Twenty years of RERTR in Russia: past, present and future

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ABSTRACT

The Russian RERTR Program started approximately 20 years ago. The USSR always supported principles and goals of the policy of nonproliferation and at the end of 70's the Soviet Government decided to create such national program. Twenty years is the sufficient time to estimate preliminary results of the realization of the program and its prospects on the future. After the first successes of the program, when the enrichment of uranium in fuel elements for foreign supplies was reduced from 80 % to 36 %, the realization of the program was suspended in connection with financial difficulties. But in the beginning of the 90's the Program has received a new pulse connected to the inclusion of Russian scientists and engineers in the international Program. Now basic directions in development of new kinds of fuel are development of works on fuel on a basis dioxide of uranium and development of fuel on a basis of U-Mo alloy. In the future to basic goals of the program the problem of the management of the spent nuclear fuel should be added. The management of HEU at the final stage of a fuel cycle becomes an important objective of the program, since the basic amount of HEU is concentrated in storage of SNF.

FIRST YEARS. CHOICE OF WAYS.

In the first years of operation of research reactors for increasing of parameters of these reactors the enrichment of uranium in fuel elements and assemblies consecutively increased. Firstly to 20%, later to 36% and at last to 90%. This technical policy was realized in former USSR from 50's to 70's. Similar processes took place in reactors of Soviet design constructed outside the USSR. But it's necessary to emphasize that the maximum enrichment in fuel elements and assemblies exported from former USSR was always limited by the level of 80%.

At the end of 70's soviet representatives participated in the work of International Nuclear Fuel Cycle Evaluation (INFCE) and in particular in the discussions on problems of the fuel cycle of research reactors. USSR supported the problem of reduce of the enrichment of uranium in these reactors.

> In the chapter 1.4. of the INFCE report of Working Group 8 that discussed problems of fuel cycle of research reactors is emphasized that **"Proliferation resistance can be increased by:**
> 1. **Enrichment reduction preferably to 20% or less which is internationally recognized to be a fully adequate isotopic barrier to weapons usability of ^{235}U;**
> 2. **Reduction of stockpiles of highly enriched uranium;**
> 3. **Reduction of the annual production of fissile materials in research reactors, although attainment of weapons-usable material would require spent fuel reprocessing."**

Those years in USSR and abroad operated a lot of research reactors, constructed under the Soviet projects, rather actively there was a process of reconstruction of reactors with increase of their power. The amount of reactors continued to be increased. Total number of foreign reactors, in which fuel elements of the Soviet manufacture with HEU were used was 11, and their total power was 99.5 MW.

According to INFCE conclusion at the end of 70's the Government of the USSR decided to launch activities on reducing fuel enrichment in research reactors with the view of contributing to-non-proliferation and supporting international efforts in this area.

. In 1978 the former USSR Ministry of Medium Engineering (currently Minatom of Russia) passed a resolution prohibiting to supply uranium with enrichment over 21% after renovation and modernization of research reactors constructed abroad with technical assistance from the USSR. In the case that the supply of fuel elements and assemblies with enrichment more than 21 % was absolutely necessary for operation of research reactor it were be required to receive a special permission of the Ministry. Clearly, for some time after this resolution had been passed, fuel elements and assemblies with enrichment of uranium more than 21 % was continued to be supplied abroad.

At the same time the works on development of new fuel have begun. The Russian Program of Reducing of Enrichment in Research and Test Reactors (RERTR) started at these years [1]. This program provided the development of new fuel elements and assemblies with higher density of uranium in fuel meat. But the questions of repatriation of SNF from foreign research reactors to USSR have remained behind frameworks of the program.

Important question was the same: is there is an intention to reduce the enrichment of uranium in operating domestic reactors? The decreasing of enrichment in more powerful and important research reactors was problematic and according to the principle of INFCE **"It is recognized that there are specific applications requiring high flux reactor operation that can only be met with high enrichment fuel".** Many Soviet research reactors were unique research reactors that require high level neutron fluxes and had very intensive experimental program. By this reason many experimenters try to explain why it's impossible to reduce enrichment of uranium in their reactors. After rough discussions it was decided to postpone the solution of this question on more later time. This opinion is true till now!

The main technical positions of the Russian RERTR were :

- Geometric sizes of fuel elements and assemblies shall be kept unchanged; only the fuel meat must be thicker;
- Excess reactivity and fuel burnup in unloaded fuel assemblies shall remain essentially as originally designed;
- The reactor power shall be kept at the original level;
- There may be only a minor increase in the fuel assemblies cost as related to unit mass of uranim-235.

These positions were very similar to the enrichment-reduction strategy of the international RERTR program.

The large calculation analyses have helped to choose density of uranium, necessary for decrease of enrichment provided that the above named technical positions will be satisfied.

Those years the main type of fuel composition in soviet research reactors was dioxide uranium in aluminum matrix. It was clear, that there is a reserve, which will allow to increase density of uranium in the fuel meat. The decision therefore was accepted to carry out development of fuel elements on the basis of this fuel composition. And it was the first Stage of the Russian RERTR Program. According to this Stage the enrichment of uranium should be reduced up to 36% on the basis of the use of uranium dioxide in aluminum matrix.

According to principles of the Program geometrical sizes of new elements and assemblies were identical fuel elements with enrichment 80 %, and neutron-physical characteristics were practically same, as well as characteristic initial assemblies with LEU.

The successful realization of the first Stage of the Russian RERTR Program has resulted in creation of new fuel compositions with high density of uranium and correspondingly fuel elements and assemblies and since 1986 the USSR and later Russia begun to supply fuel elements and assemblies for research reactors with enrichment not over 36%.

TIME OF CRISIS. NEW REALITIES.

Such supplies continue till now because the second phase of the Russian RERTR Program is not yet finished in consequence of problems of insufficient funding. The second phase of the Program provided decrease of enrichment of uranium to less than 20 % on the basis of use of new fuel compositions with higher density on uranium, for example, silicide of uranium in an aluminum matrix.

The solution of the second problem that was be formulated in the report of INFCE group was connected, mainly, to a problem of a final stage of a fuel cycle, however in that time it has remained outside of sphere of action of the Russian RERTR program. The similar situation was and with the international RERTR program. It is can only emphasize, that the situation became worse, since the transportation of SNF from sites of research reactors became less regular because of financial problems. Besides 6 countries having research reactors, were included into structure earlier USSR, but now these countries become independent, therefore have arisen new legal problems.

More than ten years the Russian RERTR program developed practically independently from the international program.

But as it said above results of the development of the program were very positive and as was earlier said it was possible to create fuel elements with enrichment 36 %,

At the end of 80's after the of the completion of the first phase of the program was removed and the problem seemed not so important for many specialists and officials. From another point of view the pressure from the IAEA has become appreciably more weak.

Besides, there were financial difficulties at realization of the program.

In view of all it the decision on suspension of works under the program also was accepted but the development of new types of fuel proceeded, though less intensively.

At the begin of 90's the Russian specialists started to contact with foreign scientists and engineers mainly with Americans and the exchange of the scientific information has become more intensive. Russian scientists participated in RERTR Meetings from 1993 and presented papers that describe the situation in the Russian program [2].

Another reality had become destroy of the USSR and political and economic reforms in Russia. Main consequences of this were same:

- Many domestic research reactors become foreign reactors;
- The Russian economy has appeared in a very uneasy situation;
- The time has required development of the Russian nuclear legislation;
- Many questions, which earlier were not discussed is open, become accessible for a mass media.

At the begin of 90's several Russian laws defined rules of export and import of nuclear materials. In November, 1995 the Federal Law on the Use of Atomic Energy has come into force. Chapter XIV of this main nuclear Law establish principles of export and import of nuclear installations, nuclear materials etc. The export and import of these goods must be conducted «**in accordance with the international obligations of the Russian Federation on the non-proliferation of nuclear weapons and the international agreements of the Russian Federation in the sphere of the use of atomic energy**».

The main document that concretize rules of export-import in nuclear field is the Decree 574 of the Government of the Russian Federation from 8 May of 1996. This decree defines conditions of export and import of nuclear materials, equipment, special non-nuclear materials and technologies. According to the definition critical nuclear production is uranium with enrichment more than 20%, plutonium, facilities for reprocessing of nuclear fuel and several another facilities. The procedure of getting of license for export-import of critical nuclear production is very strong. It's necessary to present documents which proof the necessity of supply of HEU instead of LEU, coordinate the license to many organizations and to get an approval at high governmental level.

As against the past, when Ministry of Medium Engineering defined practically completely all questions connected to policy in the field of export - import of nuclear materials, now many participants influence to procedure of acceptance of the decisions on the given problem. Major among them: Foreign Ministry, Ministry for Foreign Trade, Special Export Council. There are also a Special Export Council in Minatom of Russia, and Export Councils at the enterprises which are carrying out export of critical nuclear production. Accordingly the Licensee Procedure is very complicated.

At the same time it is necessary also to emphasize, that in many cases on acceptance of the decisions on export of nuclear materials renders influence a unsimple economic situation in Russia.

At the same time in the begin of 90's other important tendency - strengthening of influence of ideas of nonproliferation was designated also. The influence of other state structures on limitation of export of HEU has increased. Therefore works on the program were amplified and now they go on several directions. The economic difficulties essentially have complicated realization of the program of development and implementation of the fuel on a basis of silicide of uranium. On work on this direction have not received wide continuation. On the other hand there was an idea, that all research reactors can be transferred to LEU on a basis of dioxide of uranium. For this it's necessary to reach the density of uranium is 3.5-4 g/cm^3 and it could be possible to

hope that in the case of successful fabrication and test of fuel elements and assemblies that have such density of uranium it will be possible to reach required parameters of active cores with LEU.

Unfortunately works in this direction encountered on serious difficulties at the attempt to increase density of uranium up to approximately 4 g/cm^3. Nevertheless the work continues but now the proposed density of uranium is less than it was supposed earlier and equal to 2.5-3 g/cm^3. It's sufficient density for reducing of enrichment of uranium in fuel elements that have relatively big thickness (2.5 mm) but insufficient for fuel elements that have small thickness.

For estimation of the modern situation in the Russian RERTR Program it's interesting to compare some data on number and power of research reactors. Table presents such information.

Though for these years the total number of reactors has decreased, but some reactors become foreign and consequently total number of foreign reactors (and their total power) have decreased for 20 years insignificantly.

For these years three reactors were transferred to use of uranium with enrichment 36 % instead of 80 % (MARIA in Poland, LVR-15 in Czech Republic and WWR-SM in Uzbekistan) and now only reactor in Libya uses fuel with enrichment 80 %, however it is necessary to emphasize that these deliveries were made in 1980.

Table. Reactors candidates for the implementation of RERTR

Countries	Situation in 1980			Situation in 2000		
	Number of countries that have operating research reactors	Number of operating reactors	Total power, MW	Number of countries that have operating research reactors	Number of operating reactors	Total power, MW
Russia		14	345		11	290.5
Former Soviet Republics	6	6	47	3	3	26
Foreign countries	8	11	99.5	5	7	60.5
Total	9 (without former Soviet Republics)	31	491.5	9	21	377
Outside Russia		11 (outside USSR)	99.5 (outside USSR)		10	86.5

FUTURE OF RERTR. SNF IS THE NEW PROBLEM.

Now one of final goals of the program is the same as twenty years ago - the elimination of supplies of HEU in fuel elements and assemblies for foreign research reactors.

What is the perspective of using of HEU in operating research reactors? It's clear that the total number of research reactors in Russia and in foreign countries will not increase. It's possible to speak only about modernization or reconstruction of operating research reactors. These reactors have not so big power and it's possible to reduce enrichment of uranium to less than 20% without use of very high density fuel compositions.

Accordingly the amount of annually delivered uranium for the operation of research reactors will be probably reduced in the future. In the case of construction of new Russian design research reactors in foreign countries will be use only LEU.

It is necessary to note, that feature Russian reactors is use of a plenty different on a design fuel elements. Therefore realization of the RERTR program was complicated, so as it was necessary to develop many types of fuel elements and assemblies. In past years the efforts of the Russian program were concentrated on fuel elements that delivered abroad. It is necessary to note, that from total power of Russian research reactors 156 MW from 290.5 MW use fuel elements, which are not delivered on export. Several Russian research reactors of water-water type use fuel elements that use copper and iron as materials of meat and cladding and it's clear that neutron physical parameters of these reactors are not so good. By this reason it's desirable to change these materials to aluminum or may be zirconium.

Other offer is connected to development of a new fuel element of rod type, which can be used in anyone fuel assembly or reactor [3]. Whether this fuel element has same even best thermohydraulic and neutron-physical characteristics, than fuel elements of a tubular type, however it will universal and more easy for fabrication, that allows to simplify development of different fuel assemblies and to increase loading fuel in the core, that is extremely important for reduction of enrichment. Works on development of such fuel element now reach of a stage of reactor tests.

After the realization of these capabilities it's possible to discuss the problem of use of LEU. But it's necessary to emphasize that in any case in the future some Russian research reactors will continue to use HEU.

Reduction of stockpiles of HEU was one of main goals in 1980 and now this task is still actual. In this connection pertinently to pay attention that the main amount of HEU is concentrated not in storage of fresh fuel or active cores of operating reactors but in storage of spent fuel.

The total amount of uranium-235 in the form of HEU necessary for operation of research reactors candidates for the implementation of RERTR outside Russia is less than 30 kg/year. On

the other hand the amount of HEU in spent nuclear fuel at sites of foreign research reactor is much more. In some cases this amount exceeds the SQ. Besides because of small power of research reactors, their fuel rather soon loses property of self-protection. By this reason from the point of view of nonproliferation the problem of final stage of fuel cycle is more important than the problem of the supply of fresh fuel.

But the amount of HEU in the form of SNF will be increase as in Russia, and abroad. Russia has an intention to decide this problem. Different variants are possible:

- Reprocess of SNF in Russia and return of HLW after reprocessing; such possibility can be realized without changes in the legislation;
- Long-term storage or postponed decision;
- Final disposal of SNF in Russia; such possibility is preferable for many countries but it requires changes in the Russian legislation.

Several countries are ready to realize first way but not all. By this reason large efforts are undertaken to change the Russian legislation so that there will an opportunity to import SNF from foreign countries not only for reprocessing, but also on a final disposal.

It is necessary to emphasize, that in many cases the question of delivery of HEU links to the decision of a problem of SNF. Therefore in the future the questions of initial and final stages of a fuel cycle will be coordinated even more closely than now.

CONCLUSION

The Russian RERTR program started approximately 20 years ago and has achieved the progress. The USSR always supported principles and goals of the policy of nonproliferation and the Soviet Government decided to create such national program.

Twenty years is the sufficient time to estimate preliminary results of realization of the program and its prospects on the future.

After the first successes of the program, when the enrichment of uranium in fuel elements for foreign supplies was reduced from 80 % to 36 %, the realization of the program was suspended in connection with financial difficulties.

Now basic directions in development of new kinds of fuel are development of works on fuel on a basis of uranium dioxide and on a basis of U-Mo alloy.

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In the future to basic goals of the program the problem of the management of the spent nuclear fuel should be added. The management of HEU at the final stage of a fuel cycle becomes an important objective of the program, since the basic amount of HEU is concentrated just in storage of SNF.

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