SLAC-TN-72-10
Kimo Welch
July 1972

DIODE SPUTTER ION PUMP SPEED FOR HYDROGEN AND NITROGEN AS A FUNCTION OF AXIAL AND TRANSVERSE MAGNETIC FIELDS UP TO 1.2 TESLA

Introduction

The RLA bending magnet vacuum chamber is somewhat conductance limited. As a consequence, it is important that a quantitative determination be made of the synchrotron radiation gas desorbtion load to be expected during operation. This is essential, more from a standpoint of being able to predict radiation levels from gas scattering of the recirculated beam than in optimizing beam transmission to the experimentalists.

It is possible that some form of distributed pumping system, similar to SPEAR, may be required in the region of the bending magnets. As a cost compromise, perhaps one or two pump nodules may be used to aperture pump the bending magnet vacuum envelope in regions of high gas load. These would be used in conjunction with ion pumps placed between certain magnets.

SPEAR ion pumps are constructed so as to make use of the beam bending magnet magnetic field to support the electrical discharge in the distributed diode ion pump cells. Essentially constant pump speed is reported for various gases with magnetic fields greater than ~ 0.35 Tesla.[1] The SPEAR field is essentially uniform over the area of the pump. However, according to Dick Helm, in the RLA application we may expect field gradients to be on the order of 10 Tesla per meter. This is comparable to ~ 0.1 Tesla per ion pump cell. People became interested in the effect that such high gradients would have on pump speed. Due to instrumentation problems, it is very difficult to make speed measurements on pumps smaller than ~ 10 L/sec. On the other hand, a magnet capable of providing such high gradient fields even over the volume of a commercial 10 L/sec pump was not available. Therefore, as a first approach we sought to determine the effect slightly transverse (to the array of ion pump cells) magnet fields would have on ion pump speed. This was accomplished by tilting the ion pump within the magnetic field. Tests were also conducted with an axially aligned magnetic field, i.e., aligned with respect to the cylindrical pump cells.

Test Procedure

Tests were conducted on a commercially rated 11 L/sec diode sputter ion pump with titanium and tantalum cathodes. Hydrogen and nitrogen were used as test gases. Figure 1 is a schematic representation of the apparatus used in the speed measurements. With this type of system, Q, the mass flow rate, is determined by the rate-of-pressure-rise method. In calculating speed, equations work out so that absolute speed may be determined without a calibrated gauge, the calibration error being in absolute pressure at which speed is measured and not in absolute speed. Absolute pressure at which various speed measurements were made, as implied in the following figure, is probably correct to within a factor of 2, whereas the pump speed, and certainly relative changes in it, are correct to within $\sim 10-20\%$.

The Bayard-Alpert gauge shown in Fig. 1 was far enough removed from the magnet so as not to be noticeably affected by fringing fields when fields within the magnet were varied from 0 - 1.2 Tesla. Conductance between pump and gauge (the gauge was located near the gas source, but was shielded from beaming) was on the order of 2 - 5 times the advertised speed of pumps tested.

A window frame magnet with 6-inch gap, 18-inch width, and 36-inch length was used. The pump was located within a region of the magnet with a field homogeneity of approximately 1 part in 10^3. An Alpha, model 3193, digital NMR gaussmeter was used to measure magnetic field during tests.

Uniform Axial Magnet Field Test Results

Test results for the gases used, nitrogen and hydrogen, are given in Fig. 2. For purposes of comparison, relative sensitivity (i.e., pump current divided by pressure), normalized to the respective maximums, is also given in this figure. It shows a somewhat close correspondence between speed and sensitivity for the two gases. Figure 3 shows the effect nitrogen pressure has on pump speed. Similar tests for hydrogen were not run with this pump.

Transverse Magnetic Field Test Results

The ion pump was tilted $\sim 22\text{-}1/2^{\circ}$ from "proper" orientation inthe magnetic field. Speed results for nitrogen are given in Fig. 4, and for hydrogen in Fig. 5. Speed data from Fig. 2 (uniform axial fields) are shown superimposed on these data for comparison.

Discussion

Speed results observed for uniform axial fields are as expected. Speed should be proportional to sensitivity, as pointed out by Rutherford.[2] Variations in sensitivity with magnetic field, shown in Fig. 2, are typical for Penning cells with cylindrical anodes. Shuurman[3] shows the trend toward constant senstivity with decreasing pressure when exceeding a certain magnetic field.

Conn and Daglish[4] compare sensitivity of ring anodes vs. cylindrical anodes as a function of magnetic field. There is a striking similarity between relative sensitivity of their ring anodes and the sensitivity (or speed) of the tilted pump results, and their measured sensitivity of a cylindrical anode compared with the sensitivity (or speed) of the pump in a uniform axial field (i. e., Fig. 4 of this report compared with Fig. 14 of the Conn and Daglish report). This suggests the possibility that a discharge cannot be supported within the cylindrical anodes, due to problems of "cut-off" of the electron cyclotron radius at lower magnetic fields.

Figure 5 suggests that some form of low pressure pump speed "moding" is occurring. It was also noticed that it was particularly difficult to start or initiate discharge for either nitrogen or hydrogen in the tilted ion pumps at pressure much less than 1×10^{-7} Torr. However, once discharge was initiated, it could be sustained at pressures as low as 5×10^{-9} Torr. The low pump speed indicated for hydrogen at the pressures given in Fig. 5 could prove troublesome in actual application, as hydrogen is known to be a major constituent in baked high vacuum systems. On the other hand, it is conceivable that hydrogen as a constituent in the mixture of gases known to exist in high vacuum systems may be pumped more readily at these lower pressures.

On the basis of these initial results it is my opinion that, should radiation gas desorbtion loads dictate the use of some form of quasi-distributed pumping system making use of the high gradient magnetic fields of the bending magnets, a 6 - 9 month development program will be required. These studies should include: the effect of magnetic field gradient and absolute intensity, pump cell size and configuration, and operating voltage on pumping speed for hydrogen, CO, CO_2, air, and mixtures of these gases.

Acknowledgements

I would like to thank Joe Cobb for the Magnetic Measurement Group's assistance and patience during these tests, and Chris Flegal for assistance in setting up the equipment and making these very tedious speed measurements.

References

1. U. Cummings, et al., J. Vac. Sci. and Tech. 8, 348 (1971).
2. S. L. Rutherford, Trans. 10th AVS Vac. Symp., Boston, Mass. (1963), p. 185.
3. W. Schuurman, Doctoral Thesis, at Rijksuniversiteit of Utrecht, March 1966.
4. G. K. T. Conn, H. N. Daglish, Vacuum, 4, 145 (1954).

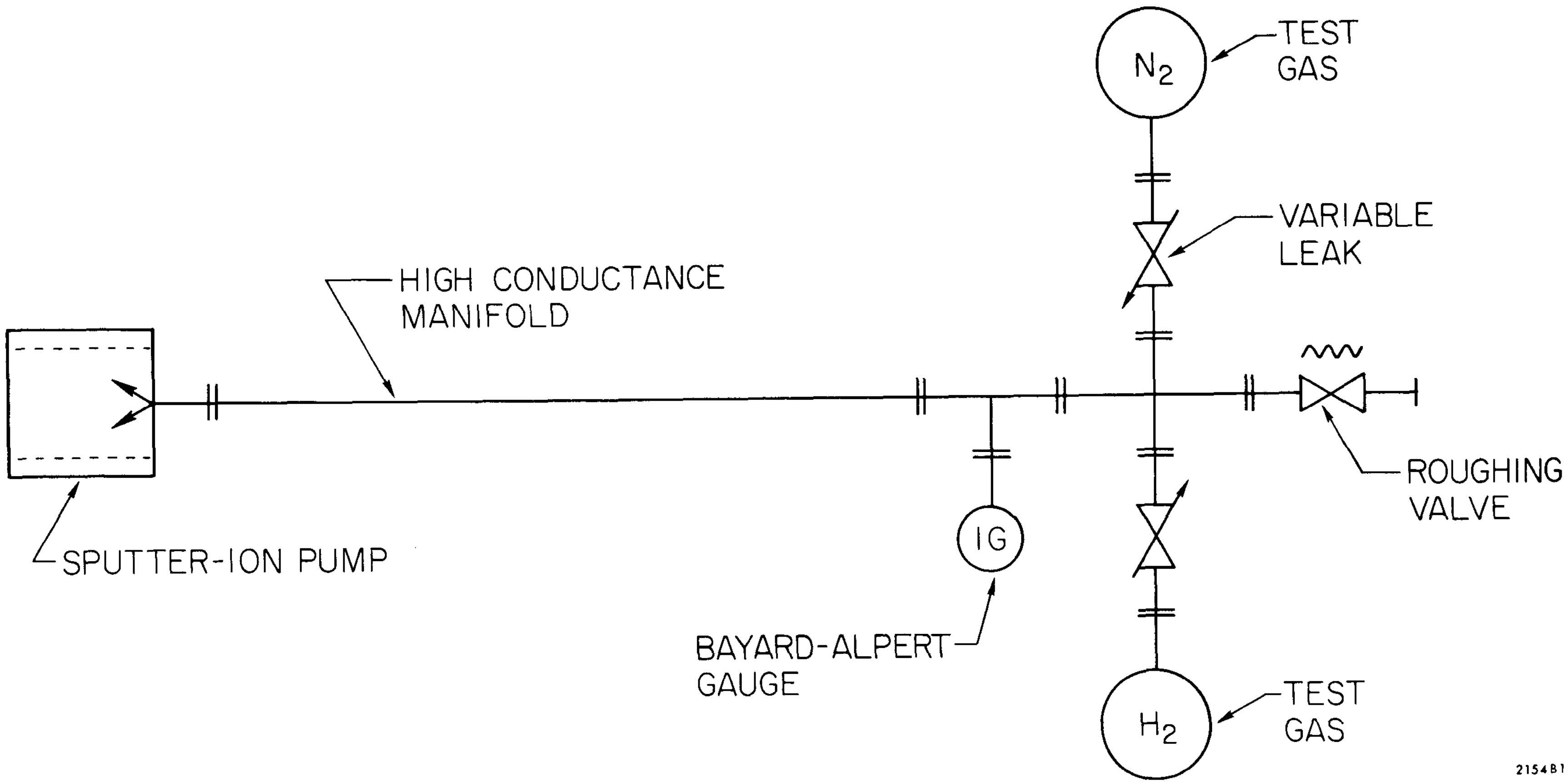

FIG. 1--Sputter-ion pump speed test apparatus.

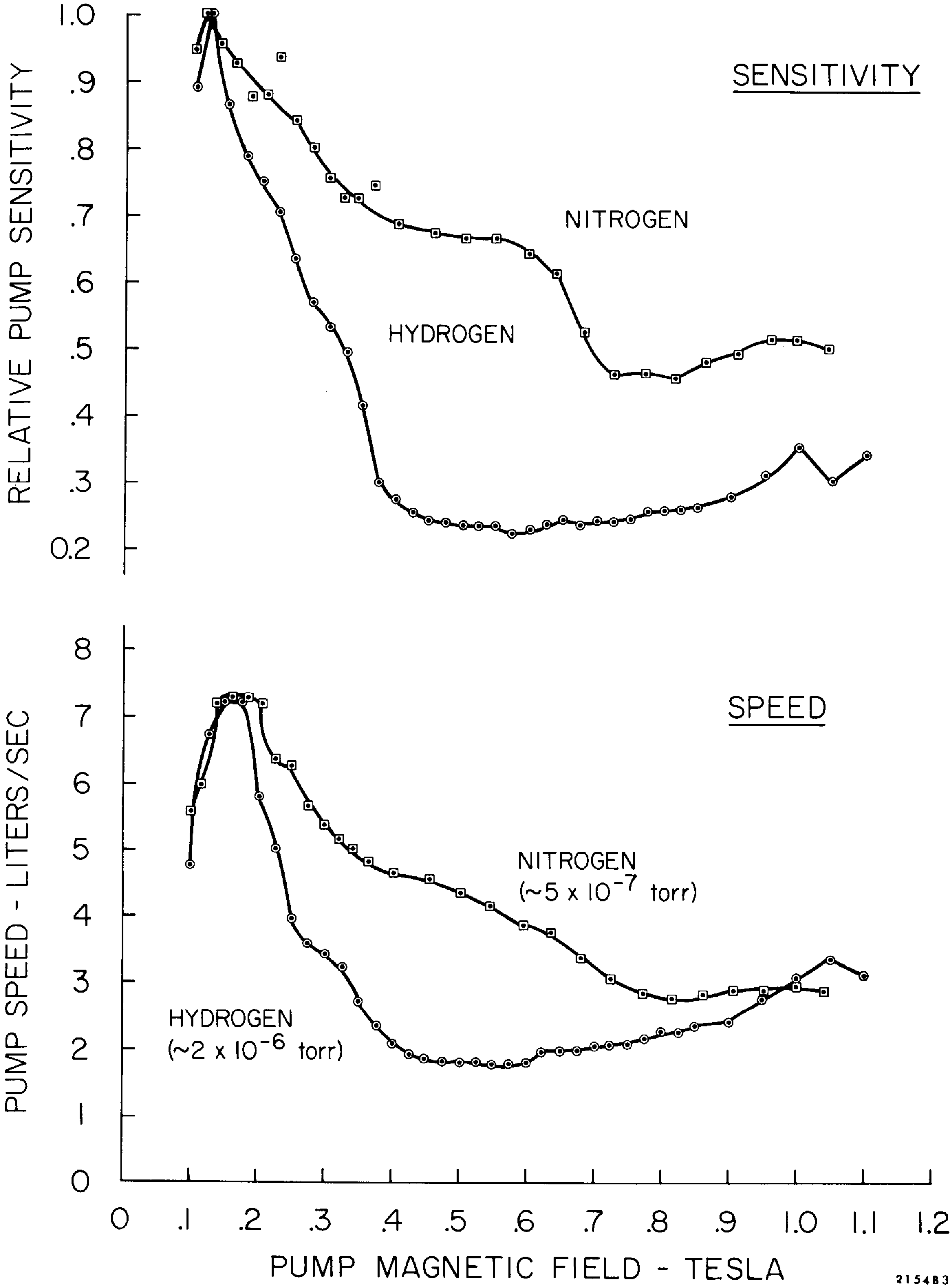

FIG. 2--Measured speed and relative sensitivity of a rated 11 liter per second sputter-ion pump for nitrogen and hydrogen as a function of uniform axial magnetic field.

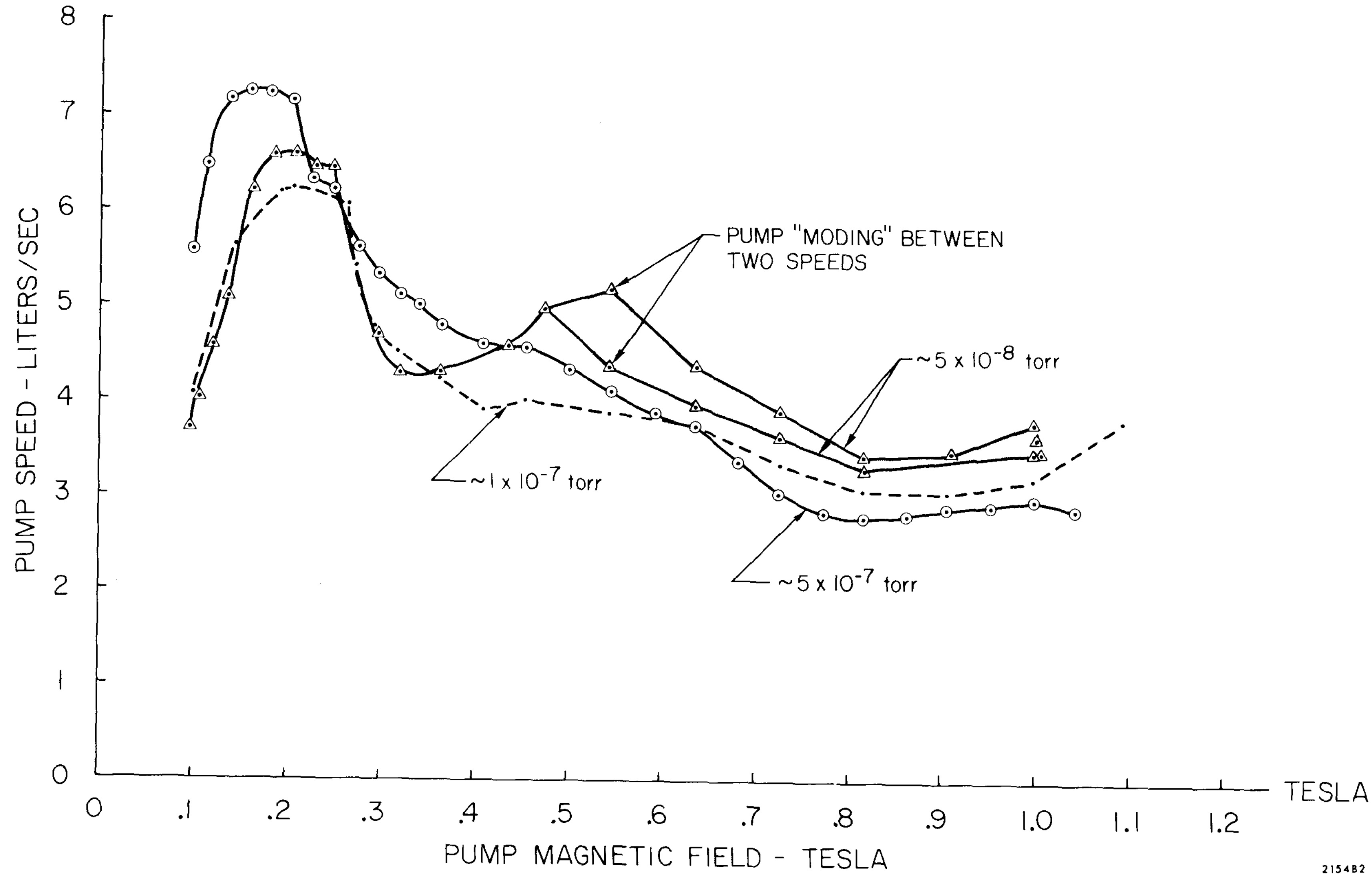

FIG. 3--Sputter-ion pump speed in liters per second for nitrogen as a function of uniform axial magnetic field and at a pressure of 0.5, 1.0, and 5.0×10^{-7} torr.

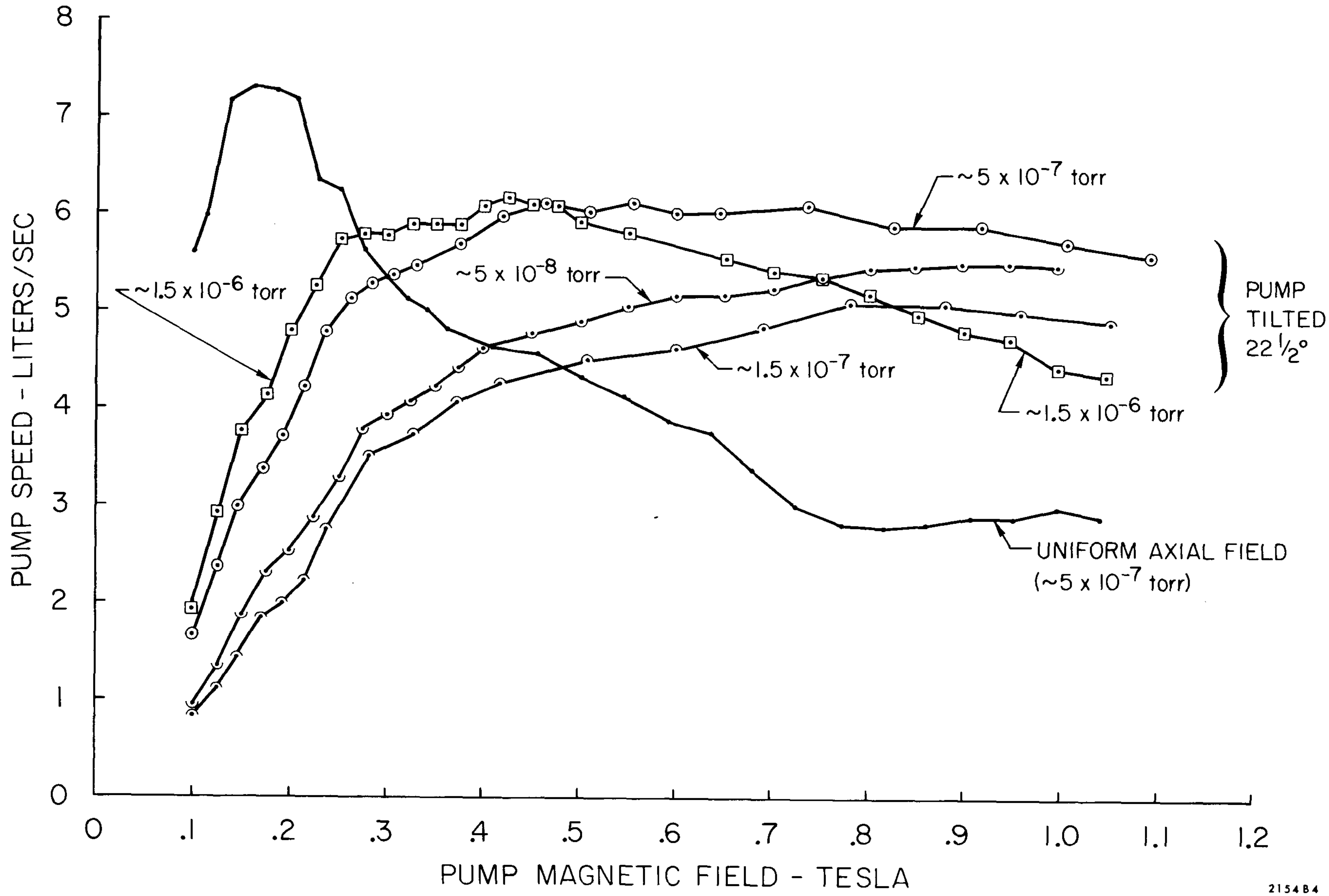

FIG. 4--Sputter-ion pump speed in liters per second for nitrogen, as a function of magnetic field with pump tilted in magnetic field $22\frac{1}{2}$ degrees.

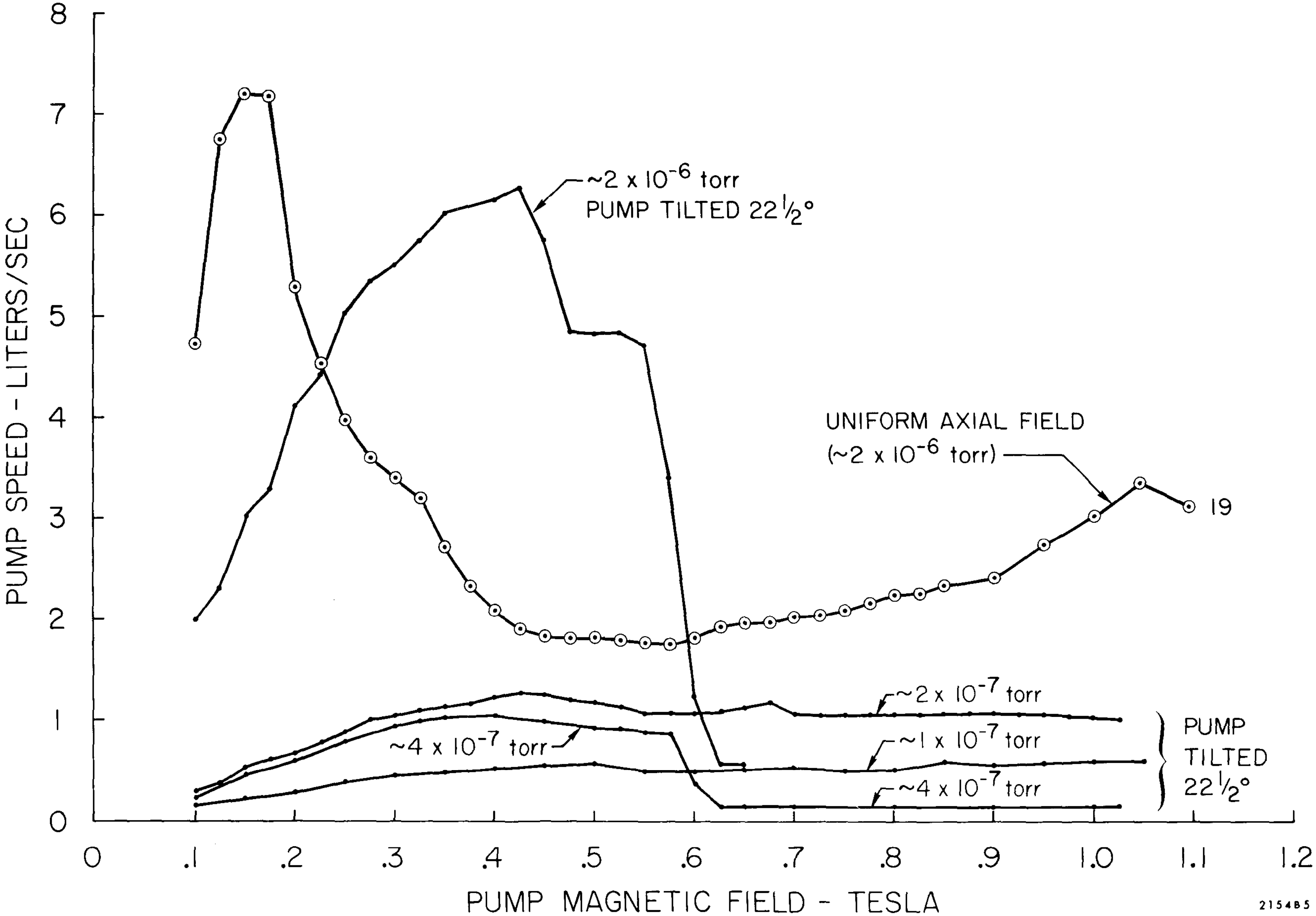

FIG. 5--Sputter ion pump speed in liters per second for hydrogen as a function of magnetic field with pump tilted in magnetic field $22\frac{1}{2}$ degrees.