MEDICAL ISOTOPE PRODUCTION WITH THE ACCELERATOR PRODUCTION OF TRITIUM (APT) FACILITY

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1 INTRODUCTION

In order to meet US tritium needs to maintain the nuclear weapons deterrent, the Department of Energy (DOE) is pursuing a dual track program to provide a new tritium source. A record of decision is planned for late in 1998 to select either the Accelerator Production of Tritium (APT) or the Commercial Light Water Reactor (CLWR) as the technology for new tritium production in the next century. To support this decision, an APT Project was undertaken to develop an accelerator design capable of producing 3 kg of tritium per year by 2007 (START I requirements). The Los Alamos National Laboratory (LANL) was selected to lead this effort with Burns and Roe Enterprises, Inc. (BREI) / General Atomics (GA) as the prime contractor for design, construction, and commissioning of the facility. If chosen in the downselect, the facility will be built at the Savannah River Site (SRS) and operated by the SRS Maintainance and Operations (M&O) contractor, the Westinghouse Savannah River Company (WSRC), with long-term technology support from LANL. These three organizations (LANL, BREI/GA, and WSRC) are working together under the direction of the APT National Project Office which reports directly to the DOE Office of Accelerator Production which has program authority and responsibility for the APT Project.

2 DESCRIPTION OF APT

The APT, which is shown schematically in Figure 1, is made up of four major subsystems which are described briefly below[1].

2.1 Accelerator System

The Accelerator System consists of the following subsystems:

- Proton injector to develop and maintain a continuous 100-mA current.
- Radio Frequency Quadrupole (RFQ) to focus and accelerate the proton beam to 7 MeV (kinetic energy)
- Coupled-cavity Linac (CCL) to accelerate the proton beam to 211 MeV.
- Superconducting Linac (SCL) to accelerate the proton beam to its final energy of 1700MeV. The design is modular so that the portion of the accelerator up to 1030 MeV can be completed to produce 1.5 kg/yr of tritium and then a decision can be made as late as 2002 to add the last section if the START I production level is still required.

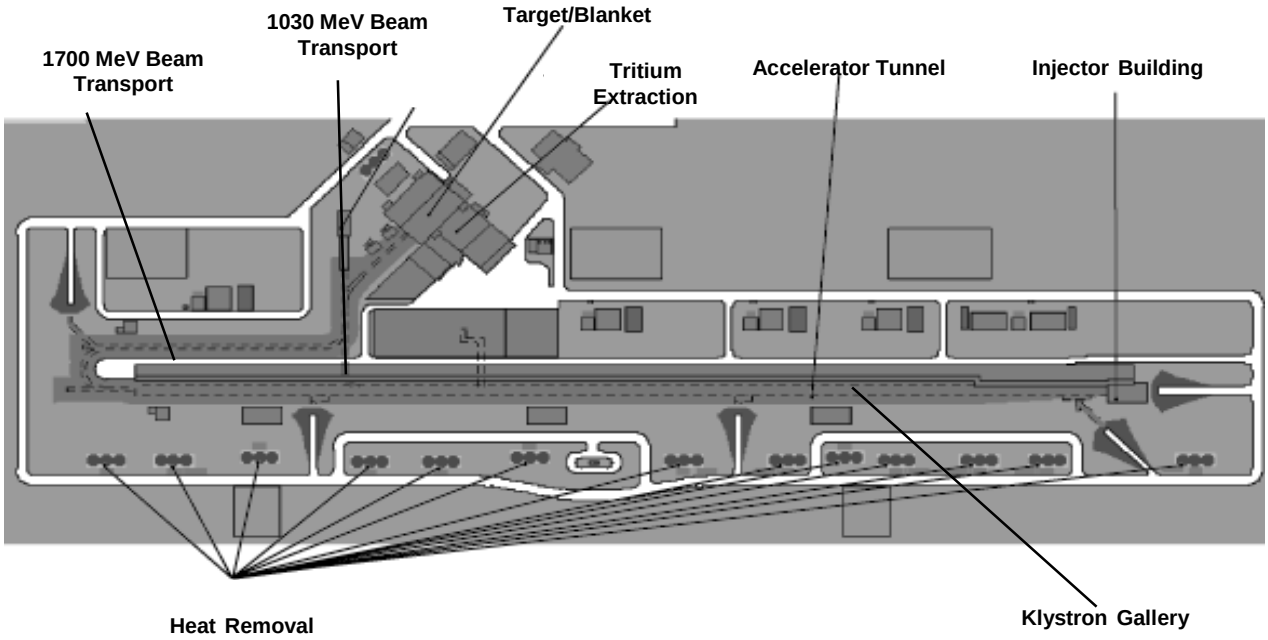

Fig. 1 APT Plant Layout

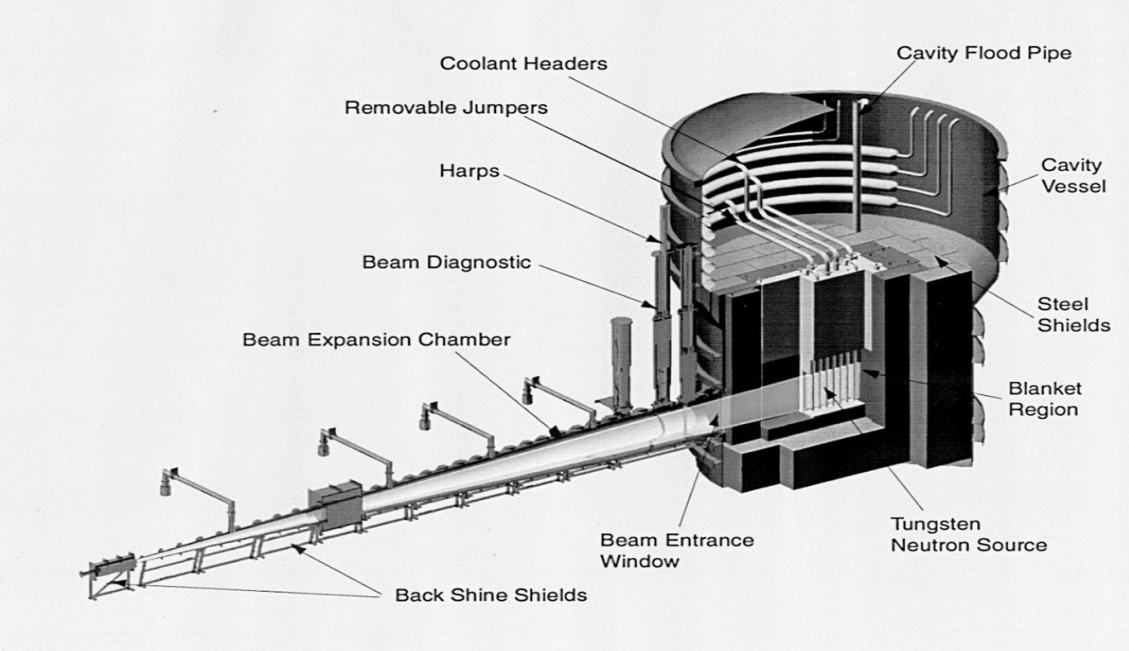

Fig. 2 APT Target/Blanket

2.2 Target/Blanket (T/B) System

The Accelerator System provides a proton beam that is expanded and directed to a T/B assembly shown in Figure 2. The T/B assembly consists of a tungsten clad target in which neutrons are produced by spallation surrounded by a blanket in which additional neutrons are produced in lead. The neutrons are thermalized by collisions in the lead and in light-water and are subsequently captured in He-3 to produce tritium.

2.3 Tritium Separation Facility (TSF)

The TSF operates by extracting tritium from a tritium, hydrogen, and He-3 mixture returned from the T/B System in a recirculating He-3 loop. The He-3, hydrogen and tritium mixture also contains impurities such as water, methane, ammonia and small quantities of radioactive materials. Hydrogen isotopes are separated from the He-3 and sent to an Isotope Separation System where the tritium is separated from hydrogen. The He-3 is purified and recycled to the T/B assembly.

2.4 Balance of Plant (BOP) Systems

The BOP Systems support the integrated operation of the accelerator, T/B, and TSF, and provide the facility buildings that house them. The BOP System designs are driven by the required electric power input, the generated waste heat to be removed throughout each facility and the need to handle radioactive materials remotely.

3 MEDICAL ISOTOPE PRODUCTION WITH APT

The APT T/B will produce a high energy, high flux proton and neutron irradiation environment that is unique in the field of isotope production[2]. In addition to converting He-3 to tritium, it can be used to create isotopes for medical applications. Although the primary mission of the APT is to create tritium for the nuclear weapons deterrent, an ancillary isotope production mission is possible without significantly impacting tritium production. Because of the unique irradiation environment, and the large volume of space available, the APT has the potential to provide a significant source of research, diagnostic, and therapeutic isotopes to the medical community.

The capability for the irradiation of medical isotope targets is feasible within the scope of the T/B material surveillance program. The centerpiece of this program is a “rabbit” system that allows the insertion and removal of material surveillance coupons directly into several (up to seven) locations within the T/B assembly. Double wall tubes with a continuous flow of water provide a cooled environment for small (approximately 1.4 cm diameter by 6.3 cm long) target capsules. These capsules are moved in and out of the irradiation positions using hydraulic pressure. The design of the tungsten neutron source in the APT T/B allows for a large volume of potential irradiation positions directly in the high proton and neutron flux regions.

A small hot cell located nearby in an adjoining room is used to remove the capsules from the ”rabbit” tubes and load them into shipping casks for transfer to a processing facility. Location of a private processing facility at the site boundary is a possibility. As an option to shipping casks, it is also possible to use pneumatic transfer tubes from the hot cell to the processing facility to speed the transfer.

Radioisotopes production in the APT target/blanket was analyzed to determine production rates and radiopurity of several isotopes that are of interest to the medical community. These include Cu-67, Ge-68, Sr-82, In-111, Re-186, Sm-153, Pd-103, P-32, Sc-47, and Ga-67. The isotopes were produced by nuclear spallation of natural (non-enriched) target materials by high-energy protons and neutrons. Significant production rates, high radiopurity and specific activity were achieved for most of the isotopes. In addition, the calculations showed that for 11 liters of target volume placed directly in the proton beam the decrease in tritium production was less than 2%.

4 THE POTENTIAL IMPACT OF APT ON MEDICAL ISOTOPE NEEDS

Leaders of the biomedical science community met recently in Dallas[3] to discuss the importance of developing an adequate supply of radionuclides to support clinical practice, research, education and training, and new treatments. The group acknowledged that the present supply of radionuclides is insufficient to meet current and projected future needs.

As an example, the recent development of specific delivery agents such as monoclonal antibodies that can target specific tumor cells and carry radiotherapeutic materials to those cells has led to a major advance in radiotherapy. Other healthcare areas with great potential include bone pain palliation, brachytherapy applications in inoperable tumors, nuclear cardiology and positron emission tomography (PET) procedures. For these to become available in routine practice there must be a supply of reasonably priced, high purity radionuclides

The proposed APT facility has the potential to supply the much-needed radionuclides. Although the charter for APT does not include radionuclide production, the facility has the potential to make a significant contribution with little impact on tritium production. The biomedical community leaders learned of preliminary calculations of production yields, specific activities and radionuclidic purities for the nuclides listed above. This wide variety is possible from APT because, unlike reactor facilities, both energetic protons and neutrons are available in quantity.

Working as a team, the group developed the following statement in support of including radionuclide production in the APT charter:

“The APT facility will provide a unique resource for the production of substantial quantities of high specific activity radionuclides resulting in enormous scientific, research and education opportunities. These radionuclides will be especially useful in advancing healthcare for diagnosis and in the rapidly growing area of radionuclide therapy. We therefore support an expansion of the APT project charter to include designing into a biomedical radionuclide production capability. This initiative should not draw from existing radioactive materials research or production programs, as it is fundamental to the overall DOE mission, extending rather than replacing existing efforts, with downstream benefits which are vast for the nation.”

There was general agreement within the group that any new opportunity for radionuclide production and development gained by construction of the APT facility should be jointly pursued by the National Institutes of Health (NIH), DOE, and the Department of Defense (DOD), with NIH being the lead agency.

5 CONCLUSIONS

The APT will produce a high energy, high flux proton and neutron irradiation environment that is unique. Medical isotope production in APT has the potential to provide downstream benefits which have been judged by the biomedical community to be “vast for the nation”. Although the primary mission of the APT is tritium production, significant medical isotope production is possible with little impact on tritium production.

REFERENCES

1. “Accelerator Production of Tritium Conceptual Design Report”, LA-UR-96-4847 (March, 1997).
2. Cappiello, M., E. Pitcher, H. O’Brien, “APT Design Overview and Isotope Production Capability”, LA-UR-98-1793, (May, 1998).
3. “Proceedings of the Medical Isotope Work-shop”, Medical University of South Carolina, Charleston, S.C. (June, 1998).