OPERATIONAL EXPERIENCE OF PENNING H^- ION SOURCES AT ISIS.

R Sidlow, P J S Barratt, A P Letchford, M Perkins, C W Planner
ISIS Facility, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, UK.

ABSTRACT

Over the past eleven years the performance of the Penning H^- ion source has kept pace with the development of the ISIS Pulsed Spallation Neutron Source to its current consistent and reliable operation at 200 μA. To maximise the availability of the Spallation Source it has been necessary to develop a number of ion-sources that have a high consistency of performance. These can be changed quickly when ISIS is operational without the need for re-tuning of the high intensity accelerators. Design features of the source to obtain the required output current and duty cycle with an acceptable lifetime are described together with operational experience. Consistent repeatable performance for a number of sources has been achieved by improved refurbishment techniques and quality control.

1 INTRODUCTION

The original development of the H^- ion source has been reported earlier [1]. Since then the source has been developed considerably, in line with the development of ISIS.

The source is based on the original Dudnicov design and incorporates a 90° gradient field analysing magnet after extraction with extended pole tips to produce the Penning field for the source. The basic geometry of the Dudnicov discharge region has been retained but the remainder of the design has been changed for ease of manufacture and assembly and to improve performance. The source is mounted separately from the magnet assembly for ease of installation. Design features and operational performance are described together with refurbishing technique.

2 SOURCE DESIGN FEATURES

The source is mounted on the high voltage end of the 665 kV dc medium gradient accelerating column, which forms the pre-injector for the linac. Power supplies and other services are housed on an adjacent high voltage platform inside a Faraday shield.

A schematic diagram of the assembled source is shown in Figure 1. The cathode, anode , aperture plate and extraction electrode are of molybdenum, with the source body and extractor support plate of stainless steel. The cathode is supported in the body by an insulating sleeve of machinable ceramic and is conduction cooled through a copper spacer and 0.6 mm thick mica sheet.

Caesium is supplied from a copper boiler, which houses a 3 gm ampoule of high purity caesium, and is fed to the source through a 6 mm stainless steel transfer line. Two separate heater circuits control the temperatures of boiler and transfer line. The glass ampoule is only cracked once the installed source has been satisfactorily tested.

Hydrogen is supplied via a pulsed piezo-electric gas valve, with the valve pulses regulated to stabilise the mean gas vacuum pressure in the magnet assembly vacuum chamber. Holes in the source body and anode conduct the hydrogen gas and caesium to the discharge region.

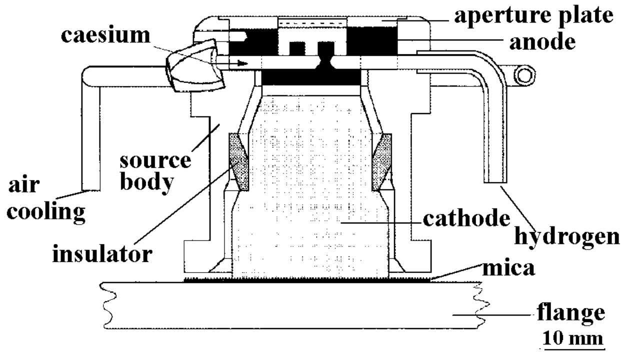

Figure 1. Schematic of ISIS H^- ion-source

The poles of the 90° analysing magnet are set into the sides of a stainless steel 'cold box', which is maintained at about –5°C to condense excess caesium emitted from the source. The box is separated from the rest of the magnet iron by a 3 mm gap and the whole assembly operates at extraction voltage. Copper leaf springs connect the cold box to the source extractor and diaphragm plate.

The accelerating column vacuum is de-coupled from the source and magnet assembly chamber by a diaphragm plate that has a 30 mm diameter x 120 mm tube fitted to its centre. The source is pumped by a 2000 l/s turbo pump.

A viewing port allows the extraction gap region and arc discharge to be observed by reflection in the polished surface of the extractor plate. Thermocouples monitor the source anode, cathode and body temperatures.

The ion source arc is fed from two power supplies connected in parallel through diodes. One is a dc supply of 2 A maximum at up to 700 V, the second a current

Table 1. Source Parameters		
Source dimensions		units
Cathode to cathode separation	5.0	mm
Anode slot dimensions	10 x 2	mm
Anode thickness	3.5	mm
Aperture slit dimension	10 x .6	mm
Extractor gap	2.3	mm
Source magnetic field :	~0.16	T
Bending magnet :		
Centre gap	25	mm
Angle	90	°
Field gradient (n)	1.0	
Centre magnetic field	0.23	T
Bending radius	80	mm
Diaphragm (source/column) tube aperture (length x diameter)	120 x 30	mm
Typical operating parameters		
Arc current	35-45	A
pulse width	400-650	μs
repetition rate	50	Hz
Extraction Voltage	18	kV
pulse width, typically	230	μs
Typical operating temperatures		
Cathode	490-530	°C
Anode	450-600	°C
Source body	390-460	°C
Cs boiler	165-175	°C
Cs transport Line	300	°C
H^- pulsed beam at 665 keV	35	mA
Normalised emittances at 665 keV		
Horizontal	~180	π mm mr
Vertical	~250	π mm mr

stabilised pulsed supply of 80 A maximum at up to 320 V. The dc supply is used to heat the source to a temperature at which the low impedance, high current, ‘caesium mode‘ discharge may be established.
A list of the main source parameters is given in Table 1

3 SOURCE PREPARATION

There are six operational ion sources and each source is fitted with a new anode, cathode , support insulator and aperture plate. Before assembly all components are first scrubbed and ultrasonically cleaned in detergent, alcohol and acetone and then vacuum baked. After assembly and alignment, the source is tested before storing under vacuum. Testing includes operation of the source in the high impedance mode with hydrogen, using the dc supply at 700 V x 100 mA to establish the integrity of the source and its services.

4 SOURCE OPERATION

After installation on the pre-injector column the source is heated and conditioned to check its integrity by using the dc arc supply, the boiler heating and by pulsing the high voltage extractor. The boiler is then pinched to crack the glass of the caesium ampoule and set initially at 190°C. The arc impedance rapidly falls until it abruptly drops to a very low impedance, ‘caesium mode’, at which the pulsed arc supply takes over, delivering high current pulses. The dc supply is usually switched off at this point.

Optimisation of the source begins by balancing the power, varying the arc pulse width against the source body air cooling to stabilise cathode and body temperatures. The boiler temperature is then lowered to give stable operation with low noise. A 665 keV H^- beam is then established and further optimisation is done to achieve a 35 mA beam at minimum arc current. Re-optimisation may be required during the life of a source to maintain output.

5 SIGNIFICANT DEVELOPMENTS

Throughout the commissioning of ISIS there has never been the facility to develop the ion source in parallel to operations. Consequently developments occurred in response to the changing demands of the machine on the source performance. The pre-injector was used whenever possible. The developments include equipment external to the ion source but which has a dramatic effect upon its performance, particularly its reliability.

5.1 The Ion Source

A 1 mm deep recess separates the aperture from the plasma to reduce fast electrons. The material to form this was integral to the anode. Over heating caused rapid erosion with a consequent loss of output limiting the useful life of the source to about 14 days. Cooling has been improved by making the material integral with the aperture plate and tightening this down with domed hexagonal headed screws to give extra torque. With this arrangement, erosion is minimal after 27 days of continuous operation.

Cathode temperature is an essential parameter for stable source operation. Monitoring the temperature is difficult because the cathode is at voltage. The problem has been solved by using a thermocouple inside an aluminium nitride thimble, which is a good electrical insulator but has a high thermal conductivity.

Good source operation depends on the anode temperature being regulated by thermal conduction to the source body. The molybdenum anode fits into two sockets in the body. Improved performance has been obtained by making this an interference press fit to achieve better thermal contact. A more stable source arc has resulted with less anode erosion that has even allowed anodes to be reused.

5.2 EHT Column

EHT column breakdowns create rf fields which have penetrated the shield of the platform enclosure and damaged electronic components or corrupted the control signals. The source arc could be extinguished and recovery would take time and shorten its operational life. Problems associated with this have been considerably reduced by improving the connection between the EHT column and the platform using high power rf finger connection and by improving the noise immunity of the electronic equipment.

5.3 The Bouncer

A Cockroft-Walton EHT generator supplies the -665 kV to the pre-injector column via a 10 MΩ feed resistor, a 0.01 μf reservoir capacitor, and a 10 kΩ resistor linked to the platform. The energy in a column breakdown with this arrangement was considerable. It would damage electronics and switch off the supply on over current.

The 10 kΩ resistor has been replaced by a 1 MΩ resistor and a 'Bouncer'[2] employed to stabilise the platform voltage when the pulsed beam current is accelerated. Column breakdowns are quenched and the platform voltage recovers in less than 60 ms. The effects of the rf fields on ion source electronics has reduced significantly.

5.4 Electrode configuration and aperture tube

The column inner electrode configuration has been changed such that the first two electrodes are a similar conical arrangement to the other 14. They prevent electrons stripped from the H^- beam reaching the glass insulators between the electrodes and charging them until discharge occurs. A reduction in the number of EHT breakdowns ensued.

After changing the first two electrodes there appeared evidence of caesium being deposited from direct line of sight to the source. This has been prevented by fitting a 120 long x 30 mm diameter tube to the diaphragm plate. This had the additional advantage that the column pressure was further reduced resulting in a concomitant reduction in EHT breakdowns. The lens action of the tube to the first electrode did not produce any significant focal effect on the beam at 665 keV.

5.5 Ion source supply filter

The ion source arc discharge produced an oscillation of about 15 MHz which severely affected the two arc power supplies and extracted beam. A π filter and snubber placed immediately after the source stopped the problem.

5.6 Computer Control System

A new computer control system[3] was installed on the platform in 1995. This is based on a commercial PC control system, Group 3 Technology Ltd, New Zealand, supplied by Schaefer Instruments Ltd., Wantage Oxfordshire. The system is susceptible to noise from EHT break downs so considerable care had to be taken to ensure a good noise immune installation. A special applications program, WinPhido, had to be written to enable control via the VAX main computer control system. WinPhido is a DDE (Dynamic Data Exchange) client and server as well as a PHIDO (Packet Handler for ISIS Data Operations) client and server. This system has worked with high reliability and has allowed much tighter control of the ion source parameters. As a result source failures are now rare and they usually reach the end of their life by exhausting the caesium charge. The charge of caesium has been increased by 1 gm to 3 gm which extended the life from 21 to 27 days with no significant increase in source erosion. It is planned to fit a 5 gm charge in the near future with the expectation of extending the source life to include a complete ISIS cycle.

CONCLUSION

A consistent performance is obtained from each of the six operational ion sources due mainly to the quality control of refurbishment and the reliability of the supplies. They each give a stable output of about 35 mA H^- beam at 665 keV and should the lifetime be extended to include a complete ISIS cycle the objectives of the developments will have been achieved.

REFERENCES

[1] P E Gear and R Sidlow, Proc 2nd Int. Conf. Low-energy Ion Beams, Bath, 1980, Inst. Phys. Con. Ser No 54, p284.

[2] M Perkins et al, EPAC 96, MO P 106 G.

[3] M Perkins et al, EPAC 96, TU P 081 L.