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Technology Development for the Accelerator Production of Tritium

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1. INTRODUCTION

The Accelerator Production of Tritium (APT) Core Technology Plan (CTP) [1] delineates a program of Engineering Development and Demonstration (ED&D) activities that support design and construction of the APT facility. The goal of the ED&D programs is to provide critical data necessary for the APT to be built on schedule, based on a demonstrated technical foundation to avoid costly over design.

On December 22, 1998, Secretary of Energy Bill Richardson announced that commercial light water reactor program will be the primary tritium supply technology for the United States. The Secretary designated the APT as the "backup" technology for tritium supply. As the tritium supply backup, APT will prepare a preliminary design package for the plant, and will complete the essential technology development to support that design. A reduced ED&D program is therefore still necessary. Details of the modified program scope and schedule are still being evaluated by the Project.

The ED&D activities are driven by formal, articulated Design Data Needs (DDN). The DDNs are identified by the APT design team and transmitted to the APT Technology Office (TPO) where these DDNs are evaluated and prioritized. The evaluation criteria include several factors:

- Can reasonable extrapolations be made from existing data?
- Is a new measurement needed?
- Will it be possible to provide the data within the budget and time available?

In some cases the result of this evaluation is to require a more conservative plant design to compensate for the unavailability of supporting data. When appropriate, a test program is then undertaken to provide the necessary data. This formalized, systems-engineering approach to evaluating the DDNs has led to the establishment of an extensive Engineering Development program aimed at reducing technical as well as cost and schedule uncertainties.

2. ENGINEERING DESIGN AND DEVELOPMENT (ED&D) PROCESS

A systems engineering approach, illustrated in Figure 1, is used to identify and resolve cost, scope, and technical risk issues related to design requirements

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Figure 1. APT design approach.

APT program objectives are translated into goals, requirements, and functions that must be met by the design. During the design process, design data needs (DDN) are identified by the relevant design leaders whenever the existing data base are insufficient to fully support a design. At that time, an assumption has to be made that is then confirmed or modified based on the outcome of the ED&D program. If the completed design meets performance goals and adequate performance is achieved, the design process is complete. If the outcome of the ED&D activity does not support assumptions made earlier that were required to proceed with the design, the design must be modified and new design data needs must be formulated and addressed.

There are four major areas where ED&D activities are underway:

- 1) The Low Energy Demonstration Accelerator (LEDA), where the principal activity is to fabricate and operate a linac that produces a high quality, ~ 20 MeV, 100 mA, continuous proton beam.
- 2) High-energy RF linac technology, to develop and test component prototypes for normal conducting and superconducting high-energy linac structures (cavities, cryomodules, power couplers, etc.). Included are activities in development and enhancement of RF power systems and high-energy beam transport components.
- 3) Target/Blanket performance and Materials Studies, including measurements of n/p and T/p; radiation damage effects from high energy, high-flux proton and neutron irradiation; and radiation transport-code data development and/or enhancement.

- 4) Tritium Separation Facility (TSF) studies, which are primarily aimed at determining tritium-processing efficiencies under conditions expected in the APT plant.

Key ED&D activities identified by the above process include:

- Demonstrate 100-mA proton beam @ 100% duty cycle through the LEDA Radio Frequency Quadrupole (RFQ)
- Demonstrate 100-mA proton beam @ 100% duty cycle through a Coupled Cavity Drift Tube Linac (CCDTL) section to a final energy of ~ 10 MeV
- Determine Proton/neutron irradiation effects on T/B materials
- Develop and/or improve Radiation transport codes and nuclear data libraries
- Confirm and develop engineering design data for separating tritium from ^3He
- Confirm five-cell $\beta=0.64$ superconducting cavity manufacturability and cavity performance; fabricate and test a cryomodule for the $\beta=0.64$ cavities
- Confirm manufacturability and performance of 210-kW coupler and RF window assembly for SC cavities
- Determine performance, reliability, and failure modes of new high-energy beam transport (HEBT) raster expander prototype
- Determine performance and manufacturability of key RF distribution components, including waveguide switch, phase shifter, and waveguide valve
- Determine performance and operability of beam diagnostics for measuring transverse intensity distribution in linac and HEBT. This includes flying wire profile diagnostic and gas fluorescence diagnostic

3. CONCLUSIONS

The ED&D described in the previous sections will provide technical data on the performance of all critical components of the APT facility. Results will be compared with requirements given in the Preliminary Design Package and the System Design Descriptions. These data will be utilized to establish confidence in the design, in the predicted plant availability, and to reduce cost when the data warrants design simplification. Thus, if at a later date it is decided to build the APT plant, this will allow the facility to be built correctly the first time, on schedule, without recourse to costly over-design. It should also speed the commissioning process and ensure that full capacity production is attained on schedule.

The planning process used to develop the elements of the CTP has been described. This program is expected to provide the needed data within the projected schedule and resources. Specific schedules for delivery of data and descriptions of the needed data are contained in the Design Data Needs. The total cost of the ED&D program is on the order of 10% of the project cost and is considered a very good investment. The CTP will be judged a success when the data produced warrants design simplifications that allow reduction of design margins and cost. Present day contingency estimates for the project greatly exceed 10% and it is expected that CTP data will warrant reduction of those contingencies by more than the cost of data production. Even results that do not simplify the design or reduce cost are considered very important and successful if they firmly establish performance, so that the design is validated and the cost certified within the existing contingencies. Nevertheless, there is technical risk in some APT components that warrant careful attention. It is to be expected that some results could be disappointing and may require design changes that increase cost moderately beyond the existing contingencies or cause moderate schedule slips.

With the Department of Energy's selection of the APT as the backup tritium supply option, the decision was made to carry the APT development to the stage that a Preliminary Design Package (PDP) could be generated. In order to accomplish an adequate PDP the technology development described in the CTP must be completed to support the preliminary design. While that means that not all of the ED&D activities will be completed, the essential technologies will be developed and tested to support the PDP. The CTP will be revised to reflect the changing scope required to support the PDP. The development of LEDA and the superconducting technologies continue to be major activities within the ED&D program. The current schedule calls for the ED&D activities to be completed by the end of Fiscal Year 2002.

4. REFERENCES

1. APT Core Technology Plan, Los Alamos National Laboratory Report APT-CTP-002, August 2, 1997