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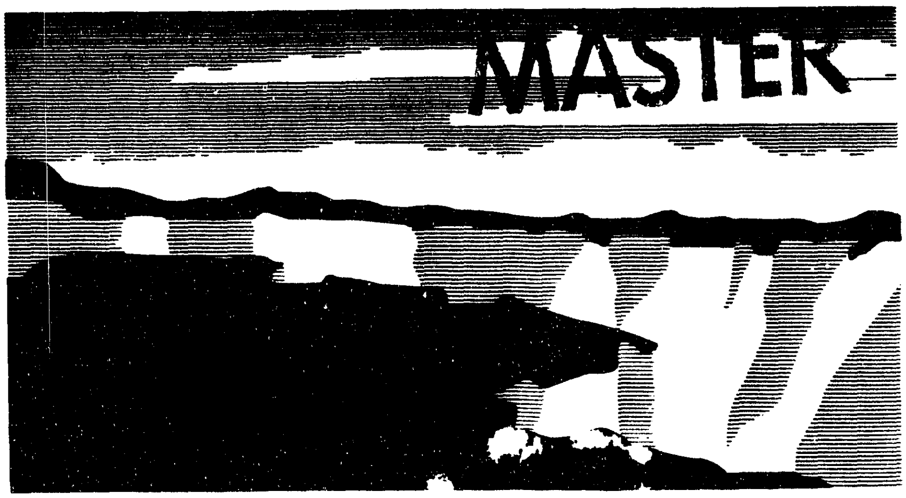


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# Target/Blanket Design For The Los Alamos Apt System

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**Abstract:** The Accelerator Production of Tritium (APT) concept proposes the production of tritium by means of an accelerator and target system. The Los Alamos APT design incorporates a high-energy, high-current proton accelerator, a tungsten neutron source, a lead neutron multiplier, and a moderating blanket that contains $^3He$ for the production of tritium. This innovative system makes use of existing spallation neutron source technology, and proven design concepts. Inherent safety and environmental features include low decay heat, the absence of fissile or fertile material, no criticality concerns, no potential for overpower transients, and the fact that no high level waste is produced.

## INTRODUCTION

In late 1989, an APT concept was reviewed by the DOE's Energy Research Advisory Board for the 1988 goal requirement, and more recently, by a JASON panel in 1992 for a reduced requirement equal to 3/8 to 1/2 of the 1988 goal [1,2]. Both reviews were positive about the APT technology but pointed out the need for a program of confirmatory engineering and development to resolve key technical issues and demonstrate performance in critical areas. The JASON report stated, "The Panel believes that APT is a technology that appears feasible and practical for producing tritium in the quantities specified, and with a start-up date consistent with the currently projected national goal."

As an alternative to the reactor concepts, and in response to the panel reviews, the US Department of Energy is now supporting development of a reference preconceptual design for an accelerator-driven spallation-neutron facility to produce tritium. Los Alamos, Brookhaven, and Sandia National Laboratories formed a team together with several industrial participants that include Bechtel, Northrop/Grumman, Babcock & Wilcox, Westinghouse, Maxwell, and General Atomics, to develop the APT design. The National Laboratories provide the in-depth expertise and experience in the science and technology, while the industrial participants complement the laboratories with unique and extensive experience related to APT in the design and construction of high technology facilities.

The APT tritium-supply option consists of a powerful linear accelerator that bombards a spallation target with high-energy protons. Neutrons are produced in the spallation target and are absorbed in a blanket material to produce tritium. Two spallation targets are currently under investigation: (1) a tungsten neutron source proposed by Los Alamos and (2) a lead neutron-source proposed by Brookhaven. In the tungsten neutron source concept, the neutrons are captured by gaseous $^3He$ an isotope of helium, which is circulated through the system, thus producing tritium. In the Brookhaven concept, the centrally located solid lead neutron source is surrounded with a blanket of lithium-aluminum. Tritium is produced by capture in $^6Li$.

## THE $^3$HE TARGET/BLANKET CONCEPT

The $^3He$ target/blanket system is depicted in Fig. 1. The incident proton beam is expanded to a "beam spot" size of 0.5 m by 1.0 m. The beam passes through a double-wall vacuum interface window that is constructed of inconel, and is cooled with $D_2O$. The protons then enter a 1.3-m diam. by 3.5-m long vessel also made of inconel that contains $^3He$ at moderate pressure, and approximately 100 tungsten rod bundles that are distributed along the length of the vessel. The protons impinge on the tungsten and produce high-energy neutrons through the process of

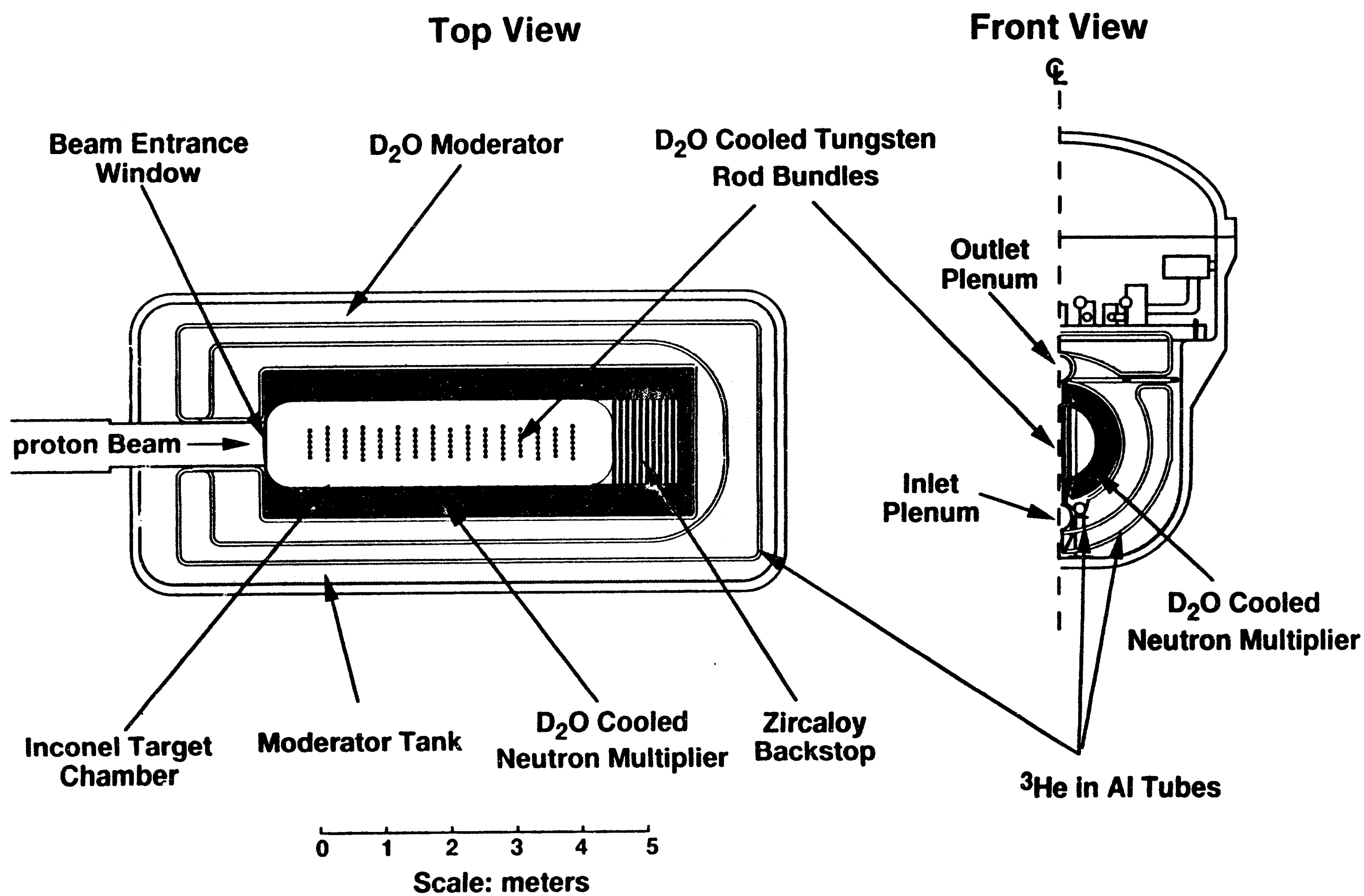


Fig. 1. Target/blanket layout.

spallation. Behind the inconel vessel is a proton backstop made of zirconium and lead that provides an additional source of neutrons, and fully stops the proton beam.

The inconel vessel is surrounded by an annulus of lead that is cooled with $D_2O$. Neutron multiplication occurs in the lead through additional spallation and (n,xn) reactions. Surrounding the lead is a thin annulus of $^3He$ contained in aluminum tubing, a $D_2O$ moderator, another annulus of $^3He$, and a $D_2O$ reflector. Neutrons are moderated to near thermal energies in the $D_2O$. Tritium is produced through neutron capture in $^3He$ that is circulated and processed continually. Thermal neutrons that are scattered back into the neutron source are preferentially captured in the $^3He$, thereby reducing the parasitic capture in the tungsten. The entire assembly of the neutron source vessel and surrounding blanket of lead, $^3He$ and $D_2O$, are contained in a steel vessel. The $^3He$ is processed continually to remove the tritium.

The preconceptual design of the beam entrance window and the choice of structural material for the neutron source is based on the extensive experience at the Los Alamos Meson Physics Facility (LAMPF), where the beamstop window is a double-walled inconel-718 structure with water cooling. The APT window will operate at similar stress levels and proton fluence. The lifetime estimate for the neutron source is 2.2 years at 75% capacity. At this time, the beam entrance window will achieve a proton fluence of about 1.5 by $10^{22}$ p/cm$^2$. This is similar in magnitude to the proton fluence that the LAMPF window had experienced when it was taken out of service. The LAMPF window had not failed and could have perhaps operated much longer. It is therefore possible that we could safely operate the target/blanket much longer than 2.2 years.

The choice of tungsten as the neutron source was made based on the extensive experience with tungsten spallation sources at the Los Alamos Neutron Scattering Center, its high temperature capability, and its high neutron production rate. The disadvantage of tungsten is its moderate neutron absorption cross section. This is overcome in the design by increasing the potential for leakage of high energy neutrons from the tungsten and decoupling the thermal neutrons using the $^3He$ gas.

The tungsten neutron source is in the form of rod bundles that are cooled with low pressure $D_2O$. Each bundle is hexagonal with 91 rods per bundle. The tungsten operates at a peak power density of about 2 MW/l. To provide adequate surface area for cooling, the rods are approximately 0.317 cm in diameter. Recent experiments at Los Alamos have verified the thermal-hydraulic design with both cold and hot flow tests. These tests confirm that even at the peak power conditions, a power increase of a factor of 2.3 is required to reach boiling.

Heat is generated in the target/blanket components because of proton, neutron, and other high-energy particle interactions. Separate heat removal systems have been designed for the tungsten neutron source and the moderator because the heat removal requirements are different in each system. In addition, the moderator acts as the heat sink for the beam entrance window; the target lead; the proton beam backstop region; the $^3He$ in the chamber and in the blanket tubes; and the moderator tank structural components. The coolant systems operate at low temperatures and pressures.

The target/blanket Heat Transport Systems consist of three separate and independent heat transport systems that remove the thermal energy from various components of the target/blanket system under normal and off-normal conditions. These systems are: (1) tungsten heat transport systems, (2) moderator tank heat transport systems, and (3) $^3He$ heat transport systems. Together, these systems remove the thermal loads under normal operations and provide cooling capability for anticipated operational occurrences, design basis events, and selected beyond design basis events for the target/blanket

In the design of these systems, there were several important considerations. These include safety, reliability, operation, maintenance, and the use of existing technology. The target/blanket heat transport systems are based on the "defense-in-depth" principle, and utilize both active and passive cooling systems with redundancy to provide high assurance that important safety functions are achieved. For example, the tungsten and moderator heat transport systems use two 50% loops to remove the energy generated in these systems and to mitigate the effects of large-break loss-of-coolant-accidents (LBLOCAs). Active residual heat removal in each of these systems is provided by two 100% forced-flow cooling systems (only one system is needed to remove the decay heat) that allow small piping sizes and the use of existing nuclear reactor technology. Two independent active residual heat removal systems prevent the complete loss of cooling from a single failure.

In addition, the tungsten and moderator coolant systems have been designed for passive decay heat removal by natural circulation in the event that the active systems are unavailable. The design for natural circulation is provided by establishing sufficient thermal center elevation differences between the primary heat sources, the primary heat exchangers, the secondary heat exchangers, and the water-to-air heat exchangers in the secondary loop. Redundancy in passive decay heat removal is provided because only one loop in natural circulation is required to remove the decay heat. No operator action, valve motion, or active system responses are required to accomplish the transition to natural circulation decay heat removal. Detailed system analyses show that during an unprotected LBLOCA, which is a beyond design basis event, the rod bundles are cooled by natural circulation in the unbroken loop, and remain below 160°C (320°F).

The $^3$He heat transport systems remove and transport the energy generated in the $^3$He in the neutron source assembly and blankets to the moderator in the moderator tank. The use of the moderator as a heat sink for the $^3$He simplifies the overall system design and reduces the costs of separate additional systems.

The target/blanket heat transport systems also provide intermediate loops or barriers between the primary loops and the third loops that dump the heat to the atmosphere to reduce the probability of radionuclide leakage from the plant to the environment. This, combined with the very low decay heat (0.9% of full power) and high temperature materials, provides a significant safety margin.

## SUMMARY OF APT ADVANTAGES AND DISADVANTAGES

Environmental Discriminators. APT has several environmental advantages over nuclear reactor technology for tritium production. Nuclear reactors generate significant annual amounts of high-level and transuranic wastes requiring on-site management, reprocessing and/or storage, and eventual disposal, whereas APT does not generate any such wastes. Elimination of the need to produce enriched uranium will have significant environmental advantage within the nuclear weapons complex. Most of the radioactive waste from APT will result from the target materials. Existing facilities can provide final disposal of these materials as mixed solid waste with acceptable impacts.

Safety Discriminators. APT is inherently safer than a nuclear reactor. The lack of fissile material avoids all criticality concerns, and eliminates reactivity accidents and overpower transients. In the APT concept, the accelerator can be shut down very quickly (approximately 0.1 ms), providing a unique safety advantage. APT has much lower stored energy, decay heat, and radioactive material inventory than a reactor. This will simplify the design and operation of safety systems in the APT compared with a reactor. For the worst conceivable accidents, the source term will be low relative to a reactor producing the same amount of tritium. Nevertheless, the APT design will include engineered safety systems to prevent and mitigate the consequences of potential accidents.

Other Advantages. Development of the APT concept will enhance the United States' leadership position in a new technical field, namely accelerator-driven transmutation technology useful for other applications including nuclear waste disposition, plutonium disposition, isotope production, and materials research.

Disadvantages. A significant concern for APT is the electricity requirement to power the accelerator. The amount of power required is currently available now and in the foreseeable future from the grid at several sites. In more advanced accelerator designs, the potential exists to reduce this power requirement by 20% to 40%. Also, lower tritium production requirements reduce the power demand, making the accelerator option more attractive.

## CONCLUSION

The APT concept is a new tritium-supply option that does not require the use of nuclear reactors. The Los Alamos $^3$He target/blanket concept incorporates a water-cooled tungsten neutron source, a lead neutron multiplier, and a heavy water moderator. Helium-3 gas circulating through the system creates tritium, and reduces the parasitic capture in the tungsten. The design makes use of existing spallation neutron source technology, and proven design concepts.

The thermal-hydraulic design of the neutron source has been verified with experiments showing a significant margin of safety. The APT is a low temperature and pressure system, making the release of radionuclides a low probability in the event of an accident. Inherent safety features include the low decay heat, absence of criticality concerns and overpower transients, and low-level waste production. The conservative coolant system design provides cooling during all potential design basis and beyond design basis events. Because of safety and environmental advantages, the APT offers a low impact and cost competitive approach compared with reactors for tritium production.

## REFERENCES

[1] Papay, L.T. et al, "Accelerator Production of Tritium (APT)," Energy Research Advisory Board Report, DOE/S-0074 (February 1990).

[2] Drell, S. et al, JASON Report, JSR-92-310 (January 1992).