ZERO GRADIENT SYNCHROTRON (ZGS) HIGH ENERGY POLARIZED PROTON BEAM PROGRAM-INJECTOR SYSTEM*

E. F. Parker, J. Madsen, N. Sesol, R. L. Stockley, and R. E. Timm
Argonne National Laboratory
Argonne, Illinois

Introduction

The injector system for the ZGS polarized proton program is diagrammed in Fig. 1. Conceptually, the system is quite straight forward. It consists of a 750-keV preaccelerator, PA-II, with a high gradient accelerating column, a beam transport line, and beam monitoring devices coupled to the existing 50-MeV linac. The system is, in fact, not very straight forward as a result of the physical size and complexity of the ion source, the very low beam current, the need to measure a new beam parameter (polarization), and the operational requirement that both PA-II and the regular ZGS preaccelerator, PA-I, operate simultaneously.

The polarized proton ion source (PPIS) is a so-called "atomic beam" type source[1] manufactured by the Auckland Nuclear Accessories Co., Ltd., of Auckland, New Zealand. The pertinent characteristics of the PPIS are given in Table I. Figure 2 is a photograph of a similar source. The 20-keV source beam is matched into the accelerating column by means of an electrostatic quadrupole doublet.

Table I

PPIS Characteristics

Beam Current	6-12 μA dc
Energy	20 keV
Polarization	≥ 75%
Number of Controls	15 continuously variable 16 off-on 64 monitor points
Physical Size	6 x 7 x 12 ft + 4 racks of electronics
Power	30 kW, 3 phase, 60 Hz
Weight	8,000 lbs
Polarization Direction	↑ ↓
Reversing Time	2-3 s

As shown in Table I, the PPIS requires a large number of controls. The controls system was designed under the philosophy outlined in Ref. 2. It is capable of monitoring 64 transducers and controlling 32 bistable controls. High voltage-to-ground transmission is by means of four fiber optic bundles. The system has two manual control points, one (local) in the source terminal and one(remote) in the Main Control Room (MCR) and allowances for computer control.

The vacuum system for the PPIS consists of five 6-in diffusion pumps, an ion pump, and a titanium sublimation pump. The diffusion pumps are used to pump the atomic beam sections of the source where the gas load is quite heavy. The ion and sublimation pumps are used to pump the ionizer. Since the largest source of unpolarized protons is due to ionization of background gas, good vacuum in the ionizer is a must.

Preaccelerator

The power supply for the preinjector is a 400-Hz, 1-mV Cockcroft-Walton made from an old 500-kV test set and spare parts from our Haefely power supply. The terminals for both the power supply and source are rectangular prisms 6 x 6 x 2 ft and 8 x 11 x 14½ ft respectively. Both terminals are of a rib and panel construction having 6-in radii of curvature on all corners.

The source terminal dimensions were dictated by the size of the PPIS and the enclosure. The source requires a minimum height of about 12 ft, a minimum width of 8 ft, and a minimum floor area of 65 ft^2. The enclosure was a storage room adjacent to the existing preinjector (PA-I). The floor was removed from the room and all of the conduits, power panels, etc., were removed from the walls. The walls were made uniform and conducting by hanging screen wire from Unistrut beams attached to the walls. The individual panels of wire were seamed by soldering the edges together. The minimum width and length of the terminal and the limited size of the enclosure allows a separation of only six ft between the power supply terminal and the screen wire walls. While this is much less than one would like for this type of wall and terminal construction, the system has been tested to over 800 kV with no terminal-to-wall sparks or corona.

The 30 kW of 3-phase, 60-Hz power required by the PPIS is provided by a 37.5 kVA generator driven by a 50-hp hydraulic motor. We elected to go with a hydraulic drive because of its reasonable cost and to avoid the design problems associated with a safe reliable insulated shaft capable of transmitting 50 hp up to the terminal.

The accelerating column is a single 7.5-in gap structure having 4.5-in diam entrance and exit apertures. This column is essentially like our regular column[3] except that the ceramics are welded instead of epoxied together. The column is surrounded by a phenolic fiber pressure vessel filled with 75% N_2 and 25% CO_2 at 37 psi gauge pressure.

Beam Line

The beam transfer line between the preaccelerator and the linac (Fig. 1) consists of 14 dc magnetic quadrupoles and two pulsed 90° bending magnets. The first 11 quads are 10-in effective length, 4-in bore magnets. The last quadrupole triplet is a 4-8-4-in array having a 3-in bore. Since this last triplet is common to both preinjector beam lines, the tunes for both lines must allow the same settings for these magnets. The 90° magnets have an effective length of

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9.5 in. These magnets must be pulsed so that alternate linac pulses can be derived from each preinjector and beam can be transported to the 750-keV polarimeter for analysis between beam pulses. The first quadrupole is 62 in from the anode of the accelerating column. This large separation greatly simplified column mounting and is allowed because of the small emittance of the PPIS.

Diagnostics

The 750-keV beam current is monitored at two places along the beam line by two plunging Faraday cups. The Faraday cups are mounted on ZGS flip target motors. They are dropped into the beam for approximately 500 ms and removed sequentially just before injection time. The current is read by a sample and hold circuit and displayed in the MCR as a fixed number which is updated each machine cycle. Beam position and profile in both planes are measured just upstream of each 90° magnet by rotating helical wire beam scanners.

The beam polarization can be measured at 750 keV and 50 MeV. The 750-keV polarization will be measured using the standard left-right asymmetry technique with the reaction $Li^6(p\alpha)He^3$. At 750 keV and a lab scattering angle of 110°, this reaction has a polarization efficiency of 50%. At this angle, the He^3 ion has a well-defined energy of about 3 MeV so it will be easy to detect in an almost noise-free fashion using a surface barrier detector and single channel analyzer. The geometrical arrangement of the polarimeter should allow a measurement accuracy of a few percent and a data rate that will give adequate counting statistics in two or three min. The outputs of the left and right single channel analyzers are fed to the MCR computer which computes the polarization and displays either the latest value or the average of the last N pulses.

The 50-MeV polarization measurement will be made by looking at the left-right asymmetry in the protons elastically scattered by a carbon target. At 40 MeV and 60° lab scattering angle, this reaction has a polarization efficiency of about 65%. This polarimeter, designed and built at the University of Michigan, consists of a carbon filament viewed by two 3-counter telescopes. Energy degraders between the second and third counters completely absorb protons from the first excited state of carbon while transmitting elastic protons with approximately 10 MeV. Threshold discrimination plus a fast triple coincidence requirement should effectively reduce the neutron, gamma, and electron background to a negligible level. The outputs of these counter telescopes are fed to the MCR computer which computes the polarization and displays it at the source control console.

The vacuum system consists of a 10-in double baffled mercury diffucion pump and two 1200 l/s ion pumps located at the base of the accelerating column. System pressure after initial bake-in is $< 2 \times 10^{-7}$ torr.

Present Status

As of the writing of this report, the preaccelerator and beam line have been completed and are being operated with an H^- ion source to provide H^- ions to the ZGS booster. The ion source, 90° magnets, and linac are being pulsed between normal ZGS injector pulses. With the exception of the magnetic triplet just upstream of the linac, the two pulses are independent and not interactive in any way.

The two polarimeters will be installed in March, 1973. The ion source is in the final states of construction and is scheduled for delivery to Argonne in May, 1973, with installation to follow immediately thereafter.

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References

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[2] Ronald E. Timm, paper No. H-33, this conference.

[3] R. Perry, Proceedings of the 1970 Proton Linear Accelerator Conference, National Accelerator Laboratory, Batavia, Illinois, October, 1970, p. 993.

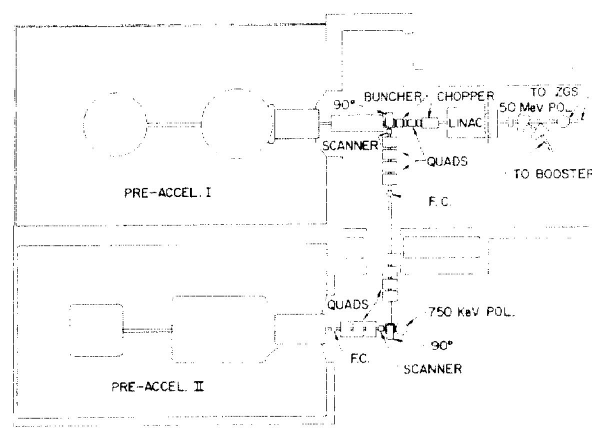

Fig. 1 Polarized Proton Injection System

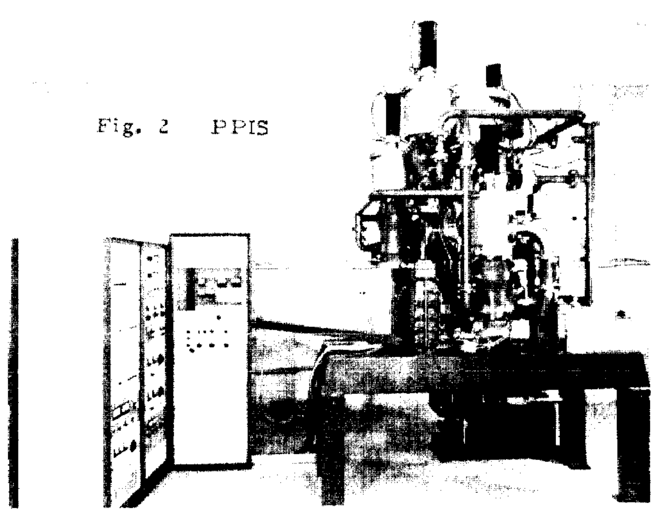

Fig. 2 PPIS