

Edited by A L Nichols

The running of the UK Nuclear Science Forum is financed by the Industry Management Committee (IMC) comprising Nuclear Electric Limited, Scottish Nuclear Limited and British Nuclear Fuels Limited and their successor companies.

August 2000

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Executive Summary

The UK Nuclear Science Forum (UKNSF) meets twice every year in London to discuss issues of direct relevance to forum members, and to review nuclear data for application in the UK nuclear industry. Work of immediate interest includes the measurement and evaluation of decay data (eg half-lives and gamma-ray emission probabilities), fission yields and thermal neutron cross sections; all known UK studies in 1999 are summarised in this document. Specific applications and international links of relevance in the field of nuclear data are also described.

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1. INTRODUCTION

The UK Nuclear Science Forum (UKNSF) is the main body for technical discussions within the UK of the measurement and evaluation of nuclear data (e.g., neutron cross sections, decay data and fission yields). Membership ranges across approximately 20 organisations, including nuclear plant operators, vendors, regulators, non-energy applications, academia, and various data measurers and evaluators. The Forum also has the support of the UK Department of Trade and Industry and the nuclear-based Industry Management Committee (IMC), and acts 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 1999 on 6 May and 16 November (Chairman, A L Nichols (AEA Technology, Harwell) and Secretary, R W Mills (BNFL plc)). UKNSF members have also assisted the NEA-Nuclear Science Committee and the IAEA-Nuclear Data Section during the year to formulate new programmes and define data-file priorities.

Dr D Hittner (Framatome, and Vice-president of Comité Francais des Donnêes Nucléaire (CFDN)) was invited to attend the UKNSF meeting in May. The roles of CFDN and UKNSF were compared, and possible areas of co-operation were identified. These exchanges have continued, with the attendance of Dr S M Judge (AEA Technology and UKNSF) at the November meeting of CFDN. The UKNSF representative gave a presentation to the CFDN on the work of the UKNSF. While the main differences between the two committees were noted (UKNSF also covers data needs for non-nuclear energy applications and has a fuller co-ordinating role), their aims have much in common (maintaining priority request lists for nuclear data, and encouraging best practices). Both forums recognise the value of maintaining informal links, and encouraging an awareness of nuclear data activities in the different countries. Such links would help to build a network of expertise and options for the training of scientists starting in the field. Representatives will continue to attend the other committee's meetings on an annual basis (there is much contact already on an international basis, so more frequent attendance was not felt necessary).

2. MEASUREMENTS

2.1 Primary and Secondary Standards of Radioactivity and Radionuclide Decay Data (contact: S A Woods (Radioactivity Measurement Group, Centre for Ionising Radiation Metrology, National Physical Laboratory, Teddington))

Work has continued on the primary and secondary standardisation of radionuclides identified as being of importance to the UK measurement community, in parallel with studies of selected decay scheme parameters. NPL has also provided recommended radionuclide decay data upon demand.

(a) Standardisations of ^{11}C, ^{18}F, ^{54}Mn, ^{131}I, ^{229}Th, ^{238}Pu, ^{239}Pu and ^{244}Cm have been completed.

(b) Emission probabilities have been determined for selected gamma-ray transitions following the decay of ^{229}Th (1).
(c) Standardisations of ^{152}Eu and ^{204}Tl are on-going, the latter involving an international collaboration under the auspices of BIPM to improve counting capabilities.
(d) The method of Digital Coincidence Counting has continued to be developed. Custom-built hardware and 32 bit data analysis software for real-time data collection and compression has been validated against analogue $4\pi\beta$-γ coincidence counting systems and secondary standard re-entrant ionisation chambers.
(e) A review of thorium measurement techniques in the workplace has been completed (2).
(f) Standardisation facilities have been extended through the installation of a prototype Triple-to-Double Coincidence Ratio counting system.
(g) Evaluations of the decay schemes of ^{56}Co, ^{85}Kr, ^{94}Nb, ^{103}Ru, ^{106}Ru/^{106}Rh and ^{243}Am are on-going, as part of an IAEA-CRP to provide internationally-recommended radionuclide decay data.

Financial support is provided by the National Measurement System Policy Unit for the UK Department of Trade and Industry.

2.2 Decay Data Studies

(T D MacMahon (Department of Nuclear Science and Technology, HMS Sultan, Gosport))

Measurements undertaken in previous years on specific actinide decay data are in the process of being published in the open literature:

(a) relative emission probabilities of gamma rays emitted by ^{226}Ra and daughters (3);
(b) half-life of ^{233}Pa (4).

2.3 Surveying Licensed Nuclear Sites for Land Contaminated by Radioactivity

(A R Meehan and M E Phillips (BNFL-Magnox, Berkeley), and D R Weaver (University of Birmingham))

British Nuclear Fuels Ltd (BNFL) is involved in an extensive programme of site investigations to determine the nature, level and extent of land contaminated by radioactivity.

A mobile survey system - Large Area Radiological Characterisation (LARCH) system - has been designed and developed to produce rapid and cost-effective characterisations of outdoor land areas for near-surface gamma-emitting contaminants. The system combines the technique of *in situ* gamma-ray spectroscopy, which is capable of rapidly identifying and quantifying individual gamma-ray emitting radionuclides, with modern automated positioning technologies – a differential global positioning system (DGPS), and a laser ranging device (ATS) that are used to navigate to and record measurement locations accurately. An all-terrain four-wheel drive vehicle provides a platform for the system, and displays within the cab illustrate system status and real-time data capture. Survey data are analysed using a customised peak-fitting program, and are presented graphically by means of a geographical information system (GIS). Analysis of the gamma-ray spectrum is also used to provide an indication of the average depth of contamination.

The system has been used to carry out extensive land surveys on more than a dozen licensed nuclear sites throughout the UK. Such a controlled device is used for clearance monitoring of land, and to drive a targeted sampling programme in areas that warrant further investigation.

2.4 Plutonium Mass Measurements

(S Croft (Harwell Instruments), and L Bourva and D R Weaver (University of Birmingham))

A research programme has been undertaken to improve the measurement accuracy of passive neutron coincidence counting (PNCC) when applied to plutonium safeguards. This work has involved joint efforts between Harwell Instruments Limited, University of Birmingham, Institute for Transuranium Elements (ITU, Karlsruhe, Germany) and the European Commission Directorate of Euratom Safeguards (DCS, Luxembourg).

Work has continued on computational methods for the determination of the neutron leakage self-multiplication (M_L). A substantial revision to the existing MEPL code has been carried out to address practical measurements in the on-site laboratory PNCC. These changes included the incorporation of neutron scattering effects and higher order calculations for the determination of prompt multiplication. The resulting software (MEPL 2.0) can also determine the neutron multiplication effect from reflected neutrons into the material. The end result is a code that is simple and quick to use, returning leakage self-multiplication values over the specified parameter range that are essentially equivalent to full Monte Carlo results. The MEPL 2.0 approach is considered to be a deployable tool for the analysis of OSL data using a known M_L.

A mathematical development of the multiplicity shift register interpretation model has been performed to allow doublet and triplet gate utilisation factors to be derived from experimental data using a ^{252}Cf source of known strength. Results from the MCF Monte Carlo calculations (applied to the determination of the passive neutron coincidence gate utilisation factors of the multiplicity shift register electronics) have been compared with results derived from experimental measurements of these parameters using a calibrated ^{252}Cf source. The comparisons of the MCF code data with these experimental results showed that the absolute accuracy of the computations is better than when the traditional single-exponential approximation is used. This work has shown that the MCF code has the ability to reproduce experimental results within 2%, thus enabling more accurate predictive calculations to be performed at the design stage.

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 and fission products). These studies have been undertaken to assist in the development of the Joint Evaluated Fission and Fusion Files (JEFF).

Table 1: UKNSF Decay Data and Fission Yield Libraries - Status Table, December 1999.

Data	Present status	File development
Fission product decay data	UKFPDD-2 evaluations (ENDF-5 format) were submitted for JEF-1.1 and partially included. Some of these evaluations have been converted to ENDF-6 format and carried through to JEF-2.2.	None, but see UKPADD-6.1 below.
Activation product decay data	UKPADD-6.1 library (ENDF-6 format) has been completed: comprehensive decay-scheme data for 452 activation products and specific fission products have now been evaluated for this library.	Decay data for further sets of radionuclides (mainly activation products) are being evaluated, as agreed through EAF Fusion programme (see Section 3.1.1).
Heavy element and actinide decay data	UKHEDD-2.2 evaluations (ENDF/B-VI format) have been submitted to the NEA Data Bank.	UKHEDD-2.2 includes recommended decay data for Pa-234g, Pa-234m and Th-234.
Fission yields	UKFY-2 was submitted and accepted for JEF in 1990. After minor modifications (to achieve consistency with JEF-2.2 decay data and to allow for missing decay data), a final version of UKFY-2 was incorporated into JEF-2.2. A new draft evaluation was produced in 1994 (UKFY-3), maintaining consistency and allowing for missing decay data.	An update is envisaged when JEFF-3 decay data become available (ensuring consistency with JEFF-3 decay data, and including fewer approximations for missing decay data); this updated file will be submitted for inclusion in JEFF-3.

3.1.1 Activation and Fission Product Decay Data

(A L Nichols (AEA Technology, Harwell))

(a) Completed and on-going work programmes

Lists of problematic fission-product nuclides were agreed in 1994/95, including a number of radionuclides of importance in decay-heat calculations for which no decay-scheme data have been measured. Discrete decay-data evaluations have been undertaken from 1996 onwards (Table 2), along with the preparation of theoretical decay-data files for those nuclides lacking quantitative studies. This work was completed in 1999, with the evaluation of decay data for ^{87}Br and the issue of a dedicated report (5).

Table 2: Discrete Decay-Data Evaluations - Fission Products .
Evaluations include related metastable states and daughter radionuclides when deemed appropriate (although not listed below).

Nuclide	Importance	Priority
45-Rh-106	Instrumentation for recycling	high
57-La-140	Fission product standard	high
62-Sm-147	Instrumentation for recycling	high
34-Se-79	Radiotoxicity	high
40-Zr-93	Radiotoxicity	high
50-Sn-126	Radiotoxicity	high
51-Sb-127	Reprocessing	medium
53-I-132	Reprocessing	medium
52-Te-132	Reprocessing	medium
53-I-138	Reprocessing/Delayed neutron emission	medium
59-Pr-143	Reprocessing	medium
59-Pr-144	Reprocessing	medium
65-Tb-161	Reprocessing	medium
35-Br-88	Delayed neutron emission	medium
35-Br-89	Delayed neutron emission	medium
35-Br-90	Delayed neutron emission	medium
37-Rb-94	Delayed neutron emission	medium
39-Y-98m	Delayed neutron emission	medium
53-I-137	Delayed neutron emission	medium
39-Y-99	Delayed neutron emission	low
51-Sb-135	Delayed neutron emission	low
53-I-139	Delayed neutron emission	low
35-Br-87	Delayed neutron emission	low
35-Br-91	Delayed neutron emission	low
37-Rb-95	Delayed neutron emission	low
37-Rb-93	Delayed neutron emission	low
33-As-85	Delayed neutron emission	low

The decay data files of approximately 50 radionuclides within EAF (European Activation File) have also identified as problematic or incomplete when used for fusion-reactor applications (Table 3). Approximately 28 other radionuclides have been added to this list for completeness. One aim is to generate the recommended decay data files in ENDF-6 format for use in JEFF-3.

As outlined above, the discrete decay data for a number of fission- and fusion-based radionuclides have been evaluated during 1999: ^{77}Ga, ^{82}As, ^{82m}As, ^{87}Br, ^{170}Ho and ^{170m}Ho. Theoretical decay-data files were also produced for approximately 30 short-lived fission products. All of these data have been incorporated into the UKPADD-6.1 library (6). This work continues with respect to the remaining nuclides to be evaluated (see footnote # of Table 3).

(b) New work programme
The European Fusion Programme requires adequate decay-data files for a wide range of radionuclides (7, 8). As part of an extensive exercise to improve the quality of such data files, the EAF-99 decay data for 180 radionuclides were assessed in detail (as defined in Table 4). The aim was to produce an abbreviated list of nuclides that require more detailed evaluations of their discrete decay data.

Various anomalies and inconsistencies were detected from analyses of the recommended decay data to be found in ENSDF (9, 10), and comparing them with the equivalent discrete data to be found in JEF-2.2 (11) and EAF (8) through JEFPC (12) and the EASY-EAF interrogation code (13), respectively. These assessments revealed evidence for discrepant (and erroneous) decay-data files within JEF-2.2 and EAF: hence, recommendations have been made for new decay-data evaluations for 110 of these radionuclides. EAF and JEF-2.2 would also benefit from rigorous, code-based testing of their contents in order to quantify the discrepancies within individual data files. An agreed QA procedure needs to be developed and implemented to define the method of library assembly, and prevent *ad hoc* modifications and additions to the files at a later date without fully appreciating their impact on other parameters.

These studies have been funded by British Nuclear Fuels plc and UK Atomic Energy Authority (Fusion Division).

Table 3: Decay-Data Evaluations - Fusion Activation Products.

Nuclide		
7-N-17	(49-In-112m)	(76-Os-190m)
(25-Mn-58)	56-Ba-129	(76-Os-191m)
25-Mn-58m*	56-Ba-129m*	76-Os-195*
31-Ga-77	58-Ce-147	77-Ir-187#
33-As-82	59-Pr-143	(77-Ir-190)
(33-As-82m)	59-Pr-144	(77-Ir-190m)
34-Se-79*	(59-Pr-144m)	77-Ir-190n
34-Se-79m	59-Pr-150	(77-Ir-191m)#
38-Sr-87m	(61-Pm-152)	77-Ir-191n**#
39-Y-96*	(61-Pm-152m)	(77-Ir-192)#
(39-Y-96m)	61-Pm-152n*	77-Ir-192m#
(39-Y-96n)(?)	(65-Tb-156)	(77-Ir-192n)#
41-Nb-100	65-Tb-156m*	77-Ir-197#
(41-Nb-100m)	65-Tb-156n*	77-Ir-197m**#
43-Tc-97*	67-Ho-160**	78-Pt-193*
43-Tc-97m	67-Ho-160m	(78-Pt-193m)
46-Pd-109	67-Ho-160n**	(78-Pt-197)#
(46-Pd-109m)	67-Ho-161	(78-Pt-197m)#
46-Pd-112	(67-Ho-161m)	(79-Au-192)#
(47-Ag-107m)	(67-Ho-170)	79-Au-192m#
(47-Ag109m)	67-Ho-170m	(79-Au-197m)#
(47-Ag-114)	72-Hf-178m	80-Hg-199m
47-Ag-114m*	72-Hf-178n	(82-Pb-201)
(47-Ag-115)	72-Hf-180m	82-Pb-201m*
47-Ag-115m*	75-Re-191*	83-Bi-208*
48-Cd-107	75-Re-192*	84-Po-208*
49-In-112	76-Os-185	

* No gamma lines in EAF/JEF library.
** No EAF/JEF data file.
\# Still to be evaluated.
Nuclides in parenthesis have not been requested, but are included for completeness.

Table 4: EAF Decay Data Files Assessed for Content.

Nuclide				
5-B-8	41-Nb-98	55-Cs-137	69-Tm-162m	85-At-219
5-B-12	42-Mo-103	55-Cs-139	69-Tm-176	88-Ra-230
5-B-13	42-Mo-105	55-Cs-140	70-Yb-169	89-Ac-224
7-N-12	43-Tc-103	56-Ba-126	72-Hf-168	89-Ac-229
7-N-17	45-Rh-104	56-Ba-141	72-Hf-171	90-Th-224
14-Si-31	45-Rh-110	56-Ba-142	73-Ta-185	90-Th-226
17-Cl-36	45-Rh-111	56-Ba-143	74-W-174	91-Pa-227
18-Ar-37	46-Pd-109	57-La-137	74-W-176	91-Pa-228
19-K-46	46-Pd-113m	57-La-143	76-Os-180	91-Pa-230
21-Sc-49	47-Ag-103m	58-Ce-145	76-Os-196	91-Pa-234m
24-Cr-55	47-Ag-110	58-Ce-147	77-Ir-184	91-Pa-235
25-Mn-58m	48-Cd-102	58-Ce-149	77-Ir-185	91-Pa-238
26-Fe-63	48-Cd-104	59-Pr-134	77-Ir-187	92-U-228
28-Ni-67	48-Cd-107	59-Pr-134m	77-Ir-192m	92-U-230
31-Ga-77	48-Cd-119	59-Pr-143	77-Ir-197	92-U-231
32-Ge-80	48-Cd-123	59-Pr-144	78-Pt-184	92-U-235m
33-As-79	49-In-106	59-Pr-147	78-Pt-187	93-Np-233
33-As-80	49-In-106m	59-Pr-149	78-Pt-202	94-Pu-237m
33-As-82	49-In-112	59-Pr-150	79-Au-187m	94-Pu-244
33-As-82m	49-In-114	61-Pm-155	79-Au-192m	95-Am-237
34-Se-81	49-In-116	63-Eu-146	79-Au-193	95-Am-239
35-Br-72m	50-Sn-110	64-Gd-163	79-Au-193m	95-Am-244m
36-Kr-89	50-Sn-123	64-Gd-165	79-Au-199	95-Am-247
37-Rb-81m	50-Sn-129	65-Tb-146m	79-Au-202	96-Cm-246
37-Rb-89	50-Sn-130	66-Dy-149	80-Hg-190	96-Cm-248
37-Rb-90m	50-Sn-130m	66-Dy-152	80-Hg-191	96-Cm-250
38-Sr-92	50-Sn-131	67-Ho-158	80-Hg-192	97-Bk-245
38-Sr-93	50-Sn-131m	67-Ho-158n	80-Hg-205	97-Bk-253
38-Sr-94	52-Te-114	67-Ho-161	81-Tl-193	98-Cf-246
39-Y-90	52-Te-121m	67-Ho-163	81-Tl-197	98-Cf-250
39-Y-91	53-I-136m	67-Ho-164	81-Tl-206	98-Cf-252
39-Y-94	54-Xe-121	67-Ho-170m	81-Tl-207	99-Es-254
39-Y-95	54-Xe-122	68-Er-158	82-Pb-199m	99-Es-256m
39-Y-96	54-Xe-137	68-Er-167m	83-Bi-210	100-Fm-253
39-Y-97m	54-Xe-139	68-Er-172	84-Po-209	100-Fm-255
40-Zr-99	55-Cs-123m	69-Tm-161	85-At-212m	100-Fm-257

3.1.2 Heavy Element and Actinide Decay Data
(A L Nichols (AEA Technology, Harwell))

The decay data for an agreed set of actinides and their heavy-element decay products are in the process of being evaluated (Table 5). This list of 31 nuclides arose from a knowledge and assessment of decay-data measurements published over recent years (from the mid-1980s onwards). Full decay-scheme evaluations were completed in 1999 for $^{235, 236, 238}$U and ^{244}Cm. An evaluation of the decay data for ^{242}Cm is partially completed, and references have been fully assembled for $^{241, 242, 242m}$Am, so that detailed studies can begin in 2000.

Table 5: Actinide Decay Data Evaluations

Nuclide
Radium Ra-226 and daughters, (Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210 and Po-210)
Thorium Th-228 and daughters (Ra-224, Rn-220, Po-216, Pb-212, Bi-212g, Bi-212m, Po-212, Pb-208 and Tl-208)
Uranium U-235, U-236, U-238
Neptunium Np-237
Plutonium Pu-236, Pu-239, Pu-241
Americium Am-241, Am-242g, Am-242m
Curium Cm-242, Cm-244

3.2 International Decay Data Evaluation Project
(T D MacMahon (Department of Nuclear Science and Technology, HMS Sultan, Gosport))

Participation continues with collaborators at AEA Technology (UK), Idaho Falls, Brookhaven National Laboratory and Lawrence Berkeley Laboratory (USA), LPRI(France), PTB (Germany), CIEMAT (Spain) and Khlopin Radium Institute (Russia) to provide evaluated decay scheme data for the following:

(a) ENDSF,
(b) new Table of Radionuclides by LRPI/PTB (14, 15),
(c) IAEA decay database.

3.3 Review of the Thermal and Low-energy Resonance Neutron Capture Cross-sections for ^{95}Mo, ^{99}Tc, ^{103}Rh, ^{109}Ag, ^{143,145}Nd, ^{152}Sm and ^{155}Gd

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

Thermal and low-energy resonance neutron capture cross-sections have been reviewed for ^{95}Mo, ^{99}Tc, ^{103}Rh, ^{109}Ag, ^{143,145}Nd, ^{152}Sm and ^{155}Gd, as part of the co-ordinated NEA Data Bank programme of investigations into the neutron data of fission products. The aim of the reviews was to provide evaluated data for inclusion in JEFF-3:

(a) present JEF-2.2 files are recommended for ^{109}Ag, ^{155}Gd, ^{143,145}Nd and ^{152}Sm;
(b) BROND-2.2 file is recommended for ^{103}Rh;
(c) JENDL-3.2 file is recommended for ^{95}Mo.

There are large differences between the resonance parameters adopted by the different evaluations of ^{99}Tc. The present work recommends the use of a set of parameters based upon the high-resolution measurements of Watanabe and Reeder (16) and Adamchik *et al* (17). (Further measurement and evaluation for ^{99}Tc is underway as part of the JEFF programme.)

This work was carried out on behalf of the IMC, and is currently undergoing peer-review.

3.4 Fission Product Yield Evaluations

(RW Mills (BNFL plc, Sellafield))

The UK has continued international collaboration with colleagues in the USA, China, France, Germany, Japan, Netherlands, Russia and Sweden, through the forum of the IAEA-CRP on Fission Product Yield Data Required for the Transmutation of Minor Actinide Nuclear Waste. A work programme has been defined for this CRP, beginning with the collection of yield data for high-energy fission reactions.

An IAEA document describing the previous CRP on the Evaluation of Fission Product Yields has been significantly revised during the year and will be published in 2000.

Work on the Fission Product Yield Evaluation for JEFF-3T has also begun with a review of reported problems in JEF-2.2 and draft UKFY3 evaluations. Justified concerns will be addressed in the production of a revised evaluation for JEFF-3T in 2000.

4. APPLICATIONS DEVELOPMENT

4.1 Reactor Physics, Shielding and Criticality Applications

(N R Smith, C J Dean and R J Perry (AEA Technology, Winfrith))

During the course of the year, there has been a gradual movement towards the adoption of JEF-2.2 based libraries for reactor physics (WIMS), criticality (MONK), shielding (MCBEND) and inventory (FISPIN) applications. The improved accuracy observed for many of the benchmark studies has added significantly to the confidence in the new libraries, and this has been augmented by good performance in inter-comparison exercises when JEF-2.2 is compared with other data sources.

Developments to the epi-thermal capture cross-sections of ^{235}U (NEA/WPEC-18) have been adopted in the JEFF-3 starter file (JEFF-3T). Some improvements are seen for benchmarks with hard spectra, although the wider-ranging changes in agreement are not all welcome. Industry experience of test libraries for systems with hard spectra has been favourable (ANSWERS Software Service Annual Seminar – May 1999).

The desire to improve the internal cross-checking capabilities of the Monte Carlo codes MONK and MCBEND, and provide increased choice have led to the production of ENDF/B-VI-revision 3 and JENDL-3.2 libraries. Extensions have been made to all libraries to provide consistent contents – this approach has meant 'borrowing' evaluations in some cases where a particular nuclide is not present in one of the main data sources.

Continuing validation activity has been undertaken for MONK (joint AEA Technology/BNFL project), drawing on output from the International Criticality Safety Benchmark Evaluation Project (ICSBEP). Studies have included:

- TRIGA reactor benchmark with intermediate enrichment uranium (~20%),
- boron carbide rods in low-enriched uranium nitrate solution,
- low-enriched UO_2 lattices in water containing dissolved gadolinium,
- unreflected and reflected sphere of ^{233}U (using various reflectors),
- water-reflected uranium metal sphere,
- arrays of water-moderated uranium (4.31 wt% and 2.35 wt% ^{235}U) rods with various reflectors.

Two results stand out from the above validation analyses. Firstly, for the TRIGA reactor benchmarks, the modelling by MONK of bound hydrogen in zirconium hydride is an important contribution to being able to reproduce the experimental results. Secondly, the fast ^{233}U data in JEF-2.2 are out of line with other international evaluations, leading to an under-prediction of multiplication for the metal spheres; this deficiency has been addressed for JEFF-3T.

A review of the sensitivity of WIMS to fission spectrum data has been undertaken on behalf of HSE/IMC (AEAT/R/NS-0021 – enquiries to IMC). Improvements of the order of 200-300 pcm could be achieved by adopting isotopic spectra for MOX systems. Further work has focussed on similar sensitivities for MCBEND.

Progress with the new collision processing and data library package for MONK and MCBEND (BINGO) has been maintained, with the data library production package now complete (joint AEA Technology/BNFL project). Testing a version of 'BINGO in MONK' will commence in 2000.

Work is underway (joint AEA Technology/IMC project) on improving the resonance data modelling in WIMS. Developments to both data library and code methods are being investigated, and will feature in a future release of the code.

An updated version of NJOY (NJOY 97.62W17) has been installed to support both the production of BINGO libraries and current library enhancements for WIMS, MONK and MCBEND.

The development of a cross-section sensitivity option for MONK has been completed and is currently being evaluated (joint AEA Technology/BNFL project). This option will appear in the next release, MONK8B. An IMC project has enabled the inclusion of the data uncertainty module WINCOV in the MCBEND code package.

A review of ^{58}Fe(n,γ) thermal cross-section values has been undertaken for IMC and best estimate values have been derived.

4.2 Examination of GENEX with the Criticality Code MONK

(C Atterbury (University of Birmingham, based at BNFL Springfields), R J Brissenden (BNFL Consultant), S M Connolly (BNFL Springfields) and D R Weaver (University of Birmingham))

Work started in October 1999 (as part of a PhD) to examine the UK criticality code MONK with emphasis on the use of GENEX. The latter code uses evaluated resonance parameters and other nuclear data to generate primary cross sections, and can be adopted as a check on NJOY and to provide a better representation of the unresolved region. The cross sections output from GENEX can be made available to MONK via a pre-processor.

The initial aims of the programme are:

- examine existing evaluations of some elements where difficulties have been encountered;
- assess the shortcomings of some recent evaluations;
- compare evaluation methodologies;
- examine fitting techniques of SAMMY and REFIT;
- study Lynn theory of fission reactions as applied in GENEX.

5. INTERNATIONAL CO-OPERATION

5.1 Development of European Activation File

(R A Forrest (UKAEA Fusion, Culham))

Development of the European Activation File (EAF) has continued under the Nuclear Data Programme of the Euratom Fusion Technology Programme. EAF covers the neutron-induced cross sections and decay data libraries that are required as input to the FISPACT inventory code.

Most of the effort has been involved in a significant updating of the methods that are used to evaluate, select and process the activation cross section data. The new tool (SAFEPAQ-II) uses relational databases and a user-friendly Windows interface to ensure that all the tasks can be carried out efficiently. A priority in this development has been ensuring that Quality Assurance can be applied to library production. The first version of the software is now ready to be distributed to an external contractor, for use in work identified with EAF-2001. The storage of nuclear data in relational databases, rather than in an ENDF formatted text file is a major advance. SAFEPAQ-II will make library generation more efficient, and will be improved further to enable library validation using integral data generated by various European laboratories.

The evaluation of decay data for nuclides in the EAF decay data library has continued (Nichols), and the next version will use the newly prepared UKPADD-6.1 library (18).

5.2 JEFF Programme

(C J Dean (AEA Technology, Winfrith), A L Nichols (AEA Technology, Harwell), D J Edens (BNFL Magnox, Berkeley), R A Forrest (UKAEA, Culham) and R W Mills (BNFL plc, Sellafield))

UK specialists continue to contribute to a number of OECD/NEA and IAEA programmes involving nuclear data development, particularly those undertaken as part of the NEA-based JEFF Project.

(a) JEF-2.2 Documentation

Comprehensive documentation of JEF-2.2 has been edited and assembled by J Rowlands. There are 15 chapters covering the following topics:

EVALUATIONS IN JEF-2.2

Chapter 1. Summary of the sources of JEF-2.2 evaluations in the General Purpose Library

Chapter 2. The JEF-2.2 Radioactive Decay Data Library

Chapter 3. The JEF-2.2 Fission Yield Libraries

Chapter 4. Thermal scattering data

JEF-2.2 VALIDATION STUDIES

Chapter 5. Thermal reactor validation studies

Chapter 6. Fast reactor validation studies

Chapter 7. Criticality validation studies

Chapter 8. Shielding validation studies

Chapter 9. Decay heat validation studies

Chapter 10. Delayed neutron validation studies

Chapter 11. Delayed neutron summation calculations

Chapter 12. Validation of the JEF-2.2 General Purpose File by means of cross-section adjustment studies

A SUMMARY OF REQUIRED AND PROPOSED IMPROVEMENTS FOR JEFF-3

Chapter 13. A list of known errors in JEF-2.2

Chapter 14. Plans for new decay data evaluations. UK work undertaken after BNFL/CEA and UKAEA reviews of JEF-2.2 Decay Data Files: 1996-2000

Chapter 15. Validation studies made using JEF-2.2 with new evaluations included

Final publication is an OECD document (JEFF-Report 17) and CD-ROM in 2000, with hyperlinks to all JEF/DOCs referenced in the text.

(b) General Purpose Cross Section Library
The starter file for JEFF-3T has been assembled. Despite the initial aim of taking most data from EFF-3.0 and JEF-2.2, there are a fairly large number of new evaluations taken from other sources (mainly due to developments in libraries from which JEF-2.2 adopted earlier evaluations, eg. new JENDL-3.2 files). The QA procedure includes the generation of data in the 15 energy groups used in the JEF-2.2 assessment of Fort, which allows the review of data trends at an early stage. Difficulties in processing certain files are being resolved by issuing the library to selected users so that typical data can be generated. The practical interaction between the NJOY processing code and the files can be assessed and problems resolved. A major aim is to make the files available for clean-core benchmarking within the project. JEFF-3T evaluation of ^{235}U is under test in the UK for the harder spectral thermal systems where the revised resonance capture is yielding important improvements. The maximum incident neutron energy in JEFF-3T is 20MeV, covering fission and fusion needs. There are proposals to extend future JEFF-3 files to 150MeV to cover Accelerator Driven Systems and transmutation. However current benchmarking is

indicating discontinuities at 20MeV where previously independent high energy files are spliced onto the main fission and fusion evaluations.

UK evaluators have assessed the quality of the data for a number of nuclides and made their results available to the JEFF programme. These studies include a number of fission products seen as important to burn-up credit. Absorption of the results into JEFF-3 has proved difficult due to the lack of complete ENDF-6 evaluations. UK industry is now sponsoring work leading to possible replacement evaluations in the thermal and resolved resonance regions where this exercise is judged to be worthwhile. The aim is to make available new files for ~10 fission products in 2000- 2001; when replacement thermal files are needed, they will be added to files recommended for fast reactor studies.

(c) Special Purpose JEFF-3 Libraries
UK contributions to decay data and fission yield evaluations are described elsewhere in this report (Sections 3.1 and 3.4). UKPADD-6.1 and UKHEDD-2.2 decay-data libraries were issued in February 2000, including ENDF-6 files from previous UKPADD and UKHEDD releases plus new/updated files where appropriate.

There is an urgent drive to produce the JEFF-3T starter library for decay data and fission yields by April 2000. The plans for these decay-data files are:

(1) adopt UKPADD-6.1 with decay scheme data for 452 radionuclides (combination of activation products, gamma-ray standards and limited set of fission products);
(2) adopt UKHEDD-2.2 with decay scheme data for 126 radionuclides (important actinides in fission reactors, and their natural decay products (heavy elements));
(3) fission products not found in (1) to be extracted from ENSDF via RADLST technique, and checked for consistency (as priority action);
(4) all other radionuclides not covered by (1) + (2) + (3) to be extracted from ENSDF via RADLST technique, and checked for consistency;
(5) insert entries for stable isotopes.

A consistent energy balance is considered important, and AEA Technology staff at Winfrith are developing the program EFIZCON to perform this function.

Improvements, mainly to cumulative fission yields, will result in the issue of version 2 of UKFY3; this file will be generated by R W Mills of Sellafield, and is proposed for adoption as part of JEFF-3T (see Section 3.4).

Version 99 of the European Activation File has been issued by R A Forrest of Culham for fusion studies (see Section 5.1), and has been adopted as the activation file for JEFF-3; consistency of data for reactions common to this file and the main JEFF-3 library is being sought.

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