GROWING DIMENSIONS

SPENT FUEL MANAGEMENT AT RESEARCH REACTORS

BY IAIN G. RITCHIE

More than 550 nuclear research reactors are operating or shutdown around the world. At many of these reactors, spent fuel from their operations is stored, pending decisions on its final disposition. In recent years, problems associated with this spent fuel storage have loomed larger in the international nuclear community. Concerns principally focus on the ageing fuel storage facilities, their life extension, and the ultimate disposal of spent fuel assemblies. At both research and test reactors, spent fuel is being stored for longer periods than originally planned and in larger quantities.

In efforts to determine the overall scope of problems and to develop a database on the subject, the IAEA has surveyed research reactor operators in its Member States. Information for the Research Reactor Spent Fuel Database (RRSFDB) so far has been obtained from a limited but representative number of research reactors. It supplements data already on hand in the Agency's more established Research Reactor Database (RRDB).

Drawing upon these database resources, this article presents an overall picture of spent fuel management and storage at the world's research reactors, in the context of associated national and international programmes in the field.

GLOBAL CONTEXT

Two main programmes dominate activities for management, interim storage, and ultimate disposal of spent nuclear fuel from research and test reactors:

The Reduced Enrichment for Research and Test Reactors (RERTR) Programme. Initiated in the United States in support of its nuclear non-proliferation policy, this programme is directed at the conversion of research reactors from the burning of high-enriched uranium (HEU) to low-enriched uranium (LEU). It is now nearly a worldwide programme with the full support of the Russian Federation and ongoing discussions with China. The RERTR programme has already limited and will, if it becomes global, eventually eliminate all trade in HEU for research reactors to the ultimate benefit of the international community. In many cases, however, the conversion to LEU has compounded the problems of spent fuel management because the facilities in question have been left with the spent HEU and in a few cases have had to deal with a greater throughput of LEU fuel after conversion.

The "Take-Back" Programme. When research reactors were first commissioned decades ago, it was assumed in most cases that the spent fuel would eventually be shipped back to the country where it was originally enriched, the country of origin. At many facilities, the return of spent fuel to the country of origin has not yet happened for various reasons. As a result, in some countries, ageing and corroding fuel is currently stored in facilities that were not designed for such long-term storage. The two main countries of origin are the United States and Russian Federation. In May 1996, the United States confirmed its intention to take back foreign research reactor fuel of US origin, thereby resuming an earlier policy. It is hoped that other supplier countries and partners in RERTR will follow suit and implement their own take-back programmes for foreign research reactor spent fuel they originally supplied.

Although the IAEA has fully supported RERTR since its inception, it was not until 1993 that the Division of Nuclear Fuel Cycle and Waste Technology extended its programme to focus specifically on spent fuels from research and test reactors. These activities now cover the collection, analysis and dissemination of information on storage, management and related experience with spent fuels, formulation

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of norms, and provision of technical assistance to developing Member States.

A number of concerns were immediately apparent at the beginning of 1993. Many research reactors were in a crisis situation or rapidly approaching a crisis situation. In every case, this was due to spent fuel storage and management problems and the constraints of national laws. It was clear that the capacity for spent fuel storage had been reached or was close to the limit at many research reactors and there were concerns from a materials science point of view about ageing materials in ageing storage facilities.

The IAEA's activities in this area have been formulated to address these concerns. But the first step was to obtain an overall picture of spent fuel management and storage worldwide.

As of December 1997, the IAEA's Research Reactor Database (RRDB) contained information on 589 reactors regionally distributed around the world. Of these, 269 were operational and 303 were shutdown. Additionally, twelve were under construction, six planned, and one whose status was not completely verified.

The age distribution of operational research reactors in the RRDB peaks in the range of 30 to 40 years. In fact, 19% of the reactors are in the age range of 20 to 29 years and 51% in the range of 30 to 39 years. A large fraction, 46%, of operational research reactors operate at a thermal power of 100 kW or less. Almost all of these 122 reactors have fuel for life and will not have spent fuel problems until they permanently shut down.

SCOPE OF PROBLEMS

Based on responses to questionnaires sent to IAEA Member States, the Agency is developing a Research Reactor Spent Fuel Database (RRSFDB). Though its coverage to date is limited to about 210 research reactors, analysis of available information enables a clearer definition of the types of problems that countries are facing. In the months and years ahead, it will be important to keep building the database so that a clearer and more accurate picture can emerge and problems are adequately addressed. Analysis of the data so far paints the following picture.

A large variety of fuel types and fuel assembly geometries are in use in research and test reactors. Consequently, special storage conditions are often necessary, as well as different types of transport casks and different techniques for dealing with failed fuel.

Most research reactor fuels are shipped in assembly form. For this reason, in RRSFDB, spent fuel numbers are recorded in assemblies, where a fuel assembly is defined as "the smallest fuel unit that can be moved during normal reactor operation or storage". At any particular facility, several different spent fuel types or spent fuels of different enrichments are usually stored. For example, the store may contain one or more types of HEU from before core conversion and one or more types of LEU following conversion.

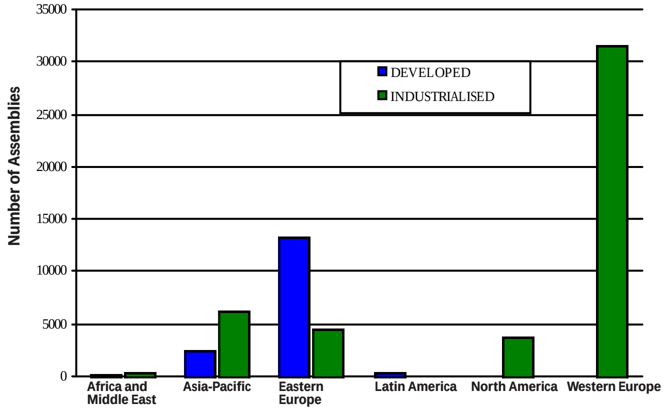
Overall, there are 62,870 spent fuel assemblies stored in the facilities that have responded to the RRSFDB questionnaires to date and another 32,932 assemblies in the standard cores. Of these 62,870 assemblies, 46,394 are in industrialized countries and 16,476 are in developing countries, while 22,686 are HEU and 40,184 are LEU.

The distribution of fuel types among the reactors in the RRSFDB shows that a significant percentage (28%) are classified as "other" types. This underlines the fact that many experimental and exotic fuels exist at research reactors around the world, posing problems for their continued storage, transportation, and ultimate disposal.

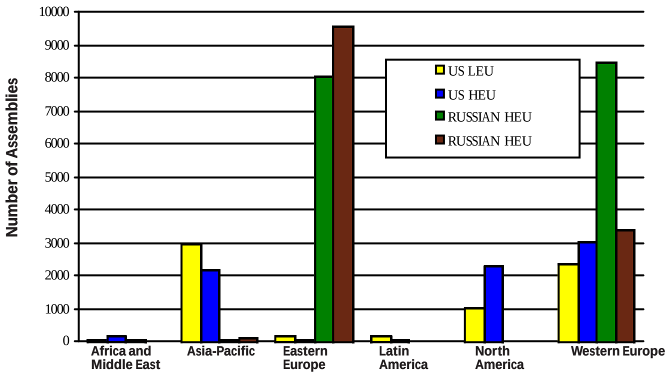
By region, the majority of spent fuel assemblies are stored in industrialized countries. *(See graph page 30.)* In examining the origins of the enrichment of spent fuel in the RRSFDB, the data shows, as expected, that the US supplied all of the enriched fuel in North America and most of that in Asia-Pacific, while Russia (or the former Soviet Union) supplied most of the enriched fuel in Eastern Europe.

Fuel of US and Russian origin fuel involves totals of 7756 HEU and 6775 LEU assemblies of US-origin and 13,035 HEU and 16,620 LEU assemblies of Russian-origin. Of interest is the fact that HEU outweighs LEU in North America, whereas the reverse is true in Western Europe. *(See graph page 30.)* To some extent this is because more research reactors in Western Europe have undergone core conversion than is the case in North America. It is worth noting that a significant fraction of Russian-origin HEU was originally enriched to only 36%, while most US-ori-

DISTRIBUTION OF RESEARCH REACTOR SPENT FUEL AMONG DEVELOPING AND INDUSTRIALIZED COUNTRIES



GEOGRAPHICAL DISTRIBUTION OF US- AND RUSSIAN-ORIGIN URANIUM FUEL BY ENRICHMENT



gin HEU was originally enriched to 90% or more.

The numbers of US-origin and Russian-origin HEU and LEU spent fuel assemblies at foreign research reactors which might be involved in take-back programmes also were compared. At present 15,531 spent fuel assemblies of US-origin are located at foreign research reactors, while the equivalent number of Russian-origin is 29,673.

As previously noted, the RRSFDB involves only a limited number of the known research reactors in the world; nevertheless these data give an idea of the scope of the problem represented by research reactor fuels. On the basis of these data and a rough knowledge of the numbers of assemblies used each year, projections indicate a rising trend over the next eight years.

Storage Methods. By far the most commonly used form of spent fuel storage is the at-reactor pool, pond or basin. Since the average age of these facilities in the RRSFDB is 25 years, the success of wet storage where the water chemistry has been well controlled is remarkable. In fact, many aluminium clad Material Test Reactor fuels and aluminium pool liners show few, if any, signs of either localized or general corrosion after more than 30 years of exposure to research reactor water. In contrast, when water quality was allowed to degrade aluminum clad, fuel is seriously corroded.

Data also show that many facilities also have an auxiliary away-from-reactor pool or dry well. At away-from-reactor facilities, the trend is to transfer fuel from wet storage to dry storage, which avoids some of the expense of water treatment facilities and their maintenance.

Clearly, dry storage requires less monitoring and maintenance than wet storage and at most dry storage facilities the operators monitor the activity continuously. Several, however, are recognizing the importance of assessing the moisture content of dry storage facilities.

The IAEA survey also addressed the concerns expressed by reactor operators about their spent fuel management programmes. Not surprisingly, the majority are concerned about the final disposal of their fuel. This is followed by concerns about limited storage capacity, and materials degradation. Surprisingly, finance is of lesser concern now than in previous responses to the IAEA questionnaire. Presumably, this is due, at least in part, to the US "take-back" programme, which is paying for the disposal of spent research reactor fuel from the lower income countries possessing fuel of US origin.

FINDING SOLUTIONS

The global picture that has emerged from the IAEA's analysis of spent fuel management at research reactors underscores the need for greater international cooperation to resolve outstanding problems and issues. This includes broadening the aware-

SUPPORTING NEEDS

Through various avenues, the IAEA is supporting national and global efforts related to spent fuel management at research and test reactors. Besides compiling and maintaining databases on research reactors and their associated spent fuel management programmes, the Agency has actively supported the USA's programme called Reduced Enrichment at Research and Test Reactors (RERTR), which addresses nuclear non-proliferation goals.

It further has been involved, as an observer, in most meetings of the "ad hoc" group of research reactor operators, known as the Edlow Group, which successfully sought to return US-origin spent fuel from foreign research reactors. Towards this end, the IAEA Director General, in July 1993, wrote to the Secretary of the US Department of Energy and, in February 1995, to the Minister of Atomic Energy of the Russian Federation, suggesting that these major partners in RERTR could facilitate the non-proliferation goal of RERTR by taking back foreign research reactor fuel. To aid the US take-back programme, especially for developing Member States, the Agency has organized activities to help its Member States prepare their spent fuel for shipment back to its country of origin. Major activities have included a training course held at Argonne National Laboratory, USA, from 13-24 January 1997 and the preparation of draft technical guidance, *Guidelines Document on Technical and Administrative Preparations Required for Shipment of Research Reactor Spent Fuel to its Country of Origin.*

Other recent activities have involved national and international experts in the preparation of a Safety Guide, *Design, Operation and Safety Analysis Report for Spent Fuel Storage Facilities at Research Reactors*, which has been submitted for publication. During 1997 the IAEA further convened a Technical Committee Meeting to collect and evaluate information on procedures and techniques for the management of failed fuels from research reactors and an Advisory Group Meeting on the Management and Storage of Experimental and Exotic Spent Fuels from Research and Test Reactors. Also, the Agency offers advice through IFMAP, the Irradiated Fuel Management Advisory Programme, to operators of spent fuel storage facilities and more tangible assistance to developing Member States through the IAEA's Technical Assistance and Co-operation programmes.

Recognizing that the degradation of materials, equipment, and facilities through ageing is becoming of more concern to many operators, the Agency has organized several activities in the materials' science field. Prominent among these was the preparation of a document on the durability of nuclear fuels and components in wet storage, which is being published by the Agency. This document contains information on aluminium clad fuels used in research reactors developed as part of a Coordinated Research Project (CRP) on Irradiation Enhanced Degradation of Materials in Spent Fuel Storage Facilities. Another CRP is devoted specifically to research reactor fuel cladding and focuses on the monitoring and control of corrosion in wet storage. These programmes are supplemented by a series of regional workshops that have been organized to deal with all aspects of spent fuel handling, management, storage and preparation for shipment.

ness of the scope and urgency of concerns.

It is also clear that take-back programmes of foreign research reactor fuels, if and when they are implemented, will not continue indefinitely. At some stage in the not too distant future (in 2006 for foreign research reactors with US-origin fuel), research reactor operators will be faced with having to find their own solutions regarding the permanent disposal of their spent fuel. For countries with no nuclear power programme, the construction of geological repositories for the relatively small amounts of spent fuel from one or two research reactors is obviously not practicable. For such countries, access to a regional interim storage facility and eventually a regional or international repository for research reactor fuel would be an ideal solution. The time is ripe for serious discussion of regional or international solutions and to begin planning for the day when neither take-back programmes nor the reprocessing option might be available. ❐