

FINAL REPORT

**TEKTITE I - TWO GAS ATMOSPHERE
SENSOR SYSTEM DEVELOPMENT**

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PERKIN-ELMER

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SENSOR SYSTEM DEVELOPMENT

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for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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1. INTRODUCTION

The development of the Two Gas Atmosphere Sensor System for Langely Research Center under NASA Contract NAS1-6387 has led to the availability of instrumentation for monitoring and controlling the major constituents of the atmosphere within enclosed, inhabited environments. The four prototype systems which were fabricated as part of the original contract have all been applied to various monitoring applications and have operated successfully. The TEKTITE I undersea experiment offered an ideal opportunity to further demonstrate the capabilities of the Two Gas Atmosphere Sensor and at the same time to provide useful atmospheric control information.

TEKTITE I was a multiagency/industry program to determine the capability of a small group of men to satisfactorily perform a scientific research mission while living isolated on the ocean floor under saturated diving conditions for a long period of time.

The program was jointly sponsored by the Navy, National Aeronautics and Space Administration, and the Department of Interior, with the participation by the U.S. Coast Guard. The prime contractor was the General Electric Company, which furnished the undersea habitat and assisted in program planning and scientific mission coordination. TEKTITE I was the first undersea program to be undertaken by a group of federal agencies, in cooperation with private industry.

Four marine scientists lived for a period of sixty days, beginning February 15, 1969, in the TEKTITE I habitat on the ocean floor at a depth of approximately fifty feet. The site was Great Lameshur Bay, St. John, Virgin Islands. This location was chosen for its favorable climate, clear waters, and abundant tropical plant and animal life.

The four marine scientists, all from the Department of Interior, swam from the habitat each day to conduct various scientific projects. They virtually lived in a marine laboratory, both on the ocean floor and in the habitat's working spaces. This environment provided an unprecedented opportunity for intimate long-term marine investigation.

While the four marine scientists conducted their underwater research mission, they were continuously observed by Navy and NASA behavioral and biomedical teams. The objectives here were to identify man's psychological and physiological reactions to a long-term mission performed in an isolated, hostile environment common to undersea and space missions.

The valuable knowledge gained in oceanography was also a significant derivative from this program. The application of the Two Gas Sensor in this hostile environment provided useful information to guide the design of future systems of this type for use in either undersea or space applications.

The cooperative nature of the Tektite program allowed Langely Research Center to supply a modified Two Gas Atmosphere Sensor System for installation in the Tektite habitat. Also, the structure of the program required that Perkin-Elmer interface with several agencies during the installation and operation of the instrument. While these conditions were generally satisfactory, it is believed that the involvement of many people and facilities that were unfamiliar with the operation of the Two Gas Sensor may have had some significant effect upon the results of this effort. Future applications of this type should allow for increased liason and training to minimize these variables in logistics.

2. MISSION REQUIREMENTS

The requirements of the TEKTITE I application were to provide a modified Two Gas Atmosphere Sensor System to monitor the partial pressures of nitrogen, oxygen, and carbon dioxide within the Tektite habitat. A readout for water vapor was also to be provided, but was not of primary concern. The initial requirements for the mission are briefly described in Table 2-1. The most significant feature of the design requirements was the need to have a relatively compact system with a self-contained calibration system which could sample from and operate in the high pressure environment of the Tektite habitat. This requirement necessitated the adaptation of a different type of inlet leak, as well as the design of an enclosure to house the mass spectrometer to protect it from the excessive pressures anticipated.

A nontechnical factor which had a significant impact upon the system design was the extremely tight schedule which resulted from the need to meet specific interface dates at the Philadelphia Naval Shipyard, and finally, at the Tektite site in the Virgin Islands.

TABLE 2-1

PRELIMINARY REQUIREMENTS FOR TEKTITE ATMOSPHERIC ANALYZER

I. PROGRAM INTENT

- A. Monitor and, in conjunction, control crew environment
 - 1. Two Gas System - Air + N₂ at 2.55 atmosphere (filtered)
 - a. N₂ partial pressure approximately 1800 torr
 - b. O₂ partial pressure 152 to 165 torr
 - c. CO₂ partial pressure 2 to 8 torr
 - 2. Expected length of test - 60 days

II. ENVIRONMENT, GENERAL

- A. Local pressure ~ 42 feet - H₂O (37.5 psia) plus tide changes (±1 foot) and barometric pressure change.

TABLE 2-1 (Cont)

PRELIMINARY REQUIREMENTS FOR TEKTITE ATMOSPHERIC ANALYZER

- B. Relative humidity 50% nominal at pressure, 100% during power shortage
 - 1. Salt latent
- C. Local temperature: 80 to 90°F
 - 1. Optimum temperature 82°F for crew comfort

III. GENERAL M.S. SYSTEM REQUIREMENTS

- A. Configuration
 - 1. System configuration to be in keeping with weight and volume of present Two Gas Sensor System. Limitation on reduction of weight and volume to be consistent with availability of commercial hardware and economic limitations.
 - 2. Configuration to be controlled by good design to maintain aesthetic value. Nineteen-inch rack mounting to be utilized. Available area 32-1/2 x 17-3/4 x 14 inches.
 - 3. System operator not to be required except for:
 - a. System monitoring
 - 1) Calibration by "press to test" once a day for first week, once every 3 to 4 days thereafter.
 - 2) Emission regulator current
 - 3) Ion pump current
 - b. Minimum maintenance
 - 1) Filter system replacement
 - 2) Emergency shut down in case of power failure.
 - 4. System enclosure
 - a. Pressure tight for total system
 - b. Hermatic sealed connectors

TABLE 2-1 (Cont)

PRELIMINARY REQUIREMENTS FOR TEKTITE ATMOSPHERIC ANALYZER

5. Installation and handling
 - a. Submersion installation not required
 - b. Normal instrument handling
- B. Electrical
 1. No limitation on power consumption
 - a. Limited by good design practices
 2. Available power
 - a. 60Hz 110Vac
 3. Four-channel continuous local voltmeter readout
 - a. Accuracy: ± 2.0 torr on O₂ output and $\pm 2.0\%$ on CO₂ output
 - b. Commercially available meters supplied
 4. Four-channel remote digital voltmeter readout
 - a. Accuracy: 0.5% to 0.25% (meters)
 - b. Commercially available meters supplied
 5. Emission regulator current and ion pump current readout local
 6. External line amplifiers will be provided for remote and local readout by installation contractor.
- C. System Inlet
 1. Varian leak modified to include calibration system inlet and valving.
 2. Heater and temperature controller required.
 3. Flow meter required to control inlet pressures nominal inlet pressure supplied at 9 in H₂O.

TABLE 2-1 (Concluded)

PRELIMINARY REQUIREMENTS FOR TEKTITE ATMOSPHERIC ANALYZER

4. Filtration of sample inlet and outlet.
 - a. Replaceable particle filter - 1 sintered metal depth filter.
 - b. Micro or Millipore secondary fixed filter.
 5. Sample Time 1 to 2 min during operation, faster during calibration.
- D. Special System Considerations
1. Ion pump
 - a. Commercially available 11 l/s (Ultek).
 - b. Magnetic shielding may be required due to close coupling with analyzer.
 2. Power supply
 - a. Breadboard power supply to provide 5KV and operate from 28Vdc.
 - b. Emergency dc power source for ion pump.
 3. System calibration required
 - a. Gas sample equivalent to expected atmosphere.
 4. No military or NASA Specifications imposed.
 - a. Good practice should control workmanship and materials.

3. SYSTEM DESIGN

The Tektite Atmospheric Analyzer was a modified form of the Two Gas Atmosphere Sensor System. The modifications which were required for the Tektite application were primarily centered in the areas of the sample inlet system, addition of a self-contained ion pump and pump power supply, addition of the necessary monitor and control functions, addition of a calibration system, and the addition of a pressure housing for the mass spectrometer as well as the packaging of the overall system.

A functional block diagram of the Tektite Atmospheric Analyzer is shown in Figure 3-1. Briefly, the operation of the system can be described as follows. A sample of the Tektite habitat atmosphere is received from a sample transport line which is attached to the ventilation system ahead of the carbon dioxide scrubber. This sample enters the sample inlet port, flows through the sample inlet and calibration plumbing, and through the variable leak valve. The valve is modified to be a flow-through design allowing most of the sample to pass by the leak, back to the inlet system and out through the sample exhaust where it is dumped into the cabin. A small quantity of the sample leaks through the valve seat and into the ion source of the Two Gas Sensor where it is ionized and subsequently analyzed. Four simultaneous outputs are provided corresponding to the partial pressures of water vapor, nitrogen, oxygen, and carbon dioxide. The variable leak valve has a heater which is driven through a temperature controller which regulates the temperature to 50°C.

The operation of the Two Gas Sensor is supported by an 11 liter per second Ultek D-I ion pump which is mounted to the analyzer through an adaptive fixture. A one-quarter inch I.D. roughing port was also provided for initial pump down of the analyzer. This port is sealed off by a safety-wired Nupro valve.

The ion pump is powered by a breadboard 5KV power supply. This supply operates from either the 28-volt system power supply or a 30-volt battery pack. The switchover between these power sources is controlled by a relay so that when the system power is off the ion pump operation is maintained via the battery pack. This scheme allowed the ion pump to be continuously operated during shipment, storage, installation, and also, in the event of power failure, within the habitat.

The monitors and controls for the system were housed in an analyzer control panel. All of the monitor and control functions are shown in the block diagram. The Two Gas Sensor, ion pump, and pump power supply were housed within a pressure enclosure with an internal pressure of one atmosphere. This protected the analyzer section of the mass spectrometer from being distorted by

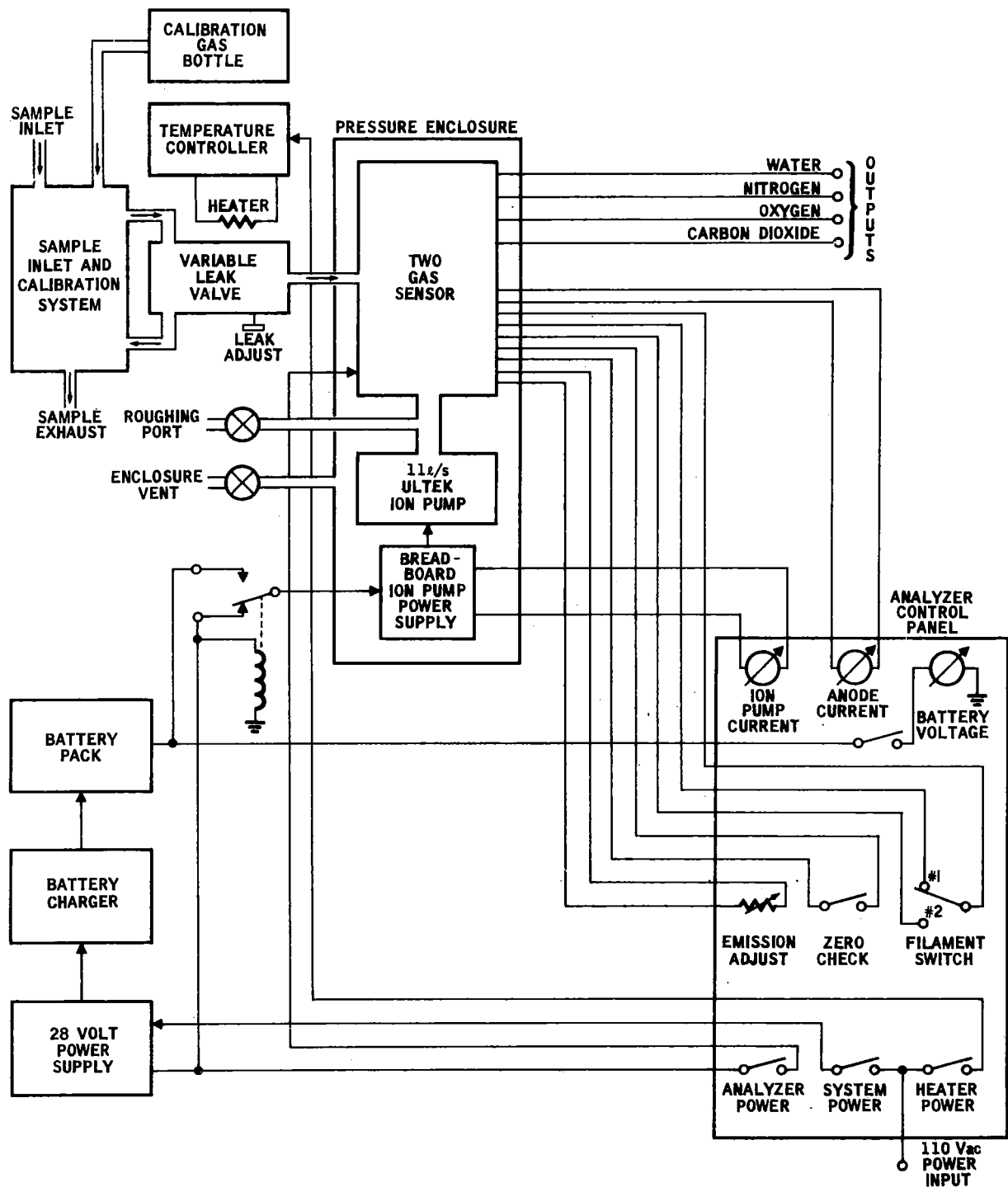


FIGURE 3-1. Tektite Atmospheric Analyzer Functional Block Diagram

the 2.3 atmospheres of pressure which exists within the Tektite habitat when it is at installation depth. The ion pump and its supply are also placed within the pressure housing in order to provide the cleanest interface and avoid the need for high voltage feedthroughs. The pressure housing also doubled as a hermetically-sealed enclosure to maintain a moisture-free environment to avoid electrical leakage which would effect the electrometer amplifiers.

A further discussion of the operation of the system and a photograph of the complete atmospheric analyzer is given in the Operation and Maintenance Manual which is included as an Appendix.

3.1 TWO GAS ATMOSPHERE SENSOR SYSTEM

A detailed description of the Two Gas Atmosphere Sensor System has been provided in other publications and will not be given here.¹

In general, the Two Gas Atmosphere Sensor System is a mass spectrometer system which will provide four simultaneous and linear output voltages which are proportional to the partial pressures of oxygen, carbon dioxide, water vapor, and nitrogen. A basic schematic block diagram of the system is shown in Figure 3-2, which may be conveniently divided into two subsystems; the analyzer subsystem and the electronics subsystem.

The analyzer subsystem consists of an inlet system which admits the gas to be sampled by the system, an ionization section which ionizes the sample to form the charged particles which are then resolved in the magnetic sector. An ion pump maintains the internal vacuum necessary for operation of the instrument. The electronics subsystem consists of the various circuits required to supply the voltages and currents for the operation of the analyzer as well as for the amplification of the ion current outputs. The two subsystems are housed in a system enclosure with the necessary inputs and outputs. A more detailed description of the system is given in the following paragraphs.

The inlet system on the original sensor consists of a viscous flow capillary line that samples the atmosphere at one standard atmosphere and reduces the pressure to several torr by means of the pressure drop in the flow channel. At the point where the nominal pressure is seven torr, the flow is sampled by an orifice that provides a molecular flow into the ion source. The capillary line is approximately six feet in length, which allows some flexibility in the location of the sampling point relative to the mass spectrometer. A rough pump is required for maintaining the flow through the capillary line. This inlet system was not suitable for sampling the high pressure within the Tektite habitat and, therefore, it was replaced with the variable leak valve as discussed in Paragraph 3.2.

¹Two Gas Atmosphere Sensor System (Mass Spectrometer) Phase II(a) - Phase II(b) Final Report, March 1969, Contract NAS1-6387 Prepared for NASA - Langley Research Center, Hampton, Virginia.

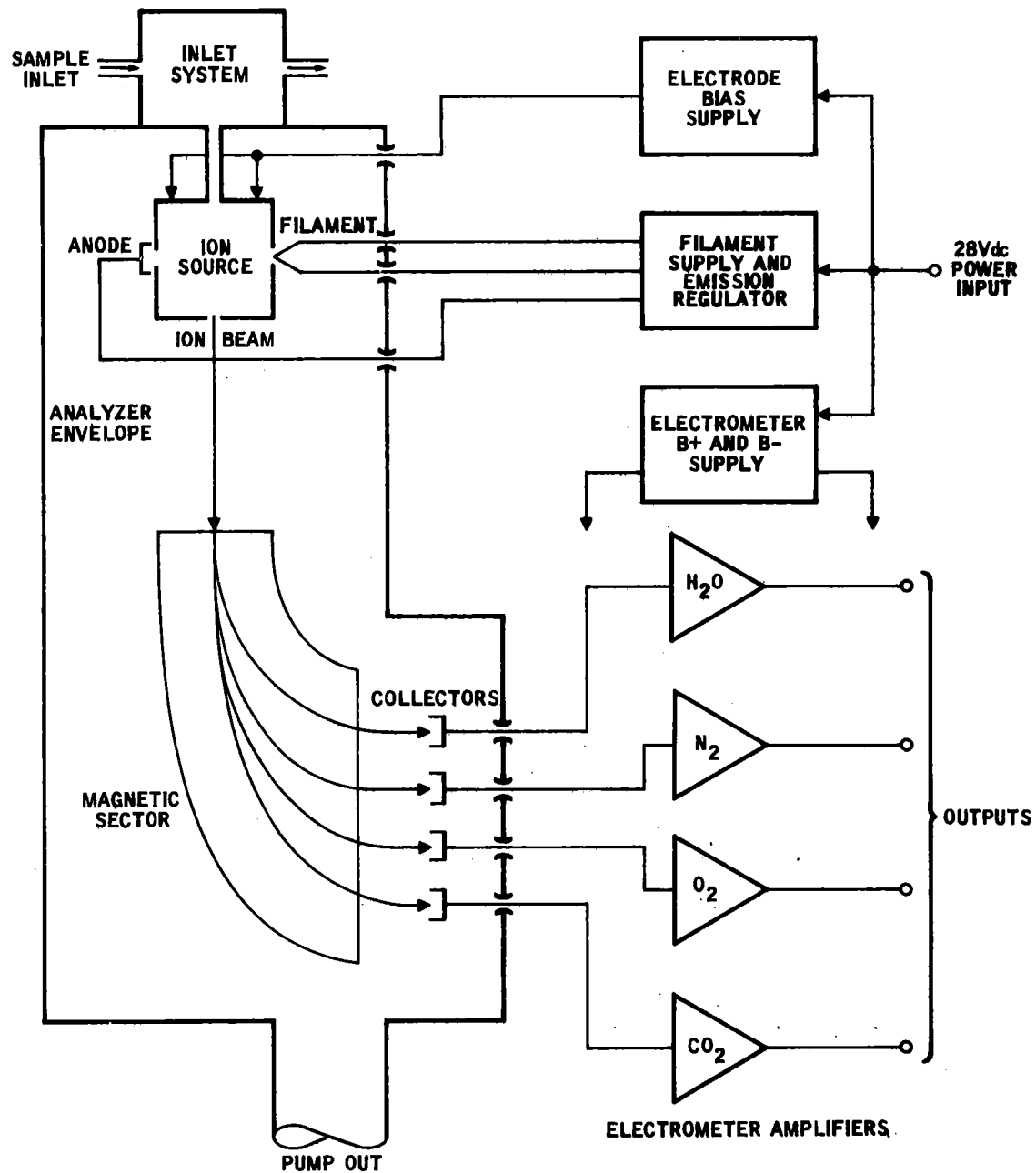


FIGURE 3-2. Two Gas Atmosphere Sensor System Block Diagram

The ion source, which is contained in the analyzer housing is a dual filament, nonmagnetic type that employs two electron guns that are mounted in an orthogonal configuration. The filaments are 0.003 inch diameter tungsten-rhenium wire. The ion source has a limited gas conductance to isolate the ionizing region from undesirable variations in the filament and ion pump regions which can cause variations in the sensitivity. The ions exit from the ion source at the exit slit and are injected into the magnetic sector region of the analyzer. This is a 90-degree magnetic sector which disperses the ion beam according to the mass-to-charge ratios of the ions while correcting to first order for the angular spread of the ion beam. Four ion current collectors are located on the focal plane of the analyzer and receive the ions from water vapor (m/e 18), nitrogen (m/e 28), oxygen (m/e 32), and carbon dioxide (m/e 44). The position of the collectors is adjustable to facilitate the simultaneous collection of these species. The magnetic field of 4000 gauss is supplied by the Alnico V permanent magnet.

Electrical connections to the mass spectrometer tube are made thru several single and nine-pin feedthroughs. The electronic circuits required for operation of the analyzer include the following: (1) an electrode bias supply which provides voltages for the ion source focusing electrodes; (2) a filament supply and emission regulator for the control of the ionizing electron beam; (3) the four electrometer amplifiers for amplification of the ion current signals; and, (4) a ± 10 volt power supply for the B^+ and B^- voltages that operate the electrometers.

The basic Two Gas Atmosphere Sensor System is shown in Figure 3-3.

In adapting the Two Gas Sensor for the Tektite application, one of the most important considerations is the proper sizing of the feedback resistors in the electrometers. This is based upon a knowledge of the ion source sensitivities for the various components and their maximum partial pressures within the ion source. These calculations are shown in Table 3-1. These figures are based upon a worst case total pressure of 2.33 atmospheres (34.2 psia) and a nominal pressure of about 2.2 atmospheres (32.3 psia). The nominal total pressure level was based upon a submersion depth of 40 feet. The ion source sensitivity was adjusted to make the best possible use of the allowable full-scale outputs of the electrometer amplifiers as well as the available values of feedback resistors.

The ion source output currents given in Table 3-1 are based upon an ion source pressure of about 1.7×10^{-4} torr which is achieved with a 40 cc/s ion source conductance and an inlet leak conductance of 4×10^{-6} cc/s.

3.2 VACUUM SYSTEM

An important requirement of the Tektite application was the need for a self-contained ion pump to maintain the internal vacuum level of the mass spectrometer. It was further required that the vacuum system be compact so that the overall system would fit within the volume limitations defined in Section 2. It was also necessary that the vacuum system be designed so that the internal

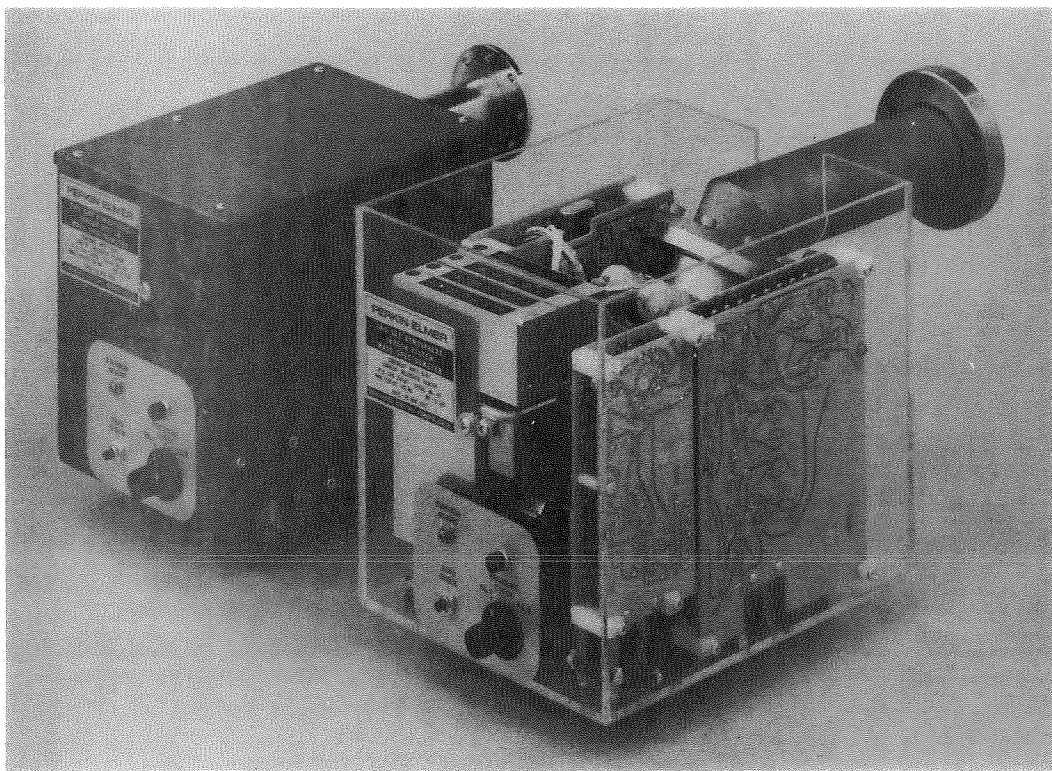


FIGURE 3-3. Two Gas Atmosphere Sensor System

TABLE 3-1

ION SOURCE OUTPUT CURRENTS

Constituent	Sample Pressure (Torr)		Ion Source Sensitivity (Amps/torr)	Ion Current Output (Amps)		Electrometer Amplifier Feedback Resistor (Ω)	Output Voltage (Volts)	
	Max	Nom		Max	Nom		Max	Nom
O ₂	380	158	6.0×10^{-7}	2.28×10^{-11}	9.5×10^{-12}	2×10^{11}	4.56	1.9
CO ₂	15	4	8.8×10^{-7}	1.32×10^{-12}	3.52×10^{-13}	5×10^{12}	6.9	1.76
H ₂ O	30	15	5.6×10^{-7}	1.68×10^{-12}	8.4×10^{-13}	5×10^{12}	8.4	4.2
N ₂	1578	1478	8×10^{-7}	1.26×10^{-10}	1.18×10^{-10}	5×10^{10}	6.3	5.9
Total	1770	1670	-	-	-	-	-	-

vacuum could be continuously maintained. A roughing port was provided for initial pump down and in case the system might have to be roughed down in the event of a loss of vacuum.

The Two Gas Sensor was designed to be operated with a four liter per second ion pump. The laboratory vacuum systems with the sensors had been previously operated utilizing 15 liter per second ion pumps which were conductance limited to give a pumping speed of four liters per second. It was decided, in view of the compressed nature of the schedule and the lack of direct experience with smaller ion pumps, that the largest possible ion pump would be employed which was consistent with the size limitations placed upon the overall package. The pump that was selected was the 11 liter per second D-I ion pump which is manufactured by the Ultek Division of Perkin-Elmer. A drawing of this pump is shown in Figure 3-4.

In addition to providing the best compromise between size and pumping speed for the application, this ion pump also has the advantage of possessing a minimum fringe magnetic field so that it can be located in close proximity to the mass spectrometer without detrimental effects. It was found that in its final position, the ion pump fringe field was less than 10 gauss at the point corresponding to the center of the ion source. The existing ion source was adequate to further reduce this level to the point where it had no appreciable effect upon the ion source operation.

The ion pump was mounted to the analyzer through a short vacuum adapter with the appropriate flange connections at each end. The line going to the roughing port was also welded into this adapter.

The design of the ion pump power supply is discussed in Paragraph 3.4. The ion pump requires an anode voltage of 4.75KV to maintain a pumping speed of 11 liters per second. The power supply which was designed, delivered a voltage in excess of 5KV at normal operating loads so that the actual pumping speed was something in excess of the stated value.

The nominal operation pressure for the ion pump is determined by dividing the gas load in torr-cc/s by the pumping speed in cc/s. The nominal source pressure of 1.7×10^{-4} torr times the source conductance of 40 cc/s gives a gas load of 6.8×10^{-3} torr-cc/s which results in a pump pressure of 6.2×10^{-7} torr. The I/p ratio for the 11 liters per second ion pump is 100 amps/torr. Therefore, the nominal ion pump current is 62 microamperes. This figure was utilized in determining the load current requirements for the ion pump power supply as well as sizing the ion pump current meter for the control panel.

3.3 INLET LEAK

One of the most difficult problems in the design of the Tektite Atmospheric Analyzer was the determination of a suitable inlet leak for admitting the sample from the Tektite habitat atmosphere as a nominal pressure of 2.2 atmospheres into the ion source where the nominal pressure was to be on the order of 10^{-4} torr. The existing viscous flow capillary pressure divider system which was part of the Two Gas Sensor was designed to operate at a pressure of about

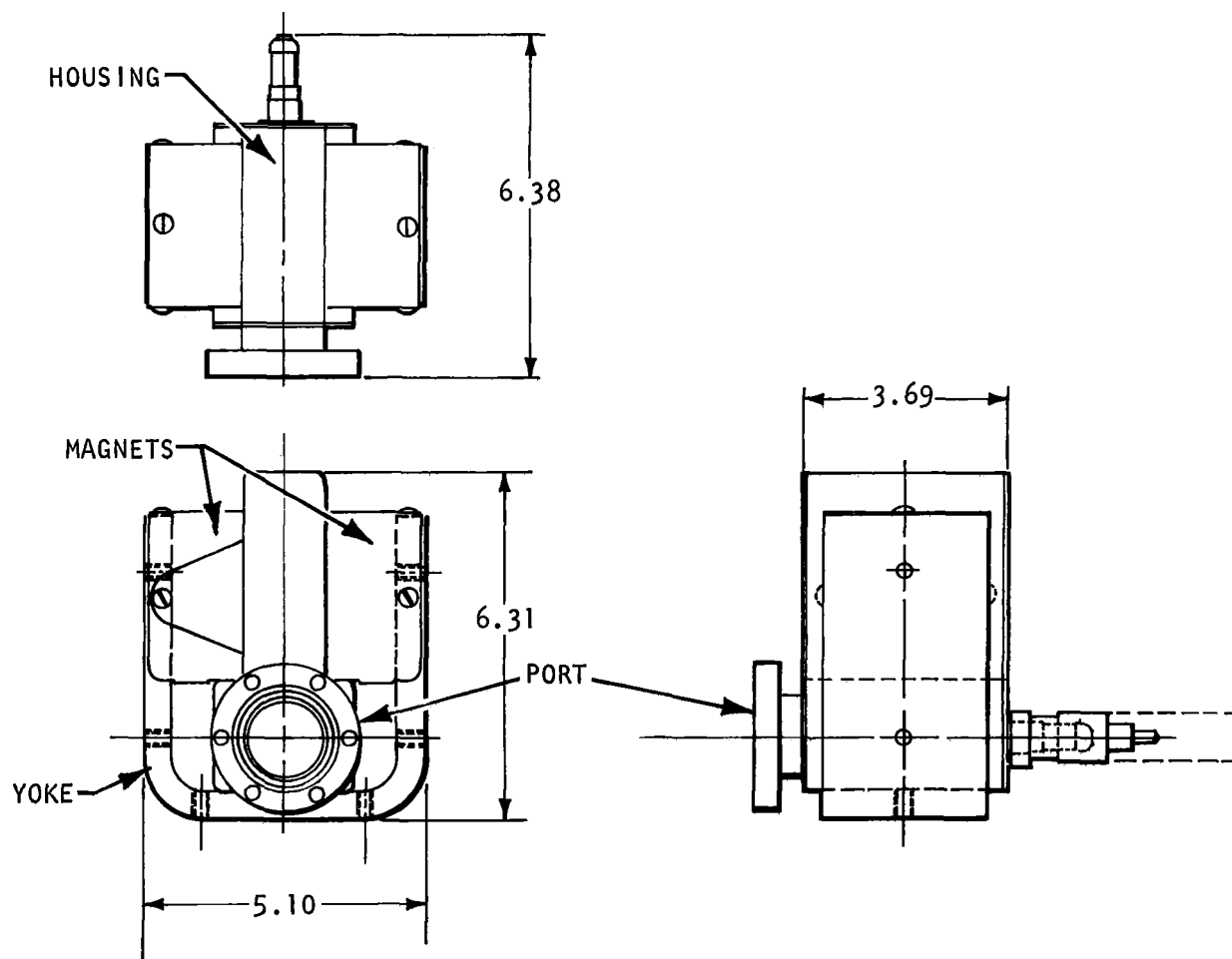


FIGURE 3-4. Ultek 11 Liter/Second D-I Ion Pump

0.5 atmospheres and was therefore unsuitable since it would give too high a pressure for successful operation. It was determined that a modification of this approach to accept higher pressures would not be feasible since an excessively long line would be required which would be difficult to implement in the installed condition. More important, this approach would require a supporting roughing pump in the form of a mechanical rough pump which would dump noxious oil fumes into the habitat atmosphere.

Perkin-Elmer was in the process of developing a direct molecular inlet leak for the Two Gas Sensor, but this program was not far enough along to give the required degree of assurance that this approach was sufficiently reliable. There was not sufficient time in the program to expend effort upon further leak development and, therefore, it was decided to utilize a commercial leak.

The variable leak valve manufactured by Varian Associates had given good service in the laboratories at Perkin-Elmer for introducing samples from one atmosphere and slightly above into vacuum systems at pressures on the order of 10^{-6} torr. It was believed that this leak valve could be adapted to the Tektite requirements with a minimum amount of effort. The variable leak valve is formed by the interface between an optically flat sapphire plunger and a copper anulus with a flat surface which forms the valve seat. A linkage system with a high mechanical advantage allows the position of the sapphire flat to be adjusted relative to the copper seat. This valve may be baked in the closed position to temperatures in excess of 400°C without degradation so that the analyzer can be baked out with the leak installed.

The adjustable feature of the valve's conductance had a special importance for the Tektite application. Most of the initial testing had to be done under laboratory conditions, that is, at one standard atmosphere. By opening the leak a little further than normal, it was possible to simulate the pressure levels which would exist within the mass spectrometer at the Tektite habitat pressures. This technique was also of value during installation and interfacing with the output meter panel. Furthermore, the ability to close the leak off entirely was of value since it allowed background pressure and output levels to be checked and kept the system sealed off during transit and storage. This reduced the ion pump load current and extended the life of the battery pack.

A cross sectional drawing of the valve is shown in Figure 3-5. An enlarged view of the seat region is shown in Figure 3-6. The adjustment characteristic for the leak is shown in Figure 3-7. Note that the required conductance is well within the capability of the leak.

There were three important questions to be answered about the inlet leak: 1) How nonlinear was it?; 2) How stable was it?; and 3) What was its temperature coefficient? These questions were answered by a brief experimental program which is described in Section 4. It was expected that the leak would function in the viscous or perhaps the critical flow region in which case a nonlinear or offset linear pressure flow characteristic would be obtained. This was not believed to be a serious problem since the worst case pressure variations during operation were expected to be about plus or minus three percent. It was found in

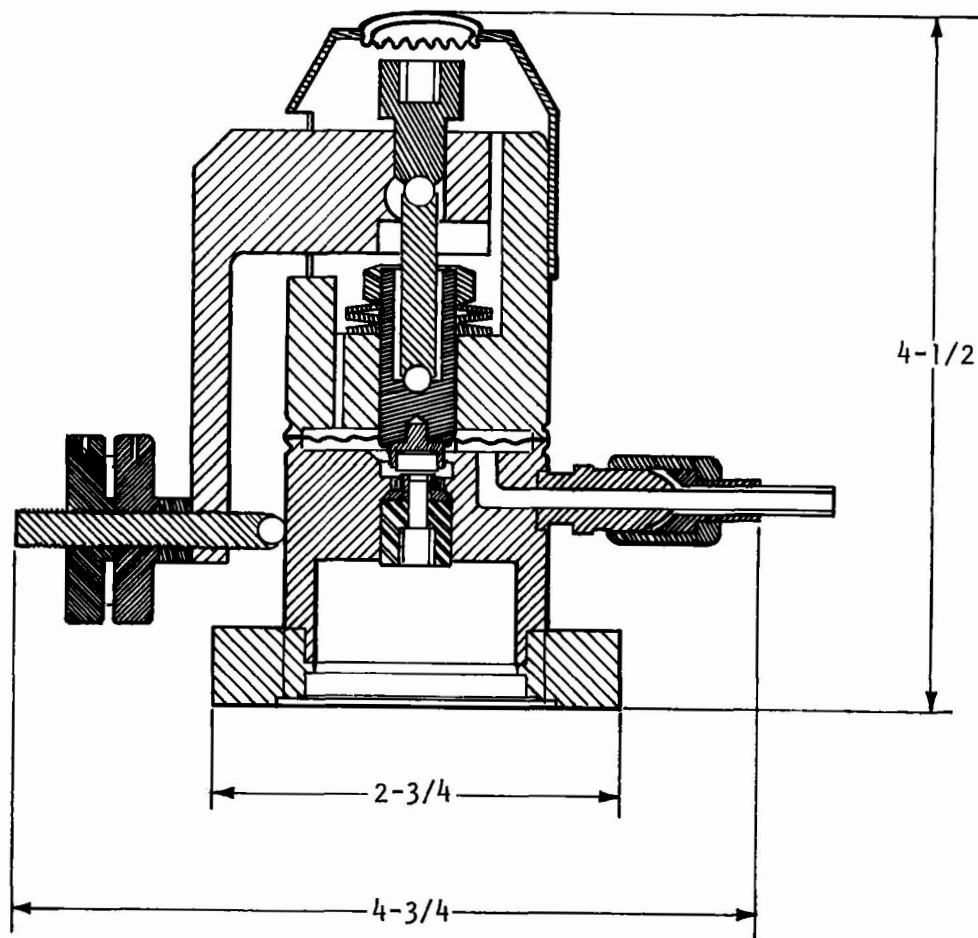


FIGURE 3-5. Variable Leak Valve Outline Drawing

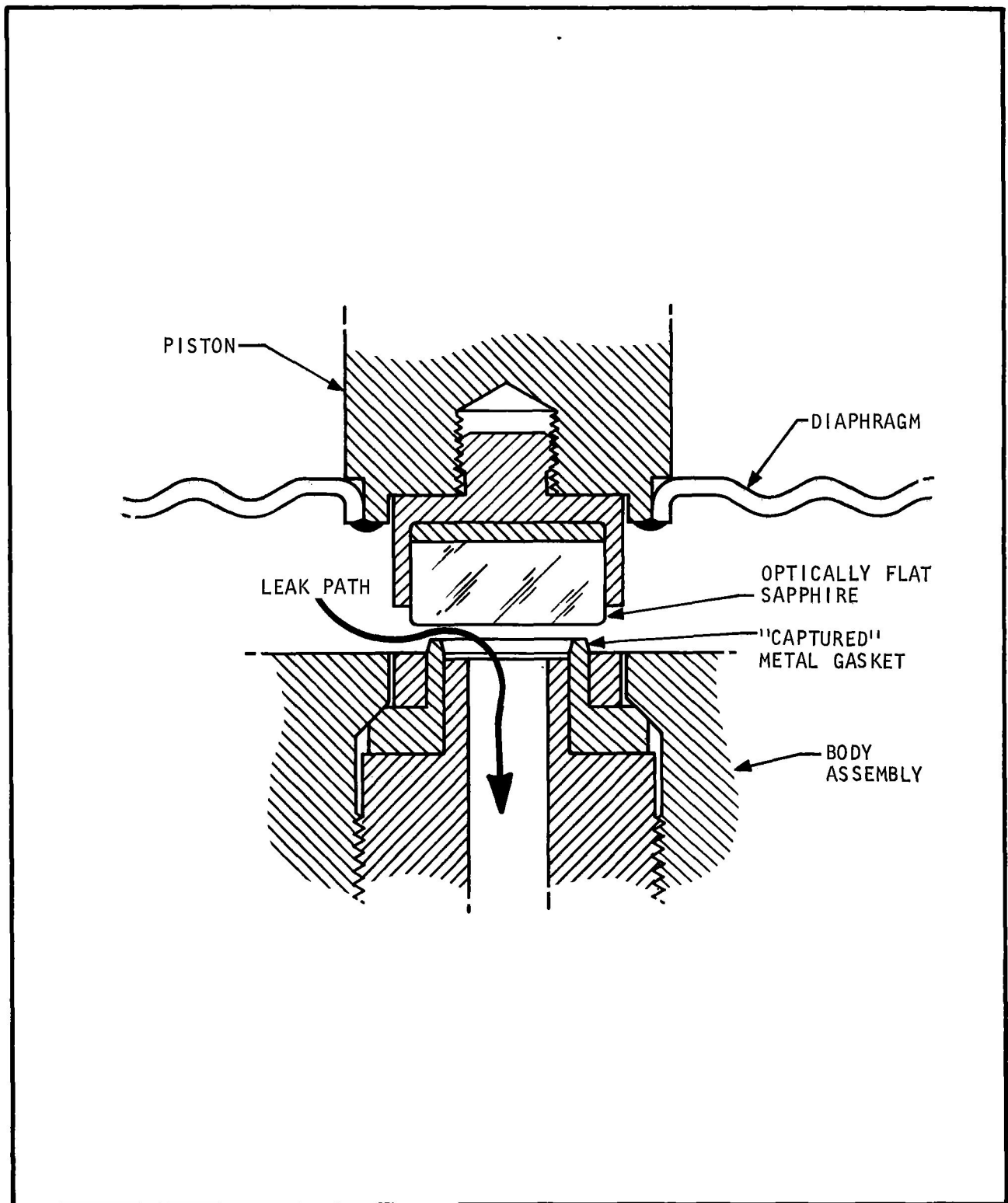


FIGURE 3-6. Variable Leak Valve Sealing Mechanism

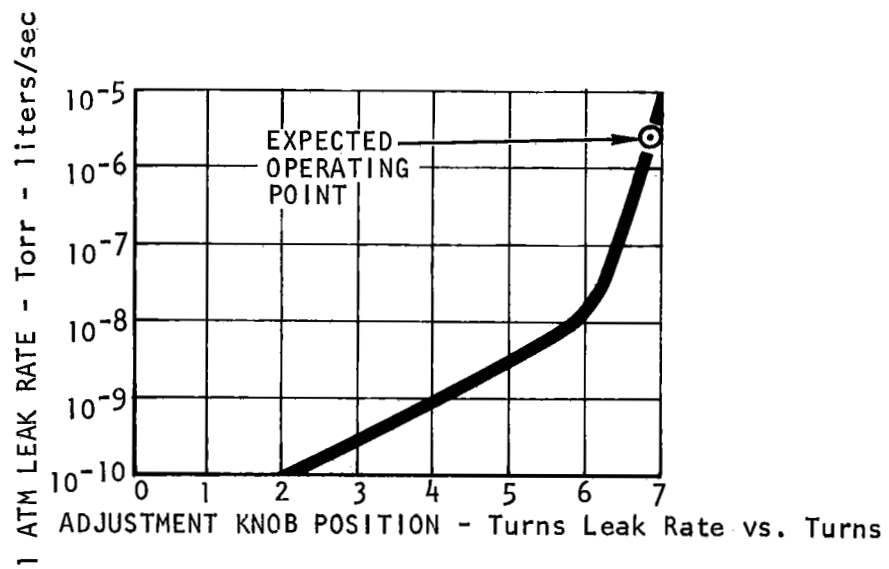


FIGURE 3-7. Leak Adjustment Characteristic

practice that the correction to the total system sensitivity, which had to be made as the result of total pressure variations, was negligible.

The temperature stability of the inlet leak was found to represent a more significant problem and it was necessary to incorporate a heater and temperature controller to keep the leak at a constant temperature. Again data regarding this is presented in later sections.

The mechanical stability of the leak was not tested quantitatively and, therefore, it is difficult to make an accurate statement regarding it. There was some evidence of creep in the mechanical linkage which would cause the conductance to vary for a period after adjustment, but it is not known if later variations occurred. It is evident from the adjustment characteristic shown in Figure 3-7 that slight variations in the position of the piston will cause large variations in the leak conductance. This is definitely a drawback to this type of leak, however, in view of the other constraints, it appeared to be the best choice available.

3.4 ELECTRONICS SUBSYSTEM

The electronics subsystem for the serial number 2 prototype Two Gas Sensor was used to support the operation of the analyzer. The emission regulator was slightly modified to correct an oscillating condition which had appeared when the circuit was operated with the ion source filaments. With the resulting modification there was an acceptable range of emission levels over which oscillation did not occur. It was recognized that this modification was of the nature of a fix, but there was not sufficient time to incorporate a more complete redesign. Subsequently, effort has been expended in this area and a new design is currently being evaluated.

The electrometer amplifiers required new feedback resistors in order to obtain near full-scale values on all channels as discussed in Paragraph 3.1. This was the first time that values as large as 5×10^{12} ohms had been employed on the Two Gas Sensor. Although there was no problem in using these values, they did indirectly cause an offset in the electrometer zeros when the leakage resistance of the collector feedthrus became low as the result of a faulty high temperature vacuum bakeout. The voltage divider for the electrode bias supply was modified after new voltage values were determined from the test of the analyzer.

In addition to these minor changes to the basic Two Gas Sensor electronics, some additional circuitry was required. An ion pump power supply was designed to supply the high voltage for the ion pump anode. The design was based upon an earlier effort carried out under contract NAS1-6387. The circuit was of straight forward design, a saturating core DC/DC converter with a voltage quadrupler on the output. This circuit was breadboarded and checked out prior to integration with the ion pump. The circuit was utilized in breadboard form in the Tektite system. The failure which subsequently occurred in the circuit during the mission was in no way resultant from the use of a breadboard.

A charging circuit was designed to charge the battery pack during normal operation to full voltage. When the system power was off, the ion pump power supply was powered by batteries.

Two commercial circuits were employed in the system: a 28-volt power supply and a phase control type of temperature regulator.

3.5 CALIBRATION SYSTEM

In order to verify the operation of the Tektite Atmospheric Analyzer during the course of the submersion period, a calibration system was needed. Where as the Two Gas Sensor had demonstrated stable operation for corresponding periods of time in other applications, it was felt that the use of an untried inlet leak, the relatively lower level of CO₂, and the somewhat different sampling conditions of Tektite dictated that a calibration system be employed. Earlier calibration techniques, which had been employed in conjunction with the Two Gas Sensor, had been based upon an absolute pressure measurement of a calibration gas. This required a pressure gauge. It was decided in the interest of compactness of the overall system, that an accurate pressure gauge could not be included in the system and, therefore, a relative calibration was decided upon. In this type of system the pressure of the calibration gas is referenced to the ambient pressure. In this case, this did not cause a reduction in the accuracy of the calibration since an accurate double revolution pressure gauge was mounted directly above the atmospheric analyzer within the habitat.

The calibration system employed a number four gas cylinder which contained 11 atmospheric cubic feet of calibration gas. The flow of the calibration gas could be switched into the inlet system in place of the sample gas. The calibration gas was then dumped into the atmosphere after passing by the inlet leak. The function of the calibration and inlet system is more fully described in Appendix A, the Operation and Maintenance manual.

3.6 ENCLOSURE AND SYSTEM PACKAGE

The primary feature of the system packaging was the need for pressure housing to protect the analyzer from the 2-1/3 times atmospheric pressure which existed within the Tektite habitat. A rectangular housing was designed which was fabricated from one-quarter inch thick stainless steel. The housing had a front cover which was bolted to a flange on the enclosure and compressed a Buna-N O-ring gasket. Two gasketed electrical connectors transmitted voltages to the mass spectrometer within the housing. One connector carried the output voltages, while the other supplied the input voltages as well as the interface between the analyzer, ion pump, and the control panel.

Three gas flow connections were made through the top of the pressure housing by welded fittings. These were for the sample inlet, roughing line, and the purge line for the pressure housing itself. The sample inlet line was connected to the variable leak valve while the other two lines were connected to Nupro valves. All of these valves were mounted on the top of the pressure housing. It was felt that it would be important to have some indication of a leak in the housing, should one develop, since this would result in the possible failure of the system.

There was not sufficient room to mount an appropriate absolute pressure gauge and, therefore, it was decided to try a humidity indicator. A litmuous type of indicator was mounted in the front cover. Before the pressure housing was sealed, it was purged with dry nitrogen in order to get the indicator to read a low value of humidity. It was determined that if a leak occurred, a sufficient amount of water vapor would change the humidity indication. It was found in practice, that it was not possible to get the inside of the housing sufficiently dry to keep the humidity indicator at the low (less than ten percent) level. Consequently, there was no indication of any leaks which might have occurred. The pressure integrity of the enclosure was checked on several occasions and found to be satisfactory.

The Mass Spectrometer System with its associated electronics were mounted to a base plate along with the ion pump and its power supply. The base plate slid into the pressure housing and the necessary vacuum and electrical connections were made to the top of the pressure housing. (This design was the source of some severe difficulties which will be described in later sections.) The vacuum connections were made by means of Cajon fittings with in-house fabricated copper gaskets.

The analyzer control panel, flow meter, and inlet system valving were mounted in a chassis at the top of the system. The control panel was attached to a removable chassis which also housed the main power supply, the battery charging circuit, and the batteries. The remainder of the inlet system plumbing was located in the space between the upper chassis and the pressure housing. The temperature controller was mounted on a panel at the back of this central region.

By disconnecting the inlet system lines, the total system could be broken in two parts for ease of installation and handling within the Tektite habitat. The fully assembled system is shown in Figure 2-2 of Appendix A.

4. INITIAL TEST

The initial test of the instrument comprised that part of the testing prior to shipment of the system to the Philadelphia Naval Shipyard for initial integration with the Tektite habitat. During this phase of the testing, each of the components of the system were checked out and then integrated for a brief system test. The following paragraphs briefly describe this test activity.

4.1 VARIABLE LEAK TEST

One of the most important phases of the initial test effort was the determination of the properties of the variable leak valve to be used as the inlet leak for the atmospheric analyzer. Prior to testing, the leak was modified to a flow through configuration and a special pressure housing was fabricated in which the leak valve could be installed. It was important that the same pressure exist on both sides of the diaphragm since this was the condition in which the leak would have to function. Tests were run to establish flow versus pressure, adjustment characteristics, and temperature characteristics. This data is shown in Figures 4-1, 4-2, and 4-3. The data shows the following: a) The deviation from linear operation is inconsequential over the expected operating pressure range and, therefore, the leak can be assumed to have a constant conductance in this range; b) One-eighth of a turn of the adjusting knob gives about a factor of two change in conductance. The adjustment of the knob is therefore very critical. A two percent change will result from a knob rotation of less than one degree; c) The temperature coefficient for the leak is about three percent per degree Fahrenheit. This implies that a tight temperature control would be required.

The results of the leak test effort indicated that while the variable leak appeared to be satisfactory for the intended application, it would have to be tightly temperature controlled or it would be difficult to adjust precisely and it might be subject to some conductance drift as a result of creep in the mechanical linkage.

4.2 ANALYZER TEST

Analyzer preparation followed normal procedures which have been followed in earlier tests on the Two Gas Sensor. The ion source was disassembled and new filaments of 97% W-3% Re were installed. The analyzer was pumped down and the filaments burned in slowly for maximum life. Then the electron guns were tuned up for maximum electron beam transmission to the anodes. The ion current peaks were measured and it was found that while the peak shapes and resolution were very good, the m/e 18 and m/e 44 peaks were not aligned with the

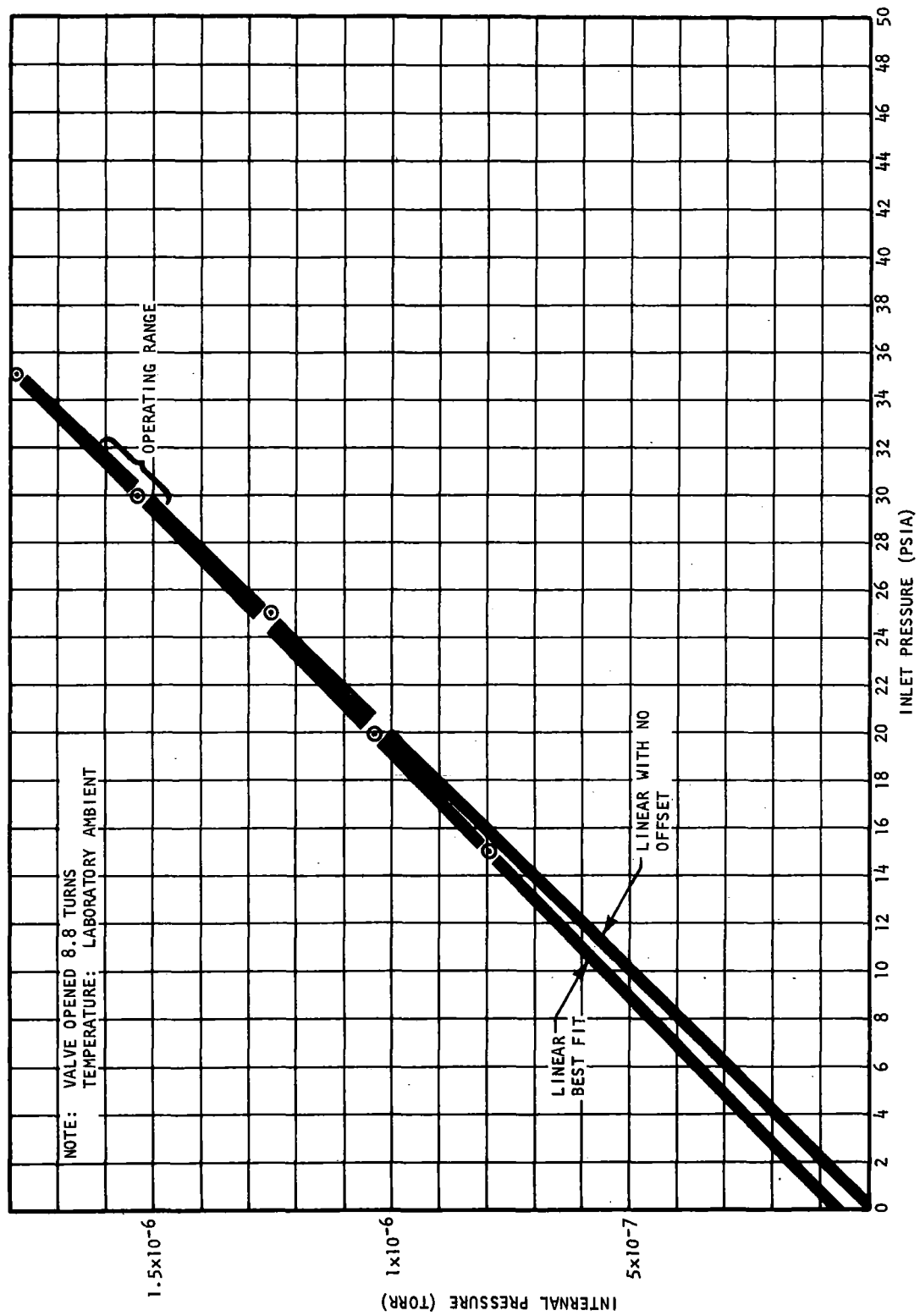


FIGURE 4-1. Variable Inlet Leak Conductance Characteristic

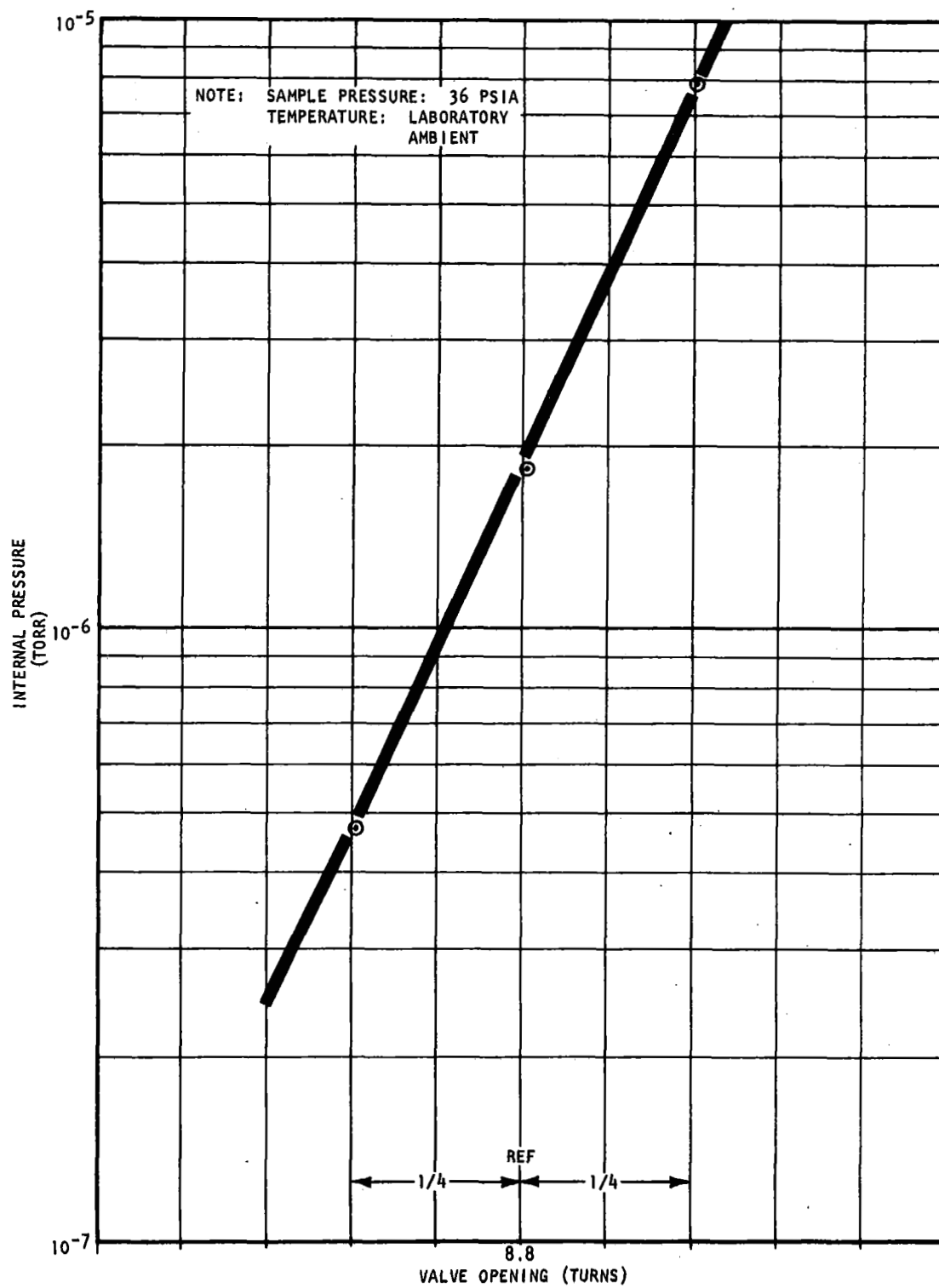


FIGURE 4-2. Variable Leak Valve Adjustment Characteristic

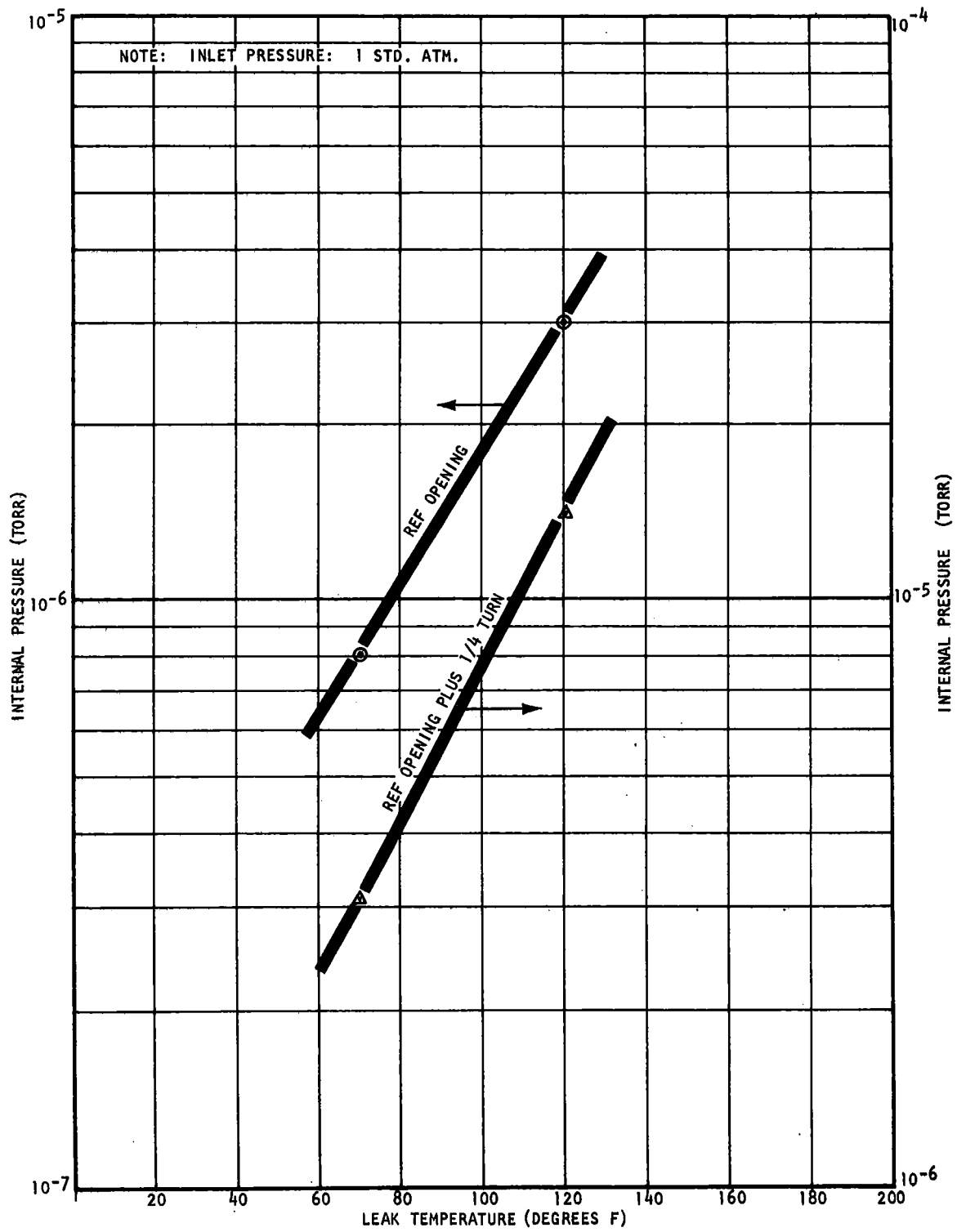


FIGURE 4-3. Variable Leak Valve Temperature Characteristic

m/e 28 and m/e 32 peaks. It was found after repositioning the collectors with the maximum possible spacing, the peaks were still not well aligned. By re-tabbing the slit in the ground shield in front of the m/e collector, the alignment was improved. The final peak alignment obtained during the analyzer test program is shown in Figure 4-4. Note that the available region for operation is a little less than half of the individual peak talk widths.

The available operating region was acceptable in view of the stability of the electronics and the analyzer magnet. It is of interest to note that the accelerator voltage is extremely low for this instrument. This is apparently due to a mechanical misalignment of the analyzer. The relatively high degree of separation between m/e 40 and m/e 44, compared with other analyzers on the Two Gas Sensor program, suggests that the net result of the misalignment and the low acceleration voltage is that the m/e 44 collector is closer to the alpha focal point which gives a reduced ion beam width. After the peak alignment process was completed, the ion focusing was tuned up and the ion source sensitivity measured. A final set of ion source voltages was obtained which allowed the proper electrode voltage divider string to be designed.

4.3 SYSTEM INTEGRATION

The analyzer and ion pump were assembled with the flanged vacuum adapter and the inlet leak and roughing lines capped off. The system was given a preliminary bakeout in this configuration at 180°C. The ion pump current was below one microampere after the bakeout. This corresponds to a pump pressure of less than 1×10^{-8} torr. A background spectrum was scanned and the partial pressures of CO₂ and H₂O were 1.8×10^{-7} and 3.4×10^{-8} torr respectively. These pressures are higher than the ion pump pressure, but this is possible if the outgassing is coming from the ion source by virtue of the differential pumping.

The nominal levels of water vapor and carbon dioxide in the Tektite atmosphere are 0.90 and 0.24 percent respectively. This will correspond to ion source partial pressures of approximately 2×10^{-6} and 5×10^{-7} torr respectively. If a five percent accuracy is required on these outputs, then the background contribution in the ion source must be less than 1×10^{-7} and 2.5×10^{-8} torr respectively. The levels achieved in the preliminary bakeout were not this low. It was apparent that an extended bakeout at 250°C would be necessary to achieve the required background levels. Furthermore, particular attention would have to be paid to heating the ion source and inlet leak regions due to the high differential pumping ratio.

At this point, the analyzer ion pump assembly was integrated with the inlet leak and roughing line. They were attached through the wall of the pressure enclosure and then to the analyzer by means of extension tubes. This allowed the analyzer to be placed in front of the pressure housing in an easily accessible location and still have all of its vacuum connections properly made. This not only allowed the operation of the system to be fully studied, but also provided the means for baking out the entire vacuum system including the inlet leak and roughing line valve prior to final installation in the pressure enclosure.

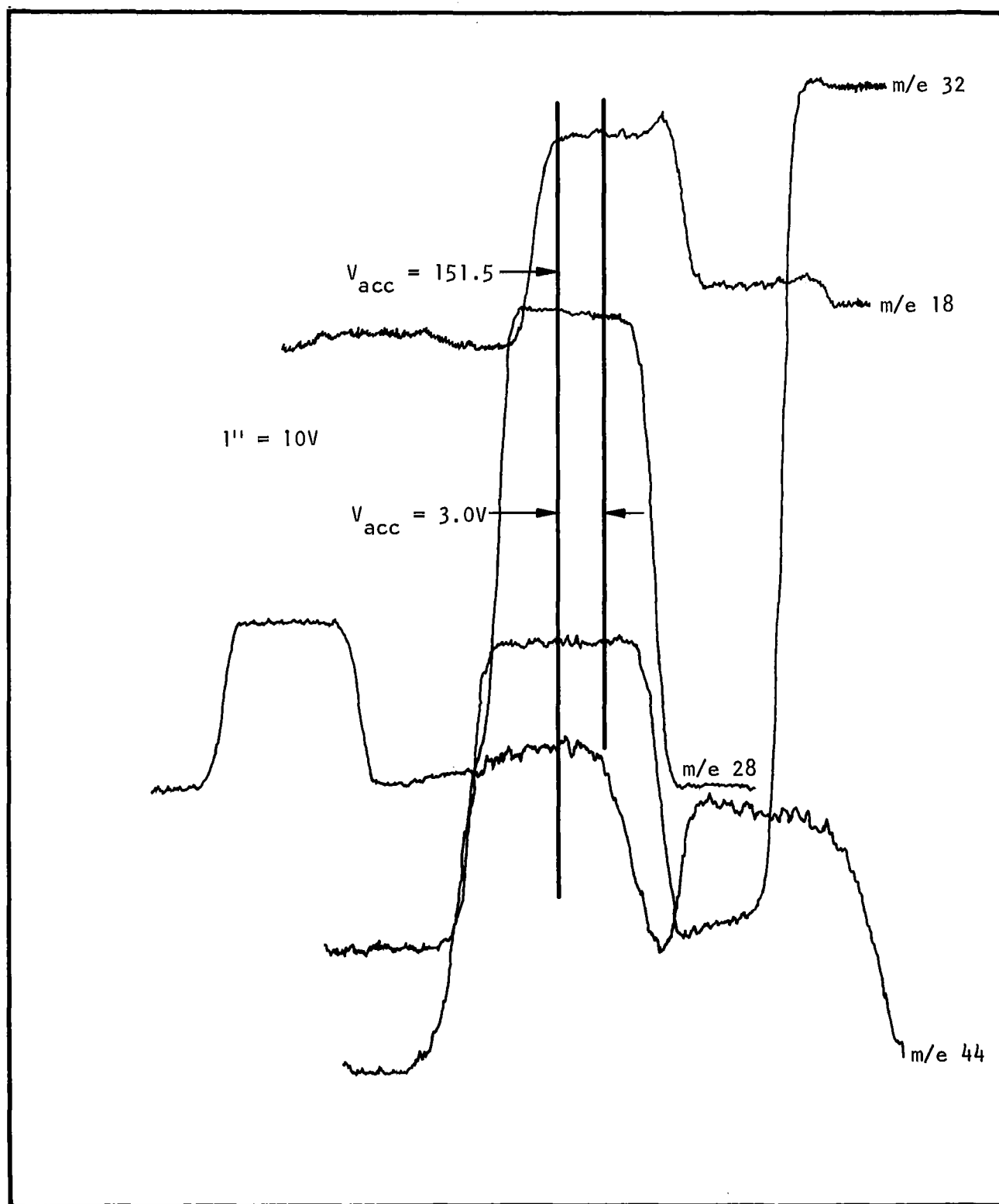


FIGURE 4-4. Peak Alignment

Even though the analyzer could be baked out in this configuration, it was necessary to vent it again in order to place it inside the pressure enclosure. It was obvious that this would defeat the purpose of the bakeout unless the analyzer was carefully purged with an ultra dry gas. This difficulty could have been eliminated if the vacuum connections had been made through the pressure housing cover, rather than through the top of the housing itself. Other considerations dictated the design configuration which was used, but any future application of this type should allow a final bakeout to be conducted and then the final system assembly completed without venting the system. This will lead to much lower background pressures and more accurate results.

A bakeout was conducted on the system, but the pressure would not come down to the low level obtained earlier. A leak was suspected, but none was found. A second bakeout gave similarly negative results. A leak with a long time constant was finally located in the swagelok fitting on the extension tube for the roughing line. The leak was repaired, but the repeated bakeouts at relatively high pressure were extremely detrimental to the ion pump. A background pump current on the order of 150 microamperes was observed during testing. This was the result of field emission from whiskers which had formed on the cathodes of the pump. Later, when the pump was disassembled, a great deal of flaked-off material was found. It was necessary to replace the pump with a new unit after the preliminary installation of the Atmospheric Analyzer in the Tektite habitat at the Philadelphia Naval Shipyard.

The electronics subsystem was integrated with the analyzer and after assuring that all circuits were working properly, the system was placed in the pressure enclosure. At this point there was little time remaining before the instrument had to be shipped for the preliminary integration. During the remaining time, several tests were run to investigate the stability of the system with the new inlet leak valve. It was soon found that additional thermal insulation would be necessary around the valve in order to achieve a minimum variation in valve temperature. Also, the temperature regulator, which was an on-off type, did not seem to be capable of sufficiently tight regulation and finally when a circuit failure occurred within the controller, a new proportional control type of pressure regulator was purchased. This regulator was not integrated with the system until after the return of the instrument from Philadelphia. The final tests which were conducted on the instrument prior to Philadelphia integration were without the benefit of a temperature controller. These test results are given in Appendix B.

At the conclusion of these tests, the Tektite Atmospheric Analyzer was shipped to the Philadelphia Naval Shipyard where it was integrated with the habitat. During shipment, the ion pump was operated on the battery pack and performed as expected. At the installation site, the analyzer was physically installed in the habitat and provisions were made for reinstallation of the sensor at the final test site. The system was operated only briefly. Integration of the analyzer with the output meters was not possible due to a failure in the associated isolation system. Finally the Atmospheric Analyzer was returned to Perkin-Elmer where it underwent final testing prior to delivery to the Virgin Islands.

5. FINAL TEST

After return of the system to Perkin-Elmer several changes were made in the system prior to initiation of final testing:

- a. A filament was replaced which had been burned out by an operator error.
- b. The electrometer amplifier zero check switch was replaced by a spring return toggle switch to avoid recurrence of the operator error.
- c. A new Ultek ion pump was installed in place of the one which had been damaged by the faulty bakeouts.
- d. A new proportional control temperature regulator was installed in place of the on-off type which had failed.
- e. The insulation around the inlet leak valve was improved to achieve better temperature stability.

The analyzer was returned and a system bakeout performed. Some difficulties were encountered with small leaks, but these were sealed. Also, the valve in the roughing line was replaced with an all stainless steel valve. After another bakeout, the ion pump current reached 0.1 microampere, representing a pressure of approximately 1×10^{-9} torr. This was sufficiently low to assure acceptable background leaks. The instrument, however, still had to be taken off of the extension tubes and placed in the pressure enclosure.

Before this, tests were run on the instrument stability as well as other parameters. The results of a run made after the improvement in valve temperature stability was achieved are shown in Figure 5-1. The run shown is a one-hour run and demonstrates remarkable stability after the first fifteen minutes. This stability was better than that exhibited in earlier tests and leads to the conclusion that at least part of the problems which were encountered resulted from inlet leak valve temperature variations.

During the final series of tests, several problems were encountered which had to be dealt with. These eliminated the possibility of extended operating tests and performance verification tests. In some instances they affected the final performance of the instrument. These difficulties could have been overcome except for the extremely tight schedule which was required in order to interface with the Tektite schedule. Problem areas which were encountered included: electrometer amplifier zero drift caused by low leakage resistance on

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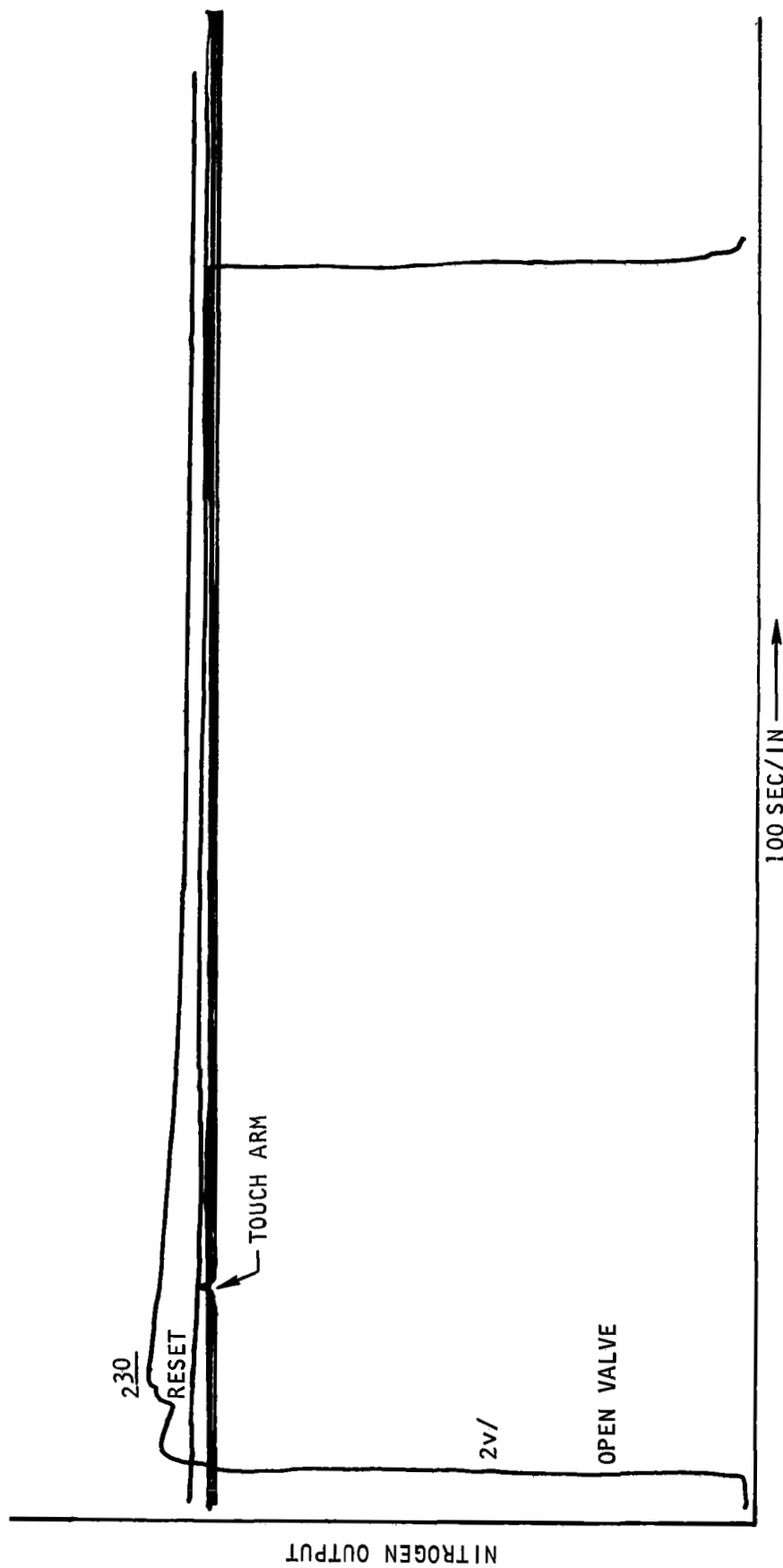


FIGURE 5-1. Temperature Stability

the collector feedthru pins; system grounding; mechanical interfacing with the pressure housing caused by different dimensions on the replacement ion pump; shift in peak positions caused by twisting of the analyzer housing from mechanical interference; and high background partial pressures of H₂O and CO₂ resulting from repeated venting of the analyzer in order to fit it in the pressure housing. It was finally necessary to accept high backgrounds and a compromise ion energy setting which left the instrument operating on the edge of the m/e 18 (H₂O) peak. A best guess setting for the electrometer amplifier zeros was made and the pressure enclosure was sealed and purged with dry nitrogen.

The Atmospheric Analyzer was then transported to Wiley Laboratories in Norco, California where a pressure test was run on the complete system in a pressure vessel. The system was placed in a large, walk-in pressure tank and located in front of a window where the various meters and gauges could be externally monitored. The outputs from the system were connected to a cable allowing external monitoring. Three tests were run which consisted of: a power-off test to verify that an immediate catastrophic failure would not occur; a power-on test with the sample inlet leak valve closed to note any variations in the anode current or background outputs thus indicating if the sensitivity of the analyzer was changing; and finally, a test with the inlet leak valve to verify the sampling characteristics of the system. In each test the pressure was run up to 21 psig or 35.7 psia which exceeded the final operating pressure by about four psi. The initial test showed no effects. The sample flow rate thru the calibration inlet system changed only slightly. Therefore, a sample flow rate could be preset and the resulting change, when the environment was pressurized, would not affect the output.

During the second run, the outputs were monitored. The instrument remained fully operational from ambient to 35.7 psia and back to ambient. The water background was very high during this test, starting out at 2.955 volts and drifting down during the run to 2.170 volts. There was no effect resulting from the increased external pressure.

The inlet leak valve was opened prior to the third run and a reduced inlet pressure level on the standard calibration gas mixture. The pressure in the pressure chamber was raised in five psi steps from ambient to 15 psig and then in one psi steps to about 21 psig. The pressure was raised slowly as limited by the inlet flow rate from the pressure source. The pressure regulator on the calibration gas bottle maintained a nearly constant pressure differential in the calibration inlet system above the pressure in the chamber, thereby causing the inlet pressure at the variable inlet leak valve to track the pressure in the pressure chamber. The output of the nitrogen channel is shown in Figure 5-2. At each pressure level a slight drop in the output was noted. This is probably due to the initial stabilization effect in addition to a decline in the chamber temperature resulting from the expansion of the incoming gas. A plot of the nitrogen output, as a function of total pressure, as determined from this pressure run is shown in Figure 5-3. This data agrees very well with the data taken on the inlet leak valve (see Figure 4-1) and demonstrates that the slight nonlinearity in the output is due entirely to the characteristic of the valve.

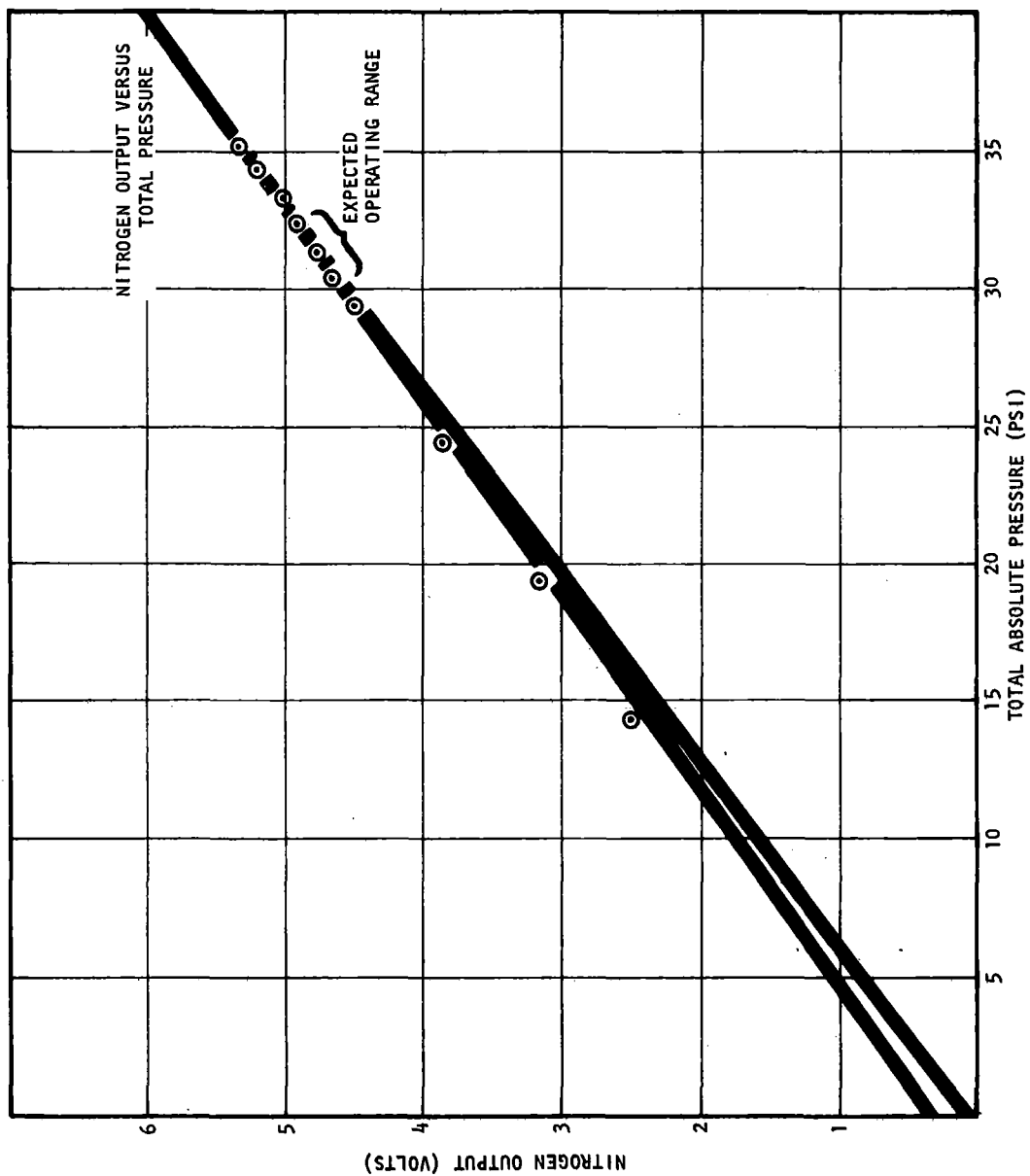


FIGURE 5-2. Operating Pressure Test (Sheet 1 of 2)

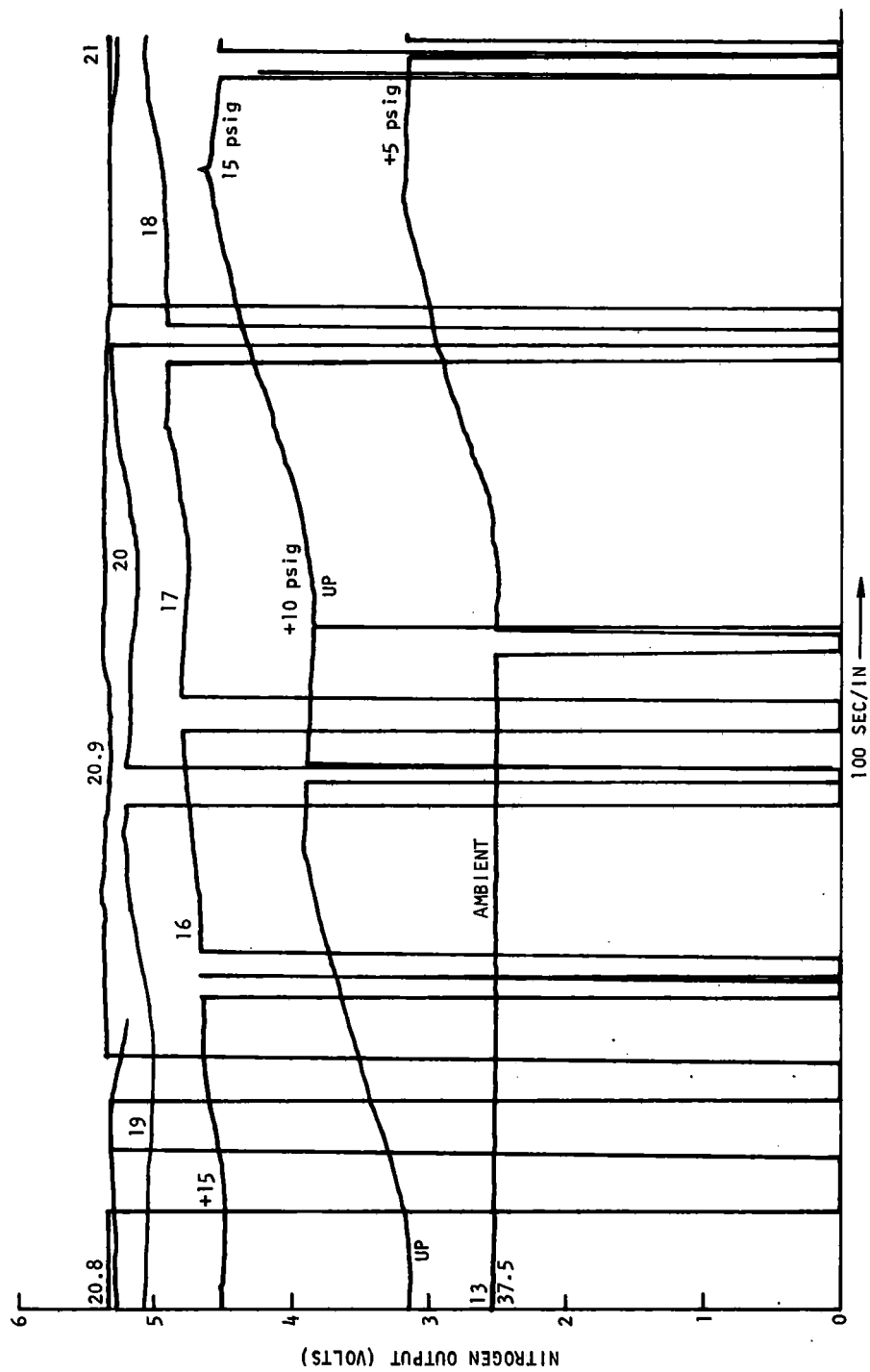


FIGURE 5-2. Operating Pressure Test (Sheet 2 of 2)

One effect which was noted during this pressure run was a drop in the water output when the pressure was raised from 17 to 18 psig. This drop was sharper than the general downward drift which was normally observed in the water background. This was attributed to a shift in the H_2O peak caused by a mechanical movement resulting from flexing of the pressure housing and transmission of this movement to the analyzer envelope. As stated earlier, the ion energy setting operating point caused the operating point to be on the edge of the m/e 18 peak. Later, during installation in the Tektite habitat, the water output was found to register very low which indicated that a further shift had occurred which moved the operating point well off of the water peak.

A check of the pressure inside of the pressure housing showed it to have remained constant during the pressure test indicating that no significant leaks were present in the housing. The pressure test was concluded and the instrument was returned to Perkin-Elmer and prepared for shipping to the Tektite site. The ion pump remained operational during transit, powered by the battery pack.

6. INSTALLATION AND CHECKOUT

When the Tektite Atmospheric Analyzer was uncrated at the Tektite site, it was found to have been slightly damaged in transit. Evidently the crate had been dropped and the control panel was bent. Fortunately, the vacuum integrity had been maintained and the ion pump current registered two microamperes. It is possible that the damage may have caused a further shift off the water peak. The instrument was disassembled by separating the calibration inlet system, control console, and pressure housing, and these pieces were raised into the command bridge. They were reassembled and the instrument was installed in the bay which had been reserved for it.

After installation, the system was turned on and the background and electrometer amplifier zero levels were checked. The following levels were observed:

	Electrometer Zeros	Background Outputs
H ₂ O	+0.20V	-1.5V
N ₂	-0.0085V	-0.006V
O ₂	+0.006V	-0.002V
CO ₂	+0.065V	-0.145V

The water and carbon dioxide electrometer zeros were not as close to zero as would have been desirable, but this was converted in the output meter panel. The water and carbon dioxide backgrounds were also high, but it was expected that these would drift down over the following few days. The high H₂O output indicated that the operating point was at least part of the way up on the mass peak.

A calibration sample was introduced and the output levels correlated well with the ion pump current indicating that the sensitivity of the instrument had not shifted significantly during transit. Initial runs versus time indicated some sensitivity drift. The variations with time were of a back and forth nature and indicated that the control loop on the inlet leak valve temperature was not stable. When a cover was placed over the plumbing bay where the valve was located, the stability of the output was improved significantly. Variations in the nitrogen output could be correlated with changes in the ion pump current lending further credibility to the view that inlet leak conductance stability

was the problem. The magnitude of the wandering with the cover in place was less than plus or minus two percent. Data taken on other days when there was less activity in the habitat and a more constant temperature showed variations of less than plus or minus one percent over a one-hour period. It was expected that once the habitat was in place with only the aquanauts inside that the temperature would be much more stable and adequate performance would be obtained. It was also obvious that the temperature controller on the inlet leak valve could not hold the temperature tightly enough. This was due to the large thermal mass of the valve and the insufficient gain and power of the controller.

During the next few days the instrument was left on as much as possible, including over night, in an attempt to get the background current levels down. The H₂O and CO₂ levels came down to 0.15 and 0.18 volts respectively. The CO₂ background level was significant enough to cause a change in the calibration procedure for that channel. It was assumed that the CO₂ channel sensitivity would have the theoretical value relative to the nitrogen sensitivity and the calibration gas was used to establish the magnitude of the CO₂ background. The direct measurement with the valve closed was not adequate since when the sample is admitted, the oxygen partial pressure causes the filament to drive harder, increasing the ion source temperature and causing an increase in the outgassing rate and a consequent rise in the background pressure levels.

During the checkout of the instrument, it was noted that when sampling on air, the water output remained quite low, near the background level. The typical output on the H₂O meter was about one torr. Considering the temperature and relative humidity in the habitat, the output should have been closer to 15 to 20 torr. The low output was suspected to be due to the shift off of the water peak, but this could not be verified. If the instrument had not been confined in the pressure housing, it would have been possible to check the peak alignment and perhaps adjust it.

The Atmospheric Analyzer was interfaced with the output meter panel and the meter gain circuits were adjusted for the nominally expected levels. It was not possible to do a final calibration on the instrument since the ambient pressure on the surface is much less than the operating pressure when submerged.

A calibration check was done at one atmosphere using a calibration gas mixture and then the partial pressures for an air sample were measured. The results are shown in Table 6-1. Note that when adjusted for the low water reading, the results are very good.

The instrument was left with the valve closed and the analyzer off until after submersion of the habitat. A startup procedure and calibration procedure was generated and appears in the operation manual in Appendix A.

TABLE 6-1
CHECK OF CALIBRATION ON AIR

	Calibration Sample	Habitat Air
Nitrogen	696.0 torr	600.0 torr
Oxygen	77.5 torr	153.0 torr
Carbon Dioxide	1.5 torr	2.6 torr
Water	<u>0.0 torr</u>	<u>1.0 torr</u>
	775.0 torr	756.6 torr
Additional Water (Based on 44% R.H. and 85°F)		<u>18.0 torr</u>
Total		774.6 torr
Actual Total Pressure		775.0 torr

7. OPERATION DURING THE TEKTITE MISSION

The Tektite habitat was submerged on 13 February 1969 and turned on by General Electric Company personnel. Due to insufficient familiarity with the instrument and its operating procedures on the part of the personnel at the Tektite site, it was necessary for Perkin-Elmer to return to the site. The operation of the instrument was observed over a three-day period and several calibrations made. The data which was taken during this period is shown in Table 7-1. For the most part, the agreement obtained by adding the partial pressures and comparing them with the total pressure is very good. Of the twenty readings taken on the habitat meters, ten have less than one percent disagreement, and only four have worse than 3.6 percent agreement. The worst reading was obtained just after the entire habitat had been purged with additional nitrogen to reduce the oxygen partial pressure. It is likely that this had a significant effect upon the habitat circulation and temperature which affected the inlet leak valve.

It should be noted that the agreement between the habitat meters and the communication van meters was not always good. In one instance, after the instrument and meters had been calibrated, a discrepancy of about eight percent was recorded. This was very likely due to a reading error, but this is not known. Considering the accuracies of the meters and the difficulty in reading them accurately, it is unlikely that consistent data better than a few percent could be obtained.

In the opinion of the Perkin-Elmer representative, the instrument was functioning properly. Sensitivity variations were being observed which were probably due to the inlet leak valve. With periodic calibration, it was believed that sufficient accuracy would be maintained.

The Tektite Atmospheric Analyzer was operated until 18 February 1969 when a failure occurred in the ion pump power supply. This was a breadboard unit, the design of which had been accomplished in a relatively short time period specifically for the Tektite application. Perkin-Elmer personnel were sent to the site and under their direction the analyzer was removed from the habitat and brought to the surface for repair. An initial repair led to a second failure while the analyzer was on the surface.

The two on-site failures of the ion pump power supply for the Tektite project were both traced to transformer failures in the high voltage section of the DC/DC converter. Failure of the transformer resulted in failure of the two converter transistors.

TABLE 7-1. Tektite Operational Data

Date	Time	Habitat (Torr)				Van (Torr)				P _{TOT} (PSIA)	P _{TOT} (Torr)	Σ Habitat	Σ Van	Habitat	Notes
		H ₂ O	N ₂	O ₂	CO ₂	H ₂ O	H ₂	O ₂	CO ₂						
2-12	0936	3.4	1350	330	7.2	1.0	1330	338	7.0	31.6	1632	1690.6	1676.0	+3.6%	Before calibration by P-E direction
2-13	1306	2.9	1280	320	5.5	2.0	1270	317	5.35	31.7	1635	1608.4	1594.4	-1.6%	Habitat
2-14	1052	9.7	1300	329	3.5	8.5	1200	305	3.5	32.0	1650	1642.2	1517.0	-0.5%	Habitat
2-14	1230	3.0	1300	328	4.0	3.0	1300	335	4.0	31.85	1642	1635.0	1642.0	-0.4%	Habitat
2-14	1657	2.5	1510	155	1.9	2.1	1510	155	1.9	31.65	1635	1669.4	1669.0	+2.1%	Calibration
2-14	1742	2.3	1570	160	2.4	2.5	1580	160	2.4	31.65	1635	1734.7	1744.9	+6.1%	Habitat after N ₂ purge
2-13	0936	-	1470	164	4.2	-	1460	167	4.1	-	1635	1638.2	1631.1	+0.2%	Calibration Gas
2-13		-	1300	320	6.8	-	1300	325	6.6	-	1635	1626.8	1631.6	-0.5%	Habitat Air
2-13		-	1300	320	7.3	-	1300	328	7.0	-	1635	1627.3	1635.0	-0.5%	Habitat Air
2-13	1306	2.2	1260	316	5.6					31.7	1635	1583.8		-3.1%	After power interruption & habitat activity
2-13		2.9	1280	320	5.5	2.0	1270	317	5.35	31.7	1635	1608.4	1594.4	-1.7%	After power interruption & habitat activity
2-13	1436	2.5	1505	165	4.4					-	1635	1676.9		+2.5%	Calibration
2-13	1446	2.1	1470	164	4.1					31.7	1635	1640.2		+0.3%	Calibration
2-13	1502	2.5	1300	325	5.8					-	1635	1633.3		-0.1%	Habitat
2-13	1514	2.7	1300	325	5.9					31.7	1635	1633.6		-0.1%	Habitat
2-13	1518					1.0	1245	310	6.0	-	1635		1561.0		Habitat
2-13	1556	2.6	1290	322	6.4						1635	1621.0		-0.9%	Habitat
2-13	1630	5.0	1290	322	7.4					31.7	1635	1624.4		-0.6%	Habitat
2-14	0905					6.5	1190	305	3.5	-	1635	-	1505.5		Habitat
2-14	0923	4.0	1250	320	3.5					31.95	1650	1577.5		-4.4%	Habitat after overnight
2-14	1158	2.8	1425	160	4.0					31.95	1650	1591.8		-3.5%	Calibration
2-14	1208	2.5	1480	165	4.1					31.92	1650	1651.6		+0.1%	Calibration

After the second failure the transformers were returned to the manufacturer for analysis before fabrication of any additional replacements. Tests showed that the first unit had shorted from primary to secondary. The second unit failure was identical except that the short was not evident at lower voltage, but became apparent at about 500 volts, thereby limiting the output.

A replacement unit was fabricated using additional primary to secondary insulation. As a precautionary measure, a complete power supply was fabricated at the Pomona facility and subjected to extensive worst case analysis (as a verification of the initial design) and operational extremes. Although the worst case analysis verified the design, additional transient protection was incorporated in light of the line transients experienced at the project site. These modifications were for suppression of collector and base transients in the converter and peak current limiting in the collector circuit of the converter.

Using the new transformer design, the circuit was subjected to extremes of input voltage and output load. The nominal input voltage and output load. The nominal input voltage of 28 volts was raised to a maximum of 40 volts and the nominal output load of less than 100 microamperes was increased to 1000 microamperes. This test was run as long as practical in light of the increased power dissipation of the converter transistors. When it became apparent that the transistors could not dissipate the added heat, the input was returned to 32 volts and the test continued for approximately 18 hours.

During the test, transients were checked along with peak collector current. These were verified to be well within the limits of the components.

The unit was packed and hand-carried to the site, arriving within four and one-half days after the second failure. Additional verification was made at the site along with calibration of the instrument before installation. Operation was as expected and within specifications.

The Atmospheric Analyzer continued to operate from 1 March 1969 until 4 April 1969 when it was turned off at the direction of the site personnel. The last recorded calibration of the analyzer occurred on 7 March 1969 after which the instrument exhibited a slow downward drift in outputs for a period of 12 days. The outputs fell approximately six percent during this period. After this point in time, the instrument operated with a variation of less than plus or minus 0.7 percent for a period of ten days. On 29 March 1969, a ten percent jump in ion pump current was noted and this was accompanied by a jump in the outputs. It appears that a malfunction in the inlet leak, or perhaps in the temperature controller of the inlet system, caused the inflow of sample to increase. The problem became more severe during the next few days requiring the inlet leak to be closed down to obtain outputs at the proper level. Finally the instrument was turned off due to a condition which caused the ion pump current to read off scale on the 100 microampere range. Unfortunately the system was shut down before sufficient information could be transferred by telephone to Perkin-Elmer to allow the cause of the high current to be ascertained. It is not known whether the mass spectrometer outputs were reading high at the

time the instrument was turned off. The computer-recorded data which has been reviewed by Perkin-Elmer does not reflect the high ion pump current which had been indicated by the direct telephone communications. Ion pump current was logged only once a day and perhaps spurious increases in the current were not observed at the times when data was logged. The Tektite Atmospheric Analyzer will undergo evaluation at Perkin-Elmer to determine the status of the instrument and the cause of the shut down.

In reviewing the computer-recorded data, it is apparent that the instrument performed in a much more consistent way during the 21-day period when no calibrations were made. There were 12 days during which calibrations were made and during this time the data was more erratic. This indicates that some difficulty was encountered by the aquanauts in carrying out the calibration procedure. Also, the opening and closing of the door over the plumbing bay, and the continued adjustment of the inlet leak valve, probably led to variations in the leak conductance. It is also worth noting that during the period when the most consistent data was recorded, all of the habitat readings were made by the same aquanaut. This may have eliminated some of the variation which would have been indicated if different people had read the meters.

8. CONCLUSIONS

The Tektite Atmospheric Analyzer is the first mass spectrometer instrument which has been applied to an undersea environment and the program, as a whole, must be considered as a success. The Two Gas Atmosphere Sensor System was shown to be capable of monitoring the atmosphere of the Tektite habitat and providing useful information for atmosphere control purposes. Problems which occurred with the hardware were almost entirely located in the supporting equipment which was either of commercial quality or which had been rapidly designed without the benefit of a carefully planned development program. Items such as the inlet leak, ion pump, leak temperature controller, and ion pump power supply fall in this category. It is certain that if additional effort could have been expended in these areas, that the system performance would have been much improved.

Considering the short period for performance on the program, ten weeks for the system design, fabrication and test, four weeks for modification and final test, and one week for installation and final checkout, the instrument functioned very well. A great deal of informative knowledge was gained about the design and application of an atmospheric sensor for undersea applications. Any future design would benefit greatly from this.

It was also clear from the Tektite effort that closer liaison between the instrument supplier and the user is essential if the installation, operation, calibration, and maintenance of the Atmospheric Sensor is to be carried out smoothly. A more straight forward means of calibration, or no calibration at all, would also lead to much better results. A closed loop mode of operation will be incorporated on future applications which will automatically correct for the majority of the variations within the system. This will also allow imperfect inlet systems, such as the variable leak valve, to be employed without affecting the outputs. With this type of system the direct control of the major atmospheric constituents becomes feasible. This would eliminate the need for continuous monitoring and manual control of the atmosphere.

In conclusion, the Tektite Atmospheric Analyzer demonstrated that mass spectrometer instrumentation, and in particular the Two Gas Sensor, has a definite place in the field of undersea exploration where monitoring and control of life-support atmospheres is essential. The operation of a mass spectrometer in the high pressure environment of an undersea habitat was demonstrated, as well as the ability to sample continuously from such a high pressure environment. Long term operation of a mass spectrometer atmospheric analyzer under relatively unattended conditions was also shown to be feasible. The continuous and simultaneous monitoring of the major atmospheric constituents and then display within the habitat and at a remote location was also demonstrated. The

feasibility of periodic calibration of a multichannel mass spectrometer using a calibrated gas mixture was proved and it was shown that relatively untrained personnel could carry out this task.

The flexibility of the Two Gas Atmosphere Sensor would allow it to be applied to a wide range of potential undersea applications. The monitoring and control of the major atmospheric constituents within many types of habitats at various depths could be carried out. By increasing the number of ion current collectors other lower level constituents such as hydrogen, methane, and total organics can be monitored with the addition of an accumulator cell inlet system which is now under development for NASA/Langley Research Center. The small size of the mass spectrometer makes possible its application as a back pack unit which could be utilized with SCUBA equipment. In addition to atmospheric monitoring the Two Gas Sensor can be applied to biological measurements such as measuring the metabolic rate of aquanauts under various conditions of stress. It is evident that many possibilities exist for the application of the Two Gas Atmosphere Sensor in undersea environments.

APPENDIX A

OPERATION MANUAL

TEKTITE ATMOSPHERE ANALYZER SYSTEM

SPO No. 30200
NASA Contract Number
NAS1-8631

Prepared For
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Langley Research Center
Hampton, Virginia

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1. THEORY OF OPERATION

The Tektite Atmosphere Analyzer System can be divided roughly into four parts. These are: 1) the inlet system, 2) the calibration system, 3) the mass spectrometer and 4) necessary support equipment for the above. The inlet system performs several functions, the most important of which is the reduction of the pressure of sample gas from an ambient of two and one-half atmospheres to 2×10^{-4} torr, that is, 2×10^{-4} millimeters of mercury. This pressure reduction is accomplished with a special valve which has a precisely adjustable leak rate.

The rest of the inlet system consists of filters to extract all dust particles and other contamination from the air of larger size than approximately one micron, and metering valves and a flow meter to control the sample gas flowing thru the leak valve. A schematic of the inlet and vacuum systems is shown in Figure 1-1.

The calibration system provides a gas mixture of precisely known composition which makes possible the absolute calibration of the instrument. The calibration system consists of a pressure bottle containing calibration gas, a pressure regulator, and a metering valve.

The mass spectrometer is the central part of this atmosphere analyzing system. A mass spectrometer is an instrument which analyzes a chemical compound or mixture according to its atomic mass number. The mass spectrometer used in the Tektite Atmosphere Analyzer is a single focusing magnetic sector instrument. The mass spectrometer consists basically of three parts. These are: 1) the ion source, 2) the analyzer section, and 3) the collector and readout electronics. The ion source takes the incoming low pressure gas mixture and passes an electron beam thru it causing ionization. Ions are charged molecules or atoms and are sensitive to electric and magnetic fields. The ions are accelerated by fields of several hundred volts to fairly high velocity at which point they enter the analyzer section of the mass spectrometer which, reduced to its basic function, consists of nothing more than a magnet. This magnet deflects the ions from their normal straight paths into paths describing arcs of various radii of curvature. The heavier the ion, or the higher the mass number of the ion, the less it will be deflected by the magnetic field, therefore, ions of large mass will move in arcs of large radius while ions of low mass will move in small radius arcs. This will produce separation of the various ions produced by ionizing the given gas mixture. The ions now proceed to a series of collectors which are positioned to intercept the different masses. In the Tektite Atmosphere Analyzer, there are four collectors which are used to detect four particle masses. These are mass 18, or water, mass 28, or nitrogen, mass 32, or oxygen, and mass 44, or carbon dioxide. The ions, upon hitting the collectors, will cause an electric current to flow thru an external circuit. These currents are extremely small, on the order of 10^{-12}

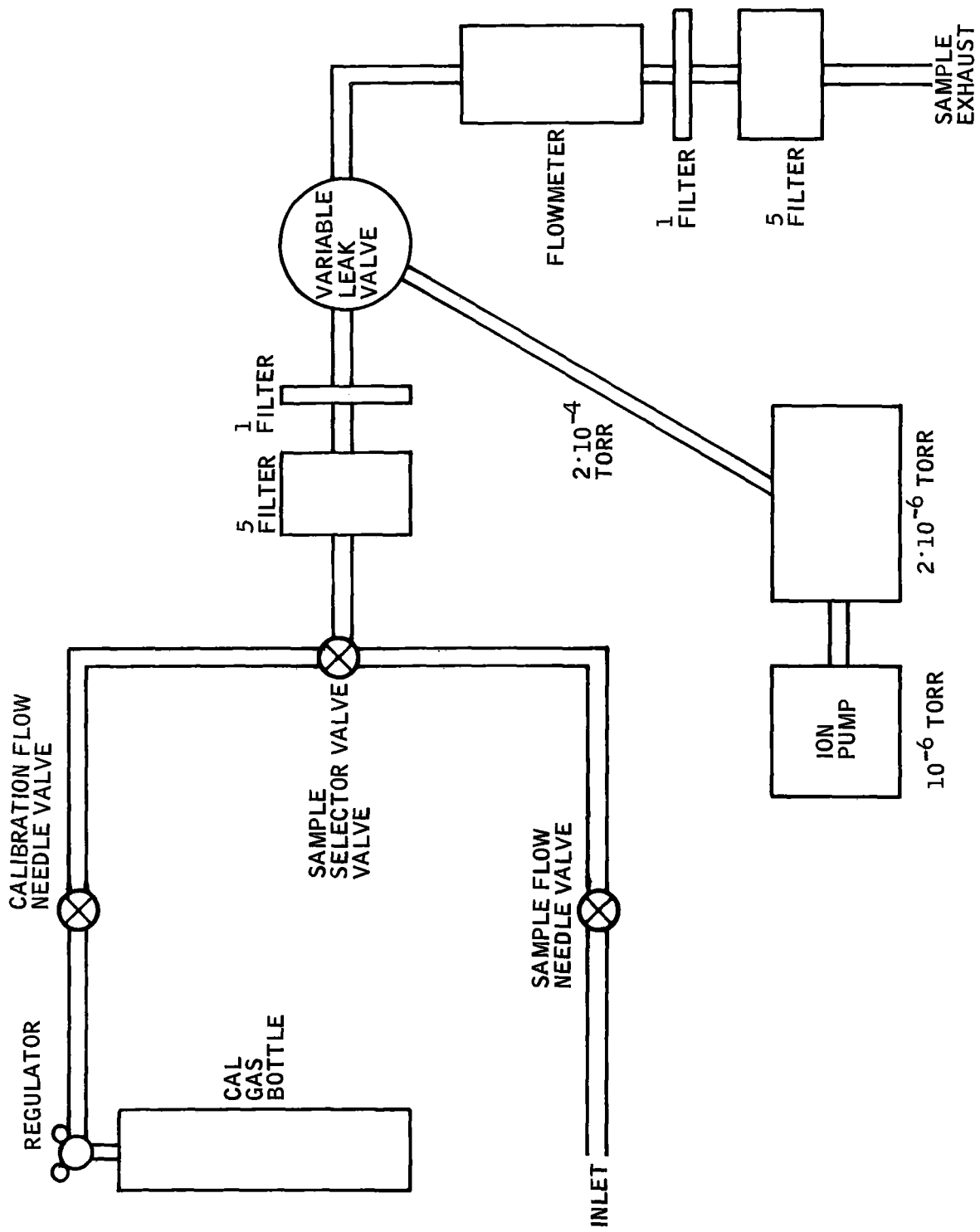


FIGURE 1-1. Inlet and Vacuum Systems Schematic

amperes, therefore, very sensitive electrometer amplifiers are used to amplify these currents for further processing. The outputs of these amplifiers are then proportional to the currents that pass thru the collectors, which in turn are proportional to the relative partial pressures of the particular constituent in the incoming gas mixture.

The fourth section of the Tektite Analyzer System is the support equipment required for the other three sections; this includes the ion vacuum pump that maintains a low pressure in the analyzer, the pressure housing, power supplies, and various other auxilliary equipment.

2. SYSTEM DESCRIPTION

The following is a brief functional description of the Tektite Atmosphere Analyzer. To simplify the system description, each part of the system referred to has been assigned an index number as shown in Figure 2-2. Sample gases, upon entering thru the quarter-inch sample line, pass into the analyzer thru the inlet connector (1). The sample gas then passes thru a needle flow control valve on the front panel of the instrument (2). After passing thru the flow controlling valve, the sample gas goes to the mode selector valve (4) which determines the mode of operation, that is, operating in the calibration mode or the normally operating sample mode. After passing thru the mode selector valve, the gas is filtered by a two stage inline filter (6a and b). On the sample outlet, corresponding sets of filters (7a and b) are present. The gas mixture then passes thru a sample flow meter (8) which determines the rate of gas flow thru the instrument and therefore, the pressure drops thru it. At this point, the gas passes into and thru the variable leak valve (9). This variable leak valve is fitted with a temperature control system (10a, b, and c). The front panel switch (11) controls the heater for the inlet valve. The calibration gas mixture is stored in a pressure tank (12) with regulator (13). Passing thru the regulator, the sample gas goes to the needle flow control valve then to the selector valve, previously mentioned. After passing thru the leak valve, the gas to be measured (either the sample gas or the calibration gas), passes thru a small diameter line (16) into the analyzer contained in the pressure vessel at the bottom of the instrument (17). Inside the pressure vessel are: a mass spectrometer (18), the related electronics for the mass spectrometer (19), ion pump (20), and the power supply for the ion pump (21). The pressure vessel is used to prevent the ambient pressure of two-and-one-half atmospheres from crushing the mass spectrometer which cannot withstand such pressures. The ion currents coming out of the mass spectrometer are detected and amplified by four electrometers (22). The main power to the mass spectrometer is provided by a 28Vdc power supply (23), requiring a 115 volts ac input.

There is a front panel switch (24) which controls the operation of the 28 volt power supply. Other items on the front panel are (25) the ion pump meter switch, and (26) the ion pump current meter. These monitor the current flowing to the ion pump from the high voltage supply and, therefore, indirectly monitor the analyzer pressure which is an important parameter in this instrument. There are two other meters on the front panel of the Tektite Analyzer. One of these is (28) the emergency battery voltage indicator. This indicates the stage of readiness of the emergency batteries which are used for powering the ion pump in a power off situation. The other front panel meter is the emission current meter (29). This meter measures the current passing from the filament in the ion source and gives an indication of the sensitivity at which the source is being operated. Directly connected with the ratings seen on the emission current meter is the dial directly underneath it which is the emission adjust potentiometer. This controls the amount of current flowing from that filament (30).

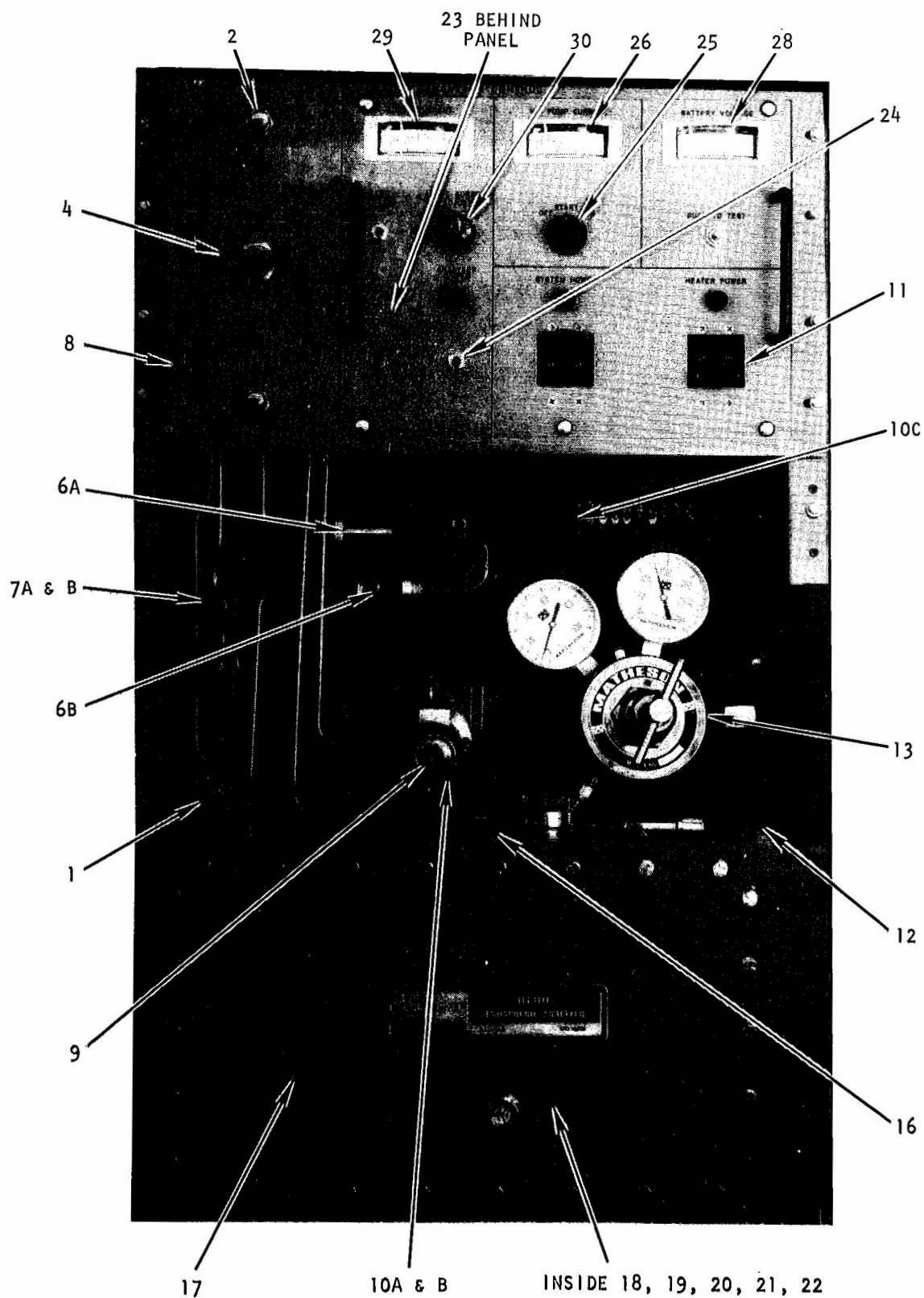


FIGURE 2-2. Atmospheric Analyzer Controls and Indicators

3. NORMAL OPERATING INSTRUCTIONS

3.1 START-UP PROCEDURE

- a. Check that the ION PUMP CURRENT OFF/START/RUN switch is in the RUN position. Reading should be nominally $2\mu\text{A}$ (the first division).
- b. Check BATTERY VOLTAGE by pressing PUSH TO TEST button. The voltage should be 26 volts or above.
- c. Check positions of the following controls prior to any further changes:
 1. ION PUMP CURRENT switch to RUN
 2. SAMPLE/CLOSED/CALIBRATE valve and FLOW METER to CLOSED position, FLOW METER at zero.
 3. ANALYZER POWER switch to OFF
 4. FIL 1/FIL 2 switch to FIL 1
 5. ANODE CURRENT ADJUST to zero (full CCW)
 6. HEATER switch to OFF
 7. VARIABLE LEAK to OFF position (full CW)
- d. HEATER POWER switch to ON
- e. SYSTEM POWER switch to ON
- f. Set ZERO CHECK switch to ON and hold while switching ANALYZER POWER switch to ON. A full-scale pulse on the ANODE CURRENT meter should be noted. After the pulse, release the zero check switch.
- g. Output meters on the ATMOSPHERE READOUT panel will show some deflections at this time, however, they should all drop to zero or low levels after a minute or two. Do not adjust any of the meters at this time.
- h. Release lock on ANODE CURRENT ADJUST knob by turning outer ring CCW. The ANODE CURRENT ADJUST is turned clockwise until the ANODE CURRENT meter reads $17.5\mu\text{A}$. The current will not start to come up until setting is at least 4.00 on knob dial. The output meters will show some deflections especially on H_2O and CO_2 channels.

- i. Wait 90 minutes for warm-up of valve heater and electrometers.
- j. Admit sample of TEKITE atmosphere by turning SAMPLE/CLOSED/CALIBRATE valve to SAMPLE. NOTE: CO₂ scrubber blower must be on in order to obtain sample. Open sample needle valve until flow is maximum for at least 30 seconds then adjust flow until a reading of 5 is obtained on the flow meter (observing black ball thru sight glass of flow meter).
- k. Hold the ANALYZER in this condition for a one hour stabilization period. At the end of this time some nominal readout for each gas will be noted, for example, 1 to 2 mmHg for N₂ and O₂ respectively and about 0.5 mmHg for H₂O and CO₂.
- l. A sample may now be admitted to the ATMOSPHERIC ANALYZER. The INLET LEAK valve is located in the plumbing bay just below the ANALYZER CONTROL panel, behind a side-opening door. The INLET LEAK valve is identified by two knobs on the top of the insulated valve assembly roughly the geometric center of the bay.

The sample is introduced by turning the double-knob CCW looking from the top. Use the yellow marker pointer to count turns. About 5-1/2 revolutions will be required with the last revolution very carefully applied. The ION PUMP CURRENT should be carefully watched during this process. The ION PUMP CURRENT OFF/START/RUN switch must be in the RUN position. At about 4-3/4 turns, the ION PUMP CURRENT will increase. Carefully adjust the INLET LEAK valve until a reading of 60 to 70 is obtained on the ION PUMP CURRENT meter. Immediately close the bay door to maintain steady-state temperatures within the bay.
- m. Allow one hour for stabilization. During this time a rough check can be obtained by summing all the meter outputs of the ATMOSPHERE READOUT panel and comparing it to the absolute pressure. The gauge is located in the ATMOSPHERE EGS CONTROL panel which reads out in psi and requires a conversion to mmHg by multiplying by 51.7, or

$$51.7 P_{\text{total}} = P_{\text{N}_2} + P_{\text{O}_2} + P_{\text{CO}_2} + P_{\text{H}_2\text{O}} \quad (\text{in mmHg}).$$

3.2 CALIBRATION PROCEDURE

- a. Open plumbing bay door and open the valve on the gas bottle, one or two turns is sufficient. Note pressure and record.
- b. Set output pressure by adjusting regulator until a reading of about two to four psi is obtained. Close the door.
- c. Turn SAMPLE/CLOSED/CALIBRATE flow-switching valve from SAMPLE to CALIBRATE. Adjust needle control valve on this panel until the silver ball is about full scale, hold for 15 to 30 seconds then slowly close needle control valve until a flow of two on the black ball is obtained.

- d. Leave ANALYZER in this condition for 15 to 30 minutes for stabilization.
- e. While waiting, set the ZERO CHECK switch to ON and while holding, note output of meters on ATMOSPHERE READOUT panel. Minor zero adjustments should be corrected using the meter zero adjust screw located on the face of the meter. This adjustment will probably not be required.
- f. While waiting, note and record the HABITAT PRESSURE taken from the WALLACE-TIERNAN gauge in the ECS Control Panel. Using one of the attached charts, obtain the true partial pressure of the N_2 , O_2 , and CO_2 in the particular gas sample being calibrated. H_2O is a minute value and can be disregarded.
- g. Before making any further calibration adjustment, note and record all meter outputs as well as the HABITAT total pressure.
- h. If the N_2 meter readout does not compare with that value obtained from the calibration chart, open the plumbing bay door and carefully adjust the INLET LEAK valve. This should be done with EXTREME CARE since a small adjustment is all that is required. When the correct readout is obtained, close the plumbing bay door to maintain thermal equilibrium on the valve.
- i. Additional minor adjustments may be made by adjusting the METER ADJUST potentiometer of the NITROGEN meter, (using a screwdriver). If difficulty is encountered in adjustment to N_2 calibration by steps 2.8 or 2.9, the ANODE CURRENT ADJUST can be used to calibrate. However, this is not desirable if the ION PUMP CURRENT has not exceeded 60 to 70 μA .
- j. The OXYGEN meter may now be adjusted to the proper calibration valve using the O_2 METER ADJUST knob.
- k. The CO_2 meter reading is now taken and if the reading is higher than that given in the CALIBRATION TABLE, it can be adjusted by using the CO_2 METER ADJUST knob to obtain the calibration value. If the true value cannot be reached by adjustment of the METER ADJUST knob, subtract the true value from the actual reading to obtain a background value. This background must then be subtracted on all subsequent readouts of CO_2 .

4. MAINTENANCE

The Tektite Atmosphere Analyzer is equipped with two sets of two-stage air line filters. These filters remove dust particles and aerosols from the gasses flowing into the leak valve. In normal operation these filters can become clogged. During calibration flow if the flow controlling valve has to be opened unusually far, the inlet filters probably need replacement. The inlet filters (6a and b, Figure 2-2) will be the only ones normally needing replacement. A supply of replacement filter discs has been provided for replacement purposes. The metal depth filters will not normally require replacement. Filter replacement should be accomplished as rapidly as possible to avoid excessive contamination at the inlet lines. The outflow filters will need replacement only in rare cases where reverse flow has occurred. The emergency batteries for the ion pump have an operating life of approximately 600 hours and an unlimited shelf life. If for some reason changing the batteries during power failure conditions becomes necessary, the leak valve should be closed completely to prevent excessive pressure buildup.

5. EMERGENCY PROCEDURES

5.1 EXTERNAL EMERGENCIES

External emergencies are those relating to abnormalities outside the instrument proper. These include power failure, power shortage, and flooding. In a power failure situation, the ion pump will automatically switch over to battery operation, preventing contamination of the vacuum system. The leak valve should be closed in any prolonged power failure, as this will reduce the pressure in the analyzer and extend the life of the emergency batteries. In a limited power failure or power shortage situation, the instrument can be operated with reduced power drain by shutting off the heater. The accuracy of the analyzer will be impaired, but approximate atmosphere determinations will still be possible. If flooding is imminent, and 30 seconds or one minute is available, all the valves should be closed and power turned off.

5.2 INTERNAL EMERGENCIES

Internal emergencies are those relating to abnormal operation of the instrument itself.

If, for some reason, the ion pump current goes past 40 in the start position and remains there for more than five minutes, the leak valve should be closed. If this does not reduce the pressure within a few minutes, the emission control should be turned all the way counterclockwise. If the ion current goes off-scale in the start position for more than one minute, the pump should be shut down. Restart of the system after shutdown will require a sorption roughing pump and external high voltage supply. Perkin-Elmer Aerospace Systems should be consulted, if necessary, to restart the pump.

The anode current meter should always read 17.5 microamperes. If the anode current deviates more than one microampere from this value, it should be reset to 17.5 microamperes. If a continuing drift or instability is observed, the emission regulator is probably malfunctioning. If there is a marked change in anode current, the instrument should be turned off and valved off.

TABLE 1. CALIBRATION CHART FOR CYLINDER #1

Constituents:

Nitrogen 91.25%
 Oxygen 8.48%
 Carbon Dioxide 0.26%
 Water 0.01%

Habitat Absolute Pressure in psi	True Partial Pressure in Torr			
	Nitrogen	Oxygen	CO ₂	Water
31.0	1457	135.6	4.16	0.2
31.1	1462	136.0	4.17	0.2
31.2	1467	136.5	4.19	0.2
31.3	1472	136.9	4.20	0.2
31.4	1477	137.4	4.21	0.2
31.5	1483	137.8	4.23	0.2
31.6	1488	138.2	4.24	0.2
31.7	1493	138.8	4.26	0.2
31.8	1498	139.2	4.27	0.2
31.9	1502	139.7	4.28	0.2
32.0	1507	140.2	4.29	0.2
32.1	1511	140.6	4.30	0.2
32.2	1516	141.0	4.32	0.2
32.3	1521	141.4	4.33	0.2
32.4	1526	141.8	4.34	0.2
32.5	1530	142.2	4.36	0.2
32.6	1534	142.6	4.37	0.2
32.7	1539	143.1	4.39	0.2
32.8	1544	143.5	4.40	0.2

TABLE 1 (Cont)

Habitat Absolute Pressure in psi	True Partial Pressure in Torr			
	Nitrogen	Oxygen	CO ₂	Water
32.9	1549	143.9	4.41	0.2
33.0	1554	144.4	4.43	0.2
33.1	1559	144.8	4.44	0.2
33.2	1563	145.3	4.46	0.2
33.3	1568	145.7	4.47	0.2
33.4	1573	146.1	4.49	0.2
33.5	1577	146.6	4.50	0.2
33.6	1581	147.0	4.51	0.2
33.7	1586	147.5	4.53	0.2
33.8	1591	147.9	4.54	0.2
33.9	1596	148.3	4.55	0.2
34.0	1601	148.8	4.56	0.2

TABLE 2. CALIBRATION CHART FOR CYLINDER #2

Constituents:

Nitrogen 89.76%
 Oxygen 10.02%
 Carbon Dioxide 0.21%
 Water 0.01%

Habitat Absolute Pressure in psi	True Partial Pressures in Torr			
	Nitrogen	Oxygen	CO ₂	Water
31.0	1435	161	4.3	0.2
31.1	1440	161	3.4	0.2
31.2	1445	162	3.4	0.2
31.3	1450	162	3.4	0.2
31.4	1455	163	3.4	0.2
31.5	1460	163	3.4	0.2
31.6	1465	164	3.4	0.2
31.7	1470	164	3.5	0.2
31.8	1475	165	3.5	0.2
31.9	1480	165	3.5	0.2
32.0	1485	166	3.5	0.2
32.1	1490	166	3.5	0.2
32.2	1494	167	3.5	0.2
32.3	1498	167	3.5	0.2
32.4	1502	168	3.5	0.2
32.5	1507	168	3.5	0.2
32.6	1510	169	3.5	0.2
32.7	1515	169	3.5	0.2

TABLE 2 (Cont)

Habitat Absolute Pressure in psi	True Partial Pressures in Torr			
	Nitrogen	Oxygen	CO ₂	Water
32.8	1519	170	3.6	0.2
32.9	1522	170	3.6	0.2
33.0	1528	171	3.6	0.2
33.1	1532	171	3.6	0.2
33.2	1538	172	3.6	0.2
33.3	1542	172	3.6	0.2
33.4	1548	173	3.6	0.2
33.5	1551	173	3.6	0.2
33.6	1558	174	3.6	0.2
33.7	1561	174	3.7	0.2
33.8	1566	175	3.7	0.2
33.9	1570	175	3.7	0.2
34.0	1575	176	3.7	0.2

TABLE 3. CALIBRATION CHART FOR CYLINDER #3 (Matheson 8732)

Constituents:

Nitrogen	92.41%
Oxygen	7.31%
Carbon Dioxide	0.27%
Water	0.01%

Habitat Absolute Pressure in psi	True Partial Pressure in Torr			
	Nitrogen	Oxygen	CO ₂	Water
31.0	1478	117	4.3	0.2
31.1	1483	117	4.3	0.2
31.2	1487	117	4.3	0.2
31.3	1492	118	4.3	0.2
31.4	1497	118	4.3	0.2
31.5	1502	118	4.3	0.2
31.6	1507	119	4.3	0.2
31.7	1511	119	4.3	0.2
31.8	1516	120	4.4	0.2
31.9	1521	120	4.4	0.2
32.0	1526	120	4.4	0.2
32.1	1531	121	4.4	0.2
32.2	1536	121	4.4	0.2
32.3	1540	121	4.4	0.2
32.4	1545	122	4.4	0.2
32.5	1549	122	4.5	0.2
32.6	1554	123	4.5	0.2
32.7	1559	123	4.5	0.2
32.8	1563	123	4.5	0.2

TABLE 3 (Cont)

Habitat Absolute Pressure in psi	True Partial Pressure in Torr			
	Nitrogen	Oxygen	CO ₂	Water
32.9	1568	124	4.5	0.2
33.0	1573	124	4.5	0.2
33.1	1578	124	4.5	0.2
33.2	1583	125	4.6	0.2
33.3	1587	125	4.6	0.2
33.4	1592	126	4.6	0.2
33.5	1597	126	4.6	0.2
33.6	1602	126	4.6	0.2
33.7	1606	127	4.6	0.2
33.8	1611	127	4.6	0.2
33.9	1616	127	4.6	0.2
34.0	1621	128	4.7	0.2

TABLE 4. CALIBRATION CHART FOR CYLINDER #4 (Matheson DL7475)

Constituents:

Nitrogen 91.84%
 Oxygen 7.9%
 Carbon Dioxide 0.25%
 Water 0.01%

Habitat Absolute Pressure in psi	True Partial Pressure in Torr			
	Nitrogen	Oxygen	CO ₂	Water
31.0	1469	126	4.0	0.2
31.1	1474	127	4.0	0.2
31.2	1478	127	4.0	0.2
31.3	1483	128	4.0	0.2
31.4	1488	128	4.0	0.2
31.5	1492	129	4.0	0.2
31.6	1497	129	4.0	0.2
31.7	1502	130	4.0	0.2
31.8	1506	130	4.1	0.2
31.9	1511	130	4.1	0.2
32.0	1516	131	4.1	0.2
32.1	1521	131	4.1	0.2
32.2	1526	132	4.1	0.2
32.3	1530	132	4.1	0.2
32.4	1535	133	4.1	0.2
32.5	1540	133	4.2	0.2
32.6	1544	133	4.2	0.2
32.7	1549	134	4.2	0.2
32.8	1554	134	4.2	0.2

TABLE 4 (Cont)

Habitat Absolute Pressure in psi	True Partial Pressure in Torr			
	Nitrogen	Oxygen	CO ₂	Water
32.9	1559	135	4.2	0.2
33.0	1564	135	4.2	0.2
33.1	1569	136	4.2	0.2
33.2	1563	136	4.3	0.2
33.3	1568	136	4.3	0.2
33.4	1573	137	4.3	0.2
33.5	1577	137	4.3	0.2
33.6	1582	138	4.3	0.2
33.7	1587	138	4.3	0.2
33.8	1591	139	4.3	0.2
33.9	1596	139	4.3	0.2
34.0	1611	139	4.4	0.2

APPENDIX B

DATA SUMMARY OF DATA TAKEN PRIOR TO PRELIMINARY
INTEGRATION AT PHILADELPHIA NAVAL SHIPYARD

The following discussion presents, briefly, the results of the system tests conducted prior to shipment of the Tektite Atmospheric Analyzer to the Philadelphia Naval Shipyard for the initial integration with the Tektite habitat.

RUN NO. 1 - PRELIMINARY STABILITY TEST

Test duration - 41 hours

Sample - Standard calibration gas

A general downward drift in all of the outputs was noted. During the last 24 hours of the test, the drifts were -12 percent on the CO₂ channel, -4.3 percent on the N₂ channel, and -2.7 percent on the O₂ channel. These drifts were not correlated with changes in the inlet leak temperature. Stabilization of the valve setting is expected to be part of the cause for the changes. The larger variation in the CO₂ output is believed to be due to a gradual downward drift in the CO₂ background. A high water background was noted.

RUN NO. 2 - STABILITY TEST

Test duration - 5 hours 40 minutes

Sample - Calibration gas

Fair stability was exhibited after the first hour of the test. Over the final four hours, the decline in the outputs was a little over two percent.

RUN NO. 3 - CONTINUED STABILITY TEST

Test duration - 17 hours

Sample - Standard calibration gas

A substantial fall off in outputs was noted almost continuously during the test period. The initial drop is expected to be due to the warming up of the ion source in the presence of the oxygen sample leading to an increase in source conductance and a decrease in ion source outputs. The N₂/O₂ ratio held within about plus or minus one percent which indicates that the fall off may very well have been due to the temperature of inlet leak variations. The water background dropped significantly overnight.

RUN NO. 4 - TEST ON SECOND ELECTRON GUN AND FLOW VARIATION TEST

Test duration - 3 hours 30 minutes

Sample - Standard calibration mixture

This run was made to demonstrate the performance on the second electron gun. After the first eight minutes, the stability was fairly good. The N_2/O_2 ratio was about the same as for electron gun No. 1.

A second object of this test was to determine what the effect of flow rate variations in the inlet system would have on the output. A very small effect was noted for a large variation in flow rate. It was, therefore, determined that the flow rate setting was not critical.

RUN NO. 5 - SAMPLE CHANGE TEST

This test was performed to determine how rapidly the outputs would respond to a change in sample composition. The system was started out on the calibration inlet using calibration gas. The sample was then changed to the normal sample inlet side and air was forced thru the inlet system. After a significant change in composition as reflected by the changes in the outputs, new levels were reached within less than five minutes, which appeared to be within normal stability as indicated on earlier runs.

RUN NO. 6 - WET VS DRY NITROGEN

This test was run to determine the rate at which water output would respond to changes. First, a wet nitrogen sample was admitted and the water output went up slowly over a two-hour period. Indications were that a substantial time constant would exist with respect to water changes. At 1:17 p.m. the sample was switched to dry nitrogen. Again after one-half hour, a stable level had not been reached. It was suspected that most of the delay was in the sample flow system, but additional time was not available to run substantiating tests.

	TIME	TEMP	WATER	NITROGEN	OXYGEN	CO ₂
	4.020	74.90	-.3854	-4.977	-1.881	-2.226
	4.190	74.90	-.3805	-4.484	-1.704	-2.108
NOV 2	4.380	75.00	-.3957	-4.385	-1.665	-2.088
	7.340	74.60	-.4373	-4.232	-1.607	-2.034
	7.440	74.60	-.4392	-4.232	-1.607	-2.028
	10.06	74.20	-.4381	-4.227	-1.606	-2.005
	8.000	72.80	-.3090	-4.105	-1.559	-1.859
NOV 3	8.070	72.80	-.3100	-4.113	-1.563	-1.866
	3.340	74.10	-.3548	-4.030	-1.533	-1.775
	3.400	74.10	-.3498	-4.026	-1.535	-1.777
	8.180	74.10	-.3488	-3.981	-1.518	-1.679
NOV 4	8.250	74.40	-.3513	-3.984	-1.521	-1.682
	8.350	74.10	-.3488	-3.942	-1.504	-1.665
	8.490	74.20	-.3537	-4.001	-1.527	-1.688

RUN NO. 1

	TIME	TEMP	WATER	NITROGEN	OXYGEN	CO ₂
NOV 4	8.585	74.20	-.3239	-3.994	-1.493	-1.670
	9.000	74.20	-.3129	-3.736	-1.422	-1.601
	9.020	74.20	-.3109	-3.655	-1.390	-1.574
	9.040	74.20	-.3099	-3.621	-1.377	-1.562
	9.100	74.20	-.3109	-3.576	-1.357	-1.542
	9.200	74.60	-.3137	-3.520	-1.340	-1.525
	9.500	74.20	-.3189	-3.503	-1.334	-1.517
	10.48	74.70	-.3059	-3.361	-1.283	-1.452
	11.20	74.90	-.3087	-3.368	-1.285	-1.457
	12.02	74.90	-.3038	-3.346	-1.277	-1.446
	1.060	74.50	-.3010	-3.349	-1.279	-1.443
	2.400	74.80	-.2922	-3.281	-1.252	-1.408

RUN NO. 2

	TIME	TEMP	WATER	NITROGEN	OXYGEN	CO ₂
	6.570	74.50	-1.187	-4.698	-1.778	-2.140
	6.580	74.50	-1.121	-4.505	-1.711	-2.078
	7.000	74.50	-1.054	-4.335	-1.650	-2.040
	7.050	75.00	-.9201	-4.037	-1.535	-1.954
	7.100	75.00	-.8543	-3.940	-1.497	-1.949
NOV 4	7.150	75.00	-.7586	-3.737	-1.419	-1.885
	7.200	75.00	-.6715	-3.617	-1.377	-1.864
	7.300	75.00	-.5931	-3.581	-1.364	-1.898
	7.500	74.10	-.4206	-3.444	-1.312	-1.937
	8.520	73.00	.2181	-2.950	-1.135	-1.341
NOV 5	10.57	73.10	.2122	-2.993	-1.153	-1.327
	11.50	73.40	.2111	-2.987	-1.153	-1.319

RUN NO. 3

TIME	TEMP	WATER	NITROGEN	OXYGEN	CO ₂	
12.12	73.80	-.2704	-6.257	-2.409	-2.492	
12.14	73.80	-.2708	-5.860	-2.266	-2.390	
12.20	73.90	-.2709	-5.377	-2.083	-2.255	
1.220	73.80	-.3070	-5.349	-2.078	-2.306	
2.010	73.80	-.3131	-5.351	-2.077	-2.307	Flow 2 units
2.020	74.00	-.3130	-5.403	-1.987	-2.357	Flow 150 units
2.030	74.00	-.3030	-5.376	-1.976	-2.343	Flow 150 units
2.040	74.00	-.2860	-5.311	-1.951	-2.317	Flow 2 units
2.050	74.00	-.2830	-5.321	-1.954	-2.311	Flow 150 units
2.070	74.00	-.2710	-5.294	-1.945	-2.295	Flow 150 units
3.010	74.10	-.2223	-5.125	-1.969	-2.163	Flow 2 units
3.400	74.10	-.2352	-5.172	-1.990	-2.191	Flow 2 units

RUN NO. 4

TIME	TEMP	WATER	NITROGEN	OXYGEN	CO ₂	
6.500	74.80	-.2406	-5.572	-2.054	-2.193	
6.520	74.80	-.2357	-5.458	-2.018	-2.176	
6.580	74.80	-.2289	-5.343	-1.979	-2.162	
7.100	74.80	-.2094	-5.045	-1.868	-2.068	Calib. gas
7.200	74.50	-.2056	-5.143	-1.903	-2.118	
7.250	74.50	-.2046	-5.160	-1.910	-2.125	7:25
7.300	74.50	-.2262	-4.458	-4.024	-.7377	
7.350	74.50	-.2567	-4.265	-3.953	-.7112	
7.400	74.50	-.3344	-4.316	-4.009	-.7141	Dry Air
7.500	74.70	-.4466	-4.387	-4.083	-.7651	
7.550	74.70	-.4876	-4.401	-4.090	-.7847	
8.000	74.70	-.5042	-4.315	-4.013	-.7866	8:00
8.050	74.40	-.4757	-5.094	-1.920	-2.280	
8.100	74.50	-.3964	-5.145	-1.914	-2.266	
8.150	74.50	-.3521	-5.165	-1.919	-2.254	Calib. gas
8.200	74.50	-.3207	-5.107	-1.896	-2.201	
8.250	74.20	-.2891	-4.968	-1.916	-2.122	
10.27	73.30	-.2221	-5.038	-1.963	-2.037	

RUN NO. 5

TIME	TEMP	NITROGEN	
11.20	73.60	-5.594	
11.25	73.60	-5.446	
11.30	73.60	-5.524	
11.35	73.60	-5.567	
11.45	73.90	-5.368	
11.50	73.90	-5.399	
11.55	73.90	-5.458	
12.20	73.90	-5.438	
1.150	73.90	-5.188	WET N ₂
1.200	74.00	-5.241	
1.250	74.10	-5.356	DRY N ₂
1.300	74.10	-5.165	
1.400	73.90	-5.196	
1.500	74.00	-5.051	
2.000	74.00	-5.040	

RUN NO. 6