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Disposition of Excess Russian Weapon HEU and Plutonium

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Today, there are hundreds of tons of highly enriched uranium (HEU) and separated plutonium in the Russian Federation and the United States that are no longer needed for military purposes. Reducing these huge stockpiles of weapons-usable material is important to national and international security. Russia and the United States have made considerable progress in reducing their HEU stockpiles in recent years. In contrast to the progress of HEU disposition, disposition of US and Russian excess weapons plutonium has yet to begin.

Why Disposition?

These large stocks of plutonium and HEU could readily be turned back into nuclear weapons, should political circumstances change in the future. Hence, reducing or eliminating these large excess stocks, rather than simply storing them forever, would be an important contribution to achieving deep and irreversible nuclear arms reductions, which, in turn, could strengthen international political support for measures to strengthen the global non-proliferation regime.

In principle, disposition of these large stocks—which means physically transforming them into forms that would be difficult and costly to recover for use in nuclear weapons—could also decrease the risk that some portion of them could be stolen and fall into the hands of terrorists or proliferating states.

Certainly, the security benefit of disposition depends on the fraction of the stocks to which disposition is applied. A disposition programme that still left enough plutonium and HEU to rapidly rebuild nuclear arsenals would do little to contribute to irreversible arms reductions, and eliminating only a quarter or a third of the potentially vulnerable stockpiles would do little to reduce the risk of nuclear theft.

Fissile material disposition may also serve a "good housekeeping" purpose, avoiding the costs and hazards of storing this material indefinitely; this, indeed, appears to be the motivation behind the disposition plans for a significant portion of the plutonium that Russia and the United States have declared excess to their military needs.

Russia's Fissile Material Stocks

The production of nuclear-weapon materials was one of the primary objectives for the United States and Soviet Union in their competition during the Cold War. As the result, huge quantities of fissile materials were produced. With regard to production of HEU, the both United States and Soviet Union/Russia produced it not only for weapons but also for nuclear submarines and naval vessels.

Russia has very large quantities of fissile materials but has never released information on how much HEU and weapon-grade plutonium it produced. While a small part of these materials were expended in tests, currently some part is in weapons, and significant quantities are in stockpiles accumulated from dismantled warheads or materials produced for weapons but never actually used in warheads. Estimates by non-governmental analysts, which are uncertain, suggest that, when the Soviet Union collapsed, Russia possessed something in the range of 1,250 tons of HEU and over 110 tons of weapons-grade plutonium, including the material in the warheads.[1] As of the end of 2011, Russia had an estimated 720±120 tons of HEU and 127±8 tons of weapons-grade plutonium.

Declarations of Excess

Russia declared that 500 tons of its HEU (roughly 40% of the estimated total) is excess to its military needs and agreed to blend this material to low-enriched uranium (LEU) for sale in the US market, as discussed below. In the 1990s, Russian President Boris Yeltsin declared that "up to" 50 tons of Russia's weapons-grade plutonium was excess to military needs, but the only portion of the total stock that Russia has definitely committed to disposition is the 34 tons covered by the 2000 US–Russian Plutonium Management and Disposition Agreement; this represents a quarter of Russia's estimated total stock of weapons-grade plutonium.

Disposition of Excess Russian HEU

Currently two programmes intended for HEU disposition are under way in Russia: the US–Russian HEU Purchase Agreement, and the Material Consolidation and Conversion project. In addition to these two programmes, Rosatom is also using enriched uranium for up-blending German reprocessed uranium in fuel production for Western pressurized water reactors.[2]

The US–Russian HEU Purchase Agreement

In 1993, the United States and Russia reached an agreement under which Russia committed to down-blend 500 tons of 90% enriched uranium recovered from dismantled warheads to the enrichment of 4 or 5%. The United States committed to buy, over a 20-year period, this down-blended uranium for use in light water reactors. This agreement is now being implemented. Approximately 30 tons of HEU are being blended each year, and the 500-ton agreement is expected to be completed in 2013. By the end of 2011, Russia

1 International Panel on Fissile Materials, *Global Fissile Material Report 2010. Balancing the Books: Productions and Stocks*, 2010, chp. 4, <www.fissilematerials.org/ipfm/site_down/ipfmreport10.pdf>

2 Mark Hibbs, "Framatome, Elektrostal looking to double business in down-blended HEU fuel", *Nuclear Fuel*, vol. 27, no. 17, 2002, p. 1.

had delivered to the United States 12,739 tons of LEU down-blended from about 442.5 tons of HEU, equivalent to 17,698 nuclear warheads eliminated.[3]

The blending process for this HEU is not complex from a technical point of view. The HEU weapon components are cut into metal shavings and then baked to convert them to oxide. The oxide is dissolved, put through a solvent extraction to remove impurities, and converted back to oxide. After that, the 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, and the resulting LEU is stored pending shipment to the United States. (Blendstock enriched to 1.5% is used rather than natural or depleted uranium to dilute undesirable isotopes in the HEU, such as U-232 and U-234; the blendstock is produced by stripping enrichment tails.) In Russia, cutting the components into shavings, oxidization and purification are performed at the Siberian Chemical Combine (SCC) in Seversk, Tomsk region, and the Mayak Production Association in Ozersk, Chelyabinsk region. The purified HEU oxide is converted to hexafluoride at Seversk and at the Electrochemical Plant in Zelenogorsk, Krasnoyarsk region. There are three enrichment plants in Russia—SCC in Seversk, the Electrochemical Plant in Zelenogorsk, and the Urals Integrated Electrochemical Enterprise in Novouralsk, Sverdlovsk region.

In September 1993, the United States and Russia agreed on transparency measures to be used by the US side at the Russian HEU down-blending facilities and by the Russian side at the US facilities, to provide assurance that the LEU being delivered in fact comes from HEU metal, and that it is only used for peaceful purposes once in the United States.[4] The US inspectors make several visits each year to the facilities where the HEU metal weapon components are cut into shavings and converted to oxide. At the blending facilities, the United States has continuous monitoring equipment for three pipes: one carrying 90% enriched UF_6, one carrying 1.5% enriched UF_6 used to down-blend the HEU, and the pipe carrying the final product, LEU at 4.5% enrichment. Russian inspectors make visits to the US fuel fabrication facilities where material is fabricated into reactor fuel.

Material Consolidation and Conversion Project (MCC)

Under this programme, the US Department of Energy has been working jointly with Rosatom to transfer the HEU from Russian research institutes where it is no longer needed to the Research Institute of Atomic Reactors in Dmitrovgrad (RIAR) and the Scientific Production Association Luch in Podolsk for conversion to LEU. While the main purpose of this programme is to reduce the number of sites with HEU, it also supports the down-blending of HEU to LEU. In addition to RIAR and Luch, 16 other Russian institutions are participating in this programme, many of which are sending HEU to RIAR and Luch. The MCC is interested primarily in material more than 80% enriched and more than 50% uranium by weight. MCC plans to blend 17 tons of HEU to LEU by the end of 2015.[5]

3 United States Enrichment Corporation, “Megatons to Megawatts”, <www.usec.com/russia-contracts/megatons-megawatts>, as of 30 January 2012.

4 For a description, see Matthew Bunn, with James Platte, “Highly Enriched Uranium Transparency”, in *Nuclear Threat Initiative Research Library: Securing the Bomb*, 2006, <www.nti.org/e_research/cnwm/monitoring/uranium.asp >. See also V. Rybachenkov, “Practical Prerequisites for the Implementation of Transparency and Verification Measures on Fissile Materials”, presentation at the international workshop International Cooperation in the Combat against Nuclear Terrorism and the Role of Nuclear Arms Control, Geneva, 17–18 December 2002.

5 US Department of Energy, *FY 2008 Congressional Budget Request: National Nuclear Security Administration*,

The rate of down-blending is about 1.5 tons of HEU per year, divided between RIAR and Luch. By the middle of fiscal year 2008 some 10 tons of HEU had been down-blended.[6] The down-blended material is being shipped to the Machine Building Plant (MSZ) in Elektrostal.

Up-Blending West European Reprocessed Uranium

The Russian nuclear fuel producer and supplier concern TVEL has been fabricating fuel for West European pressurized water reactors and boiling water reactors since 1996, using their reprocessed uranium blended with Russian HEU.[7] Using the equipment supplied by the French company AREVA, MSZ has already produced more than 1,000 fuel assemblies for utilities in Germany, Sweden, Switzerland and the Netherlands.[8]

The production of one ton of fuel from reprocessed uranium requires some 35 kg of HEU, if the HEU is enriched to 90% U-235. If the annual rate of fuel production is about 200 fuel assemblies per year, that results in the disposition of 3.5 tons of HEU annually. Taking into account that, by the end of 2009, TVEL had produced 2,000 fuel assemblies, some 35 tons of HEU (90% equivalent) had been disposed as a part of fuel manufacturing with reprocessed uranium.[9] This material, like the MCC material, is in addition to the 500 tons covered by the HEU purchase agreement.

Further Reductions in HEU Stocks

There is no public indication that Russia has set specific requirements for the quantities of weapons-grade fissile materials that it needs for its weapons arsenal and for future naval reactor use. That makes it difficult to estimate how much additional HEU and weapons-grade plutonium might be declared excess as a result of further reductions in Russia's warhead stocks. If Russia and the United States each reduced their stocks of deployed nuclear warheads as established by the New START treaty to the level of 1,550, that could free up hundreds of tons of additional material for disposition.

It is unlikely, however, that Russia will continue any version of the US–Russian HEU Purchase Agreement after it expires in 2013. The Russian Federal Atomic Agency chief Sergei Kirienko has indicated that Russia will not continue the programme after 2013.[10] With its economy growing and greatly increased federal funding for the nuclear sector, Russia does not need revenue from the HEU deal in the way it did in the early 1990s. Moreover, the way the deal is currently implemented makes it less profitable for Russia than simply marketing enrichment services commercially.

Also, some experts believe that sales of an enrichment service is more important to Rosatom than uranium sales. Russia wants to get commercial access to the US enrichment

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2007, p. 474, <www.cfo.doe.gov/budget/08budget/Content/Volumes/Vol_1_NNSA.pdf>.

6 See <http://nnsa.energy.gov/mediaroom/pressreleases/04.24.08>.

7 Ann MacLachlan and Michael Knapik, "TVEL eyes collaboration to serve U.S. market", *Nuclear Fuel*, vol. 29, no. 20, 2004.

8 "AREVA representatives have pointed out the high quality of fuel fabrication at MSZ", *Atom Pressa*, no. 46, 2006.

9 "Na OAO Mashinostroitelny zavod izgotovlena dvukhtysyachnay TVS zapadnogo obrazsa", Nuclear.Ru, 29 May 2009, <www.nuclear.ru/rus/press/nuclear_cycle/2112914/>.

10 Alexander Emeliyanov, *"Renaissance on Kirienko"*, *Rossiyskaya Gazeta*, 5 July 2006.

market after 2013. While Russian sales of enrichment services to the United States are currently blocked, under the HEU–LEU deal Russia supplied about 5.5 million separative work units (SWU) per year to the United States—that is 44% of the US utility requirements.[11] After 2013 Rosatom would like to have 20–25% of the US SWU market and it needs assurances that US trade laws will not be used to block Rosatom SWU sales in the United States.

Disposition of Excess Russian Plutonium

Plutonium Disposition Options

Unlike HEU, weapons-grade plutonium cannot simply be eliminated as a potential weapons material by dilution with a non-fissile isotope. All plutonium isotopes can support an explosive chain reaction and only plutonium-238, which is available in only small quantities, is considered unusable for weapons. Nuclear weapon designers prefer to use weapons-grade plutonium, containing typically more than 90% Pu-239. Plutonium containing substantial percentages of other isotopes generates far higher spontaneous neutron fluxes, heat generation and radiation fields, which complicate nuclear weapon design. Nevertheless, a nuclear bomb with an assured, reliable yield in the kiloton range can be made with reactor-grade plutonium.

A meeting of international experts held in Paris in October 1996 in response to a call from the Group of Eight Nuclear Safety and Security Summit held in Moscow earlier that year, and a 1997 study by a joint scientific commission reporting to the US and Russian presidents, all concluded that the two least problematic approaches to plutonium disposition would be:

1. Mixing the plutonium with uranium, fabricating it into mixed oxide (MOX) fuel and irradiating the material in existing reactors; or

2. Immobilizing the plutonium with high-level wastes.[12]

Russia has always seen its excess plutonium as an asset that should be used to produce energy. In the context of the closed-fuel-cycle policy adopted by Russia for the long term, this means that priority should be given to the MOX option and not to immobilization and disposal as a waste. While the United States and Russia have some experience in producing MOX fuel, they do not have the technical infrastructure to undertake plutonium disposition. For the MOX option they both need plants for converting plutonium metal to oxide and new MOX fuel-fabrication facilities.

Russian-US Plutonium Management and Disposition Agreement

The United States and Russia have been discussing what to do with their excess weapons-grade plutonium since the early 1990s.[13] In this discussion Russia has taken

11 Daniel Horner and Michael Knapik, "Tenex's Mikerin says US-Russia HEU deal won't run beyond 2013", *Nuclear Fuel*, vol. 31, no. 13, 19 June 2006.

12 John P. Holdren and Evgeniy P. Velikhov, co-chairs, *Final Report of the US-Russia Independent Scientific Commission on Disposition of Excess Weapons Plutonium*, 1997, <http://bcsia.ksg.harvard.edu/BCSIA_content/documents/fnlrpt.pdf>.

13 In 1998, the two sides reached an agreement providing a legal framework for technical cooperation on

the view that, if other states want Russia to burn weapons-grade plutonium soon, rather than waiting until it becomes an economic fuel for future fast neutron reactors, then they should pay the full costs of doing so, including the design, construction and operation of the planned facilities to produce MOX fuel, and of the reactor modifications required to adapt existing reactors to use the fuel. In 2000 Russia and the United States concluded their Plutonium Management and Disposition Agreement (PMDA), committing each to eliminate 34 tons of weapons-grade plutonium.[14]

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 US plutonium disposition programmes: each party will dispose of no less than 34 tons of weapons-grade plutonium (isotope ratio of Pu-240 to Pu-239 not more than 0.1) in the form of light water reactor fuel;
- possibility of disposition of additional plutonium which may be withdrawn from nuclear weapons programmes in the future; and
- assurances to Russia that the United States and other states would provide full funding for the whole disposition programme.

The agreement also called for bilateral and International Atomic Energy Agency (IAEA) monitoring, beginning at least at the moment when the material arrived at a fuel fabrication or immobilization facility, to confirm that the parties were fulfilling their obligations.

Most of the Russian mixed plutonium was to be fabricated into MOX fuel for existing reactors in a new MOX plant. A joint US–Russian study on cost analysis and economics of plutonium disposition envisioned that 14.5 tons of Russia's excess plutonium would be used in the BN-600 fast neutron reactors and the rest in VVER-1000 light water reactors.[15] The estimated cost for the Russian disposition programme was about $1.8 billion.

The Lost Decade

It was originally envisioned that a full-scale MOX plant would be operating in Russia by 2007. But due to several reasons it was recognized that this facility would not begin operation until 2017–2018, a delay of at least ten years.[16]

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disposition technologies; 1998 also saw the conclusion of a Russian–French–German agreement on technical cooperation related to plutonium disposition.

14 US Department of Energy, *Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation*, 2000, <www.nnsa.doe.gov/na-20/docs/2000_Agreement.pdf>. In order to keep the isotopics of weapons-grade plutonium secret, it was agreed that the excess weapons plutonium could be mixed with up to four tons of reactor-grade plutonium, for a total of 38 tons of separated plutonium.

15 Joint US–Russian Working Group on Cost Analysis and Economics in Plutonium Disposition, *Cost Estimates for the Disposition of Weapon-Grade Plutonium Withdrawn from Russia's Nuclear Military Programs*, 2001.

16 Joint US–Russian Working Group on Cost Analysis and Economics in Plutonium Disposition, *Analysis of Russian-Proposed Unified Scenario for Disposition of 34 Metric Tons of Weapon-Grade Plutonium*, 2006.

One reason for the delay is a dispute over the liability of US contractors for any damages due to their contributions to Russia's plutonium disposition programme. This was only resolved in a US–Russian protocol signed on 15 September 2006.[17]

Funding has also been a problem. The newly estimated cost for the Russian disposition program increased from about $1.8 billion in 2000 to $4.1 billion. However, the G-8 Summit Plutonium Disposition Planning Group that was set up to develop an international financing plan to assist the Russian plutonium disposition programme accumulated only $800 million. In 2007, the US government informed Russia that "it does not plan to provide assistance beyond the $400 million already pledged".[18]

Another complication stemmed from the fact that the 2000 US–Russian plutonium disposition agreement called for using most of the excess plutonium as MOX in the VVER-1000 light water reactors. However, the Russian nuclear establishment came to the final conclusion that the use of MOX fuel in light water reactors does not correspond to the long-term Russian strategy for nuclear power development, and therefore financing of plutonium disposition in light water reactors from the state budget is not reasonable.[19] In their view the plutonium should be used in fast neutron reactors, where it could be recycled repeatedly to generate more plutonium without building up troublesome higher actinides.

During subsequent US–Russian consultations it was agreed that for, disposition of its excess plutonium, Russia would use the fast neutron reactors BN-600 and BN-800 (which is currently under construction) instead of the VVER-1000 light water reactors. To reflect new realities both sides have developed a Protocol to the 2000 PMDA agreement that was signed in April of 2010. One year later the modified PMDA agreement was ratified by the Russian Duma and it entered into force in July 2011.

Amended 2000 PDMA Agreement

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

- Each party will dispose of 34 tons of excess plutonium by irradiation of MOX fuel in power reactors. The overall quantity of 34 tons will consist of 25 tons of plutonium in the form of pits and clean metal and of 9 tons of plutonium oxide. For Russia this means plutonium oxide that was produced after 1997.
- Russian plutonium will be disposed of in the fast neutron reactors BN-600 and BN-800. The completion of modifications of the BN-600 is slated for 2013–2014 and the end of construction of the BN-800 for 2012–2013. Disposal of plutonium in the BN-600 reactor is to be conducted without a radial plutonium reproduction zone and the BN-800 reactor will work with a ratio of plutonium reproduction of less than 1.

17 H. Josef Hebert, "US, Russia resolve plutonium dispute", Associated Press, 15 September 2006.

18 Second annual report of the International Panel on Fissile Materials, 2007, p. 38, <www.fissilematerials.org/ipfm/site_down/gfmr07.pdf>.

19 "2000 Plutonium Management and Disposition Agreement", US Department of State, 13 April 2010, <www.state.gov/r/pa/prs/ps/2010/04/140097.htm>.

- Each party will undertake 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 shall start consultations with the IAEA with the view of concluding an agreement on verification measures for the national plutonium disposition programmes.
- The US Government could provide up to $400 million for the activities to be undertaken in the Russian Federation pursuant to this Protocol. This financial assistant might be used 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 programme ($100 million). The implementation of the Russian programme is not dependent on the presence or absence of any additional donor 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 programme.

Disposition is targeted to begin in 2018.

The State of Implementation of the Russian Plutonium Programme

Several sites are involved in the utilization of excess plutonium. The construction of the BN-800 reactor is under way at the Beloyarskaya nuclear power plant (Sverdlovsk region). Its physical startup is planned for September 2013 and its full-scale operation for the first quarter of 2014.[20] The initial fuel load will be hybrid—it will consist of uranium and MOX fuel. A transition to 100% MOX fuel will be completed by 2017, and from the beginning of 2018 the BN-800 will loaded by MOX produced with excess weapons-grade plutonium.

The MOX fuel pellets for the initial load of the BN-800 is being produced at the Production Association Mayak in Ozersk, Chelyabinsk region. The production of fuel assemblies will be done at the Institute of Atomic Reactors at Dimitrovgrad, Uliyanovsk region. The uranium fuel will be produced by MSZ.

The complex for the industrial MOX fuel production for the BN-800 reactor will be located at the MCC.[21] The construction of this complex is already initiated within the framework of the Federal Target Programme, "Nuclear Energy Technologies of the New Generation for the Period 2010–2015 and until 2020". The estimated cost of construction is 7 billion roubles.[22] The capacity of the complex will be 400 pellet MOX fuel assemblies (or 8 tons) per year and, for the production of MOX fuel pellets,14 tons per year. Rosatom plans to put it in operation before commissioning the BN-800 reactor, which is scheduled for 2014.

20 See <www.nuclear.ru/rus/press/nuclearenergy/2124052/>.

21 See <www.nuclear.ru/rus/press/nuclear_cycle/2117460/>.

22 See <www.atomic-energy.ru/news/2011/06/03/22978>.

Establishing Verification Measures

In September 2010, Minister of Foreign Affairs of Russia S. Lavrov and US Secretary of State H. Clinton sent a joint letter to IAEA Secretary-General Y. Amano asking for the Agency's assistance in the development of a legally binding international mechanism controlling the bilateral Agreement on plutonium.

Currently the intensive trilateral dialogue on the development and establishment of the verification measures is ongoing in the IAEA. The team of Russian experts is headed by Vladimir Kuchinov, and the team of the US experts by Michael Guin. Not much is known about this consultation but Russian experts involved in this process do not expect serious difficulties.

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