NPBTS--OVERVIEW AND CAPABILITIES*

C. L. Fink, A. H. Novick, F. O. Bellinger, F. R. Brumwell,
C. T. Roche, M. Rosing, T. J. Yule, and C. R. Hummer
Argonne National Laboratory
9700 S. Cass Avenue, EP/207
Argonne, IL 60439

Abstract

The Neutral Particle Beam Test Stand provides a versatile facility for scientific and engineering studies on large-diameter, low-divergence neutral and charged particle beams. It consists of a linac that accelerates H^- atoms to 50 MeV at 10-12 mA and two experimental areas. Typical pulse widths are 30-150 μs at repetition rates of 0.5-30 Hz. A small rms-emittance is achieved by using a series of collimators to shave the 1.6 π-mm-mr emittance measured at the output of the linac. Typical current in the experimental areas is 500-600 μA. Experimental area A has been used to study the physics of beam diagnostics and foil neutralization and to measure (p,n) reaction cross sections. Experimental area B has a series of quadrupole objectives built by Los Alamos National Laboratory to reduce beam divergence. Typical beam characteristics are rms diameters of 10-20 cm and a full-angle divergence (rms) of 12-24 μr. The facility contains a wide variety of diagnostics including segmented Faraday cups, beam toroids, stripline beam-position monitors, and wire scanners. In addition, several new diagnostic systems for large-diameter beams have been developed by Argonne and Los Alamos.

Introduction

The Neutral Particle Beam Test Stand (NPBTS) at Argonne National Laboratory was developed to study physics and engineering issues of magnetic optics and beams diagnostics for large-diameter, low-divergence H^-, H^0, or H^+ beams. The facility uses the linac of the Intense Pulse Neutron Source (IPNS) Facility [1] to provide a 50-MeV H^- beam. Since the emittance at the output of the linac is too large, collimators are positioned in the transport line prior to the experimental area to reduce the linac emittance. The optical tune of the transport line and the collimator locations within the transport line are chosen such that the edges of the collimators define an approximately elliptical area in x and y phase space. The beam from the transport line then enters a series of quadrupoles that produces an expanded beam with low divergence.

The facility is funded by the United States Army Strategic Defense Command (USASDC) for experimental research in support of the Neutral Particle Beam (NPB) Program. The transport lines were designed and constructed by Argonne National Laboratory (ANL) while Los Alamos National Laboratory (LANL) was responsible for the magnetic optics downstream of the transport line as well as the magnet diagnostics [2].

Facility Overview

Figure 1 shows the layout of the NPBTS. The 50-MeV H^- beam from the IPNS linac passes through a matching transport line (Figure 2) before being bent into one of the two beamlines that transport and shape the beam for use in experimental area A or B. The matching transport line contains the first collimator (C1) used to reduce linac beam emittance and a two-cavity debuncher to reduce the energy spread of the beam.

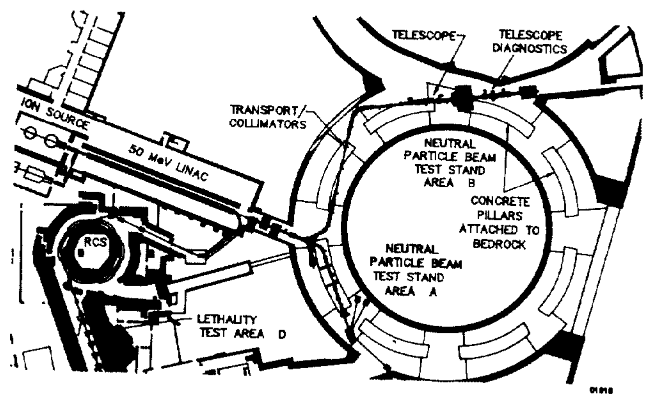

Figure 1: Layout of the NPBTS Facility.

The two transport lines and the associated experimental areas start after the switching magnet (BM-503) and are labeled A and B. Because of flexible beam control in transport line B and because of the large-bore telescope, B has become the primary experimental area at the present time. Experimental area A, however, was extensively used in the early operation of the facility to study basic physics issues in beam diagnostics, foil neutralization, and (p,n) reaction cross sections.

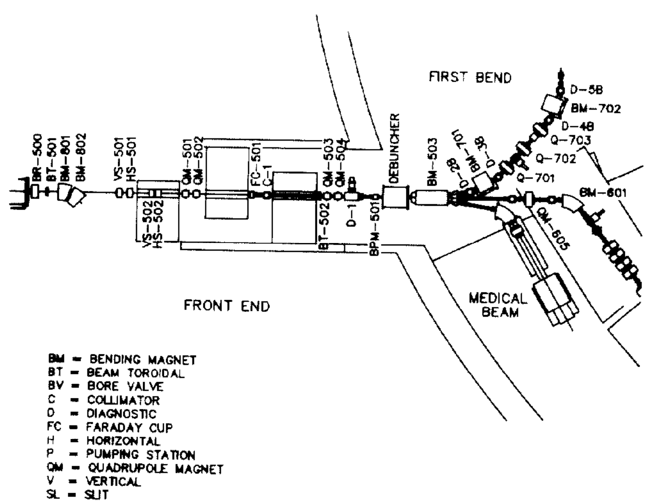

Figure 2: Sketch of the transport line between the linac and the switching magnet BM-503 used to direct the beam into transport lines A or B.

Experimental Area A

Experimental area A (Figure 3) was developed to provide basic physics information on beam diagnostics and high-energy neutralization devices. As such, transport line A required only a limited ability to control beam emittance and/or Twiss parameters.

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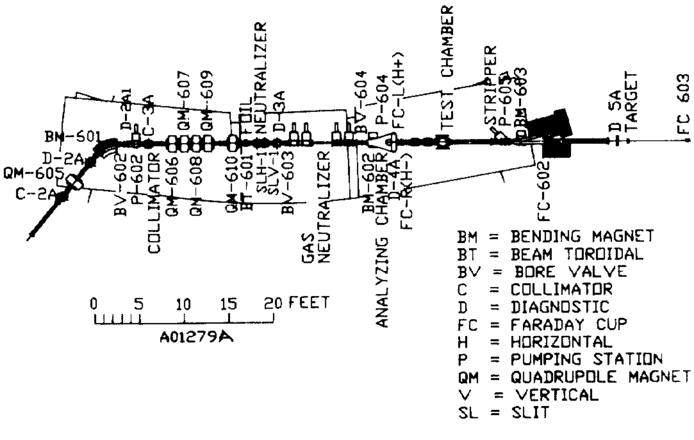

Figure 3: Layout of the end of transport line A and experimental area A.

The basic design philosophy in line A is to produce a waist at collimator C1 and to subsequently image the C1 waist at collimator C3-A. Since C3-A occurs after a 40° bending magnet, the width of C3-A controls beam dispersion. The five quadrupoles after the bend are used to produce a small-diameter parallel beam or a focused beam at various downstream locations. Control of beam intensity is accomplished using collimators C1 and C2-A. Typical beam parameters are currents of 10 nA to 5 mA and beam diameters of 2 to 4 cm. The experimental area has provision for both gas and foil neutralizers. The analyzing magnet (BM-602) directs the H^-, H^0, and H^+ beams from the neutralizer into separate Faraday cups for determining neutralization efficiencies. There are also several experimental chambers for the testing of beam diagnostics and for measuring neutron spectra from (p,n) reactions.

Experimental Area B

Experimental area B (Figure 4) is used to study the magnetic optics required to produce large-diameter beams with low divergence and to develop diagnostics to characterize these beams. The beam reaches the experimental area by means of a long transport line (Figure 4) that contains two achromatic bends, a long drift section located between the bends, and four matching quadrupoles after the second bend. The collimators (C3-B through C5-B) are located in the drift section and are used along with C1 to reduce the linac emittance. The beam tune in the transport line is designed [3] so that the phase advance at each collimator results in the edges of the collimators forming an approximate ellipse in phase-space. The four quadrupoles located after the second achromatic bend are used to match the beam to the telescope.

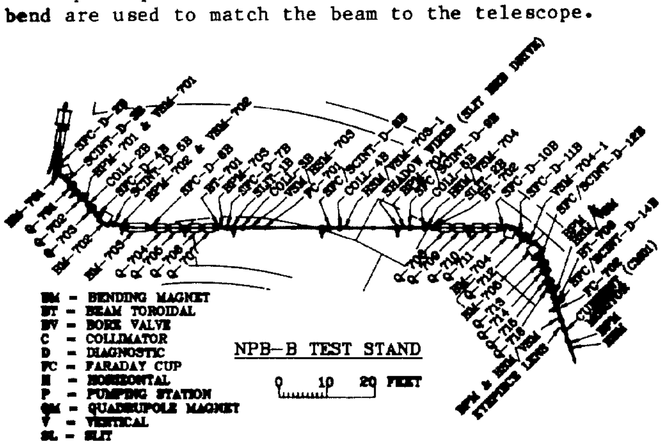

Figure 4: Layout of transport line B.

Experimental area B (Figure 5) currently has a series of quadrupoles to reduce beam divergence [4] (Figure 6), a magnet diagnostic using a Hartmann mask [5] (Figure 7), and an experimental area to test various beam diagnostics. Typical operational beam parameters are a 5-10 cm rms-radius with full-angle rms-divergences of 12 to 20 microradians in the center of the beam. Located inside the objective lens of the telescope are octupole and sextupole correctors made from cosine-wound printed circuit boards [6].

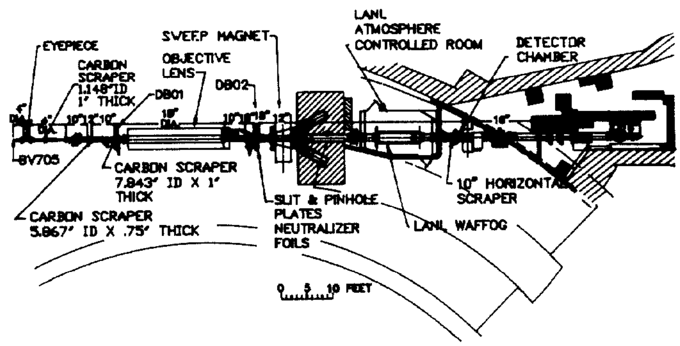

Figure 5: Layout of experimental area B.

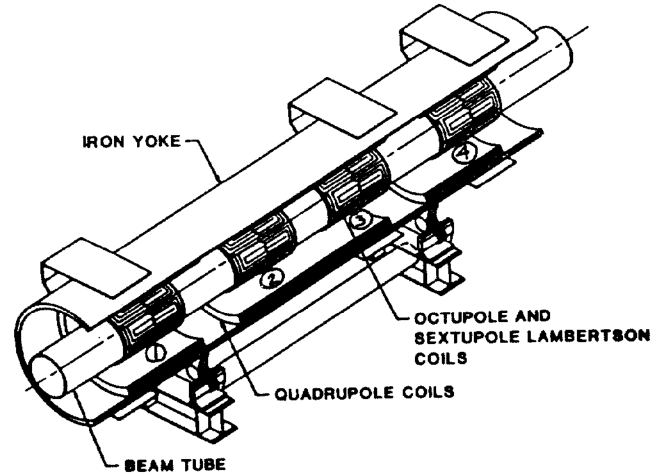

Figure 6: Sketch of the large-bore telescope.

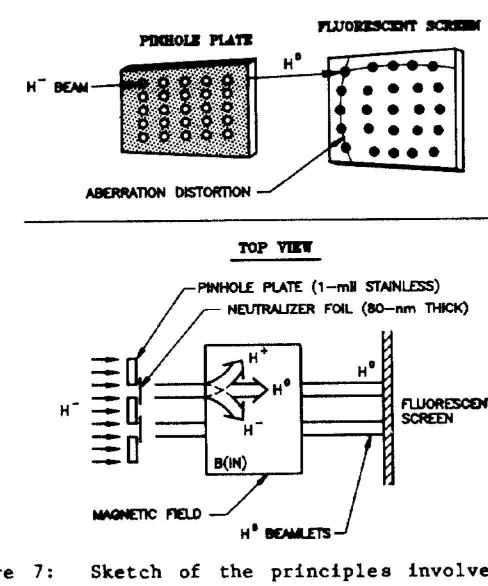

Figure 7: Sketch of the principles involved in the telescope diagnostic system.

Facility Parameters

The two-dimensional phase-space distribution has been measured [7] at the exit of the linac using a moving slit and a segmented Faraday cup (SFC). Figure 8 shows a typical result for the vertical direction. Typical laboratory rms-emittance values (39% of the beam) are 1.8 π-mm-mr (x and y) for a linac current of 10-12 mA and a pulse width of 120 μs.

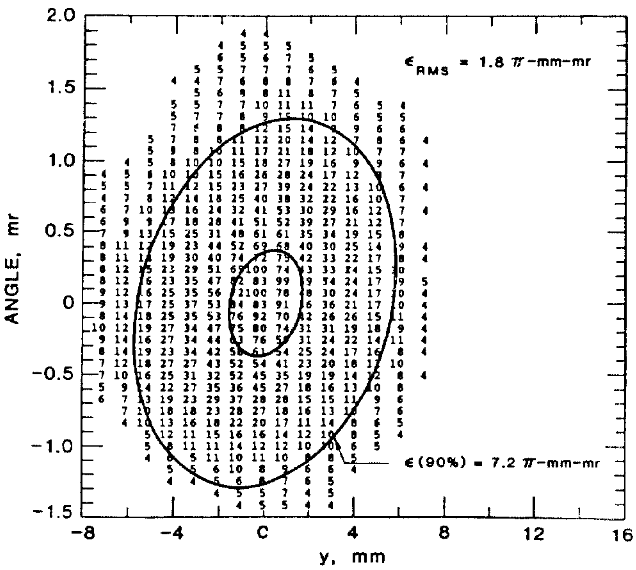

Figure 8: Two-dimensional phase-space distribution measured at the exit of the linac.

The two-dimensional phase-space distribution has also been measured after the last collimator C5-B (at moving slit SL-2) and before the second bend. This measurement is used to determine the emittance going into experimental area B.

The momentum spread of the beam was measured by operating the first bend in a dispersive rather than an achromatic mode. Typical values of $\Delta P/P$ are 5×10^{-4} with the debuncher off and 2×10^{-4} with the debuncher on.

Facility Diagnostics

The facility has a wide range of diagnostics available for tuning the transport line and for measuring beam conditions in the experimental area. SFCs [8] are used to provide vertical and horizontal profiles of the beam within the transport line. Recently, a scintillator screen and a camera system have been added to each of the SFC diagnostic stations to allow simultaneous collection of two-dimensional information on beam profiles.

A series of five directional-coupler (stripline) beam position monitors (BPMs) [9] are located in the transport line between the linac and experimental area B. These stripline devices were designed by LANL and are being used to monitor beam jitter,

The principle diagnostic device for determining telescope aberrations is a pepper-pod screen similar to that described in Reference 10. A sketch of the operation of this system is shown in Figure 7. It is interesting to note that this system is similar to the Hartmann mask technique for determining optical wavefronts. The current system was developed by LANL [5].

Recently, a pinhole diagnostic [11] (using a pepper-pod concept similar to that used in the telescope diagnostic) has been developed to allow the determination of the beam Twiss parameters at the entrance to the telescope. Because this diagnostic uses neutral particles, it has the advantage that it can be positioned anywhere within the beamline.

Because of the small divergence of the beam after passing through the telescope, the measurement of divergence requires a detector system with a high spatial resolution. For example, if a beam of 12-μr divergence (full angle) passes through a small pinhole with a 25-μm diameter, then the resulting beamlet will have expanded to 120 μm at a distance of 10 m. Thus, spatial resolutions on the order of 10 to 50 μm are required to measure this divergence. In addition, the efficiency of the detector system must be high since there are typically only 5,000 to 10,000 particles in the beamlet from the pinhole. LANL has been using a light intensifier system [5] while ANL has been investigating the use of a CCD video camera placed directly in the beam [12].

Summary

The NPBTS has proved to be a very versatile facility for studying magnetic-optics and diagnostic issues for 50-MeV H^-, H^0, and H^+ beams over the past three years. The concept of emittance control using various collimator slits allows the routine production of H^- and H^0 beams with normalized rms-emittances less than 1.0 π-mm-mr with total beam currents of ~600 μA. The large-bore telescope, the telescope diagnostic, and the associated beamline diagnostics of the facility provide a high degree of versatility in providing and measuring a wide range of beam conditions. Finally, the success of the facility has been due to the close cooperation of Argonne and Los Alamos National Laboratories.

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