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# The U.S. Program to Produce Tritium Using Commercial Light Water Power Reactors: An Update

## Status as of May 2016

Tritium is a vital component of every U.S. nuclear weapon. Tritium only exists in trace amounts in nature and the U.S. has had to create its entire tritium stockpile by exposing lithium to neutrons in nuclear reactors. Due to its radioactivity, 5.5% of tritium decays away every year. Therefore maintaining a tritium stockpile requires continuing production.

Between 1948 and 1988 the U.S. produced tritium in plutonium production reactors at Hanford and Savannah River by irradiating a lithium aluminum alloy.[2] U.S. tritium production ended in 1988 when the K reactor at Savannah River was shut down for safety reasons. Due to the decline of the U.S. nuclear stockpile with the end of the Cold War, which significantly reduced tritium requirements, tritium was not produced during the 1990s.

As its tritium stockpile continued to decay away, the U.S. restarted production in 2003 using the commercial power reactor Watts Bar 1 located in Tennessee. I have previously written about the tritium production program at this reactor.[3] Watts Bar 1 is operated by the Tennessee Valley Authority (TVA). To allow higher fuel enrichments and thereby longer fuel cycles, Watts Bar 1 (like most light water power reactors), uses boron containing burnable absorber rods to suppress excess reactivity at the start of a fuel cycle. To produce tritium the boron is replaced by lithium (in the form of lithium aluminate) to create tritium-producing burnable absorber rods (TPBARs). The TPBARs are irradiated for one fuel cycle (18 months). They are then removed and are sent to Savannah River where the tritium is extracted.

The tritium production at Watts Bar 1 has been less than expected. Production was hampered by higher than expected tritium leakage from the TPBARs. The radiation exposure to plant workers and the public resulting from these enhanced tritium releases was not very large but the releases exceeded the amount that was used to approve the environmental impact statement (EIS) submitted to approve tritium production at Watts Bar 1. Though the initial plan called for Watts Bar 1 to irradiate up to 2,304 TPBARs per 18 month fuel cycle, Watts Bar 1's operating license was limited to just 204 TPBARs per fuel cycle. To slow the rate of decline of the tritium stockpile, in May 2009 the operating license was amended to allow the irradiation of 704 TPBARs per fuel cycle.

[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 and a faculty member of the Pardee RAND Graduate School, this paper is not related to any RAND project or the Pardee RAND Graduate School and therefore these organizations should not be mentioned in relation to this paper. I can be reached at GregJones@proliferationmatters.com

[2] Gregory S. Jones, "History of U.S. Tritium Production 1948-1988," June 12, 2017. Link

[3] Gregory S. Jones, "U.S. Increased Tritium Production Driven by Plan to Increase The Quantity of Tritium per Nuclear Weapon," June 2, 2016. Link

Efforts to redesign the TPBARs to reduce the tritium leakage failed. Instead a supplemental EIS was issued in February 2016 which took into account the increased tritium leakage from the TPBARs.[4] A request was then submitted to change the license of Watts Bar 1 to allow the irradiation of up to 1,792 TPBARs per fuel cycle.

Until 2014 the National Nuclear Security Administration (NNSA) expected that tritium production at Watts Bar 1 alone would be sufficient to supply U.S. nuclear weapons. However, plans to significantly increase the amount of tritium contained per weapon increased tritium requirements and necessitate the production of tritium in a second reactor. The supplemental EIS allows for this second reactor to be either Watts Bar 2 or one of the two reactors that the TVA operates at its Sequoyah site. It was generally expected that the second reactor would be at the Sequoyah site. The NNSA planned that by the mid-2020s, each reactor would be irradiating 1,504 TPBARs per 18 month fuel cycle which would produce 1,400 grams of tritium. The total for the two reactors would be 2,800 grams of tritium per 18 month fuel cycle or 1,870 grams per year.

**Developments since May 2016**

This was the state of U.S. tritium production at the end of May 2016. Since that time, there have been a number of developments. In June 2016 the NNSA issued a record of decision (ROD) on the supplemental EIS selecting the Preferred Alternative, Alternative 6.[5] This alternative allows for the irradiation of up to 2,500 TPBARs per fuel cycle in two reactors, either one of which could be located at the Watts Bar or Sequoyah sites. Note that the actual plans still call for the irradiation of 1,504 TPBARs per fuel cycle in each reactor, producing a total of 2,800 grams of tritium per 18 month period. In April 2017 the TVA issued a ROD stating that it intended to implement Alternative 6 of the supplemental EIS.[6]

In August 2016 the operating license of Watts Bar 1 was amended to permit the irradiation of 1,792 TPBARs per fuel cycle.[7] In spring of 2017 Watts Bar 1 was refueled which ended fuel cycle 14 and started cycle 15. The NNSA planned to increase the number of TPBARs irradiated in cycle 15 to 1,104 as part of the ramp up to 1,504 (see Table 1). This appears to have taken place though I have not found positive confirmation of this fact.

In June 2016, the NNSA asked the TVA to consider Watts Bar 2 to be the second tritium producing reactor instead of one of the reactors at the Sequoyah site. This is somewhat surprising for several reasons. First, at the time Watts Bar 2 had not yet started commercial

[4] "Final Supplemental Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor," U.S. Department of Energy and National Nuclear Security Administration, DOE/EIS-0288-S1, February 2016.

[5] Department of Energy, Production of Tritium in Commercial Light Water Reactors, Record of Decision, *Federal Register*, Vol. 81, No. 120, June 22, 2016, pp. 40685-40689.

[6] Tennessee Valley Authority, Production of Tritium in Commercial Light Water Reactors, Record of Decision, *Federal Register*, Vol. 82, No. 64, April 5, 2017, pp. 16653-16655.

[7] Nuclear Regulatory Commission, Tennessee Valley Authority; Watts Bar Nuclear Plant, Unit 1; Maximum Number of Tritium Producing Burnable Absorber Rods, License amendment; issuance, *Federal Register*, Vol. 81, No. 153, August 9, 2016, pp. 52716-52717.

operation.[8] Second, unlike the two Sequoyah reactors, Watts Bar 2 is not licensed to produce tritium. Finally, it had been considered advantageous to diversify the location of tritium production to help improve security of supply.

There are advantages to choosing the Watts Bar 2 reactor. It is licensed to operate longer than the Sequoyah reactors[9] and there is already a large water storage tank at the Watts Bar site to help manage tritium discharges, whereas one would need to be constructed at the Sequoyah site.

On the other hand the Watts Bar 2 reactor has just started operation and does not have a track record of consistent operation. Further, it was 80% completed in the 1980s, when construction was stopped. Construction resumed in 2007 and the reactor was not completed until 2015. It is not clear what effect this long delay might have on the reactor's reliability. Already a design flaw knocked the reactor off-line for four months in 2017.

Never-the-less plans are moving ahead to start tritium production at Watts Bar 2, starting with its fuel cycle 4 in the fall of 2020. A request for a license amendment was supposed to have been submitted by the TVA near the end of 2017 to allow tritium production at Watts Bar 2, though it is unknown whether this has actually taken place. Watts Bar 2 also needed to start being fueled with unobligated uranium starting with its cycle 2 (fall 2017 to spring 2019).[10] It is unknown whether this has taken place.

The tritium production program at Watts Bar 1 continues to experience unspecified problems that are reducing the amount of tritium being produced.[11] Love et al. report that the TPBAR irradiation during cycle 14 (fall 2015 to spring 2017) produced almost 10% less tritium than expected due to "programmatic and operational issues." For these same reasons, it is "likely" that the tritium production during the current cycle 15 (spring 2017 to fall 2018) will be "less than desired." For cycle 16 (fall 2018 to spring 2020) it is expected that "operational issues will limit tritium production." As the tritium production continues to fall short of what was expected, increasing tritium production appears to be becoming urgent. According to Love et al., "the DOE [Department of Energy] wants as much tritium as possible as early as they can get it."

The recently released Nuclear Posture Review has confirmed tritium production shortfalls: "U.S. production of tritium…is now insufficient to meet the forthcoming U.S. nuclear force sustainment demands…"[12] Underlining the importance of increasing tritium production, the report states that unless there is "a marked increase in the planned production of tritium in the next few years, our nuclear capabilities will inevitably atrophy and degrade below requirements."

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[8] Watts Bar 2 started commercial operation in October 2016.

[9] Sequoyah 1 is licensed until September 2040, Sequoyah 2 is licensed until September 2041 and Watts Bar 2 until October 2055.

[10] Unobligated uranium is material that has no peaceful use restrictions. Since the U.S. can no longer produce enriched uranium, it is facing a shortage of unobligated uranium. For more on this issue see: Gregory S. Jones, "U.S. Increased Tritium Production Driven by Plan to Increase The Quantity of Tritium per Nuclear Weapon," June 2, 2016. Link

[11] EF Love, ML Stewart, BD Reid and KA Burns, "Tritium Production Assurance," Pacific Northwest National Laboratory, June 5, 2017.

[12] "Nuclear Posture Review," Office of the Secretary of Defense, February 2018, p. 62.

Sources differ on the exact TPBAR irradiation schedule. The NNSA's Stockpile Stewardship and Management Plan was published in November 2017 but in prior years it was published in March. The plan's discussion of tritium production appears to be current only as of March 2017. Therefore, in Table 1, I have used Love et al.'s, TPBAR irradiation schedule instead. The tritium production schedule at Watts Bar 2 is more aggressive than the one from 2016.[13] It remains to be seen if the production at Watts Bar 2 can meet this schedule and whether the tritium production rate at Watts Bar 1 can be improved.

**Table 1**

**Actual and Projected TPBAR Irradiation**

| Approximate fuel cycle dates | Reactor | Number of TPBARs irradiated |
|---|---|---|
| Fall 2003 to Spring 2005* | Watts Bar 1 | 204 |
| Spring 2005 to Fall 2006 | Watts Bar 1 | 204 |
| Fall 2006 to Spring 2008 | Watts Bar 1 | 204 |
| Spring 2008 to Fall 2009 | Watts Bar 1 | 368 |
| Fall 2009 to Spring 2011 | Watts Bar 1 | 204 |
| Spring 2011 to Fall 2012 | Watts Bar 1 | 544 |
| Fall 2012 to Spring 2014 | Watts Bar 1 | 544 |
| Spring 2014 to Fall 2015 | Watts Bar 1 | 704 |
| Fall 2015 to Spring 2017 | Watts Bar 1 | 704 |
| Spring 2017 to Fall 2018 | Watts Bar 1 | 1,104?** |
| Fall 2018 to Spring 2020 | Watts Bar 1 | 1,408 |
| Spring 2020 to Fall 2021 | Watts Bar 1 | 1,552 |
| Fall 2020 to Spring 2022*** | Watts Bar 2 | 704 |
| Fall 2021 to Spring 2023 | Watts Bar 1 | 1,504 |
| Spring 2022 to Fall 2023 | Watts Bar 2 | 1,104 |
| Spring 2023 to Fall 2024 | Watts Bar 1 | 1,504 |
| Fall 2023 to Spring 2025 | Watts Bar 2 | 1,504 |
| Fall 2024 to Spring 2026 | Watts Bar 1 | 1,504 |
| Spring 2025 to Fall 2026 | Watts Bar 2 | 1,504 |
| Spring 2026 to Fall 2027 | Watts Bar 1 | 1,504 |
| Fall 2026 to Spring 2028 | Watts Bar 2 | 1,504 |

*This was the sixth fuel cycle for Watts Bar 1. The current fuel cycle (spring 2017 to fall 2018) is the fifteenth fuel cycle.
**I have been unable to confirm the TPBAR loading for this fuel cycle.
***Watts Bar 2 fuel cycle four.

[13] Gregory S. Jones, "U.S. Increased Tritium Production Driven by Plan to Increase The Quantity of Tritium per Nuclear Weapon," June 2, 2016. Link