DISPOSITION OF EXCESS WEAPON GRADE PLUTONIUM – PROBLEMS AND PROSPECTS

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The process of bilateral reduction of strategic offensive nuclear arms which started with the entry into force in 1994 of the Russian-American START-1 Treaty highlighted the problem of disposition of substantial quantities of weapon grade fissile materials – highly enriched uranium (HEU) and plutonium – extracted from dismantled nuclear warheads. The scale of the problem can be understood from the following figures. During almost fifty years of the Cold War the United States have produced more than 110 tons of weapon grade plutonium.[2] There is no official data about the Soviet production of this material. Nevertheless, a recent expert assessment of this quantity — 129.8 tons[3] — is noteworthy. This figure matches well with the data calculated by using the following logical chain: during the Moscow Summit on Nuclear Security in 1996 the President of Russia expressed the intention to put under IAEA control the Chelyabinsk storage of fissile materials, where 40% of Russian military plutonium will be contained[4]. Taking into account that in accordance with the Minatom data, the planned capacity of this storage was about 50 tons, this gives 125 tons of this material produced in the USSR. During the same period, based on experts' assessments, the USSR produced 1250 tons of HEU, and the USA – 850 tons[5].

Specificity Of Weapon Grade Plutonium Disposition

HEU disposition is conducted by reducing the concentration of the fissile isotope U-235 from 93-95%, typical for weapon grade uranium, to 3-5% during the process of HEU blending down by natural or slightly enriched uranium. The resulting low enriched uranium can be used for the production of nuclear power plants' fuel, notably this disposition method is appropriate from the economical point of view. In the framework of the Russian-American intergovernmental 1993 HEU/LEU Agreement that provides for blending down 500 tons of uranium extracted from the Russian nuclear weapons into low enriched uranium for the American nuclear power plants (NPPs) over a period of twenty years, Russian experts developed an outstanding technology of HEU dilution. This technology allows for creating a final product meeting the national US standard requirements. Since 1993 three Rosatom enterprises

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[2] Global Fissile Material Report 2010. Fifth annual report of the International Panel on Fissile Materials, p.28, http://www.fissilematerials.org/ipfm/site_down/gfmr10.pdf.
[3] Anatoli Diakov, The History of Plutonium Production in Russia, Science and Global Security, Volume 19, Number 1, January-April 2011.
[4] Moscow Summit on Nuclear Security, April 1996, "International Life" publishing house.
[5] Global Fissile Material Report 2010, pp. 58, 28.

have blended down approximately 450 tons of HEU, which provided for about 10% of the cumulative yearly quantity of electricity produced in the USA.

However, blending down cannot be applied to the disposition of the weapon grade plutonium. Plutonium does not exist in the nature and it is a material of artificial origins. Plutonium is produced in a variety of isotopic mixtures in a nuclear reactor, starting with Pu-239 as a result of a neutron capture by U-238. Weapon grade plutonium has about 90% of a fissile isotope Pu-239. In accordance with IAEA definitions any plutonium containing less than 80% of non-fissile isotope Pu-238 is considered as a direct use material, which in principle can be directly used in a nuclear explosive device[6]. It is worth mentioning that for uranium this threshold is determined by the U-235 enrichment level over 20%. Taking into account that only insignificant quantities of Pu-238 are being produced worldwide (about several tens of kg per year) its use as a blender of the weapon grade plutonium is practically unfeasible. Neither the so-called civil plutonium separated by chemical treatment of the nuclear reactors' spent fuel can be used for these purposes. The typical concentration ratio of isotopes Pu-239 and Pu-240 in such a fuel is 60 to 40 and, therefore, in accordance with IAEA definitions, civil plutonium cannot be used for blending down of weapon grade plutonium into the form unusable for the production of a nuclear explosive device.

The Background

The pinnacle of the expert discussions concerning the choice of suitable weapon grade plutonium disposition alternatives fell on the middle of the 1990s, but the real turning point, which has created a favorable atmosphere for the international cooperation in this field, was the Moscow Summit on Nuclear Security in 1996. The declaration of the Summit confirmed the importance of converting the excess weapon grade fissile materials into spent fuel or other forms equally unusable for the production of nuclear weapons. The participants of the meeting expressed their resolution to determine the disposition strategy of such materials, including options of weapon grade plutonium conversion into mixed uranium-plutonium (MOX) fuel for NPPs as well as vitrification, together with radioactive waste.[7] Also were approved the plans for small-scale technological demonstrations and pilot facilities construction.

In accordance with the summit recommendations an international expert meeting was held in Paris in October 1996 to consider alternative ways of weapon grade plutonium disposition. As a result of the discussions and taking into account the fact that the main quantity of the separated plutonium in the world is located in the spent fuel (over 2000 tons), the experts came to the conclusion that, from an economic and ecological point of view, plutonium irradiation in the MOX fuel of power reactors (typical isotope composition for a light water reactor – 5% of plutonium and 95% of

[6] IAEA Safeguards, Glossary, State Committee on the Use of Atomic Energy, Moscow 1983.
[7] Solidifying plutonium powder together with radioactive waste by their mixing with glass-forming materials.

depleted uranium) is the most suitable option. Vitrification was named as a viable additional alternative.

The next important step was a Joint Statement by the Presidents of Russia and the United States in September 1998 concerning the principles of plutonium management no more needed for defense purposes. The Heads of States confirmed the intention of each country to withdraw from their nuclear weapon programs about 50 tons of plutonium and to transform it in such a way that it would not be possible to use this material for the production of nuclear explosive devices. The Presidents agreed that both governments will cooperate in achieving this goal and urged other countries, including G-8 states, to join a common effort. It was also stated that the parties would start negotiations without delay to conclude an appropriate intergovernmental agreement.

Russian-American 2000 Agreement

In accordance with instructions given by the Presidents negotiations were held in 1999-2000 to develop such an agreement. The work has been concluded by the summer 2000 and the Prime Minister of the Russian Federation Mikhail Kasyanov and the US Vice-President Al Gore signed the Intergovernmental Agreement Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes, on August 30 and September 1, 2000 respectively.

The most important provisions of the Agreement are:

- irreversible transformation of excess weapon grade plutonium into forms unusable for nuclear weapons;
- parallelism and parity of the Russian and American plutonium disposition programs: each party will dispose of no less than 34 tons of weapon grade plutonium (isotope ratio of Pu-240 to Pu-239 not more than 0.1) in the form of light water reactors' fuel;
- possibility of disposition of additional plutonium, which may be withdrawn from nuclear weapons' programs in the future;
- transparency for the international community assured by mutual monitoring and inspection activities with respect to plutonium, blend stock, spent plutonium fuel, immobilized forms and disposition facilities. In addition, each party shall begin consultations with the IAEA in order to conclude appropriate arrangement with the Agency to allow it to implement verification measures;
- assurances to Russia concerning the provision of uninterrupted technical and financial assistance at all stages of the Russian plutonium disposition program implementation.

The Agreement contains the provision that the parties undertake all efforts in order to finalize the construction of the necessary industrial facilities and putting them into service before December 30, 2007 with the plutonium disposition rate not less than 2 tons per year. However, Russia is not obliged to start such construction before the

conclusion of a multilateral agreement on international assistance to the Russian program.

In accordance with the article XIII the Agreement is applied provisionally from the date of signature and shall enter into force on the date of the last written notification that the Parties have fulfilled the national procedures required for its entry into force. For Russia it means that the Agreement enters into force upon its ratification by the State Duma.

The Lost Decade

It would seem that after such a dynamic start in the development and signing of the Agreement real prospects of its prompt implementation were opened but the events that followed knocked illusions on the head.

In accordance with the G-8 Summit decision a Plutonium Disposition Planning Group was set up to develop an international financing plan to assist the Russian plutonium disposition program. During the four-year period of its activities the declared cumulative donor pledge came to $850 million ($400 million from the USA and $450 million from other G-8 donors), whereas, according to Russian assessments, the sum should be at least 4 billion USD. In 2007, the American side informed the Russian side that the donor contribution of $800 million is final and will not be supplemented[8]. During the negotiations with foreign donors the Russian party insisted that the financing of the Russian weapon grade excess plutonium should come from external sources. Moreover, Russian experts came to the final conclusion that financing of the plutonium disposition in light water reactors from the state budget is not suitable since the long-term Russian nuclear energy strategy does not provide for the use of the MOX fuel in light water reactors[9]. However, due to the fact that the refusal to implement the 2000 Agreement could complicate US-Russian relations and might have a negative impact on international efforts for strengthening of the nuclear non-proliferation regime, the Russian party initiated the development of such a scenario in the national plutonium disposition programs, which would match the nuclear energy plan in Russia and would be acceptable to both parties.

As a result of intensive Russian-American consultations the USA agreed that Russia would use fast neutron reactors BN-800 (in the process of construction) and BN-600 (in operation since 1980) instead of light water reactors VVER-1000 for the purposes of its national plutonium disposition program.

Subsequently, the parties started developing a Protocol to the 2000 Agreement, which would introduce changes reflecting the new realities. It took three years to finalize the work, and the document was signed by the Minister of Foreign Affairs of Russia Sergey Lavrov and the US Secretary of State Hillary Clinton on April 13, 2010

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[8] Second annual report of the International Panel on Fissile Materials p. 38, 2007, http://www.fissilematireals.org/ipfm/site_down/gfmr07.pdf.

[9] Plutonium management and disposition Agreement US Department of State, Office of the spokesman April 13, 2010.

in the course of the Washington Nuclear Security Summit. In addition, in September 2010 the Ministers sent a joint letter to the IAEA Secretary General Yukiya Amano asking for the Agency's assistance in the development of a legally binding international mechanism controlling the bilateral Agreement on plutonium.

Specifics Of The Renewed Arrangement On Plutonium Disposition

It took an additional year for the Russian State Duma to ratify the Russian-American Agreement as modified by the Protocol. It entered into force on July 13, 2011 after the exchange of diplomatic notes in Washington by Sergey Lavrov and Hillary Clinton. At the same time, a Protocol on civil liability for nuclear damage, signed by the parties in 2006, was ratified[10].

Among the basic changes introduced in the 2000 Agreement are the following:

- Each party disposes of 34 tons of excess plutonium by irradiation of MOX fuel in power reactors. The overall quantity of 34 tons consists of 25 tons of plutonium in the form of metallic weapons components or metal as well as 9 tons of oxide. Russian plutonium is disposed of in the fast neutron reactors BN-600 and BN-800 and the USA use light water reactors. The completion of the BN-600 modification is slated for 2013-14 and the end of the BN-800 construction– for 2012-13. High temperature gas cooled modular reactors may be brought into play after their development and construction. Disposal of plutonium in the BN-600 reactor is conducted without a radial plutonium reproduction zone and the BN-800 reactor works with the ratio of plutonium reproduction of less than 1.
- Each party undertakes all necessary efforts in order to complete as soon as possible the construction and commissioning of the reactors and other facilities necessary to achieve the plutonium disposition rate of 1.3 tons per year.
- The parties start consultations with IAEA with the view of concluding an agreement on verification measures for the national plutonium disposition programs.
- The US Government shall provide for $400 million for the activities to be undertaken in the Russian Federation subject to the availability of the appropriated funds. These funds should not be used for the construction of the BN-800 reactor but may serve for conducting design, research and experimental work as well as for the procurement of necessary equipment ($300 million) and for the monitoring of the Russian plutonium program ($100 million). The disbursement of these resources is accomplished on the basis of the Milestone Implementation plan presented by Rosatom and agreed upon by both parties.
- The Executive Agents of the Agreement (Rosatom and the US Department of Energy) undertake efforts to attract funds from other donors but the implementation of the Russian program is not dependent on the presence or absence of such

[10] The key provision of the Protocol stipulates that the Russian party does not present any claims to the US Government, its personnel or contractors for the damage inflicted to the Russian Government in the course of the implementation of the Agreement except the cases when the Russian Government considers that actions or inaction of the US representatives were committed with the intent to cause damage.

additional funding. However, the Government of the Russian Federation has the right to suspend or discontinue the implementation of the Agreement if the US Government decides to discontinue the declared assistance to the Russian program.

- The estimated date of the beginning of the Russian and American plutonium disposition is 2018. In case of a high temperature gas cooled reactor commissioning in 2019-21 the plutonium disposition rate may be increased.

The American Plutonium Program – State Of Affairs[11]

The construction of the US complex for the disposition of excess weapon grade plutonium started in August 2007 at the former military nuclear Savannah River Center (South Carolina). It comprises three units:

- a facility for plutonium pits dismantlement and conversion of metallic plutonium into dioxide powder;
- a facility for the production of MOX fuel;
- a waste solidification building, which is to handle the high and low activity waste from MOX and pit disassembly operations.

The $4.8 billion MOX facility is scheduled to complete construction and begin start-up operations in October 2016 with a yearly throughput of 3.5 tons of weapon grade plutonium. A license for the industrial production technology was acquired from AREVA, the French nuclear corporation, which has a reputable practical experience in this field (according to certain sources the cost of the deal was about $100 million). The facility is near 60% complete: the construction of 11 out of 16 auxiliary buildings as well as the main electric substation has been finalized, the delivery of the technological equipment has started and the testing of glove boxes was initiated. Overall 1800 workers and engineers are engaged in the construction project.

With the view of expanding the range of the MOX fuel consumers the design of the second MOX fuel production line for the boiling light water reactors was initiated (in addition to the main production line, which is intended to support pressurized light water reactors). For the same purposes a decision has been made to deliver MOX fuel to the consumers with a 20% discount in comparison with the cost of the traditional uranium fuel. But even with this discount the consolidated income to the Federal budget from the MOX fuel sales may come to $1-2 billion. Among potential consumers figures a renowned energy corporation, the Tennessee Valley Authority, with whom the US Department of Energy signed a letter of intent about the delivery of the MOX fuel to five light water reactors. The Waste Solidification building is also 60% ready and may be commissioned in 2013. The situation around the plutonium pits dismantlement and metallic plutonium conversion facility is more complicated: its design and location at the site are not yet determined. Although there is no clarity regarding its estimated cost, it was decided that the facility must be operational not

[11] Department of Energy, NNSA FY 2012 Congressional Budget Request, pp. 377-382, http://www.nnsa.energy.gov; NNSA MOX fuel fabrication, http://www.nnsa.energy.gov, February 14, 2011.

later than 2018. Since this facility is a supplier of a feed stock to the MOX plant, which has to start its work in 2016, a decision was taken to fill a two year gap by delivering plutonium dioxide powder from the Savannah River stocks as well as from a small scale conversion facility ARIES at the Los Alamos National Laboratory (the first certified 240 kg of such oxide were delivered in October 2011). A substantial role in confirming the safety of the new nuclear fuel was played by the irradiation in one of the American power reactors of four experimental MOX assemblies produced in France in 2007 with the use of 100 kg of the US weapon grade plutonium. The examination of these assemblies, including non-destructive essays, did not present any anomalies in the fuel elements.

The Implementation Of The Russian Plutonium Program

Three sites for the location of the MOX fuel production for the BN-800 were considered in Russia: the Production Association Mayak (Chelyabinsk region), the Siberian Chemical Combine (Tomsk-7) and the Siberian Mining and Chemical Combine (Krasnoyarsk-26). After long discussions a decision was taken to locate the plant for the industrial MOX fuel production for the BN-800 reactor at the Siberian Mining and Chemical Combine in Zheleznogorsk.[12]

The construction of this plant with the estimated cost of 7 billion rubles[13] is being conducted within the framework of the Federal Target Program, "Nuclear technologies of the new Generation for 2010-15 and for 2020 prospective". The project provides for the production of the pelletized MOX fuel from the weapon grade plutonium as well as from dioxide plutonium available at the Combine. The plant is slated to become operational by the end of 2014 and its yearly production will be 400 fuel assemblies. It was previously thought that the Combine would produce uranium-plutonium granules only which later on would be used for the production of the vibropacked fuel. However, since vibropacked technology needs further improvement, a decision was taken to switch to the production of pelletized MOX fuel.

The construction of the BN-800 reactor is conducted at the Beloyarsk NPP site (Sverdlovsk region). Its physical startup is planned for September 2013 and its full-scale activation – for the first quarter of 2014[14]. Initially a so-called hybrid zone using MOX and uranium fuel will be used in the reactor with the average plutonium content in the MOX fuel of 22%. It is supposed that there will be two types of the MOX fuel in the initial reactor core load: pelletized and vibropacked. The pellets for the MOX fuel will be produced at the Mayak PA and their assembly will be accomplished at the Reactor Construction Research Institute (Dimitrovgrad, Ulyanovsk region). Vibropacked MOX fuel will also be produced at this Institute and the uranium fuel – at the Machine Building Plant (Electrostal, Moscow region). A small-scale production of the pelletized fuel is already being conducted at the "Packet" facility at

[12] http://www.nuclear.ru/rus/press/nuclear_cycle/2117460/
[13] http://www.atomic-energy.ru/news/2011/06/03/22978/
[14] http://www.nuclear.ru/rus/press/nuclearenergy/2124052/

Mayak.[15] With the commissioning of the MOX plant at Zheleznogorsk in 2014 a transition to 100% MOX loading of the BN-800 core will start and will be completed by the year 2017.

Another noteworthy issue is the practical implementation of the American financial contribution to the Russian plutonium program. As noted above the modified plutonium Agreement stipulates that the transfer of funds would be accomplished after Rosatom would have provided a national plutonium Milestone Plan with the indication how much money is needed for each milestone. In her presentation at the Moscow Center for Energy & Security Studies in August 2011, Laura Holgate, Senior Director for WMD Terrorism and Threat Reduction at the US National Security Council, declared that the American side has not yet received such a document which excludes the possibility of a confirmation by the US Congress of the DOE target budget requests concerning Russia (for this particular reason the Congress has already declined two such yearly requests for $100 million each). Nevertheless one may assume that this issue will be resolved in the next few months since the Rosatom leadership would hardly renounce such a considerable external contribution to the Russian weapon grade plutonium disposition program the pinnacle of which will presumably fall on 2012-13.

Conclusion

The entry into force of the Russian-American Agreement on the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes became an important step on the way to nuclear disarmament and the strengthening of the WMD non-proliferation regime. For the first time, a mutual arrangement was reached on irreversible conversion of substantial volumes of the basic direct use fissile material into the form unsuitable for the production of nuclear weapons.

A parallel implementation of the national plutonium programs supported by a stable financing was initiated. The conversion in the course of the forthcoming 15-20 years of the "raw material" sufficient for the production of 17 000 nuclear warheads into the fuel of nuclear power plants will be the outcome of this outstanding international project.

January 17, 2012.

[15] http://www.nuclear.ru/rus/press/nuclear_cycle/2124056/