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TWO GAS ATMOSPHERE SENSOR SYSTEM
PHASE II DEVELOPMENT - FINAL REPORT

By FRANK BRISCOE

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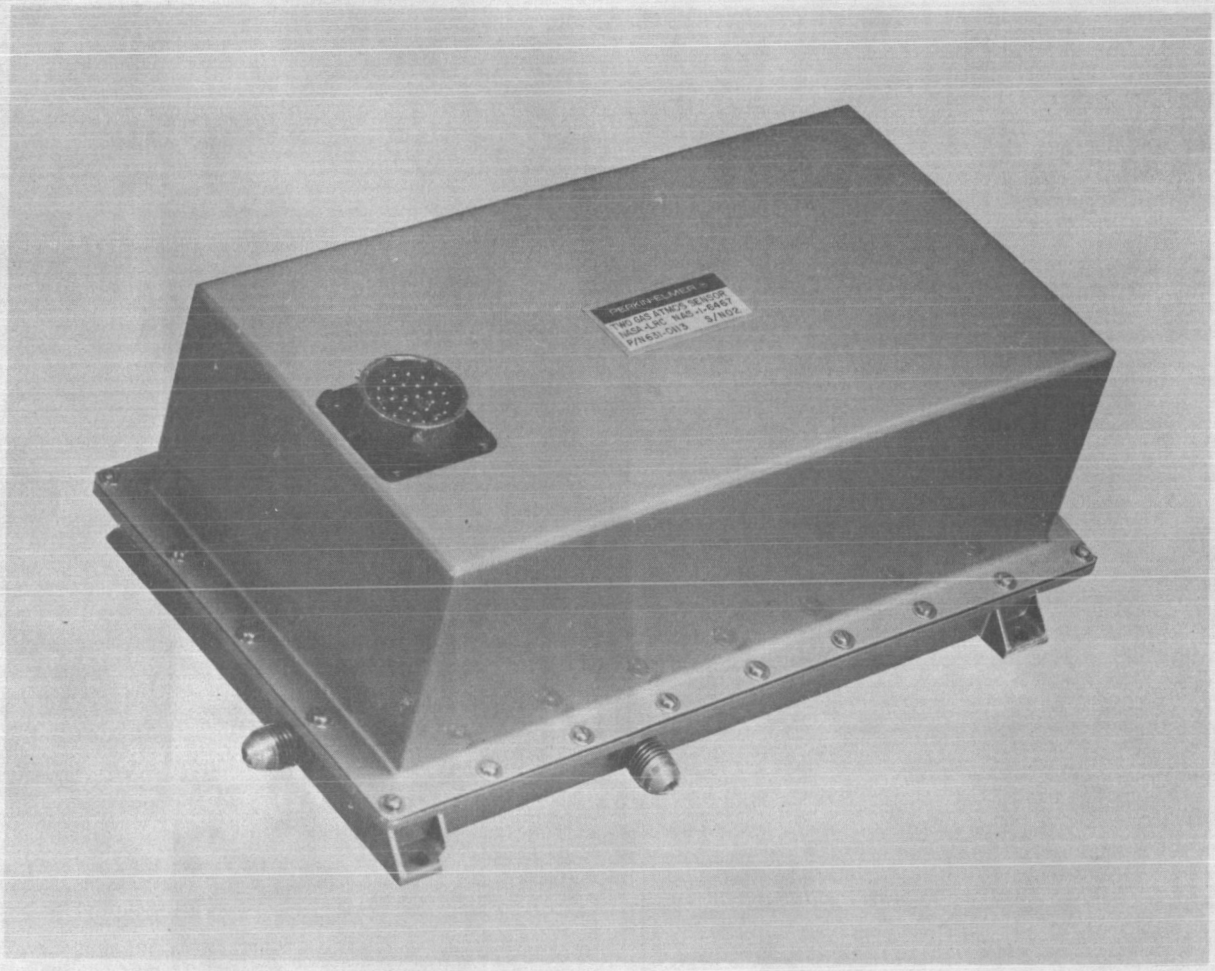


Figure 1. Two Gas Atmosphere Sensor System

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ABSTRACT

The intended use of a diluent gas with oxygen for long duration aerospace missions requires the development of a sensor system to accurately measure the partial pressures of the mixed gas constituents.

This report summarizes the results of a Phase II program to design, develop, and test a Two Gas Atmosphere Sensor System based on photometric techniques.

The report also discusses the Phase I study effort of a previous contract and describes the technical approach for this program. The Phase IIa design effort and the Phase IIb fabrication effort are presented. An assessment of performance is made and recommendations for future work are made.

The program has consisted of a detail design based on the recommendations of the study program, implementation of the approved design, and an assessment of the performance of the resulting units.

Four units have been fabricated and tested under this program.

SECTION I

INTRODUCTION

The proposed use of a Nitrogen-Oxygen atmosphere or a Helium-Oxygen atmosphere for life support systems of future manned spacecraft requires the development of a sensor system to accurately measure the partial pressures of the principal gases. Recognizing this requirement, a Phase I Study and Phase II Detail Design and Fabrication effort was performed by the Perkin-Elmer Corporation, Norwalk, Connecticut for the National Aeronautics and Space Administration, Langley Research Center, Langley Station, Hampton, Virginia, under Contracts NAS1-5678 and NAS1-6467. The study was in progress from 15 November 1965 to 15 March 1966. The Phase II program for the fabrication of four pre-flight models is the subject of this report.

This instrument, designated as a Two Gas Atmosphere Sensing System, provides partial pressure information of the principal gases as an analog electrical signal for integration into a functional atmosphere control system.

The Phase I report[1] recommended an optical photometric concept as appropriate for this sensor. The design concept developed during the study program utilizes two sensor channels and a total pressure transducer to provide five different measurements (partial pressure of O_2, CO_2, H_2O, N_2 or He, and total pressure) and electrical signals proportional to these measurements for monitoring and possible application to cabin atmospheric control systems.

The work done under the Phase I study resulted in recommended overall requirements for the system. This system is a logical and desirable improvement of the present technology. The system described in this report represents advanced techniques utilizing state-of-the-art components and concepts that result in a sophisticated system capable of application to many future programs.

In the Study Report, the application of the Two Gas Atmosphere Sensor System to a future spacecraft model was reviewed for the recommended operational criteria. Investigation of the visual readout compatibility of the system indicated that the output readily lends itself to the display of the portions of the partial pressure ranges that are considered most significant. For example, there is no appreciable difficulty encountered in displaying the analog voltage for the oxygen partial pressure having a range of 0 to 5 volts, for a variation in oxygen partial pressure of some arbitrary limits, such as 125 to 250 millimeters Hg of partial pressure. Likewise, the zero point on the total pressure indication can be set at some selected point and does operate over a range of 200 to 400 millimeters Hg of total pressure. There are a minimum number of operational supplies required for the duration of the missions indicated.

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[1] Two Gas Atmosphere Sensor System, Conceptual Design Study, Phase I Final Report. NASA Document CR66175.

The goal of the continuous closed-loop operation of the system, described in more detail later in this report, automatically compensates for changes in its reference, permitting continuous performance throughout the mission without the use of laboratory type controls or adjustments in either zero or span. It is this aspect of the design that facilitates the utilization of the proposed system in an extended duration spacecraft mission.

There are unresolved difficulties at present with the water vapor and oxygen channel span stabilities. These are a result of the design problems of the UV sample cell and are discussed in Section V. These problems have not been resolved due to funding limitations under the present contract, but additional work is planned in this area. At present, the philosophy on the maintainability of the system is to use high reliability components which would preclude the necessity of either maintenance in the field or during the mission.

Assessments have been made in the Study Report of the applicable sensor technology with respect to the specified basic requirements. With respect to zero gravity operation, it is felt that no degradation of the system's performance will occur under zero-G conditions. The performance of the system is not impaired by exposure to hard vacuum. The accuracy and response time necessary for control have been synthesized on the basis of a suggested spacecraft model. There is no difficulty encountered in the response time requirement and the accuracy requirement was judged to be within the performance capability of the proposed instrument. However, the accuracy requirement has not been demonstrated on the water vapor and oxygen channels at the present time.

The operational life of the system is not known, but is anticipated to extend well beyond any other previous sensing method. There are no wearout components or systems within the Two Gas Atmosphere Sensor and operation in terms of years can be anticipated with occasional adjustment in the analog circuitry due to aging. Shelf life of the system is also undetermined, but investigation of our vendors' studies and our own studies has shown no degradation of performance after a 3 to 5 year shelf life. The critical item in the determination of the shelf life would be electronic components, such as the sintered-anode low leakage tantalum capacitors, and the formation of UV absorptive films over long term sampling of unclean samples. This latter effect has not been fully evaluated and requires additional work to be completely defined.

The energy, material, and atmospheric sample requirements of the system are minimal. It is only necessary to apply a 28 volt supply to energize the sensor; to mount it on a suitable dimensionally stable surface; and to provide a few inches of water pressure head at a representable sample point. No other special considerations need be given to the installation in a spacecraft or in the laboratory. The system should be independent of orientation and practically independent of normal environments. However, the results of tests on the first production unit have shown an attitude sensitivity attributable to orientation in the earth's field affecting the photomultiplier detector. The detector requires shielding, which has not been accomplished in the present design.

Shock and acceleration stresses, temperature stresses, acoustical noise, sand and dust, salt spray, or rain should not impair or change the performance of the system. Selected vibrational stresses at particular frequencies and amplitudes may, of course, cause a resonance of the system and impair its operation at those particular points. However, operation before and after these frequencies can be achieved and the system can be anticipated to be independent of vibrational stresses below 3 to 5 g's over the frequency range from 5 to 2000 Hz.

All of the output signals, as well as provisions for the input power and for operation of the equipment in a test mode and a zero check mode, are provided by the single power plug. No switches are provided on the sensor as all switching would be done either on a control panel or externally to the system. All of the sample gas enters through a flared-tube inlet port, passes through the various sample compartments, and is eluted from the flared-tube output port.

A pressure drop of only a tenth of an inch of water is necessary to provide the 10 second response of the system. Special considerations have been given in this configuration for a smooth flow of gas through the sample system and to provide these compartments with regular uniform cross sections with a minimum of trapped volumes or tortuous diffusion paths, which would extend the response time of the sensor.

The conceptual model of the study report approach is shown in figures 2 and 3.

PRESENTATIONS

Four formal presentations were made during the Phase II program. The first presentation was made at NASA/LRC on October 4, 1966 to personnel of NASA centers and the Department of Defense. The presentation covered the work accomplished under Phase I of the contract and the work planned under Phase II.

On October 5, 1966, the preliminary design review took place at NASA/LRC to present the design criteria, drawings, parts list, and design status.

A presentation at NASA Headquarters, Washington, D.C., took place on October 28, 1966 to the NASA office of Advanced Research and Technology.

A development test fixture (figure 5) was made and exhibited at the Phase IIa Design Review at NASA/Langley on March 31, 1967. The fixture, made from the detail design drawings, shows the actual configuration of the final design.

A three-minute narrated 16 mm color film showing the assembled breadboard and itemizing the function of the system and the components was produced and delivered to NASA Headquarters in January 1967.



Figure 2. Conceptual Model, Two Gas Sensor

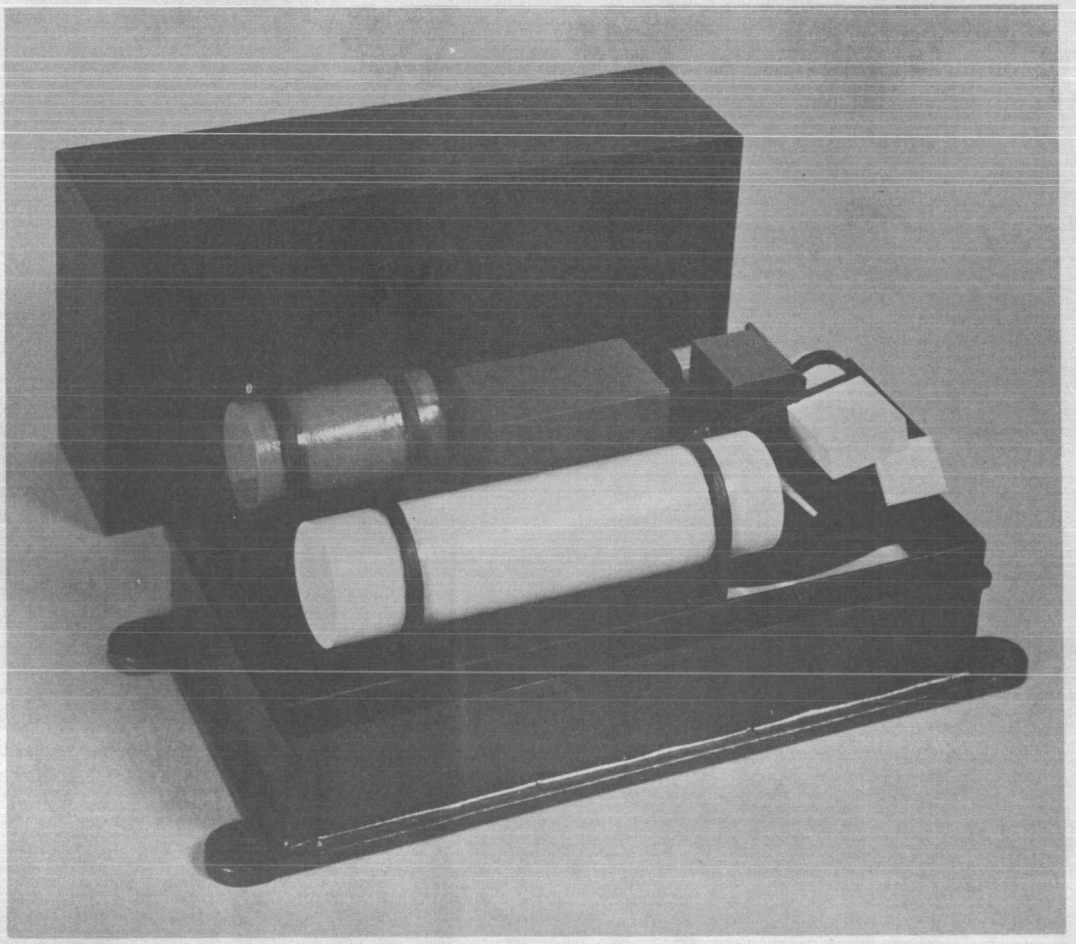


Figure 3. Conceptual Model, Two Gas Sensor - Cover Removed

SECTION II

SYSTEM DESCRIPTION

A. OVERALL SYSTEM

The infrared CO_2 channel uses a dual filament incandescent lamp as a source of energy and a silicon lens system to gather this energy and focus it on an optical chopper. This chopper is driven by a limited-rotation motor with flexure bearings. The modulated energy is then detected by an infrared detector, which supplies information to the electronic amplifiers.

The ultraviolet O_2 and H_2O channel uses a specially designed ultraviolet lamp and a grating monochromator and shares the common torsional chopper with the infrared channel for maximum utilization of components. A photomultiplier detector is used to measure the modulated ultraviolet energy.

High-quality discrete electronic components and integrated circuits, which are mounted in the miniature welded modules, are used for the electronic systems of both the infrared and ultraviolet channels.

The total pressure is measured by a potentiometric total-pressure transducer. This transducer system does not contain any optical members and its associated electronic system is of a construction similar to that used with the infrared and ultraviolet channels.

This particular system has been selected for several reasons. It has been shown in the study report of the conceptual design that the most reliable system would be one using a torsional chopper and maximum utilization of integrated circuits. In addition, as was again described in detail in the study report, this method provides the maximum signal-to-noise information to the detectors and is least susceptible to environmental stresses that may be imposed on the system. An important reason for the final selection of this system is that it is a natural development of an improvement on the present Apollo CO_2 Sensor. It has taken advantage of the solutions to many difficult problems, which have been experienced on the existing systems, and it encompasses the maximum utilization of design information obtained during the conceptual design study.

The ultraviolet system uses an ultraviolet lamp, which is the source of the energy to be measured in the oxygen and water system. It is supplied by a current regulated, dc high voltage supply. By stabilizing the input current to the lamp, we have reduced the excursions of the radiated energy and hence have reduced the requirements for the automatic gain control or ratio computation and stabilization.

The optical system consists of a Fastie-Ebert grating monochromator followed by a sample cell and detector. It was necessary to use a dispersive system, rather than a smaller filter system, since there were no filters suitable for this spectral region. Wherever possible, reflecting rather than transmitting elements have been used to permit better transmission of ultraviolet energy through the system.

The energy from the lamp passes through the high performance grating monochromator, which disperses the output energy and places the selected wavelengths at the proper slits and allows chopping by the torsional chopper.

The ultraviolet lamp is a special xenon-filled arc lamp developed by Perkin-Elmer. This development is discussed in Section III. The xenon (Xe) pressure is chosen to give an output for wavelengths as long as 2000A and a sharp peak at 1470Å (sample wavelength). By aligning the optics so that this sharp peak is centered on the sample slit, it can be determined that the selected wavelengths are emerging from both slits, since the separation of the slits and the dispersion of the monochromator are known.

The spectral absorption characteristics of oxygen and water vapor in the vacuum ultraviolet portion of the spectrum (figure 4) show that the maximum absorption of oxygen is near 1470Å and the maximum ratio of water vapor to oxygen is near 1750Å. With the concentrations encountered in the Two Gas Atmosphere Sensor, the 1470Å signal is almost entirely a result of the O_2 absorption.

In the 1750Å region, the oxygen absorbance is made identical to that at 1470Å by the proper selection of the sample cell path length.

By dividing the 1750Å signal, made up of the combined O_2 and H_2O, by that of 1470Å, which is only the O_2, a stabilized H_2O signal can be obtained. This technique requires great stability of the spectral content at the slits and is discussed in Section VB.

The chopped monochromatic energy passes through the special ultraviolet sample cell. This sample cell uses sapphire windows of selected ultraviolet purity to contain the sample gas. The special design of the sample cell slits and the chopping blade of the torsional chopper allows the detector to observe first a 1470Å signal that passes through the gas in the sample cell and next a 1470Å signal that passes through a non-absorptive portion of the sample cell. Thus, two signals of 1470Å wavelengths are alternately received by the detector. The signal passing through the non-absorptive portion of the cell, which would be unattenuated by the gas, is used as the reference wavelength for the automatic gain control system. The 1470Å and the 1750Å signals that pass through the gas in the sample cell are the oxygen and the combined oxygen and water vapor signals, respectively. By utilizing the same wavelength, that is, 1470Å for both the gas signal and the reference signal, a system is obtained with maximum stabilization of the oxygen signal.

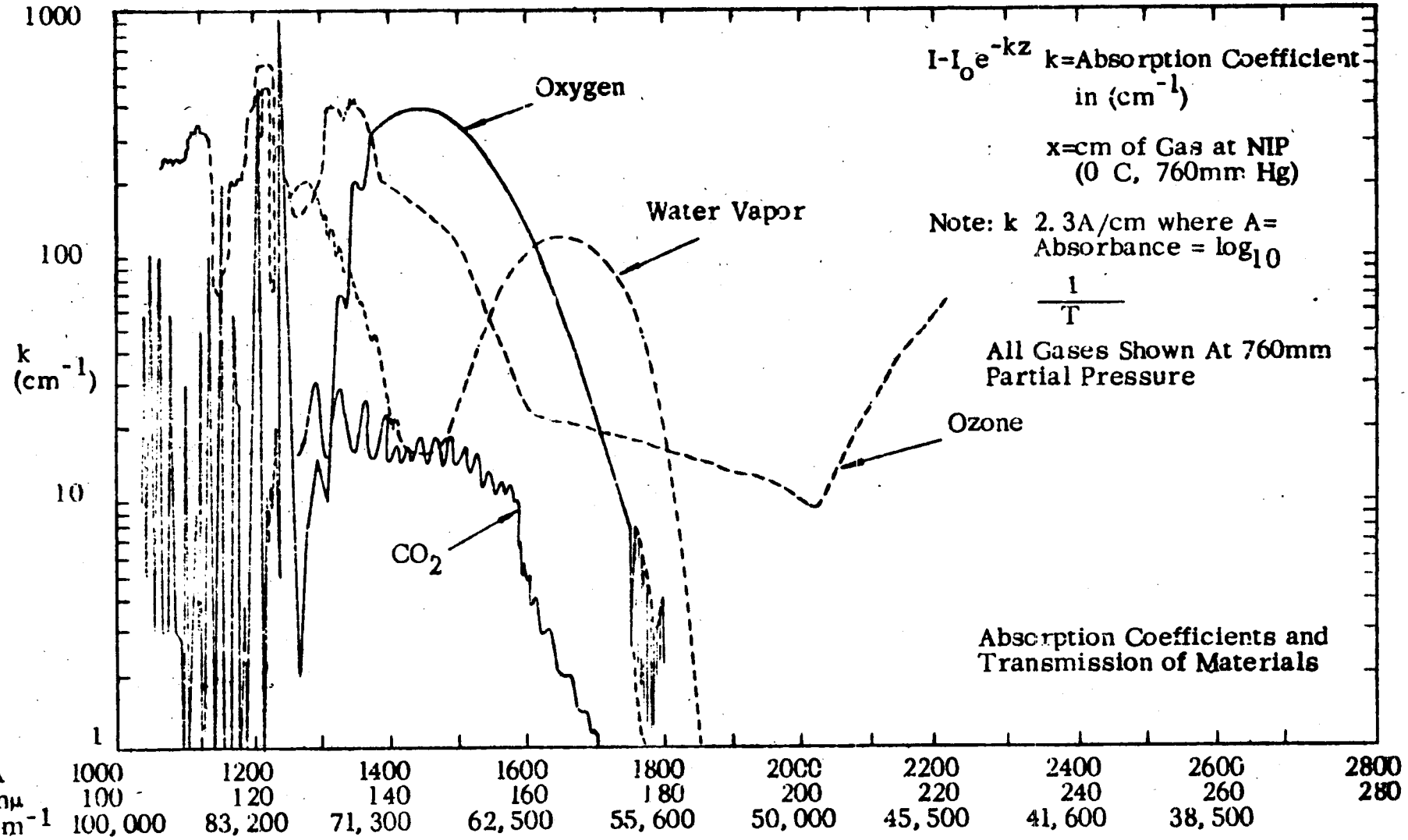


Figure 4. Relative Absorption of Gas Constituents

Test data obtained from the first units has shown that the non-absorptive reference cell approach has led to appreciable long-term drifts, due to the formation of an absorptive film on the sample cell. This allows a differential signal to be formed between the sample and reference paths that cannot be compensated by the signal processing system. The solution to this problem, which is discussed in Sections V and VI, is to expose the reference cell to the sample atmosphere.

The UV channel output (the signal obtained by the UV detector) consists of four different levels of information. The first is the reference signal obtained from the 1470Å signal passing through a non-absorptive sample cell. The second is the 1470Å signal passing through the gaseous sample cell. The third is a zero reference signal obtained by blanking the optical signal. Fourth and final is the 1750Å signal which passes through the gaseous sample cell. This sequence of signals is repeated each cycle. The four levels of signals are obtained at four discrete steps in the position of the chopper blade, which is driven by a torquer motor.

The torquer motor is a low power, wide band device with flexure bearings. It is described in detail in the study report and in Section IIIG. Perkin-Elmer has had good results in using torquer motors of this type on a TIROS radiometer program, NASA Contract No. 5-3894.

The torsional chopper has the advantage that it can be made to dwell at a particular location in space, allowing the maximum amount of information to be transmitted to the detector. Additionally, being a wide band device very similar to a dc meter movement, it can respond to square wave inputs and can be programmed to stop at particular images in space. It should be noted that the torsional chopper does not require lubrication and that, during operation, its flexure bearings would be stressed at angular rotations much below rating to ensure long life.

Because of the dwell time provided by the torsional chopper, a sampling method of detection of the signal information can be used. This is a decided advantage since minor variations in the chopping geometry of the signal can be effectively blanked out in the signal processing channel.

The photomultiplier used with this system is a multistage solar-blind multiplier phototube with a transparent cesium telluride photocathode and sapphire window. This device was selected due to its high performance and ruggedized configuration, which makes it compatible with future space flight model designs. The multiplier features the venetian blind construction consisting of successive fused kovar and 7052 glass rings. The dynode divider resistors are welded in place to the kovar rings and the entire unit is encapsulated for maximum structural strength.

The electrical output from the photomultiplier tube is amplified by a low noise preamplifier. The output of the amplifier supplies the AGC (automatic gain control) device, which will basically be a diode biased to

vary its dynamic impedance and compensate for changes in the reference channel. This signal is provided to a variable gain amplifier and to a dc restorer with the first of the timing pulses applied for demodulation.

The electronic system consists essentially of two AGC loops each of which provides an analog ratio computation; that is, the circuit automatically and continuously divides the combined oxygen and reference signal by the reference signal to provide a stabilized oxygen signal. The second AGC loop works in a similar manner. In this latter case the water vapor, oxygen, and reference signal is divided by the oxygen and reference signal to yield a stabilized water vapor signal. The synchronous demodulation timing pulses are shorter in duration than the position of the torquer angular position. In this way the leading edge of the signal pulse, which may contain a transient, is blanked out from the signal processing information.

The stabilized electrical outputs from the oxygen water vapor and CO_2 channels are combined in an analog summing circuit with the signal from the total pressure transducer. The output of this circuit is then related to the partial pressure of the diluent gas. Each of the four outputs provided by the system has redundant outputs that are electrically independent of each other. That is, either output could be shorted to ground without affecting the level of the other.

The AGC loop for the principal closed loop, that is, the stabilizing circuit for the oxygen, uses the high voltage power supply of the photomultiplier as the control element of this loop. This is a common practice with instruments of this type and provides a maximum dynamic range of an AGC or gain control system. It also reduces the specific regulation requirements of the high voltage power supply. Each of the major loops has a circuit to change the normal Beer's Law response of an optical absorption sensor to a linear output. This is necessary in order to compare and provide easy scale expansion to the outputs.

The CO_2 monitoring subsystem is basically a very simple infrared lens-filter system. The design is based upon models developed under NASA Contract No. NAS9-1191 and NAS9-2255 by The Perkin-Elmer Corporation.

Basically, the system is a single beam, dual wavelength, filter radiometer with ratio readout. The dual filter, is mounted opposite the shutter openings of the O_2-H_2O monitor subsystem. The filters are located at a point in the optical system where a small image of the source is formed in space. As the chopper moves the dual filter back and forth across the light beam and a light baffling mask, energy is interrupted at the sample and reference wavelengths.

The infrared CO_2 sensor channel begins with a dual filament incandescent tungsten lamp, which provides sufficient 4 micron energy per watt of input power. This lamp is driven from a converter, which is common to all the electronic circuits. Normal operation of this lamp would be 4 to 5 volts at 40 to 50 mA dc. The lamp, normally rated at 60,000 hours, would be operated at a lower voltage for extended life.

The energy from the lamp is collimated by a silicon lens system through a sample path which contains the gas to be measured. After passing through the sample cell, the energy is brought to a focus on the IR chopper blade. At this end of the chopper are mounted the two thin film interference filters. The filters are referred to as optical spike filters because of their transmission characteristic. The 4 micron (or reference) filter transmits only the reference information for the CO_2 channel. The 4.27 micron interference filter transmits only that energy which is to be absorbed by the CO_2 band. These spike filters are spectrally narrow to prevent any interaction between them. As the torsional chopper moves the filters back and forth through the focal point of the beam, the optical energy is converted to an ac waveform and this information is focused onto the infrared detector.

The detector is a thermistor bolometer with a self-compensating element and a sapphire window.

The CO_2 sensor channel uses a discrete semiconductor as the AGC device. A stabilized signal is then passed through an analog amplifier and to a dc restorer where the synchronized detection or sampling method takes place. Timing pulses provide the 4 micron reference information for the AGC loop. The output of the low frequency amplifier is applied to a linearizer circuit, similar to that used on the UV channels to allow the logarithmic output to be made linear, which is considered most useful for the analog output operations that may be required. All of the electronic input required for the CO_2 sensor channel is supplied from the common converter circuit.

In summary, the entire electronic system consists of 3 stabilized AGC loops combined with a total-pressure transducer. All 3 stabilized loops operate in a similar manner to provide long term system stability.

All of the electronics are mounted in cordwood type, welded modules, designed to be suitably encapsulated for long life, lightweight, and stable operation under varying environmental conditions.

The optical compartment is backfilled with nitrogen. During alignment and initial adjustments, the optical compartment is flushed with the nitrogen flow to prevent optical absorption of oxygen or CO_2 in either channel.

After alignment and the proper performance have been demonstrated, the system is sealed, evacuated, and backfilled with the inert gas. After the final seal, the system is ready for continuous operation. The electronic compartment is hermetically sealed from the optical compartment and is sealed from the outside environment to protect it from salt spray, sand, and dust.

Adjustments and calibrations of the system are made from the electronic side of the sensor and consist of potentiometer adjustments prior to final calibration and acceptance tests. The total pressure transducer and the electronic system are packaged in an integral housing. The total package design goals were a volume of approximately 120 in^3, weight less

than 5 pounds and input power less than 5 watts. A development fixture made during the Phase IIa program, figure 5, shows the final configuration of the instrument. Figure 6 shows the internal layout with the environmental cover removed. The electronic system, packaged in nine welded modules, is supported by a hermetic cover containing the IR, UV, and P_T components.

The system design goals were to directly measure the partial pressure of O_2, CO_2, and H_2O with accuracies of 2 percent, 2 percent, and 5 percent, respectively.

The system was also to measure P_T with an accuracy of 1 percent and compute the partial pressure of N_2 or H_2 from these measurements to an accuracy of 5 percent. The optical absorption metrology used in this system was, as a goal, to have the following characteristics:

1. Long Operation and Shelf Life - The system has no wearout or consumable components.

2. Insensitive to Magnetic Fields, Ambient Temperature, or Gravity. (There is a magnetic field problem which is discussed in Sections V and VI.)

3. Operation at Ambient Pressure - The system requires no auxiliary gas pumping or vacuum system and was designed to be unaffected by vacuum exposure. However, some misalignments are evident when the instrument, in its present configuration, is subjected to changes in ambient pressure, as detailed in Section V.

4. No lubrication is required.

5. No specific operation use attitude was to be necessary.

6. Fast Response Time - System will have a response time constant of 10 seconds.

7. Flight qualification design compatibility was to be achieved.

8. No Gas Consumption - Sensor was designed to require no reference gas, for calibration purposes, nor does the system consume any of the sample gas.

9. Automatic Gain Stabilization - Long term electronic stability.

10. Low Sample Flow Rates With Minimum Pressure Drops - Continuous monitoring and readout.

The system is designed to utilize linear integrated circuits to reduce bulk and enhance reliability.

B. ELECTRONIC SYSTEM DETAIL

A complete understanding of system operation (figure 7) must include the detail logic and functional electronic circuit design information.



Figure 5. Development Fixture - Phase IIa

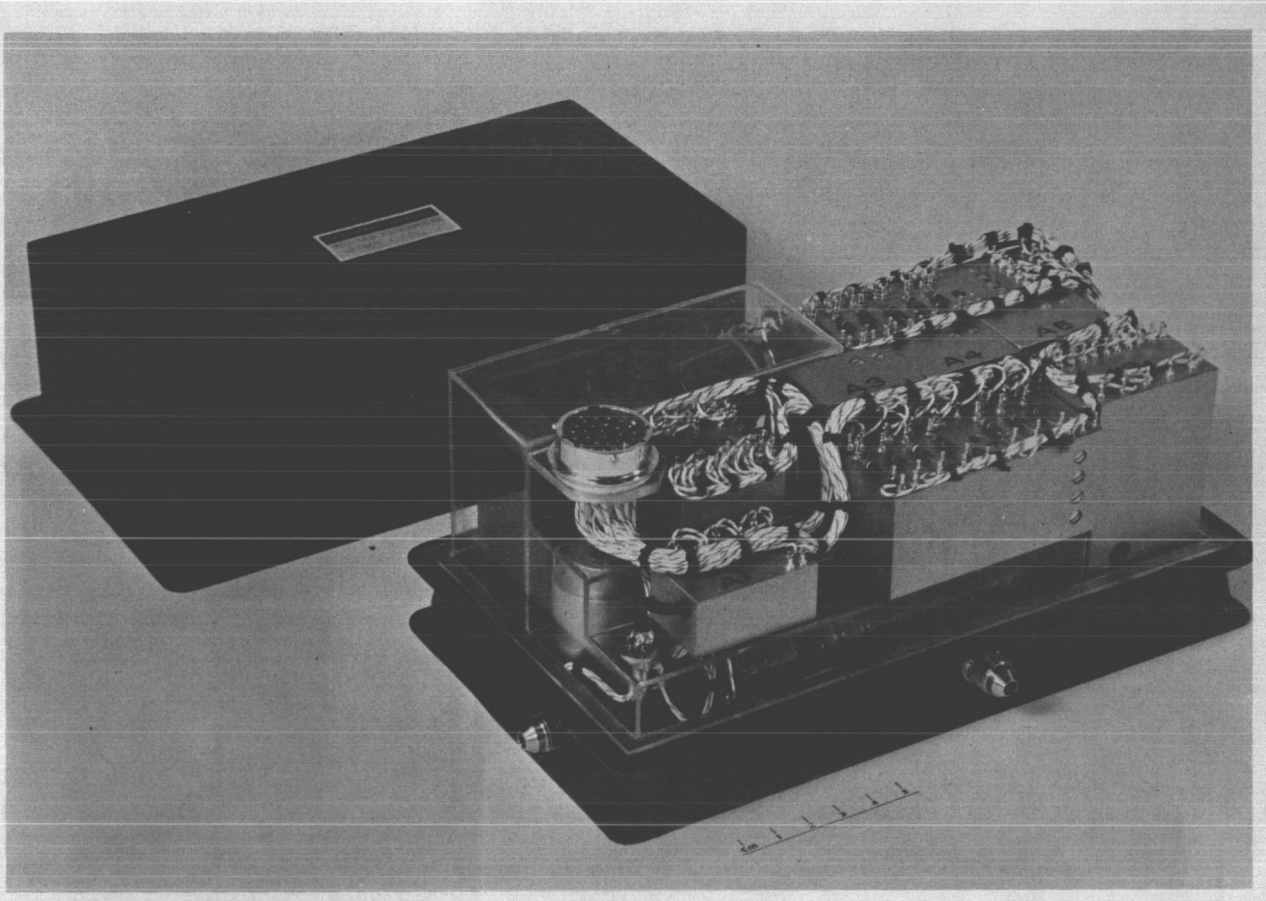


Figure 6. Development Fixture, Phase IIa - Cover Removed

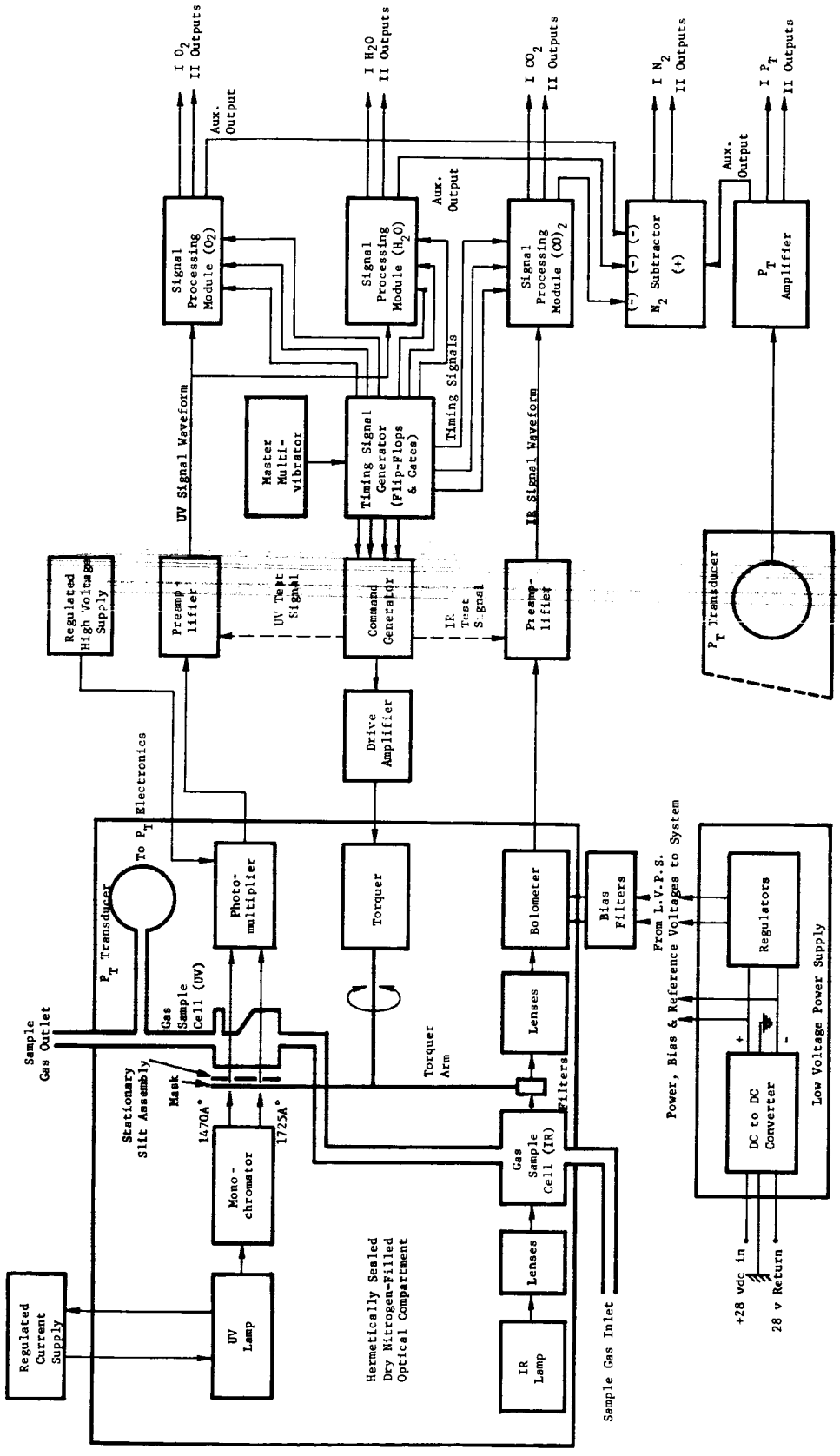


Figure 7. Two Gas Sensor Block Diagram

This section provides that detailed explanation. The approach is to discuss the formation and utilization of the UV and IR waveforms and their time distribution. The derivation of the signal processing equations is presented and the output voltage linearity technique is discussed. Detail information is given on the timing generator, torquer driver, supplies, and other support subsystems.

The motion of the torquer is a four step waveform as shown in (a), figure 8. The four rest positions of the torquer arm relative to the stationary UV slits and IR beam are shown in figure 9. It can be seen that the masks allow light to pass through only one slit at a time and only one IR filter.

During TS4, 1470Å light passes through the O_2 slit and the O_2 sample cell (0.004-inch path length), and strikes the photomultiplier. The 4.27 μ filter is in the IR beam during TS4.

During TS1, 1470Å light passes through the reference slit (zero sample gas path length) and strikes the photomultiplier. The 4.0 μ filter is in the IR beam.

During TS2, 1725Å light passes through the water slit, the water sample cell (0.100-inch path length), and onto the photomultiplier. The IR beam is blocked off.

During TS3, all the UV slits and the IR beam are blocked so there is no output from the photomultiplier and bolometer.

Thus it can be seen that the relationship of the fixed and moving slits and filters, shown in figure 9, determines the relationship between the torquer motion waveform, shown in (a), figure 8, and the UV and IR signal waveforms, shown in (b) and (c), figure 9.

The spikes on the UV and IR signal waveforms are caused by flashes of light through the reference slit and the 4.0 μ filter, respectively, as the torquer moves from the -2° to the +6° position.

The photomultiplier high voltage and the reference slit length (long dimension) are adjusted during alignment of the sensor to make the reference peak ((b), figure 8) approximately 300 mV above the black level. The lengths of the O_2 and water slits are adjusted so that the heights of the O_2 and water peaks of the UV signal waveform are equal (within ±5 percent) to that of the reference peak when the sample cell is filled with dry nitrogen.

The wavelength of the light passing through the water slit is adjusted by adjusting the vertical position of the slit so that the change in the height of the water peak of the signal waveform is equal to the change in height of the O_2 peak when a dry oxygen-nitrogen mixture is passed through the UV sample cell.

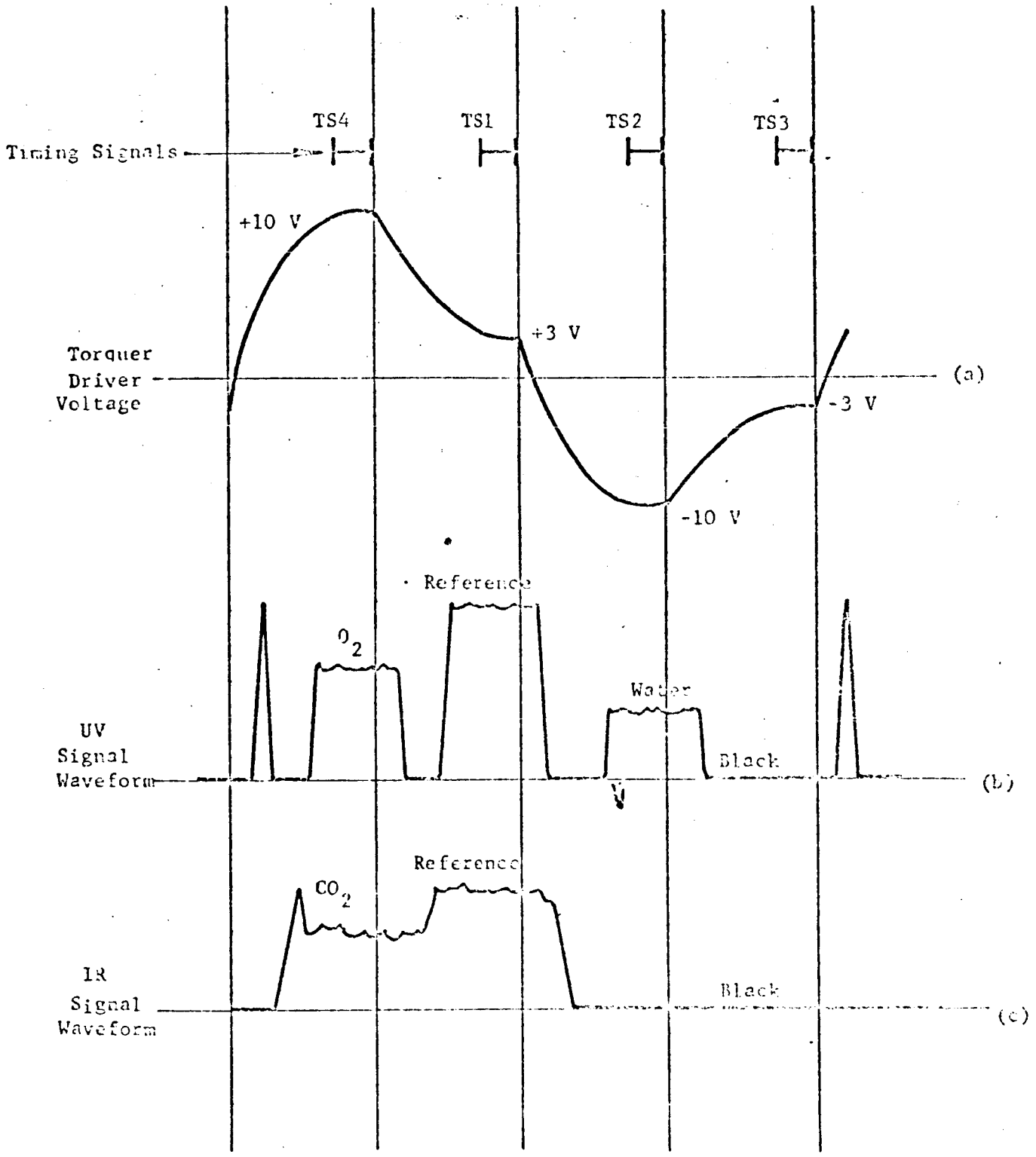
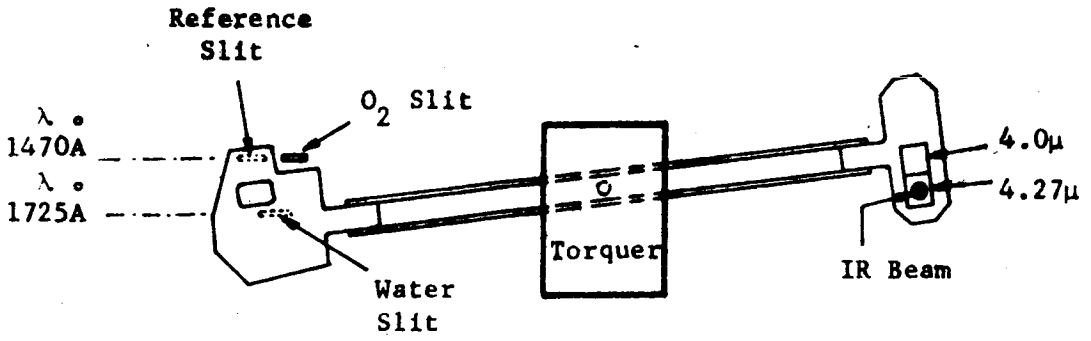
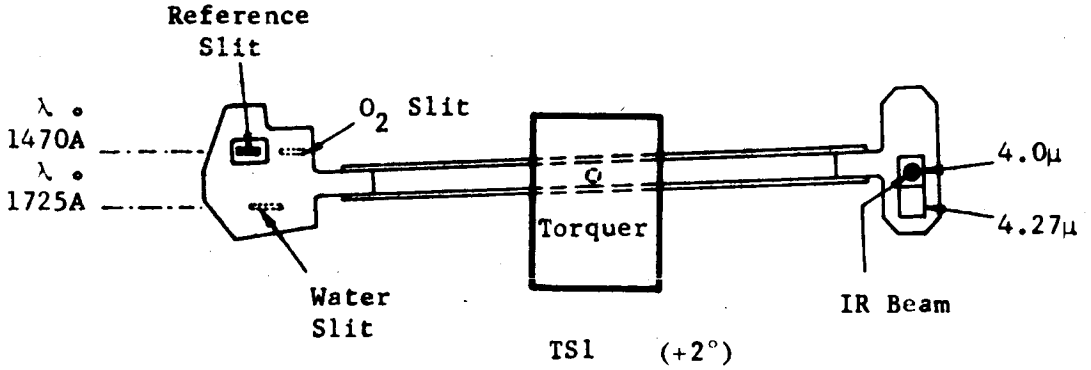


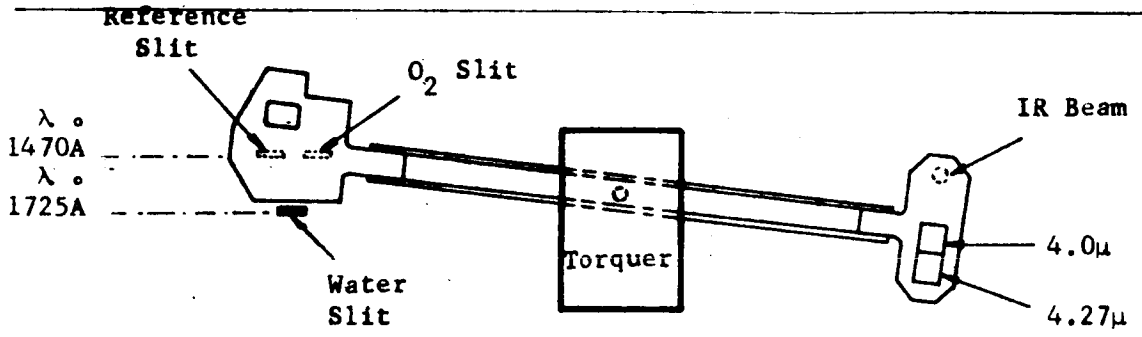
Figure 8. Two Gas Signal Waveforms



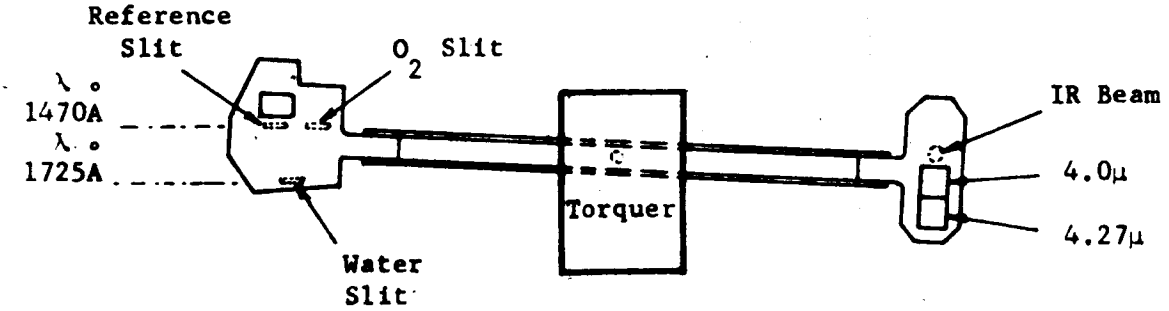
TS4 (+6°)



TS1 (+2°)



TS2 (-6°)



TS3 (-2°)

Figure 9. Torquer Positions

The fabrication of the IR filters is controlled so that the amounts of energy passing through the 4.0 and 4.27 μ filters are equal, and therefore the reference and CO_2 peaks of the IR signal waveforms are equal when nitrogen is in the IR sample cell. The heights of the reference and unabsorbed CO_2 peaks are adjusted to approximately 300 mv at the IR preamp output by changing the IR lamp voltage. A 5.5 v peak-to-peak lamp voltage is required, which in turn requires a value of 47 ohms for R8 module A9.

The signal waveform from the UV preamplifier, along with the three timing signals per module, is fed to the oxygen and water vapor signal processing modules, which produce dc output voltages linearly proportional to partial pressure over a specified range of partial pressures.

The IR signal waveform, along with three timing signals, goes to the CO_2 signal processing module.

1. Signal Processing

The signal processing is accomplished in five steps: demodulation (sampling), linearization, temperature multiplication, amplification, and offset.

The demodulation is accomplished by a synchronously operated dc restorer and a "sample and hold" gate, as shown in figure 10. Linearization is accomplished by the linearizer, variable attenuator, and the synchronously operated AGC circuit.

This process will be explained in detail using the oxygen module as an example.

The dc restorer is operated during TS1 to clamp the reference peak to zero volts. The sample and hold gate operates during TS4, producing a negative dc voltage e_2 at its output as shown in (a), figure 11. The AGC integrator operates during the black level (TS3), increasing or decreasing the gain of the variable attenuator until the black level is clamped to $-V_x$, the voltage at the output of the linearizer. The linearizer is a simple resistive voltage divider whose output V_x, is $V_x = K_L e_2 + (1-K) V_{REF}$.

The result of the derivation is:

$$e_2 = - \frac{I(REF) - I(O_2)}{I(REF) + G\, I(O_2)} \left| V_{REF} \right| \text{where } G = \frac{K_L}{1-K_L} = \frac{100K}{R_{LIN}} \qquad (1)$$

or

$$e_2 = - \frac{1 - \frac{I_o}{I(REF)} e^{-\alpha \ell C_{O_2}}}{1 + G \frac{I_o}{I(REF)} e^{-\alpha \ell C_{O_2}}} \left| V_{REF} \right| \qquad (2)$$

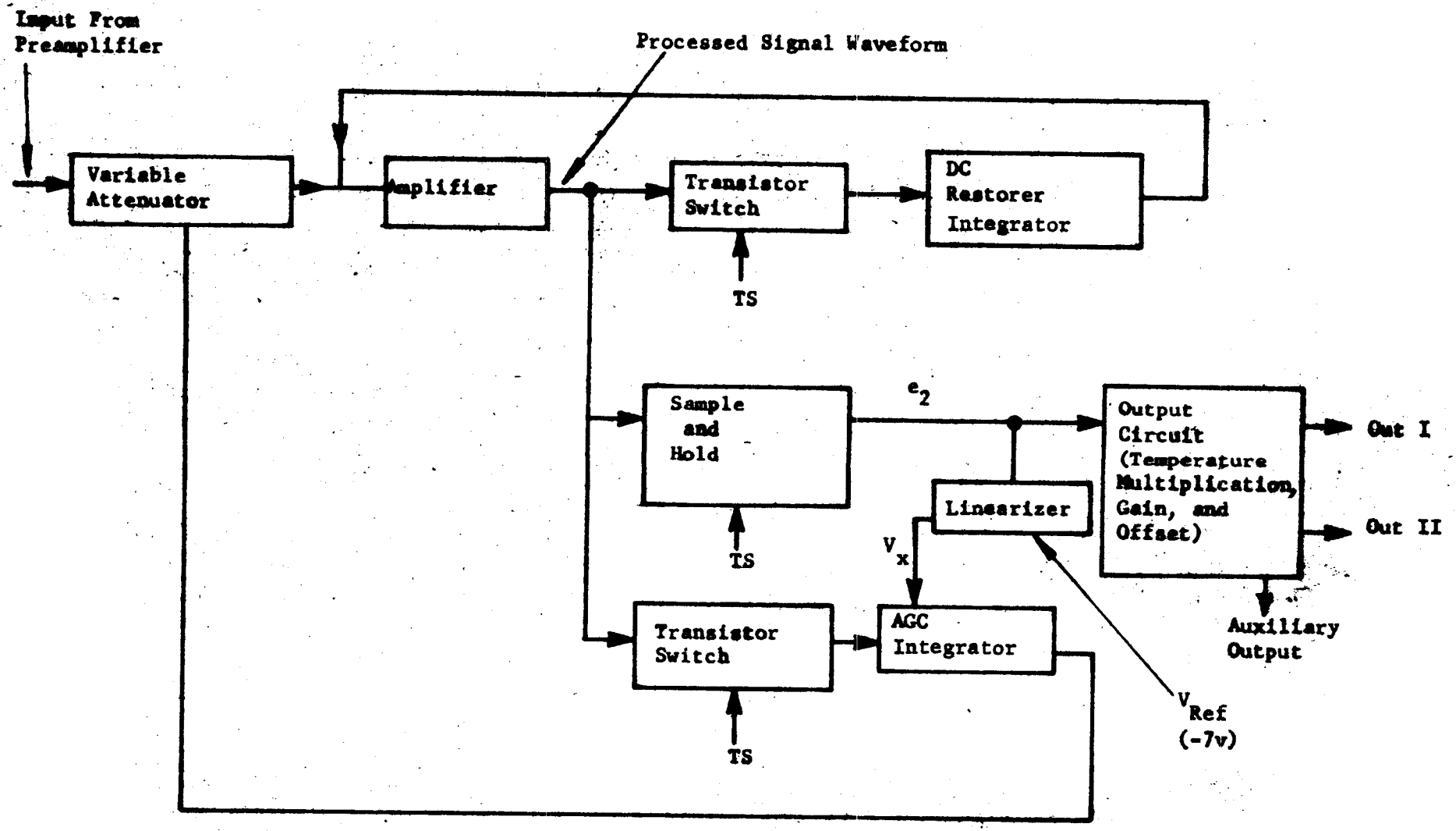
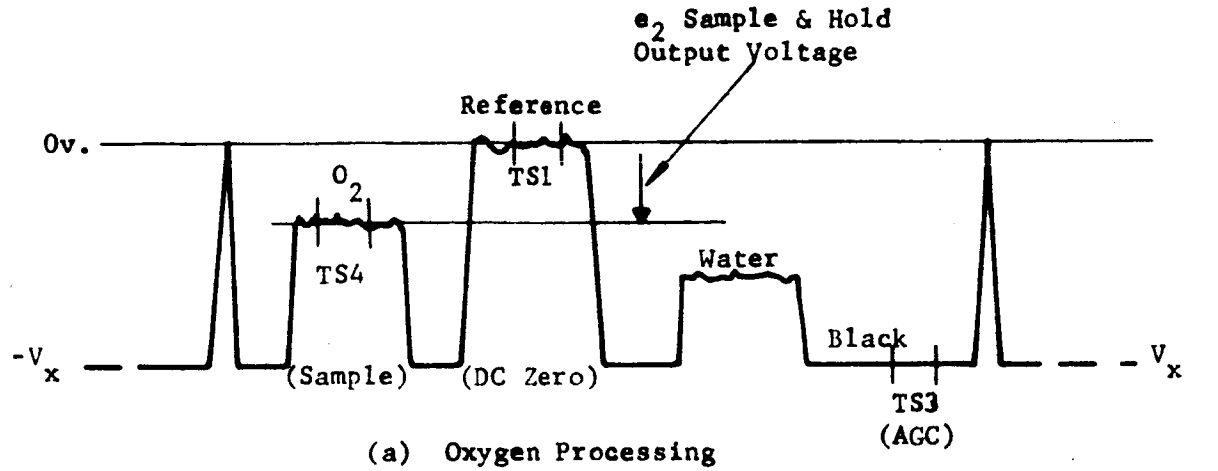
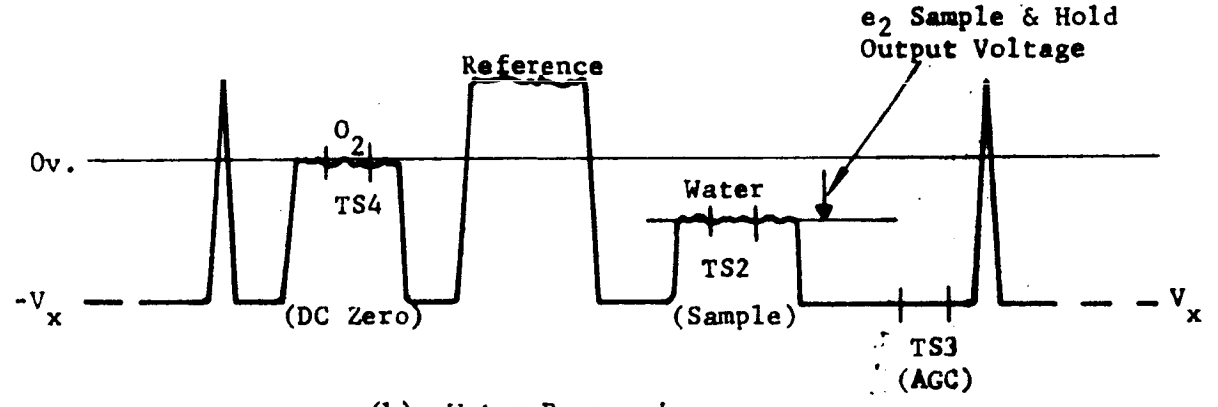


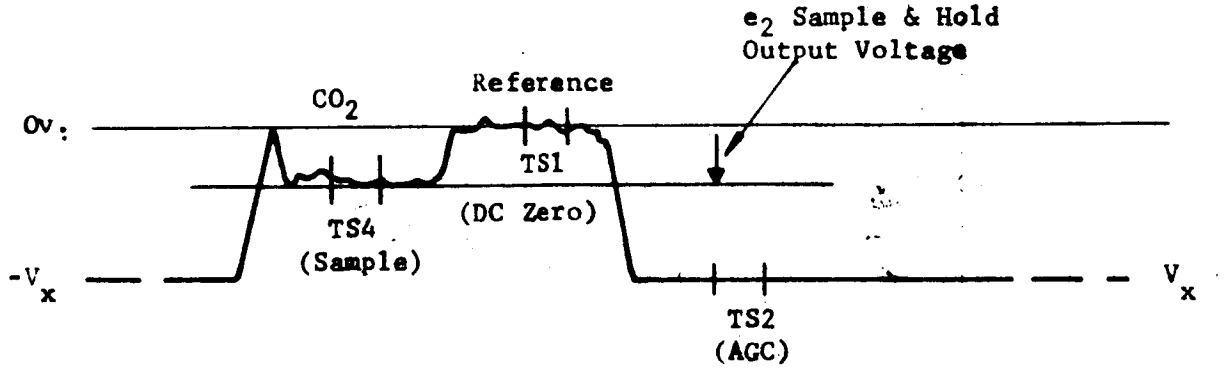
Figure 10. Signal Processing Module



(a) Oxygen Processing



(b) Water Processing



(c) CO_2 Processing

Figure 11. Processed Signal Waveforms

Since the sensor is adjusted so that $I_o = I(REF)$

$$e_2 = - \frac{1 - e^{-\alpha \ell C_{O_2}}}{1 + Ge^{-\alpha \ell C_{O_2}}} \left| V_{REF} \right| \tag{3}$$

Figure 12 is a plot of

$$e_2 = (1 + G) \frac{1 - e^{-A}}{1 + Ge^{-A}} \tag{4}$$

as a function for A for different values of G. The function is multiplied by (1 + G) to more nearly simulate the output of the sensor, as the slope of the function $\frac{1 - e^{-A}}{1 + Ge^{-A}}$ decreases as G is increased, and, therefore, the output gain of the sensor must be increased so that the range of output values remains the same for the given range of A values.

It can be seen from figure 12 that a value of G close to 2 gives the most nearly linear output. It was found experimentally that a G value of 1.6 gave the most linear oxygen output.

2. Output Circuit

The output of the sample and hold circuit is a voltage that is linearly proportional to oxygen molecule concentration in the sample cell. The relationship between concentration and partial pressure is $P_{O_2} = C_{O_2} T$ where T is absolute temperature. The output stage contains a thermistor, which modifies the output by a factor proportional to $\frac{T}{T_o}$ where T is the absolute temperature and T_o is the temperature at which the sensor was aligned. The output stage is a simple operational amplifier performing the following operation:

$$V_{OUT} = - K \frac{T}{T_o} e_2 + \left(1 + K \frac{T}{T_o}\right) V_{OFF} + \delta \tag{5}$$

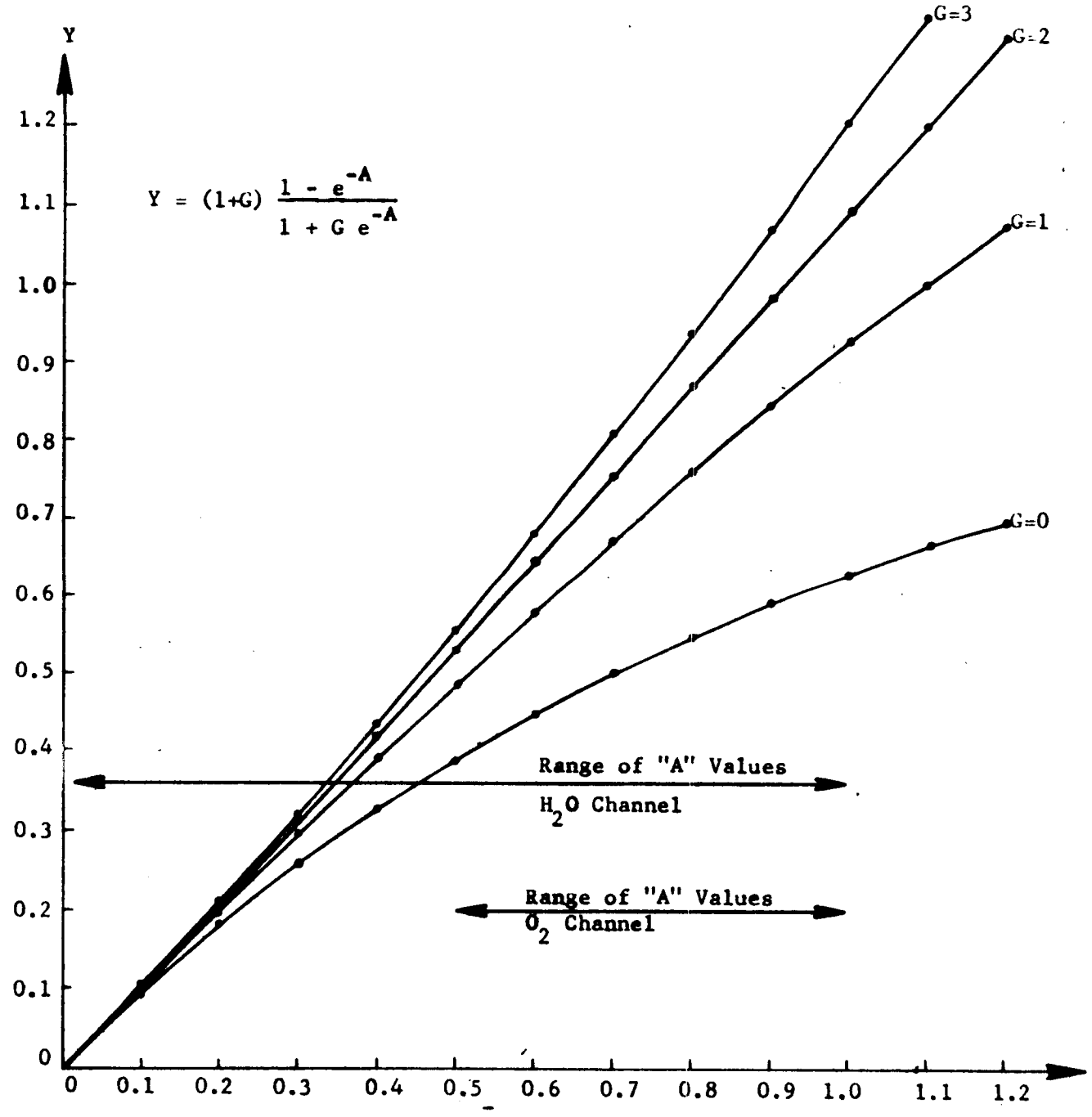


Figure 12. Output for Different Linearity Factors

where

K is the gain
T is the absolute temperature
T_o is the temperature at which the sensor was aligned
V_{OFF} is an adjustable offset voltage

δ is a fixed offset in the emitter followers.

Substituting Eq. (2) in Eq. (5) gives the complete equation for the operation of the signal processing module:

$$V_{OUT} = K \frac{T}{T_o} \frac{1 - \frac{I_o}{I(REF)} e^{-\alpha \ell C_{O_2}}}{1 + G \frac{I_o}{I(REF)} e^{-\alpha \ell C_{O_2}}} \left| V_{REF} \right| + \left(1 + K \frac{T}{T_o}\right) V_{OFF} + \delta \qquad (6)$$

The three adjustments available are

G - linearity adjust
K - output gain
V_{OFF} - output offset (positive or negative)

Since, for the proper choice of G, the output of the sample and hold circuit, e_2, can be made very nearly linear in C_{O_2}, Eq. (6) can be simplified to

$$V_{OUT} = K \frac{T}{T_o} \beta C_{O_2} + \left(1 + K \frac{T}{T_o}\right) V_{OFF} + \delta \qquad (7)$$

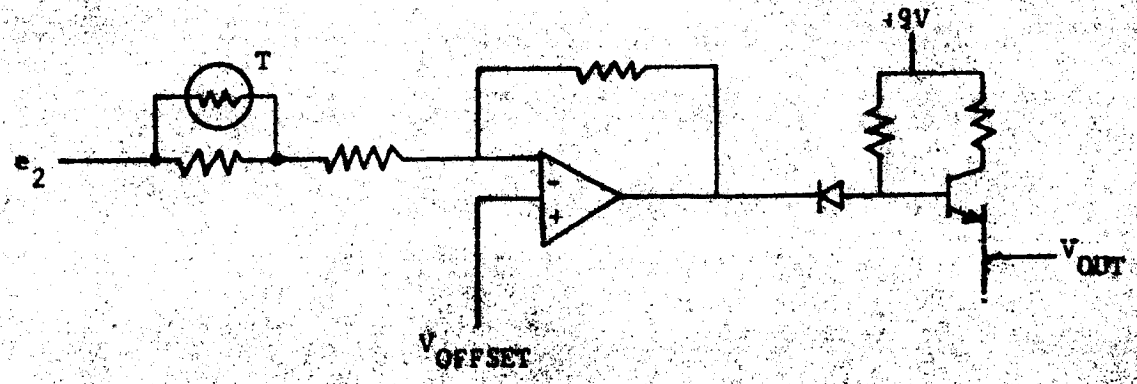
which, since $TC_{O_2} = P_{O_2}$, can be further simplified to

$$V_{OUT} = K' P_{O_2} + V'_{OFF} \qquad (8)$$

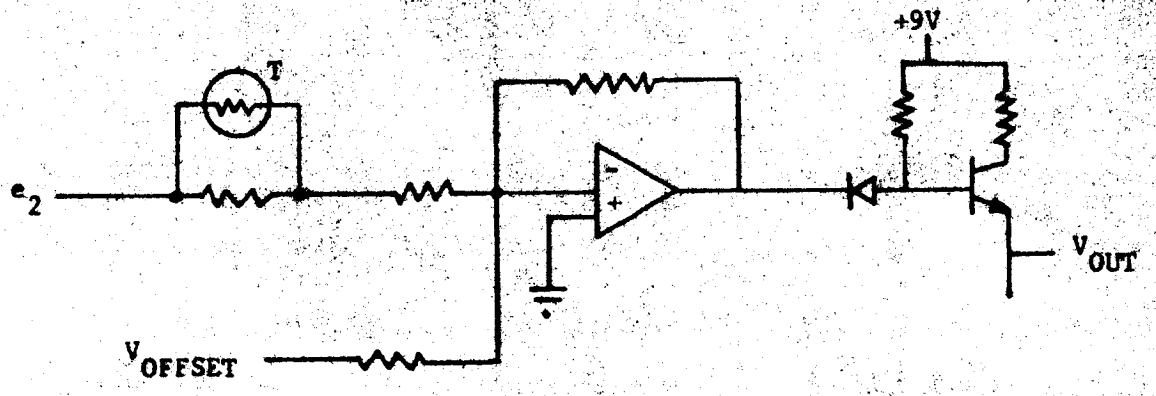
where K' and V'_{OFF} are both adjustable to give the desired output span and zero.

There is an error in the design in that V'_{OFF} in Eq. (8) is a function of temperature. This means that the zero will shift with temperature. The error can be corrected by a relatively simple change in the configuration of the output circuit as shown in figure 13.

As stated earlier, the oxygen channel uses a linearity factor of G=1.6. The range of A values is 0.5 to 1.0. (Values less than 0.5 produce



(a) Present Output Circuit



(b) Revised Output Circuit

Figure 13. Output Circuit

a negative output voltage because of the offset zero, and values greater than 1.0 produce an off-scale output.)

It was possible to balance I_o and I(REF) to within ± 2 percent. Values of I_o between 0.95 I(REF) and 1.05 I(REF) shift the e_2 zero in figure 12 up or down by plus or minus 0.05 and cause a negligible change in the slopes and curvatures of the curves.

3. Water Signal Processing

The circuitry used to extract the water vapor partial pressure information from the UV signal waveform is identical to that used for the oxygen processing. The only differences are the sequence of the timing signals applied to the module, the linearity factor, and the output gain and offset.

As shown in figure 11, the dc restorer is operated during the oxygen signal peak, clamping it to zero volts. The sample hold gate is operated during the water signal peak, and the AGC integrator is operated during the black interval. The REF peak is ignored. By analogy to Eq. (1), the output of the sample gate is

$$e_2 = - \frac{I(O_2) - I(H_2O)}{I(O_2) + GI(H_2O)} \left| V_{REF} \right| \tag{9}$$

This may be rearranged and expanded to give

$$e_2 = - \frac{1 - \dfrac{I_{o\ 1725} \exp\left(-\alpha_{O_2\ 1725}\, \ell_2\, C_{O_2}\right) \exp\left(-\alpha_{H_2O\ 1725}\, \ell_2\, C_{H_2O}\right)}{I_{o\ 1470} \exp\left(-\alpha_{O_2\ 1470}\, \ell_1\, C_{O_2}\right)}}{1 + G \dfrac{I_{o\ 1725} \exp\left(-\alpha_{O_2\ 1725}\, \ell_2\, C_{O_2}\right) \exp\left(-\alpha_{H_2O\ 1725}\, \ell_2\, C_{H_2O}\right)}{I_{o\ 1470} \exp\left(-\alpha_{O_2\ 1470}\, \ell_1\, C_{O_2}\right)}} \left| V_{REF} \right| \tag{10}$$

The optics have been adjusted so that

$$I_{o\ 1725} = I_{o\ 1470} \tag{11a}$$

and

$$\alpha_{O_2\ 1725}\, \ell_2 = \alpha_{O_2}\, \ell_1 \tag{11b}$$

therefore Eq. (10) reduces to

$$e_2 = - \frac{1 - \exp\left(-\alpha_{H_2O}\ 1725\ \ell_2\ C_{H_2O}\right)}{1 + G \exp\left(-\alpha_{H_2O}\ 1725\ \ell_2\ C_{H_2O}\right)} \tag{12}$$

which, for the proper choice of G, becomes

$$e_2 = - \beta\ C_{H_2O} \tag{13}$$

The output becomes

$$V_{OUT} = K' P_{H_2O} + V'_{OFF} \tag{14}$$

K' and V'_{OFF} are adjustable for the required gain offset.

The range of A values is from 0 to 1.0 for the specified range of H_2O vapor partial pressures. The effect of a 5 percent change in $I_{o\ 1470}$ will be a 5 percent zero shift in e_2, with a negligible change in linearity. If the optics are not adjusted so that $\Delta I(H_2O) = \Delta I(O_2)$ for dry oxygen-nitrogen mixtures, there will be "cross talk" from the oxygen channel into the water channel output voltage.

The optimum value of G was not determined experimentally for the water channel because of difficulty in repeatably generating accurately known water vapor partial pressures. At present a value of G = 1.0 is being used.

4. CO_2 Processing

As shown in (c), figure 11, the CO_2 signal processing is very similar to the oxygen processing. The reference peak is clamped to zero volts, the black level is clamped to $- V_x$, and the sample-and-hold circuit operates during the CO_2 signal peak. The output circuit is identical to the oxygen and water processing with the exception of the K and V_{OFF} values.

The sample and hold output is

$$e_2 = - \frac{1 - \dfrac{I(CO_2)}{I(REF)}}{1 + G \dfrac{I(CO_2)}{I(REF)}} \tag{15}$$

and the output should be

$$V_{OUT} = K'P_{CO_2} + V'_{OFF} \tag{16}$$

Although values of G as large as 20 were tried, it was impossible to linearize the CO_2 output because absorption is not exponential with CO_2 concentration. For a fixed optical system design, fixed optical filter bandwidth, and at constant total pressure CO_2, the absorption is approximately

$$I(CO_2) = I_o\ 4.27\left(1 - C_1\ P_{CO_2}\right) \tag{17}$$

where C_1 is a function of P_T and the optical design.

For a 0 to 20 mm range of CO_2 partial pressures at 7.0 psia total pressure, $I(CO_2)$ ranges from I(REF) to 0.4 I(REF).

The CO_2 output voltage is as shown in figure 14.

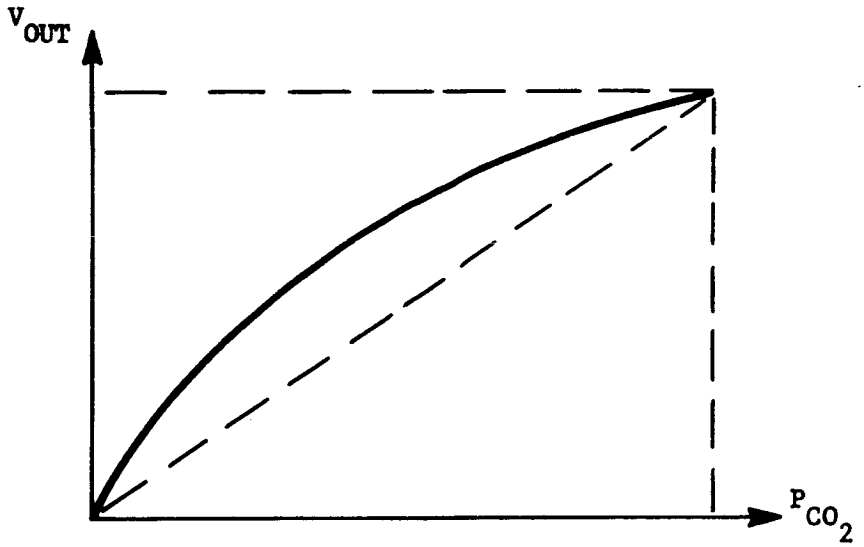


Figure 14. CO_2 Output Voltage

This is for a linearization constant of 2.1, which is a compromise between better linearity and increased output noise. Span and zero stability are good, and output noise is 60 mV peak-to-peak.

5. P_T Circuit

The total pressure circuit uses a diaphragm-rheostat-type absolute pressure transducer in the feedback loop of an operational amplifier. The circuit and equations describing its operation are shown in figure 15.

In the last equation, R_1 has the primary affect on the output voltage span, and V_{OFF} has the primary affect on the output zero. However, the adjustments do interact, and they must be made alternately until the desired results are achieved.

In operation the circuit has a hysteresis of 1 percent of the full scale output voltage, because the transducer is used over only one-third of its full scale range.

6. Diluent Subtractor

The diluent subtractor is an operational amplifier circuit that subtracts the properly weighted oxygen, carbon dioxide, and water vapor output voltages from the weighted total pressure output voltage. The circuit is shown in figure 16.

The circuit is calibrated by adjusting R_1, R_2, and R_3, to give the correct change in V_{OUT} for a given change in each of the three input voltages. Next R_a is adjusted for the correct change in V_{OUT} for a given combination of the four input voltages. When performed in this order, the adjustments are independent and very easily accomplished.

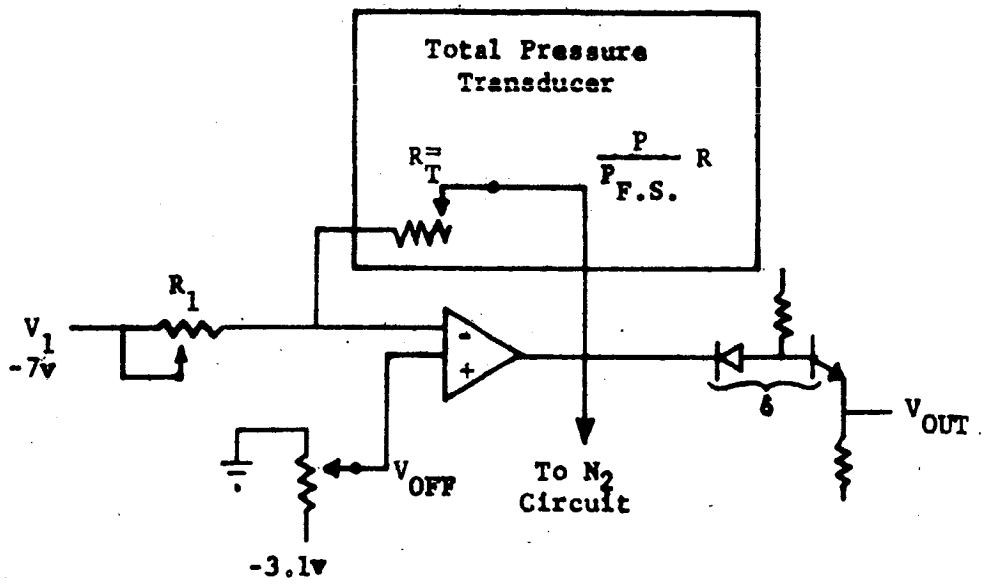
7. Timing Signal Generator

The timing signal generator consists of an astable master multivibrator, two divide-by-four counters, and a system of inverters and nor gates.

The first divide-by-four counter produces two waveforms at one-fourth of the master multivibrator frequency as shown in figure 17; one is symmetrical and one has a duty cycle of one fourth.

The symmetrical waveform is fed to the second divide-by-four counter, which produces the four sequential pulses C, D, E, and F as shown in figure 17. These four waveforms are gated with the asymmetrical waveform from the first divider to produce the timing signals TS4, TS1, TS2, TS3 that occur during the last quarter of waveforms C, D, E, and F, respectively.

The timing signals are used to turn on the appropriate functions in the signal processing modules after the torquer arm has stopped and the peaks of the signal waveforms have reached their full values.



$$V_{OUT} = -\frac{R_T}{R_1} V_1 + \left(1 + \frac{R_T}{R_1}\right) V_{OFF} + \delta$$

$$= \frac{R_T}{R_1}\left(V_{OFF} - V_1\right) + V_{OFF} + \delta$$

$$V_{OUT} = \frac{P}{P_{F.S.}} \frac{R}{R_1} \left(V_{OFF} - V_1\right) + V_{OFF} + \delta$$

$$V_{OUT} = \frac{P}{15} \frac{10K\Omega}{R_1} \left(7 - \left|V_{OFF}\right|\right) - \left|V_{OFF}\right| + \delta$$

Figure 15. Total Pressure Circuit

8. Torquer Command Generator

The torquer command generator consists of four saturating transistor switches driven by waveforms C, D, E, and F and four adjustable resistors connected to the outputs of the switches. The output of each switch is either plus or minus 7 volts when its input is high, and zero volts when the input is low. The adjustable resistors R_1 through R_4 generate a four step waveform of positive and negative currents that is amplified to drive the torquer.

9. Torquer Driver

The torquer driver is a power amplifier with current and dv/dt feedback.

The steady-state angular displacement of the torquer arm is proportional to the current through the torquer, which, in turn, is proportional to the command current I_n. This is shown by the following equations:

$\theta = K_\theta I_t$ where K_θ is the angular displacement per ma, and the electrical parameters are defined in figure 17.

$$\text{Since } I_n = -I_f = -\frac{E_s}{R_f} = -\frac{I_T R_s}{R_f}$$

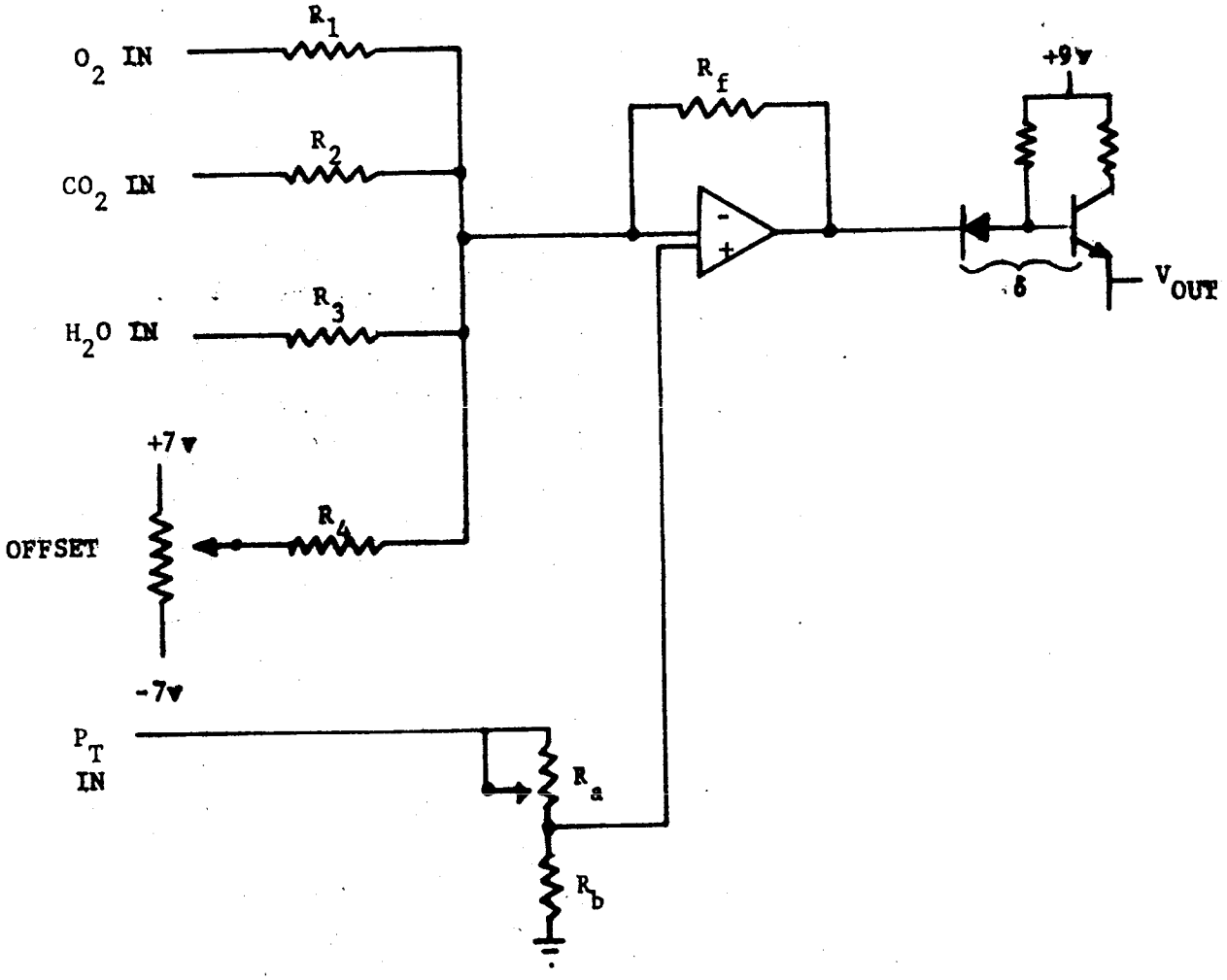
$$\theta = -K_\theta \frac{R_f}{R_s} I_n$$

or

$$\theta = -K_\theta \frac{R_f}{R_s} \frac{V_n}{R_n}$$

where V_n is plus or minus seven volts and the R_n's are adjustable. The feedback capacitor C limits the dv/dt and dI/dt through the torquer to values that will not shock the torquer arm-torsional spring combination into mechanical oscillation. It takes 15 milliseconds to move the torquer arm from one position to the next position. The arm then remains stationary for 5 milliseconds, during which time one of the timing signals is "on".

The timing signal generator-torquer combination has been very reliable and easily adjusted. The torquer angles can be adjusted by watching the UV signal waveform (figure 8) on an oscilloscope and adjusting each of the four variable resistors in succession until the tops of the three signal peaks are flat, with no dips or extraneous pips, and there are no pips during the black interval.



$$V_{OUT} = -R_f\left(\frac{V_{O_2}}{R_1} + \frac{V_{CO_2}}{R_2} + \frac{V_{H_2O}}{R_3} + \frac{V_{OFF}}{R_4}\right) + \left(1 + \frac{R_f}{R}\right)\left(\frac{R_b}{R_a + R_b}\right) V_{P_T}$$

Figure 16. Diluent Subtractor Circuit

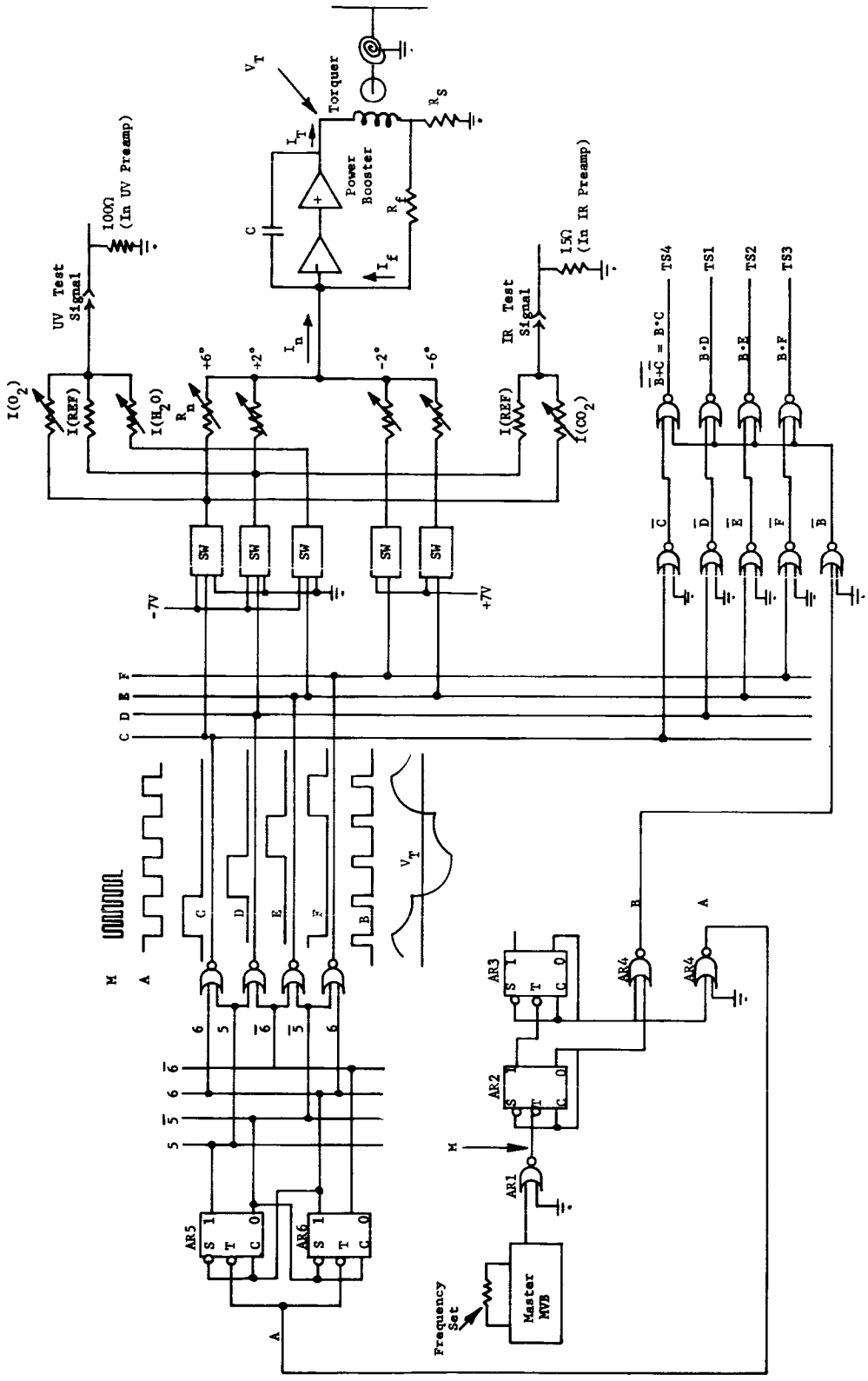


Figure 17. Timing Signal Generator and Torquer Driver Circuits

10. Test Signal Generator

There are two more sets of adjustable resistors connected to the outputs of the saturating switches in the torquer command generator. They are used to generate millivolt-level signals, which are applied to the UV and IR preamplifier inputs to simulate the optical signal waveforms. They can be used to check the operation of the electronics by turning off the UV and/or IR lamps, connecting the test signals to the preamplifiers, and checking the signal processing output voltages for a preset value.

11. UV Lamp Power Supply

The operation of the UV lamp power supply is such that the lamp current is maintained at a fixed value, and the lamp is allowed to set its own operating voltage. This is accomplished by the use of interacting current and voltage regulator loops. See figure 18. The current regulator loop operates by increasing or decreasing the drive to the current sink depending on whether the voltage across the current sensing resistor decreases or increases relative to the reference voltage. The impedance of the current sink is about 300 KΩ, while the sum of the other impedances in the lamp current loop is less than 30 KΩ. This means that high voltage power supply ripple and instantaneous variations in the operating voltage of the lamp are absorbed by the current sink instead of causing fluctuations in loop current.

The voltage regulator loop adjusts the high voltage power supply output to keep the dc voltage across the current sink constant. An amplifier converts the difference between the current sink voltage drop and a fixed multiple (RI/R2) of the reference voltage into a control current. If a disturbance increases the current sink voltage, the control current increases. This decreases the width of the pulses that drive the high voltage power supply, which in turn decreases the output voltage. This decrease returns the current sink voltage to its correct value. Both the voltage and current regulating amplifiers contain low-pass filters so that the loops do not respond to the power supply ripple frequency (approximately 9Kc).

The high voltage power supply consists of a saturating switch, a 10 to 1 step-up flyback transformer, and a rectifier and filter capacitor. The energy stored in the transformer core is proportional to the square of the time that the switching transistor is saturated. When the transistor is switched off the stored energy is delivered to the secondary circuit as a high voltage spike.

Since the energy per pulse is proportional to the square of saturation time, and since the energy drawn from the rectifier is linearly proportional to time (constant current), the output voltage will be proportional to saturation time.

When the supply is first turned on, the lamp loop current is zero and the current sink voltage is zero. Therefore the control current is zero

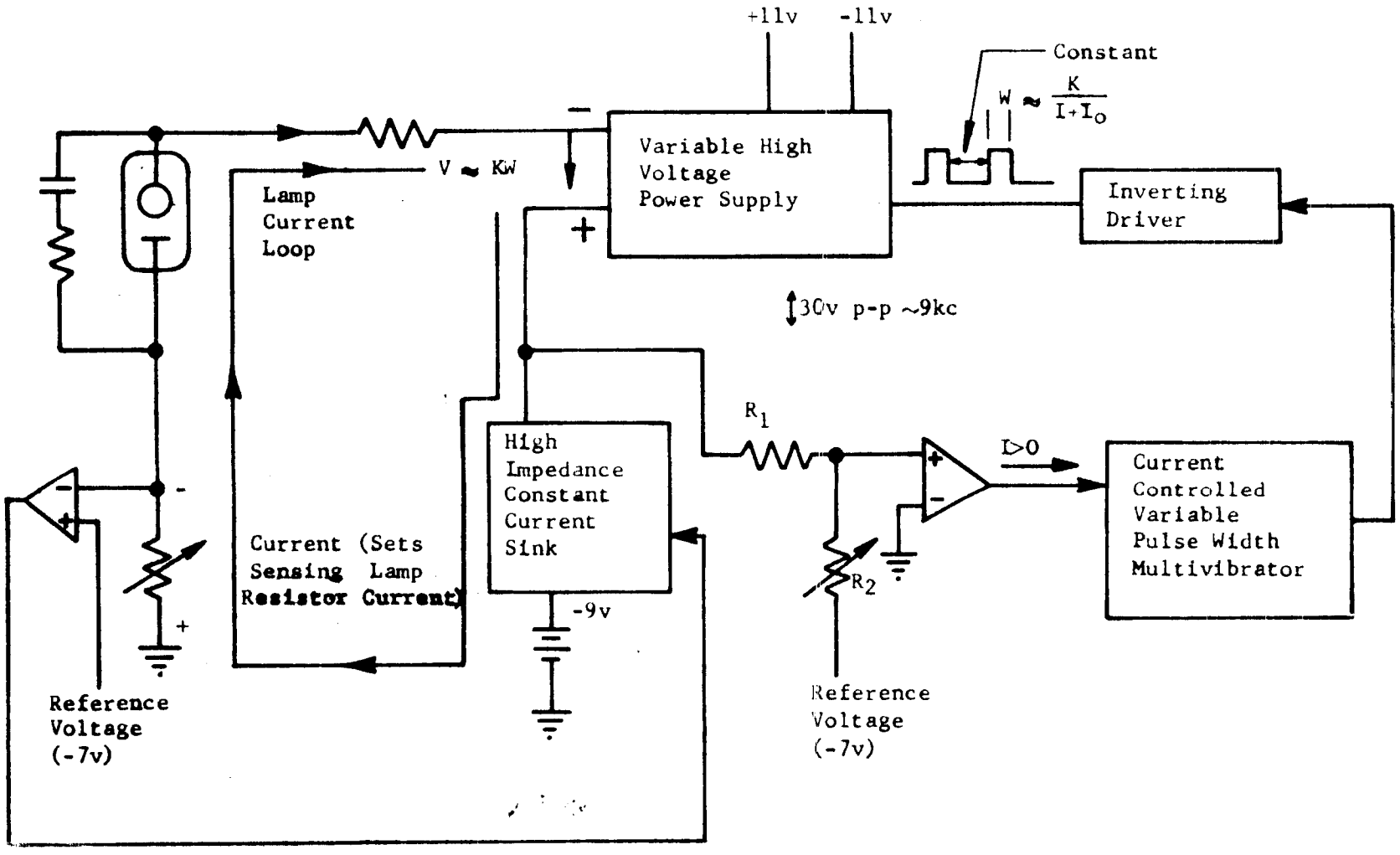


Figure 18. UV Lamp Power Supply

and the driving pulse width is at its maximum value. With no load on it the power supply filter capacitor charges rapidly toward its maximum value of 2.2KV (limited by a 220-volt zener across the transformer primary).

When the lamp fires (usually at 1 to 2 KV) a series resistor limits the starting current transient. A 100-volt zener protects the current sink from overvoltage and a pair of diodes protect the current sensing amplifier input during the starting current spike.

The series RC network in parallel with the lamp has two functions: it stabilizes the regulator loop and it stabilizes the lamp for minimum noise voltage generation. Without the network the lamp generates enough noise to swing the current sink between saturation and cutoff, disrupting the operation of the current regulating loop.

In all the sensors, the lamp current has been set at 3.0 mA dc. At this current the lamps run at 82 vdc. The current sink voltage is set at 40 vdc. Superimposed on this is 30v peak-to-peak of power supply ripple and 10v peak-to-peak of lamp voltage noise. The off time of the power supply driver is 70 μsec and the range of on times is 8 to 88 μsec. When operating a lamp at 82v and 3 mA and with a sensor input voltage of 28.0v, the on time is between 26 and 30 μsec.

12. Photomultiplier High Voltage Supply

The basic circuits of the photomultiplier high voltage supply and regulator are very similar to those of the UV lamp power supply and loop voltage regulator. The differences are in the power supply grounding, voltage sensing arrangement, amplifier gain (higher for better regulation), and driver pulse width ranges.

In this regulator, the photomultiplier dynode voltage divider resistors (figure 19) are used to sense the high voltage supply output. The regulator senses the difference between the reference voltage and a set fraction (R_R/R_D) of the high voltage. If the high voltage increases (goes more negative), the difference goes negative. This increases the multivibrator control current, decreasing the power supply drive pulse width and therefore decreasing the power supply output voltage.

The stabilizing network across the dynode resistors is necessary to prevent changes in the photomultiplier signal current, which subtracts from the dynode return current, from shocking the regulator loop into oscillation.

The output voltage can be adjusted from less than 1000 volts to 2000 volts by changing R_D. The driver off time is 20 μsec and the on time range is 6 to 66 μsec. The sensors have been adjusted to give a photomultiplier high voltage of -1050 volts. This gives a dynode divider current of

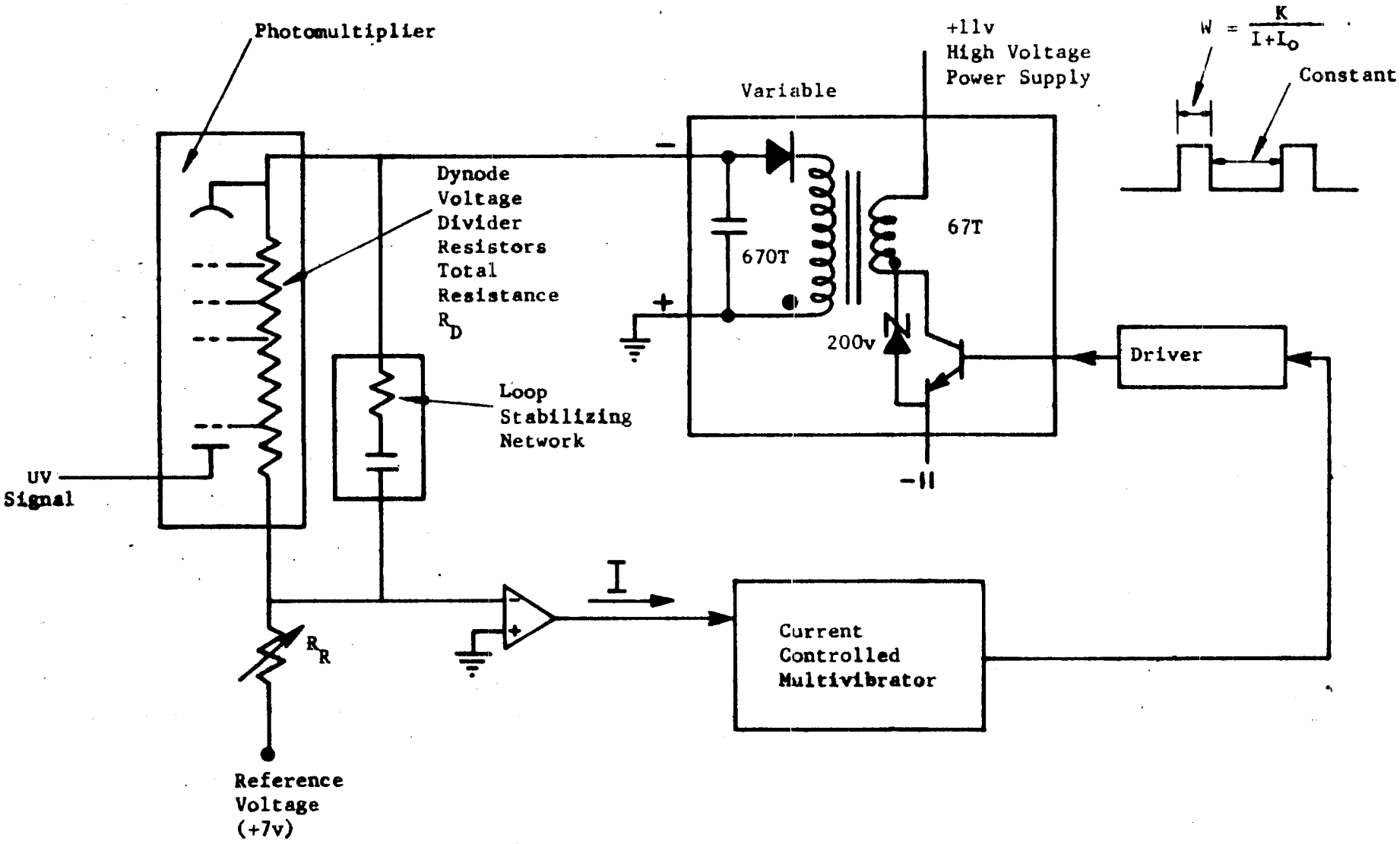


Figure 19. Photomultiplier High Voltage

18 μA and a peak photomultiplier signal current of 0.03 μA. (300 mV peak-to-peak VV preamplifier output). The driver "on" pulse width is 18 μsec for a 1050 volt high voltage output.

13. UV Preamplifier

The UV preamplifier is a low-noise F.E.T. input current to voltage converter. The small signal input impedance is essentially a short circuit, being less than 1 KΩ over its frequency range. The transresistance (V_{OUT}/I_{IN}) is 10 volts per microampere. The frequency response extends from dc to 1 kc., with a 6 db/octave roll-off above 1 kc. Output resistance is less than 300Ω.

In operation the output signal level is approximately 300 mV peak-to-peak with a dc offset of -1.5 volts.

Preamplifier and photomultiplier noise are negligible compared to lamp (light modulation) noise, which is 100 mV peak-to-peak for a 300 mV peak-to-peak signal.

14. IR Preamplifier

The IR preamplifier also is a low-noise short-circuit input current to voltage converter with a transresistance of 300 volts per microampere. The frequency response extends from 1 Hz to 1 kc, with a 12 db/octave roll-off below 1 Hz and a 6 db/octave roll-off above 1 kc. Typical signal levels are 300 mV peak-to-peak, 30 mV peak-to-peak noise, and -0.5 vdc offset voltage.

15. Bolometer Bias Supply

A bias of plus and minus 38 vdc is necessary for the operation of the bolometer. As shown in figure 20, this voltage is supplied by the dc to dc converter, the 40 volt regulator, and a bias filter.

The output of the dc to dc converter is plus and minus 54 vdc.

The 40 volt regulators are series-pass types. The -40 volt supply is regulated to a fixed multiple of +6.2 volts, which is derived from the +7 volts supply through a resistor-capacitor-emitter follower filter. The +40 volt supply is regulated to track the -40 volt supply.

The bias filters are active bridged T low-pass filters using Darlington connected emitter followers to provide gain and as dc pass elements.

16. Low Voltage Power Supply

(a) DC to DC Converter.

The dc to dc converter converts a nominal 28 vdc input to the voltages required to operate the sensor,

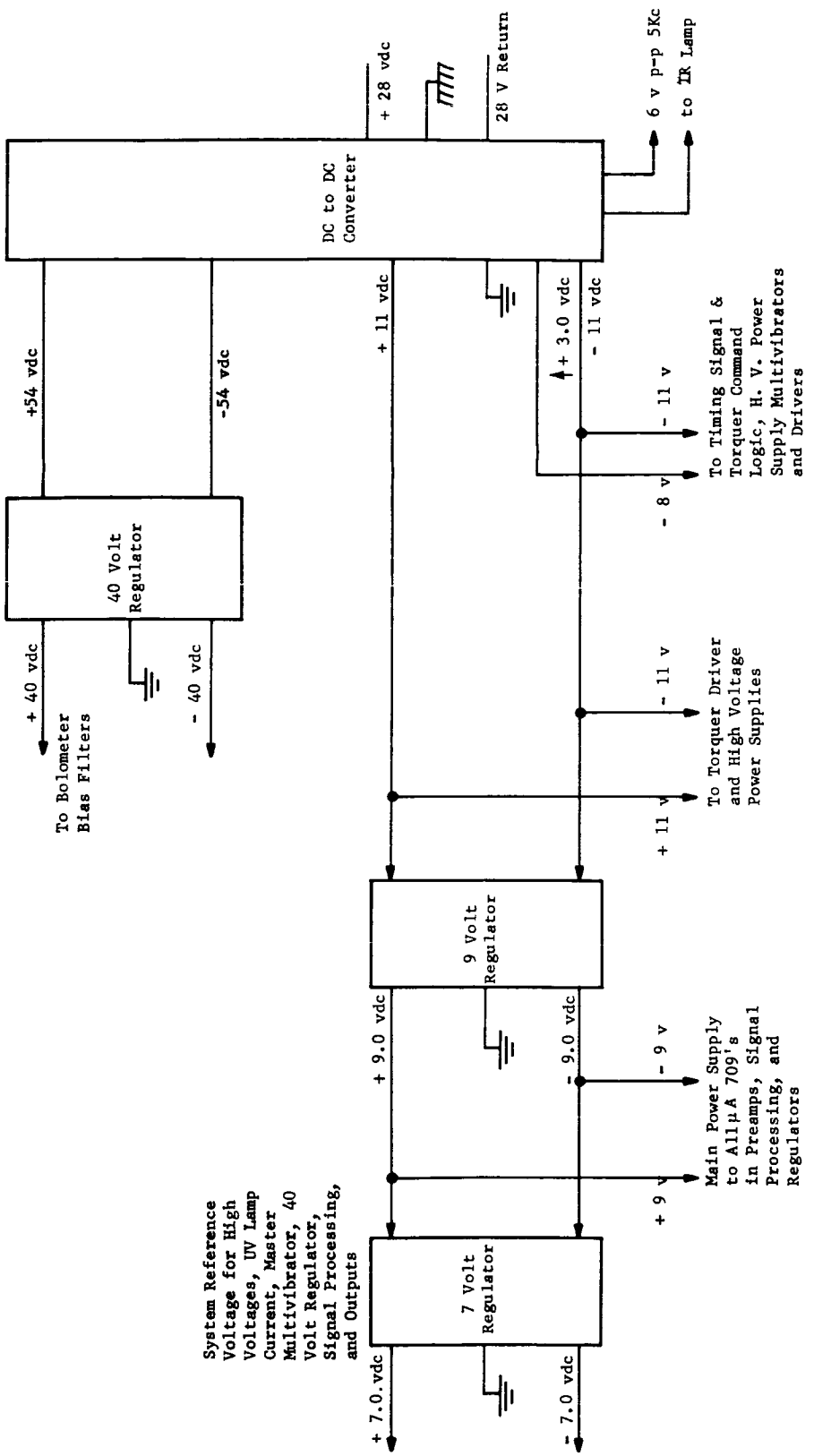


Figure 20. Two Gas Sensor - Low Voltage Power Supply

and it provides isolation between the power supply and signal grounds. It is a self-saturating circuit using four transistors in a bridge-type circuit. There is a conducted EMI filter and a reverse-polarity protection diode in the 28 volt circuit. There are three secondary windings. One tapped center-tapped winding provides plus and minus 11 vdc full-wave rectified for the main power supply and plus and minus 54 vdc half-wave rectified for the bolometer bias regulators. A second winding provides 3.0 vdc full-wave rectified for the timing signal logic and high voltage drivers and the multivibrators. A third winding provides 10 volts peak-to-peak at 5 kc for the IR lamp. There is provision for a series resistor to set the IR lamp current.

(b) 9 Volt Regulators.

The 9 volt regulators are series-pass types. The +9 volt regulator contains a temperature compensated reference diode and a starting pull-up circuit. The -9 volt supply tracks the +9 volt supply.

(c) 7 Volt Regulators.

The +7 volt regulator contains a temperature compensated reference diode and is tied into the +9 volt regulator starting circuit. The -7 volt regulator tracks the + 7 volts. Both regulators are series-pass types. The 11 volt supplies have approximately 0.65 volt peak-to-peak of ripple, due primarily to torquer current peaks. The 9 volt supplies have less than 30 mV peak-to-peak of ripple, and the 7 volt supplies less than 3 mV peak-to-peak.

SECTION III

PHASE IIa ACTIVITY

The Two Gas Atmosphere Sensor has been developed under a two phase program. Phase I consisted of the system study leading to the recommendation of the present system. The mock-up models shown in figures 2 and 3 represent the packaging concept at that time. The second phase of the program has consisted of the detail design and tests of an engineering breadboard, shown in figures 37 and 38. On the basis of the verification testing of the breadboard and the completion of the detail design, work proceeded with the fabrication of four pre-flight models for laboratory demonstration.

The entire program has been conducted along parallel paths of a full flight qualified program without the detail documentation and full implications of quality and reliability specifications. This is being accomplished by implementing the significant portions of these programs and using existing high reliability and quality methods during the design and fabrication phases.

A. PROGRAM PLAN

Perkin-Elmer Engineering Report No. 8328, Phase II Technical Plan described the recommended program for the continuation of the Two Gas Atmosphere System activity. NASA/LRC requested the sensor concept and development program to be in accordance with this report.

Phase IIa was, by contract definition, that first portion of the program which provided a preliminary design of the sensor system, fabricated breadboard sensor subsystems, provided a test plan and performed tests on the breadboard. A final design was provided to LRC for review and approval prior to implementing the design in Phase IIb. Phase IIa work was performed over a 9 month period from July 22, 1966 to May 3, 1967.

B. SUMMARY OF ACTIVITY OF PHASES IIa AND IIb

The major milestones for the program are shown in figure 21. The initial work on the program consisted of developing the program plan and management controls and assigning design personnel to areas of technical responsibility as a result of initial design reviews. The areas of technical difficulty were identified as the development of the IR and UV sources, the UV sample cell design, and the breadboard detail design. The first circuits to be designed were the timing generator and the torquer drive. A preliminary design data package was started for submission in September 1966.

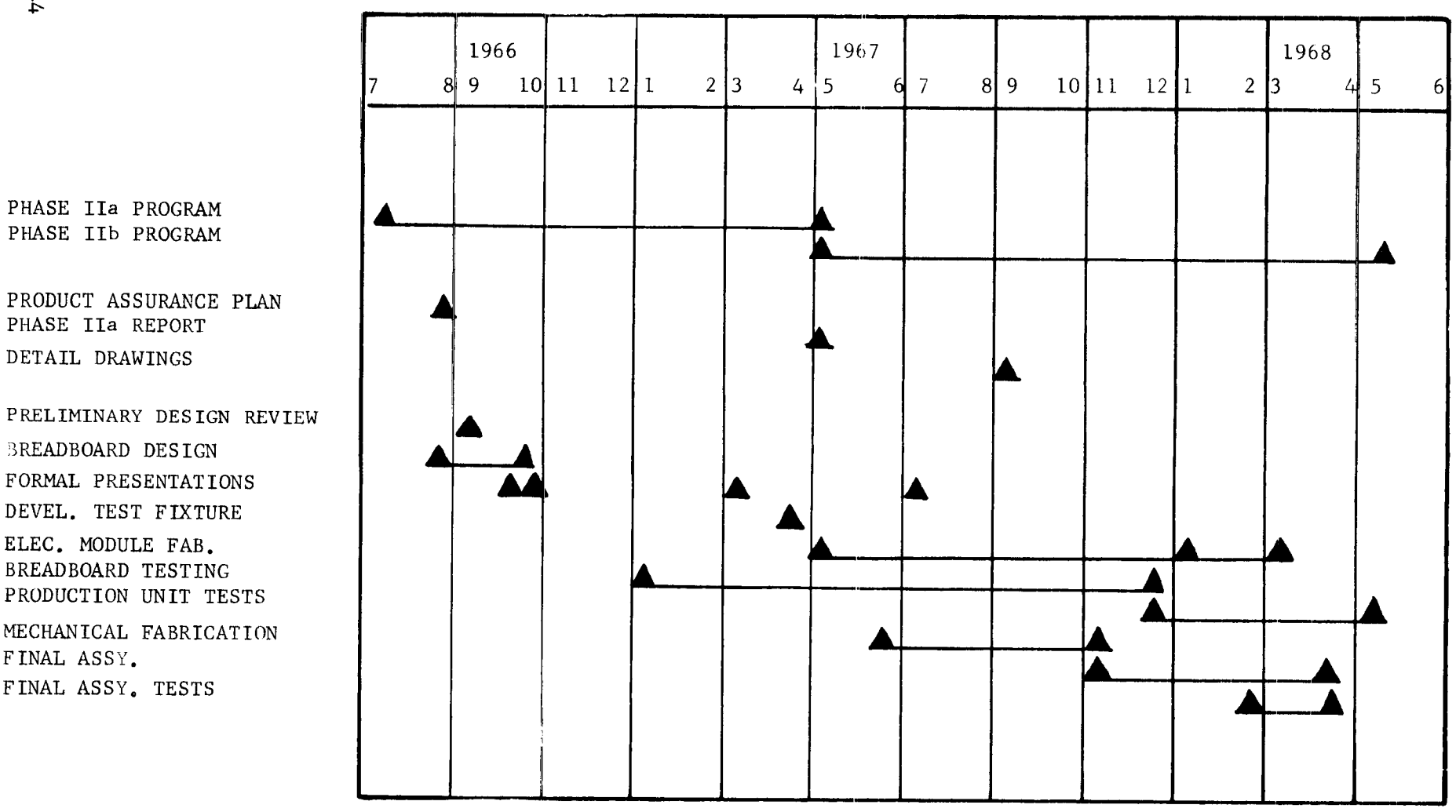


Figure 21. Milestone Schedule for the Two Gas Sensor Program

The Product Assurance Plan was reviewed by NASA/LRC on September 9, 1966. The breadboard design, definition of the optical system variables, and preparation for the October 5 presentation were also made during September.

A reliability math model was constructed in agreement with the development of the detail circuit designs. A reliability prediction was developed showing an MTBF of 10,973 hours. Critical area analysis began as the detail circuit schematics and parts lists were available. The critical area and configuration analysis continued through the entire Phase IIa effort.

During October 1966, two presentations were made, the Product Assurance Program Plan and the preliminary design review were submitted, and the detail design continued. Parallel procurements of UV sources were underway. The breadboard design was completed and fabrication began. The first torsional chopper was received and tested. The selection of a thermistor bolometer detector in place of the InSb PEM device was made based on the thermistor's higher impedance and better spectral detectivity.

From November 1966 through January 1967, the principal work was the testing of the breadboard and the continuation of the final design. During this time, the electronic module design was started and the UV monochromator was finalized. The work on the stress analysis, critical area analysis, and updating of the math model continued during this period. The circuit stress analysis was performed using "ECAP" computer program.

On March 31, 1967 a formal presentation of the Phase IIa detail design was made at NASA/LRC. The presentation consisted of a review of the program, detail presentations of the ultraviolet system and its components, the IR system with its new lens design, the pressure transducer, the electronic system, and the electronic stress analysis. The development test fixture was exhibited, as well as the breadboard.

The procurement of production parts took place in April as well as the submission of the Phase IIa report. The major emphasis on procurement continued through May. All of the production optical and electronic parts were ordered by June. The electronic breadboard was tested in June. This test showed stability within the design requirements over 20°F to 160°F.

The principal activity during July was concerned with the details of the fabrication efforts for the mechanical parts and the electronic welded modules.

First Article Configuration Inspection was performed on the first module in August. The principal activity during this period was extensive vendor liaison to expedite the detail part fabrication.

Assembly of the final units began in September 1967. All assembling of optical and mechanical parts was completed in November 1967. Problems encountered in the completion of the modules gated the schedule from July until their completion, although other difficulties were experienced during this time.

A stability test was performed in November using production assemblies. This test showed less than ±1 percent drift in span and zero during an overnight test.

Extensive troubleshooting of the electronic modules took place in December and delayed final assembly of the units. The first electronic system was operational in January 1968. It was felt at this time that the detail interface problems were solved.

The first unit was extensively tested during February, while assembly continued on the remaining units. An unexplained problem with O_2 drift was observed and confirmed with a second unit test. This is discussed in detail in Sections IVF and V.

The four units were completely assembled by the end of April. The remaining activity during May was the final acceptance testing and preparation of the Final Report.

C. PRELIMINARY DESIGN REVIEW

In accordance with the contractual requirements of the program a Preliminary Design Review package was submitted on September 29, 1966. This package consisted of thirty-nine (39) exhibits, sketches, drawings, parts lists and photographs, and a narrative description of the design.

The design concept and anticipated performance remained essentially the same as that presented in the technical proposal. The purpose of the exhibits was to clarify our approach to this design. The review discussed the:

UV System
IR System
Electronics
Package Design
Pressure Transducer
Breadboards

The UV system was to use an EMR No. 541-05M-09 photomultiplier that was 1.9 inches shorter than the standard 14 dynode design. This was due to high energy anticipated from early breadboard tests. The several alternate UV source designs were presented. It was anticipated at this time that a special short capillary source would be used in the final design. The optical system was presented as being the same as originally proposed.

The IR optical system design change to use a source aperture was first introduced at the PDR. This was to improve the performance by removing the effect of changes in the source position during use. At the preliminary design review it was still our intent to use a PEM InSb detector. This was later changed to a bolometer when the chopping frequency was determined.

The electronic design at this time was identical to the originally proposed design. It is interesting to note that the final electronic system is almost identical to that which was originally proposed.

The pressure transducer decision had not been made at the time of the PDR, but we did favor a potentiometer type transducer.

Engineering Report No. 8768, Preliminary Design, Phase IIa Report, issued May 3, 1967, discussed the detail work in the first half of the contract and summarized the work performed prior to the preliminary design review.

D. UV SUBSYSTEM AND COMPONENTS

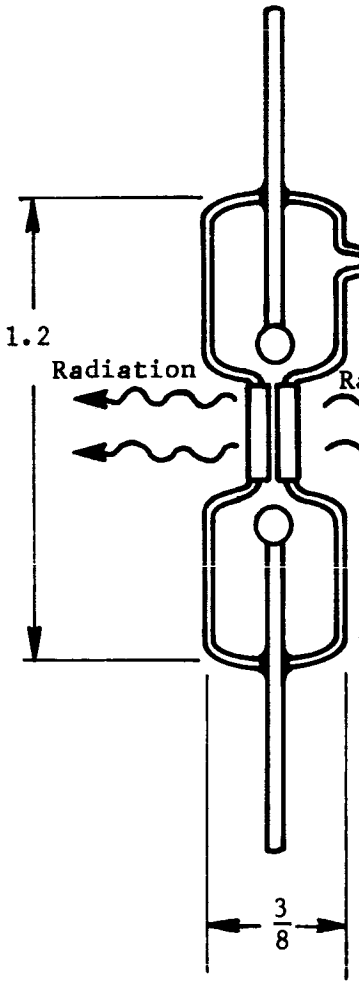
The ultraviolet subsystem consists of the UV source, the monochromator, the sample cell, and the photomultiplier detector. This subsystem required a major development effort and is a major contribution to the program. The program has developed a good miniature UV discharge source, a fast miniature monochromator, and has performed material tests and studies to clearly show the direction for future applications.

1. Ultraviolet Source Lamps

One of the major activities of both the Phase IIa and IIb portions of the program was to develop a suitable ultraviolet source lamp for the Two Gas Atmosphere Sensor. This effort began with a rigorous survey of prospective vendors. The list of vendors contacted for the development of a Source Lamp is as follows:

a. Electro Mechanical Research, Princeton, N.J.
b. Chicago Miniature Lamp Works, Chicago, Illinois
c. Sylvania
d. E. G. & G
e. Tab Glass, Burlington, Mass.
f. Westinghouse, Elmira, New York
g. Atomic Specro Lamps, Melbourne, Australia
h. Tucor, Inc., Div. of Electronic Specialties, Thomaston, Conn.
i. P.E.K. Labs, Sunnyvale, California
j. Xenon Corporation, Watertown, Mass.
k. Engelhard Hanovia, Inc., Newark, New Jersey
l. Fisher & Porter, Hatboro, Pennsylvania
m. Fredericks Co., Pennsylvania
n. Robert K. Hassler Company, Altadena, California
o. G.B.L. Associates, Alexandria, Virginia

On September 1, a conceptual engineering sketch (shown in figure 22) of a prototype xenon lamp was issued. This lamp used a capillary sapphire rod separating two end bells. It was requested that all joints be fused and no adhesive or epoxy seals be used. The electrodes were to be molybdenum or tantalum. The concept was to use UV grade sapphire, which would allow the ultraviolet emission from the side of the capillary. There were no responses to this particular design.



Filling Gas: Xenon, 170 Torr ± 5%
Electrodes: Molybdenum or Tantalum
Leads: Solderable
End Bells: Glass
Capillary: UV Grade Sapphire 1/4 Long by 1/8 Dia., with a 0.020 ±0.002 Dia. Hole. Polish O.D. and I.D. of Capillary.
All Joints to be welded or fused. No Epoxies, Glyptal, etc. to be Used.

Rated Power: Between 0.05 Watt and 0.50 Watt D.C.
Running Voltage: ~200VDC
Starting Voltage: ~1000VDC
Spectral Output: The Xenon Emission from 1470Å to 1900Å is the Range of Interest.

Figure 22. Prototype Xenon Lamp

In order to ascertain lamp operation in the 1470 and 1725 Angstrom regions as a function of current, tests were performed during September 1966 that measured the intensity of these two regions as a function of lamp current. The test specimen for this use was an open electrode configuration that had been obtained from an earlier program. The results of this test are shown in figure 23. The ratio of the 1725Å lamp output to the 1470Å output is shown in figure 24. The V-I characteristics of this particular lamp is also plotted in figure 25.

Early in September, a preliminary specification outlining the requirements for the source design and four possible configurations of source lamps were submitted to prospective vendors. The four designs were an end-on capillary lamp using Kovar electrode rings, a hollow cathode lamp, an open electrode lamp with selected pellets for cathode and anode, and finally, an end-on capillary using internal anode and cathode structures. These were defined in Perkin-Elmer drawings, 631-1001, 631-1002, 631-1003, and 631-1004. Early in October of 1966, an order was placed with Tab Glass of Burlington, Massachusetts to produce the configuration specified in Drawing No. 631-1003. The lamp was to be filled to 100 torr fill pressure and to have a sapphire window fused to a glass body.

Of the vendors contacted, eight selected to "no bid" to the requirements. The prices quoted on the various lamps range from $50 each to $3,985 each. The decision based on workmanship, delivery time, and technical approach was to award the contract to the Tucor Division of Electronic Specialties Company, in Thomaston, Connecticut. This design was designated as a longitudinal lamp, Perkin-Elmer Part Number 631-0013. It was in effect a miniature geisler tube of low pressure, 100 torr, operated with the cold cathode. The lamp is excited by a regulated dc power supply. The lamp is 1-1/8 inches long with a body diameter of 5/16 inch. (See figure 45 for final lamp.) The body contains an indented window of UV grade sapphire, so that the UV sensor optical system uses the lamp capillary as the entrance slit. This is accomplished with a physical slit of 1/2 millimeter by 4 millimeters cut into the lamp's alumina ceramic body. The sapphire window (Perkin-Elmer Part Number 631-1106) is sealed to the alumina ceramic body by brazing at 250°C for 14 hours. The anode material is kovar and the cathode is a barium getter wire. The outer and inner flanges are heliarc welded to form a hermetic seal. After filling the lamp with xenon gas to 100 torr, the copper exhaust tubing is pinched off. All exposed metal surfaces are gold plated. This lamp has the following electrical start-up and running characteristics:

Cold Start-Up - 1400 volts
After 1 minute operation - no greater than 3000 volts
Cooling time to prevent 400 volt restart - 15 minutes
Running voltage - 3 milliamps at 85 volts

Later in the program, the restart voltage was reduced to 350 volts with the application of an electrical conductive coating covering part of the alumina ceramic body and the anode. This external coating aids in dissipating charges built up on the inside of the capillary. During January 1967, tests were run to determine the signal-to-noise ratio of existing end-on capillary lamps filled with 30 torr xenon. This data is plotted on figure 26. One of the basic considerations in the selection of the side-looking or longitudinal capillary lamp is that it was

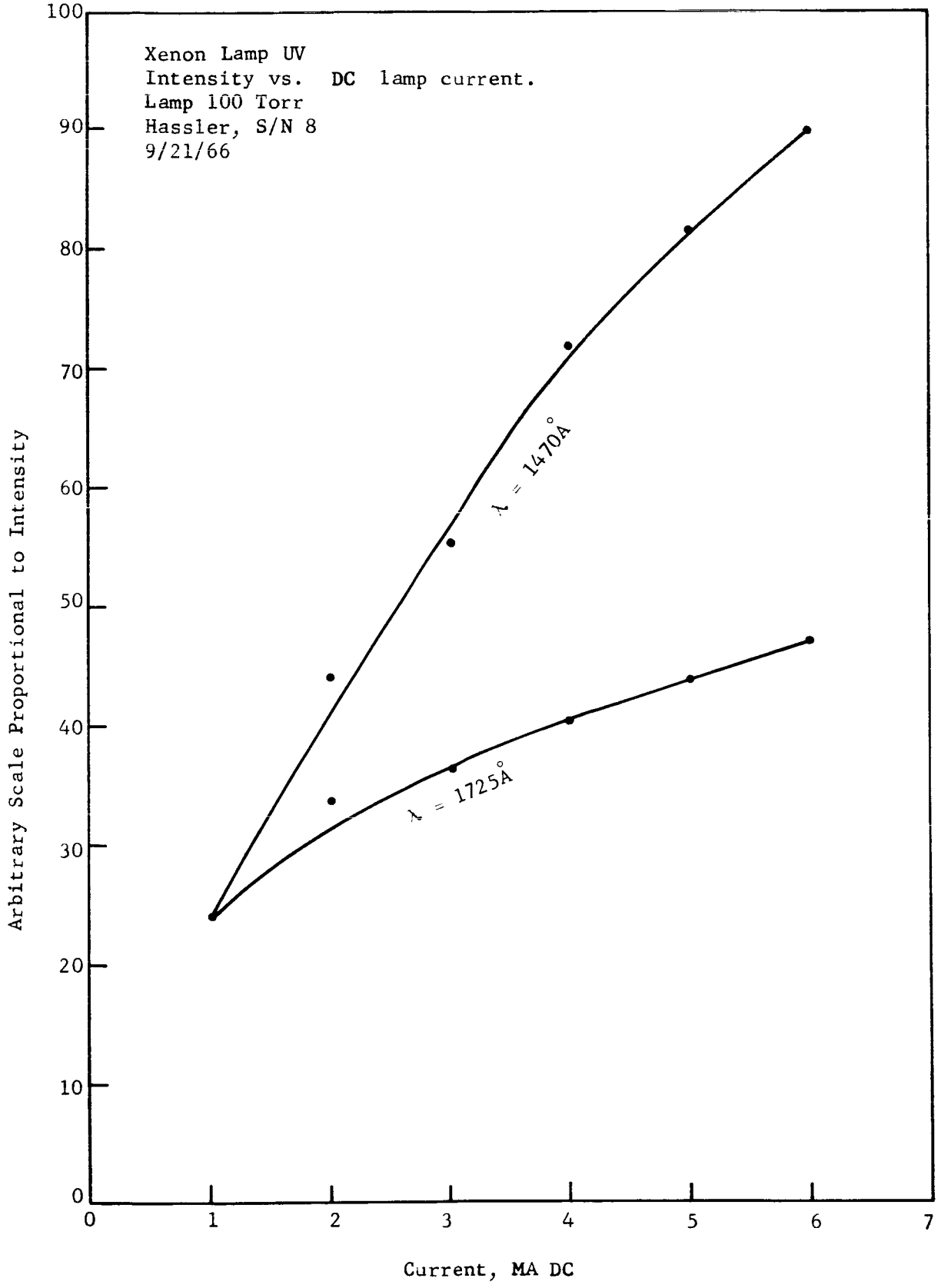


Figure 23. Lamp Operation in the 1470 and 1725 Angstrom Regions as a Function of Lamp Current

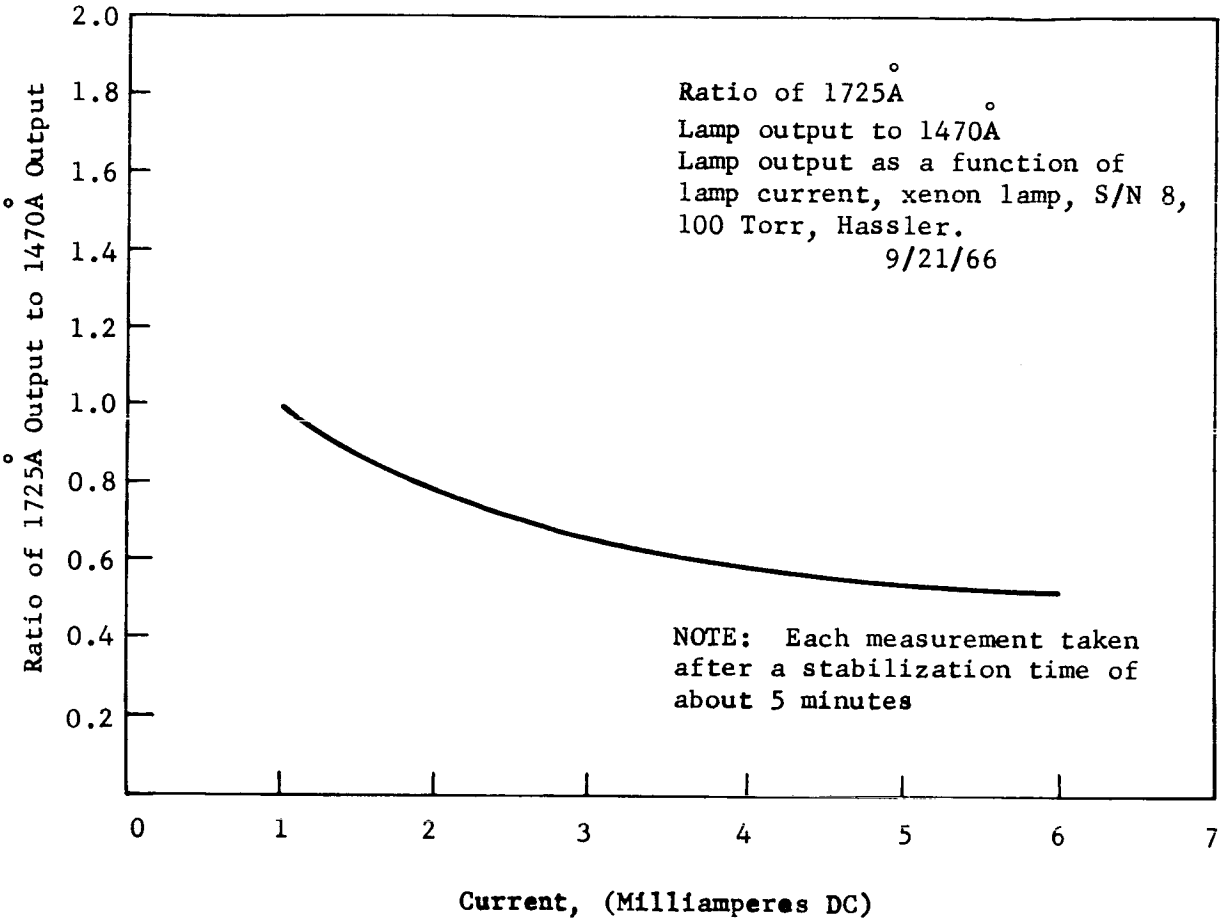


Figure 24. Ratio of 1470Å Output to 1725Å Output

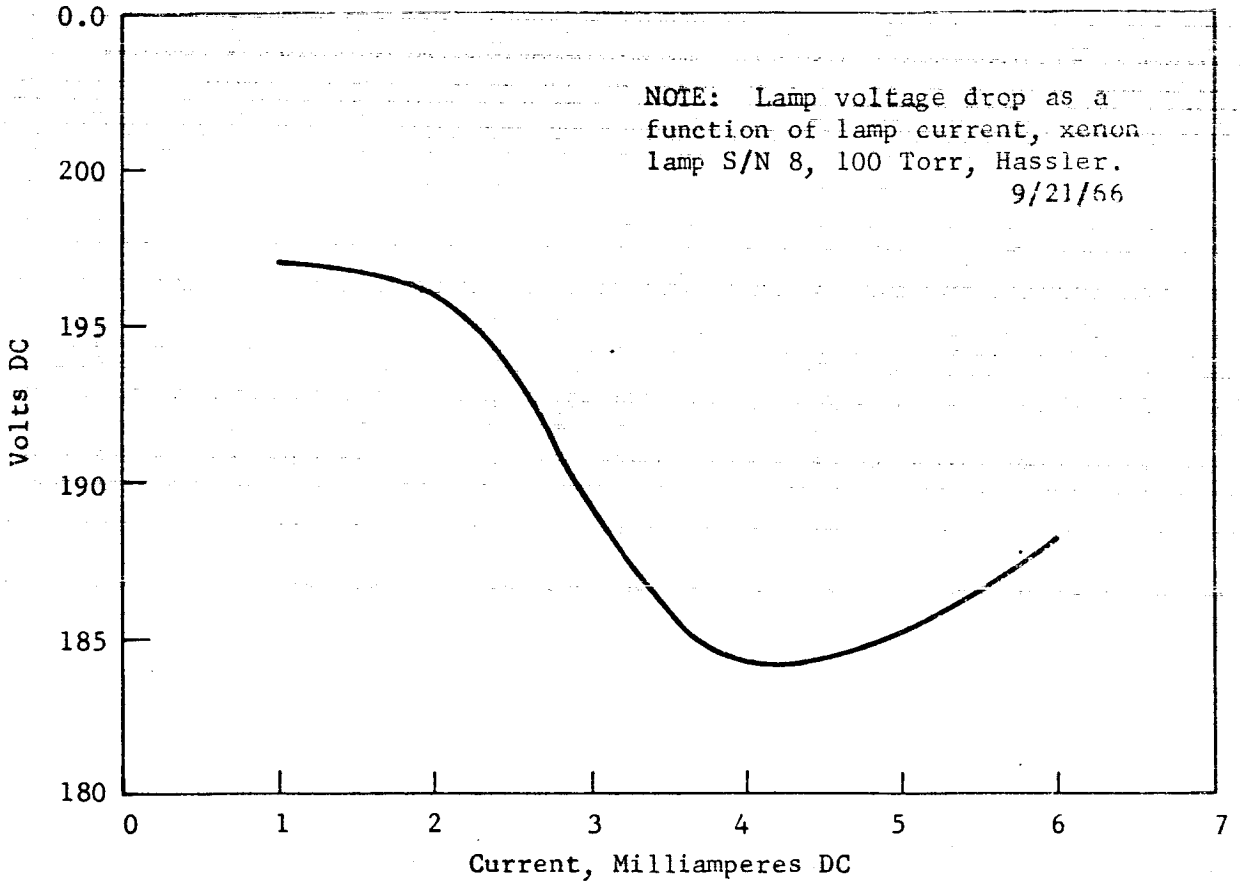


Figure 25. Voltage to Current Characteristics

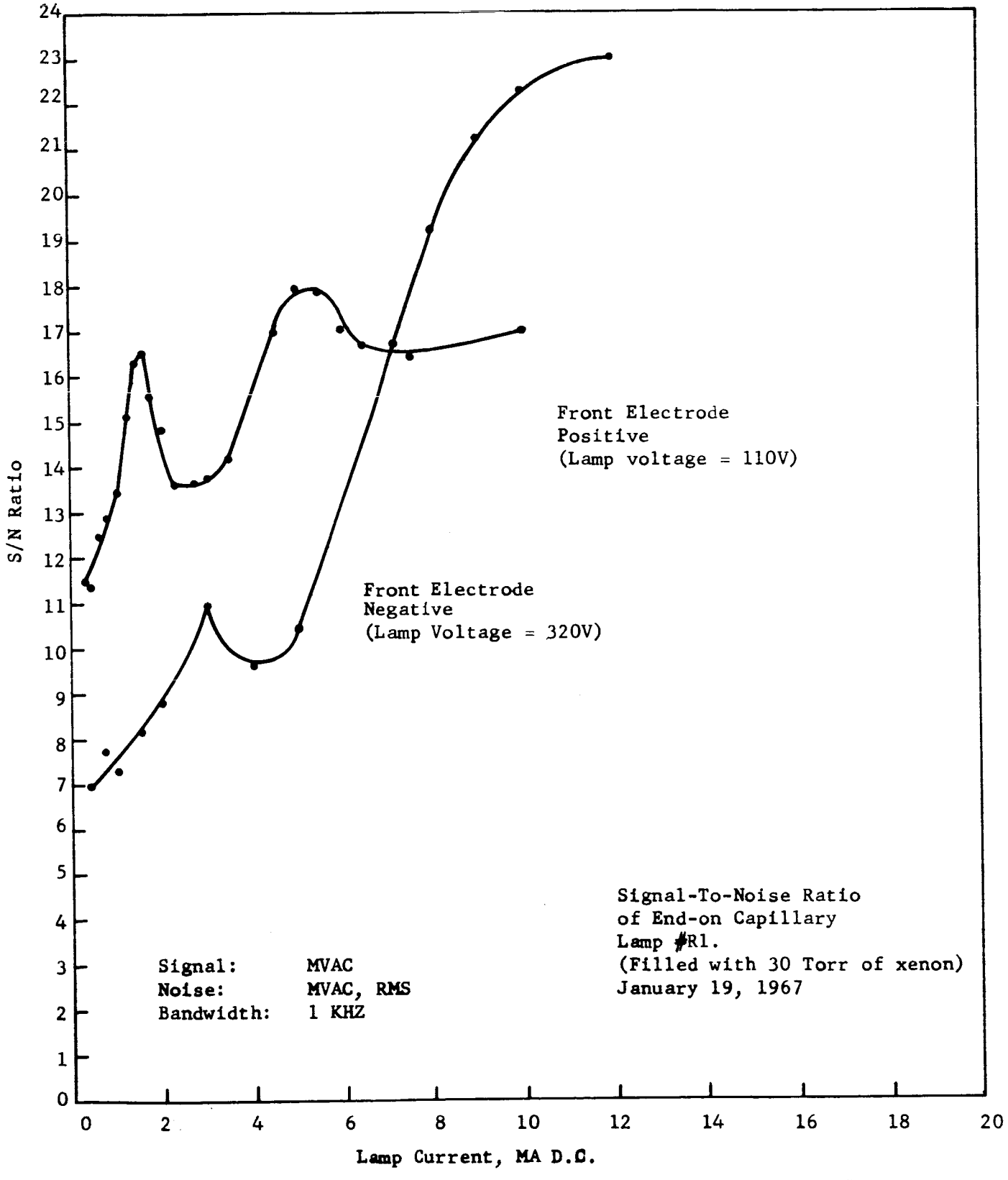


Figure 26. Signal-to-Noise Ratio of End-on Capillary Lamp #R1

the only design that completely prevents the discharge from wandering. This had been a particularly difficult problem in the previous designs. It can also be used at the monochromator focal plane, which eliminates the entrance slit and will give considerably more light than the end-on capillary if used in this manner.

A backup lamp design was considered, which used a graded seal end-on capillary with a sapphire window. This lamp had the advantage that it was fairly simple to fabricate, but it had the disadvantage that the discharge could wander between the front end of the capillary and the anode.

2. UV Materials

The effect of temperature on the optical windows was studied to some extent during the early phases of the program. The work of Laufer, Pirog, and McNesby[2] of the NBS Institute for Basic Standards presented data on calcium fluoride and synthetic sapphire, showing the transmittance cutoff as a function of temperature. The calcium fluoride cutoff was well beyond the region of interest for temperature up to 140°C. On the other hand, the sapphire exhibited a transmittance isotherm as a function of wavelength, which at 1470 Angstroms, showed approximately 0.04 percent reduction in transmission per degree C. This was considered to be a negligible decrease in transmission for our purposes.

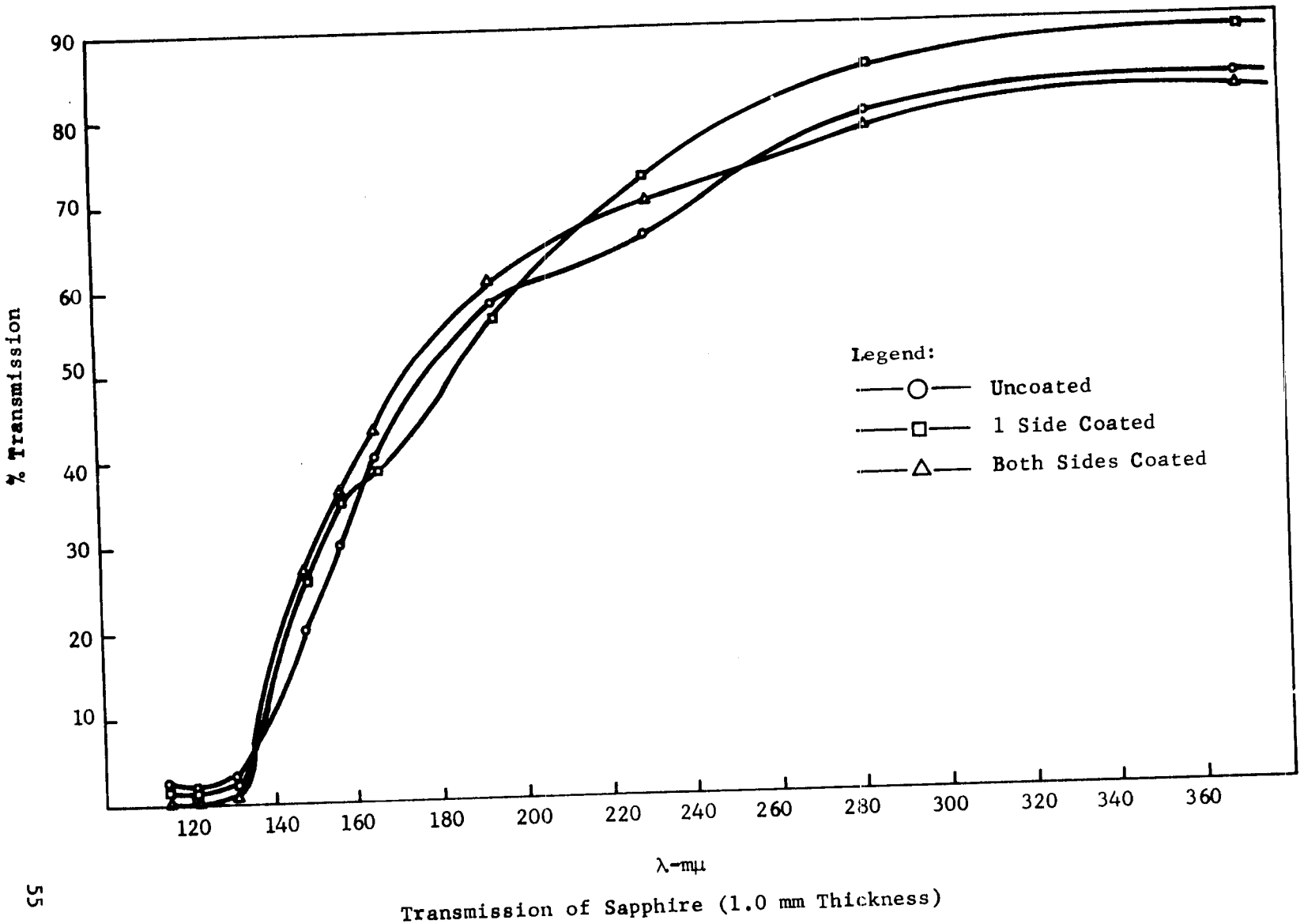
During Phase IIa, a set of experiments was carried out to determine the feasibility of anti-reflection coatings on sapphire windows in the region of 1400Å to 1500Å. An additional requirement was that the coated optics be durable; therefore, a single film of MgF_2 was used. Measurement of transmission and reflection was made on the Jarrell-Ash vacuum UV monochromator. Figure 27 shows the results which were obtained. The following conclusions were made from the results of this data:

a. Our measurement indicates that sapphire does not have a reflective index of 6.0 at 1470Å as reported by Linde. Instead, it shows a real portion of the index of approximately 2.0, with a reflection of approximately 10 percent, that is, highly absorptive.

b. The $\lambda/4$ MgF_2 at 1500Å is an effective anti-reflection coating on sapphire; however, its only practical use will be limited to the elimination of ghost images. A substantial increase in transmission may be realized only on very thin pieces of sapphire because of the high absorption.

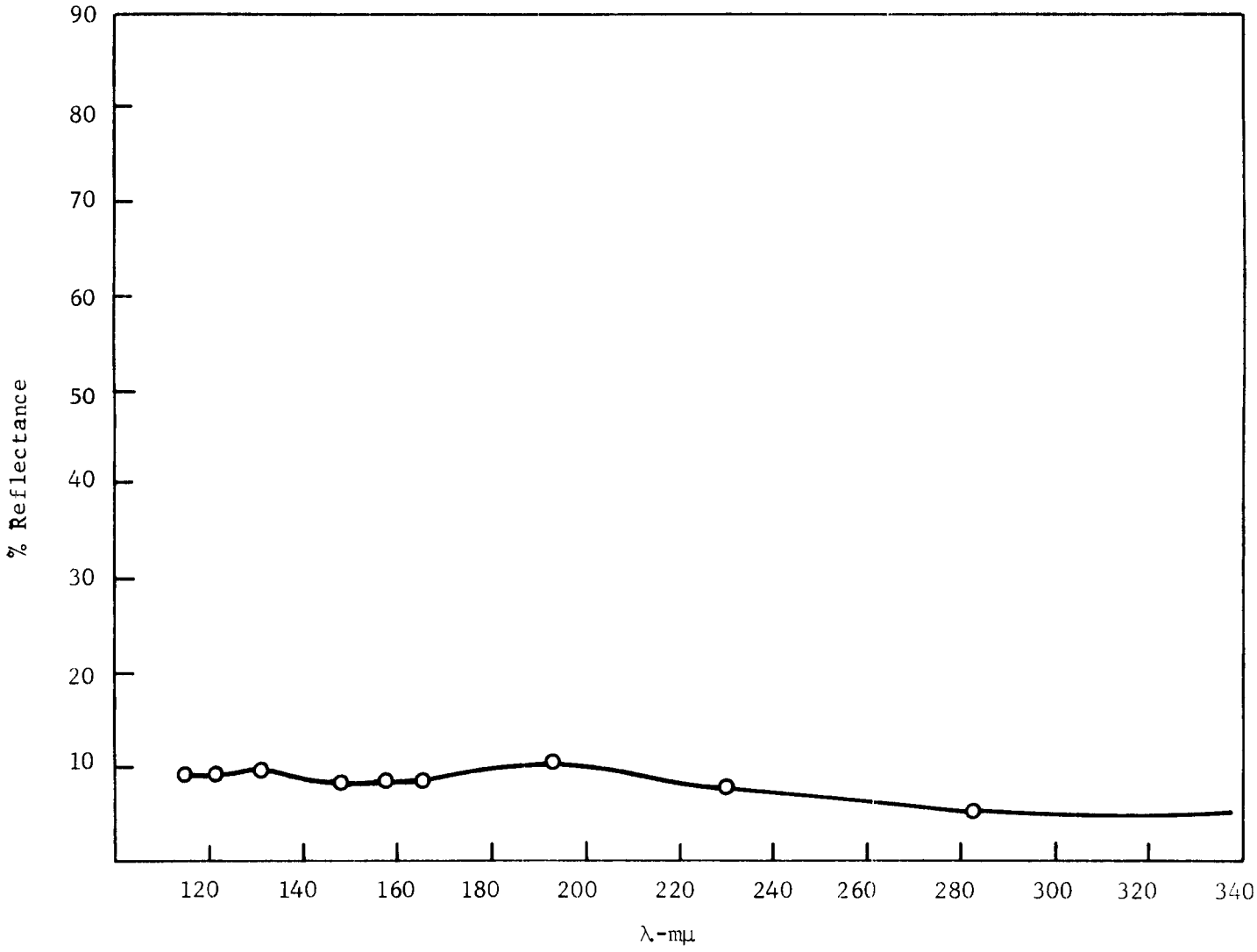
c. MgF_2 is absorbing in this region. It is evident for the reflection of a sapphire surface coated with MgF_2. In addition, a piece of Irtran I (MgF_2), two millimeters thick, shows no transmission or reflection below 2000Å.

[2] Journal of the Optical Society of America, Vol. 55, No. 1 (1965).



Transmission of Sapphire (1.0 mm Thickness)

Figure 27. Measurement of Transmission and Reflectance of Sapphire Window (Sheet 1)



Single Surface Reflection of Uncoated Sapphire

Figure 27. Measurement of Transmission and Reflectance of Sapphire Window (Sheet 2)

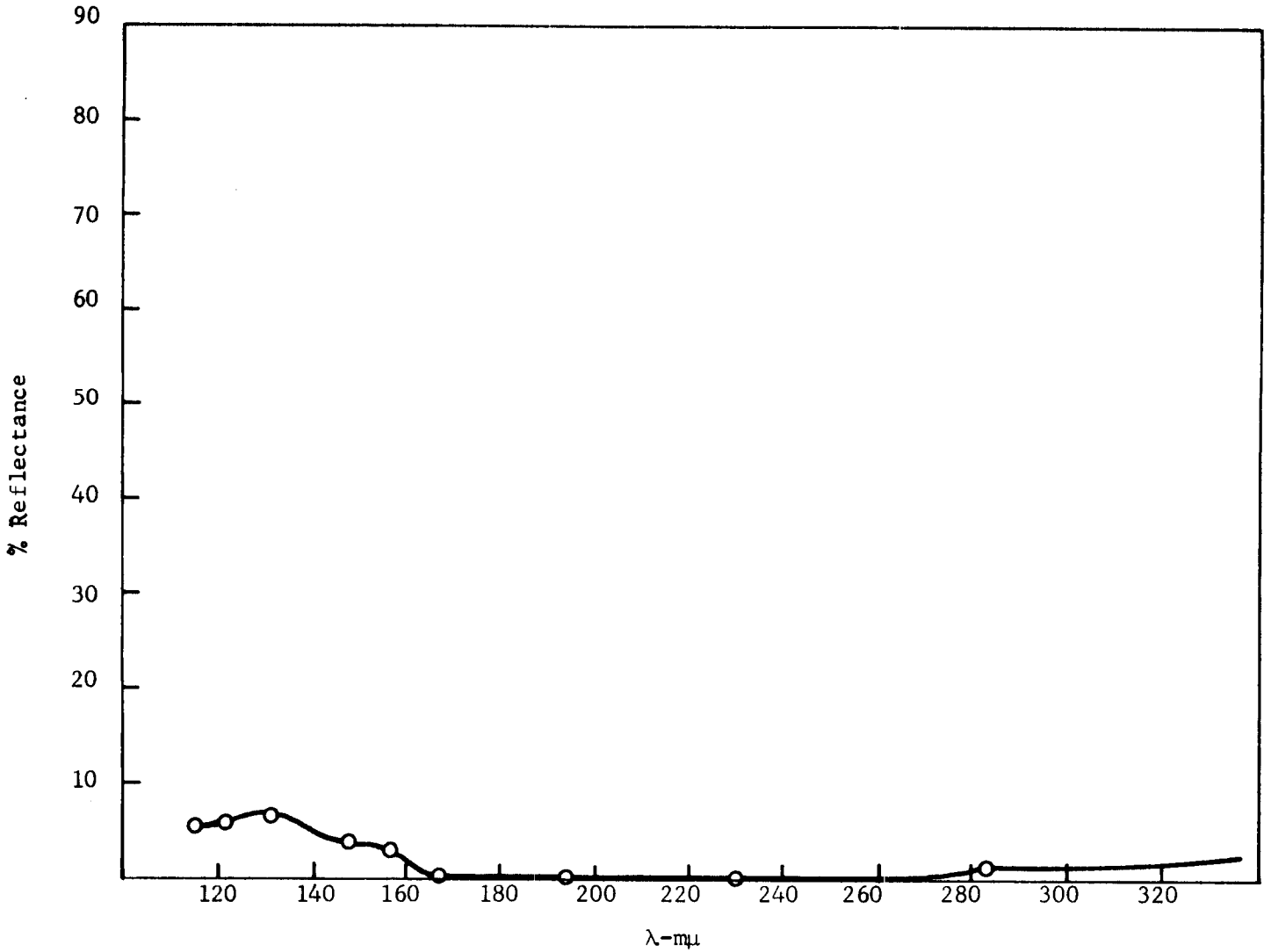


Figure 27. Measurement of Transmission and Reflectance of Sapphire Window (Sheet 3)

d. It appears that the index of thin MgF_2 films is dispersive in this region. The transmission curves indicate that 250Å is not a 1/4 wave at 1400Å, but more nearly 3/8 wave. Perhaps a better controlled, thinner film would yield a more appreciable transmission gain.

In November 1966, an investigation was made into protective coatings for calcium fluoride. A substrate, one inch in diameter and two millimeters thick, was coated on both sides with sapphire (Al_2O_3) at 1 micron. These films were prepared by electron beam gun evaporation. The object was to determine whether or not suitable transmission characteristics could be maintained with the hope that the Al_2O_3 would provide some protection for the CaF_2 substrate.

Visible transmission measurements were made on a Model 450 Perkin-Elmer spectrophotometer and reflection and transmission measurements were made in the UV on a Jarrell-Ash monochromator. The following table lists the values obtained.

Comparison of these values with the values of uncoated CaF_2 indicate that the Al_2O_3 is strongly absorbing in the ultraviolet.

By varying the coating process parameters, the absorption can be reduced, but probably not by a significant amount, particularly at the shorter wavelength.

During September 1966, transmission measurements were made on two samples of sapphire including reflection and scattering losses. The sapphire samples were one millimeter thick; the measurements were made on the Model 450, Perkin-Elmer Spectrophotometer, and the Jarrell-Ash monochromator. The transmission curves obtained from these tests are shown in figure 28. For comparison purposes, the UV transmission spectra of CaF_2 obtained prior to this contract is shown in figure 29.

During the winter of 1966, extended tests were performed with CaF_2 samples to determine the effect of liquid water on the ultraviolet transmission of windows. These tests were made at 1470Å and 1720Å. This data is plotted in figure 30. The plot demonstrates the degradation of transmission of CaF_2 at these wavelengths after the CaF_2 sample has been immersed in liquid water for a one month period. In figure 31, the effect of water immersion over a 220 hour period is shown.

Various studies were made on methods to provide seals of the sapphire and calcium fluoride to either glass or metal. The technique which appeared most desirable consisted of first painting the glass seat area adjacent to the window with platinum paint and baking at 500°C with a slow cooling, overnight, to room temperature. Silver chloride is then applied to the window seat and the inside shoulders of the glass. The glass is heated with a torch and a strip of silver chloride is touched to the platinized glass. Finally, the window is placed in position on the glass seat and the entire assembly is placed in an oven at room temperature. The temperature is raised to 490°C over a period of approximately 1 hour and slowly cooled overnight to ambient temperature. After the seal is completed, it is recommended that all exposed silver chloride surfaces be painted with lacquer in order to retard solarization of the silver chloride.

λ	R (Two Surfaces)		T	
1150Å	8%	(a)	2%	(a)
1480Å	8%	(a)	2%	(a)
1560Å	8%	(a)	2%	(a)
1930Å	8%	(a)	6%	(a)
2300Å	8%	(a)	15%	(a)
2830Å	10%	(a)	53%	(a)
3710Å	14%	(a)	78%	(a)
3600Å	-	-	72%	(b)
3700Å	-	-	72%	(b)
3800Å	-	-	76%	(b)
3900Å	-	-	83%	(b)
4000Å	-	-	87%	(b)
4250Å	-	-	80%	(b)
4500Å	-	-	76%	(b)
5000Å	-	-	90%	(b)
5625Å	-	-	78%	(b)
6500Å	-	-	92%	(b)
7500Å	-	-	81%	(b)

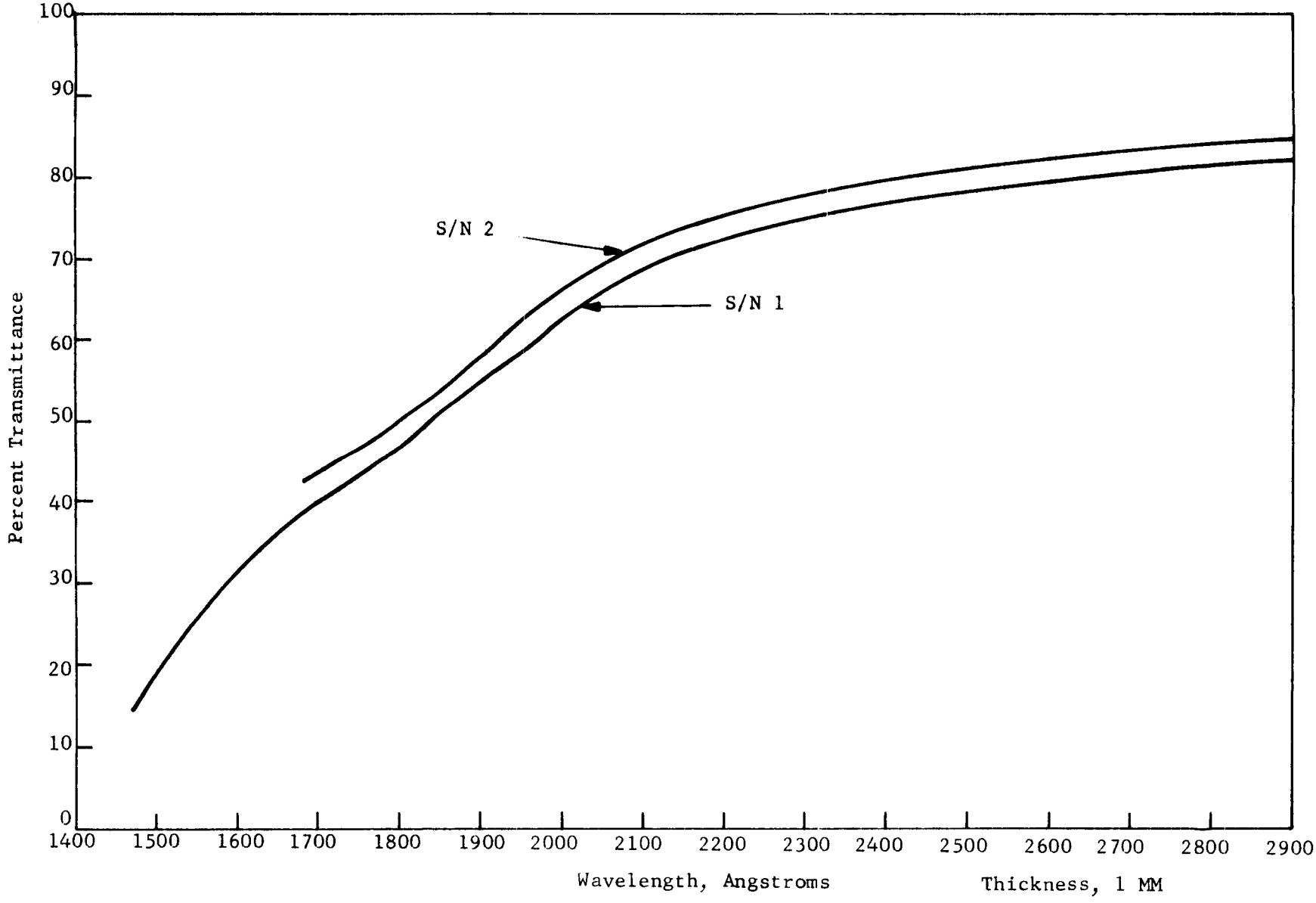


Figure 28. Transmittance of Two Samples of Sapphire, Including Reflection and Scattering Losses

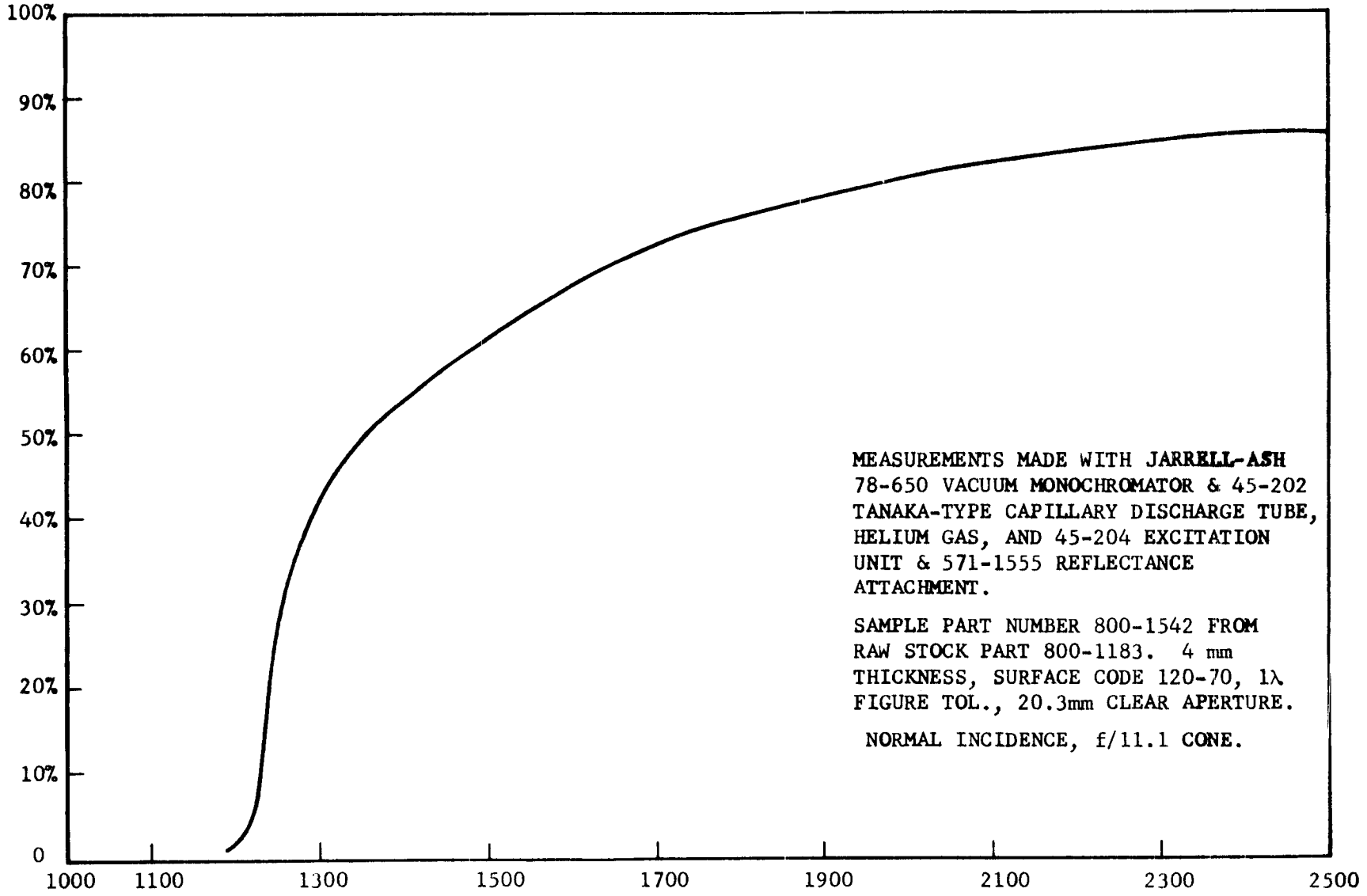


Figure 29. UV Transmission of Calcium Fluoride (CaF_2)
(Includes Reflectance Losses)

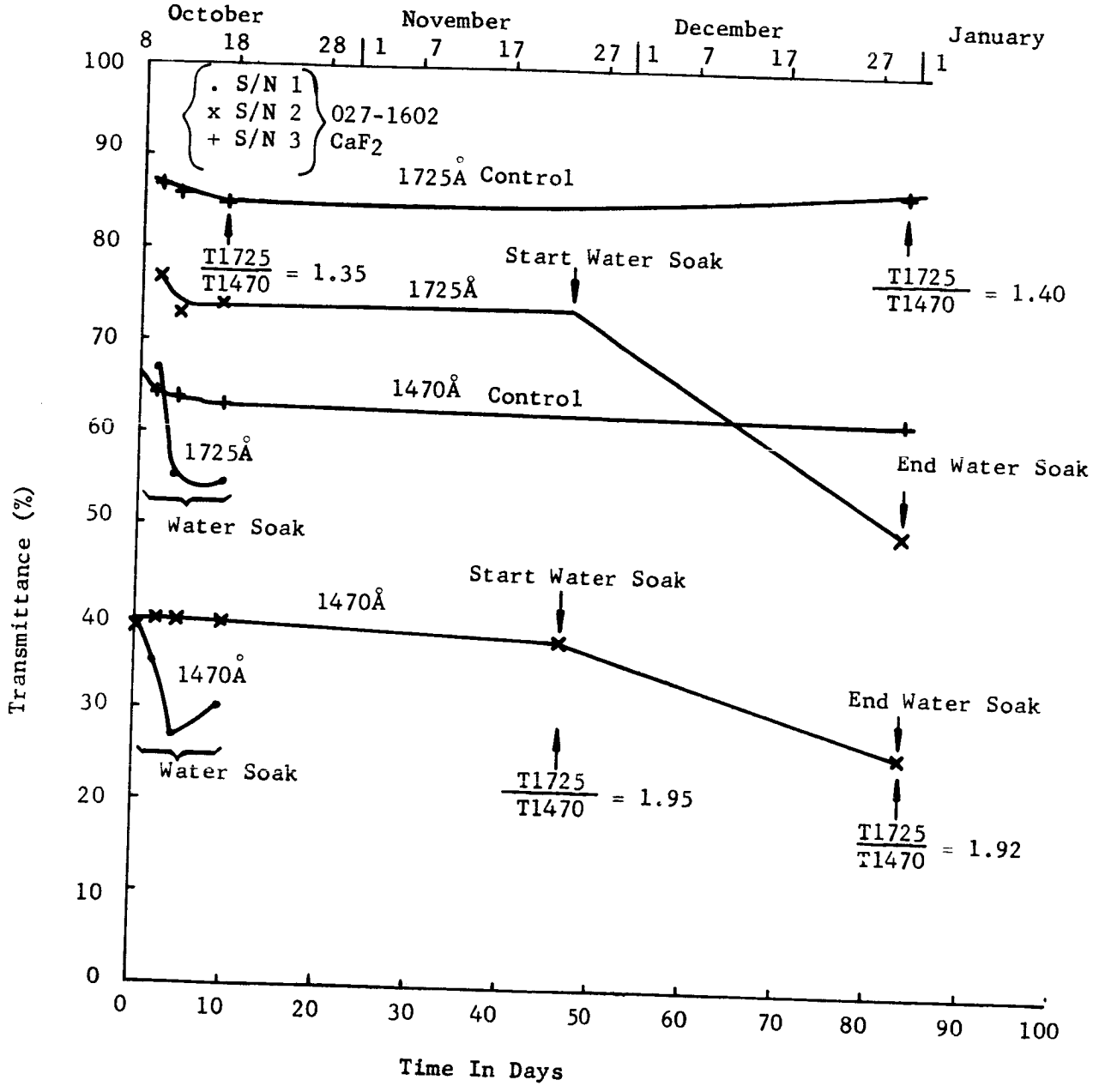


Figure 30. Effects of Liquid Water on the UV Transmittance of Calcium Fluoride Windows

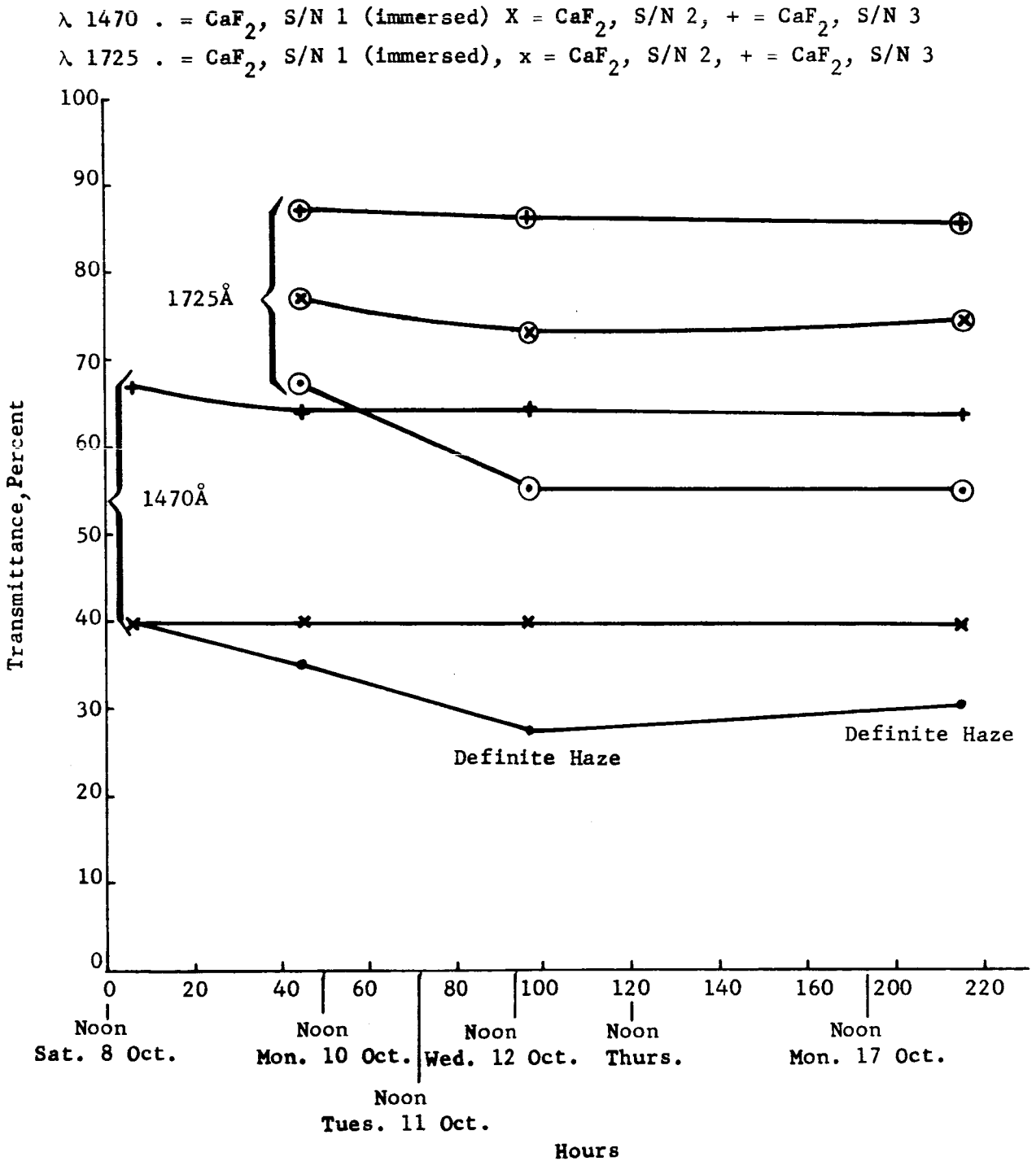


Figure 31. Effect of Water Immersion on Calcium Fluoride Windows

This is a technique used for ultraviolet sensitive phototubes with calcium fluoride windows. Tubes manufactured by this technique have maintained a vacuum of 10^{-7} millimeters mercury, after a degassing bake at 350°C. This method is applicable for the sealing of sapphire windows to pyrex glass and for calcium fluoride seals.

3. UV Optics

The photomultiplier detector was selected for its high performance and small rugged construction. It is a multistage solar-blind multiplier phototube with a semitransparent cesium telluride photocathode and a UV grade sapphire window. The multiplier features the venetian blind dynode construction and hard glass kovar rings in an encapsulated package. The spectral sensitivity of the tube extends from 1450Å to 3500Å. The tube, part number 631-1231, is made by Electro-Mechanical Research, Inc. of Princeton, New Jersey.

Consideration was given to a tube with a cesium iodide photocathode deposited on a calcium fluoride window. This E.M.R. detector is not affected by room light (completely solar-blind), but the tube has a higher price and a long delivery. It was rejected primarily because of the manufacturer's uncertainty about its performance.

In May of 1966, the ITT Industrial Labs of Fort Wayne, Indiana, issued a newsletter describing a UV image dissecter tube that would be most appropriate for the oxygen-water-vapor measurement. This television-type camera tube is scanned electronically, allowing extremely rapid spectral scanning to be performed without any mechanical movement. The dissecter tube, designated by ITT as UVissector camera tube, contains an electron imaging section and a secondary emission electron multiplier separated by a long narrow slit aperture that serves as an effective slit to a monochromator. The sampling of the spectrum takes place by sweeping the electron image of the spectrum across the slit aperture. This is carried out by the magnetic fields generated by electro-magnetic coils surrounding the tube. The number of electrons passing through the aperture at any instant of time represent the light intensities for the spectral bandpass determined by the spectrophotometer slit width. The output signal is then amplified and can be utilized with conventional techniques. The cost of these tubes is almost three times the cost of the proposed solar-blind photomultiplier.

The high cost of this unit, in addition to the larger size and higher input power, was deemed to be an inappropriate tradeoff against the deletion of the optical chopper on the UV assembly, since this chopper was also required in any case for the IR system. The part number of the tube that was considered is F4054.

The UV Monochromator (figure 32) uses the source lamp capillary, 631-0013, as the entrance slit. A mask in front of the source limits the speed of the system and prevents a non-dispersed energy from reaching the detector. The primary mirror (607-1004) collimates the incident energy to the grating and re-images it on the exit slits. The exit slits are part of the UV sample cell assembly (631-0107) shown in figure 43.

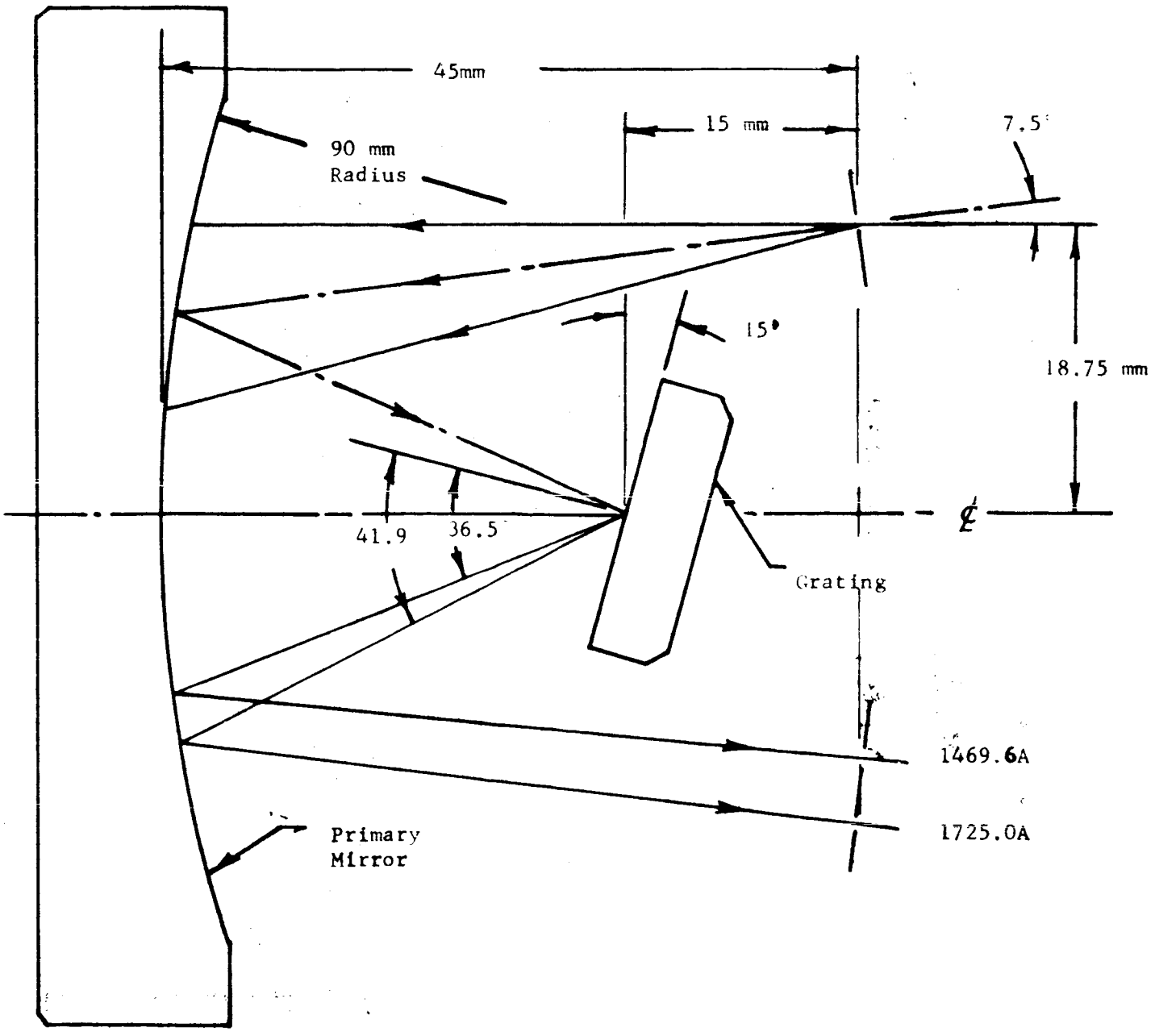


Figure 32. The UV Monochromator

The ultraviolet energy dispersion is obtained from a modified Perkin-Elmer plane grating, 303-1320, which is cut to smaller dimensions as 631-1220. The basic specification for the standard grating is:

2880 lines per millimeter

22.0° nominal blaze angle

$\lambda/2$ figure, 0th order

λ figure, diffracted wavefront at nominal blaze

0.2 percent ghosts

68.6 millimeter square size

10 millimeter thickness

64 millimeter square ruled surface

PE Spec 1003 coating

120-50 surface code

45 percent efficiency at 2000Å

E. IR SUBSYSTEM AND COMPONENTS

Figure 33 shows the complete IR assembly. The layout dimensions and detail part numbers for the lenses, source, filter, and detector are shown on drawing 631-1227 (figure 34).

1. IR Optics

The source (631-1217) is a miniature dual filament lamp that illuminates an aperture (631-1215). The aperture is then imaged on the optical filter chopper through the 38-millimeter long sample cell. The chopped image of the filter is then re-imaged on the 1/2 millimeter square thermistor bolometer detector.

The assembly is mounted on a plate, which permits alignment of the elements prior to assembly into the main unit. This has been found to be very convenient. A similar technique should be used for the UV monochromator. The sample cell is sealed from the inert environment around the assembly. The sample gas is purged through the cell by nickel tubing, which is connected to the UV cell and the pressure transducer. The total pressure drop of the sample line is approximately 1/10 of an inch of water at 100 cc per minute flow.

2. IR Detector

The detector assembly (631-0103) is electrically isolated from frame ground to allow the bolometer shield to be connected to signal ground.

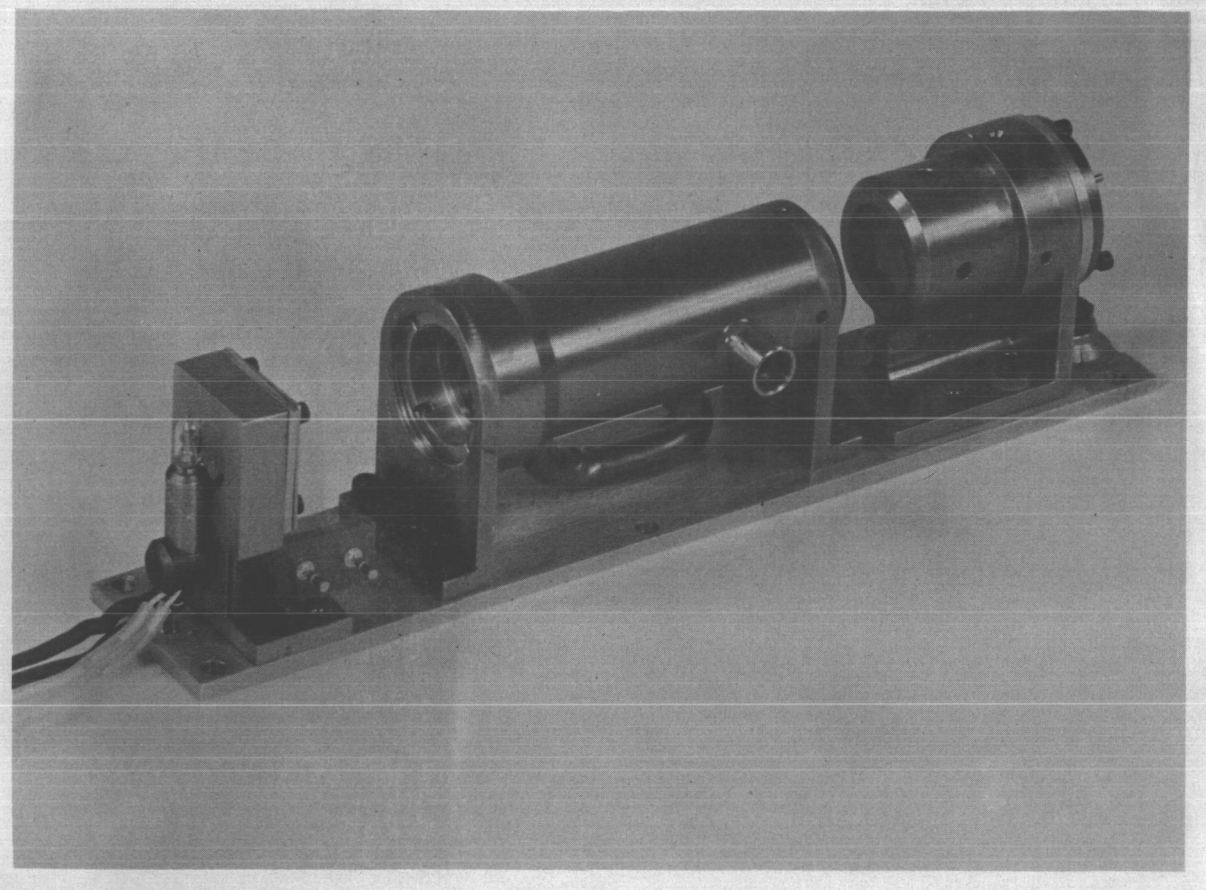


Figure 33. The IR (Infrared) Assembly

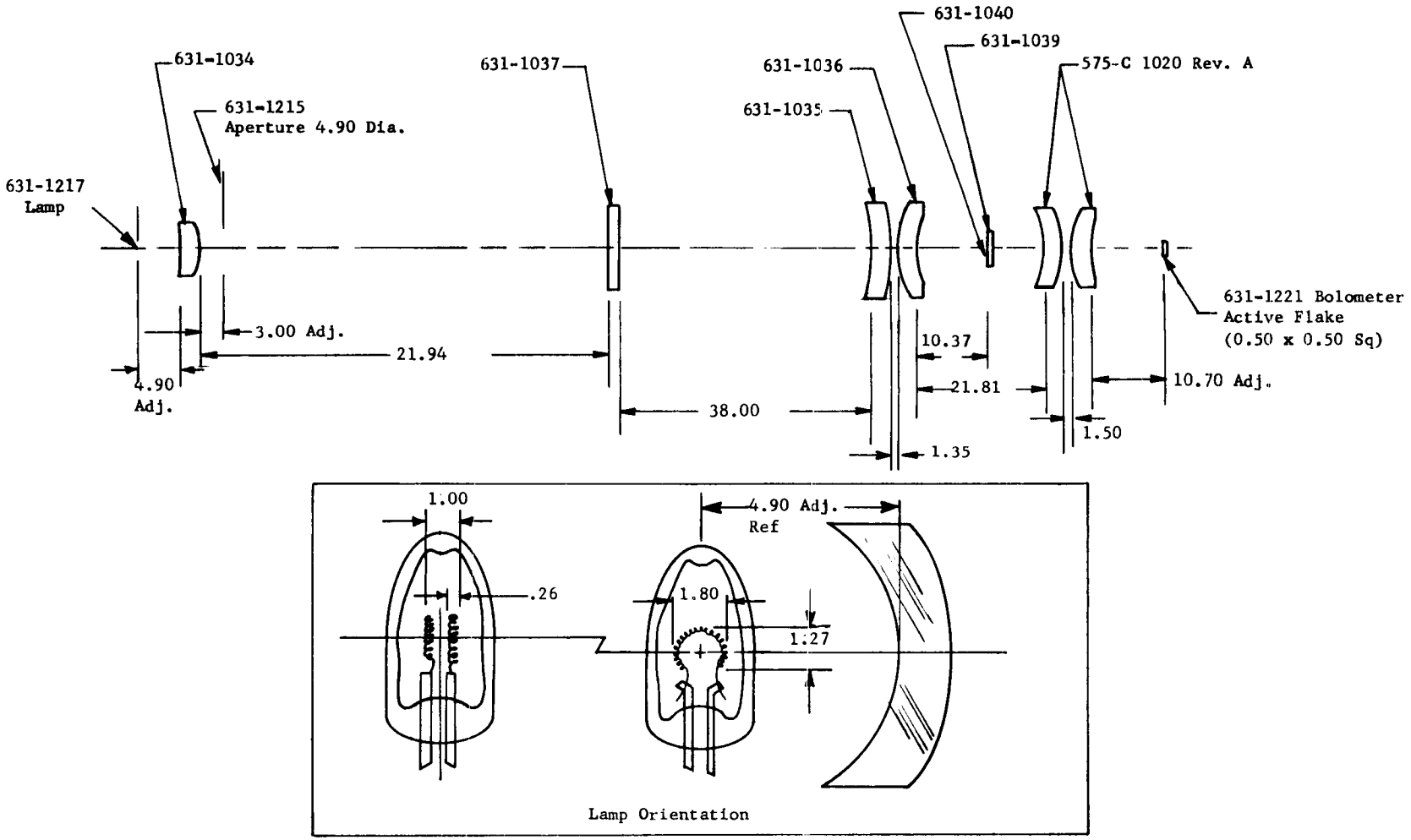


Figure 34. IR Optical Schematic

F. ABSOLUTE PRESSURE TRANSDUCER

Following the direction specified in the contract, an investigation was made into various types of absolute pressure transducers. The technical proposal for Phase II had recommended a potentiometer type as being most suitable. However, the study continued and a comparison was made of a potentiometer, a strain gauge, and a variable reluctance type. The principal advantage of the potentiometer type was its direct application to our system and its electrical simplicity. The strain gauge had the principal disadvantage that it required a more elaborate electronic system for its use. This requirement was even more severe for the variable reluctance type, which required an ac input/output circuit and a synchronous demodulator electronic system for its use.

It was determined at the conclusion of the study that a potentiometer type would only be considered because of the system electronic requirements. The strain gauge type did not lend itself to practical gain control due to the floating characteristics of the internal bridge circuit. The variable reluctance unit required additional electronics and was not easily adaptable to gain control. The first order of specifications which were considered were a weight below 3 ounces and a static error band of less than ±2 percent, including a 50°F temperature rise. A survey of prospective vendors was reduced to Bourns which supplied a unit of ±1.7 percent accuracy, Computor Instruments, which supplied an instrument of 1.8 percent accuracy, and Servonic, which supplied two units of better than ±1 percent accuracy.

The Servonic unit was selected because of its excellent accuracy and weight values and instrument design considerations. All sealing was welded except for the electrical connector, which was an Apollo approved glass to metal hermetic seal. The special unit we required was very nearly the same as their Model 3031 low pressure transducer. This unit measured one inch OD by 1 inch long and weighed 1.8 ounces. Although subminiature and light weight, the unit will withstand 100 g's acceleration with an error of less than 1 percent. The high level ac or dc output can be used without further amplification. The hermetically sealed stainless steel case affords protection against dust, sand, and salt spray to the internal mechanism. The transducer is specifically designed for high accuracy during severe environmental stress. Its compactness and exceptionally reliable performance characteristics made it the ideal selection for this use. The transducer uses a single aneroid capsule as the sensing element. The capsule displacement is transmitted by a unique metal belt linkage system to the wiper element of a precision wire-wound potentiometer. The entire moving system is counterbalanced to minimize errors.

The preliminary specification, which was submitted to Servonic on January 3, 1967, specifies a 10,000 ohm winding resistance and a pigtail electrical connection. Resolution was to be ± 1/4 percent over the range of 0 to 15 psia. The overall accuracy of the transducer, including temperature effects, was to be within ± 1 percent without electronic temperature compensation. Refer to Appendix A for an analysis applicable to problem of accuracy. The preliminary specification for the pressure transducer was

defined in Perkin-Elmer drawing 631-1152. On January 26, 1967, Servonic responded to our request with a bid suggesting a modification of their standard Model 3261 pressure transducer as the most applicable to our requirement. The difference between the Model 3261 and the Model 3221 was that the former is a single stack capsule, which will withstand 200 percent overpressure, while the latter is a multistack capsule that will withstand a 2000 percent overpressure.

An order was placed in February 13, 1967 for a prototype transducer in accordance with our drawing 621-1052. On March 6, 1967 production quantities were ordered in accordance with our drawing 631-0014. The units were received on March 21, 1967. The units were examined visually for dimensional compliance, surface finish, identification markings, and pressure fittings. The weight was 2.31 ounces. Electrical tests were performed showing the potentiometer resistance to be 10,000 ohms nominal with an installation resistance greater than 100 megohms, and a noise of less than 100 ohms. The error band for the units under test, defined as the allowable deviation from straight line drawn through zero pressure at 300 ohms and full pressure at 9700 ohms, and including the effects of nonlinearity, hysteresis, repeatability, resolution, and the change due to temperatures from ±40°F to plus 90°F, was less than ±50 ohms. Each unit was subjected to a proof pressure of 22.5 psia for one minute.

G. OPTICAL CHOPPER

As a continuation of the study effort for an optical chopper, a quotation request was initiated on February 17, 1966 to M.F.E. Inc. of Cambridge, Massachusetts, for a prototype torsional chopper in accordance with engineering requirements and for five production units of approved design. The requested performance requirements were ± 6° motion with an input power of 60 milliwatts, a minimum possible size and weight, a 4 months continuous operating life, linearity of ± 2 percent over the 6° deflection, hysteresis of less than 1 percent, repeatability error of less than 2 percent, and critical damping with 90 percent of the final value reached in 6 to 8 milliseconds. The bearings that were specified were Bendix Flexure Pivot Bearings with ± 15° ratings.

In early March, M.F.E. responded with a request for deviations to the extent that 100 milliwatts would be required with an angular motion of ± 5°. M.F.E. proposed a unit very similar to their part number R-4-400.

After a visit to the vendor's facility, a purchase order was issued for a prototype optical chopper with 125 Hertz resonance, a two-coil configuration of 200 ohms per coil, with 1/4 inch lamination stack, and a 1 inch by 2 inch cross-section, using Bendix ± 15° flexure bearings. The actual performance of this first prototype required 0.21 watt at 125 Hertz, using two Bendix bearings - part numbers 5005-600 and 6005-600. The unit required 46 milliamps at 4.6 volts for a 5° deflection. Operation with a frequency of approximately 90 cycles required an input power of 100 milliwatts.

The first unit received was returned to the vendor because of incorrect positioning of the rotor assembly in the case. One spring in the flexure bearing was bent and the rotor was detented at one point within its normal travel range. This unit was repaired by the vendor and returned to Perkin-Elmer, where it was installed into the Breadboard System for tests. The returned unit required 52 milliamps at 10 volts for a 5° deflection.

The torsional chopper (631-1029) on its mounting bracket with the assembled chopper arm (631-0121) is shown in figure 35. The left-hand side of the chopper arm contains the 4.0 micron and 4.27 micron filters. The right-hand side is the UV channel chopper. The operation of the chopper is discussed in Section IIB.

H. BREADBOARD

The breadboard was constructed to operate as a functional engineering model to perform component tests, determine system variables and to act as a control for comparison with the production units.

The breadboard consists of two major sections: an optical-mechanical section, and an electronic section. The optical-mechanical assembly is shown in figure 36. This unit contains the UV source, the monochromator, the O_2 sample cell, and the UV detector. It also contains the optical chopper and the IR channel components. The assembly is capable of being subdivided into the UV channel and IR channel.

The IR side contains an adjustable sample cell path to permit optimum design of that section. The assembly was used in a purged, inert atmosphere.

The complete breadboard is shown in figure 37. The elctronic breadboard contains one circuit card for each welded module and is completely functional. A typical circuit card is shown in figure 38.

The electronic breadboard proved invaluable as an aid in the welded module effort. It was used first to develop the test criteria and later as a test model to simulate malfunctions experienced during manufacturing.

The following tests were performed on the breadboard:

1. Determination of Beam Diameter at IR Chopper

The purpose of the test was to see if the optical beam diameter at the infrared chopper is satisfactorily small to insure both IR and UV system operation. The measured beam diameter of 0.76 mm exceeds the design value of 0.50 mm and required redesign for the final design. This redesign involved the majority of the lenses within the IR system, and resulted in an increase in size of the system, necessitating a relocation of other major components within the sensor.

2. IR Bulb Image Location Test

The purpose of the test was to determine whether the stop or the bulb filament is imaged on the bolometer detector. The breadboard infrared

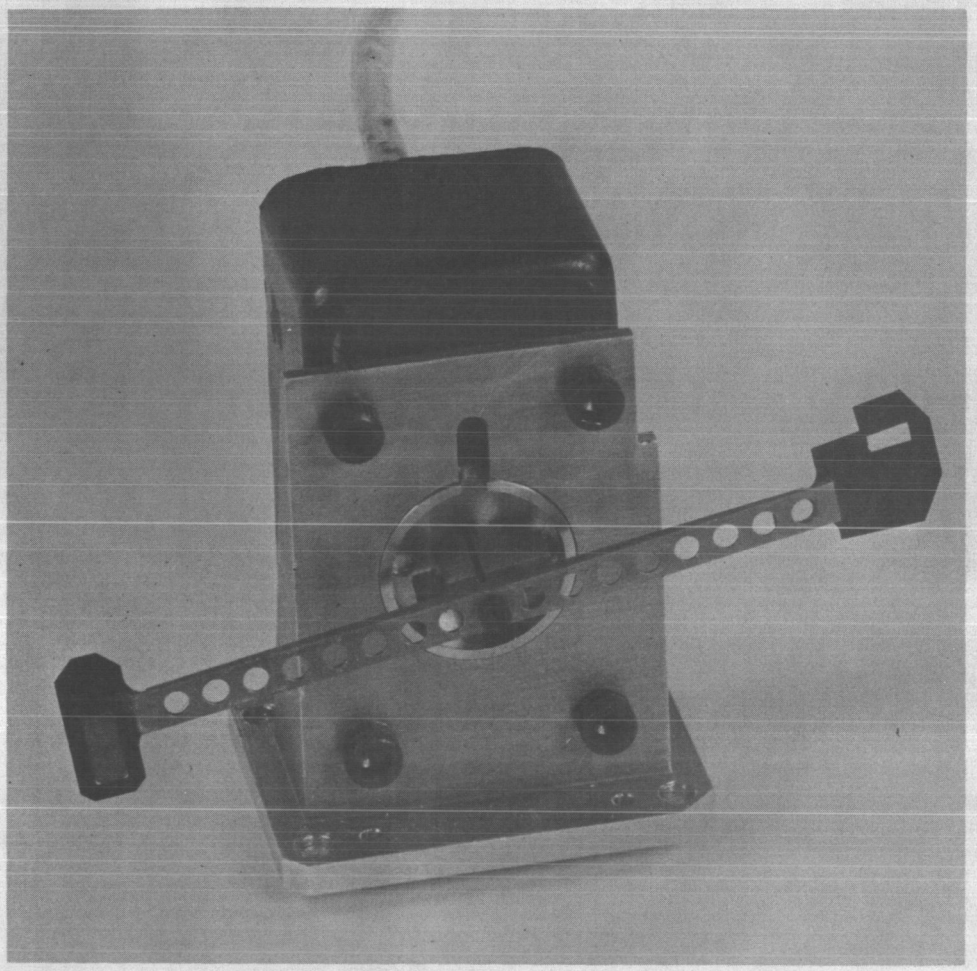


Figure 35. Torsional Chopper

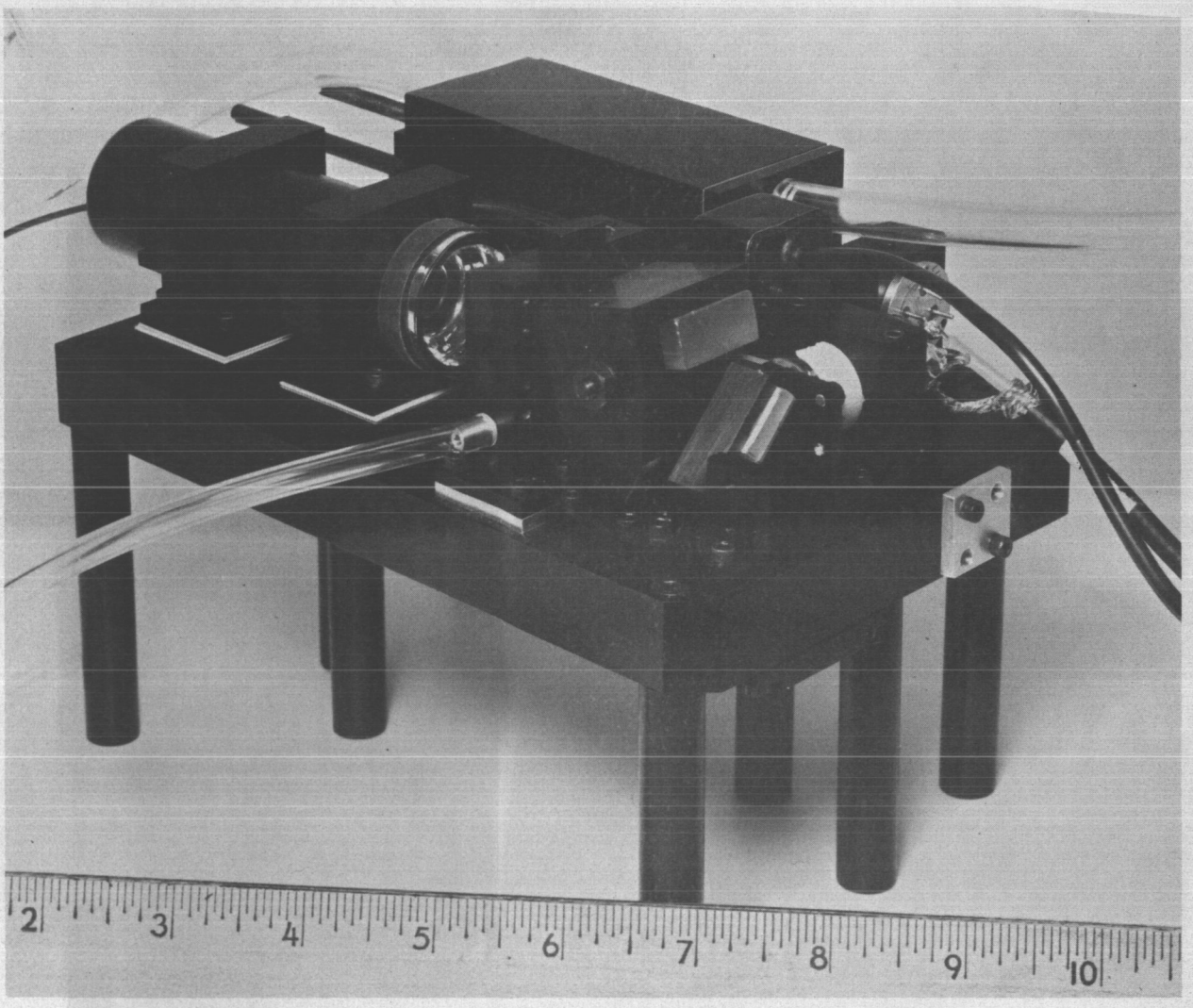


Figure 36. Optical-Mechanical Assembly (Breadboard)

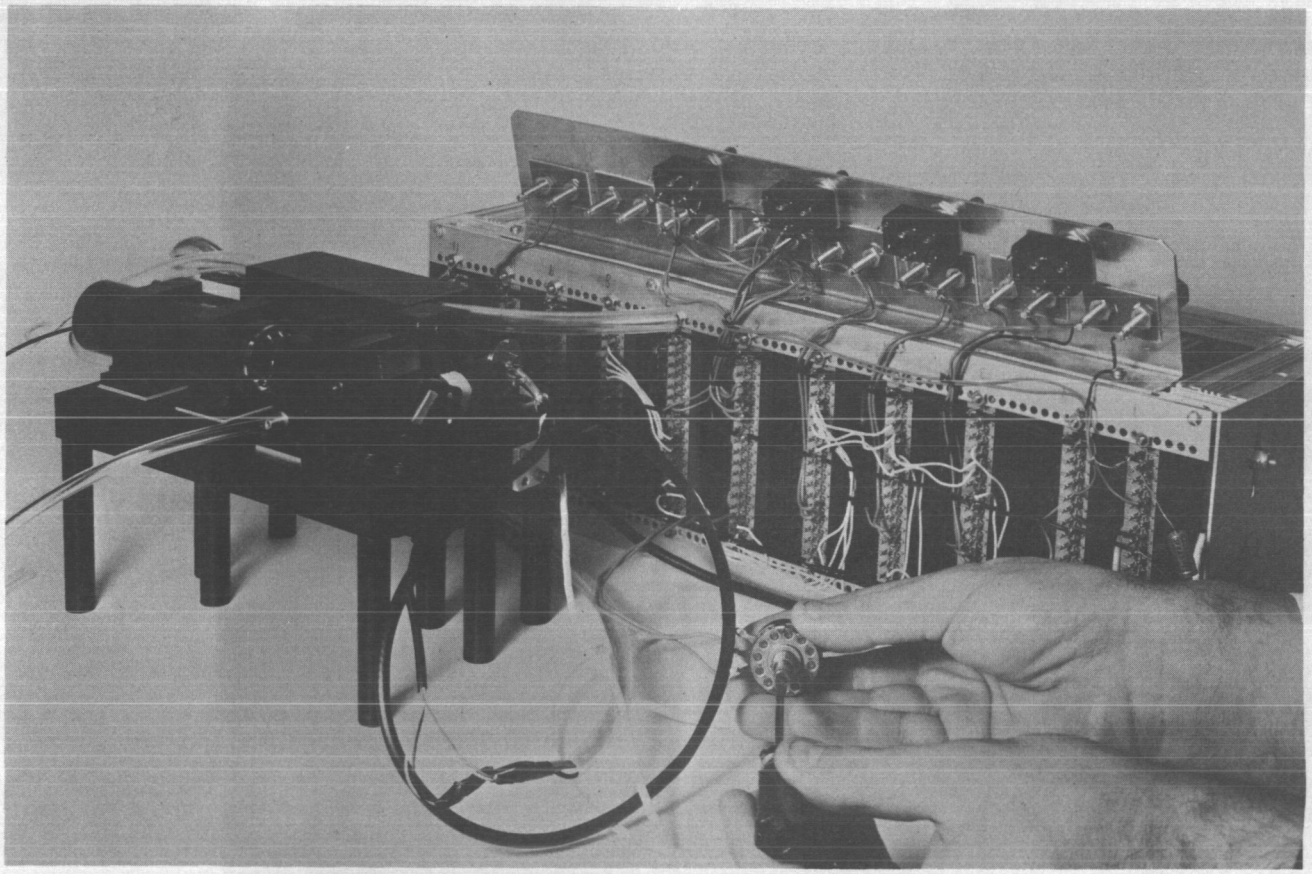


Figure 37. Complete Breadboard

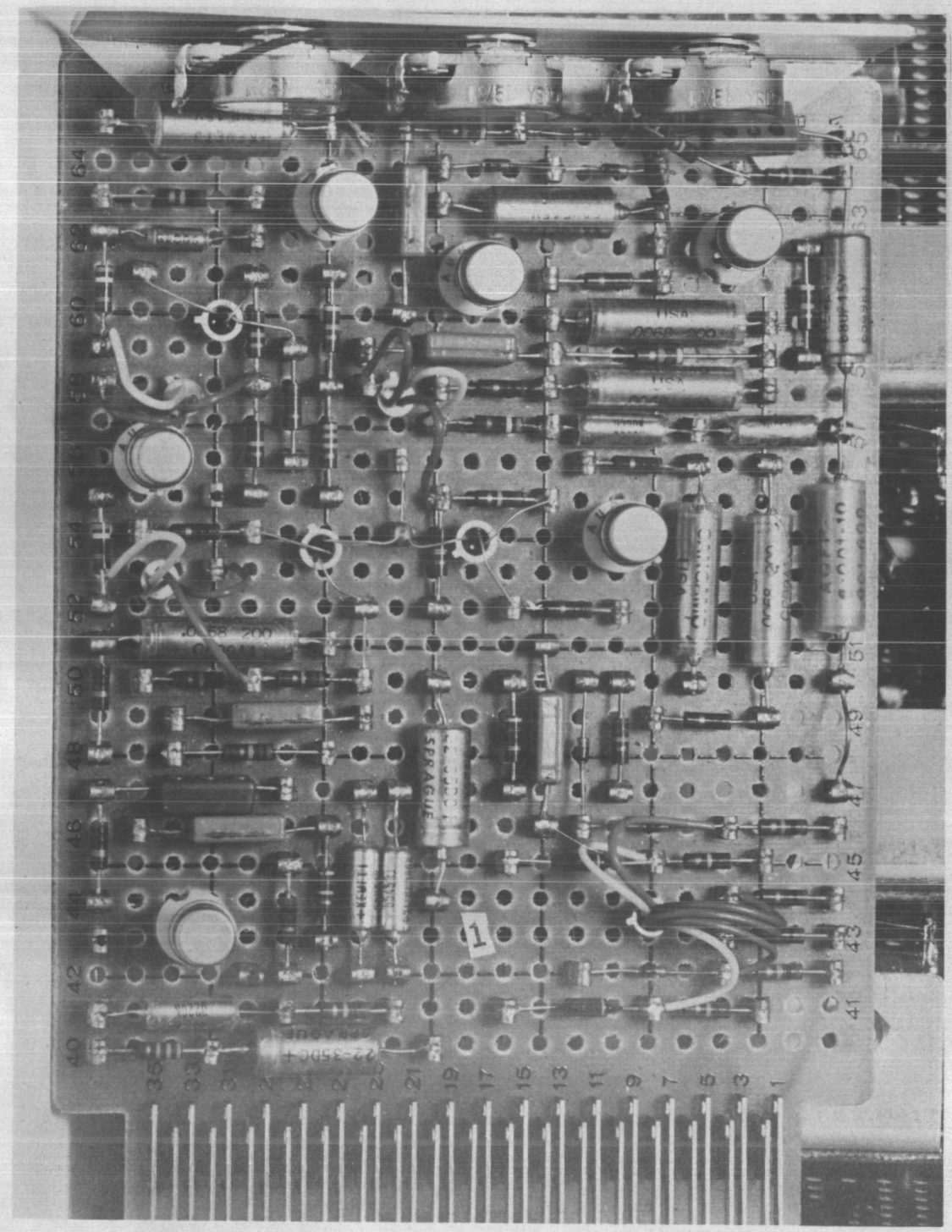


Figure 38. Typical Circuit Card

optical alignment was acceptable. The image stop of 4.9 mm diameter is imaged on the detector.

3. Infrared Source Movement Effects

The purpose of the test was to determine the system reaction to longitudinal and axial bulb filament movement. The system performance is not hampered by longitudinal bulb movement since only signal intensity changes. System output is insensitive to axial bulb movement.

4. Infrared Sample Cell Absorption Test

The purpose of the test is to obtain data for evaluation of optimum cell length for the CO_2 channel. Cell lengths of 3.5 cm to 6.0 cm were used. Curves were obtained, for each cell length, of transmittance versus partial pressure of CO_2 for total pressures of 760, 600, 400, and 250 mm Hg. (See figure 39.) The CO_2 partial pressures ranged from 0 to 20 mm Hg. Curves were obtained of transmittance versus total pressure for CO_2 partial pressures of 5, 10, 15, and 20 mm Hg. (See figure 40.) The shorter cell length seemed superior.

Tests were run to obtain additional transmittance data with a 2.2 cm and 4.0 cm cell length. (See figure 41 .) From all of the test-runs, an optimum cell length of 3.8 cm was determined. (See figure 42.)

5. UV Alignment and Gas Tests

Tests were run to align the optics of the UV channel using visible light. By rotating the grating and positioning the entrance and exit slits, an image was lined up horizontally and vertically. During these tests, it was concluded that the alignment and adjustments would be easier if the two folding mirrors could be eliminated. This was accomplished.

Tests were run in a dark room to align the grating in the ultraviolet. Gas tests were run in a nitrogen filled environment to locate the 1470Å line output of a 150 torr xenon lamp. The wavelength of the 1470Å peak was verified by passing 100 percent oxygen through the 0.004 inch sample cell. Similar tests were run to detect H_2O vapor by bubbling nitrogen through water.

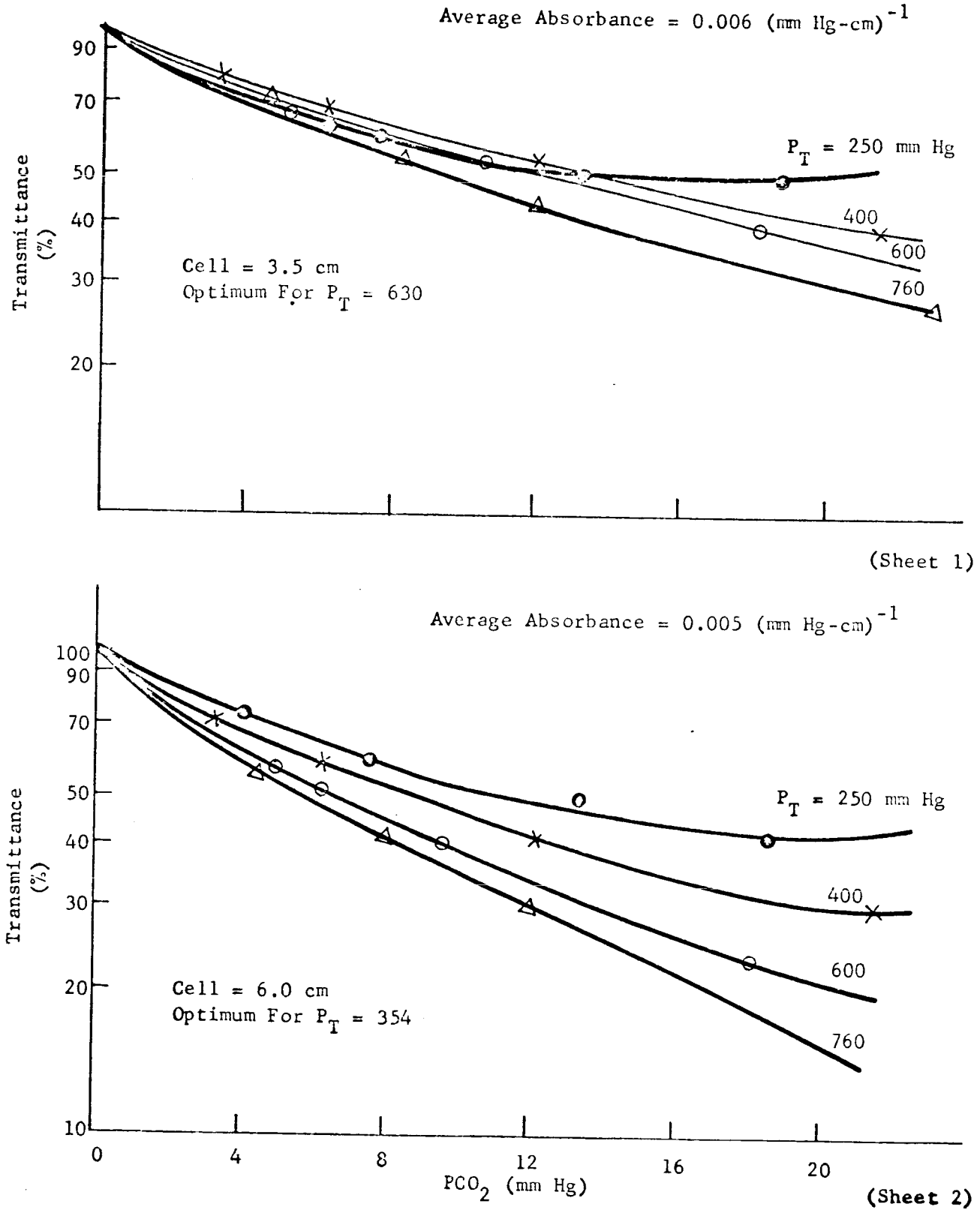


Figure 39. Transmittance versus PCO_2 for Various Partial Pressures

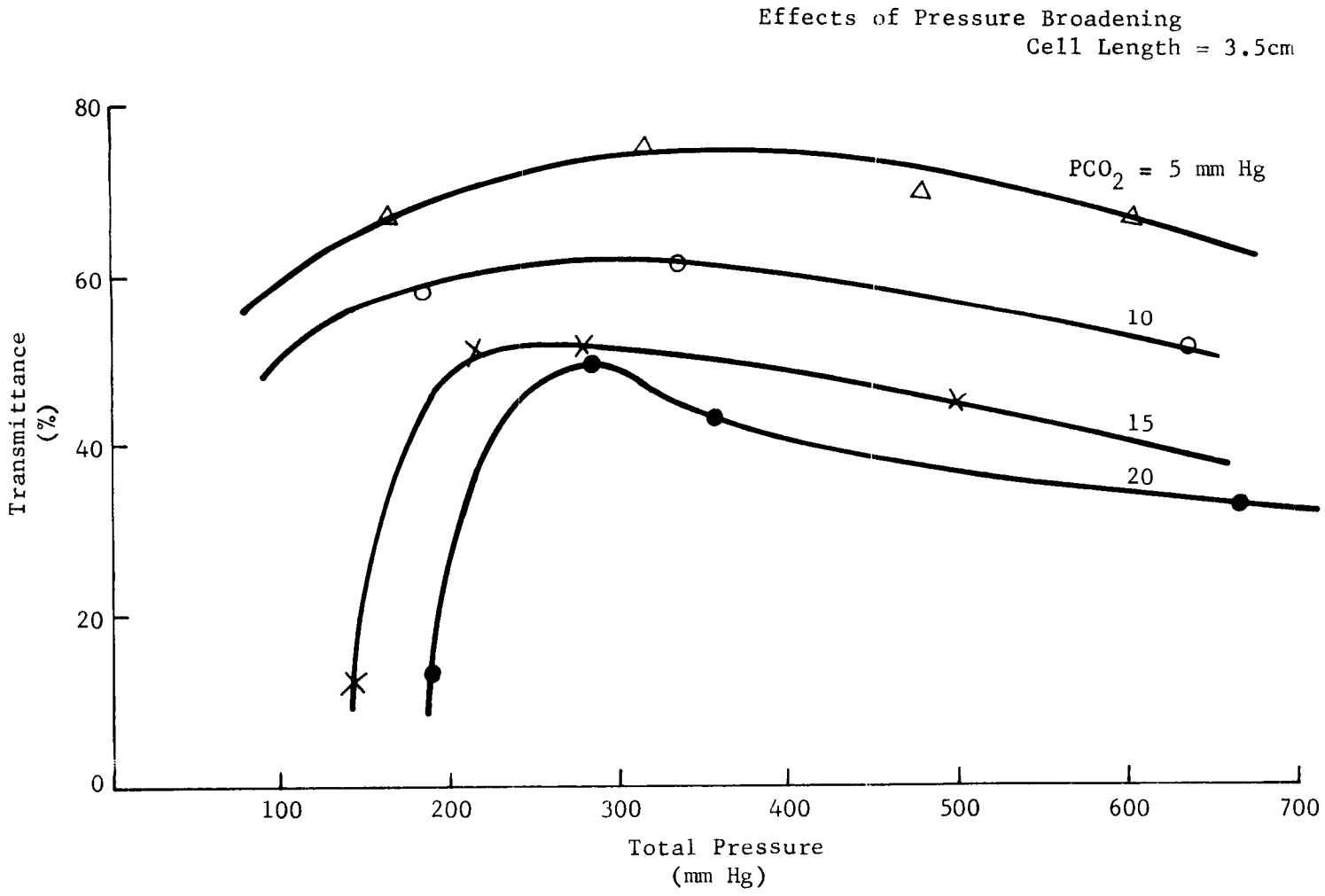


Figure 40. Transmittance versus Total Pressures (Sheet 1)

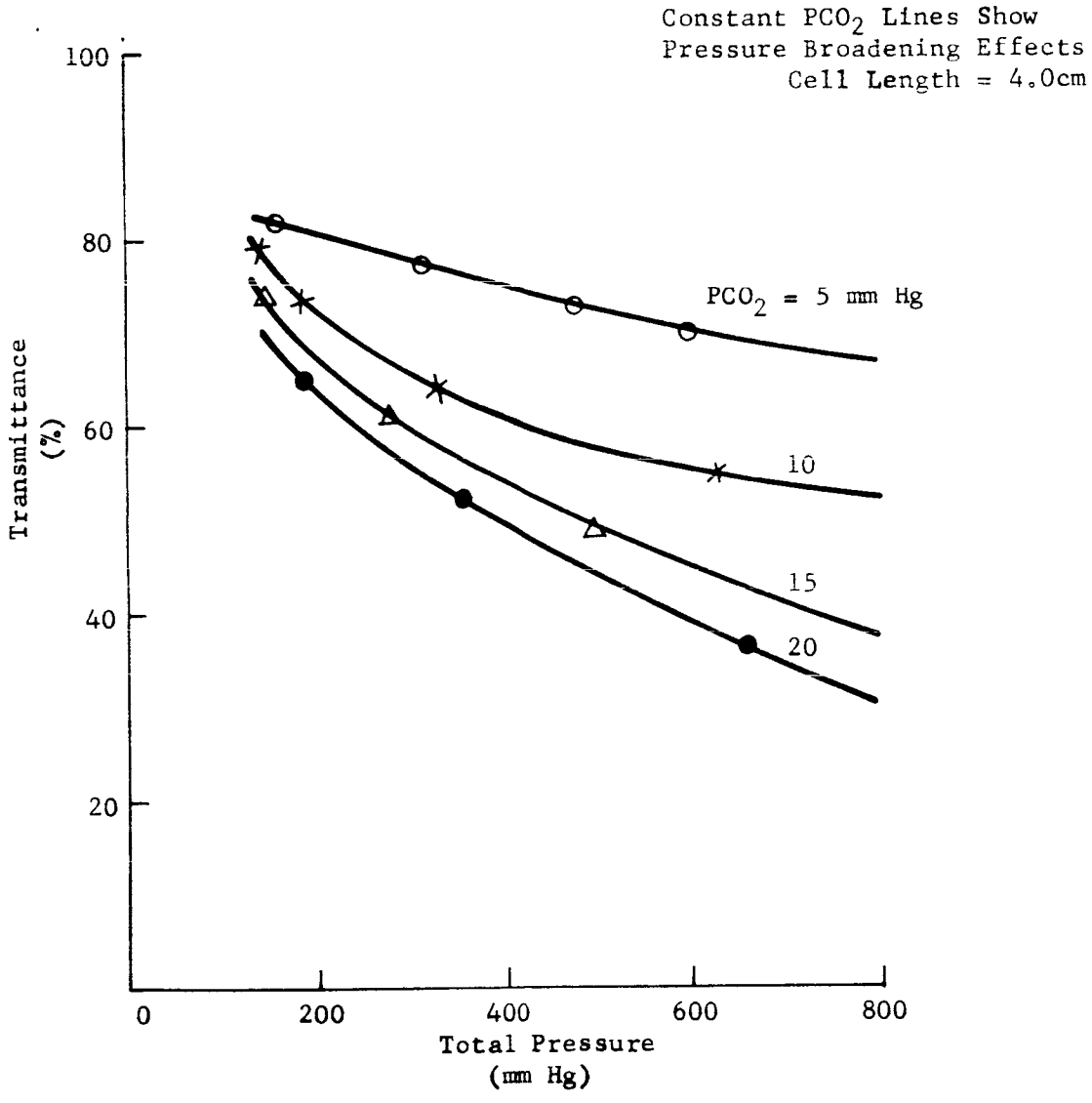


Figure 40. Transmittance versus Total Pressures (Sheet 2)

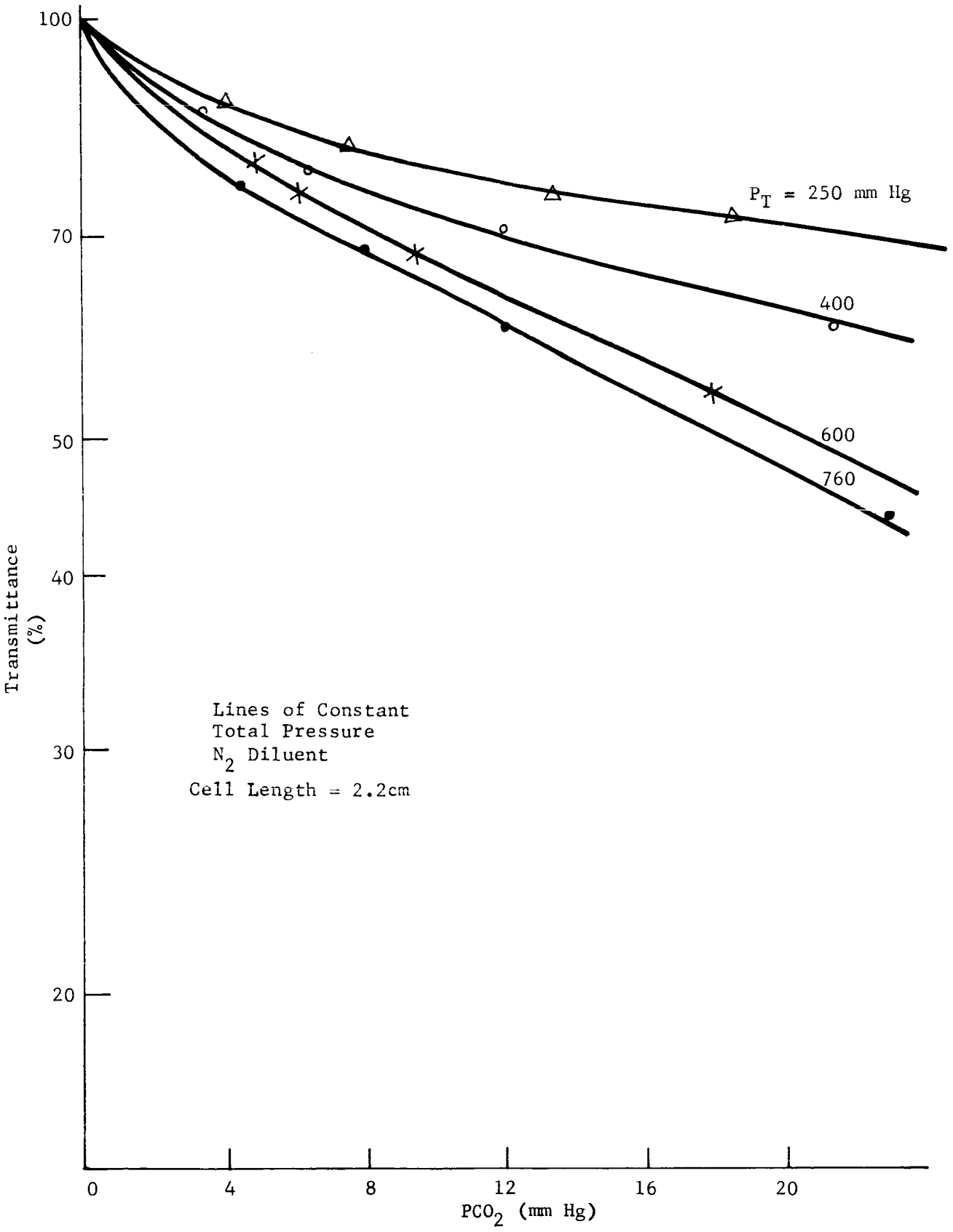


Figure 41. Transmittance versus Total Pressures (Sheet 1)

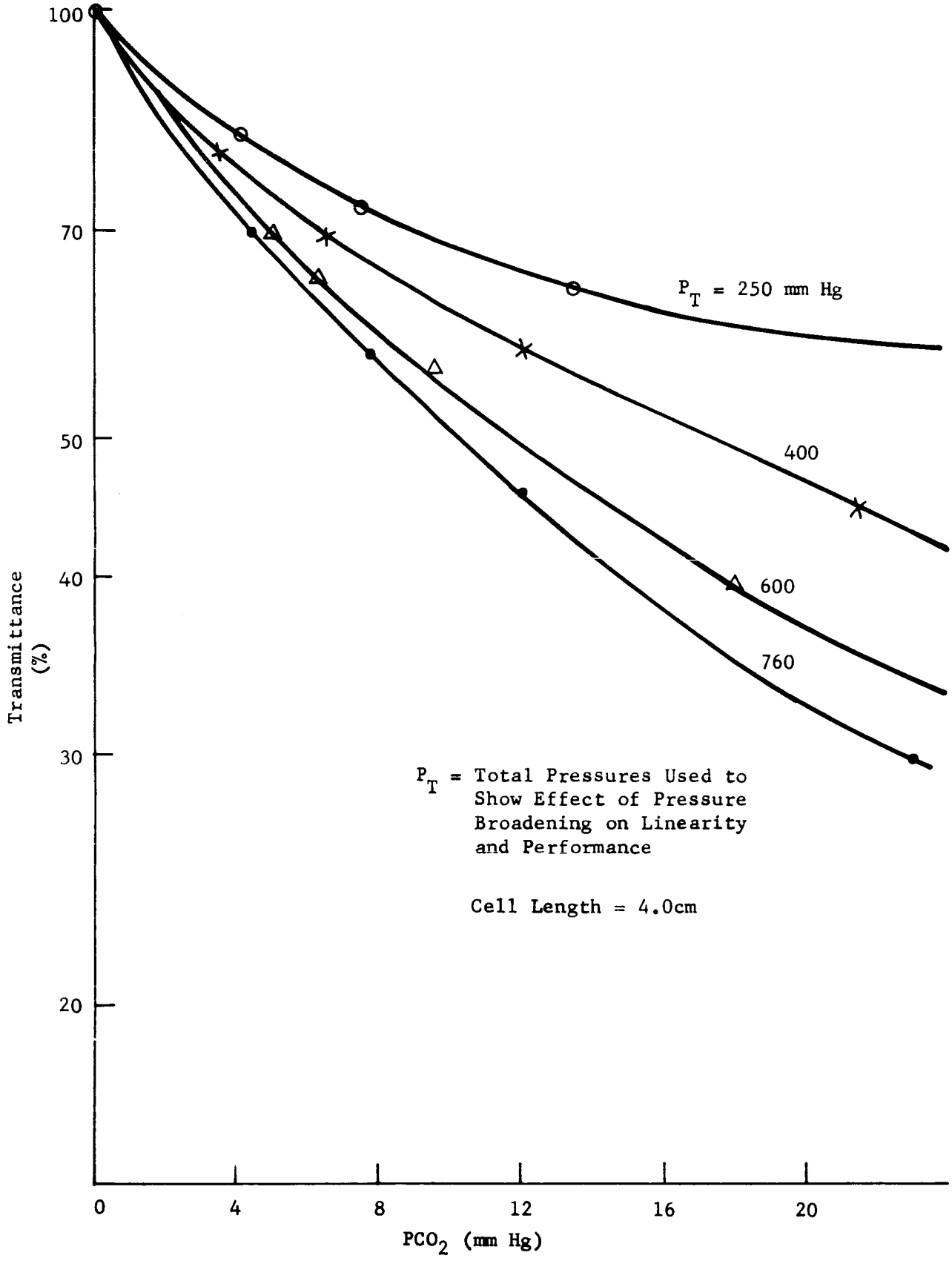


Figure 41. Transmittance versus Total Pressures (Sheet 2)

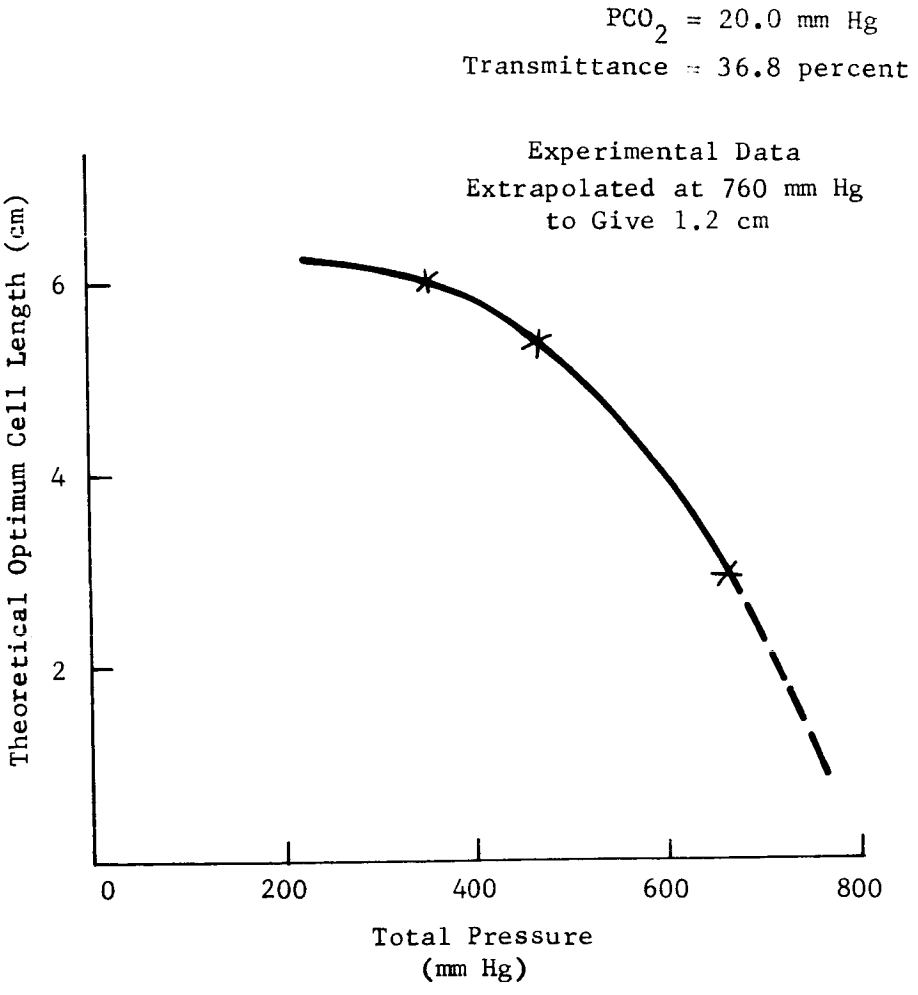


Figure 42. Optimum Cell Length versus Total Pressure

J. FINAL DESIGN

The final design was completed on May 3, 1967 with the submission of the Phase IIa Report. The basis of the design was to provide a system consistent with the formulated mission profile regarding environmental stresses and the conceptual spacecraft model used during the Phase I study. The design criteria given in Table I were established and used as design goals during Phase IIa.

The original estimate of power and weight has been improved from 5 watts, 6-1/2 pounds to 4-1/2 watts, 4 pounds 14 ounces. The general approach and technique have remained unchanged from the original approach of the Phase I study.

Areas of major problems were:

(1) The design of the UV sample cell to meet the minimum pressure drop and response requirements of the original proposal.

(2) The development of the detail design of a rugged, torsional chopper that can be made to dwell at a particular location in space, allowing the maximum amount of information to be transmitted to the detector.

(3) Development of a miniature, low power UV source with long life and specified spectral emission.

(4) Design and fabrication of a miniature, fast UV monochromator.

TABLE I. DESIGN CRITERIA

Electrical:	Power - 28 VDC ± $\frac{1}{2}$ V, 5 watts, max.		
	Ripple - $\frac{1}{2}$ V_{pp}, <± 52 V, 100 μsec spikes		
	Impedance - 50 Ω		
Mechanical:	Size - 110 in^3 (3.5 x 3.9 x 8.0 in)		
	Weight - < 6-1/2 lb.		
Analytical:	Output Voltages - (0 - 5 volt)		
	a. PO_2	125-250 mm Hg	±2% accuracy
	b. PH_2O	0-30 mm Hg	±5% accuracy
	c. PCO_2	0-20 mm Hg	±2% accuracy
	d. P_{Total}	0-760 mm Hg	±1% accuracy
	e. PN_2	100-300 mm Hg	±5% accuracy
	Response Time - 10 sec for 63% of step input.		
Environmental:	Temperature (operating) 40°F to 90°F (storage) -65°F to 200°F		
	Acceleration - ±5 g axial ±1 g lateral		
	Vibration (random) 0.06 g 2/Hz (60 - 400 cps)		
	Acoustics - 157 db overall (0.0002 dyne/cm^2)		
	Attitude - any		
	Pressure - 21 psia to vacuum (10^{-4} mm Hg)		
	Rain - MIL-STD-810 - Method 506		

TABLE I. DESIGN CRITERIA (CONT)

Environmental:	Salt Fog - MIL-STD-810 - Method 509
	Fungus - MIL-STD-810 - Method 508
	Sand and Dust - MIL-STD-810 - Method 510
	Humidity - Zero and 100% R.H. (0°F to 100°F)
	EMI - To be defined
Life:	Storage - 3 years
	Operating without calibration - 120 days
	Operating (total) 1 year
Sample Gas Conditions:	Total Pressure (P_T) 362 ± 11 mm Hg alternate: 760 mm Hg
	Oxygen Partial Pressure (PO_2) 181 ± 5.5 mm Hg
	Nitrogen Partial Pressure (PN_2) Diluent for P_T
	Carbon Dioxide Partial Pressure (PCO_2) < 7.6 mm Hg Brief Excursions to 15 mm Hg
	Water Vapor Pressure (PH_2O) 2.2 to 27.1 mm Hg
	Temperature 40°F to 90°F
Power Penalty:	1/2 lb/watt
Product Assurance Guides	
	Product Assurance Plan
	NPC 250-1 (Reliability)
	NPC 200-4 (Wiring)
	NPC 200-2 (Quality Assurance)

(5) Design and fabrication of a miniature IR optical system with a sealed sample cell.

(6) Design and fabrication of a sophisticated electronic system having 840 components in a total volume of less than 30.5 in^3, for a packaging density of 27.5 components/in^3.

The UV Sample Cell Assembly (631-0107) is shown in figure 43. The UV source is shown in its final position at the top of the assembly. The upper slit on the face of the assembly is for the O_2 channel at 1470A. The lower slit is adjustable by means of the bottom cam to permit wavelength tuning of the water vapor channel. The sample lines are shown on the right of the assembly.

The hermetic cover (631-0106) is shown in figure 44. This assembly was made by a dip-brazed process due to its complexity and tolerance requirements. The purpose of this part is to act as a leaktight cover on the optical sections and to provide a mounting support for the welded modules. The complexity of its form is to permit the most efficient utilization of the total volume of the sensor. There are only a few cubic inches in the entire sensor that are not occupied by components. It is estimated that 90 percent of the total volume of 122 in^3 is occupied by the system components.

The nickel tubing on the cover is to permit the filling of the inert gas in the optical compartment. These tubes are pinched off and solder-sealed after filling. The feedthrough electrical connectors are potted after wiring to provide strain relief and high voltage breakdown protection.

Figure 45 shows several of the principal components of the system. The photomultiplier detector is shown on its mounting brackets. The grating, UV source, and primary mirror are shown unmounted. The pressure transducer is shown prior to connecting the gas sample lines.

Figure 46 shows the optical compartment components before the UV sample cell and the sample lines are installed.

K. RELIABILITY

The Design Assurance Department provided the reliability input to the program and made its most significant contribution during the Phase II effort. The principal activities in the Reliability Program may be summarized as follows:

(1) Reliability prediction
(2) Reliability mathematical model
(3) Critical area analysis
(4) Worst stress case analysis
(5) Parts selection
(6) Configuration analysis

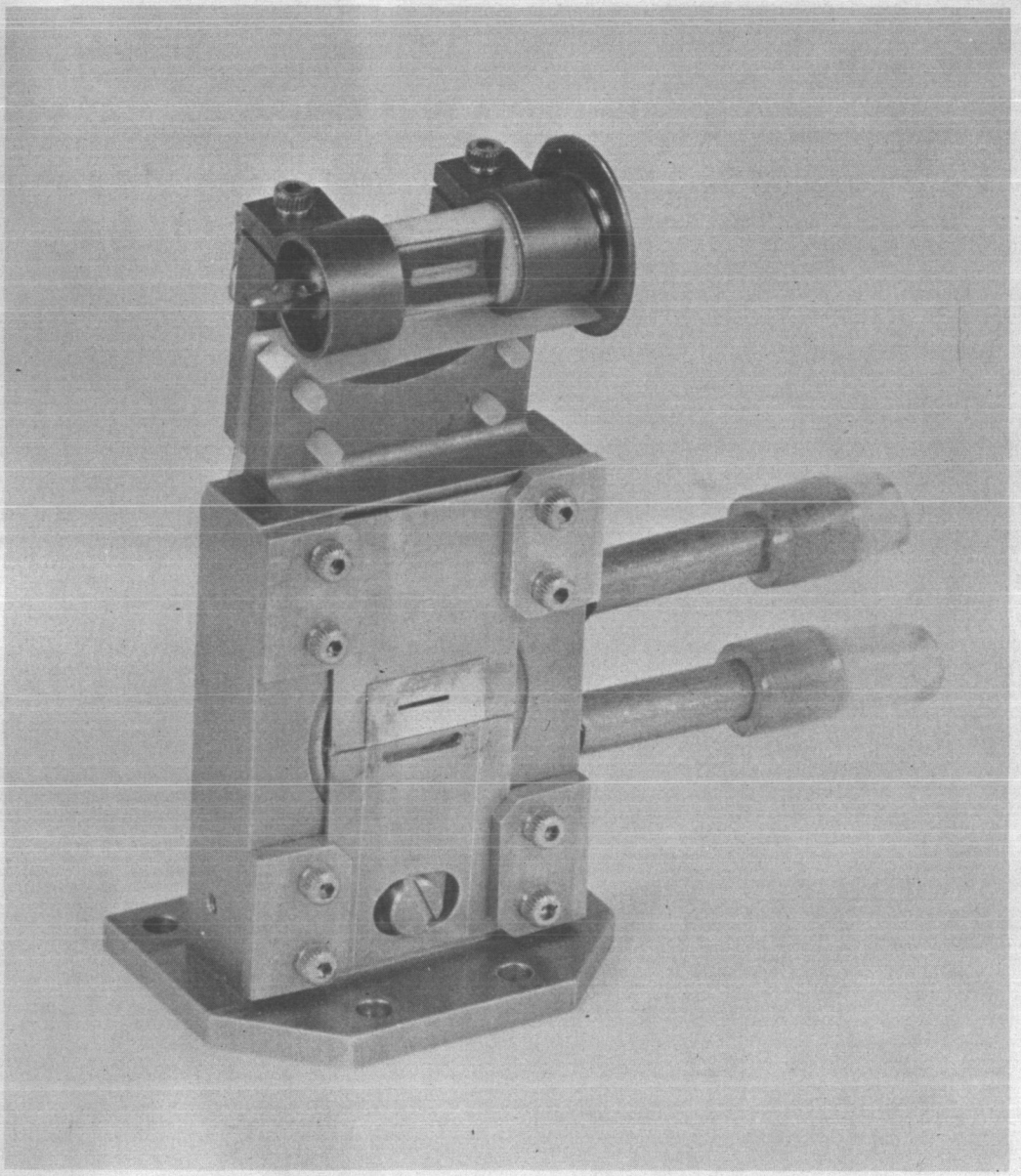


Figure 43. The UV Sample Cell Assembly

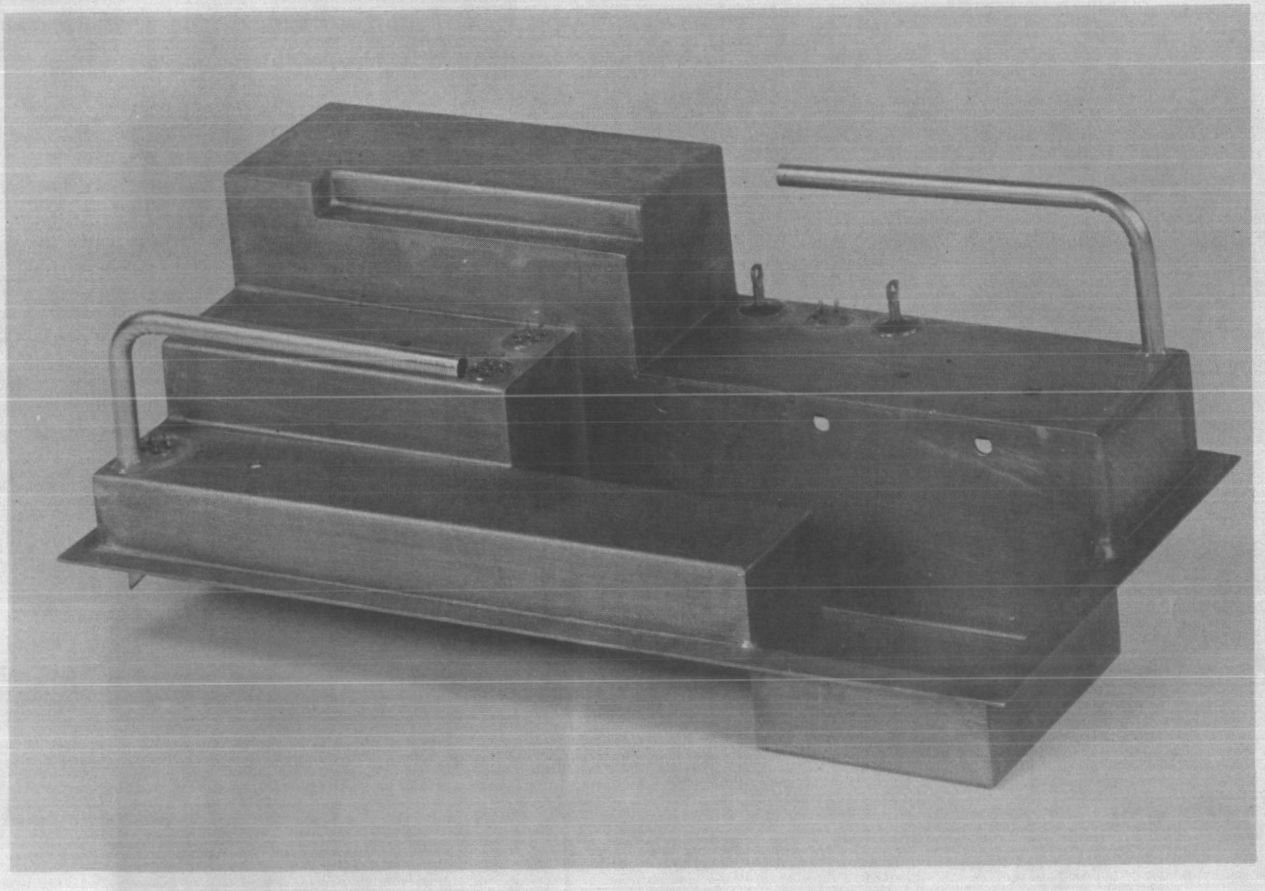


Figure 44. Hermetic Cover

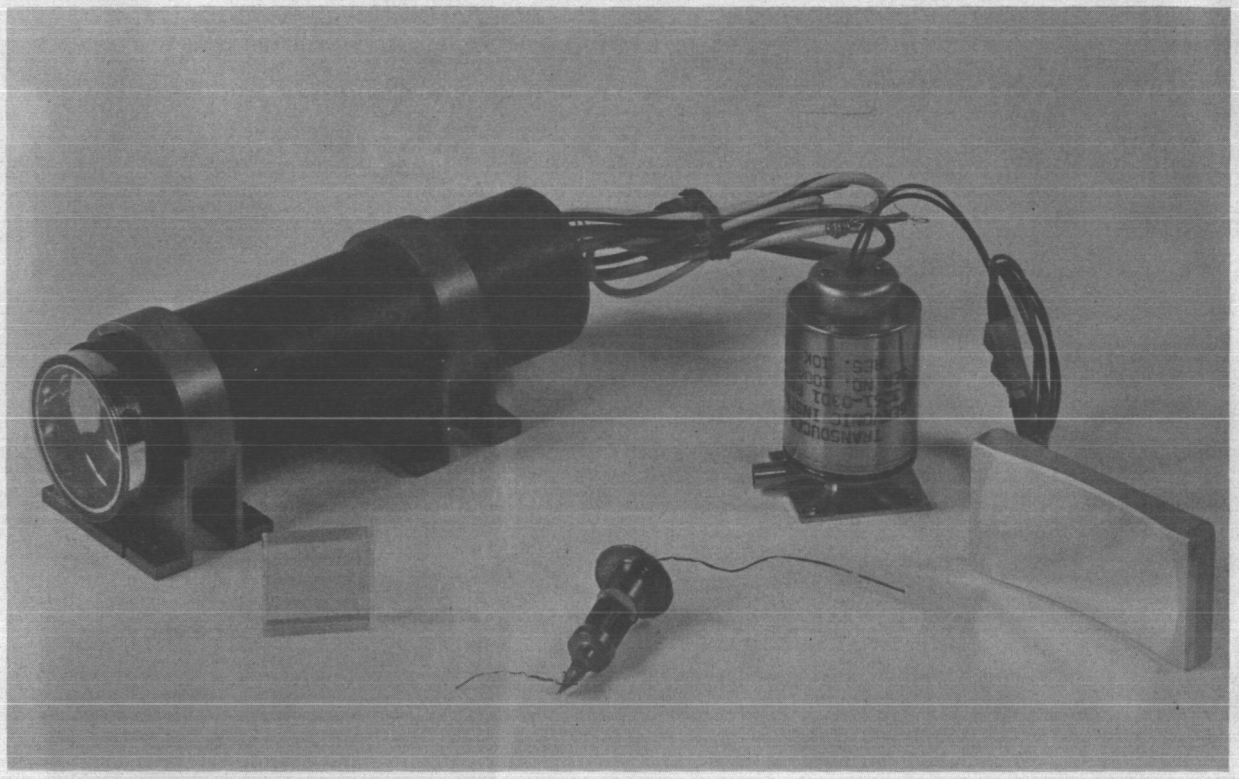


Figure 45. Photomultiplier Detector, Grating, UV Source, Primary Mirror, and Pressure Transducer

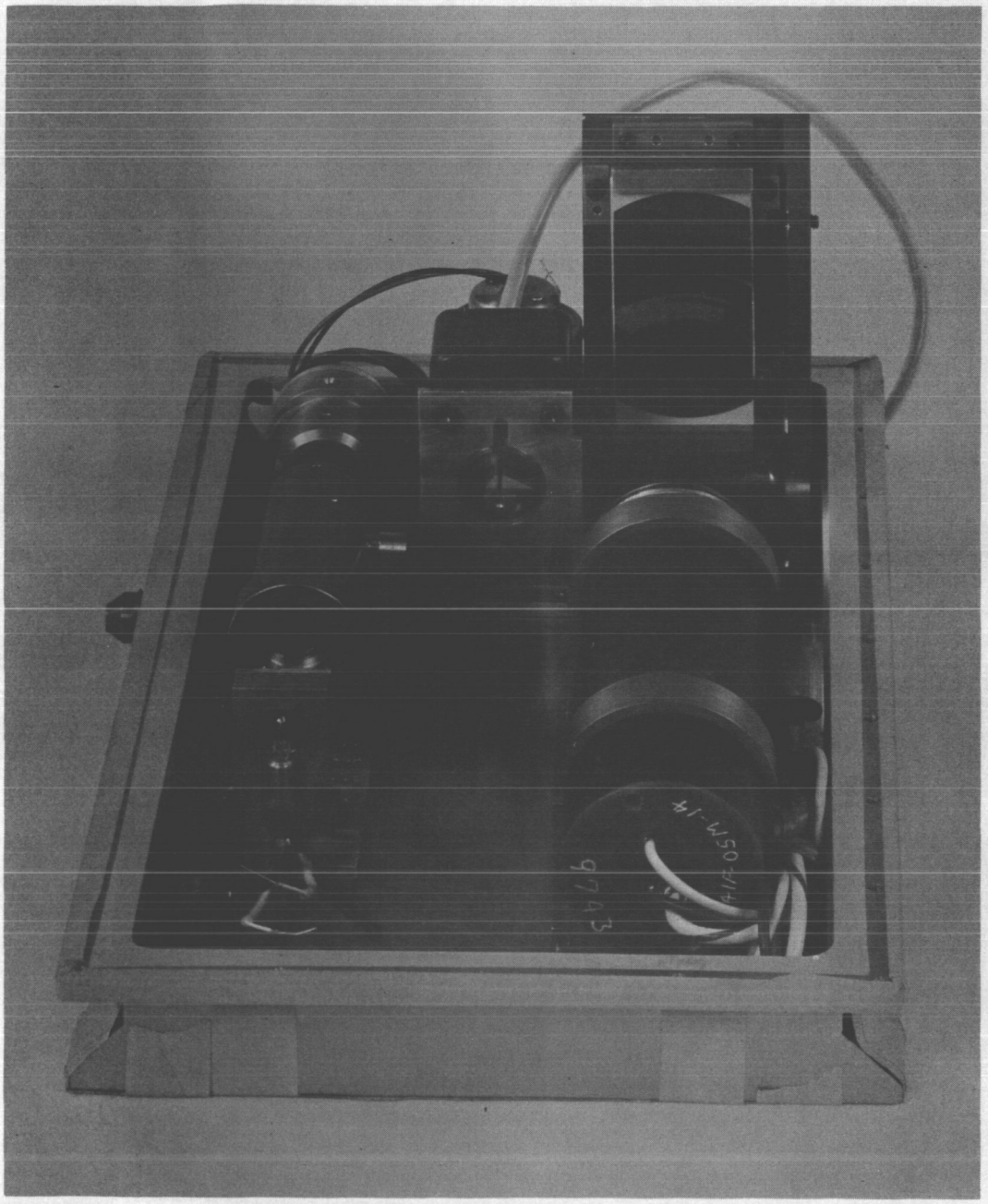


Figure 46. Optical Compartment Components

(7) Design review
(8) Customer and vendor liaison
(9) Monthly status report

A reliability prediction was performed on the Two Gas Atmosphere Sensor System utilizing the data obtained on the stresses from the Worst Case analysis. Failure rate calculations were performed in accordance with the procedures of MIL-HDBK-217A, Reliability, Stress and Failure Rate Data for Electronic Equipment; Martin-Denver Reliability Application and Analysis Guide; and Perkin-Elmer secondary data. Operational environments were used as an application parameter for failure rate calculations. The prediction was updated several times during the program and a final prediction was made at the completion of the program. Figure 47 represents the reliability prediction for the Two Gas Atmosphere Sensor.

A mathematical model of the Two Gas Atmosphere Sensor was constructed during the Phase II program. This is shown in figure 48. Derivation of each functional block indicated on the math model is accomplished by summing failure rates of all components within that particular block. In this manner every major item assembly unit in the entire system will be evaluated in terms of its individual reliability contribution. The effects on system reliability of other factors such as redundancy and operating requirements are disclosed by the Reliability Block diagram. Reliability problem areas have been indicated by the math model and subsequent improvements made, wherever possible.

A critical area analysis was performed on those areas which were considered to have a major impact upon the reliability of the overall system. These items included:

(1) The Infrared source
(2) The Ultraviolet source
(3) The Torsional chopper
(4) Optical material, particularly the sapphire used in the UV sample cell
(5) The Gas compartment and hermetic cover seals
(6) The Total Pressure Transducer
(7) The individual electronic modules and the components used in these modules

The electronic modules or individual circuits were comprehensively analyzed by Design Assurance Engineering to meet the operational specifications and requirements. Design Assurance jointly, and then independently, reviewed the assemblies to insure that the specifications could be attained and that proper design procedures were being utilized.

Using computer programs, the Design Assurance Group performed a worst case analysis on all of the electronic circuits. The representative sample of this program is presented in this section.

CHANNEL / MODULE	CHANNEL FAILURE RATES				SYSTEM FAILURE RATES
	Pt, N_2	CO_2	O_2	H_2O	
01000 Module A9	14.361	14.361	14.361	14.361	14.361
02000 Module A8	8.0625	8.0625	8.0625	8.0625	8.0625
03000 IR Lamp	1.000	1.000	——	——	1.000
04000 Optics	0.050	0.050	——	——	0.050
05000 Module A7	13.365	13.365	13.365	13.365	13.365
06000 UV Lamp	0.200	——	0.200	0.200	0.200
07000 Optics	0.050	——	0.050	0.050	0.050
08000 Opt. Chopper	0.401	0.401	0.401	0.401	0.401
09000 Samp. Cell	0.007	0.007	——	——	0.007
10000 IR Detector	0.500	0.500	——	——	0.500
11000 Module A1	3.471	3.471	——	——	3.471
12000 Module A3	7.771	7.771	——	——	7.771
13000 Samp. Cell	0.007	——	0.007	0.007	0.007
14000 Photomult.	1.000	——	1.000	1.000	1.000
15000 Module A2	1.1695	——	1.1695	1.1695	1.1695
16000 Module A3	7.771	——	7.771	——	7.771
17000 Module A3	7.771	——	——	7.771	7.771
18000 Transducer	7.000	——	——	——	7.000
19000 Module A6	17.175	——	——	——	17.175
TOTAL F.R.	91.132	48.9885	46.387	46.387	91.132
MTBF	10973 HRS	20413 HRS	21558 HRS	21558 HRS	10973 HRS

Figure 47. Reliability Prediction by Channel

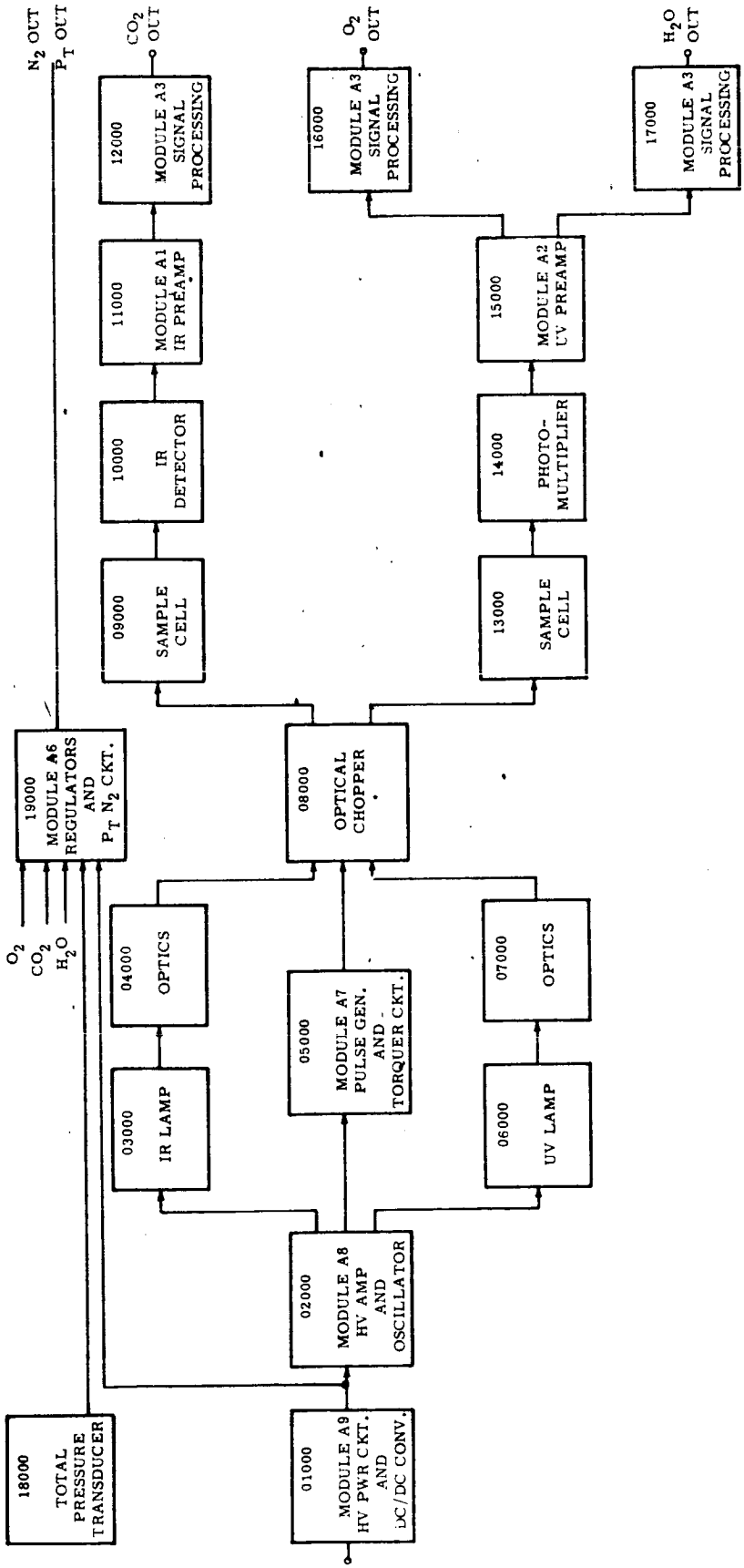


Figure 48. Two Gas Atmosphere Sensor Reliability Mathematical Model

DESCRIPTION: Two Gas Sensor-Module Al IR Preamp

CODE NO.: 631-0001

RELIABILITY ENGINEERING ANALYSIS

GENERAL INFORMATION				STRESS ANALYSIS			FAILURE MODE ANALYSIS	FAILURE EFFECTS ANALYSIS	THERMAL FAILURE RATE	APPLICATION FACTORS			CRITICALITY FACTOR	TIME (HOURS)	RELIABILITY EXPONENT
				STRESS											
DESCRIPTION OF ITEM	SYMBOL REFERENCE	FUNCTION OF ITEM	MODE	A RATED	B OPERATED	RATIO B/A	FAILURE THERMAL	FAILURE EFFECT ON CIRCUIT	λ'	K_E	K_A	DERATING	β	t	$(\lambda' t\ K_E\ K_A\ \beta)$
Capacitor CSR13B566KM	C1			6V	1.2	0.2			0.07						
Capacitor CSR13B566KM	C2			6V	1.2	0.2			0.07						
Capacitor CSR13F685KM	C3			35V	0.29	0.08			0.053						
Capacitor CSR13F685KM	C4			35V	0.29	0.08			0.053						
Capacitor CSR13J275KM	C5			100V	40	0.4			0.17						
Capacitor CKR06CW104KM	C6			100V	40	0.4			0. 0054						
Capacitor CKR05CW220KM	C7			200V	0.25	<0.01			0.005						
Capacitor CSR13J275KM	C8			100V	40	0.4			0.17						
Capacitor CKR05CW102KM	C9			200V	0.25	<0.01			0.005						
Capacitor CSR13D686KM	C10			15V	7	0.47			0.31						
Capacitor CSR13F685KM	C11			35V	0.25	<0.01			0.053						
Capacitor CKR06CW104KM	C12			100V	40	0.4			0.005						
Capacitor CSR13D226KM	C13			15V	5.2	0.34			0.13						
Capacitor CSR13F685KM	C14			35V	0.25	<0.01			0.053						
Capacitor CKR06CW472KM	C15			200V	<18	<0.01			0.053						
Capacitor CKR05CW220KM	C16			200V	0.25	<0.01			0.005						
Capacitor CKR05CW221KM	C17			200V	<18	<0.01			0.005						
Capacitor CKR06CW104KM	C18			100V	18	0.18			0.005						
Capacitor CSR13G105KM	C19			50V	0.25	<0.01			0.053						

COMMENTS

Module Al Total Failure Rate - 3.368 Failures/Million Hours

ISSUE DATE	PREPARED BY	APPROVED BY
June 3, 1968	H.K.Chesters	L.Pabian

DESCRIPTION: Two Gas Sensor-Module Al IR Preamp

CODE NO.: 631-0001

RELIABILITY ENGINEERING ANALYSIS

GENERAL INFORMATION				STRESS ANALYSIS			FAILURE MODE ANALYSIS	FAILURE EFFECTS ANALYSIS	THERBLIG FAILURE RATE	APPLICATION FACTORS			CRITICALITY FACTOR	TIME (HOURS)	RELIABILITY EXPONENT
				STRESS											
DESCRIPTION OF ITEM	SYMBOL REFERENCE	FUNCTION OF ITEM	MODE	A RATED	B OPERATED	RATIO B/A	FAILURE THERBLIG	FAILURE EFFECT ON CIRCUIT	λ'	KE	KA	DERATING	β	t	$(\lambda' t K_E K_A \beta)$
Diode 600-4521-002	CR1			250mw	< 1mw	<0.01			0.10						
Diode 600-4521-002	CR2			250mw	< 1mw	<0.01			0.10						
Diode 600-4521-002	CR3			250mw	< 1mw	<0.01			0.10						
Diode 600-4521-002	CR4			250mw	< 1mw	<0.01			0.10						
Diode 600-4521-002	CR5			250mw	< 1mw	<0.01			0.10						
Diode 600-4521-002	CR6			250mw	< 1mw	<0.01			0.10						
Diode 600-4521-002	CR7			250mw	< 1mw	<0.01			0.10						
Diode 600-4521-002	CR8			250mw	< 1mw	<0.01			0.10						
Microcircuit U5B770931X	AR1			250mw	<100mw	<0.4			0.40						
Transistor 2N2973	Q1			750mw	< 1mw	<0.01			0.10						
Transistor 600-4762-002	Q2			400mw	< 1mw	<0.01			0.20						
Transistor 600-4762-002	Q3			400mw	< 1mw	<0.01			0.20						
Transistor 2N3821	Q4			300mw	2.4mw	<0.01			0.20						
Transistor JAN 2N930	Q5			300mw	1.2mw	<0.01			0.1						

COMMENTS

ISSUE DATE	PREPARED BY	APPROVED BY
June 3, 1968	H.K.Chesters	L.Pabian

FORM 2-0322-00

PERKIN-ELMER

DESCRIPTION: Two Gas Sensor-Module A1 IR Preamp

CODE NO.: 631-0001

RELIABILITY ENGINEERING ANALYSIS

GENERAL INFORMATION				STRESS ANALYSIS			FAILURE MODE ANALYSIS	FAILURE EFFECTS ANALYSIS	THERBLIG FAILURE RATE	APPLICATION FACTORS			CRITICALITY FACTOR	TIME (HOURS)	RELIABILITY EXPONENT
DESCRIPTION OF ITEM	SYMBOL REFERENCE	FUNCTION OF ITEM	MODE	STRESS A RATED	STRESS B OPERATED	RATIO B/A	FAILURE THERBLIG	FAILURE EFFECT ON CIRCUIT	λ'	KE	KA	DERATING	β	t	$(\lambda' t K_E K_A \beta)$
Resistor RC05GF472J	R1			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF472J	R2			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF105J	R3			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF124J	R4			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF124J	R5			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF105J	R6			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF105J	R7			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF272J	R8			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF150J	R9			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF102J	R10			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF474J	R11			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF105J	R12			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF105J	R13			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF223J	R14			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF393J	R15			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF104J	R16			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF274J	R17			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF105J	R18			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF102J	R19			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF152J	R20			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF393J	R21			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF105J	R22			125 mw	<1mw	<0.01			0.0035						

COMMENTS

ISSUE DATE	PREPARED BY	APPROVED BY
June 3, 1968	H.R.Chesters	L.Fabian

DESCRIPTION: Two Gas Sensor-Module Al IR Preamp

CODE NO.: 631-0001

RELIABILITY ENGINEERING ANALYSIS

GENERAL INFORMATION				STRESS ANALYSIS			FAILURE MODE ANALYSIS	FAILURE EFFECTS ANALYSIS	THERBLIG FAILURE RATE	APPLICATION FACTORS			CRITICALITY FACTOR	TIME (HOURS)	RELIABILITY EXPONENT
DESCRIPTION OF ITEM	SYMBOL REFERENCE	FUNCTION OF ITEM	MODE	STRESS A RATED	STRESS B OPERATED	RATIO B/A	FAILURE THERBLIG	FAILURE EFFECT ON CIRCUIT	λ'	K_E	K_A	DERATING	β	t	$(\lambda' t K_E K_A \beta)$
Resistor RC05GF331J	R23			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF124J	R24			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF473J	R25			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF563J	R26			125 mw	<1mw	<0.01			0.0035						
Resistor RC05GF473J	R27			125 mw	<1mw	<0.01			0.0035						

COMMENTS

ISSUE DATE	PREPARED BY	APPROVED BY
June 3, 1968	H.R.Chesters	L.Pabian

FORM 2-0322-00

PERKIN-ELMER

In accordance with the contract, a failure modes and effects analysis (FMEA) was not performed, however the failure modes and effects were considered during the analysis.

Wherever possible, parts were selected that were qualified to existing military specifications. State-of-the-art or newly developed components were used only when test data could be obtained from the manufacturer, verifying that the component was capable of meeting the requirements necessary for proper performance. In general, high reliability parts of established failure rates were used whenever possible. As an alternate, Military Standard parts as defined by the QPL, or drawings or standards, were formalized when nonexistent. Regardless of the specification on the parts, all of the semiconductors used in the program were subjected to X-ray screening, which has proven to be an effective screening method for these parts.

Qualitative configuration analysis was performed on the system. The analysis consisted of tradeoff studies during recent design reviews of the merits of reliability versus maintainability, cost, and time. Studies were performed on the replacement of the least reliable elements and the resultant system weight versus the weight of providing redundancy. This study led to the selection of a dual filament for the IR source, as an example of increased reliability with no loss of weight or functional performance.

The Design Assurance Department reviewed all designs, drawings, and specifications, during the Phase IIa effort, to assure that the reliability aspects of the performance were given due consideration. These reviews were performed throughout the program and were supplemented with informal, almost continual reviews between Design Assurance personnel and the Project Designers. The components and design were reviewed for their ability to meet the operational life and shelf life requirements. Standardized components were used wherever possible, and mechanical, thermal, and electrical stress levels were considered.

Design Assurance Engineering did participate in the review of the reliability requirements of part specifications with vendors supplying major components to the system. Corrective action for various problems with vendors, reliability, processes, and procedures were made by Design Assurance to guide the program in the proper selection of these specifications.

The Design Assurance Project Engineer provided monthly status reports to the project. The information contained in these reports formed a part of the monthly status report that was forwarded to NASA/LRC.

L. ELECTRONIC MODULES

1. Functional Description

The electronic system is illustrated in block diagram form in figure 7. The following functional description of the electronic system was used as a guide during fabrication of the welded modules and serves to illustrate, in summary, the operation of the system.

FUNCTION DESCRIPTION OF
THE ELECTRONIC MODULES USED FOR THE
TWO GAS ATMOSPHERE SENSOR SYSTEM

REFERENCE: SPO 27442

PART NUMBER - 631-0001

DESIGNATION - Module A1, IR Preamp

FUNCTION - This module amplifies a thermistor bolometer output to a suitable level for processing and demodulation circuits. It filters the detector bias voltage which is supplied at ±40 volts. It features fast turn characteristics with diode limiting. It uses an integrated circuit amplifier to develop the principal gain. The input stage is an FET to provide low noise. The trans-resistance of the amplifier is 800 megohms.

The IR test signal terminal #13 allows injection of a simulated signal to test purposes.

INPUT-OUTPUT CHARACTERISTICS - The input is 0.4 nanoamps p-p. The output is 300 MV p-p nominally. The required operation drive bias is ±9 VDC regulated to ±1/3%.

A reference bias of +7 VDC regulated to ±1 MV is required.

SIGNAL FREQUENCY - A complex waveform with a PRF of 20 Hz.

BANDPASS - 1 Hz to 1 Kc. The high frequency rolloff is 20 db/oct. The low frequency rolloff is 60 db/oct.

CRITICAL AREAS - The signal input line to Q4, R11 and C7 is very susceptible to pickup.

SPECIAL CONSIDERATIONS - The circuit requires overall continuous electrostatic shielding and a well shielded input line. Inputs and outputs must be well separated.

CODE IDENT. 46555	PERKIN-ELMER ELECTRO-OPTICAL DIVISION, NORWALK, CONN.	DATE: 4-10-67

SPECIFICATION

PART NUMBER - 631-0002

DESIGNATION - Module A2, UV Preamp.

FUNCTION - This module amplifies a photomultiplier output to a suitable level for processing and demodulation circuits. It uses an integrated circuit amplifier to develop the principal gain. The input stage is an FET to provide low noise. The transresistance of the amplifier is 10 megohms.

INPUT-OUTPUT CHARACTERISTICS - The input is 30 nanoamps p-p. The output is 300MV p-p nominally. The required operating drive bias is ±9 VDC regulated to ±1/3%.

A reference bias of +7 VDC regulated to ± 1 MV is required.

SIGNAL FREQUENCY - A complex waveform with a PRF of 20 Hz.

BANDPASS - 1 Hz to 1Kc. The high frequency rolloff is 20 db/oct. The low frequency rolloff is 40 db/oct.

CRITICAL AREAS - None.

SPECIAL CONSIDERATIONS - The circuit requires overall, continuous electrostatic shielding and a well-shielded input line. Inputs and outputs must be separated.

PREPARED BY	APPROVED	APPROVED	APPROVED	PE SPEC	REV	SHEET

SPECIFICATION

PART NUMBER - 631-0003, 631-0004, 631-0005

DESIGNATION - Module A3, Signal Processing.

FUNCTION - This module amplifies the input complex waveform, provides an AGC function, demodulates the signal in sample and hold amplifiers and integrators, and provides buffer amplifiers for the DC output signals. The sample and hold integrators are integrated circuits. The AGC element is a bipolar transistor operated in an inverted connection. Redundant outputs are provided by the buffer amplifier. Temperature compensation for the gas measurement is provided by an external thermistor. Course gain of the DC output is provided by an external resistor. The output signal course zero is selected by an external resistor.

INPUT-OUTPUT CHARACTERISTICS - The input is a complex waveform of 300 MV p-p nominally with a range of 10 MV p-p to 5v p-p at a PRF of 20 Hz.

The output is 0 to 5 VDC. Sampling drive voltages consisting of narrow pulses 3.3 msec duration, 1 v p-p, at a PRF of 20 Hz are required.

The required operating drive bias is ±9 VDC, regulated to ±1/3%. A reference bias of ±7 VDC regulated to ±1 MV is required.

BANDPASS - The input bandpass is 1/2 Hz to 1 Kc. The output bandpass has a 1 second step response.

CRITICAL AREAS - None

SPECIAL CONSIDERATIONS - The circuit requires overall continuous electrostatic shielding.

SPECIFICATION

PART NUMBER - 631-0006

DESIGNATION - Module A6, Regulators P_T, N_2 circuit.

FUNCTION - A ±11 VDC bias is regulated to ±9 VDC at ±1/7%. This is provided as bias to other circuits. In addition, it is regulated to ±7 VDC at ±1 MVDC.

The output from the pressure transducer is amplified in an integrated circuit and provided as redundant outputs.

Inputs to the module representing CO_2, H_2O and O_2 are subtracted from the total pressure signal, amplified and buffered, and provided as redundant outputs.

The characteristics of the analog operations are determined by external resistors. R1 sets the zero offset of the P_T output.

R_2 sets the zero offset of the N_2 output. R3, R4, R60 and R61 determine the coefficients in the analog subtraction.

Fine adjustments are provided for the previous functions except for CO_2 and H_2O signals.

INPUT-OUTPUT CHARACTERISTICS - All DC signals are 0 to 5 VDC. A bias of ±11 VDC regulated to ±10% is required.

A bias of ±9 V regulated to 1/3% is required.

A bias of ±7 V regulated to ±1 MV is required.

SIGNAL FREQUENCY - DC

BANDPASS - DC to 1 Kc (not significant)

CRITICAL AREAS - None

SPECIAL CONSIDERATIONS - The circuit requires overall continuous electrostatic shielding.

PREPARED BY	APPROVED	APPROVED	APPROVED	PE SPEC	REV	SHEET

SPECIFICATION

PART NUMBER - 631-0007

DESIGNATION - Module A7, Pulse Generators and Torquer Circuit.

FUNCTION - The circuit contains a 200 Hz square wave oscillator, which is the clock for the system. The output is divided by flip-flops. The outputs of the flip-flops are gated together to provide the torquer chopper drive signals, sampling pulses and the test signals for the system. A torquer drive amplifier is provided. The flip-flops and gating functions are provided by 12 integrated circuits.

An external resistor R1 determines the clock frequency. The external resistors R32, 33, 34 determine the shape of the complex test signal waveform. R35, 36, 37 and 38 in conjunction with potentiometers R28, 29, 30 and 31 determine the four angular positions of the torquer chopper.

INPUT-OUTPUT CHARACTERISTICS - The required operating drive bias is ±11 VDC regulated to ±10%. +3V ±10% bias is required at a -11 VDC level to produce the -8 VDC bias on terminal 7. ±7 VDC reference bias regulated to ±1 MV is required.

SIGNAL FREQUENCY - Narrow pulses at a PRF of 20 Hz.

BANDPASS - Not applicable to these switching circuits.

CRITICAL AREAS - None

SPECIAL CONSIDERATIONS - The circuit requires overall continuous electrostatic shielding.

SPECIFICATION

PART NUMBER - 631-0008

DESIGNATION - Module A8, H.V. Ampl and Oscillator.

FUNCTION - This module is part of three overall feedback loops, remaining portions of which are in 631-0009. This circuit senses the PM tube high voltage, the UV source lamp current and regulator circuit and compares these parameters with fixed references. The differences are amplified and used to control two variable pulse width oscillators and a current sink. The current sink is in 631-0009. A 60 DC signal from the converter in 631-0009 is regulated to ± 40 VDC to drive the bias filters in 631-0001.

INPUT-OUTPUT CHARACTERISTICS - A sample of the HV for the PM tube dynode string, a voltage from a control element in the lamp regulator (used to keep the high voltage level within the range of the control circuit), and a sample of the lamp current are inputs to the system.

A DC signal to drive the UV source lamp control element and two variable pulse width pulse trains (which are used to drive the HV power switches in 631-0009) are outputs from the module.

The regulated operating drive bias is ±11 VDC regulated to ±10%. ±9 VDC regulated to ±1/3% is required.

+3 VDC ±10% bias is required at a -11 VDC level to produce the -8 VDC bias on terminal 24. ±60 VDC ±10% is required for the bias regulator.

SIGNAL FREQUENCY - The variable pulse width trains are a PRF of 10 Kc. Both the width and PRF are variable over approximately 5 to 20 Kc.

BANDPASS - Not applicable to this circuit.

CRITICAL AREAS - The bias regulator's summing points, terminal 2 of AR1 and AR2, should be isolated from the oscillators Q12, Q16, Q17 and associated components.

SPECIAL CONSIDERATIONS - The circuit requires overall continuous electrostatic shielding.

CODE IDENT. 46555	PERKIN-ELMER ELECTRO-OPTICAL DIVISION, NORWALK, CONN.	DATE: 4-10-67

SPECIFICATION

PART NUMBER - 631-0009

DESIGNATION - Module A9, H.V. Power Circuit, DC to DC Converter

FUNCTION - This module contains the high voltage sections for the PM tube and the UV source lamp. In addition, it contains the DC to DC converter used to supply the bias voltages and power to other modules.

The high voltage is developed using a flyback transformer and rectifier-filter.

The DC to DC converter is a simplified full wave, push-pull configuration which is driven by the main 28 VDC input power. It provides isolation between signal and power grounds.

An EMI filter is provided on the input power line.

INPUT-OUTPUT CHARACTERISTICS - The input is 28 VDC ±10%. The outputs are: ±60 VDC; ±11 VDC; +3 VDC referenced to -11 VDC; -1700 VDC (photomultiplier bias, variable); -2000 VDC UV lamp drive prior to firing, -200 VDC operating; 5 VRMS at 5 Kc for the IR lamp.

A -9 VDC bias regulated to ±1/3% is required.

SIGNAL FREQUENCY - The DC to DC converter operates at 5 Kc nominally. The flyback section operates at 10 Kc nominally.

BANDPASS - Not applicable to this circuit.

CRITICAL AREAS - The base of Q6 should be isolated from the high voltage pulses. The high voltage line from either side of CR18 and also the line from either side of CR16 and R6 should be carefully positioned. Terminals 6 and 15 are to be pig-tail shielded leads to protect operating personnel and reduce radiated interference.

SPECIAL CONSIDERATIONS - The circuit requires overall continuous grounded electro-magnetic shielding (mu-metal or equivalent).

PREPARED BY	APPROVED	APPROVED	APPROVED	PE SPEC	REV	SHEET

The final configuration of the welded modules prior to final potting is shown in figure 49.

2. Procurement Specification

The welded module program was initiated with the issue of the Procurement Specification No. 5289, which defines the requirements for this critical assembly.

3. Acceptance Test Specification

The acceptance test specification defining the acceptance criteria for the modules was developed during the Phase IIb program. Each module from each set was subjected to the specified tests at the completion of assembly and again after a high temperature soak just prior to final potting.

The potted modules were tested to a combination of this specification and simulations using the breadboard.

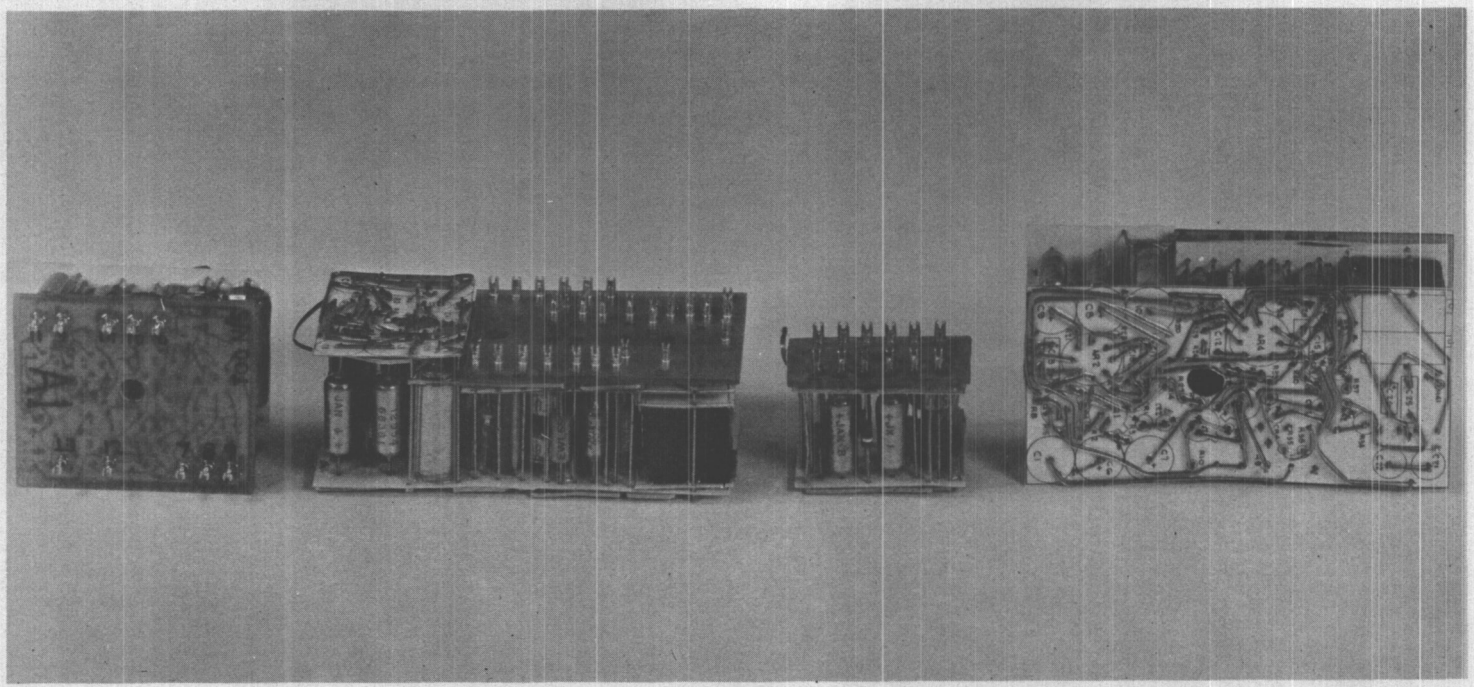


Figure 49. Welded Circuit Modules Prior to Final Potting

PROCUREMENT SPECIFICATION

MODULE ASSEMBLY - ELECTRONIC, WELDED

1. SCOPE

1.1 SCOPE - This specification covers the requirements for an Electronic Welded Module Assembly (hereafter called Module Assembly) to be used as part of a flight prototype instrumentation system for manned spacecraft.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids, form a part of this specification.

SPECIFICATIONS

Military

MIL-E-5400	General Specification for Aircraft Electronic Equipment

NASA

NPC 250-1	Space System Contractors, Reliability Program Provisions for
NPC 200-4	Hand Soldering of Electronic Connections, Quality Requirements for
NPC 200-2	Space System Contractors, Quality Program Provisions for

2.2 The following non-government specification and drawings, of the latest revision, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Perkin-Elmer Corporation

P-E SPEC 5073	Potting Compound
P-E SPEC 5201	Process Specification, Elastomeric Buffer Coating

DRAWINGS

Perkin-Elmer Corporation

631-0001		Module A1 I.R. Preamp Assembly
	Sheet 1	Assembly
	Sheet 2	Schematic & Parts List
631-0002		Module A2 U.V. Preamp Assembly
	Sheet 1	Assembly
	Sheet 2	Schematic & Parts List
631-0003 631-0004 631-0005		Modules A3, A4, A5 Signal Processing
	Sheet 1	Assembly
	Sheet 2	Schematic
	Sheet 3	Parts List
631-0006		Module A6 Regulators & P_T, N_2 CKT
	Sheet 1	Assembly
	Sheet 2	Schematic
	Sheet 3	Parts List
631-0007		Module A7 Pulse Generators & Torquer CKT
	Sheet 1	Assembly
	Sheet 2	Schematic
	Sheet 3	Parts List
631-0008		Module A8 HV Ampl. & Osc.
	Sheet 1	Assembly
	Sheet 2	Schematic
	Sheet 3	Parts List
631-0009		Module A9 H.V. Pwr. Ckts. DC/DC Converter
	Sheet 1	Assembly
	Sheet 2	Schematic & Parts List

DRAWINGS (Con't)

631-0010 System Wiring Diagram

631-1000S Module Space Layout

3. REQUIREMENTS

3.1 PRE-PRODUCTION - This specification makes provision for preproduction testing. Quantities of pre-production units, as specified by the buyer, shall be tested and inspected by the buyer to insure conformance with all requirements of Sections 3 and 4 of this specification.

3.2 COMPONENTS - The Module Assembly shall consist of nine potted circuit modules which will be interconnected by the buyer using a point-to-point wiring harness with solder connections shown in 631-1233. All interconnection terminals and potentiometer adjustment screws shall be accessible after assembly in 631-1000S.

3.3 SELECTION OF SPECIFICATIONS AND STANDARDS - Specifications and standards for necessary commodities and services not specified herein shall be selected in accordance with the supplier's highest grade internal standards.

3.4 MATERIALS

3.4.1 POTTING MATERIAL: The final potting material used for the circuit and cabling modules shall be Emerson and Cuming type "Stycast" No. 1090 low-weight epoxy casting resin. This resin shall be cured in accordance with P-E Spec. 5073. An elastomeric buffer shall be applied prior to the final potting in E.C. 1090, in accordance with P-E Specification 5201.

3.4.2 PROTECTIVE TREATMENT: When materials are used in the construction of the Module Assembly that are subject to deterioration when exposed to the environmental conditions of Paragraph 3.7.2, they shall be protected against such deterioration in a manner that will in no way prevent compliance

with the performance requirements of this specification. The use of any protective coatings that will crack, chip, or scale with age or extremes of climatic and environmental conditions shall be avoided. Non-nutrient materials shall be employed, using MIL-E-5400 as a guide.

3.5 DESIGN

3.5.1 GENERAL: The basic sub-assemblies employed in the Module Assembly are nine circuit modules. A circuit module is an encapsulated group of electronic components, stacked in close physical proximity to one another and electrically connected, by welded connections only, on a circuit matrix film or by point-to-point welded connections. Connections extending from the circuit matrix are welded to turret plated beryllium copper terminals. Jumpers are provided internal to the circuit module to insure compatability with the specified functional schematics and wiring diagrams. With the sole exception of Module A9, all modules require electrostatic shields to provide shielding between modules and at the ends of the module assembly. Module A9 requires an electro-magnetic shield. Exceptions to welded connections must be approved by Perkin-Elmer.

3.5.2 ELECTROSTATIC SHIELDING: Modules A1 thru A8 are to be electrostatically shielded by electroless copper plating or equivalent followed by a protective coating of electroplated cyanide bright gold or the equivalent for high anti-galling characteristic and high resistance to wear and corrosion.

3.5.3 ELECTROMAGNETIC SHIELDING: Module A9 is to be electromagnetically shielded by the use of a mu metal or equivalent magnet shield can which will completely cover five sides of the module. No special header is required.

3.6 CONSTRUCTION: The circuit modules shall be constructed to withstand all the environmental requirements of Section 3.7.2 and shall protect all encapsulated components within the modules from these conditions. The modules shall withstand repeated assembly (soldering and unsoldering) and removal from the completed assembly without loosening of the wiring terminals. Wiring terminals encapsulated in a 1090 header are not acceptable. Fiberglass or other suitable material shall be used. The construction shall not in any way reduce the functional circuit performance of the individual or assembled modules.

3.6.1 PACKAGING: The electronic modules shall incorporate all solid state modular construction and shall be capable of complying with the essential requirements as a guide set forth in NASA Specifications

a) NPC 250-1

b) NPC 200-4

c) NPC 200-2 all referred to in Section 2.1

The design and processes used shall be capable upon direction from the buyer, of complying with the requirements of the NASA specifications with a minimum of changes to the existing programs.

Strict compliance with the NASA specifications is not a requirement at this time.

3.7 PERFORMANCE

3.7.1 GENERAL: The following requirements refer to the Module Assembly and where applicable, to the individual components making up this assembly.

3.7.2 ENVIRONMENTAL REQUIREMENTS

3.7.2.1 ACCELERATION: The Module Assembly shall withstand 5g axially and 1 g laterally for a five-minute duration in each of three mutually perpendicular axes.

3.7.2.2 ACOUSTICS: The Module Assembly shall withstand a noise level of 157 db while in an environment at 0.0002 dynes/cm^2.

3.7.2.3 RANDOM VIBRATION: The Module Assembly shall be operable after exposure to random vibration of 0.06 g^2/cps from 60 cps to 400 cps on each of three mutually perpendicular axes. The range shall be swept at 1/2 octave/minute.

3.7.2.4 TEMPERATURE:

3.7.2.4.1 STORAGE TEMPERATURE: The Module Assembly shall be operable after exposure to the following temperatures: -65°F to +200°F

3.7.2.4.2 OPERATING TEMPERATURE: The Module Assembly shall meet the requirements of Section 3 while exposed to 40°F to 90°F.

3.7.2.5 HUMIDITY - The Module Assembly shall be operable after exposure to 0 to 50 percent relative humidity from 0°F to 100°F.

3.7.2.6 ALTITUDE - The Module Assembly shall be capable of operating continuously with an ambient pressure of 21.0 psia to 1×10^{-4} mm Hg.

3.7.3 LIFE

3.7.3.1 SHELF LIFE - The Module Assembly shall have a shelf life of three years in the deactivated state and suitably packaged for storage.

3.7.3.2 ACTIVE LIFE - The Module Assembly shall be operable for 120 days without requiring calibration. It shall furthermore have an operating life of one year.

3.7.4 DETAILS OF SUBASSEMBLIES - Each circuit module shall conform to 631-1233 and 631-0001 thru 631-0009 for circuit interconnections, electronic parts, test points, electrical adjustments and physical size. Any exceptions, deletions or additions to these drawings must be submitted to the buyer for approval prior to implementation.

3.8 INTERCHANGEABILITY - All modules, or assemblies having the same part number of designation shall be functionally and dimensionally interchangeable.

3.9 DIMENSIONS - The maximum permissible dimensions are shown in sheet 1 of 631-0001 thru 631-0009. Reduction in any dimension is desirable, but no trade-off of size for performance is permitted.

3.10 WEIGHT - A minimum-weight assembly is desired. The module assembly shall weigh less than lbs. The addition of heavy mechanical supports within any module shall be avoided. Minimum epoxy weight is required.

3.11 FINISH - No external finish shall be necessary except as specified in Paragraph 3.4.2.

3.12 IDENTIFICATION OF PRODUCT - Each circuit module shall be permanently marked in accordance with 631-10008. Terminal marking shall be adjacent to the terminal. Part No., name, etc.,may be on the side of the assembly.

3.13 BUYER FURNISHED PROPERTY

3.13.1 An operating breadboard shall be provided by the buyer at the request of the supplier to assist in the supplier's acceptance tests. The breadboard shall contain the same circuits and parts as the completed module.

3.14 WORKMANSHIP - The highest quality and standard of workmanship is expected in the fabrication of the equipment covered by this specification.

4. QUALITY ASSURANCE PROVISIONS - An incoming parts inspection (GO - NO GO) is required by this specification. All electronic parts will be purchased by the Perkin-Elmer Corporation, and delivered to the supplier. The testing procedure shall be determined by negotiations with the supplier prior to issuance of any purchase orders.

5. PREPARATION FOR DELIVERY - All units shall be preserved and packaged in accordance with the manufacturer's best practice.

5.1 MARKING FOR SHIPMENT AND STORAGE - Interior packages and exterior shipping containers shall be marked with the following nomenclature:

The Perkin-Elmer Corporation
Electro-Optical Division
50 Danbury Road
South Wilton, Connecticut

6. NOTES

6.1 INTENDED USE - The Module Assembly shall be installed into an aluminum housing containing the remaining components of a complete instrumentation system. The complete system shall be tested to be approved as a flight-

prototype system. If a failure should occur after the acceptance tests, it is the intention to replace the damaged module with a spare module. Complete interchangeability is then of prime importance as specified in Paragraph 3.8.

DESIGN CRITERIA

REQUIREMENTS

Electrical:

Power - 28 VDC ± $\frac{1}{2}$ V, 5 watts, max.

Ripple - $\frac{1}{2}$ V_{pp}, <± 52 V, 100 usec spikes

Impedance - 50 Ω

Mechanical:

Size - 110 in^3 (3.5 x 3.9 x 8.0 in)

Weight - < 6-1/2 lb.

Analytical:

Output Voltages - (0 - 5 volt)

a.	PO_2	125-250 mmHg	±2% accuracy
b.	PH_2O	0-30 mmHg	±5% accuracy
c.	PCO_2	0-20 mmHg	±2% accuracy
d.	P_{Total}	0-760 mmHg	±1% accuracy
e.	PN_2	100-300 mmHg	±5% accuracy

Response time - 10 sec for 63% of step input.

Environmental:

Temperature (operating) 40°F to 90°F
(storage) -65°F to 200°F

Acceleration - ±5 g axial
±1 g lateral

Vibration (random) 0.06 g 2/cps (60 - 400 cps)

Acoustics - 157 db overall (0.0002 dyne/cm^2)

Altitude, attitude - any

Pressure - 21 PSIA to vacuum (10^{-4} mmHg)

Life: Storage - 3 years

Operating without calibration - 120 days

Operating (total) 1 year

Sample Gas Conditions:

Total Pressure (P_T) 362 ± 11 mm Hg alternate: 760 mm Hg

Oxygen Partial Pressure (PO_2) 181 ± 5.5 mmHg

Nitrogen Partial Pressure (PN_2) Diluent for P_T

Carbon Dioxide Partial Pressure (PCO_2) < 7.6 mmHg
Brief Excursions to 15 mm Hg

Water Vapor Pressure (PH_2O) 2.2 to 27.1 mmHg

Temperature 40°F to 90°F

Power Penalty: 1/2 lb/watt

Product Assurance Guides

Product Assurance Plan

NPC 250-1 (Reliability)

NPC 200-4 (Wiring)

NPC 200-2 (Quality Assurance)

Ignition Proof:

Rain - MIL-STD 810 - Method 506

Salt Fog - MIL-STD 810 - Method 509

Fungus - MIL-STD 810 - Method 508

Sand and Dust - MIL-STD 810 - Method 510

Humidity - Zero and 100% R.H. (0°F to 100°F)

EMI - To Be Defined

ELECTRONIC MODULE
ACCEPTANCE TEST SPECIFICATION
TWO GAS ATMOSPHERE SENSOR

ACCURACY OF TEST EQUIPMENT

All dc voltages are measured with an 11 meg. 3% VTVM.

Output voltages (dependent variables) are measured with the same instrument used to set the power supply and reference voltages.

Waveform amplitudes and levels are measured using an oscilloscope whose vertical amplifier is calibrated to ±3% accuracy.

Frequencies, pulse lengths and rise times, and time relationships are measured using the oscilloscope's calibrated horizontal sweep. Calibration accuracy is ±5%.

Times longer than 1 second are measured with a VTVM and a sweep second hand. Accuracy is ±20%.

MODULE A1

ACCEPTANCE TEST SPECIFICATION

1.1.1 With no connections to the module other than the two ohmmeter leads, the d.c. resistances between the following pairs of pins should be as follows:

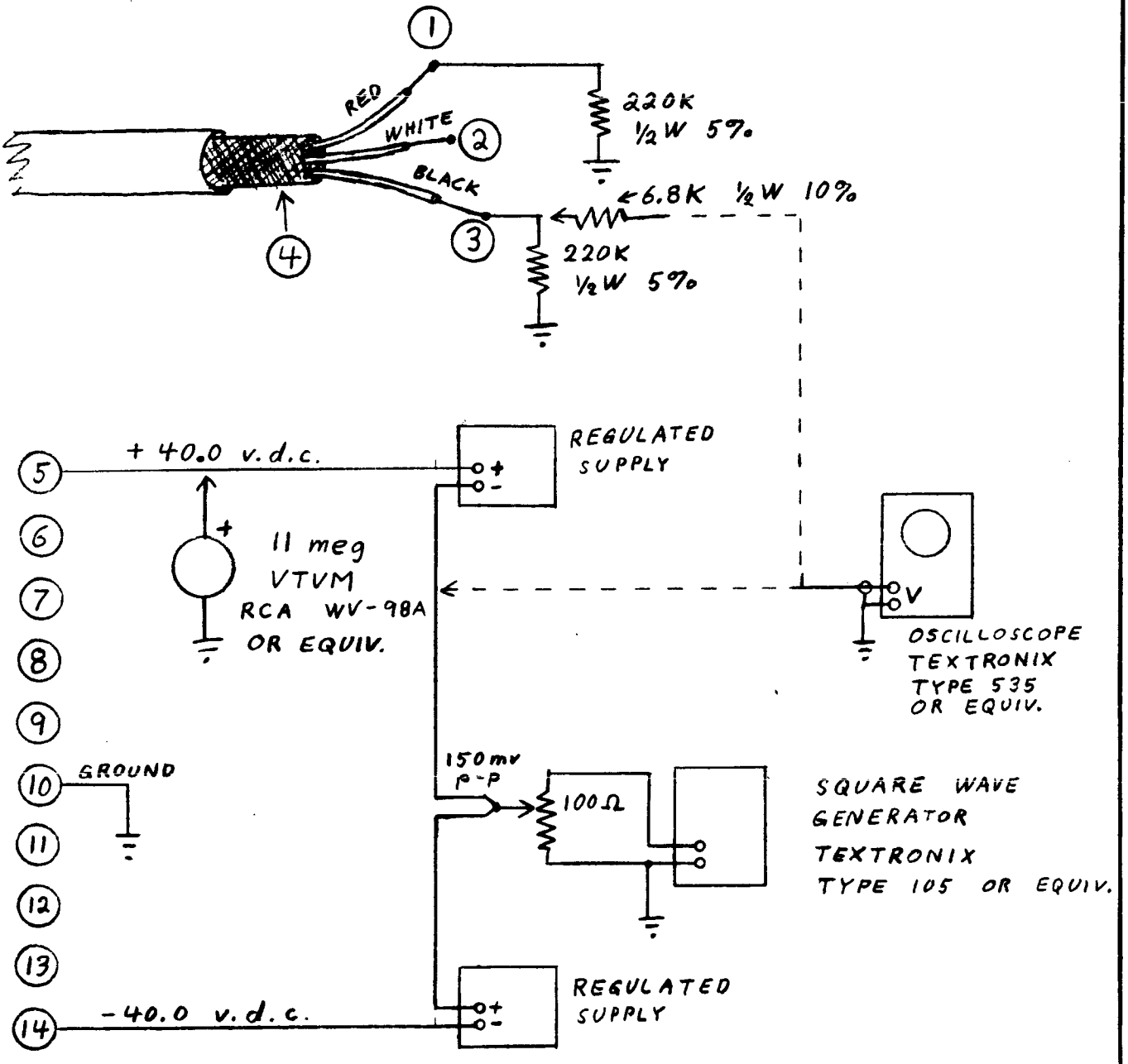
10 to 4	less than 0.2Ω
10 to 11	less than 0.2Ω
10 to 12	less than 0.2Ω
10 to 13	15Ω ±5%

1.2.1 A) Connect the module as shown in Fig. 1.1. Adjust the square wave generator and the regulated supply to produce a d.c. level of +40.0 v.d.c. with 150 mv p-p of 50 cps square wave ripple, both measured at pin 5.

The voltage at the red wire (pin 1) should be 38.0 ±0.5 v.d.c. with less than 1.0 mv p-p of ripple or spikes as the generator frequency is slowly varied from its low frequency limit (approximately 10 cps) to 1.5 kc.

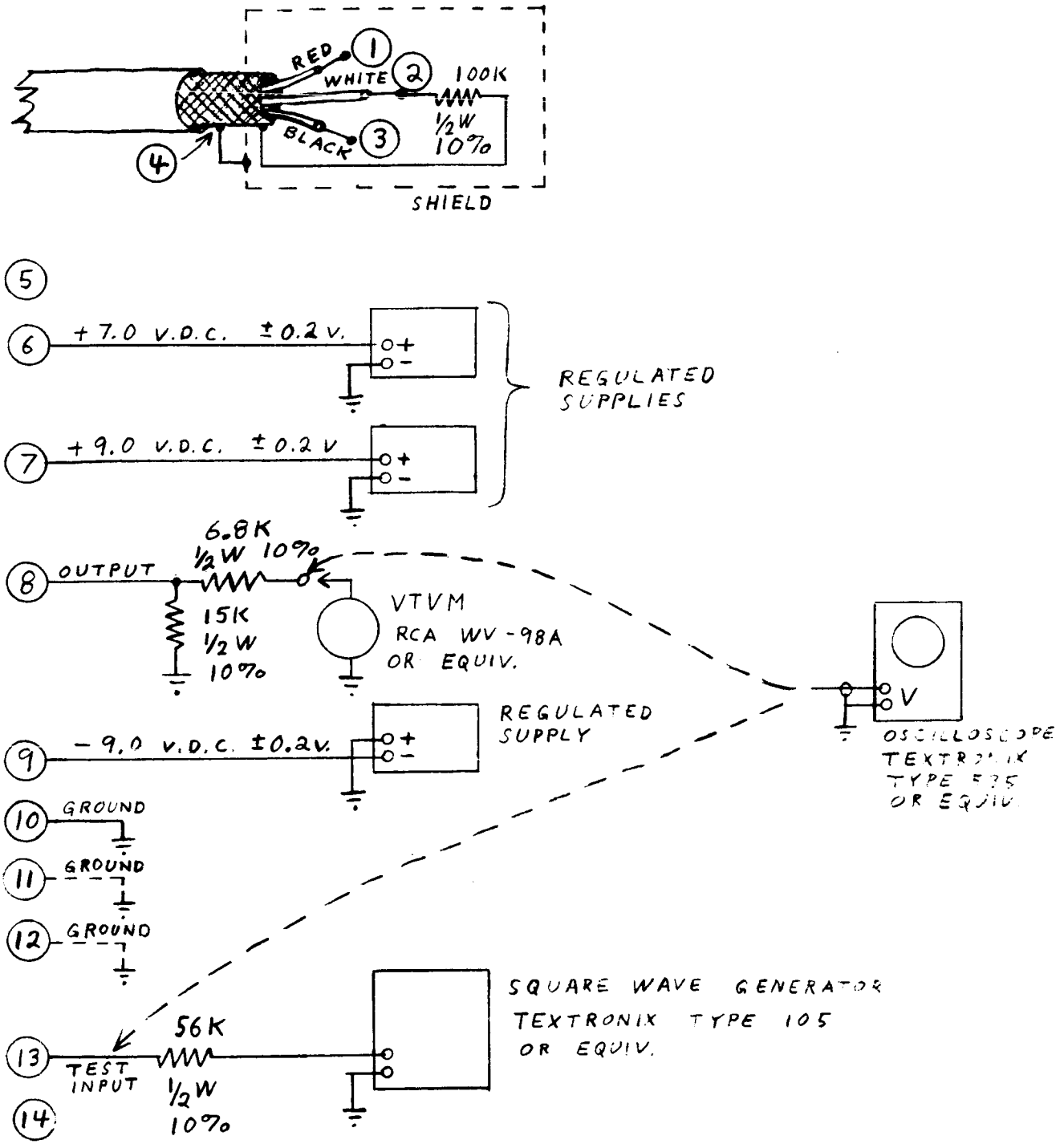
1.2.2 Connect the square wave generator and the regulated supply to give -40.0 v.d.c. with 150 mv p-p of 50 cps. square wave ripple both measured at pin 14.

The voltage at the black wire (pin 3) should be -38.0 ±0.5 v.d.c. with less than 1.0 mv p-p of ripple or spikes as the



Power supplies may be operated independently

FIGURE 1.1.



Turn on all three power supplies simultaneously

FIGURE 1.2.

W. Clouser PREPARED BY	APPROVED	APPROVED	APPROVED	PE SPEC	REV	SHEET 4/30

generator frequency is slowly varied from its low frequency limit to 1.5 kc.

1.3.1 Enclose the bottom and sides of the module in a grounded shield Connect the module as shown in Fig. 1.2 and apply the required power supply voltages.

With no input to pin 13, the output (pin 8) d.c. level should be between 0.0 and -0.5 v.d.c. When displayed on a d.c. coupled scope at 20 mv/cm and 0.5 cm/sec., the output should show less than 50 mv p-p of random fluctuation. There should be no oscillation visible at 20 mv/cm and sweep speeds between 100 msec/cm and 0.1 usec/cm.

1.3.2 Adjust the generator to give a 5.0 mv p-p 167 cps square wave at pin 13.

The output (pin 8) should be a rounded square wave with an amplitude of between 1.5V and 2.0V p-p.

1.3.3 Adjust the generator to give an output (pin 8) of 2.0 V p-p. The rise and fall times (0 to 75%) should be between 300 and 500 usec. with no overshoot or ringing.

Decrease the output amplitude to 300 mv p-p. There should be no change in wave shape.

1.4.1 ACCEPTANCE CRITERIA - The module is acceptable if:

1. The outputs of the filters are plus and minus 38.5 v.d.c. ±0.5V with less than 1.0 mv p-p of ripple for inputs of plus

and minus 40.0 v.d.c. with 150 mv p-p of ripple.

2. The output d.c. level is between 0.0 v.d.c. and -0.5 v.d.c.

3. The module does not oscillate with no input, and the random noise at the output is less than 50.0 mv p-p.

4. The voltage amplification and rise times are as specified, with no overshoot or ringing.

MODULE A2

2.1.1 With no connection to the module other than the two ohmmeter leads, the d.c. resistances between the following pairs of pins should be less than 0.1 ohm unless otherwise specified.

3 to 4

5 to 6

7 to 8

9 to 2

9 to 10

9 to 14

12 to 13

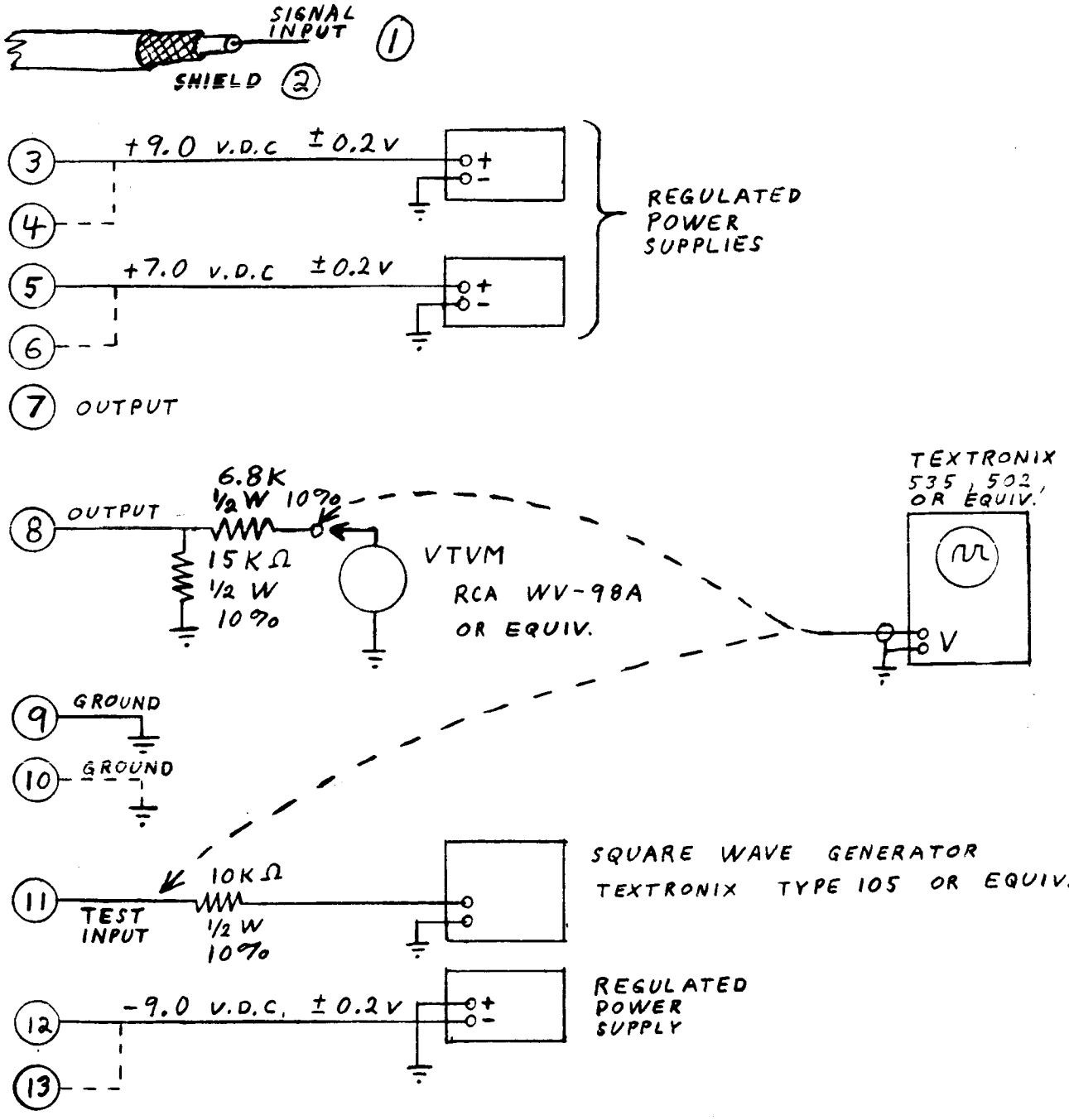
10 to 11 100Ω ±5%

Do not proceed with other tests unless these resistances are as specified.

2.2.1 Connect the power supplies and the 15k resistor to the module as shown in Fig. 2.1.

Shield pin 1 and disconnect the 10k resistor from pin 11.

The d.c. level at the output (pin 7) should be between -0.2



Turn on ±9 volt supplies simultaneously then bring the +7 volt supply up to 7.0 v.d.c. over a 5 second interval. Turn off all three supplies simultaneously.

FIGURE 2.1.

and -1.2 v.d.c. as measured with a VTVM.

The output, as measured with an oscilloscope having a sensitivity of 50 mv/cm, should be pure d.c. with no oscillation or noise visible at sweep rates of from 100 msec/cm to 1 usec/cm. The only exception is a maximum of 10 mv peak to peak power frequency ripple.

(If stray pickup is excessive, check the test equipment for residual ripple and the power supplies for less than 10 mv p-p of ripple. It may be necessary to enclose the bottom and four sides of the module in a grounded shield.)

2.2.2 Connect the 10k resistor and square wave generator to pin 11. Connect the oscilloscope to pin 11 and adjust the generator to give a 50 mv p-p 250 cps square wave at pin 11. The output waveform should be a rounded square wave with an amplitude of between 470 mv and 620 mv p-p and with no overshoot, ringing, oscillation or noise other than the permissible 10 mv p-p power supply ripple.

Increase the input amplitude to give an output amplitude of 2.0 v p-p.

The rise and fall times (0 to 75% of transition) of the output waveform should be 220 usec. $\pm$40 usec with no oscillation or ripple visible.

2.3.1 ACCEPTANCE CRITERIA - The module is acceptable if:

1. the d.c. resistances are as specified

2. the output d.c. level is within the specified limits

3. the peak to peak output amplitude is within the specified limits for the 50 mv p-p input

4. the output waveforms and transition times are as specified.

MODULE A3

3.1.1 With no connection to the module other than the two ohmmeter leads, the d.c. resistances between the following pairs of pins should be less than 0.1 ohm:

3 and 27

7 and 8

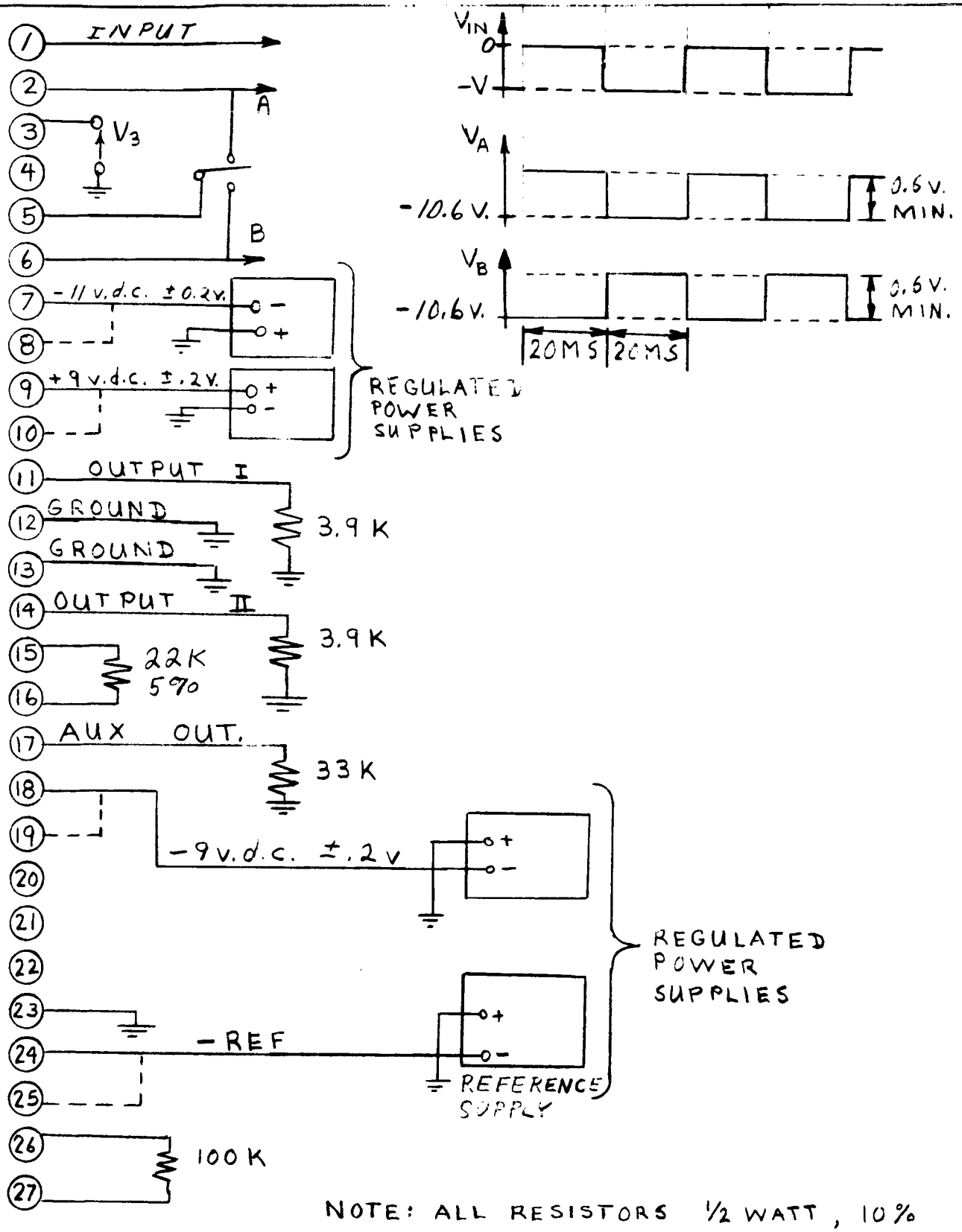
9 and 10

12 and 13

3.2.1 Connect the module as shown in Figure 3.1. Temporarily ground pin 4. Turn on the +9, -9, and -11 volt supplies simultaneously. Adjust the signal generator to give a 1.5v p-p 25 cps square wave. Check to see that the voltage levels and phase relationships of the signals at pins 1, 2, and 6 are as specified in Fig. 3.1.

Set R1 (suggested signal source, Fig. 3.2) to give a 20 mv p-p signal at pin 1. Set the reference supply to give -3.0 v.d.c. at pin 24.

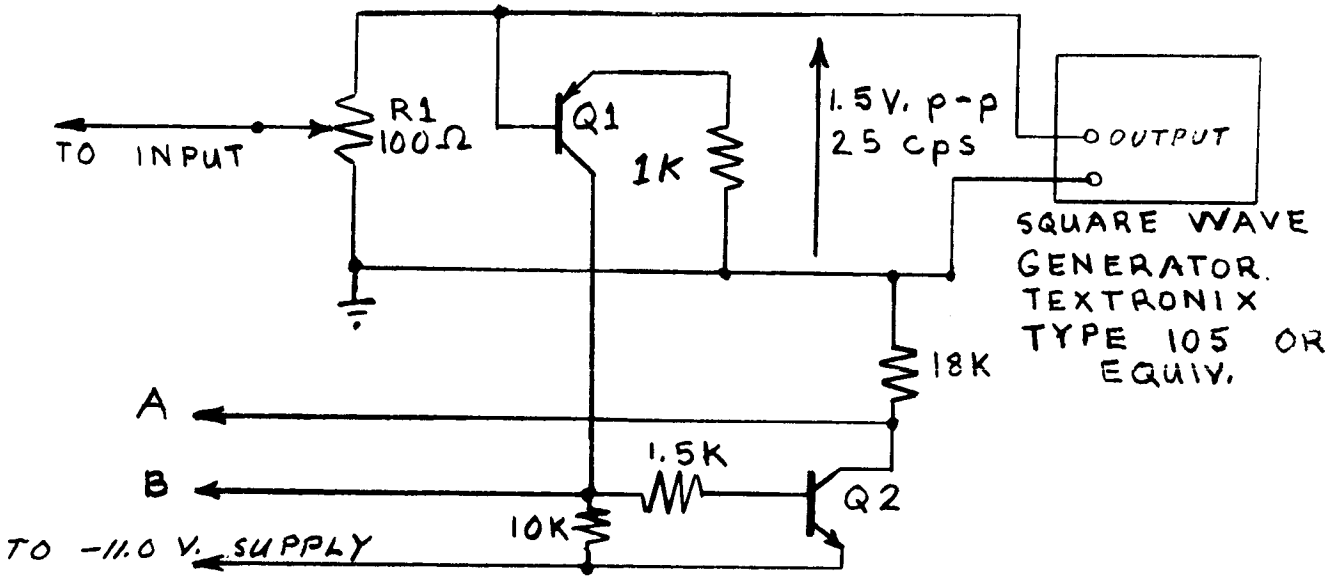
With the switch in position A, the voltage at pin 3, V_3, should settle to 0.0 v.d.c. $\pm$0.05 v in one minute.



NOTE: ALL RESISTORS ½ WATT, 10%

FIGURE 3.1.

PREPARED BY	APPROVED	APPROVED	APPROVED	PE SPEC	REV	SHEET
						10/30



1. This circuit will only work with the Textronix type 105 or other generator with negative offset voltage and 50 Ω output impedance.
2. Q1 - 2N3906 or other inexpensive silicon PNP medium speed switch.
3. Q2 - 2N3904 or other inexpensive silicon NPN medium speed switch.
4. All resistors 5% 1/2 W

SUGGESTED SIGNAL SOURCE

FIGURE 3.2.

3.2.2 When the switch is flipped to position B, V_3 should swing slowly to -3.0 v.d.c., taking between 5 and 8 seconds to reach -2.7 v.d.c., and should settle to -3.0 v.d.c. $\pm$0.05v. within one minute.

3.2.3 Use R1 to increase the input amplitude, V_{IN}, (pin 1) to 1.5 v. p-p in steps of 0.5v.

After each step V_3 should momentarily go more negative than -3.0 v.d.c., then settle back to -3.0 v. $\pm$0.05v. in about 15 seconds after each step.

3.2.4 After V_{IN} has been increased to 1.5V p-p and V_3 has settled to -3.0 v.d.c. $\pm$0.05v., flip the switch to position A. V_3 should decay to -0.3v in 5 to 8 seconds, and to -0.05 v.d.c. or less in one minute.

3.2.5 Reduce the input amplitude to 20 mv p-p and flip the switch to position B. V_3 should climb back down to -3.0 v.d.c. $\pm$0.05v. in less than one minute.

3.2.6 With the switch still in position B, change the reference supply to -4.0 v.d.c. V_3 should settle to -4.0 v.d.c. $\pm$0.05v in less than one minute.

3.3.1 Flip the switch to position A and leave it there. Set the reference supply at -1.00 v.d.c. The auxiliary output voltage (pin 17) should change from 0.0 v.d.c. $\pm$.10v to a value between -1.05 v.d.c. and -1.30 v.d.c. (depending on position of

R45) as R43 (ref. to print no. 631-0003) is turned from one end of its rotation to the other.

3.3.2 With pin 17 more negative than -1.00 v.d.c. both output voltages (pins 11 and 14) should be between -0.40 and -0.80 v.d.c.

3.3.3 Use R43 to set the auxiliary output voltage to zero. Unground pin 4 and connect pin 4 to the reference supply. With the reference supply at -1.00 v.d.c. the auxiliary output voltage should change from +2.65 v.d.c. $\pm$0.20v to +3.25 v.d.c. $\pm$-.20v. as R45 is turned from one end of its rotation to the other.

3.3.4. When the auxiliary output voltage is +3.25v. each of the two output voltages (pins 11 and 14) should be within +0.00v. -0.20v. of the auxiliary output voltage, and within $\pm$0.05v. of each other.

3.3.5 Increase the negative reference supply voltage until the auxiliary output voltage is +6.20 v.d.c. The output voltages (pins 11 and 14) should be between +5.30 and 6.00 v.d.c.

3.4.1 ACCEPTANCE CRITERIA - The module is acceptable if:

1. the d.c. resistances are as specified
2. with the specified waveforms at the input and at points A and B with the switch in position B $V_3 - V_{REF} \pm 0.05$ v.d.c. for any value of V_{REF} between 0.00 and -4.00 v.d.c. and any value of V_{IN} between 20 mv p-p and 1.5v p-p.

3. with the switch in position A V_3 = 0.00 $\pm$0.05 v.d.c. for the ranges of V_{IN} and V_{REF} specified above.

4. When the switch is flipped from A to B or from B to A, V_3 reaches 90% of its final value in 5 to 8 seconds and is within $\pm$0.05 v.d.c. of the final value in one minute.

5. The auxiliary output and the two output voltages are as specified for the specified settings of R43 and R45 and values of V_{REF}.

MODULE A4 AND A5

ACCEPTANCE TEST SPECIFICATIONS

4.1.1 Module 4 is electrically identical to module 3. The test procedure and acceptance criteria are the same as for module 3.

5.1.1 Module 5 is electrically identical to module 3. The test procedure and acceptance criteria are the same as for module 3.

MODULE A6

6.1.1 With no connections to the module other than the two ohmmeter leads, the d.c. resistances between the following pairs of pins should be less than 0.1 ohm unless otherwise specified.

1 and 2	23 and 24	
4 and 5	27 and 28	
6 and 7	34 and 35	
6 and 8	13 and 29	2.5k to 7.5K (R29)
9 and 10	15 and 25	0 to 2.0K (R28)
11 and 12	18 and 33	0 to 5.0K (R46)
13 and 14		
13 and 16		
18 and 21		
18 and 22		
19 and 20		

6.2.1 Connect the module as shown in Figure 6.1. Turn on the plus and minus 11 volt supply simultaneously and wait 5 seconds.

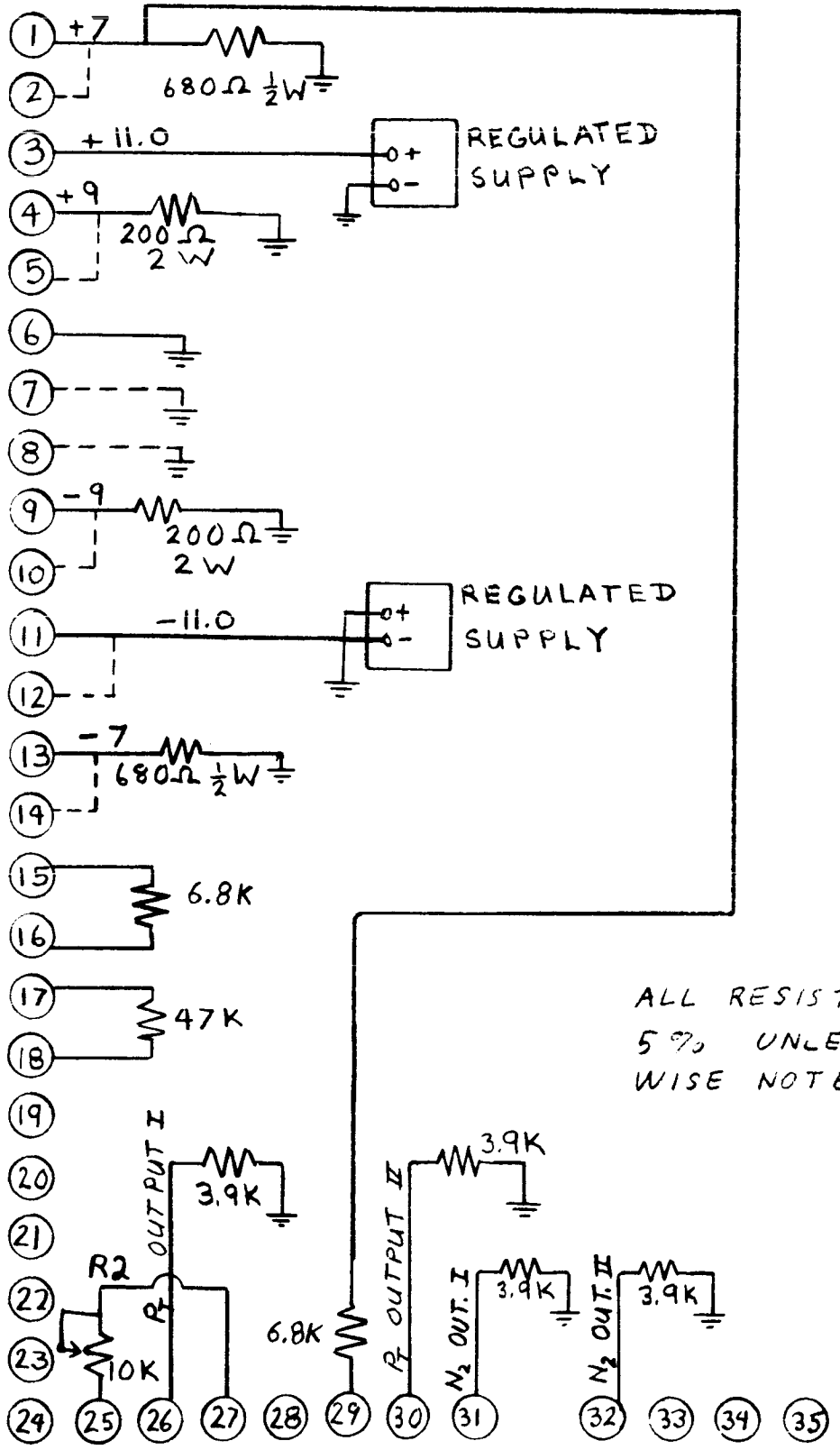

+7
680Ω ½W
+11.0
REGULATED SUPPLY
+
-
+9
200Ω 2W
-9
200Ω 2W
-11.0
REGULATED SUPPLY
+
-
-7
680Ω ½W
6.8K
47K
ALL RESISTORS ½W 5% UNLESS OTHERWISE NOTED
3.9K
OUTPUT I
R2
R2
10K
6.8K
3.9K
R2 OUTPUT II
3.9K
N2 OUT. I
3.9K
N2 OUT. II
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35

FIGURE 6.1.

The voltage at pin 4 should be +9.00 v.d.c. ±0.50v and should remain constant to within ±0.05v. as the +11v. supply is independently varied between +10.0 and +12.5 v.d.c.

The voltage at pin 9 is nominally -9.00 v.d.c. and should remain within ±0.20v. of the value of the voltage at pin 4 as the -11v. supply is independently varied between -10.0 and 12.5 v.d.c.

6.2.2 The voltage at pin 1 should be +7.00 v.d.c. ±0.40v.

The voltage at pin 13 is nominally -7.00 v.d.c. and should be within ±0.05v. of the value of the voltage at pin 1.

6.3.1 Temporarily disconnect one end of the 47K resistor from pin 17 and ground the free end. Adjust R43 (ref. to print no. 631-0006) to give +2.50 v.d.c. at pin 31. The voltage at pin 32 should be +2.50 v.d.c. ±0.05v. (Measure with the same meter used to measure pin 31, or use an identically calibrated one).

6.3.2 Reconnect the 47K resistor to pin 17. Both N_2 outputs (pins 31 and 32) should change smoothly from a value between -0.40 and -0.80 v.d.c. to a value between +5.30 and 6.00 v.d.c. as R35 is turned from one end of its rotation to the other.

6.4.1 Remove one end of the 6.8K resistor from pin 16 and temporarily ground the free end. Both P_T outputs (pins 26 and 30) should remain at values between -0.40 and -0.80 v.d.c. as R37 is

varied through most of its range, and should go to -0.10 v.d.c. ±0.10v. as R37 reaches one end of its rotation.

6.4.2 Leave R37 at this end of its rotation. Reconnect the 6.8K resistor to pin 16. With R2 (Fig. 6.1) near the center of its rotation, set R28 at the end of its rotation that gives the least positive voltage at pin 26. Both P_T outputs should vary from -0.10 v.d.c. ±0.10v. to +5.60 v.d.c. ±0.40v. as R2 is turned from one end of its rotation to the other.

6.4.3 Use R2 to set the voltage at pin 27 to +2.50 v.d.c. The voltage at pins 26 and 30 should be between +2.35 and +2.50 v.d.c., and should be within ±0.05v. of each other.

6.5.1 ACCEPTANCE CRITERIA - The module is acceptable if:

1. The d.c. resistances are as specified in 6.1.1
2. The +9, +7, -7 and -9 volt outputs are as specified in 6.2 under the conditions given in 6.2
3. The N_2 outputs are as specified under the conditions given in 6.3
4. The P_T outputs are as specified under the conditions given in 6.4.

MODULE A7

7.1.1 With no connections to the module other than the two ohmmeter leads, the d.c. resistances between the following pairs of pins should be less than 0.1 ohm unless otherwise specified.

1 and 2

5 and 6

8 and 9

10 and 13

11 and 14

12 and 15

12 and 16

18 and 19

21 and 23

21 and 25

21 and 27

30 and 31

32 and 33

32 and 34

35 and 36

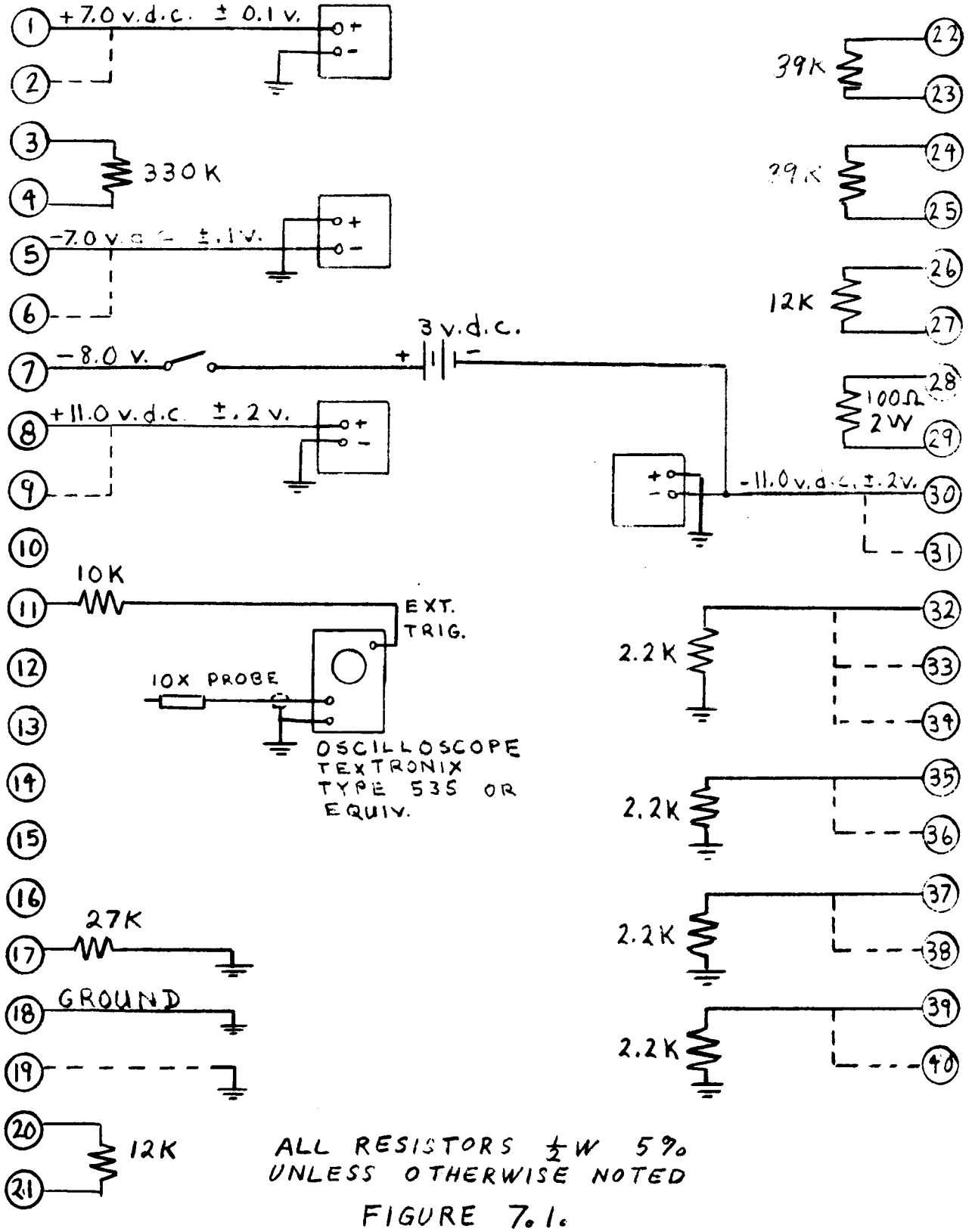
37 and 38

39 and 40

10 and 15 133K $\pm$5K

18 and 29 25 $\pm$2 Ω

7.2.1 Connect the module as shown in Fig. 7.1. For the moment, do not connect the resistors to pins 24 and 26. Turn on all four power supplies simultaneously, then connect the 3 volt battery to pin 7. Set the oscilloscope for V = 2 v/cm



ALL RESISTORS ½W 5%
UNLESS OTHERWISE NOTED

FIGURE 7.1.

PREPARED BY	APPROVED	APPROVED	APPROVED	PE SPEC	REV	SHEET
						20/30

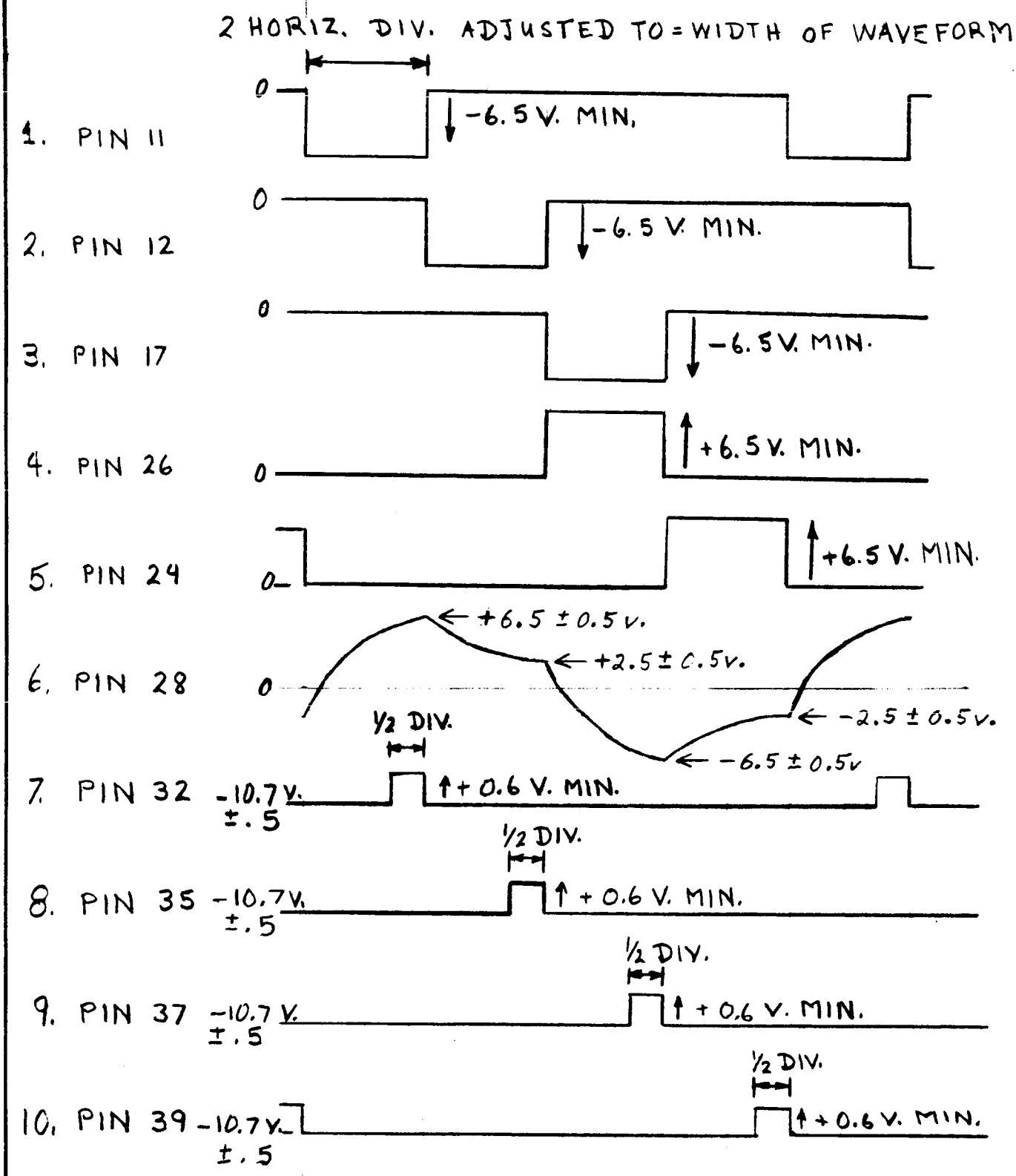

2 HORIZ. DIV. ADJUSTED TO = WIDTH OF WAVEFORM 1
1. PIN 11
0
-6.5 V. MIN.
2. PIN 12
0
-6.5 V. MIN.
3. PIN 17
0
-6.5 V. MIN.
4. PIN 26
0
+6.5 V. MIN.
5. PIN 24
0
+6.5 V. MIN.
6. PIN 28
+6.5 ± 0.5 v.
+2.5 ± 0.5v.
0
-2.5 ± 0.5v.
-6.5 ± 0.5v
½ DIV.
7. PIN 32
-10.7 V. ± .5
+0.6 V. MIN.
½ DIV.
8. PIN 35
-10.7V. ± .5
+0.6 V. MIN.
½ DIV.
9. PIN 37
-10.7 V. ± .5
+0.6 V. MIN.
½ DIV.
10. PIN 39
-10.7 V. ± .5
+0.6 V. MIN.

FIGURE 7.2.

D.C. coupled, H = 10 msec/cm, and negative d.c. external triggering. Connecting the scope probe to pin 11 should display waveform 1 of Fig. 6.2. The width of the -6.5V level should be 20 ±3 msec.

7.2.2 Adjust the sweep rate so that the -6.5v. level occupies 2.0 horizontal divisions. Check waveforms 2 through 5 of Fig. 7.2 Their amplitudes, levels, and time relationships to waveform 1 should be as specified on Fig. 7.2. Rise times should be unreadably fast at 10 msec/cm, and there should be no superimposed noise to ripple visible.

7.2.3 Connect the resistors to pins 24 and 26, and connect the scope probe to pin 28. This should display waveform 6. Set R31 through R34 at the ends of their rotations that minimize the amplitudes of the breakpoints. The waveform, time relationship to waveform 1, and breakpoint amplitudes should be as specified in Fig. 7.2. There should be no superimposed noise or high frequency oscillation visible.

7.2.4 Set the scope to 0.5v/cm (a.c. coupled if necessary) and check waveforms 7 through 10. Their amplitudes, time relationships, and widths should be as specified, with fast risetimes and no superimposed noise or level shifts.

7.3.1 Acceptance Criteria - The module is acceptable if:

1. the d.c. resistances are as specified.

2. waveforms 1 through 11 are as specified.

MODULE A8

8.1.1 With no connections to the module other than the two ohmmeter leads, the d.c. resistances between the following pairs of pins should be less than 0.1 ohm.

1 and 2

1 and 3

4 and 5

6 and 7

8 and 9

10 and 11

10 and 12

10 and 13

14 and 15

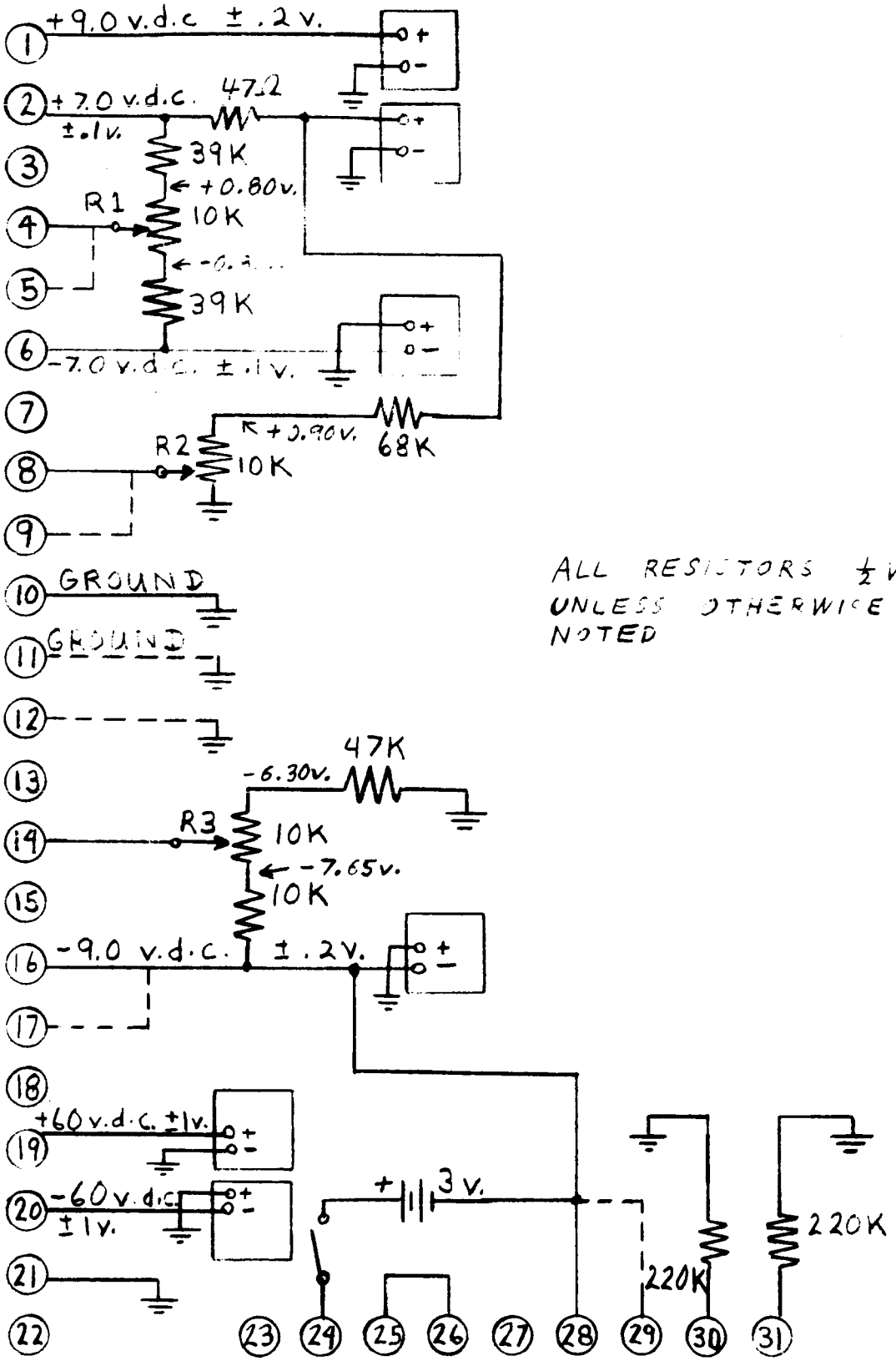
16 and 17

23 and 24

23 and 25

28 and 29

8.2.1 Connect the module as shown in Fig. 8.1. Turn on the ±60v. supplies. After one second simultaneously turn on the four low voltage supplies, then connect the 3 volt battery to pin 24. To turn off, disconnect the 3 volt battery and the four low voltage supplies in that order, then wait ten seconds before turning off the ±60 volt supplies.



ALL RESISTORS ½W 5% UNLESS OTHERWISE NOTED

FIGURE 8.1.

PREPARED BY	APPROVED	APPROVED	APPROVED	PE SPEC	REV	SHEET
						24/30

MIN 7±2 μSEC (R1 AT NEGATIVE END)
MAX 70±10 μSEC (R1 AT POSITIVE END)

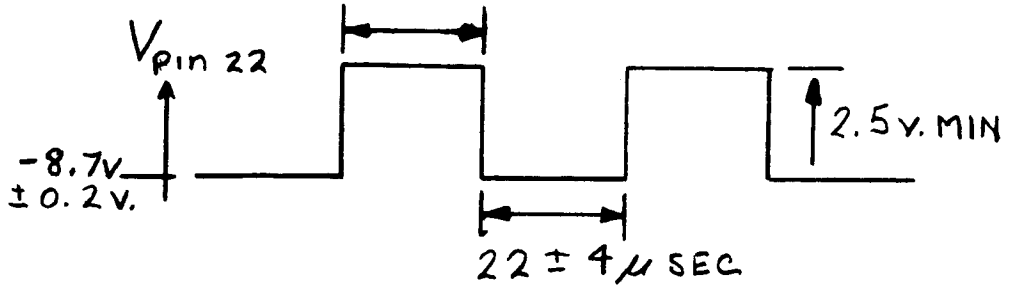


FIG. 8.2a

MIN 24±4 μSEC. (R2 AT POSITIVE END)
MAX 225±20 μSEC. (R2 AT GROUNDED END)

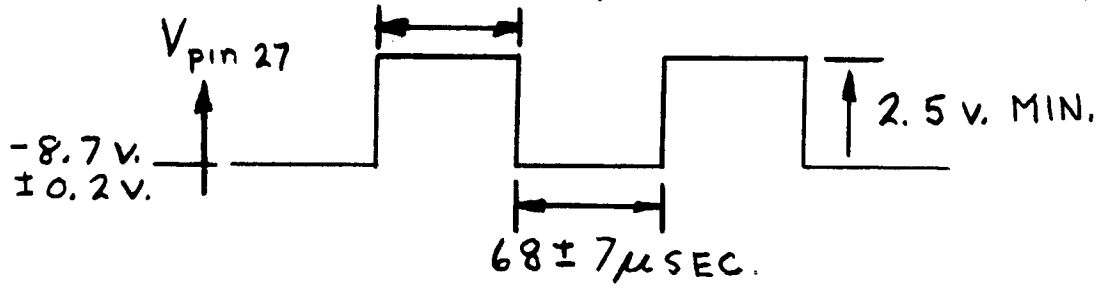


FIG. 8.2b

The waveform at pin 22 should be as shown in Fig. 8.2A. As R1 is rotated from negative to positive through the center third of its rotation the length of the positive part of waveform 8.2A should change smoothly and rapidly from the minimum value specified to the maximum. The length of the negative part should remain within the specified limits regardless of the position of R1. (jitter caused by 60 cycle pickup can be eliminated by grounding the pot shaft.)

8.2.2 The waveform at pin 27 should be as shown in Fig 8.2B. As R2 is rotated from negative to positive through the most positive third of its rotation, the length of the positive part of waveform 6.2B should change smoothly and rapidly from its specified maximum to its minimum. The length of the negative part should remain within the specified limits.

8.2.3 As R3 is turned from its most negative end to its least negative end, the voltage at pin 18 should change smoothly from -9.0 to -7.4 v.d.c. $\pm$0.2v.

8.3.1 For a reference voltage of +7.0 v.d.c. (pin 2) the voltage at pins 31 should be between -39.0 and -44.0 v.d.c. and should not vary by more than $\pm$0.1 volt as the voltage on pin 20 is varied between -50 and -60 v.d.c.

F. The magnitude of the positive voltage at pin 30 should be within $\pm$1.0 volt of the value of the negative voltage at pin

31, and should not vary by more than ±0.1 volt as the voltage on pin 19 is varied between +50 and +60 v.d.c.

8.4.1 Acceptance Criteria - The module is acceptable if:

1. the d.c. resistances are as specified

2. the period (length) of waveform 6.2A changes from minimum to maximum as R1 goes from negative to positive, and the lengths and amplitude are as specified.

3. The period of waveform 6.2B changes from maximum to minimum as R2 goes from zero to positive, and the lengths and amplitudes are as specified.

4. The voltage at pin 18 changes from -9.0 to -7.4v. as R3 goes from most to least negative.

5. the output of the +40v. regulator is as specified.

6. The output of the -40v. regulator is as specified.

9.1.1 With no connection to the module other than the two ohmmeter leads, check for the following d.c. resistances:

pin 7 to lead 6 shield	less than 0.1 Ω
pin 7 to lead 15 shield	less than 0.1 Ω
pin 7 to pin 11	less than 0.1 Ω

MODULE A9

9.2.1 Connect the module as shown in Fig. 9.1. With 28.0 v.d.c. applied between pins 1 and 3, the input current should be less than 150 ma.d.c. Check for the following voltages:

pin 4 +60 v.d.c. ±10v.

pin 17 -60 v.d.c. ±10v.

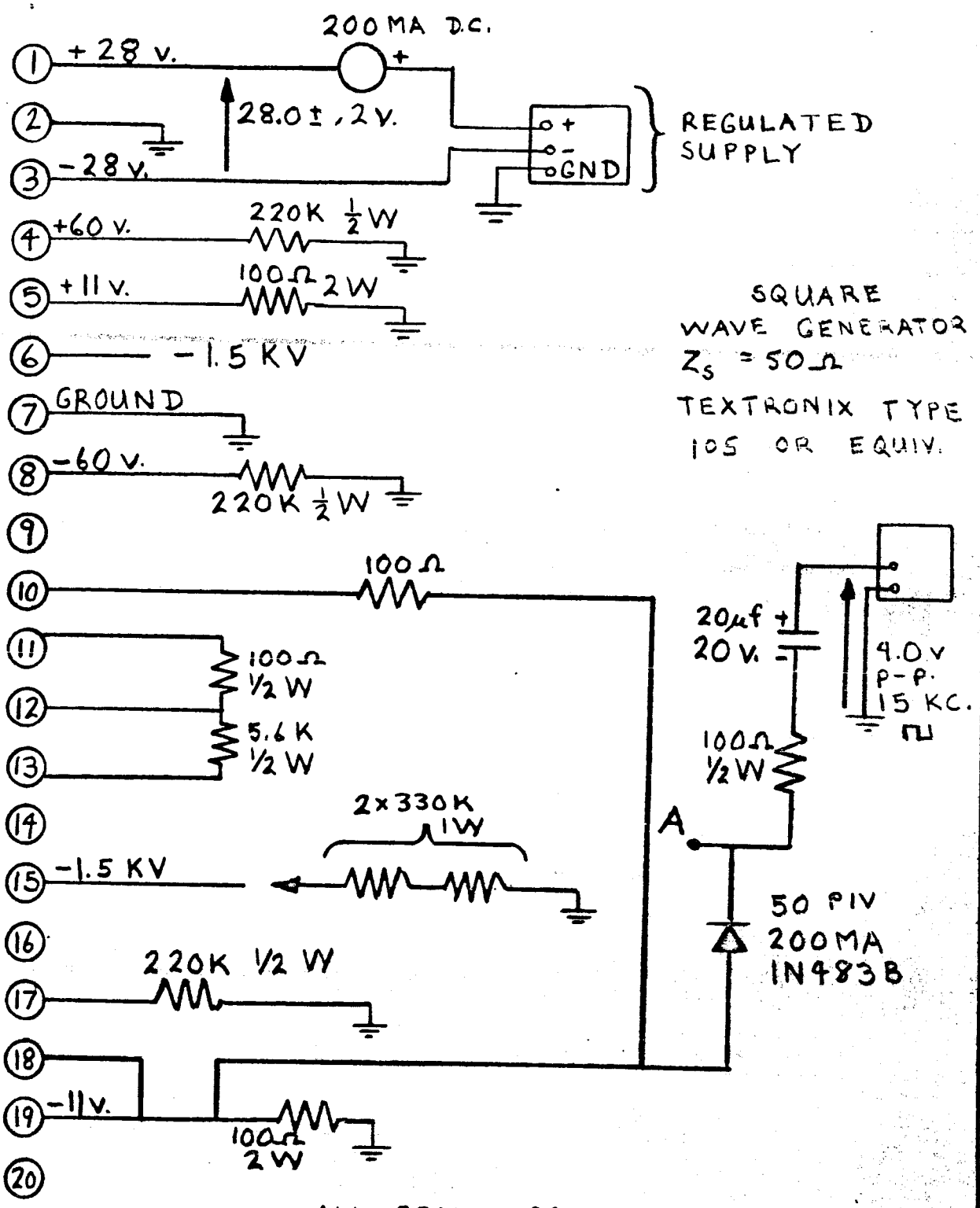

200 MA D.C.
+28 v.
28.0 ± .2 v.
-28 v.
+
-
GND
REGULATED SUPPLY
+60 v.
220K ½W
+11 v.
100Ω 2W
-1.5 KV
GROUND
-60 v.
220K ½W
SQUARE WAVE GENERATOR
Z_S = 50Ω
TEXTRONIX TYPE 105 OR EQUIV.
100Ω
100Ω ½W
5.6K ½W
2x330K 1W
-1.5 KV
220K ½ W
-11v.
100Ω 2W
20μf + 20 v. -
4.0 v p-p. 15 KC.
100Ω ½W
A
50 PIV 200MA IN483B
ALL RESISTORS 5%

FIGURE 9.1.

pin 5 +11.0 v.d.c. ±0.5v.

pin 19 -11.0 v.d.c. ±0.5v.

pin 10 -8.0 v.d.c. ±0.5v.

pin 12 symmetrical square wave frequency 5kc ±2kc min. amplitude 8.7v. p-p

pin 13 rounded square wave, same amplitude and frequency as pin 12, transition time approximately 1/4 of the period.

9.2.2 Adjust the signal generator to produce 4.0v. p-p 15kc symmetrical square wave at its output. Connect point A to pin 9 and readjust the generator output to 4.0v. p-p. Using an 11 megohm VTVM (RCA WV 98A or equivalent) measure the voltage at the center conductor of lead 6. This should be between -1.2 kv.d.c. and -1.5 kv.d.c. The d.c. input current should not exceed 200 ma. with the VTVM connected.

Remove wire A from pin 6 and connect it to pin 20. Measure the voltage at the center conductor of lead 15. This should be between -1.2 kv.d.c. and -1.5 kv.d.c. into the 11 megohm load. The input current should not exceed 200 ma. Connect the 660K load resistance to lead 15. The high voltage should drop to -550 v.d.c. ±60v. The voltage at pin 16 should be -10.3 v.d.c. ±0.5v.

When the 220K resistor is removed from pin 17, the voltage

at pin 16 should change to +85.0 v.d.c. ±10.0 v.d.c.

9.3.1 Acceptance Criteria - The module is acceptable if:

1. the voltages given in 9.2.1 are as specified.
2. the high voltage power supplies operate as specified.
3. the voltage at pin 16 changes as specified.
4. the d.c. input current does not exceed 150 ma.

with the high voltage power supplies inoperative or 200 ma with either one of the high voltage supplies operative under any condition.

SECTION IV

PHASE IIb ACTIVITY

A. SUMMARY OF ACTIVITY

Phase IIb is defined as the second portion of the contract in which four prototype sensors were manufactured, acceptance tested, and delivered to NASA/LRC.

This phase began with the part procurement, fabrication, and test of the optical, mechanical, and electronic components and assemblies. The major effort in terms of lead time and coordination was the fabrication of the welded modules which is described in the next section.

The actual assembly of the optical-mechanical section is quite rapid. The major assembly time is in the wiring of the modules.

The alignment and calibration procedures require approximately 80 hours per unit. The alignment is complicated by the inert gas purge, which is required. The calibration procedure requires linearization, zero and span adjustment of the partial pressure channels, and set up of the difference computation for the pN_2 output. This normally requires 40 hours to set up.

The alignment and calibration procedures are outlined later in this section of the report.

B. WELDED MODULE FABRICATION

Welded module Pre-bid Meetings for prospective vendors were held beginning December 15, 1966. Meetings were held with the following companies:

Spacecraft, Inc.
Huntsville, Alabama

Kerfott Products, Division of
General Precision Corporation
Clifton, New Jersey

United Aircraft Corporation
Farmington, Connecticut

Wens, Incorporated
Hawthorne, California

Electronic Packaging Industries
Anaheim, California

Electronic Specialty Company
Portland, Oregon

The Perkin-Elmer Corporation
Aerospace Systems
Pomona, California

The information supplied to each vendor consisted of nine individual module schematics, a systems wiring diagram, a module space layout, and the procurement specification, PE Spec 5289. Three of the prospective vendors no-bid; the remaining six vendors offered responsive quotations, which ranged in total sell price from $9,332 to $176,792. Based on technical confidence and a cost proposal that was considered to be realistic for the required effort, the module program was awarded to the Perkin-Elmer Aerospace Systems directorate in Pomona, California.

The program plan was to layout all modules using matrix techniques that were consistent with the module size and density restriction. Terminal boards were 0.032 inch glass epoxy material. It was considered that standard practices would be adhered to with regard to electrical component clearance, matrix conductive spacing, piece part size, etc. However, recognizing the potential requirement for compliance to NASA specifications, efforts were made to use MSFC Standard 271 and NPC 200-4 as guides in the performance of the work. The testing of these modules was assumed to be primarily throughput; that is, checking input against output. The criteria for these tests is described in Section III.

It was planned to test each module before and after encapsulation with Stycast 1090. The first test was to verify performance to requirements while it was still possible to correct possible errors or replace faulty parts. The second test would verify that the modules perform as expected after encapsulation. It was also considered that some analysis and engineering review time would be extended by the fabrication facility to assure adequate understanding of the circuit and operational requirements. This would insure that package modules operated as expected from the breadboard test. This engineering effort consisted of a preliminary engineering analysis of circuits, critical grounds, impedance and signal levels, and special shielding for isolation requirements. All modules were subjected to a preliminary analysis by both electronic and mechanical packaging engineers to clearly identify the unique requirements of each module. The analysis did precede the packaging layout. It was recognized that a Design Review of the finished package layout prior to release for fabrication best assured that the design criteria would indeed be met or bettered. Both engineering and quality representatives participated in the review activity. The analysis resulted in a set of instructions to the designer that guided him in the placement of parts, required density, design techniques, thermal considerations, and critical dimensions.

The entire design consisted of seven distinct welded modules. One module is used three times in a set for a total of nine modules per set. The program was controlled so the first module to be designed was reviewed prior to the installation of the design on the other modules. This module then became a model for the design of all other modules. A first article configuration inspection was performed after the first module of this type was assembled and before subsequent modules of that type were released for assembly. The purpose of this inspection was to catch any errors in design, however improbable, prior to assembly of the majority of parts. Each module was inspected at several critical steps in its assembly flow. These included kitting, pre-welding, part placement, post-welding, and post-conformal coating.

The anticipated delivery schedule was delivery of all modules between the period of July 6, 1967 and August 1, 1967. The lead circuit designer visited the Aerospace facility on April 27 to dicuss, in detail, the specific requirements of this design. The procurement requisition for the entire lot of 45 modules was issued May 1, 1967. Updated schematics and interconnecting wiring drawings were sent to Aerospace on May 2, 1967. The initial contact with the Project Engineer at Aerospace was made on May 10, 1967. A request for an increase in the height of Module A1 was received and granted on May 17, 1967. During the remainder of May, various small changes were made to the drawings as clarifications and corrections of typographical errors. On June 13, 1967, the Project Manager visited Aerospace Systems to finalize the details of the fabrication. It was determined at that time that Aerospace would encapsulate and shield the modules. However, it was felt best to perform system tests prior to final potting.

The first of the preliminary test specifications were delivered to Aerospace on June 15, 1967. Detail drawings were completed on Modules A1 and A2 on June 23, 1967. During the period from May 1 to June 23 the design was initiated on all modules except one. Design was completed on two modules and partially completed subassemblies were obtained. Material was ordered for the production of the modules and for module test equipment. Drafting and design times were anticipated to be higher than first proposed because of the density of several of the modules were above average and therefore required more layout time.

On July 11, 1967, the first major batch of semiconductors had been x-rayed and were forwarded for assembly. It was recognized at that time that Module A9 required an increase in size. Approximately 1000 detail parts were sent to Aerospace on July 12, 1967. Detail drawings for Module A6 were received on July 14, 1967. On July 14 it was determined that the requested increase in size of Module A9 was not compatible with the overall package and the only increase permitted was for an "L" shaped section to this module. On July 14, 1967, a complete lot of JANTX2N2222A transistors was rejected because of failure to pass the x-ray inspection. An entire lot had to be reordered. On July 17, 1967 it was determined that the proposed increase in size of Module A9 was possible. On July 28, 1967 all module designs except A9 were released from the engineering area. It was noted at that time that a great deal of difficulty had been encountered during the Design and

Drafting effort, which had resulted in unanticipated expenditures. The problem was basically one of part and component packaging density, compounded by the unusual modular configuration. Increases in cost were necessary due to the unforeseen packaging complexity. The remainder of the activities during July consisted of verification of specific part numbers and determination of procurement status records. An additional 400 components were supplied on August 1, 1967.

In order to reduce the anticipated overrun, the scope of the Aerospace task was reduced. Various plans were formulated in early August to reduce the overrun costs wherever possible. On August 16, all of the A2 modules were completed. Difficulty was being experienced in the other module configurations due to shortages of specific parts. On August 22, a Langley Research Center Quality Representative visited and inspected the first set of welded A2 modules. Up to that period, design was complete on all modules, drawings were released on three modules with the remainder in the final stages of checking prior to release.

On August 23, the forecasted delivery date of the modules was the end of October 1967. Difficulty was experienced on August 23 as Aerospace was not sure of the condition of the potting mold. Additional delivery of discrete components in small lots were made during August. Five of the A2 modules with test data were received in Norwalk on August 25, 1967.

By September 6, Aerospace had completed four units of Module A1 and had begun fabrication of Modules A3, A4, and A5. The decision was made that the modules would be encapsulated in Wilton and that this task would be deleted from the Aerospace scope of work. A request for the potting material and the molds were made at that time. On September 7, it was estimated that the remainder of the electronic components would be available by September 15. A detailed investigation was made into the reason for the additional delay.

Detailed drawings for modules A6, A7, A8, and A9 were received on September 12, 1967. Four of the A1 modules were received on September 14, 1967. On September 15, it was determined that the potting molds were not available and that the potting material had not been secured. On September 18, the status of the component procurements was summarized. At that time, 3,423 components were required and all but 99 had been procured and received. On September 20, 1967, the Project Manager again visited Aerospace to discuss the delivery problem. It was requested that Aerospace formulate and implement a maximum effort production schedule. On September 22, a schedule for the completion of all modules was 20 days after September 21.

The technical program report from Aerospace dated September 23, 1967 summarized the activity of the previous month. It was pointed out in this report that considerable difficulty had been experienced in the design of the shield for the A9 module. Approximately all of the engineering effort had been completed for the program, and approximately half the manufacturing and test efforts were completed. It was established on October 5, 1967 that all parts needed to complete the fabrication of the modules were at Aerospace.

On October 16, the first difficulties with modules were experienced. These difficulties occurred during the test where the operation was not in accordance with the anticipated performance.

Eight modules consisting of A6, A7, and A8 were received on October 24, 1967. On October 27, an additional seven modules were received. On November 3, 1967, six modules were shipped, leaving the remainder of the back order to be three modules of A9. These modules were subsequently shipped to Wilton for troubleshooting and final assembly. All of the modules were received by January 19, 1968.

On March 18, all the modules were completely checked out, repaired as necessary, and interconnected into the system for final test. Three sets of modules were encapsulated with Stycast 1090, while the fourth set of modules remained unpotted to facilitate systems tests at a future date.

In summary, the program has shown that it required nine months from the point of the receipt of an acceptable proposal until receipt of the final finished four sets of welded modules. It required an additional three months to troubleshoot and test, pot, and interconnect these modules into the system. The lead time for the modules was over twice that which was originally anticipated.

C, OPTICAL FABRICATION

The optical fabrication consisted of the grating, the primary mirror, the silicon lenses, IR filters, and sapphire and calcium fluoride windows for the UV sample cell.

No difficulty was experienced with the lenses, primary mirror or filters. The grating was improperly sized and had to be re-done and the sapphire windows were re-ordered due to low transmission of the initial lot.

The lenses and windows were bonded to the respective cells and mounts using 3M Co. EC 2216 B/A adhesive.

The UV sample cell assembly is shown in figure 43. The IR sample cell assembly is shown in figure 36.

The small calcium fluoride windows used in the UV sample cell were cemented with a butt-seal joint using PE Spec 5244. . They were examined under a 20X microscope for a suitable seal and were backed up with an application of 3M Company EC 2216 B/A adhesive. A final application after assembly of General Electric Vacuum Leak Sealer while the system was under vacuum assured a leak tight seal.

The first production lamp with the longitudinal design was received on August 1, 1967. This lamp was operated at 35 milliamps and 85 volts during the exhaust cycle. It had an initial firing of 1700 volts. The lamp could be operated at up to 90 milliamps at 45 volts. During the processing of burn-in, a leak

developed and the voltage gradually built up to 150 volts at 7 milliamps until the lamp could no longer be fired. The problem with the leakage was that the ceramic body was too porous and that air leaked in at the seal of the sapphire window and the ceramic body. A delay was caused in the procurement of a replacement lamp due to the difficulty in obtaining sufficient ceramic body material. Unfortunately, when the ceramic body material was received, it was physically oversized and unusable because of difficulties with the ceramic material. It was not until September 1, 1967, that the first useful ultraviolet xenon lamp was received from Electron Specialties. This lamp was designated as T42A1E by the vendor. The principal difficulty was that the ceramic parts, which were ordered on March 2, 1967, with a promised four-week delivery, were not received in useful fashion until August 21, and even at that time, they had to be reworked using ultrasonic sandblasting techniques in order to be useful for the design. This lamp was filled to 30 torr with xenon and had a firing voltage of 1200 to 1400 volts. It was baked at 350°C for 14 hours. The background pressure before the xenon filling was 5×10^{-7} torr. The voltage dropped during burn-in at 30 milliamps to 67 volts.

Spectral runs of the first lamp demonstrated that the fill pressure was not high enough to give a suitable ratio between the 1470Å and the 1725 continuum. It was determined by an evaluation of the spectral distribution that the fill pressure of 80 torr would be most suitable. In mid-September a second lamp was filled to this pressure and tested on a Jarrell-Ash monochromator. The emission spectra for this lamp is shown in figure 50. After tests were performed on the 80 torr lamp, it was determined that a slightly higher pressure would be required, and the final specification was set at 100 torr of xenon. The 80 torr lamp was to be retained for life tests.

The four production lamps were delivered on October 12 and had firing voltage characteristics of 1950 volts dc to 2100 volts dc, and the voltage drop during operation was from 78 volts dc to 67 volts dc. These tubes were serial numbered 225-2-3-4-5. The sapphire windows used for these lamps is shown as Perkin-Elmer Part Number 631-1106.

The backup lamp previously described was purchased from the Doran Product Inc., of Norwalk, Connecticut. This lamp was shown in Doran drawing No. SK-DP-7-026. The lamp contained a 0.026-inch ID capillary with molybdenum electrodes, 0.005 thick. These lamps are the end-on capillary type. In their fabrication procedure, they were baked and pumped down to 2 by 10^{-7} torr at 450°C for 4 hours. They were then filled with 30 millimeters of xenon, tested and then pumped down to 5 by 10^{-6} torr. The getters were then heated to a glow at 8.5 amps for three minutes. The lamps were operated at 5 milliamps at 250 volts for 10 minutes, and then 10 milliamps at 250 volts with a voltage drop of 75 volts for 5 minutes. The lamps were then pumped out again and filled with 30 torr of xenon, cut off, and finally tested. The final fill pressure was 30 torr of xenon. Six lamps of this series were delivered on March 28, 1967. It was unfortunate that, in the firing of the getter, a number of the lamps had a deposit of the barium getter material directly in front of the capillary discharge path. The barium getter material was removed from the lamp faces by heating the lamps from 230 to 290 degrees F. The appearance of the lamps was good, and their initial performance was excellent. However, over a period of a few weeks, all the lamps gradually leaked air, discoloring the getter material, and destroying their functional performance characteristics.

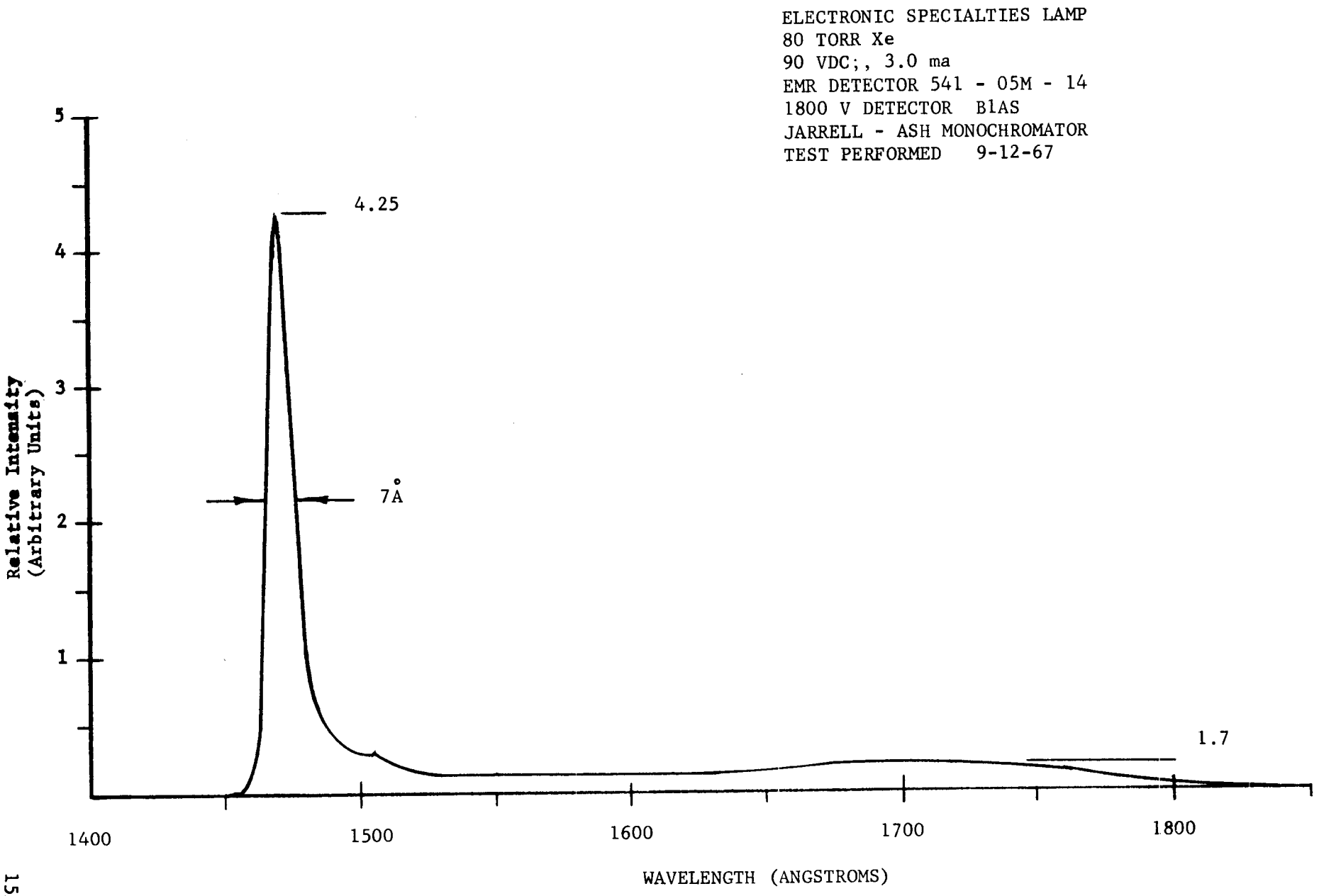


Figure 50. UV Source Emission Spectra for 80 Torr Lamp

OPTICAL CEMENTING EPOXY

1. SCOPE:

1.1 This specification describes an acceptable material and the preferred procedure to be used when bonding glass.

2. REQUIREMENTS:

2.1 MATERIALS: The following materials are required for Bonding:

Material	Part No.	Manufacturer
Base	37-128	Wyndham Chemical Co.
Hardener	37-600	10640 S. Painter Ave.
		Santa Fe Springs, Calif.

2.2 CONTAINER: Mix in Pyrex or plastic container

3. BONDING PROCEDURE:

3.1.1 PREPARATION OF PARTS: All parts shall be handled with clean disposable plastic gloves during and after preparation. Work is to be performed under a clean hood.

3.1.2 Clean the surfaces to be cemented using methyl alcohol and a circular motion starting from center of element and working outward.

3.1.3 Repeat above, using certified pure acetone.

3.1.4 After elements have been thoroughly cleaned, match surfaces to be cemented for fit. (smoothness of surfaces, etc.).

3.2.1 PREPARATION OF MATERIALS: Before proceeding further, read and follow the directions detailed in caution box.

CAUTION

Both the base (37-128) and the hardener (37-600) contain toxic and caustic components. Use rubber gloves and/or protective creams when handling these products. Use goggles or a face shield and avoid splashing.

Use only with adequate ventilation and avoid prolonged breathing of vapors. Avoid contact with skin and eyes. In case of contact, immediately flush with plenty of water; for eyes, get prompt medical attention; for skin, clean with soap and water or alcohol. Remove contaminated clothing and shoes; wash thoroughly before reuse. Wash hands before eating or smoking.

3.2.2 MIXING RATIO: (By Weight) Four (4) parts of base (37-128) to one (1) part of hardener (37-600).

3.2.3 The components must be mixed thoroughly to avoid straiae effects.

3.2.4 If bubbles develop, these may be drawn out with a vacuum.

3.2.5 Maximum Pot Life is one hour. However, it is recommended that any mix be not used for longer than 20 minutes.

4. APPLICATION:

4.1 Apply the prepared cement in drops to the concave element until the cement covers the surface uniformly with a film of .01 to .02 millimeters.

4.2 Bring the convex surface in contact with the cement, using a light circular movement on the convex element to spread the film evenly and to remove the air bubbles.

4.3 Use a fixture or other appropriate means to properly align the elements and to maintain the alignment during curing.

5. CURING

5.1 This is an air-dry cement

5.2 After intimate contact is achieved, no further pressure is required during curing cycle.

5.3 The cement reaches an initial set in two hours.

5.4 The assembly should cure for 24 hours before further handling.

6. DISASSEMBLY:

6.1 Freshly cemented elements can be readily separated within the first 24 hours.

6.2 For assemblies firmly cemented; Immerse cemented elements in solvent, dimethyl formamide, and place in oven at 180°F to 200°F for 24 hours, or longer depending upon size of element.

7. REFERENCE INFORMATION:

7.1 Refractive index of cement: 1.517

7.2 There is no appreciable outgassing for space or vacuum applications.

7.3 No information is presently available on reaction of cement in laser applications.

7.4 The cement apparently builds up no stress in the cemented elements. Elements tested to date under a polariscope recorded no induced strain, or no change in figure of the noncemented surfaces.

7.5 The cement has been temperature tested as follows:

Hot Test	+ 180°F	12 Hours
Cold Test	- 68°F	12 Hours

7.6 This cement is not suitable for use in the U.V. region.

7.7 Transmittance and absorbance tests have been run. There is no difference between this cement and PECO SPEC 502 Cement (A.O. 805).

7.8 This cement is approved for use in place of PECO SPEC 502 Cement.

Over a six month period during the fabrication cycle, the longitudinal lamps have been used almost continually with no apparent degradation due to leakage. The lamps are quite noisy in operating as UV sources, and several of the lamps have exhibited a dual mode of operation, operating at either 85 volts or at 105 volts. The noise spectra is not a problem with the present design but it does limit the general usefulness of the lamp to other programs. The 105 volt operating point is significantly more noisy than the lower voltage point. There is some visible flicker of the cathode discharge in the capillary, which can be observed during operation of the lamp. It is felt that a smaller dimension capillary would restrain the motion of the discharge and that a magnetic bias could appropriately be applied to stabilize the position of the discharge in space. Slightly more masking of the capillary would be desirable to eliminate a slight flicker that can be observed in that area. Tests have been made with the Jarrell-Ash monochromator that show no changes in the spectral distribution along the length of the discharge. The future work required in the UV source area is the design of a more quiet source with an absolutely stable spatial configuration of its discharge.

D. MECHANICAL FABRICATION

1. Solderable Surface Specification

In an attempt to form a solderable surface for the hermetic cover to base flange seal, a special process specification, PE Spec 5335 (attached) was generated and implemented. The actual performance of the electroless nickel plating was excellent and good results were obtained without difficulty. However, the problem caused by the large flanges and, hence, good thermal conductivity of the base prevented the use of the soldered seal. The redesign effort to rework the flanges for use as a welded lip seal or soldered seal could not be permitted during Phase IIb due to the pressures of schedule and costs.

2. Potting Molds

The electronic "cordwood" assemblies were vacuum impregnated with Emerson & Cuming Stycast 1090 SI, a two-part encapsulant, using metal dip mold fixtures. After curing and stripping off the metal mold, the pouring face was finished to the proper dimension by belt sanding. The potted modules were then masked and sprayed with Eccocoat CC-2 conductive surface coating, forming an electrostatic conductive shield.

The metal dip mold fixtures were made of 2024 Aluminum milled to size and then buffed to a high luster polish. One dimension was made approximately one-half inch longer than the cordwood electronics to permit overfilling of the potting material. These fixtures were dipped in a vessel of molten metal and immediately removed. During this brief period of immersion a shell of metal freezes to the pattern. This shell is easily removed from the pattern fixture and forms a perfect mold for the casting resin.

The molten metal used was CERROTRU, a trade name, melting at 281°F which has the interesting property of expanding after it has solidified just enough (0.0005 inch per inch) to allow for easy removal from the master fixture.

PROCESS SPECIFICATION

ELECTROLESS NICKEL ON ALUMINUM

1.0 SCOPE

This specification overs one process for the preparation of aluminum surfaces for the application of a thin electroless nickel film by immersion. This film allows conventional soldering techniques to be used with the aluminum.

2.0 PROCEDURE

The following procedure is applicable to aluminum alloys 43, 218, 319, 356, 380, 1100, and 6061 (T-55).

2.1 Preclean

2.1.1 Preclean to remove grease, oil and buffering compounds. Enthone, Inc. Emulsion Cleaner #75 full strength at room temperature may be used. Immerse the aluminum part for 10 to 60 seconds. A conventional vapor degreasing or suitable solvent may be used.

2.1.2 Rinse in a cold water spray.

2.2 Mild-Etch Soak Cleaning

2.2.1 Prepare a solution of the soak cleaner by mixing: 8 oz. of Enthone, Inc. "Enbond" #NS-35 powder to a gallon of clean water. Mix in a stainless steel, fiberglass or

plastic lined container.

> CAUTION: THIS SOLUTION IS MIDLY ALKALINE. CONTACT OF THE SALTS OR SOLUTION WITH THE EYES OR SKIN IS TO BE AVOIDED. IN CASE OF CONTACT, FLUSH SKIN OR EYES WITH COPIOUS AMOUNTS OF COOL, CLEAN WATER. IN CASE OF CONTACT WITH THE EYES, MEDICAL ATTENTIONS SHOULD BE OBTAINED.

2.2.2 Heat and use the solution at 180°F ±5°F.

2.2.3 Immerse the aluminum part for 30 seconds to 5 minutes. Remove after a mild etch has been obtained.

2.2.4 Remove the aluminum part and cold water rinse. A light smut may have formed on the piece which is removed in the subsequent process.

Safely store and clearly identify the solution.

2.3 Acid Etch (Pickling and Activating Agent)

2.3.1 Prepare a mixture of the acid solution by mixing:

Nitric Acid, 36°Be'	2 volumes
Sulfuric Acid, 66°Be'	1 volume
Water	1 volume
"Acetane 70"	1 lb/gal.

("Acetane 70" by Enthone, Inc.)

Mix in a polyethylene tank.

> CAUTION: DO NOT BREATH THE VAPORS FROM THE ACETANE CONTAINER DUE TO THE SLIGHT EVOLUTION OF HYDROFLUORIC ACID GAS.

USE ONLY IN A VENTED HOOD TO PROTECT THE OPERATOR. DO NOT ALLOW THE SALTS OR SOLUTION TO COME IN CONTACT WITH THE SKIN OR EYES. IF CONTACT IS MADE, FLUSH OFF PROMPTLY WITH COLD WATER AND APPLY SODIUM BICARBONATE SOLUTION. IF CONTACT WITH THE EYES IS MADE, FLUSH WITH PLENTY OF COLD WATER AND OBTAIN MEDICAL ATTENTION. WEAR RUBBER GLOVES. DO NOT ALLOW THE SOLUTION TO GET UNDER THE FINGER NAILS.

2.3.2 Immerse the aluminum part at a room temperature for 15 to 30 seconds.

2.3.3 Remove the part and rinse in cold water.

2.3.4 Discard the solution in accordance with laboratory recommended practice.

2.4 Electroplate

2.4.1 Prepare a mixture of the electroplating solution in the following manner:

a) Fill a tank with 1/5 gallon of water.

b) Slowly add Enthone, Inc. "Alumon D" salts to the water with continuous agitation.

CAUTION: TOO RAPID ADDITION OF SALTS MAY CAUSE BOILING AND ERUPTION OF THE SOLUTION.

Keep the temperature of the solution below the boiling point.

c) After the salts have dissolved, dilute to a total volume of one gallon.

Alternate

a) Mix one part "Alumon D Liquid" by Enthone, Inc. to 4 parts water by volume and stir throughly. This solution doesn't heat during mixing.

2.4.2 Use solution at 75°F. Immerse the aluminum part for five seconds and remove. If a spongy zinc coating is evident, use the alternate double dip method.

2.4.2.1 Double Dip Method

a) Immerse the aluminum part for 5 to 30 seconds.

b) Strip the zinc coating with a fresh nitric acid bath.

c) Immerse the aluminum part in the "Alumon D" solution of paragraph 2.4.2 for 5 seconds.

2.4.3 Rinse in cold water.

2.5 Electroless Nickel Plating

2.5.1 Prepare a mixture of the plating solution as follows:

"Enplate NI-410A"	2 parts by volume
"Enplate NI-410B"	1 part by volume
Water (deionized)	13 parts by volume

Mix in a clean stainless steel, glassware, vitreous enamel or polyproplyene tank. The solution capacity is 75 to 100 in^2/gal.

2.5.2 Heat to 190°F±2°F useing a water bath around the plating mixture tank.

2.5.3 Preheat the aluminum part to 190°F±5°F.

2.5.4 Immerse the aluminum part in the solution until sufficient nickel build-up is accomplished. Use mild agitation. Plating rate is 0.3 to 0.5 mils/hr. A thickness of 0.0005" is sufficient for soldering on aluminum.

2.5.5 Remove from the plating solution. Cold water rinse. Dry.

2.6 For plating on aluminum alloys 2011, 2024, 6061 and 7075 use the following procedure:

2.6.1 Same as 2.1.1 thru 2.2.4

2.6.2 Same as 2.3.1 thru 2.3.4 except limit the immersion of 2.3.2 to 15 seconds.

2.6.3 Same as 2.4.1

2.6.4 Immerse for 30 seconds in the solution at room temperature.

2.6.5 Same as 2.4.3 thru 2.5.5.

3.0 Summary of the physical properties of the electroless nickel film:

Specific gravity	7.85
Melting point	1635°F (890°C)

Coefficient of thermal expansion	$7.22(10^{-6})/^{o}F$
Adhesion to steel	30,000-60,000 psi
Hardness as plated	49 Rockwell C
Applicable specifications	MIL-C-26074A

4.0 The materials mentioned in this specification may be purchased from the Enthone Corporation, West Haven, Connecticut.

After molding, the slush molds were cut to allow insertion of the terminal boards for the cordwood. The molds were sprayed with MS-122 Fluorocarbon release, the electronic cordwood was inserted into the mold, and the molds then were sealed with TC-527 Mold Seal, baked at 100°F, and then vacuum encapsulated.

3. UV Absorption Cell

Following receipt of bids for the construction of the original design of the UV sample cell, it was decided to simplify the design in order to reduce the anticipated high cost of the original design. The UV sample cell design, therefore, is somewhat modified from the design proposed during the design phase of this effort.

E. QUALITY CONTROL

The Quality Assurance Department has conducted the quality program on this project generally in accordance with Perkin-Elmer Engineering Report No. 8505, "Product Assurance Plan for the Two Gas Atmosphere Sensor," dated August 30, 1966. The primary impact of the quality program has been during the Phase IIb portion of the program. The quality assurance activity has been concerned with the following areas during the program:

(1) Contract Review
(2) Design Review
(3) Control of Purchased Material
(4) Control of Perkin-Elmer operations
(5) Drawing and Change Control
(6) Equipment calibration
(7) Control of nonconforming material
(8) Quality Engineering

Quality Assurance has continually reviewed the contract for the definition of the functional requirement of the deliverable items and the description of the special requirement imposed in the quality area. It was the intent of this program to use major portions of NASA document NPC 200-2 as a guide in the development and operation of the Quality program.

Quality Assurance has participated in all design reviews. Designs were examined to verify that the proposed sensor was compatible with the contractual requirements and that considerations were given for future manned space applications. After design reviews, Quality Assurance examined the designs from an inspection viewpoint and performed tolerance studies on the detail parts. Areas that were difficult to inspect were brought to the attention of the project manager and changed where possible, or special detail inspection instructions were issued.

Quality Assurance has reviewed all Purchase Orders for compliance in the following areas:

(1) Assurance that the proper quality requirements are imposed on vendors.

(2) Verification that the vendors were required to submit adequate documentation, such as material analysis reports, certifications, and test data, with each shipment.

(3) Formulation of Quality Assurance inspection for each article. All parts used on the Two Gas Atmosphere Sensor Program received 100 percent incoming inspection.

(4) Assurance that procurement is made from Perkin-Elmer approved sources. If a new source was developed for the program, then a quality audit was performed to verify the vendor's acceptability to Perkin-Elmer's Quality Department.

Assembly and fabrication operations were inspected at key points during the manufacturing cycle. Quality Assurance Engineering has provided special instruction for critical areas, as necessary. Inspection records have been maintained for all inspection operations and remain on file at Perkin-Elmer for customer review.

The Quality Assurance Department has reviewed the final acceptance test plan and procedure and has contributed to the development of the standard procedures and test criteria specified in this document. Quality Assurance will witness the final acceptance test and will verify the packaging and deliverable documentation.

Quality Assurance has verified that the change control system for the drawings has been properly implemented.

All test equipment, tools, gauges, and other equipment that affected the quality of the end item, or was used to verify the quality of the hardware, was under the control of Perkin-Elmer's Calibration System. Quality Assurance verified that all equipment was calibrated as specified.

All articles that required special finishes or treatment were processed in Perkin-Elmer approved facilities. Process certifications were requested and received from all such vendors before the items were released from inspection.

Optical coatings were under the control of Perkin-Elmer Optical Inspection Group. Transmission characteristics of representative test lines were evaluated by Quality Assurance.

All material that was inspected and found to be nonconforming to the specifications during Phase IIb was acted on in accordance with Perkin-Elmer material review procedures.

Discrepancies to the drawings and specifications were reported by inspection on nonconforming material notices and submitted to Quality Assurance Engineering and Project Engineering for disposition. The consideration of the disposition was in accordance with Perkin-Elmer standard procedures or the items were returned to the vendor. Wherever nonconformances could be reworked to the drawings, such rework was performed. Articles awaiting disposition were identified and were segregated from the acceptable parts until a final agreement with the project could be determined.

Quality Assurance Engineering directed the entire Quality Assurance effort on this program. This effort consisted of the following functions:

(1) Developing and implementing a detailed inspection plan prior to the onset of Phase IIb. This was done with the previously mentioned report (No. 8508).

(2) Issuing written inspection procedures where deemed necessary.

(3) Serving as a quality assurance representative for all material review action.

(4) Participating in design reviews

(5) Coordinating the activities of the various inspection groups.

(6) Developing and maintaining suitable liaison between Quality Assurance and the various internal and external organizations within the company.

F. DEVELOPMENT TESTS

1. O_2 Stability Tests

On December 5, 1967, an overnight stability test was performed on the first production optical-mechanical assembly. The test used the complete electronic breadboard for the readout. The test circuit was as shown in figure 51.

The change in pO_2 was 40mv in 16 hours, which corresponds to a shift of 2mm Hg pO_2 over this period, with no compensation for temperature or barometric changes.

Saturated vapor was introduced with no detectable change in the pO_2 reading. The sample gas was premixed 29.3 percent O_2 in N_2. A three hour test with 9.6 percent O_2 in N_2 showed no detectable change.

The oxygen span stability was tested during the period from February 21 through February 25, 1968. A review of the data shows an upscale drift of 0.34 to 0.38 percent per hour with 204mm Hg, pO_2 input. For a smaller concentration of 181mm Hg pO_2, the drift was 0.30 percent per hour. After introducing water vapor into the system, the drift was 0.4 percent per hour for the first 24 hours and 0.34 percent per hour for the next 12 hours.

During the period from February 26 through February 27, a 228mm Hg pO_2 sample showed a 0.034 percent per hour drift over 17 hours. When nitrogen was used as a sample for 12 hours, there was a downscale change equivalent to 0.034 percent per hour. This data supports the idea of an O_2 induced absorptive film discussed later in this report.

On February 28, 1968, tests were conducted to determine the built-in test signal stability. The results showed a ±0.8 percent maximum change in 50 hours.

The O_2 span stability was tested on March 26 to show a 0.3 percent per hour drift. On March 27, a similar test showed an oxygen drift rate of 0.2 percent per hour and 0.06 percent per hour for the CO_2 channel. This test was repeated on March 29 to show 0.3 percent per hour for O_2 and no change in the CO_2 channel over a 16 hour period.

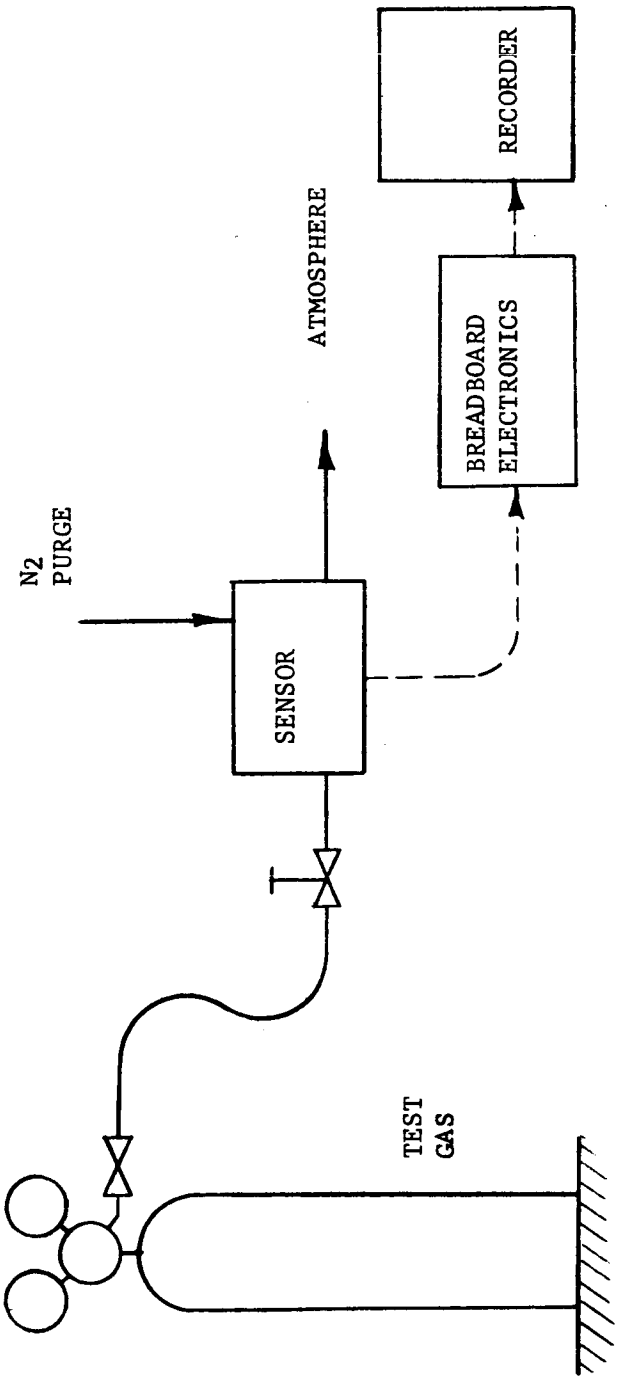


Figure 51. Test Circuit for O_2 Stability Test

2. O_2 and CO_2 Stability Tests

Additional O_2 and CO_2 channel stability tests were performed on the second sensor from March 31, 1968 to April 11, 1968. The test arrangement that was used is shown in figure 52. Premixed gas samples were used at a sample flow of 100 cc/min and a total pressure of 7.0 psia. The optical section was purged with prepurified nitrogen during the tests.

The change in the pO_2 channel output over a 50 hour period is shown in figure 56. The theory that the formation of an absorptive film was proportional to the O_2 concentration and was removed with an N_2 purge was partially tested with the results shown in figure 57.

The change in pCO_2 channel output over a 50 hour period is shown in figure 58.

G. ALIGNMENT PROCEDURE

1. IR Prealignment

Assemble the bolometer assembly, sample cell assembly with lenses, and source-lens assembly on the IR subassembly baseplate (see figure 33). Connect the bolometer to the bias supplies and preamplifier in Module A1. Modulate the lamp with a 4.0 volt peak-to-peak, 15 Hz square wave. Rotate the lamp so that the lit filament is close to the lens and is parallel to the face of the lens. Adjust the position of the lamp relative to the lens and the relative positions of the three subassemblies on the baseplate to maximize the amplitude of the square wave at the output (pin 8) of Module A1. An amplitude of greater than 300 millivolts peak-to-peak should be attainable. Tighten down the lamp and all the subassemblies in the position that gives maximum output and put a drop of No. 2216 structural adhesive on each bolt head.

2. UV Prealignment

Assemble all the UV optical components except the torquer and the photomultiplier on the main baseplate. Adjust the upper slit so that it is slightly above the centerline of the upper sample cell, and adjust the lower slit so that it is slightly above the centerline of the lower sample cell. Operate the UV lamp from the power supply in Modules A8 and A9, or preferably from an external power supply.

Adjust the opposing screws on the grating bracket so that the visible primary image of the lamp falls just below the upper slit. The grating should be very nearly vertical. Alternately rotate the lamp about its axis and move the sample cell assembly and/or grating bracket toward or away from each other until the brightest possible, sharply focused image is formed.

The image should be slightly wider than the slit, and should be adjusted so that it overfills both sides of the slit by an equal amount. This can be done by moving the lamp axially or by moving either the sample cell or the minor bracket sideways.

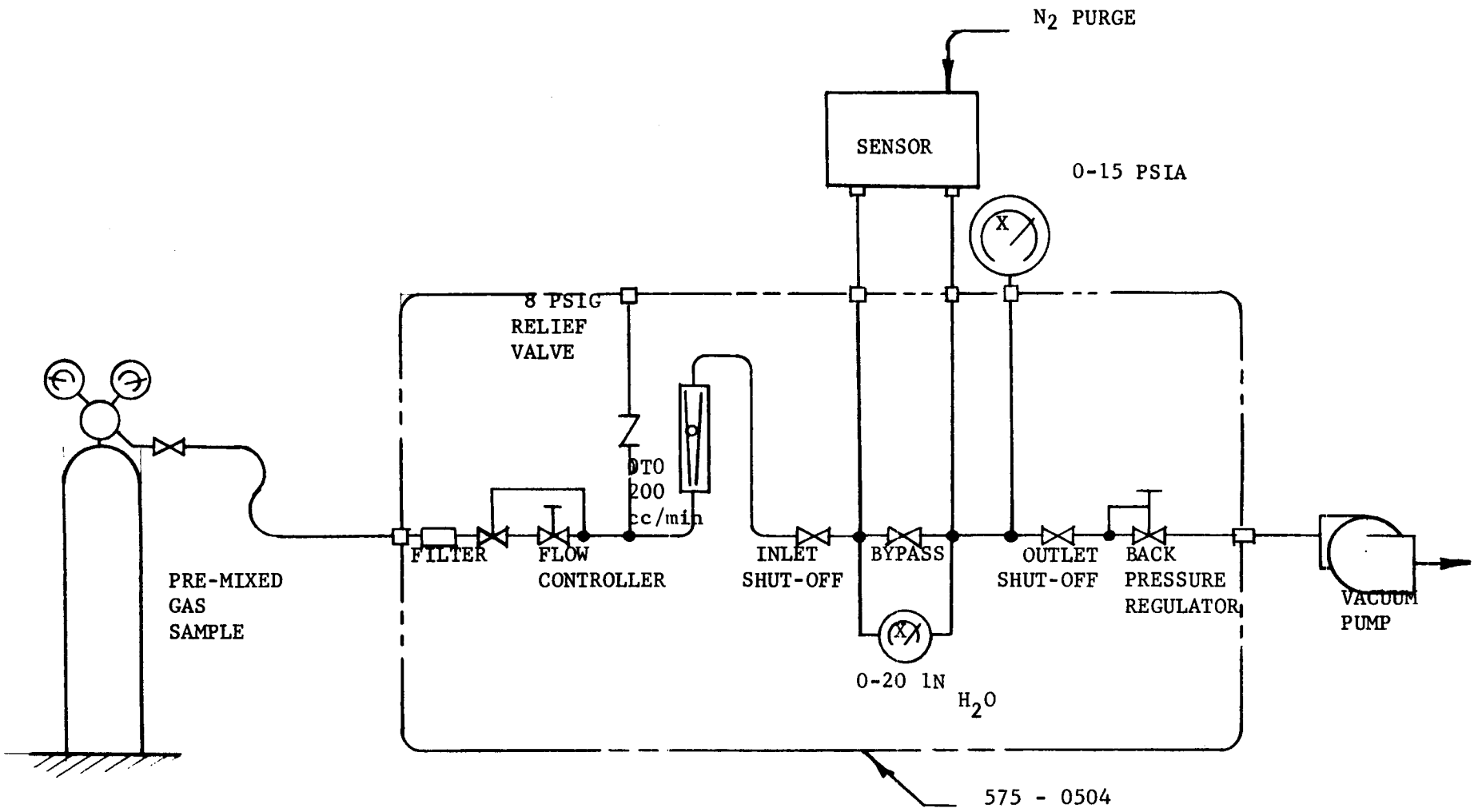


Figure 52. Test Arrangement for O_2 and CO_2 Stability Tests

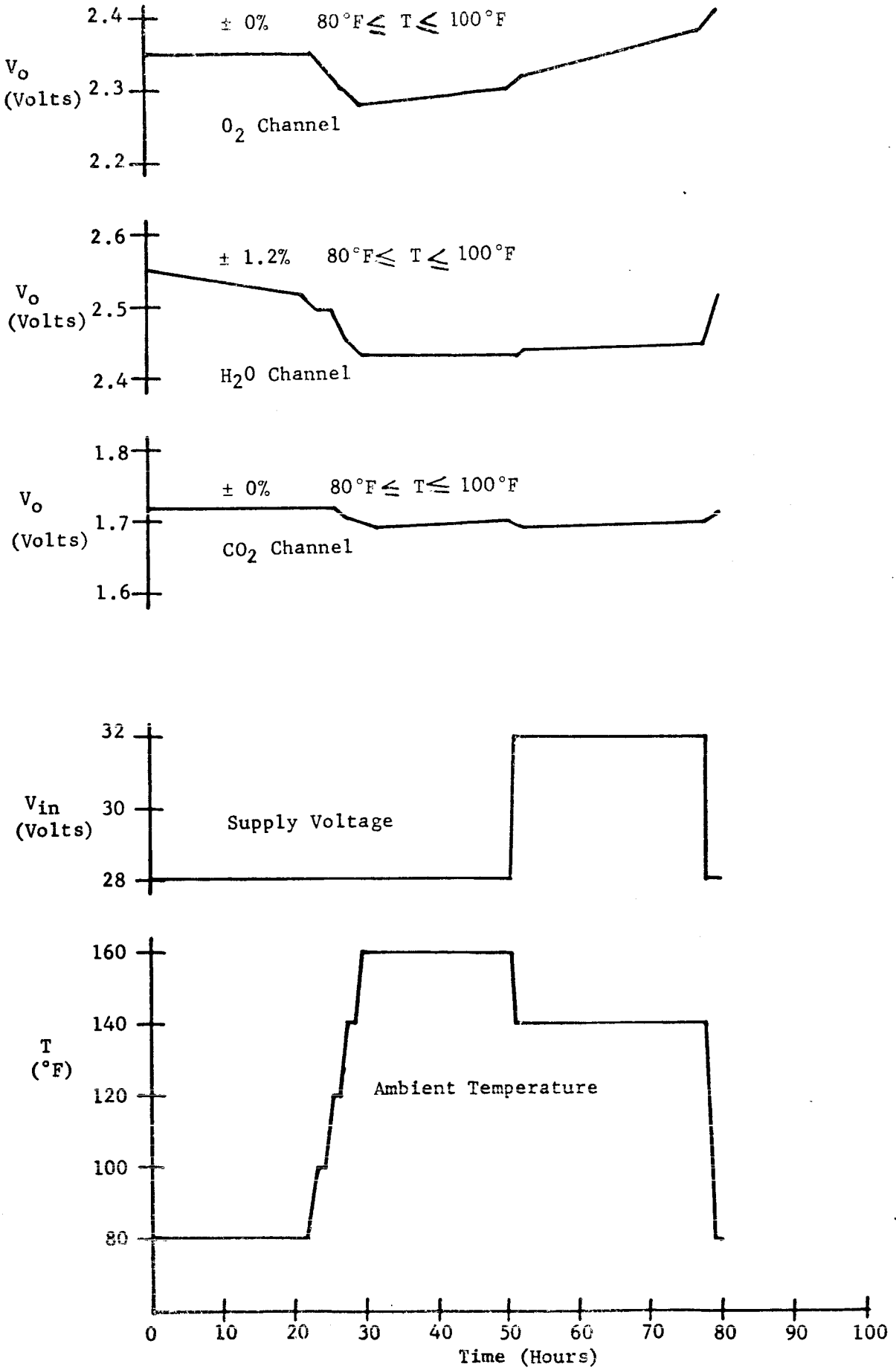


Figure 53. Breadboard Electronics Span Stability

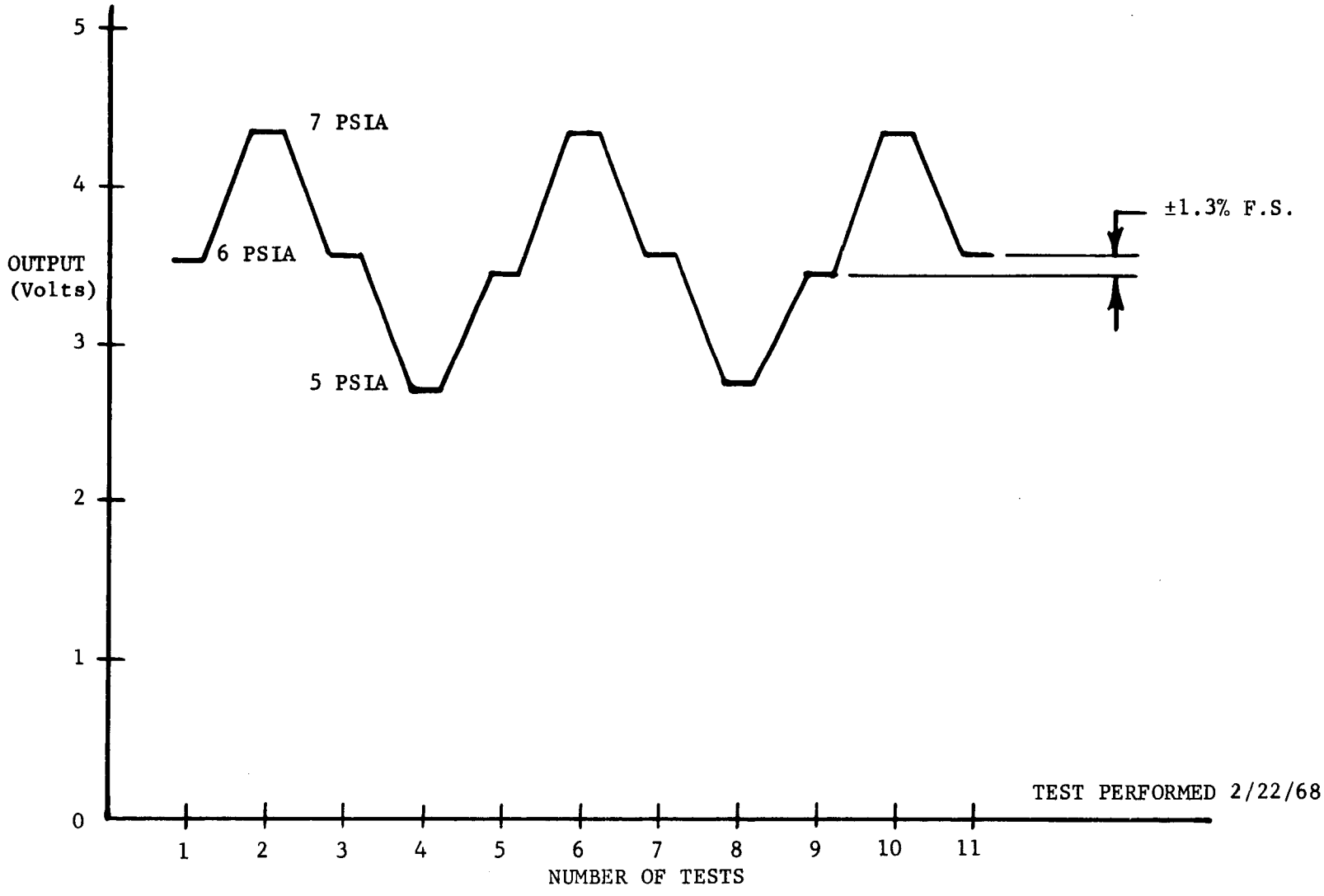


Figure 54. Total Pressure Error Band Data

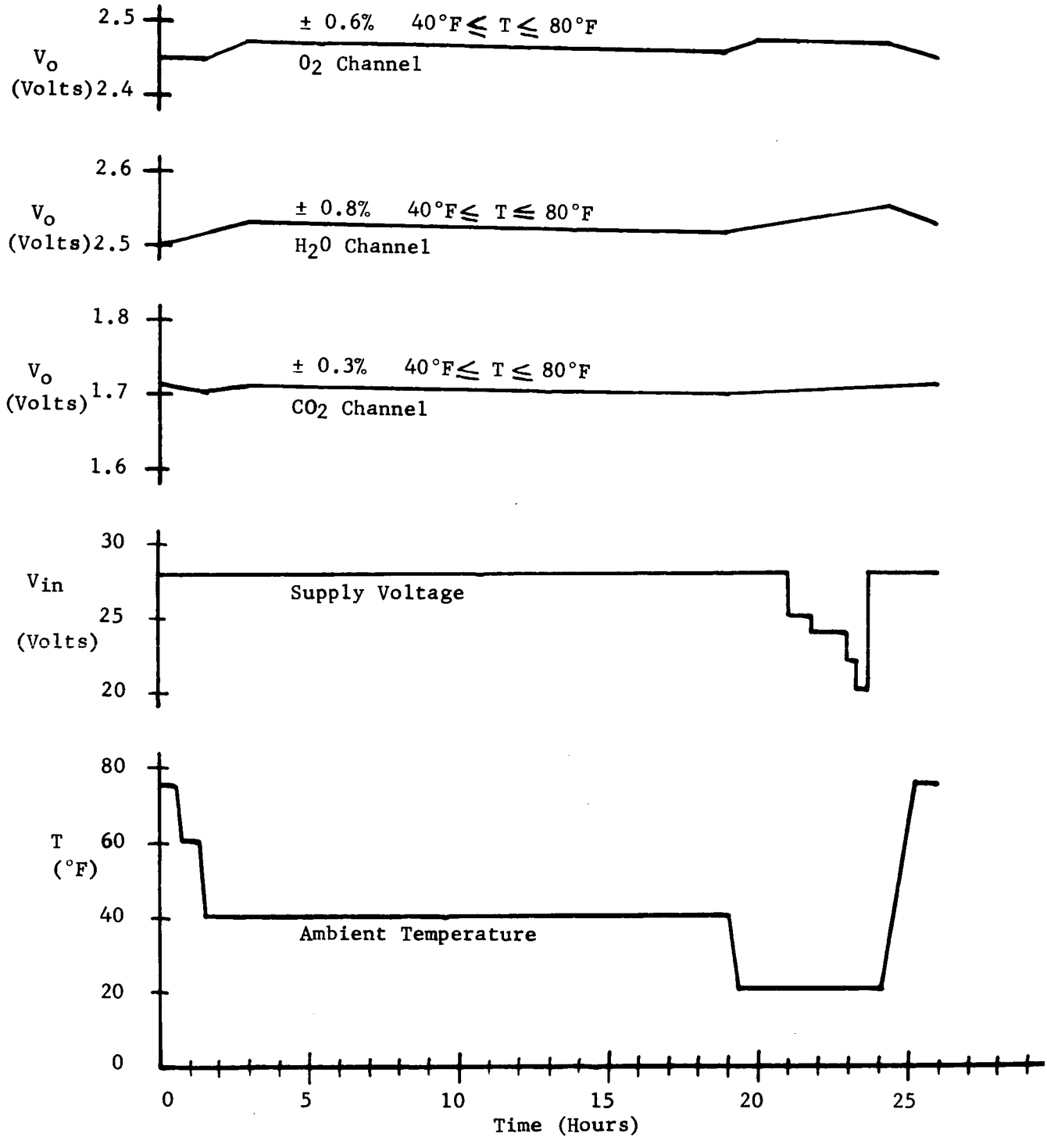


Figure 55. Breadboard Electronics Span Stability

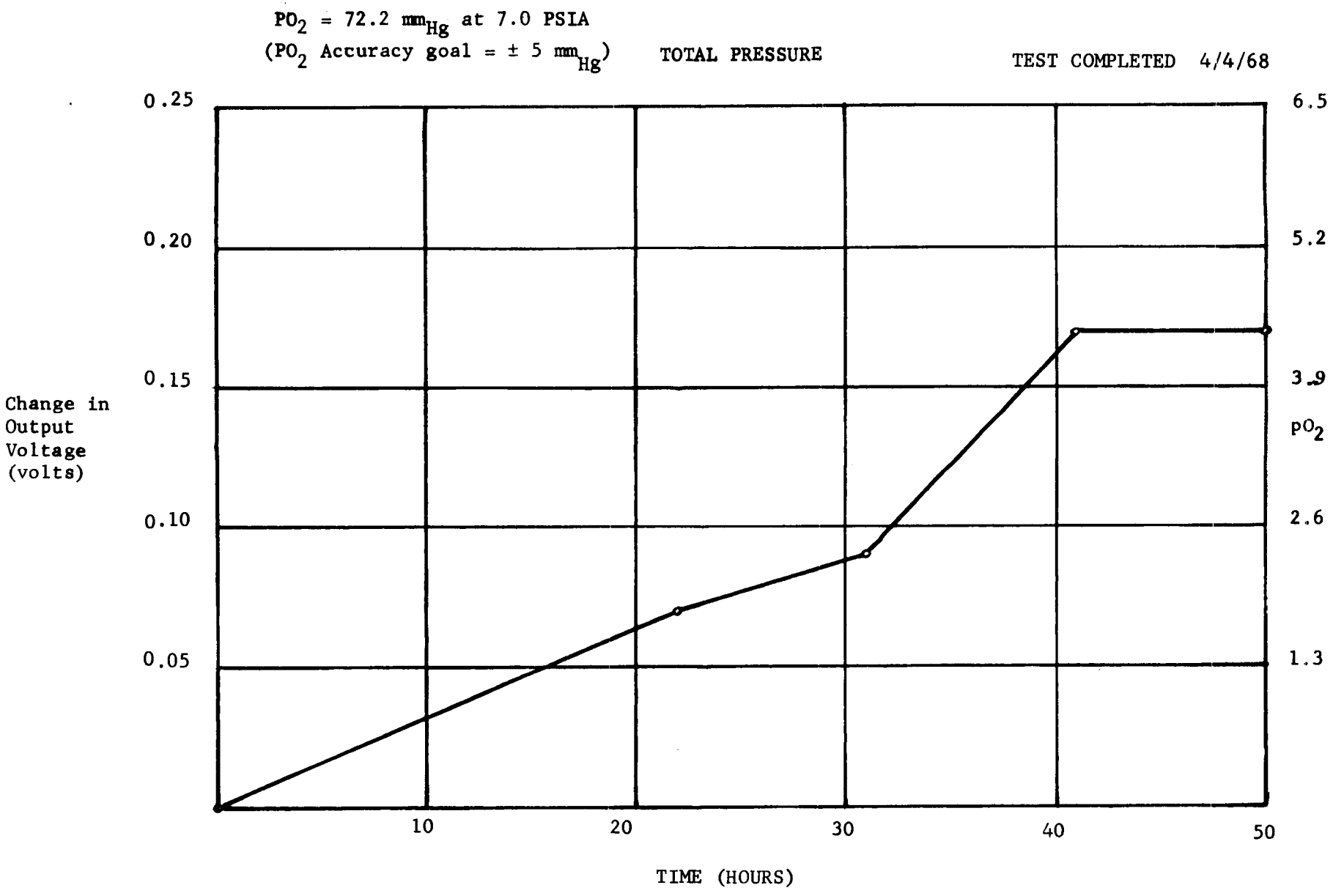


Figure 56. Change in PO_2 Output

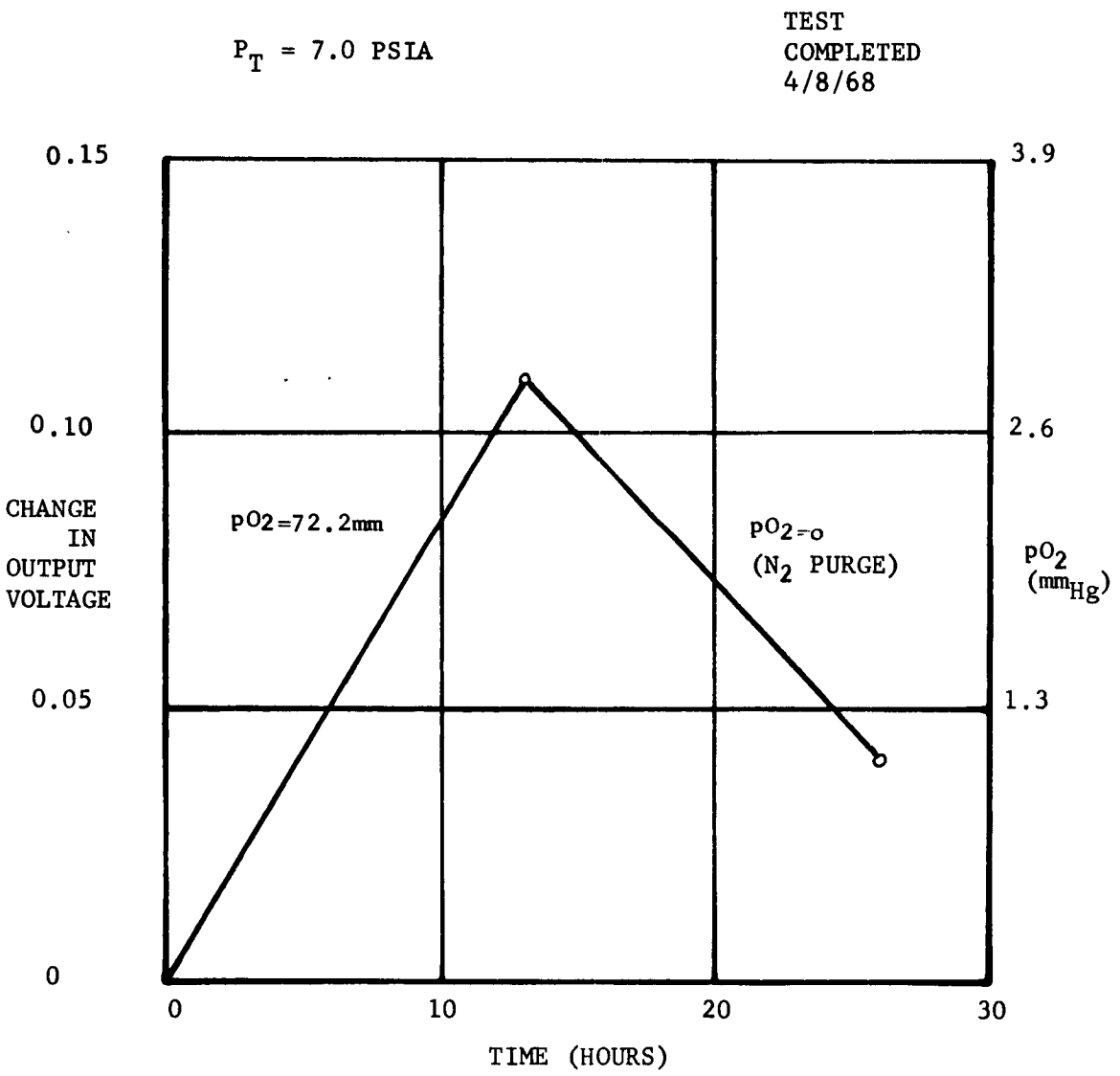


Figure 57. Oxygen Channel Output With Oxygen and Zero Sample Gas

pCO_2 = 17.9 mm_{Hg} at 7.0 PSIA total pressure
(pCO_2 Accuracy goal = ± 0.4 mm_{Hg})

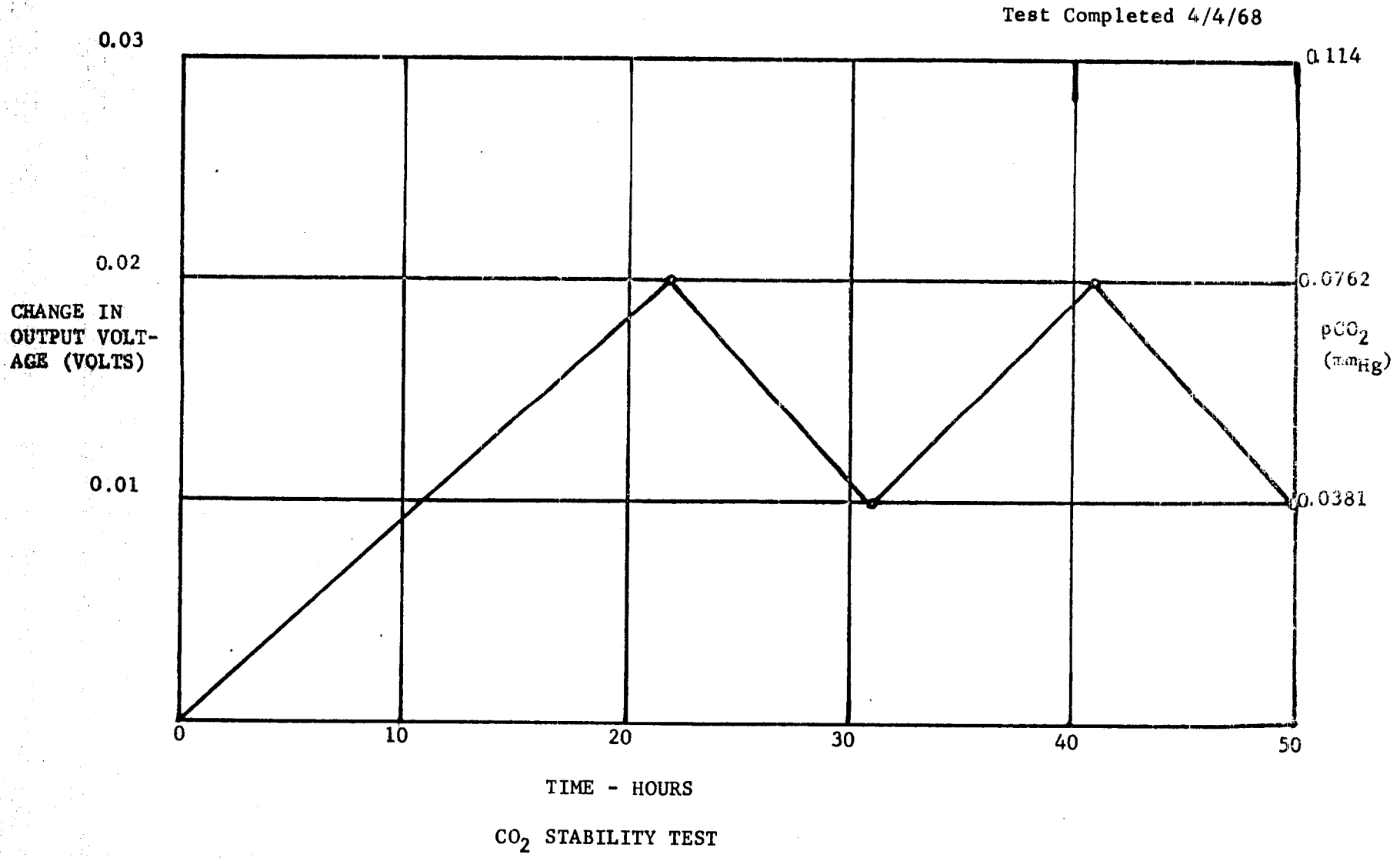


Figure 58. Change in pCO_2 Output

Rotate the face of the grating downward until the image is just above the lower slit. The image will defocus slightly, but should still symmetrically overfill the slit slightly. If the image moves horizontally as the grating is rotated, rotate the mirror bracket on the baseplate and move the sample cell assembly horizontally until the image is properly centered and does not move horizontally when it is moved vertically.

The focusing and centering adjustments interact and must be "juggled" alternately until the image is sharply focused and properly centered over each slit.

When the proper alignment is achieved, tighten down the mounting bolts for the primary mirror bracket, sample cell assembly, upper slit clamps, and the lamp holder.

Another alignment procedure that gives equally good or even better results is performed as follows.

Place a high-intensity source of diffused light behind the sample cell assembly. Rotate the grating so that the white light (primary) images of the upper and lower slits alternately fall into the lamp capillary. The positions of the lamp, sample cell assembly, and primary mirror bracket are adjusted until both images are sharply focused and properly centered on the face of the lamp capillary.

3. Alignment of UV Channel, IR Channel, and Torquer

    a. Mount the arm on the torquer in a horizontal position.

    b. Bolt the IR channel assembly loosely to the main baseplate.

    c. Mount the torquer and arm and adjust it so that the UV mask moves parallel to the face of the slit assembly at a distance of about 0.030 inch.

    d. Mount the photomultiplier and make the necessary electrical connections to the photomultiplier, UV lamp, bolometer, IR lamp, and torquer. Turn the sensor on and monitor the IR signal waveform at pin 8 of Module A1. Move the IR subassembly longitudinally and laterally to maximize the height of the reference peak. If the maximum is less than 300 millivolts peak-to-peak with 4.0 vdc on the lamp, change the thickness of the bolometer shim in 0.010 inch steps, and repeat the IR subassembly positioning adjustments until a maximum greater than 300 millivolts peak-to-peak is obtained. Tighten the IR subassembly down in this position.

e. Set up a dual channel "scope" so that the IR signal waveform can be observed simultaneously with either the torquer drive waveform (pin 28 of Module A7) or any one of the four timing signals TS1 through TS4. Adjust R31 and R40 on Module A7 for the minimum torquer drive voltage that will give a flat CO_2 peak on the IR signal waveform during TS4 as shown in figure 8(c). Adjust R32 and R41 to the center of the range of values that gives a flat REF peak during TS1.

f. Open the oxygen slit width wide on the UV sample cell assembly, and close the lower (water) slit width off completely. Set the photomultiplier high voltage to 1200 volts. Rotate the grating so that the primary image falls on the upper slits. Monitor the UV signal waveform at pin 7 of Module A2 and rotate the grating backward toward the face-up position until the waveform is less than 1.0 volt peak-to-peak. Adjust the width of the oxygen slit so that the heights of the oxygen and REF peaks are equal to within ±10 percent. (NOTE: The only ambient light allowable during UV monochromator adjustments is dim red or amber incandescent illumination.)

Adjust R31, R40, R32, and R41 until the tops of the oxygen and reference peaks are flat during TS4 and TS1, respectively. (See figure 8(b).) Move the upper slit vertically if it is impossible to get flat-topped peaks on the UV and IR signal waveforms simultaneously by adjusting the four resistors. The primary image should be repositioned each time the slit is moved. Tighten the upper slit clamps when the proper position is found.

If the "+10v" peak of the torquer drive waveform is not between +7.0v and +9.5v at the end of this procedure, stop the torquer, loosen the hub, reposition the arm on the torquer shaft, and repeat the adjustment of the four resistors. (NOTE: Nominal values should be used for R42 and R43 during the adjustment of R31, R32, R40, and R41.)

g. Place the optical assembly in a box that can be very thoroughly purged with dry N_2, while allowing necessary electrical connections to be made and providing for access to the grating position, lower slit position, and slit width adjustments. Leak-free gas connections to the UV sample cell are also necessary.

h. Purge the box and the sample cell thoroughly with dry nitrogen. Rotate the grating backwards. The height of the UV signal waveform should drop off to zero, and then pick up suddenly to several hundred millivolts when the

grating is tilted back about 15 degrees. This is the 1470Å line. The waveform amplitude should rise, peak, and drop to a lower value in less than two turns of the grating adjustment screw. Readjust the reference slit width until the two peaks are as nearly equal as can be seen on the oscilloscope.

i. Flush the sample cell with an O_2-N_2 mixture calculated to give about 30 percent absorption in a 0.004 inch path length at 1470Å. "Rock" the grating back and forth across the 1470Å peak to find the point at which maximum absorption occurs.

   The point of maximum absorption can be found more accurately by temporarily disconnecting R32 from Module A5, and looking for the maximum change in the voltage at pin 3 of Module A5 when the gas in the sample cell is changed back and forth between dry N_2 and the dry O_2-N_2 mixture. It may be necessary to readjust the oxygen slit width during the rocking procedure to keep the two UV signal peaks equal. Lock the grating adjustment screws when the point of maximum absorption is found.

j. Flush the sample cell with N_2, and adjust the lower slit width until the height of the water peak is equal to the height of the oxygen peak. Adjust R33 and R42 to the maximum value (minimum negative torquer drive voltage) that will give a flat-topped water signal peak during TS2. Before finalizing the adjustments of R33 and R42, check to see that there are no light "flashes" on the IR signal waveform during TS2. Adjust the lower slit vertical position to the point that gives equal changes in the heights of the water and oxygen peaks when the sample cell flush is alternated between dry N_2 and dry O_2-N_2 mixture.

k. Adjust R34 and R43 to the center of the range of values that does not give any light flashes during TS3 on either the UV or IR signal waveform.

l. If the torquer drive amplifier "clips" or if the difference in the heights of the "10 volt" torquer drive peaks is greater than 2 volts, stop the torquer, reposition the arm on the shaft, and readjust the torquer angle resistors.

m. After rechecking all adjustments, put a drop of No. 2216 epoxy on all mounting and adjustment screws in the IR, UV, and torquer assemblies. Fasten the slit width adjustments securely with epoxy, being careful not to cover any of the slits or to build up enough epoxy to interfere with the torquer arm motion.

n. This completes the alignment of the optical assembly. The sample gas lines that interconnect the IR and UV sample cells, the P_t transducer, and the fittings on the baseplate remain to be assembled. This must be done with care to avoid disturbing the positions of the UV sample cell and IR subassembly. The remainder of the adjustments on the electronic modules are performed after the optical compartment has been sealed.

The adjustment procedure for Modules A3 through A5 is given in the following Section, IV H, Calibration Procedure.

The adjustment procedure for Module A6 is given in Sections II.B.5 and II.B.6.

H. CALIBRATION PROCEDURE

The calibration procedure consists of selecting the proper linearization, zero, and span resistors to permit adjustment within the range of the trim potentiometers in the A3 (CO_2), A4 (H_2O), or A5 (O_2) modules.

The chopper waveform of the UV channel at terminal 7 or 8 of Module A2 should be observed. The three peak heights should be approximately equal with a 100 percent N_2 sample. Then observe the IR channel at terminal 8 of Module A1.

Monitor the voltage of terminal 3 of A3, A4, or A5 Module, depending on the channel being calibrated. Connect a 10K to 100K ohm decade across the terminals for R32 of A3, A4, or A5 Module. Vary the partial pressure of the sample gas in steps, while varying the value of R32 at each step. Plot the data as V_3 versus pO_2 for the family of resistance values. Select R32 for the most linear curve over the total range of partial pressure. A nominal value for R32 for the O_2 channel is 60K.

The total change in voltage at terminal 3 for the total change in partial pressure is denoted as V_1. The gain (G) of the signal processing module must now be adjusted so that

$$V_1(G) = 5V$$

The gain is determined by

$$G = \frac{R45 + R46}{9.85K}$$

R45 is a 5K series trim potentiometer, so its value is used as 2.5K. R46 is then determined from

$$G = \frac{5}{V_1} = \frac{R46 + 2.5K}{9.85K}$$

or,

$$R46 = \frac{49.2K}{V_1} - 2.5K$$

A nominal value of R46 for the O_2 channel is 30K.

Having selected the gain resistor, the next step is to set the zero point of the calibration curve. The output voltage is related to the circuit variables by:

$$V_o = -GV_1 + (1 + G)\, V_{OFFSET} - 0.1$$

where V_{OFFSET} is the buck-out voltage selected from a resistor divider made up of R47, a 5K potentiometer, and a 12.1K resistor connected between the +7v and -7v reference bias supplies.

$$V_{OFFSET} = \frac{V_o + GV_1 + 0.1}{1 + G}$$

R47 may then be selected from:

$$R47 = \frac{169K}{V_{OFFSET} + 7} - 14.6K$$

The nominal value of R47 for the O_2 channel is 15K ohm.

IV-I

ACCEPTANCE TEST PLAN AND PROCEDURE

TWO GAS ATMOSPHERE SENSOR
PART NUMBER 631-0113

SERIAL NUMBER _____

DEVELOPED FOR: NATIONAL AERONAUTICS & SPACE ADMINISTRATION

LANGLEY RESEARCH CENTER

LANGLEY STATION, HAMPTON, VA.

NASA CONTRACT NUMBER NAS1-6467, L-5908-D

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1.0 INTRODUCTION

1.1 Scope: This acceptance test plan and procedure defines the tests to be conducted on each Perkin-Elmer Two Gas Atmosphere Sensor, Part Number 631-0113, prior to delivery to NASA Langley Research Center. The purpose of these tests is to demonstrate the sensor system capability to perform system performance criteria. Compliance with this specification is sufficient to provide a valid measure of overall quality, and provide assurance that the required quality is present in each end item.

1.2 Test Facilities and Equipment: Unless otherwise specified herein, the Perkin-Elmer Corporation or their subcontractors shall be responsible for providing the material, equipment, and facilities required for performing tests in accordance with this document.

1.3 Applicable Documents: The following documents form a part of this test plan and procedure to the extent specified herein:

NASA Documents

NASA Contract NAS1-6467, containing Statement of Work L-5908-D dated June 20, 1966.

1.4 Classification of Tests: The tests specified herein are classified into the following categories:

a. Class 1 - Nonoperating
b. Class 2 - Operating

1.5 Technical Description of Sensor: The test specimen is designated as Perkin-Elmer part number 631-0113, Two Gas Atmosphere Sensor. This device is a combination of sensors based primarily on photometric techniques to measure the partial pressures of gasseous carbon dioxide (CO_2), oxygen (O_2), water vapor (H_2O), nitrogen (N_2) and total pressure (P_T).

The CO_2 measurement is made by the use of infrared absorption. The O_2 and the H_2O measurements are made by the use of ultraviolet absorption. The N_2 measurement is made by using the difference between the total pressure and the sum of the partial pressures of O_2, H_2O, and CO_2. The total pressure is measured by a potentiometric transducer which allows P_T to be provided as an output.

The sensor consists of two main compartments enclosed in an overall environmental cover. The electronics system, packaged in nine welded modules are mounted on an inner hermetically sealed cover which contains the optical components. Scaling of the amplifier and computer circuits is performed at final alignment by the use of trim resistors external to the modules.

The design criteria for this system is summarized as follows:

Electrical

Power 28 VDC ± 1/2 VDC, 5 Watts
Ripple 1/2 V_{pp}
Impedance 50Ω

Mechanical

Size	110 in^3
Weight	6-1/2 lb.

Analytical (All outputs 0 to 5 VDC)

PO_2 Range	125 to 250 mmHg
PO_2 Accuracy	±2% F
PH_2O Range	0 to 30 mmHg
PH_2O Accuracy	±5% FS
PCO_2 Range	0 to 20 mmHg
PCO_2 Accuracy	±2% FS
P_T Range	100 to 400 mmHg, 760 mmHg
P_T Accuracy	±1% FS
PN_2 Range	100 to 300 mmHg
PN_2 Accuracy	±5% FS

Response Time

10 sec for 63% of step input

Life

3 year storage

120 day operation without calibration

1 year total operating life

Temperature

40°F to 90°F (operating)

2.0 CONDITION OF TEST

2.1 Test Facilities: The tests herein described shall be performed at Perkin-Elmer or at facilities approved by Perkin-Elmer.

2.2 Test Equipment: The equipment used to perform the tests herein described shall be approved by the Perkin-Elmer Program Manager prior to its use. Detail designation, description and identifying number for each piece of equipment shall be provided with the data record of each test on each unit.

2.3 Personnel: The tests herein specified shall be performed only by engineering personnel designated by the Perkin-Elmer Project Manager.

2.4 Test Specimen: The tests specified herein shall be conducted on each fully assembled Perkin-Elmer Two Gas Atmosphere Sensor. The specimen shall be identified by part name, part number, and serial number.

2.5 Position During Test: Unless otherwise specified in the specific test procedure, the test specimen shall maintain its normal use attitude during the test.

2.6 Test Sequence: The tests specified herein shall be conducted in the following sequence:

a. Examination of Product
b. Weight
c. Volume
d. Leakage
e. Power Consumption
f. Calibration

2.7 First Article Tests: First Article Tests are those in which certain basic performance parameters of the first unit are tested which are not covered by the acceptance testing of subsequent units. These tests are, as a minimum:

1. Electrical power ripple susceptibility
2. Output Impedance
3. Altitude
4. Attitude

3.0 TEST PROGRAM ADMINISTRATION

3.1 Test Surveillance:

3.1.1 Test Notification: NASA/LRC shall be notified no later than 48 hours prior to start of acceptance tests on each sensor.

3.1.2 Witnessing of Tests: All tests will be witnessed by a Perkin-Elmer engineer who will be responsible for the manner in which the test is performed. The responsible engineer will be designated by the Perkin-Elmer Program Manager. The signature of the designated engineer and the Program Manager shall constitute certification that the test data has been correctly reported. The tests may be witnessed by a representative of NASA-LRC but his signature is not required.

3.2 Deviations and Variations: Any deviations or variations from this document shall be approved by the Perkin-Elmer Program Manager, and will be reported in the test report.

3.3 Test Reports:

3.3.1 Failure Reports: In the event that any unusual difficulty or questionable condition occurs it will be reported immediately to NASA/LRC. Recommendations for corrections will be provided to NASA/LRC within 48 hours after the difficulty is determined.

3.3.2 Final Test Report: A final test report shall be issued for each sensor. The report shall contain the data herein required and shall be in the form of this document when suitably completed.

4.0 TEST PROCEDURES

4.1 Class 1 - Nonoperating Tests: Class 1 tests are those in which operation of the sensor is not required in order to assure its meeting requirements. This category includes workmanship, sensor weight, volume and leakage.

4.1.1 Examination of Product: The test specimen shall be visually examined for satisfactory material, secured fastenings, cleanliness, exterior finish and adequately soldered connections. The test specimen shall be free from cracks, dents and harmful scratches.

4.1.2 Weight: The purpose of this test is to determine the actual weight of a fully assembled test specimen including gas fittings, but excluding mating fittings and mating electrical connector.

4.1.2.1 Test Procedure:

a. Verify the null or zero setting of the scale.

b. Place the test specimen on the scale.

c. Record the total weight and complete the following table.

Weight _____ lbs. _____ oz.

Scale Accuracy _____ ± oz.

Scale Mfg. _____

Scale Part Number _____

Scale Serial Number _____

Test Engineer _____ Date _____

4.1.3 Volume: The purpose of this test is to record the size and volume of the test specimen.

4.1.3.1 Test Procedure:

a. Measure the length, width and depth of the test specimen excluding flanges, fittings and the connector.

b. Record the data and compute the volume

length _____ inches

width _____ inches

depth _____ inches

accuracy of measurement ± _____ inches

volume _____ inches

Test Engineer _____ date _____

4.1.4 Leakage: The purpose of this test is to verify that the hermetic seals of the inner cover and sample lines are sound.

4.1.4.1 Test Procedure:

a. Cap off one gas fitting.

b. Connect the mass spectrometer leak detector to the remaining fitting.

c. Place the test specimen in a plastic bag and purge the bag with helium.

d. Measure and record the indicated leakage rate after 5 minutes and again after 30 minutes.

Leakage rate (5 minutes) _____

Leakage rate (30 minutes)_____

Leak detector designation:

_____

_____

Identification number _____

Accuracy _____

Test Engineer _____Date _____

4.2 Class 2 - Operational Tests: The operational tests are performed to demonstrate the system dynamic performance. Included in these tests are power consumption, calibration, response time, temperature and repeatability.

4.2.1 Power Consumption: The purpose of this test is to determine the electrical power input required by the operating test specimen.

4.2.1.1 Test Procedure:

a. Apply power to the test specimen from a DC power supply. Adjust the input voltage to 28 VDC.

b. Record the input voltage and input current within 30 seconds of turn-on time.

c. Record the input voltage and input current after 5 minutes of continued operation.

d. Increase the input voltage to 28.5 VDC. Repeat step (c).

e. Decrease the input voltage to 27.5 VDC. Repeat step (c).

30 Sec Input Voltage (28VDC nominal) _____ volts

30 Sec Input Current _____ ma

5 Min. Input Voltage (28 VDC nominal) _____ volts

5 Min. Input Current _____ ma

28.5 (nominal) voltage _____ volts

current _____ ma

27.5 (nominal) voltage _____ volts

current _____ ma

Voltmeter designation _____

_____

Identification number _____

Accuracy _____

Milliammeter Designation _____

_____

Identification number _____

Accuracy _____

Power Supply Designation _____

_____

Identification number _____

Test Engineer _____ Date _____

4.2.2 Calibration: The purpose of this test is to obtain calibration curves for reference during subsequent NASA testing and evaluation.

4.2.2.1 Test Setup:

The test specimen shall be connected as shown in Figure

The ambient temperature during this test shall be 70° ± 10°F.

4.2.2.2 Test Procedure, Total Pressure and PN_2 Calibration:

a. Apply power to the test specimen. Adjust the input power to 28.0 VDC ± 0.3 VDC.

b. Apply 100 percent N_2 to the test specimen.

c. Adjust the test specimen sample pressure to 7.0 PSIA (362 mmHg) at a flow rate of 200 cc/min.

d. Start the recorder and identify the PO_2, PH_2O, PN_2, PCO_2 and P_T channels. Identify the serial number of the test specimen. Record the date, operator and test conditions.

e. Reduce the total pressure at 5 minute intervals to the nominal values of 6.0 psia (310 mmHg), 5.0 psia (258 mmHg), 4.0 psia (206 mmHg), 3.0 psia (155 mmHg), 2.0 psia (103 mmHg).

Record the actual gauge readings.

Nominal P_T	Measured P_T	P_T Channel Output Voltage	PN_2 Channel Output Voltage
362 mmHg			
310			
258			
206			
155			
103			

f. Record any unusual characteristics: _____

_____

_____

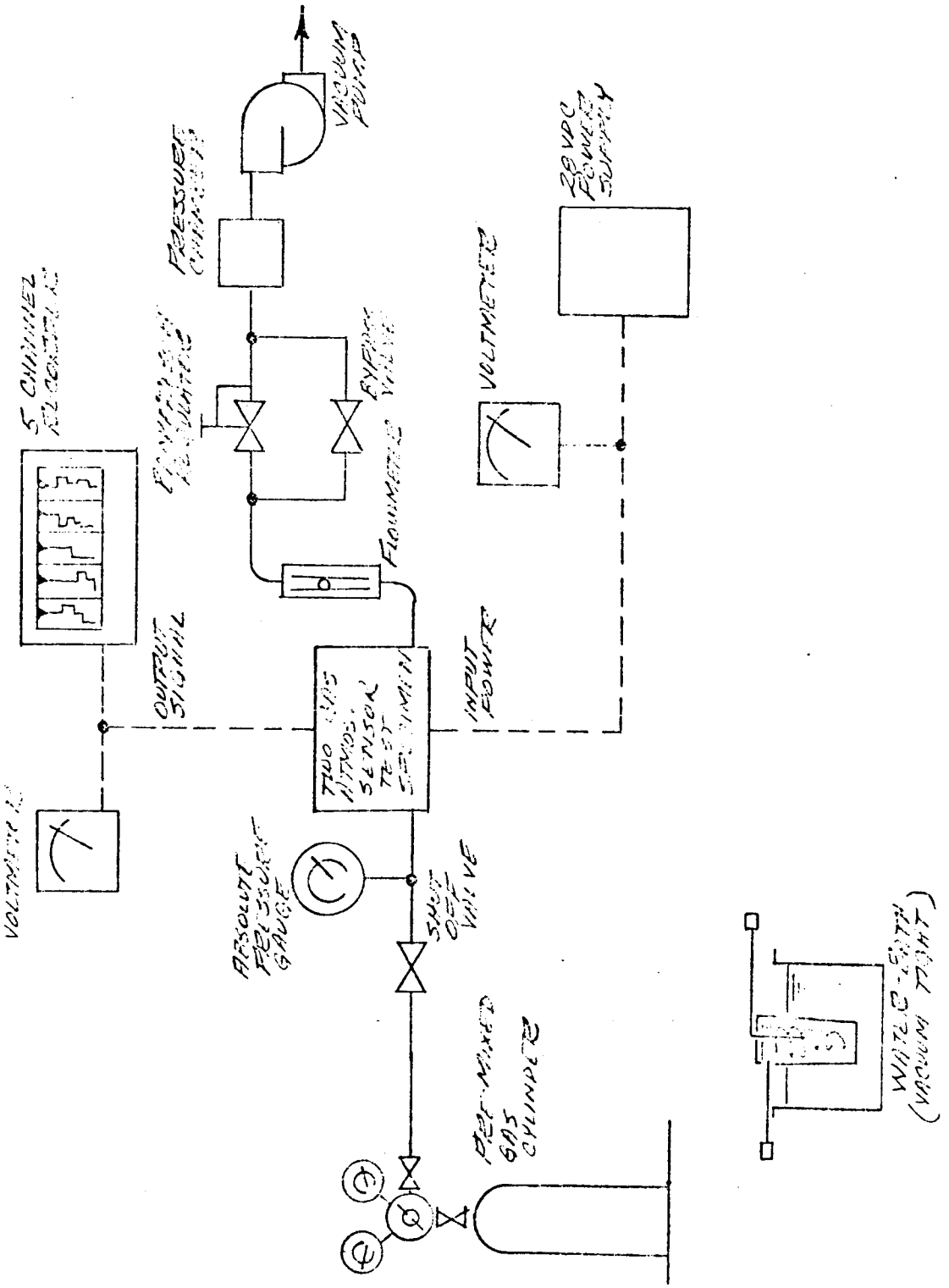


FIGURE 1. OPERATIONAL TEST SET-UP

PREPARED BY	APPROVED	APPROVED	APPROVED	PE SPEC 5338	REV A	SHEET 16 of 3

Test Engineer _____ Date _____

4.2.2.3 Test Procedure PCO_2 Calibration:

a. Repeat step 4.2.2.2 (a), (b), (c), (d).

b. Shut off the recorder, disconnect the N_2 supply, and connect a nominal 1.4% (vol.) CO_2 in N_2 mixture supply to the test set-up. Purge the test specimen sample lines. Adjust the total pressure to 7.0 psia (362 mmHg) at 200 CC/min flow rate. Turn on the recorder and record for five minutes or until the output is stabilized.

c. Repeat step 4.2.2.3 (b) using a nominal 2.8% CO_2 in N_2 mixture.

d. Repeat step 4.2.2.3 (b) using a nominal 4.2% CO_2 in N_2 mixture.

e. Repeat step 4.2.2.3 (b) using a nominal 5.2% CO_2 in N_2 mixture.

f. Repeat steps 4.2.2.2 (b), (c), (d).

Nominal CO_2 Mixture	Actual CO_2 Mixture	PCO_2 mmHg	PCO_2 Channel Output Voltage
1.4%	_____	_____	_____
2.8%	_____	_____	_____
4.2%	_____	_____	_____
5.2%	_____	_____	_____

g. Record any unusual characteristics:

_____

_____

_____

Test Engineer _____ Date _____

4.2.2.4 Test Procedure, PO_2 Calibration:

a. Repeat step 4.2.2.2 (a), (b), (c), (d).

b. Shut off the recorder, disconnect the N_2 supply, and connect a nominal 28% (vol.) O_2 in N_2 mixture supply to the test set-up. Purge the test specimen sample lines. Adjust the total pressure to 7.0 psia (362 mmHg) at 200 cc/min flow rate. Turn on the recorder and record for five minutes or until the output is stabilized.

c. Repeat step 4.2.2.4 (b) using a nominal 36% O_2 in N_2 mixture.

d. Repeat step 4.2.2.4 (b) using a nominal 42% O_2 in N_2 mixture.

e. Repeat step 4.2.2.4 (b) using a nominal 48% O_2 in N_2 mixture.

f. Repeat step 4.2.2.4 (b) using a nominal 55% O_2 in N_2 mixture.

g. Repeat step 4.2.2.4 (b) using a nominal 64% O_2 in N_2 mixture.

h. Repeat step 4.2.2.4 (b) using a nominal 71% O_2 in N_2 mixture.

i. Repeat steps 4.2.2.2 (b), (c), (d).

Nominal O_2 Mixture	Actual O_2 Mixture	PO_2 mmHg	PO_2 Channel Output Voltage
28%			
36%			
42%			
48%			
55%			
64%			
71%			

j. Record any unusual characteristics:

_____

_____

_____

Test Engineer _____ Date _____

4.2.2.5 Test Procedure, PH_2O Calibration:

a. Repeat step 4.2.2.2 (a).

b. Connect the water bath test set-up shown in figure 1.

c. Adjust the test specimen sample pressure to 7.0 PSIA (362 mmHg) at a flow of 100 cc/min.

d. Agitate the water bath to maintain constant temperature. Add cold water or ice to the bath to maintain the internal water temperature to a nominal 35°F. Record the temperature.

e. Repeat step 4.2.2.2 (d).

f. Record for 5 minutes.

g. Turn off the recorder.

h. Increase the temperature of the water bath to 50°F. Record the temperature.

i. Repeat steps (e), (f), (g).

j. Increase the temperature of the water bath to 65°F. Record the temperature.

k. Repeat steps (e), (f), (g).

l. Increase the temperature of the water bath to room temperature (77°F nominally). Record the temperature. Disconnect the water bath.

m. Repeat steps 4.2.2.2 (b), (c). Flush with nitrogen for 15 minutes.

n. Turn off the recorder. Disconnect the input power. Remove the test sample lines. Cap off the gas fittings. Cap off the power connector.

Nominal Water Bath Temperature	Actual Water Bath Temperature	Vapor Pressure mmHg	PH_2O Channel Output Volts
35°F			
50°F			
65°F			
77°F			
		Zero	

o. Record any unusual characteristic:

_____

_____

_____

Test Engineer _____ Date _____

TABLE 1. TEST EQUIPMENT (See Figure 1)

Gasses pO_2 _____ _____ Certified Accuracy _____

in _____ _____

N_2 _____ _____

_____ _____

_____ _____

PCO_2 _____ _____

in _____ _____

N_2 _____ _____

_____ _____

_____ _____

pN_2 _____ _____

_____ _____

Pressure Gauge

Designation _____

Model Number _____

Identification Number _____

Accuracy _____

Range _____

Last Calibration Date _____

Next Required Calibration Date _____

Flow Meter

Designation _____

Model Number _____

Identification Number _____

Accuracy _____

Range _____

TABLE 1. TEST EQUIPMENT (See Figure 1)

Flow Meter (cont.)

Last Calibration Date _____

Next Required Calibration Date _____

Recorder

Designation _____

Model Number _____

Identification Number _____

Accuracy _____

Range _____

Last Calibration Date _____

Next Required Calibration Date _____

Voltmeters

Designation _____

Model Number _____

Identification _____

Accuracy _____

Range _____

Last Calibration Date _____

Next Required Calibration Date _____

Power Supply

Designation _____

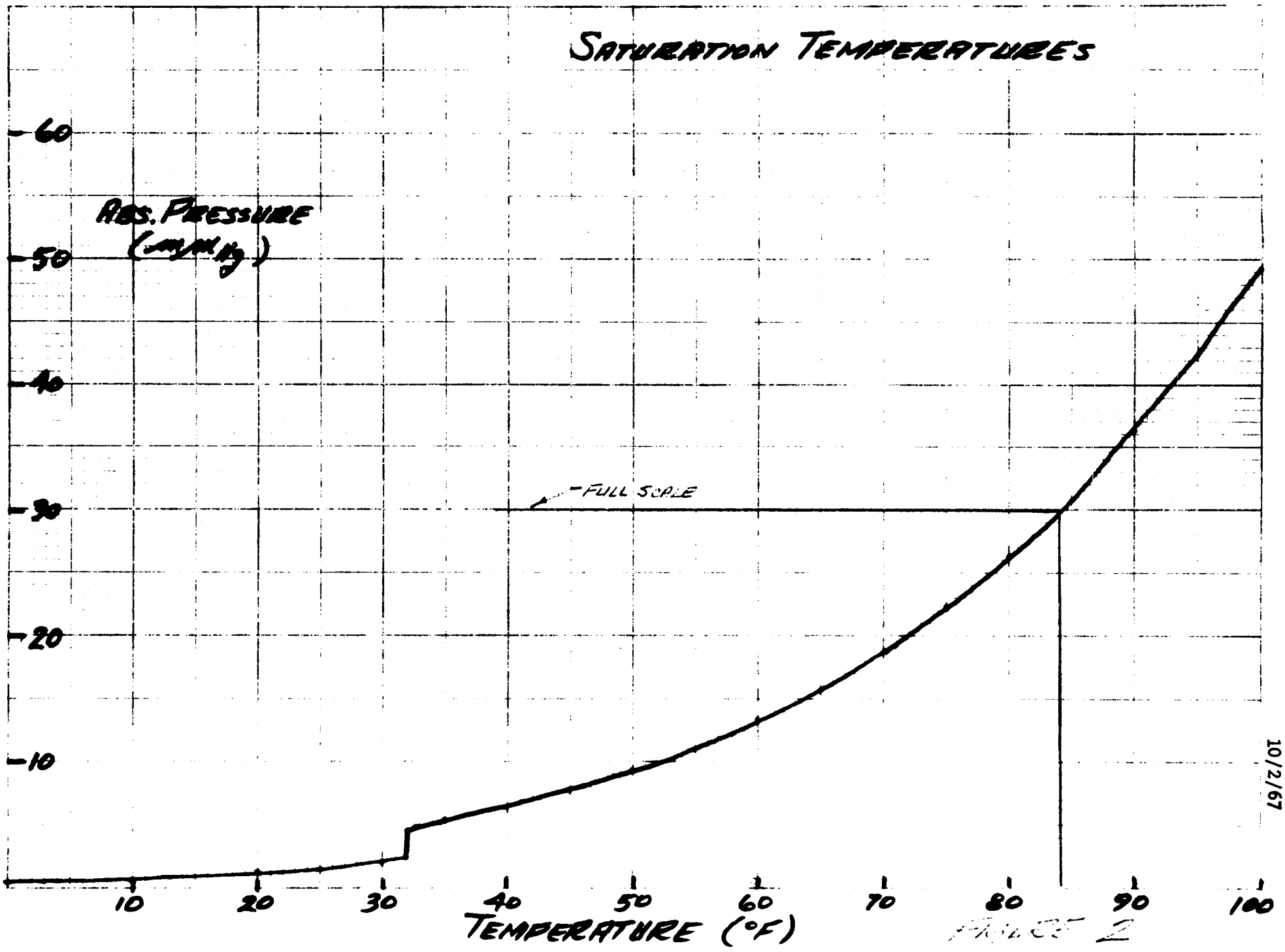
Model Number _____

Identification _____

Last Calibration Date _____

Next Required Calibration Date _____

Test Engineer _____ Date _____



5338A

23 of 33 205

10/2/67

NO. 318A 20 DIVISIONS PER INCH BOTH WAYS 150 BY 200 DIVISIONS
CODEX BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS.
PRINTED IN U.S.A.

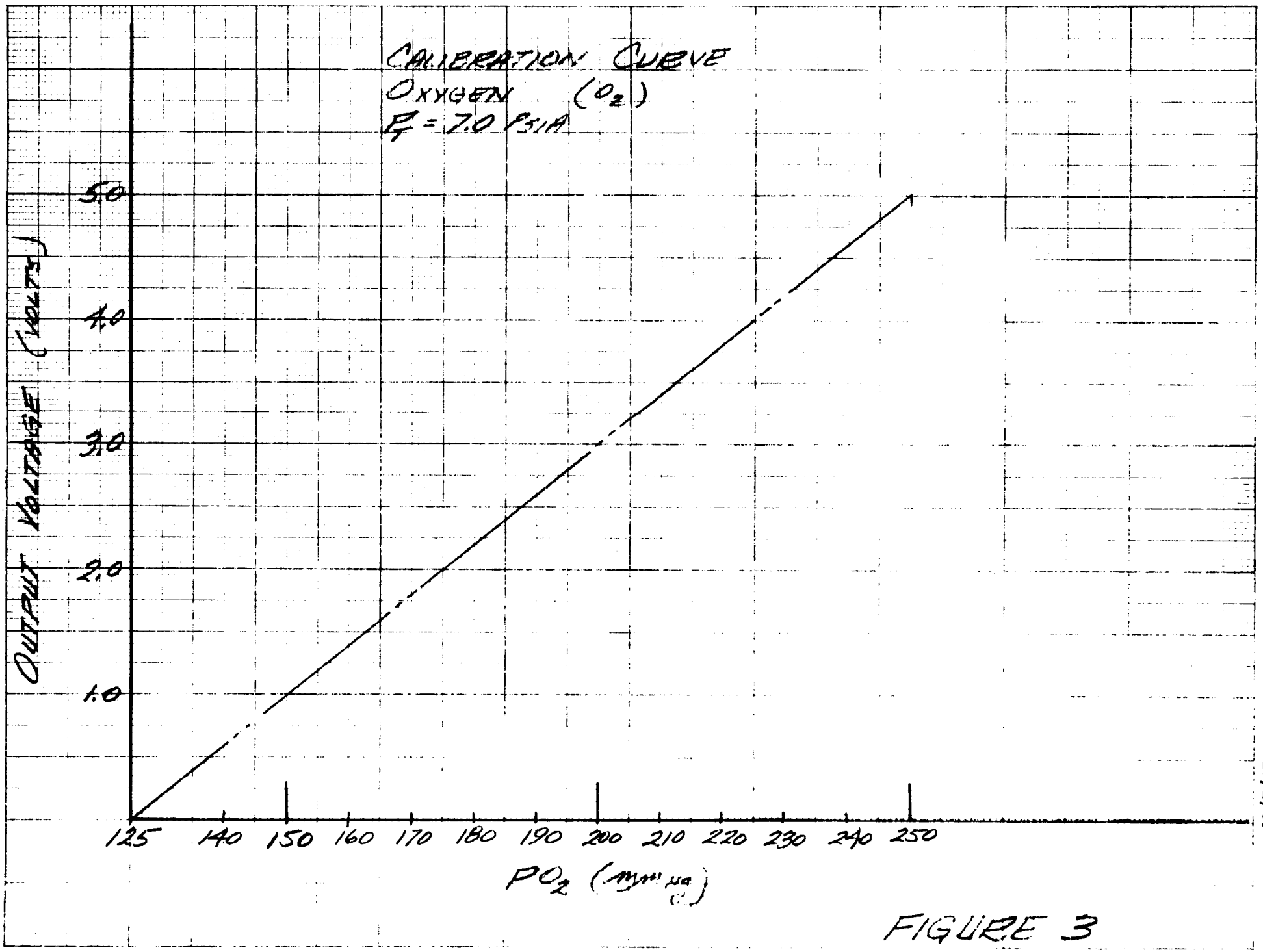


FIGURE 3

NO. 315 10 DIVISIONS PER INCH BOTH WAYS 10 BY 10 DIVISIONS.
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PRINTED IN U.S.A.

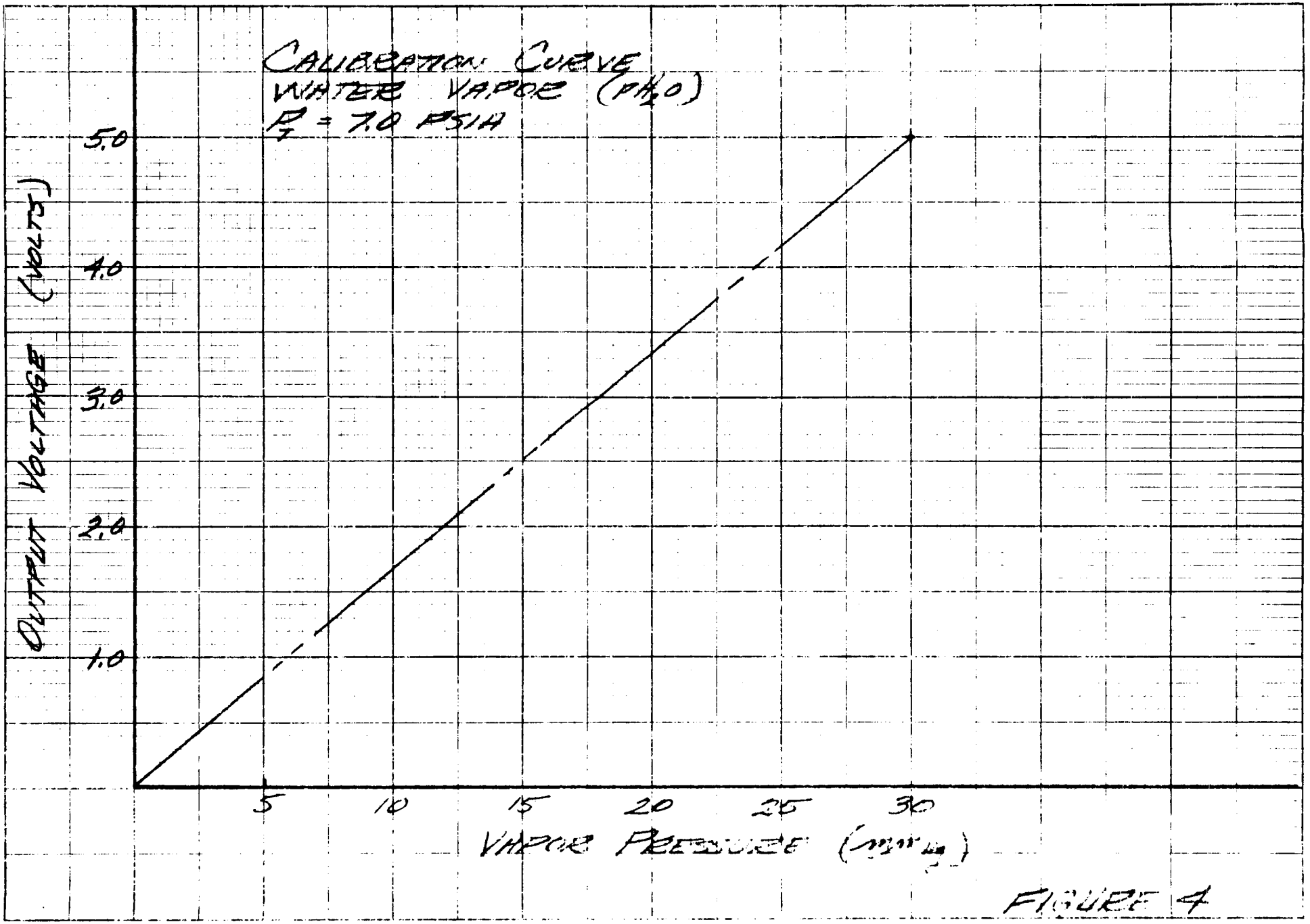


FIGURE 4

10/2/67

NO. 318A. 20 DIVISIONS PER INCH BOTH WAYS. 150 BY 200 DIVISIONS.

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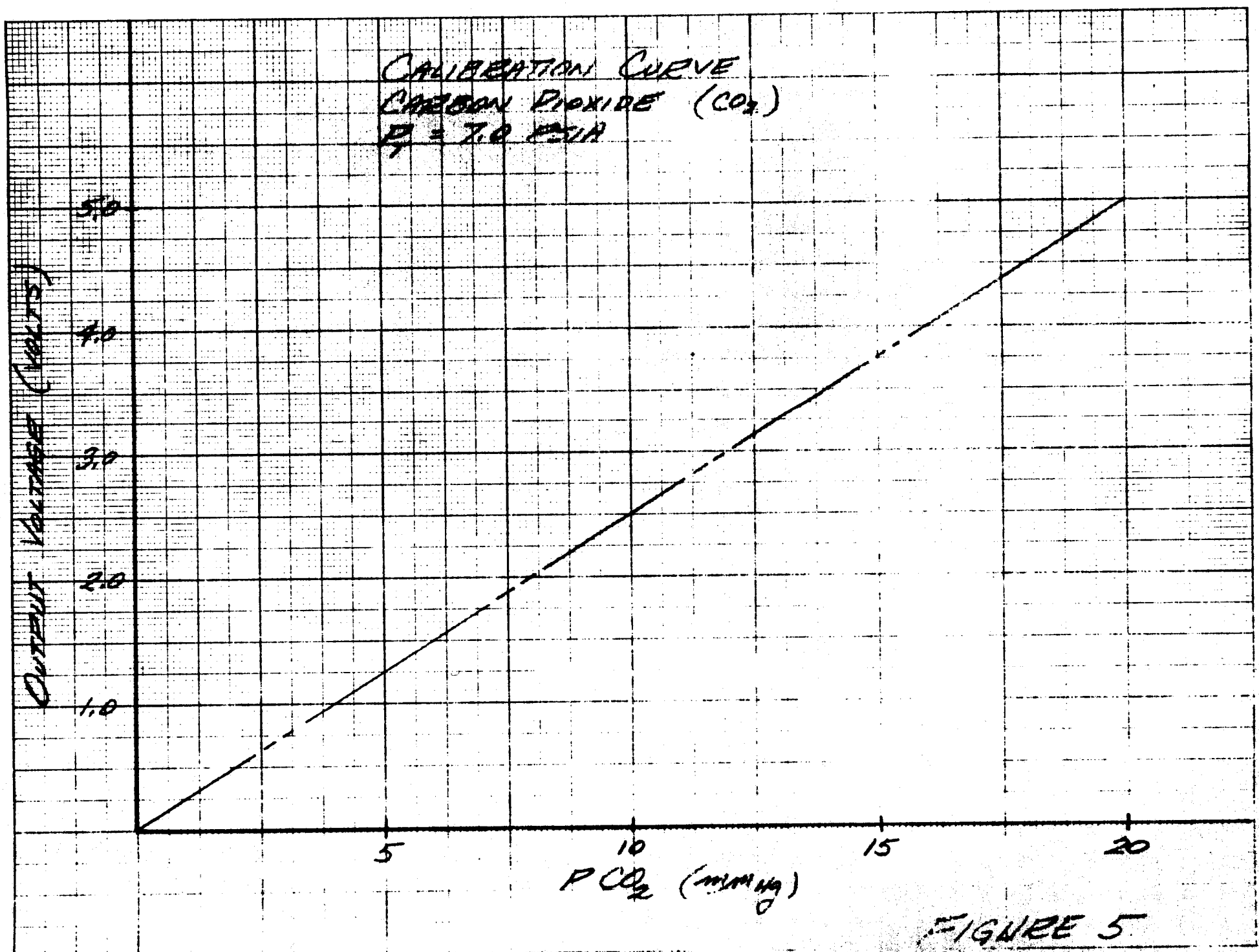


FIGURE 5

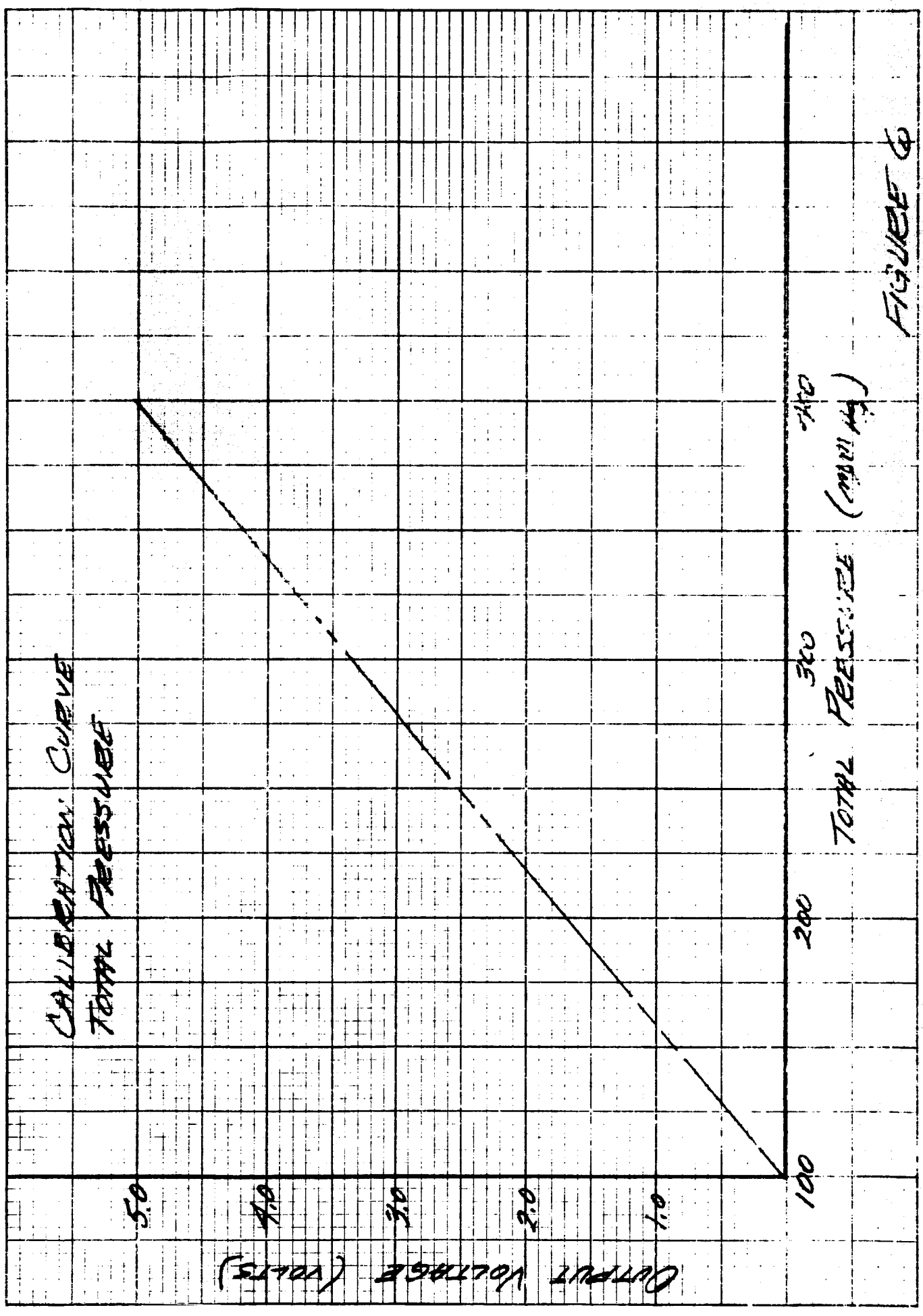


FIGURE 6

NO. 315 10 DIVISIONS PER INCH BOTH WAYS 10 BY 10 DIVISIONS
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NO 315 10 DIVISIONS PER INCH BOTH WAYS 70 BY 100 DIVISIONS. KEUFFEL & ESSER CO. NEW YORK

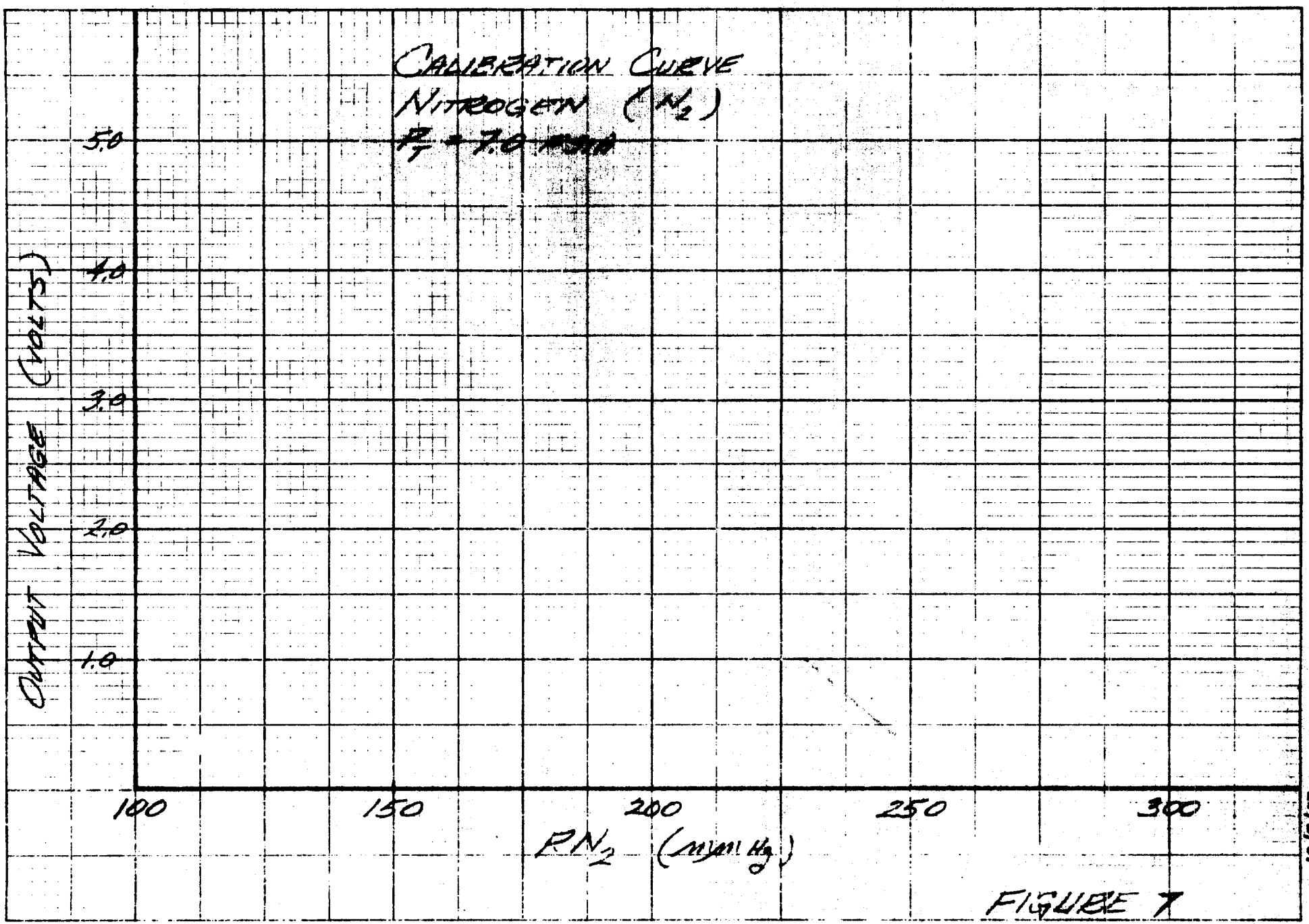


FIGURE 7

4.2.3 Response Time: The purpose of this test is to determine the time required by the specimen to reach 90% of a step value of an input partial pressure change.

4.2.3.1 Test Setup: The test specimen shall be connected up using the same arrangement as described under Section 4.2.2, Calibration.

4.2.3.2 Test Procedure, Response Time:

a. Apply power to the test specimen; adjust the input power to 28.0 vdc $\pm$ 0.3 vdc.

b. Apply 100 percent N_2 to the test specimen.

c. Adjust the test specimen sample pressure to 7.0 psia (362 mmHg) and flow rate of 200 cc/min.

d. Shut off the N_2 supply and connect the nominal 5.2% CO_2 in N_2 mixture supply, adjusting the total pressure to 7.0 psia (362 mmHg) at 200 cc/min flow rate.

e. Disconnect the mixed sample gas line and reconnect the N_2 purge line.

f. Start the recorder and set chart spped to one foot per minute or faster. Identify the pO_2, pH_2O, pN_2, pCO_2, and P_t channels. Record the date, operator and test conditions.

g. Disconnect the N_2 purge line and quickly reconnect the CO_2 in N_2 line simultaneously marking a start line on the chart recorder.

h. Note the rise in output signal. Continue chart recorder record until the output signal has stabilized. Record from the chart record the time required to reach 90% of the final value of the step input and also the final value of the step input.

4.2.3.3 Repeat Section 4.2.3.2, parts (b) through (h) using the nominal 71% O_2 in N_2 gas mixture and then gain using the N_2 water bath of 77°F for the pH_2O step input.

RUN #1

STEP INPUT GAS NOMINAL	ACTUAL MIXTURE	ACTUAL PARTIAL PRESSURE	FINAL VOLTAGE VALUE	TIME TO RISE 90% FINAL VOLT. VALUE
5.2% CO_2 in N_2	----	----	----	----
71% O_2 in N_2	----	----	----	----
77°F H_2O in N_2	----	----	----	----

RUN #2

			----	----
			----	----
			----	----

RUN #3

			----	----
			----	----
			----	----

Record any unusual characteristics: _____

_____

_____

Test Engineer _____ Date ___

4.2.4 Temperature Effects: The purpose of the test is to determine the change in output signal, if any, of the specimen when subjected to a temperature environment of 40°F to 90°F.

4.2.4.1 Test Setup: The test specimen shall be connected using the same arrangement as described under Section 4.2.3, except the input and output gas lines and the connector cable shall be attached to the specimen which is located in the thermostatically controlled temperature chamber.

4.2.4.2 Test Procedure, Test Effects:

a. Apply power to the test specimen; adjust the input power to 28.0 vdc ± 0.3 vdc.

b. Apply 100 percent N_2 to the test specimen.

c. Adjust the test specimen sample pressure to 7.0 psia (326 mm) and flow rate of 200 cc/min.

d. Record all output signal voltages at room temperature, using a short run of the chart recorder. Record actual room temperature.

e. Decrease chamber temperature to 40°F, recording the output signals and noting the temperature of the chamber on the chart record.

f. Increase chamber temperature to 90°F recording the data as in Step (e).

g. Return specimen to room temperature and when stabilized, record output signals.

h. Disconnect N_2 purge gas and connect sample gas consisting of a nominal mix of 10% O_2 and 1.0% CO_2 in N_2. Record actual mixture. Adjust test specimen sample pressure to 7.0 psia (362 mmHg) and flow rate of 200 cc/min.

i. Repeat Steps (d) through (g).

NITROGEN PURGE RUN

SET TEMP.	ACTUAL TEMP	TOTAL PRESSURE	pCO_2	pO_2	pH_2O	pN_2
Room	----	----	----	---	----	---
40°F	----	----	----	---	----	---
70°F	----	----	----	---	----	---
Room	----	----	----	---	----	---

SAMPLE MIXTURE RUN

Room	----	----	----	---	----	---
40°F	----	----	----	---	----	---
70°F	----	----	----	---	----	---
Room	----	----	----	---	----	---

TEMPERATURE OVEN

Designation _____

Model Number _____

Identification Number _____

Accuracy _____

Range _____

Last Calibration Date _____

Next Required Calibration Date _____

Record any unusual characteristics: _____

_____

_____

Test Engineer _____ Date _____

4.2.5 Repeatability: The repeatability of the specimen can be determined from the data required in Section 4.2.3, Response Time, and also from the data acquired in Section 4.2.2, Calibration. Complie the data and examine the accuracy of the identical tests run on the sample at various times.

J. DRAWINGS AND SPECIFICATIONS

Copies of all drawings and specifications were sent to NASA/LRC several times during the program. This section contains the family tree (figure 59) and parts list which specify the equipment.

Figures showing the schematic diagram for each module, an interconnecting diagram, the optical-mechanical assembly, and the final assembly drawing are included for reference (figures 60 through 69).

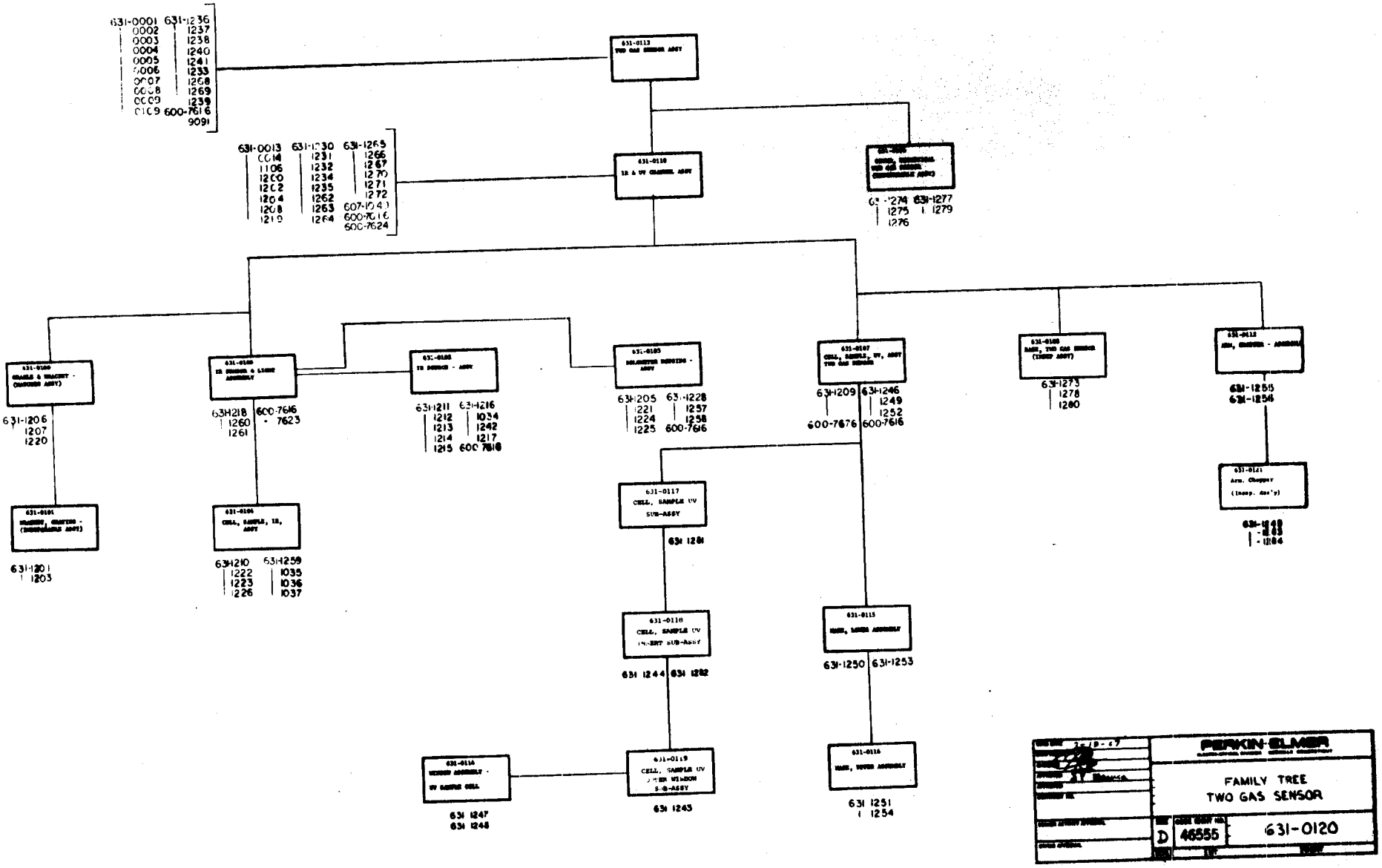


Figure 59. Family Tree - Two Gas Sensor

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0001 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO | WO | LOT | QTY. REQ. | QTY. REL.

PART NAME Module A_1 Ir. Preamp.

SHEET 1 OF 2 | ISSUED BY | DATE

NEXT ASSEMBLY

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV. | PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-001	Module A_1 Ir. Preamp.			1	X									
		U5B770931X	Micro Circuit (μA709)	24			1									
		C5R13B566KM	Capacitor 56uf 10%GV	3			2									
		C5R13F685KM	6.8uf 10% 35V	7			4									
		C5R13J275KM	2.7uf 10% 100V	2			2									
		CKR06CW104KM	.1uf 10% 100V	38			3									
		CKR05CW220KM	22pf 10% 200V	2			2									
		CKR05CW102KM	1000pf 10% 200V	5			1									
		C5R13D686KM	68uf 10% 15V	1			1									
		C5R13D226KM	22uf 10% 15V	11			1									
		CKR06CW472KM	4700pf 10% 200V	23			1									
		CKR05CW221KM	220pf 10% 200V	22			1									
		CSR13G105KM	Capacitor 1.f 10% 50V	6			1									
		600-4521-002	Diode (1N914B)	43			8									
		2N2973	Transistor	10			1									
		600-4762-002	(2N2605)	7			2									
		2N3821		2			1									
		JAN2N930	Transistor	5			1									
		RC05GF472J	Resistor 4.7K 5% 1/8w	17			2									
		RC05GF105J	1meg	9			7									
		RC05GF124J	120K	3			3									
		RC05GF272J	2.7K	3			1									
		RC05GF150J	15 Ω	1			1									
		RC05GF102J	1K	17			2									
		RC05GF474J	470K	7			1									
		RC05GF223J	22K	17			1									
		RC05GF393S	Resistor 39K 5% 1/8w	8			2									
		218	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-001 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO	OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE
WO LOT								
QTY. REQ.								
QTY. REL.								

PART NAME Module A_1 Ir. Preamp.

SHEET 2 OF 2 | ISSUED BY | DATE

NEXT ASSEMBLY

REV.

PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		RC05GF104J	Resistor 100K 5% 1/8w	16			1									
		RC05GF274J	270K	6			1									
		RC05GF152J	1.5K	42			1									
		RC05GF331J	330	21			1									
		RC05GF473J	47K	3			2									
		RC05GF563J	Resistor 56K 5% 1/8w	4			1									
			TOTAL													

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-002 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

PART NAME A_2 - UV Preamp.
SHEET 1 OF 1 ISSUED BY L.E.W. DATE
NEXT ASSEMBLY

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME		SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0002	A_2 - UV Preamp				1	X									
		U5B770931X	Micro Circuot ~~μ~~ A709					1									
		CSR13G105KM	Capacitor	(1.0 ~~μ~~f 10% 50V)				2									
		CSR13F685KM		(6.8 ~~μ~~f 10% 35V)				2									
		CKR05CW150KM		(15pf 10% 200V)				1									
		CKR05CW221KM		(220pf 10% 200V)				1									
		CKR06CW472KM		(4700pf 10% 200V)				1									
		CKR06CW104KM	Capacitor	(.1 ~~μ~~f 10% 100V)				1									
		2N3821	Transistor					1									
		RC05GF105J	Resistor	(1.0M 5% 1/8w)				2									
		RC05GF101J		(100 ~~Ω~~ 5% 1/8w)	1			1									
		RC05GF392J		(3.9K 5% 1/8w)	1			1									
		RC05GF104J		(100K 5% 1/8w)				1									
		RC05GF274J		(270K 5% 1/8w)				1									
		RC05GF683J		(68K 5% 1/8w)	4			1									
		RC05GF152J		(1.5K 5% 1/8w)				1									
		RC05GF684J	Resistor	(680K 5% 1/8w)	3			1									
		RC05GF331J	Resistor	(330 ~~Ω~~ 5% 1/8w)				1									
		220	TOTAL														

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-003 REV (0004, 0005)

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

PART NAME Module A3 Signal Processing
SHEET 1 OF 2 | ISSUED BY | DATE
NEXT ASSEMBLY

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-003	Module A3 Signal Processing			3	X									
		U5B770931X	Microcircuit				5									
		C5R13E476KM	Capacitor 47µf 10% 20V	6			2									
		CKR05CW471KM	470pf 200V	4			1									
		CKR05CW221KM	220pf 200V				5									
		CKR05CW271KM	270pf 200V	3			1									
		CKR06CW104KM	1µf 100V				5									
		C5R13C107KM	100pf 10V	7			2									
		C5R13C336KM	33µf 10V	6			2									
		CKR06CW472KM	4700pf 200V				4									
		C5R13G105KM	1µf 50V				1									
		C5R13D226KM	22µf 15V				2									
		CKR05CW102KM	Capacitor 1000pf 10% 200V				1									
		600-4521-002	Diode 1N914B				4									
		JAN(TX)1N752A	Diode, Zener	13			3									
		JAN(TX)2N2222A	Transistor	24			4									
		2N2945	Transistor	14			3									
		2N2973	Transistor				1									
		RC05GF222J	Resistor 2.2K 5% 1/8w	3			1									
		RC05GF153J	15K	9			2									
		RC05GF271J	270	3			1									
		RC05GF223J	22K				3									
		RC05GF474J	470K				2									
		RC05GF152J	1.5K				8									
		RC05GF183J	18K	7			1									
		RC05GF102J	1K				3									
		RC05GF224J	220K	20			4									
		RC05GF472J	Resistor 4.7K 5% 1/8w				3									

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0003 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO	OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE
WO LOT								
QTY. REQ.								
QTY. REL.								

PART NAME Module A3 Signal Processing

SHEET 2 OF 2 | ISSUED BY | DATE

NEXT ASSEMBLY

REV. PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
						3	X									
		RC05GF393J	Resistor 39K 5% 1/8w				2									
		RC05GF331J	330Ω 5% 1/8w				4									
		RC05GF104J	100K 5% 1/8w				2									
		RC05GF274J	270K 5% 1/8w				1									
		RN55C1003F	100K 1% 1/10w	4			1									
		3250W501-502	.VAe 5K 5% 1/2w	14			2									
		RN55C----F	Resistor --- 1% 1/10w	9			3									
		RN55C8251F	Resistor 8.25K 1% 1/10w	3			1									
		RN55C3571F	Resistor 3.57K 1% 1/10w	3			1									
		RN55C1212F	Resistor 12.1K 1% 1/10w	3			1									
		GB33P-2	Resistor, Thermal 2.96K	3			1									
		222	TOTAL													

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-006 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442 | WO | LOT | QTY. REQ. | QTY. REL.

PART NAME A6 Module

SHEET 1 OF 2 | ISSUED BY | DATE

NEXT ASSEMBLY

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV. | PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-006	A6 Module			1	X									
		U5B770931X	Microcircuit (μA709)				4									
		C5R13D226KM	Capacitor (22uf 10% 15V)				2									
		C5R13D335KM	(3.3uf 10% 15V)				2									
		CKR06CW472KM	(4700pf 10% 200V)				4									
		CKR05CW221KM	(220pf 10% 200V)				4									
		CKR06CW104KM	Capacitor (.1uf 10% 100V)				14									
		600-4534-001	Diode, Zener (FCT 1125)	2			2									
		600-4521-002	Diode, (1N 914B)				6									
		JAN(TX)1N752A	Diode Zener				4									
		JAN 2N930	Transistor				1									
		JAN2N2905A	Transistor	1			1									
		2N2973					3									
		JAN2N2907A		6			3									
		JAN(TX)2N2219	Transistor	1			1									
		JAN(TX)2N2222A	Transistor				1									
		RN55C---F	Resistor (Nom. Val. 47.5K 1% 1/10w)	1			1									
		RN55C---F	(Nom. Val 3.32K 1% 1/11w)	2			1									
		RN55C1002F	(10K 1% 1/10w)	1			1									
		RN55C3402F	(34K 1% 1/10w)	2			2									
		RC05GF681J	(680 5% 1/8w)	2			2									
		RC05GF332J	(3.3K 5% 1/8w)	2			1									
		RC05GF103J	(10K 5% 1/8w)	2			1									
		RN55C1001F	(1K 1% 1/10w)	2			2									
		RN55C4702F	(47K 1% 1/10w)	2			2									
		RC05GF152J	(1.5K 5% 1/8w)				4									
		RC05GF223J	(22K 5% 1/8w)				4									
		3250W-501-502	Resistor Var (5K 5% 1/2w)				4									
			TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0006 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442 | WO | LOT | QTY. REQ. | QTY. REL.

PART NAME A6 Module

SHEET 2 OF 2 | ISSUED BY | DATE

NEXT ASSEMBLY

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV. | PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME		SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
							1	X									
		RN55C2492F	Resistor	(24.9K 1% 1/10w)	1			1									
		RN55C----F		(301K 1% 1/10w)	1			1									
		RN55C----F		(200K 1% 1/10w)	1			1									
		RN55C3012F		(30.1K 1% 1/10w)	1			1									
		RC05GF104J		(100K 5% 1/8w)				4									
		RC05GF102J		(1K 5% 1/8w)				4									
		RC05GF224J		(220K 5% 1/8w)				5									
		RN55C-----F		(14.7K 1% 1/10w)	1			1									
		RN55C-----F	Resistor	(38.3K 1% 1/10w)	1			1									
		RN55C3901F		(3.9K 1% 1/10w)	1			1									
		RN55C2002F		(20K 1% 1/10w)	1			1									
		RN55C1102F		(11K 1% 1/10w)	1			1									
		RN55C2212F		(22.1K 1% 1/10w)	2			2									
		RC05GF122J		(1.2K 5% 1/8w)	2			2									
		RC05GF183J		(18K 5% 1/8w)				2									
		RC05GF331J		(330Ω 5% 1/8w)				4									
		RC05GF151J		(150Ω 5% 1/8w)	2			2									
		3250W-501-502		(2K 5% 1/2w)	1			1									
		RN55C6491F		(6.49K 1% 1/10w)	1			1									
		224	TOTAL														

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0007 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

PART NAME A7 Module Pulse Generators & Rquer Ckt.

SHEET 1 OF 2 | ISSUED BY | DATE

NEXT ASSEMBLY

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME		SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0007	A7 Module				1	X									
		9591021	Microcircuit	(MW μL 910)	8			8									
		9591321	Microcircuit	(MW μL 913)	4			4									
		U5B770931X	Microcircuit	(μA709)				1									
		C5R13B566KM	Capacitor	(56 μf 10% 6V)				1									
		CKR06CW103KM	Capacitor	(.01 μf 10% 200V)	7			2									
		C5R13G334KM		(.33 μf 10% 50V)				1									
		CKR06CW472KM		(4700pf 10% 200V)				1									
		CKR05CW221KM		(220pf 10% 200V)				1									
		CKR06CW104KM		(.1 μf 10% 100V)				1									
		C5R13E155KM		(1.5 μf 10% 20V)	2			2									
		CKR05CW102KM	Capacitor	(1000pf 10% 200V				1									
		600-4521-002	Diode	(1N914B)				5									
		JAN2N930	Transistor					2									
		JAN2N2907A						3									
		JAN(TX)2N2222A						7									
		2N2945						5									
		JAN(TX)2N2432	Transistor		3			3									
		RN55C----F	Resistor	(392K 1% 1/10w)	1			1									
		RC05GF473J		(47K 5% 1/8w)				1									
		RN55C3323F		(332K 1% 1/10w)	1			1									
		RC05GF153J		(15K 5% 1/8w)				1									
		RC05GF332J		(3.3K 5% 1/8w)				1									
			TOTAL														

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0007 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

PART NAME A7 Module
SHEET 2 OF 2 ISSUED BY DATE
NEXT ASSEMBLY

REV. PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME		SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
								X									
		RC05GF152J	Resistor	(1.5K 5% 1/8w)				6									
		RC05GF822J		(8.2K 5% 1/8w)	4			4									
		RC05GF683J		(68K 5% 1/8w)				2									
		RC05GF224J		(220K 5% 1/8w)				3									
		RN55C3321F		(3.32K 1% 1/10w)				1									
		RN70C24R9F		(24.9Ω 1% 1/2w)	1			1									
		RN55C1003F		(100K 1% 1/10w)				1									
		RN55C3322F		(33.2K 1% 1/10w)	1			1									
		3250W-501-502		(5K 5% 1/2w)				4									
		RN55C----F		(2.2K 1% 1/10w)	2			1									
		RN55C----F		(70K 1% 1/10w)	1			1									
		RN55C----F		(50K 1% 1/10w)	1			1									
		RN55C----F		(12.4K 1% 1/10w)	2			2									
		RN55C----F		(??K 1% 1/10w)	1			1									
		RN55C----F	Resistor	(??K 1% 1/10w)	1			1									
		RN05GF104J	Resistor	(100K 5% 1/8w)				4									
		RC05GF331J	Resistor	(330Ω 5% 1/8w)				1									
		RC05GF562J	Resistor	(5.6K 5% 1/8w)	2			2									
		RC05GF472J	Resistor	(4.7K 5% 1/8w)				2									
		226	TOTAL														

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-008 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

PART NAME Module A8 H.V. Ampl & OSC

SHEET 1 OF 2 | ISSUED BY | DATE

NEXT ASSEMBLY

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0008	Module A8 H.V. Ampl. & OSC			1	X									
		U5B770931X	Microcircuit (UA709)				2									
		CKR05CW820KM	Capacitor (82pf 10% 200V)	1			1									
		CKR06CW683KM	(.068uf 100V)	1			1									
		CKR05CW471KM	(470pf 200V)				1									
		CKR06CW103KM	(.01uf 200V)				3									
		CKR06CW472KM	(4700pf 200V)				4									
		CKR05CW221KM	(22pf 200V)				2									
		CKR06CW104KM	(.1uf 100V)				4									
		CKR06CW152KM	(1500pf 200V)	3			2									
		C5R13C107KM	(100uf 10V)				1									
		C5R13J564KM	Capacitor (.56uf 10% 100V)	4			2									
		600-4521-002	Diode (1N914B)				8									
		2N2973	Transistor				3									
		600-4762-002	(2N2605)				5									
		2N3635		2			2									
		2N3501		3			2									
		JAN2N930					1									
		JAN(TK)2N2222A	Transistor				4									
		RN55C----F	Resistor (220K 1% 1/10w)	1			1									
		RC05GF----J	(68K 5% 1/8w)				1									
		RC05GF123J	(12K 5% 1/8w)	2			2									
		RC05GF154J	(150K 5% 1/8w)	1			1									
		RC05GF563J	(56K 5% 1/8w)				3									
		RC05GF273J	(27K 5% 1/8w)	2			2									
		RN65C1004F	(1M 1% 1/4w)	3			3									
		RC05GF103J	(10K 5% 1/8w)				1									
		RC05GF183J	Resistor (18K 5% 1/8w)				2									
			TOTAL													

REV.

PART NO.

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0008 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

OPER. SEQ.	OPER. CODE	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

PART NAME Module A8 H.V. Ampl & OSC
SHEET 2 OF 2 ISSUED BY DATE
NEXT ASSEMBLY

REV. PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
							X									
		RN65C1503F	Resistor (150K 1% 1/4w)	1			1									
		RC05GF274J	(270K 5% 1/8w)				1									
		RC05GF223J	(22K 5% 1/8w)				3									
		RC05GF152J	(1.5K 5% 1/8w)				6									
		RC05GF472J	(4.7K 5% 1/8w)				3									
		RC05GF331J	(330Ω 5% 1/8w)				2									
		RC05GF220J	(22Ω 5% 1/8w)	2			2									
		RC05GF153J	(15K 5% 1/8w)				2									
		RC05GF102J	(1K 5% 1/8w)				2									
		RC05GF221J	Resistor (220Ω 5% 1/8w)	2			2									
		RC05GF334J	Resistor (330K 5% 1/8w)	1			1									
		RN55C----F	Resistor (2210Ω 1% 1/10w)				1									
		228	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0009 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442 | WO LOT | QTY. REQ. | QTY. REL.

PART NAME Module A9

SHEET 1 OF 1 | ISSUED BY | DATE

NEXT ASSEMBLY

REV. | PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0009	Module A9			1	X									
		SWD 10	Inductor 10 μh	2			2									
			Transformer, Converter	1			1									
			Transformer High Volt.	2			2									
		2N3501	Transistor				1									
		2N3739	↕	2			2									
		2N2102	↕	2			2									
		2N4036	Transistor	2			2									
		RC07GF----J	Resistor (33 5% 1/4w)	1			1									
		RC20GF474J	↕ (470K 5% 1/2w)	1			1									
		RC20GF103J	(10K 5% 1/2w)	1			1									
		RC05GF470J	(47Ω 5% 1/8w)	2			2									
		RC20GF472J	↕ (4.7K 5% 1/2w)	1			1									
		RC05GF272KM	Resistor (2.7K 5% 1/8w)				2									
		UZ210	Diode, Zener	1			1									
		1N3286	Diode	2			2									
		UZ220	Diode, Zener	1			1									
		UTR22	Diode	7			7									
		UTR42	Diode	2			2									
		600-4521-002	Diode (1N914B)				4									
		UZ222		1			1									
		600-0505-001	Capacitor .01uf 3kv	2			2									
		C5R13G685KM	↕ 6.8uf 10% 35V				1									
		C5R13D226KM	22uf 10% 15V				2									
		C5R13G226KM	22uf 10% 50V	1			1									
		CKR06CW103KM	.01uf 10% 200V				2									
		C5R13J564KM	↕ .56uf 10% 100V				2									
		CKR06CW152KM	Capacitor 1500pf 10% 200V				1									
			TOTAL													

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0108 REV. B

REV.

PART NO.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO	
WO	LOT
QTY. REQ.	
QTY. REL.	

PART NAME Base Two Gas Sensor

SHEET 1 OF 1 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0110

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0108	Base Two Gas			1	X									
		631-0108-001	Base				1									
		631-0108-002	Fitting				2									
		230	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0112 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

PART NAME Arm Chopper-Assy.
SHEET OF | ISSUED BY | DATE
NEXT ASSEMBLY 631-0110

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0112	Arm Chopper-Assy				1	X								
		631-1255	Filter, 21					1								
		631-1256	Filter, 22					1								
		631-1245	Arm					1								
			Cement					A/R								
			TOTAL													

PART NO. REV.

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0101 REV.

PERKIN-ELMER

E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

OPER. SEQ.	OPER. CODE	STD. HRS /UNIT	SET-UP		TOTAL LOTS STD	START DATE	FINISH DATE

PART NAME Bracket Grating Assy

SHEET 1 OF 1 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0100

REV.

PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0101	Bracket, Grating Assy (Insep Assy)					1	X							
		631-0101-1	Bracket						1							
		631-1201	Screw						2							
		631-1203	Nut						2							
		232	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0100 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

PART NAME Cradle & Bracket Assy

SHEET 1 OF 1 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0110

OPER. SEQ.	OPER. CODE	STD. HRS/UNIT	SET-UP		TOTAL LOT STD.	START DATE	FINISH DATE

REV. | PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISS.	QTY. B.O.	CODE
		631-0100	Cradle & Bracket Assy				1	X								
		631-0101	Bracket Grating Assy					1								
		631-1206	Pin					2								
		631-1207	Cradle					1								
		631-1220	Grating					1								
			Cement					A/R								
			TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0104 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

PART NAME Cell, Sample IR. Assy.

SHEET 1 OF 1 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0105

REV. | PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0104	Cell, Sample IR. Assy					1	X							
		631-1210	Cell, Sample, I.R.						1							
		631-1222	Ring, Retaining Window						1							
		631-1037	Window						1							
		631-1035	Lens, Element #2						1							
		631-1226	Spacer, I.R. Sample Cell						1							
		631-1036	Lens, Element #3						1							
		631-1223	Ring, Retaining, Ele. #3						1							
		631-1259	Spacer, Window						1							
		234	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0103 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

OPER. SEQ.	OPER. CODE	STD. HRS. UNIT	SETUP		TOTAL LOT STD.	START DATE	FINISH DATE

PART NAME Bolometer, Housing Assy
SHEET OF | ISSUED BY | DATE
NEXT ASSEMBLY 631-0105

REV. PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0103	Bolometer, Housing Assy					1	X							
		631-1221	Bolometer, Thermistor						1							
		631-1205	Housing, Bolometer						1							
		631-1228	Spacer						1							
		631-1224	Ring, Retaining						1							
		631-1225	Spacer, Lens						1							
		631-1257	Lens Element #4						1							
		631-1258	Element #5						1							
		600-7616-003	Screw, Cap, Socket HD (#0-80x1/4)						3							
			TOTAL													

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0102 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442 | WO | LOT | QTY. REQ. | QTY. REL.

PART NAME Source, Light IR. Assy

SHEET OF | ISSUED BY | DATE

NEXT ASSEMBLY 631-0105

OPER. SEQ.	OPER. CODE.	STD. HRS UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV. | PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISS.	QTY. B.O.	CODE
		631-0102	Source, Light IR. Assy					1	X							
		631-1213	Base & Lamp (Insep Assy)						1							
		631-1217	Lamp						1							
		631-1211	Bracket						1							
		631-1212	Extension, Lamp Base						1							
		631-1214	Spacer						1							
		631-1215	Aperture						1							
		631-1216	Ring, Retaining						1							
		631-1034	Element #1						1							
		631-1242	Board, Terminal						1							
		MS51021-11	Screw, Set Socket (4-40x1/4)						2							
		600-7616-102	Screw, Cap Socket (4-40x3/16)						4							
		600-7616-021	Screw, Cap Socket (2-56x1/8)						1							
		236	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO 631-0105 REV.

PERKIN ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
W.O. LOT
QTY. REQ.
QTY. REL.

PART NAME IR Sensor & Light Assy

SHEET 1 OF 1 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0110

REV.

PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	S.M.	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISS.	QTY. B.O.	CODE
		631-0105	I.R. Sensor & Light Assy				1	X								
		631-0102	Source Light IR Assy					1								
		631-0104	Cell, Sample, I.R. Assy					1								
		631-0103	Housing, Bolometer Assy					1								
		631-1218	Plate, Mounting					1								
		631-1260	Bushing					4								
		631-1261	Insulator					1								
		600-7616-023	Screw, Cap, Socket HD 2-56x1/4					10								
		600-7623-007	Nut, Hex, Plain 4-48					1								
			Screw, Set', Socket 4-48x3/8					1								
			TOTAL													

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-1221 REV.

REV.

PART NO.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442	
WO	LOT
QTY. REQ.	
QTY. REL.	

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

PART NAME Bolometer, Thermistor Assy

SHEET 1 OF 1 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0103

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-1221	Bolometer, Ther. Assy						1							
		238	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0115 **REV.**

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

PART NAME Mask, Lower Assy
SHEET 1 OF 1 | ISSUED BY | DATE
NEXT ASSEMBLY 631-0107

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0115	Mask, Lower Assy					1	X							
		631-1250	Substrate, Lower						1							
		631-1253	Mask, Lower						1							
			Cement						H/R							
			TOTAL													

REV.

PART NO.

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0116 **REV.**

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

PART NAME Mask Upper Assy

SHEET 1 OF 1 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0107

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0116	Mask Upper Assy					1	X							
		631-1251	Substrate, Upper						1							
		631-1254	Mask, Upper						1							
			Cement						A/R							
		240	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0114 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

PART NAME Window Assy U.V. Sample Cell

SHEET 1 OF 1 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0119

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0114	Window Assy. U.V. Sample Cell					1	X							
		631-1247	Window, L.H.						1							
		631-1248	Window, R.H.						1							
			Cement						A/R							
			TOTAL													

REV.

PART NO.

FORM 2-0277*00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0119 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO	OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE
WO LOT								
QTY. REQ.								
QTY. REL.								

PART NAME Cell, Sample UV Outer Wind.

SHEET OF | ISSUED BY | DATE

NEXT ASSEMBLY 631-0118

REV. PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0119	Cell, Sample UV Outer Wind.					1	X							
		631-0114	Window, Assy						1							
		631-1243	Window, Outer						1							
			Epoxy						A/R							
		242	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0118 REV.

PERKIN ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

OPER. SEQ.	OPER. CODE	STD. HRS. UNIT	SETUP		TOTAL LOT STD	START DATE	FINISH DATE

PART NAME Cell, Sample UV Insert Sub.

SHEET OF | ISSUED BY | DATE

NEXT ASSEMBLY 631-0117

REV. PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISS.	QTY. B.O.	CODE
		631-0118	Cell, Sample UV Insert Sub					X	1							
		631-0119	Window Outer						1							
		631-1282	Cell, Sample, UV Insert						1							
		631-1244	Window, Lower						1							
			Epoxy						Fl/2							
			TOTAL													

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0117 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

PART NAME Cell, Sample UV Sub-Assy
SHEET OF | ISSUED BY | DATE
NEXT ASSEMBLY 631-0107

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV. | PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0117	Cell, Sample UV Sub-Assy					X	1							
		631-0118	Cell, Sample UV Insert						1							
		631-1281	Cell, Sample UV Housing						1							
			Epoxy						A/R							
		244	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

ART NO. 631-0107 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

PART NAME Gas, Sample, UV Assy
SHEET OF | ISSUED BY | DATE
NEXT ASSEMBLY 631-0110

REV. PART NO.

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0107	Gas, Sample, UV Assy				1	X								
		631-0117	Cell					1								
		631-0115	Mask Lower Assy					1								
		631-0116	Mask, Upper Assy					1								
		631-1246	Cam					1								
		631-1249	Pin					1								
		631-1252	Cleat					4								
		600-7676-015	Screw, Set, Flat Pt #080x1/41g					1								
		600-7676-103	Screw, Cap, Socket HD #4-40x1/41g					8								
			TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

ART NO. 631-0121 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO	OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE
WO LOT								
QTY. REQ.								
QTY. REL.								

PART NAME Arm, Chopper Assy

SHEET OF | ISSUED BY | DATE

NEXT ASSEMBLY 631-0110

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0121	Arm, Chopper Assy				1	X								
		631-1245	Arm, Chopper					1								
		631-1283	Chopper, UV					1								
		631-1284	Chopper IR					1								
		631-1255	Filter λ 1					1								
		631-1256	Filter λ 2					1								
			Epoxy					A/R								
		246	TOTAL													

PART NO. REV.

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0106 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

PART NAME Cover Hermetical

SHEET OF | ISSUED BY | DATE

NEXT ASSEMBLY 631-0113

REV. PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0113	Cover Hermetical			1	X									
		631-1279	Cover Internal				1									
		631-1277	Bracket Mounting				1									
		631-1274-1	Stud Threaded				2									
		631-1274-2	Stud Threaded				1									
		631-1274-3	Stud Threaded				1									
		631-1275	Stud Tapped				4									
		631-1276-1	Tubing				1									
		631-1276-2	Tubing				1									
		MS3113H16-26	Connector				1									
			~~Connector~~				2									
			Connector				4									
			TOTAL													

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0113 **REV.**

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO | WO | LOT | QTY. REQ. | QTY. REL.

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

PART NAME Two Cas Sensor Assy

SHEET OF | ISSUED BY | DATE

NEXT ASSEMBLY

REV.

PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0113	Two Gas Sensor Assy		1	X										
		631-0001	Module A1			1										
		631-0002	Module A2			1										
		631-0003	Module A3			1										
		631-0004	Module A4			1										
		631-0005	Module A5			1										
		631-0006	Module A6			1										
		631-0007	Module A7			1										
		631-0008	Module A8			1										
		631-0009	Module A9			1										
		631-0109	Cover			1										
		631-0110	IR + UV Channel Assy			1										
		631-1239	Spacer Module			1										
		631-1237	Gasket Cover			2										
		631-1238-001	Screw, Module			1										
		631-1238-002	Screw, Module			2										
		631-1238-003	Screw, Module			2										
		631-1238-005	Screw, Module			1										
		631-1236	Spacer, Connector													
		631-1240	Gasket, Connector			A/R										
		600-7616-021	Screw, Cap, Socket 2-56x1/8			12										
		600-9091-006	Plate, Identification			1										
			Sealing & Retaining Compound			A/R										
			Nut, Hex			2										
		248	TOTAL													

FORM 2-0277-00

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0110 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO 27442
WO LOT
QTY. REQ.
QTY. REL.

PART NAME IR & UV Channel Assy

SHEET 1 OF 2 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0113

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-0110	IR & UV Channel Assy			1	X									
		631-0100	Grating & Bracket Assy				1									
		631-0105	IR Assy				1									
		631-0107	Cell, U.V Assy				1									
		631-0121	Arm, Assy				1									
		631-0108	Base, Weldment				1									
		631-0014	Transducer, Pressure				1									
		631-1200	Bracket, Mirror				2									
		631-1202	Block				4									
		631-1204	Bracket, Chopper				1									
		631-1208	Bracket, Lamp				1									
		631-1219	Bracket, Photo multiplier				1									
		631-1230	Mirror				1									
		631-1231	Photomultiplier				1									
		631-1232	Motor Chopper				1									
		631-1234	Mask, UV				1									
		631-1235	Hub				1									
		607-1049	Lamp				1									
		600-7616-102	Screw, Cap, Socket HD 4-40x3/161g				20									
		600-7616-103	4-40x1/41g				2									
		600-7616-109	4-40x3/41g				4									
		600-7616-022	2-56x3/161g				9									
		600-7616-023	2-56x1/41g				3									
		600-7616-024	2-56x5/161g				4									
		600-7616-001	0-80x1/81g				5									
		600-7616-002	Screw, Cap, Socket HD 0-80x3/161g				2									
		600-7624-001	Washer Flat #0				4									
			TOTAL													

PART NO. REV.

CC: IBM, QC, WORK, STORES, FILE

PART NO. 631-0110 REV.

PERKIN-ELMER
E-O DIVISION
MANUFACTURING DEPT.
BILL OF MATERIALS & RELEASE SHEET

SPO
WO LOT
QTY. REQ.
QTY. REL.

OPER. SEQ.	OPER. CODE.	STD. HRS /UNIT	SET-UP		TOTAL LOT STD	START DATE	FINISH DATE

PART NAME IR & UV Channel Assy

SHEET 2 OF 2 | ISSUED BY | DATE

NEXT ASSEMBLY 631-0113

REV.

PART NO.

REV.	ITEM NO.	PART NUMBER	PART NAME	SUM	1	2	3	4	5	6	7	8	QTY. REQ.	QTY. ISSD.	QTY. B.O.	CODE
		631-1262-001	Tube, Union				2									
		631-1262-002	Tube, Union				1									
		631-1262-003	Tube, Union				2									
		631-1263	Tube Inlet, IR				1									
		631-1264	Tube Outlet IR				1									
		631-1265	Tube Outlet UV				1									
		631-1266	Tube, Transducer				1									
		631-1267	Tube, Sleeve				6									
		250	TOTAL													

FORM 2-0277-00

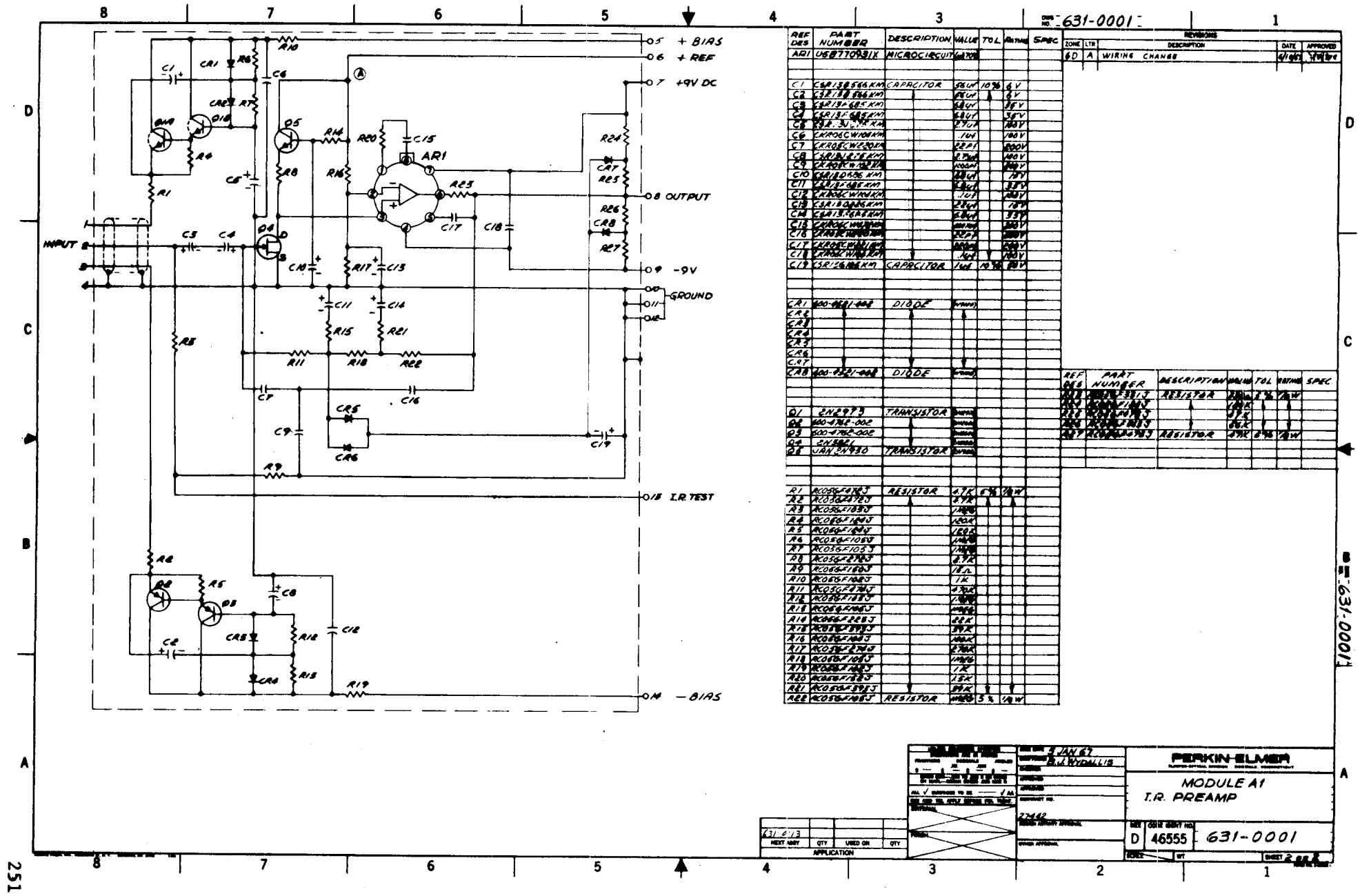


Figure 60. IR Preamplifier - Module A1

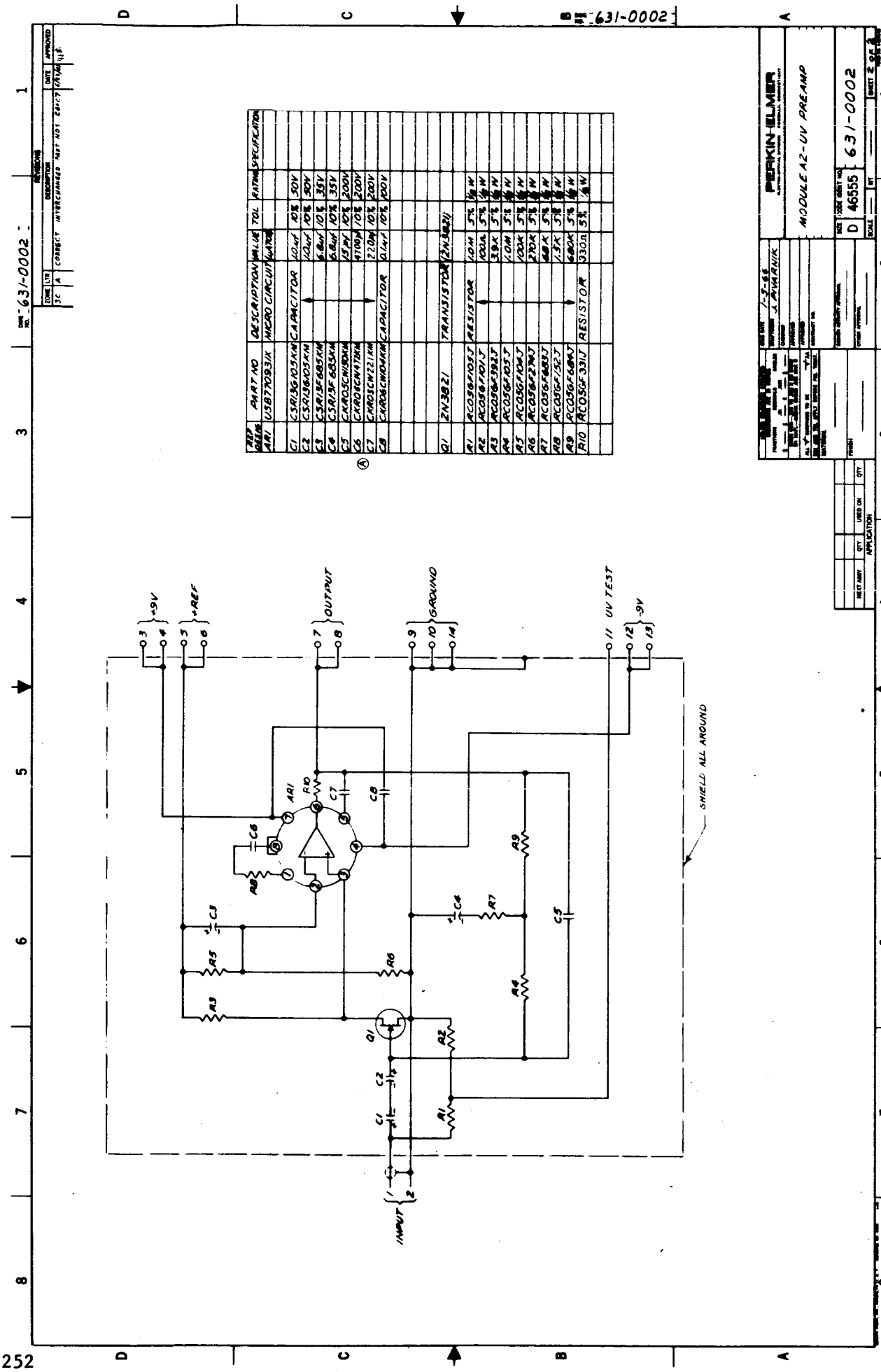


Figure 61. UV Preamplifier - Module A2

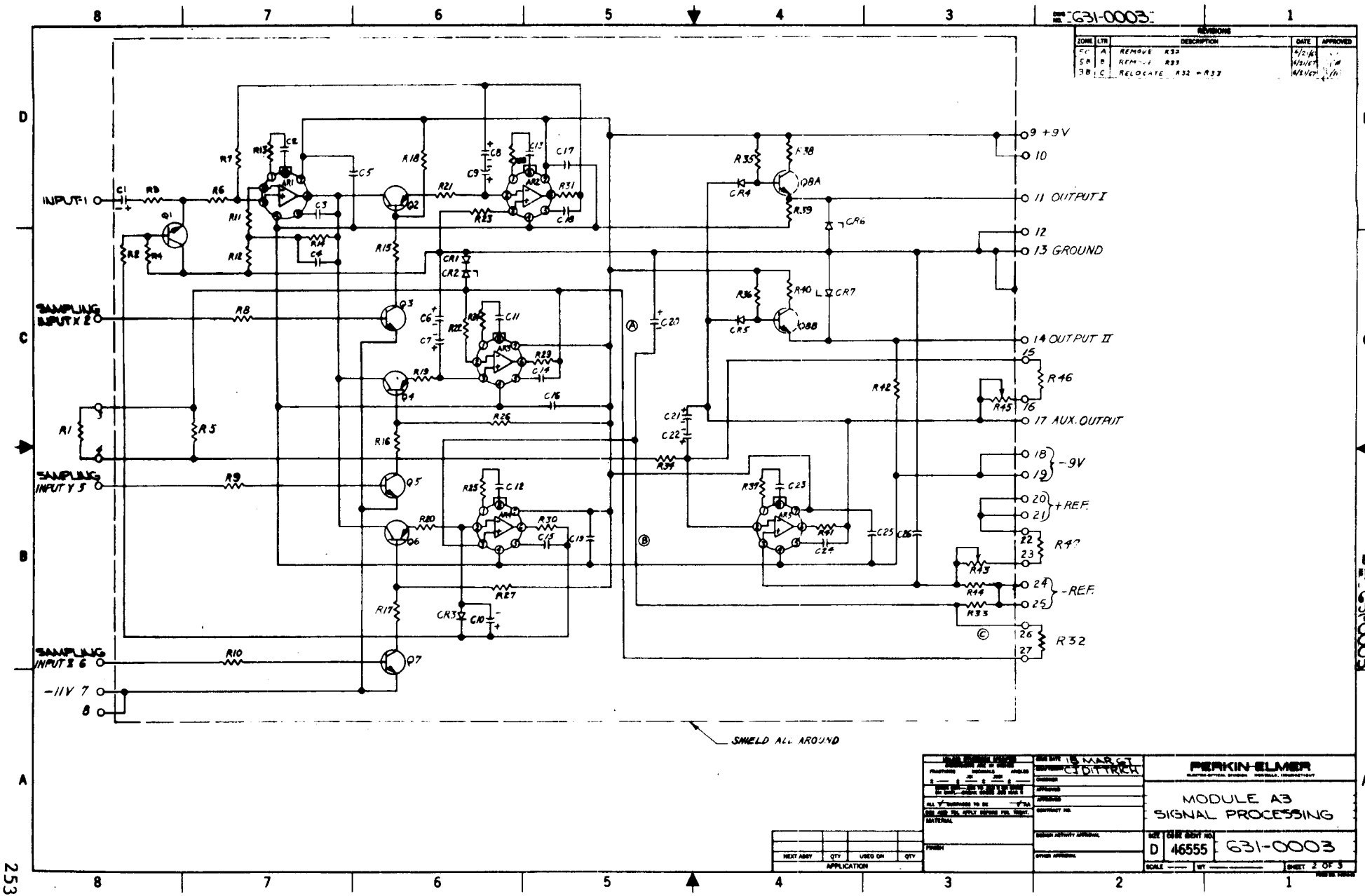


Figure 62. Signal Processing - Module A3

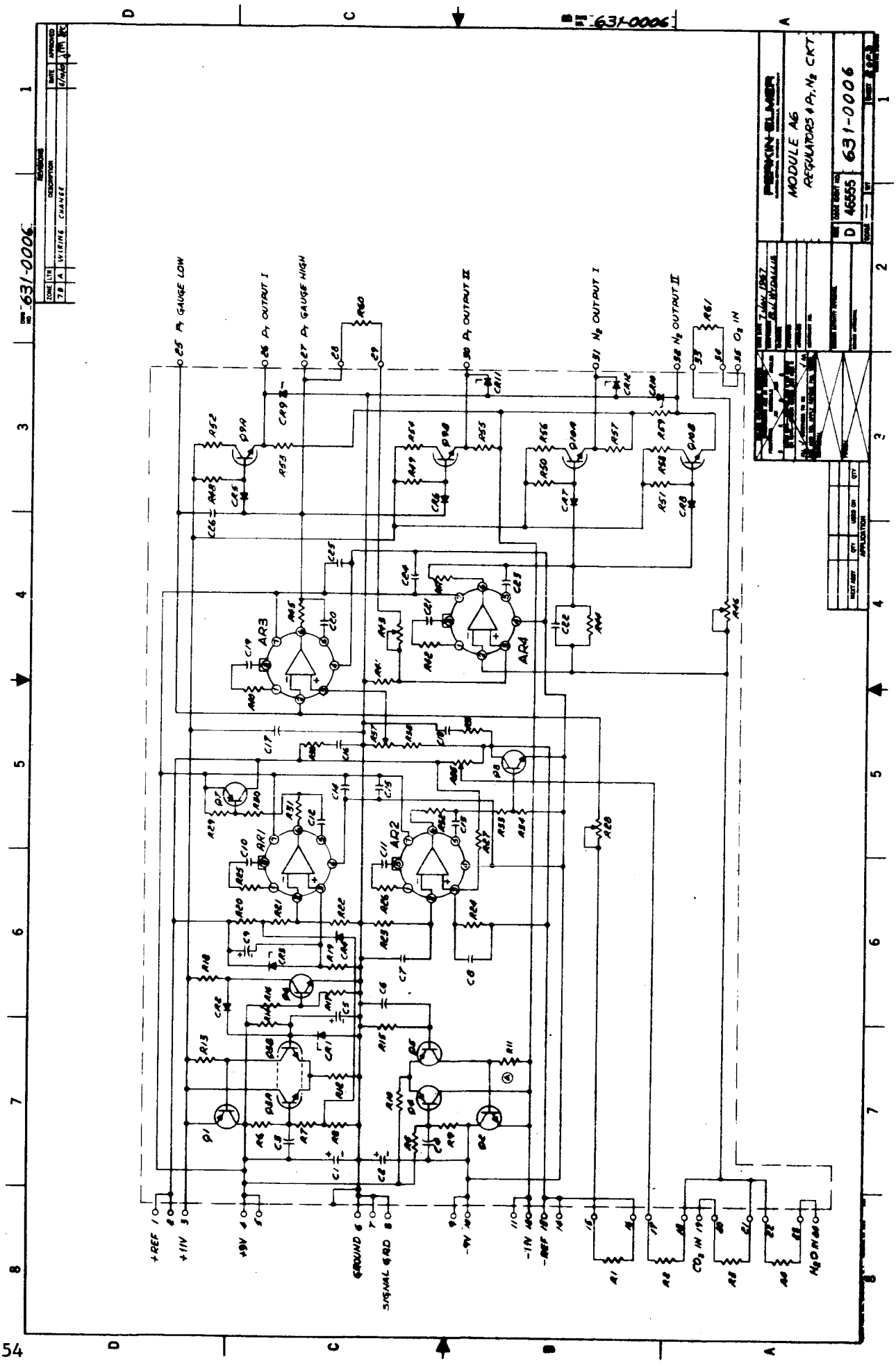


Figure 63. Regulators and $P_T N_2$ Circuit - Module A6

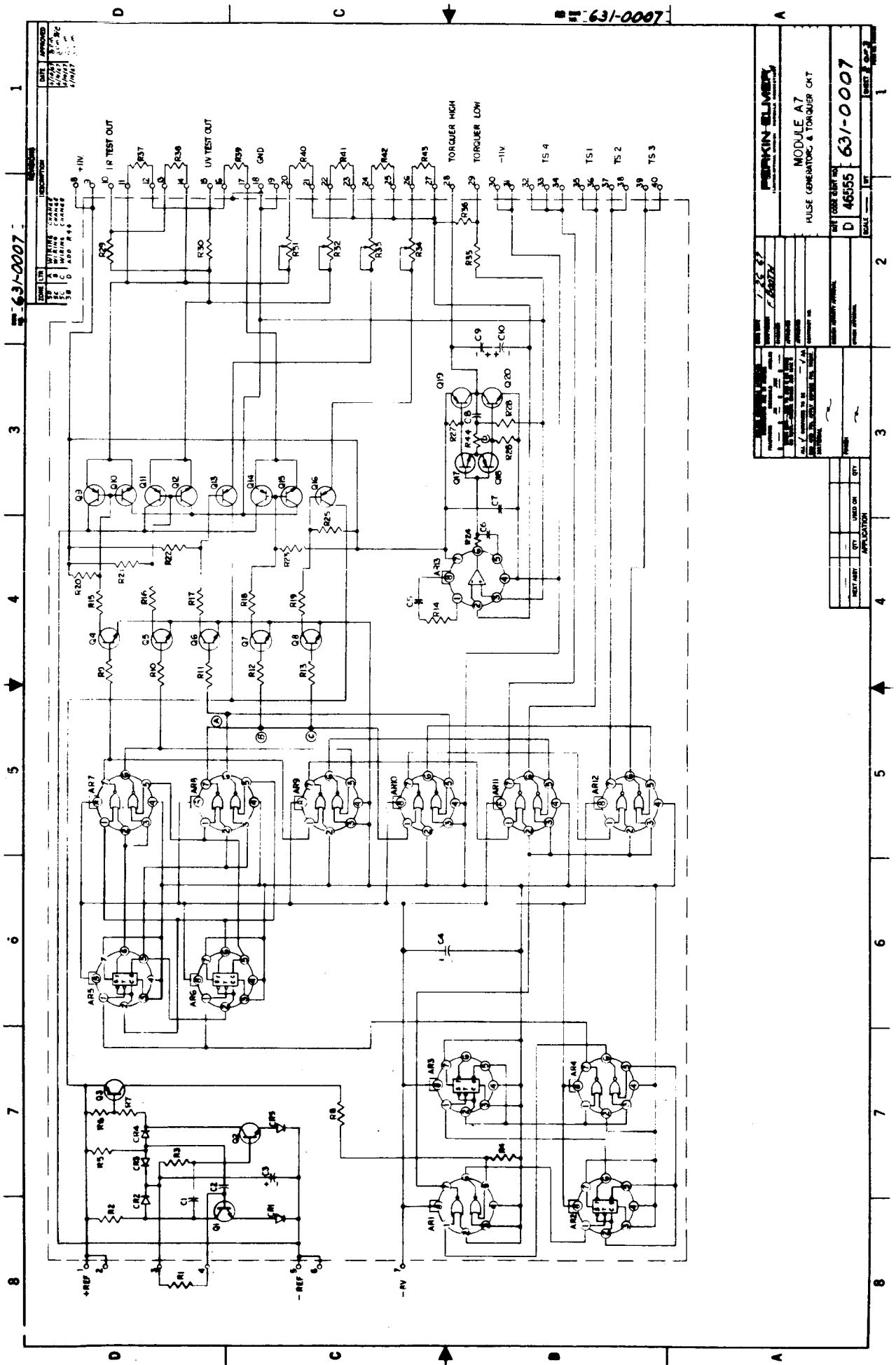


Figure 64. Pulse Generators and Torque Circuit - Module A7

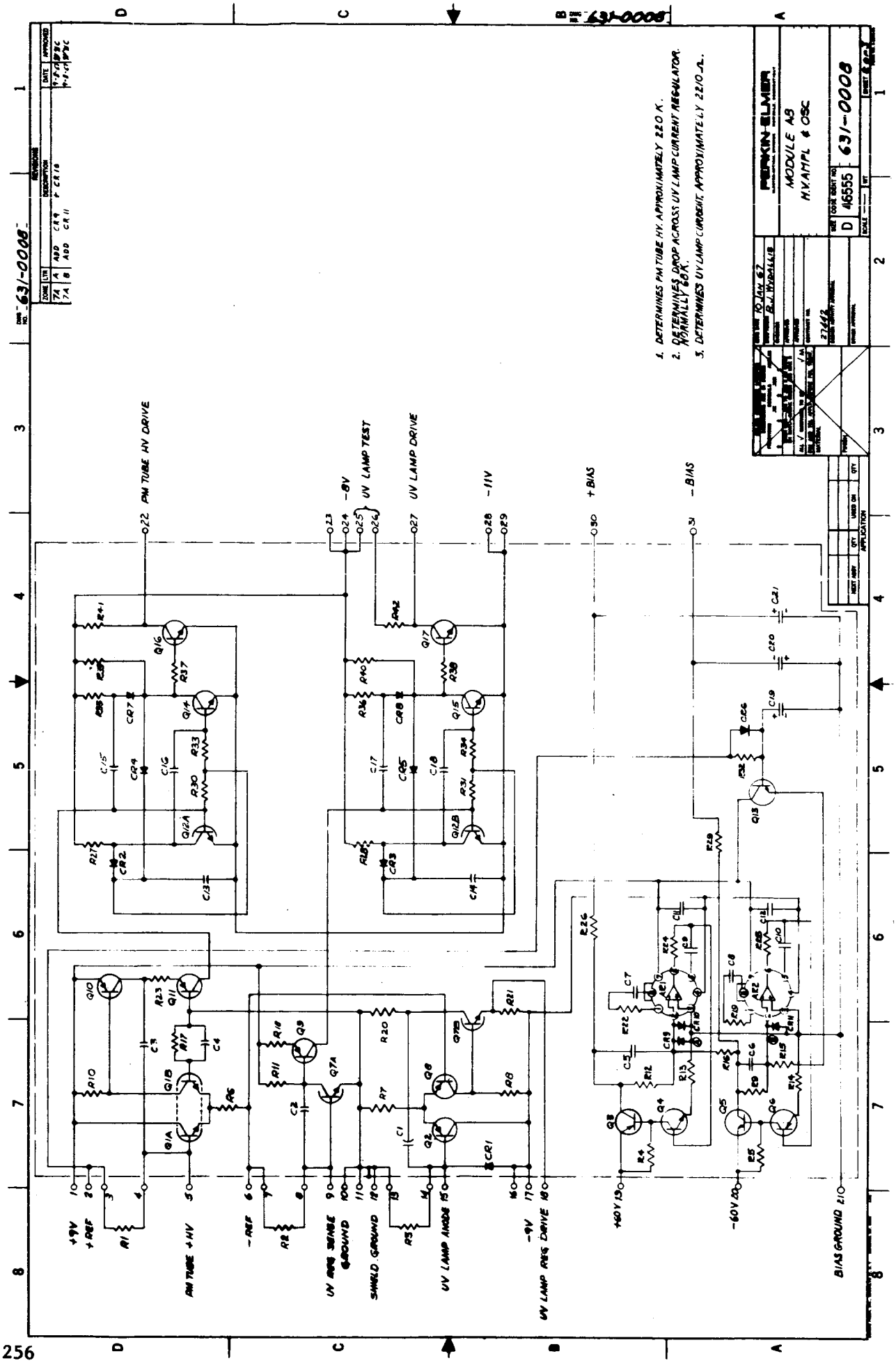


Figure 65. High Voltage Amplifier and Oscillator - Module A8

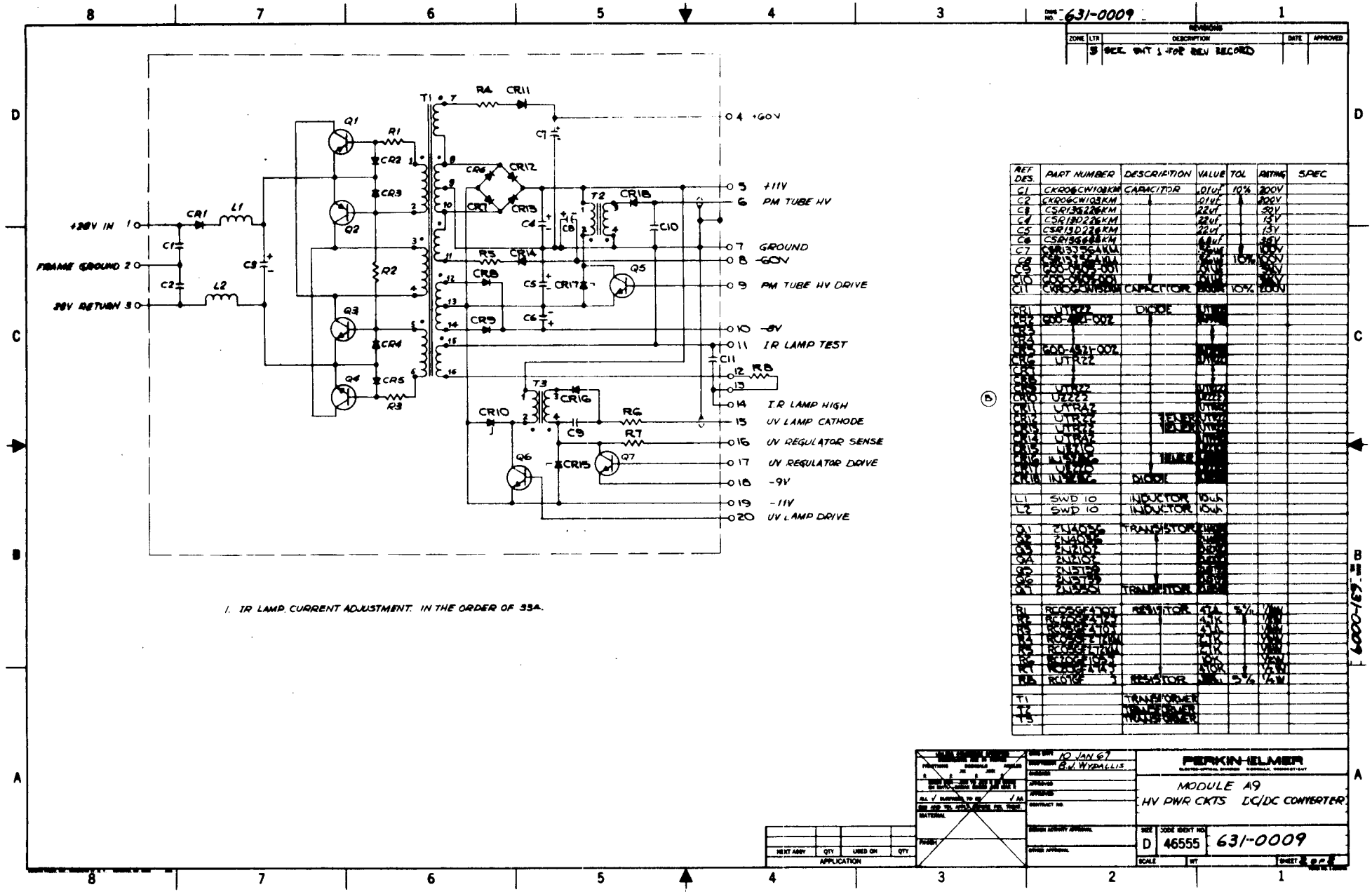


Figure 66. High Voltage Power Circuits and DC/DC Converter - Module A9

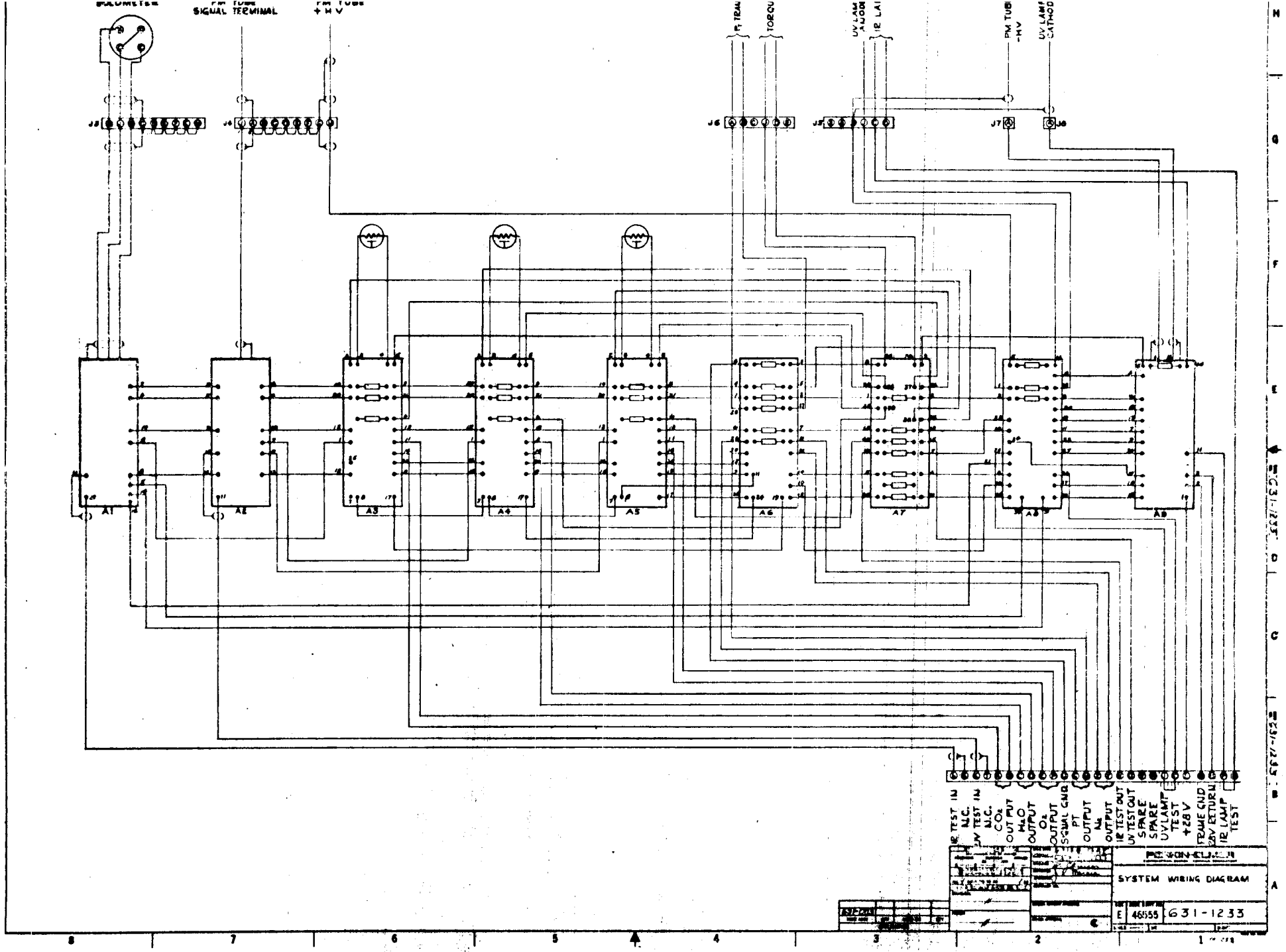


Figure 67. System Wiring Diagram

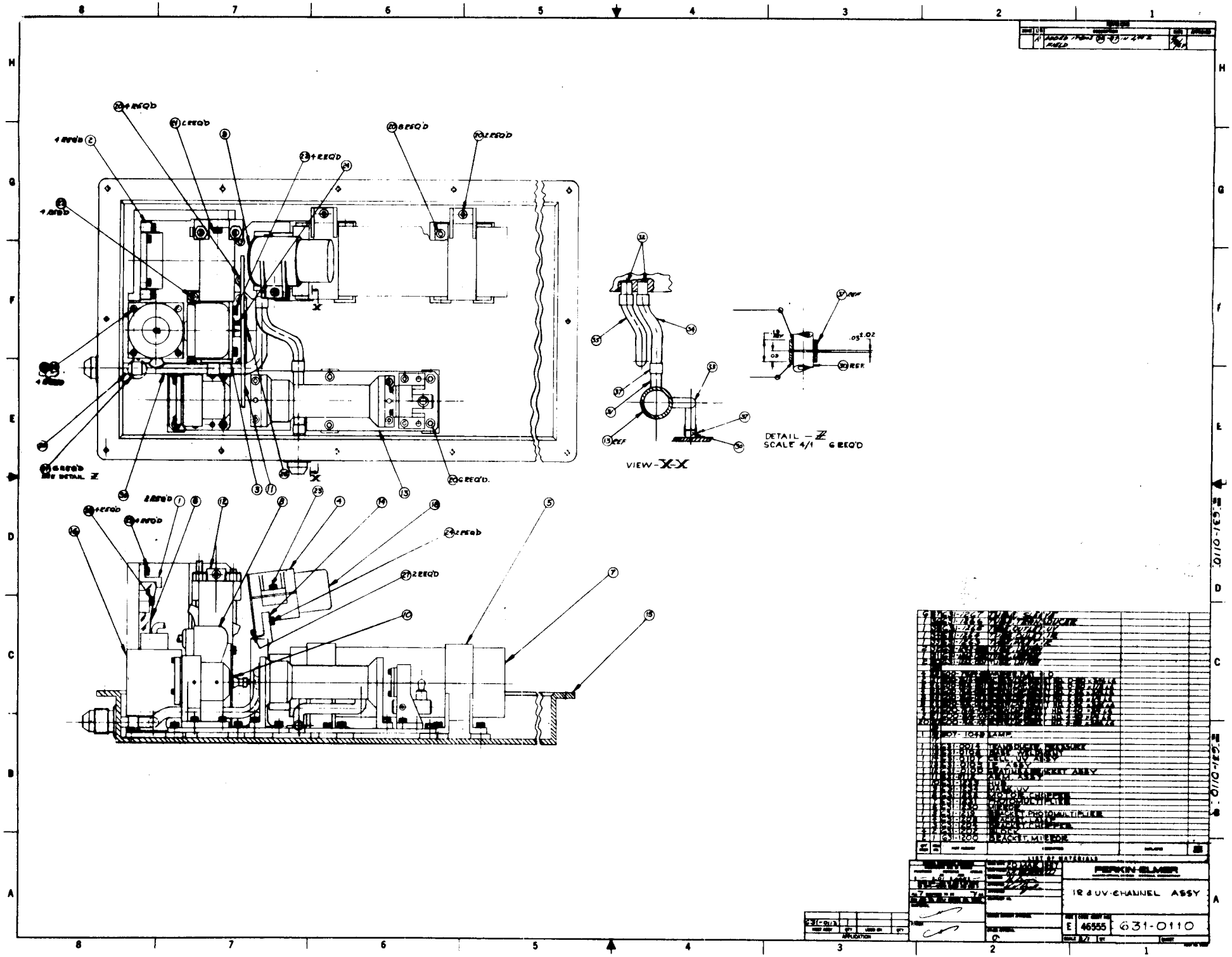


Figure 68. Infrared and Ultraviolet Channel Assembly

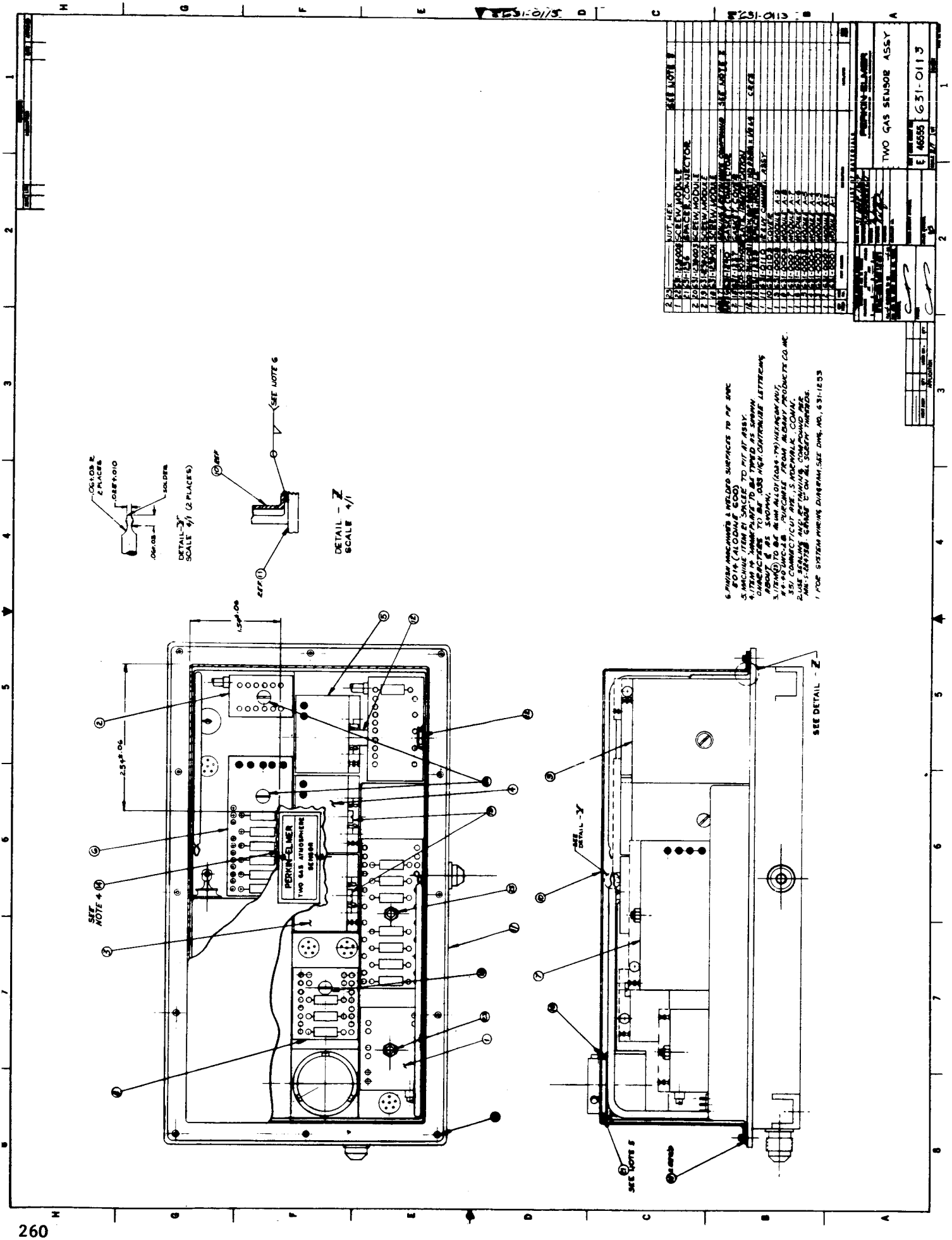


Figure 69. Two Gas Sensor Assembly

SECTION V

ASSESSMENT OF PERFORMANCE

The assessment of performance of the fabricated hardware is made first with respect to the performance goals for the program and then with respect to additional criteria that were developed as the units were tested.

The performance goals and actual operation of the system may be summarized as follows:

Weight:

The goal was 6.5 pounds. This has been improved to 4.8 pounds.

Volume:

The goal was 110 in^3. The actual volume is 122 in^3.

Power:

The goal was 5 watts at 28 vdc. The actual power consumption is 4.7 watts.

Oxygen Partial Pressure (PO_2):

Range - Zero to 250 millimeters Hg with expanded scales for a 0 to 5 volt dc output corresponding to 125 to 250 mm Hg partial pressure of oxygen (with available alternate ranges). This has been done.

Accuracy - ±2 percent of full scale. This has been met for short term operation only.

Water Vapor Pressure (PH_2O):

Range - Zero to 30 mm Hg for a 0 to 5 volt dc output.

Accuracy - ±5 percent of full scale. The range and accuracy of the H_2O channel has not been demonstrated.

Carbon Dioxide Partial Pressure (PCO_2):

Range - Zero to 20 mm Hg partial pressure of carbon dioxide corresponding to a 0 to 5 volt dc output. This has been done.

Accuracy - ±2 percent of full scale. This has been met.

Total Pressure (P_T) Characteristics:

Range - 100 to 400 mm Hg total pressure corresponding to 0 to 5 volts dc full scale output. (Available for 1 atmosphere P_T as an option.) This has been done.

Accuracy - ±1 percent of full scale. This has been demonstrated to be ±1.3 percent.

Nitrogen Partial Pressure (PN_2):

Range - 100 to 300 mm Hg corresponding to 0 to 5 volt dc output. This has been done.

Accuracy - ±5 percent of full scale. This is derived from the O_2 signal and hence exhibits only short term stability.

A. SYSTEM PERFORMANCE

The following performance characteristics are common to the entire Two Gas Atmosphere Sensor System:

Operating Temperatures	-	40° to 90°F. This has been demonstrated for the electronics only.
Storage Temperature	-	65° to 200°F. This has not been demonstrated.
Vibration, Acceleration, and Shock	-	Manned Spaceflight Missions. This has not been tested.
Attitude	-	There should be no preferred use attitude, but this is unresolved at present.
Altitude	-	No limitation on operating or storage altitude. This has not been tested.
Operating Life	-	One to three years (estimated)
Storage Life	-	Estimated in excess of three years
Required Operational Supply	-	28 volt dc supply ±4 volts. Transients and reverse polarity protection have been provided by an EMI filter on the input power line. A provision has also to be made on the output to limit the output voltage swing from -1 to +7 volts in the event of equipment failure.
Handling and Storage	-	Recommended to be accomplished by the use of specially designed carrying case, which will isolate the sensor from extreme environmental conditions and be a useful storage provision and general protective device for the sensor system.
Response Time	-	Less than 10 seconds to reach 90 percent of the step value of input partial pressure change with a pressure drop of less than 3 inches of water (primarily pneumatic). This has been met.
Flight Qualification	-	The system is designed to meet typical flight qualifications as defined by the reference programs. No qualification tests have been performed.

B. SUBSYSTEMS PERFORMANCE

During the functional testing of the first two units, several design deficiencies were encountered which require additional work before the units can be considered fully operational and within the specified design goals for the system. In summary, the problem areas are:

1. Drift in the output of the oxygen channel
2. Susceptibility to rotation in the earth's magnetic field
3. Susceptibility to changes in ambient pressure
4. Untested performance of the water vapor channel
5. Incomplete sealing of the hermetic cover assembly

1. PO_2 Channel

The PO_2 channel meets the requirements for zero and span calibration and linearity. The oxygen calibration is independent of total pressure of the sample gas.

The oxygen channel has exhibited a drift rate of approximately 5 to 7 percent of full scale over 24 hour periods. This drift is fairly consistent from unit to unit, always exhibiting a positive increase, which apparently indicates an increase in the oxygen partial pressure. Systems tests have reasonably verified that the drift problem is not associated with the electronics system, but rather it is caused by a mechanism of the sample cell interacting with various concentrations of oxygen. The effect that we have observed can be accounted for in either of two mechanisms; either there is an increase in absorption of the oxygen cell, or an apparent decrease in absorption from the reference cell on the 1470Å energy slit. The most likely cause of this effect is an apparent film that forms on the oxygen sample cell in the presence of both the ultraviolet energy and the oxygen gas. A reduction in the absorption of the reference cell is difficult to synthesize at this time. Tailor, Chubb, and Kreplim[3] have reported on the transmission diminution of vacuum ultraviolet lamp windows, which may partially explain the mechanism of the film formation. The reference paper describes the decay of the response of UV sample chambers when the detectors are exposed to radiation from high intensity helium discharge lamps. The mechanism proposed in this paper was that the cause of the decay was a buildup of an absorbing film upon the UV transmitting windows employed in the system. It was felt that the film was produced from photodisassociated pump oil. Data presented in this paper shows that detectors, which were irradiated through a vacuum path, had a drastic decrease in response, which suggests that the attenuation of radiation might be traced to the vacuum pump oil.

The authors describe a model of film buildup and transmission loss based on decomposition of the oil vapors. It was believed that the far ultraviolet quanta traversing the imperfect vacuum between sample windows photodisassociated the residual oil molecules which then condensed on the windows. The resulting accumulating film on the window is highly absorbent in the far UV and reduces the emergent far UV flux. As a result, the process of film buildup occurs at an ever decreasing rate. An empirical relationship was developed which showed that the decrease in emergent flux is proportional to the square of the flux emerging from the window times a constant made up of the absorption coefficient of the film constituent. The coefficient is proportional to the fraction of the oil fragments produced in the gas that strike the window and condense to form a film, and the number of oil molecules per unit volume, their cross section per unit area, and also the path length through the gas.

In summary, the transmittance diminution is caused by the formation of an attenuating film on the surface of the UV window. The film is formed as a result of the fragmentizing of vacuum pump oil molecules by the ultraviolet. The rate at which the window transmittance diminishes is a function of the lamp intensity, the absorption coefficient of the film constituents, and the production rate of the film. It is evident that the calibration of the

[3] Tailor, Chubb, and Kreplim, Journal of Optical Society of America, Vol. 55, 9, 1965.

system must be made in an oil free environment, if long term stability is to be obtained. However, this effect can be counteracted by exposing the reference cell to the same atmosphere seen by the analytical sample cell and ratioing out the common formation of the interference film. The total energy absorbed by this film is quite small and well within the region of the AGC operation. It is suggested that a slight modification to the sample cell be made to allow this provision to be added. In the design of the present cell, the reference path does not see the sample gas and, hence, remains constant. If indeed a film does form, on the sample side, then a change in the ratio will result.

Tests on optical degradation by Heath and Sacher[4] investigated the effects on the transmittance of CaF_2 and sapphire for UV use when subjected to irradiation by high energy electrons. The result showed that CaF_2 exhibited a marked degradation in the transmittance in the 1725Å region compared to that obtained at 1470Å. Sapphire, on the other hand, exhibited no observable change in transmission over this wavelength region. It is unfortunate that the sample cells we assembled do contain windows of CaF_2 on the photomultiplier side of the cells.

2. Magnetic Field Effects

During the development testing of the first two sensors, it was determined that in the present design the PO_2 channel output is susceptible to the movement in the earth's magnetic field.

When the effect of the earth's field became apparent, the manufacturer of the photomultiplier (EMR, Princeton, New Jersey) was contacted.

The available data on EMR photomultiplier tubes with venetian blind construction indicates that a magnetic field of 4 Gauss produces a maximum change in output of 5 percent. It was assumed, but not specifically stated, that this applied at a nominal current gain of 10^6. Since the earth's magnetic field is about 0.18 Gauss, it should result in a maximum output variation of about 0.2 percent.

The problem has apparently occurred in our design due to the high energy available from the monochromator and the resultant reduced current gain (10^3 at 1050 v) at which we are operating the photomultipliers.

Magnetic shielding should be provided on all units to reduce to attitude sensitivity. This can be accomplished by special formed magnetic shields, or shielding can be accomplished by wrapping the tube with Netic-Conetic foil available from Perfection Mica Company, Magnetic Shield Division, Chicago, Illinois. The Conetic material is AA foil (0.004 inch thick) wrapped to 0.015 inch thickness. This shields against low intensity magnetic field (0 to 2 Gauss). The Netic material is S3-6 foil (0.004 inch thick) wrapped to 0.025 inch thickness. This shields against fields from 2 to 4 Gauss.

A magnetic shield was installed on unit S/N 03 but its effect was untested.

[4] E.E. Heath, P.A. Sacher, Applied Optics, 5, 943 (June 1966).

3. Ambient Pressure Changes

After the seals were made on the hermetic cover flanges, a test was performed to determine the susceptibility of the PO_2 channel to internal positive pressures of up to 5 psi above ambient. The effect is an output change of 4 percent per psi. This should be less than 0.1 percent per psi for acceptable design. The cause of the error is the deflection of the housing base which causes a resultant defocusing and translational motion of the UV sample cell.

An analysis follows which first establishes the measurement error in terms of the exit energy spectral content and then investigates several mechanisms which can contribute to changes in the spectral output.

a. Alignment Consideration in UV Section of Two Gas Sensor

The initial consideration is the development of the measure of the error which can be experienced in the oxygen channel as a function of changes in the spectral output.

A sketch of the two gas sensor monochromator is shown in figure 70. It consists of a UV source, a reflector, a grating, and an exit slit. The function of the monochromator is to generate radiation at 1470Å for the oxygen channel and at 1750Å for the water vapor channel.

The following analysis investigates some of the considerations relating to alignment of the optical elements in the monochromator.

(1) Measurement of Susceptibility to Errors Due to a Shift in Average Wavelength

Assuming a monochromatic radiation at 1470Å, the transmission through an absorbing medium is given by:

$$I = I_o e^{-\beta C x} \qquad (1)$$

where I = intensity of transmitted radiation

I_o = initial intensity

β = absorption coefficient at 1470Å

C = concentration of absorbing medium (oxygen)

x = path length

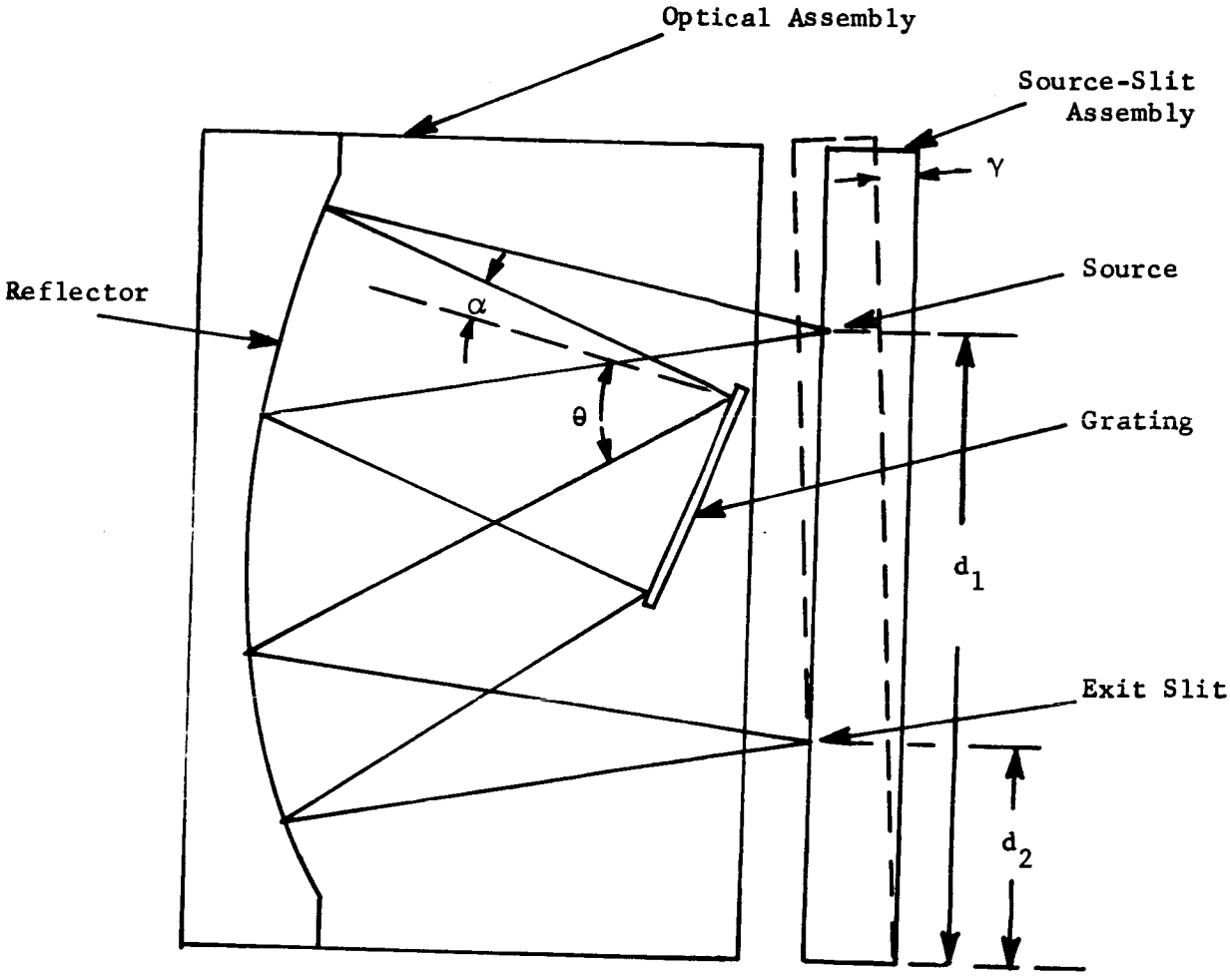


Figure 70. Two Gas Sensor Monochromator

The ratio from which the oxygen concentration is computed is:

$$R_o = \frac{K I_o}{I_o e^{-\beta C x}} \tag{2}$$

hence

$$R_o = K e^{\beta C x} \tag{3}$$

It is evident from Eq. (3) that what is actually being measured is the product βCx. Assuming the path length x is constant and known, but the absorption coefficient is changing because of a change in wavelength, the resulting error in C (which will keep R constant) is given by:

$$(\beta+\Delta\beta)(C+\Delta C) - \beta C = 0 \tag{4}$$

where

$\Delta\beta$ = change in β

ΔC = resulting error in C

From Eq. (4)

$$\frac{\Delta C}{C} = - \frac{\Delta\beta}{\beta} \tag{5}$$

where $\Delta\beta/\beta$ is the normalized error in β and $\Delta C/C$ is the normalized measurement error. The percentage error per unit wavelength is obtained by dividing Eq. (5) by $\Delta\lambda$ and multiplying by 100. Hence

$$E_o = - \frac{\Delta\beta/\Delta\lambda}{\beta} 100 \tag{6}$$

where

E_o = normalized measurement error (%/Å)

$\frac{\Delta\beta}{\Delta\lambda}$ = slope of absorption curve

Since the slope of the absorption curve is changing rapidly, the value of E_o will vary considerably depending upon where the slope is evaluated. Using the plots of relative absorption in figure 11, page 29 of the Two Gas Sensor Design Study Report (P.E. Report No. 8287), the slope at and around 1470Å was evaluated and is tabulated below.

λ(Å)	$\beta(cm^{-1})$	$\Delta\lambda$(Å)	$\Delta\beta$	$(\frac{\Delta\beta}{\Delta\lambda})$	$E_o (\frac{\%}{Å})$
1440	353	-30	3	-0.1	+0.03
1470	350	0	0		
1500	320	+30	-30	-1.0	+0.3

The tabulated values show that at the oxygen analytical wavelength of 1470Å, an error of approximately 0.1%/Å will be experienced. For a 1 percent error, the average spectral content at the exit slit must be maintained to within 10Å.

Using the same approach for the water vapor channel, it can be shown that the ratio from which water vapor is determined is proportional to the quotient of the transmission at 1470Å through a relatively short absorption path to the transmission at a nominal wavelength at 1750Å through a relatively long absorption path. The equation for R_w is

$$R_w = \frac{K_1 \, e^{-\beta_1 C_o x_1}}{e^{-\beta_2 C_o x_2} \, e^{-\beta_3 C_w x_2}} \tag{7}$$

where

β_1 = absorption coefficient of oxygen at 1470Å

β_2 = absorption coefficient of oxygen at 1750Å

β_3 = absorption coefficient of water vapor at 1750Å

C_o = concentration of oxygen

C_w = concentration of water vapor

x_1 = absorption path length of oxygen channel

x_2 = absorption path length of water channel

The path lengths are selected so that nominally

$$\beta_1 x_1 = \beta_2 x_2 \tag{8}$$

and

$$R_w = K_1 \, e^{\beta_3 C_w x_2} \tag{9}$$

Assuming an error in wavelength of the radiation through the water channel, the ratio will be

$$R_w' = K_1 e^{\Delta\beta_2 C_o x_2} \, e^{(\beta_3+\Delta\beta_3) C_w x_2} \tag{10}$$

The error in C_w is obtained by computing the change (ΔC_w) in C_w which will make $R_w' = R_w$. Hence

$$e^{\Delta\beta_2 C_o x_2} \, e^{(\beta_3+\Delta\beta_3)(C_w+\Delta C_w) x_2} - e^{\beta_3 C_w x_2} = 0 \tag{11}$$

and

$$\Delta\beta_2 C_o x_2 + (\beta_3+\Delta\beta_3)(C_w+\Delta C_w) x_2 - \beta_3 C_w x_2 = 0 \tag{12}$$

from Eq. (12)

$$\frac{\Delta C_w}{C_w} = - \frac{\Delta\beta_3 + \frac{C_o}{C_w}\Delta\beta_2}{\beta_3} \tag{13}$$

and

$$E_w = - \left[\frac{\frac{\Delta\beta_2}{\Delta\lambda} + \frac{C_o}{C_w}\frac{\Delta\beta_2}{\Delta\lambda}}{\beta_3} \right] \tag{14}$$

(2) Conclusion

It is seen from Eq. (14) that the error in the water vapor channel is a function of oxygen concentration. Using the absorption curves of oxygen and water vapor from figure 11, of P.E. Report No. 8287, the percentage error is tabulated below for two situations.

The first case corresponds to 30 mm/Hg vapor pressure with no oxygen present, while the second case has the same vapor pressure but 280 mm/Hg partial pressure of oxygen.

Mixture	$\frac{C_o}{C_w}$	λ(Å)	$\frac{\Delta\beta_3}{\Delta\lambda}$	$\frac{\Delta\beta_2}{\Delta\lambda}$	β_3 (cm^{-1})	E_w ($\frac{\%}{Å}$)
$C_o = 0$	0	1750	-0.87	0.17	59	1.5
C_o = 280 mm Hg, C_w = 30 mm Hg	9.3	1750	-0.87	0.17	59	4.2

The slopes in the above table are average values between 1720Å and 1750Å.

This means that the output error is significantly greater in the water vapor channel for changes in the spectral content of the exit energy. As a result of this increased sensitivity, the stability of the average wavelength must be 1.0Å or less.

b. Defocus Effects

A sketch of the monochromator is shown in figure 70. Nominally the object plane, containing the entrance slit, is located at a distance from the reflector equal to the focal length so that the radiation incident on the grating is collimated. Similarly, the first order spectrum at any wavelength is also collimated and is focused at a distance from the reflector equal to the focal length.

If the system is defocused by rotating the source-slit assembly through an angle γ as shown in figure 70, the radiation incident on the grating will no longer be collimated. This causes the focal plane to be shifted away from the reflector. Furthermore, by reference to figure 70, it may be seen that the exit slit is shifted toward the reflector. Both effects are additive and cause the exit slit to be out of the focal plane. This causes a change in both the intensity and spectral distribution of the radiation passing through the exit slit. The following

analysis presents a qualitative description of the effect by computing the size of the blurred image of the entrance slit in the plane of the exit slit. This is done for a wavelength equal to 1470Å and an angle γ equal to 0.2 degree which is the estimated order of magnitude of γ that could result from a differential pressure of 5 psi between interior and exterior of the optical compartment.

An equivalent thin lens system is shown in figure 71. It is introduced solely for the purpose of making it easier to trace the rays in the system. The parameters in figure 71 are defined as follows.

h = height of entrance slit

α = angle of incidence of central ray on grating

θ = angle of reflection of first order spectrum

h'= image of h

d = spacing of grating

The direction of the first order spectrum is that for which the optical path difference between adjacent reflections is one wavelength and by reference to figure 71 is related to α, d, and λ by the following equation.

$$d \sin \theta - d \sin \alpha = \lambda \tag{15}$$

The change in angle of incidence ($\Delta\alpha$) corresponding to light coming from the top of the entrance slit h is given by

$$\Delta\alpha = \frac{h}{f} \tag{16}$$

where

$\Delta\alpha$ = change in angle of incidence
f = focal length

Hence $\Delta\theta$ is given by

$$d \sin (\theta+\Delta\theta) - d \sin (\alpha+\Delta\alpha) = \lambda \tag{17}$$

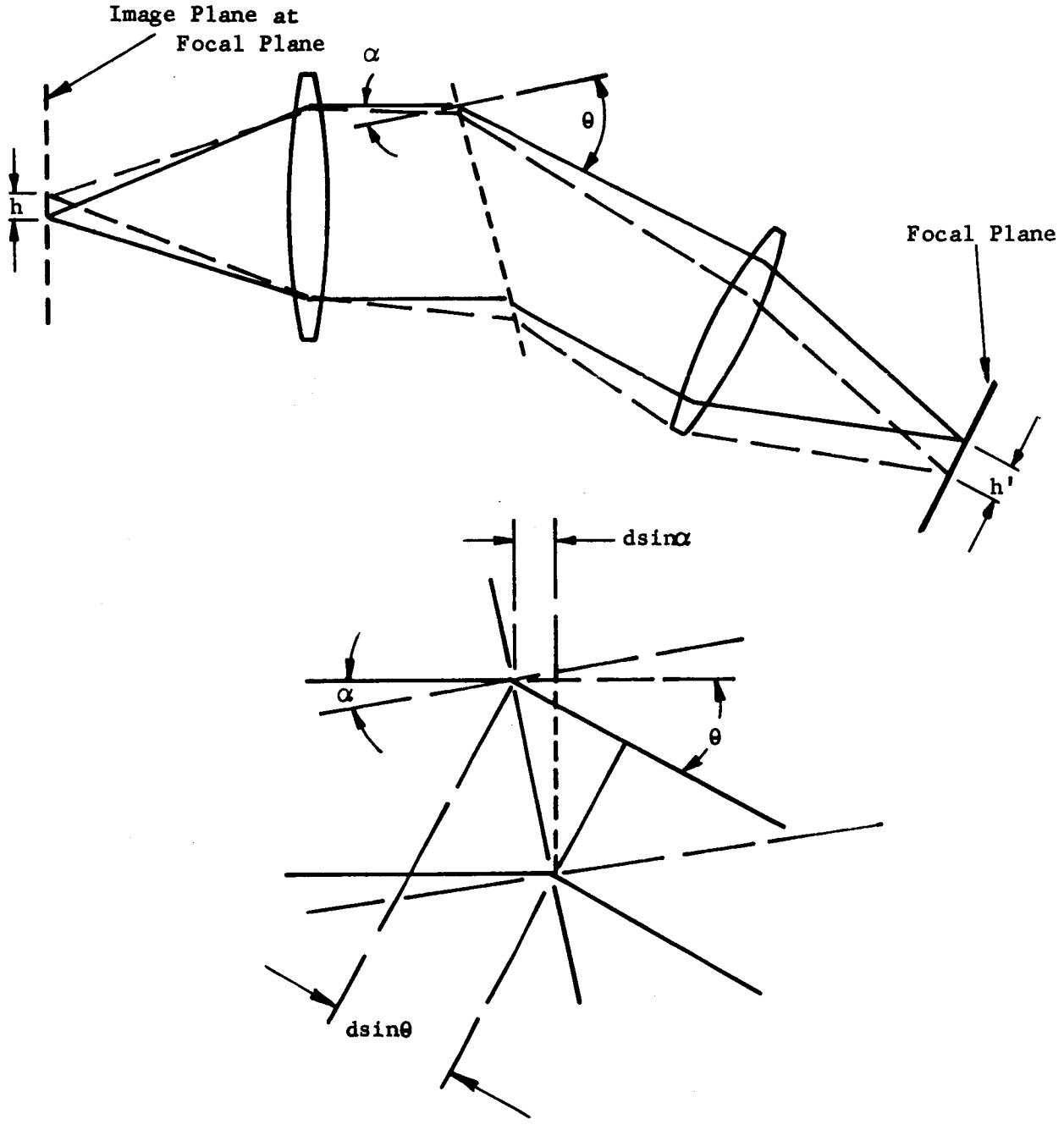
$$(\sin\theta \cos\Delta\theta + \sin\Delta\theta \cos\theta)-(\sin\alpha \cos\Delta\alpha + \sin\Delta\alpha \cos\alpha) = \frac{\lambda}{d} \tag{18}$$

since

$$\left.\begin{aligned} &\cos\Delta\theta \approx \cos\Delta\alpha \approx 1 \\ &\sin\Delta\theta = \Delta\theta \\ &\sin\Delta\alpha = \Delta\alpha \end{aligned}\right\} \tag{19}$$

$$\sin \theta + \Delta\theta \cos\theta - \sin \alpha - \Delta\alpha \cos \alpha = \frac{\lambda}{d} \tag{20}$$

$$\Delta\theta = \Delta\alpha \frac{\cos \alpha}{\cos \theta} \tag{21}$$



$$d\sin\theta - d\sin\alpha = \lambda$$

Figure 71. Location of First Order Spectrum

The image (h') of h is therefore given by

$$h' = f\Delta\theta \tag{22}$$

$$h' = f\Delta\alpha \frac{\cos\alpha}{\cos\theta} \tag{23}$$

$$h' = h \frac{\cos\alpha}{\cos\theta} \tag{24}$$

The parameters of the system are:

$$d = 1/2880\text{mm}$$

$$h = 0.5\text{mm}$$

$$\alpha = 15°$$

Substituting $\lambda = 1470\text{Å}$ and the above values of α and d into Eq. (15) and solving for θ yields

$$\theta = 43°$$

Hence the magnification is given by

$$m = \frac{\cos\alpha}{\cos\theta} = 1.32 \tag{25}$$

If the system is defocused a small amount Δs the image plane will be shifted an amount $\Delta s'$. In the absence of the grating, $\Delta s'$ would be equal to Δs. The effect of the grating is to magnify the shift by m. Hence for small Δs

$$\Delta s' = 1.32\ \Delta s \tag{26}$$

By reference to figure 70

$$\Delta s = \gamma d_1 \tag{27}$$

$$t = 0.120 \text{ inch}$$

$$E = 10 \times 10^6 \text{psi (aluminum)}$$

Based upon the above numbers, the value of y_m is

$$y_m = 0.0181 \text{ inch} \tag{29}$$

and the order of magnitude at γ is given by

$$\gamma = \frac{0.0181}{4.5} \approx 0.2 \text{ degree} \tag{30}$$

Using the above value of γ and

$$d_1 = 2 \text{ inch}$$
$$d_2 = 1 \text{ inch}$$
$$f/\# = 3$$
$$h = 0.020 \text{ inch}$$

The magnitude of Δs from Eq. (29) is

$$\Delta s = 0.0068 \tag{31}$$

Hence

$$\frac{\Delta s}{h} = \frac{0.0068}{0.020} = 0.34 \tag{32}$$

and

$$\frac{\gamma d_2}{h'} = \frac{0.0034}{1.32(0.020)} = 0.129 \tag{33}$$

The effect of relative rotation of source-slit assembly with respect to the optical assembly on the geometry at the exit slit is shown drawn to scale in figure 72. By scaling from figure 72, the expansion in the size of the image in the shifted exit plane at $\lambda = 1470$Å is approximately

$$\frac{\Delta A}{A} = 32\%$$

Ideally the radiation through the exit slit should be monochromatic at the nominal analytical wavelength. For the assigned values of the parameters, the magnitude of the nominal wavelength fails by about 32 percent. This is not a serious consideration because of the high energies available. However, at the same time, adjacent wavelengths are smeared at the exit slit plane, allowing some radiation at adjacent wavelengths to pass through the exit slits. This is the most significant effect, in that it changes the average absorption coefficient and contributes to a measurement error. In summary, the defocusing effect causes a broadening of the spectral distribution which can contribute to the measurement error.

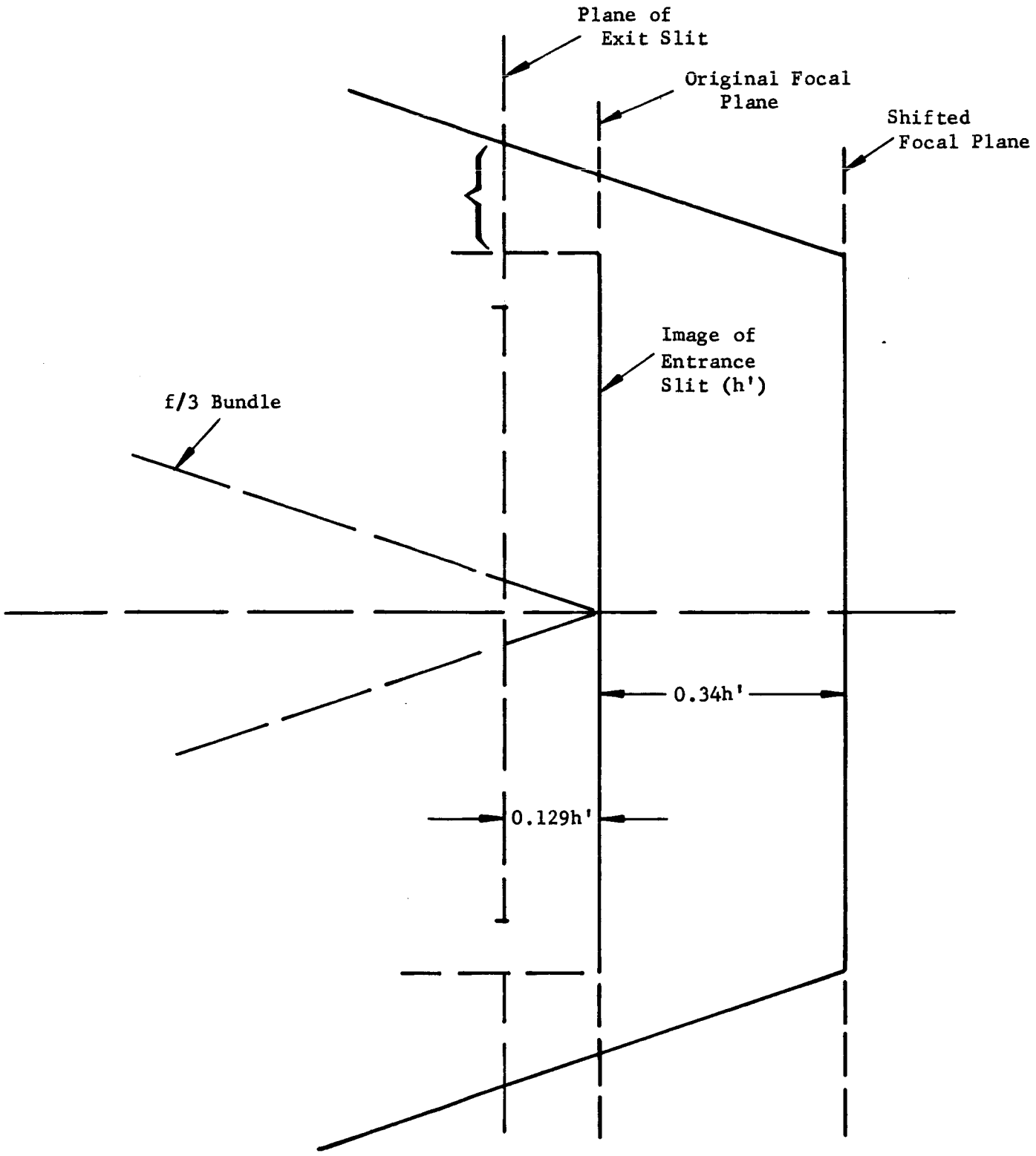


Figure 72. Effect of Rotation in Geometry at Exit Slit

..c. Translational Motion of UV Sample Cell

If the source-slit assembly is translated in a direction normal to the optical axis and the axis of the cylindrical reflector, the image of the entrance slit at any wavelength and the exit slit will travel in opposite directions relative to each other. Hence, the average wavelength through the slit will change. The magnitude of the change in λ may be computed by perturbing Eq. (15) and thereby computing the increment in λ due to increments in α and θ. Hence from Eq. (15)

$$d \sin(\theta+\Delta\theta) - d \sin(\alpha+\Delta\alpha) = \lambda + \Delta\lambda \tag{34}$$

Expanding Eq. (34) by means of the identity

$$\sin(A+B) = \sin A\cos B + \sin B\cos A \tag{35}$$

and making small angle approximation for $\Delta\theta$ and $\Delta\alpha$ yields

$$\Delta\lambda = \Delta\theta\, d \cos\theta - \Delta\alpha d \cos\alpha \tag{36}$$

If now the source-slit assembly is translated an amount Δy then, by reference to figure 71,

$$\Delta\alpha = - \frac{\Delta y}{f} \tag{37}$$

$$\Delta\theta = + \frac{\Delta y}{f} \tag{38}$$

Substituting the above into Eq. (36) yields

$$\frac{\Delta\lambda}{\Delta z} = \frac{d}{f} (\cos\theta + \cos\alpha) \tag{39}$$

Substituting the values for d, f, θ, and α into Eq. (39) yields

$$\frac{\Delta\lambda}{\Delta y} = 1.99 \text{ Å/mil} \tag{40}$$

If Δy were equal to the deflection of the case under a 5-psi pressure differential (see Eq. (29)), the shift in the center wavelength at the exit slit would be approximately

$$\Delta\lambda = 34\text{Å} \tag{41}$$

This shift in center wavelength may be compared with the tabulated error for the oxygen channel to show approximately a 3.4 percent error due to the translational motion. With the water vapor channel, the change in wavelength should be controlled to better than one Å so that the required value of Δy should be less than 0.0005 inch for 7.0 psi differential.

d. Sensitivity to Grating Rotation

By reference to (A), figure 73, the relation between angle of incidence, direction of exit slit, and wavelength is given by

$$d \sin\theta - d \sin \alpha = \lambda \tag{42}$$

where

α = angle of incidence with respect to grating normal
θ = direction of first order spectrum with respect to normal
λ = wavelength

If the direction of incident radiation and position of exit slit remain fixed while the grating is rotated, the increment in λ for a rotation δ is given by (see (B), figure 73)

$$d \sin(\theta-\delta) - d \sin(\alpha-\delta) = \lambda+\Delta\lambda \tag{43}$$

where

δ = rotation angle of grating
$\Delta\lambda$ = increment in wavelength through exit pupil

Solving Eq. (43) for $\Delta\lambda/\delta$, using small angle approximations for δ, yields:

$$\frac{\Delta\lambda}{\delta} = d\,[\cos\alpha - \cos\theta] \tag{44}$$

Equation (44) is shown plotted as a function of angle of incidence in figure 74. The value of θ in Eq. (44) is given by Eq. (42) as a function of α and λ.

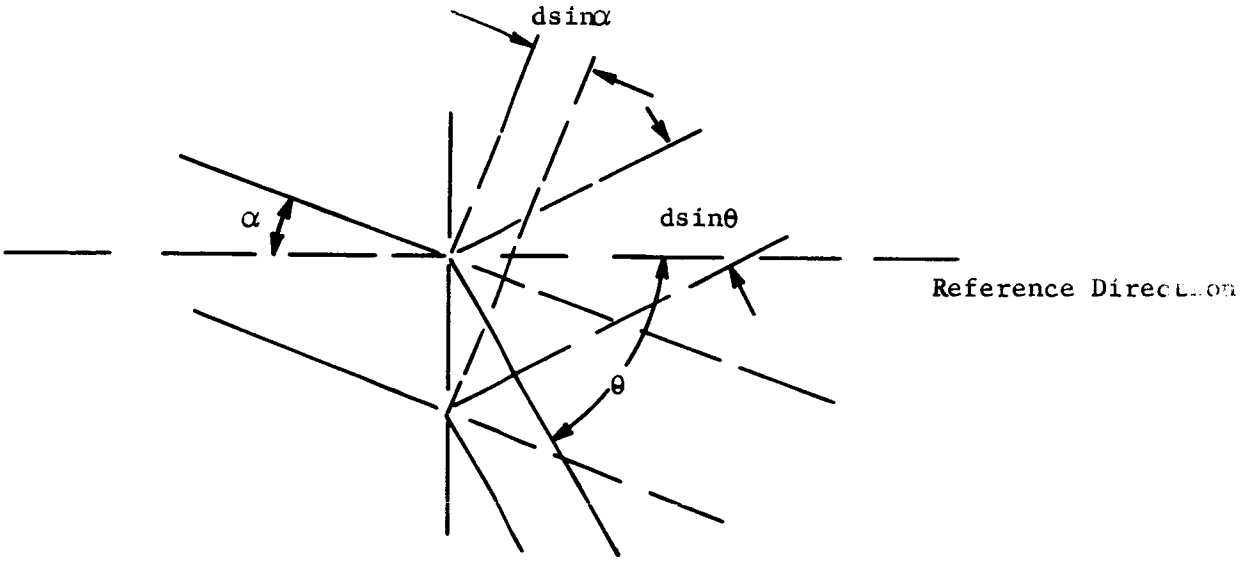
From the curve of figure 74, it can be seen that the sensitivity to grating rotation is approximately 12Å/degree. Again, using the tabulated value of 10Å for the oxygen wavelength change, the rotation angle stability should be better than 0.9 degree for a 1 percent measurement error. The water vapor channel, which is more susceptible to the wavelength change, requires a rotation stability of 5 arc-minutes.

4. Water Vapor Channel

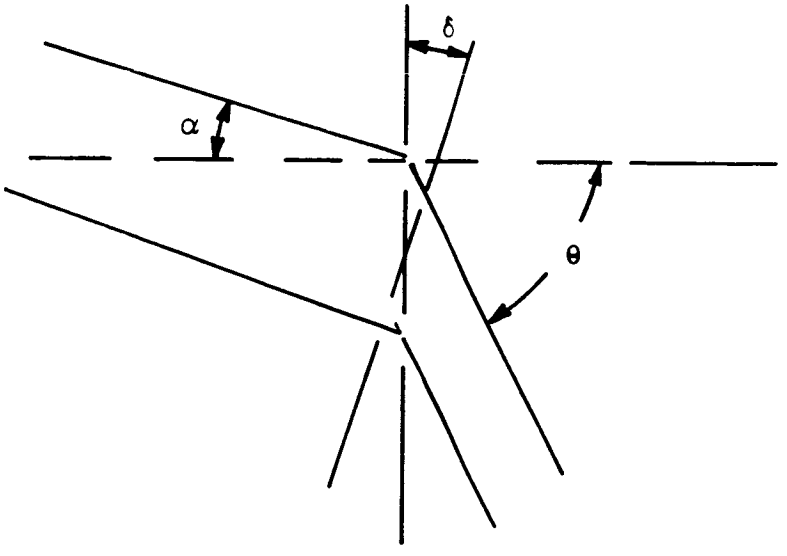
The performance of the water vapor channel remains untested due primarily to difficulty encountered in establishing a proper test fixture. The initial test system shown in figure 52 became saturated and did not provide reproducible vapor samples.

5. Hermetic Sealing

The gas lines have been tested to 10^{-8} std cc/sec helium leakage rates. The hermetic cover has been partially sealed but still exhibits leaks around the electrical feed-thrus.. During the sealing process, the hermetic covers did withstand a one atmosphere differential pressure with internal vacuum. The covers have been tested to 20 psia positive internal pressure.



(A) $d \sin \theta - d \sin \alpha = \lambda$



(B) $d \sin(\theta-\delta) - d \sin(\alpha-\delta) = \lambda + \Delta\lambda$

Figure 73. Grating Geometry

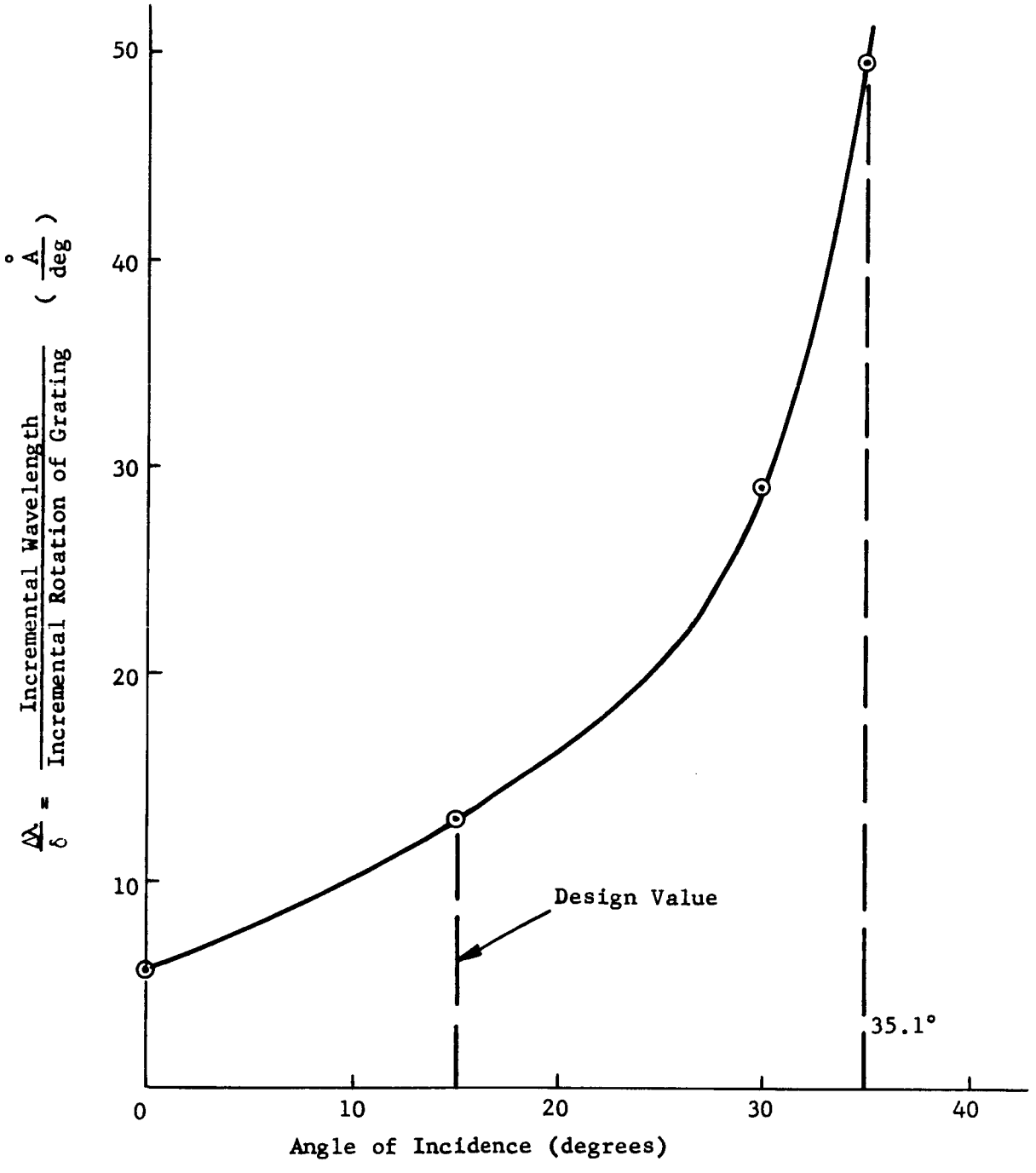


Figure 74. Ratio of Incremental Wavelength to Incremental Rotation of Grating as a Function of Angle of Incidence

SECTION VI

RECOMMENDATIONS FOR FUTURE WORK

Phase I of the program established the feasibility of a recommended design approach for a photometric sensor. Phase IIa established a base-line design and Phase IIb implemented the design in the fabrication and test of four units. Many of the detail difficulties experienced with the Phase IIa design were solved during the fabrication phase. Additional difficulties with the design still exist and require additional work to implement their solution. The design limitations appear to be well defined and their solution is straightforward. The proposed solutions, which can be accomplished by reworking the existing hardware, consist primarily of changes to the mechanical mounts.

The work required may be summarized as follows:

a. Remount the UV sample cell, chopper, and monochromator on a single structure, which is independent of deflections of the base housing or hermetic cover. This change is necessary because the present configuration is subject to pressure induced deflections of the base housing as discussed in Section V.

b. Magnetically shield the photomultiplier detector in the UV channel.

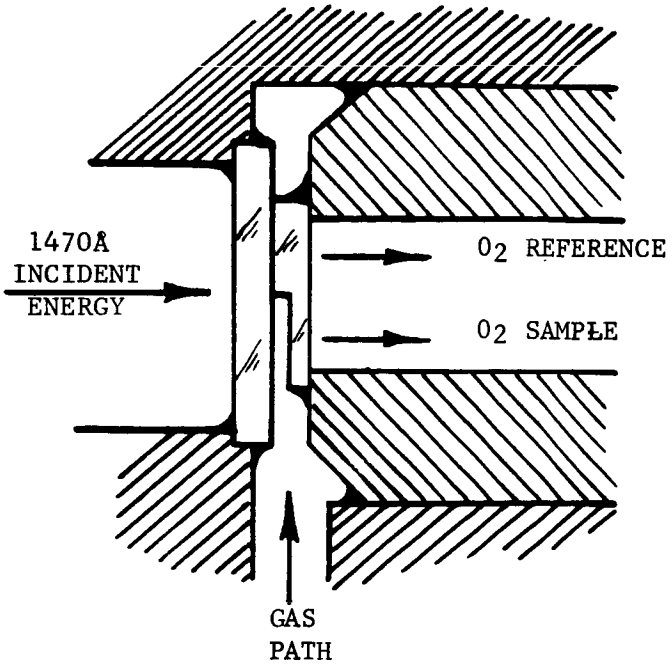
c. Increase the f/no. of the UV monochromator to decrease cross-talk between channels and allow a higher voltage on the PM tube. This change is accomplished by a smaller aperture in front of the UV source.

d. Separate the UV sample cell to permit the sample gas to enter the reference beam. This is shown in figure 75.

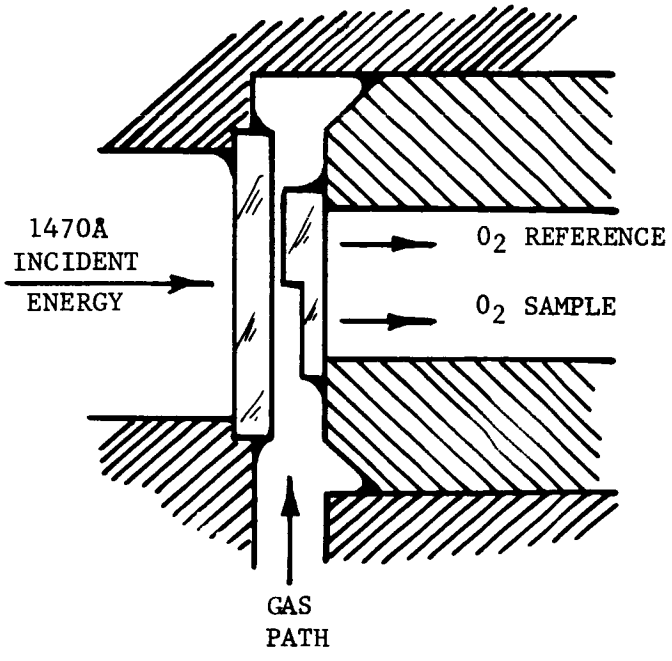
e. Magnetically bias the discharge arc in the UV source to stabilize its position. Some additional attention may be necessary to determine the exact course for, and the required changes to correct, the bistable operation of the UV lamp.

f. Complete the seal of the hermetic cover.

There are no major recommendations for specific changes in the circuit design as presently implemented. The circuits meet the requirements of the system and perform satisfactorily. The unit has not been subjected



PRESENT
UV SAMPLE CELL
CONFIGURATION



PREFERRED
UV SAMPLE CELL
CONFIGURATION

Figure 75. UV Sample Cell Configuration

to an EMI Qualification Test and therefore remains untried in this area. Package redesign considerations could be made but are considered of second-order importance to the program.

The CO_2 linearization is not completely adequate if a strict linear output is required. Instead of the logarithmic compensation that is provided, we feel that selection of a diode break point function generator, having a 5 or 6 point compensation with adjustable slopes, would provide sufficient linear output for any application. This electronic system compensation would require approximately 2 cubic-inches of volume for an additional 30 components. There also could be a modification to the CO_2 Sensor channel to incorporate a gain variation as a function of pressure by using the pressure transducer input. This would allow the CO_2 output to be independent of total pressure.

The high voltage range for the photomultiplier has a control range of 500 to 1600 volts with no changes in the present design. The tube is now operating at between 1050 volts and 1150 volts. This voltage should be increased to 1500 volts for better performance of the photomultiplier. It could be extended to 2500 volts with minor modifications of the high voltage supply.

APPENDIX A

ERROR ANALYSIS OF NITROGEN DETERMINATION SPECIFICALLY INCLUDING EFFECT OF CONSTANT CARBON DIOXIDE AND WATER VAPOR LEVELS AND TOTAL PRESSURE TRANSDUCER ACCURACY.

System Nominal Partial
Pressure Values (millimeters of Mercury)

H_2O = 14.0

CO_2 = 3.8

O_2 = 181.0

N_2 = 163.2

P total = 362.0

Define:

ϵ_N = Percent (%) error in H_2O pressure determination

ϵ_C = Percent (%) error in CO_2 pressure determination

ϵ_O = Percent (%) error in O_2 pressure determination

ϵ_N = Percent (%) error in N_2 pressure determination

ϵ_T = Percent (%) error in Total pressure determination

Dalton's Law of partial pressures states that the total pressure of a gas mixture is the sum of the partial pressures of the constituents at the same temperature as the mixture. In equation form:

$$P_T = P_H + P_C + P_O + P_N$$

solving for the nitrogen partial pressure P_N

$$P_N = P_T - P_O - (P_H + P_C)$$

$$\epsilon_N = \% \text{ error in } P_N = \frac{\text{Error in } P_N \text{ (calculated)}}{P_N \text{ Nominal}} \times 100 = \frac{\left[P_{T_\epsilon} - P_{O_\epsilon} - (P_{H_\epsilon} + P_{O_\epsilon})\right]}{163.2} \times 100$$

$$\epsilon_N = \left(\frac{P_{T\epsilon}}{163.2} - \frac{P_{O\epsilon}}{163.2} - \frac{P_{H\epsilon} + P_{C\epsilon}}{163.2} \right) \times 100$$

$$= \left[\left(\frac{P_T}{362.0} \right) \times \frac{362.0}{163.2} - \frac{P_O}{181.0} \times \frac{181.0}{163.2} - \left(\frac{P_H}{14} \times \frac{14}{163.2} + \frac{P_C}{3.8} \times \frac{3.8}{163.2} \right) \right] \times 100$$

$$= \epsilon_T \times \frac{362.0}{163.2} - \epsilon_O \times \frac{181.0}{163.2} - \left(\epsilon_H \times \frac{14}{163.2} \times \epsilon_C \times \frac{3.8}{163.2} \right)$$

$$\epsilon_N = 2.218\ \epsilon_T - 1.109\ \epsilon_O - (.08578\ \epsilon_H + .02321\ \epsilon_C)$$

Since errors may be positive or negative

$$|\epsilon_N| = |2.278\ \epsilon_T - 1.109\ \epsilon_O - (.08578\ \epsilon_H + .02321\ \epsilon_C)|$$

$$|\epsilon_N| \leq |2.218\ \epsilon_T| + |1.109\ \epsilon_O| + |.0859\ \epsilon_H| + |.0233\ \epsilon_C|$$

at worst

$$\boxed{\epsilon_N = 2.218\ \epsilon_T + 1.109\ \epsilon_O + (.08578\ \epsilon_H + .02321\ \epsilon_C)}$$

basic equation

where only positive signs are taken for the % errors

1. Assume all four gases are monitored with nominal errors $\epsilon_O = 2\%$ $\epsilon_H = 5\%$ $\epsilon_C = 2\%$ and $\epsilon_T = 1\%$. The nitrogen error is:

$$\epsilon_N = 2.218 \times 1 + 1.109 \times 2 + (.08\ 578 \times 5 + .02321 \times 2) = 4.911\%$$

(using 4 sensors)

2. Using constant CO_2 and H_2O values.

Under worst environmental conditions, P_H may deviate from 27.1 to 2.2 mm.

$$\frac{27.1 - 2.2}{14 \text{ Nominal}} = \frac{24.9}{14} = 178\% \text{ change or } \pm 89\%$$

Likewise P_C may deviate from 7.6 mm to nearly 0.0 mm

$$\frac{7.6 - 0.0}{3.8 \text{ Nominal}} = 200\% \text{ change or } \pm 100\%$$

The nitrogen % error calculated for these worst conditions then is:

$$\epsilon_N = 2.218 \times 1 + 1.109 \times 2 + (.0857 \times 89 + .02321 \times 100) = 14.39\%$$

(using no CO_2 and H_2O Sensors)

The nominal error using constant values for P_C and P_H are determined setting $\epsilon_H = \epsilon_C = 0$.

$$\epsilon_N = 2.218 \times 1 + 1.109 \times 2 + (0 + 0) = 4.436\%$$

3. Influence of total pressure transducer accuracy.

It is quite clear that the percentage error in the nitrogen determination increases 2.218% for every 1% error in the transducer. Differentiating the above basic equation with respect to the total pressure error shows this directly.

$$\frac{\partial \epsilon_N}{\partial \epsilon_T} = 2.218$$

Using constant values for P_{H_2O} and P_{CO_2}, the total pressure transducer accuracy required to keep the nominal error at 5% is:

$$5 = 2.218\ \epsilon_T + 1.109 \times 2 + (0 + 0)$$

$$2.218\ \epsilon_T = 2.782$$

$$\epsilon_T = 1.255\% \quad \text{or} \quad \epsilon_T = 1\text{-}1/4\%$$

If the total pressure transducer accuracy is not 1% but 1-1/4% the nominal ϵ_N error becomes:

$$\epsilon_N = 2.218 \times 1\ 1/4 + 1.109 \times 2 = 5.000\% \text{ previously } 4.911\%$$

The maximum possible ϵ_N becomes:

$$\epsilon_N = 2.218 \times 1\ 1/4 + 1.109 \times 2 + (.08578 \times 89 + .02321 \times 100) = 14.95\%$$
(Previously 14.39%)

Again, both these figures correspond to using no CO_2 and H_2O sensors. If all four gas sensors are employed

$$\epsilon_N = 4.911 + 1/4 \times 2.218 = 5.466\%$$
(Previously 4.911%)

A summary chart of the above points follows. An additional row has been inserted to give a four sensor nominal value of 5.00%

NITROGEN LEVEL ACCURACY			Pressure Transducer Accuracy
Constant Values for CO_2 and H_2O		Sensors for CO_2 - H_2O - O_2	
Nominal Value	Worst Environmental Value	Nominal Worst Value	
4.44%	14.39%	4.91%	±1%
4.45%	14.40%	5.00%	±1.004%
5.00%	14.95%	5.47%	±1-1/4%

It is clear from this chart that to hold the nominal nitrogen error to 5%, a 1-1/4% transducer is tolerable when constant values of H_2O and CO_2 are used. But a 1% transducer is needed if the three gas sensor technique is employed.

The advantage of the three sensor computation technique is that the worst possible nitrogen error is 5% while that of the system using constant values is 14.4%.

Transducer Requirement Conclusion:

In either event, whichever computation technique is used, the transducer accuracy must be in the ±1% neighborhood as shown above.