RERTR 2016 – 37TH INTERNATIONAL MEETING ON
REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS

OCTOBER 23-27, 2016
RADISSON BLU ASTRID HOTEL
ANTWERP, BELGIUM

The Use of Highly-Enriched Uranium as Fuel in Russia

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ABSTRACT

As a large user of highly-enriched uranium (HEU), Russia has a special role in the international HEU minimization effort. In 2016, it operated 59 reactors and research facilities that use HEU—more than half of the world's total—as well as a fleet of 57 nuclear-powered military and civilian ships with 85 reactors. All these applications are estimated to consume about 9 tons of HEU annually, an equivalent of 3.3 tons of 90% enriched HEU. In addition, about 9 tons of unirradiated HEU (6 tons of 90% HEU equivalent) is associated with 38 research facilities in ten organizations throughout Russia. This paper considers the history and current status of HEU use in Russia and outlines strategies for HEU minimization. It shows that the scale of HEU use and the wide range of applications involved present a serious challenge for engaging Russia in the international efforts to reduce the use of HEU.

1. Introduction

Highly-enriched uranium (HEU) presents a unique challenge from the nuclear security point of view. The material is widely used in a range of non-weapon military and civilian applications, such as naval and research reactors or critical research facilities, which makes it vulnerable to diversion or loss. Substantial amounts of HEU are constantly moving through the fuel cycle, creating constant nuclear security risk. Although military uses of HEU carry with them substantial nuclear security risks, civilian research facilities, which may lack sufficient protection, are especially problematic. Understanding of the inherent security risks associated with the continuing use of HEU and of the nuclear proliferation risks associated with these activities helped initiate an international effort, led by the United States and supported by many states, to reduce the use of HEU in civilian applications. Over the past decades, this effort has made significant progress in removing the material from research facilities throughout the world and reducing the number of countries that have access to HEU. Further progress in HEU minimization will critically depend on participation of Russia, which currently operates more

HEU facilities than the rest of the world combined and is committed to continue to use the material in a wide range of applications.

2. The use of HEU in Russia

Russia has never declared the size of its HEU stock or disclosed detailed information about the facilities that use the material. Independent estimates suggest that it has about 680 tons of HEU, although this number is characterized by a very large uncertainty of about 120 tons. About 160 tons of HEU is probably in assembled nuclear weapons, active as well as reserve and awaiting dismantlement. An equivalent of about 25 tons of 90% HEU is believed to be in use in the naval fuel cycle, primarily in cores of operational naval reactors. Most of the remaining 500 tons of HEU appears to be in the custody of Rosatom and may be stored in bulk form or in weapon components.

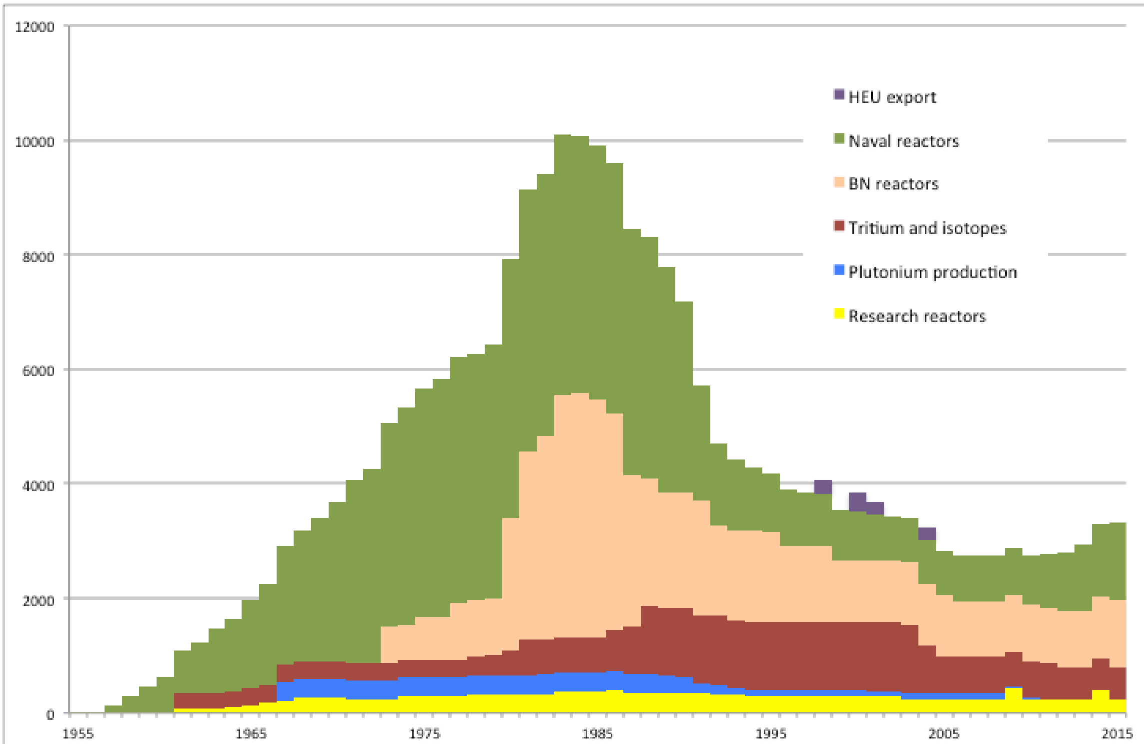

Figure 1. Estimated consumption of HEU as fuel in the Soviet Union and Russia, kg of 90% HEU equivalent.

As of May 2016, Russia operated 59 facilities that use HEU. This number includes research reactors, critical assemblies, isotope production and power reactors, as well as naval prototypes. This is more than a half of the 116 HEU such facilities that were operational globally.[1] In addition, Russia has a fleet of 57 nuclear-powered ships with 85 nuclear reactors that use HEU fuel (49 submarines, 2 surface military ships, and 6 icebreakers with 72, 4, and 9 reactors respectively). Although Russia's nuclear complex has significantly reduced its consumption of HEU in the last two decades, it still requires a large amount of highly-enriched uranium to operate.

As of 2016, Russia is estimated to use an equivalent of about 3.3 tons of 90% HEU annually.

Most of this material is used in fuel of naval reactors, which are believed to use HEU with enrichments ranging from 21% to 90%. These reactors consume about 1.6 tons of 90% HEU equivalent in 5 tons of HEU of various degrees of enrichment each year. Submarine reactors consume about 4.6 tons of HEU of various enrichments, which is equivalent to 1.4 tons of 90% HEU. Civilian ships require about 0.38 tons of HEU (0.23 tons 90% HEU) annually. The second largest HEU consumer is fuel for breeder reactors. The material used in these reactors has relatively low enrichment – 17% LEU and 21% and 26% HEU, but the amount of enriched uranium is rather large. The BN-600 reactor will require about 3.7 tons of HEU annually, which corresponds to about 1 ton of 90% HEU equivalent. The BN-800 reactor uses HEU in its initial core, but it is expected to switch to plutonium fuel.

Tritium production reactors account for significant HEU demand as well. Russia operates two 1000 MWt reactors that were built for tritium production—Ruslan and LF-2/Lyudmila, which have been converted to produce mostly civilian industrial isotopes. As of 2016, with one of the two reactors, Ruslan, shut down for modernization, tritium and other industrial isotopes production requires about 0.5 tons of 90% HEU. Starting in 2017, when the second reactor is expected to return to service, the total consumption will increase to 1.1 tons of 90% HEU (increasing the total annual HEU demand to about 3.9 tons of 90% HEU). Russian research reactors are estimated to consume about 0.23 tons of 90% HEU annually. Russia also used HEU fuel elements in its plutonium production reactors, but this use was discontinued when the last such reactor was shut down in 2010. Figure 1 shows evolution of HEU consumption in the Soviet Union and Russia.

In addition to the new material that is required to manufacture new fuel, there are significant amounts of HEU associated with various research facilities, such as pulsed reactors or critical assemblies. It is estimated that as of 2016, about 9 tons of HEU (6 tons of 90% HEU equivalent) was associated with 38 research facilities in ten organizations throughout Russia.

3. Progress in HEU minimization

It should be noted that Russia has made substantial progress in reducing the number of its research facilities that use HEU and actively participated in the effort to convert Soviet-origin reactors abroad. As can be seen from Figure 2, in 1990 Russia had about 100 HEU facilities on its territory (this excludes other Soviet republics). By 2016 this number was reduced to 59, mostly by shutting down and decommissioning old reactors and research facilities. There was only one case of reactor conversion – Argus, operated by the Kurchatov Institute, was converted to LEU in 2014.

The conversion of Argus was a result of a joint U.S.-Russian program that was launched in 2010. The program included conversion feasibility studies for six Russian reactors and some joint work on development and testing of LEU fuels. The six reactors included in the program were IR-8, OR, and Argus in the Kurchatov Institute, IRT at the Moscow Engineering Physics Institute, IRT-T at the Tomsk Polytechnic Institute, and MIR.M1 at the Research Institute of Atomic Reactors, NIIAR, in Dimitrovgrad. The studies confirmed the feasibility of conversion, but the practical work on conversion was limited to Argus. Moreover, in December 2014 Russia indicated that it will not continue the conversion program and in October 2016 formally suspended all cooperation with the United States in this area.[3]

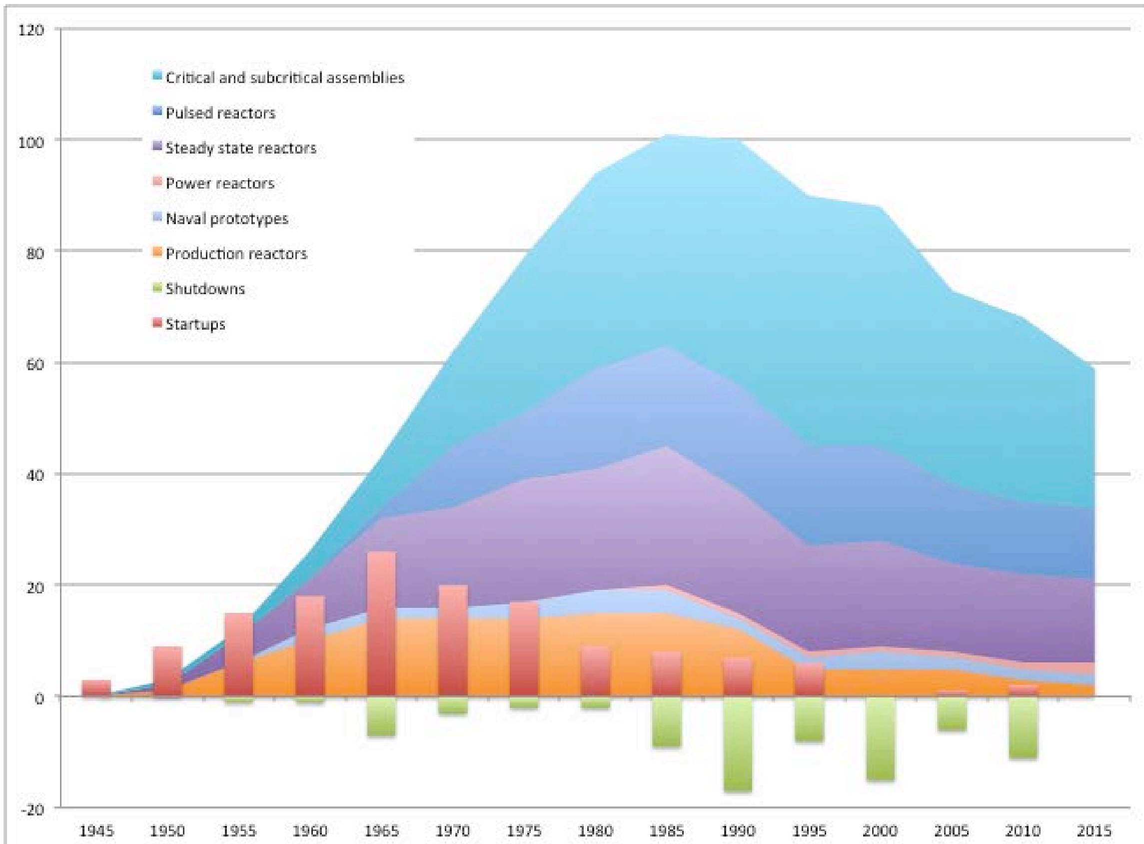

Figure 2. The number of Russia's HEU reactors and critical facilities that use HEU as fuel.

Even though Russia has pulled out of the joint U.S.-Russian reactor conversion effort, it may continue to reduce the number of HEU facilities. Some of this work is done within the framework of the Federal Targeted Program on Nuclear and Radiation Safety. Economic factors would probably play a crucial role. For example, of the two IRT-type reactors that were included in the U.S.-Russian feasibility studies, IRT-MEPhI and IRT-T, the first one is likely to be converted while the second will continue to use HEU fuel until at least 2035. The difference is that the IRT-T reactor in Tomsk provides its operator with significant revenue. One can expect that conversion would be easier where fuel development and certification work has already been done elsewhere. For example, the VVR-Ts reactor at the Obninsk branch of the Karpov Scientific Research Institute of Physical Chemistry could probably use the LEU fuel developed for the VVR-K reactor in Kazakhstan.

In most cases, however, operators may not have strong interest in reactor conversion. There are only a few instances where conversion can completely eliminate HEU from the site. The IRT-MEPhI and IRT-T reactors are among those, as are VVR-Ts and the IVV-2M reactor at the Institute of Reactor Materials. The only other site that can be targeted for a complete cleanout is the Scientific Research Institute for Instruments (NIIP) in Lytkarino. The institute operates the BARS-4 pulsed reactor and is upgrading the IRV-M2 steady-state reactor. It is possible that, with the right incentives and sufficient funding, NIIP can forego the IRV-M2 upgrade and decommission the BARS-4 facility. In sum, it is possible that even in the absence of U.S.-

Russian cooperation, Russia will make steps toward minimizing the use of HEU.

Creating a clear international norm of avoiding the use of HEU would be extremely helpful in maintaining pressure on Russia to reduce its HEU use. This norm, however, may take some time to establish. The current international HEU minimization effort, largely managed by the U.S. M^3 program (formerly GTRI), is in practice limited to civilian research reactors. It explicitly excludes important applications, such as naval reactors or reactors that are used in military programs. But even within its scope, the M^3/GTRI program has not yet produced an international consensus on the need to completely eliminate HEU from civilian research. The United States and Europe are likely to continue to use HEU in at least a few civilian research reactors for decades to come. This leaves Russia in a position to argue that its policy toward civilian uses of HEU is in line with the generally accepted practice, even if the number of HEU reactors it operates is considerably larger than in any other country. Moreover, Russia has taken advantage of the inconsistent HEU minimization policy in Europe and positioned itself as an alternative supplier of HEU. For example, in 2015 Russia supplied HEU metal for fuel of the German FRM-II reactor.[4] A clear policy on high-performance research reactors may help better define priorities of the minimization effort and encourage earlier shutdown of non-essential facilities.

4. Conclusion

In summary Russia has made significant progress in reducing its use of HEU, closing down HEU-using research facilities, and helping to remove the material from third countries. Further progress in this area will critically depend on whether the minimization effort will address the entire range of applications that use HEU, civilian as well as military – from breeder reactors to tritium production. This would require a development of a coordinated comprehensive approach to global HEU minimization that would be supported by the Russian nuclear community as well as Russian political leadership.

5. Acknowledgments

This paper presents summary of results of the project “The use of HEU in Russia” that was carried out by the International Panel on Fissile Materials at the Program on Science and Global Security, Princeton University. The project was funded by the MacArthur Foundation.

6. References

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