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UK NUCLEAR SCIENCE FORUM

PROGRESS REPORT: DATA STUDIES DURING 1994

Edited by A L Nichols

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1. INTRODUCTION

During 1990, the Health and Safety Commission (HSC) took over the sponsorship role from the UK Department of Energy for nuclear safety research in relation to established commercial reactors and systems under construction for commercial use. The UK Health and Safety Executive (HSE) managed these safety responsibilities on behalf of the HSC, and the agreed work was funded by Nuclear Electric, Scottish Nuclear and British Nuclear Fuels plc under a generating capacity linked-levy arrangement. It was agreed in 1992 that the HSE should review the organisation of nuclear safety research in the UK. New arrangements were formulated in August 1993 and will be fully in place by 1 April 1995. Part of the nuclear research is co-ordinated under the auspices of the Industry Management Committee (IMC), comprising the three licensees and HSE. Technical programmes of work are overseen by thirteen Technical Working Groups (TWG), one of which covers reactor physics, shielding and criticality, the main 'applications' areas of nuclear data in deterministic and Monte-Carlo codes.

Funding of the UK contribution to the OECD/NEA databank by DTI will cease when the new arrangements start in April 1995. This function will be taken over by the IMC and implemented by the TWG covering nuclear data applications. The interests of minority users will not be affected by this transition and the funding arrangements are intended to provide improved management of UK resources and more effective communication between nuclear evaluators and applications areas in industry.

For over 20 years, the UK Chemical Nuclear Data Committee (UKCNDC) provided an appropriate audience in the UK for technical discussions involving the measurement and evaluation of radionuclide decay data and fission product yields. A similar arrangement was also maintained for neutron cross sections and resonance integrals by the Differential and Integral Data Steering Group (DIDSG). However, over recent years, many changes have occurred in the emphasis of the UK nuclear programme that has resulted in a need to re-assess the requirements for a UK forum to provide reliable communication links between regulators, data users and data producers, and through these communications establish consensus policies towards nuclear data issues. Other requirements are identified with monitoring and advising on the activities of various international bodies and committees, particularly the NEA-Nuclear Science Committee and the IAEA Nuclear Data Section. Thus, wide ranging discussions took place during 1994 to determine the need for a UK forum to undertake the primary function of satisfying and servicing the needs of the relevant governmental bodies, industry and academic customers.

A final meeting of the UKCNDC was held on 11 January 1994, as efforts focused on defining the needs, if any, for a broader forum to cover a wider number of technical topics and act as a communications network. After extensive debate, terms of reference were drafted and a constitution evolved for a committee to be entitled the UK Nuclear Science Forum (see Appendix 1). The UKNSF has the support of the UK Department of Trade and Industry and the nuclear-based Industry Management Committee (IMC), as described above. The IMC will agree administrative arrangements to monitor databank activities in consultation with the UKNSF, and these will be developed during FY 1995/96. Two meetings of the newly-formed UKNSF were held on 5 May and 1 December 1994 (Chairman, A L Nichols (AEA Technology, Harwell) and Secretary, R W Mills (BNFL plc)). Membership covers nearly 20

different organisations, including nuclear plant operators, vendors, regulators, non-energy applications, and data measurers and evaluators. As a consequence, the progress report for 1994 covers a wide range of activities.

UKNSF(93)P2 lists all DIDWP, DIDWG and DIDSG papers issued between 1973 and 1993. Although not complete, the master versions of these papers are now stored in the Winfrith records office after being moved from Harwell. Initial enquiries for copies should be addressed to the Secretary of the UKNSF.

2. MEASUREMENTS

2.1 Measurement and Evaluation of Nuclear Data

(S A Woods, M J Woods, J L Makepeace, V E Lewis, D H Woods and N E Bowles (National Physical Laboratory, Teddington))

The resources available to undertake activities relating to the measurement and evaluation of nuclear data have remained at a low level during the twelve months covered by this report. This contrasts with the demand for NPL to provide recommended radionuclide decay data, which has been high. Two projects have an active status:

(i) Nuclear decay scheme data for 53 radionuclides have been reviewed. These data have been selected from the JEF2.2, ENSDF and UKPADD-2 data files. It should be noted that the radionuclides are primarily those for which NPL has supplied standards and are in addition to those appearing in IAEA-TECDOC No.619.

(ii) The standardisation and measurement of selected decay scheme parameters of ^{237}Np has commenced. Similar work on ^{243}Am has been completed and will be reported at ICRM'95, Paris.

2.2 Decay Scheme Data

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

(i) ^{239}U beta branching ratios: ^{239}U beta decay and ^{243}Am alpha decay both lead to excited states of ^{239}Np. Studies of the gamma-ray spectra from the two decays allow the ^{239}U beta branching ratios to be determined from the ^{243}Am alpha branching ratios. New ^{243}Am alpha data are being used in conjunction with gamma-ray data measured at Imperial College some time ago, to re-calculate the ^{239}U beta branching ratios.

(ii) ^{234m}Pa decay scheme: recent discussions of uncertainties in ^{234m}Pa gamma-ray emission probabilities has prompted a complete re-evaluation of all published data, and an attempt has been made to deduce a self-consistent decay scheme taking into account internal conversion coefficients.

(iii) Half-life of ^{233}Th: experiments are being evaluated to determine the half-life of ^{233}Th produced by the neutron capture reaction.

(iv) ^{226}Ra decay scheme: an investigation is being carried out into reported inconsistencies in the gamma-ray emission probabilities in the decay of ^{226}Ra.

2.3 Delayed Neutron Measurements for the Fast Fission of ^{235}U and ^{238}U

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

Work is being carried out with financial support from the former European Fast Breeder Reactor Programme (contact: A Filip, CEA Cadarache, France). The aim of the project is to measure the absolute value for the yield of delayed neutrons from the fast fission of ^{238}U. However, measurements are also to be taken using ^{235}U so that comparison with agreed values for this radionuclide will hopefully demonstrate the consistency of the technique and add validity to the ^{238}U studies.

The experiments involve the use of the 3MV Dynamitron accelerator and the Low Scatter Cell within the School of Physics and Space Research at the University of Birmingham. Using this facility neutron beams of order 1×10^9 n sr^{-1} s^{-1} and monoenergetic energies between 3 and 6 MeV (with ~ 100 keV energy spread) can be obtained using deuteron bombardment of a titanium deuteride target. The associated angular dependence of the target neutron yield has been measured using indium foil activation. This is of particular interest since the uranium foils are placed very close to the deuterium target to facilitate maximum irradiation against Dynamitron run times.

Due to the small number of delayed neutrons, the De Pangher Long Counter gave a very low count rate during a test run, typically one count per second for sample irradiation. This would require many hours of Dynamitron time to obtain suitable counting statistics even for just one sample. Thus a new high efficiency counter has been constructed, comprising a piece of high density polyethylene moderator and an array of BF_3 tubes. The finer details of this design were modelled using the Monte Carlo code MCNP with ENDF/B-V data files.

2.4 An Epithermal Neutron Beam for Use in Boron Neutron Capture Therapy

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

Work is underway at the University of Birmingham to produce an epithermal neutron beam for use with Boron Neutron Capture Therapy (BNCT). Protons incident upon a thick lithium target are used to produce epithermal neutrons that are then adopted to produce the desired spectrum for BNCT. 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. Work in 1994 involved measurements of yields and spectra from the bare target and activation foils around the moderator assembly. These results are being used to compare with Monte Carlo evaluations.

2.5 Cross-Section Measurements

(C J Dean (Winfrith))

The CERES programme involved the use of the DIMPLE reactor at Winfrith and the MINERVE reactor at Cadarache to study neutron absorption by actinides and fission products in irradiated uranium and mixed oxide (MOX) reactor fuel. Phase I showed that JEF-2.2 nuclear data closely predicted changes in reactivity with fuel burnup. Phase II

considered resonance and thermal integral data for 12 major fission products representing 70% of overall fission product neutron absorption. The fission product absorbers are ^{95}Mo, ^{101}Ru, ^{103}Rh, ^{109}Ag, ^{133}Cs, ^{147,149,152}Sm, ^{143,145}Nd, ^{153}Eu and ^{155}Gd. The DIMPLE measurements have been analysed using the WIMS deterministic code with a JEF-2.2 nuclear data library. Results from MINERVE were reported at the December JEF meeting, and gave different conclusions from the UK experiment/analysis. Investigations are continuing and will be reported when more definitive conclusions can be made.

The ASPIS steel/graphite experiment is a study of the influence of spectrum softening on neutron damage at the interface between graphite moderator and Fe shield regions of Magnox reactors.

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 Files (JEF).

Table 1: *UKNSF Decay Data and Fission Yield Libraries - Status Table, December 1994.*

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
Activation product decay data	UKPADD-2 evaluations (ENDF/B-VI format) have been submitted to the NEA Data Bank.	96 additional nuclides have been evaluated by A L Nichols (AEA) to produce UKPADD-3. Minor corrections and re-evaluations have also been made to 12 of the data files from UKPADD-2 (now to be part of UKPADD-3).
Heavy element and actinide decay data	UKHEDD-2 evaluations (ENDF/B-VI format) have been submitted and absorbed into JEF-2.2.	Decay data for Pa-234g and Pa-234m have been evaluated for incorporation into UKHEDD-2.
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.	A new evaluation (UKFY-3) is being undertaken by R W Mills.

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

An assessment by Yamamuro and Iijima resulted in the identification of approximately 90 radionuclides from specific (n,x) reactions that will be generated in the core region (1). An agreed list of 87 radionuclides was formulated in July 1993 to which a further nine nuclides

have been added as daughters of direct relevance to the original dataset. Evaluations are being made to improve the UK decay-data files for these radionuclides, and so contribute to the continued evolution of the JEF library:

^{53}Mn, ^{60}Fe, ^{60m}Co, ^{66}Ni, ^{67}Cu, ^{81}Kr, ^{81m}Kr, ^{83m}Kr, ^{85}Kr, ^{85m}Kr, ^{83}Rb, ^{84}Rb, ^{84m}Rb, ^{86}Rb, ^{86m}Rb, ^{83}Sr, ^{83m}Sr, ^{90}Sr, ^{91}Y, ^{91m}Y, ^{88}Zr, ^{91}Nb, ^{91m}Nb, ^{92}Nb, ^{92m}Nb, ^{103m}Rh, ^{105}Rh, ^{105m}Rh, ^{103}Pd, ^{107}Pd, ^{107m}Pd, ^{105}Ag, ^{105m}Ag, ^{106}Ag, ^{106m}Ag, ^{111}Ag, ^{111m}Ag, ^{115}Cd, ^{115m}Cd, ^{115m}In, ^{119}Sb, ^{120}Sb, ^{120m}Sb, ^{129m}Xe, ^{131m}Xe, ^{133}Xe, ^{133m}Xe, ^{129}Cs, ^{131}Cs, ^{132}Cs, ^{131}Ba, ^{131m}Ba, ^{140}Nd, ^{147}Nd, ^{143}Pm, ^{144}Pm, ^{146}Pm, ^{147}Pm, ^{148}Pm, ^{148m}Pm, ^{149}Pm, ^{151}Pm, ^{151}Sm, ^{153}Sm, ^{149}Eu, ^{150}Eu, ^{150m}Eu, ^{156}Eu, ^{150}Gd, ^{151}Gd, ^{153}Gd, ^{175}Yb, ^{171}Lu, ^{171m}Lu, ^{172}Lu, ^{172m}Lu, ^{173}Lu, ^{174}Lu, ^{174m}Lu, ^{177}Lu, ^{177m}Lu, ^{173}Hf, ^{177m}Hf, ^{177n}Hf, ^{177}Ta, ^{183}Ta, ^{178}W, ^{183m}W, ^{201}Tl, ^{202}Tl, ^{202}Pb, ^{202m}Pb, ^{203}Pb, ^{203m}Pb, ^{203n}Pb and ^{205}Pb.

All decay data for these radionuclides have been evaluated in preparation for the creation of a data library in ENDF-6 format. Efforts have begun to assemble these data in conjunction with UKPADD-2 ((2) 236 radionuclides) and generate a new library of 328 radionuclides to be called UKPADD-3 (Table 2). Rigorous consistency checks will be made to confirm the validity and completeness of the data before the library is released.

A small number of positron-emitting radionuclides from UKPADD-2 were re-evaluated in preparation for the formation of UKPADD-3. These evaluations focussed on EC/positron ratios and the resulting emission probabilities of ^{13}N, ^{18}F, ^{26}Al, ^{26m}Al, ^{34}Cl, ^{34m}Cl, ^{38}K and ^{38m}K. The decay data of ^{34}P were also re-evaluated.

Table 2: Summary of Decay Data in UKPADD-3 Library

Nuclide	Decay Modes	Date of Evaluation (month/year)
1-H-3	β^-	October 1982
2-He-6	β^-	October 1982
2-He-8	β^-, β^- n (0.12)	October 1982
3-Li-8	$\beta^-\alpha$	April 1992
3-Li-9	β^-, β^- n (0.495)	April 1992
4-Be-7	EC	October 1982
4-Be-8	α	April 1992
4-Be-10	β^-	October 1982
4-Be-11	β^-, $\beta^-\alpha$ (0.030)	October 1982
5-B-12	β^-, $\beta^-\alpha$ (0.0158)	October 1982
5-B-13	β^-, β^- n (0.00276)	October 1982
6-C-14	β^-	October 1982
6-C-15	β^-	October 1982
7-N-13	EC	October 1982/December 1994
7-N-16	β^-, $\beta^-\alpha$ (0.0000120)	October 1982
8-O-19	β^-	October 1982
9-F-18	EC	October 1982/December 1994
9-F-20	β^-	October 1982
10-Ne-23	β^-	October 1982
11-Na-22	EC	November 1982
11-Na-24	β^-	November 1982
11-Na-24m	IT, β^- (0.005)	November 1982
11-Na-25	β^-	October 1982
11-Na-26	β^-	November 1982
12-Mg-27	β^-	November 1982
12-Mg-28	β^-	November 1982
13-Al-26	EC	November 1982/December 1994
13-Al-26m	EC	November 1982/December 1994
13-Al-28	β^-	November 1982
13-Al-29	β^-	November 1982
13-Al-30	β^-	November 1982
14-Si-31	β^-	November 1982
14-Si-32	β^-	November 1982
15-P-32	β^-	November 1982

Table 2 (Cont)

Nuclide	Decay Modes	Date of Evaluation (month/year)
15-P-33	β^-	November 1982
15-P-34	β^-	November 1982/December 1994
16-S-35	β^-	November 1982
16-S-37	β^-	November 1982
17-Cl-34	EC	November 1982/December 1994
17-Cl-34m	EC (0.52), IT (0.48)	December 1982/December 1994
17-Cl-36	β^-, EC (0.019)	December 1982
17-Cl-38	β^-	December 1982
17-Cl-38m	IT	November 1982
18-Ar-37	EC	December 1982
18-Ar-39	β^-	December 1982
18-Ar-41	β^-	January 1983
18-Ar-42	β^-	December 1982
19-K-38	EC	December 1982/December 1994
19-K-38m	EC	December 1982/December 1994
19-K-40	β^-, EC (0.107)	December 1982
19-K-42	β^-	February 1983
19-K-43	β^-	December 1982
19-K-44	β^-	March 1990
20-Ca-41	EC	December 1982
20-Ca-45	β^-	January 1992
20-Ca-47	β^-	April 1992
20-Ca-49	β^-	December 1982
21-Sc-44	EC	January 1983
21-Sc-44m	IT, EC (0.0123)	January 1983
21-Sc-46	β^-	February 1983
21-Sc-46m	IT	February 1983
21-Sc-47	β^-	December 1991
21-Sc-48	β^-	February 1983
21-Sc-49	β^-	December 1982
21-Sc-50	β^-	January 1992
21-Sc-50m	IT, β^- (0.0125)	January 1992
22-Ti-45	EC	April 1992
22-Ti-51	β^-	January 1992
23-V-48	EC	February 1983

Table 2 (Cont)

Nuclide	Decay Modes	Date of Evaluation (month/year)
23-V-49	EC	February 1983
23-V-52	β^-	January 1992
23-V-53	β^-	April 1992
23-V-54	β^-	April 1992
24-Cr-49	EC	January 1983
24-Cr-51	EC	August 1989
24-Cr-55	β^-	February 1992
25-Mn-53	EC	November 1993
25-Mn-54	EC	December 1991
25-Mn-56	β^-	January 1992
26-Fe-53	EC	January 1992
26-Fe-53m	IT	January 1992
26-Fe-55	EC	January 1992
26-Fe-59	β^-	December 1991
26-Fe-60	β^-	January 1994
27-Co-55	EC	February 1992
27-Co-56	EC	April 1992
27-Co-57	EC	January 1992
27-Co-58	EC	July 1991
27-Co-58m	IT	July 1991
27-Co-60	β^-	December 1991
27-Co-60m	IT, β^- (0.0025)	January 1994
28-Ni-57	EC	January 1992
28-Ni-59	EC	December 1991
28-Ni-63	β^-	July 1990
28-Ni-65	β^-	December 1991
28-Ni-66	β^-	August 1993
29-Cu-62	EC	February 1992
29-Cu-64	EC, β^- (0.3886)	January 1992
29-Cu-66	β^-	January 1992
29-Cu-67	β^-	August 1993
30-Zn-63	EC	March 1991
30-Zn-65	EC	January 1990
33-As-74	EC (0.66), β^- (0.34)	October 1990
34-Se-75	EC	January 1990

Table 2 (Cont)

Nuclide	Decay Modes	Date of Evaluation (month/year)
35-Br-79m	IT	February 1990
35-Br-80	β^-, EC (0.083)	September 1990
35-Br-80m	IT	September 1990
35-Br-82	β^-	December 1989
35-Br-82m	IT, β^- (0.024)	December 1989
36-Kr-79	EC	January 1990
36-Kr-79m	IT	January 1990
36-Kr-81	EC	May 1994
36-Kr-81m	IT, EC (0.000025)	May 1994
36-Kr-83m	IT	October 1993
36-Kr-85	β^-	April 1994
36-Kr-85m	β^-, IT (0.211)	April 1994
37-Rb-83	EC	October 1993
37-Rb-84	EC, β^- (0.032)	February 1994
37-Rb-84m	IT	August 1993
37-Rb-86	β^-, EC (0.000052)	April 1994
37-Rb-86m	IT	April 1994
38-Sr-83	EC	October 1993
38-Sr-83m	IT	October 1993
38-Sr-85	EC	February 1992
38-Sr-85m	IT, EC (0.134)	February 1992
38-Sr-89	β^-	January 1991
38-Sr-90	β^-	May 1994
39-Y-88	EC	March 1990
39-Y-89m	IT	January 1991
39-Y-90	β^-	February 1992
39-Y-90m	IT	February 1992
39-Y-91	β^-	April 1994
39-Y-91m	IT	April 1994
40-Zr-88	EC	May 1994
40-Zr-89	EC	January 1991
40-Zr-89m	IT, EC (0.0666)	January 1991
40-Zr-93	β^-	April 1990
40-Zr-95	β^-	November 1990
41-Nb-91	EC	April 1994

Table 2 (Cont)

Nuclide	Decay Modes	Date of Evaluation (month/year)
41-Nb-91m	IT, EC (0.024)	April 1994
41-Nb-92	EC	September 1993
41-Nb-92m	EC	September 1993
41-Nb-93m	IT	April 1990
41-Nb-94	β^-	January 1990
41-Nb-94m	IT, β^- (0.0050)	January 1990
41-Nb-95	β^-	November 1990
41-Nb-95m	IT, β^- (0.034)	November 1990
42-Mo-93	EC	March 1990
42-Mo-93m	IT, EC (0.0012)	March 1990
42-Mo-99	β^-	October 1990
43-Tc-99	β^-	July 1990
43-Tc-99m	IT, β^- (0.000037)	July 1990
44-Ru-103	β^-	May 1990
45-Rh-102	EC	December 1990
45-Rh-102m	EC (0.75), β^- (0.20), IT (0.05)	December 1990
45-Rh-103m	IT	May 1994
45-Rh-104	β^-, EC (0.0045)	June 1990
45-Rh-104m	IT, β^- (0.0013)	June 1990
45-Rh-105	β^-	January 1994
45-Rh-105m	IT	January 1994
46-Pd-103	EC	May 1994
46-Pd-107	β^-	November 1993
46-Pd-107m	IT	November 1993
47-Ag-105	EC	January 1994
47-Ag-105m	IT, EC (0.0034)	January 1994
47-Ag-106	EC, β^- (0.005)	January 1994
47-Ag-106m	EC	January 1994
47-Ag-107m	IT	July 1990
47-Ag-108	β^-, EC (0.029)	October 1990
47-Ag-108m	EC, IT (0.087)	January 1992
47-Ag-109m	IT	March 1990
47-Ag-110	β^-, EC (0.0030)	November 1991
47-Ag-110m	β^-, IT (0.0127)	November 1991
47-Ag-111	β^-	July 1994

Table 2 (Cont)

Nuclide	Decay Modes	Date of Evaluation (month/year)
47-Ag-111m	IT, β^- (0.005)	July 1994
48-Cd-109	EC	March 1990
48-Cd-111m	IT	January 1991
48-Cd-113	β^-	January 1991
48-Cd-113m	β^-, IT (0.0012)	January 1991
48-Cd-115	β^-	May 1994
48-Cd-115m	β^-	May 1994
49-In-111	EC	January 1991
49-In-111m	IT	January 1991
49-In-113m	IT	February 1991
49-In-114	β^-, EC (0.0050)	February 1992
49-In-114m	IT, EC (0.035)	February 1992
49-In-114n	IT	February 1992
49-In-115	β^-	March 1990
49-In-115m	IT, β^- (0.050)	May 1994
49-In-116	β^-	January 1992
49-In-116m	β^-	January 1992
49-In-116n	IT	January 1992
50-Sn-113	EC	February 1991
50-Sn-113m	IT, EC (0.089)	February 1991
50-Sn-117m	IT	January 1990
50-Sn-119m	IT	January 1992
50-Sn-121	β^-	January 1992
50-Sn-121m	IT, β^- (0.224)	January 1992
50-Sn-123	β^-	April 1991
50-Sn-123m	β^-	April 1991
50-Sn-125	β^-	October 1991
50-Sn-125m	β^-	October 1991
50-Sn-126	β^-	September 1990
51-Sb-119	EC	November 1993
51-Sb-120	EC	November 1993
51-Sb-120m	EC	November 1993
51-Sb-122	β^-, EC (0.0237)	July 1991
51-Sb-122m	IT	July 1991
51-Sb-124	β^-	November 1990

Table 2 (Cont)

Nuclide	Decay Modes	Date of Evaluation (month/year)
51-Sb-124m	IT, β^- (0.25)	December 1990
51-Sb-124n	IT	December 1990
51-Sb-125	β^-	January 1992
51-Sb-129	β^-	March 1992
51-Sb-129m	β^-, IT (0.15)	March 1992
52-Te-125m	IT	July 1991
52-Te-129	β^-	June 1992
52-Te-129m	IT, β^- (0.31)	June 1992
53-I-125	EC	January 1992
53-I-126	EC (0.563), β^- (0.437)	October 1990
54-Xe-125	EC	October 1991
54-Xe-125m	IT	October 1991
54-Xe-127	EC	March 1991
54-Xe-127m	IT	March 1991
54-Xe-129m	IT	September 1994
54-Xe-131m	IT	September 1994
54-Xe-133	β^-	September 1993
54-Xe-133m	IT	September 1993
55-Cs-129	EC	September 1994
55-Cs-131	EC	September 1994
55-Cs-132	EC, β^- (0.018)	August 1994
55-Cs-134	β^-, EC (0.000003)	March 1992
55-Cs-134m	IT	March 1992
55-Cs-135	β^-	July 1991
55-Cs-135m	IT	July 1991
55-Cs-136	β^-	October 1991
55-Cs-136m	β^- (0.5), IT (0.5)	October 1991
55-Cs-137	β^-	November 1990
56-Ba-131	EC	November 1994
56-Ba-131m	IT	November 1994
56-Ba-133	EC	January 1992
56-Ba-133m	IT, EC (0.000101)	March 1992
56-Ba-137m	IT	November 1990
58-Ce-139	EC	May 1992
58-Ce-139m	IT	May 1992

Table 2 (Cont)

Nuclide	Decay Modes	Date of Evaluation (month/year)
60-Nd-140	EC	November 1993
60-Nd-147	β^-	June 1994
61-Pm-143	EC	November 1993
61-Pm-144	EC	August 1993
61-Pm-145	EC, α (2.8×10^{-9})	July 1991
61-Pm-146	EC (0.66), β^- (0.34)	July 1994
61-Pm-147	β^-	June 1994
61-Pm-148	β^-	October 1993
61-Pm-148m	β^-, IT (0.05)	October 1993
61-Pm-149	β^-	February 1994
61-Pm-151	β^-	August 1994
62-Sm-145	EC	July 1991
62-Sm-146	α	July 1990
62-Sm-151	β^-	February 1994
62-Sm-153	β^-	August 1994
63-Eu-149	EC	February 1994
63-Eu-150	EC	November 1994
63-Eu-150m	β^-, EC (0.12)	November 1994
63-Eu-152	EC, β^- (0.280)	July 1992
63-Eu-152m	β^-, EC (0.28)	July 1992
63-Eu-152n	IT	July 1992
63-Eu-154	β^-, EC (0.0002)	May 1992
63-Eu-154m	IT	May 1992
63-Eu-155	β^-	December 1991
63-Eu-156	β^-	October 1994
64-Gd-150	α	December 1994
64-Gd-151	EC, α (10^{-8})	February 1994
64-Gd-153	EC	August 1994
65-Tb-157	EC	March 1991
66-Dy-157	EC	October 1991
66-Dy-159	EC	April 1991
70-Yb-175	β^-	December 1993/November 1994
71-Lu-171	EC	March 1994
71-Lu-171m	IT	November 1993
71-Lu-172	EC	December 1993

Table 2 (Cont)

Nuclide	Decay Modes	Date of Evaluation (month/year)
71-Lu-172m	IT	December 1993
71-Lu-173	EC	July 1994
71-Lu-174	EC	November 1993
71-Lu-174m	IT, EC (0.0058)	November 1993
71-Lu-177	β^-	February 1994
71-Lu-177m	β^-, IT (0.226)	February 1994
72-Hf-173	EC	July 1994
72-Hf-174	α	July 1991
72-Hf-175	EC	February 1992
72-Hf-177m	IT	February 1994
72-Hf-177n	IT	February 1994
72-Hf-181	β^-	January 1992
73-Ta-177	EC	September 1994
73-Ta-179	EC	March 1991
73-Ta-180	EC, β^- (0.181)	March 1991
73-Ta-180m	EC, β^- (0.20)	March 1991
73-Ta-182	β^-	December 1991
73-Ta-182m	IT	December 1991
73-Ta-182n	IT	December 1991
73-Ta-183	β^-	June 1994
74-W-178	EC	September 1994
74-W-181	EC	August 1991
74-W-183m	IT	June 1994
74-W-185	β^-	January 1991
74-W-185m	IT	January 1991
74-W-187	β^-	October 1991
79-Au-198	β^-	December 1987
79-Au-198m	IT	April 1992
80-Hg-197	EC	March 1992
80-Hg-197m	IT, EC (0.069)	March 1992
80-Hg-203	β^-	March 1991
81-Tl-201	EC	September 1993
81-Tl-202	EC	April 1994
81-Tl-204	β^-, EC (0.022)	November 1991
82-Pb-202	EC	December 1993

Table 2 (Cont)

Nuclide	Decay Modes	Date of Evaluation (month/year)
82-Pb-202m	IT, EC (0.091)	December 1993
82-Pb-203	EC	March 1994
82-Pb-203m	IT	March 1994
82-Pb-203n	IT	March 1994
82-Pb-204	α	November 1991
82-Pb-204m	IT	November 1991
82-Pb-205	EC	December 1993 (also in UKHEDD-2.1)
83-Bi-207	EC	August 1991
86-Rn-223	β^-	December 1992
90-Th-228	α	June 1989 (also in UKHEDD-2.1)
90-Th-231	β^-	April 1991 (also in UKHEDD-2.1)
93-Np-239	β^-	May 1991 (also in UKHEDD-2.1)
95-Am-241	α, SF (3.77×10^{-12})	May 1991 (also in UKHEDD-2.1)
95-Am-243	α, SF (3.7×10^{-11})	December 1989 (also in UKHEDD-2.1)

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

A new and improved version of the UK Heavy Element and Actinide Decay Data Library has been assembled (UKHEDD-2.1). Minor corrections have been made to some of the spontaneous fission data, and the new data files for Pa-234m and Pa-234g have been incorporated into the database.

3.2 JEF-PC: A PC-computer Based Program to Display Data From the JEF-2.2 Library (D R Weaver (University of Birmingham))

The School of Physics and Space Research at the University of Birmingham has maintained involvement in the development of programs to provide convenient means of displaying data from the JEF library. This culminated in the Autumn of 1994 when the program was released commercially by the OECD; details can be obtained from the NEA Data Bank (3). The involvement of the University of Birmingham during 1994 has concerned the final "beta" testing of the code and the resolution of the remaining problems, particularly those concerning the modules which display the data from the JEF library. Development of the main driver module "Nucleus" (used to display the Chart of the Nuclides) was undertaken at the NEA Data Bank in collaboration with CSNSM Orsay.

3.3 JEF-X (R F Evans and D R Weaver (University of Birmingham))

The JEF-PC Nuclides Database has been produced with the aim of allowing a method of fast and easy access to the new JEF-2.2 (Joint Evaluated Data File) and above all to allow user-friendly access to this file using a mouse in a Windows-based environment. JEF-X (UNIX - based equivalent) is currently being developed at the University of Birmingham; this unit displays decay and cross section data for over 2000 ground state and metastable state nuclides and will eventually contain fission yield data. JEF-X operates in a workstation environment under the UNIX operating system and should be accessible from any console or X-terminal. The source code (JEF-X.f) is written in FORTRAN 77, and the graphics are achieved with GKS (Graphical Kernel System). These studies are being sponsored by British Nuclear Fuels plc.

3.4 Fission Product Yield Evaluations (M F James (consultant to BNF plc), R W Mills (BNF plc) and D R Weaver (University of Birmingham))

The UK fission product yield evaluation programme has continued with work focussed on the production of a new evaluated library (UKFY3) which is an extension to the previous UKFY2 library (the latter is described in AEA reports AEA-TRS-1015, 1018 and 1019). The data collection, analysis, modelling, production of complete yields sets and final adjustment to physical constraints have been completed.

The new library UKFY3.0 has been sent to the NEA Data Bank as an initial contribution to the JEFF3 file. This is the first version of the file as changes in the decay data in JEFF3 will need to be included in the modelling and adjustment procedures for the final file to be self-consistent. The UK group also remains involved in the IAEA Coordinated Research Programme on the Compilation and Evaluation of Fission Yield Nuclear Data and the JEF evaluation programme of the NEA.

3.5 Cross-Section Evaluations (C J Dean (Winfrith))

R A Forest has been involved in the preparation of version 3.1 of the European Activation File. The file contains cross section data for neutron induced reactions (0 to 20MeV) on 729 targets and includes 12,899 reactions with non-zero cross sections. The targets include isotopes of all elements H to Cm which have half-lives > 0.5 days. Ground and metastable state targets and daughters are given. The file is in ENDF-style (but not ENDF/B-VI) format. Many of the cross sections depend on nuclear theory but data have been selected from evaluations when these are available. Normalisation to measured 14 MeV data has been applied. This database presents a valuable source of neutron activation data for both fusion and fission reactors, and has been condensed to 100, 175 and 69 groups for applications. A continuing programme of development is identified to extend the data to cover a further 386 reactions.

The activation data have been applied to the study of stainless steel activation in potential fusion first-wall/blankets.

4. NUCLEAR DATA PROCESSING

JEF-2.2 and other evaluated data have been reformed into group cross-section libraries using mainly the NJOY code. Methods of library generation have been developed at Winfrith (HSE/IMC funding), including the selection of a list of fission products represented in WIMS (using existing cross-section data based on JEF-1 and earlier evaluations coupled with JEF-2.2 decay and yield data). The cross sections in the resulting 1995 WIMS data library are based on JEF-2.2, and represent a good example of the close relationship between core physics and fuel inventory calculations.

5. INTERNATIONAL COOPERATION

The UK contributes to several NEA/OECD and IAEA programmes involving nuclear data development, particularly the Joint Evaluated File (JEF). UK representatives report back to the UKNSF and raise items of importance to members. Attendance has included December 1993 JEF working group meetings and June and December 1994 meetings. During 1993 JEF-2.2 cross section files were frozen for benchmark testing: these tests are still in complete, but a considerable number of papers have been presented covering reactor physics, shielding and criticality. JEF-2.2 is seen to give comparable results with existing UK libraries for fission uranium-fuelled systems, without adjustments to those libraries. It has become necessary to design methods benchmarks to resolve code differences which now seem as large as the data effects.

JEFF3 will now be developed, which involves updating individual evaluations as needed over a 5 year programme. It would enable application libraries based on JEF-2.2 to be appended if any data item had significant effect on required physics results. JEFF3 will use JEF-2.2 and European Fusion File EFF-2.4 as source data bases. A common JEFF3 database will be developed for fission and fusion applications in Europe. International collaboration through the NEANSC measurement and evaluation working groups will continue.

Evaluated nuclear data libraries installed at Winfrith for application library development include JEF-1.1, JEF-2.2, ENDF/B-VI revision 2, JENDL-3.1, ENDL-84, and IRDF-90.

Developments have been made with the INTER code to generate version 6.8; INTER is a Brookhaven National Laboratory (BNL) code used to calculate 2200 m/s and thermal cross sections, resonance integrals and fission spectrum averaged plus 14 MeV cross sections. Improvements were implemented at Winfrith, and the code has been used to generate data for JEF Report 14.

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APPENDIX 1

UNITED KINGDOM NUCLEAR SCIENCE FORUM

Constitution, 5 May 1994

1. The name of the organisation shall be the United Kingdom Nuclear Science Forum, with the accepted abbreviation UKNSF and referred to hereinafter as "the Forum".

2. The Forum will interface with the UK Department of Trade and Industry (DTI) on all appropriate matters.

3. Close liaison shall be maintained with the UK nuclear industry through the Industry Management Committee comprising representatives of British Nuclear Fuels plc, Nuclear Electric and Scottish Nuclear Ltd or whatsoever other body which shall have responsibility for the payment of the UK contribution to the costs of the NEA Data Bank.

4. The Chairman and Secretary of the Forum, subject to the agreement of the Management of their organisation(s), shall be appointed by a majority of the members of the Forum at the time; the position of these appointments will be reviewed every 3 years.

5. Members of the Forum shall be appointed by the Chairman, with the approval of a majority of the members present at a meeting of the Forum, the quorum for which shall be ten excluding the Chairman and Secretary.

6. Meetings may be hosted by any member organisation which shall be prepared to bear the costs thereof, excluding expenses of members deriving from their attendance.

7. Changes to the Constitution will be made at meetings of the UKNSF with the approval of a majority of members at the time.

Terms of Reference for the UK Nuclear Science Forum
9 February 1995

The UK Nuclear Science Forum will serve as a focal point for users of nuclear data and of the services provided by the NEA Data Bank and IAEA Nuclear Data Section, and will be available to meet DTI's needs for advice on these matters.

1. The UK Nuclear Science Forum (UKNSF) is responsible to the DTI for maintaining UK interfaces with the IAEA Nuclear Data Section and the Nuclear Science Committee of the NEA. The Forum will provide briefings and advice to UK representatives who attend meetings of the key international bodies (i.e. NEA-NSC and IAEA-NDS).

2. Membership of the UKNSF is open to all bona fide users of the NEA Data Bank services or those whose work depends on the use of such services, and includes:

   (i) policy makers,
   (ii) data users,
   (iii) data measurers,
   (iv) data evaluators.

   Membership will vary over time; the Chairmanship and Secretaryship will be cycled amongst the membership.

3. Financing of the UK contribution to the NEA Data Bank is set out in DTI-UKNSF agreement on the Subscription to the NEA Data Bank.

4. The Forum will seek advice from appropriate UK bodies responsible for nuclear applications.

5. The objectives of the NSF are as follows:

   (a) Act as UK focus for matters relating to the Nuclear Science Committee of the NEA and the IAEA Nuclear Data Section.
   (b) Provide a communications link between regulators, data users and data producers to assist in establishing UK policy with respect to said data issues.
   (c) Provide an interface with relevant national committees in other countries and with international committees (i.e. NEA-NSC and INDC).
   (d) Advise on and monitor the activities and memberships of the relevant international committees.
   (e) Ensure the UK is fully represented in the development of international data libraries, and ensure that such libraries are adequate for UK needs.
   (f) Provide peer-review reports of measurements, evaluations and tests of basic nuclear data, and identify needs and discrepancies in these data.
   (g) Identify programmes of work to improve the quality of nuclear data libraries on the basis of "fit for purpose".
   (h) Engender expertise in measuring, evaluating, processing, testing and using nuclear data in the UK.

(i) Decide by discussions between users and producers of data the best and most user-friendly ways of making data available to the scientific community, and assist in achieving this objective by encouraging suitable publications and software development.

6. Nuclear data will constitute the major technical specialisation of the Forum. This area includes:

(i) radioactive decay data,
(ii) fission yields,
(iii) neutron production and reaction cross-sections,
(iv) spectra and angular distributions of emitted particles,
(v) integral data (e.g. (α,n) for thick targets),
(vi) charged-particle and photon cross-sections.

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