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A Neutral and Ion Mass Spectrometer for Environmental Gas Composition of the Apollo Telescope Mount Experiment No. T-030

Final Report

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submitted by

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Abstract

A neutral particle and positive ion mass spectrometer developed for use on the Apollo Telescope Mount (ATM) is described. A mass range of 100 atomic mass units is swept exponentially in approximately 12.5 seconds. The 0 to 5 volt analog output signal is produced by a logarithmic electrometer. The electronic components are entirely solid-state devices. A description of the accompanying ground support equipment and a set of operating instructions are included. Recommendations related directly to the ATM operations and requirements, including environmental test operations, are given.

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1. Introduction

The artifical atmosphere in the neighborhood of a spacecraft consists of gaseous and particulate constituents which originated on or within the spacecraft itself. These constituents, being foreign to the ambient atmosphere, are considered to be contaminates which alter the local atmospheric composition and therefore must be defined before using the spacecraft as a platform for in situ or remote sensing experiments. The contaminates are expelled from the spacecraft by several mechanisms, such as, leaks, outgassing, scouring of surface deposits by impact of atmospheric particles resulting from the translational motion of the spacecraft, waste elimination and rocket exhausts and therefore may have concentrated or diffusive origins. The present work is part of an effort to determine the composition and distribution of the gaseous contaminates within this artifical atmosphere.

When this information is combined with the results of the particulate measurements a complete picture of the aureole of the spacecraft can be formulated. While the immediate problem concerns the Apollo Telescope Mount (ATM), the first Apollo Applications Program (AAP) exercise, all subsequent AAP flights will require real time monitoring of the local environment. This is especially true where scientific experiments requiring in situ measurements form a portion of the scientific effort. Meaningful data will result only if the influence of the presence of the spacecraft is understood and accounted for in the data processing.

The proposed procedure for accomplishing this end was to use a mass spectrometer from the Orbiting Geophysical Observatory program and follow the general procedures given in the Summary section of the T-030 Experiment Proposal where the following statements were made; "The OGO Series mass spectrometer sweeps through a mass range of 0 to 50 amu for both neutral particle and positive-ion measurements, which are made alternately. This unit has been modified in the laboratory to extend the mass range to 100 amu. The modification is simple and therefore can be included without difficulty. Since the modified unit measures total concentration of all contaminants having masses greater than 100 amu, initial flight test results may indicate the need for additional extension of the mass range of the instrument. It is possible to extend the mass range to 300 amu and still retain the present configuration ..... Once an indication of the severity and nature of the contamination problem has been obtained, the course of action for follow-on measurements would be determined. Should more sophisticated experiments be necessary, the mass range of the spectrometer could be increased and a longer, more maneuverable boom would be introduced to acquire a more complete mapping of the local flow field. Such an approach would allow the gross definition of the contamination problem to be obtained as rapidly as possible and also permit initiation or a more detailed investigation if the early flight tests and the ATM mission indicate that more comprehensive information is necessary." Also in Section 4C (of the same proposal) Items 2, 3, 5 and 6 stated that the total concentrations of neutral particles and positive ions having molecular weights in excess of the 100 amu will be obtained in addition to the total concentrations of both neutrals and positive ions regardless of molecular weight.

The approach suggested by the sponsor, which was ultimately implemented, was formulated to develop what was believed to be a suitable spectrometer at minimum cost by making the simplest modifications to the OGO spectrometer and not attempting to extend the mass range to 300 amu for the initial ATM flight.

This was done by utilizing an unused back-up OGO mass spectrometer doubling the mass range and adding automatic filament switching to its operational characteristics. When this goal was accomplished a redesign of the spectrometer was initiated. Using integrated circuit techniques to help reduce the required volume of the spectrometer, a completely new electronics package was designed such that the spectrometer could pass through the Scientific Airlock on Apollo Spacecraft. This permitted use of the boom assembly from Experiment T-027 to deploy the spectrometer beyond the skin of the spacecraft to permit *in situ* gaseous composition measurements to be made within the aureole. These measurements will be correlated with the various spacecraft operations and functions to ascertain which, if any, directly influence the local gaseous composition.

By comparing the gaseous composition spectra obtained during flight with laboratory models of the signatures of molecular compounds, identification of the contaminates can be accomplished. Thus, the source of undesirable contaminates can be eliminated or minimized on subsequent flights. By successive improvement of following spacecraft, a relatively "clean" spacecraft can be realized.

2. The Mass Spectrometer

2.1 General

The instrument is a radio frequency mass spectrometer which makes use of a varying quadrupole electrostatic field to separate the various constituents of an incoming ionic gas into components of like mass-to-charge ratios. The separated components then drift out of the electrostatic field toward a collector which serves as the input to an electrometer which generates an amplified output voltage proportional to input ion current. Fig. 1 is a schematic representation of the analyzing section of a quadrupole mass spectrometer

The quadrupole field is composed of ac and dc components (see Fig. 1). The dc is derived by rectification of the r-f voltage which is varied in amplitude by applying a dc sweep voltage to the voltage controlled r-f oscillator. The dc to ac voltage ratio determines the mass resolution of the spectrometer. Theoretically, a dc to ac ratio of 0.23 will provide a half-amplitude width of 2 atomic mass units (amu) at 40 amu. This resolution, namely 20, will be constant for all mass values greater than about 10 amu. Below 10 amu owing to time-of-flight considerations, the resolution varies with mass number since the half-amplitude width remains relatively constant at approximately 1 amu.

To perform ambient neutral particle composition measurements, it is necessary to provide an ion generator upstream from the quadrupole inlet aperature. For this instrument, a thermionic ion source (Figs. 1 & 2) is employed to ionize the ambient neutral particles before they enter the quadrupole. The ion source consists of an annular plate on which is mounted an accelerating grid which has the configuration of an inverted, truncated pyramid. On each side of the accelerating grid is an "M" shaped rhenium filament. Only one filament is energized during any operational period; the remaining three filaments are used as spares which are automatically switched into the filament circuit should the active filament fail. These filaments are supported between insulated feedthroughs on the plate and insulated hangers attached to the outer extremity of the accelerating grid. A discussion of the operation of the ion source is given in Section 2.2.

The electronic circuitry associated with the spectrometer consists of an electrometer, an r-f oscillator and rectifier, a filament emission regulator, operation logic, and a synchronous power supply. The mechanical and electrical characteristics of these electronic subsystems are discussed in Section 2.3. A block diagram of the complete instrument is shown in Fig. 3.

2.1.1 Mechanical Characteristics

The complete spectrometer assembly occupies an eight inch cubical volume and weighs approximately 8.3 pounds. (See Fig. 4). A cylinder having double lateral walls, which are electrically insulated from each other, houses the quadrupole. The cylinder axis coincides with the fore-and-aft axis of the cubical box. The electrometer, oscillator-rectifier, emission regulator, and logic circuitry each occupy a single 0.020 inches thick magnesium card which stands vertically and is parallel to the axis of the cylinder, (see Fig. 5). These cards are of a plug-in type which are inserted from the top of the package and connect electrically with a multicontact connector mounted on the base plate of the package (see Fig. 6). Each card is held in place by screws through the front, back and top surfaces of the package and by spring-loaded contact-finger stock on the base plate. The power supply is divided into two chasses; one, a T-section, is attached to the base plate immediately below the cylinder and is inserted through a port in the back panel; the other, a short card similar to the full-length cards, is located above the cylinder and is attached to the front, back and top of the package. The former contains the basic power supply and the latter the regulation circuits for the power supply.

The instrument package is of box-beam construction with all dynamic and static loads being carried to the base plate by way of the front and back panels. The base plate is mounted to a mounting platform by means of six 10-32 machine screws, two in the front flange and four in the back flange.

With the exception of the cylinder, which is gold-plated aluminum, all the structural members of the package are magnesium or aluminum sheet, the aluminum being used where magnesium had insufficient tensile strength. All magnesium members were surface treated with Dow No. 9 to make the surfaces as black as possible. Similarily, aluminum members were anodized black. To provide good electrical and thermal interfaces and prevent corrosion at interfaces between mating members, this surface treatment was omitted on all interface areas; instead, a gold plate was applied. The gold-plating process consisted of a copper plate on a zinc flash coat followed by the appropriate thickness of gold plate with current reversal.

Between the oscillator-rectifier card and the logic card is a full length electrical shield card which is gold-plated on the oscillator-rectifier side and anodized on the logic card side. Similarly, a short shield is provided between the oscillator-rectifier and the power supply regulator cards. This card is coated in a similar manner and has contact-finger stock to insure good contact with the outer surface of the quadrupole cylinder.

2.1.2 Duty Cycle and Logic

The Apollo Prototype Spectrometer has a basic sweep time of approximately 16 seconds; during this time interval, the mass scale is swept from approximately 100 amu to zero.

Four sweeps in neutral mode are alternated with four ion sweeps, resulting in a total cycle time of about 2 minutes. Cycles are repeated automatically unless interupted by external control.

Each sweep begins with a two second period of zero dc rod voltage for the purpose of measuring the sum of all constituents above 100 amu. Following this sub-period, a dc voltage is applied to the rods and the rod ac and dc voltages are swept exponentially from a maximum to zero, producing a mass scan from 100 to 0 amu. The output signal is obtained from a logarithmic response electrometer. A Bendix Channeltron electron multiplier is used as a preamplifier for the electrometer, and, when turned on, produces a gain of about 100. Electrometer output is the prime instrument output which has a range of 0 to 5 vdc (or 0 to -5, if the electron multiplier is not used).

The second data-output channel is provided with a commutated signal that has a commutation rate of approximately 1.2 samples per second. Seven different signals are monitored to give the experimenter confidence that the equipment is operating properly. An illustration of the logic sequences and the monitored data is shown in Fig. 7. The seven signals which are monitored are: 1) the d-c voltage which is applied to the quadrupole rods in the spectrum mode; 2) the filament emission current in neutral-particle mode; 3) a signal indicating the electron multiplier is being supplied with operating potentials; 4) the filament voltage; 5) circuit ground; 6) a voltage that identifies which of the four filaments is in use; and 7) a voltage that indicates the temperature in the vicinity of the ion source.

The basic monitor circuit performs at least 16 commutations during each 16-second sweep period. The 16 output signals are not divided equally among the seven monitor signals, but are arranged as follows:

A) The d-c sweep is sampled on channels 1, 3, 5, 7, 9, 11, 13 and 15. From these eight samples during each sweep, the sweep amplitude may be checked.

B) The filament emission current in neutral mode is sampled twice during each commutation cycle on channels 2 and 10.

C) Each of the other six positions are alloted one channel each as follows: Channel 4, cone power; channel 6; filament voltage; channel 8, circuit ground; channel 12 not used; channel 14, filament identification; and channel 16, ion source temperature.

2.1.3. Thermal Characteristics

Included in the mechanical design are provisions for maintaining a nearly uniform temperature throughout the instrument package. The materials used were magnesium and aluminum which have good thermal conductron properties. All surfaces were blackened to enhance radiative heat balance while the gold-plated interfaces permit good heat conduction across them.

All possible high heat sources were mounted near the base plate or were provided with additional heat sink components as required.

In designing the package it was assumed that all heat had to be conducted through the experiment base plate into the mounting plate. To provide good thermal contact between these two plates, the experiment base plate is gold plated.

A thermal dissipation of approximately twelve watts occurs in the ion source. However since this dissipation is external to the instrument and since all surfaces in the vicinity of the ion source are gold plated, little heating of the instrument package should result. For one complete cycle of operation (128 seconds), the average thermal dissipation occuring within the package is approximately 9.5 watts during standby and 15 watts during operation.

2.1.4 Electrical Characteristics

The flight instrumentation package was designed to operate with or without an input 2461 cps sync signal at voltage levels between +23 vdc and +35 vdc. Synchronous power supply operation is achieved for peak-to-peak sync signal levels in the neighborhood of three volts or greater. In the absence of an external sync signal, the power supply operating frequency is in the neighborhood of 2400 cps.

Two power commands are required to make the flight instrumentation completely operational. The first power command (PC 1) energizes the power supply, the electrometer, and various control and monitor circuits. The primary purpose of this standby condition is to provide a warm-up period in which the electrometer can achieve stable operation. A warm-up period of at least one hour is required for optimum operating characteristics. Power dissipation during standby operation is approximately 9.5 watts.

The second power command (PC2), which must follow PC1, energizes the remainder of the instrumentation. The total dissipation in the PC2 circuit is approximately 0.4 watts. Should PC2 be activated prior to PC1, the spectrometer will remain dormant until PC1 is activated, at which time, all instrumentation will be energized; however, the electrometer will not be stabilized due to lack of thermal equilibrium. All power, except the 0.4 watts in PC2 is transmitted through PC1. This includes the 9.5 watts dissipated during standby and either the additional average wattage of 4.5 watts dissipated during ion mode, or the additional average wattage of approximately 24.0 watts required during neutral particle analysis.

Impulse Command 1 (IC 1) operates the filament select relay by means of a capacitor discharge. Impusle Command 2 (IC2) is used to disable the electron multiplier cone when extreme electrometer saturation is experienced. The dissipation in use of IC 1 is minimal due to the relatively long (10 seconds) period for capacitor recharge. IC 2 requires approximately 0.4 watts for a period somewhat less than 50 milliseconds.

Two analog output channels, each having an output impedance of approximately 100 ohms, are provided. One channel is direct output from the electrometer, and requires a frequency response of approximately 200 cps or if an analog-to-digital converter is used, a sampling rate of at least 50 samples per second is required to reproduce representative spectra. The second output is a commutated voltage monitor channel which has a sampling rate of approximately 1.2 samples per second.

2.2 Ion Source

The ion source, as mentioned in Sec. 2.1 and depicted in Figs. 1 and 2, is essential to ambient neutral particle composition measurements because the spectrometer is sensitive only to charged particles. The energy levels in the ion source must be closely controlled in order that the ionization level of each ambient constituent be known precisely. Since the extent of the ionizing region within the ion source is not well known, the geometrical configuration of the ion source was developed experimentally; the criteria being a maximum output ion current for minimum input filament power, especially at low pressures.

The grid portion of the ion source serves a dual purpose. When the spectrometer is operating in ion mode, the obtaining of meaningful data is predictated upon a knowledge of the configuration of the incoming ambient ion stream. This requires that the plasma sheath upstream from the spectrometer inlet port remain planar regardless of the acceleration potential at the inlet port. The ion source grid performs this function. As an added precaution, the "Sheath Contour Screen" is mounted around the extended portion of the ion source prior to launch to insure a planar configuration of the plasma sheath beyond the lateral extent of the ion source itself.

To facilitate operation of the flight instrument package during bench test two auxillary filament simulators have been incorporated. One consists of a fixed resistor within the instrument package. When this is used a fixed simulated emission current signal is supplied to the emission regulator in order that a true representation of the filament dissipation may be obtained.

The other filament simulator is a dummy ion source mounted in a separate container. This device is utilized for most bench tests, especially when emission current adjustments are made. In order to use the "Dummy Ion Source" a special adaptor (1002 D) is inserted in the Monitor Cable (1002). This disconnects the flight package ion source and connects the "Dummy Ion Source." All instrument controls operate in their normal manner.

2.2.1. Mechanical Characteristics

Three design goals were established prior to the development of the present ion source - simplicity, small cross-section, and light weight. Fig. 2 shows a version of the ion source. The grid is supported using a welded post-and-beam frame which is welded to an annular base plate. Use of 304 stainless steel for the frame and base plate is dictated by low-magnetic and tensile strength requirements. After assembly, these parts are gold-plated.

The lateral grid wires are platinum-clad-tungsten. This combination permits the use of small wire which has good surface conductivity and at the same time has high strength. The grid on the front surface is stainless steel. The feed-through that supports the bottom of each filament utilizes a glass bead or insulation and is spot-welded to the ion source base. The hangers that support the top of the "M" rhenium filament are made by imbedding platinum-clad-tungsten wire in a glass bead and spot welding them to the cross-bar at the top of the ion source. The filament support loops are platinum-clad-tungsten also.

Gold-plated 304 stainless steel screws with appropriate insulators are used to attach the ion source to the inner cylinder. Orientation of the ion source with respect to the analyzing section is shown in Figs. 1 and 8.

2.2.2 Electrical Characteristics

When operating in the neutral particle mode, the accelerating grid has a potential of approximately + 50 volts dc, the filament is heated, and the spectrometer inlet aperature is at ground potential. Electrons, emitted from the filament, are accelerated toward the grid, pass through it, and bombard neutral particles that migrate through the front end of the grid. The grid potential causes these generated ions to be accelerated toward the inlet aperature while repelling any ambient ion that may tend to drift toward the grid enclosure. In the ion mode, the accelerating grid is at ground potential, the filament is off and the inlet aperature has a potential of -50 volts dc. Thus, the grid enclosure shields ambient ions from the -50 volts dc prior to entry within the enclosure and prevents any focusing or defocusing of the incoming ion stream.

During operation in neutral particle mode, the electron current collected by the grid is used to indicate the emission level of the active filament. This current is used as an input signal to the emission regulator which controls the filament temperature in order that a fixed filament emission current be maintained regardless of ambient conditions.

2.3 Electronic Instrumentation

The following sections describe briefly the various circuits that compromise the associated electronic instrumentation necessary for proper operation of the spectrometer

2.3.1 Mechanical Design

In Sec. 2.1.1 a description of the support structure for each of the electronic circuits was presented. The metal cards are drilled and teflon insulated feed-throughs and stand-offs are used to support all wiring and the smaller components. Large components are strapped or bolted to the card. Upon completion of all electrical and mechanical tests, conformal potting material is used as needed to secure wires and components more firmly to the circuit cards. Note that the logic card employs a printed-circuit board mounted on a metal card: this type of construction was utilized in order to mount the required components in the allotted space.

2.3.2 Electrical Design

The following discussions briefly describe the major electronic components, their over-all characteristics, and the functions they perform. Fig. 3 shows an over-all block diagram of the spectrometer electronic components, Fig. 9 is the base wiring diagram.

2.3.2.1 Power Supply

The experiment power supply consists of a duty-factor regulated inverter operating in synchronism with the spacecraft-supplied 2461 cps sync. signal. The duty-factor regulator maintains a regulation factor of about 10% for load changes of 200% and regulation to less than 1% for input line voltage changes from +23 to +45 vdc. The various voltages used in the experiment are derived from separate secondary windings on the main inverter toroid transformer. An input filter having a time constant of 1 msec. is used to smooth the current drawn by the duty factor regulator and to prevent excessive noise feedback into the spacecraft power source. The power supply will free-run at a frequency close to 2461 cps (depending on temperature) in case of a failure in the sync. signal.

The secondary voltages are +6, +30, -30, +50, -50, -150 and -2000 vdc. A portion of the ± 30 vdc undergoes additional regulation because of the stringent requirements of the electrometer. A circuit diagram is shown in Figs. 10a and 10b. Fig. 11 shows the orientation of the power supply relative to the outer cylinder.

2.3.2.2 RF Oscillator and Rectifier

The Oscillator card contains the circuits necessary to provide an amplitude swept rf voltage, with or without accompanying dc voltage, to the quadrupole. RF energy is generated in a push-pull, class B oscillator operating at 2.4 mc. into a high-Q tuned collector load. DC voltage is obtained by rectifying and filtering a portion of the rf. A sweep of rf voltage is obtained by operating the oscillator from a swept dc voltage that is generated on the oscillator card. The sweep circuit consists of an RC network producing an exponential output wave which is power amplified and applied to the rf oscillator. The trigger circuit which discharges the sweep capacitor is generated in the sequencer card as a master clock pulse and is also used to initiate changes in operating modes for the entire instrument. A relay in the oscillator card removes the dc voltage (rectified rf) from the quadrupole for about 2 seconds at the beginning of each sweep to produce the "zero dc" mode of operation. A schematic diagram of the rf oscillator and rectifier circuit is shown in Fig. 12.

2.3.2.3 Electrometer

The electrometer used in this instrument is a dc coupled, logarithmic response, all solid state design using a FET input state and an integrated circuit operational amplifier. The minimum detectable input of this electrometer is about 5 pa which produces an output of 0.5 volt. For inputs between 5 and 100 pa, the output is approximately linear (with an offset) being 2.5V for 100 pa input. Above 100 pa, the output is logarithmic with a gain of about 1 volt per decade increase of input, for inputs not exceeding 1 uA. Electrometer calibration curves must be used to reduce instrument output data if anything more than first order approximations are desired. A circuit diagram is shown in Fig. 13.

2.3.2.4 Emission Regulator

The emission regulator maintains a constant, pre-selected plate current in the thermionic diode composed of the heated filament and the grid of the ion source. This diode operates in temperature saturation and control is achieved by varying filament current. Pre-set currents in the range 1-10 ma. may be controlled. An isolation amplifier provides a monitor voltage output proportional to the controlled current for incorporation into the experiment monitor channel. A Ledex relay controlled by IC 1 is used to switch the four active filaments and two dummys. Precision voltage regulators supplying the electrometer card are mounted on the emission regulator.

A schematic diagram of the emission regulator is shown in Fig. 14.

2.3.2.5 Logic

The logic circuit for this instrument consists essentially of a seven stage binary counter driven from an internal 1 pulse per second (pps) clock. The first four stages are used to develop a 16 step monitor multiplexer for transmission of housekeeping data while the last three states control oscillator sweeps and ion-neutral functions. Fig. 7 illustrates the time relationships of the various signals in and from the sequencer. A schematic diagram of the logic circuit is shown in Fig. 15.

2.3.2.6 Electron Multiplier

To achieve the desired range of sensitivity and still maintain a reasonable electrometer time constant, it was necessary to insert a preamplifier ahead of the electrometer input. The pre-amplifier utilized is a single stage, conically shaped, solid state electron multiplier. It is mounted coaxially with the collector, thereby serving as the collector when energized. Fig. 8 shows the location and orientation of the electron multiplier. It is designed explicity for the present application in a manner such that when a voltage of approximately -1200 vdc is impressed across the length of the cone, it will have a current gain of approximately 100.

3. Ground Support Equipment

3.1 General

The ground support equipment (GSE) consists of two units which suffice to perform state-of-health tests on the experiment package. GSE 1 simulates the function of the spacecraft as a source of power and command signals. GSE 2 serves as a monitor unit; it also contains a triangular wave generator to provide electrical stimulus for checking the condition of the electrometer. The two GSE units may be used together with the isolated experiment or GSE 2 may be used alone when the experiment is powered by the spacecraft or the S/C simulator. In either case correlation between experiment output signals relayed by the spacecraft telemetry and those observed on the monitor is possible. Experiment calibration, as opposed to state-of-health checks, requires the use of a vacuum system in addition to the two GSE units.

3.2 Electrical

3.2.1 Cabling Diagram

Fig. 16 is a block diagram showing cabling connections between the GSE and the experiment. There is one cable between the experiment and each GSE unit, and each unit requires a source of 115v, 60 cps power. Dotted lines show alternate connections for power from the spacecraft and for insertion of the filament adapter, the dummy filament adapter, and flight plug. Two sets of cables are available, namely, 15 feet and 30 feet in length. Either set may be used or they may be plugged together to make a set 45 feet long.

3.2.2 Circuit Diagrams

Figs. 17 and 18 are schematic diagrams for the GSE 1 (Power Supply) and GSE 2 (Monitor), respectively. Figs 19, 20 and 21 show the two cables, and the filament adapter assignments respectively.

3.2.3 Descriptions

3.2.3.1 GSE 1 - Power Supply

GSE 1 furnishes all signals and stimuli ordinarily supplied by the spacecraft to the experiment. A 28 vdc power supply is required for experiment prime power. A 2461 cps sync. signal is supplied from a tuning fork oscillator. The sync signal may be attenuated or shut off to check the effects of low voltage or missing sync signals on the experiment power supply. Impulse commands are supplied from a relay which is actuated by a series capacitor. Uniform pulses of about 50 m/sec are provided. Power command and master power switches and fuses are provided.

3.2.3.2 GSE 2 - Monitor

GSE 2 provides facilities for the observation of experiment signals. GSE 2 also contains a control circuit which inhibits the experiment mode sequence allowing for continuous operation in a fixed mode, or continuous sequencing may be used, duplicating flight operation. Visual observation of monitored experiment signals is achieved by means of a transistorized voltmeter, or by use of an external device such as an oscilloscope. Signal selection is performed by means of a rotary switch, which connects the voltmeter to any one of 11 inputs.

It should be noted that all experiment signals with the exception of the electrometer are contained in the sampled monitor output, and that provision for continuous observation of these signals with GSE 2 is provided for convenience in check-out and calibration, and for checking the operation of the sampling monitor.

A triangular wave generator is used in conjunction with a series capacitor to provide electrical stimulus to the electrometer. Input currents in the ranges of $\pm 10^{-10}$ and $\pm 10^{-12}$ amperes are available when a 20 pf capacitor is used.

3.2.3.3 Filament Adaptor

The ion source is equipped with four filaments three of which are spares which can be switched in individually by impulse command in case of failure. Filaments can be operated only in a vacuum of $<10^{-5}$ torr. To forestall inadvertent room pressure operation, and subsequent burn-out, the flight instrumentation package contains a dummy filament (resistor) which may be used during checkout of the experiment. The active filaments are wired through the monitor plug and a filament adaptor must be inserted to complete the filament circuits. To facilitate checking (in a vacuum chamber) an adapter plug

(1002T) is inserted in series with the cable 1002. This completes the filament circuits and also allows normal use of GSE 2. Because of the high currents involved, it is desirable to insert the adapter plug directly into experiment package jack J2. However, it is possible, if necessary, to use the adapter at any point between connectors J201 and J2. (See Fig. 16).

3.2.4 Operating Instructions

3.2.4.1 General

The spectrometer, while being relatively simple in concept, is a sophisticated electronic instrument which can be easily damaged by improper or careless operation. Hence, it is essential that the following instructions *be followed precisely in order to avoid damaging* the instrument.

3.2.4.2 Operation Using GSE 1 and GSE 2

1. Set the following GSE 1 controls to the "OFF" position: The POWER and VOLTAGE ADJUST controls of the external power supply and the POWER ON switch; set POWER ON switch on GSE 2 to OFF position.
2. Connect cables 1001 and 1002 between instrument and GSE 1 and GSE 2, respectively. (use of external, "Dummy Ion Source" requires the insertion of the "Dummy Ion Source" adaptor (1002D) between J2 and P2 or between J201 and P201 and P201 if J2 and P2 are not available.
3. Connect cables 1004 and 1005 to local ac line.
4. Set PWR COM 1 (S/C PC1) and PWR COM β (S/C PC2) to OFF position and IMPULSE toggle switch to position 2 (S/C IC 2).
5. Set SYNC to ON position and adjust SYNC AMP control to the middle of its range.
6. Set PWR ON and the external power supply switch to ON position and VOLTAGE ADJUST so that power supply voltmeter reads 28 VDC.
7. Turn PWR COM 1 in GSE 1 and PWR ON in GSE 2.

8. Depress IMPULSE button. (This turns off voltage supply to the electron multiplier, this voltage is automatically restored each time PWR COM 1 is turned off and then on again.)

   Note: If red flag saftey switch is closed, step 8 may be omitted.

9. Set IMPULSE toggle switch to position 1 (IC 1).

10. If the instrument is to be placed in a vacuum chamber, the "Sheath Contour Screen" may be removed and the "Filament Adaptor" (1002T) must be inserted between J2 and P2. If the portable vacuum system and "Plasma Generator" are used, the "Sheath Contour Screen" must be removed.

11. Upon achieving a sufficient vacuum ($<10^{-5}$ Torr) within the chamber, use the procedure indicated above. (Note: if the pressure within the vacuum chamber $<10^{-4}$ torr Step 8 may also be eliminated.)

3.2.4.3 Test Controls

During the use of each of the following test controls, it is assumed that the complete instrument package is operating properly with a supply voltage of 28 VDC and 2461 cps square wave sync signal of 6 volts peak to peak prior to conducting the tests.

1. On GSE 1 the external power supply VOLTAGE ADJUST control and voltmeter provide a convenient means of checking the operation of the instrument at a wide range of voltage settings.

2. On GSE 1 the SYNC AMP control provides a means of adjusting the amplitude of the 2461 cps square wave between peak-to-peak voltages of 0 and 10 volts. By means of the SYNC switch, the sync signal can be completely removed thereby checking the free-running characteristics of the instrument package.

3. Adjacent to the SYNC switch, two jacks are provided to bring out an unattenuated sync signal for such purposes as synchronizing the sweep on a cathode-ray oscilloscope.
4. On GSE 2 a multiple position switch and a voltmeter are provided to permit observation of up to 13 different monitor voltages within the instrument package. A chart on GSE 2 indicates the monitored functions and their corresponding switch positions and the amplitude of normal indications.
5. To the left of the monitor voltmeter on GSE 2 are 6 jacks for permitting the displaying of data on external display devices. The data available on each of the 6 channels is indicated on the chart mentioned above.
6. Below these jacks is a toggle switch and push-button switch marked AUTO INDEX. Placing the toggle switch in the down position, locks the instrument package into one of the modes of operation indicated in Fig. 7. The instrument will continually repeat this mode until the push-button switch is depressed, or until the toggle switch is returned to the AUTO position, at which time normal mode sequencing will be resumed. The mode can be locked into any position by simply placing the AUTO INDEX toggle switch down and holding the push button until the instrument has stepped around to the desired mode position.

4. Mass Spectrometer for ATM (Experiment T-030)

4.1 General

The OGO mass spectrometer was modified to extend the mass range from 50 amu to 100 amu and to provide automatic filament switching upon filament failure thereby converting it to the Apollo protytype mass spectrometer. This prototype spectrometer has been delivered to Marshall Space Flight Center.

After the above work was well underway, the Scientific Airlock and the boom assembly for Experiment No. T-027 were made available for deployment of Experiment T-030. At that time a reconfiguration of the T-030 envelope was undertaken to permit mounting on the boom and passage through the Scientific Airlock. In conjunction with the new envelope design, which reduced the overall size of the electronics package, a redesign of most electronic circuits was also undertaken to incorporate integrated circuits wherever possible thereby greatly reducing the volumetric requirements of the circuitry. A mock-up of T-030, without the interface assembly for attachment to the T-027 boom assembly is shown in Fig. 22. The redesigned electronic cirucits were mounted on breadboards as individual subassemblies. A lack of funding did not permit interconnection of the subassemblies to form an operating breadboard of the electronic circuits forming the spectrometer. Incorporated in the new circuitry were new logic circuits that included an ion source cleaning sequence with the automatic filament switching and other spectrometer operational logic. The assembled breadboards are shown in Figs. 23 and 24.

Due to lack of information concerning the boom and its electric control system, a control unit for programming and controlling the orientation of the boom experiment platform, relative to the spacecraft, was not designed. Also, since the location of one or several Scientific Airlocks was never firmly established, no program could be formulated for a sequential positioning of T-030 in order to take representative samples of the local gaseous environment. In order to design a self-contained programmer to fully utilize the azimuth and elevation capabilities of the T-027 boom assembly a complete description of the flight boom assembly and the station, or stations, of the boom locations must be known.

4.2 Installation

To provide adequate coverage of the local environment it is recommended that at least two Scientific Airlocks be provided in the Workshop portion of the ATM, one on the sunlit side and the other diametrically opposite. The workshop should provide adequate space for storage and deployment of experiments and boom assemblies, thereby reducing the danger of damaging the instruments when they are handled by the astronauts. The two locations are necessary to investigate the influence of spacecraft skin temperature and flight velocity upon the distribution of gaseous contamination constituents.

4.3 Astronaut Participation

The astronaut will be required to remove the T-030 experiment from storage, attach it to the boom platform, deploy the experiment and boom assembly and start the automatic sequencing of the spectrometer by switching electrical power to the experiment and boom control. Upon completion of a series of measurements, he will be required to repeat these steps in reverse order to deactivate the experiment and return it to storage or mount it on another boom assembly. The astronaut will not be required to perform any tasks related to operation of the spectrometer itself.

4.4 Data Processing

The University of Michigan is equipped to process digital flight data using the PDP-8 Data Acquisition system in the High Altitude Engineering Laboratory, the PDP-9 section of the hybrid computer in the Simulation Center and the IBM 360 in the University Computing Center. Complete data processing programs for spectrometer data reduction and analysis have already been formulated for the PDP-8 and IBM-360 as part of the OGO program. These existing programs can be easily adapted for use on the PDP-9 computer. The final choice of computing system will depend upon availability of computing time, the amount of data to be processed, the degree of urgency in obtaining immediate results, and the level of funding to accomplish this end.

Before processing, all flight data is passed through a "quick look" facility consisting of an incremental plotting system that generates analog strip charts directly from digital data stored on magnetic tape. This process permits the inclusion of computer program adjustments to account for overall data quality and to compensate for the presence of excessive noise and data omissions. This greatly reduces the amount of computer time spent in attempting to process low quality and/or faulty data. The data processing programs, referred to above made extensive use of selected spacecraft "housekeeping" data with appropriate time correlation. Hence, "housekeeping" data requirements will be established when the spacecraft data system is defined.

Analysis will consist initially of assigning the observed environment constituents to (1) geophysical phenomena or (2) spacecraft emissions. Methods of assigning observed constituents to (1) will draw extensively upon our own OGO measurements of atmospheric composition, published results of other aeronomy satellites and sounding rockets, as well as current theoretical models. Remaining constituents will be considered to be contamination species which will be grouped into spectrometer contaminate composition patterns and compared with laboratory signatures of appropriate compounds, such as those being formulated by Dr. Thomas R. Edwards at MSFC. Upon identification of particular species, the times of their occurance will be correlated with the times at which the various spacecraft functions occured to attempt identification of the actual source of the contaminate.

4.5 Design Qualification Testing

The program outlined below constitutes a complete test program for the prototype instrument. Satisfactory demonstration of the ability of the prototype instrument to withstand these environmental tests qualifies the instrument design. Acceptance of the design and fabrication of the Qualification Test Model is subject to satisfactory performance throughout the complete test program. Testing of flight and back-up flight instruments will be less severe, however, final acceptance will be contingent upon satisfactory performance of the complete test program including environmental tests of the completely assembled spacecraft.

The instrument shall perform satisfactorily under conditions expected to exist during time of operation in earth orbit and be able to withstand, with no out-of-tolerance degradation, all environmental conditions expected to be encountered during storage, shipment, handling, stand-by, preflight and rocket boost prior to the operational period. Environment design qualification tests for instruments are intended to simulate conditions which are more severe than field and flight conditions in order to provide better assurance of detecting design deficiencies; however, the conditions are not intended to be severe enough to excite unrealistic modes of failure.

The apparatus used in conducting tests shall be capable of producing and maintaining the test conditions required with the experiment under test installed or in the apparatus and operating or non-operating, as required. Standard conditions for conducting experiment functional checkout prior to or after environmental exposures shall be as follows;

Temperature - $25 \pm 3^{o}C$

Relative Humidity - 55 percent or less

Barometric Pressure - Room ambient

The required environmental design qualification tests are outlined below. The test sequence for design qualification of the spectrometer shall coincide with the order given in this outline.

4.5.1 Weight and Center of Gravity

The mass property determination is included as part of the environmental exposure to effect design control. The weight and center of gravity of the instrument shall be determined within the following limits

Weight - 0.01 pound or 5% of the total weight, whichever is greater

Center of Gravity - 0.1 inches

4.5.2 Temperature

The experiment shall be tested in a chamber with forced air circulation in accordance with the procedures indicated below. Humidity conditions shall be controlled such that the percentage of water vapor does not exceed that which can exist at standard conditions.

4.5.2.1 Storage Temperature

While non-operative, subject the instrument to temperatures of $-40^{o}C$ for 6 hours and $+70^{o}C$ for 6 hours. After each exposure, and following stabilization of the instrument temperature at room ambient conditions, operate the instrument to verify its performance.

4.5.2.2 Operational Temperature

While non-operative, the instrument temperature shall be stabilized at the temperatures indicated below for the control temperature. The instrument shall then be operated while maintaining the chamber ambient temperature at the specified control temperature. The test duration begins when the temperature of the operating instrument is stabilized, i.e., when no temperature sensor varies more than 1^{o} C per hour. The test sequence will consist of three steps, namely:

Step	Control Temp.	Duration	Inst. Cond.
1	$-20^{o}C$	1 hour	Operate
2	$+60^{o}C$	1 hour	Operate
3	$+25^{o}C \pm 5^{o}C$	--	Performance Check

4.5.3 Humidity

Use a humidity chamber with temperature control and forced air circulation. Maintain a relative humidity of 95 percent, at a temperature of $30^{o}C$, in the immediate vicinity of the instrument for 24 hours. Following this exposure, and at the stated conditions, operate the instrument and check its performance. Should improper performance be observed, change exposure conditions to 55 percent relative humidity and $25^{o}C$ and record the "drying time" required to re-establish proper operation.

4.5.4 Vibration

Use a rigid fixture which simulates the actual attachment of the instrument to the spacecraft to attach the instrument to the vibration generator. Attach a calibrated accelerometer to the mounting fixture near the instrument for the purpose of controlling the applied vibration. Three additional accelerometers, one aligned with the control accelerometer, shall be mounted on the fixture near the interface between the fixture and the instrument such that their axis are mutually orthogonal. These accelerometers will be used to monitor the input along the axis of vibration and the resulting lateral motion ("cross-talk"). The instrument will not be operated during the vibration tests, however performance checks shall be made after the vibration test of each of the three orthogonal axes.

4.5.4.1 Sinusoidal Vibration

Record continuously the signals from the three monitor accelerometers during all sinusoidal vibration tests. The overall vibration generating and monitoring system shall be calibrated for frequency response and amplitude linearity characteristics to values 1.25 times the maximum expected to be recorded during the tests. All records shall be of the permanent type and shall be properly identified and retained to demonstrate conformance. Included shall be a description of any mechanical instability of the instrument during any phase of the vibration schedule, including frequency or frequency band width where the instability and resonance was detected and the corresponding axis of the subassembly found to be most sensitive to vibrational excitation.

4.5.4.2 Sinusoidal-Swept Frequency Exposure

The applied frequency shall be swept from the lowest to the highest frequency once for each range. Time rate of change of frequency shall be proportional to frequency at the rate of 2 minutes per octave. The following test conditions shall be used:

Thrust axis

Frequency Range (hz)	Level
10-22	0.5 inches constant displacement
22-120	13g (0 to peak)
120-400	4g (0 to peak)
400-2000	7.5 g (0 to peak

Lateral axes (2)

Frequency Range (hz)	Level
10-40	15 in/sec vector linear velocity
40-200	10 g (0 to peak)
200-400	3 g (0 to peak)
400-2000	7.5 (0 to peak)

4.5.4.3 Random Motion Vibration

During the random vibration test, signals from the control accelerometer shall be passed through a band-pass filter-type analyzer which has been adjusted to scan the test spectrum in the applicable test-duration time. The filter bandwidth shall be as narrow as allowed by the test time and the length of the spectrum to be traversed. Permanent records shall be made during the specified random vibration test, properly identified, and retained to demonstrate conformance with the test specifications. A report of any mechanical instability of the instrument during any phase of the vibration schedule shall be reported. Included shall be a statement indicating the area within the test spectrum where instability was detected and the corresponding axis of the instrument found to be most sensitive to vibrational excitation.

4.5.4.4 Random Motion Vibration Exposures

Gaussian random vibration shall be applied with the "g-peaks" clipped at three times the root-mean-square acceleration specified below. With the instrument installed on the stand, the control accelerometer response shall be equalized such that the specified power spectral density (PSD) values are within ± 3 db throughout the frequency band. The filter roll-off characteristic above 2000 hz shall be at a note of 40 db/ octave or greater. The following tests shall be conducted in each of the orthogonal axis for 6 minutes.

Frequency Range (hz)	PSD Level (g^2/hz)	Acceleration (g-rms)
20-1000	0.1	11.3
1000-2000	0.1 to 0.006 transition at the rate of 12 db/octave	11.3

4.5.5 Shock

The instrument shall be attached to a mounting fixture in a manner which simulates the actual mounting of the instrument to the spacecraft. Shock testing will be conducted along the three orthogonal axes, as indicated below. The instrument will be non-operational during the test but performance checks will be made prior to and at the conclusion of the test along each axis. Half-sinusoidal wave shape pulses shall be applied in conformance with the following schedule:

Direction	Level	Duration (m sec)
Thrust Axis	30	6
Lateral Axes (2)	15	12

4.5.6 Acceleration

The instrument shall be attached to a mounting fixture in a manner which simulates the actual mounting of the experiment to the spacecraft. The static acceleration at the center of gravity of the instrument shall be $14 \pm 1.4g$ along the thrust axis for a duration of 3 minutes. Performance checks shall be made before and after the test.

4.5.7 Thermal-Vacuum/Space-Thermal Simulation

These tests are intended to simulate the orbital thermal environment for the instrument. Temperature-soak or solar-simulation/cold wall tests (to simulate solar and black space radiation environments) are to be conducted as appropriate. For all tests, chamber pressure shall be maintained at 5×10^{-5} mm Hg or less. The spectrometer shall be operated only after these conditions have been reached.

Control temperature for these tests shall be measured at the instrument baseplate (mounting base) and provisions for maintaining the surrounding temperatures equal to the control test temperature shall be provided. Temperature stabilization shall be considered achieved when no temperature sensor varies more than $1^{\circ}C$ per hour.

During solar-simulation /cold-wall tests, cold wall temperatures shall be maintained at $-185^{\circ}C$ or less. The instrument shall be oriented during these tests to simulate the worst orbital condition for incident thermal radiation. Considerations shall also be given to simulating worst sun-to-shade or shade-to-sun conditions.

4.5.7.1 Thermal-Vacuum/Space-Thermal Exposures

Thermal control of the instrument while on the spacecraft will be accomplished by controlling the temperature of the baseplate of the instrument, therefore the mounting fixture shall simulate the mounting bracket or the spacecraft, and, in addition have provisions for monitoring the temperature of the baseplate and maintaining the temperature at some prescribed value by heating or cooling of the fixture.

Operation of the instrument during solar-simulation/cold-wall exposures shall be based upon anticipated orbital conditions and operations. During the test, the instrument shall be located within its orbital flight container, if one has been deemed necessary to effect satisfactory thermal control.

The following schedule shall apply:

1) Expose instrument to cold wall for an appropriate duration while maintaining the instrument baseplate temperature at $-20^{\circ}C$ for at least 24 hours after stabilization.

2) Expose instrument to solar simulation for an appropriate duration while maintaining the instrument baseplate temperature at $+60^{\circ}C$ for up to 12 hours after stabilization.

3) Temperature-soak test with instrument baseplate maintained at $+60^{\circ}C$ for a duration after stabilization which, supplementing (2) above, will total 24 hours.

4.6 Required Resources

4.6.1 General

The following estimates are based upon several assumptions concerning the fabrication of the flight spectrometer, the boom assembly, the design qualification and flight acceptance testing procedures, and the data processing program.

It is assumed that at least four spectrometers will be fabricated in our laboratory by our personnel; that the mechanical and electrical characteristics of the boom assembly together with all interface specifications will be completely defined; that all design qualification and flight acceptance testing will be performed at MSFC by MSFC personnel and monitored by University of Michigan personnel; and that the data reduction will be performed in our laboratory by our personnel, and the data analysis will be a joint effort with MSFC and University personnel cooperating as described in Section 4.4.

4.6.2 Time Schedule

The date of initiation of work on this program will be the date of contract award. Starting from this date and assuming that all necessary component parts and supplies are readily available, the following tentative calendar of events will be used:

Event	Months after contract award
Delivery of Engineering Model	9
Complete Experiment Integration Requirements Document	12
Complete Qualification Test Plan	15
Complete Qualification Test Procedure	17
Delivery of Qualification Test Model	18
Complete Design Qualification Test	20
Delivery of First Flight Model	22
Complete Flight Acceptance Testing of First Flight Model	23
Delivery of Backup Flight Model	24
Complete Flight Acceptance Testing of Backup Flight Model	25

4.6.3 Facilities

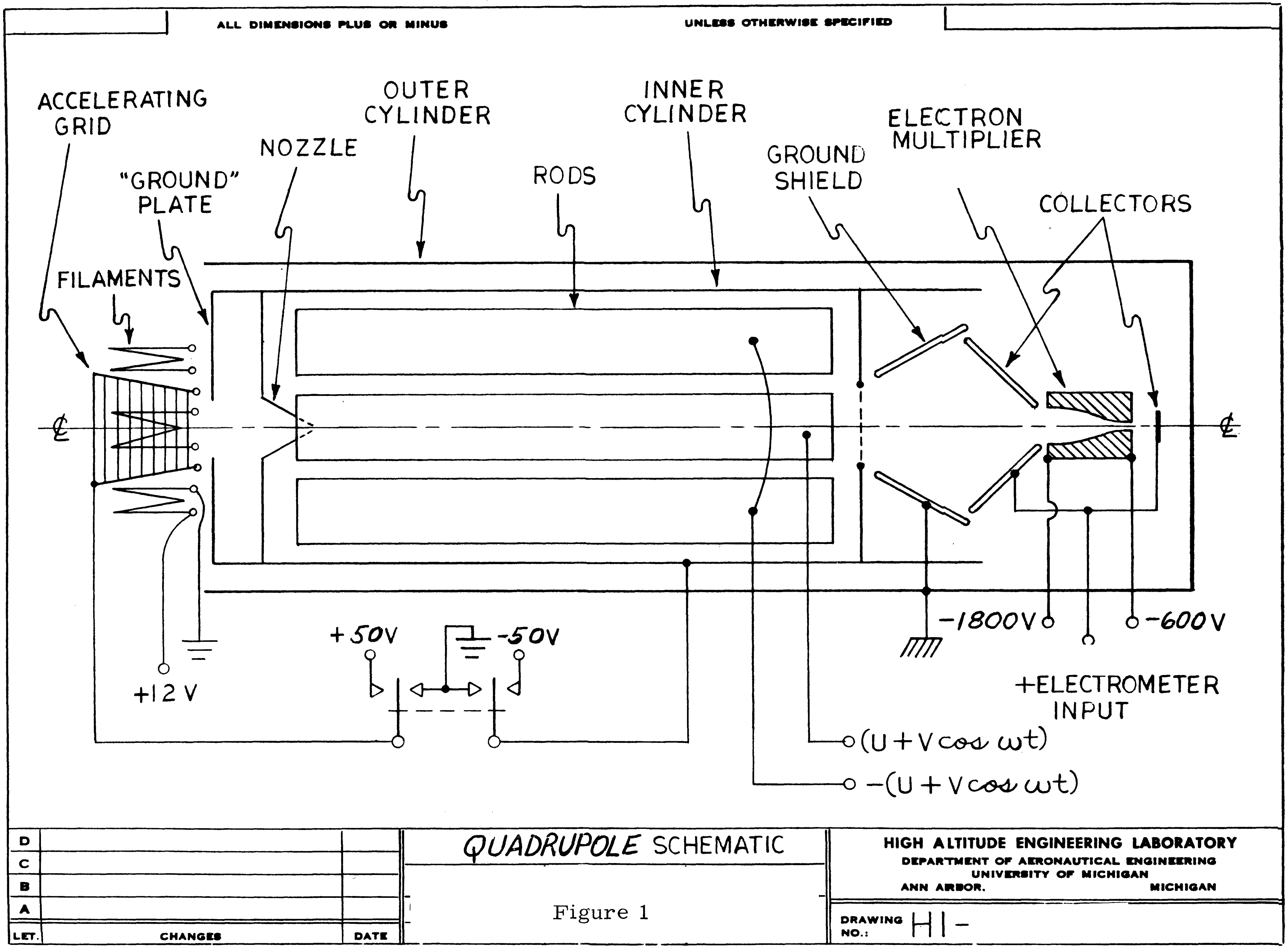
Generally all required facilities are available at the High Altitude Engineering Laboratory to complete the fabrication, bench testing, and calibration of the engineering qualification and flight models. Local outside vibration test facilities may be required to perform design integrity testing of preliminary design units prior to actual fabrication of the engineering model. If a cold-wall assembly could be provided for an existing 3'x4' vacuum chamber, which is capable of operation at pressures in the 10^{-10} torr range, preliminary thermal vacuum and thermal control tests could be performed in our laboratory prior to delivery of flight models. Such a facility would also greatly expedite the design of a satisfactory thermal control system for flight instruments.

If the flight data are supplied on 7-track magnetic tape, these data can be reduced using the facilities of the High Altitude Engineering Laboratory. If 9-track magnetic tape is used, the flight data must be converted and put on 7-track magnetic tape using the facilities of the University Computing Center. A computer controlled A/D conversion and magnetic tape storage system is available for calibration and testing of all models following fabrication. A strip chart plotting system is directly interfaced to the A/D system to permit presentation of an analog read-out when desired.

All required ground support equipment for both laboratory and field operations are readily available and will be immediately usable after only minor modifications are made.

4.6.4 Preliminary Fund Estimates

Engineering Model	$120, 000
Experiment Integration Requirements Document	30, 000
Qualification Test Plan	40, 000
Qualification Test Procedure	25, 000
Qualification Test Model) First Flight Model) - Backup Flight Model)	300, 000
Total Cost	$515, 000



ALL DIMENSIONS PLUS OR MINUS
UNLESS OTHERWISE SPECIFIED
ACCELERATING GRID
"GROUND" PLATE
FILAMENTS
NOZZLE
OUTER CYLINDER
RODS
INNER CYLINDER
GROUND SHIELD
ELECTRON MULTIPLIER
COLLECTORS
+12 V
+50V
-50V
-1800V
-600V
+ELECTROMETER INPUT
(U+V cos ωt)
-(U+V cos ωt)
QUADRUPOLE SCHEMATIC
HIGH ALTITUDE ENGINEERING LABORATORY
DEPARTMENT OF AERONAUTICAL ENGINEERING
UNIVERSITY OF MICHIGAN
ANN ARBOR. MICHIGAN
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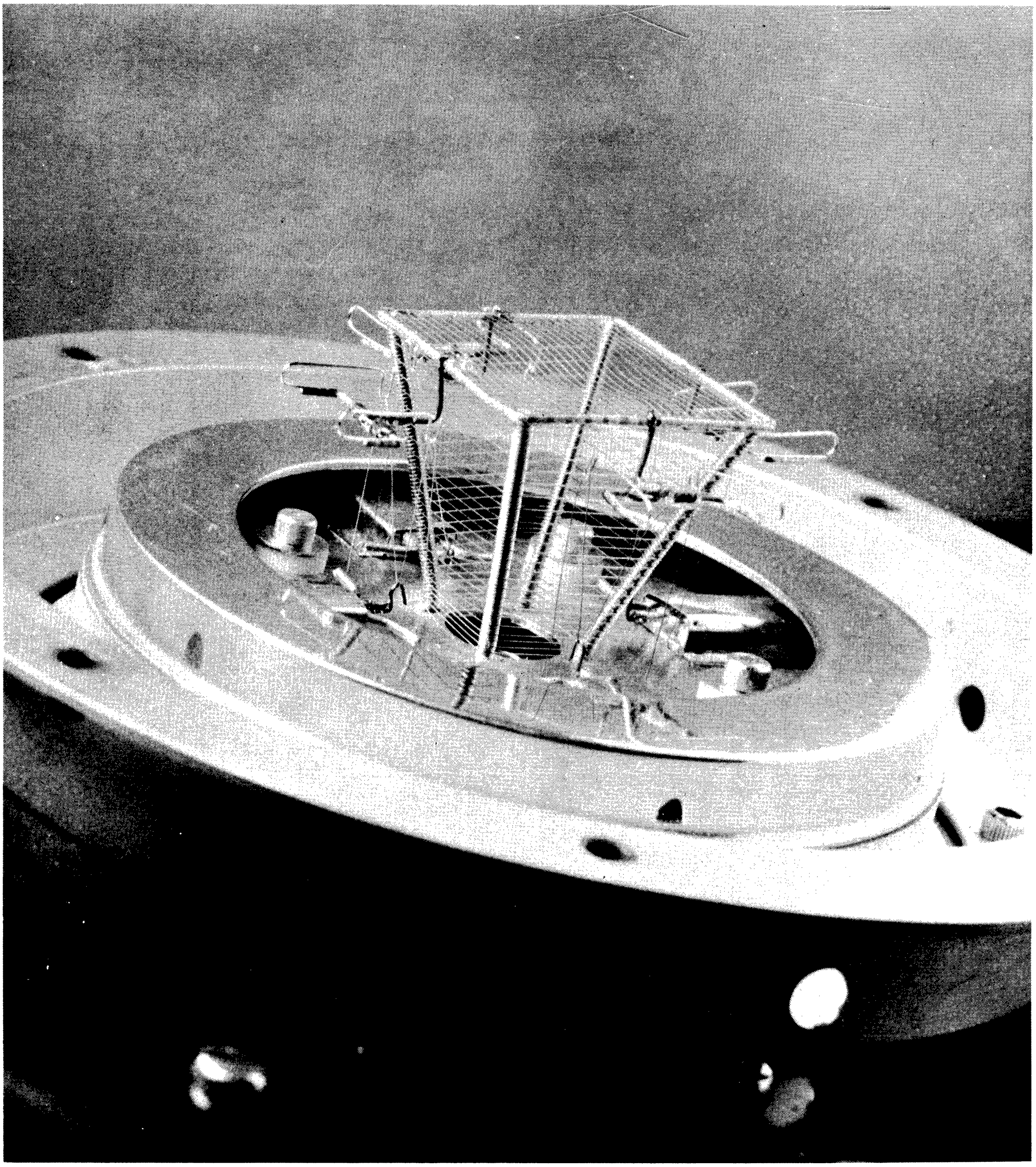
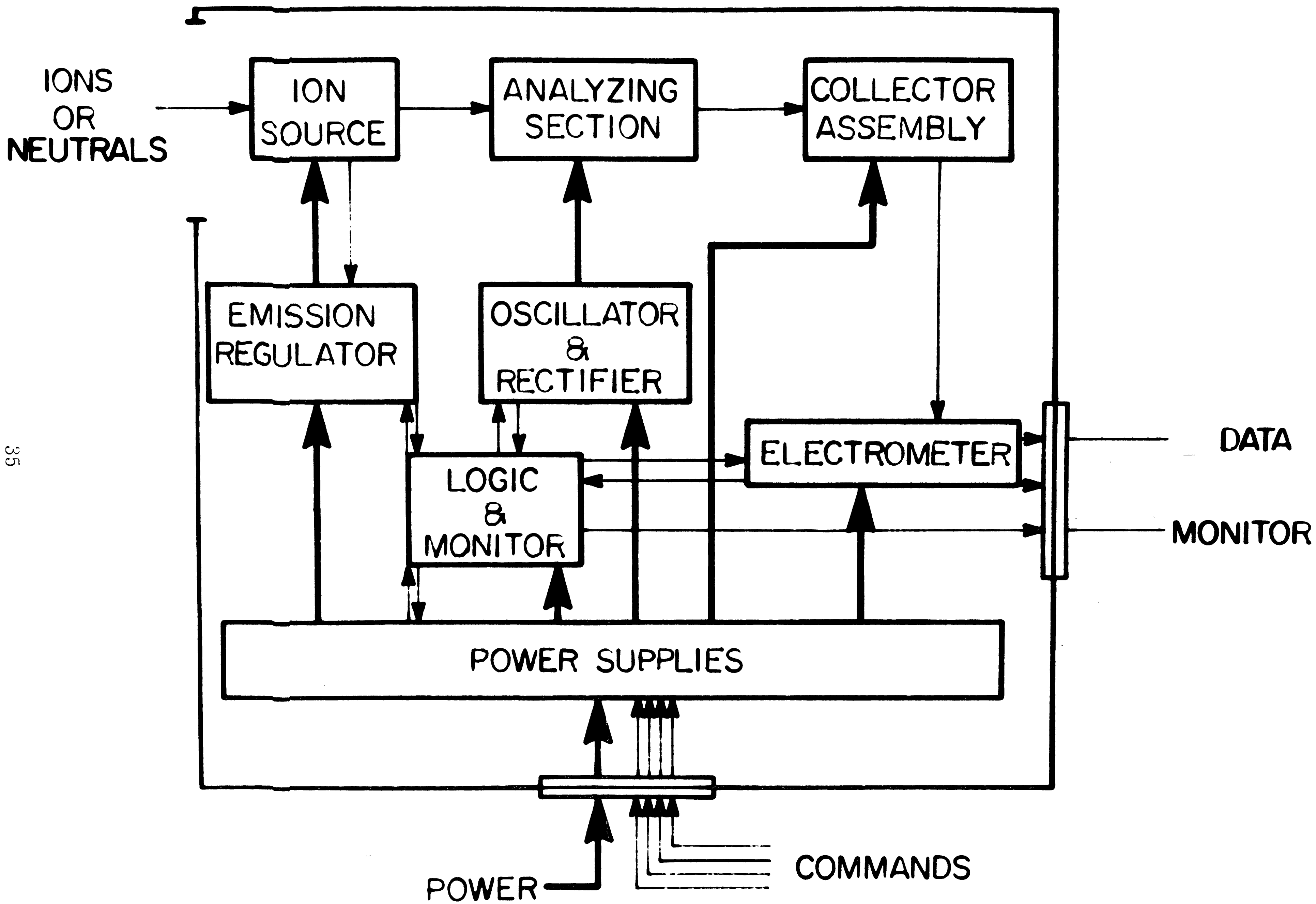
Figure 1

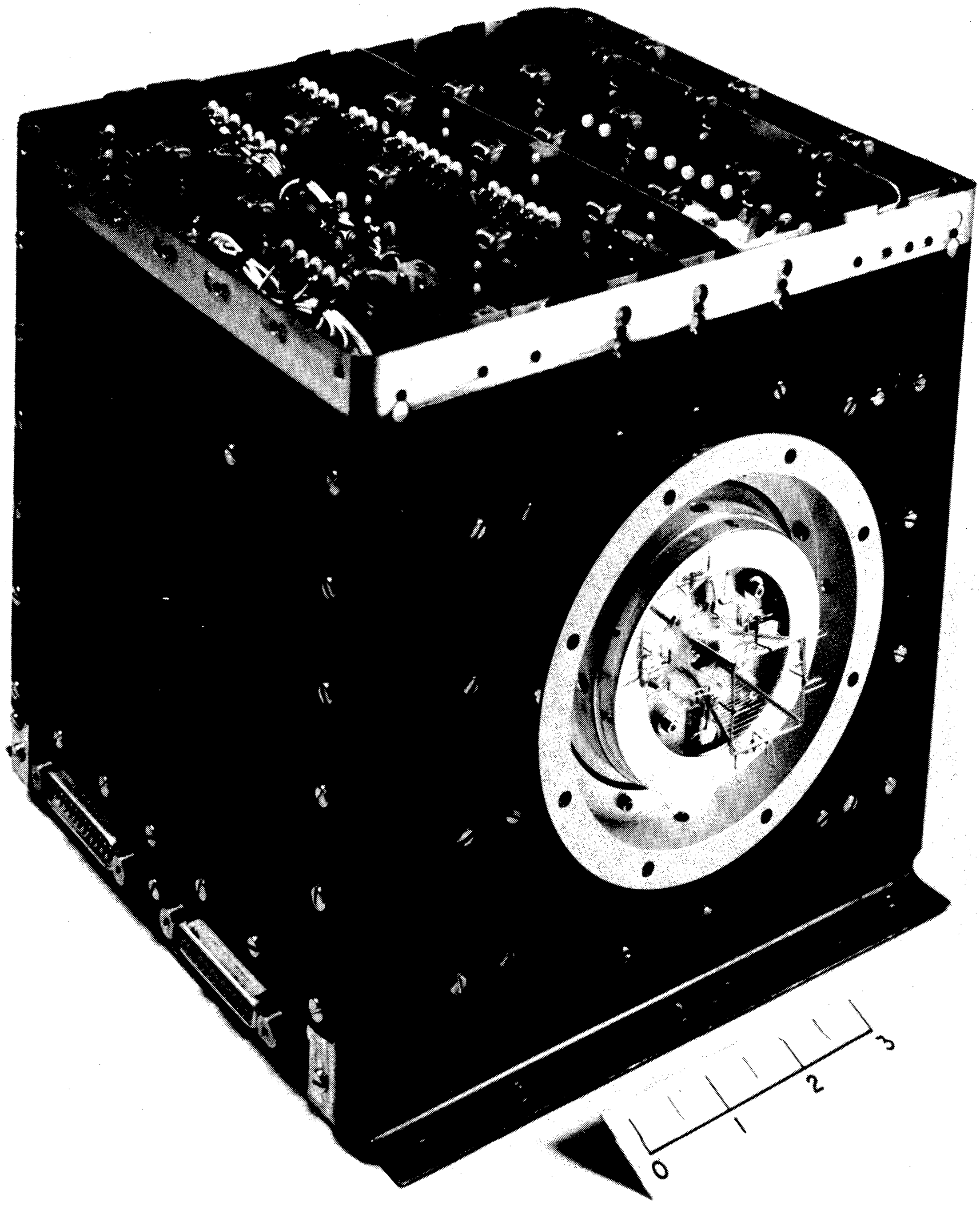


ION SOURCE

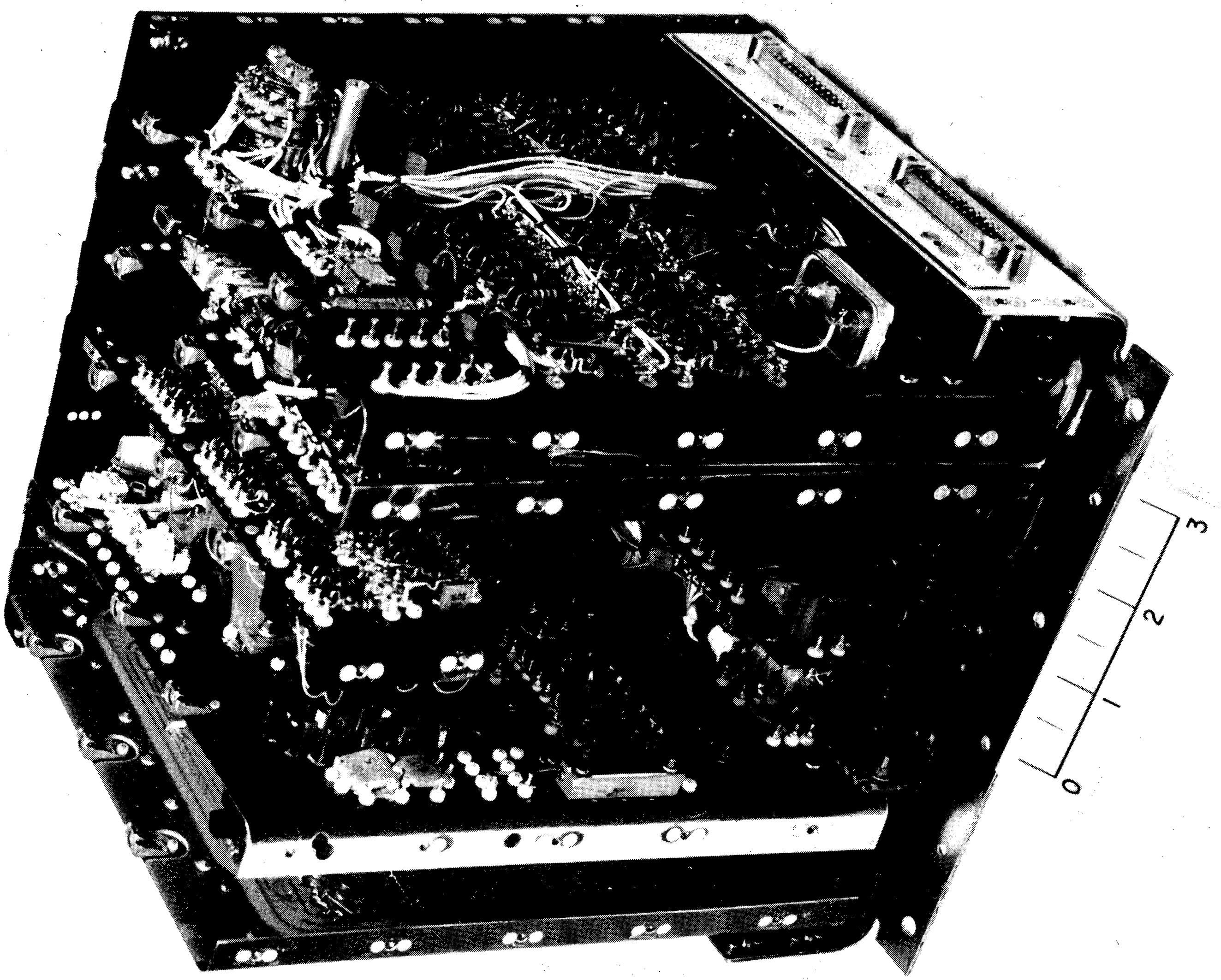
Figure 2



SPECTROMETER
BLOCK DIAGRAM
Figure 3

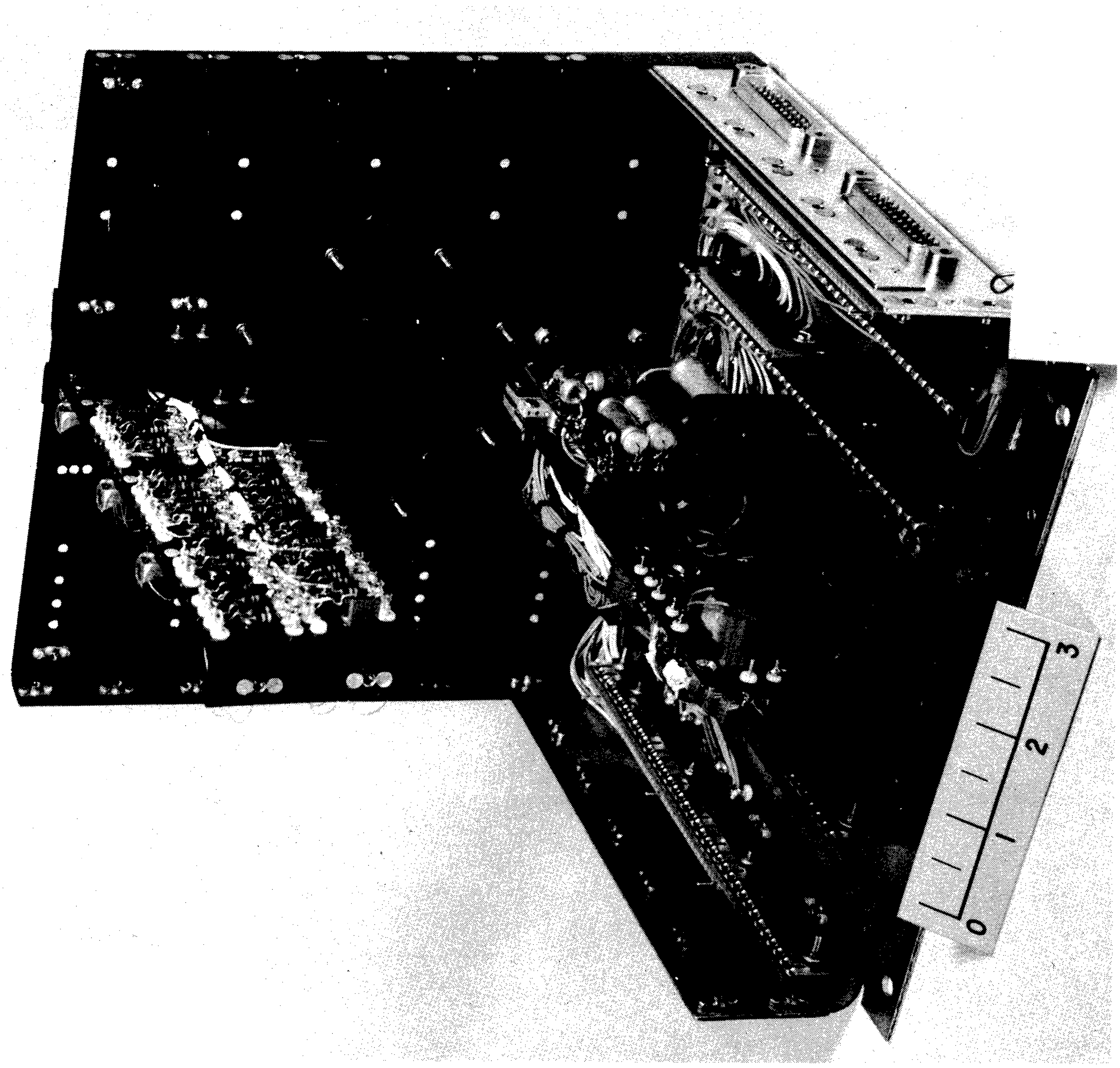


APOLLO PROTOTYPE SPECTROMETER
(top removed)
Figure 4

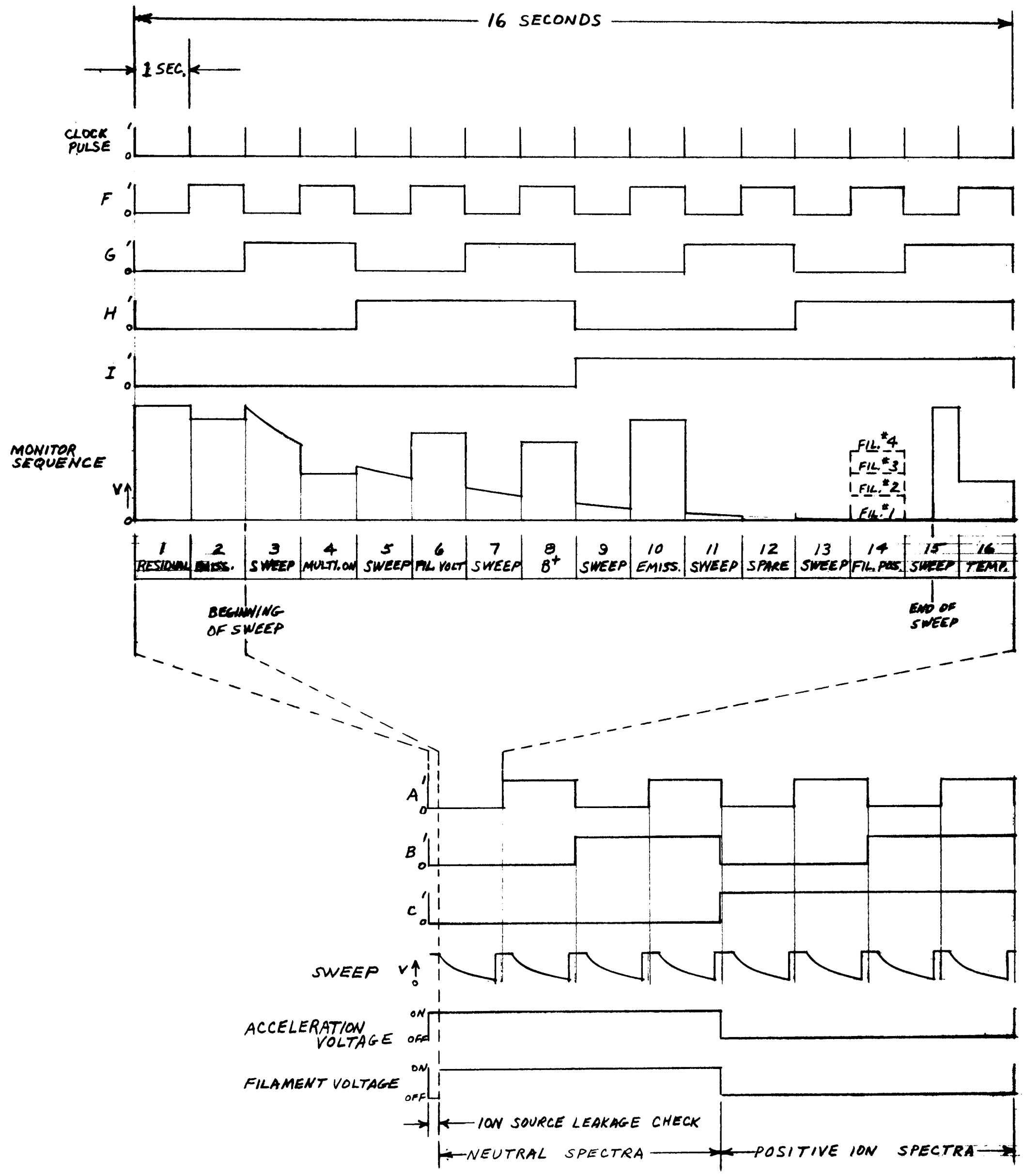


APOLLO PROTOTYPE SPECTROMETER
(rear view; top, back and one side removed)

Figure 5

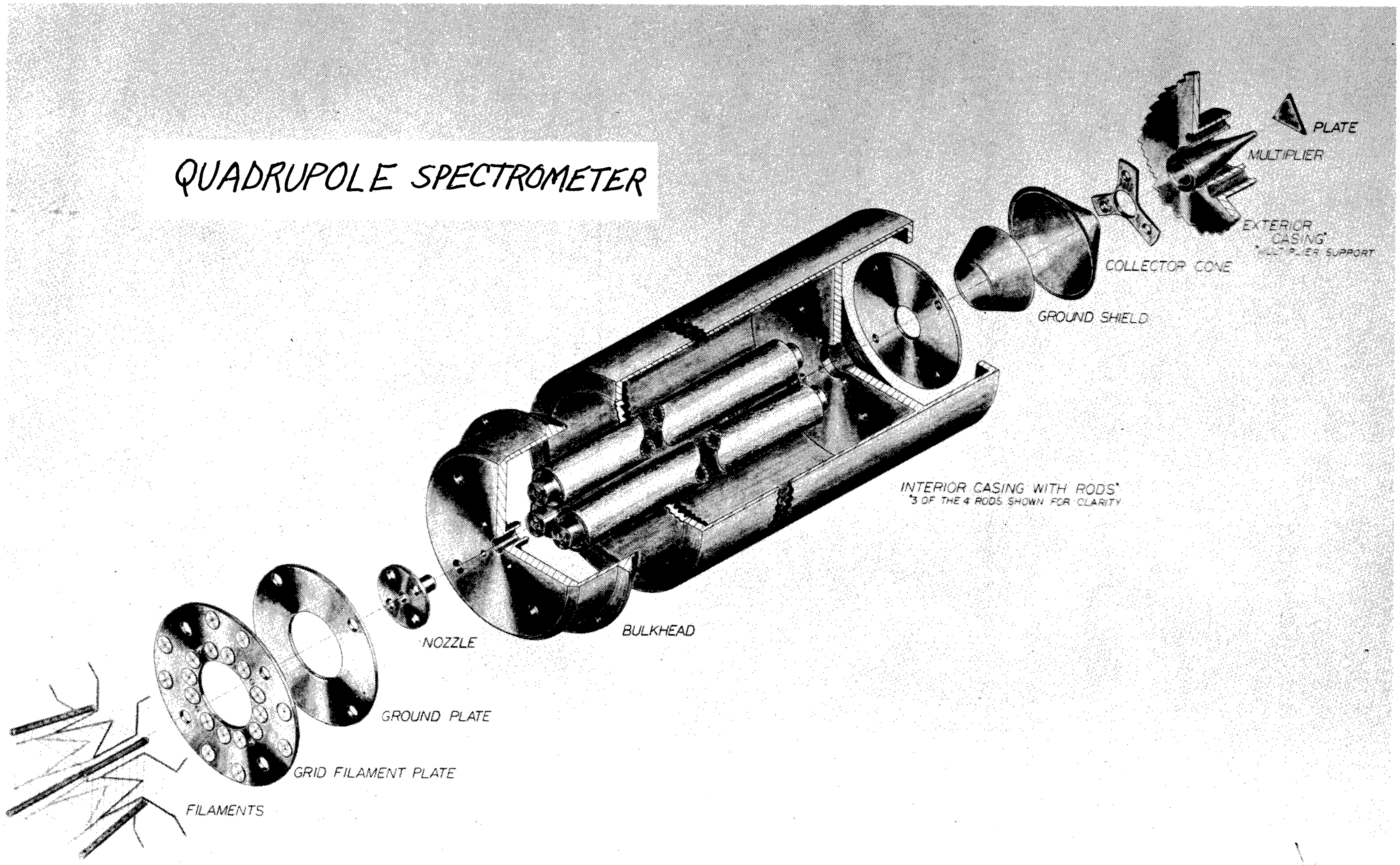


APOLLO PROTOTYPE SPECTROMETER
POWER SUPPLY AND BASE WIRING
Figure 6

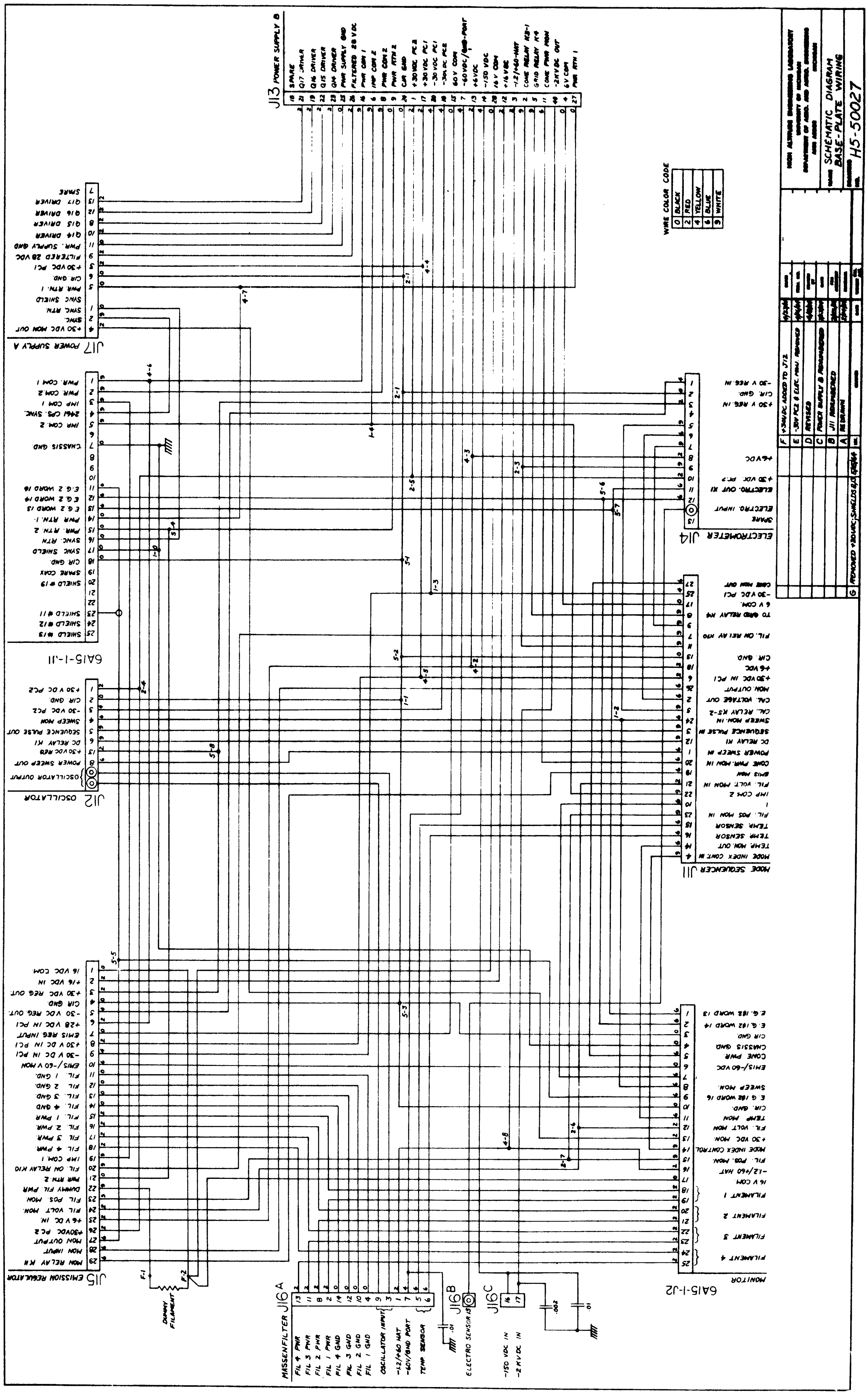


OPERATIONAL AND MONITORING SEQUENCES

Figure 7

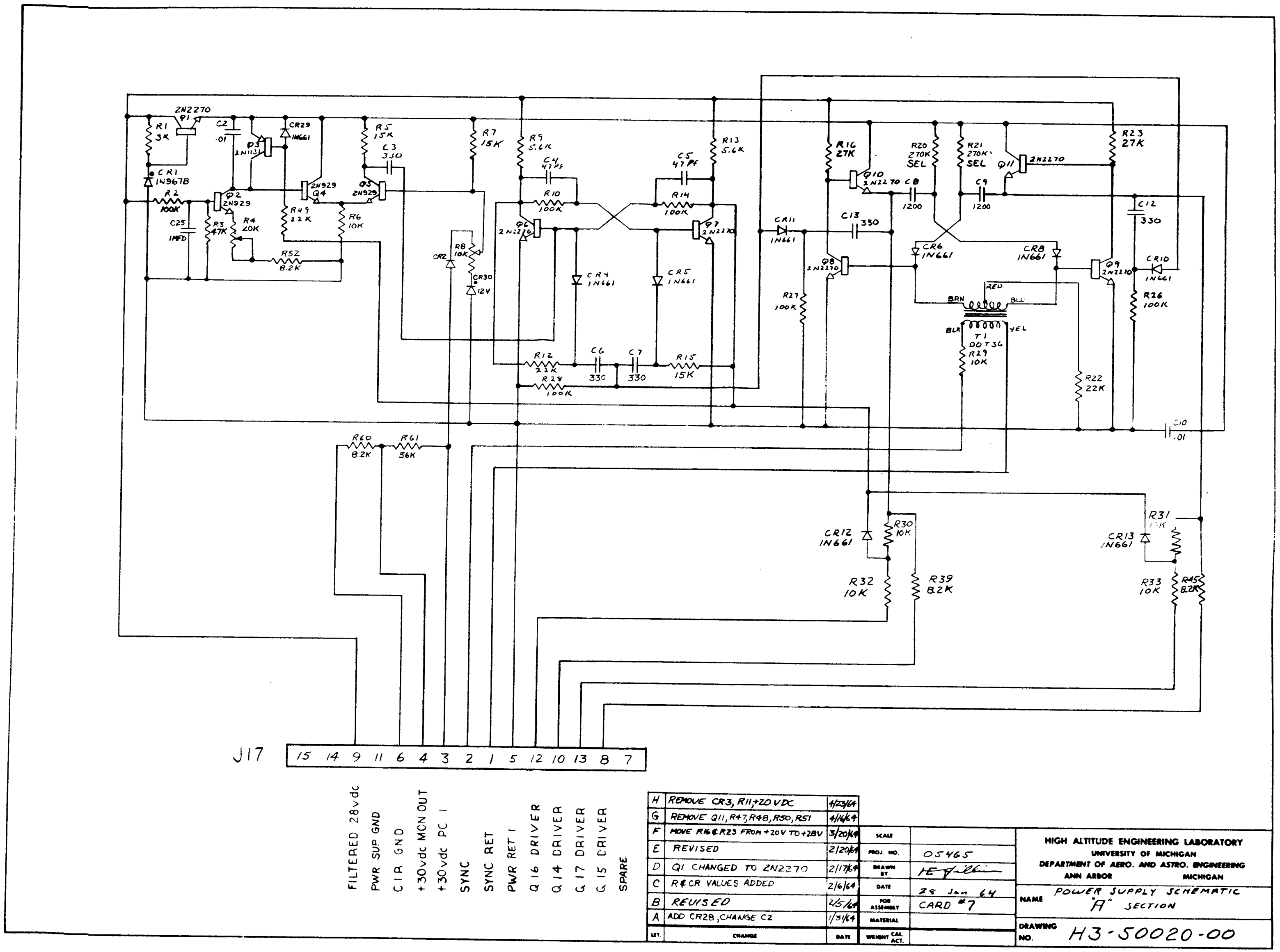


QUADRUPOLE MASS SPECTROMETER ANALYZING SECTION
(exploded view)
Figure 8



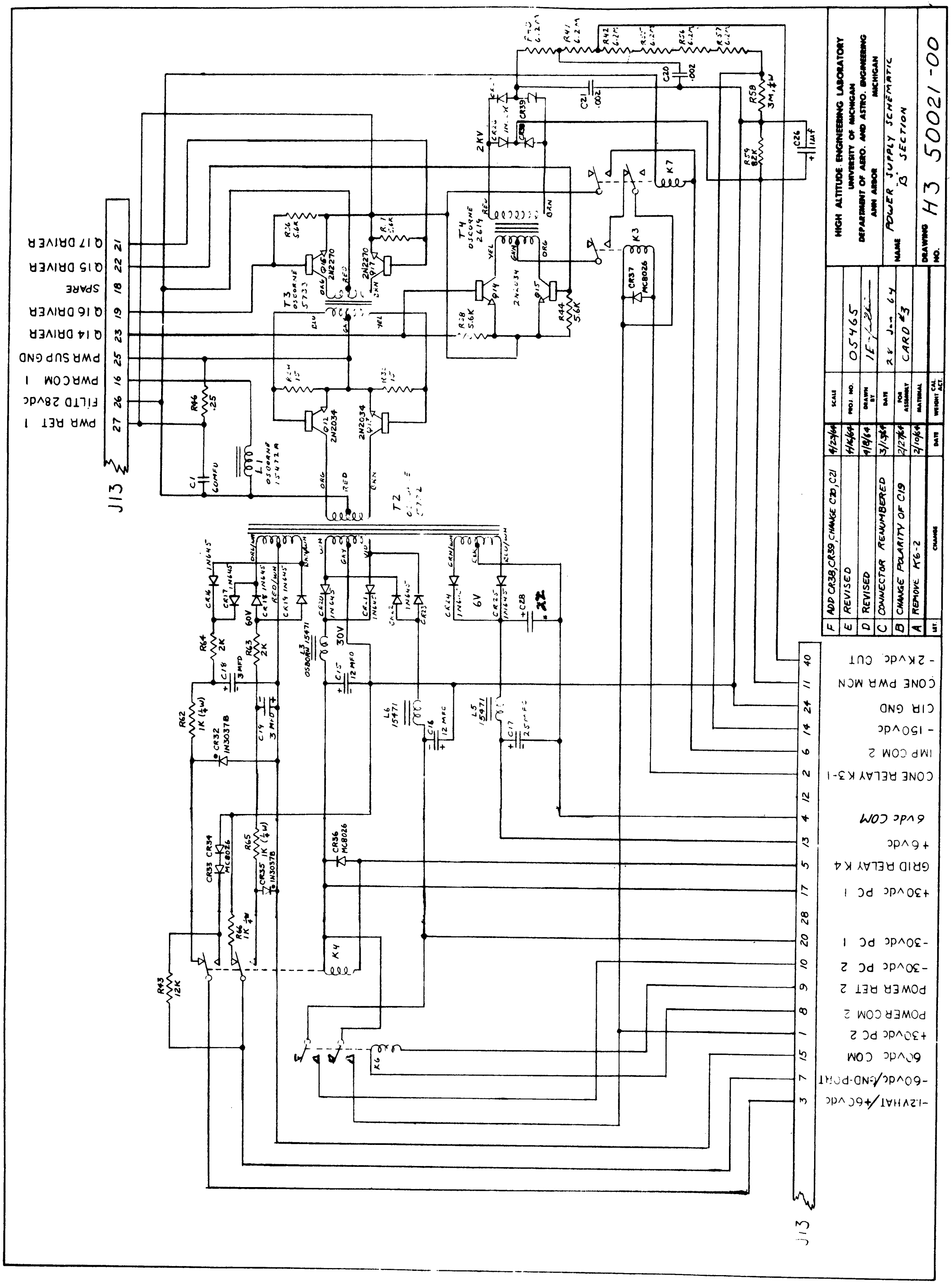
BASE WIRING

Figure 9

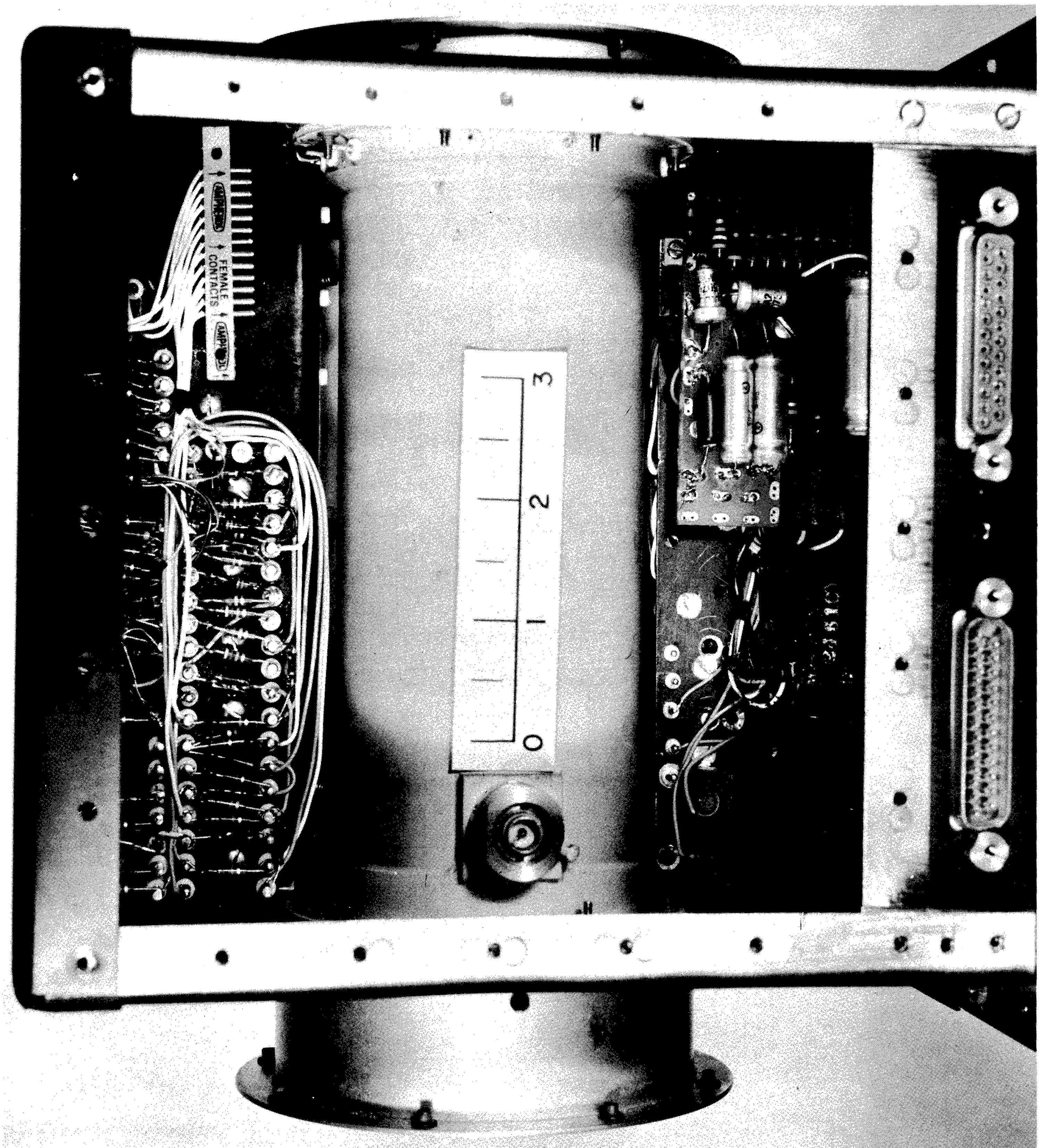


POWER SUPPLY DIAGRAM
(regulation section)

Figure 10a

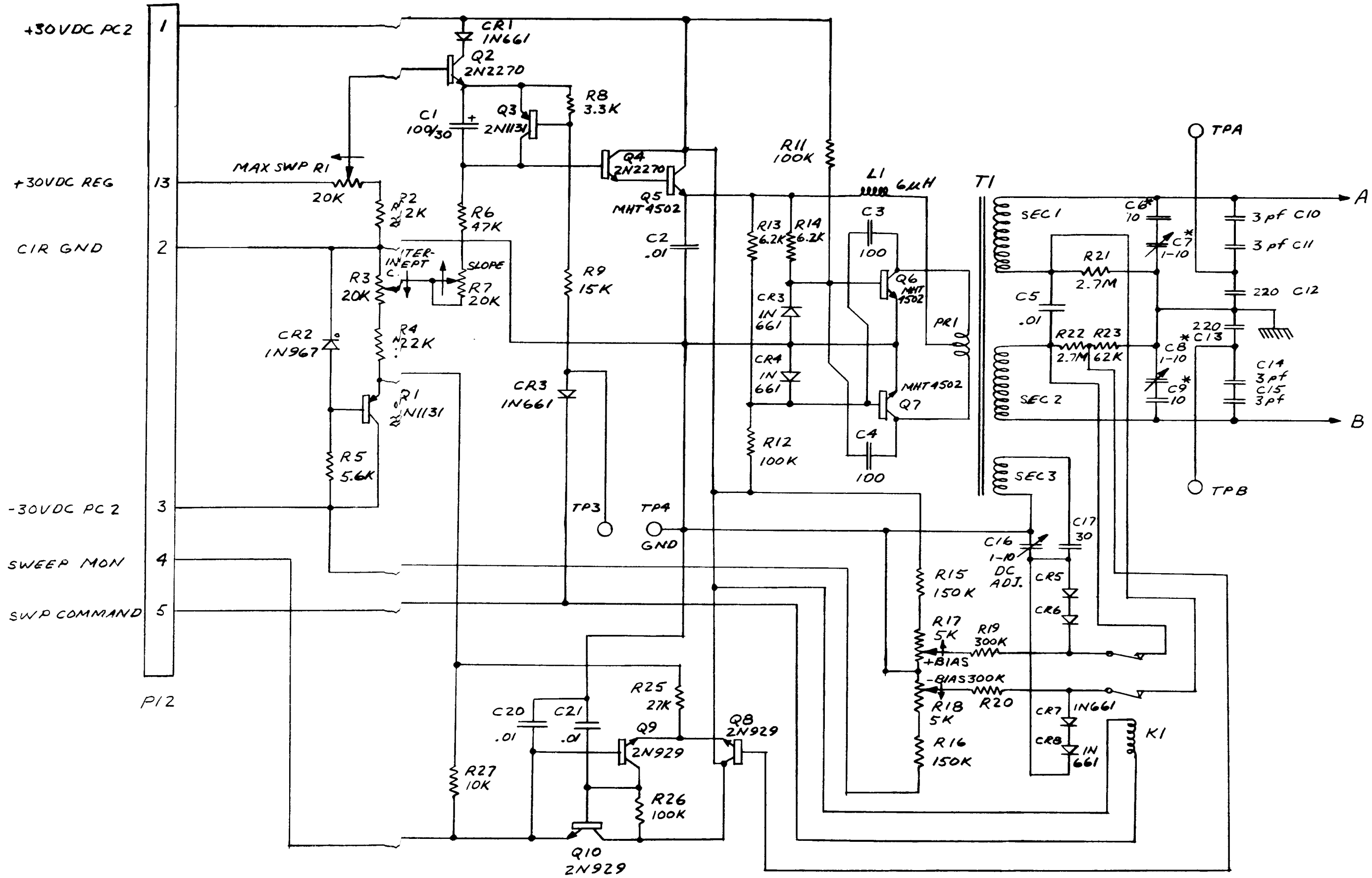


POWER SUPPLY DIAGRAM
(power section)
Figure 10b



QUADRUPOLE CYLINDER AND POWER SUPPLY
(rear view)

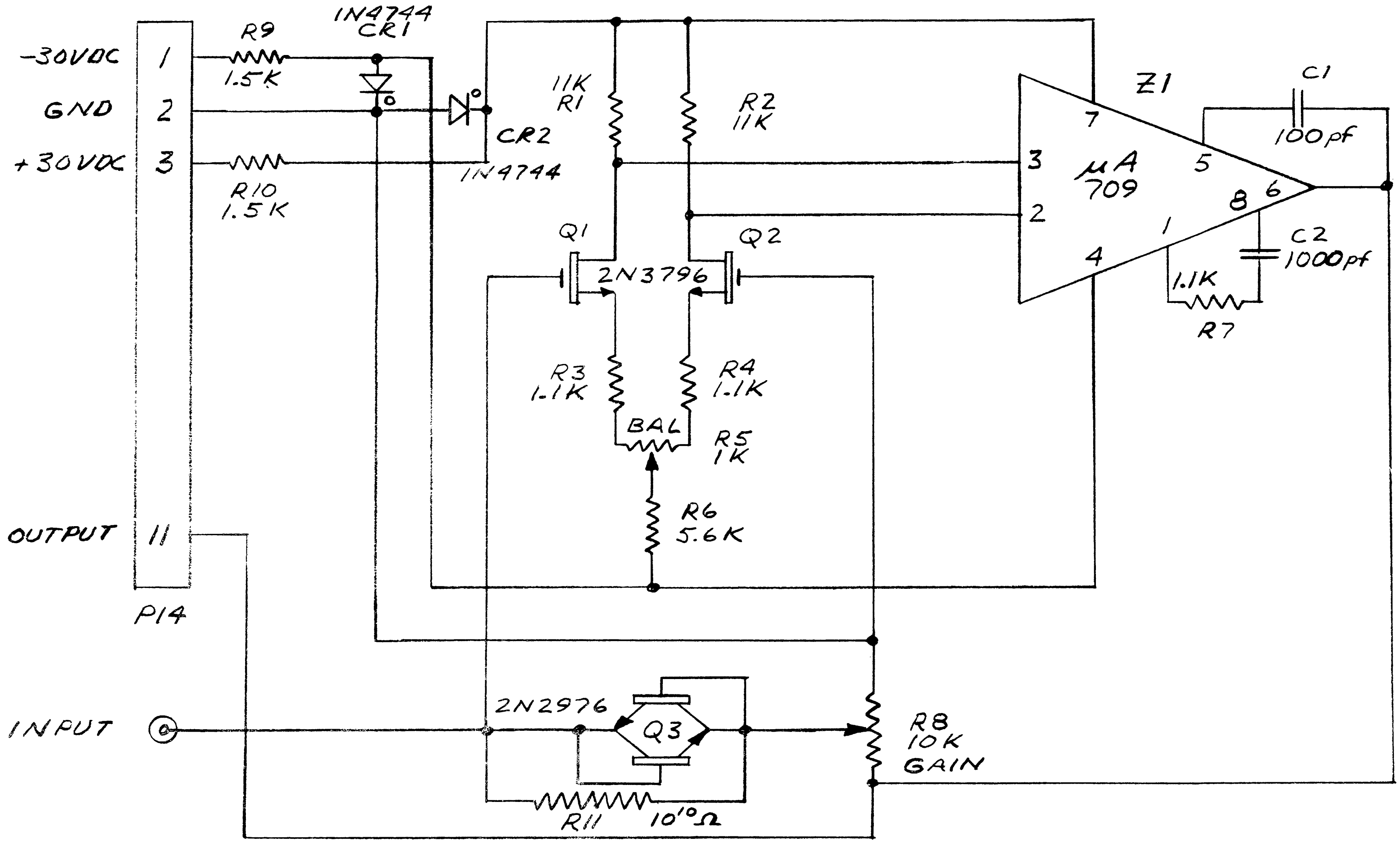
Figure 11



NOTES: T1 CORE - CF215 GAPPED CENTER ONLY .080".
PRIMARY - 2T #24AWG ON 5/8 OD TUBE, CENTER TAPPED
SEC 1 - 26T #31AWG SPACED 56T/IN ON 13/16 OD TUBE
SEC 2 - 29T #31AWG SPACED 56T/IN ON 1" OD TUBE
SEC 3 (DC) 7T #31AWG SPACED 56T/IN ON 1" OD TUBE
RODS PRESENT LOADS OF 39pf TO GROUND FROM A & B.
* C6 AND C7 OR C8 AND C9 BUT NOT ALL FOUR ARE USED.

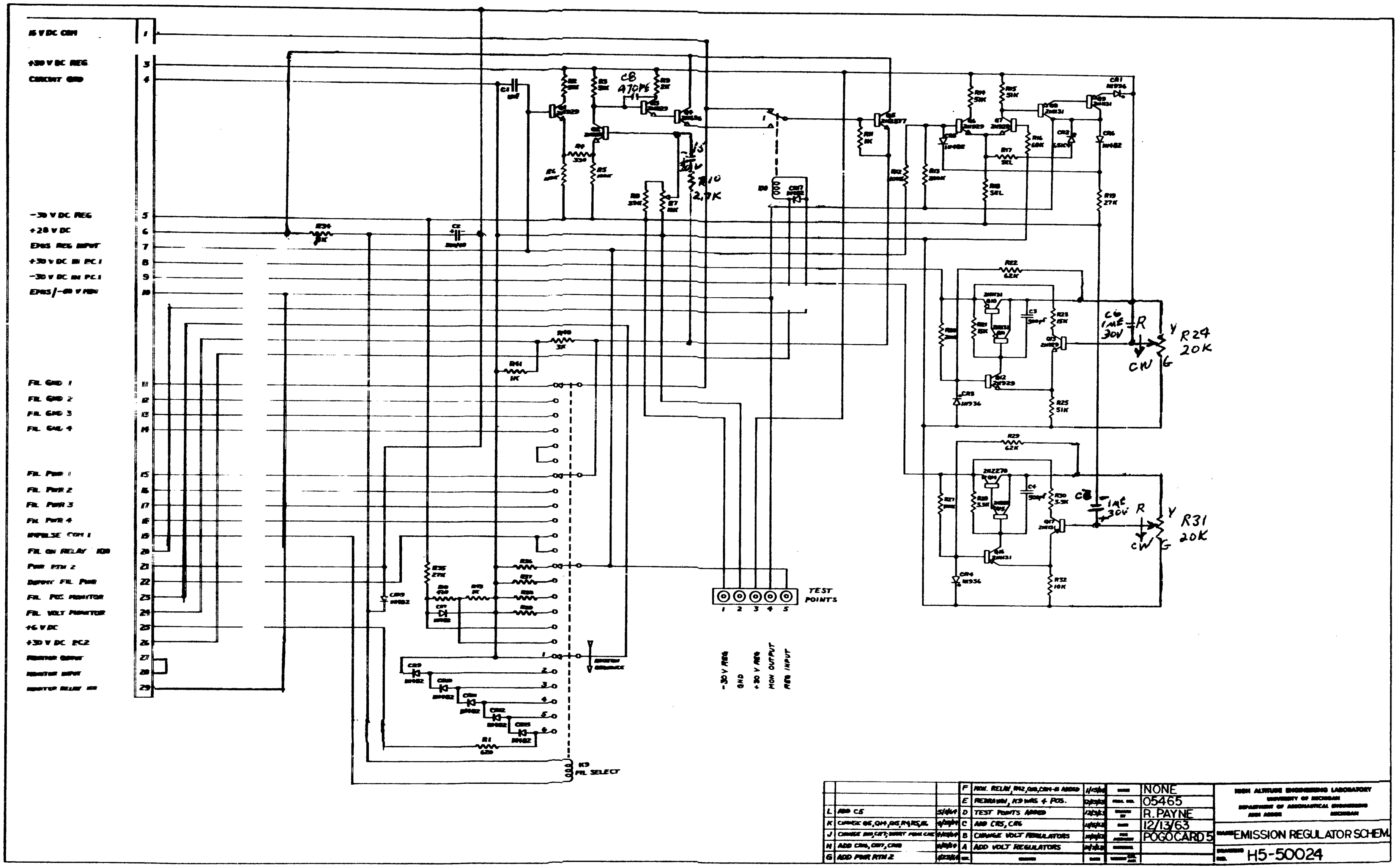
RF OSCILLATOR - RECTIFIER DIAGRAM

Figure 12



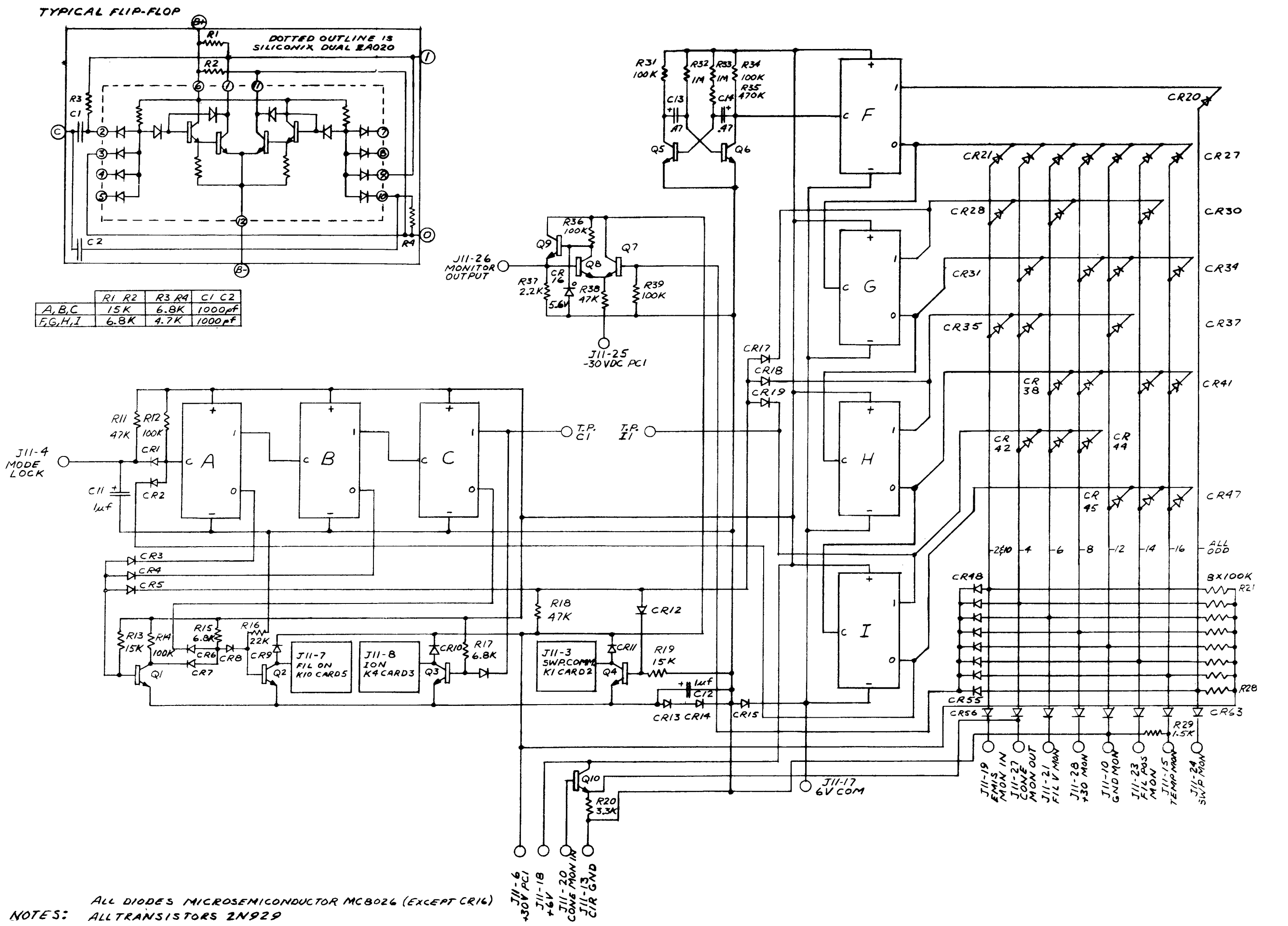
ELECTROMETER DIAGRAM

Figure 13



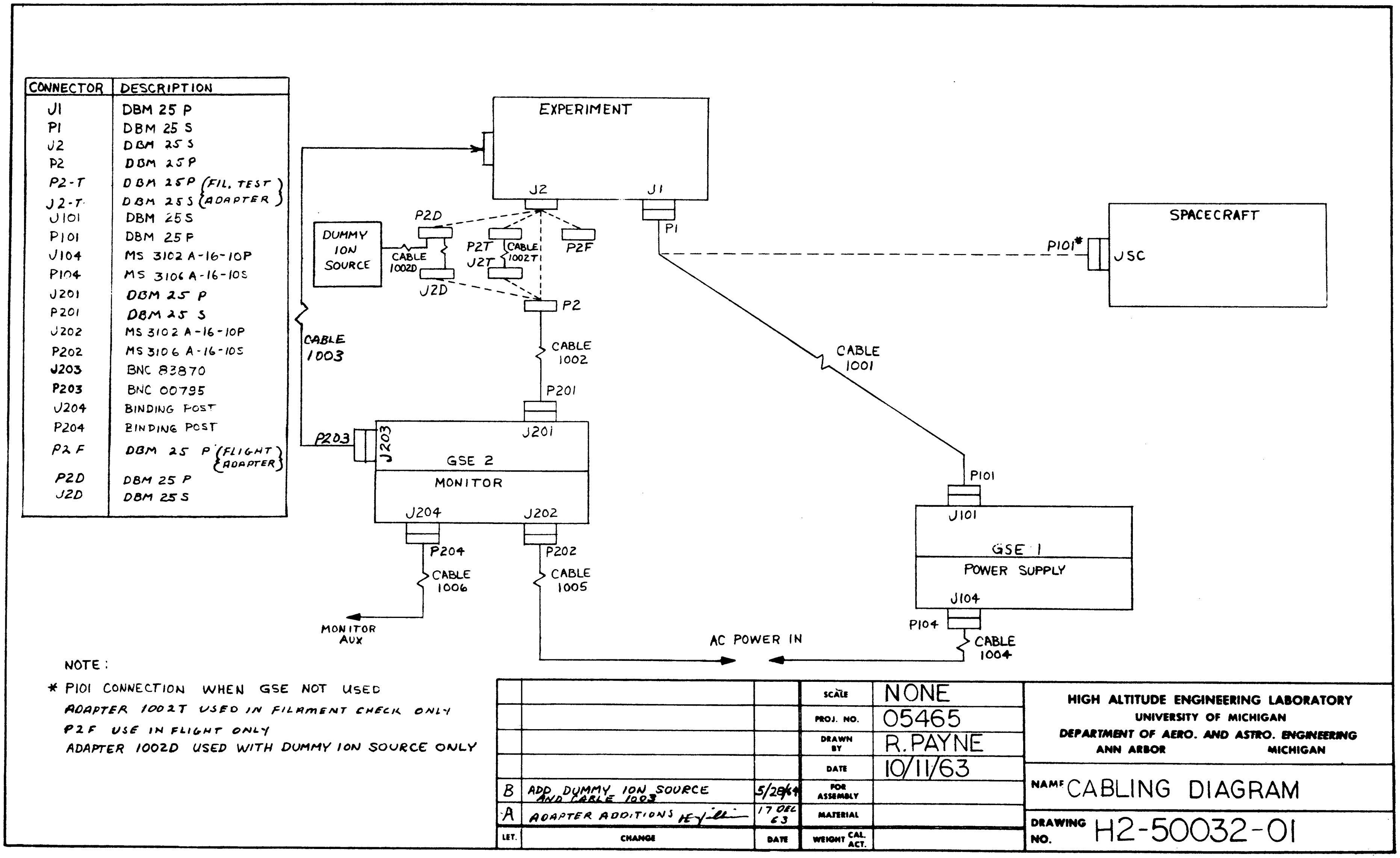
EMISSION REGULATOR DIAGRAM

Figure 14



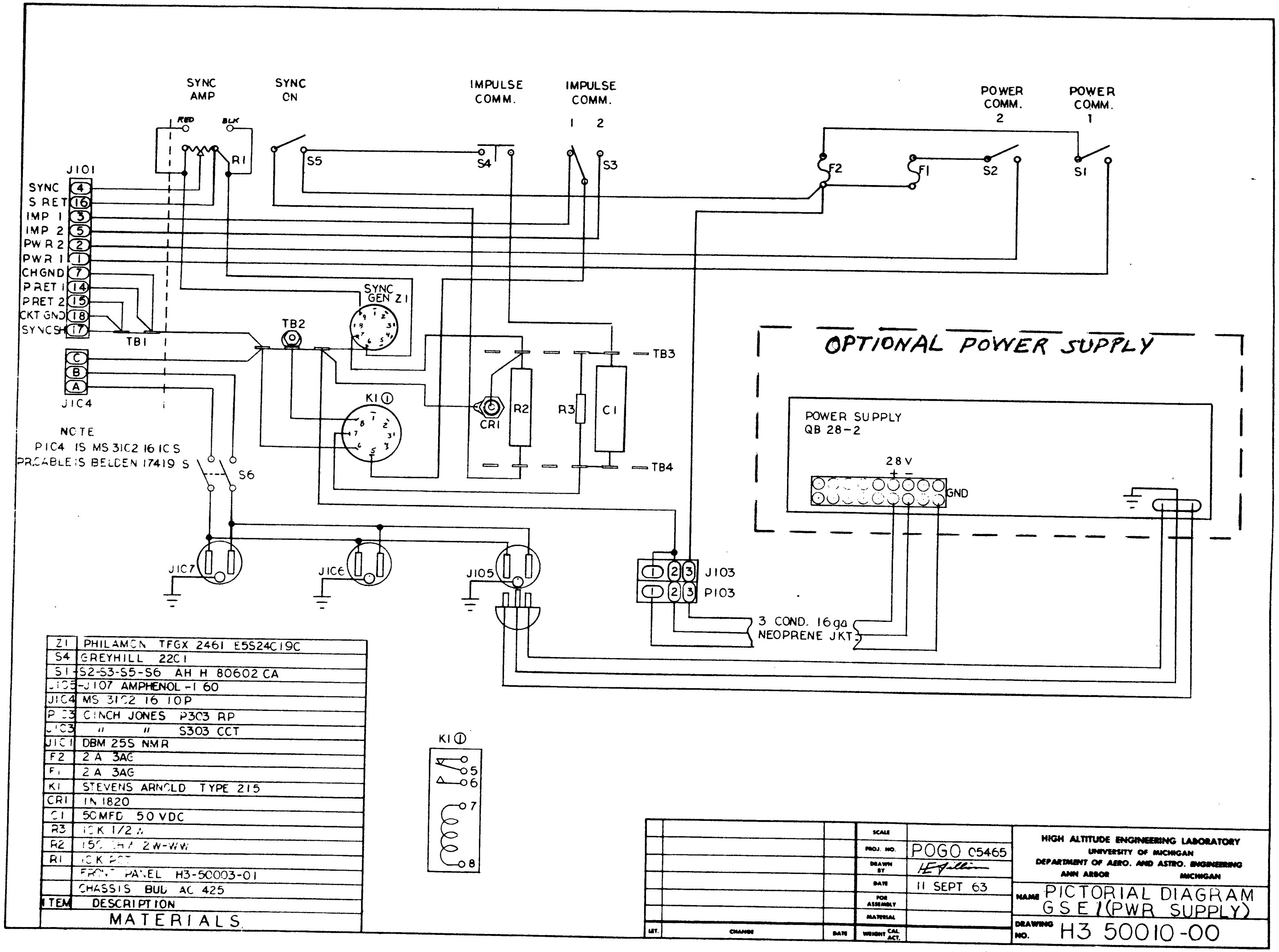
LOGIC CIRCUIT DIAGRAM

Figure 15



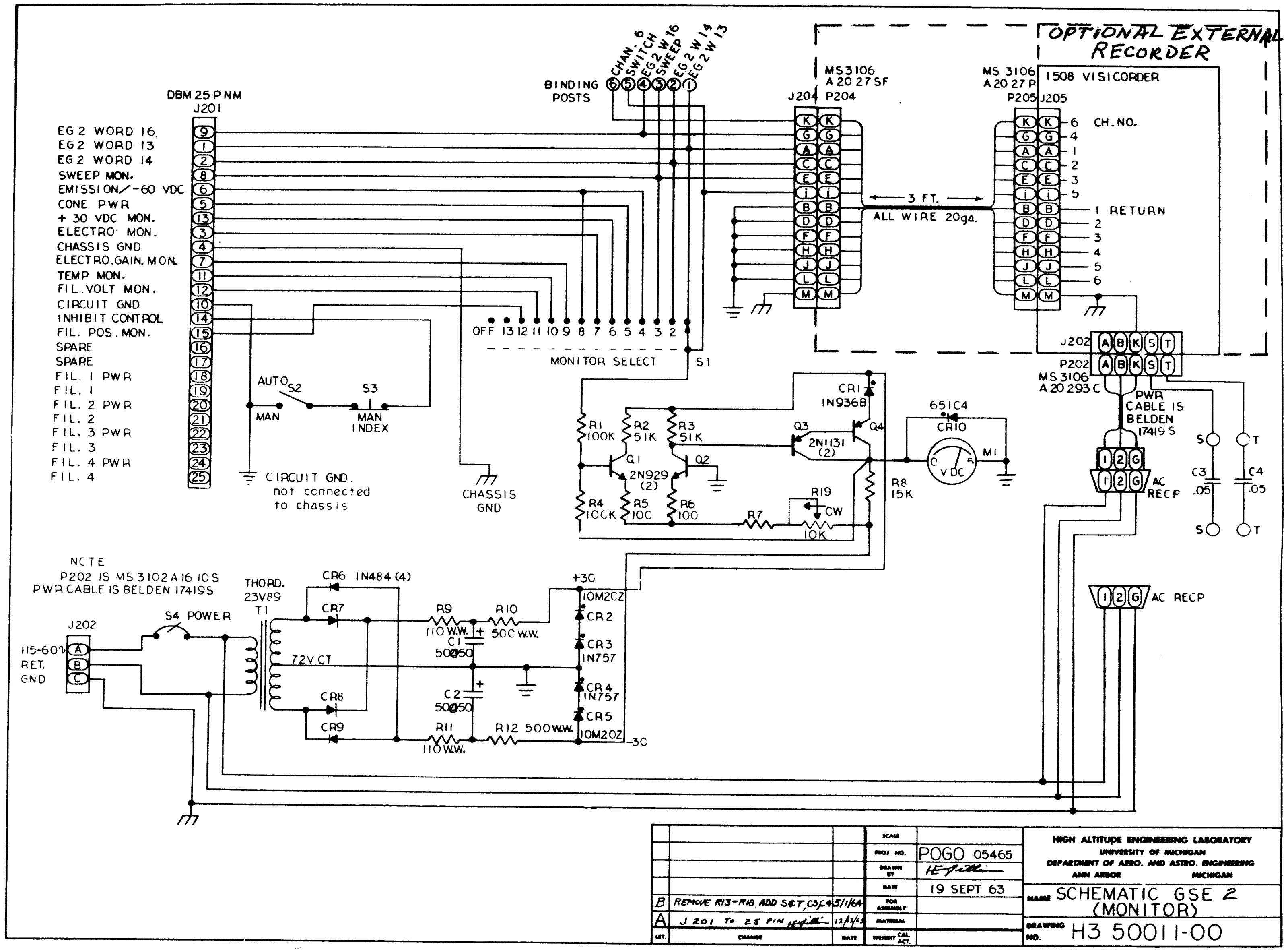
GSE CABLING BLOCK DIAGRAM

Figure 16



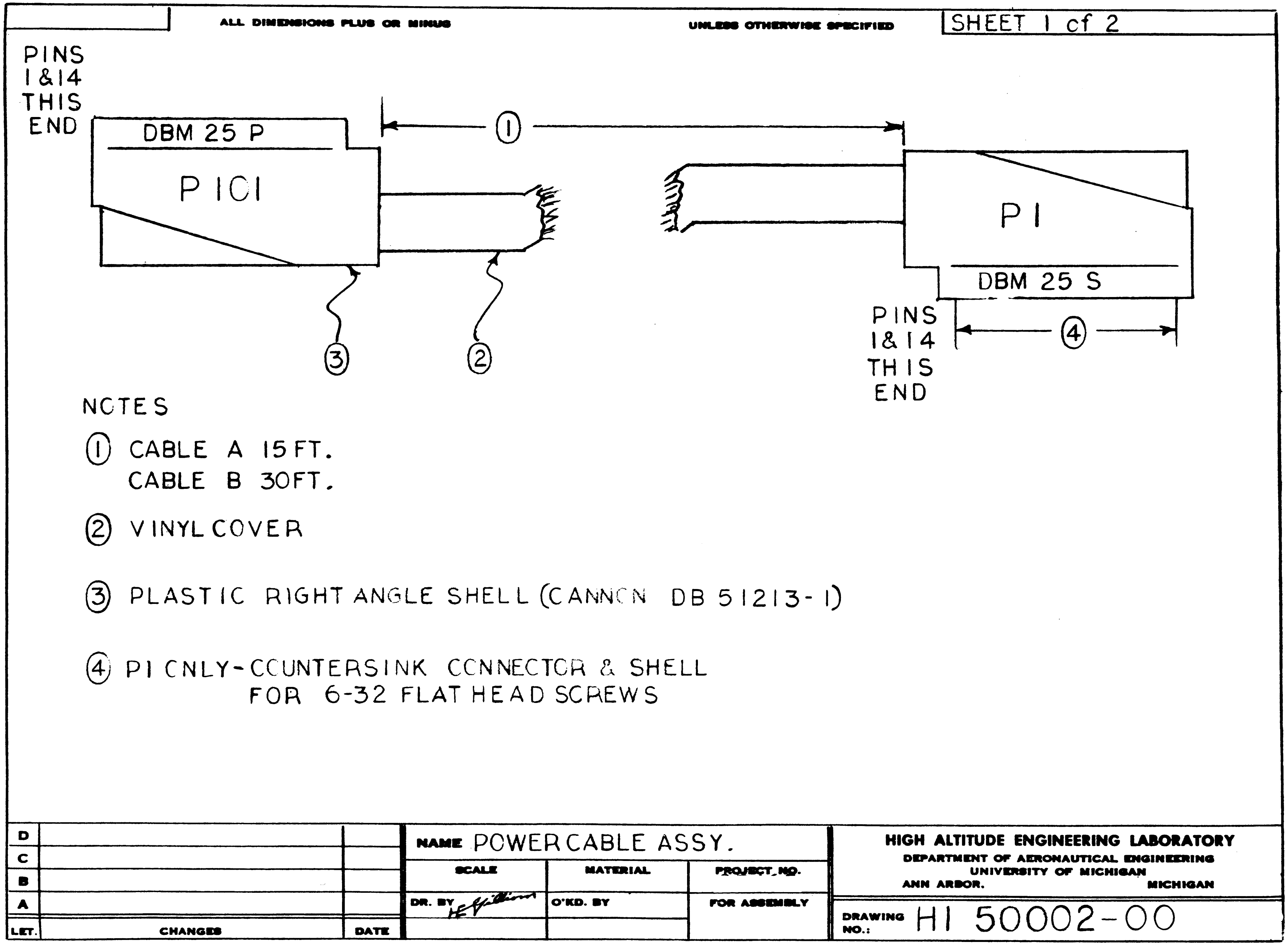
GSE 1 (POWER SUPPLY) DIAGRAM

Figure 17



GSE 2 (MONITOR) DIAGRAM

Figure 18



GSE 1 POWER CABLE (1001) DIAGRAM
Figure 19a

ALL DIMENSIONS PLUS OR MINUS ... UNLESS OTHERWISE SPECIFIED — Sheet 2 of 2

P 101 Connector DBM 25 P NM — Connecting GSE 1 J101

P 1 Connector DBM 25 S NM — Connecting Experiment J1

P 101 Pin	P 1 Pin	Gage	Type	Function	Color	Notes
1	1	20	C	Power Command 1	YEL	Twist with Pin 14
2	2	20	C	Power Command 2	YEL	Twist with Pin 15
3	3	20	A	Impulse Command 1	BRN	
4	4	22	D	2461 CPS Sync.	RED	Twist with 16 Shield with 17
5	5	20	A	Impulse Command 2	GRN	
6	6	20	A	Spare	WHT	
7	7	20	A	Chassis Ground	GRY	
8	8	24	B	Spare Shielded		
9	9	-	B	Shield Cont. Pin 8		
10	10	20	A	Spare	BLU	
11	11	24	B	Spare - EG 1 & 2 Word 16		Not connected to P 1
12	12	24	B	Spare - EG 1 & 2 Word 14		(Floated)
13	13	24	B	Spare - EG 1 & 2 Word 13		Connected to P101 end only
14	14	20	C	Power Return 1	ORG	
15	15	20	C	Power Return 2	ORG	
16	16	22	D	Sync. Return	BLK	
17	17	-	D	Sync. Shield		
18	18	20	A	Circuit Ground	BLK	
19	19	-	F*	Coax Spare		
20	20	-	F*	Shield - Coax Spare		
21	21	20	A	Spare	RED	
22	22	22	A	Spare	VIO	
23	23	24	B	Shield for Pin 11		Not connected to P1
24	24	24	B	Shield for Pin 12		(Floated)
25	25	24	B	Shield for Pin 13		Connected to J101 end only

LET	CHANGES	DATE
D		
C		
B		
A		

NAME Experiment Power Cable

Length A - 15' B - 30'

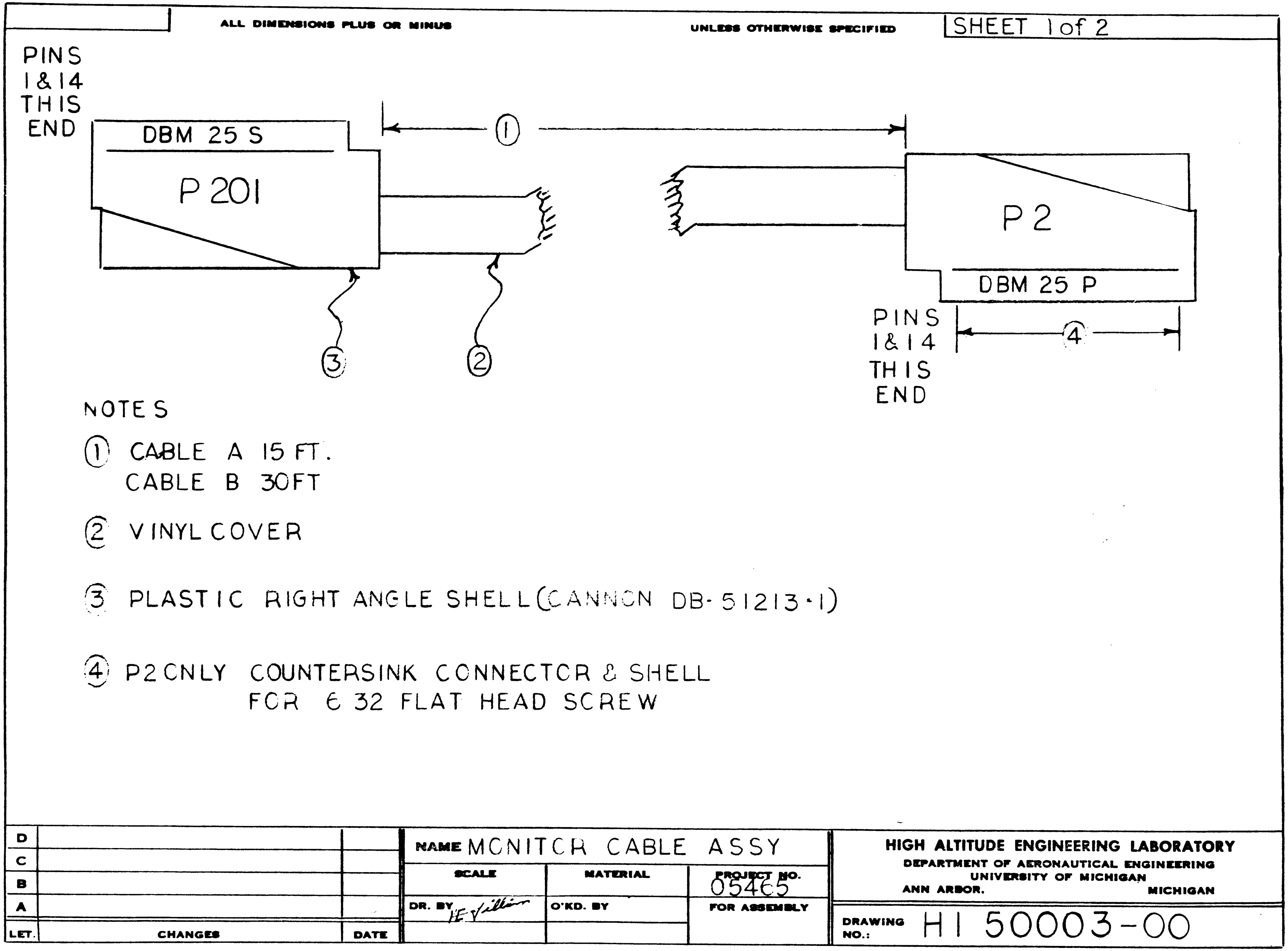
PROJECT NO.

DR. BY H. Gilliam — CK'D. BY — FOR ASSEMBLY

HIGH ALTITUDE ENGINEERING LABORATORY
DEPARTMENT OF AERONAUTICAL ENGINEERING
UNIVERSITY OF MICHIGAN
ANN ARBOR. MICHIGAN

DRAWING NO.: H1 50002-00

GSE 1 POWER CABLE ASSIGNMENTS
Figure 19b



GSE 2 MONITOR CABLE (1002) DIAGRAM

Figure 20a

ALL DIMENSIONS PLUS OR MINUS ... UNLESS OTHERWISE SPECIFIED — Sheet 2 of 2

Connector DBM 25 S NM — Connecting GSE 2 J201

Connector DBM 25 P NM — Connecting Experiment J2

P 201 Pin	P 2 Pin	Gage	Type	Function	Color	Notes
1	1	24	B	EG 1 & 2 Word 13		
2	2	24	B	EG 1 & 2 Word 14		
3	3	20	A	Electro Monitor	ORG	Shield Cont. for Pins 1-2-9
4	4	20	A	Chassis Ground & Shield Cont.	BLK	Connect Shields to P2 only -
5	5	20	A	Cone Power	GRN	Pin 4
6	6	20	A	Emission & -60 VDC	BRN	
7	7	20	A	Electro Gain Monitor	RED	
8	8	20	A	Sweep Monitor	YEL	
9	9	24	B	EG 1 & 2 Word 16		
10	10	20	A	Circuit Ground	BLK	
11	11	20	A	Temperature Monitor	BLU	
12	12	20	A	Filament Volt Monitor	ORG	
13	13	20	A	+30 VDC Monitor	YEL	
14	14	20	A	Inhibit Control	VIO	
15	15	20	A	Filament Pos. Monitor	WHT	
16	16	20	A	Spare	GRN	
17	17	20	A	Spare (24)	GRY	
18	18	20	A	Filament 1 Power	GRN	Filament 1 Interlock
19	19	20	A	Filament 1	WHT	" " "
20	20	20	A	Filament 2 Power	RED	Filament 2 Interlock
21	21	20	A	Filament 2	GRY	" " "
22	22	20	A	Filament 3 Power	BLU	Filament 3 Interlock
23	23	20	A	Filament 3	BRN	" " "
24	24	20	A	Filament 4 Power	VIO	Filament 4 Interlock
25	25	20	A	Filament 4	ORG	" " "

LET.	CHANGES	DATE
D		
C		
B		
A	Add filament check - H.G.	

NAME Experiment Monitor Cable

Length A - 15' B - 30' — PROJECT NO. 05465

DR. BY H. Gilliam — CH'KD. BY — FOR ASSEMBLY

HIGH ALTITUDE ENGINEERING LABORATORY
DEPARTMENT OF AERONAUTICAL ENGINEERING
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

DRAWING NO.: H1 50003-00

GSE 2 MONITOR CABLE ASSIGNMENTS
Figure 20b

ALL DIMENSIONS PLUS OR MINUS UNLESS OTHERWISE SPECIFIED

P_J 2T	P_J 2T	Connector DBM 25 P NM / Connector DBM 25 S NM			Connecting / Connecting
Pin	Pin	Gage	Type	Function	Notes
1	1	20	Buss	EG 1 & 2 Word 13	Cont. between P2T and J2T
2	2	20	Buss	EG 1 & 2 Word 14	
3	3	20	Buss	Electro Monitor	
4	4	20	Buss	Chassis Ground & Shield Cont.	
5	5	20	Buss	Cone Power	
6	6	20	Buss	Emission & -60 VDC	
7	7	20	Buss	OSC. Monitor	
8	8	20	Buss	Sweep. Monitor	
9	9	20	Buss	EG 1 & 2 Word 16	
10	10	20	Buss	Circuit Ground	Use 20 GA Buss Pins 1-17
11	11	20	Buss	Temperature Monitor	
12	12	20	Buss	Filament Voltage Monitor	
13	13	20	Buss	+30 VDC Monitor	
14	14	20	Buss	Inhibit Control	
15	15	20	Buss	Filament Pos. Monitor	
16	16	20	Buss	Spare	
17	17	20	Buss	Spare	Cont. between P2T and J2T
18	18	20	Buss	Interlock Jumper Filament 1 Power	Tie to P2T - 19
19	19	20	Buss	Interlock Jumper Filament 1	Tie to P2T - 18
20	20	20	Buss	Interlock Jumper Filament 2 Power	Tie to P2T - 21
21	21	20	Buss	Interlock Jumper Filament 2	Tie to P2T - 20
22	22	20	Buss	Interlock Jumper Filament 3 Power	Tie to P2T - 23
23	23	20	Buss	Interlock Jumper Filament 3	Tie to P2T - 22
24	24	20	Buss	Interlock Jumper Filament 4 Power	Tie to P2T - 25
25	25	20	Buss	Interlock Jumper Filament 4	Tie to P2T - 24

LET.	CHANGES	DATE
D		
C		
B		
A		

NAME Filament Test Adapter

Length 2 inches

PROJECT NO. 05465

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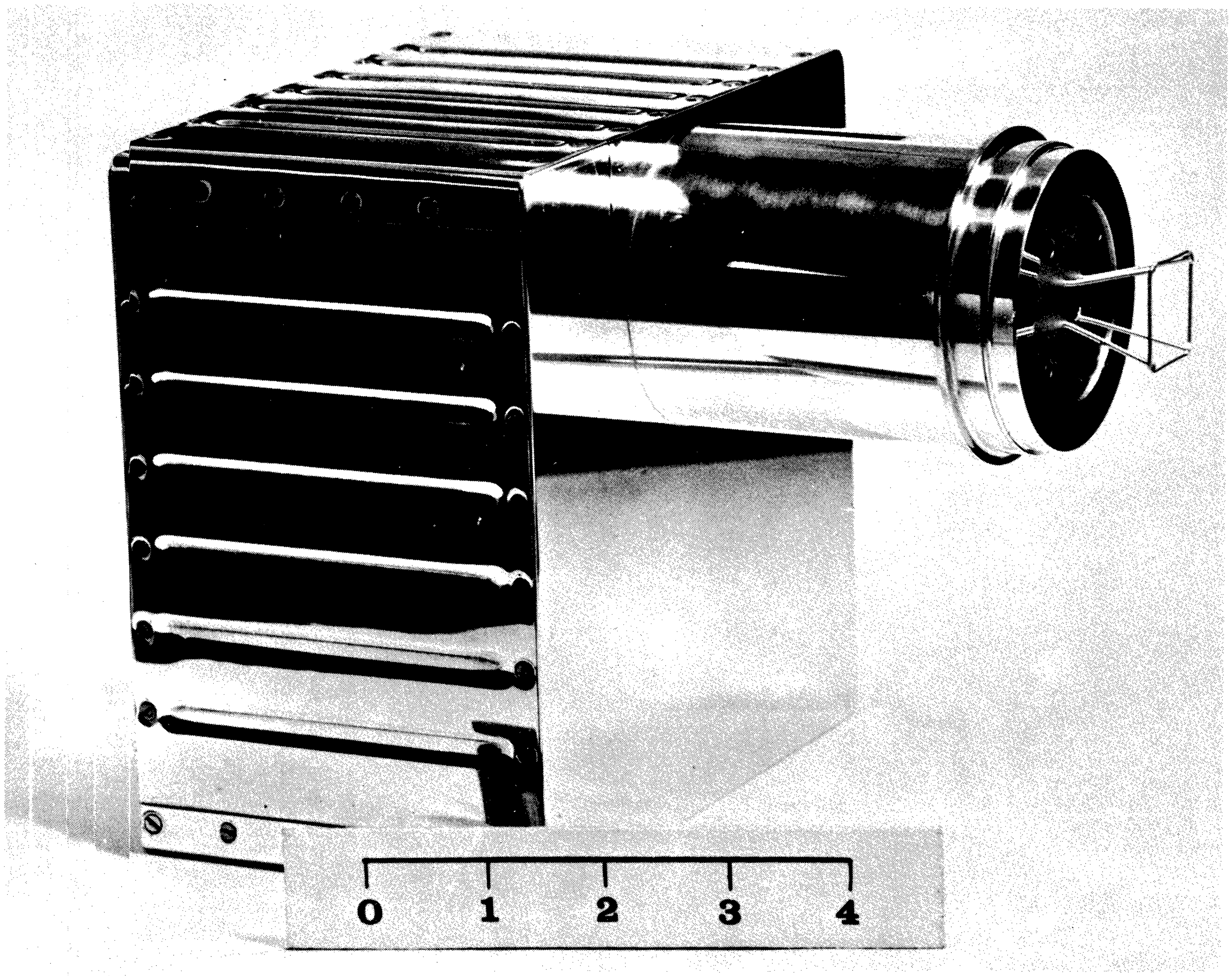
ANN ARBOR. MICHIGAN

DRAWING NO.: H1 50055 -00

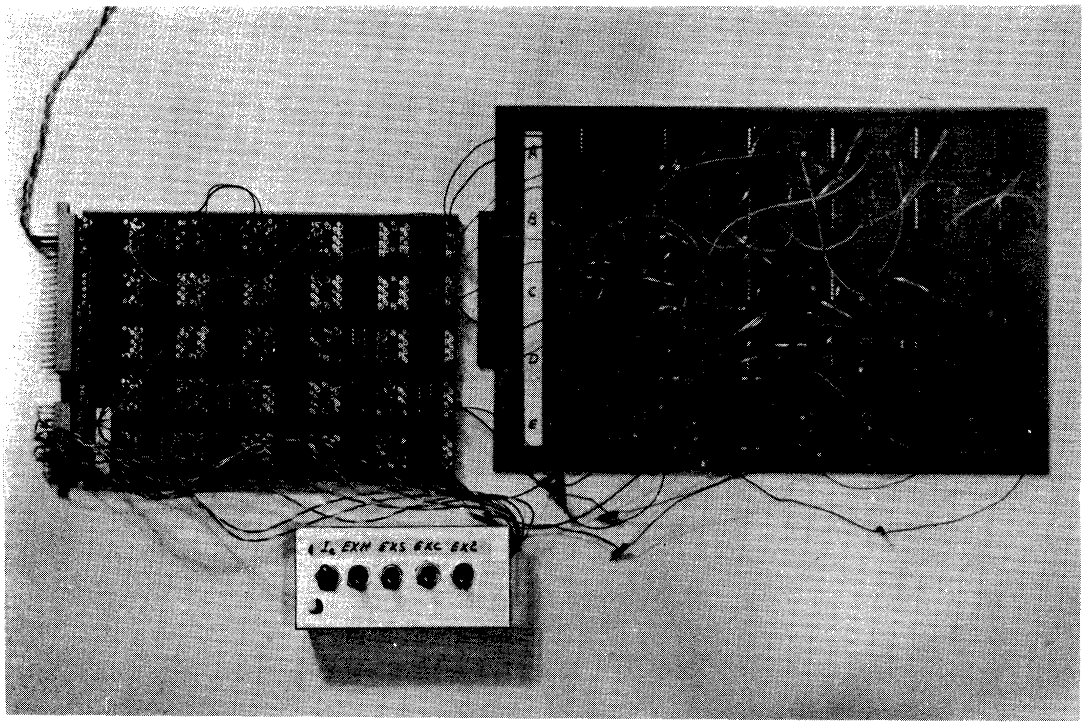
FILAMENT TEST ADAPTOR PLUG ASSIGNMENTS

Figure 21



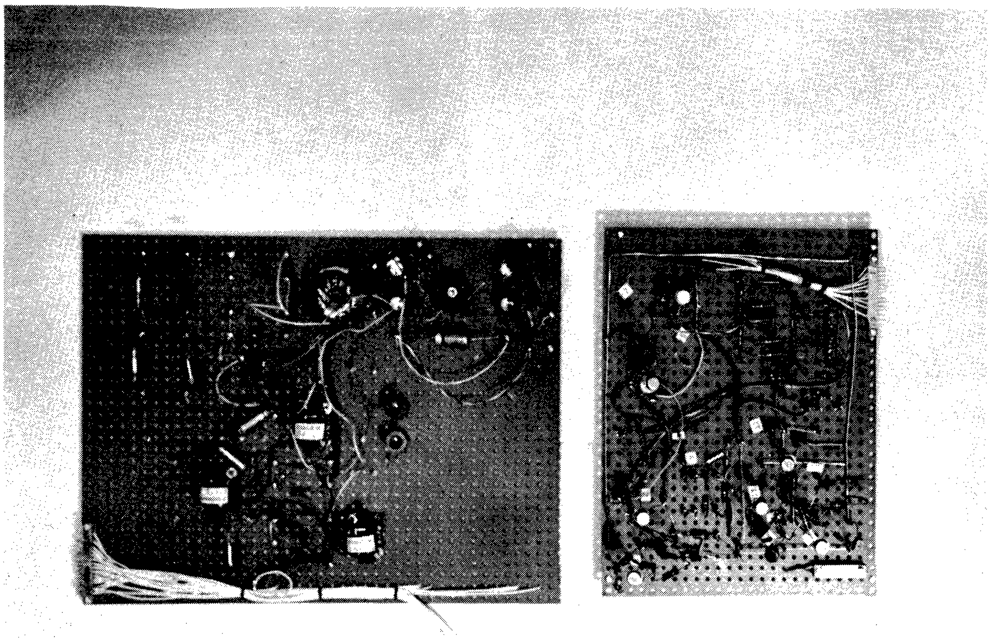
T-030 EXPERIMENT MOCK-UP

Figure 22



LOGIC CIRCUIT BREADBOARDS

Figure 23



POWER SUPPLY BREADBOARDS
(Preliminary)

Figure 24