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PERFORMANCE OF THE H⁻ ION SOURCE FOR THE INTENSE PULSED NEUTRON SOURCE*

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Summary

In January of 1983, a magnetron type H^- ion source was installed in the Intense Pulsed Neutron Source (IPNS) at Argonne National Laboratory. The higher available H^- current has helped enable the weekly average intensity of the Rapid Cycling Synchrotron (RCS) to be increased from 8 μA to over 12 μA. After two years of operation, the reliability of the source producing 40 mA of H^- ions at a 30 Hz repetition rate continues to be excellent.

Introduction

Prior to 1983, a duoplasmatron H^- source[1] had been used to supply negative ions to the RCS. This source had operated very reliably for several years, however, the low brightness of the source was beginning to prevent any further intensity increases in the accelerator. At that time a magnetron type ion source with a grooved cathode was installed.

This source and other required ancillary equipment have been described previously in detail.[2,3,4] The layout of the source system as installed in the 750 kV terminal is shown in Fig. 1. Briefly, the extractor electrode is at terminal ground and the source including the arc supply, gas supply, and cesium supply are pulsed to a negative 20 kV potential. The H^- beam is bent horizontally 90° by the magnetic dipole. The beam is then focused by three dc quadrupole magnets and injected into the column. A vacuum valve containing an insulated beam stop is used to isolate the column and source vacuum systems. A small amount of nitrogen gas is continuously injected into the downstream end of the 20 keV beam line just before entrance into the column. This gas raises the pressure sufficiently in the beam line to provide effective beam neutralization.

Operation

The source and electronic design have essentially been unchanged since installation in 1983. With two years of operating experience, a rather routine source turn on and operating procedure has been achieved. A typical operating schedule for the accelerator requires continuous operation for two or three weeks with perhaps one week down after each run. The ion source is normally turned off completely if the accelerator is to be off for more than one or two days.

Turn on of the source is normally started about 24 hours before beam is required in the accelerator. This period of time has been found to be sufficient for the source to condition itself to operating current levels. In the early days voltage breakdown between anode and cathode could become a difficult problem during source turn on with the frequency and intensity of the sparking increasing after each operating cycle. This sparking was determined to be caused by excessive cesium vapor having been injected into the source during the previous operating period. It has been found that if one better matches the amount of cesium vapor injected with the amount required to sustain a sufficient arc, little or no sparking will occur during the next start-up.

The source is started at a 15 Hz pulse rate and within a few hours the source can be left unattended

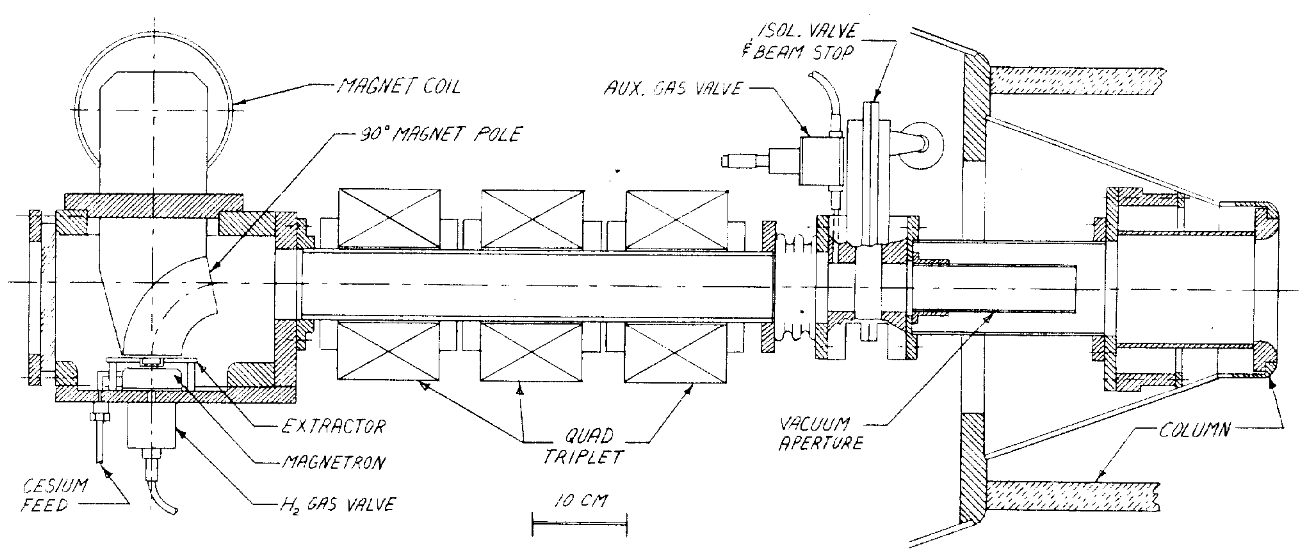

Fig. 1 Top view of the H^- source and beam line in the 750 kV terminal

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to condition itself. The arc current is left at a pulse current of 80 A for overnight conditioning. After pulsing over night, the arc current is lowered to the nominal operating current of 40 A and the pulse rate switched to the required 30 Hz. The extractor voltage is then raised to the nominal operating level of 20 kV. As with the source sparking, extractor breakdown can also be eliminated with the proper amount of cesium flow. Normally the extractor can be raised from zero to full voltage in only a few minutes with minimal if any sparking. The source is then fully operational and normally the source parameters will not require adjustment until the source is turned off perhaps two weeks later.

A typical photograph of the arc voltage and current pulses are shown in Fig. 2. Note that the voltage is increasing along the width of the pulse. This voltage can be flattened with either more gas or more cesium flow. However, this shape does not effect the beam intensity and is a good guide for proper cesium flow. The voltage usually increases from 140 to 170 V along the pulse duration. Figure 3 shows a normal extractor voltage and current waveform and Fig. 4 shows the H^- beam pulse as observed on the beam stop in the 20 keV beam line. Table I lists the typical operating parameters for normal source operation.

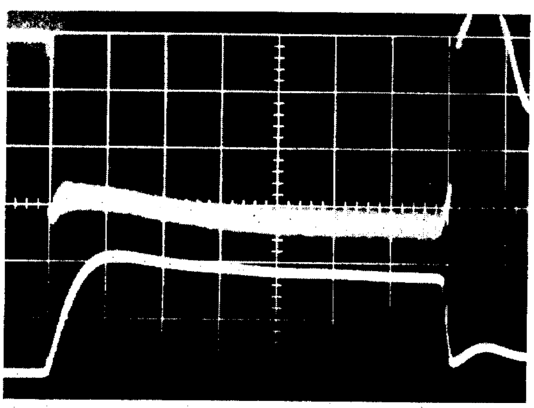

Fig. 2. Top: arc voltage (50 V/division)
Bottom: arc current (20 A/division)
Horizontal scale: 10 μs/division

To enable the source to operate under constant conditions, the arc rate is held constant and the beam repetition rate and pulse width are controlled with the 750 kV chopper system.[5] The front edge of the beam pulse which has a poor rise time due to incomplete space charge neutralization is deflected by the chopper. The trailing edge of the beam is chopped with 1 μs resolution to control the injected pulse width. The chopper is also used as a safety backup enabling the source extractor to pulse continuously when beam in the accelerator is inhibited.

The cesium supply system has perhaps taken the longest to achieve an understanding of its performance. Any minor modifications in the feedline which effects the impedance of the cesium vapor flow may change the required boiler temperature drastically.

With the fairly long distance (1 m) from the source to the entrance to the column, we decided not to install a refrigeration system to aid in the condensation of the cesium vapor evolving from the source. In the past two years, there was one episode of column sparking that appeared to be due to cesium entering the column. This was during a period when excessive cesium was being injected into the source. The column cleaned itself up nicely and has shown no sustained damage. Whether this episode would have been eliminated had we been using a refrigeration system is unknown.

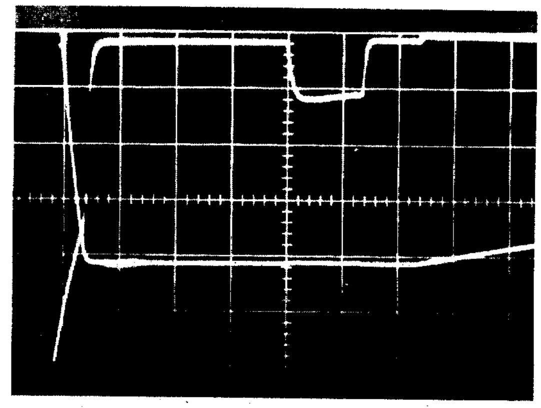

Fig. 3. Top: extractor current (200 mA/division)
Bottom: extractor voltage (5 kV/division)
Horizontal scale: 50 μs/division

The Veeco PV-10 piezo electric valve used to pulse the hydrogen gas into the source has performed above expectations. The first valve did not start to give trouble for over 5500 hours which translates to over 600 million pulses at our 30 Hz repetition rate.

The computer controlled system which automatically adjusts the valve pulse width to keep the average source box pressure constant has proved to be invaluable. Since the source hydrogen gas flow is normally adjusted near the minimum required to sustain a good arc, minor changes in the pressure due to small valve temperature variations could cause large changes in arc conditions.

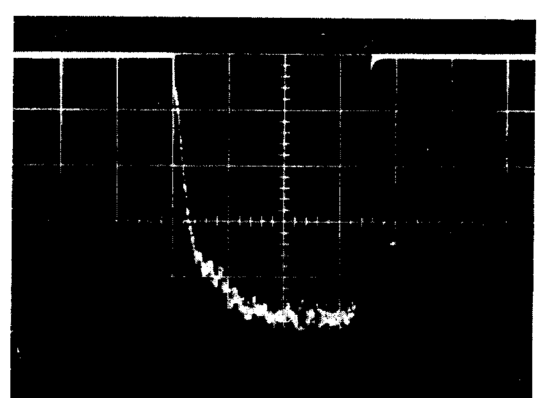

Fig. 4. 20 keV H^- beam pulse (10 mA/division)
Horizontal scale: 20 μs/division

Table I.

Repetition rate	30 Hz
Arc width	80 μs
Arc current	30-40 A
Arc voltage	140-170 V
Cathode temperature	380°C
Source body temperature	180°C
Cesium boiler temperature	120°C
Cesium valve temperature	250°C
Cesium feedline temperature	250°C
Extractor voltage	20 kV
Extractor current	200 mA
Hydrogen gas flow	4.5 atmospheric cm^3/min
Source box pressure	4×10^{-5} Torr
20 keV beam line pressure	9×10^{-6} Torr
Column pressure	1.5×10^{-6} Torr

The source has been taken apart and cleaned only three times in the past two years. The operating time between cleanings has averaged about 3000 hours. The cleanings have been at times of convenience rather than necessity. After 3000 hours the peak beam intensity may have decreased 15% at the most. A new source cathode was installed when the source was last taken apart. This was the first time the cathode had been changed since installing the source and was done for effect rather than for excessive erosion. No change was noted in source operation or beam intensity after installing the new cathode. We attribute the long operating periods before source maintenance is required to the use of the grooved cathode which allows source operation with low arc current and is more resistant to contamination than the standard magnetron source. Perhaps even more important is our careful control of the boiler temperature to prevent excessive cesium from collecting in the source.

The source microprocessor control system has had no difficulty in operating in the harsh environment of the 750 kV terminal. There have been no arc-induced failures of the controls.

In both 1983 and 1984, the ion source and preaccelerator combined have performed trouble free for more than 99.5% of the scheduled operating time.

Future Plans

The grooved cathode H^- magnetron source has performed so well for our requirements that no modifications or improvements have been necessary. However, this summer we plan to try increasing the anode to cathode spacing in the back of the source which should allow operating the arc discharge at a lower pressure as suggested by Alessi.[4]

Acknowledgments

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References

1. J. A. Fasola, "H^- Source Development at ANL," IEEE Transactions on Nuclear Science, Vol. NS-24, No. 3, p. 1597 (June 1977).

2. V. Stipp, A. DeWitt and J. Madsen, "A Brighter H^- Source for the Intense Pulsed Neutron Source Accelerator System," IEEE Transactions on Nuclear Science, Vol. NS-30, No. 4, p. 2743 (August 1983).

3. C. W. Schmidt and C. D. Curtis, "A 50 mA Negative Hydrogen Ion Source," IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, p. 4120 (June 1979).

4. J. G. Alessi and Th. Sluyters, "Regular and Assymmetric Negative Magnetron Sources With Grooved Cathodes," Review of Scientific Instruments, Vol. 51, No. 12, p. 1630 (December 1980).

5. A. Rauchas and R. Zolecki, "Injected Beam Chopper System for the Intense Pulsed Neutron Source Accelerator System," IEEE Transactions on Nuclear Science, Vol. NS-30, No. 4, p. 2947 (August 1983).