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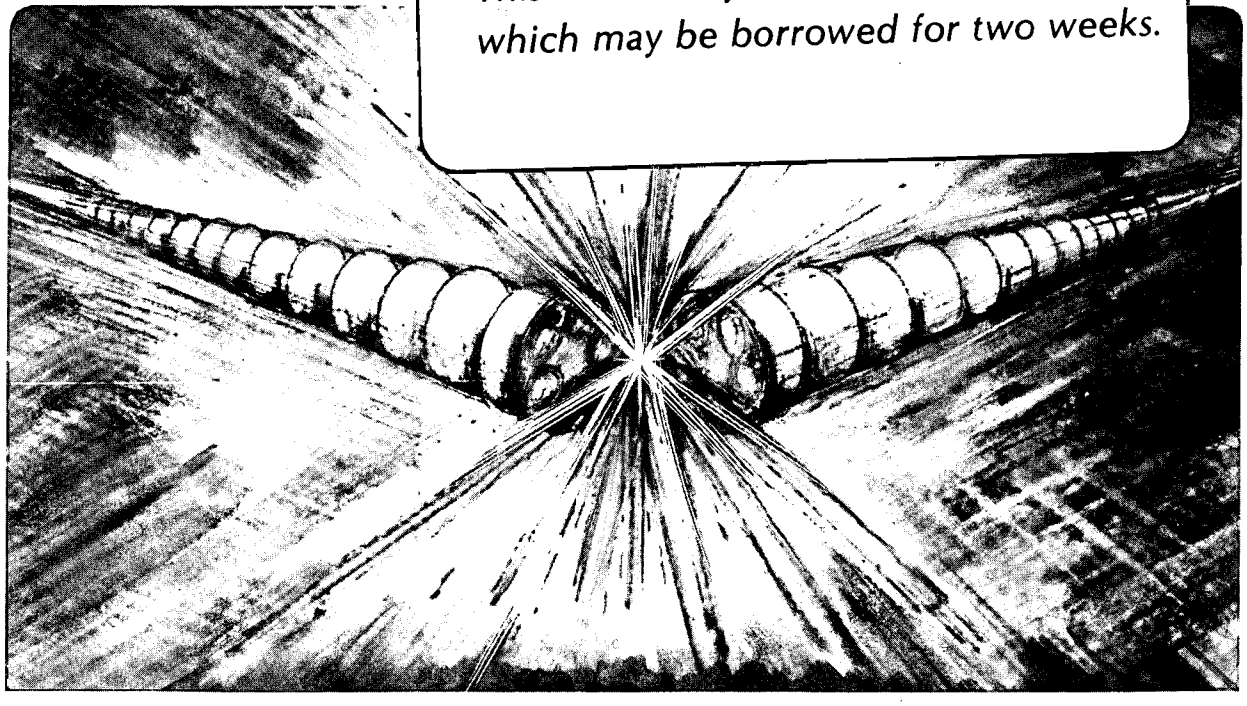

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WATER FLOW CALORIMETRY MEASUREMENTS OF HEAT LOADS FOR A VOLUME PRODUCTION H^- SOURCE*

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Abstract

The design of volume-production H^- sources requires the knowledge of heat loads on the source components. The arc and filament heater power input to a 20 cm diameter x 23 cm long source can be 50 kW or higher, practically all of which is absorbed in the cooling water. Water flow calorimetry measurements were made to determine the heat loads on the bucket walls, grid no. 1, and magnetic filter rods. The measurements are presented for two different filament locations, for three different values of arc power, and for three values of source gas pressure.

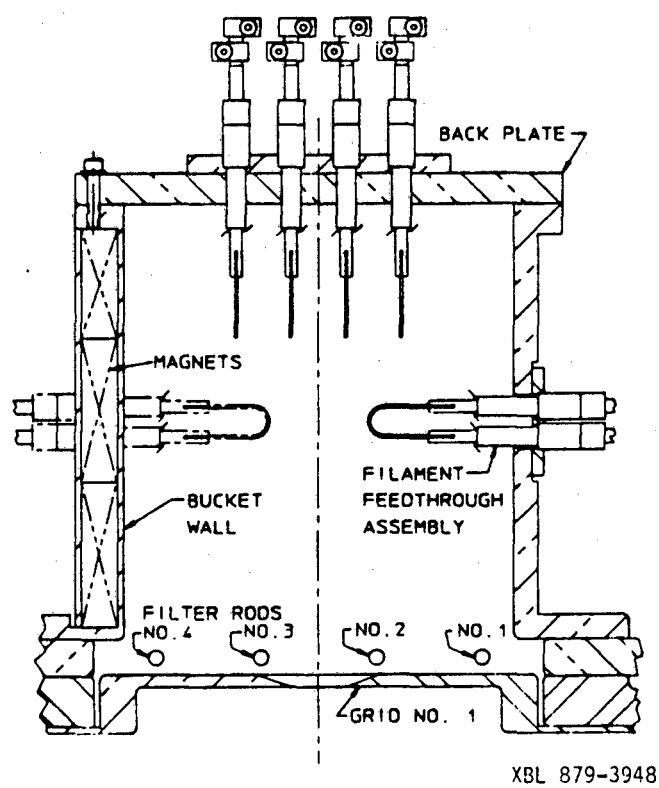

Fig. 1 Cross section of volume-production source.

Description

A cross section of the source is shown in Fig. 1. It consists of a cylindrical bucket 20 cm I.D. x 23 cm long, closed on one end by the back plate and on the other by grid no. 1. All the exposed surfaces are copper with water cooled passages. Ten equally spaced rows of samarium colbalt magnets surround the body and four rows of magnets fit on the back plate. The four magnetic filter rods next to grid no. 1 contain neodynium magnets. A total of eight filaments are mounted on the source, four on the back plate and four on the body at 54, 126, 234, 306 degrees from the 12 o'clock position. The filaments are 0.152 cm in diameter and have a total length of 7.62 cm. The filaments are mounted in molybdenum chucks which screw into the water cooled copper feedthroughs. Separate water calorimetry circuits were provided for the bucket wall, back plate, grid no. 1, filter rods, and the filament feedthroughs. Only the total water flow was measured for the four filter rods. The physics of a volume production H^- source is described in [1].

Two sets of tests were conducted, one with all eight filaments operating and one with only the four filaments on the bucket wall operating. During these tests the hydrogen gas flow was adjusted to give a cold gas pressure of 11.5 mTorr inside the source. An additional set of tests were conducted at source gas pressures of 8.5 and 14.5 mTorr. In all tests the exposed surfaces are at anode potential. Typically the filament heater current is initiated and then 6.75 sec later the arc current is turned on. During the time the arc current is on the heater current is stepped down and the total power contribution from the heater current is small. The heater voltage is 5 V.

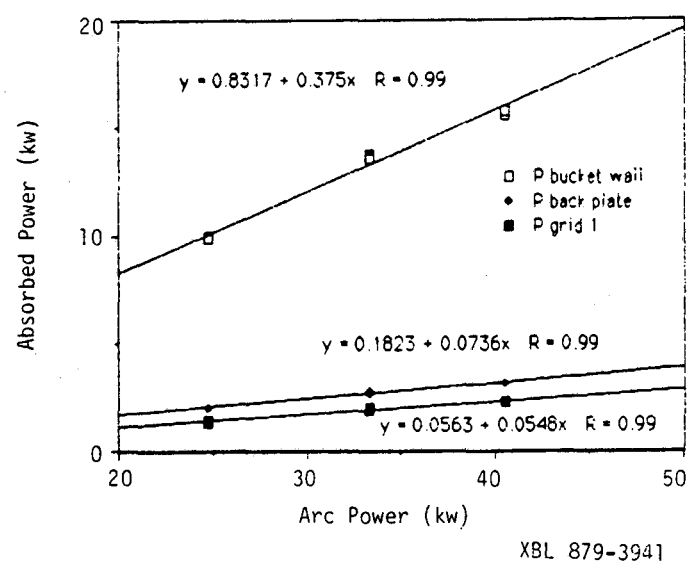

Fig. 2 Measured absorbed power for the bucket walls, back plate, and grid no. 1.

Eight Filament Tests

The tests were conducted for arc duration of 1.5, 3.0, and 4.5 seconds. Arc power levels of 24.8 kW (225 A/ 110 V), 33.3 kW (350 A/95 V), and 40.5 kW (450 A/90 V) were used. The test data was plotted as energy absorbed vs. arc on time. The energy absorbed at zero time corresponds to the filament heater power contribution. Fig. 2 and 3 show arc power vs. absorbed power for the filter rods, bucket wall, back plate, and grid no. 1. For these figures the heater power has been subtracted. It can be seen that the absorbed power increases linearly with

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arc power. Totaling the power absorbed shows that 54 percent of the arc power is absorbed by the exposed components. The remainder of the input power is removed in the water cooled filament feed-throughs. An energy balance accounts for all of the input energy within ± 10 percent. Table 1 shows the results expressed in percent of arc power absorbed.

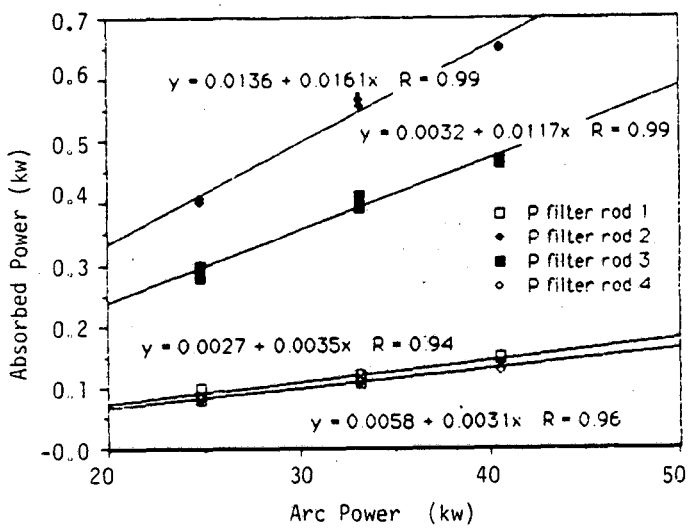

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Fig. 3 Measured absorbed power for the filter rods.

Table I

Measured percent of arc power absorbed

	8 Filaments		4 Filaments
Bucket Wall	37.5		43.3
Back Plate	7.4		7.9
Grid No. 1	5.5		5.6
Filter rod No. 1	0.3		0.3
No. 2	1.6		1.7
No. 3	1.2		1.2
No. 4	0.3		0.3
Total	53.8		60.3
Average		57.1	

Four Filament Test

Again the tests were conducted for arc duration of 1.5, 3.0, and 4.5 seconds. Only one arc power level of 33.4 kW (352 A/95 V) was used. The test results expressed in percent of arc power absorbed are shown in Table 1. The results are nearly the same as for the eight filament test.

Variable Pressures Tests

The tests were conducted for arc duration of 3.0 seconds and power of 33.3 kW (350 A/95 V). Figure 4 shows the power absorbed by the bucket wall as a function of source pressure. The absorbed power for the back plate also increased with pressure, but the absorbed power for grid no. 1 decreased with pressure, dropping about 10% when the pressure increased from 8 mTorr to 14.5 mTorr. In all cases the gas pressure is determined from the measured gas flow rate during the test and the gas flow vs. cold pressure calibration curve.

Discussion

Table II shows the surface areas of the different components and the predicted percent of arc power absorbed if the absorption is scaled with the exposed area. Because of the magnets on the bucket wall, the back plate, and in the filter rods the major power loading should be concentrated on the magnet cusp lines and not uniformly distributed over the exposed surface area. The magnet cusp lines are clearly visible as discolored areas on the bucket wall and back plate. The filter rods do not show such discolored areas. However, as can be seen from Table I and II scaling the absorbed power with the exposed surface areas gives reasonable values for all components except the filter rods no. 2 and 3. This indicates that of the total power absorbed, the largest part is due to radiation, and this is uniformly distributed on all the exposed surfaces. An estimate of this component can be made from the power absorbed on grid no. 1. It is shielded from the plasma by the magnetic filter rods, and therefore the heat load from the plasma by ion and electron bombardment should be small.

From the present data it is not possible to clearly seperate the uniform heat flux component and the component concentrated on the magnet cusp lines. The conservative design criteria, for the back plate and bucket wall, is to assume that all of the arc power is deposited on the magnet cusp lines.

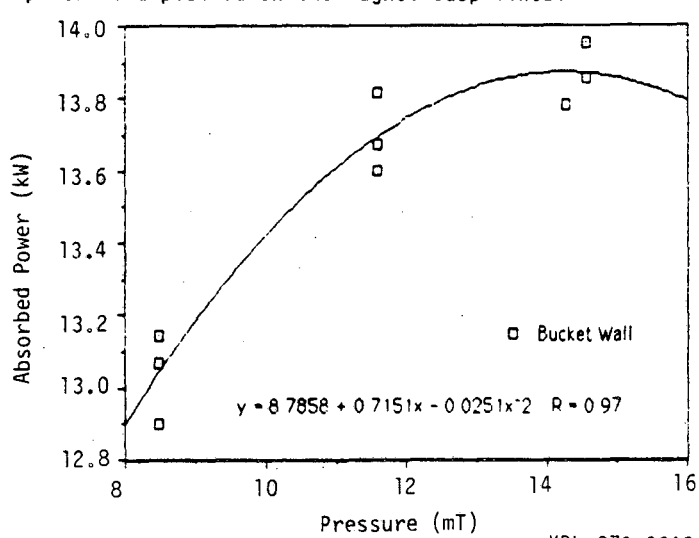

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Fig. 4 Measured absorbed power vs. source pressure.

Table II

Predicted percent of arc power absorbed scaled with exposed area

	Area-cm^2		Percent
Bucket Wall	1445.0	.697 x 57 =	39.7
Back Plate	314.0	.151 x 57 =	8.6
Grid No. 1	265.0(2)	.128 x 57 =	7.3
Filter rod No. 1	9.1(1)	.0044 x 57 =	0.3
No. 2	15.4(1)	.0074 x 57 =	0.4
No. 3	15.4(1)	.0074 x 57 =	0.4
No. 4	9.1(1)	.0044 x 57 =	0.3
Total	2073.0		57.0

Note 1: Projected area
2: Area minus filter rod area

Conclusion

The test data show that:

1. 54 to 60 percent of the arc power is absorbed by the exposed areas and the remainder by the water cooled filament feedthroughs.
2. The absorbed power increases linearly with arc power.
3. The location of the filaments does not affect the percent of power absorbed by the exposed components.
4. The absorbed power for the individual components scales directly with the exposed area.

The thermal design criteria for the source is to avoid damage to the exposed surfaces and to keep the magnet temperature below 100 C. For heat transfer calculations, using the conservative approach, the power absorbed by the back plate and the bucket wall is applied to the magnet cusp line area. The cusp line length is the magnet length and in this case the cusp lines have a width of 0.3 cm. For grid no. 1 the absorbed power is applied to the entire exposed area. For the filter rods, in the absence of better information, a suitably large safety factor has to be used. For source pressure other than 11.5 mTorr, adjustments can be made using suitable ratios from Fig. 4.

References

[1] K. N. Leung, K. W. Ehlers, and R. V. Pyle, "Optimization of H^- Production in a Magnetically Filtered Multicusp Source," Rev. Sci. Instrum. 56, 364 (1985).

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