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H⁻ SOURCE DEVELOPMENT at ANL*

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Summary

The H⁻ source development program at ANL¹⁻⁷ has produced the first operational source for direct H⁻ injection into a proton synchrotron and is now directed toward the development of a 30 Hz H⁻ source for booster injection into a synchrotron. On October 1, 1976, direct injection of 50 MeV H⁻ ions into the ANL Zero Gradient Synchrotron (ZGS) and stripping of the H⁻ to obtain protons for acceleration to full energy became the normal mode of operation. With >6 mA of 50 MeV H⁻ beam injected and ~10¹² protons per mA accelerated to full energy during each cycle, new ZGS intensity records have been established.⁸ In the operational tandem-acceleration H⁻ source, a single-aperture source grid is followed by a multislot parallel-ribbon extraction grid. Full and fractional energy H⁻ ions derived from H⁺, H₂⁺ and H₃⁺ are produced by electron attachment in a target gas consisting of the hydrogen outflow from the plasma source. Power dissipation in the extractor grid, and lifetime considerations, limit the repetition rate to ~1 Hz. A source which uses two or more aligned multiaperture grids to minimize grid dissipation is being developed for 30 Hz injection into the rapid-cycling booster-injector^{9,10} for the ZGS.

A modification of this source will be combined with a recirculating supersonic sodium vapor jet charge exchange cell to obtain a greater H⁻ yield. A sodium cell has been built and is being tested.^{11,12}

Introduction

On October 1, 1977, direct injection of 50 MeV H⁻ ions into the ANL Zero Gradient Synchrotron (ZGS) and stripping of the H⁻ to obtain protons for acceleration to full energy became the normal mode of operation for unpolarized proton runs. The operational H⁻ source is a tandem acceleration source in which positive ions are extracted from a hydrogen plasma at ground potential and accelerated to energy eV₊ where V₊ is the positive-ion-beam voltage. Typically, the negative extraction voltage corresponding to V₊ ranges from 15 kV to 23 kV. The accelerated beam enters immediately into a charge exchange cell where it is converted into an equilibrium mixture of positive ions, negative ions, and energetic neutrals in a target gas consisting of the H₂ outflow from the plasma source. Gas flow into the source is continuous; the outflow is pulsed. The space charge of the positive ion beam entering the charge exchange cell is neutralized by free electrons produced by ionizing collisions of beam particles with target-gas molecules. H⁻ ions derived from H_j⁺, j = 1, 2, 3 emerge from the charge exchange cell with energies eV₊/j and are accelerated in the second accelerating gap of the tandem source to energies eV₊(1 + 1/j). The H⁻ ions emerging from the source with these energies are accompanied by neutrals with

energies eV₊/j. Some of these neutrals will pick up electrons from the background gas and become negative ions. Thus a drifting H⁻ beam measured at some distance from the exit of a tandem-acceleration source will have six components with relative energies 1, 3/4, 2/3, 1/2, 1/4, and 1/6. This multicomponent H⁻ beam is accompanied by heavy negative ions derived from positive impurity ions in the arc plasma.

The operational source is the culmination of a longterm effort which has a) reduced the heavy ion fraction of the negative ion beam from 60% to 2%, b) produced a source which provides the operational reliability required for H⁻ injection into a proton synchrotron and c) increased the 50 MeV current from 0.75 mA to 7 mA. Most of this effort has been documented elsewhere¹⁻⁷ and will not be discussed here.

The Operational Source

The operational 1 Hz H⁻ source assembly is shown in Fig. 1. The cathode is a modification of the S-1000 dispenser cathode made by Semicon Associates of Lexington, Kentucky. The intermediate electrode and the flux return for the source magnet are made of mild steel; all other source components are nonmagnetic. Type 102 OFHC is used for the Anode I insert, for the exit-grid portion of the source grid and for the sputter shield attached to the last segment of the charge exchange cell. Type 101 OFHC is used for Anode II. W-3Re is used for the parallel ribbons which form the multislot extractor grid, for the wires in the screen material employed in the suppressor and grounded grids and for the brushes used to bleed off charge from the pyroceram chopper wheel. The valve (gas shutter) housing is made of 304 stainless steel. The subassembly consisting of the source grid mounting plate, the grounded grid plate and everything in between is sealed with gold rings and held together by tie rods torqued to 125 in-lbs. The extractor, suppressor and grounded grids can be removed and replaced without breaking the assembly. Except for the OFHC used in the source grid insert and the W-3Re used in the grids, all metallic components in the gold-sealed subassembly are made from 304 stainless steel. Insulators which form parts of the vacuum envelope are made of alumina, with sealing surfaces furnished to 10_μ in or better.

The chopper wheel of the 30 Hz rotating gas shutter^{4,13} is a 36.83 cm diameter pyroceram disc, 0.432 cm thick, with eight slots equally spaced along a 30.48 cm diameter circle. Each slot is 2.54 in long in the azimuthal direction and 1.27 cm wide in the radial direction. The disc rotates at 225 rpm. Clearance between the disc and Anode II is adjusted under vacuum by means of bellows which supports the ferrofluidic feedthru-coupler in the drive assembly; the clearance is several times larger than the design value of 5 x 10⁻³ cm to compensate for a slight wobble in the wheel. The phase of the wheel is determined by a photo detector and a light source which illuminates

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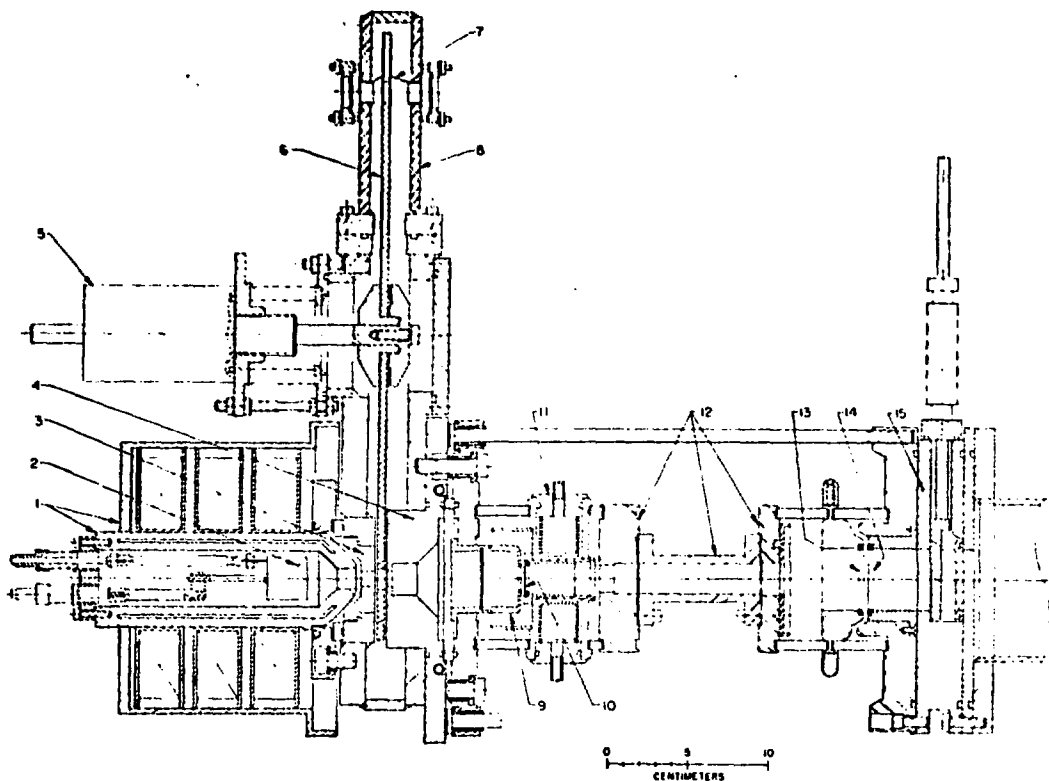


Fig. 1. Operational 1 Hz H^- Source Assembly. (1) Intermediate Electrode and Flux Return. (2) Cathode. (3) Anode I. (4) Anode II. (5) Ferrofluidic Drive Unit. (6) 30 Hz Gas Shutter. (7) Brushes. (8) Valve Housing. (9) Source Grid. (10) Extractor Grid. (11) Field Shaping Magnet (M-2). (12) Charge Exchange Cell. (13) Suppressor Grid. (14) Grounded Grid. (15) Isolation Valve.

the detector each time a slot passes an aligned pair of windows in the top cover of the valve (gas shutter) housing.

The source grid has a single 1.53 cm diameter aperture through which positive ions are extracted from a plasma boundary at or very near the plane of the aperture. The ions are accelerated across the 0.254 cm gap between the source grid and the parallel-ribbon W-3Re extraction grid. Each ribbon is 7.62×10^{-3} cm wide and 5.08×10^{-2} cm wide. The center-to-center spacing between ribbons is 3.30×10^{-2} cm. The ribbons are inserted into grooves in a type 316-L stainless steel ring. The method of manufacture is described in Reference 6.

The suppressor and grounded grids are stretched W-3Re wire-screen grids spot welded to 304 stainless steel rings. The wire diameter is 6.35×10^{-3} cm; wire-to-wire spacing is 8.47×10^{-2} cm and grid transparency is 85.6%.

Efforts to make the power supply for the field shaping solenoid, M-2, immune to high voltage transients in the 750 kV terminal have not been successful and the magnet is not used at this time.

Operating Parameters of the 1 Hz Source

Typical operating parameters are shown in Table I.

Table I Typical 1 Hz Source Parameters

Arc Current	60-80 A avg.
Arc Pulse Width	700-1000 μ sec
Arc Pulse Rate	30 Hz
Extractor Voltage	15-23 kV
Extractor Current	15-18 A
Extractor Pulse Width	500-650 μ sec
Extractor Pulse Rate	1 Hz max
Charge Exchange Cell	
Bias Voltage	200-600 V
Source Magnet (M-1)	4000 A-turns
Cusp Magnet (M-2)	Not Used
Source Pressure	100-140
Average Gas Flow	0.13 Torr 1/s
H^- Beam Current	33 mA

Uncorrected Gauge Reading

Waveforms obtained on the test bench are shown in Fig. 2.

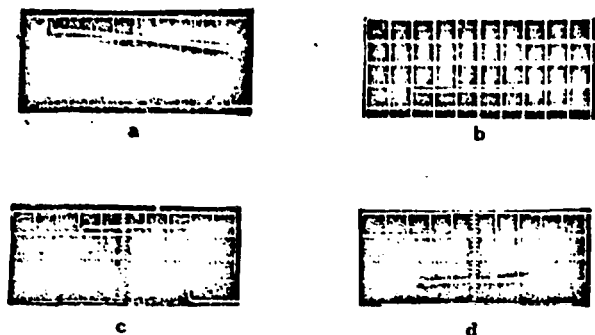


Fig. 2 a) arc current, 20A/cm; b) extraction voltage, 5 kV/cm; c) extractor current, 5A/cm; d) H^- beam, 11 mA/cm. Sweep speed: 100 μ sec/cm

On the test bench, the H^- beam current is measured after magnetic analysis which does not completely resolve the various H^- components. Magnetic analysis of on-axis beam with pin-hole optics indicates that the full energy component is $\geq 70\%$ of the total beam. The beam is measured $\sim 2m$ from the source, after transport through a beam line which simulates the Preaccelerator I (PA-I) beam line but is somewhat less restrictive. When the laboratory beam line is replaced by the PA-I beam line $\sim 10\%$ less beam is transported to the collector.

During studies of H^- injection into the ZGS in September 1976, ~ 25 mA of 750 keV H^- beam reached an aperture plate just in front of the linac, with the RF buncher removed. Almost all of the beam went through the 1.27 cm aperture and was accelerated to 50 MeV. More than 6 mA (up to 7 mA) of 50 MeV beam was transported to the ZGS.

With the buncher installed and running, the average 50 MeV H^- current is down by a factor of two due to a transport problem (inability to simultaneously match the beam through the buncher apertures and into the linac with the present transport system), the presence of off-energy H^- beam components (derived from H_2^- and H_3^-), and droop in the PA-I voltage. (The 750 kV buncher, designed to minimize voltage droop due to beam loading during H^+ acceleration, does not work as efficiently with the reversed polarity required for H^- acceleration.)

30 Hz Source

In this assembly, the extraction geometry of the 1 Hz source is replaced by one using two or three aligned multiaperture grids. The present grid set has 269 apertures with 0.081 cm diameters in each grid. The usable grid diameter is 1.96 cm; the grid transparency is 50%. The beam current depends on the pulse rate. With two aligned copper-tungsten grids, an average current of 13 mA (15 mA peak) is obtained at 1 Hz; a flat 12 mA beam can also be obtained. At 30 Hz, a flat 8.8 mA beam is obtained. Addition of a third aligned grid reduces the 30 Hz current to 7.3 mA. The extractor current in the 30 Hz source is lower by a factor of 4 than the current in

the 1 Hz source. Grid misalignment and uncontrolled thermal expansion (oil canning) may account for the rate effect and the lower-than-expected beam current. A new set of grids has been fabricated and given a slightly spherical shape to give the kind of controlled expansion that has been achieved in ion thrusters and CTR ion sources. The technique for making grids has improved considerably and very good alignment is expected with the new set of two grids (see Fig. 3).

After further development, a modification of the 30 Hz source will be combined with a sodium vapor cell currently under development^{11,12} to obtain a greater H^- yield.

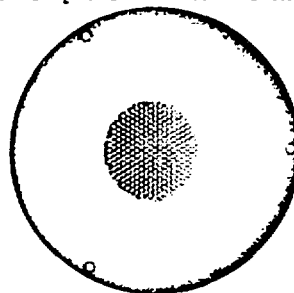


Fig. 3 Light transmission through a nested grid pair (zero gap)

References

1. J. A. Fasolo, Proc. 1970 Proton Linear Accelerator Conf., National Accelerator Laboratory, Batavia, Illinois, Vol. 2, p. 1055
2. J. A. Fasolo, G. J. Marmer and J. S. Moenich, IEEE Trans. on Nucl. Sci., NS-18 (3) p. 94 (1971)
3. J. A. Fasolo, G. J. Marmer and J. S. Moenich, Proc. Symp. on Ion Sources and Formation of Ion Beams, Brookhaven, BNL 50310, p. 231 (1971)
4. J. A. Fasolo, G. J. Marmer, J. S. Moenich, J. A. Abraham, A. J. Gorka and R. E. Timm, Proc. Second Int. Conf. on Ion Sources, Vienna, Austria, Sept. 11-16, 1972
5. J. A. Fasolo, A. J. Gorka and J. S. Moenich, IEEE Trans. on Nucl. Sci., NS-20 (3) p. 142 (1973)
6. J. A. Fasolo, J. S. Moenich, J. Abraham and A. J. Gorka, Proc. Second Symp. Ion Sources and Formation of Ion Beams, Berkeley, LBL-3399, VIII-5 (1974)
7. J. A. Fasolo, IEEE Trans. on Nucl. Sci. NS-22 (3) p. 1665 (1975)
8. C. W. Potts, "Negative Hydrogen Ion Injection into the Zero Gradient Synchrotron", This conference.
9. R. L. Martin, IEEE Trans. on Nucl. Sci., NS-18 (3) p. 953 (1971)
10. J. D. Simpson, IEEE Trans. on Nucl. Sci., NS-20 (3) p. 198 (1973)
11. H. R. Hiddleston, J. A. Fasolo, D. C. Minette, R. E. Chrien and J. A. Fredrick, Proc. 1976 Proton Linear Accelerator Conf., Chalk River, Ontario Report No. AECL 5677, p. 387 (1976)
12. H. R. Hiddleston, "Progress in Sodium Vapor Charge Exchange Cell Development", This conference.
13. A. J. Gorka, J. S. Moenich and K. D. Kellogg, IEEE Trans. on Nucl. Sci., NS-20 (3) p. 127 (1973)