SPENT FUEL MANAGEMENT IN THE USSR AND NEW WAYS TO SOLVE THE PROBLEM OF LONG-LIVED TECHNOGENEOUS RADIONUCLIDES

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ABSTRACT

Fundamentals of the concept of the nuclear fuel cycle in the USSR are stated. Existing and outlined ways of spent nuclear fuel (SNF) management are presented for various types of reactors (WWER-440, WWER-1000 and RBMK). Alternative ways of handling SNF long-lived radionuclides are shown in comparison, and parallel to disposal in geological formations, transmutation and disposal into outer space.

INTRODUCTION

In spite of the slump in the nuclear power engineering development after the Three Mile Island accident, and to an ever greater degree, after Chernobyl, about 400 GW of electric power (17% of the world power output) is generated at nuclear power plants nowadays. It should be noted, estimating about further prospects of the world nuclear power, that ever broader sections of the population, including ecologists, come to understand that humankind won't do without its development in the near future. This gives reason to hope for a new upsurge of nuclear energetics already in the near future, although it is economics and most importantly, not only necessity but safety, that should be the main argument in its favor. Safety must be provided by solving two main problems: Development of a safe reactor and ensuring reliable isolation of radioactive waste.

Considering options of the nuclear fuel cycle (open and closed), it should be noted, that only about 1/3 of spent fuel is reprocessed at present. This situation is caused, probably, by doubts in the economic efficiency of reprocessing, apprehension of uncontrolled spreading of plutonium in the world, and sometimes, wishing to avoid the problem of handling radioactive wastes of radiochemical industry.

Such an approach seems ungrounded. Economic indices are subject to conjecture variations. This also concerns the price of natural uranium. In a very long-term aspect, gradual exhaustion of all kinds of natural resources must make their maximum deep use economically necessary. Waste burial in the form of SNF isn't most reliable also from the viewpoint of radiation safety. The design of fuel assembly and the chemical form of fuel meet the requirements of use in a reactor, but are not optimal as far as burial is concerned. It should be especially stressed that great amounts of uranium and all plutonium which is dangerous for an enormous period of time, will be concentrated in burial assemblies. This is why in the Soviet Union the concept which is accepted about expediency of regenerating the fuel of WWER type reactors will be the basis of its nuclear power engineering in a predictable period.

To realize this concept, the first native plant for reprocessing SNF of nuclear power plant (NPP) has been put into operation in the USSR; its capacity fully satisfying reprocessing demands of both home and foreign NPP's with WWER-440 reactors, as well as the fuel of research installations and other highly enriched materials. The rate of WWER-440 SNF coming in is about 150 tons/year from NPP's in the USSR and about 90 tons/year from foreign NPP's.

The fuel cycle of WWER-440 reactors is closed by uranium already, because regenerated uranium is used for manufacturing fuel assemblies of RBMK-1000. The next task is to involve the fuel cycle the plutonium produced in the course of reprocessing.

In 1991, spent fuel of NPP with WWER-1000 reactors will be taken out from ten power units out of 18 active ones; in the year 2000, by optimistic estimates, from 28 power units, taking into account planned time of units' putting into operation, fuel campaigns and SNF cooling.

A new reprocessing plant is being created to realize the closed fuel cycle for WWER-1000 reactors. The SNF comes in to this plant in transport containers that arrive at the reception section of the storage facility at the plant. The capacity of this storage facility is 3,000 tons of uranium. The storage facility is already active now, with 500 tons of fuel delivered to it. The storage facility is assumed to receive up to 650 tons/year by 2000.

A transport cask is extracted from a container under water in the reception section of the storage facility, and fuel assemblies (FA) must be reloaded into a special compartment of the storage pond for control of the fuel burnup. In this compartment, there is an installation for input, nondestructive control of the burnup and the content of uranium and plutonium in FA. The method is based on measuring the cesium-134 and cesium-137 activity ratio, as well as the intensity of the FA's own neutron radiation. The measuring installation consists of a gamma-radiation collimator mounted into the storage pond wall, a gamma spectrometer with a Ge (Li) detector, a neutron detector and a loading machine. The fuel burnup measurement error in WWER-1000 FA will be 10%.

Casks with assemblies completed by the fissile materials content will get from the storage facility into a chamber where they will then be installed into a special loading machine and directed to the section of FA preparation for reprocessing. The assemblies' tailing parts will be separated by the electrocontact method and the FA will be fragmented there. The operations of FA extraction from the cask, conveying them for the cutting off of the tailing and putting the active core into the cutting unit's bed, will be done by special manipulators. The FA active core, without a dismantling into fuel elements, is subject to fragmentation by a press unit. Then fuel fragments go a nuclear-safe apparatus (period action ring-type dissolver).

The catching of nitrogen oxide, iodine-129 and carbon-14 from the gaseous phase formed in fuel dissolution will be done in columns washed with water and a sodium hydroxide solution. The largest amount of tritium will be removed with condensates formed in nitric acid regeneration. Taking into account the global character of the hazard of krypton-85 release into the atmosphere, the off-gas purification from it is envisaged at the plant. For this purpose, methods of krypton adsorption on activated carbon at low temperatures, freon absorption and cryogenic distillation, undergo experimental testing at present.

The solutions will be cleared from solid suspensions on cartridge cermet filters of periodic action with use of an inert material and silted layers.

The basis of the uranium and plutonium isolation technology, their purification from the main amount of fission products and their separation, is an extraction process that proved to be effective in irradiated fuel reprocessing, using an organic mixture of tributyl phosphate (TBP) in a hydrocarbon diluent. Uranium in the form of uranyl nitrate hexahydrate melt will be directed to obtain hexafluoride, and then will go to separating production for additional enrichment and further manufacturing of fuel elements. Plutonium is envisaged to be used for manufacturing mixed fuel for WWER-1000 reactors.

The WWER-440 and WWER-1000 SNF reprocessing permits the carry out partitioning of wastes, with separation of individual groups of radionuclides, depending on the life-time, the radiation and radiological hazard for further final localization of high-level wastes (HLW).

The reprocessing of RBMK irradiated fuel is economically inexpedient at the existing prices for regenerated uranium and plutonium. Therefore SNF of RBMK reactors, after in situ and intermediate storage, is assumed to be placed in a centralized long-term storage facility.

In the case of fuel reprocessing, there are especially hazardous long-lived radionuclides, both in gaseous effluents of the fuel cutting and dissolution units and, in small quantities, in high-level raffinates of the first extraction cycle. As is known, the ideology of long-lived radionuclide handling used to be reduced to the tasks of obtaining waste in the solidified form and long-term storage or disposal of the solid products in geological formations. Prospective investigations are directed to the perfection of this theme, as well as application of principally new methods.

Recently, research in the Soviet Union in an ever-growing measure is coming to the conception that it is only a rational combination of traditional methods of waste management and new technical approaches that can ensure a profound solution to the problem.

In this connection, estimations and specific developments are carried out in a number of directions, among which we should consider:

- The partitioning of long-lived radionuclides,
- The substantiation of the possibilities of applying nuclear transmutation of long-lived radionuclides
- The estimation of radioactive waste disposal in outer space

We understand under radioactive waste partitioning there is firstly, separation of the radioactive material from stable salts present in the waste, and secondly, separation of radionuclides by isolating them in a radiochemically pure form or in a group form, depending on the planned general scheme of waste management.

According to technico-economical studies performed, solution of even only the first task is quite expedient. The separation of salts ensures a sharp decrease of the mass of solidified high-level waste and gives a reduction of expenses on its preliminary storage for lowering the heat release and further burial.

The broadcast possibilities of partitioning are ensured by the extraction technology using metal-carbollyls. Chemical bases of this process and initial technological experiments were conducted jointly by the V. G. Khlopin Radium Institute (USSR) and the Nuclear Research Institute (Czecho-Slovakia). Further tests on an industrial scale were carried out at an irradiated fuel reprocessing plant.

The main radiotoxicity of HLW at cooling time of the order of tens of years is determined by cesium-137 and strontium-90. After the lapse of a period of time of 1,000 years of radionuclides will decay, and the wastes' dangerousness will be stipulated mainly by transuranium elements (TUE), as well as by some long-lived fission products (first of all, by iodine-129 and technetium-99). As there are difficulties in predicting the behavior of solidified HLW being buried in deep geological formations for a period over 1,000 years, suggestions arise about using nuclear transmutation of the most long-lived radionuclides. It is suggested for this purpose to irradiate corresponding targets or mixed fuel in nuclear reactors, thermonuclear installations, as well as in charged particle high-flux accelerators.

The reprocessing of long-lived radioactive waste of nuclear power engineering with the use of transmutation must be done using the principle of nonaccumulation of waste in the system, i.e., the rate of waste formation must be balanced with the rate of its elimination. This condition should be fulfilled with an averaging over a long period of time, with equal amounts of radioactive waste established in the whole system.

Evidently, the main object of transmutation may be transuranium elements. In comparing thermal and fast reactors as applied to their use for transmutation of TUE isolated in SNF reprocessing, preference is given to fast reactors for a number of reasons.

It should be mentioned that realization of TUE transmutation requires great technological developments in the part of isolating from SNF and incorporation into special kinds of nuclear fuel. Great programs of reactor tests are also needed.

As to the issue of the long-lived radionuclides' disposal outside this planet, preliminary estimates show that this task is in principle solvable using known and in a considerable measure mastered means of space technology. Besides, the acting international agreement doesn't hinder such a use of cosmic space.

Outer space may be used for final isolation of especially hazardous wastes, provided any influence of these wastes on the near-earth space be excluded even in the remote future. A long-term astrophysical forecast of the wastes' fate is more reliable than a similar forecast applied to changeable-in-time geological formations. It is expedient to subject to space isolation the most long-lived radionuclides. The low gamma activity and the small volume of these radionuclides allow the use of already existing technical systems for launching into outer space.

At the same time, a considerable improvement of the available and development of new radiochemical technologies will be required for isolation of especially hazardous radionuclides in the concentrated form with their corresponding encapsulation. Wastes placed in special containers must withstand routine and emergency loads in transportation, as well as in re-entry, an impact against rocky ground, submersion in ocean depth, and explosion of the launcher rocket and fire at launching.

CONCLUSION

In connection with the method's specifity, its fate will depend, besides substantiation of the economic acceptability and solution of all of the problems of technical character, on the possibility of proving its sufficient safety. Evidently, the broad public opinion will be formed under the conditions of a prior rejection of this way. Therefore, it is only an in-depth study of all of the questions, as well as broad information that may lead to real application of long-lived radionuclides' space disposal.

As presented in this paper, review of new trends on rendering long-lived radioactive waste harmless shows that a radical solution to the problem requires extraordinary efforts.