RISING DEMANDS

MANAGEMENT OF SPENT FUEL FROM NUCLEAR POWER PLANTS

BY PETER H. DYCK AND MARTIN J. CRIJNS

Last year about 10,000 tonnes of heavy metal were discharged as spent fuel from the world's nuclear power plants after use for the production of electricity. This spent fuel was placed in storage at specially designed facilities, kept and monitored for later retrieval either for reprocessing or later disposal in repositories.

In the coming years, the storage of greater quantities of spent fuel for longer periods of time is projected. As a result, the world's nuclear industries are building new storage facilities, expanding existing ones, and putting into practice technologies to ensure more effective long-term storage.

This article presents an overview of approaches that countries are following for the management of spent fuel from nuclear power plants, and briefly describes selected IAEA activities in the field.

BASIC APPROACHES

Spent fuel management encompasses an integrated series of technical operations. They begin with the discharge of spent fuel assemblies from a power reactor and end either with their direct disposal (open, or "once-through" fuel cycle); or with their reprocessing and the final disposal of the associated high-level wastes (closed fuel cycle). Direct disposal involves steps that would place the spent fuel in a location, such as a geological repository, under conditions which would not permit its later removal. Reprocessing operations separate the fissile plutonium and uranium from the waste materials for reuse as recycled fuel in reactors.

Originally the intention behind the closed fuel cycle concept was to recycle the separated plutonium and uranium in fast-breeder reactors. However, delays and cancellations of breeder programmes have led to the recycling of the separated fissile materials in thermal reactors already operating. Presently, thermal recycling of plutonium (as mixed-oxide, or MOX, fuel) is being carried out mainly in Belgium, France, Germany, Japan, and Switzerland. Thermal recyling of uranium is being carried out in the Russian Federation and in the United Kingdom, and is planned in Germany.

A third option for managing spent fuel is the deferral of decisions and involves interim storage. The approach enables operators to monitor the stored spent fuel continuously and to retrieve it later for either direct disposal or reprocessing. Most countries with nuclear power programmes follow this option. *(See table, next page.)* The selection of a spent fuel strategy is a complex decision with many factors to be taken into account, including aspects of policies, economics, safeguards, and environmental protection. A common feature in most countries, independent of the spent fuel management strategy being followed, is the ongoing need for additional storage capacity.

CHANGING PRACTICES

In earlier days of nuclear power development, countries following the closed fuel cycle generally stored spent fuel at the reactor in storage pools, in which the assemblies are submerged underwater in racks or contained in canisters, and, after transportation, in storage pools at a reprocessing plant.

However, the lack of enough storage capacity at reprocessing plants altered the picture. At the same time, not all countries selected the closed fuel cycle option and instead chose to store the spent fuel pending decisions as to its final disposal. As a result, nuclear utilities started expanding their storage pool capacity for spent fuel. Additionally, pool-type storage facilities were built either on the reactor site or elsewhere. Since then, no final disposal sites for spent fuel have been built, and the

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Mr. Dyck is a staff member in the IAEA Division of Nuclear Fuel Cycle and Waste Technology, and Mr. Crijns is a consultant in the Division.

demands for long-term storage have intensified. In response, other storage technologies, involving emplacement of spent fuel in dry gaseous environments using casks, silos or vaults, have been developed and are typically located at sites away from the reactor (AFR).

Various types of wet and dry storage facilities now are in operation or under construction in different countries. Spent fuel can be safely stored for long time periods, and some has been stored for more than 30 years.

Overall, a variety of different technologies and systems are in use or planned. In most countries, storage pools at reactors are or will be reracked with high-density neutron absorber racks, to make more efficient use of available storage space. In some cases, ultra high-density racks (for example, in Slovenia and South Africa) will be used to store the spent fuel for the planned lifetime of the reactor. For AFR storage pools, improved steel containers and canisters are used to store the fuel more compactly so as to increase storage capacity.

In 1997, the annual spent fuel arisings from all types of reactors in nuclear power plants amounted to about 10,500 tonnes of heavy metal (tHM). The total amount of spent fuel accumulated worldwide at the end of 1997 was about 200,000 tHM and projections indicate that the cumulative amount generated by the year 2010 may surpass 340,000 tHM. About 130,000 tHM of spent fuel is presently being stored in at-reactor or AFR storage facilities awaiting either reprocessing or final disposal. *(See table, next page.)*

SPENT FUEL MANAGEMENT APPROACHES IN DIFFERENT COUNTRIES

Country	Deferred Decision	Direct Disposal	Reprocessing
Argentina	◆		
Belgium	◆		●
Brazil	◆		
Bulgaria	◆		●
Canada		■	
China			●
Czech Republic	◆	■	●
Finland		■	
France			●
Germany		■	●
Hungary	◆		●
India			●
Italy	◆		●
Japan			●
Korea Rep. of	◆		
Lithuania		■	
Mexico	◆		
Netherlands			●
Pakistan	◆		
Romania		■	
Russian Fed.		■	●
Slovakia		■	●
Slovenia	◆		
South Africa		■	
Spain		■	
Sweden		■	
Switzerland	◆		●
UK			●
Ukraine	◆	■	●
USA		■	

***Note**: Some countries use different approaches for different types of fuel. Additionally, some countries follow one approach while evaluating different approaches that might be applied in the future.*

The quantity of accumulated spent fuel is over twenty times the present total annual reprocessing capacity. Assuming that part of the spent fuel to be generated in the future will be reprocessed, the amount to be stored by the year 2010 is projected to be about 230,000 tHM. Since the first large-scale repositories for final disposal of spent fuel are not expected to be in operation before then, the indications are that interim storage will be the primary option well into the next century.

NATIONAL DEVELOPMENTS

Over the past three years, countries have taken important steps to improve their capabilities for effectively managing spent fuel. They include:

- In Canada, two AFR dry interim storage facilities were put into operation during 1995 and 1996.
- In the Czech Republic, the dry storage facility at Dukovany, with a capacity of 600 tHM, was licensed in January 1997 for a 10-year period. By the end of 1997, it was loaded with 232 tHM.

STORAGE CAPACITIES AND INVENTORIES IN SOME COUNTRIES IN 1997

(tonnes of heavy metal)

Country	At Reactor Capacity	At Reactor Inventory	Away-from-Reactor (AFR) Capacity			AFR Inventory
			In Operation	Being Built	Planned	
Brazil	576	130				
Bulgaria	828	387	600			356
Canada	31,407	22,555	8567		14,496	1930
China		177		550		
Czech Republic	480	306	600			232
Finland	676	204	1047			684
France	11,290	5795	14,400			9159
Germany	4561	2756	7767	585		594
Hungary	480	357	160			54
Japan	9920	5800	213	3000		169
Korea Rep. of	5251	3072	609	812		609
Lithuania	2093	1380		352		
Romania	940	100				
Russian Fed.	5230	3480	13,800	1900	13,000	6046
Slovakia	480	150	600			523
South Africa	670	392				
Spain	4390	2000				
Sweden	1500	730	5000		3000	2703
UK	3345	1035	11,153			7157
Ukraine	3051	1650	2000			1695
USA	60,700	35,300	2164	2000	43,000	2164
Total	**147,868**	**87,756**	**68,680**	**9199**	**73,496**	**34,075**

■ In France, the MELOX plant for mixed-oxide fuel reached the licensed throughput of 120 tHM. It was also decided to load MOX fuel in 28 reactors, including twelve that already were using it.

■ In Hungary, a modular vault dry storage facility was put into operation in 1997 and loaded with 54 tHM by the end of the year.

■ In India, the new reprocessing plant at Kalpakkam completed trial runs required for licensing.

■ In Japan, the 3000 tHM wet storage facility at Rokkasho Mura is waiting for local approval to start operation. A programme is planned for using MOX fuel in light-water reactors beginning in 1999.

■ The Republic of Korea is reviewing future options after the cancellation, due to geological reasons, of the central interim storage site it selected earlier. At Wolsung, a 609 tHM dry store facility has been built and a 812 tHM dry store facility is under construction. Additionally, plans proceed for the construction of an experimental facility for the reuse (refabrication) of spent fuel from light-water reactors in a pressurized heavy-water reactor.

■ In the Russian Federation, an interim wet storage facility for 2000 tHM of spent fuel from RBMK reactors has been put in operation at the Smolensk nuclear plant.

■ Sweden continues with the design of a plant for encapsulation of spent fuel prior to final disposal. Completion of a license application is planned early in the next century. Also, licensing steps have been taken to expand the central storage facility (CLAB) with an additional capacity of 3000 tHM for operations by 2004.

■ In the United Kingdom, an operating license for the Thermal Oxide Reprocessing Plant (THORP) has been granted by the regulatory authority after a period of public consultation. The planning application by NIREX for the construction of a rock characterization facility at Sellafield was denied. Future options are under review.

■ In Ukraine, a dry cask storage facility for use at the Zaporozhe site is under review by the regulatory authority.

■ In the USA, three new dry storage facilities were placed in operation at nuclear power plant sites. Several dry storage systems are under review by the US Nuclear Regulatory Commission for use at reactor sites and at other sites.

GLOBAL COOPERATION & THE IAEA

Together with an advisory group of experts from its Member States, the IAEA regularly reviews the status and prospects of spent fuel management for power reactors, studying important developments and trends and identifying technical areas requiring greater cooperative efforts.

One aspect of the Agency's work has focused on the interest of countries in the greater use of remote technologies for handling spent fuel elements. Such technologies are used when spent fuel is discharged from the reactor, as well as for activities related to reprocessing and final packaging in the case of the spent fuel's direct disposal.

High interest also is being shown in the technology and safety aspects of a regional spent fuel storage facility. Several countries having small nuclear programmes face the problem of storing and disposing of their used fuel. From an economical point of view, they see little sense in building their own storage facilities. Experts working through the IAEA have started to collect and evaluate information on a regional spent fuel storage facility, a concept which in principle seems feasible.

The IAEA is assisting countries of Central and Eastern Europe operating the main types of nuclear power plants that were built there (WWER and RBMK reactors). This is being done through an extra-budgetary programme on the safety of WWER and RBMK nuclear power plants initiated in 1995 and funded by the Japanese government. In October 1997, experts attended a technical committee meeting and workshop on the commissioning of dry storage facilities. They discussed in depth the major steps involved in the commissioning of facilities; resource requirements; licensing procedures; radiological protection objectives; safety fundamentals; and standards and practices. In 1998, the IAEA is planning a workshop, among other activities, on the safety of long-term spent fuel storage, with emphasis on spent fuel from WWER and RBMK reactors.

As part of this extrabudgetary programme, several countries have completed computer code and modeling studies on spent fuel behaviour. The KFKI Atomic Research Institute in Hungary, for example, has done thermo-hydraulic calculations of spent fuel behaviour during long-term dry storage conditions using the COBRA-SFS code. The model description and manual were documented, and relevant handbooks were prepared. One result is that this code is now available to all IAEA Member States operating WWER nuclear plants to improve the safety of spent fuel storage.

One particular area that is drawing increasing interest from countries is the concept of "burnup credit" as it applies to the licensing of spent fuel management systems. The term refers to the reduction in reactivity of burned nuclear fuel that occurs from the change in its composition during irradiation inside the core; the data are established through physics calculations of the fuel. For spent fuel storage and transport systems, the use of the burnup credit holds the promise of achieving greater efficiencies. For example, it would allow closer packing of spent fuel, thereby increasing the storage capacity, and it can be applied to increase the capacities of transport casks for spent fuel to reduce the number of shipments needed. There are other applications as well, related to transportation, storage, disposal, and reprocessing operations. While the major incentive for the concept's use is economic, it also holds advantages in terms of public health and safety and environmental protection. Experts convened by the IAEA recently examined this subject, and the Agency will be publishing a technical document covering the status of national practices and the implementation of burnup credit in spent fuel management systems.

The IAEA additionally has published three safety documents on spent fuel management from nuclear power plants. They include a guide on the safe storage of spent fuel from power reactors; a guide on the operation of these facilities; and a document on the preparation of safety analysis reports for spent fuel storage.

These and other activities are directed at helping countries to effectively respond to the emerging technical challenges of spent fuel management. So far, about 40 years of experience exists in the long-term storage of spent fuel from nuclear power plants. However, much longer storage periods are expected, and further steps will be needed to improve storage technologies and methods. ❐