DISPOSITION OF EXCESS WEAPON GRADE PLUTONIUM: NEW DEVELOPMENTS

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The status of the Russian and the American national "plutonium" programs implemented within the framework of the US-Russian intergovernmental Agreement concerning the management and disposition of plutonium designated as no longer required for defense purposes and related cooperation (PMDA)[3] has been studied in a number of papers[4].

It was stated that unlike the weapon grade uranium (HEU) disposal the disposition of weapon grade plutonium met with substantial technical and financial difficulties. To mention only the fact that it took several years to reach an agreement on plutonium disposition method through irradiation in civil power reactors. On the other hand the design and construction of corresponding "plutonium" facilities required even at the initial stage considerable investments from each side.

The entry into force in 2011 of the modified PMDA Agreement gave hope that a parallel launch of the national plutonium programs – subject to stable long term financing – will lead to the creation in 2016-2017 of a necessary infrastructure allowing each side to start the conversion of excess weapon grade plutonium into mixed uranium-plutonium (MOX) fuel and its irradiation in power reactors.

But the course of events refuted such a forecast. Discussions were renewed in the USA on the possibility of using alternative plutonium disposition methods. The US Department of Energy has formed an expert group to study these alternatives and decided to slow down the construction of the MOX plant till the conclusions of the group are ready. It is evident that the eventual repudiation by the American side of the previously agreed upon method of plutonium disposition will have an influence on the implementation of the PMDA Agreement. The assessment of the extent of such an influence would not be possible without recalling the "history of the ques-

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[3] Agreement between the Governments of Russia and the USA concerning the management and disposition of plutonium designated as no longer required for defense purposes signed on August 30 and September 1 respectively. Its modified version entered into force in July 2011.
[4] M. Bunn and A. Diakov, "Disposition of Excess Plutonium, Global Fissile Material Report," Chapter 3, 2007, http://fissilematerials.org/library/gfmr07.pdf ; V. Rybachenkov, "Disposition of Excess Weapon Grade Plutonium – Problems and Prospects," December 25, 2011, http://www.armscontrol.ru/pubs/disposition-of-excess-weapon-grade-plutonium.pdf .

tion" as well without taking into account the current status of the national plutonium programs.

The background

At the Moscow Summit on Nuclear Security in April 1996 the President of the Russian Federation Boris Eltsin declared that in connection with the process of bilateral nuclear disarmament Russia would release 500 tons of HEU and about 50 tons of weapon grade plutonium from its military program. Later, this position of Russia was officially reconfirmed in the statement of the Russian President to the 41th Session of the IAEA General Conference in September 1997.

The release of huge amounts of weapon grade nuclear materials put into the agenda the problem of their disposition.

From the point of view of the Nuclear Nonproliferation Treaty the management of excess weapon grade nuclear materials should meet the following requirements:

- make them unusable in nuclear weapons thereby providing the irreversibility of the nuclear arms reductions;
- exclude the risks of their theft and trafficking;
- promote the creation of the monitored regime of nuclear weapons and nuclear materials destruction;
- be economically sound.

One has to note that for the period of the 1990-th the elimination of risk that some portion of weapons nuclear materials could be stolen has been one of the incentives for their rapid disposition.

From technical perspective the disposition of excess HEU is not complex and is economically justified. The HEU weapons components are converted into oxide and after purification uranium oxide is converted to uranium hexafluoride (UF_6). The UF_6 is then blended by piping a stream of highly enriched UF_6 together with a stream of 1.5% enriched UF_6 to the level of 4-5% U-235 enrichment and the resulting material is used for the production of nuclear fuel for civil reactors.

Weapon grade plutonium disposition is more complicated from the technical point of view and, what is particularly important, demands substantial financial expenses.

The international experts meeting held in Paris in the fall 1996 has chosen two preferable plutonium disposition methods meeting the requirements of the "spent fuel" standard:

- immobilizing the plutonium with high-level radioactive waste;
- fabrication it into mixed oxide (MOX) fuel and irradiating the material in civil nuclear reactors.

The logic of such a standard was dictated by the fact that the main volume of plutonium produced in the world is located in the spent nuclear fuel having a high radia-

tion protection. Both of the chosen methods ensure protection from theft due to the high radiation level. But immobilization does not guarantee full irreversibility since mixing plutonium with radioactive waste does not change its isotopic composition and does not exclude in principle the possibility of plutonium extraction from the mixture. MOX fuel looks more attractive from the irreversibility point of view given that the plutonium isotopic composition is changed due to irradiation, which makes plutonium less usable for nuclear weapons.

In accordance with the US-Russian agreement of July 1998, a Joint Steering Committee was created with the purpose of coordinating scientific and technical work related to the disposition of excess weapon grade plutonium. To evaluate the overall costs of plutonium disposition in Russia a joint working group was established.

From the beginning the Russia's strategy to weapon plutonium excess management was based on two premises:

- plutonium is a valuable energy resource. In the context of the closed fuel cycle concept adopted in Russia this means that priority in the plutonium disposition should be given to its use in the fuel of civil nuclear reactors;
- since plutonium disposal have to be subsidized, to accelerate the beginning of the program of its disposition the U.S. and other Western countries should provide full funding for the whole Russian disposition program.

The Joint Steering Committee worked out the PMDA agreement, which was signed in August 2000.

In accordance with the document each of the sides pledged to dispose of 34 tons of its excess weapon grade plutonium by loading it into MOX fuel and irradiating in civil nuclear reactors.[5] The Agreement provides for synchronization of plutonium disposition by the sides (beginning of the process, its pace, etc.). Article IX stated that the beginning of disposition by each side was conditioned by the availability of an appropriate financing. Moreover the implementation of the Russian program presupposed provision of the financial assistance by the USA and some other Western countries. At the moment of the signature of the Agreement the cost of the Russian program was estimated to about $1.8 billion in year-2000 dollars.[6]

It was expected that the implementation of the Agreement would start in the second half of the year 2009 and the disposition programs finalized in 2025. In Russia fast reactor BN-600 and four light water reactors VVER-1000 at the Balakovo NPP were planned to be used for fuel irradiation, light water reactors – in the USA.

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[5] In accordance with the Agreement USA pledged to convert to MOX fuel only 27 tons of metallic plutonium. The remaining 7 tons consisting of plutonium dioxide and plutonium waste were supposed to be disposed of by immobilization.

[6] Cost Estimates for the Disposition of Weapon Grade Plutonium Withdrawn from Russian's Nuclear Military Program, Second Report of the Joint US-Russian Working Group on Cost Analysis and Economics in Plutonium Disposition, March 2001.

But from the very beginning the practical implementation of the PMDA agreement met with substantial difficulties. Among them one can enumerate divergent approaches of the sides to the problem of civil liability as well to the size of Western financial assistance. The dispute on the liability issue has been formally resolved by a 2006 Protocol but the question of financing revealed to be more complicated.

As a result of negotiations on sources and mechanisms of financing the overall international financing package pledged by the Western contributors amounted to $850 million by the end of 2005.

At the same time the value of the Russian disposition program has increased from $1.8 to $4 billion. In April 2007 the US side notified Russia that the donor contribution of $850 million was a final one.

Under these circumstances financing of the program from the Russian budget was not considered advisable since plutonium disposition through MOX fuel for light water reactors did not correspond to the country's long-term strategy of the nuclear power development. The lack of external assistance led in fact to a denunciation of the Agreement.

In view of the fact that repudiation of the PMDA Agreement could negatively influence Russian American relations as well as ties with other countries Rosatom initiated a study of such a disposition scenario which would correspond to the Russian nuclear energy development plans and would be acceptable for both sides.

Following consultations held in 2007 the US side agreed with Rosatom proposals concerning the implementation of the Russian excess plutonium disposition program. In November 2007 the US Energy Secretary S. Bodman and the head of the Russian Federal Agency for Atomic Energy S. Kirienko signed a joint statement related to a new plan for the disposition of 34 tons of excess plutonium.

According to this document the disposition of Russian weapon grade plutonium will be carried out by loading it into MOX fuel and its further irradiation in the fast neutron reactor BN-600, which is actually been operated at the Beloyarsk NPP, and in the BN-800 reactor, which is under construction at the same site. Later on necessary changes in the 2000 Agreement were agreed upon and a modified Agreement worked out which was signed in 2010 and entered into force in July 2011.

In compliance with the modified Agreement each side pledged to start the disposition of 34 tons of excess plutonium (25 tons in the form of metal and 9 tons in dioxide) in 2018 and to finalize the process in 15 years. Both sides were supposed to use the same disposition method through use in the MOX fuel and its subsequent irradiation in civil nuclear reactors (in light reactors for the USA and in fast neutron reactors for Russia).

Status of the Russian disposition program

It should be right away noted that Rosatom, the Russian executive agent for the Agreement, successfully implements the national plutonium program without introducing any amendments of a fundamental character. The construction of the BN-8OO reactor is actively going on (Zarechny, Sverdlovsk region) and its physical startup was planned to happen at the end of 2013.[7]

A technological complex for the production of MOX fuel for initial loading of the BN-800 reactor was launched in a test mode at the Research Institute of Atomic Reactors (NIIAR, Dimitrovgrad, Ulyanovsk region). The cost of the facility is 1.7 billion rubles.[8] In the beginning stage the reactor will use a mixed active zone on the basis of uranium and MOX fuel in two options: in pellets (to be produced at the MAYAK combine, Chelyabinsk region) and vibropacked produced at the NIIAR.[9] The beginning of the initial fuel loading was expected in December, which gives evidence of a real progress of the program.[10] The BN-800 reactor active zone will be converted to the exclusive use of mixed uranium-plutonium fuel in 2016 when a new MOX plant (estimated cost 7 billion rubles) starts its operation at the Mining-Chemical Combine (GKHK, Zheleznogorsk, Krasnoyarsk territory).[11]

One has to note that weapon grade plutonium disposition in fast neutron reactors has some peculiarities. Foremost it is the possibility of producing more plutonium than it consumes and whose quality may even surpass that of the weapons plutonium. It is exactly for this reason that Article VI of the PMDA Agreement imposes a ban on spent fuel and blankets reprocessing during the disposition process until disposition of plutonium covered by the PMDA is complete.

Status of the American plutonium program

According to the recent NNSA data the estimated cost of the MOX-fuel plant which is being constructed at the Savanna River nuclear Center (South Carolina) has increased from $4.8 to 7.7 billion and its commissioning shifted from 2016 to 2019 although $3.7 billion has been already invested in the construction of the facility.[12]

Taking into account these circumstances as well as a budget sequester enacted in 2013 (including the reduction of defense expenses by $ 454 bln till 2021) the NNSA

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[7] "Physical startup of the BN-8OO reactor at the Beloyarsk NPP will begin in December 2013" (in Russian), http://www.atomic-energy.ru/news/2013/11/22/45188 , 22.11.2013.
[8] "NIIAR has finalized retooling the complex for the production of the innovative nuclear fuel" (in Russian), http://sdelanounas.ru/blogs/40259 , 05.09.2013.
[9] Ibid.
[10] "The BN-800 physical startup begins" (in Russian), http://ria.ru/atomtec_news/20131225/986340644.html, 25.12.2013.
[11] "GKHK prepares to launch a MOX-fuel plant in 2014" (in Russian), http://krsk.sibnovosti.ru/business/253101, 07.11.2013.
[12] D. Horner, "US Revisits Plutonium Disposition Plan," *Arms Control Today*, May 2013, http://www.armscontrol.org/act/2013_05/US-Revisits-Plutonium-Disposition-Plan .

announced in its detailed justification for its budget request for fiscal year 2014 that the US Administration is conducting an assessment of alternative plutonium disposition strategies in fiscal year 2013 and identifying options for fiscal years 2014 and onward. As a result the NNSA "will slow down the MOX project and other activities associated with the current plutonium disposition strategy during the assessment period".[13]

In pursuance of this directive the NNSA FY 2014 financing related to construction of the MOX plant was reduced by $115 million in comparison to 2012 ($435 million). Moreover the budget line for construction of the MOX plant has zeroes for the four fiscal years starting with 2015.

Aiming at neutralizing the rumors circulating in the expert community that the measures undertaken by the Administration may abrogate the US-Russian plutonium arrangement D. Poneman, the DOE Deputy Secretary, declared in an interview that despite reports that the Administration is considering a slow down or suspension of MOX the US commitment to the Agreement is not in question. The Secretary went on saying that the US wants to resolve a plutonium disposition issue in an optimal way from technical and economical points of view and that he already informed his Russian partners about this.[14]

Currently an expert group created by the decision of the DOE Secretary E. Moniz completes its analysis of alternative plutonium disposition strategies and has to present its conclusions not later than January 2014 with the view of incorporating them in the NNSA FY 2015 budget request.

John MacWilliams, DOE Senior Advisor who led the effort declared that after having considered about 30 alternatives the group ultimately has focused on three main options[15]:

- Immobilization with high-level reprocessing waste.
  The group opted for a "can-in-canister" approach in which plutonium first would be immobilized in cans of glass or ceramic. Those cans would be placed on a rack inside standard canisters after which molten high-level-waste glass would be poured into the canisters. In that conception, each canister would hold about 28 kilograms of plutonium.
  In experts opinion such an immobilization and storage process could be organized by repurposing the partly constructed MOX fuel fabrication plant at Savanna River (60% readiness). It is likely to give substantial economic effect

[13] US Department of Energy,"FY 2014 Congressional Budget Request: National Nuclear Security Administration," DOE/CF-0084, April 2012, p. DN-112.
[14] D.Horner, *op. cit.*
[15] T.Clemens, E.Lyman, F.von Hippel, "The future of plutonium disposition," *Arms Control Today*, July-August 2013, http://armscontrol.org/aqct/2013_0708/The-future-of-Plutonium-Disposition ; K.Fletcher, "DOE decision on plutonium disposition plans expected next month," *Nuclear Weapons & Materials*, November 22, 2013, p.6, Exchange Monitor publications Inc.

since only a part of building would be required because immobilization does not require the plutonium feed purified as extensively as for fabrication into MOX fuel.

- Immobilization without high-level waste.
  Plutonium could be embedded in a ceramic matrix and then stored securely pending disposal. Alternatively DOE could dispose of the immobilization forms in boreholes, three to five kilometers deep, which should complicate unauthorized access to the sensitive material.
- Placement of excess plutonium into the DOE Waste Isolation Pilot Plant (WIPP) (caverns mined out in a salt deposit 650 meters under southeast New Mexico). No radiation barrier against potential intruders is provided for in this option.

It should be noted that all the three options do not comply with Article III of the Agreement, which defines the disposition method as loading plutonium into MOX fuel and its irradiation in civil nuclear reactors. Besides that two last options do not correspond to the spent fuel standard. That is why a deviation from one of the basic provisions of the Agreement would hardly find a positive response from Russian experts who always asserted that a real weapon grade plutonium disposition is possible only through its irradiation in MOX fuel of civil nuclear reactors thus assuring an irreversible withdrawal from weapon's program. At the same time other approaches proposed by Americans do not exclude the possibility of a premeditated withdrawal of weapon grade plutonium from the place of its storage and its repeated use in weapons.

Possible influence of US decisions on the implementation of the Agreement

It seems that whatever decisions are taken by the US Administration concerning the strategies of excess weapon grade plutonium disposition they would hardly have an influence on the process of plutonium disposition by the Russian side. The Federal Target program of Russia "Nuclear energy technologies of a new generation for the period 2010-2015 and till 2020" provides for the use of fast neutron reactors with MOX fuel as a basic element of advancement towards a closed fuel cycle and the plutonium disposition is embedded in this program.

The question however arises what effect will have American decisions on the destiny of the Agreement and whether the sides would be in a position to find mutually accepted solutions for its preservation.

One can guess with a certain degree of probability that even in the case of repudiation by Americans of the previously agreed upon disposition method the two sides will do their best to preserve the Agreement. This is predetermined in the first place by an aspiration to avoid negative political consequences for nuclear disarmament

process and for nuclear nonproliferation regime, which could emerge if the Agreement is broken down.

Apparently in the process of developing such an arrangement today's realities, which substantially differ from those 20 years ago when the excess weapon grade materials disposition problem was first raised, should be taken into consideration.

As mentioned above the main incentive for excess nuclear materials disposition at that time was the necessity to eliminate the risk of their theft and illegal trafficking dictated by a concern related to inadequate physical protection of these materials in Russia. Since then the situation has drastically changed. At the MAYAK combine and at the GKHK modern big capacity storages equipped with advanced physical protection systems have been constructed. Was put into operation a modern State system of accounting and control of nuclear materials. Methods of maintenance staff training were adjusted in accordance with modern requirements. All these measures have significantly diminished the risks of theft and illegal trafficking of nuclear materials in Russia.

The necessity to make the process of nuclear disarmament irreversible was an additional motivation for excess nuclear materials disposition. One has however to note that as a result of reductions carried out in the two last decades the level of nuclear armaments has been manifold cut down and therefore the declared excess quantities of weapon grade plutonium can not constitute a basis for the reversibility of this process. A maximum possible quantity of nuclear warheads of each of the sides is determined by the loading capacity of their delivery means. To have the number of warheads in bigger quantity then allowed by this capacity does hardly have any sense.

As it is known, in accordance with the New Start Treaty the number of carriers possessed by each side by 2018 should not exceed 700 units. For the US, taking into account the maximum loading capacity of delivery means, the necessary number of warheads constitutes about four thousand units. As expert's assessment show, to maintain such arsenal of nuclear warheads no more than 20 tons of plutonium is necessary. Let's also take into consideration the fact that even after deduction of declared 34 tons of excess plutonium the US and Russian nuclear arsenals still have each more than 50 tons of this material sufficient to produce about 12500 warheads.

It becomes clear in this context that disposition of declared quantities of excess plutonium is not a determining factor having influence on irreversibility of nuclear arms reductions and rather has a symbolic character.

Taking this into account we are of the view that Russia may agree with any disposition method, which the USA would deem acceptable. In return the Russian side would have the right to repudiate the provision of the Agreement prohibiting spent fuel and blanket reprocessing till the full disposition of 34 tons of excess plutonium is over. Moreover, taking into consideration the opinion of American experts about

equivalence of weapon grade and civil reactor plutonium for weapons purposes the Russian side could also insist on the increase of the plutonium disposition share in the form of dioxide. This would give Russia a possibility to include in the disposition process a part of 48 tons of civil plutonium, which is stored at the MAYAK combine.[16]

Another basic principle of the Agreement – parallelism or concurrency of American and Russian national plutonium programs – could also be revisited. But such a revision is feasible only if this does not create difficulties for the development and implementation of the international monitoring procedures stipulated by the Agreement. It seems that if the US side chooses an alternative plutonium disposition method, preservation of the international monitoring provision in the Agreement will not be a priority for Russia. But still there is an understanding in the Russian expert community that preservation of an international monitoring is an important issue in the context of possible involvement of other nuclear states in the process of nuclear armaments reductions.

January 13, 2014

[16] IAEA. Communication received from the Russian Federation concerning its policies regarding the management of plutonium. November 23, 2012, INFCIRC/549/Add 9 /14.