DRAFT

The UK JEF International Benchmarking Programme: Current Status and Future Programme.

N T Gulliford

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1. Background

The Joint Evaluated File (JEF) is an international collaboration set up to establish a single consistent nuclear data library for use in a wide range of nuclear applications.

With the release of JEF2.2 in mid 1992, an extensive programme of integral benchmark testing is being undertaken by the various JEF Project members In the UK this work is carried out mainly by AEA Technology, funded through the HSE & IMC Research Programme . At Winfrith the Benchmarking Programme has provided validation in the Reactor Physics, Shielding and Criticality areas through a range of analyses of experiments in the DIMPLE, NESTOR and ZEBRA reactors and other international benchmark experiments.

There are two main aims of the programme:-

1) To establish a set of clean, high precision benchmark comparisons to provide validation, or derive adjustments, for the JEF2.2 basic nuclear data library.

2) To validate the use of JEF2.2 data in UK codes for a range of applications.

The experiments selected for the benchmarking programme therefore include a number of very simple geometries, with few isotopes, for verification of the basic isotope data, along with other experiments covering composite materials used in the nuclear industry.

This note gives a summary of progress to date and outlines the proposed programme for 1994/95.

2 Summary of Benchmarking to Date

Tables 1-3 give a summary of the UK JEF2.2 Benchmarking Programme performed to date in the reactor physics, shielding and criticality areas. Details of the results have been published in references 1-6 and presented at meetings of the JEF Benchmarking Working Group (7).

The following main conclusions have been drawn from the benchmarking to date.

1) In all areas, (reactor physics, shielding and criticality), the JEF data performed generally as well as, and often better than, existing adjusted UK libraries.

2) Benchmarking results for plutonium systems showed less consistent agreement than uranium systems indicating significant adjustments may be required for some plutonium isotope cross-sections.

3) There is a shortage of reliable, high precision benchmark experiments in the open literature for plutonium systems.

In response to points 2) and 3), the UK benchmarking programme for 1993/94 includes a number of plutonium benchmarks. Preliminary results, (and results from the French programme), indicate that the large overpredictions (2-3%) in keff seen for the 1992/93 plutonium/polythene benchmark are not typical and are probably due to experimental error.

3 Current Status of JEF libraries in the UK

The current version of the JEF Nuclear Data File is JEF2.2, which was released in 1992 for benchmarking purposes. The results of the benchmarking from the various participants are collated for analysis at CEA Cadarache to produce a set of recommended adjustments which will be submitted for peer review at the JEF Working Group on Benchmark Evaluation and for approval by the JEF Steering Group. In the UK, the results of the benchmarking are reported in detailed benchmark document form to the HSE and the main conclusions are disseminated to the UK nuclear industry through various committees and working parties such as the UK WPC, the CNDC, the RPMWG and the ANSWERS Users Seminars.

The current planning is for a release of JEF3 in 1995, although this will be strongly dependant on the amount of effort that can be made available to the JEF Project for data evaluation. It is estimated that the re-evaluation will require a total of about 7man-years effort, and on the basis of the current resources available, the work will take about 18 months.

With the uncertainties in the date for a release of the JEF3 library, and in the light of the generally good results obtained in all applications using JEF2.2 it has been suggested that JEF2.2 should be released as soon as possible for general use. Consideration should also be given to the possibility of making adjustments directly to the application libraries if there is a clear indication of possible improvements, (eg plutonium data), from the benchmarking programme. This would allow the UK Industry to benefit early from the work of the JEF Project, while retaining the option of adopting the final version of JEF3 when it becomes available.

It is noted however, that there are some potential drawbacks from this approach.

One of the fundamental aims of the JEF Project is to produce a single consistent data library suitable for all applications. 'Tweaking' of individual application libraries

would effectively limit the validation database to those benchmarks which can be analysed with each code. For plutonium isotopes in particular, there is a shortage of high quality benchmark data. Some modern experiments in this area are commercial property and as such may not be available for analysis in the UK.

The introduction of an 'interim' library will introduce an extra iteration in the benchmark validation process; however, once all the models are set up, the process of repeating the calculations is less onerous.

4 Future Programme

4.1 Integral Benchmarking

Tables 1-3 also show the remaining experiments available in the MONK, MCBEND and WIMS validation databases. The highlighted items form the provisional JEF Integral Benchmarking Programme for 1994/95. This list has been selected to provide an extensive validation base for applications in the UK industry, with the aim of providing sufficient validation to support the general use of JEF data before the end of 1995.

Figure 1 and Table 4 give a summary of the major steps required to achieve that aim. Following the 1994/95 benchmarking programme an assessment of adjustment requirements will be made. On the basis of results to date, it is likely that little or no adjustment will be required for uranium isotopes. The situation for plutonium isotopes is currently less clear. The programme for 1994/95 is designed, within the limits of available data, to provide sufficient information on which a preliminary adjustment to the applications library could be made, ahead of the re-evaluation for JEF3 which will be based on a wider selection of experiments.

By the end of the 94/95 financial year, the position regarding the release date for JEF3 should also be clearer. This will give the UK industry the opportunity to decide whether to proceed with the option of releasing adjusted (or unadjusted) versions of JEF2.2 or to wait for the general release of JEF3. Obviously, the programme for 1995/96 will depend entirely on that decision, and on the amount of JEF2.2 adjustment required. An indication of the main tasks involved in each option is shown in Table 4.

The highlighted programme in Tables 1 to 3 represents a significant extension to that originally envisaged, and would require about £100k above the prevoius estimate for the continuation of the project.

4.2 Shielding Benchmark Experiment in ASPIS

JEF benchmarking in the shielding area has covered single material experiments for iron, water and graphite. A mixed iron/water benchmark has also been analysed, and will be reported as part of the 1993/94 programme.

There is strong support from the UK industry for a proposed graphite/iron benchmark

experiment in the ASPIS facility of NESTOR to demonstrate the use of JEF data for calculations where spectral changes in the neutron flux through the shielding materials play a major part in the calculation of dose-rates. Analysis of the AGR bottom shield simulation (see Table 2) will also provide useful validation in this area, although the experiment was designed primarily to investigate streaming effects. The JANUS stainless steel benchmark is included in the analysis programme for 1994/95, to extend the validation database to cover this important composite material.

A proposal for a new ASPIS experiment, and analysis using JEF, will be submitted for funding from the 1994/95 HSE & IMC Research Programme.

5 Conclusions

This note summarises the forward programme for the UK JEF Benchmarking Programme in 1994/95 and outlines the options for the general release of JEF application libraries in the UK. A proposal to release adjusted JEF2.2 application libraries in the UK ahead of the release of JEF3 would represent a significant change to the current philosophy of the JEF Project, but offers the UK the possibility of access to improved nuclear data at an earlier date.

The 1994/95 programme will be presented for endorsement by the JEF Working Group on Benchmarking and Evaluation in December 1993. In the UK, proposals for a continuation of the HSE & IMC Research Programme, as summarised in this note are currently being prepared.

References

1 D Hanlon Assessment of JEF2.2 Nuclear Data Library for LWR Lattice Calculations AEA-RS-1253

2 N R Smith et al Benchmarking JEF2.2 with MONK AEA-RS-1238

3 H F Locke Benchmark Testing of JEF2.2 Data for Shielding Applications :Analysis of the Winfrith Water Benchmark Experiment AEA-RS-1232

4 G A Wright Benchmark Testing of JEF2.2 Data for Shielding Applications :Analysis of the Winfrith Iron Benchmark Experiment AEA-RS-1232

5 D Hanlon Assessment of JEF2.2 Nuclear Data Library for Fuel Transport Flask Criticality Calculations AEA-RS-1247

6 J Perry C J Dean JEF2.2 Benchmarking Calculations for Thermal Reactor Pin Cells using WIMS at Winfrith LWPC/P(92)47 JEF/DOC/395

7 N T Gulliford Note on the June 1993 JEF Working Group Meeting on Benchmarking and Evaluation WPC/P189

Table 1 Summary of MONK Validation Programme for JEF.

By the end of the current financial year the following experiments will have been analysed as part of the MONK validation project and re-calculated as part of the JEF benchmarking project.

1. 2.35% UO_2 pins in water - various fixed absorbers
2. 4.75% UO_2 pins in water - various pitches
3. 4.31% UO_2 pins in water - various fixed absorbers
4. PuO_2/polystyrene compacts - 11.46% Pu240, H:Pu ratio = 5, Plexiglas reflector
5. Plutonium nitrate solution - 4.6% Pu240, various reflectors
6. Mixed UO_2/PuO_2/polystyrene compacts - 7.86% Pu (of which 8% Pu240), H:(U+Pu)=51.85, Plexiglas reflector
7. 2.46% UO_2 pins in water - close proximity storage
8. Metal uranium spheres - bare and reflected
9. Intersecting cylinders of uranyl fluoride
10. Cylinders of mixed nitrate solution
11. Mixed oxide pins in water
12. Plutonium metal spheres - bare and reflected

Of the existing MONK6 core validation database the following experiments remain to be studied:

- **3x3x3 array of high enriched uranyl nitrate solution**
- clusters of 4.31% UO_2 pins with various reflecting walls
- clusters of 2.35% UO_2 pins with various reflecting walls
- lattice of 4.75% UO_2 pins in sodium nitrate solution
- water moderated high enriched plates of uranium/aluminium alloy
- lattice of 4.74% UO_2 pins with lead reflector
- **$U(4.98)O_2F_2$ solutions - spheres and annuli**
- **high burnup plutonium nitrate solution cylinders (43% Pu240)**
- **plutonium nitrate spheres (2.5% Pu240)**
- **mixed oxide fuel pins with various absorbers**
- **mixed oxide compacts with various reflectors and absorbers**

Table 1 Continued.....

- **mixed oxide fuel pins in mixed nitrate solution**
- **mixed nitrate solutions with various levels of moderation**

In addition the following experiments could usefully be added to the validation database:

- **Japanese/US mixed oxide experiments with a range of fuel compositions.**
- **Low enriched UO_2 powder exponential experiments (LEMUR, Springfields).**
- **DIMPLE S06 cores (PWR Mock-up)**
- ZEBRA intermediate spectrum cores
- Hanford 'dissolver' experiments
- Plutonium nitrate solutions with boron and hafnium poisons

Table 2 Summary of McBEND Validation Programme for JEF

Name	Description	Analysed With JEF2.2 ?
Winfrith water benchmark	50cm water High energy detectors Cf sources	Yes, 1992/93
Winfrith graphite benchmark	70cm graphite Fission plate source	Yes, 1993/94
NESDIP 2	As for NESDIP 1 but larger fission plate	Yes, 1993/94
JANUS Iron88 benchmark	67cm mild steel Fission plate source	Yes, 1992/93
Low energy water benchmark	40cm water Thermal detectors AmBe source	No
JANUS Stainless steel benchmark	**18cm mild steel, 40cm stainless steel Fission plate source**	**No**
JANUS stainless steel/sodium	18cm mild steel, 22cm stainless steel, 90cm sodium Fission plate source	No
JANUS stainless steel/boron carbide (4 variants)	5cm or 10cm boron carbide within stainless steel shield Fission plate source	No
JANUS boron carbide benchmark	18cm mild steel, 53cm boron carbide, 90 cm sodium Fission plate source	No
JANUS sodium benchmark	18cm mild steel, 290cm sodium Fission plate source	No
REPLICA	Replica of PCA benchmark (iron/water shield simulating RPV) Fission plate source	No
NESDIP 1	As for REPLICA but larger shield components	No
NESDIP 3	Radial shield Fission plate source	No
NESDIP cavity, coolant duct and nozzle	Simulated cavity, etc of PWR with NESDIP3 radial shield	No

AGR bottom shield simulation	**Simulated AGR bottom shield**	**No**
HBRobinson PWR reactor	Cavity and surveillance capsule measurements Reactor source	No
Belgian reactors *	Cavity and surveillance capsule measurements Reactor source	No

* Provisional : AEA are hoping to obtain measurement data from various Belgian reactors. This could be used to validate JEF2.2 data in a practical reactor situation.

Experiments in bold type are AEA suggestions for the 1994/95 programme (two experiments can be analysed).

Table 3 Summary of WIMS Validation Programme for JEF

Name	Description	Analysed with JEF2.2 JEF/DOC/395
Graphite Moderated		
Magnox		
BICEP	**22 Experiments U Metal (U nat. + some enrichment) Al clad, air cooled, pincell geometry. AEEW-R235 Barclay (AEEW- R473) analysed 26 expts. More cases could be added if needed.**	**Expt. 2.7 and 10.**
Hanford	**5 Experiments Natural U rods in Al, air cooled, pincell geometry. Barclay (AEEW- R473) analysed 6 expts.**	
AGR		
CORPIO	Windscale AGR fuel cluster - enrichment 1.8%. CO_2 cooled. 2 ring cluster (7 and 14 rods) Studies temperature coefficients. (298 + 660K)	
Hinkley B	CAGR 2.55% enrichment burnup to 25GWD/Te. Used to compare cross pin power tilts and compositions calculated with earlier libraries. However AMPNK/P(86)6 reported PIE measurements of isotopic ratios which can be compared with calculations. (WIMSE experimental test case.) Other PIE studies will be considered including production of Am and Cm.	
Heysham 2 Reactor 8	A 2 stage case. A CAGR unpoisoned 2.6 W/O used in an NNC study to compare WIMS and ARGOSY fuel temperature coefficients (AMPNK/P(85)20) is available in the data base. It is validated against an ARGOSY calculation comparing measured fuel temperature coefficients for Heysham 2. (AMPNK/P(89)1). It would probably be better to set up the Heysham 2 case directly.	
Dungeness B	**Commissioning expts, including rod removal in stages, critical cases are available from Les Hutton. (A large number of MONK5W cases.)**	
Light Water Moderated		
ORNL	**5 Experiments. Bare spheres of Uranyl nitrate Spheres (93% U235) and H_2O adjusted to criticality by boric acid. (CESWG benchmarks)**	
TRX	**1.3% enriched uranium metal clad in Al. Triangular pitch varied lattice spacings. TRX1 and 2 are included as pincells. TRX1-4 are included in CESWG. Full core loadings are described for Monte Carlo. There are no measured bucklings for TRX3 and 4.**	**TRX 1 and 2**

Table 3 Continued.....

DIMPLE	5 Experiments, 3% enriched UO_2 pins clad in stainless steel, varying moderator to fuel ratio. R1,R2,R3/100H and S01. R1 at 80 and 20K. Improvements to the S01 model are required. Later DIMPLE cases are benchmarked using MONK6 simple WIMS models may be included in parallel.	All reported
Brookhaven	10 experiments, 3% enriched UO_2 pins clad in stainless steel, varying moderator to fuel ratio and concentration of boric acid.	All reported
ESADA	11 experiments, PuO_2/UO2 pins clad in Zr, fixed pin size with varying pitch, boron poisoning, and Pu240 percentage.	
KRITZ-1	46*46 UO_2 pins, Zircaloy clad at 20, 90, 160, and 210K. (1.35W% U235) An improved model from D Powney should be used.	
KRITZ 2.1	44*44 UO_2 pins (1.86W% U235) 19.7C and 248.5C boron poisoned. Available from D Powney.	
KRITZ 2.13	40*40 UO_2 pins (1.86W% U235) 22.1 and 243C boron poisoned. Available from D Powney.	
KRITZ 2.19	25*24 PUO_2/UO_2 pins 21.1 and 235C boron poisoned. Available from D Powney.	
Heavy Water Moderated		
Wurenlingen	3 experiments, natural uranium pins clad in Al, varying square pitch in pincell geometry.	All reported
Savannah River	4 experiments natural uranium pins clad in Al, varying hexagonal pitch in pincell geometry.	All reported
"Rowlands" PWR Pincell	Not an experimental assembly. A typical PWR pincell is being used by the JEF working group to obtain detailed comparisons of METHODS and DATA PROCESSING in Europe. This should be included in the WIMS data base, possibly replacing the similar calculation already present. It is defined in JEF/DOC/359.	
Un-moderated		
Homogeneous Metal	2 experiments to determine the enrichment of uranium metal giving Kinfinity of unity. Kajanskij gives 5.54 atom percent U235. Darrouzet gives 5.56 atom percent U235. (Tests fast energy range data)	

Table 3 Continued.....

Homogeneous oxide	2 experiments to determine the enrichment of uranium oxide giving Kinfinity of unity. Dulin gives 7.49 atom percent U235. Darrouzet gives 7.39 atom percent U235.
Snell	Natural Uranium (kinfinity=0.45) with a large negative buckling (-0.0119cm**2) to give Keff=1.0.
Lemur Criticality Safety Experiments	**4 sub-critical intermediate spectrum experiments, 2% enriched UO_2 with differing H/U ratios. An external source was used to irradiate each experiment. Fluxes measured in the experimental material enabled critical sizes and material bucklings to be determined. Modeled in WIMS as homogeneous regions with input bucklings.**
Others	
ZED2	71 cases from Chalk River; including 7 pin uranium carbide fuel; 7, 19, and 28 pin uranium oxide fuel and thorium fuelled assemblies. Coolants include D_2O, axial Air, and organic compounds. These CANDU assemblies have end gaps between the pins which can be worth 200-300 PCM in K.

Table 4 Outline of Options for Release of JEF Libraries in the UK

Option 1. Wait for JEF3. Estimated Start -January 1994

Main Tasks	Estimated Duration	Remarks
Re-Evaluate Basic Data	18 months	JEF Project Task.
Process with NJOY	3 months	
Re-run Validation Cases	3 months	
Release Application Libraries	1 month	
Test User Libraries	?	Establish QA route to Winfrith Validations

Option 2. Release Unadjusted JEF2.2 Application Libraries. Estimated Start -June 1995

Main Tasks	Estimated Duration	Remarks
Release Application Libraries	1 month	
Test User Libraries	?	Establish QA route to Winfrith Validations

Option 3. Release Adjusted JEF2.2 Application Libraries. Estimated Start -June 1995

Main Tasks	Estimated Duration	Remarks
Apply Adjustments	3 months	Duration depends on required adjustments
Re-run Validation Cases	3 months	
Release Application Libraries	1 month	
Test User Libraries	?	Establish QA route to Winfrith Validations

Figure 1 Summary of Proposed JEF Benchmarking Programme

MAIN TASKS

1. Complete 93/94 Programme
2. Define 94/95 Programme
3. Complete 94/95 Benchmarking
4. Assess Adjustment Requirement
5. Choose Option (see below and Table 4)
   - i) Wait for JEF3
   - ii) Release JEF2.2 without adjustment
   - iii) Release JEF2.2 with adjustments to application libraries.

KEY MILESTONES

1. Approval by HSE & JEF Working Group — December 1993
2. Benchmark Reports to HSE — March 1994
3. Benchmark Reports to HSE (including summary of adjustment requirement) — March 1995
4. Agreement of relevant UK Code User Committees. — May 1995

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