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National Nuclear Security Administration Tritium Supply Chain

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Executive Summary

Savannah River Site plays a critical role in the Tritium Production Supply Chain for the National Nuclear Security Administration (NNSA). The entire process includes:

- Production of Tritium Producing Burnable Absorber Rods (TPBARs) at the Westinghouse WesDyne Nuclear Fuels Plant in Columbia, South Carolina
- Production of unobligated Low Enriched Uranium (LEU) at the United States Enrichment Corporation (USEC) in Portsmouth, Ohio
- Irradiation of TPBARs with the LEU at the Tennessee Valley Authority (TVA) Watts Bar Reactor
- Extraction of tritium from the irradiated TPBARs at the Tritium Extraction Facility (TEF) at Savannah River Site
- Processing the tritium at the Savannah River Site, which includes removal of non-hydrogen species and separation of the hydrogen isotopes of protium, deuterium and tritium

The Savannah River Site maintains subject matter expertise in handling and processing hydrogen isotopes. In addition to supplying materials for the United Sates nuclear stockpile, hydrogen isotopes are used for other useful applications, including targets for the National Ignition Facility (NIF) and various research and development activities across the NNSA Nuclear Security Enterprise. The quantities of tritium at SRS are closely monitored and accurately measured, as the total NNSA tritium inventory is maintained by the NNSA Office of Nuclear Material Integration (ONMI). Some of the techniques necessary to accurately measure tritium quantities at SRS include mass spectrometry and calorimetry. This paper will describe the tritium production procedure, which supplies tritium gas for Savannah River Site to process. The entire production procedure includes support from several entities outside the NNSA organization.

NNSA Management of Tritium Production

Tritium production for NNSA applications is managed through the Tritium Readiness Program, which reports through the Materials Management Program under the Assistant Deputy Administrator for Stockpile Management. Ultimately, the program is maintained in the NNSA Defense Programs.

Although there are some minor needs for tritium in the private sector, the majority of tritium is used for NNSA Defense Programs. Some of the characteristics of tritium which require the Tritium Readiness Program to produce tritium are:

- Tritium gas is an integral part of the U.S. nuclear stockpile.
- Tritium is filled into bottles (gas transfer systems) that are rotated to the Department of Defense (DoD) periodically.
- Tritium is not consumed, but decays at ~5.5% per year.
- Tritium has a 12.3 year half-life.
- Tritium decays into Helium-3, a valuable gas for neutron detectors and other purposes.
- Tritium Readiness must produce enough tritium to replace the decay in the inventory.
- The requirements for tritium are computed by NNSA based on negotiations with the DoD on weapons types, numbers, refill cycles, etc., plus R&D, surveillance and other requirements.

Due to long term changes in NNSA infrastructure, the capability to produce tritium at NNSA sites is no longer available. The decision was made to utilize Tennessee Valley Authority (TVA) reactors to house the process to irradiate lithium empregnated aluminum rods to produce tritium. The tritium bearing rods are then shipped to Savannah River Site, where the tritium gas is extracted, then moved to facilities supporting the NNSA Defense Program mission.

<u>Tritium Production Process</u>

Tritium is an isotope of hydrogen and rarely occurs naturally in the earth's environment. It is more commonly found in earth's upper atmosphere, when various species interact with cosmic rays. Therefore, to make tritium in abundance, it is formed by the following reaction (Figure 1):

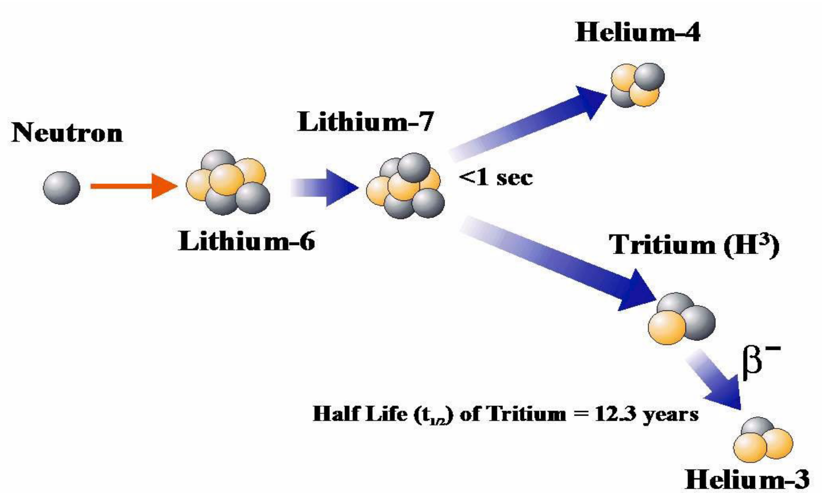

Figure 1 Tritium Production Reaction

The tritium is formed by neutron activation of lithium-6. For the NNSA production, the neutrons are supplied by a domestic supply of low enriched uranium (LEU). Because of global treaty obligations, LEU cannot originate from foreign sources and the technology used to enrich the uranium must be US based. The LEU must be “unobligated”. This process is currently performed at the TVA, which is a corporation of the U.S. government formed during the New Deal of the Great Depression in 1933. The lithium-6 is present in the form of a Tritium Producing Burnable Absorber Rod (TPBAR), which is produced by WesDyne Corporation in South Carolina. The TPBARs were designed and are supported technically by the Department of Energy (DOE) Pacific Northwest National Laboratory in the state of Washington. The TPBARs are composed of lithium aluminate pellets encased by a zircaloy liner, which are housed in stainless steel tubes with aluminide coating. A TPBAR is depicted below in Figure 2:

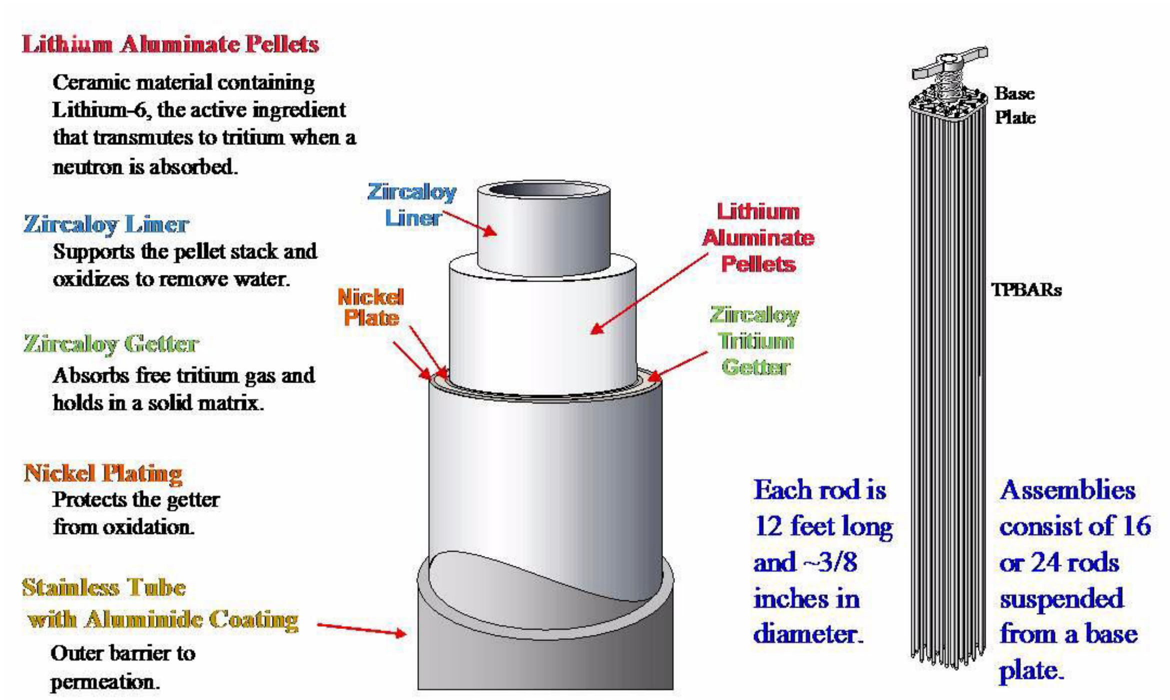

Figure 2 Tritium Producing Burnable Absorber Rod (TPBAR) Composition

A series of TPBARs are loaded into a TVA reactor where they are exposed to LEU for length of time to allow a significant amount of tritium to be absorbed into the zircaloy getters. The TPBARs are then removed and transported to the NNSA Savannah River Site (SRS) in South Carolina. At SRS, the TPBARs are loaded into the Tritium Extraction Facility (TEF), where the gases are extracted and the tritium is separated for future use. NNSA must work with TVA and the Nuclear Regulatory Commission to determine the number of TPBARs in each reactor cycle and the frequency at which the TPBARs are loaded into the reactor.

The overall schedule is dependent on the TVA reactor usage plans. Also, the extraction of tritium from the TPBARs at Savannah River Site is scheduled to meet staffing capabilities and the schedule of the TEF to operate without going through extensive requalification processes. The general process flow is depicted in Figure 3 below:

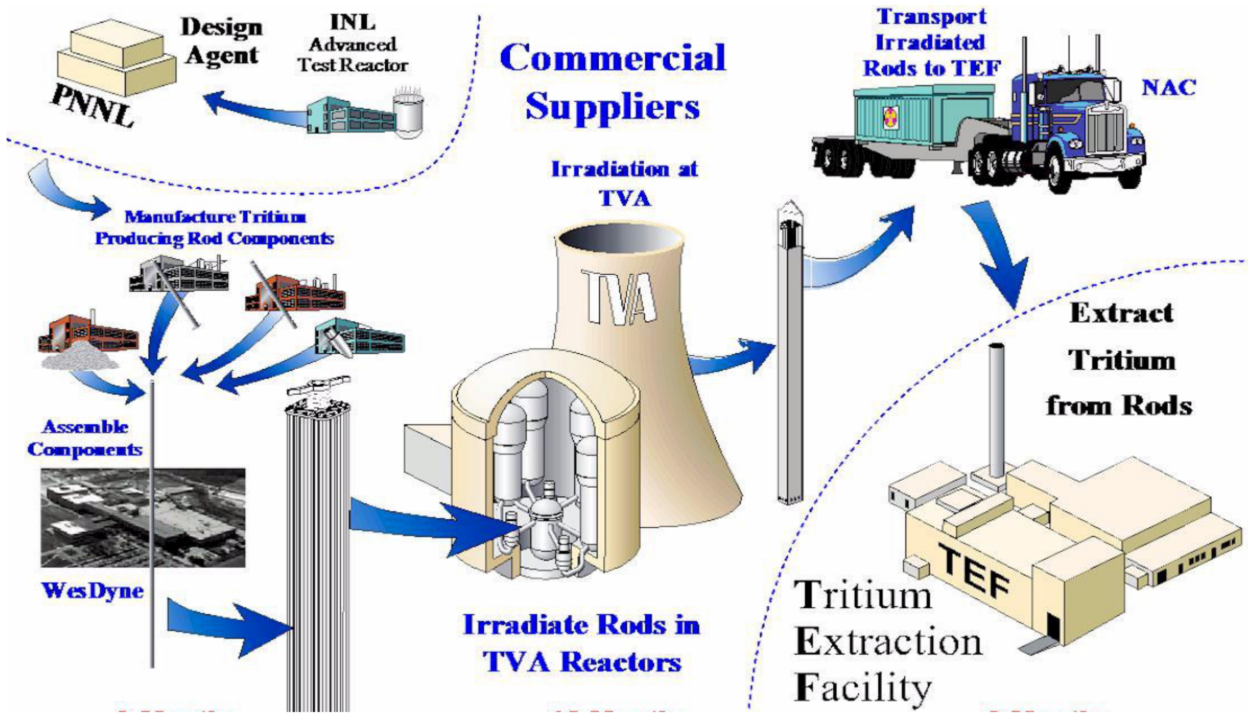

Figure 3 Tritium Production Process Flow

Tritium Demand

Very little tritium is actually consumed in NNSA processes; the tritium production mostly replaces tritium that decays. The accountability of tritium includes the following needs:

- Active stockpile weapons stored in the field
- Active stockpile weapons that are in transit (active stockpile pipeline) to be deployed in the field or from the field to be unloaded and potentially reclaimed
- Minimal level required to maintain tritium processing at Savannah River Site
- Inactive or hedge stockpile weapons that do not have tritium loaded, but have specific quantities of tritium stored and Savannah River Site if they need to be loaded in the future
- Research and Development (R&D) for investigating longer lived systems and non-weapons-related applications
- Function testing of fielded and stored systems (through surveillance programs) to validate effectiveness of existing designs
- A reserve amount to address the contingency of tritium production not being available for some number of years

Therefore, the tritium production must address tritium lost through radioactive decay, R&D testing, surveillance testing and trace levels lost through gas processing. As stockpile numbers continue to decrease, the overall level of tritium may also go down. The inventory of tritium is qualitatively depicted in Figure 4 below:

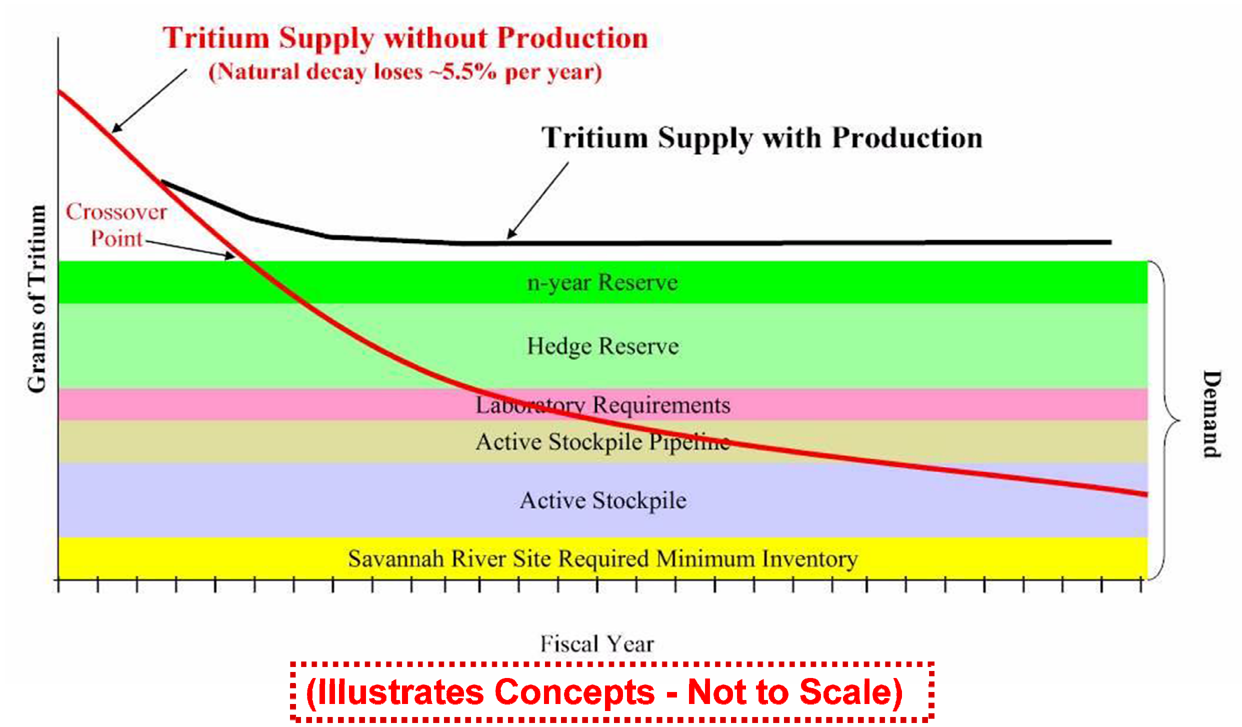

Figure 4 Tritium Applications Considered for Inventory

<u>Issues Affecting Tritium Demand, Supply and Production</u>

One of the components necessary to produce tritium is LEU. LEU is used in reactors to supply neutrons which irradiate lithium, as described earlier. Through treaty obligations, the United States cannot use "obligated" LEU from foreign sources or use LEU that is enriched with technologies developed from other countries. The "unobligated" LEU for the TVA reactors which produces tritium for NNSA Defense Programs has been supplied by the United States Enrichment Corporation (USEC) at the Paducah Gaseous Diffusion Plant. This process is not efficient versus other technologies, so the plan is to move to a US gas centrifuge technology at a USEC facility in Portsmouth, Ohio called the American Centrifuge Plant (ACP). ACP is schedule to come online in Fiscal Year 2014. The USEC facilities produce LEU for NNSA and non-NNSA applications and therefore compete with other companies to supply LEU. Given the global reduction in demand for LEU, the price has dropped dramatically. It may not be economically feasible for USEC to maintain their production of LEU. Another potential source of LEU would be to down-blend high enriched uranium (HEU) which is not obligated under existing treaties. However, NNSA Defense Programs would be competing with DoD Navy Nuclear Programs to utilize HEU.

Another issue affecting the production of tritium is managing the amount of tritium that could potentially contaminate the cooling water within the reactor. The amount of tritium which permeates through containment materials has limited the number of TPBARs which can be irradiated during a given cycle at TVA. NNSA is studying TPBAR physics to design new systems to minimize potential tritium releases. Additionally, TVA has been examining engineering methods to control released amounts of tritium to the cooling water. Currently, TVA utilizes one reactor for the production of tritium. An alternative to producing more tritium would be to use more than one reactor or reducing TPBAR exposure periods, as the permeation effect becomes stronger later on in the production cycle.

Summary and Path Forward Options

Tritium is vital to NNSA needs for Defense Programs. The process to produce tritium at a TVA reactor has proved to be challenging, both technically and politically. NNSA will continue to use this process and address these challenges as they arise. However, NNSA can also pursue other potential processes, such as small modular reactor (SMR) technology. The time frame for such a new technology is most likely to be several decades into the future.