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From HEU Minimization to HEU Elimination: The Case of Research and Test Reactors

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ABSTRACT

This paper reports from the second international symposium on HEU minimization that was held in Vienna in February 2012 co-hosted by the Governments of Austria and Norway and the Nuclear Threat Initiative, with particular emphasis on the elimination of exotic facilities. The main recommendation from this event was to shift the focus of international dialogue from minimization to the elimination of civilian uses of HEU. Careful considerations was made at the symposium to review the number and type of the more than one hundred facilities world-wide still operating using HEU. Conversion of many of these facilities to LEU should be feasible, given political and economic support, but there are also many facilities for which there is no clear path towards HEU elimination. This is particularly the case among specialized pulsed reactors and critical assemblies, which have not traditionally been part of the GTRI/RERTR conversion program. Discussions about the elimination of HEU from civilian applications must consequently include further deliberations about the future and justification of these facilities.

1. Introduction

From January 23 to 25 2012 the Governments of Austria and Norway and the Nuclear Threat Initiative co-hosted the 2nd International Symposium on HEU Minimization in cooperation with the IAEA. The Symposium took place in Vienna, and gathered 114 participants with both technical and policy backgrounds from different countries and organizations. The Symposium built on the results from the first symposium on HEU minimization held in Oslo in 2006 and reviewed the progress made and the remaining challenges and possible new measures to address them. The output from the symposium was a summary document outlining several recommendations, which was submitted as a working paper to the NPT PrepCom in 2012[1]. One of the key recommendations was to shift the international dialogue from HEU minimization to the elimination of civilian uses of HEU. Several other recommendations were also made. Some which support the work towards elimination of HEU from civilian uses will be detailed through this paper, but in addition to these more area specific recommendations there were also some broader issues raised. Perhaps the most prominent of those were the call made for increased transparency in HEU use and stockpiling around the world through such measures as developing international standards or guidelines for public declarations of HEU inventories on a regular basis with consistent form and content. Member states of the IAEA were also encouraged to recognize and support the expertise and capacity of the Agency to further assist international HEU minimization endeavors.

2. The current scope of HEU minimization activities

Over the 34 years since its inception, the RERTR program has proved very successful in converting HEU fuelled reactors, especially so after the formation of the GTRI program in 2004. It should be noted, however, that a large portion of the reductions in global HEU consumption from civilian research and test reactors have also come from shut-downs of facilities [3]. While the world's largest consumers of HEU are the propulsion reactors in the nuclear navies, the military sphere also contains a number of facilities that could be described as research and test reactors related to propulsion reactor development, nuclear weapon development and nuclear weapon effects studies. In many cases these reactors will pose similar non-proliferation and security challenges as civilian HEU fuelled facilities, and should thus not necessarily be summarily excluded from HEU minimization efforts.

3. Current status of HEU fuelled research and test reactors worldwide

The current operational research and test reactors worldwide, both civilian and military, are given in Table 1. The table includes research and test reactors divided into the categories steady state, pulsed, and critical and sub-critical assemblies. The table also includes other reactors utilizing HEU either as targets in medical isotope production or as fuel in breeder and isotope production reactors and naval reactor prototypes.

	Steady state reactors	Pulsed reactors	Critical and subcritical assemblies	LEU reactors w/HEU targets	Other facilities	*Total*
Belarus			1			1
Belgium	1					1
Canada	2			1		3
China	2		1		1	4
Czech Republic				1		1
France	3	2	2	1		8
Germany	1					1
Ghana	1					1
India					1	1
Iran	1					1
Israel	1					1
Italy	1					1
Jamaica	1					1
Japan	2		3			5
Kazakhstan	2	1	1			4
The Netherlands	1					1
Nigeria	1					1
North Korea	1					1
Pakistan	1					1
Russia	15	15	26		7	63
Switzerland	1					1
Syria	1					1
United Kingdom	1	1	1		1	4
United States	7	2	6		4	19
Uzbekistan		1				1
Total	47	22	41	3	14	127

Table 1 Operational HEU fuelled reactors worldwide [2], based on updated information from [3]

There are 41 critical assemblies listed in table 1, this category can be further broken down into:

Mock-up of HEU fuelled reactors (7):

WWR-K CA (WWR-K) in Kazakhstan

CA MIR.M1 (MIR.M1), CA-SM (SM-3), PIK FM (PIK) in Russia

ATRC (ATR) in USA

In addition to these mock-ups of research reactors, Russia also operates the Emphir-2M / EFIR-2M and MAKET assemblies, used in the development of the military isotope production reactors Ruslan and Lyudmila respectively [13]. WWR-K CA in Kazakhstan is probably already converted as a part of the ongoing conversion process of the WWR-K.

Fast reactor development (6)

Zero Power Fast Reactor in China, MASURCA and MINERVE in France, FCA Tokai in Japan,

BFS-1 and BFS-2 in Russia.

Weapons related (7)

COMET, FLATTOP, GODIVA, PLANET and TACS in USA

FKBN-2 and FRBN-2M in Russia

Naval Propulsion (7)

Delta, Kvant, SF-1, SF-7, ST-1125, ST-659 in Russia

NEPTUNE in the United Kingdom

Space Reactors (4)

AKSAMIT / RP-50, ISKRA, FS-1M, Nartsiss-M2 in Russia

Other (10)

YALINA-Booster in Belarus, KUCA, MITI Standard Pile in Japan

Astra, OKUYAN, FS-2, SO-2M SubCA, STEND-4, STEND-5, UKS-1M in Russia

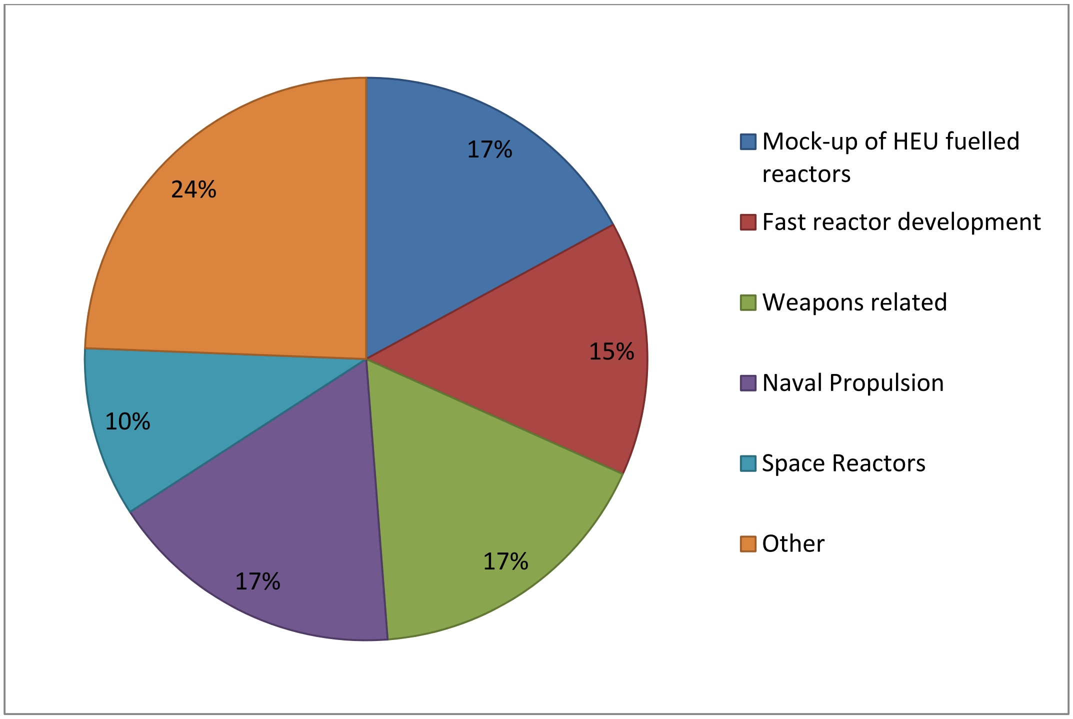

Figure 1 - Break-down of HEU fuelled Critical Assemblies

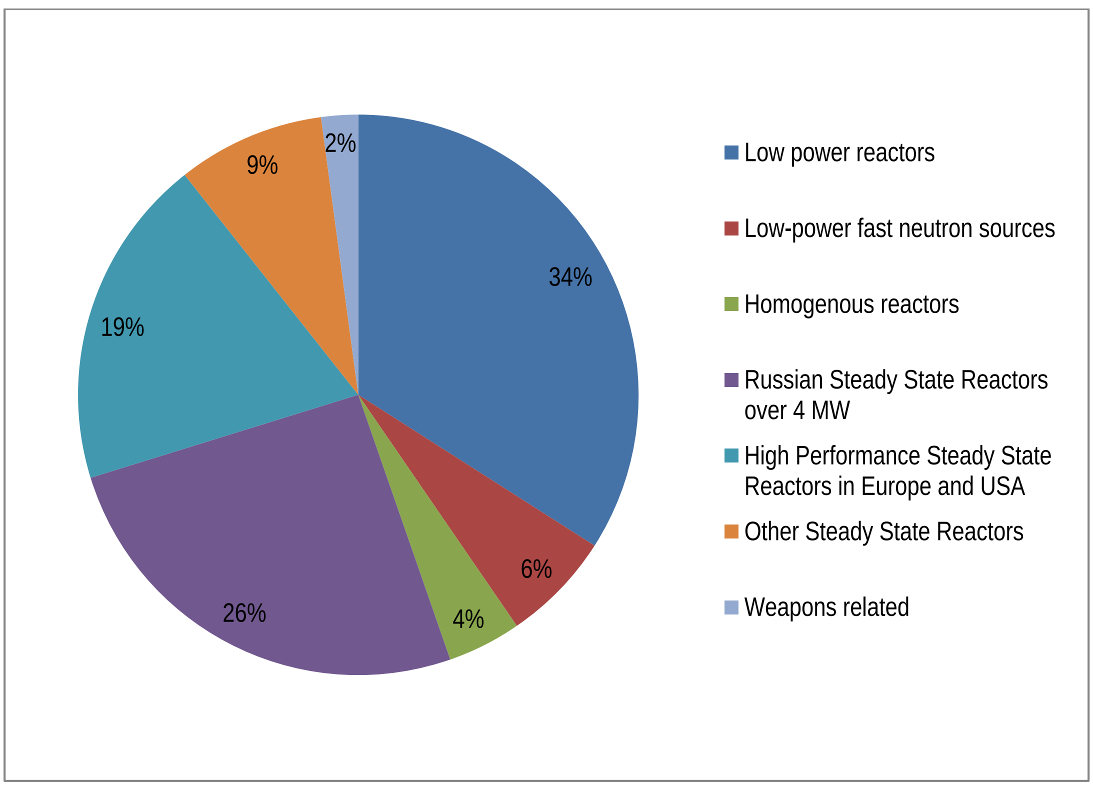

Figure 2- Break-down of HEU fuelled Steady State Reactors

There are 22 Pulsed Reactors:

Weapons related (14)

CALIBAN and SILENE in France

BARS-5, BIGR, BIR-2M, BR-1, BR-K1, FBR_L, GIR 2, Igrik, VIR-2M, Yaguar (NHUAR) in Russia

VIPER in the UK

Fast Burst (FBR) in USA

SILENE Facility is planned to be dismantled in 2012 [5]

Fuel Transient Testing (2)

IGR in Kazakhstan

TREAT in USA

TREAT is mothballed, and has not been in operation since 1994, but the option of restarting it at some point is kept open, which is probably also why the GTRI keeps this reactor on their list of candidates for conversion.

Other (6)

BARS-1, BARS-4, BARS-6, Hydra, Priz in Russia

Photon in Uzbekistan

Photon is planned to be decommissioned [6].

The following 47 Steady State reactors are given in Table 1:

Low power reactors MNSR/Slowpoke/Argonaut (16)

IAE and SZ in China (MNSR), GHARR-1 in Ghana (MNSR), ENTC MNSR in Iran (MNSR), NIRR-0001 in Nigeria (MNSR), PARR-2 in Pakistan (MNSR), SRR-1 in Syria (MNSR)

Slowpoke Alberta and Slowpoke Saskatchewan in Canada, UWI CNS SLOWPOKE in Jamaica

UTR KINKI in Japan (Argonaut), LFR in the Netherlands (Argonaut)

CONSORT in the UK, NTR General Electric in USA, GAMMA and OR in Russia

CONSORT and LFR are awaiting decommissioning, CONSORT will be shut down this year [7]. LFR should also be shut-down by now [8].

Low-power fast neutron sources (3)

PROSPERO in France, RSV TAPIRO in Italy and YAYOI in Japan

Homogenous reactors (2)

AGN 211 P in Switzerland and ARGUS in Russia

ARGUS has completed feasibility study for conversion to LEU [10]

Russian Steady State Reactors over 4 MW (12)

IR-8, IRT-T (Tomsk), IRV-M2, IVV-2M, MIR.M1, BOR-60, VVR-Ts, VVR-M, IRT-2500 (MEPhI), RBT-10/2, RBT-6 and SM-3

In addition it is expected that the 100MW PIK reactor in St. Petersburg will soon be started up. IR-8, IRT-T and IRT-2500 have completed feasibility studies [10], and recent announcements from Russia means that these will probably be converted. [11] It is presently not clear exactly what the scope of the newly announced Russian conversion effort is, and what it means for conversion of other reactors where feasibility studies have not yet been performed.

The announcement also covers conversion from HEU to LEU targets in medical isotope production, but only the domestic production at the VVR-Ts reactor located at Obninsk Branch of Karpov Institute is mentioned, making it still unclear what, if any, plans there are for conversion of the HEU based medical isotope production in the SM-3, RBT-6 and RBT-10 reactors at NIIAR in Dmitrovgrad which is the production that is exported internationally through MDS Nordion [12].

High Performance Steady State Reactors in Europe and USA (9)

ATR, HFIR, MITR-II, MURR UNI., NBSR in USA

BR-2 in Belgium

ORPHEE and RHF in France

FRM-II in Germany

In addition the Jules Horowitz Reactor in France is scheduled for start-up in 2014 using 27% enriched fuel [14].

Other Steady State Reactors (4)

IRT-DPRK in North Korea

IRR-1 in Israel

EWG1 and WWR-K Alatau in Kazakhstan

Weapons related(1)

ACRR USA

4. HEU Elimination for Research and Test Reactors

What can be seen from the above categorizations of the 110 HEU fuelled research and test reactors are that there is a broad spread over different categories of facilities. It is worth noting that less than half of the identified reactors are of the steady state type, and that the majority are actually represented by the pulsed and critical facilities. This is the reason that one of the recommendations coming out of the Second International Symposium on HEU Minimization was that the scope of conversion efforts should be expanded to include critical assemblies and pulsed reactors. Many of the pulsed and critical facilities are located at defense sites and serve to support weapons programs as their main mission, but these defense related facilities also perform some functions relevant for civilian purposes such as e.g. code validation, dosimetry and radiation effects on space components. When it comes to discussing the elimination of HEU from the civilian sector the services these defense installations provide the civilian sector with should be taken into account.

Critical assemblies

Among the civilian critical assemblies, there are several that has as their purpose to mock-up existing or develop new HEU fuelled reactors. Their existences are thus closely related to the continued, or future, existence of the related steady state reactors. What seems clear is that if all steady state test and research reactors can be fuelled by LEU in the future, the same should apply to critical assemblies made for investigating core parameters for such reactors.

Russia has recently announced that it will use LEU for its new class of civilian nuclear powered ice breakers. This must be seen as a hopeful sign that civilian nuclear propulsion reactors can be fuelled by LEU in the future, also making redundant on-shore HEU facilities related to design and testing of such reactors. This also relates to a recommendation from the Symposium that civilian HEU fuelled civilian vessels should be phased out or converted, and that a global norm should be established that LEU will be used in place of HEU in any new nuclear-powered civilian vessels.

From the above mentioned facilities it stands out that Russia, as the only country, has several facilities dedicated to space propulsion research. The justification for these facilities should of course be closely related to how justified, and how practical, it would be to deploy actual HEU fuelled space propulsion reactors.

Perhaps most challenging in the context of the listed critical assemblies is the issue of research and development of fast breeder reactors. While the fast reactors themselves does not require HEU, there is foreseen a role for HEU in the testing and demonstration phase [9].

Pulsed reactors

Most of the pulsed reactors are part of weapons programs. The only operational civilian pulsed reactor outside Russia, the Photon in Uzbekistan, is scheduled for decommissioning. The TREAT reactor in USA has been shut-down for almost 20 years. All in all there does not seem to be much need for HEU fuelled pulsed reactors for civilian purposes. When it comes to military applications, the US recently made a solicitation through the Small Business Innovation Research (SBIR) program for alternative technologies not relying on HEU for a potential replacement for the FBR reactor [15].

Steady State Research and Test Reactors

The largest group of HEU fuelled Steady State research and test reactors is actually the one that in theory should be easiest to deal with. The main types of reactor designs here Slowpoke, MNSR and Argonaut can all operate on LEU fuel. Many of these will probably be shut-down rather than converted, and especially with the MNSR there are difficult political contexts related to several of the reactors making conversions difficult at the present time.

Perhaps the most significant recent development when it comes to HEU minimization for research and test reactors are the Russian statements that domestic reactors will begin converting to LEU. Given that suitable high-density fuel can be developed for the remaining HEU fuelled high performance reactors, the prospects for eventually eliminating HEU from civilian steady state research and test reactors should be good.

5. Conclusions

The summary of the Second International Symposium on HEU Minimization recommends that an internationally agreed norm should be developed that LEU will be used in place of HEU in any new facility or process under development, design or construction. (including in possible new applications such as space reactors). If such a norm could be agreed upon, a lot of the existing HEU fuelled research and test reactors would also lose their mission and as such would no longer be needed, such as space and naval propulsion critical assemblies. There are several of the facilities described above that could be called unique, but it is unclear in some cases whether the functions they perform really need HEU or if it is only a fact of already having a difficult to convert reactor with HEU already in place. For the HEU fuelled facilities not currently part of existing conversion efforts, justifications for their continued reliance on HEU should be made. At least for civilian purposes, it does seem that there from a technological point of view would be very few, if any, applications that require HEU and as fewer and fewer facilities remain there will be increased pressure on the remaining to justify their existence as they remain in the way for the elimination of HEU as a material for peaceful uses.

6. References

[1] "Implementing the action plan of the 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, in particular action 61: second International Symposium on the Minimization of Highly Enriched Uranium", NPT/CONF.2015/PC.1/WP.1, March 15, 2012

[2] "Facilities: Research and isotope production reactors", http://www.fissilematerials.org/, August 17, 2012

[3] O. Reistad and S. Hustveit, "HEU Fuel Cycle Inventories and Progress on Global Minimization", The Nonproliferation Review, Volume 15, Issue 2, 2008

[5] H. Glandais, "VALDUC Laboratory Criticality Experiment Facilities", Workshop on Future Criticality Safety Research Needs, Pocatello, Idaho, USA, September 21-22, 2009

[6] U. Salikhbaev, "HEU Minimization at Institute of Nuclear Physics, Uzbekistan", International Symposium on Highly Enriched Uranium Minimization Vienna, January 23-25, 2012.

[7] "Final Responses to the EU 'Stress Tests' for Nuclear Reactors for the CONSORT II Research Reactor", Imperial College London, October 8, 2012

[8] K. Bakker, K. de Groot, R. Kuperus, "Transfer of the Low Flux Reactor (LFR)", Technical Meeting on Low-Power Critical Facilities and Small Reactors, Ottawa, Ontario, Canada, November 1-2, 2010

[9] M. Salvatores, H. Khalil, G. Bignan, R. Hill, R. Jacqmin, J. Tomasi, "Advanced fast reactor development requirements: Is there any need for HEU?" Nuclear Engineering and Design 237 (2997) 814-822

[10] "US, Russian Federation Sign Joint Statement on Reactor Conversion" NNSA Press Release, June 26, 2012

[11] P. Podvig "Russia to begin conversion of its research reactors to LEU in 2013", International Panel on Fissile Materials Blog, http://www.fissilematerials.org/blog/, October 4, 2012

[12] K. Vessels, "HEU For Isotope Production in Canada and Russia: Expansion or Phaseout?", Global HEU Phaseout NPPP Policy Research Project, http://www.heuphaseout.org/, April 20, 2011

[13] P. Podvig and S. S. Voss, "Use of highly-enriched uranium in Russian reactors", INMM 50th Annual Meeting, July 12-16, 2009

[14] "Construction starts on Jules Horowitz", World Nuclear News, March 21, 2007

[15] "Alternative Source for Neutron Generation", SBIR Topic Number A12-088, May 24, 2012