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TWO GAS ATMOSPHERE SENSOR SYSTEM
FINAL REPORT

Prepared under Contract No. NAS1-8192
THE PERKIN-ELMER CORPORATION
Pomona, California

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ABSTRACT

A theoretical ion focusing analysis, laboratory test data and system operating instructions are presented. The analyzer was designed as an atmospheric control sensor for manned closed environments.

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TWO GAS ATMOSPHERE SENSOR SYSTEM

FINAL REPORT

SUMMARY

The basic Langley Two Gas Atmosphere Sensor System was modified to include helium (m/e 4) and argon (m/e 40) to its monitoring capability. The basic analyzer was designed to monitor water (m/e 18), nitrogen (m/e 28), oxygen (m/e 32) and carbon dioxide (m/e 44). The sensor's inlet system was modified to produce optimized performance at three different total pressure conditions required for the test program.

An output monitor and calibration assembly mounted in a portable console was fabricated to permit continuous visual monitoring of the six output signals and provide a standard calibration gas at selected total pressure levels.

Collector positions for m/e ratios of 18 through 44 had been previously determined by theoretical calculations using simplified assumptions about the magnetic fringe fields. These assumptions are not valid for low m/e ratios since these particles spend most of their time in the fringe field and are affected in ways that cannot be adequately predicted by theoretical calculations. A numerical technique was developed to predict the collector position for helium (m/e 4). The actual position of water (m/e 18) as determined in test was used as a check of the numberical process.

The technique utilized measured the strength of the magnetic induction at points in the plane of the particle trajectory with a gaussmeter. Then the differential equations of motion were solved for the measured field using numerical techniques and a digital computer. The method proved to be very accurate and provided the actual location of helium (m/e 4) at the predicted location.

The location of the m/e 44 and m/e 32 collectors and the angles at which the ion beams enter their respective collectors had been determined during previous contracts. An estimate of the location of the m/e 40 collector was obtained by taking two-thirds of the distance between the m/e 32 and m/e 44 collectors as the location of the m/e 40 collector. The m/e 40 angle was determined similarly as two-thirds of the difference between the m/e 32 and m/e 44 angle added to the m/e 32 angle. A value for the m/e 40 beam width equal to the previously determined m/e 44 beam width was used. This was taken as a safe upper limit because actually the m/e 40 beam width is smaller than the m/e 44 beam width. The m/e 40 collector slit was chosen to be the same size as the m/e 44 collector slit opening.

The electrometers for the masses were chosen to give a -5V output voltage for the maximum ion current expected.

The capillaries were designed using data compiled from previous experience. The basic design was then modified, if necessary, in the laboratory until the desired ion source pressure was obtained. The modification consisted of cutting off or adding a piece of capillary tubing.

INTRODUCTION

The goal of this contract (NAS 1-8192) was to develop a system capable of simultaneously monitoring helium, water vapor, nitrogen, oxygen, argon and carbon dioxide in a closed laboratory cabin atmosphere. It was assumed that such a sensor would form an integral part of an atmospheric control loop. To achieve this, the Engineering Test Model (ETM) of the Two Gas Atmosphere Sensor System manufactured under Contract NAS 1-6387 was modified to include helium and water vapor.

A brief resume of this sensor system's development is presented to trace the development of the analyzer. The first phase under Contract NAS 1-5679 was a study directed toward the selection of the type and configuration of mass spectrometer best suited for the task. A single focusing 90 magnetic sector instrument was selected based upon a computer optimization. The ion source, the support electronics and the sample inlet system were also thoroughly analyzed and the preliminary configurations established. This effort culminated in a final report which was completed in March of 1966. Later that same year Contract NAS 1-6387 was awarded for the second phase of the program. This covered the design, fabrication and test of an ETM and the fabrication and test of four flight prototype units. The first part of this effort, designated as Phase IIa, covered the development and test of the ETM. The ETM was successfully demonstrated at Langley Research Center in April 1967.

The ETM was later upgraded to flight prototype status and tested on the McDonnell Douglas Space Cabin Simulator for a period of 60 days. This test demonstrated that the instrument could function reliably for an extended period of time. During this test, the instrument was placed in control of the oxygen and nitrogen partial pressures and functioned in this capacity until its completion. The Two Gas Atmosphere Sensor System demonstrated its ability to act as the primary atmospheric monitor and measured the principal constituents of water, nitrogen, oxygen and carbon dioxide.

Contract NAS 1-8192 was awarded to Perkin-Elmer Aerospace Systems to modify the ETM for the addition of helium and argon capabilities. The modifications incorporated were: Changing the filament material to a material which has demonstrated greater longevity, adding monitored outputs for helium and argon, and repackaging the system to accomodate these modifications. Additionally, capillary and bypass atmosphere sampling assemblies for the desired sample pressure levels were designed, fabricated and tested.

The basic analyzer is furnished with a laboratory vacuum support system, an output monitor and a calibration assembly.

The complete system is to be used during extended atmospheric monitoring tests at Brooks Air Force Base, School of Aerospace Medicine, San Antonio, Texas.

Z-Axis Focusing for Mass 4. - An investigation of the z-axis focusing for mass 4 was needed in order to determine if a portion of the ion beam would be lost due to collisions with the analyzer wall. A degradation of the beam intensity by losses because of collisions with the analyzer wall lowers the sensitivity of the mass spectrometer and gives a current reading not indicative of the partial pressure of the ionic species.

The z-axis focusing of the two gas sensor consists primarily of two parts. They are:

a. Focusing due to focusing electrode

b. Focusing due to fringe field of magnet

Focusing due to the z electrodes is independent of the mass of the ion. An analysis of the focusing effects of the z electrodes is found in the Langley Phase II Final Report.

Z-axis focusing due to the magnetic fringe field, of course, is mass dependent. The z-axis focusing close-up for mass 4 acts to spread (defocus) the ion beam; whether z-axis focusing is focusing or defocusing is dependent on the angle the ion beam makes with the pole face (see Figures 1 and 2).

Focusing occurs when ϵ is positive, that is increasing towards the center of curvature. Defocusing occurs when ϵ is negative. Analyzing the computer trajectories for mass 4 shows that ϵ for mass 4 is negative, defocusing. A derivation of the angle of deflection in z-axis focusing follows:

The force acting on an ion (see Figure 1) in a magnetic field can be expressed in terms of force components.

$$\frac{e}{m}(V_y B_z - V_z B_y) = \ddot{x}$$

$$\frac{e}{m}(V_x B_z - V_z B_y) = -\ddot{y}$$

$$\frac{e}{m}(V_x B_y - V_y B_x) = \ddot{z}$$

$$B_x = 0$$

therefore,

$$\ddot{z} = V_x B_y \left(\frac{e}{m}\right)$$

$$V_x = \dot{y} \tan \epsilon$$

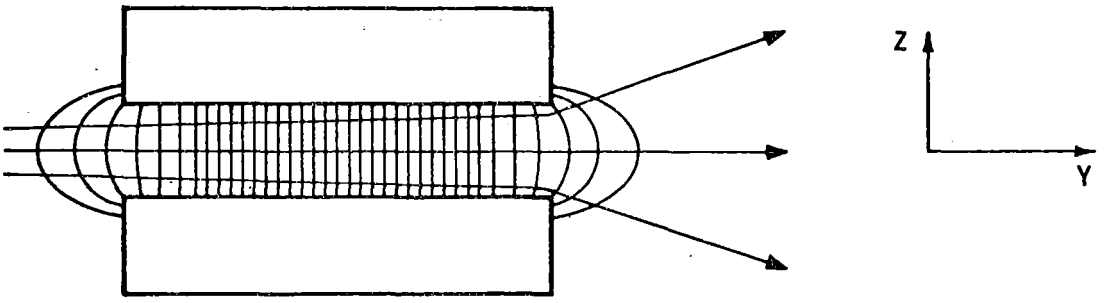

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FIGURE 1
Z-Axis Focusing

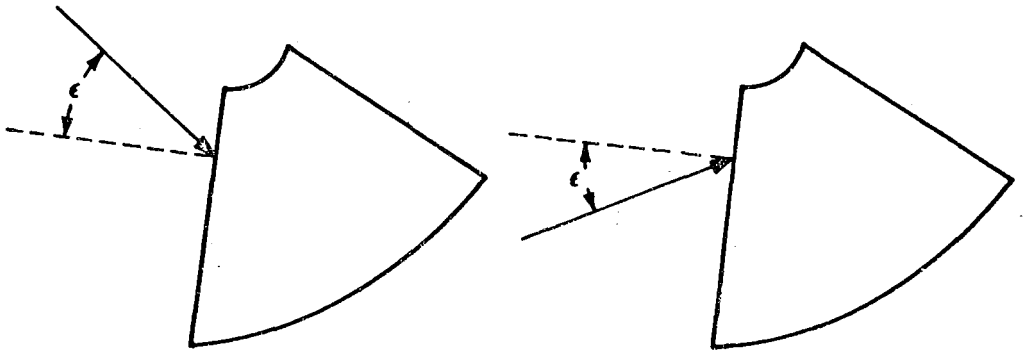

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FIGURE 2
Z-Axis Focusing and Defocusing

$$V_x = \frac{dy}{dt} \tan \epsilon$$

$$\ddot{z} = \frac{dy}{dt} \tan \epsilon \, B_y \frac{e}{m}$$

$$\int_o^t \left(\frac{d^2z}{dt^2}\right) dt = \tan \epsilon \, \frac{e}{m} \longleftarrow \int_\infty B_y \, dy$$

$$\dot{z} = \frac{e}{m} \tan \epsilon \int_\infty^o B_y \, dy$$

In order to calculate $\int_\infty^o B_y \, dy$, use $\oint B \cdot ds = 0$ along the path shown in Figure 3.

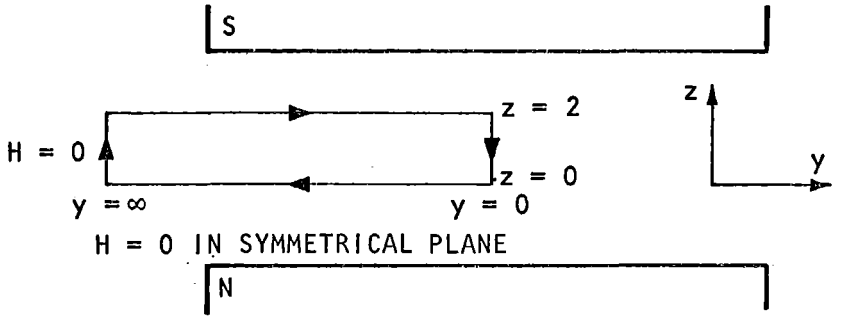


FIGURE 3
Ampere's Circuital Law Diagram

$$\oint B \cdot ds = 0$$

$$\oint B \cdot \vec{ds} = \int_\infty^o B_y \, dy + \int_z^o B_z \, dz + \int_o^\infty B_y \, dy + \int_0^z B_z \, dz$$

$z = Z$ $\quad y = 0$ $\quad z = z$ $\quad y = \infty$

$$0 = \int_{\infty}^{o} B_y \, dy + B_z \int_{z}^{o} dz + \int_{o}^{\infty} \underset{\downarrow o}{o \cdot dy} + \int_{0}^{z} \underset{\downarrow o}{o \cdot dz}$$

therefore,

$$\int_{0}^{\infty} B_y dy = B_z \int_{z}^{0} dz$$

$$\int_{\infty}^{0} B_y dy = B_z Z$$

Using solution for $\int_{\infty}^{o} B_y \, dy$

and obtain

$$\dot{z} = \frac{e}{m} \tan \epsilon \; Bz$$

The angle of delfection is given by z/v_o

$$v_o = \frac{reBz}{m}$$

therefore,

$$\alpha = \frac{z \tan \epsilon}{r}$$

where z is the half height of the beam entering the field and r is radius of the ion. For a length path of c in the field a change in z of

$$c \sin \alpha \doteq c\alpha = \frac{cz \tan \epsilon}{r}$$

is obtained.

Of course there is a similar deflection of the beam when it exits the field. But mass 4 is collected inside the field and consideration of the exit defocusing is not needed (see Figure 4).

Next evaluate α and αc

$$r = 1.08 \text{ cm}, \; c = (.75)(2.54)\text{cm}$$

$$\epsilon \cong 8° \longrightarrow 15°, \; c = 1.93 \text{ cm}$$

(ϵ is determined from plots of computer data)

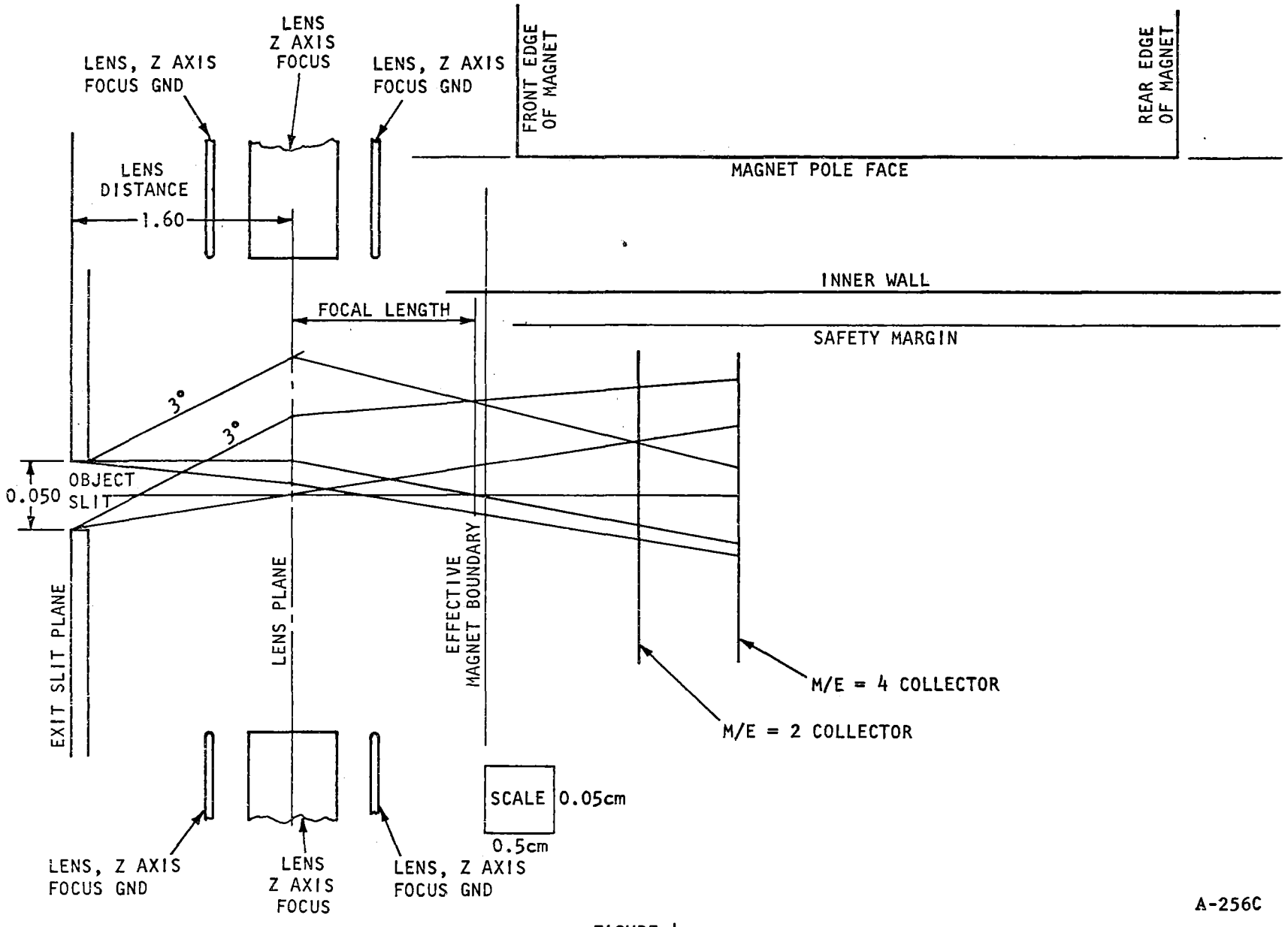


FIGURE 4
Z-Axis Focus Design Schematic With Trajectory Construction

$$\alpha = \frac{\tan \epsilon}{r}$$

for $\alpha = 8°$

$$L = \frac{(0.075)(0.104)}{1.08} = 0.00725 \qquad \alpha = 0.423°$$

for $\epsilon = 15°$

$$\alpha = \frac{(0.075)(0.267)}{1.08} = 0.0193 \qquad \alpha = 1.1°$$

for $\epsilon = 8°$

$$Lc = 0.014 \text{ cm}$$

for $\epsilon = 15°$

$$\alpha c = 0.0376 \text{ cm}$$

The mass 4 collector is 1.93 cm from the magnet boundary and has a half height of 1.35 cm in the z direction. By merely adding the αc value to the deflection of the worst case shown in Figure 4 the effects of the electrode and fringe field are found. Figure 4 shows the focusing effects of the lens. Noting that the worst case is about .035 cm from the safety margin line and about .05 cm from the end of the collector. Therefore z-axis defocusing does not cause loss of ion, at least within accuracy of the derivation and measurement of ϵ.

ANALYZER TEST AT PERKIN-ELMER AEROSPACE SYSTEMS

General. - After performing the modifications discussed in the Introduction the instrument was first tested using bench electronics and a laboratory vacuum system. Testing began on September 10, 1968 and followed a basic outline consisting of filament conditioning, ion source tuneup, analyzer tuneup, capillary test, and data evaluation. The next phase of the testing was performed on the end item vacuum system with fully integrated electronics and capillary inlet system. The following paragraphs describe the data which was acquired during this testing.

Filament conditioning. - Since part of the modification involved changing the filament material from 75% tungsten 25% rhenium to 97% tungsten 3% rhenium for extended filament life. The new filaments were slowly brought up to the operating level over a period of one half hour each. This served to gradually outgas the filament and relieve any stresses incurred in the fabrication processes. This was done with the laboratory electronics in a mode where all emitted electron current was collected on adjacent surfaces as opposed to the operational mode where the emission is suppressed by the filament shield being

being negative to the filament bias. Both filaments were found to have nominal characteristics.

Ion source tuneup. - Since this analyzer had been fully operational as a Two Gas Sensor System prior to modification, the previously used voltages were used for the initial tuning voltages. Ion source tuneup was accomplished quickly and without difficulty. All source parameters were well within the nominal limits.

Analyzer tuneup. - Tuneup of the instrument entailed magnet positioning, peak alignment, sensitivity measurement, crosstalk measurement, Z-axis focus lens tuning, ion focus lens tuning, and with the addition of the m/e 4 collector, source mass discrimination evaluation.

Referring to the data plots and graphs included in this section the ion source was initially tuned for maximum sensitivity of m/e 28 with an arbitrary magnet position setting. All peaks were then scanned to determine in a preliminary manner the peak shape, resolution and collector alignment with respect to a given accelerating potential. Initially analyzer performance was quite poor, indicating the magnet position was far from the desired operating point. Numerous magnet positioning iterations were performed and good performance was achieved. The position of the magnet was then fixed and a line scribed around the magnet pole face on the analyzer envelope for location. It was found that additional collector mechanical positioning was unnecessary and all m/e peaks were well centered about an accelerator potential of 161.1 volts. The computer analysis described in the Introduction can probably be the major single contributor to this accuracy. Figure 5 is an overlay scan plot of the alignment and also shows excellent peak shape and peak resolution. At this time some of the peaks did have sloping tops, however, this was later corrected by Ion focus lens voltage adjustments.

Another aspect of the ion source tuneup which was done before many of the other tests but formally documented late in the program, was that of Z-axis lens voltage adjustment. This lens controls the Z-axis beam divergence and with proper adjustment should maintain the beam width within the width of the collector slits. Testing demonstrated this to be the case since as the lens potential is increased the m/e 4 and 28 outputs increased and then flattened out above approximately 150 volts.

After all source lens voltage adjustments were made the analyzer basic sensitivity tests were done for those gases which could give meaningful data. That is, no sensitivity check was made for either O_2 or CO_2 since O_2 is very reactive and CO_2 was not immediately available. Basic sensitivity measurements were made by letting the sample gases into the vacuum system without the source being differentially pumped. The end item vacuum system supplied with the analyzer is not equipped with a variable leak valve since this type of test was only necessary for initial analyzer evaluation. It was found that the basic sensitivity for the following gases were:

$$\text{Helium} - 1.8 \times 10^{-7} \text{ amps/torr at } 15\ \mu\text{A } I^{-}_{\text{anode}}$$

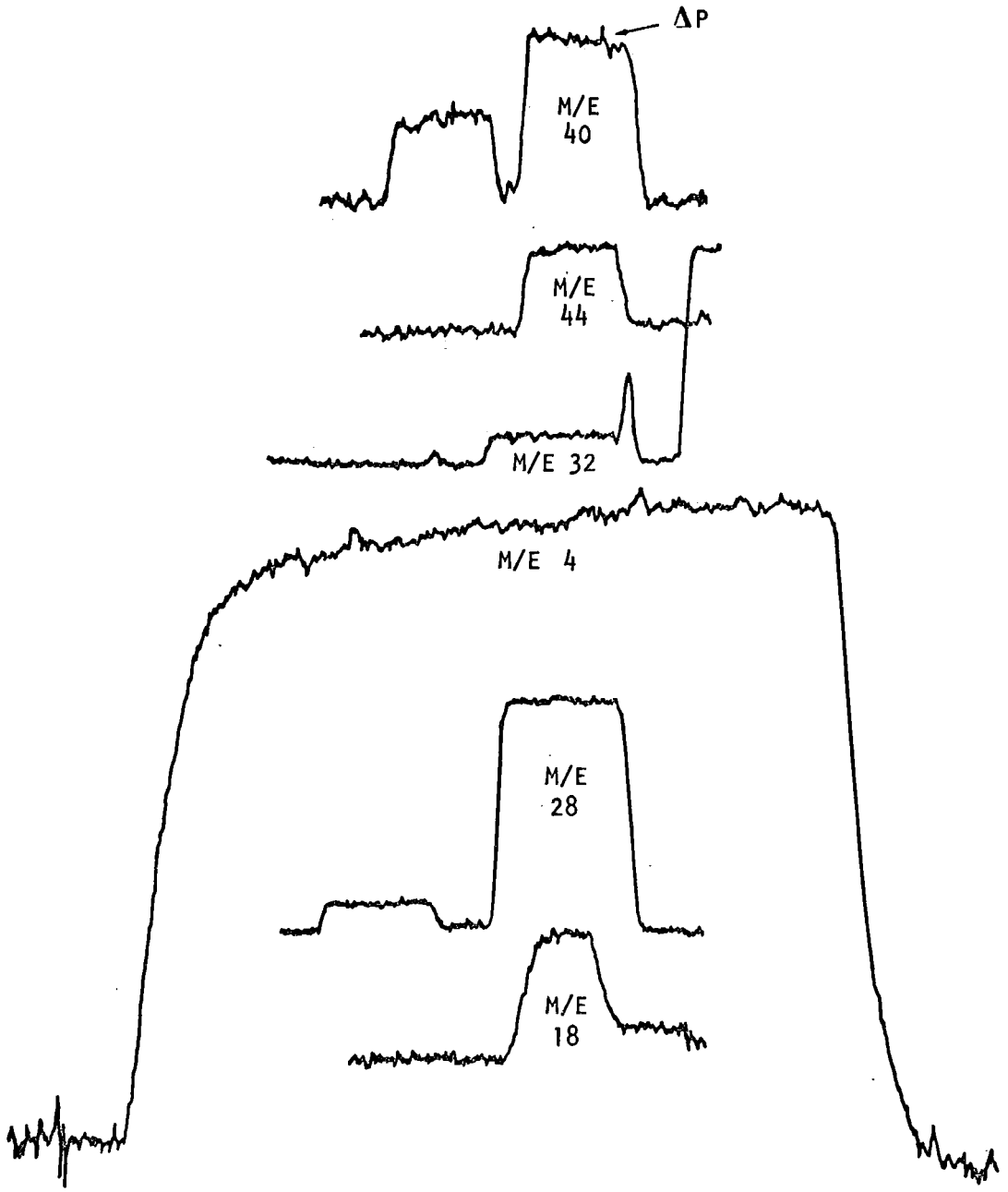


FIGURE 5
Collector Alignment After IF Tuning (m/e 4)

Nitrogen - 1.0×10^{-6} amps/torr at 15 μA I^-_{anode}

Argon - 1.35×10^{-6} amps/torr at 15 μA I^-_{anode}

This information is also helpful in determining the Ion source pressure with differential pumping. The output in volts as read on the meter panel can be easily converted back to current by; $I^+ = \frac{V_{out}}{R_{fb}}$ where R_{fb} is the amplifier feedback resistor the values of which are:

He - 5×10^{11} ohms

H_2O - 1×10^{12} ohms

N_2 - 1×10^{11} ohms

O_2 - 2×10^{11} ohms

A - 1×10^{12} ohms

CO_2 - 5×10^{11} ohms

It was then desirable to check the effects of the magnetic fringe fields upon the source since the analyzer now included m/e 4 which is easily affected by fields of low intensity. This was accomplished in two ways and was done for both electron guns considering the difference in orientation. The first method of evaluation was to compare the ion focus lens voltages required for maximum output for m/e 4 and 28. While some differences were seen it was of negligible magnitude. The second method to confirm this was to adjust the anode potentials of both guns to deflect the electron beam and thus move the ionizing region. If mass discrimination were occurring the peak ion current for m/e 4 and 28 would have been at different voltages. Again only minor affects could be seen.

Crosstalk measurements on the m/e 32 and m/e 44 collectors with nitrogen and argon samples revealed no significant levels. The analysis was made by running the analyzer at two pressure levels and examining the m/e 32 and 44 peak tops for slope changes.

Upon completion of this testing phase the instrument was integrated with its electronics, capillary and bypass lines and placed on the end item vacuum system. The electronics were checked out and performed satisfactorily. The emission regulator was found to regulate to ±0.15% through the full range of source pressures with a pure oxygen sample. The use of oxygen here represents an extreme case since the filament work function changes and thus drive requirements vary widely.

Output linearity versus pressure runs were then made with the various capillary sampling systems. These tests were first done using pure nitrogen samples and the results indicated good linearity over the design pressure ranges as may be seen in Figures 6, 7 and 8. Output linearity versus pressure testing with a pure helium sample was not conclusive due to the pumping difficulty incurred with this gas.

The last test was that of m/e 28 output linearity versus pressure using the standard mix. Linearity here was excellent as may be seen in Figure 9. The capillary configurations for the various sample pressures are as follows:

200 Torr - Short Capillary, Short Bypass

400 Torr - Medium Length Capillary, Long Bypass

800 Torr - Long Capillary, Short Bypass

GENERAL INFORMATION AND OPERATING PROCEDURE

General. - This instrument is a modified Two Gas Atmosphere Sensor System (see Figure 10). The principal modifications are:

a. The filament material has been changed to 3 MIL diameter 97% W - 3% Rh for longer filament life.

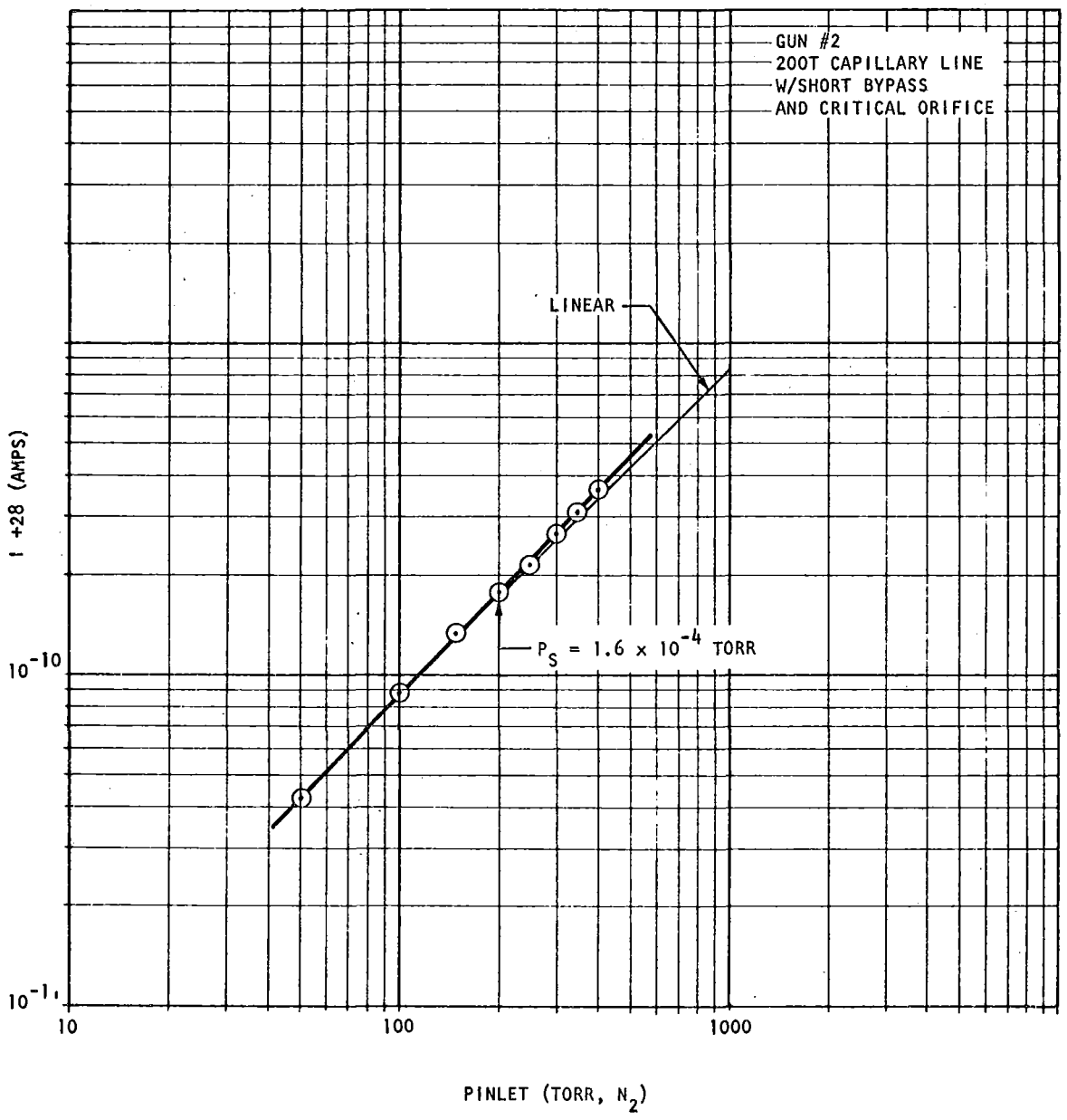
b. Three capillary lines have been supplied for sampling at pressures of 200, 400 and 800 torr. These lines must be used with the proper bypass lines, that is there are two different bypass line lenghts. The short line is for use with the 200 and 800 torr capillaries and the long bypass line is for use with the 400 torr capillary line.

c. The instrument is housed in a specially designed package which combines serviceability with an approximation of the spacecraft hardware configuration.

d. A modified collector assembly is employed to enable the continuous monitoring of m/e 4, 18, 28, 32, 40 and 44. This required the addition of two collectors and amplifiers for m/e 4 and m/e 40.

The instrument in its present form will function satisfactorily in a normal laboratory environment. However, the electronics have not been compensated over temperature extremes and therefore they should be maintained at as constant a temperature as possible.

The instrument has been shipped in a fully assembled condition. Information has been provided for disassembly and assembly of the system should this be necessary.



BASIC SENSITIVITY 1.1 x 10^{-6} A/T @ 15 μSEC

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FIGURE 6
Output Linearity Versus Pressure

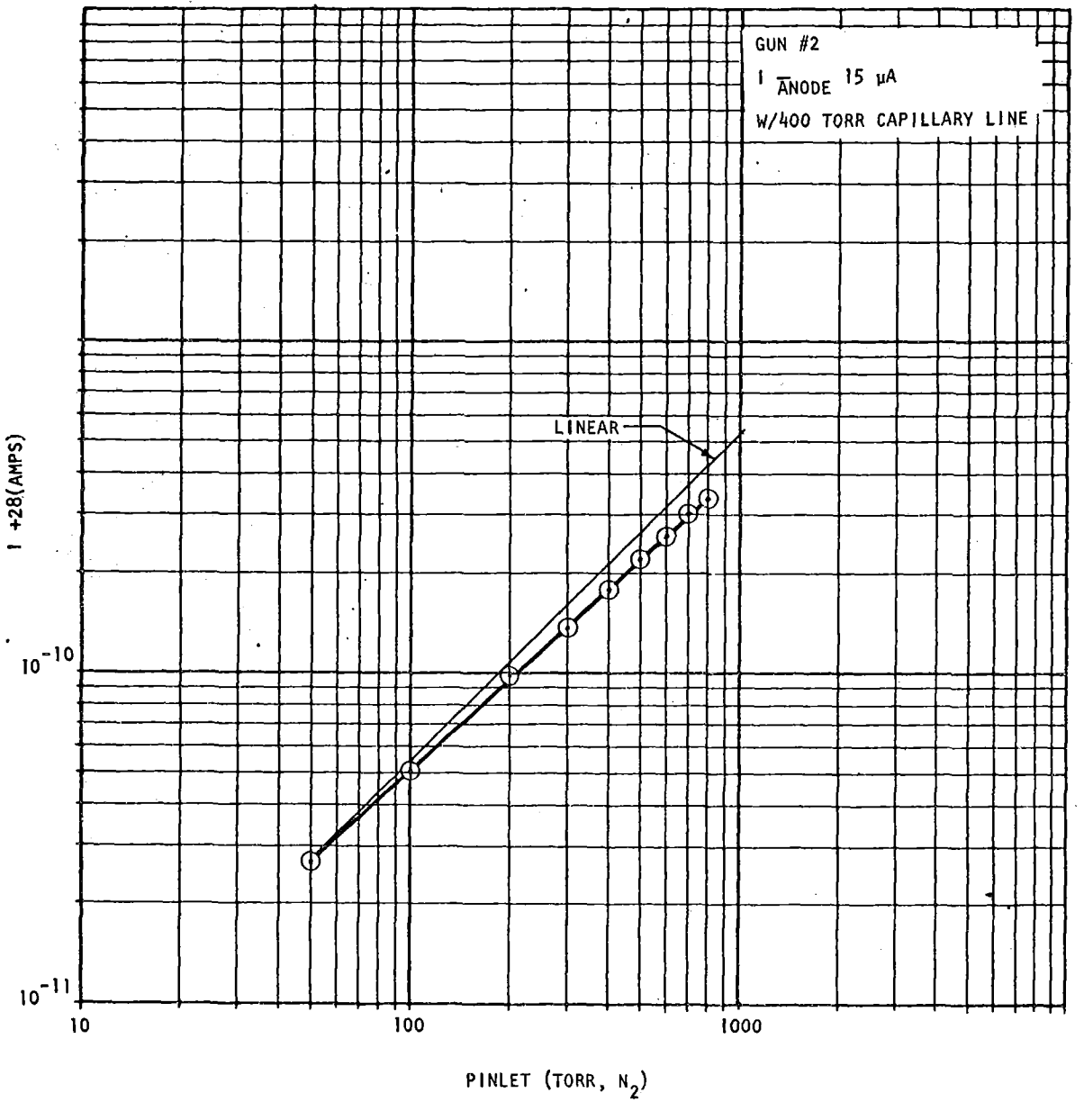

FIGURE 7
Output Linearity Versus Pressure

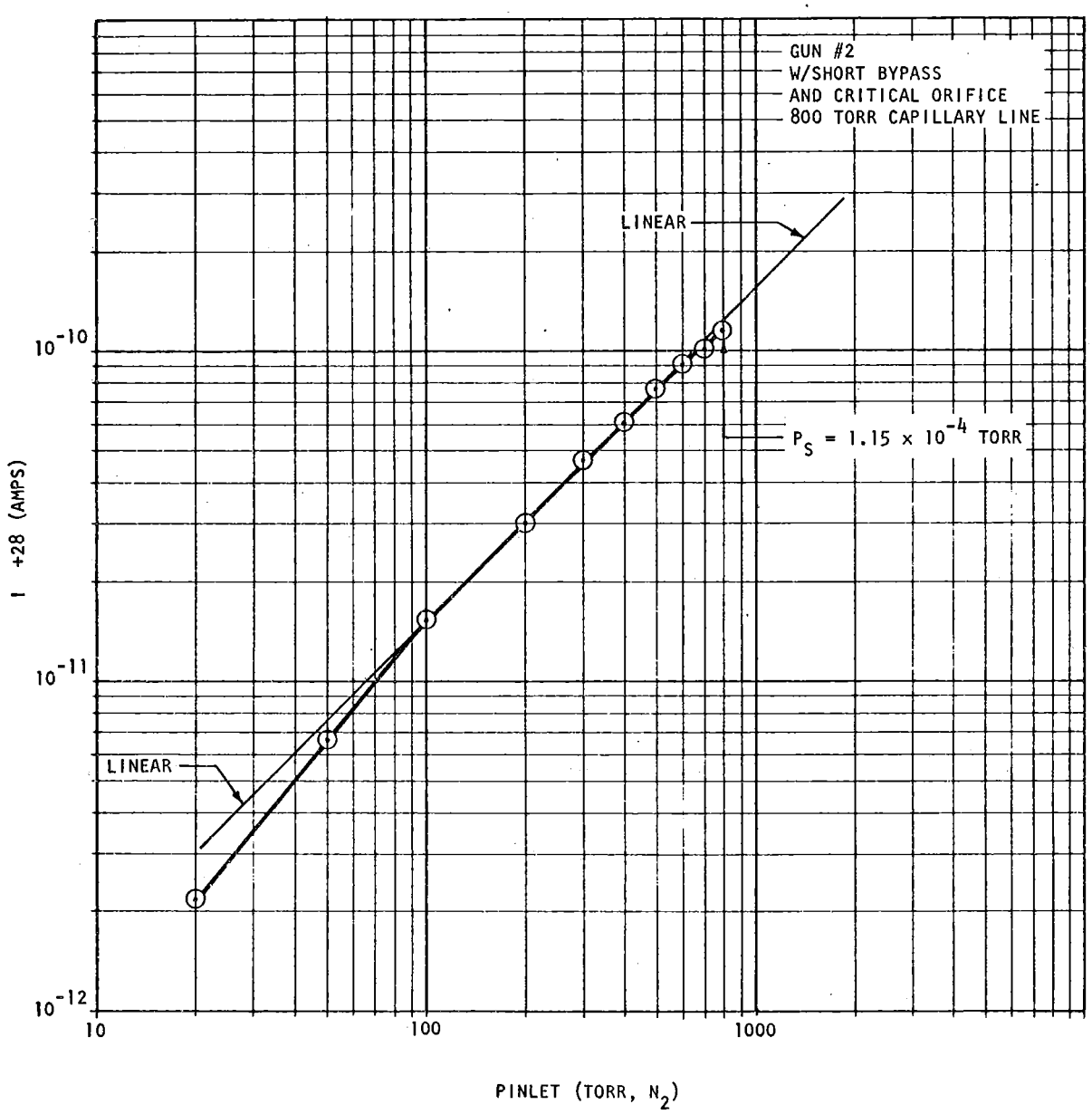

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FIGURE 8
Output Linearity Versus Pressure

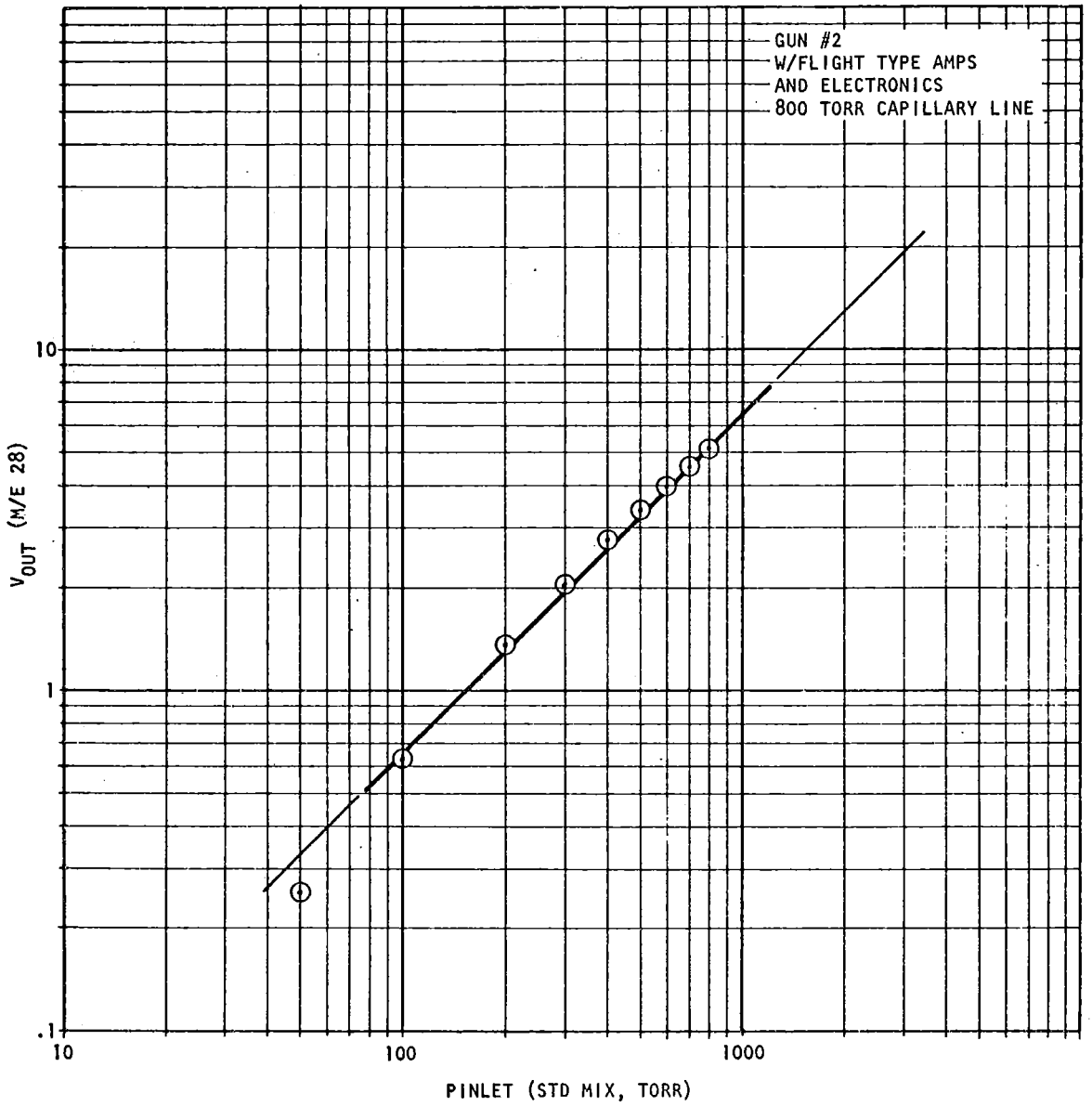

FIGURE 9
Output Linearity Versus Pressure Using Standard Mix

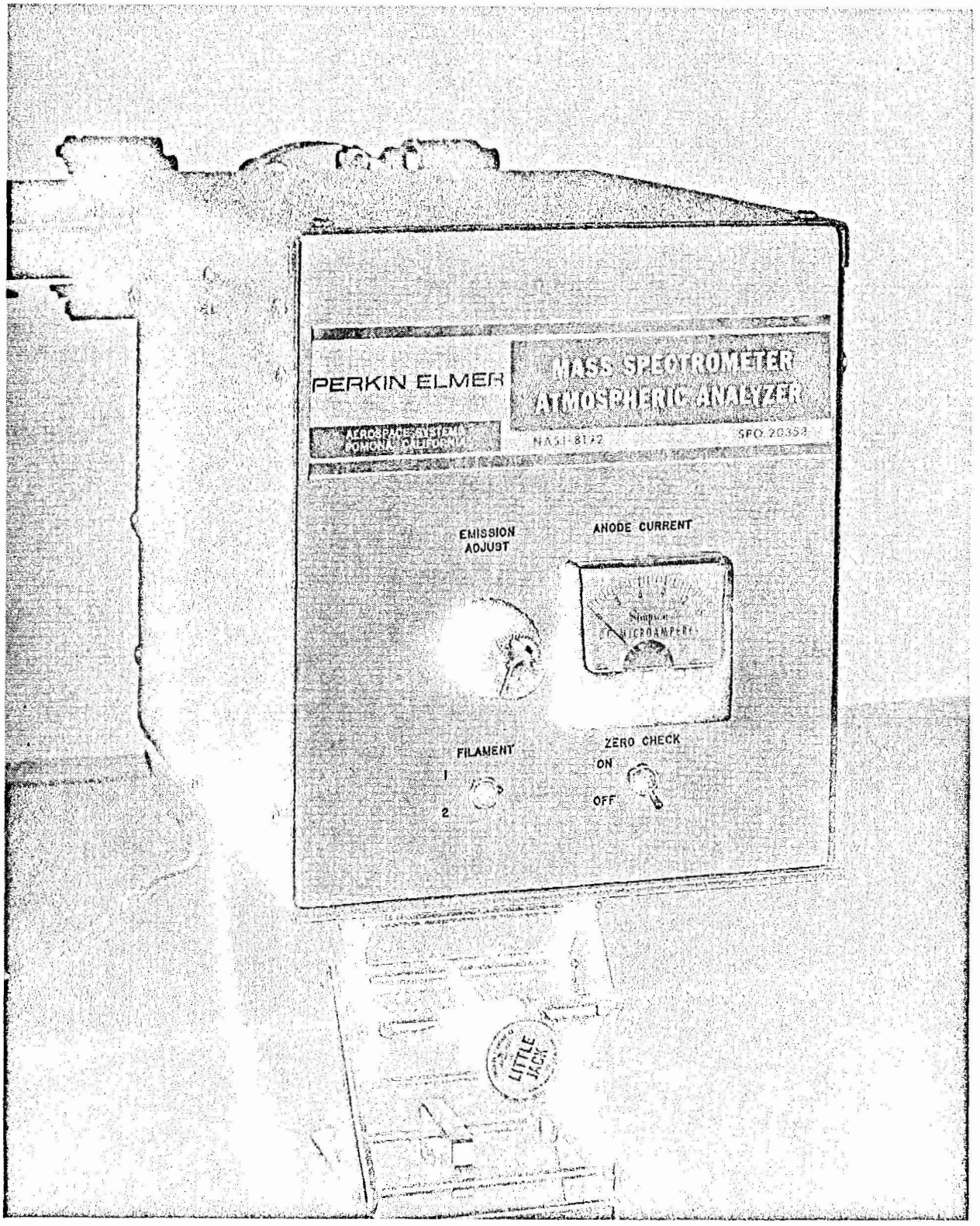

FIGURE 10
Mass Spectrometer Atmospheric Analyzer

The vacuum system is equipped with an Ultek D.I. Pump for extended pumping periods where noble gases are major constituents. The system is also arranged for pumping on the capillary bypass line with either a cryosorb pump or a rough pump and in the case of use with the rough pump a molecular sieve trap has been provided to minimize oil backstreaming into the bypass line.

CAUTION

Do not attempt to pump noble gases using the cyrosorb pump as it will not pump these gases.

ANALYZER

Power. - The system operates from 28 ±1/2 Vdc and requires approximately 3.8 watts of power.

Outputs. - There are six outputs, one for each channel (He, H_2O, N_2, O_2, A and CO_2) which range from zero to -8 volts. (See Figure 11, Output Monitor and Calibration Assembly.)

Electrical output connections. - A six foot cable has been provided for making connection to the output monitoring and calibration assembly.

Vacuum. - The primary vacuum is applied through a 2-3/4" diameter Varian Conflat flange. A pumping speed of at least 4 liters/sec is required at that point. Any higher value of pumping speed will be beneficial since it will reduce the pressure in the region of the filament and prolong filament life.

Capillary line. - The inlet end of the capillary lines are fitted with a stainless steel tube which can be mated to a 1/4" Swagelok fitting. There is a Millipore filter inside of the end piece to protect the capillary line. Care should be taken in handling the end of the capillary to insure that it does not come into contact with a severly contaminated sample.

Bypass line. - The end of the bypass lines must be pumped on when a sample is flowing in the capillary line. Due to adjustments which have been made in the inlet system the manifold pressure in somewhat dependent upon the pumping speed at the end of the bypass line.

Mechanical support. - The instrument with its electronics may be supported from the Varian flange, however, for improved mechanical rigidity an additional adjustable support has been provided (Little Jack).

Monitors. - A panel with six meters for the simultaneous monitoring of helium, water, nitrogen, oxygen, argon and carbon dioxide outputs is located on the calibration system cabinet. Each meter has a separate sensitivity switch for full scale measurements of 0.3, 1, 3 and 10 volts. An output connector and

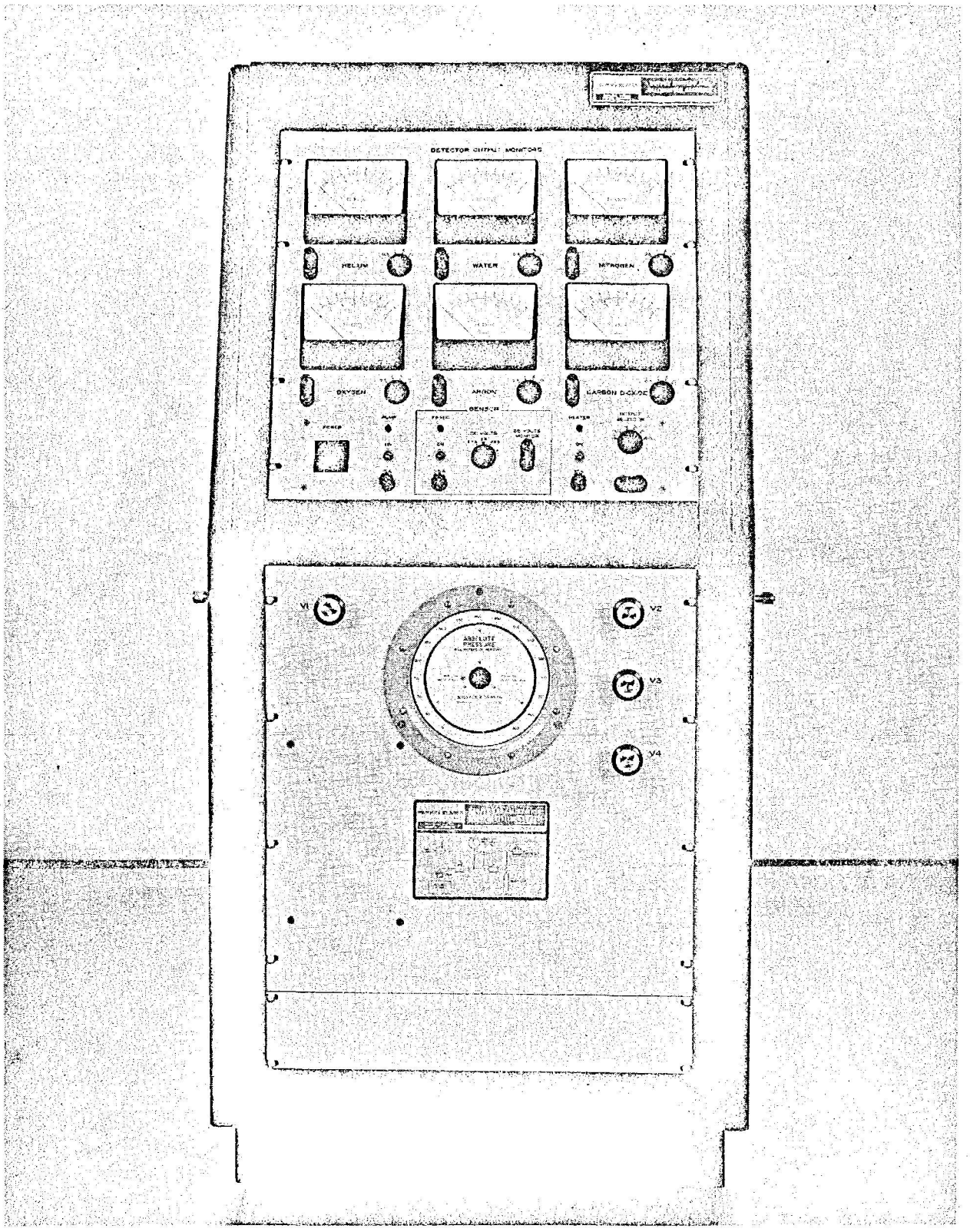

FIGURE 11
Output Monitor and Calibration Assembly

cable has been provided for external signal processing of each channel and is accessible through the rear door of the cabinet. Additionally, a selectable output is located on the front panel for single channel observation with a recorder.

Calibration inlet system. - The calibration system is a gas sampling unit for applying fixed pressures of known gas samples to the inlet of the capillary line. A flow schematic is provided on the front panel. Additionally, a high pressure bottle of standard gas mixture is mounted inside of this cabinet. This standard sample is composed of:

He - 10%

N_2 - 67%

O_2 - 20%

A - 1%

CO_2 - 2%

and must be used for the calibration of the analyzer.

ADJUSTMENTS, MONITORS AND CALIBRATION SYSTEM

The following adjustments are described which may be required during normal operation. There are other potentiometric adjustments which are on the various circuit boards which should not require adjustment. If difficulties arise which necessitate this type of adjustment Perkin-Elmer will provide the necessary information and direction at such time as it is required.

Filament switch. - On the front of the chassis there is a filament selection toggle switch marked FILAMENT 1 and 2. When switching filaments it is recommended that the emission adjust potentiometer be turned down.

Emission adjust. - This potentiometer, located on the front of the chassis, controls the level of the ionizing current, that is, that current reaching the anode of the ion source. When in a full CCW position, there will be no measurable emission current but the filament will be on at a LOW level. When turning up the emission it should be turned slowly in a CW direction until the emission current comes up (about 0350 - 0400 on the dial). Once the emission regulator is operating less caution is required in turning the potentiometer. If the potentiometer is turned up too far the emission will increase until the emission regulator runs out of drive. It is not possible to burn out the filament by improper adjustment of the potentiometer. The potemtiometer will be in the zero position when the instrument is received.

Zero check. - There is a toggle switch located on the front of the chassis used to deflect the ion beam in order to check the zero levels of the detectors.

a. Start the roughing pumps on both the calibration and vacuum systems and turn on the thermocouple gauge (see Figure 12).

NOTE

Because there is an automatic vent valve on the main vacuum system which activates upon the removal of main power, it will always be necessary to rough the trap, vac-sorb pump and lower plumbing from atmospheric pressure upon either initial pump down or after subsequent periods where the main power has been removed.

b. Open the valve on the upper plumbing which isolates the roughing system and mass spectrometer and open the bypass line valve on the back panel of the mass spectrometer. Make certain the capillary line valve is closed. Rough out the vac-sorb pump, trap, capillary bypass line and mass spectrometer to at least five microns.

NOTE

In order to achieve a five micron roughing pressure it may be necessary to bake out the vac-sorb pump and trap. This is done by closing the valve on the upper plumbing which isolates the mass spectrometer from the roughing system and the bypass isolation valve. It is assumed here that the ion pump has remained sealed and at a low pressure. If this is not the case it will also be necessary to rough out the ion pump.

c. After reaching a system pressure of five microns or less, close the valve on the upper plumbing which isolates the roughing system from the mass spectrometer.

d. Before starting the ion pump set the power unit RANGE SELECTOR switch at 5 kv and the START-RUN switch to START.

e. Turn on the ion pump power unit, at this time, the voltage will be about 300-500 volts and current approximately full scale, 150 mA.

f. Within a few moments, the pump will start. This is indicated by a rise in voltage, to above 2000 volts and a decrease in current.

g. After the pump has started, set the RANGE SELECTOR switch at one of the current positions and the START-RUN switch to RUN. The voltage will rise to 4750 volts and remain constant.

h. From this point, the pump will continue to pump the system down without further attention. If the power unit is left unattended,

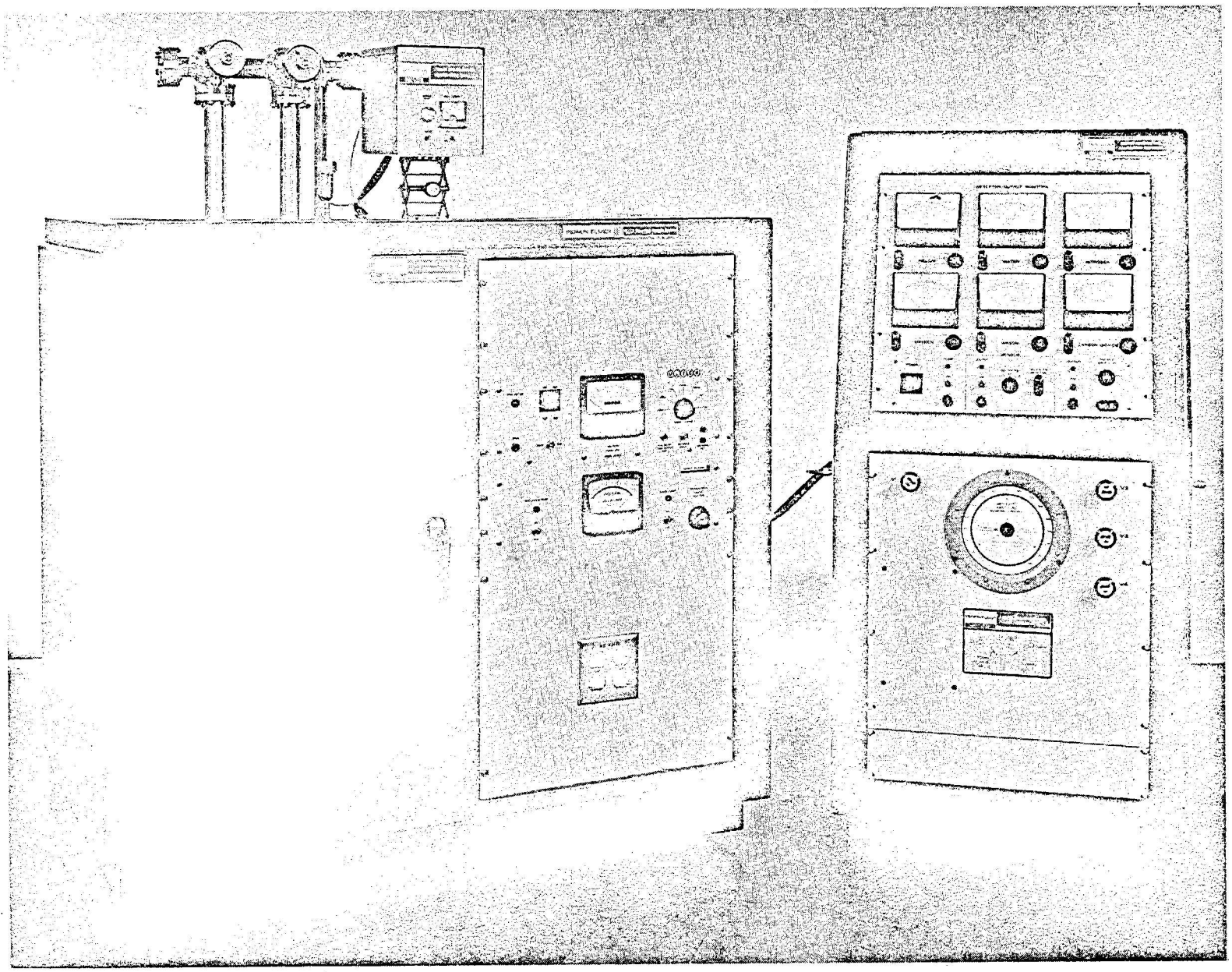

FIGURE 12
Calibration and Vacuum Systems

set the RANGE SELECTOR at 5 kv or 200 ma so that the meter will not be damaged by reading more than full scale for an extended period if a pressure rise should occur.

i. Open the ion pump isolation valve. The system pressure should reduce to 1×10^{-6} torr within a few minutes.

j. Set the emission control, on the front panel of the mass spectrometer, to zero.

k. Check the ion pump pressure on the log scale. This should be 1×10^{-6} torr or lower.

l. The 28 volt power supply, which supplies power to the analyzer, is equipped with a power failure protection device which must be reset each time after the system power is removed. This reset is a red push button on the rear apron of the read out chassis and is accessible through the rear door on the calibration assembly. Prior to turning on the 28 volt power push the reset button. This device is included to avoid accidental burn out of the filaments in the analyzer should there be a power failure.

m. Turn on the 28 volt power.

n. Select the filament desired and slowly raise the emission control until anode current can be seen on the meter. (Emission will be seen on the anode meter between 0350 and 0400 settings of the KNOBPOT.)

o. Set the emission level to about 10 microamperes.

p. Allow 30 minutes for the instrument to become stable before calibration.

q. Regulation of the anode current may be checked in two ways. First, the input power should be variable from 27.5 to 28.5 volts, using the SENSOR DC VOLTS selector switch, with no change in anode current. Also when the capillary is sensing an oxygen rich atmosphere, the anode current will not remain the same as it was at background unless it is being properly regulated.

r. Test data has been appended which gives the operating pressures and output voltages at our final test. Comparisons can be made with these measurements.

s. A set of ion source voltages have also been included (see Table 1). These need not be checked unless incorrect operation is noted or suspected.

t. A sample gas can now be admitted to the desired sample pressure. It is assumed that the sample pressure will not exceed the operating level prescribed for the various capillary-bypass combinations.

TABLE 1

ION SOURCE VOLTAGES[a]

MEASUREMENT	SOURCE VOLTAGES	MEASUREMENT	SOURCE VOLTAGES	MEASUREMENT	SOURCE VOLTAGES
P 101		P 102		P 103	
Fil.-2	-----	E.A.-2	265.6	F.S.-1	56.5
Fil.-2	-----	E.F. 2B	65.1	E.F.-1B	90.3
Z-Axis B	176.7	E.F. 2A	56.7	E.F.-1A	69.9
OPEN	-----	AN-1	181.5	Slit Plate	0
OPEN	-----	ACC. Lens	161.1	I.F.-A	154.0
Z-Axis-A	176.7	I.F.-B	0	AN-2	181.5
Fil.-1	-----	F.S.-2	56.5	REP.	172.0
Fil.-1	-----	OPEN	-----	E.A. 1	265.7
OPEN	-----	M.S.-GND	_____	OPEN	-----

[a]Filament Reference: 67.8 volts.
Filament Material: .003" dia., 97% tungsten, 3% rhenium wire.

Measuring Instrument Used: Fluke, Differential voltmeter, model 803B.
All measurements relative to ground and entered on m/e 28 peak with Magnet Flux Level of 4.15 Kg as measured on Bell, model 240 Gaussmeter.

u. The anode current can then be adjusted to obtain the desired output levels. The anode current should not be set in excess of full scale (15 microamperes), however, damage should not be incurred if this occurs momentarily. All four outputs should move proportionally. The detectors have a maximum output of approximately -8 volts. Therefore, for the maximum system gain the N_2 output should be set near 9 volts at the maximum expected N_2 partial pressure. A comparison should be made at the 10 μA anode current level to see that approximately the same volt/torr relationship is obtained as is given in the test data.

v. To calibrate the system, insert a sample pressure (Std. Mix) compatible to the particular capillary, bypass combination and compute the

sensitivity by:

$$\text{Sensitivity (Torr/Volt)} = \frac{(\text{Sample Pressure}) \times (\text{Constituent Percentage})_{(\text{Std. Mix})}}{\text{Constituent Output Voltage}}$$

Calibration frequency is at the discretion of the operator. However, it must be realized that due to the long time constant involved with water some time is required for the system to equalize after each calibration.