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Estimation of the effective pumping speed for two installation geometries

1 Introduction

The Main Injector ion pumps were initially supported on horizontal beam pipe stubs, but it has been suggested that this would make installation difficult due to positioning the heavy magnet in a cramped space. A possible solution is to bend the stub up by 90°. This causes concern because the bend reduces the pump effectiveness. The effective pumping speed of the 30 l/s ion pump for each of two installation geometries has to be estimated.

It is supposed that, an ion pump arranged at intervals of 240 inches is connected to an oval shaped beam pipe which is 4.75 inches wide, 2 inches high and 19 inches long in both cases. A bent stub is 2.8 inches in diameter and 11 inches long only in Case II.

It should be noted that the original pumping speed of an ion pump at 6 $\times 10^{-9}$ Torr is about 27 l/s according to the pumping speed curve of the 30 l/s VacIon pump.

2 Conductance of stubs

In the molecular flow region, the conductance for a circular pipe in air at 20°C and with dimensions in centimeters, is

$$C_p = 12.1\frac{D^3}{L}$$

where D and L are the diameter and length of the pipe respectively.

The conductance for an elliptical pipe is

$$C_{el} = 136.6\frac{a^2b^2}{L\sqrt{a^2+b^2}}$$

where a and b are the major semi-axis and minor semi-axis respectively.

For a short pipe, the conductance of the entrance aperture must be included. Hence

$$\frac{1}{C} = \frac{1}{C_p} + \frac{1}{C_{ap}}$$

$$C_{ap} = 11.6A$$

where A is the cross section area of the pipe.

For the Main Injector, the stub conductances of a dipole magnet beam pipe in a good approximation of an oval have been calculated, based on above equations, are listed in Table 1.

Table 1 Conductance of stubs l/s

no stub	horiz. stub	with elbow
∞	90	49.3

3 Effective pumping speed

The effective pumping speed S_e can be calculated as follows:

$$S_e = \frac{SC}{S+C}$$

where S is the nominal pumping speed of the pump, and C is the conductance of the connected tube.

The results of the calculation are listed in the Table 2.

Table 2 Effective pumping speed l/s

no stub	horiz. stub	with elbow
27	20.8	17.4

4 Pressure distribution along a beam pipe

If the gas load is distributed along a pipe, which occurs due to the outgassing of the surface, then the steady state is characterized by a pressure gradient along the pipe.

Consider that the pump evacuates a pipe of conductance C, closed at the end. Let the specific outgassing rate to be q. The pressure at a distance x along the pipe is

$$P_x = qB[\frac{L}{S_e} + \frac{x}{C} - \frac{x^2}{2CL}]$$

where B is the perimeter of the pipe cross section, and L is the length of the pipe. It shows that the pressure distribution is parabolic, being maximum at the closed end, i.e.

$$P_L = qBL[\frac{1}{S_e} + \frac{1}{2C}]$$

The mean pressure is

$$P_m = qBL[\frac{1}{S_e} + \frac{1}{3C}]$$

At the inlet of the pump, where x =0, the pressure is

$$P_o = \frac{qBL}{S_e}$$

And the pressure drop along the pipe is

$$\Delta P = P_L - P_o$$

$$= \frac{qBL}{2C}$$

If the mean pressure, conductance and effective pumping speed are given, the required total outgassing of the surface can be calculated. The calculations of the pressure distribution along pipes are listed in Table 3 and Table 4. The mean pressure of 1×10^{-8} Torr is the physical requirement for the Main Injector, and 5×10^{-9} Torr is necessary for the vacuum design goal.

Table 3 Pressure distribution at $P_m=1\times10^{-8}$ Torr

	no stub	horiz. stub	with elbow
P_o Torr	7.8×10^{-9}	8.3×10^{-9}	8.5×10^{-9}
ΔP Torr	3.1×10^{-9}	2.5×10^{-9}	2.2×10^{-9}
P_L Torr	1.09×10^{-8}	1.08×10^{-8}	1.07×10^{-8}

Table 4 Pressure distribution at $P_m=5\times10^{-9}$ Torr

	no stub	horiz. stub	with elbow
P_o Torr	3.9×10^{-9}	4.0×10^{-9}	4.2×10^{-9}
ΔP Torr	1.5×10^{-9}	1.3×10^{-9}	1.0×10^{-9}
P_L Torr	5.4×10^{-9}	5.3×10^{-9}	5.2×10^{-9}

5 Required average outgassing rate of materials

According to the pressure distribution along the pipe, the required average outgassing rates of the inner surface of the pipe have been calculated as follows.

Table 5 Required average outgassing rate Torr l/s cm^2

Mean pressure	No stub	Horiz. stub	With elbow
1×10^{-8} Torr	1.2×10^{-11}	9.8×10^{-12}	8.3×10^{-12}
5×10^{-9} Torr	5.8×10^{-12}	4.7×10^{-12}	4.1×10^{-12}

6 Conclusion

If the kind of pumps, pipe and the spacing between two pumps are known, it can be seen that the mean pressure in the pipe is proportional to the outgassing rate of materials. Whereas the pressure drop is independent of the pumping speed, i.e. even if the pump is extremely large. In the case of the Main Injector, an additional vertical stub will require a little lower average outgassing rate of materials. Since the effective pumping speed is rather low. The most important problem is to produce a very low outgassing rate of materials in beam pipes for both installation geometries in order to satisfy the design vacuum requirement.

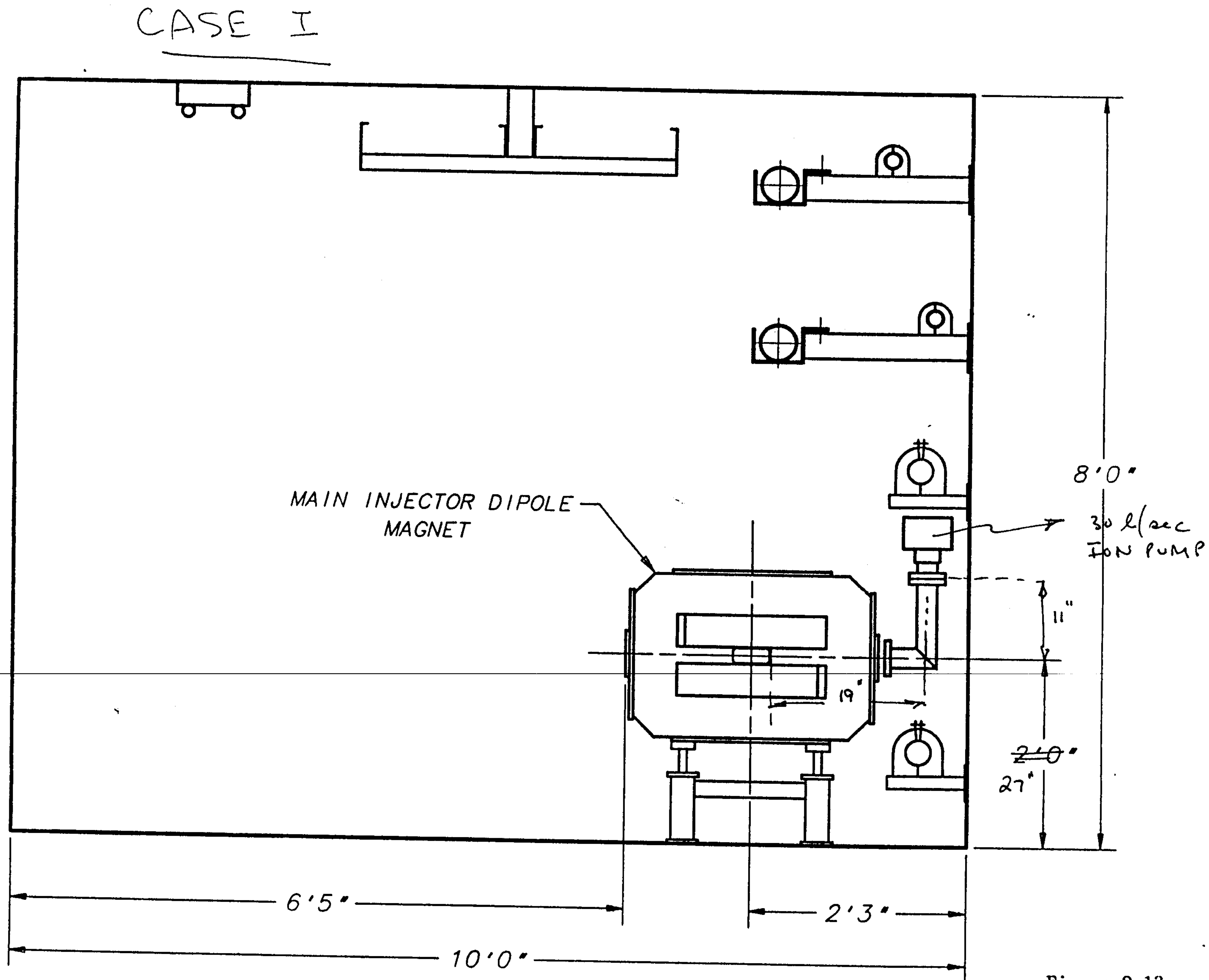
CASE I
MAIN INJECTOR DIPOLE MAGNET
30 l/sec ION PUMP
8'0"
11"
19"
2'0"
27"
6'5"
2'3"
10'0"

Figure 2-13.

30

CASE II