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Use of fast reactors for actinide transmutation

*Proceedings of a Specialists Meeting
held in Obninsk, Russian Federation, 22–24 September 1992*



INTERNATIONAL ATOMIC ENERGY AGENCY

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FOREWORD

An important feature of the activities of the International Atomic Energy Agency is to assist Member States in the safe handling and management of nuclear power and spent nuclear fuel and radioactive wastes that arise from the use of nuclear energy.

The management of radioactive waste is one of the key issues in today's political and public discussions on nuclear energy, especially the long term disposal of high level radioactive wastes. Rather than waiting for their radioactive decay, it is principally possible to reduce the period of toxicity of the actinides and long lived fission products through transmutation of these isotopes in fission reactors or accelerators.

The recycling of plutonium in liquid metal fast breeder reactors (LMFBRs) would allow 'burning' of the associated extremely long life transuranic waste, particularly actinides, thus reducing the required isolation time for high level waste from tens of thousands of years to hundreds of years for fission products only. This additional important mission for the LMFBR is gaining worldwide interest.

In the past years, an increasing number of studies have been carried out on the advanced waste management strategy (i.e. actinide separation and elimination) in various countries and at an international level. Recognizing this, the International Working Group on Fast Reactors (IWGFR) decided in 1991 to include the topic of actinide transmutation in liquid metal fast breeder reactors in its programme of specialists meetings. It was apparent that due to the expansion of supporting research programmes and the fragmented nature of information arising from these various activities it would be beneficial to co-ordinate this topic at an international level.

Support for this approach was provided by Member States and, against this background, the IAEA organized the Specialists Meeting on Use of Fast Breeder Reactors for Actinide Transmutation in Obninsk, Russian Federation, from 22 to 24 September 1992.

The Specialists Meeting made clear the increasing interest in the issue concerning long lived radioactive nuclides and toxicity aspects in nuclear waste management and the desirability to work out a co-ordinated approach to its solution.

The potential of fast reactors for reducing the long term radiotoxicity of spent fuel justifies an active programme of conceiving and developing technologies for recovering transuranics for in-core transmutation.

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SUMMARY OF THE SPECIALISTS MEETING

The Specialists Meeting on Use of Fast Breeder Reactors for Actinide Transmutation was held in Obninsk, Russian Federation, from 22 to 24 September 1992.

The meeting was sponsored by the International Atomic Energy Agency on the recommendation of the International Working Group on Fast Reactors and was hosted by the Institute of Physics and Power Engineering (IPPE) in Obninsk. The meeting was attended by 23 participants from eight countries (Belgium, France, Germany, Japan, Russia, Switzerland, United Kingdom and USA), two International organizations (IAEA and CEC) and 12 observers from Russia.

The meeting was opened by Mr. L.A. Kochetkov, Deputy Director of IPPE, who welcomed the participants on behalf of the Ministry of the Russian Federation on Atomic Energy and the IPPE. Referring to the subject of this Specialists Meeting, he emphasized the importance of the advanced waste management strategy (i.e. actinide separation and elimination). Mr. V. Arkhipov of the IAEA presented a review of IAEA activities in the field of minor actinide transmutation. The meeting was chaired by Mr. L.A. Kochetkov.

Mr. L. Koch presented a background paper on the status of transmutation, prepared at the request of the IAEA. The paper discusses the objectives and the proposed schemes for partitioning and transmutation of long living radiotoxic nuclides. In particular, the constraints for the efficiency of a P&T process guiding R&D work for a fast reactor fuel cycle are described.

Session 1: National programmes on transmutation of minor actinides and long lived fission products in FBRs
Chairmen: L.A. Kochetkov, U. Wehmann

This Session gave an overview of the national programmes followed in France, the USA, Japan and Switzerland. The programmes reflect the large effort which is being undertaken worldwide with the goal to reduce the quantities of the toxic wastes and the long term risk of geological repositories. In the technical presentations, the potential of fast reactors of standard MOX fuel design as well as of special minor actinide burner cores was illustrated.

Session 2: Physics aspects of transmutation of minor actinides and long lived fission products in FBRs
Chairmen: L.A. Kochetkov, L. Koch

The papers presented in this Session cover a variety of topics related to transmutation of actinides and fission products, ranging from heavy water blankets for a LANL type accelerator-driven reactor to the adaptation of fast reactors to transmute plutonium and radiotoxic waste from LWRs together with self-generated waste. Here the European EFR as well as the GE designed ALMR are considered and the possibilities of the Russian BN-800 are discussed.

The advantage of high thermal fluxes in fissioning Am-241 and Np-237 by their neutron capture products, Am-242 and Np-238, is pointed out. These nuclides with odd neutron and proton numbers possess very high fission cross-sections. In order to reduce the competing decay reaction,

high thermal neutron fluxes in the area of 10^{16} n/s cm^2 are needed, which cause secondary problems in the reactor itself, e.g. the buildup of tritium. One possibility to circumvent these problems is to use a stationary liquid blanket.

Session 3: Engineering aspects of transmutation using fast reactors
Chairmen: L.A. Kotchetkov, H. Sztark

Topics covered in this Session relate to transmutation of minor actinides and fission products, mainly with reactors devoted to this purpose, with specific core concepts and adapted fuels and fuel cycles.

Theoretical studies, mainly on the Russian side, review the physical parameters which govern the burning capabilities of the core while improving the safety parameters, with special concern for the voiding coefficient. The need to increase the number of free neutrons available for transmutation of minor actinides and eventually fission products is emphasized, leading to very new arrangements for core concepts, fuel and also coolant. These new ideas are in a very preliminary stage, the feasibility of such systems has to be confirmed.

In the Japanese OMEGA programme, the part concerning fast reactors was also developed, with specific studies of reactors devoted to burn actinides; M-ABR with harder neutron spectrum, P-ABR with higher neutron flux, SLLC (Super Long Life Core) with no need for refuelling. In this case also, only the neutronic feasibility has been assessed, further studies being necessary to confirm these concepts.

When comparing the "figure of merit" of all the proposed solutions, it appears again that there is a lack of a common model to normalize the hazard reduction, particularly for what concerns the reprocessing process and the related reprocessing losses. This is apparent in this Session, but also when comparing this Session to previous ones, for example for the same EFR core model which has been treated in all three sessions. The potential of fast reactors for hazard reduction seems obvious to everybody, but the way to express this potential is not the same: transmuted mass per fast reactor unit, ratio between the number of fast reactor and the number of light water reactors, long term radiotoxicity, etc. Also, the need to recycle the fission products was discussed, some of the participants being in favour of controlled deep disposal.

The separation techniques for the different wastes, especially the separation efficiency and the related losses in the residual wastes, were also discussed, while this topic was outside the scope of this meeting (separation of rare earth and curium). Nevertheless, it appears that if further progress in hazard reduction has to be achieved, improvements in separation techniques must be obtained since the amount of losses during fuel operations (reprocessing, fabrication) becomes the major part of these hazards.

The experimental background and future programme was explained by Russian papers, as well for the nuclear data as for some fuel process. Experiments performed in Japan (FCA) and in Russia (BFS) showed quite similar results, with some discrepancies in actual calculations. Further experiments are planned in BFS involving some 50 to 100 kg of Np-237. Concerning fuel, experience has been accumulated on BOR60 with oxide fuel obtained by vibropacking, irradiated up to 7.7% burnup for uranium oxide and 4.5% for mixed oxide. This type of fuel would allow simpler fabrication and reprocessing technology, and could be demonstrated on BOR60 provided fundings are available.

In summing up this session, one can observe that advanced fast reactor concepts can improve significantly the transmutation capability of classical fast reactors, provided that similar improvements are obtained in reprocessing efficiency.

Conclusions

The IAEA Specialists Meeting made clear the increasing interest in the issue concerning long lived radioactive nuclides and toxicity aspects in nuclear waste management and the desirability to work out a co-ordinated approach to its solution.

The potential of fast reactors for reducing the long term radiotoxicity of spent fuel justifies an active programme for conceiving and developing technologies for recovering transuranics for in-core transmutation.

The specialists agree that future progress in solving transmutation problems could be achieved by improvements in:

- Radiochemical partitioning and extraction of the actinides from the spent fuel (at least 98% for Np and Cm and 99.9% for Pu and Am isotopes);
- Technological research and development on the design, fabrication and irradiation of the minor actinides (MAs) containing fuels;
- Nuclear constants measurement and evaluation (selective cross-sections, fission fragments yields, delayed neutron parameters) especially for MA burners;
- Demonstration of the feasibility of the safe and economic MA burner cores;
- Knowledge of the impact of maximum tolerable amount of rare earths in americium containing fuels.