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April 25, 2023

How is China Producing the Tritium Needed for Its Nuclear Weapons?

Tritium is a vital component of all modern nuclear weapons. Tritium makes it possible to produce boosted primaries in thermonuclear weapons. According to the British, such primaries are "immune" to predetonation, which helps ensure that the weapons will produce the desired yield.[2] It is known that all weapons in the U.S., British and French nuclear arsenals today are two-stage thermonuclear weapons that use boosted primaries.

In the early years of its nuclear weapon program China's weapons were not boosted. China's first boosted nuclear test was not until 1976. China probably retained some unboosted weapons for many years thereafter. However, the "Cox report" stated that China has gained access to advanced U.S. weapons designs and conducted nuclear weapon tests based on these designs.[3] No doubt knowledge of these advanced designs accelerated China's move towards boosted weapons. China likely phased out its unboosted weapons many years ago and all of its weapons today are two-stage thermonuclear ones that use boosted primaries. By comparison, France phased out its last unboosted nuclear weapon in 1993.[4]

Since tritium is radioactive with a half-life of 12.3 years, each year 5.5% of the tritium decays away and continuing production is needed to maintain a tritium stockpile. It is believed that China produced tritium in a plutonium production reactor from 1967 to 1986. After this time, when this reactor was shut down, how was China producing its tritium? The answer to this question is unclear. Some analysts simply assume that somehow China had sufficient tritium. Others have suggested that China produced tritium by irradiating lithium in either its power or research reactors or by extracting tritium from the moderator of its heavy water power reactors. This issue has gained particular salience as it has become apparent that China has been expanding its nuclear stockpile more rapidly than previously thought and it is likely to continue to do so. This expansion requires increasing amounts of tritium.

As this paper will show, the sources suggested by other analysts are unlikely to have produced sufficient tritium to support China's past nuclear stockpile during the period 1986 to somewhere around 2010-2021. As a result, it is likely that China has operated a clandestine tritium production reactor during this period and the reactor might still be in operation today. Since such a reactor might also produce plutonium, China may have access to more plutonium than most analysts estimate.

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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] Lorna Arnold, *Britain and the H-Bomb*, UK Ministry of Defense, Palgrave, 2001, pp. 176-178.

[3] "Report of the Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China," Select Committee, United States House of Representatives, U.S. Government Printing Office, Washington, D.C.,1999, pp. 60-95. https://www.govinfo.gov/content/pkg/GPO-CRPT-105hrpt851/pdf/GPO-CRPT-105hrpt851.pdf

[4] This was the AN-51, which was the warhead for the Pluton tactical ballistic missile.

China's Tritium Production Requirements 1967 to 2035

I have estimated that in the past the U.S. used about 3.2 grams of tritium per nuclear weapon and that it is increasing the amount per weapon to 4.5 to 5.0 grams.[5] This increase is driven in part by uncertainties due to the lack of nuclear weapon testing. Given the relatively low number of nuclear tests that China has conducted, I assume that China uses 5 grams of tritium per weapon. The U.S. maintains a five year tritium reserve which increases the total amount of tritium required by about one-third. This would increase the required amount of tritium to 6.62 grams per weapon. Given the potential difficulties in producing tritium, China may well want to keep a larger reserve. A 12.3 year reserve (tritium's half-life) would double the required amount of tritium per weapon to 10 grams.

China completed a plant to extract tritium from irradiated lithium aluminum targets in early 1967.[6] It produced its first tritium product in May 1968. Most countries boost their weapons by using a deuterium tritium gas mixture but China appears, at least initially, to have used a solid lithium deuterium tritium compound. It produced the first such material in 1972. Tritium first appeared in a Chinese nuclear test in September 1976.[7]

Zhang has stated that China probably used its plutonium production reactor at Jiuquan to produce tritium, which would be consistent with U.S. experience.[8] This reactor operated between 1967 and 1986. By the time this reactor shut down, China likely had over 200 weapons, but the majority probably were not boosted since boosting was still new to the Chinese.[9] I assume that China possessed 50 boosted nuclear weapons in 1986. These weapons would have required a total of between 330-500 grams of tritium depending on whether China maintains a five year or 12.3 year reserve respectively. To have produced this amount of tritium since 1967would require a constant annual production rate between 1967 and 1986 of 28-43 grams depending on the size of China's reserve. In reality, China might have produced less than the constant rate in the early years when demand for tritium would have been low and higher than this rate in the later years to catch up when the demand increased along with the number of boosted weapons.

By 2000 all of China's nuclear weapons were probably boosted. If one assumes a 235 weapon nuclear arsenal,[10] then these weapons would require a total of 1,560-2,350 grams of tritium depending on the size of China's reserve. The required constant annual tritium production rate between 1986 and 2000 would be 150-220 grams to increase China's tritium stocks from 330-500 grams to 1,560-2,350 grams. Again, China might have produced less than the constant rate

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[5] Gregory S. Jones, "U.S. Increased Tritium Production Driven by Plan to Increase the Quantity of Tritium per Nuclear Weapon," June 2, 2016. https://nebula.wsimg.com/08a60104185a91e6db9008fb929a0873?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1

[6] JPRS Report: Science & Technology, China, "Selections from 'China Today: Nuclear Industry" JPRS-CST-88-002, January 15, 1988, p. 31.

[7] Thomas C. Reed, "The Chinese nuclear tests, 1964-1996," *Physics Today*, September 2008. https://physicstoday.scitation.org/doi/pdf/10.1063/1.2982122

[8] Hui Zhang, "China's Fissile Material Production and Stockpile," International Panel on Fissile Materials, 2017, p. 18. http://fissilematerials.org/library/rr17.pdf

[9] Hans M. Kristensen & Robert S. Norris, "Global nuclear weapons inventories 1945-2013," *Bulletin of the Atomic Scientists*, November 27, 2013, p. 78. https://journals.sagepub.com/doi/full/10.1177/0096340213501363

[10] *Ibid*.

in the early years and higher than this rate in the later years to catch up. This would avoid discontinuities in the tritium production rate between intervals.

The latest U.S. Department of Defense Annual Report to Congress estimates that in 2021, China's nuclear arsenal was 400 weapons and projects that the arsenal will continue to expand to 1,500 weapons by 2035.[11] In 2021 China would have required a total tritium stockpile of 2,650-4,000 grams depending on the size of China's reserve. For China to increase its tritium stocks from 1,560-2,350 grams to 2,650-4,000 grams between 2000 and 2021 would require a constant annual production rate of 180-270 grams. As before China might have produced less than the constant rate in the early years and higher than this rate in the later years to catch up.

To increase its nuclear stockpile to 1,500 by 2035, China will require a total tritium stockpile of 9,930-15,000 grams depending on the size of China's reserve. This increase in tritium stocks from 2,650-4,000 grams to 9,930-15,000 grams would require a constant annual tritium production rate between 2021 and 2035 of 900-1,400 grams.

The constant required annual tritium production rate for these four intervals is shown in Table 1.

Table 1

China's Required Constant* Annual Tritium Production Rate for Various Intervals Between 1967 and 2035

Interval	Production Rate in Grams
1967-1986	28-43**
1986-2000	150-220**
2000-2021	180-270**
2021-2035	900-1,400**

* In reality, China might have produced less than the constant rate in the early years and higher than this rate in the later years. Thus, there would be no discontinuities in the tritium production rate between intervals.
** The range depends on whether China maintains a five year or 12.3 year reserve.

Sources of Tritium for Boosted Nuclear Weapons

Boosting involves the fusion of equimolar mixtures of deuterium and tritium. The deuterium can be extracted from ordinary water, but tritium only exists in trace amounts in nature and must be produced by either irradiating lithium in nuclear reactors or recovering the tritium produced in the moderator of heavy water nuclear reactors.

[11] "Military and Security Developments Involving The People's Republic of China 2022, Annual Report to Congress," U.S. Department of Defense, November 29, 2022, p. 94. https://media.defense.gov/2022/Nov/29/2003122279/-1/-1/1/2022-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF

Typically, nuclear weapon states such as the United States produce tritium by irradiating lithium in a nuclear reactor. Natural lithium consists of two isotopes, lithium 6 and lithium 7. Lithium 6 comprises 7.5% of natural lithium and lithium 7 the other 92.5%. When irradiated by neutrons it is the lithium 6 that produces tritium by the reaction: lithium 6 + neutron = tritium + helium 4.

Many experts assume that the lithium must be enriched (i.e. the percentage of lithium 6 increased) in order to produce tritium in a nuclear reactor, but there is no need. Since the thermal capture neutron cross-section of lithium 6 is 942 barns and that of lithium 7 is 0.045 barns, when natural lithium is irradiated, 99.94% of the neutrons are absorbed by the lithium 6.

The U.S. used natural lithium to produce tritium in its plutonium production reactors during the 1950s. The target elements consisted of a lithium aluminum alloy that was 3.5% lithium by weight. The low percentage of lithium ensured that the lithium remained as a solid solution in the aluminum, giving the alloy good anti-corrosion properties. About 2% of the neutrons were absorbed in the large mass of aluminum in the target element and the remaining 98% were absorbed in the lithium.

The U.S. did produce enriched lithium in the 1950s as part of the development of two-stage thermonuclear weapons (hydrogen bombs). Once such material was available, it was advantageous to use it to produce tritium. The enriched lithium would reduce the number of target elements required and thereby the amount of aluminum in the reactor, which increased tritium production by about 2%.[12]

Initially, the U.S. produced tritium in its plutonium production reactors but the last of these reactors was shut down in 1988. Since 2003 the U.S. has produced tritium in the nuclear power reactors at Watts Bar. Due to the high temperatures in a nuclear power reactor, the lithium is in the form of lithium aluminate. This program has had various problems and has produced less than the desired amount of tritium.

Instead of irradiating lithium, countries with reactors that use heavy water as a moderator have the alternative of extracting tritium from these reactors. Tritium is produced as an incidental by-product of reactor operation. 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.

Park and Kim have performed detailed calculations of the tritium buildup in the Wolsong 1 reactor,[13] which is a CANDU 6 model using a heavy water moderator and coolant with a thermal output of 2,156 MW, generating 679 MW of electrical energy.[14] From their data I have calculated that for an 84% reactor capacity factor, 135 grams of tritium is produced annually in

[12] R. Nilson, "Conversion Ratio Incentive for Using Black Mint in an E-N Load," HW-63668, General Electric, Richland, Washington, January 28, 1960. https://www.osti.gov/servlets/purl/10174913
[13] 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, pp. 406-407.
[14] *World Nuclear Industry Handbook*, Nuclear Engineering International, 2004, p. 134.

the moderator and 2.3 grams in the coolant. Given the low tritium content of the reactor coolant, the moderator is the main source of tritium.

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.[15] Canada and South Korea are the only two countries known to have extracted significant quantities of tritium from their heavy water reactors. Canada has a separated tritium inventory of over 20 kilograms and South Korea over 4 kilograms.[16]

If a reactor operates at a more or less steady capacity factor, the buildup of tritium in the moderator and coolant is determined by tritium's half-life. The fraction of the equilibrium value attained at any time t (in years) is found by the equation $(1 - e^{-\lambda t})$ where λ is tritium's decay constant.[17] After one half-life (12.3 years), the tritium content would be one-half of its equilibrium content, after two half-lives (24.6 years) it would be three quarters of its equilibrium content, and so on. It would take 41 years for the tritium content to be 90% of its equilibrium value.

If a heavy water reactor has started operation fairly recently, a country desiring tritium for nuclear weapons would probably not want to wait 30 or 40 years before extracting the tritium. On the other hand, given that the tritium extraction procedure requires processing large quantities of heavy water, one would want to wait some time to allow the tritium concentration to increase. After one year, the tritium content would be only 5.5% of its equilibrium value. A good compromise would be to wait about ten years, when the tritium would be 43% of its equilibrium value. However, due to the decay of tritium during this ten year interval, only 1,036 grams of tritium would be obtained which is an annual production rate of 104 grams per year.

Note that whether a given heavy water moderated reactor is under International Atomic Energy Agency (IAEA) safeguards is not an issue. Tritium is not a safeguarded material. The word tritium does not even appear in the IAEA's Safeguards Glossary.[18]

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[15] 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. https://www.kns.org/files/pre_paper/17/173%EC%86%A1%EA%B7%9C%EB%AF%BC.pdf

[16] Gregory S. Jones, "Heavy Water Nuclear Power Reactors: A Source of Tritium for Potential South Korean Boosted Fission Weapons," February 29, 2016. https://nebula.wsimg.com/344f048726407b8951892db91c98a0b1?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1

[17] The decay constant for tritium is 0.0562 which is calculated by dividing the ln 2 (natural logarithm of 2, which is 0.6931) by tritium's half-life. The decay constant is the inverse of the mean-life.

[18] "IAEA Safeguards Glossary, 2001 Edition," International Nuclear Verification Series No. 3, International Atomic Energy Agency, Vienna, 2002. https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf

How Might China Obtain the Tritium it Requires?

1967 to 1986

Between 1967 and 1986 China's required constant tritium annual production rate was 28-43 grams. As was stated above, it is believed that China produced tritium in its Jiuquan plutonium production reactor. This reactor had a power output of 600 MWt. Due to the limited excess reactivity of natural uranium fueled reactors and the high neutron absorption of lithium, the production of tritium would require the use of enriched uranium. Based on U.S. experience at Hanford, if the entire reactor were fueled with just 0.95 percent enriched uranium, the reactor could produce about 450 grams of tritium per year.[19] This was far more than enough to meet China's needs at the time. As a result, the Jiuquan reactor was probably only partially loaded with just enough enriched uranium and lithium to meet China's tritium needs.

1986 to 2000

Between 1986 and 2000, China's required constant tritium annual production rate increased substantially to 150-220 grams. Since the Jiuquan reactor had been shut down, the key question is where was China producing its tritium? China's first CANDU reactor did not start operation until 2002, so China could not be extracting the tritium from the heavy water moderator. Instead, China must have been irradiating lithium in a nuclear reactor but which one?

China's first nuclear power reactors did not start operation until 1994. Further producing tritium in a nuclear power reactor is not as simple as using a plutonium production reactor due to the high coolant temperatures. Instead of a lithium aluminum alloy, the lithium targets must be in the form of lithium aluminate. Since at high temperatures the tritium will diffuse through most materials including stainless steel, the targets must be specially designed. The U.S. has been producing tritium in the Watts Bar power reactors since 2003 but this program has been plagued with problems and it was many years before the tritium production began to reach it goals.[20] It would take China some time before it could produce large amounts of tritium in its nuclear power reactors. This would be especially so as China's nuclear power program did not really get underway until 2002.

The only other known reactors China could have used to produce tritium during this period were its research reactors. The only Chinese research reactor that had a high enough power level to produce a large quantity of tritium was the High Flux Engineering Testing Reactor (HFETR). The reactor had a maximum power level of 125 MWt and started operation in 1980. The reactor uses 90% enriched fuel.

One can use estimates of the maximum amount of plutonium that could be produced by irradiating natural uranium targets in a highly enriched uranium fueled research reactor to

[19] "Hanford Reactor and Separations Facility Advantages, HW-78100, Hanford Atomic Products Operation, Richland, Washington, June 27, 1963, p. 20. https://www.osti.gov/servlets/purl/10184818

[20] Gregory S. Jones, "The U.S. Program to Produce Tritium Using Commercial Power Reactors: 2019 Update," January 30, 2020. https://nebula.wsimg.com/b6c10a10aeb8d61f30037f6557a1facf?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1

estimate the maximum amount of tritium that could be produced in such a reactor by irradiating lithium targets. Binford has estimated that the maximum plutonium production for a research reactor using highly enriched uranium fuel is between 0.5 to 0.65 grams per megawatt-day and he assumed that the reactor could have a capacity factor of 85%.[21] More recently, Glaser has estimated the maximum plutonium production to be between 0.4 to 0.6 grams per megawatt-day and the reactor capacity factor is 300 days per year (82%).[22] For this work I will use Glaser's mid-range (Binford's low end) estimate of 0.5 grams per megawatt-day and his capacity factor of 300 days per year. If lithium targets are used instead of uranium ones, it should be possible to produce one atom of tritium in place of every atom of plutonium. However, due to the difference in mass between plutonium and tritium, the maximum tritium production rate would be 6.31 milligrams per megawatt-day.[23]

Using the calculated maximum tritium production rate and the HFETR's maximum power, the reactor could produce about 240 grams of tritium per year, which would seem to be enough to supply the 150-220 grams per year that China needed between 1986 and 2000. However, Chinese sources have indicated that the HFETR has not operated at its maximum power but rather at 50-60 MW[24] or 50-55 MW.[25] Assuming a power of 55 MW, the HFETR would only produce about 100 grams of tritium per year, which would have been insufficient to meet China's tritium needs between 1986 and 2000. Even this production rate could be obtained only if the HFETR were used to produce nothing but tritium during this entire 15 year period. However, these same sources have stated that the HFETR has been used to produce sizable quantities of various radioisotopes and to test power reactor fuel. Further due to the underutilization of the HFETR, China tried to interest foreign entities in using the reactor and had them visit the reactor site.[26] This is hardly a step that China would take if the HFETR were operating intensively to produce tritium for nuclear weapons.

Given that there is no obvious source for tritium production from 1986 to 2000, it is hard to escape the conclusion that China operated a clandestine tritium production reactor. A 300 MWt reactor with 0.95% enriched fuel would produce about 230 grams of tritium per year.[27] This amount would have been sufficient to meet China's needs during this time period. Using fuel with a higher uranium enrichment would reduce the required power of the reactor. Using 1.2% enriched fuel, a 180 MWt reactor would also produce about 230 grams of tritium per year.

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[21] F. T. Binford, "Diversion Assumptions for High-Powered Research Reactors," ORNL-6022, Oak Ridge National Laboratory, January 1984, p. 5. https://www.osti.gov/servlets/purl/5955646

[22] Alexander Glaser, "On the Proliferation Potential of Uranium Fuel for Research Reactors at Various Enrichment Levels," *Science and Global Security*, 2006, p. 20. https://scienceandglobalsecurity.org/archive/sgs14glaser.pdf

[23] This is 0.5 grams per megawatt-day divided by 78.3 which is the ratio of the mass of Pu 239 to the mass of tritium.

[24] Xu Hanming, "Current Status of Operation and Utilization with Several Research Reactors in China," *Proceedings of the 2000 Workshop on the Utilization of Research Reactors*, JAERI-Conf 2001-017, Japan Atomic Energy Research Institute, November 2000, p. 296. https://jopss.jaea.go.jp/pdfdata/JAERI-Conf-2001-017.pdf

[25] Liu Yishu, "Current Utilization of Research Reactor on Radioisotopes Production in China," *Proceedings of the 2000 Workshop on the Utilization of Research Reactors*, JAERI-Conf 2001-017, Japan Atomic Energy Research Institute, November 2000, p.148. https://jopss.jaea.go.jp/pdfdata/JAERI-Conf-2001-017.pdf

[26] *Ibid.*, pp. 152-153.

[27] "Hanford Reactor and Separations Facility Advantages, HW-78100," Hanford Atomic Products Operation, Richland, Washington, June 27, 1963, p. 20. https://www.osti.gov/servlets/purl/10184818

Using highly enriched uranium fuel, the reactor would only need to have a power level of about 120 MWt to produce 230 grams of tritium per year.

In addition, depending on the fuel enrichment, such a reactor could also be a significant producer of plutonium which would affect estimates of how much weapon-grade plutonium China possesses. A 300 MWt reactor with 0.95% enriched fuel, would in addition to tritium, produce about 66 kilograms of plutonium per year. This would amount to a total of about 920 kilograms of plutonium over the period from 1986 to 2000. As the fuel enrichment increases, the amount of plutonium produced decreases. A 180 MWt reactor using 1.2% enriched fuel would produce 34 kilograms of plutonium per year which would amount to a total of about 480 kilograms over the 14 year period. A reactor using highly enriched fuel would produce very little plutonium.

2000 to 2021

Between 2000 and 2021 China's required constant tritium annual production rate further increased to 180 to 270 grams, compared to 150 to 220 grams between 1986 and 2000. If China did not use too large a tritium reserve, then the 230 grams per year that I calculated could be produced by a clandestine tritium production reactor would be sufficient to meet China's needs. However, if China used a large tritium reserve, then a constant production rate of 270 grams would be required. Increasing the power level of the clandestine tritium production reactor by about 20% would be sufficient to meet the high 270 grams of tritium per year goal.

However, I think it more likely that the clandestine tritium production reactor would have remained at the same power. The reactor would have provided sufficient tritium for the first ten or 15 years of this period since, during this time China's nuclear arsenal was expanding rather slowly. Then, in the last 5 to 10 years of this period, China would have had two possible methods to significantly increase its tritium acquisition.

China could have extracted tritium from the heavy water moderator of its two CANDU 600 power reactors. These two reactors started operation in 2002 and 2003. If China waited 10 years, then the extraction would have taken place in 2012 and 2013 which as stated above would have provided the equivalent of 208 grams of tritium per year (104 grams per year per reactor). This combined with the 230 grams of tritium per year from the clandestine tritium production reactor would have been more than enough meet China's needs. Using this method, the clandestine tritium production reactor could be operating even today.

The second possible method is that sometime during the 2010 to 2021 period China started producing tritium in one of its growing number of light water power reactors (LWRs) in a manner similar to the method the U.S. uses at Watts Bar. Even though the U.S program proceded slower than anticipated, by about eight years from its start, tritium production reached around 500 grams per year, which was more than China needed during this period. Such a tritium production rate from a nuclear power reactor would have made the clandestine tritium production reactor superfluous and it could have been shut down probably sometime between 2010 and 2015.

Again, if the clandestine tritium production reactor used low enriched uranium, substantial amounts of plutonium would be produced as well. If the reactor used 0.95% enriched fuel, then it would produce somewhere between 660 and 1,400 kilograms of plutonium during the periods 2000-2010 or the 2000-2021 respectively. If it used 1.2% enriched fuel, then it would have produced between 340 and 710 kilograms of plutonium. If it used highly enriched fuel, then the amount of plutonium produced would be rather small.

2021 to 2035

Given the large expansion of its nuclear stockpile that is projected to occur between 2021 and 2035, China will need to significantly expand its tritium acquisition. The latest U.S. Department of Defense Annual Report to Congress recognizes this issue and has said:

> China is also working to expand and diversify its capability to produce tritium by methods such as using tritium production targets in reactors and extraction from tritiated heavy water, according to Chinese nuclear industry reporting.[28]

Unfortunately, this report provides no specifics on how China might produce this increased amount of tritium but simply states the two general methods for acquiring tritium.

Between 2021 and 2035 China's required constant tritium annual production rate is a sizable 900 to 1,400 grams, which is a substantial increase over the 180 to 270 grams required between 2000 and 2021. The 208 grams per year (equivalent) that could be obtained by extracting tritium from both China's CANDU power reactors plus the 230 grams per year from the clandestine tritium production reactor, if it is still running today, would not be enough to meet China's tritium needs.

Clearly China will need to start producing substantial additional amounts of tritium in its LWRs in a manner similar to what the U.S. is doing at Watts Bar. The U.S. plans that at full capacity each Watts Bar reactor will produce about 930 grams per year (1,400 grams per 18 month refueling cycle).[29] China will probably need to use at least two reactors to meet its tritium requirements and may want to use several more since this would allow each reactor to use its uranium fuel more efficiently. With the ability to produce large amounts of tritium in its LWRs, China would not need to extract the tritium from its heavy water CANDU reactors nor rely on the continued operation of any clandestine tritium production reactor assuming that it one is still operating.

Conclusions

From 1967 to 1986 China was likely producing tritium in a plutonium production reactor. After that reactor shut down in 1986, China had no obvious means of producing the tritium it needed to

[28] "Military and Security Developments Involving The People's Republic of China 2022, Annual Report to Congress," U.S. Department of Defense, November 29, 2022, p. 97. https://media.defense.gov/2022/Nov/29/2003122279/-1/-1/1/2022-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF

[29] "Tritium and Enriched Uranium Management Plan Through 2060, Report to Congress," October 2015, U.S. Department of Energy, p. 11. http://fissilematerials.org/library/doe15b.pdf

boost the primaries of its two stage thermonuclear weapons (hydrogen bombs) even though China had likely converted its entire arsenal to such weapons by the year 2000. It is hard to escape the conclusion that China operated a clandestine tritium production reactor from 1986 to at least 2010-2015 and that the reactor may still be operating today.

If the clandestine reactor used 0.95% enriched uranium, then the reactor would require a power level of about 300 MWt to meet China's tritium needs. If the reactor used highly enriched uranium, then its power level would only need to be about 120 MWt. Furthermore, if China used the 300 MWt reactor with low enriched uranium fuel, then from 1986-2010 or 1986-2021, the reactor would have produced a total of about 1,600-2,300 kg of plutonium respectively, in addition to the required tritium. However, if the China used the 120 MWt reactor with highly enriched uranium fuel, then very little plutonium would have been produced. These cases illustrate the uncertainty of our estimates of China's plutonium stocks. This is especially so since if China could operate a clandestine tritium production reactor, it could also operate a clandestine plutonium production reactor.

China will need to substantially increase its tritium production if it is to expand its nuclear arsenal to 1,500 weapons by 2035. This will require China to begin producing substantial amounts of tritium in its nuclear power reactors assuming, that it has not already done so. The clandestine tritium production reactor, if it is still in operation, could be shut down once China's power reactors begin producing large amounts of tritium.