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PLT AND ISX NEUTRAL BEAM INJECTORS*

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Six high power (40 keV - 60 A) injection systems, four for PLT (Princeton Plasma Physics Laboratory) and two for ISX (Oak Ridge National Laboratory) tokamaks, have been developed, fabricated, and operated. Each injector delivers 750 kW (1000 kW) of H (D) neutral power to the tokamak plasma. An in-depth system parameter study has revealed unique features: high atomic yield (∿85%), improved ion optics due to a preacceleration technique, near steady-state operation (up to 500 msec), and a possible technique to control species yield. Routine operation includes high duty cycle (∿10%), long filament lifetime (several months), high arc efficiency, and the reliability necessary for application on a fusion device. The program status and injection parameters will be discussed.

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The properties of a 40-kV, 60-A injection system are described. Major components of this injector are (1) a plasma generator, (2) ion extractor, (3) gas cell for electron capture with bending magnet to remove the unneutralized beam, and (4) a pumping system to remove the slow neutrals (see Fig. 1).

A modified duoPIGatron[1] is utilized as the ion source. It has an arc efficiency of 1.1 A/kW extracted beam power. The extracted ion beam is composed of 85 ± 5% protons over the entire parameter range considered. This is in agreement with independent measurements made by a user.[2] Gas utilization was measured to be 11 Torr liters/sec, or a nucleon efficiency of 50% assuming an ion composition of 85% monatomic, 10% diatomic, and 5% triatomic; the gas is all diatomic. Of this gas flow rate only half was fed directly into the cathode plasma and MacKenzie plasma, while the other half was fed directly into the neutralizer cell. Therefore, a second interpretation would allow for a flow rate corresponding to a nucleon gas efficiency of somewhere between 60 and 80%.

Cooling water temperature and flow measurements are provided for all shots for virtually all surfaces likely to suffer beam impingement. A PDP-11/40 computer was utilized to provide immediate information on power deposition. Ions are extracted from a cylindrical bore aperture accelerator using displaced aperture steering[3] and transmitted through a port subtending 1.4° x 1.8° half angle from the source.

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Under normal operating conditions, the transmission through this port at optimum perveance (6.2 μperv) was about 0.40 + 0.02 of the power used to accelerate the beam. (See Fig. 1.) At this perveance about 0.15 I × V power hit the gas cell. The gas cell subtends a half angle of greater than 6° from the center of the extraction electrodes.

Utilizing a preacceleration potential[4] applied between the second anode and the emission electrode, the beam transmission to the target increased to 0.52 ± 0.03 I × V at an optimum perveance of 5.5 μ perv. (See Fig. 2.) For this perveance 0.13 I × V power hit the gas cell. Preliminary measurements of the beam intensity distribution suggest that the divergence of the half maximum is 1.0 ± .2°. Both distribution and average divergence angle are required to specify transmission. Clearly the beam distribution is far from Gaussian. Preliminary measurements of transmission to the target of a high perveance, high transparency, pseudo-Pierce emission electrode suggest that 0.52 I × V of the beam reaches the target without any applied preacceleration potential.

Injection solid angles associated with the PLT and ISX experiments are less stringent than that used for the previously mentioned test facility data. Four injection systems at 750 kW of hydrogen per beam line will be injected into PLT, and a two beam line system providing 900 kW per beam line will heat the ISX plasma.

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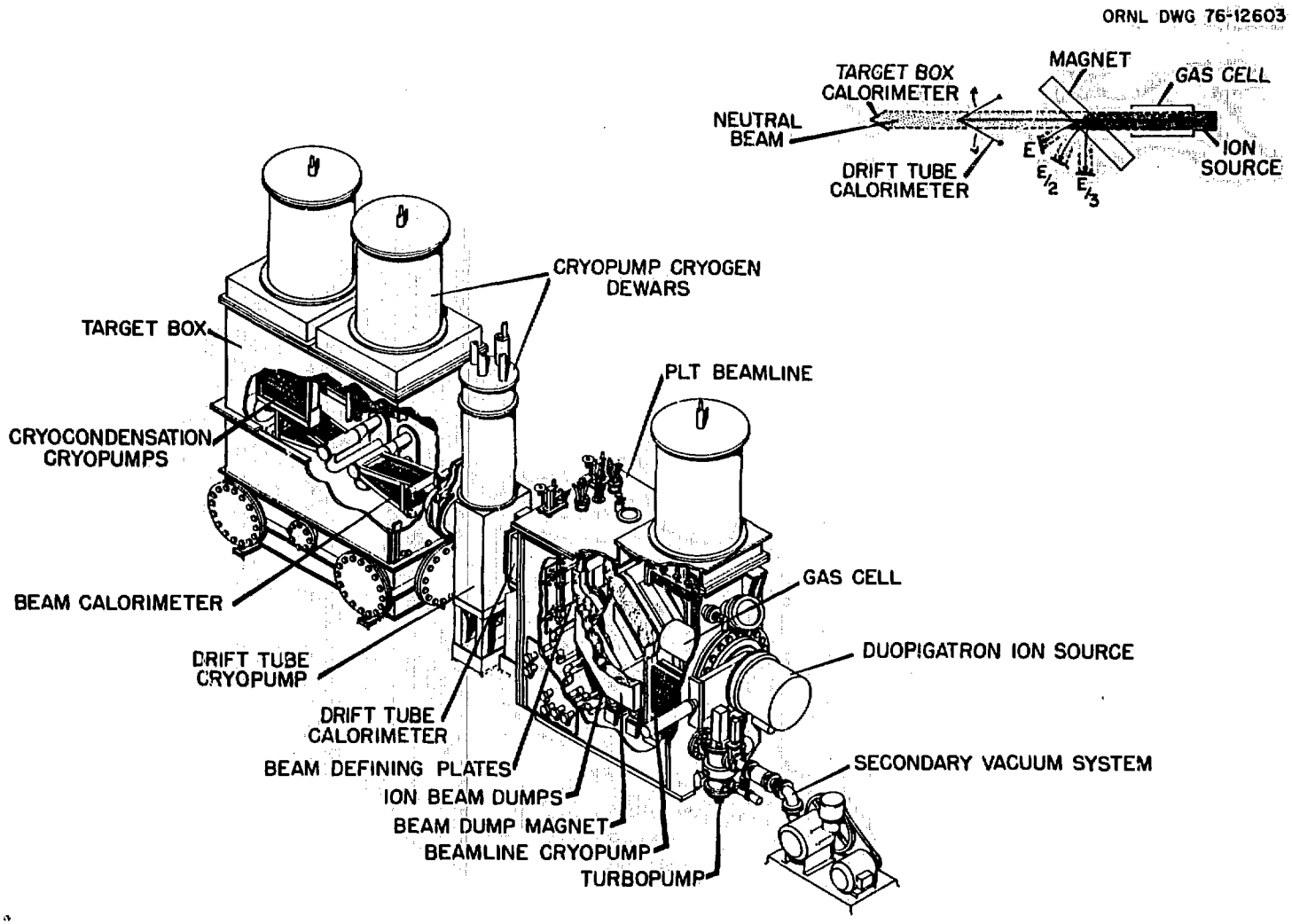

Fig. 1. ORNL/PLT Beamline and ORNL Test Facility Target Box

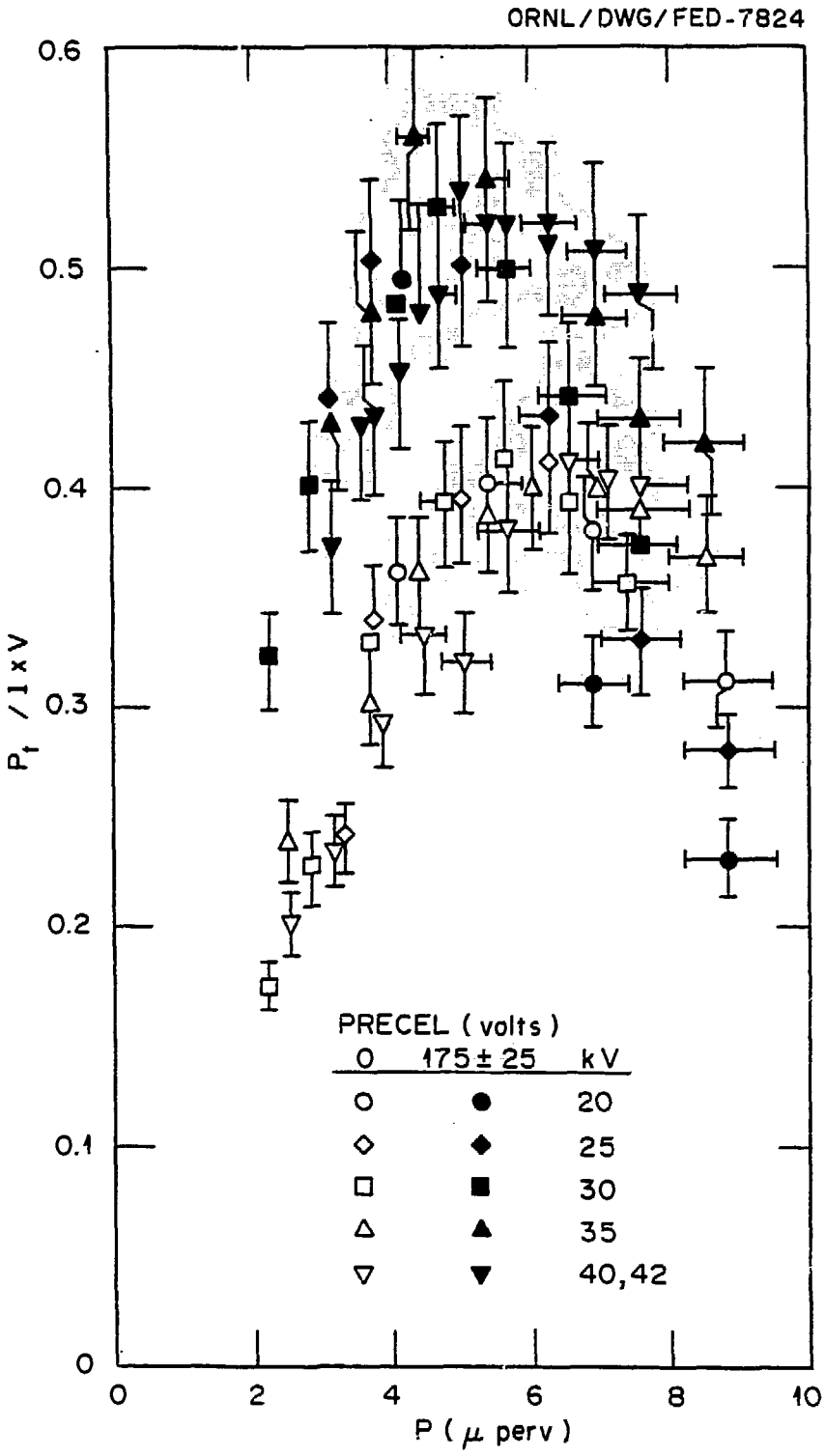

Fig. 2. Power on Target (as a fraction of I × V power) vs. Beam Perveance