NUCLEAR DATA REQUIREMENTS FOR FISSION REACTOR NEUTRONICS CALCULATIONS

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ABSTRACT

The paper discusses current European nuclear data measurement and evaluation requirements for fission reactor technology applications and problems involved in meeting the requirements. Reference is made to the NEA High Priority Nuclear Data Request List and to the production of the new JEFF-3 library of evaluated nuclear data. There are requirements for both differential (or basic) nuclear data measurements and for different types of integral measurement: critical facility measurements and isotopic sample irradiation measurements. Cross-section adjustment procedures are being used to take into account the simpler types of integral measurement, and to define accuracy needs for evaluated nuclear data.

I. INTRODUCTION

Current reactor design developments are concerned with the management of the stocks of separated plutonium and other highly radioactive materials, both minor actinide isotopes and fission products. Studies are being carried out of the most efficient ways to reduce the plutonium stocks by recycling in reactors, so as to fission the plutonium and the minor actinide isotopes produced by neutron capture.\(^1\)

Fueling of Light Water Reactors with first generation recycled plutonium is already being carried out on an industrial scale in several Western European countries, with the aim of reducing the plutonium stocks and closing the fuel cycle, thus providing a better use of resources. Studies of recycling of higher generation plutonium in thermal reactors are now being carried out.\(^1\) An alternative to incineration of plutonium, which is being considered in some countries, is activation by means of a limited irradiation in reactors. This conditioning of the plutonium reduces the risks of diversion for illegal weapons use.

The nuclear data for the higher isotopes of plutonium and the minor actinides become of greater importance in all of these developments. An accurate knowledge of the variation of plutonium isotopic composition with burnup, and with multiple recycling, is required for the assessment of enrichment requirements and safety parameters, such as voiding coefficients and the effectiveness of absorbers. Nuclear data requirements can be defined by the need to calculate all neutronics parameters with the same degree of accuracy for all types of fuel composition.

Fast reactors have a number of potential advantages for incineration over light water reactors. They have more flexibility in the quality of plutonium which they can use, the production of minor actinides per fission can be lower and there are more neutrons per fission available for incineration. Accelerator driven sub-critical systems (ADS) can provide even more neutrons per fission for use in incineration of waste. The range of nuclear data requirements then extends into the intermediate energy range, from 20 MeV up to several hundred MeV, and there are requirements for both proton and neutron interaction data. For these systems, nuclear data accuracy requirements still need to be clearly defined; it is sometimes claimed that the subcritical margin makes the ADS more forgiving with respect to data uncertainties; nevertheless, the very small margin used in many designs (\(k = 0.98\)) makes this argument irrelevant.
Interest is also returning to the thorium cycle as a way of reducing the problems of plutonium production. Nuclear data are then required for the isotopes of the U-233-thorium cycle to an accuracy comparable with that achieved for U-235, U-238, and Pu-239. The potential of lead cooling is also being re-evaluated.

The countries of Western Europe are now dependent on international organisations and cooperative projects to meet their nuclear data requirements. Indeed all countries benefit from international cooperation in the measurement and evaluation of nuclear data. The NEA Nuclear Science Committee has two Working Parties which, respectively, provide a framework for international cooperation on evaluation (the Working Party on International Evaluation Cooperation, WPEC) and on measurement (the Working Party on International Measurement Activities, WPMA). The WPEC has a subgroup which coordinates the production of the NEA High Priority Nuclear Data Request List, and this can now be viewed on the World Wide Web. The list is reviewed each year at a joint session of the WPEC and WPMA.

II. REACTOR DEVELOPMENTS REQUIRING IMPROVED NUCLEAR DATA

A major objective of current fission reactor developments in several Western European countries is the reduction of the stocks of plutonium, leading to the closure of the fuel cycle. There is also the objective of incineration of the isotopes which contribute to the long-term radiotoxicity of the waste. In Western Europe plutonium is being recycled in light water reactors in Belgium, France, Germany and Switzerland. However, the plutonium being recycled is limited at present to first generation plutonium (that is, plutonium produced in uranium fuel). Studies are in progress to make it possible to recycle all plutonium and also the minor actinide isotopes. In France there is a major programme of studies on both the incineration of long term radioactive waste materials and the long-term storage of the waste.

III. CURRENT DEVELOPMENTS BASED ON EXISTING PWR REACTOR TECHNOLOGY

In the following discussion the developments being studied in France are described, in order to be more specific. In France, where about 80% of the electricity is produced in the “Park” of about 55 PWRs, about 1 reactor in 5 now contains plutonium fuelled and the number can be extended up to about half of the reactors. MOX assemblies occupy 30% of the cores of these plutonium fuelled reactors, the remainder being UO₂ assemblies. The MOX assemblies contain fuel in three enrichment zones, this being required in order to match the fission rates in the MOX fuel pins to those in the neighbouring UOX assemblies. Such heterogeneous designs have required critical facility measurements to validate fission distribution calculations and also such safety parameters as coolant voiding coefficients. At present it is only first generation Pu which is being recycled, that is plutonium produced in uranium fuel and it will be possible to recycle all first generation Pu in this way. The JEF-2.2 library of evaluated nuclear data has been shown to be very satisfactory for the prediction of neutronics characteristics of these reactors. In particular, criticality, power distributions, rod worths, and void worths are usually calculated with an accuracy equivalent to that reached for UO₂ cores. It is expected that JEF-2.2 will soon start industrial use without any adjustment. A few problems have been observed in particular, it appears that small but non-negligible biases appear in the calculated spent fuel content for Pu-242, Am-242, and Am-243. This indicates a need for reducing the uncertainty on the evaluated capture cross sections of the higher Pu isotopes and Am.

The plutonium recovered from irradiated MOX fuel, second generation Pu, presents more of a problem for recycling because it contains a lower percentage of fissile plutonium isotopes. A consequence of recycling plutonium is that a higher proportion of isotopes of americium and curium is produced (per unit power) and the effect of this on the radiotoxicity of long-term waste is quite significant.

The aim of the current developments is to find the best ways to recycle higher generation Pu, together with the Am and Cm which is produced. To recycle all of the plutonium produced, and to reduce the existing stocks requires a higher proportion of the fuel to consist of plutonium. Two approaches are being studied. One is to fuel the whole of the core homogeneously with assemblies containing plutonium/uranium fuel rods and the second is to use heterogeneous assemblies which contain both plutonium rods and uranium rods. There are cost advantages to reducing the number of fuel rods containing plutonium, as well as permitting more flexibility in the design.

Plutonium fueling results in a harder neutron spectrum – fewer thermalised neutrons. The traditional absorbers, such as natural boron, are less
effective and other materials have to be considered. An alternative is to increase the moderation ratio and this also has the merit of reducing the higher actinide production. There are various possible ways of doing this. Ways which are being investigated include reducing the fuel rod diameter while maintaining the pitch, adopting annular fuel rods, and having the plutonium present in an inert, moderating matrix. This can be done by having the plutonium fuel in the form of a cermet (the ceramic PuO₂ plus a metal, such as zirconium) or a cerce (the ceramic PuO₂ plus a ceramic, such as cerium oxide, CeO₂). The cerce form is currently favoured.

In the homogeneous assembly designs the plutonium is mixed with enriched uranium. In the heterogeneous design annular plutonium fuel rods free from uranium (using an inert matrix) are used together with enriched uranium fuel rods present in the same assembly. In the annular rod the central channel of coolant acts as a flux trap, thus producing more thermalised neutrons. These designs are proposed for use in existing PWR reactors, and in the new French/German design of PWR, the European Pressurised Reactor, EPR. The americium and curium can be included in the plutonium fuel or in separate rods, or rigs, specially designed to make the incineration most efficient.

IV. INTEGRAL AND DIFFERENTIAL MEASUREMENT REQUIREMENT FOR THE PWR DESIGN STUDIES

The design studies require nuclear data for the higher plutonium, americium and curium isotopes, in particular the capture and fission cross-sections. Isotopic sample irradiation experiments, made in different spectra, provide data suitable for validating the differential capture cross-sections and for modifying them (in a simple way), when necessary. Data are also required for alternative possible absorbers, such as hafnium and erbium, and for the cerce inert matrix materials. Burnable poisons play a more important part in some designs. For the fission product isotopes, such as Tc-99 and I-129 for which incineration studies are being carried out, differential cross-section measurements are preferred, but integral measurements of reactivity worths made in different spectra provide a means for validating the data. An example is the CERES programme of measurements, relating to burnup credit in fuel reprocessing, made in DIMPLE, Winfrith, and MINERVE, Cadarache. Differential cross-section measurements for Tc-99 have been made at the IRMM Geel laboratories of the European Commission.

Integral measurements on zero power critical facilities are required to validate calculations of fission rate distributions in heterogeneous designs, and to confirm calculations of coolant voiding effects. Such measurements have been carried out in the EOLE facility at Cadarache, and in the VENUS facility at Mol.

The alternative to mixing the Am and Cm isotopes in the fuel is to incinerate these isotopes separately in special rigs containing materials chosen to modify the spectra. Special experiments are being carried out in zero power and in power reactors to help in the design of these.

The delayed neutron fraction is another item of data of importance. It is much smaller in a plutonium fuelled reactor than with uranium fuelling and this has consequent effects on safety parameters.

The isotopic sample irradiation experiments have shown the need for modifications to the JEF-2.2 capture data for U-235 (resonance region), Pu-242, Am-241 and Am-243, for example.

Major nuclear data requirements for future FWR studies are summarized below:

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Reaction</th>
<th>Energy Range</th>
<th>Required Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tc-99</td>
<td>Capture</td>
<td>1 eV-100 k eV</td>
<td>±10%</td>
</tr>
<tr>
<td>U-235</td>
<td>Capture</td>
<td>1 eV - 1 keV</td>
<td>±3%</td>
</tr>
<tr>
<td>Pu-240</td>
<td>Capture</td>
<td>1 eV - 1 keV</td>
<td>±5%</td>
</tr>
<tr>
<td>Pu-241</td>
<td>Capture</td>
<td>1 eV - 1 keV</td>
<td>±5%</td>
</tr>
<tr>
<td>Pu-242</td>
<td>Capture</td>
<td>1 eV - 1 keV</td>
<td>±5%</td>
</tr>
<tr>
<td>Np-237</td>
<td>Capture</td>
<td>0.1 eV - 1 keV</td>
<td>±10%</td>
</tr>
<tr>
<td>Am-241</td>
<td>Capture</td>
<td>0.1 eV - 1 keV</td>
<td>±10%</td>
</tr>
<tr>
<td>Am-243</td>
<td>Capture</td>
<td>0.1 eV - 1 keV</td>
<td>±6%</td>
</tr>
<tr>
<td>Ag, Cd, In, Er, Hf</td>
<td>Capture</td>
<td>thermal and resonance range</td>
<td>±5%</td>
</tr>
</tbody>
</table>

V. FAST REACTOR DESIGN STUDIES

Incineration of fission products in the existing thermal reactors is problematical because of the shortage of excess neutrons (per fission). There is more flexibility for incineration of both fission...
products and minor actinides in fast reactors and they are better able to use degraded plutonium, having only a small percentage of the fissile isotopes.

The fast reactor design developments aimed at reducing plutonium stocks and incinerating waste products involve the elimination of fertile breeder regions, with these being replaced by reflector regions, and a reduction in the proportion of breeder material in the core. The studies include the use of plutonium fuel in an inert matrix, such as CeO₂. The reduction in breeder material in the core and blankets has the two aims of reducing the amount of plutonium produced and making more neutrons available for incineration of waste. However, the reduction of core breeding increases the loss of reactivity with burnup, thus increasing the reactivity control requirements.

Current studies in France (the CAPRA Project) have been supported by special irradiation experiments in PHENIX and mock-up assembly studies in the fast critical facility MASURCA at Cadarache. Isotopic sample irradiation experiments have been used to validate and adjust capture cross-sections. The core designs adopted for these studies have made away with the traditional axial and radial blankets; analyses of integral experiments with direct core-reflector interfaces indicate that there exists a need to improve total and inelastic cross sections for the major structural isotopes. The shielding materials are of greater importance and measurements of iron inelastic scattering and total cross-section fluctuations in the unresolved resonance region have been made at Geel.

Fast reactor studies are typically carried out with adjusted fine group nuclear data libraries; a large effort has recently been devoted to realizing a JEF-2 based library, which indicates the need to improve the following evaluations: Pu-239 (n,2n); Pu-240 v,(n,γ), fission; Pu-241 (n,γ); Pu-242 (n,γ), fission; U-238 v, (n,n’); Na-23 (n,n), (n,n’); Fe-56 (n,n’).

New evaluations have been produced for JEFF-3 for sodium and Fe-56, taking into account the inelastic scattering measurements made at IRMM Geel. There are requirements for improvements in the accuracy of the inelastic scattering data for Th-232, U-238, Pu-239 and Pu-240. Improved capture data at keV energies are required for Th-232, U-233, Pu-240, Pu-241, and Pu-242.

VI. HYBRID SYSTEMS

In order to get more free neutrons per fission, studies are being made of accelerator-driven subcritical cores. The studies have been pioneered at Los Alamos and more recently carried out at CERN. There is interest in the project in several European countries and there is the possibility of construction of a zero-power facility in the near future, involving a European collaboration. Some studies on source-driven subcritical systems are being carried out in the MASURCA facility at Cadarache.

The current designs involve proton beams producing neutrons by the process of spallation in targets consisting of materials such as lead. Indeed, in some design studies the coolant is lead. U-233 / thorium fuelling is also being considered.

These design studies require nuclear data covering a much wider range of energies and reactions - reaction data at energies from 20 MeV to about 200 MeV for protons and to about 100 MeV for neutrons; that is, in the intermediate energy range. Much work has already been done at Los Alamos and the JEFF-3 library has been extended to include these data.

It isn't only the design of the target, and the window between the accelerator and the target, which requires this high-energy data. Shielding must be designed and irradiation damage effects assessed over the whole reactor for these very penetrating high-energy particles. The technological problems are great.

The high priority nuclear data measurement requirements have been chosen to provide data for the most important isotopes and to enable the parameters used in the theoretical models to be refined.

Nuclear data accuracy requirements for hybrid systems have not yet been clearly defined. Nevertheless, two simple observations can help set them. First, as far as the target is concerned, any uncertainty on the neutron production will directly impact the accelerator design margin, and thus its cost; an accuracy of ±10% in total neutron production appears to be a reasonable objective. On the reactor side, efficiency of neutron multiplication requires that kₚ be relatively close to 1. Consequently, uncertainties on kₚ should remain small, of the same size as for conventional reactor.
### Cross-section Measurement Requirements for the Intermediate Energy Range

<table>
<thead>
<tr>
<th>Proton induced reactions</th>
<th>20 to 200 MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutron induced reactions</td>
<td>20 to 100 MeV</td>
</tr>
<tr>
<td>Isotopes of primary interest</td>
<td>O-16, Al-27, Fe-56, Ni-58, Zr-90, Mo-100, W-184, Pb-208, Th-232, U-238</td>
</tr>
</tbody>
</table>

### VII. REQUIREMENTS FOR FUEL TRANSPORT, STORAGE, AND REPROCESSING

Improved accuracy in decay heat predictions requires the resolution of discrepancies between summation calculations and integral measurements of decay heat, in particular the underestimation of the gamma component. A number of isotopes have been proposed for remeasurement.

**Radioactive Decay Data Requirements**

Relating to the FP Decay Heat \( \gamma \)-ray

Discrepancy at Moderate Cooling Times

Parameter to be measured: The level scheme up to a high excitation and the \( \beta \)-feeding rate. Alternatively, the \( \gamma \)-ray energy release per \( \beta \)-decay:

- **Priority 1**: Tc-102, Tc-104, Tc-105
- **Priority 2**: Y-94, Y-95, Mo-102, Xe-137, Xe-138, Cs-138, Cs-139, Ba-141
- **Priority 3**: Rb-89, Mo-101, Tc-101, La-143

Parameter to be measured: \( \beta \)-branching ratio to the ground and to the isomer:

- **Priority 1**: Rh-108
- **Priority 2**: Tc-133

There are potential savings if account can be taken of burnup credit in fuel reprocessing. This has prompted the measurement of the reactivity effects of selected fission products in different thermal reactor spectra. The CERES programme has provided data for 12 fission products to an accuracy of about \( \pm 5\% \). As a consequence of this measurement programme in MINERVE (Cadarache) and DIMPLE (Winfrith) these requirements have essentially been met.

### Isotopes Studied in the CERES Programme

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Isotope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo-95</td>
<td>Sm-149</td>
</tr>
<tr>
<td>Tc-99</td>
<td>Sm-152</td>
</tr>
<tr>
<td>Rh-103</td>
<td>Nd-143</td>
</tr>
<tr>
<td>Ag-109</td>
<td>Nd-145</td>
</tr>
<tr>
<td>Cs-133</td>
<td>Eu-153</td>
</tr>
<tr>
<td>Sm-147</td>
<td>Gd-155</td>
</tr>
</tbody>
</table>

The measurements have shown that the thermal and resonance integral data in the JEF-2.2 evaluations are satisfactory for all excepting Cs-133 and Eu-153.

### VIII. INTERNATIONAL COOPERATION IN MEETING THE NUCLEAR DATA REQUIREMENTS

Here, “nuclear data” is used in the broad sense of differential and integral measurements and neutronics studies in critical and subcritical assemblies. All of these types of measurements are required in order to validate the data and methods required for the proposed new developments.

National capabilities in Western European countries are now very limited and all countries now benefit from international cooperative projects to meet their requirements. However, some countries are taking the precaution of maintaining the necessary expertise in measurement, analysis and evaluation, so that they could become self-sufficient again if necessary.

In Western Europe high-resolution differential cross-section measurements can now only be made at IRMM, the Geel laboratories of the European Community. Evaluation is being carried out within the framework of the Joint Evaluation Fission and Fusion File Project, JEFF, coordinated by a NEA Data Bank Scientific Coordination Group.

### IX. MEASUREMENT REQUIREMENTS

Although mathematical procedures have been developed for deciding on the optimum programme of differential cross-section and integral measurements needed to meet a set of accuracy requirements in reactor predictions these predictions depend on quantities which are very difficult
(impossible ?) to estimate - the cost-benefit of an improvement in accuracy and the cost of obtaining data to the required accuracy. Instead of trying to estimate these quantities it is usual to decide the requirements on the basis of broad judgements guided by calculations of the percentage contribution of a reaction to a neutronics parameter of interest (the sensitivity). Resolving discrepancies in important cross-sections, or between integral measurements and the calculated values, is also a reason for requesting improved data.

A. Uncertainty Information

Clearly it is necessary to know the accuracy of the existing evaluated nuclear data. A weakness of many current evaluations is the absence of uncertainty information and an objective of future evaluation activities should be to provide this information. In considering this requirement for uncertainty data we should remember that integral measurements are to be taken into account in deriving the final covariance matrix to be used in calculating the accuracy of prediction of reactor neutronics parameters. In many cases the accuracy of these measurements has the strongest effect on the accuracy of prediction. However, for those properties which cannot be measured in integral experiments, or involve a significant extrapolation from the integral measurements, the accuracy of the differential cross-sections is important. When resonance shielding effects are important accurate differential cross-section measurements, resolving the resonance structure, are required.

B. Achievable Accuracies

When deciding measurement requirements account should be taken of the accuracy which is achievable. In many cases it is unlikely that a higher accuracy could be obtained, using existing facilities and techniques, than that already obtained. Nevertheless it is useful to give an indication of the benefits to be obtained if the accuracy could be improved. There is a continuing programme of work to improve the accuracy of nuclear data standards relative to which other cross-sections etc. are measured, and this work, together with other developments, will provide possibilities of improved accuracies.

X. THE STATES OF THE JEF-2.2/EFF-2.4 LIBRARIES AND THE DEVELOPMENT OF THE JEFF-3 NUCLEAR DATA LIBRARY

Efforts are continuing to complete the final summary documentation for the current libraries, JEF-2.2 and EFF-2.4. Both files have been well received by the nuclear community in Europe and are already widely used. Extensive benchmarking documentation for all applications is ready or near completion and is to be issued by the end of 1998 or early 1999.

A question which has faced the JEFF Project when the development of the new library JEFF-3 was being discussed is whether the new library should include all of the best available new evaluations or whether new evaluations (relative to JEF-2.2 and EFF-2.4) should be adopted only when there has been shown to be a need for an improvement. A large effort has been devoted to the validation of JEF-2.2 and EFF-2.4 and a repeat of all of this work is to be avoided, if possible. The validation work necessary before the nuclear industry will adopt a new applications library is considerable (perhaps 100 man years). Libraries developed in the 1960s and 70s are still in use in some applications. It is primarily when the industry is faced with a new situation (such as plutonium fuelling of light water reactors) that it is keen to adopt a new, improved library, validated for the new application. Even then the industrial users might prefer to continue to use the established methods and data but with the possibility of making check calculations using an independent data set.

The essential changes to the JEFF library involve primary materials, such as U-235 (resonance capture), and Fe-56 (cross-sections above the inelastic threshold). Because of this there will be changes to the calculated values of most integral properties which have been calculated to validate the data, albeit small in some cases. The effect of the above changes on calculated reactor spectra is expected to be small (that is, of the order of the measurement uncertainties, or less) in the case of the fission product isotopes which have been validated using capture reaction rate measurements and reactivity worth measurements. The spectrum changes are also expected to have a sufficiently small effect for the capture and fission cross-section measurements used to validate the data for the minor actinide isotopes. When the data for these are found to be satisfactory in the JEF-2.2 validation studies they will be adopted unaltered in JEFF-3, even though the methodology used in other evaluations might be more refined and up-to-date.
A. The Adjustment of Cross-sections

The JEF-2.2 capture cross-sections of a number of fission product isotopes had already been adjusted on the basis of fast reactor integral measurements and the need for further adjustments is being studied. The role of adjustment in the development of the JEFF-3 library is still being considered. Clearly, when reevaluation is shown to be needed and is possible on the basis of existing measurements, as has been the case for U-235 resonance capture, this is the preferred solution. However, there are cases when the differential cross-section measurements are not sufficiently accurate or one is relying on theory to provide the data. If the integral measurements indicate a change which is within the uncertainties of the differential data (and in a way which is physically consistent) then adjustment is considered to be appropriate.

B. Choice of Evaluations for JEFF-3

In 1997, a detailed survey of candidate evaluations for the JEFF-3 starter file was carried out, and a list of recommendations prepared. In general, adoption of new evaluations was only recommended in cases where a need for improvement had been demonstrated.

Quality Assurance procedures for the assembly and maintenance of the JEFF-3 library have been developed and implemented at the NEA Data Bank.

Compilation of the JEFF-3 General Purpose Library Starter File, at the NEA Data Bank, is in progress. About 90% of the evaluations have been loaded into the database, and run through the standard ENDF checking codes. Work continues to load the remaining recommended evaluations, but in some cases the new evaluations have not yet become available. The aim is to complete the assembly of this starter file by the autumn. During the assembly and testing phase of the new library, other new evaluations may be completed and recommended for inclusion, thus yielding further changes and improvements. Also, final decisions have still to be made on fission-products, absorbers, and Am and Cm isotopes. For the fission product isotopes it is only the 24 most important isotopes which are being reviewed in detail. Intercomparisons have been made with other libraries and the total reactivity effects of fission products compared. The differences are small and it is considered unnecessary to change the evaluations for the bulk of the isotopes, even though there are some more recent evaluations in other libraries. The situation is similar for the minor actinide isotopes. For the most important fission product and minor actinide isotopes the choice is guided by the results of integral measurements together with an examination of differential cross-section measurements made since the evaluations were completed.

The release of the first version of the JEFF-3 General Purpose Starter File for the first phase of benchmark testing is planned for the final quarter of 1998. Further improvements and benchmarking should then take place in 1999/2000 with an official release of the JEFF-3 General Purpose Library in 2001 or 2002. Selected individual evaluations could be released earlier for special applications.

The comprehensive activation file EAF-97 will be a special-purpose annex of JEFF-3, and work continues to extend some of the evaluations to higher energies. The new UK Fission Yield library, UKFY-3, has been offered for inclusion in JEFF-3, and a number of nuclides important for fission and fusion applications have been reevaluated for the radioactive decay data library. Implementation of a Quality Management System for the JEFF-3 Radioactive Decay data library and the Fission Yield data library is planned to commence at the end of 1998. Assembly of the starter files will then begin in early 1999.

XI. CONCLUDING REMARKS

An important objective which is being pursued in several countries is the development of reactor designs suitable for fissioning the stocks of plutonium and minor actinide isotopes, and incinerating selected long-lived radiotoxic fission product isotopes, by-products of fission reactor operation. The reactor concepts and operating strategies which are being studied require improved nuclear data for the higher isotopes of plutonium and isotopes of americium and curium, and also for those fission product isotopes for which incineration is a practicable objective. There are also requirements for structural materials and potential new coolant materials, and for alternative control absorbers. Hybrid systems extend the energy range of interest to intermediate energies and there are requirements for proton interaction data as well as neutron data.

The NEA List of High Priority Nuclear Data Requirements has the objective of focussing the limited efforts, available worldwide for measuring and evaluating nuclear data, on the most important requirements. Reactor physicists are urged to give
careful consideration to the present and likely future needs, and to monitor the progress being made towards meeting them.

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