CURRENT STATUS OF CZECH R&D PROGRAMME IN PARTITIONING AND TRANSMUTATION

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Abstract

The transmutation of spent nuclear fuel is considered as a prospective alternative concept to the current concept based on the non-reprocessed spent fuel disposal into underground repository. The Czech research and development programme in the field of partitioning and transmutation is founded on the Molten-salt Transmutation Reactor system concept with fluoride salts based liquid fuel, the fuel cycle of which is grounded on pyrochemical/pyrometallurgical fluoride partitioning of spent fuel. The main research activities in the field of fluoride partitioning are oriented mainly towards technological research of Fluoride Volatility Method and laboratory research on electro-separation methods from fluoride melts media. The research activities in the area of transmutation are oriented to the development of modified computer codes for calculations of neutronic characteristic and to the experimental research of reactor neutronics in fluoride salt media. The Czech national concept in the area of P&T research issues from the national power industry programme and from the Czech Power Company CEZ intentions of the extensive utilisation of nuclear power in our country. The experimental R&D work is concentrated mainly in the Nuclear Research Institute Rez plc.

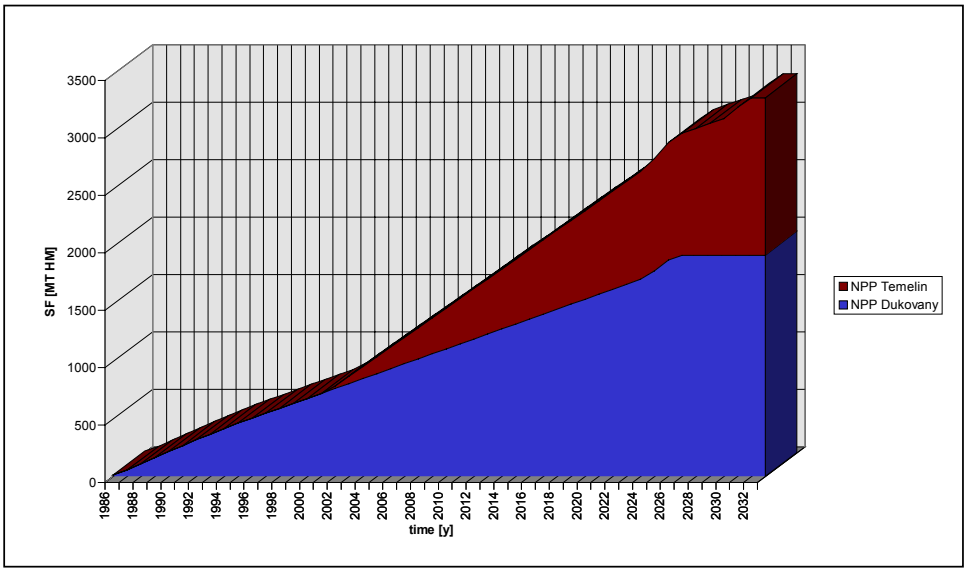
Introduction

Nuclear waste, especially spent fuel from nuclear reactors containing long-lived radionuclides represented mainly by actinides and long-lived fission products, presents a common problem for all countries operating nuclear power plants. The satisfactory solution of this problem is a factor limiting to a considerable extent the further nuclear power industry development, namely in industrial countries. The present technical and technological sum of knowledge indicates that this problem could be largely resolved by using the partitioning and transmutation technology so that the nuclear power industry may become widely acceptable for the public. Therefore also in the Czech Republic, the research activities in the partitioning and transmutation area have been caused by the belief that nuclear incineration of spent fuel represents a prospective alternative concept with respect to the current state concept based on the non-reprocessed spent fuel disposal to the deep geological repository.

Czech Power Company CEZ, which is the biggest electricity producer in the Czech Republic, is the only Czech company generating the electricity in nuclear power plants (NPP). At present, there is one NPP "Dukovany" in commercial operation on the territory of the Czech Republic with the capacity 1 760 MWe (four PWR units of 440 MWe, type VVER), the power plant was put into operation in 1985-1987. The second nuclear power plant "Temelin" with planed installed capacity 1 962 MWe (two PWR units type VVER 1 000) is now partially under commissioning process. The first reactor is in the test run for one year; the second reactor is under the commissioning process. After Temelin NPP completion, the nuclear share of electricity production in the Czech Republic will exceed 35-40%.

The spent fuel from NPP Dukovany, after discharging from reactors, spending from five to six years cooling period at reactor pools, is stored in the Spent Fuel Storage Facility at the NPP Dukovany site. The same way of the spent fuel handling is prepared for NPP Temelin where the Spent Fuel Storage Facility will also be located. The cumulative production of spent nuclear fuel is represented in Figure 1.

Figure 1. **Accumulation of the spent fuel from Czech NPPs**



According to the Czech Atomic Act, the State guarantees the safe disposal of all radioactive wastes including spent nuclear fuel. This year, Czech government adopted official state conception on radioactive waste and spent fuel management. The disposal of the non-reprocessed spent fuel in the underground repository is described as the solution, feasible by current sum of scientific and technical knowledge and expresses the certainty of safe solution of the fuel cycle back-end. For this case, the realisation of an underground repository is planed with the possibility to accept the first spent fuel after 2065. Because of the final decision how to dispose the spent fuel will have to be made in tens of years, the chance to develop technically, economically and socially more attractive alternative solution than underground disposal of non-reprocessed spent fuel is in the foreground of professional interest for present and next decades.

Partitioning and Transmutation is considered as the very promising alternative solution and the research and development in the field of P&T is therefore included in this conception. The official financial support for R&D in P&T represents therefore an important element of the conception. Financing of the R&D in the area of nuclear fuel back-end is realised from the state budget by the Ministry of Industry and Trade and through so called "Nuclear Account" administrated by Radioactive Waste Repository Authority. The main receipts of the Nuclear Account consist of fees paid by radioactive waste and spent fuel producers.

Czech R&D partitioning and transmutation programme

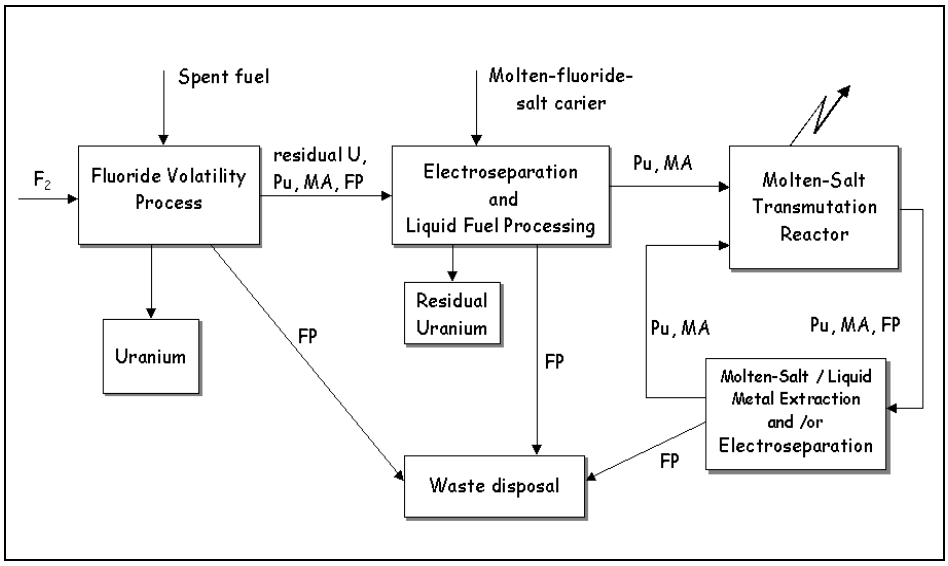
The Czech national P&T concept is based on the future use of Molten-salt Transmutation Reactor systems with fluoride salts based liquid fuel. These reactors should be directly connected with integrated partitioning technology. In the near future, these reactor systems might be conceived as critical ones and successively as sub-critical accelerator driven reactor systems. In addition to the nuclear burning of plutonium and minor actinides produced in the U-Pu cycle these reactor systems might consecutively operate within the U-Th cycle as well.

The advantage of the Molten-salt Transmutation Reactors (MSTR) demonstrates itself above all in connection with a continuous or at least quasi-continuous chemical separation process.

For such a compact coupling of MSTR with chemical reprocessing it will be very appropriate to keep fuel in one chemical form, as far as possible, in the course of the entire fuel cycle. Accordingly, if the MSTR fuel will be based on fluoride melt then the separation processes should also be based on separation techniques from fluoride melt media. Pyrochemical and pyrometallurgical technologies comply generally with this requirement. The general scheme of the MSTR fuel cycle is in the Figure 2.

The national research and development programme in the field of pyrochemical and pyrometallurgical partitioning is based first of all on the experience acquired in the past in the development and realisation of a pilot-plant fluoride technology for the reprocessing of spent fuel from the BOR-60 fast reactor. [1] At present, this experience is utilised for the development of suitable separation processes and technologies for the fluoride based MSTR fuel cycle.

Figure 2. **Simplified general scheme of MSTR fuel cycle**



Experimental and theoretical studies in the field of **pyrochemical partitioning** technology development for the MSTR fuel cycle are oriented in particular to the following areas:

- **Technological research in the field of the "Fluoride Volatility Method"** directed at the suitability verification of a technology for thermal or fast reactor spent fuel reprocessing, which may result in a product the form and composition of which might be applicable as a starting material for the production of liquid fluoride fuel for MSTR. Consequently, the objective is a separation of a maximum fraction of uranium component from Pu, minor actinides and fission products. The method is based on the direct fluorination of spent fuel by fluorine gas in a flame fluorination reactor, where the volatile fluorides are separated from the non-volatile ones, and on the subsequent purification of the components by using technological operations of condensation, sorption and rectification. According to the process design, up to 95-99% of uranium in the form of volatile UF_6 will be removed from the non-volatile fluorides incorporating plutonium (PuF_4), minor actinides and majority of fission products. In this way, the component representing the greatest share of spent fuel inventory will be removed. [2]

- **Laboratory research on electro-separation methods in fluoride melts media** in relation to the study of their properties. The effort in this field is aimed first of all to the determination of optimum conditions for uranium and fission product separations and to the selection of suitable electrolyte composition based on fluoride salt mixture. [3] The research programme in this area is further directed to the determination and study of selected physicochemical properties of fluoride melts, particularly to the:
  - solubility of selected chemical elements of spent fuel in molten fluorides;
  - standard redox potentials of individual elements;
  - melting points of the molten-salt mixtures;
  - density and viscosity of the supporting fluoride matrices;
  - data on corrosion resistance of structural materials in molten-salt media.

Figure 3. **Upper part of UF_6 condensers with the piping and measurement system**

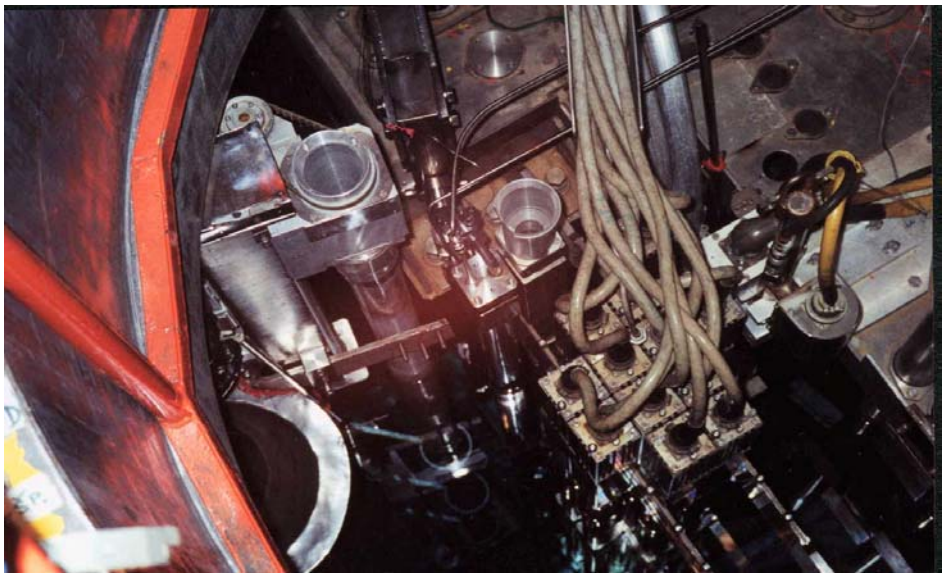
The research activities in the field of **transmutation technologies** are oriented to the following areas:

- **Development of modified computer codes** for calculations of neutronic characteristic (including time behaviour) of the Molten-Salt Reactor systems taking into account the specific features of circulating liquid fuel based on molten fluorides. The developed code OGAR calculates the evolution of fuel composition during the burnout and permits to implement different fuel feed and reprocessing strategies. Burnout calculations are done in two steps. First, the neutronic cross sections are evaluated using a popular Monte Carlo MCNP code. These cross sections are then inserted in a rate equation and the fuel evolution is calculated. The change of cross sections with the fuel composition evolution is controlled and the cross sections are recalculated if necessary. The code is mainly used for optimisation of reactor core geometry, to study neutronic properties of different carrier salts and to study the influence of different reprocessing strategies.

- **Experimental research of neutronic** and other corresponding characteristics including time behaviour) both on experimental zero power reactor VR-1 (by the methods of inserting zones and oscillation of samples as well as neutron sources) and on research reactor LVR-15 (by irradiation of samples of the transmuter core in high neutron fluxes) performed for validation of the modified computer codes employed in core analyses of the reactor systems in question. This experimental programme represents the main part of the national project SPHINX (Spent Hot fuel Incineration in Neutron fluX). Important role of SPHINX project is the experimental programme of instrumented BLANKA probes. [4] The main aims of the BLANKA programme are:

  - Experimental verification of long time behaviour of transmuter blanket which contains molten fluoride salts as a fuel and graphite as a moderator or reflector.
  - Material research-behaviour of materials in neutron and gamma fields, and materials interactions on high temperature conditions.
  - Validation of computational code.
  - Development and verification of analytical methods and techniques.

Figure 4. **View of BLANKA probe in the LVR-15 reactor**



Conclusion

Experimental research works related to the development of partitioning and transmutation technologies are concentrated mainly in the Nuclear Research Institute Rez plc, which ensures the main research and development base for the Czech Power Company CEZ. The research works are here carried out above all as a component of the national P&T programme within the framework of the "Transmutation" consortium. The participants of the national P&T programme are, in addition to the NRI Rez, SKODA Nuclear Machinery, Energovyzkum Brno Ltd., Nuclear Physics Institute of the Czech Academy of Sciences and Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University Prague. The development and realisation of P&T technologies and of the advanced nuclear reactor systems can be considered practicable within the scope of a wide international co-operation primarily for smaller countries. Therefore the important part of the research activities in the field of partitioning and transmutation has become a participation of the NRI Rez plc and other Czech institutions and companies in the PYROREP and MOST projects of the 5th Framework Programme EC. The participation in the EC projects is complementing very well with the research activities within the national programme framework.

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