IAEA ACTIVITIES IN NUCLEAR FUEL TECHNOLOGY, PERFORMANCE AND UTILIZATION INCLUDING THE ROLE OF THORIUM-BASED FUEL

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Abstract

The IAEA activities in nuclear fuel technology, performance and utilization are presented with special emphasis on thorium-based nuclear fuel. Utilization of thorium fuels in once-through cycles is discussed, as well as, in closed thorium/uranium or thorium/plutonium fuel cycles.

By the end of 1985 there were 374 power reactors in operation, with a total generating capacity of 249,6 GW(e) and about 90% thereof was generated by water-cooled reactors using UO_2 as fuel and zircaloy as cladding material.

Until now, large experience has been accumulated worldwide in nuclear fuel design, fabrication and utilization in water power reactors. Water reactor fuel fabrication plants are in operation in 15 Member States with licensed annual capacity of around 10,000 tons of heavy metal. It will meet the demand of utilities until sometime between 1990 and 1995, depending on the actual deployment of nuclear power plants and the degree of improvements in reactor and fuel performance.

For the actual parameters of fuel utilization in water-cooled power reactors the performance of fuel is satisfactory. Average failure rates are now as low as 0.01% failed fuel rods per reactor year or less. Thus, nuclear fuel cycle technology in the field of fuel fabrication and utilization is the proven technology today. It is important today and in the near future to reach the same or better level of fuel reliability under future operational and abnormal conditions.

Now it is also time to adapt nuclear plants to the requirements of the national and in some cases, multinational electricity grids, to improve economics under the level of safety, as necessary. Not the last target is the reduction of uranium consumption, plutonium and uranium recycling. In order to meet these requirements national and international projects are being performed with the aim to extend burnup (for PWRs from 33 MWd/kgU to 45 MWd/kgU by 1995), to improve fuel rod, assembly and active core design and to implement advanced fuel management schemes. Automation of fuel fabrication processes is directly linked with the production of mixed (uranium and plutonium) oxide fuels and recycling of fissile elements from used fuel. Further development of methods of characterization and Quality Control of nuclear fuel is performed, especially, regarding their feedback to fuel fabrication and behaviour.

In the current and near future water reactor fuel development is also primarily related to studies on water side corrosion, pellet cladding mechanical and chemical interaction, fission gas release, dimensional stability, the use of burnable absorber, etc.

The activity of the Nuclear Fuel Cycle Division of the IAEA in this area, has been performed under the guidance of the International Working Group on Water Reactor Fuel Performance and Technology (IWGFPT). This group comprises 21 countries with significant nuclear power programmes. Many developing countries constantly request that more efforts should be made by the Agency in order to provide them with technical advice and expertise in the development of nuclear fuel technology. Assistance has been given to Egypt, Indonesia, Republic of Korea, Romania, Yugoslavia in establishing their own fuel cycle facilities through projects performed by the Department of Technical Cooperation. The Agency financially supported participation of representatives from developing countries in meetings related to nuclear fuel fabrication and utilization.

Through Agency meetings, fellowships, technical contracts and agreements technical information was transferred to developing countries on the following subjects:

- water rector fuel fabrication,
- behaviour of water reactor fuel,
- water reactor fuel performance modelling,
- improvement of water reactor fuel utilization,
- alternate fuel and advanced reactor fuel technology,
- interim spent fuel storage of water reactors.

Developed countries have also profited from the exchange of technical information in these areas. The most helpful exchange of expertise obtained in different Member States has been performed through the initiation of three Coordinated Research Programmes, namely, on "Investigation of Fuel Element Cladding Interaction with Water Coolant in Power Reactors" (CCI), "Examination and Documentation Methodology for Water Reactor Fuel" (ED-WARF) and "Development of Computer Models for Fuel Element Behaviour in Water REactors" (D-COM).

The actual problems of reactor fuel design, fabrication and performance have been discussed, in depth, at International Seminars on "HWR Fuel Technology" (Argentina 1983), "Practical Experience in the Application of Quality Control in Water Reactor Fabrication" (FRG 1984) and "Remote Handling Equipment for Nuclear Fuel Cycle Facilities" (UK 1984). Specialists' and Technical Committee Meetings were held to discuss separate problems of fuel performance, including "Post Irradiation Examination and Experience" (Japan, 1984), "Improved Utilization of Water Reactor Fuel with Special Emphasis on Extended Burnups and Plutonium Recycling (Belgium, 1984), "External Cladding Corrosion in Water Cooled Power Reactors" (France, 1985), and "Fuel Rod Internal Chemistry and Fission Products Behaviour" (FRG, 1985).

Experience obtained by Member States in advanced fuel fabrication technology and its performance regarding all types of reactors, in order to meet the requirements in the near future, were discussed at the Advisory Group Meeting on Advanced Fuel Technology and Performance (Switzerland, 1984). At the meeting, areas which may centre main efforts and future IAEA involvement in the improvement of nuclear fuels, were defined. Due to the recommendation of the Advisory Group, the Agency is holding Technical Committee Meetings on "Utilization of Thorium Based Nuclear Fuels - Current Status and Perspectives", December 1985 and on "Properties of Materials for Water Reactor Fuel Elements and Methods of Measurement", October 1986.

A Symposium on "Improvements in Water Reactor Fuel Technology, Fabrication and Utilization" will be held in Sweden, September 1986 in order to analyse the developments in the related areas since 1978, when a symposium on a similar subject took place in Czechoslovakia.

Thorium fuel utilization, technical status and development needs were considered in detail by the INFCE Working Group 8 (1977-1980). Some aspects of the thorium fuel cycle were considered at the IAEA Nuclear Power Conferences in Salzburg (1977) and Vienna (1982), as well as, the TCM on Improved Utilization of Water Reactor Fuel with Special Emphasis on Extended Burnups and Plutonium Recycling (Mol, Belgium, 7-11 May 1984), TCM on Advanced Light and Heavy Water Reactor Technology (Vienna, Austria, 26-29 November 1984) and others. In-depth consideration of the technology of some thorium fuels was dealt with, as mentioned before, at the IAEA Advisory Group on Advanced Fuel Technology and Performance (Würenlingen, Switzerland, 4-6 December 1984).

Until the present time, considerable efforts have already been made in the area of fabrication, utilization and reprocessing of Th-based fuels for different types of reactors, namely: by FRG and USA for HTRS; FRG and Brazil, Italy - for LWRs; India - for HWRs and FBRs. Basic research on thorium fuel and thorium fuel cycles is also being undertaken by Canada, China, FRG, France, Romania, USSR and other countries. Main emphasis has been given to the utilization of thorium fuels in once-through nuclear fuel cycles, but in some projects closed thorium/uranium fuel or thorium-plutonium cycles were also considered.

The advantages in the use of U-233 and thorium in advanced thermal designs are dealt with and the potential for obtaining a self-sustaining equilibrium with perhaps a slight margin for breeding. Recycling of reprocessed U-233 from irradiated FBR blankets and HTR fuels is also considered as a worthwhile direction in the alternate fuel cycles. The utilization of U-Th oxide fuels in HTRs is a proven technology of today.

However, in spite of considerable uranium savings the utilization of U-Th oxide fuels is still limited. There are several major reasons explaining the situation. Technical concerns include the need for full remotisation of irrdiated Th fuel reprocessing and U-233 fuel refabrication due to penetrating gamma radiation from U-232 daughter products and the need for development of three stream reprocessing technology for extraction of uranium isotopes and Pu-239. The impact of these factors on the economics of the fuel cycle is also very essential.

The current situation on the uranium market seems at, first sight, unfavourable to the implementation of thorium nuclear fuels. The near-term uranium outlook is for oversupply and low prices, as in the past few years. As a consequence of the low prices (spot market price is now about $ 44/kg U in comparison with $ 112/kg U in 1977-79), uranium exploration continues to decline in WOCA. Correspondingly Reasonably Assured Uranium Resources following to uranium exploration expenses also continue to decline.

As a result, annual uranium production capability of WOCA from existing and firmly committed mines and mills is expected to be able to fill the annual reactor requirements before the end of this decade. Thereafter, additional mines and mills will be required. As lead times for uranium exploration and mining projects are 10 to 15 years and are still growing, higher levels of exploration uranium efforts will be needed if future reactor requirements are to be met. The alternative is the implementation of thorium fuel cycle.

Another aspect merit to be discussed is the potential for the reduction of uranium demand, due to improvements in reactor and fuel performance. In a paper by Stig Sandklef (Swedish State Power Board) presented at the Xth Uranium Institute Annual Symposium, 3-5 September 1985 this analysis is given for the year 1995. Advances in fuel management schemes include: extended burnup, low neutron leakage loading pattern, improved fuel designs, axial burnup shaping, natural uranium blankets, fuel reconstitution, initial core reinsertion, coast down operation, spectral shift operation, relaxation of safety constraints. Extended operating cycles and influence of capacity factors were also anlysed. It is seen that 18% uranium and 10% of separative work could be saved in 1995 if the above-mentioned advances in fuel managment are done. At the same time, implementation of extended operating cycles, increasing of capacity factor and increased power will lead to a certain increase in uranium demand and separation work. The total result shows that integral reduction in uranium demand and separative work will be very small.

This means that the world situation with uranium production and demand could be one of the factors endorsing R and D on further investigation of thorium fuel. Due to the delay in the construction of power fast breeder reactors, utilization of thorium/plutonium fuel in water cooled power reactors could be considered as one of the means of burning plutonium coming from reprocessing plants, thus, avoiding its long-term storage.

It is obvious that some uncertainty in scale of future development in thorium fuel cycles still exists and it influences the volume of national efforts in thorium resources exploration, in development of thorium fuel technology and basic research on physical, chemical and nuclear properties of thorium fuels.

Under these circumstances the Agency has contributed and will contribute to the collection and exchange of information in this area and to the co-ordination of national efforts in order to maintain and improve the knowledge of all aspects of utilization of thorium as an alternative nuclear fuel.