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Heavy Water Nuclear Power Reactors:
A Source of Tritium for Potential South Korean Boosted Fission Weapons

North Korea's nuclear test of January 6, 2016 raised speculation that it had tested a boosted fission weapon. Though many experts believe that the purpose of boosted fission weapons is to produce higher yields, the real purpose is generally to produce smaller lighter weapons using reduced amounts of nuclear material while still producing yields similar to that of unboosted fission weapons.

Boosted fission weapons use hollow cores of nuclear material (plutonium and/or highly enriched uranium). Just before detonation a tritium/deuterium gas mixture is inserted into this hollow space. The detonation of the weapon causes a fusion reaction. The energy output from this fusion reaction is small but this reaction significantly increases the efficiency of the fission reactions in the weapon. Boosted weapons can use reactor-grade plutonium without any concern for predetonation.

The deuterium for such weapons can be extracted from ordinary water but the radioactive tritium only exists in trace amounts in nature.[2] In the past tritium has been produced mainly by irradiating lithium in plutonium production reactors. Each boosted weapon likely uses on average between 3 and 4 grams of tritium per weapon. North Korea could be producing 17 grams or more of tritium per year at its plutonium production reactor at Yongbyon.[3]

North Korea's nuclear test has increased calls in South Korea for it to acquire its own nuclear weapons. Won Yoo-chul, the ruling Saenuri Party's floor leader said in a speech to the National Assembly, "We cannot borrow an umbrella from a neighbor every time it rains. We need to have a raincoat and wear it ourselves."[4]

South Korea has large stocks of plutonium produced by its nuclear power reactors. The U.S. has thus far prohibited South Korea from reprocessing the spent fuel from these reactors to extract the plutonium. However, South Korea has been pushing for this to change especially since the recent nuclear agreement with Iran grants Iran the long-term right to reprocessing.

South Korea does not have any plutonium production reactors in which to irradiate lithium to produce tritium but it does not need to. Of South Korea's 24 operating nuclear power reactors,

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[1] This paper is the product of the author's personal research and the analysis and views contained in it are solely his responsibility. Though the author is also a part-time adjunct staff member at the RAND Corporation, this paper is not related to any RAND project and therefore RAND should not be mentioned in relation to this paper. I can be reached at GregJones@proliferationmatters.com

[2] Tritium has a half-life of 12.33 years, which means that each year 5.5% of it decays away.

[3] Gregory S. Jones, "The Implications of North Korea Testing a Boosted Nuclear Weapon," January 11, 2016, http://nebula.wsimg.com/4da1b6db2152b55efe7334a70fe78781?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1

[4] "Top South Korean lawmaker calls for nuclear arms," *The Japan Times*, February 15, 2016.

four use heavy water as the moderator. South Korea has already accumulated a large stockpile of tritium extracted from the heavy water moderator of these four reactors.

Tritium is produced as an incidental by-product of the operation of heavy water moderated nuclear power reactors. Even though the thermal neutron capture cross section of the deuterium in heavy water is only 0.0005 barns, heavy water power reactors contain hundreds of metric tons of heavy water as the moderator and the production of tritium by neutron capture in deuterium is significant. From the buildup of tritium in the moderator I have calculated that a CANDU 6 heavy water power reactor (Canada's standard export model, 600 to 655 MW electrical output, 2,100 to 2180 MW thermal output) operated at an 84% capacity factor produces about 140 grams of tritium per year.[5] South Korea operates four CANDU 6 type nuclear power reactors.

The buildup of tritium in the moderator causes safety concerns due to both worker exposure and environmental releases. Processes exist to remove the tritium from the heavy water moderator using isotope separation. Typically these processes use hydrogen-water chemical exchange in the first stage, supplemented by hydrogen distillation in the later stages.

South Korea is only one of two countries known to have built commercial facilities to extract tritium from the heavy water moderator of its nuclear power plants.[6] South Korea's tritium extraction facility can remove 97% of the tritium from the heavy water and produces a tritium product that is over 99% pure.[7] The facility has operated since 2007 and South Korea has already accumulated a stockpile of over four kilograms of tritium.[8] This amount would be enough to boost over 1,000 nuclear weapons.

The tritium is being stored as titanium hydride. At room temperature the tritium is safely immobilized but the tritium can easily be recovered by heating the hydride. Tritium is not subject to any International Atomic Energy Agency (IAEA) safeguards and indeed tritium is not even mentioned in the IAEA Safeguards Glossary.[9]

Thus far the South Korean government has resisted suggestions that it to develop its own nuclear weapons, though North Korea's nuclear and ballistic missile tests are increasing the pressure for such action. If South Korea were to decide to develop nuclear weapons, it would need to take several difficult steps. These would include withdrawing from the NPT and obtaining the nuclear material for weapons presumably by reprocessing the fuel from its power reactors to obtain plutonium. In contrast South Korea already has unrestricted access to at least four kilograms of tritium. This tritium could be used to boost any nuclear weapon that South Korea might produce.

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[5] Tai-Keun Park and Seon-Ki Kim, "Tritium: its generation and pathways to the environment at CANDU 6 generating stations," *Nuclear Engineering and Design*, Vol. 163, 1996.

[6] The other country is Canada. India is known to have developed pilot-plant scale facilities to extract tritium from its seventeen operating heavy water moderated nuclear power reactors. India has not revealed whether it has developed full-scale tritium extract plants as well.

[7] K.M. Song et. al., "Introduction to Wolsong Tritium Removal Facility," *Transactions of the Korean Nuclear Society Autumn Meeting*, Pusan Korea, October 27-28, 2005.

[8] Yeon Duck Han, "Operating Experience and Effect of Wolsong Tritium Removal Facility," Presentation to IAEA Workshop in Buenos Aires, Argentina, November 7, 2013.

[9] "IAEA Safeguards Glossary, 2001 Edition," IAEA, Vienna, 2002, pp.29-30.