BNL-104700-2014-TECH

AGS/AD/Tech Note No. 282;BNL-104700-2014-IR

The AGS Cold Cathode Gauge System

H. C. Hseuh

July 1987

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

Accelerator Division Technical Note

AGS/AD/Tech. Note No. 282

July 15, 1987

H.C. Hseuh, A. Feltman, W. Zhang, J. Gabusi

The AGS Cold Cathode Gauge System

I. Introduction

Two types of cold cathode vacuum gauges are used extensively around the AGS vacuum system, the Penning type from CVC* and the newly installed inverted magnetron type from Balzers.** Both types will be powered and monitored by the Balzers control boards in the new vacuum instrumentation system. The behavior and the measuring accuracy of these cold cathode gauges are the subjects of this technical note.

II. System Description

One CVC tube was installed at every ring vacuum sector during the summers of 1982 and 1983 for vacuum monitoring. These gauges are read out manually at the RF house through CVC controllers. Due to the intrinisc characteristics of Penning discharge and the ring-shaped anode design, the low limit of the measurements is about 5×10^{-8} Torr. These Penning tubes will be obsolete when the present vacuum is further improved to below 1×10^{-8} Torr. The Balzers tubes, based on the inverted magnetron principle, have been installed in the ring since 1986. These tubes are capable of measuring down to 10^{-10} Torr range. The present plan calls for installing one Balzers tube per vacuum sector. The existing CVC tubes will be moved to the sector roughing stations which are typically operated from atmosphere to 10^{-7} Torr.

The gauge control boards from Balzers have been selected to power both types of gauge tubes and read vacuum down to 10^{-9} Torr (~ nA discharge current) range. A total of 64 Balzers boards are needed to cover the ring and the HEBTs. Up to 12 boards will be housed in one crate, and two or three crates will be located at each control house. To minimize cross talks (leakage current) between boards, each board

---

* GPH-001 Penning gauge tube from CVC Products, Inc., Rochester, NY.

** IKR 020 Inverted Magnetron from Balzers, Lichtenstein.

will be powered by an individual mother board. A schematic block diagram of the cold cathode gauge system is shown in Fig. 1(a). These Balzers boards will be activated and interlocked through the Pirani gauges (Convectron type from Granville-Phillips) in the auxiliary control chassis. The analog output signals from Balzers will be used to interlock the ion pumps, the sector valves and the roughing pumps/-isolation valves.

III. The Calibration of the Boards and the Tubes

The vacuum level is monitored through the analog output of the Balzers boards. In the lower pressure range ($P < 2 \times 10^{-5}$ Torr), the pressure-dependent discharge current is measured with a logarithmic amplifier (LogAmp). In the upper pressure range ($P > 2 \times 10^{-5}$ Torr), the board limits the discharge current to ~ 100 μA and the discharge voltage becomes a function of pressure. This discharge voltage, after correction with an active diode-resistor network, and the addition of the LogAmp output, is added up in a summing amplifier to give the analog output. A simplified layout of the Balzers board is shown in Fig. 1(b).

To ensure accurate vacuum measurements in this vacuum gauge system, the following parameters have to be known:

- the linearity and consistency of the analog output in relation to discharge current and voltage
- the behavior of both types of tubes while powered by the Balzers boards
- the calibration of tubes and boards against pressure as measured by a reference vacuum gauge.

In one investigation, the analog output of the Balzers boards was measured at different discharge currents and voltages using the setup shown in Fig. 2. In the other studies, the gauge tubes were mounted on a vacuum chamber evacuated by the combination of a turbopump and an ion pump. Both CVC and Balzers tubes were measured against a Bayard-Alpert ionization gauge or a Pirani gauge (for $> 10^{-3}$ Torr range). A variable leak valve was used to achieve the desired pressure between 10^{-9} Torr and 10^{-2} Torr. A schematic of the setup in shown in Fig. 3.

To derive the numerical relations between the current, the voltage, the pressure and the analog output, the data are fitted to first and/or second-order polynomials using POLYMATH, a multi-regression curve fitting program running on a PC. The results are summarized and explained in the following sections.

A. Analog Voltage V vs Discharge Current I and High Voltage μ

The Balzers board limits the maximum discharge to ~ 100 μA and/or ~ 3.3 KV as shown in Fig. 4, for typical measurements of discharge voltage and current versus pressure. At pressure lower than ~ 2×10^{-5} Torr, the analog output is linear to the Log(I), as shown in Fig. 5. A best fit of the measured V vs Log(I) of 14 Balzers boards gives

$$V = 0.71 + 1.34 * \mathrm{Log}(I) \quad (1)$$

here I is in nA.

At higher pressure, the discharge current topped to 100 μA and the analog output voltage from the summing amplifier becomes a function of discharge voltage as given by the following relations:

$$V = 9.1 - 0.63 * \mu \qquad \text{for } 7.3 < V < 8.3$$
$$V = 11.5 - 2.9 * \mu \qquad \text{for } 8.5 < V < 10$$

here μ is in kilovolt.

B. V versus P

To have accurate vacuum measurement, the correlation between the true vacuum level and the analog output has to be known. Here we have used a Bayard-Alpert type ionization gauge (BA gauge) as our reference gauge to calibrate both the CVC and the Balzers tubes. The results are summarized in Figures 6 to 9 and explained below.

The readings of the Balzers tubes is linearly proportional to that of the BA gauge from 10^{-4} Torr down to 10^{-9} Torr, as shown in Figures 6 and 8, and can be expressed by

$$\mathrm{Log}\ P(\mathrm{Torr}) = 0.64 * V - 9.5 \quad (2)$$

A previous measurement at prototype HITL even gave linear correlation down to low 10^{-10} Torr. Similar results were also obtained at CERN-SPS vacuum system. At 10^{-3} Torr range, the pressure calculated by Eq. (2) will be lower than the real pressure.

The behavior of the CVC tubes with Balzers boards is less than to be desired. The pressure-independent leakage of about 100 nA makes them useless for measuring vacuum below 5 x 10^{-8} Torr. At 10^{-4} Torr range, the discharge voltage does not decrease monotonously. Instead, it increases with increasing pressure around 1.5 x 10^{-4} Torr (see Figures 4 and 7). The exact mechanism of this phenomenon is not clear. One plausible explanation is the space-charge distortion of the electric field around the ring-shaped anode. More detailed investigation is required to understand this phenomenon. Two second-order polynomial functions (Fig. 9) are required to give a reasonable fit (with a variance less than 1 x 10^{-3}) of the BA gauge readings versus the analog output up to 1 x 10^{-4} Torr. However, accuracy of ~ 50% over 10^{-7} to 1 x 10^{-4} Torr still can be achieved by just using Eq. (2). Since the CVC tubes will be mostly used at the roughing stations during pumpdown, their accuracy is less critical.

IV. Summary

The following parameters are essential to the successful implementation of our new vacuum gauge system:

1. A system using Balzers boards can control several different types of tubes and still give relative accurate readings in the applicable pressure range, i.e., CVC tube at 10^{-7} to 1 x 10^{-4} Torr range, and Balzers tubes at 10^{-9} to 10^{-3} Torr range. All the boards will be calibrated and adjusted according to Eq. (1).

2. The pressure measured by the Balzers tube-Balzers board combination can be expressed by Eq. (2).

3. No first order equation can give accurate readings to CVC tube-Balzers board combination over 10^{-7} to 10^{-2} Torr range. However, by using Eq. (2), accuracy within 50% can be obtained between 10^{-7} Torr and 1 x 10^{-4} Torr. The other option is to use the formula shown in Fig. 9, which will give better accuracy over different pressure ranges.

4. The overall accuracy of the new cold cathode gauge system is estimated to be within a factor of two. The following are the major contributing factors:

   a. the calibration of the Balzers boards.

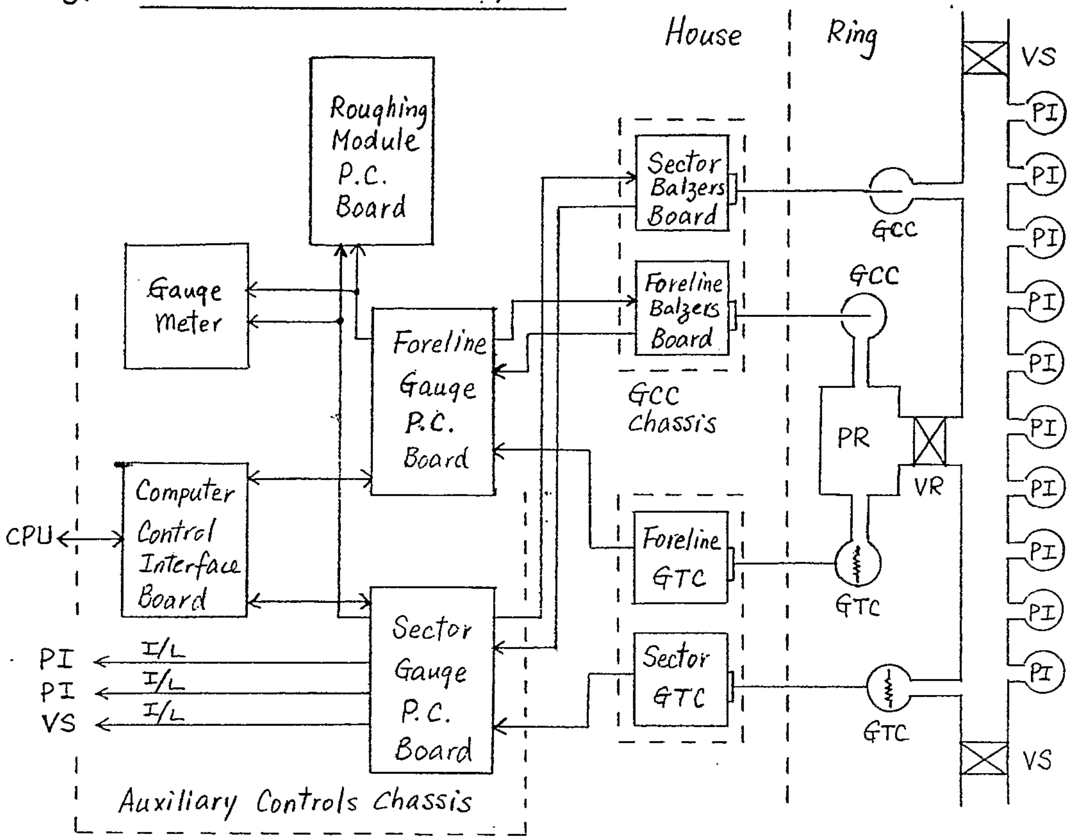
   b. the calculation of pressure using Eq. (2) for both types of tubes.

c. the leaking current of RG59 cables which is about 0.5 nA for a length of 800'.

d. the variation among gauge tubes and leakage inside the tubes which is about 100 nA for CVC tubes and less than 0.2 nA for Balzers tubes.

e. the diminishing of discharge current due to contamination and aging.

Fig. 1(a) Vacuum Gauge Block Diagram



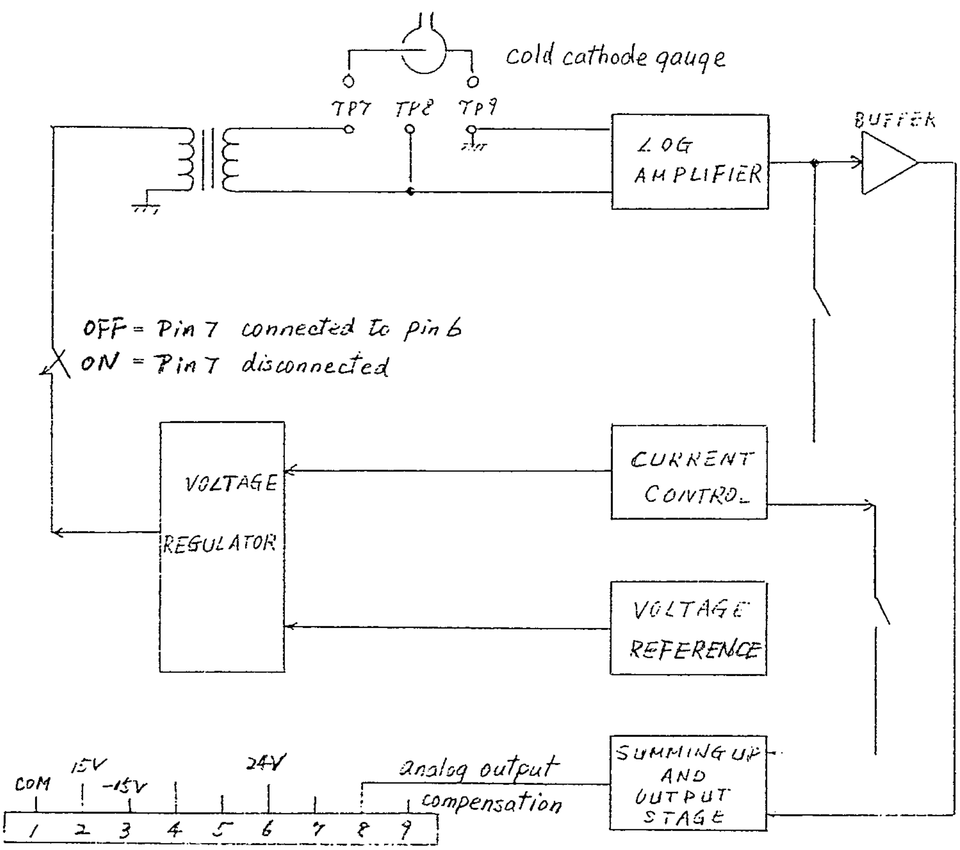
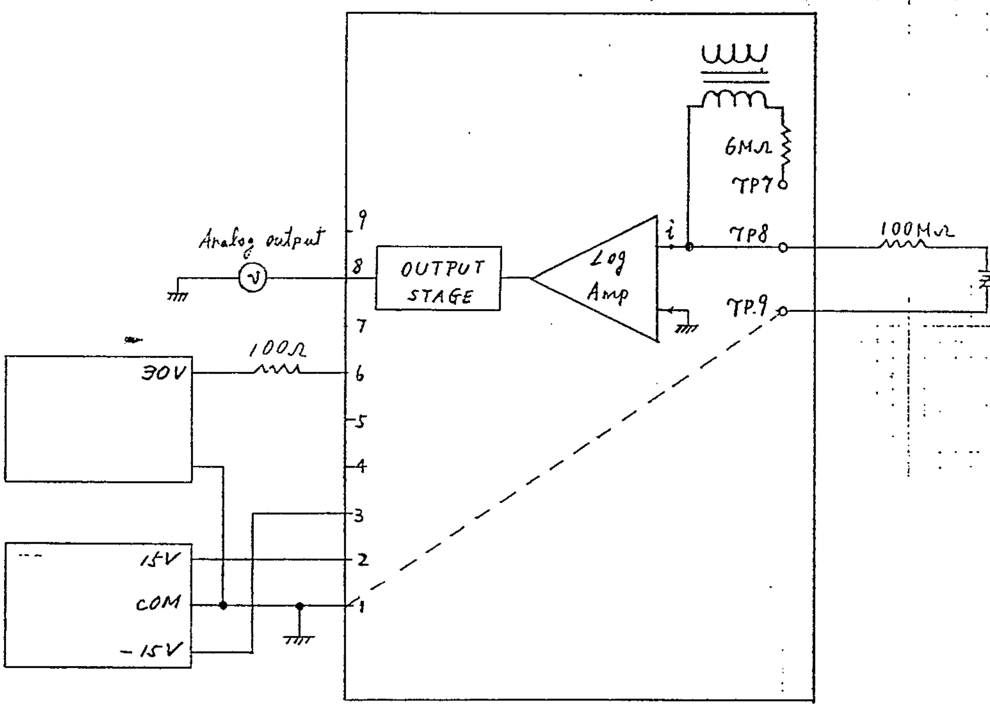
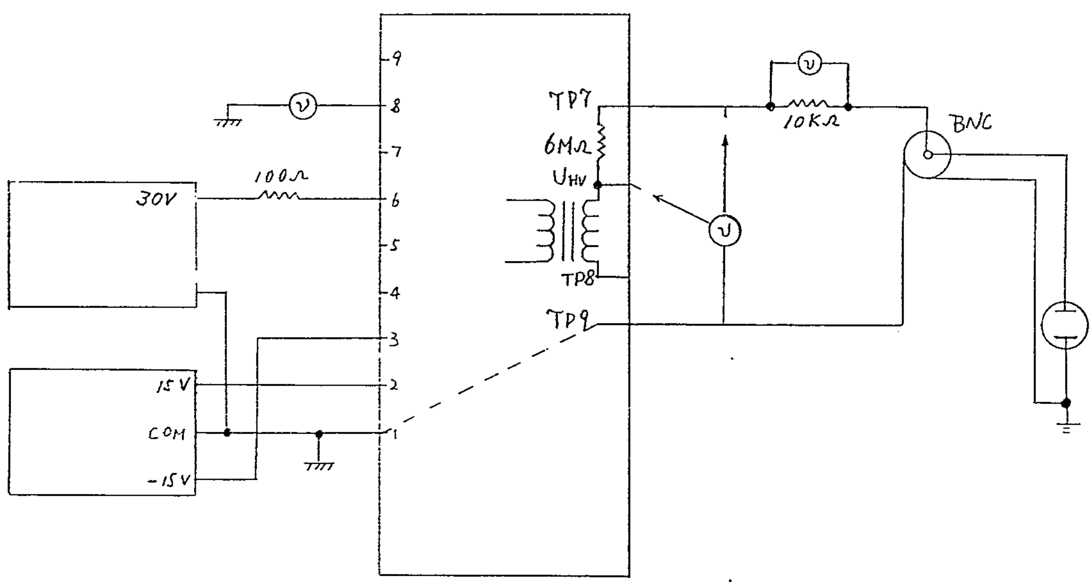


Fig. 1(b) Balzers Board



LOW PRESSURE RANGE



HIGH PRESSURE RANGE

Fig. 2. Balzers Board Test Setup

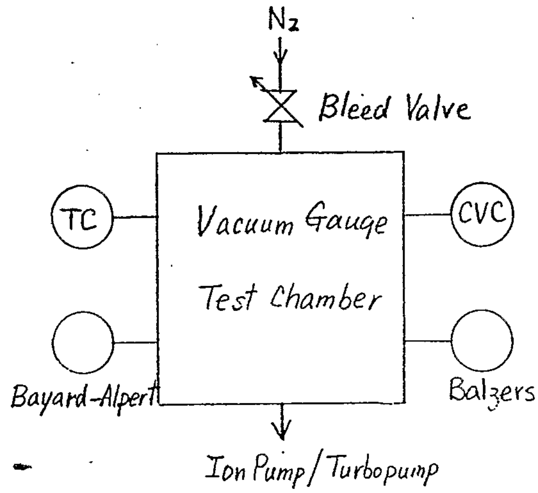


Fig. 3 Setup for Gauge Calibration

Fig. 4

HIGH VOLTAGE AND CURRENT VS PRESSURE

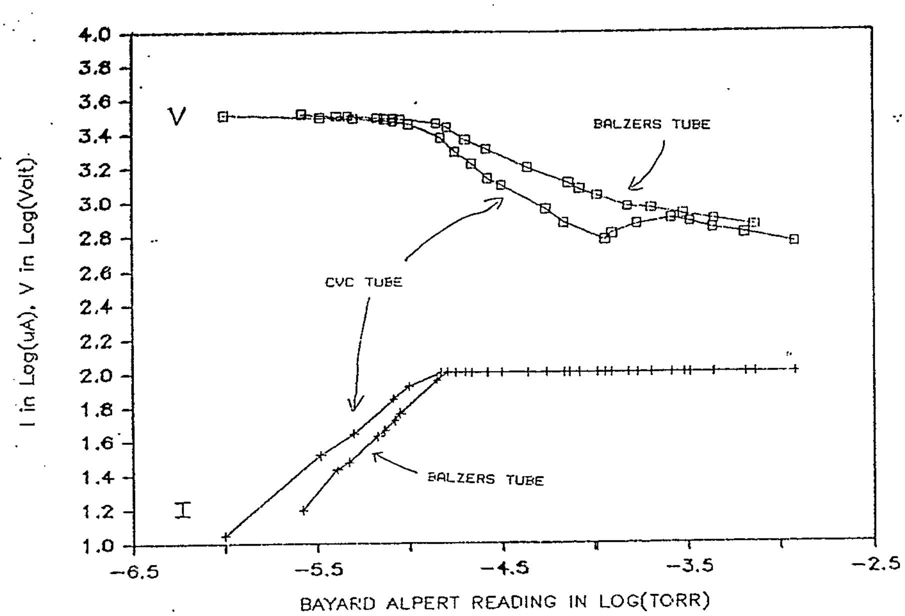


Fig. 5

BALZERS CARD -- I vs V of LogAmp

1st card – June, 1986

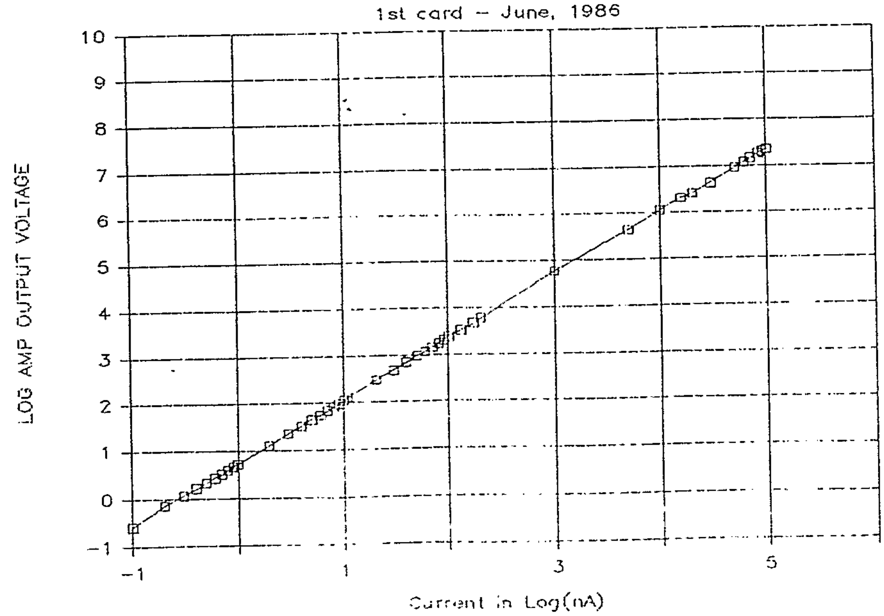
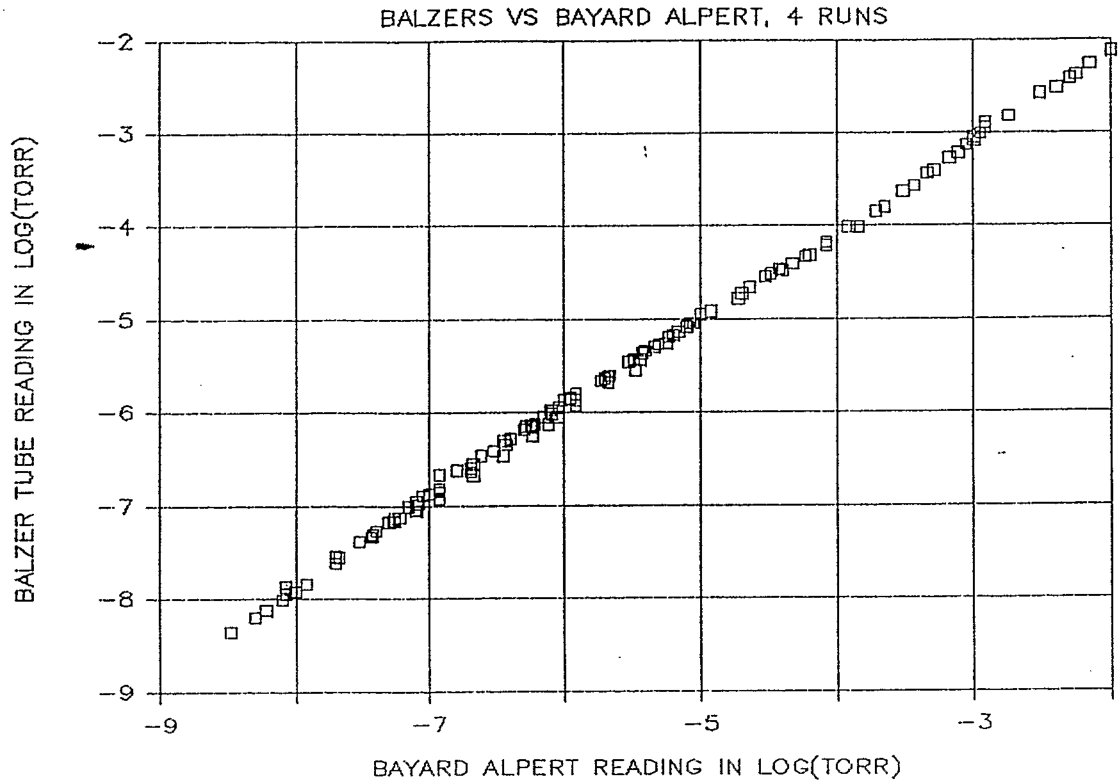


Fig. 6

COLD CATHODE TUBE CALIBRATION



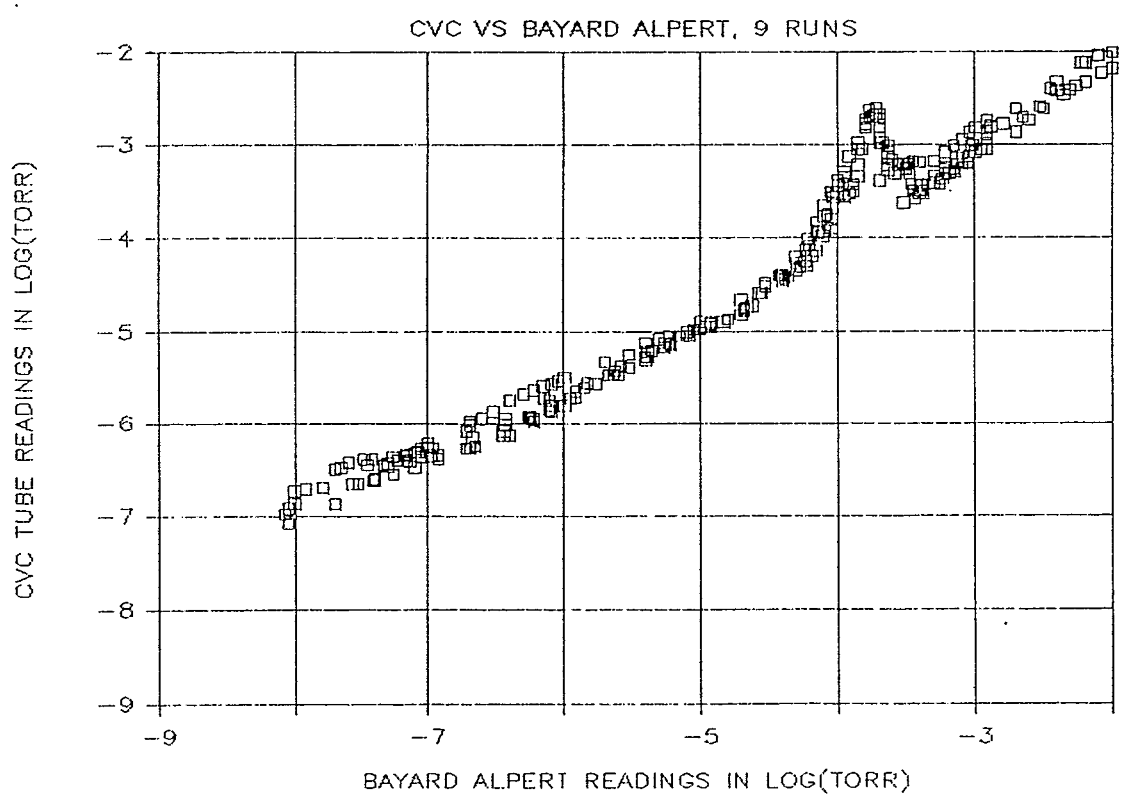
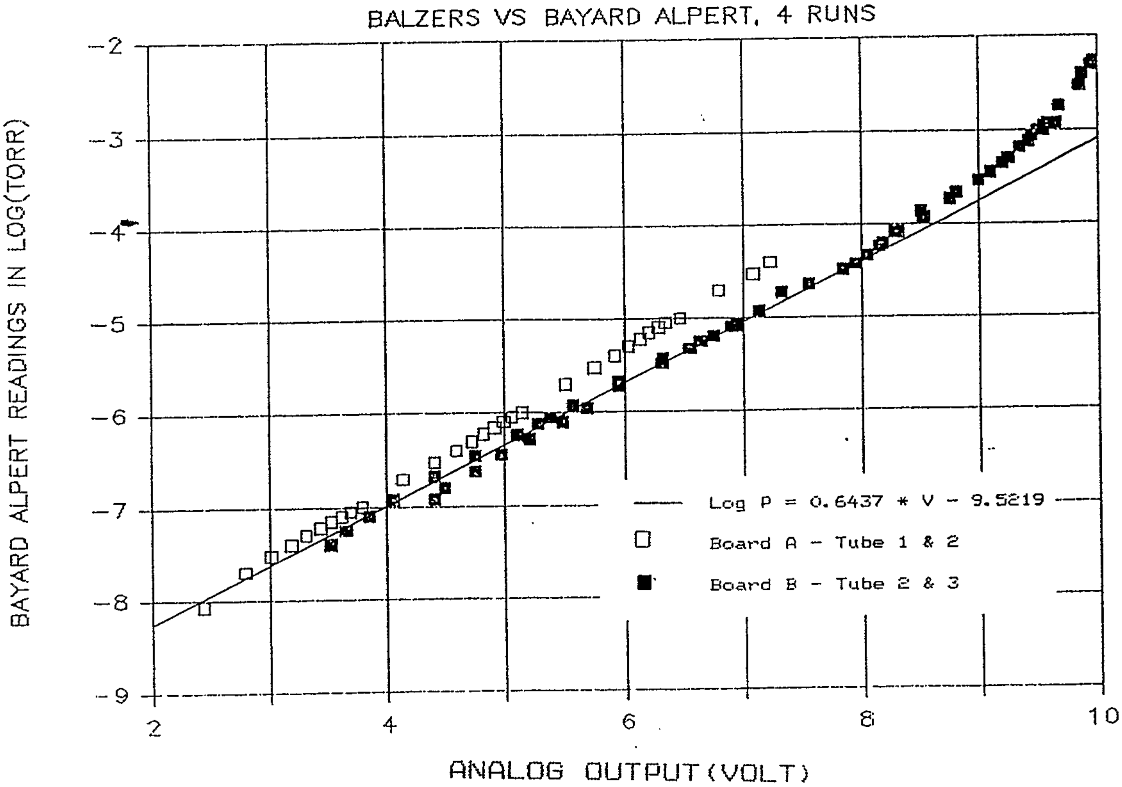


Fig. 7

Fig. 8

COLD CATHODE TUBE CALIBRATION



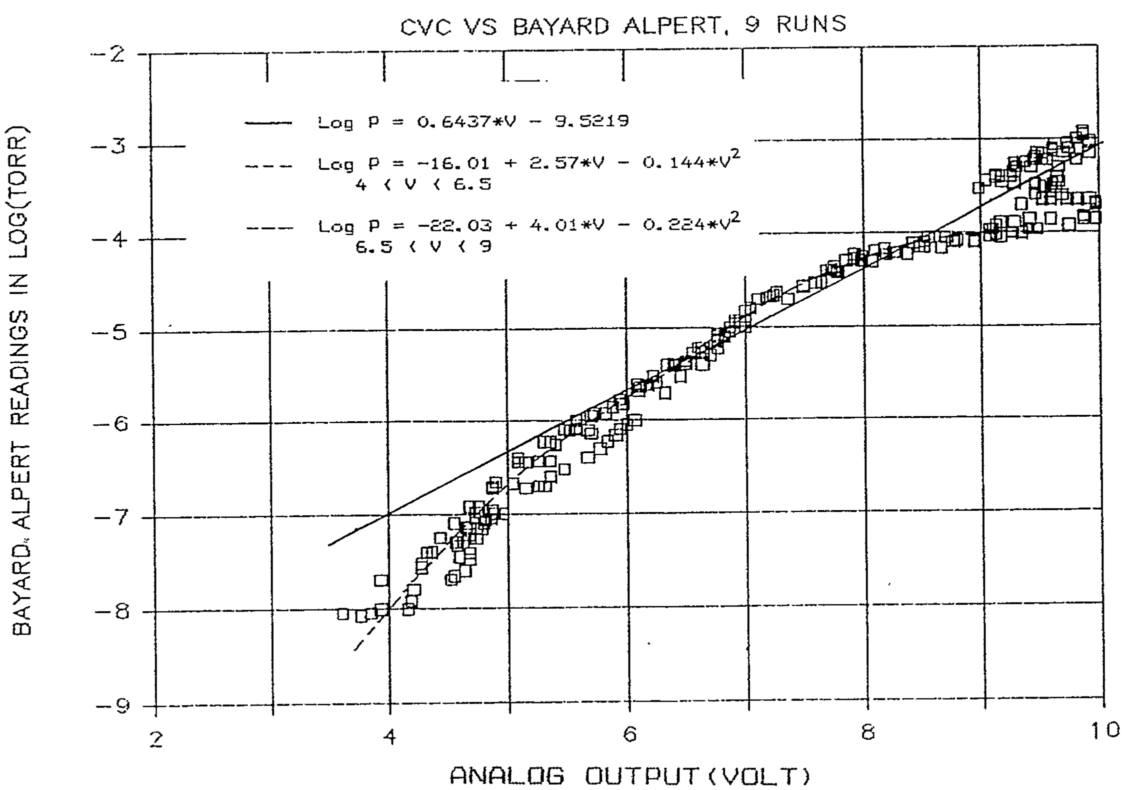


Fig. 9.