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* STAR Note 155 *
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Pressure Measurement and Gas Gain Stabilization on the STAR TPC

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Variation in the ambient pressure will affect the electron drift velocity and the avalance gas gain in the STAR TPC. This note discusses the feasibility of measuring the pressure with sufficient accuracy to either correct the drift velocity in the absence of any other calibration information, or apply a simple servo control to stabilize the gas gain by adjusting the anode potential.

Experience with the EOS TPC has shown pressure fluctuations in the range 730 - 750 mm Hg, that is, DP/P ~ 3 % (note one standard atmosphere = 14.695 lbf/in^2 = 101.325 kPa = 407.87 in (33.99feet) water). The drift velocity of electrons in the P10 (Ar + 10% CH4) gas mixture (E=120 V/cm) varied between 5.2 and 5.5 cm/us, DW/W ~ 6%. DW/W ~ 2 × DP/P, appears to be a good approximation, and assuming this to be reasonable, one can estimate the the accuracy to which the pressure must be measured. As a criterion, let's assume we desire a position accuracy of (DS) 1mm over a drift distance of 1m. Thus DS/S ~ 0.1% = DW/W = 2 × DP/P, and therfore DP/P ~ 0.05%. This suggests a pressure sensor with a 50 Pa (7.5E-04 lbf/in^2, or 0.014 in Hg) resolution, and a 11 bit (2048) dynamic range over full scale (1 atm). Pressure sensors are usually available in absolute (single port) or differential (dual port) gauges. The dynamic range may be relaxed by referencing with respect to a known pressure. For example, if the maximum change in pressure DP/P ~ 10% (extreme swings in weather), then 8 bits will suffice with a suitable differential offset. The challenge is to find sensors with the required sensitivity and temperature stability.

Another estimate for DP/P is made based upon the desire to keep the gas gain constant. Bateman [1] has derived useful formulae for Argon + 7.5% methane gas mixture, which expresses the gas gain in terms of the ratio P/T, and, furthermore verified them. Using his equation (5), reproduced here:

$$\ln G = V/74.0 \exp(-(222q+297)/V)$$

(where G = gas gain, V = anode voltage, and q = P (mbar)/T(K) (1bar ~ 1 Atm)) I have tabulated the Voltage vs Gain for different pressures. The operating point is assumed to be P=1000 mbar, T=293K.

P=1000, T=293		P=999, DP/P = 0.1%		P=998, DP/P = 0.2%		P=997, DP/P = 0.3%		P=995, DP/P = 0.5%	
Volts	Gain(G)	Gain,	DG/G %	Gain,	DG/G %	Gain,	DG/G %	Gain,	DG/G %
1300	2441	2464	0.95%	2475	1.3	2486	1.8	2509	2.8
1320	3036	3065	0.95						
1340	3781	3816	0.95	3834	1.4	3852	1.9	3888	2.8
1360	4712	4757	1.00						
1380	5881	5938	1.00	5966	1.45	5994	1.9	6052	2.9
1400	7347	7418	1.00						

P=950, T=293
DP/P = 5%

Volts	Gain	DG/G %
1300	3090	27.0
1340	4811	27.0
1380	7525	28.0

The first column show the results at the operating point while the last column is indicative of the changes to be expected for normal atmospheric variations (DP/P = 5%). Clearly, the gain can vary by as much as 28%. A pressure change of 0.1, 0.2, 0.3, 0.5 % causes almost 1, 1.4, 1.8, 2.8 % variation in gas gains respectively. Assuming, we require gain stabilization, DG/G, at the 2% level, then one must regulate the pressure by 0.3%. This (0.3%, DP ~ 0.1in Hg) is also the measurement resolution needed and should be compared with the value 0.05% derived from the spatial resolution argument given above. Obviously, gain stabalization places a less stringent demand upon the sensor specification.

If one operates the anode wires at 1340 V, (i.e, G = 3781 at P=1000 mbar) then a 5% variation in pressure would require 21V adjustment to the anode potential in order to hold the gas gain steady.

There are many solid state sensors on the market. I have reviewed Motorola specifications regarding their on-chip temperature compensated devices. Typical sensitivity range from 0.4 - 1mV/kPa (linearity 0.2% fss) and, as illustrated in their application notes, these devices can resolve 0.1in Hg. Thus one should be able to implement servo control along the lines advocated by Batemen. Measuring the pressure to 0.05% accuracy is, I believe, on the borderline of sensor capability, but not necessarily impractical.

In summary, online pressure measurements should be made on the STAR TPC. Solid state pressure sensors are cheap, and have sufficient resolution to be useful for calibration. It is possible to implement a simple servo loop to stabilize the gas gain.

[1] J.E. Bateman, RAL preprint, 1993