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Accelerator Technology for the Los Alamos ATW System*

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The Los Alamos concept for accelerator transmutation of nuclear waste (ATW) employs a high-power proton linear accelerator to generate intense fluxes of thermal neutrons (> 10^{16} n/cm^2-s) through spallation on a lead-bismuth target. The nominal beam energy for an ATW accelerator is 1.6 GeV, with average current requirements ranging from 250 mA to 30 mA, depending on application specifics.

A recent study of accelerator production of tritium (APT) led to the development of a detailed point design for a 1.6 GeV, 250 mA cw proton linac.[1] The accelerator design was reviewed by the Energy Research Advisory Board (ERAB) and found to be technically sound.[2] The Panel concluded that linac of this power level could now be implemented within the existing technology base, given an adequate component development program and an integrated engineering demonstration of the front end.

The APT linac can be taken as representing the upper bound of ATW power requirements. Its design benefits from a decade of advances in the technology of high-current ion linacs, stimulated partly by the demanding requirements of the SDI Neutral Particle Beam program. Figure 1 shows the reference APT accelerator configuration, which consists of a 2-km-long, 700-MHz, coupled-cavity linac (CCL), injected at 20 MeV by a funneled beam-launching system. The beam launcher is made up of two 100-keV injectors, two 350-MHz radiofrequency quadrupoles (RFQs) providing 125-mA proton outputs at 2.5 MeV, and two 350-MHz DTLs accelerating beams to 20 MeV. Table 1 summarizes the principal accelerator parameters, and reference 3 provides design details.

Dominant technical concerns for a high-power proton linac are beam-loss to the accelerating structures, rf system efficiency and capital costs, and reliability and longevity of components. The APT design study addressed these issues in detail, and included end-to-end beam simulations, a machine configuration layout, preliminary engineering of critical components, selection of components to match availability, an analysis of off-normal conditions and beam safety, and a cost/optimization model to confirm parameter choices. Although the average current in the APT CCL is very large, 250 times that of the highest power existing proton linac (LAMPF), the charge per bunch is only 4.5 times greater in APT than in the LAMPF CCL, because the duty factor is 1.0 and every rf bucket contains protons. Extremely low beam losses in the CCL are assured by designing the acceptance to be much larger than the beam emittance in both the transverse and longitudinal phase planes. The ratio of accelerating-structure aperture to rms beam size in the APT CCL ranges from 15 to 20.

The average proton current requirement for an ATW that could burn the technetium in the accumulated defense wastes within 30 years is about 55 mA, a factor of 5 lower than APT. To meet an aggressive implementation schedule and minimize technical risks, the best approach to such a machine might be a funneled cw linac, instead of a more efficient pulsed linac. The CCL would then have the same charge per bunch as in LAMPF, so the beam dynamics would be within a well characterized regime. Beam losses and other performance factors could be predicted with high confidence, and technical uncertainties would be minimal.

For an energy production application, the accelerator design would focus on minimizing capital and operating costs and maximizing electrical efficiency. With this emphasis a pulsed RF linac is the appropriate solution, with the peak beam current as high as practical. Using the same 250-mA peak proton current as in the APT design, RF efficiencies could be 80% or higher. For a 30-mA output, the linac duty factor would be 12%, and the total ac power requirement for the CCL would be about 100 MW.

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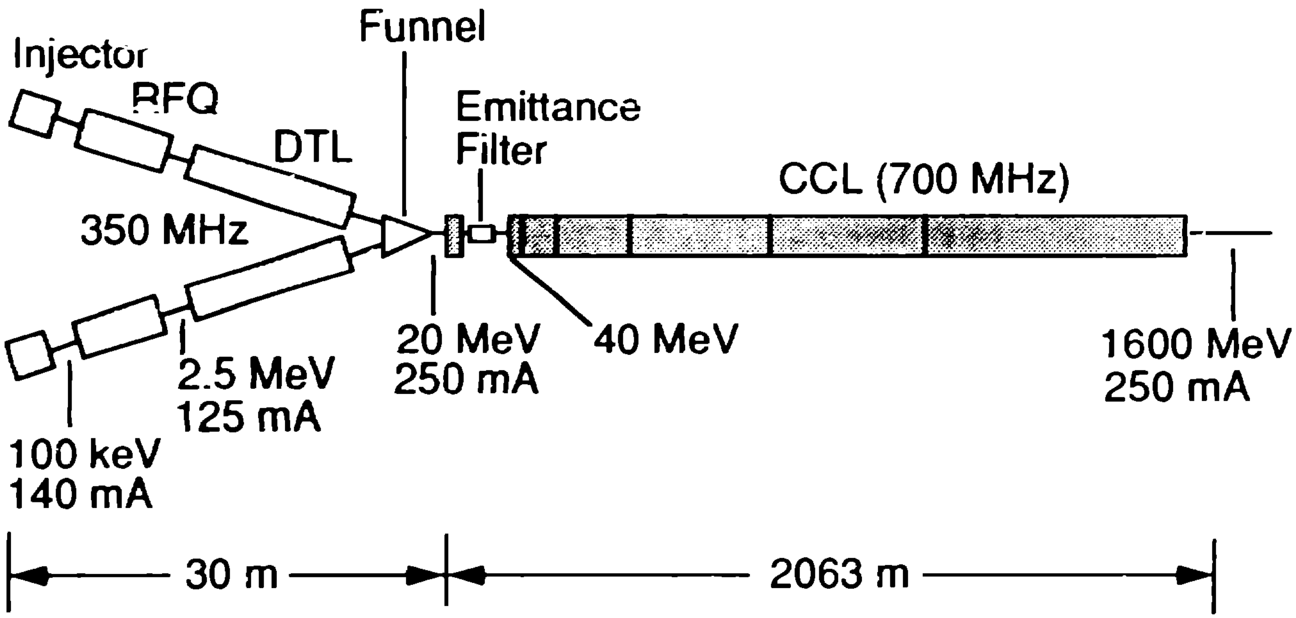

Fig. 1. Reference APT accelerator configuration

Table I
APT Linac Parameters

	DTL	CCL
Energy (MeV)	2.5 to 20	20 to 1600
Beam current (mA)	125	250
Frequency (MHz)	350	700
Accelerating structure	$2\beta\lambda$	Side-coupled
Length (m)	11.3	2063
Radial aperture (cm)	0.8	1.4 to 3.5
Accel. gradient (MV/m)	1.1 to 3.1	1.0 (lattice avg)
Copper power (MW)	1.3 (x2)	115
Beam power (MW)	2.2 (x2)	395
Beam loading	0.56	0.78
Number of klystrons	5 (x2)	470
Emittance (n-rms)		
Trans. (π mm-mrad)	0.27 to 0.58	0.61 to 0.68
Long. (10^{-6} eV·sec)	1.6 to 3.0	3.0 to 4.4