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# President's Report and Session Summaries

# of

# International Conference

# on

# Management of Spent Fuel from Nuclear Power Reactors

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## President's report

## Mr Anil Kakodkar (India)

## 2010-06-04

Dear Friends, I think we have had a productive conference this week on a very important subject "the management of spent fuel from nuclear power reactors". I have carefully listened to most of the presentations and the discussions that followed and I have also the benefit of inputs from the session chairmen and colleagues from the IAEA. It is always a challenge to condense a week of deliberations into a short conclusion. This is what I am attempting for you. At the present time most of spent nuclear fuel in the world is stored in reactor pools and in interim stores. Although it is safe and secure, as the evidence from this conference confirms, it has to be recognised that storage represents only an interim stage in any spent fuel management strategy. While in countries like France, Russia, Japan, India and others there are ongoing programmes to recycle spent fuel, there is an urgent need to move on towards final disposal options. The delay has been caused, for the most part, by the slow rate of development of geological repositories for final disposal of spent fuel. Fortunately, as we heard in presentations, there is good news on this front - the geological repository projects in Finland, Sweden and France are moving towards the licensing stage.

It will still be several decades before repositories are available in all of the major nuclear countries. For these reasons, it is becoming clear that spent fuel will have to be stored for longer periods than initially intended. Storage times may have to be extended up to 100 years and beyond. Questions then arise about the safety, security and sustainability of storage over such long time periods. In order to demonstrate safety over these time periods a good understanding of the processes that might cause deterioration of the system is needed. This conference has shown that these new priorities are reasonably well understood and studies have been presented here aimed at investigating the various phenomena that might cause the failure of storage systems over long time periods. The issue is also being increasingly recognised by regulators and we have heard about the sort of proofs that they would be looking for in licensing storage facilities over extended periods of time.

More than 60 'newcomer' countries have indicated that they are interested in developing nuclear power in their countries. Many of them have turned to the IAEA to obtain information on the implications and the infrastructures that would be required. While their initial attention tends to be on the legal, regulatory, educational and industrial infrastructures needed to start nuclear programmes, they also need to develop strategies for spent fuel management. Information about reactor systems and fuel supplies is readily available from vendors but it has proved to be more difficult for newcomers to obtain reliable information about the solutions that are required to be put into place with respect to the back-end of the fuel cycle. It would be unrealistic to expect the vendors to provide a guarantee that all back-end aspects would be provided, e.g., spent fuel reprocessing, storage and disposal. The IAEA should thus provide newcomer countries with all necessary information related to spent fuel management aspects including the long term issues so that they become intelligent buyers and no loose ends are left in terms of spent fuel management over the entire life cycle of the spent fuel.

In this context it is interesting to note that countries in which there are well established nuclear programmes seem to be learning lessons from the past. As part of the design approval process for planned new reactors in the UK, proponents are being required by the regulators to describe plans for decommissioning and radioactive waste management at the outset and, amongst other things, they are being required to explain how spent fuel can be stored,

recovered and transported for periods in excess of 100 years and how such facility lifetimes can be substantiated.

Multilateral solutions for storage, reprocessing and disposal in which there are sharing mechanisms between countries would greatly help smaller countries with small amounts of spent fuel and waste, limited resources, and, sometimes, small land areas. However, while these are being actively discussed in various fora (some under the auspices of the IAEA), none has yet materialized.

Taking into account the evidence from around the world, it appears that spent fuel is being managed safely. It was recognised, however, that standards should be continuously reviewed to reflect new knowledge and experience gained. Some areas were identified where more guidance could usefully be developed, for example, in relation to extended long-term storage and there was a suggestion that there could be greater harmonisation in certain areas, such as international requirements for dry cask design.

There is a growing awareness that the storage and transport of spent fuel are linked because each stage in spent fuel management, whether it is related to open or closed fuel cycles, involves transport. Casks were initially considered for transport only. The 'dual purpose' cask is now a well-established technology for storage. To address the interface issues between storage and transport, a holistic approach to regulation is needed in which the different timescales for transport and storage licensing are accommodated.

One focus of the conference was on understanding the degradation phenomena that might affect the storage of spent fuel over long time periods. Important potential material degradation mechanisms are: air oxidation, stress corrosion cracking, thermal creep, hydride reorientation and delayed hydrogen cracking. In several papers experimental studies were described to investigate these mechanisms. To date, the evidence is positive and suggests that the storage systems will continue to provide safety for extended time periods. These conclusions are supplemented by comprehensive programmes for the testing of metal and concrete casks involving tests to evaluate safety in scenarios involving normal operation, ageing, seismic events, and accidents (including an aircraft crash). Generally, the casks performed very well with little evidence of failures that would lead to significant safety issues.

There was recognition about the benefits of the Joint Convention; the process of exchange of information between countries promotes confidence and belief in other countries with respect to radioactive waste management. The international organizations are encouraged to continue and, if possible, to increase peer reviews and regulatory reviews. Together they provide evidence that countries are meeting their international safety obligations.

We need to emphasise that credible engineering solutions for disposal of long-lived radioactive waste are feasible and can be implemented in a manner that assures safety of people and the environment. Public acceptance about radioactive waste and its disposal however remains an issue and would require political will for forward progress in tune with the expected growth in nuclear power programmes world wide. It must be recognised that a repository is necessary regardless of whether one opts for a closed or open fuel cycle. The issue of repository thus must be effectively addressed if nuclear energy is to be more generally accepted. While the experiences in countries vary, it seems to be generally accepted that public support for nuclear projects has to be obtained by building trust through openness and transparency, and more importantly by gaining respect through sustained credible performance. The trust building process may take some time to achieve. May be there is

scope here for a well informed international technical view in respect of repositories. The involvement of local people in decisions related to the facility also helps. Similarly if local people can be educated to understand the purpose and functioning of the facility, this will alleviate many of their concerns.

Climate change concerns, the availability of uranium and its price and the philosophy held with respect to sustainable disposal of spent fuel will determine the approach towards either the nuclear recycle route or the direct disposal route. It seems that while adoption of the nuclear recycle option in some countries will lead to the enhancement of the nuclear energy potential from uranium, in some other countries there will be growth in nuclear power capacity on the basis of the once through use of uranium. In either case, it is important that the road map with respect to management of spent fuel over its entire lifecycle is clearly defined and is being acted upon.

Experience in France has shown that nuclear recycle is cost competitive and leads to more energy with less waste. A global consensus, which does not exist at the moment, should lead to a more sustainable solution to the energy and climate crisis that faces the world today.

Advances are taking place with respect to the higher burn-up of fuels, the development of fast reactors and advanced fuel cycles and while this does not bring additional considerations with respect to the management of spent fuel storage, it seems that they can be accommodated within the available management solutions.

Developments in nuclear power technology have enabled solutions to growing energy needs (and we should expect growth in nuclear power development on the basis of these solutions), and research and development may enable further advances in the future.

Most important among these is the possibility of reducing the radiotoxicity of radioactive waste to acceptable levels within a reasonable time period and bringing in greater proliferation resistance. There is urgency in realising such solutions to overcome the remaining barriers to the growth of nuclear power world-wide.

Dear Friends, you will agree with me that this conference has enabled a comprehensive discussion on a wide range of issues related to the management of spent fuel from nuclear power reactors. The exchange of information and views expressed at this conference will enable different programmes around the world to benefit from the experience of others. More importantly, the discussions here should be of significant benefit to countries about to start their own nuclear programmes. The discussions have also provided a view of the current interests and directions being pursued by the Member States of the IAEA and will facilitate the shaping of IAEA activities in this area. Let us hope that, as we exploit nuclear energy for our use, we do not deprive future generations of energy. Even more important is the aspect that we do not burden future generations with waste management problems.

Let me on your behalf and on my own behalf, once again thank the organizers for putting together this very useful conference. Thank you.

## Session 2 Strategic issues and challenges in spent fuel management

The papers in this session provided an overview of the strategies, infrastructures, and regulations in major nuclear power countries related to spent fuel management.

The presentations revealed that Russian Federation, Japan, India and France plan to reprocess their spent fuel and to recycle the products in LWRs or fast breeder reactors while Germany, Spain, the United Kingdom (in relation to its planned new reactors), and Canada plan to dispose of spent fuel directly without reprocessing. It is evident that despite the plans of countries, at the present time there is limited reprocessing capacity in the world.

In most countries, the majority of the spent fuel is being stored at the nuclear power plants where it has been generated. National plans often involve the establishment of centralised interim facilities for dry spent fuel storage or vitrified high-level waste storage until geological repositories become available. The expected times at which geological repositories will be available are often quite far into the future and interim storage periods of in excess of 100 years are being planned.

As part of the design approval process for new reactors in the UK, proponents are being required by the regulators to describe plans for decommissioning and radioactive waste management at the outset. As part of this 'Generic Design Assessment Process' they are required, amongst other things, to explain how spent fuel can be stored, recovered and transported for periods in excess of 100 years and how such facility lifetimes can be substantiated.

The issue of whether spent fuel should be regarded as a 'resource' or a 'waste' is a regular topic in the context of conferences such as this one. However, it was pointed out that in the longer term perspective it is more a question of <u>when</u> the spent fuel will come to be regarded as a resource.

It was noted that, at a time when nuclear energy is undergoing a renaissance, spent fuel management can be seen as an 'Achilles heel' because in the minds of many people it is unresolved. Furthermore, a Eurobarometer survey recently indicated that public opinions about nuclear energy would be boosted favourably it the waste question was seen to be solved.

## Session 3 Spent fuel management for smaller programmes and newcomer states

More than 60 ‘newcomer’ countries have indicated that they are interested in developing nuclear power in their countries. While information about reactor systems and fuel supplies is readily available from vendors it has proved to be more difficult for newcomers to obtain reliable information about the back-end of the fuel cycle. The IAEA has assisted by giving advice to newcomers but its guidance tends to be at too high a level for many countries.

It has to be made clear to ‘newcomers’ that, as basic conditions, they need to have safe and secure facilities, security of front-end services, security of back-end services and access to geological disposal.

The options that they have for spent fuel management are:

national storage and disposal,

reprocessing abroad, recycling and disposal nationally,

reprocessing , recycling and waste disposal abroad,

national storage, disposal in shared repositories,

fuel leasing,

retention of spent fuel as a valuable commodity.

The choice between these is not easy and some are not available or feasible for smaller countries.

It is clear that multilateral solutions for storage, reprocessing and disposal in which there were sharing mechanisms between countries would greatly help newcomer countries, especially smaller newcomer countries. However, while these are being actively discussed (some under the auspices of the IAEA), none has yet materialized.

‘Off the shelf’ solutions are not likely to be realistic in this context. It would be difficult for the vendor to provide a guarantee that all back-end aspects would be provided, e.g., spent fuel reprocessing, storage and disposal.

A problem for many countries is the size of the nuclear units on offer; they are too big (greater than 1000MW) for the needs of smaller countries.

## Session 4 Round table- Regulatory framework for spent fuel management

The Round Table addressed four questions.

The first was: Is there enough emphasis on safety standards for spent fuel management?

The general view of the experts was that, taking into account the evidence from around the world that spent fuel is being managed safely, there is no immediate need for new safety standards. It was recognised, however, that standards should be continuously updated to reflect new knowledge and experience gained and that the standards in this area had been in existence for quite some time. Some areas were identified where more guidance could usefully be developed, for example, in relation to extended long-term storage and there was a suggestion that there could be greater harmonisation in certain areas, such as international requirements for dry cask design. It was noted that it is too early for detailed standards in this area and the emphasis should still be on principles rather than on quantitative technical criteria.

The second question was: Is there sufficient international consensus on the approaches to demonstrate the safety of geological disposal?

There is a general consensus among experts in the field that geological disposal is likely to be a viable and safe technology and that, at least qualitatively, safety should be capable of being demonstrated.

A number of issues were raised however. One concerned the elements that need to be considered in a geological disposal facility safety case and how long-term integrity issues are to be addressed. It was also noted that although the introduction of the concept of retrievability in some disposal strategies might imply that there is not a full consensus on long-term repository safety, many stakeholders took comfort from the 'promise' of retrievability. There was a call for greater clarification of terminology, for example, terms such as 'retrievable', 'final closure', and 'management after closure'. The IAEA and NEA are addressing many of the issues raised here in standards and guidance. It was pointed out that these organizations have an important role to play in ensuring close collaboration between countries engaged in licensing geological repositories.

The third question was: Is it possible to achieve international consensus on the future strategy for spent fuel management?

At the present time it is not possible to have an international consensus on a strategy for spent fuel management when countries have different positions on how to regard spent fuel. However, it is possible to have a consensus on different elements of a strategy and on the basic principles underlying it.

It is recognised that uranium is a limited resource in the world and should not be wasted; recycle should be encouraged where feasible. At this time, it might be useful to have a global overview on uranium – estimates of available resources compared to likely demand and options for its further use. This is a topic that might be considered by the international organizations.

The fourth question was: How would the international instruments be used in the event of multilateral arrangements being adopted for spent fuel management?

The most relevant international instrument in this context is the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention). There was agreement about the benefits of the Joint Convention; the process of exchange of information between countries promotes confidence and belief in other countries. The Joint Convention was intended to facilitate interactions between individual countries and has no mechanism for multilateral arrangements; on the other hand it does not exclude them and has already provided a forum for discussions on the subject. A multilateral facility would have to be located on the territory of a country and it seems clear that the facility would have to operate within the regulatory requirements of that country with consequent implications to any other countries wishing to place material within the facility.

It was noted that public confidence has been enhanced by the Joint Convention but also by international peer reviews and regulatory review teams. Together they provide evidence that countries are meeting their international safety obligations. The international organizations are encouraged to continue and, if possible, to increase these types of activity.

## Session 5 Safety and licensing of spent fuel storage and transportation

In this session, countries presented their arrangements for licensing and regulating spent fuel storage facilities. On the basis of the experience gained and lessons learned, improvements in safety guidance have been developed. Some research and assessment work related to the behaviour of spent fuel in storage and in transport was also presented and the IAEA provided an update on its safety standards for the storage of spent fuel.

There is a growing awareness that the storage and transport of spent fuel are linked because each stage in spent fuel management, whether it is related to open or closed fuel cycles, involves transport. The different timescales for transport and storage licensing have to be accommodated in regulations (short transport licence validity, usually less than a decade versus storage licences valid for several decades). To address the interface issues between storage and transport, a holistic approach to regulation is needed.

Casks were initially considered for transport only. The 'dual purpose' cask is now a well-established technology for storage.

Regulators are increasingly interested in obtaining information on spent fuel ageing for safety case development related to extended storage periods and also for transportation; those responsible for spent fuel management are starting to address these issues.

The evidence required by regulators to support proposed extended storage periods (>100years) is likely to be in the form of data from accelerated tests plus evidence from the monitoring of structures.

Globally, there is extensive experience of a variety of different types of spent fuel storage technology. However, access to operational experience is rather limited and it would be useful to be able to share the information between countries having the same storage systems.

## Session 6 Round Table – Stakeholder issues

A panel of experts was assembled to address four questions related to stakeholders issues. The panel was made up of persons with a variety of life experiences. It was asked to address four questions.

The first was: What symbolism do you associate with spent fuel – what images and what attributes does it promote?

A variety of answers was given and it is clear that much depends on whether people have experience of nuclear matters or not. Those who have no direct nuclear experience may associate spent fuel with 'menace' or 'endless danger' and would not distinguish spent fuel from radioactive waste. Members of the public in towns where nuclear facilities exist or are planned may have different views mainly because they have been informed about nuclear issues and see a benefit for their communities.

The second question was: How can durable relationships be built with local people living in the vicinity of a planned spent fuel storage facility?

It seems to be generally agreed that this has to be done by building trust through openness, transparency, and respect. The trust building may take some time to achieve. Involvement in decision making related to the facility also helps as well as improvements in the education of local people with regard to understanding the purpose and functioning of the facility.

The third question was: Is spent fuel a national problem or one between the spent fuel owner and the local community?

It was generally agreed that this should be seen as a national problem but it depends on the national situation. In one of the countries represented in the panel it was dealt with entirely at the local level with no national government involvement. In another country, it started as a local issue but is now a national one.

The fourth question was: Timescales for spent fuel management – is it an issue with stakeholders?

Generally the timescale issue is difficult for people to grasp and they are not usually able to distinguish conceptually between 100, 10,000 and one million years. One community was concerned that a storage facility should not be there for more than 50 years and has obtained the agreement of the proponents on this.

## Session 7 Technological innovations for spent fuel storage

In this short session, presentations described progress in the use of burn-up credit to optimise spent fuel storage arrangements while taking due account of the need to avoid criticality. In addition, some examples were given of technological innovations relevant to spent fuel storage.

The use of burn-up credit criticality safety analysis to allow improvement in the arrangement of stored spent fuel assemblies is well established and a report was presented on advances in the subject which had been reported at a special workshop in Spain in 2009. It was concluded that there has been a significant improvement in the spent fuel assay data now available leading to more reliable assessments. Measurement studies in Belgium to improve assessment reliability were described as well as an application of the burn-up credit approach for RBMK reactors in Ukraine.

Proven solutions to problems are not always the best and a paper was presented describing a formalised approach being used in France to encourage and structure innovative ideas within an organisation. Various methods are used to generate ideas, from discussions with customers to brainstorming. The ideas are then screened and the best ones are selected for application. Examples of ideas which have come from this process are: a method for optimising spent fuel baskets, improving containment of casks, mitigation of hydrogen risks, neutron shielding, thermal and structural management and novel dry storage systems.

## Session 8 Fuel and material behaviour

With the likelihood of interim storage times being extended it is more important than ever to develop a comprehensive understanding of the behaviour of spent fuel and its cladding and containment materials.

In an opening paper, an overview was given on the general status of nuclear power with emphasis on spent fuel. ‘Managed storage’ was described as: a temporary activity, which needs to be safe and secure, for periods in excess of 100 years, in a passive system, with public acceptance. The important element which needs to be managed is ‘ageing’ (degradation phenomena). Important potential material degradation mechanisms are: air oxidation, stress corrosion cracking, thermal creep, hydride reorientation and delayed hydrogen cracking. In several papers experimental studies were described to investigate these mechanisms. To date the evidence is positive and suggests that the storage systems will continue to provide safety for extended time periods. Confirmation would be provided by surveillance of the systems.

A substantial and comprehensive Japanese programme for the testing of metal and concrete casks was described. The programme has been conducted on behalf of the national regulator. It has involved tests to evaluate safety in scenarios involving normal operation, ageing, seismic events, and accidents (including an aircraft crash). Generally, the casks performed very well with little evidence of failures that would lead to significant safety issues.

## Session 9 Managing past and damaged spent fuel

In this short session several case studies on the strategies adopted to render damaged spent fuel from nuclear power reactors and research reactors into a safe condition were described.

Another paper described problems caused by corrosion of stored Advanced Gas Cooled Reactor fuel by inter-granular attack and the method of avoiding the problem through the use of an inhibitor compatible with the storage facility.

## Session 10 Operating experience in wet and dry storage

In this session several papers were presented describing operating experience of spent fuel storage in both wet and dry conditions. The session was useful in providing for the exchange of information on common issues between experts from different countries who might otherwise not be aware of solutions developed for similar issues in their own countries. A report on an IAEA project to gather lessons learned in wet and dry spent fuel storage was also presented provided a further basis for information exchange.

Two Japanese papers were concerned with determining the status of spent fuel casks after dry storage for up to 10 years and inspection procedures were described for that purpose. The results were favourable with no signs of leakage and only minor signs of cask seal corrosion. Comments were made to the effect that in order to provide confidence that fuel recovery from the casks would be possible after several tens of years some monitoring of the state of the fuel cladding and baskets inside the casks would be necessary and should involve some destructive testing of the cask contents.

An analysis of possible regional strategies for the back-end of the fuel cycle in Central and Eastern Europe by an independent group of experts was described. It examines the potential for regional cooperation and looks to the far future when there would be a greater degree of harmonization than at present and when existing NPPs would be replaced by GEN-4 fast breeders together with regional geological repositories.

An analysis of the thermal environment in and around a store of dry storage casks using computer modelling was described. It illustrated how the study could be used to optimize the storage geometries to prevent overheating.

## Session 11 Discrete issues in managing high burn-up MOX and fast neutron reactor spent fuel

Papers from a group of countries that have decided upon pursuing the closed fuel cycle described the progress being made in fast breeder reactor research and development. Among the advantages sought are improved long-term energy security, the saving of natural resources through the recycle of uranium and reduction in the amount of radioactive waste needing disposal. Another paper discussed the options for using MOX fuel including further recycling in LWRs, future recycle in advanced fast breeder reactors or direct disposal.

The introduction of high burn-up UOX and MOX fuels has implications for spent fuel management. Some of these were summarised as: spent fuel pool upgrading to cope with extra heat generation, provisions to address the higher criticality potential, cask upgrading to allow for heat removal, repository modification to cope with higher radiation dose rates and greater potential for release to the environment. It was pointed out that most of these implications are negative and that they should be countered with the advantages of introducing high burn-up fuels. It was suggested that it could be useful for the international organizations to undertake a study that provides a more balanced and fuller picture on this.

## Session 12 Fuel reprocessing: status and challenges

Speakers from several of the countries that are committed to the closed fuel cycle described their countries' plans for recycling uranium both in the immediate and far future and elaborated on the benefits of this strategy.

A paper from the USA, which has not committed itself to the closed fuel cycle but recognises that there may be a need in future, outlined the changes that would be necessary in the regulatory framework to accommodate recycling. For the time being the NRC will look only at the mature recycle technologies, e.g. PUREX based.

The presentations provoked a discussion on the merits of recycling. Questions as to the economic justification of recycling were raised as well as on the comparative safety aspects. It was noted that for countries committed to the closed cycle the advantages of recycle and FBR technology the justification is clear but for other countries that for various reasons, including the disproportionate costs and scale required, have not committed themselves to the closed fuel cycle, the arguments are not so compelling. For these countries the policy for the immediate future has to be 'wait and see'. It remains to be seen in the future how these countries can share and cooperate in the developments.

## Session 13 Managing very long-term storage and the disposal of spent fuel

The progress being made towards the licensing of deep geological repositories in Finland and Sweden was described with emphasis on the success achieved in obtaining acceptance of the projects by the local communities in which they will be sited. It is expected that the repositories will be open for operation in the period 2020 – 2025.

Recognising that small countries will have difficulty in developing a geological repository and that each country needs access to a means for disposing of spent fuel or high-level waste, discussions have been held to investigate the concept of a multinational repository. In particular, a European initiative called the European Repository Development Organisation has been started. The project has links with the European Commission. The role of the IAEA in encouraging global multilateral initiatives was emphasised.

In recognition of the forthcoming period of studies in the USA to investigate the safety of the long-term storage of spent fuel, a data base is being established by the Electrical Power Research Institute on behalf of the USNRC. The data base will contain information relevant to all of the areas identified as needing study related to: welds and seals and their behaviour in salt atmospheres, fuel cladding/baskets, conditions that would warrant repackaging, ageing management, climate changes effects, influence of storage on transportability, record keeping and security. External organizations interested in participating in the EPRI study are being encouraged.