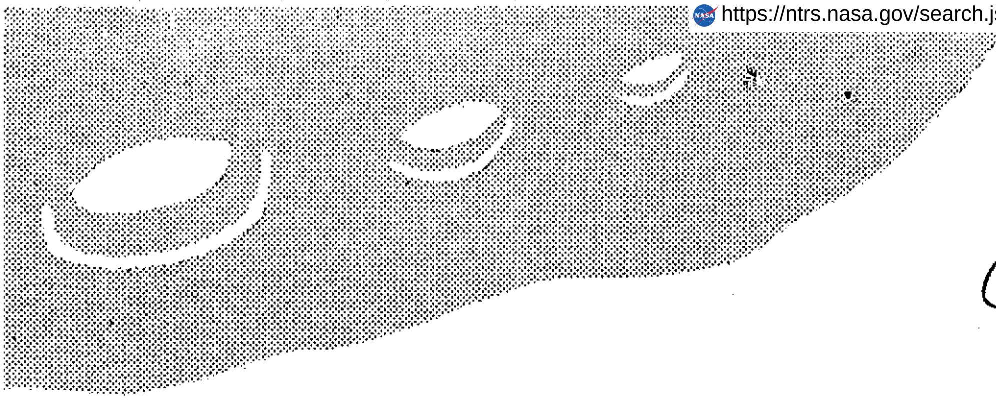


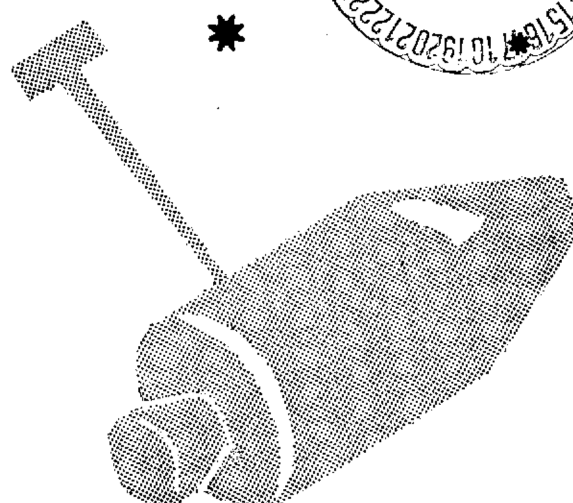
CR-134185

LUNAR ORBITAL MASS SPECTROMETER EXPERIMENT

NASA CONTRACT NO. NAS 9-10410

FINAL REPORT

(NASA-CR-134185) LUNAR ORBITAL MASS SPECTROMETER EXPERIMENT Final Report (Texas Univ.) 193 p HC $12.75 CSCL 14B
N74-17160
Unclas
G3/14 30457



THE UNIVERSITY OF TEXAS AT DALLAS
DALLAS, TEXAS

THE UNIVERSITY OF TEXAS AT DALLAS

Dallas, Texas

Document No. 151-070

15 September 1971

TYPE I DOCUMENT

LUNAR ORBITAL MASS SPECTROMETER EXPERIMENT

FINAL REPORT

Contract No. NAS 9-10410

Prepared by: W. P. Lord
Research Engineer Associate

Reviewed by: W. W. Wright
Project Manager, Test Equipment and Electronics

Reviewed by: V. A. Blevins
Project Manager, Mechanical

Approved by: J. H. Hoffman
Principal Investigator

Reviewed by: H. D. Hammack
Project Manager, Test and Check-Out

Approved by: D. R. York
Program Manager

Approved by: James M. Carroll
Project Manager, R & QA

RELEASE NOTICE

This report was prepared for release on 15 September 1971 as a contract line item. Preliminary release of sections 1 through 9 was made at that time. Final release was delayed until 15 November 1973 to permit the inclusion of final cost figures, in section 10, and a summary of scientific findings, Appendix A.

SUMMARY OF NAS9-10410 PROGRAM

The NAS9-10410 Contract was essentially the design, development, manufacture, test and calibration of five lunar orbital mass spectrometers with the four associated ground support equipment test sets. A mass spectrometer was installed in the Apollo 15 and one in the Apollo 16 Scientific Instrument Module (SIM) within the Service Module at the NASA Kennedy Space Center (KSC).

The Apollo 15 mass spectrometer was operated with collection of 38 hours of mass spectra data during lunar orbit and 50 hours of data were collected during transearth coast. The Apollo 16 mass spectrometer was operated with collection of 76 hours of mass spectra data during lunar orbit. However, the Apollo 16 mass spectrometer was ejected into lunar orbit upon malfunction of spacecraft boom system just prior to transearth insection (TEI) and no transearth coast data was possible.

UTD provided both the hardware engineering design and manufacturing for all equipment. In addition, UTD scientists served as the Principal Investigator and Co-Investigator for the scientific definition and support of the hardware during all phases of the program through installation in the space craft. The UTD PI and CO-I operated the Apollo 15 and 16 experiments from NASA/MSC mission control and subsequently analyzed all mass spectra data recovered.

This contract was commenced on 31 October 1969 and closed on 30 September 1973 with total cost of $2,015,180. The ultimate scientific value of this contract will be further extended when orbital data are correlated with the mass spectra data gathered from the Apollo 17 lunar surface mass spectrometer LACE instrument on Contract NAS9-12074.

TABLE OF CONTENTS

Paragraph		Page

SECTION 3 - ELECTRICAL DESIGN (Continued)

SECTION 4 - ENVIRONMENTAL PARAMETER DESIGN

Paragraph		Page

SECTION 4- ENVIRONMENTAL PARAMETER DESIGN (Continued)

SECTION 5 - MANUFACTURING AND R & QA STANDARDS

SECTION 6 - GROUND SUPPORT EQUIPMENT

Paragraph		Page

SECTION 7 - TEST AND CALIBRATION

Paragraph		Page

SECTION 7 - TEST AND CALIBRATION(Continued)

SECTION 8 - FLIGHT CHECK-OUT

SECTION 9 - GROUND DATA HANDLING

LIST OF ILLUSTRATIONS

LIST OF TABLES

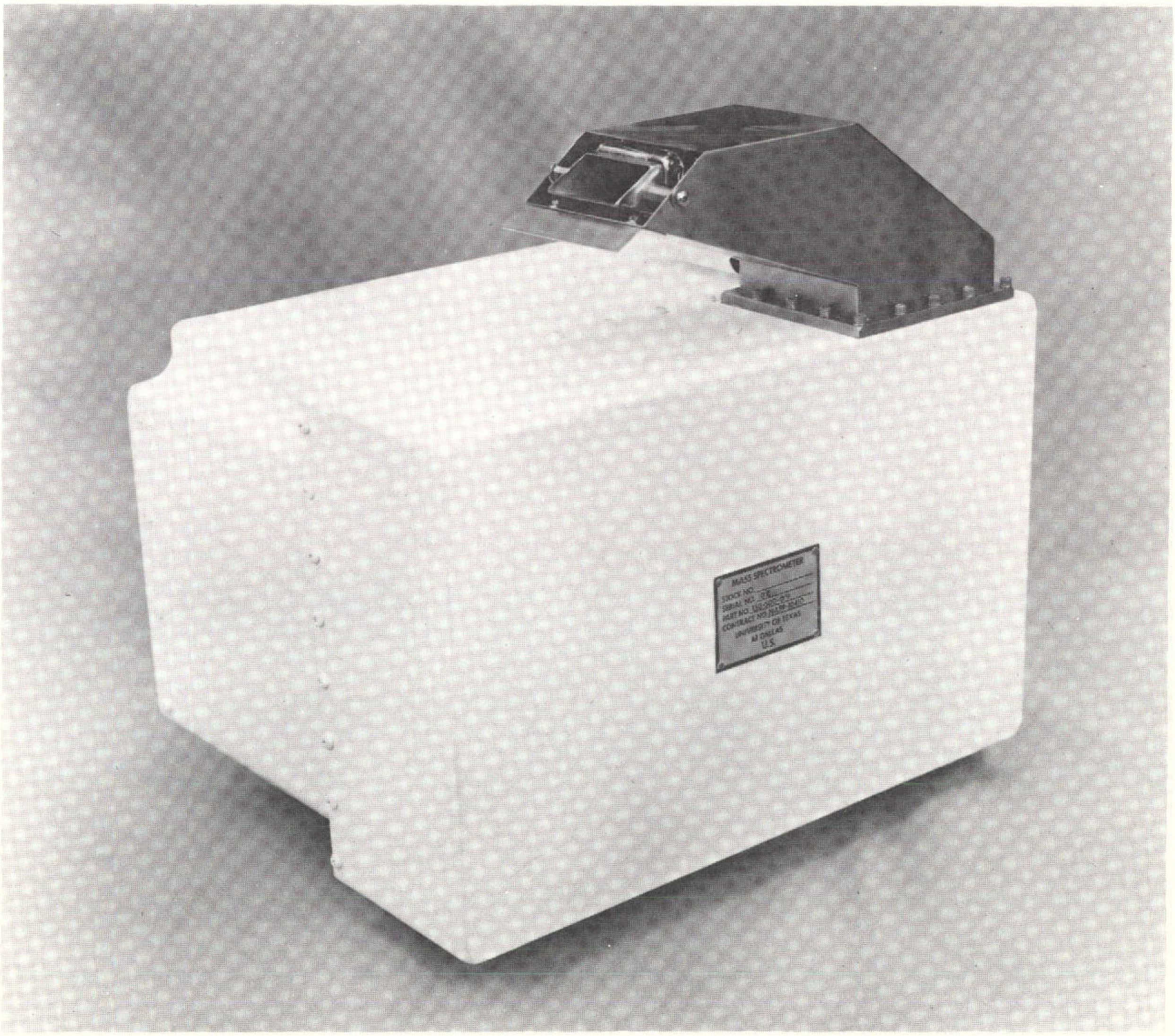


Figure 1-1. Apollo 16 Lunar Orbital Mass Spectrometer

SECTION 1

INTRODUCTION

1.1 GENERAL DESCRIPTION

The Lunar Orbital Mass Spectrometer Experiment (LOMSE) was developed by The University of Texas at Dallas for the Apollo 15 and 16 missions under NASA Contract NAS 9-10410.

Scientific objectives of the experiment are to obtain data on the composition and distribution of the lunar ambient atmosphere, and to detect transient changes in its composition. Data from the experiment will permit study of the lunar atmosphere sources, sinks and transport mechanisms. Detection of changes in the composition permits study of gases venting from the lunar surface or originating from man made sources.

The experiment instrument is a magnetic deflection type of mass spectrometer mounted on a 24-foot boom extending from the Scientific Instrument Module in Bay 1 of the Apollo Service Module. Dimensions of the instrument are 11.7 x 12.4 x 8.9 inches, and the weight is 25 pounds.

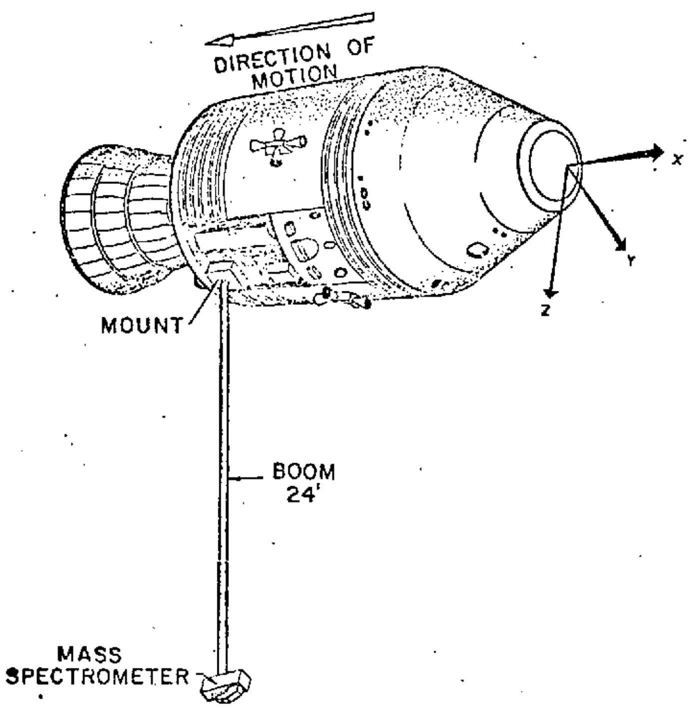


Figure 1-2. Mass Spectrometer Operational Configuration

The instrument analyzes the gases it collects by determining the concentrations of each species of molecule with mass number between 12 and 66 atomic mass units (amu). Its gas inlet plenum faces away from the spacecraft and is oriented in the -X direction of the Command and Service Module (CSM) to minimize collection of contaminant gases vented from the CSM. When the spacecraft is oriented to orbit the moon with the -X axis forward (flying backward) the native gases of the lunar atmosphere are literally scooped into the plenum in an action similar to the collection of bugs by a nighthawk flying with its mouth wide open. To determine the background contamination from the CSM, the +X spacecraft axis is pointed forward preventing native gases from entering the plenum.

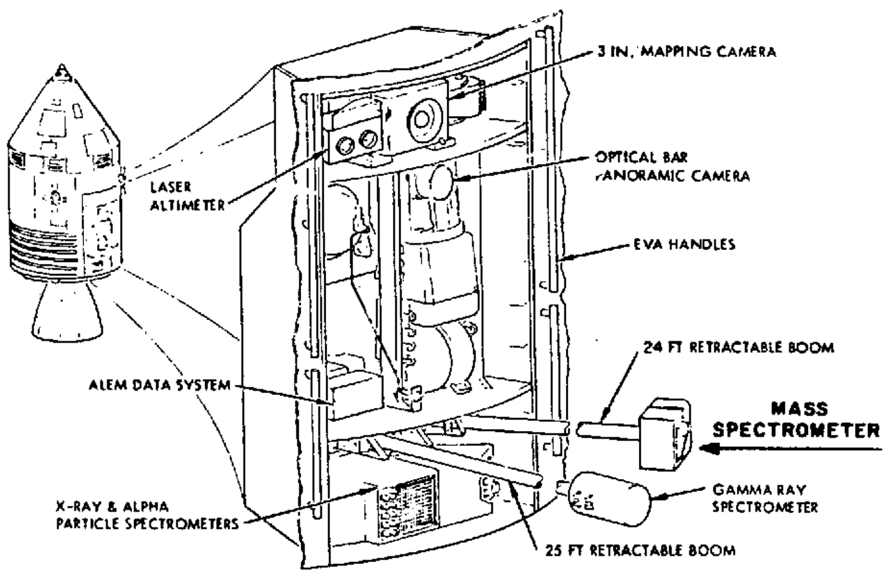


Figure 1-3. Scientific Instrument Module

Experiment operation occurs as the CSM orbits the moon, first in a 60 x 8 nm orbit, then in a 60 x 60 nm orbit while the lunar module is on the surface. Five switches on panel 230 of the Command Module activate the instrument and control the experiment modes as well as extension and retraction of the boom. These switches are operated by the astronaut since there is no direct control of the instrument from Earth.

Data are transmitted to Earth in real time via the Scientific Data System (a 64-kilo bit telemeter system) when on the Earth side of the Moon and stored in a tape recorder on the back side for subsequent transmission during the next Earth-side pass. Quick-look data are evaluated by the Principal Investigator as the mission progresses to determine optimum operational modes of the instrument. Final data processing will be by computer at The University of Texas at Dallas.

1.2 EQUIPMENT SUPPLIED

The following listed equipment was supplied:

- Mass Mockup
- High Fidelity Mockup
- Prototype Unit
- Qualification Unit
- Flight Unit No. 1
- Flight Unit No. 2
- Flight Unit No. 3
- Console Bench Test Equipment No. 1
- Console Bench Test Equipment No. 2
- Portable Ground Support Equipment

1.3 PRINCIPLES OF OPERATION

The LOMSE instrument package consists of two major units, the Analyzer Unit and the Electronics Unit. Identification of gas types and concentrations is performed by the Analyzer Unit while the counting and processing of data is performed by the Electronics Unit, which also supplies power and housekeeping functions.

Three operations are performed in the identification and measurement of gas molecules. First, neutral gas molecules from the lunar atmosphere enter the instrument plenum which points along the spacecraft's direction of motion and acts as a scoop. These molecules are bombarded by an electron beam in an ion source to produce ions.

The ions are then accelerated by an electric field and mechanically collimated into a beam that passes into a magnetic field wherein the ions are sorted to follow trajectories that are functions of the ion mass and energy. Two special trajectories lead to two collector slits where the ions are detected.

The second operation is the counting of ions that arrive at the two collector slits by type and quantity in each of two atomic mass unit ranges (12 to 28 amu and 28 to 66 amu). As the counting progresses, the third operation taking place is the formating of a compressed data word which conveys the information to Earth on the down-link telemetry channel.

Operation of the instrument is monitored by housekeeping functions which are also transmitted on the down-link telemetry channels. Power for circuit operation is developed by internal power supplies that provide voltages ranging from 5 volts to 1800 volts. Input power to the instrument is from the spacecraft 27.5 volt supply.

1.3.1 ANALYZER OPERATION

Five major components and associated power supplies make up the analyzer unit of the instrument. These components are as follows: (1) Plenum, (2) Ion Source, (3) Magnet, (4) Low-Mass Electron Multiplier, and (5) High-Mass Multiplier.

The Plenum is pointed along the spacecraft −X axis and acts as a scoop through which gases are rammed due to the motion of the spacecraft when it is flying backwards. Gas molecules emanating from the spacecraft are discriminated against due to the geometry of the Plenum. From the Plenum, molecules are directed into the Ion Source region where electron bombardment yields charged particles (ions) from the neutral molecules.

The Ion Source component employs two identical tungsten filaments one of which is heated to emit electrons and serves as a cathode, and the other which is unheated acts as an anode. In the event of failure of the number one filament, the number two filament will be heated and cathode-anode roles reversed, thus providing a redundant feature.

As a neutral gas molecule encounters the electron beam between the two filaments, one or more electrons may be dislodged. The resulting ions are drawn out of the ionizing region and collimated into a beam by a set of focusing slits and a pair of grounded slits. The velocity of the ion is a function of the voltage applied to the ion source.

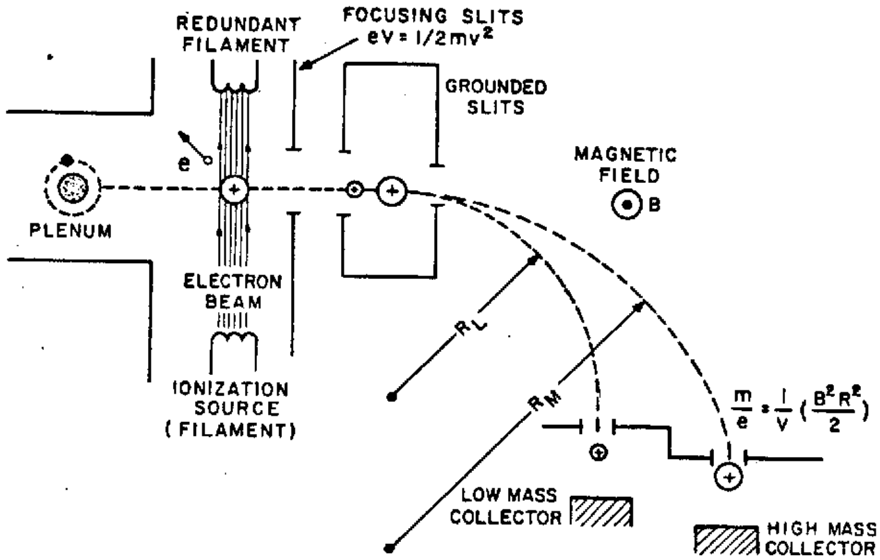


Figure 1-4. Theory of Analyzer Operation

As an ion emerges from the grounded slits, it enters a uniform magnetic field produced by a permanent magnet. The momentum of the ion determines its trajectory in the magnetic field, which has a flux density of 4,650 gauss. Two special trajectories of 1.637 and 2.500 inch radii determine the location of collection slits for the low-mass and high-mass ion detectors.

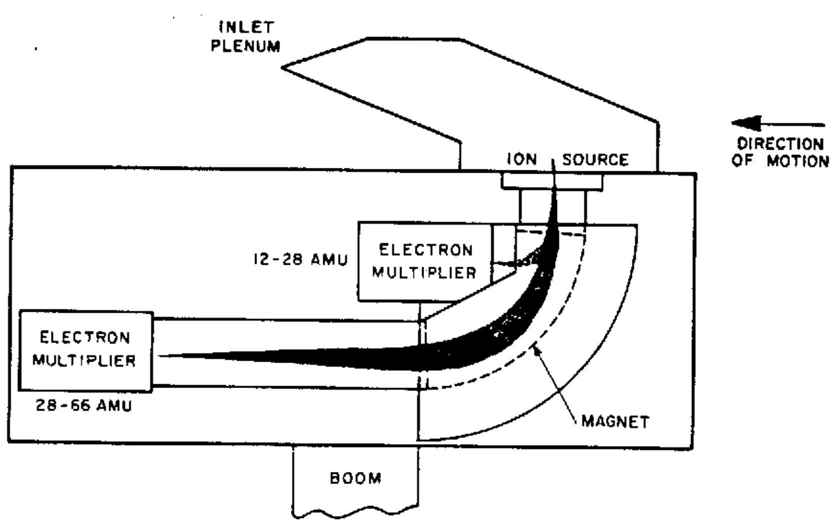


Figure 1-5. Analyzer Trajectories

The design equation for the analyzer is as follows:

$$\frac{M}{E} = K \frac{B^2R^2}{V}$$

where:

B = Magnetic Field Strength in Magnet Gap = 4650 Gauss

R = Radius of Curvature of Ion Trajectory in Magnetic Field = 1.637", 2.500"

V = Ion Accelerating Voltage = 620 to 1560 Volts

K = Constant = 3.3×10^{-4}

M = Ion Mass (AMU)

E = Electronic Charge (Units of E)

As can be seen from the equation, varying V causes ions of different mass to reach the collector slits. In this manner the mass spectrum is produced. The voltage, V, is varied in a step-wise manner from approximately 620 volts to 1560 volts in 590 steps. This voltage range causes ions in the mass range of 12 - 28 amu to be focused on the low-mass collector slit and, simultaneously, ions in the mass range of 28 - 66 amu to be focused on the high-mass slit. The following illustration shows in a typical mass spectrum the number of different kinds of gases in a vacuum chamber when pumped to a partial pressure of 1×10^{-8}torr. The ordinate is a log scale proportional to the partial pressure of the gas being observed. The mass scale is given along the abscissa.

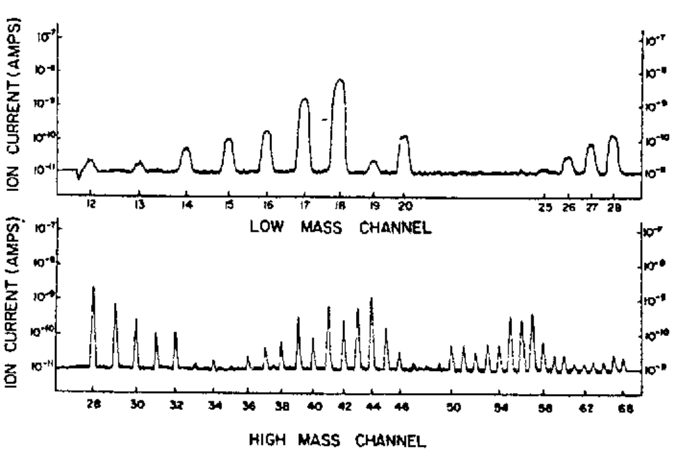


Figure 1-6. Mass Spectrum

Dwell time on each step of V is 1/10 second, thus requiring 59 seconds to scan the entire spectrum. As a result, the partial pressure sensitivity of the instrument is on the order of 10^{-13} torr (or 10^{-16} atmospheres). The minimum number of steps per mass number below mass 54 is 12; and, the mass resolution is such that at mass 39 amu there is less than 0.3 percent contribution from the mass 40 (argon) peak. The voltage step number which determines V in the equation, determines the mass of ion being detected at each collector slit. Ions passing through each collector slit impinge on an electron multiplier which amplifies the resulting charge pulse to one suitable to activate a counting system.

Operation of the electron multipliers is best understood by examining the action resulting from the impact of a single ion. The following simplified diagram illustrates the process.

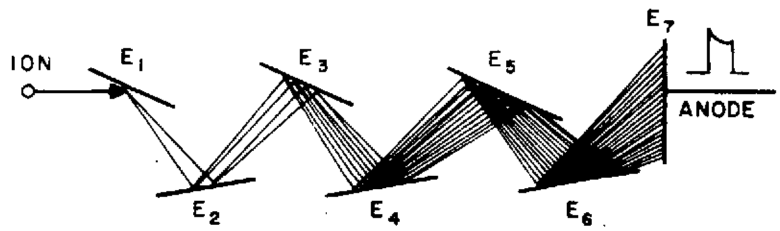


Figure 1-7. Multiplier Action

An ion is attracted by voltage E_1 and strikes the first dynode at very high velocity. Striking the plate, it dislodges, say two electrons which are attracted to the second dynode by voltage E_2. Each of these two electrons dislodges perhaps two more which are attracted on down the sequence releasing more and more electrons until there are enough electrons at the anode to generate an electric charge pulse of sufficient amplitude for detection by the pre-amplifier.

Gain of the multipliers is adjustable to either a high-gain or low-gain level by the MULTIPLIER HIGH/LOW switch, on panel 230, which controls the high voltage applied to the multiplier. The normal operation mode is LOW gain, but the HIGH gain position may be used if the multiplier gain should decrease during flight.

1.3.2 ELECTRONICS UNIT

Functional operations of the Electronics Unit consist of (1) emission control (control of electron current in the ion source), (2) pulse amplification and discrimination, (3) counting and data compression, (4) monitoring of temperatures, voltages and circuit operation, and (5) power supplies. Additional operations include the counting system and internal calibration.

The pre-amplifiers/discriminators following each multiplier perform two functions in addition to amplifying the pulse. One function is to divide the data count by two to reduce the frequency response requirements of the counting system. The other function is a discriminating operation that prevents noise from being counted as ion counts. Two discriminator levels are selectable by command. Normally, their high level setting is used, but in a high background noise situation the low level may be selected to reduce the background without significantly affecting the signal.

Discriminator level is controlled by the DISCRIMINATOR HIGH/LOW switch on panel 230. An ion pulse exceeding the discriminator level causes the discriminator to conduct and produce a valid pulse output to a counting circuit.

In processing the data, the Counting and Data Compression Sub-assembly first counts the number of ion pulses detected during each ion-accelerating voltage-step and stores the count in a 21-bit binary register. A maximum of two million pulses may be counted on each data step (equivalent to 10^{-7} torr). Switching logic compresses the 21-bit count to a special 10-bit code while maintaining 7-bit accuracy of the data. Data are telemetered in the 10-bit code format. Special programming of the ground computer decompresses the code and restores the original data count.

Synchronization of the data words to the spacecraft data system is accomplished by generating a sync pulse from one of the 10 pps telemetry word gates enabling the ground computer to keep track of the significance of the various parts of the data words. The sync pulse also is used to step the ion accelerating sweep voltages, and to control the housekeeping and monitoring data outputs.

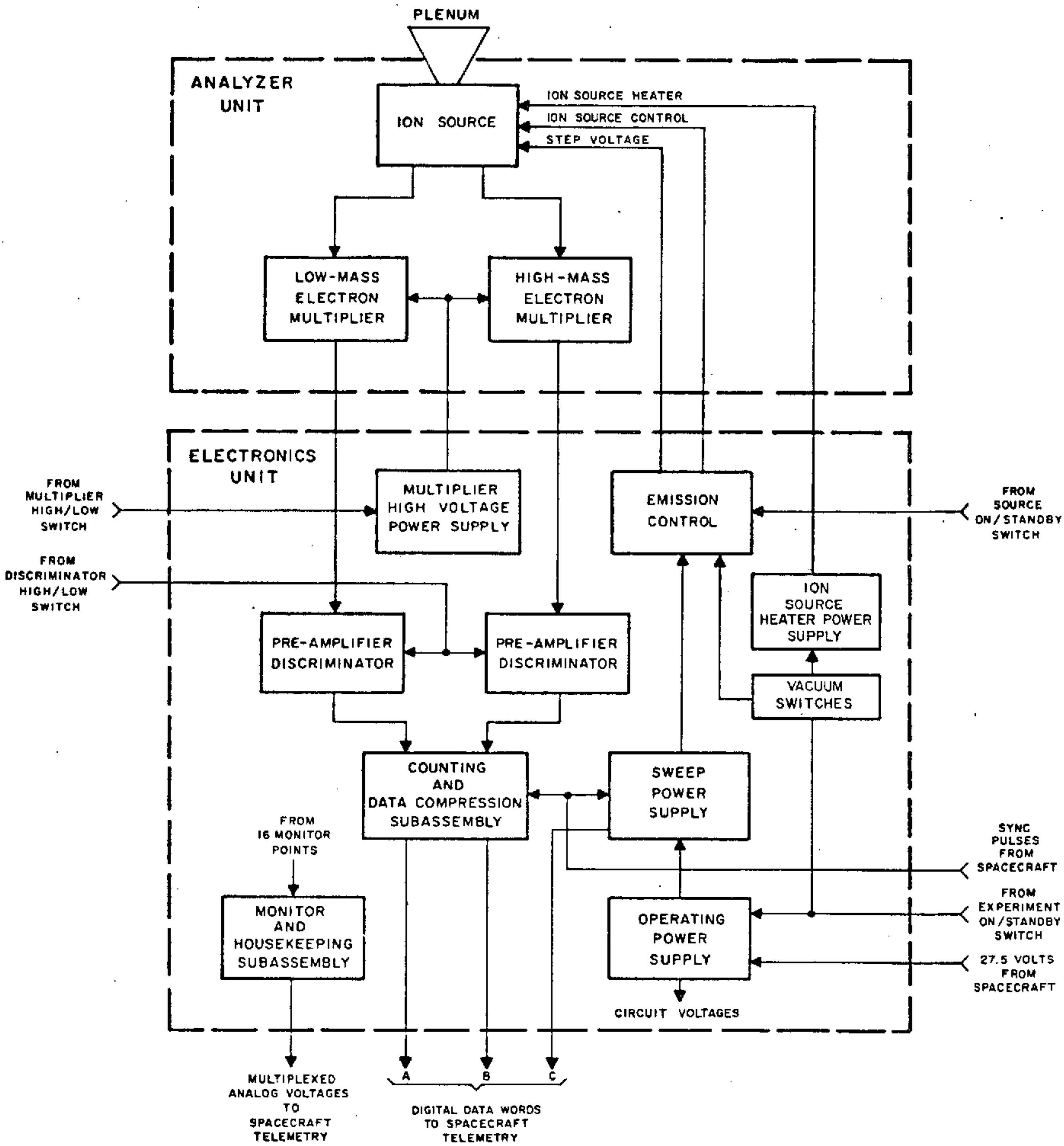


Figure 1-8. Functional Diagram

1.4 MISSION REQUIREMENTS

Three types of data-collection operations are planned.

Lunar data collection in the −X direction of flight

Lunar background data collection in the +X direction of flight

Data collection during trans-Earth-coast with varying boom lengths

Two complete revolutions per data collection period, with a minimum of three periods, are required to obtain primary data from the experiment. It is desired that data be taken from four or more orbital revolutions per period, and also that data be taken during all −X flight periods.

The most interesting scientific regions are the terminator sections and it is desired that whenever possible data be obtained within 15 degrees either side of the terminators.

One background data collection period is required in which case the spacecraft axis will be pointed in the +X direction of flight and the experiment operated for one revolution. Background data collection will be best performed near the end of the lunar orbit experiment. This operation is not to compromise the primary (−X) data collection requirements.

An additional data collection period occurs when the spacecraft is in the trans-Earth-coast portion of the mission. This period must be timed to be not less than six hours after trans-Earth injection. Data collection will occur for one hour, or more, with the boom fully extended. Then, during five 7-minute intervals with the boom retracted in increments of 1/5 boom length until the final step which occurs with the boom locked in the fully retracted position.

The boom and experiment package must be fully stowed during EVA to retrieve film from other experiments.

1.5 OPERATIONAL PROCEDURES

In addition to procedures for the three types of data collection, there is also a procedure required for initial Ion Source heater operation prior to data collection operations. Tables 1-1 through 1-4 list the procedural steps of each type of operation.

TABLE 1-1. INITIAL OPERATION

STEP	OPERATION
1	Inhibit effluent dump one hour before, and during, the following operations.
2	Inhibit RCS jets impinging on the experiment during the following operations.
3	Verify boom fully extended.
4	Place EXPERIMENT switch to STANDBY.
5	Place SOURCE switch to STANDBY
6	Maintain this configuration with source heater operating for six hours. Orientation of spacecraft is not critical during this time. Boom must remain fully extended.
7	If effluent dumps are required or if boom retraction is required, place SOURCE switch OFF 15 minutes before and leave OFF for one hour following dump or retraction. Add one-half hour to the cumulative 6-hour heater operation time for each interruption.
8	Inhibit effluent dump two hours before data collection period.
9	Operate source heater continuously for one hour before initial data collection period.

TABLE 1-2. LUNAR DATA COLLECTION PROCEDURE

STEP	OPERATION
1	Complete initial operation procedure.
2	Verify effluent dump inhibited for two hours prior to, and during, data collection period.
3	Inhibit RCS jets impinging on the experiment during the following operations.
4	Verify boom fully extended.
5	Verify SOURCE and EXPERIMENT switches in STANDBY for 30 minutes prior to data collection period.
6	Orient spacecraft for −X direction of flight.
7	Place DISCRIMINATOR switch to HIGH.
8	Place MULTIPLIER switch to LOW.
9	Place SOURCE switch to OFF.
10	Place EXPERIMENT switch ON.
11	Place SOURCE switch ON.
12	Advise Mission Control of task completion and status.
13	Operate DISCRIMINATOR and MULTIPLIER switches as requested by Mission Control.
14	Maintain spacecraft X-axis within ±5° with respect to the velocity vector.
15	Maintain this configuration for a minimum of two revolutions per data collection period. Data is desired during all −X flight times, particularly in regions within 15 degrees of terminators.

TABLE 1-3. BACKGROUND DATA COLLECTION

STEP	OPERATION
1	Verify effluent dump inhibited for two hours prior to, and during, data collection period.
2	Inhibit RCS jets impinging on the experiment during the following operations.
3	Verify boom fully extended.
4	Place EXPERIMENT switch to STANDBY.
5	Place SOURCE switch to STANDBY.
6	Maintain this configuration with source heater operating for 30 minutes. Orientation of spacecraft not critical during this time. Boom must remain fully extended.
7	Orient spacecraft for +X direction of flight.
8	Place DISCRIMINATOR switch to HIGH.
9	Place MULTIPLIER switch to LOW.
10	Place SOURCE switch to OFF.
11	Place EXPERIMENT switch ON.
12	Place SOURCE switch ON.
13	Advise Mission Control of task completion and status.
14	Operate DISCRIMINATOR and MULTIPLIER switches as requested by Mission Control.
15	Maintain spacecraft X-axis within $\pm 5°$ with respect to the velocity vector.
16	Maintain this configuration for a minimum of one revolution.

TABLE 1-4. TEC DATA COLLECTION

STEP	OPERATION
1	Verify that time of data collection is more than six hours after trans-Earth-injection.
2	Verify effluent dump inhibited for one hour prior to, and during data collection period.
3	Inhibit RCS jets impinging on the experiment during the following operations.
4	Verify that boom is fully extended. Ion Source heater operation may be performed with boom retracted to one-half boom length if necessary.
5	Place EXPERIMENT switch to STANDBY.
6	Place SOURCE switch to STANDBY.
7	Maintain this configuration with source heater operating continuously for three hours.
8	Place DISCRIMINATOR switch to HIGH.
9	Place MULTIPLIER switch to LOW.
10	Extend boom to full length if operating at less than full length.
11	Place SOURCE switch to OFF.
12	Place EXPERIMENT switch to ON.
13	Place SOURCE switch ON.
14	Advise Mission Control of status.
15	Operate DISCRIMINATOR and MULTIPLIER switches as required by Mission Control.
16	Maintain this configuration for one hour.
17	Upon completion of one hour of data collection (additional time may be used), retract the boom five feet.
18	Operate in this configuration for seven minutes.

TABLE 1-4. TEC DATA COLLECTION

STEP	OPERATION
19	Retract the boom an additional five feet.
20	Continue to obtain data in 7-minute intervals and retracting the boom five feet for each interval until the boom is fully stowed. The last external position may be more accurately determined if the boom is fully retracted and then deployed to a position four feet from the spacecraft. Operate for seven minutes with the boom fully stowed.

1.6 TEST AND CALIBRATION

Test of the instrument during manufacture requires test equipment to simulate both the command and power functions of the spacecraft and the data readout capability of Mission Control. Bench test equipment was built to perform these operations.

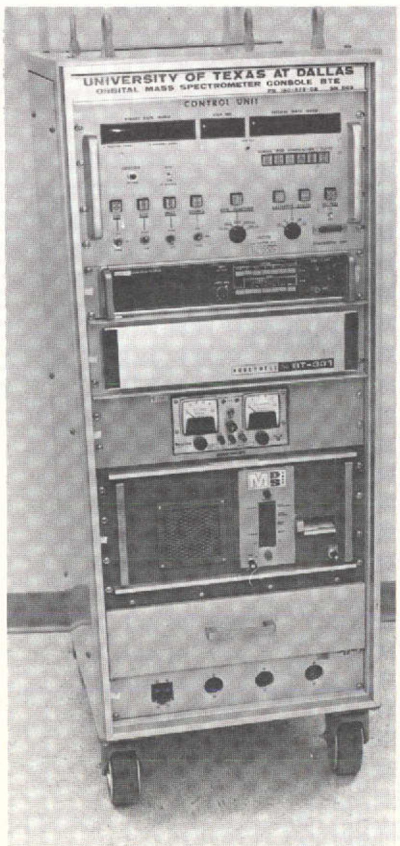


Figure 1-9. Bench Test Equipment

As the experiment is designed to be operated only in an ultra-high vacuum, such as the very rarified lunar atmosphere, all testing and calibration of the instrument is done in an ultra-high vacuum system. The vacuum chamber at The University of Texas at Dallas was used for alignment, functional test and initial calibration of the instrument.

Absolute calibration was done at the molecular beam facility at NASA Langley Research Center, Virginia, using molecular beams of known fluxes of such gases as Neon and Argon to determine the sensitivity and linearity of the instrument.

Instrument checkout at Kennedy Space Center employs both the console bench test equipment and a special, suitcase-type test set. Upon arrival at Kennedy, the instrument undergoes extensive testing using the bench test equipment. After the instrument is mated to the spacecraft the suitcase test set is used.

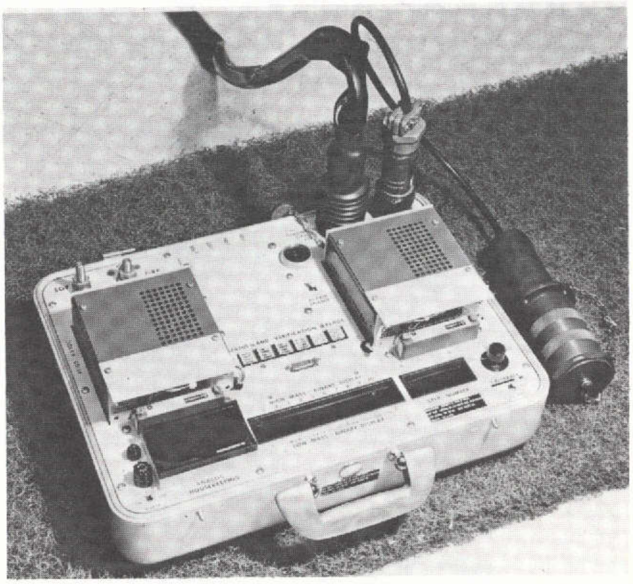


Figure 1-10. Portable Suitcase Test Set

In addition to the operational tests, the instrument received extensive environmental tests, including vibration, shock, and thermal-vacuum testing. These tests subjected the instrument to environmental conditions similar to those encountered in launch and in the temperature extremes of deep space and lunar orbit.

All final testing was carried out under the supervision of NASA Quality Assurance Inspectors.

1.7 DATA UTILIZATION

There are several areas of lunar study to which reliable data from a lunar atmosphere experiment are applicable. The information is important in investigating the probability of noble gases, carbon dioxide, carbon monoxide, hydrogen sulfide, ammonia, sulphur dioxide, and water vapor being released by lunar volcanism and from rocks and magma. Argon, for example, would be a particularly significant gas to study because of its relationship to the K—Ar dating process. Also, its isotopic composition would be of interest as the different isotopes have different origins and production mechanisms.

Mechanisms of release of gases from the surface, e.g. solar wind bombardment or volcanism, perhaps can be affirmed by knowing what the effluent gases are. Likewise, data on released gases may afford some knowledge of the chemical processes underlying the lunar surface.

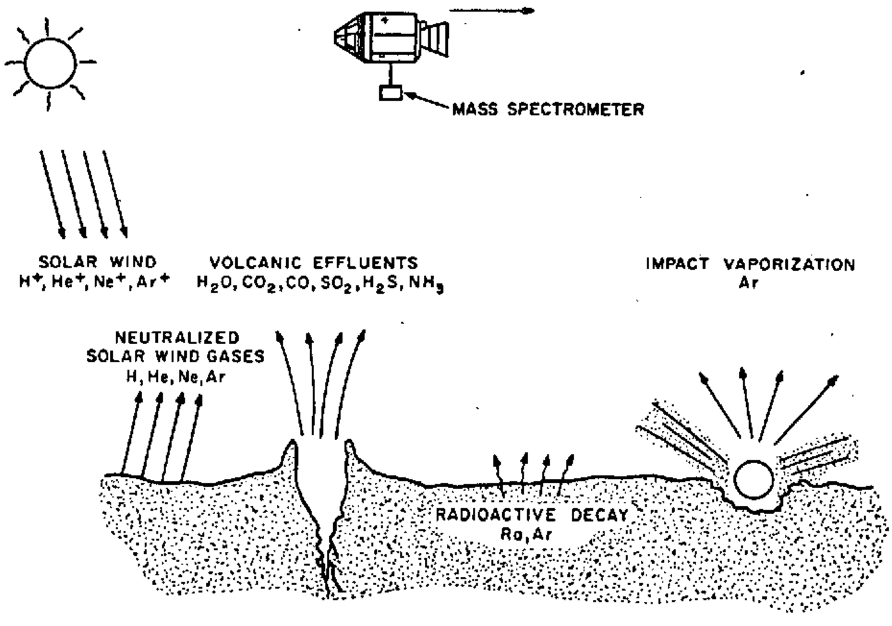


Figure 1-11. Sources of the Lunar Atmosphere

Firing of the ascent rocket of the lunar landing module is a good example of a known point source of gas on the lunar surface. The rate of spreading of this gas cloud around the Moon can be studied by the mass spectrometer in orbit, and transport rates for the various gases calculated. Also, the escape rates of gases of various molecular weights can be determined. Some of the gases from the rocket will be adsorbed on the lunar surface materials, and the outgassing rates of the adsorbed gases will be measured. From this information, the amount of contamination of the lunar atmosphere due to the firing of rocket motors near the surface can be estimated.

Finally, the experiment will provide a means for determining the natural distributions of gases in the lunar atmosphere. This information is essential if the sources, sinks, and transport of these gases are to be understood. Since the lunar atmosphere is a classical example of an exosphere, its global structure can be used to test theories on exospheric transport, which is an important process in the terrestrial atmosphere.

The distribution of neon and argon illustrate how experiment data will contribute to this facet of study. It has recently been shown that light gases with negligible production and loss rates tend to be distributed at the lunar surface as the inverse 5/2 power of temperature, while heavier gases are influenced by rotation of the Moon. Neon falls into the former category, and its concentration on the dark side is expected to be about 32 times that on the sunlit side.

Argon, being heavier, is expected to be noticeably influenced by rotation of the Moon, having slightly less dirunal variation than neon, and a longitudinal shift of its maximum toward sunrise, resulting in a concentration at sunrise that is about two times that at sunset.

Water vapor, and other condensable gases probably exist in the lunar atmosphere, but not on the dark side or near the poles where the surface temperature is below 100°K and adsorption removes every particle that comes in contact with the surface. Gases adsorbed in continuously shadowed regions near the poles are unlikely to re-enter the atmosphere, but at lower latitudes the rotation of the Moon exposes adsorbed gases to sunlight where they are released into the atmosphere. Since heating of the surface occurs rapidly at sunrise, this release probably occurs entirely within a few degrees longitude from the sunrise terminator, creating a pocket of gas. Whether this dawn enhancement can be detected at satellite altitude is speculative, depending mainly on the abundance of these gases in the lunar atmosphere.

Experiment data will enable more comprehensive studies of Earth's environment in that the Moon provides a working model to check theories and theoretical techniques. Earth's atmosphere and oceans were released from the interor by degassing and are acted upon by solar radiation in the same manner as the lunar atmosphere. Studies of lunar conditions in terms of origin, composition and distribution of an atmosphere contributes to a better understanding of Earth.

SECTION 2

MECHANICAL DESIGN

2.1 PHYSICAL CHARACTERISTICS

2.1.1 LOMSE ASSEMBLY

The LOMSE assembly (shown in Figure 2-1) consists of a neutral gas analyzer mounted on one side of a baseplate and its associated electronics mounted on the opposite side. These major constituents are discussed in Paragraphs 2.2 thru 2.4. The assembly is 12.43 inches long, 8.92 inches wide and 11.71 inches high, and weighs 25 pounds.

2.1.2 MASS PROPERTIES

Mass properties of the flight instrument are shown in Figure 2-2.

2.2 ANALYZER UNIT

The analyzer unit consists of a thermally controlled gas inlet plenum, a Nier-type thermionic ion source, a mass separating and focusing magnet and two drift tubes, collector slits, and Bendix magnetic electron-multipliers (MEM). In operation, neutral gas atoms and molecules collected in the inlet plenum are funneled into an ionization chamber where they are ionized by an electron beam generated by thermionic emission from a tungsten filament. The resulting positive gas ions are then collimated and accelerated by a series of slits ranging in potential from sweep voltage to ground. The gas ions then transverse a magnetic field where the gas species are separated into two mass ranges (12-28 amu and 28-66 amu as established by the radius of curvature and field strength of the magnet and the instantaneous sweep voltage in the relationship $m/e = 3.3 \times 10^{-4} Bg^2 r^2 / V$) and focused at the collector slits. Ions passing thru the collector slits are then counted by the MEM's and the resulting data is processed thru the electronics.

The cover over the analyzer unit is constructed from conetic material and serves the purpose of both protecting the unit and constraining its magnetic field. The field is further constrained by a conetic liner on the baseplate between the analyzer and electronic units. The inlet plenum and ion source are protected by a separate outer cover.

2.2.1 ION SOURCE

The ion source (shown in Figures 2-3 and 2-4) is a series of precisely machined and aligned slits (alpha, object, J-plate and drawout) and an ionization chamber attached to a rigid mounting plate.

The inlet of the ionization chamber is covered by a repeller grid which screens out ambient positive ions and constrains the positive ions generated within the chamber to flow thru the gas analyzer. Redundant tungsten filament assemblies are attached to two walls of the chamber. One assembly is used as the electron source and the second assembly as the electron trap, with control provisions for automatically switching functions of the assemblies in case of a filament failure. Heater assemblies are attached to the two remaining walls of the chamber to bake-out the source at 250°C prior to operation and to maintain the source at a constant operating temperature (See Paragraph 2.5).

The drawout slit is 0.080 inch wide and is machined into the bottom of the ionization chamber. The J-plates are positioned 0.040 inch apart and 0.080 inch below the drawout slit. The object slit is 0.003 inch wide and is positioned 0.140 inch below the J-plates. The alpha slit is 0.020 inch wide and is positioned 0.220 inch below the object slit.

A plenum is attached to the inlet of the ionization chamber to serve as both a scoop and funnel for ambient gases. Outer walls of the plenum are covered with heating elements to bake it out prior to operation and to maintain it within a fixed temperature range during operation (See Paragraph 2.5).

2.2.2 MAGNET

The magnet assembly is shown in Figure 2-5. The magnets are constructed from Columax V. The pole pieces and yoke from Armco ingot iron. The magnet face is shaped to bend the low mass ion beam (12-28 amu) on a 1.637-inch radius and the high mass ion beam (28-66 amu) on a 2.500-inch radius. A uniform magnetic field of approximately 4,650 gauss is established in the air gap of the magnet assembly.

2.2.3 MULTIPLIERS

Multipliers used in the LOMSE are Bendix Magnetic Electron Multipliers. The multipliers and associated buffer amplifiers are packaged in aluminum housings for electrostatic shielding purposes. The assemblies are insulated from high voltage and chassis ground by the use of vespel shoulder washers and spacers, and ceramic insulated terminals.

2.3 ELECTRONICS UNIT

The electronics unit consists of an electronic subassembly, an outer (support) housing, an inner (thermal) housing, a diagnostic connector housing, and associated cables. Thermal control measures designed into the electronics unit are described in paragraph 2.5.

2.3.1 ELECTRONIC SUBASSEMBLY

The electronic subassembly (shown in Figure 2-6) consists of 12 printed wiring board assemblies attached to a radiator plate. The PWB's are inter-connected thru two mother-boards and/or 4 flat, molded cable assemblies. Three additional cable assemblies and three discrete wires are attached to the electronic subassembly for interconnection with the analyzer unit. Typical PWB assemblies are shown in Figures 2-7 and 2-8.

2.3.2 OUTER HOUSING

The outer housing (shown in Figure 2-9) is constructed from molded epoxyglass. It attaches to the base plate as shown in Figure 2-1 and serves as a support for the thermal housing assembly.

2.3.3 THERMAL HOUSING ASSEMBLY

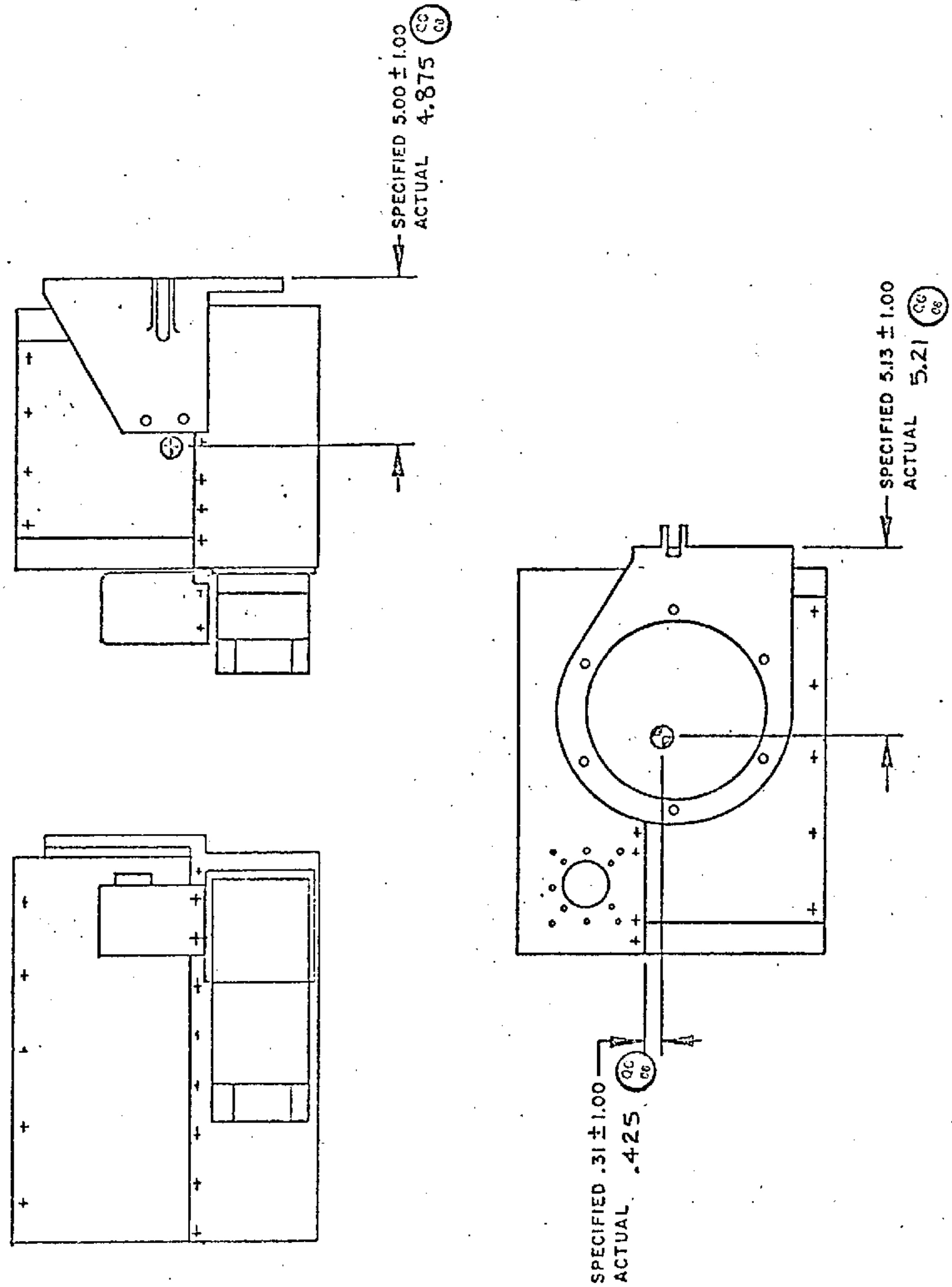
The thermal housing assembly (shown in Figure 2-10) is constructed from molded epoxyglass and the side and bottom surfaces are covered with a thermal blanket built up from alternate layers of fiberglass tissue and aluminized plastic film. It attaches to the outer housing as shown in Figure 2-1 and serves as a support for the electronic subassembly.

2.4 BASEPLATE

The baseplate (shown in Figure 2-11) is a dip brazed assembly made up of three orthoginal aluminum plates. The front and side plates contain the bolt hole patterns and clevis for attaching the LMS into the SIM bay via a deployable and retractable boom. The third plate is mutually perpendicular to the front and side plates, and serves as a mounting base for the analyzer unit on one side and for the electronic unit on the other. Cabling between the two units is routed thru cutouts in this common plate. All three plates are weight reduced by the use of hogouts and/or slots.

Page intentionally left blank

WEIGHT AND BALANCE REPORT
FOR
150-500-04 SERIAL NO. 103



CID Spec Weight is 25.00 Lbs.
Flight Instrument Spec Weight is 25.00 Lbs.
Net Weight is 24.56 Lbs.

Figure 2-2. Mass Properties

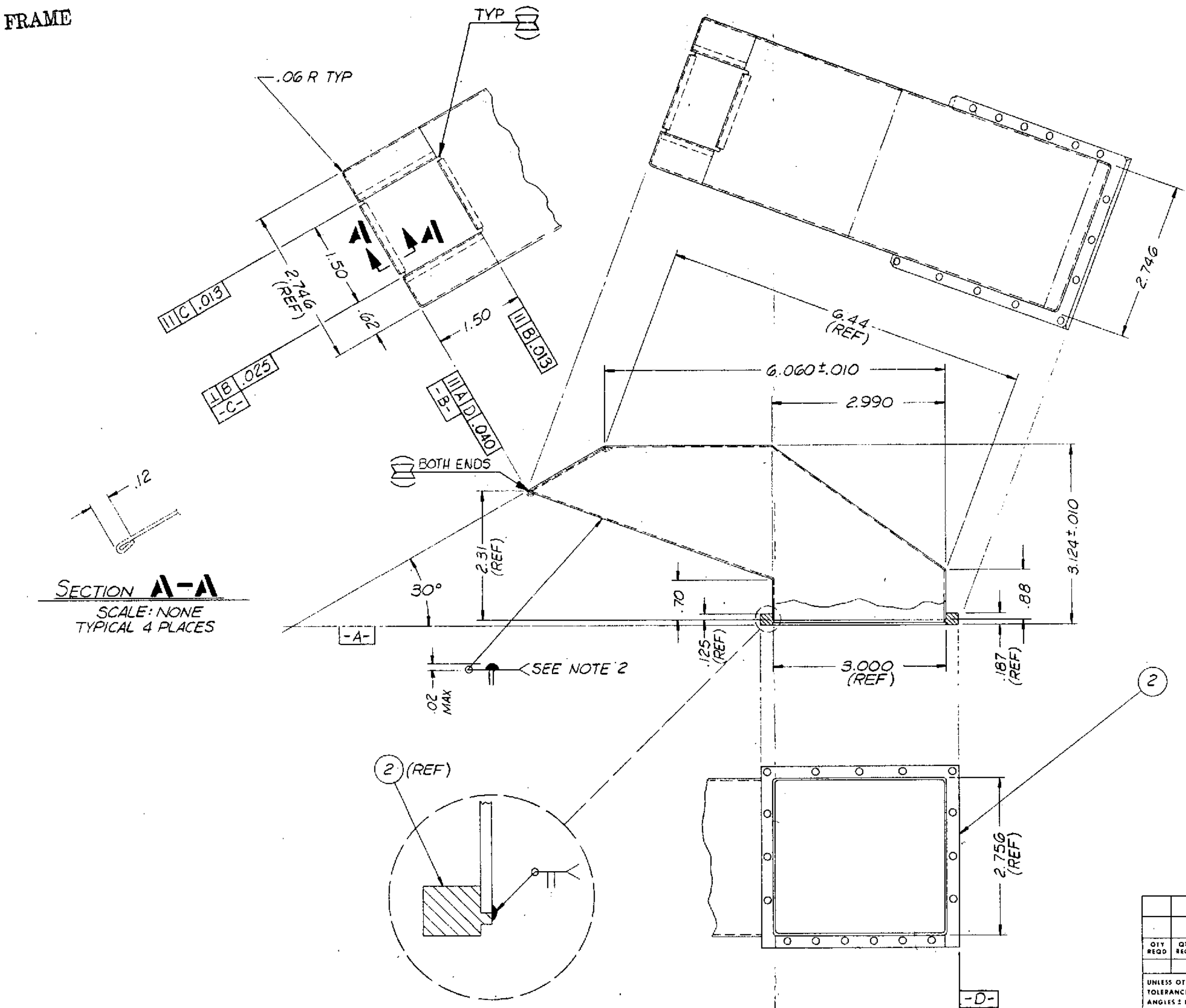
FOLDOUT FRAME

1

LTR	DESCRIPTION	DATE	APPROVAL
A	ADDED PLUG WELD PER ECO 1660-532 ADDED ‖ AND ⊥ TOLERANCES PER ECO 1660-540	4/20/71	

FOLDOUT FRAME

2



		1	2	150-695-01		FLANGE	
		X	1			SCOOP ASSY	
QTY REQD	QTY REQD	QTY REQD	ITEM	UTD PART NO	MFGR PART NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT
		-01				LIST OF MATERIALS	

UNLESS OTHERWISE SPECIFIED TOLERANCES ON: ANGLES ± 1/2° DECIMALS .XXX ± .005 .XX ± .020 MACHINE FINISH 63

MATERIAL 304 SST .024 THK PER QQ-S-766

APPLIED FINISH SEE NOTE 3

AUTHENTICATION	NAME	DATE
DRN.	Husted	2-7-71
CHK.	M. Burroughs	2/8/71
DSGN.		2/8/71
APP.		
APP.		2/8/71
APP.		2/1/71
APP.	D. R.	2/8/71

CONTRACT NO. NAS 9-10410

THE UNIVERSITY OF TEXAS AT DALLAS

SCOOP ASSY- ION SOURCE

D | CODE IDENT | 151-118 | REV A

SCALE 1/1 | WT | SHEET 1 OF 1

QTY	NEXT ASSY	QTY	USED ON
1	R150-500	1	R150-500
APPLICATION			

5. USE MINIMUM BEND RELIEFS
4. USE MINIMUM BEND RADII
3. FINISH: GLASS PEEN PER UTD NO. 150-490 NICKEL PLATE PER MIL-C-26074A, CLASS I
2. FILL ALL VOIDS AND GRIND .03 R ALONG ALL EXTERIOR WELDED EDGES
1. REMOVE ALL BURRS & SHARP EDGES

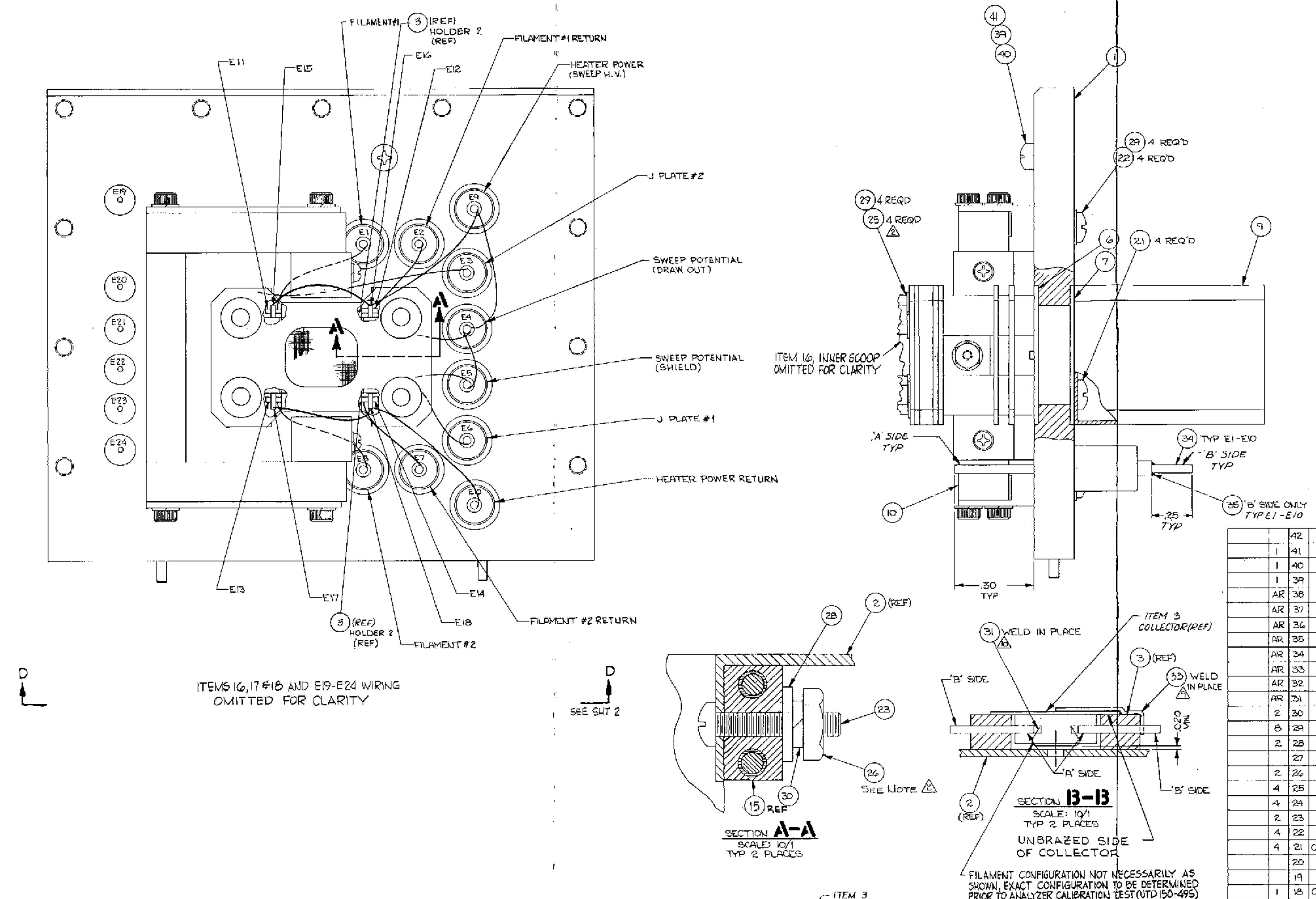
NOTES: UNLESS OTHERWISE SPECIFIED:

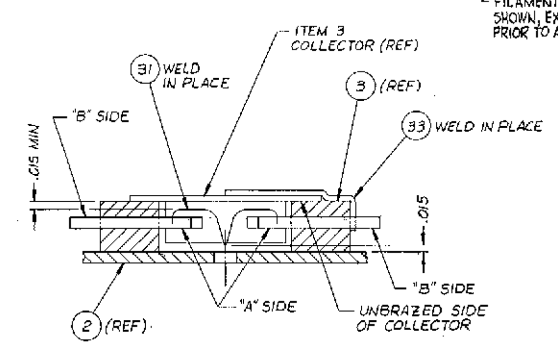
Figure 2-3. Scoop Assembly

FOLDOUT FRAME 1

FOLDOUT FRAME 2

LTR	DESCRIPTION	DATE	APPROVAL
A	REV PER ECO 1660-600		





SECTION C-C
SCALE: 10/1
TYP 2 PLACES

12. INSULATE LEADS WITH ITEM 38 AS NEEDED FOR COMPLETE INSULATION
11. SEPARATE WIRES TO PREVENT SHORTING BEFORE APPLYING ITEM 37
10. SHAPE FILAMENT AS SHOWN - FREE FILAMENT LENGTH TO BE .45 INCH
9. FLATTEN ITEM 33 TO A THICKNESS OF .012 TO .015 PRIOR TO WELDING FOR WIRE RUNS 17 & 18 ONLY
8. ARC TEST E1-E10 AFTER BRAZING ITEM 34 IN PLACE. HOOK TEST LEADS TO ITEM 1 & ITEM 34. TERMINALS MUST WITHSTAND 2200 VDC AT ROOM CONDITIONS WITHOUT ARCING
7.
6. DEFORM SCREW THREADS OF ITEM 24 SLIGHTLY TO FORM SCREW-LOCK PER UTD 150-484
5.
4. *ASSEMBLE PER ASSEMBLY PROCEDURE 150-988*
3. ALL WIRING CONNECTIONS TO BE WELDED EXCEPT THE BRAZE JOINING OF ITEM 34 TO E1 THRU E10 TERMINALS. (BRAZE PER UTD 150-452) & CONNECTIONS TO TERMINALS E25 THRU E30 TO BE SOLDERED
2. TORQUE HARDWARE PER UTD 150-451 EXCEPT AS FOLLOWS:
   ITEM 24 - 1.0 IN-LB   ITEM 26 - 1.0 IN-LB
   ITEM 25 - 4.0 IN-LB
1. ALL PARTS SHALL BE CLEAN PRIOR TO, DURING & AFTER ASSY - HANDLE WITH GLOVES. ASSEMBLE IN A CLEAN, DUST FREE AREA

NOTES: UNLESS OTHERWISE SPECIFIED:

QTY REQD	QTY REQD	QTY REQD	ITEM	SCAS PART NO	MFGR PART NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT
			42				
		1	41		MS35649-224	NUT, 2-56	
		1	40		MS35338-134	WASHER, #2 SPLIT LOCK	
		1	39		MS51957-3	SCREW, #2-56 x .25 PAN HD	
		AR	38		STD-715-B	INSULATORS	85529
		AR	37		THERMCOAT HT	CEMENT	29907
		AR	36		ALPHA 36	SOLDER,	96613
		AR	35		BRAZE 630	BRAZE FILLER MATL.	91920
		AR	34			WIRE, .050 DIA 304 S.S.	
		AR	33			WIRE, .025 DIA 304 S.S.	
		AR	32		TYPE N-1	WIRE, .020 DIA NICKEL (MIL-STD-1276)	
		AR	31			WIRE, .003 DIA TUNGSTEN 1% RHENIUM	
		2	30			WASHER #0 SPLIT LOCK, CRES	
		8	29		MS35338-135	WASHER #4 SPLIT LOCK	
		2	28		MS15795-801	WASHER #0 FLAT	
			27				
		2	26		MS35650-314	NUT #0-80	
		4	25		MS35649-244	NUT #4-40	
		4	24		NAS662C0R3	SCREW #0-80 x .188 FLAT HD	
		2	23			SCREW #0-80 x .312 PAN HD-CRES	
		4	22		MS51957-16	SCREW #4-40 x .438 PAN HD	
		4	21	C150-925		SCREW, MODIFIED	
			20				
			19				
		1	18	C151-133		INSULATOR-SHIELD	
		1	17	C151-150		TEMPERATURE SENSOR ASSY	
		1	16	E151-145		INNER SCOOP ASSY	
		2	15	D150-953		HEATER ASSY	
		4	14	B150-664-02		INSULATOR-SHIELD	
		4	13	B150-662-03		SPACER	
		4	12	B150-662-02		SPACER	
		4	11	B150-662-01		SPACER	
		1	10	C150-732		MAGNET ASSY	
		1	9	C150-733		TUBE-GUIDE	
		1	8	C150-710-02		SCREEN ASSY	
		1	7	C150-712-02		SLIT	
		1	6	C150-712-01		SLIT	
		1 PR	5	C150-736		J PLATE	
		1	4	C150-735		DRAW OUT	
		2	3	C150-682		FILAMENT HOLDER ASSY	
		1	2	C150-734		SHIELD	
		1	1	D150-744		FLANGE	

LIST OF MATERIAL

1	E151-148	1	F150-600
QTY	NEXT ASSY	QTY	USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED TOLERANCES ON ANGLES ± 1/2° DECIMALS .XX ± .03 .XXX ± .005

MATERIAL: SEE L/M

APPLIED FINISH: NONE

SOUTHWEST CENTER FOR ADVANCED STUDIES
DALLAS, TEXAS

ION SOURCE ASSY

A2A1

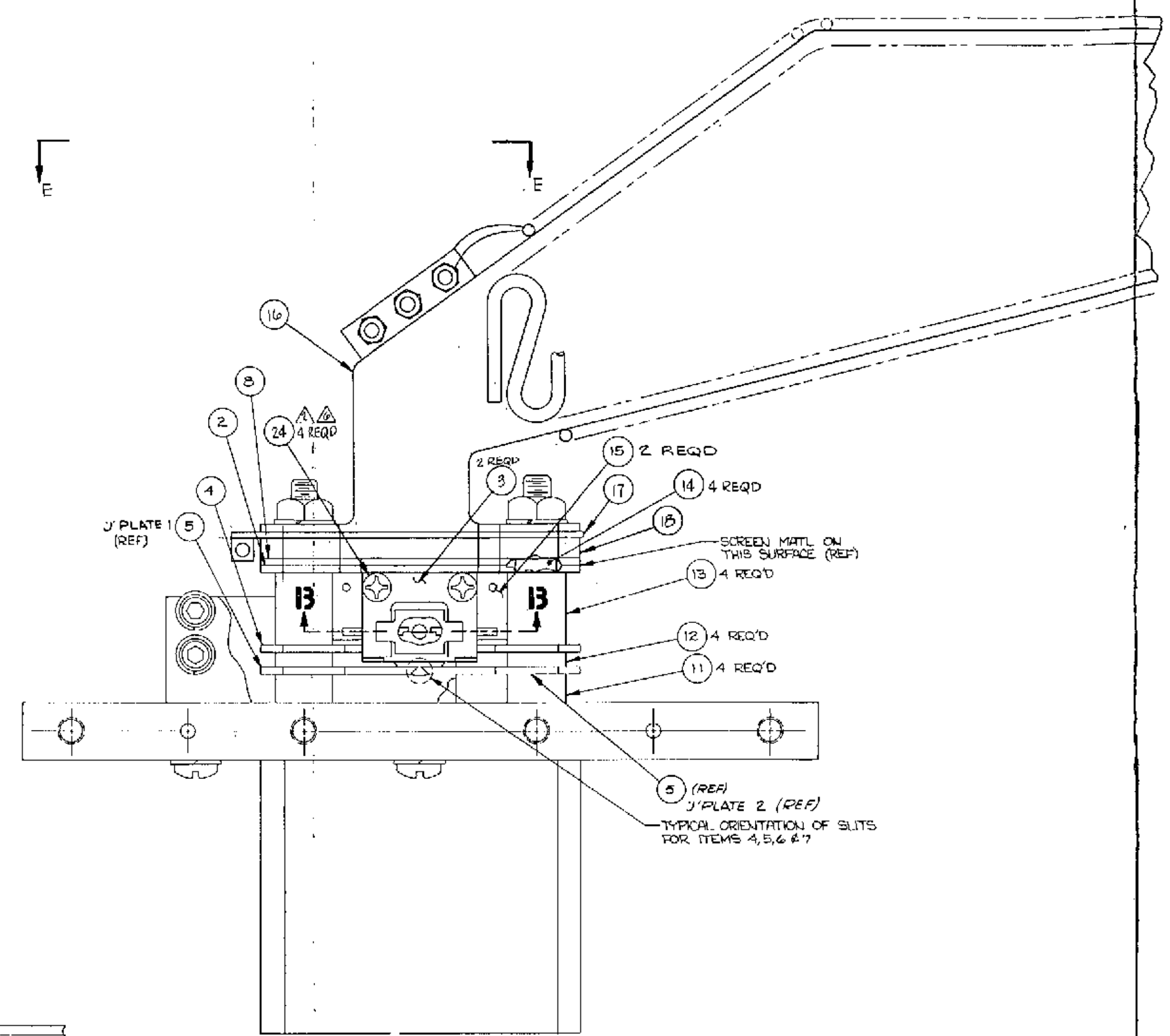
SIZE E | 151-147 | REV A

SCALE 4/1

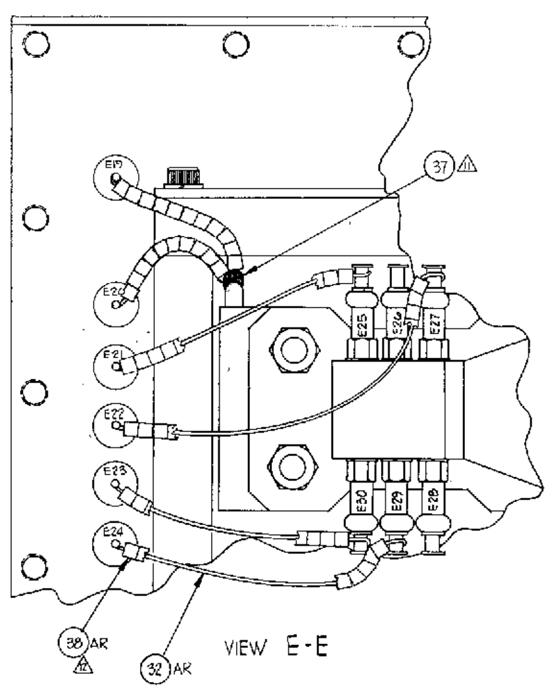
FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL
	SEE SHEET 1		

FOLDOUT FRAME 2



VIEW D-D



VIEW E-E

WIRE CHART						
RUN NO.	FROM	TO	USING ITEM #	WELD SCHEDULE FROM END	TO END	REMARKS
1	E11-A	E12-A	31	6	6	SECTION B-B-SOURCE FIL
2	E13-A	E14-A	31	6	6	SECTION B-B-SOURCE FIL
3	E4-A	E5-A	33	8	8	DRAW OUT TO SHIELD JUMPER
4	E4-A	E9-A	33	8	8	HEATER TO SHIELD JUMPER
5	E1-A	E11-B	33	8	7	FILAMENT
6	E2-A	E12-B	33	8	7	FILAMENT
7	E3-A	ITEM5-1	33	8	9	J PLATE-1
8	E4-A	ITEM 4	33	8	9	DRAW OUT
9	E5-A	ITEM 2	33	8	9	SHIELD
10	E6-A	ITEM5-2	33	8	9	J PLATE-2
11	E7-A	E14-B	33	8	7	FILAMENT
12	E8-A	E13-B	33	8	7	FILAMENT
13	E9-A	E16-B	COMP LEAD	14	–	HEATER
14	E16-B	E15-B	COMP LEAD	13	–	HEATER
15	E10-A	E18-B	COMP LEAD	14	–	HEATER
16	E18-B	E17-B	COMP LEAD	13	–	HEATER
17	E14-B	ITEM 3-1 COLLECTOR	33	7	11	COLLECTOR-SECTION B-B
18	E12-B	ITEM 3-2 COLLECTOR	33	7	11	COLLECTOR-SECTION B-B
19	E19	ITEM 17	COMP LEAD	36	–	TEMP SENSOR ASSY
20	E20	ITEM 17	COMP LEAD	36	–	TEMP SENSOR ASSY
21	E21	E25	32	37	SOLDER	SCOOP TEMP SENSOR
22	E22	E27	32	37	SOLDER	SCOOP HEATER
23	E23	E30	32	37	SOLDER	SCOOP TEMP SENSOR
24	E24	E29	32	37	SOLDER	SCOOP HEATER

QTY REQD	QTY REQD	QTY REQD	ITEM	UTD PART NO.	MFGR. PART NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED TOLERANCES ON: ANGLES ± 1/2° DECIMALS .XXX ± .010 .XX ± .030 MACHINE FINISH 63

MATERIAL

APPLIED FINISH

QTY | NEXT ASSY | QTY | USED ON

APPLICATION

AUTHENTICATION

	NAME	DATE
DRN.	W. EDWARDS	9/5/81
CHK.		
DSGN.		
APP.		
APP.		
APP.		
APP.		

THE UNIVERSITY OF TEXAS AT DALLAS

ION SOURCE ASSY

SIZE E | CODE IDENT 14614 | 151-147 | REV A

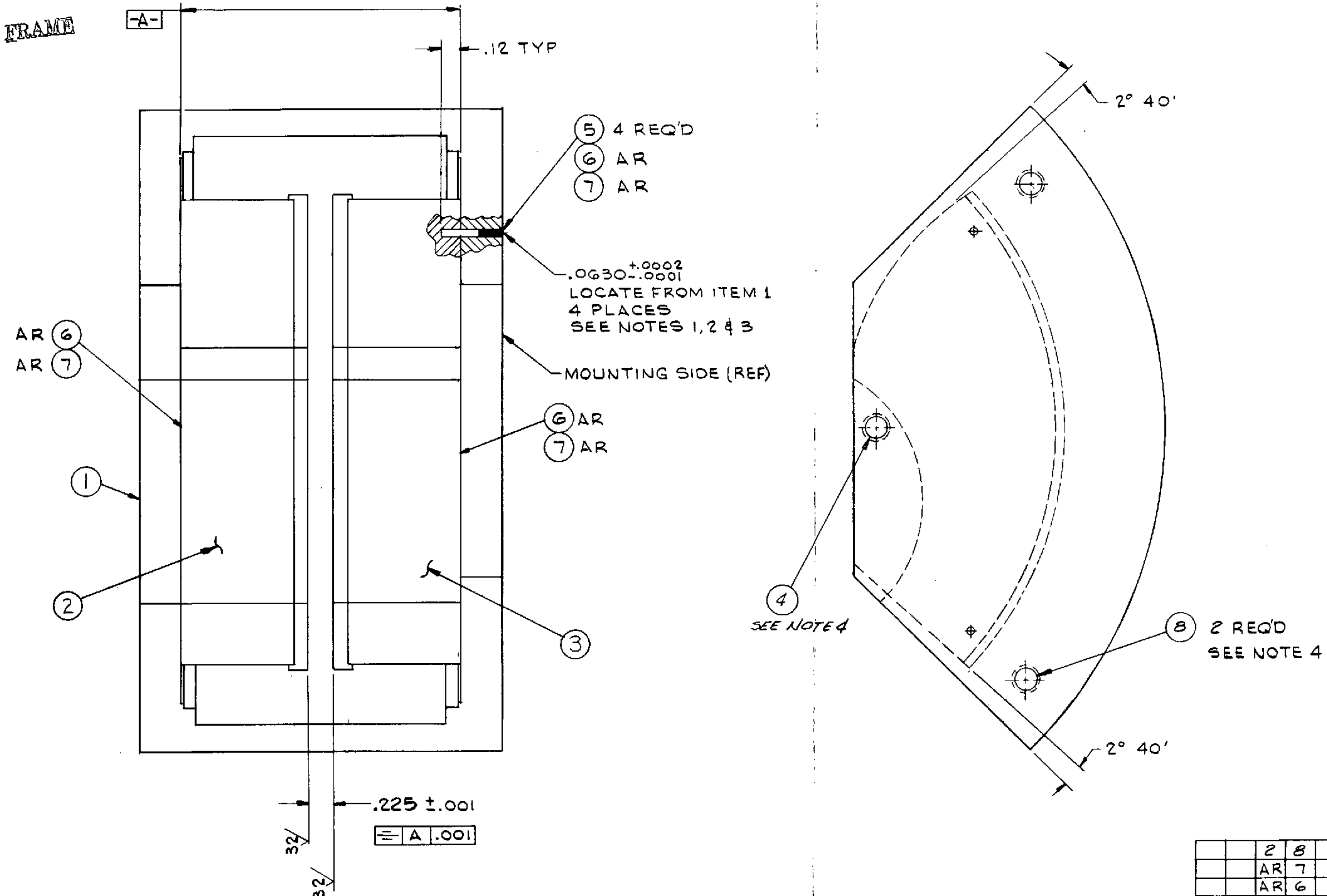
SCALE 4/1 | WT | SHEET 2 OF 2

Figure 2-4. Ion Source Assembly (Sheet 2)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

LTR	DESCRIPTION	DATE	APPROVAL
A	.215 WAS .225 PER DCN 384	8/27/70	V.A.B
B	ADDED ITEM 8 TO L/M & F/D. CHANGED QTY OF ITEM 4 FROM 3 TO 1. ITEM 5 WAS DIMENSIONED .03 TYP FROM EDGE (THIS DIM. HAS BEEN DELETED). PER DCN 404	9/17/70	
C	.225 ±.001 DIMENSION WAS .215 ±.001 PER DCN 423 9/28/70	9/29/70	



QTY REQD	QTY REQD	QTY REQD	ITEM	UTD PART NO.	MFG'S PART NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
		2	8		MS21209-F1-20	INSERT	
		AR	7		ALLOY #111	SOLDER	92194
		AR	6		ALPHA #90	FLUX	92194
		4	5		D3-312	DOWEL PIN	74171
		1	4		MS21209-F1-15	INSERT	
		1	3	C150-633		MAGNET-LOWER POLE PIECE ASSY	
		1	2	C150-632		MAGNET-UPPER POLE PIECE ASSY	
		1	1	C150-968		YOKE-MAGNET	

LIST OF MATERIALS

5. ASSEMBLE PER UTD 150-992
4. MTG HOLES TO BE FREE OF SOLDER
3. SOLDER FILL MUST BE BELOW SURFACE WITHIN +.000 -.005 ON MTG SIDE
2. INSTALL MACHINED END OF ITEM 5 INTO ITEMS 2 & 3
1. HOLES TO BE EDM TO FINAL DIMENSION

NOTES: UNLESS OTHERWISE SPECIFIED

QTY	NEXT ASSY	QTY	USED ON
1	R150-500	1	R150-500

APPLICATION

UNLESS OTHERWISE SPECIFIED
TOLERANCES ON:
ANGLES ±1/2°
DECIMALS .XXX ±.010 .XX ±.020
MACHINE FINISH 63

MATERIAL: SEE L/M

APPLIED FINISH: NICKEL PLATE .0003-.0005 PER MIL-C-26074A, CLASS I

AUTHENTICATION

	NAME	DATE
DRN.	M. Contreras	7/10/70
CHK.	J. Hostetler	7/30/70
DSGN.	V. A. Brown	7/30/70
APP.	R.M.	7/30/70
APP.	John H Hoffman	7/30/70
APP.		
APP.		7/2/70

CONTRACT NO. NAS 9-10410

THE UNIVERSITY OF TEXAS AT DALLAS

YOKE & MAGNET ASSY

D | CODE IDENT | 150-969 | REV C

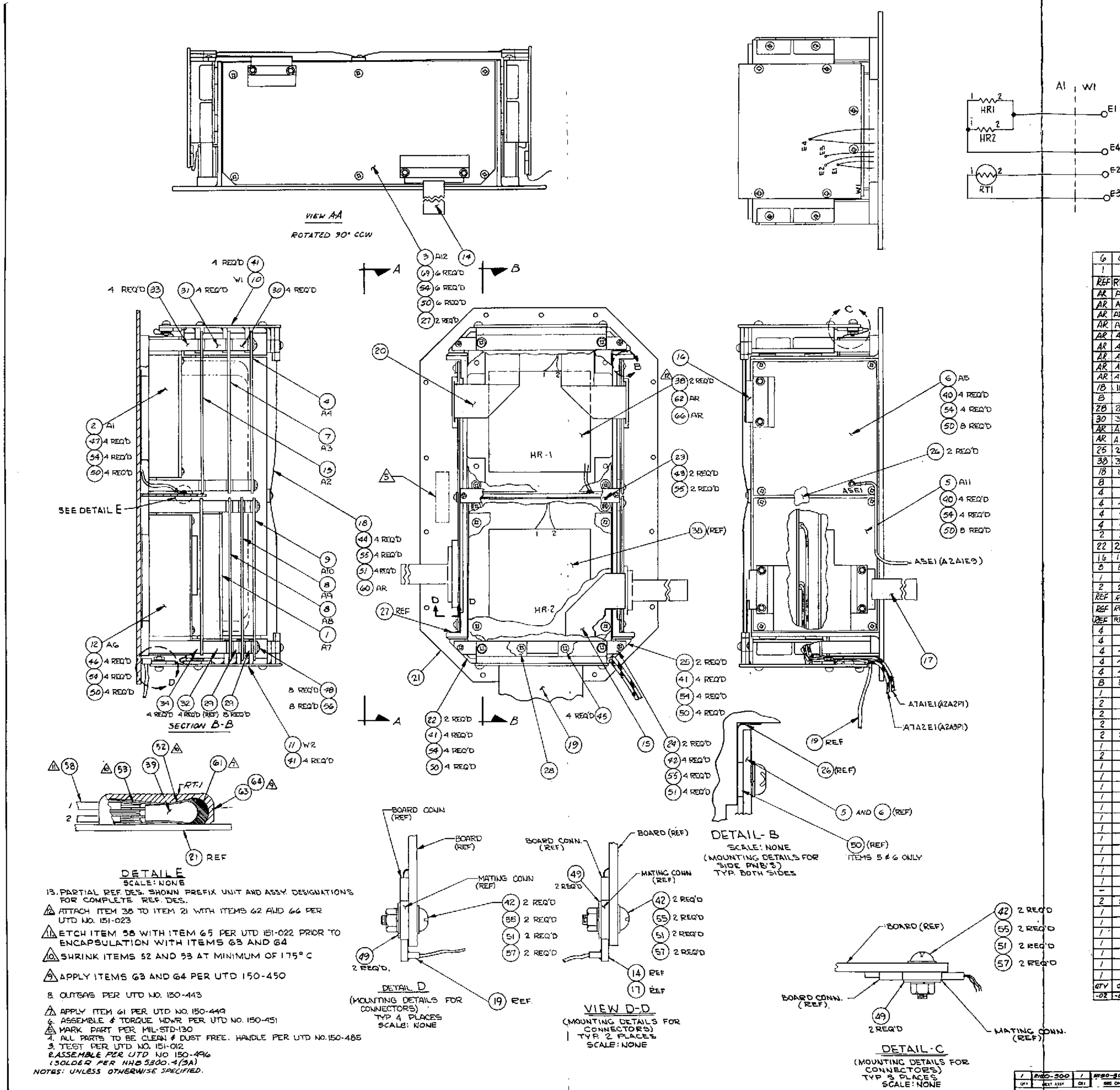
SCALE 2/1 | WT | SHEET 1 OF 1

Figure 2-5. Magnet Assembly

FOLDOUT FRAME 1

LTR	DESCRIPTION
A	REVISED PER DCN 338
B	REV PER DCN 390
C	REV PER ECO 1660-465
D	REV PER ECO 1660-479 & 1660-573

FOLDOUT FRAME 2



13. PARTIAL REF DES. SHOWN PREFIX UNIT AND ASSY DESIGNATIONS FOR COMPLETE REF. DES.

12. ATTACH ITEM 38 TO ITEM 21 WITH ITEMS 62 AND 66 PER UTD NO. 151-023

11. ETCH ITEM 58 WITH ITEM 65 PER UTD 151-022 PRIOR TO ENCAPSULATION WITH ITEMS 63 AND 64

10. SHRINK ITEMS 52 AND 53 AT MINIMUM OF 175° C

9. APPLY ITEMS 63 AND 64 PER UTD 150-450

8. OUTGAS PER UTD NO. 150-443

7. APPLY ITEM 61 PER UTD NO. 150-449

6. ASSEMBLE & TORQUE HDWR PER UTD NO. 150-451

5. MARK PART PER MIL-STD-130

4. ALL PARTS TO BE CLEAN & DUST FREE. HANDLE PER UTD NO. 150-485

3. TEST PER UTD NO. 151-012

2. ASSEMBLE PER UTD NO 150-496

1. SOLDER PER NHB 5300.4(3A)

NOTES: UNLESS OTHERWISE SPECIFIED.

QTY -02	QTY -01	REF DES	ITEM	SCAS PART NO.	MFGR PART NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
6	6		69		MS51957-15	SCREW, 4-40 x 3/8 LG PH	
1	–	A10	68	D150-813-02		PWB ASSY-HOUSEKEEPING MULT	
REF	REF		67	J151-116		INTERCONNECT DIAGRAM	
AR	AR		66		SILASTIC 201	PRIMER	16299
AR	AR		65		0107	TEFLON ETCH	05972
AR	AR		64		VERSAMID V25	CURING AGENT	86961
AR	AR		63		EPON 828	RESIN	86961
AR	AR		62		DC 3140	ADHESIVE	16299
AR	AR		61		DELTA BOND 152	ADHESIVE	05820
AR	AR		60		TEMPLACE 256	LACING CORD	82110
AR	AR		59		SN63	SOLDER (QQ-S-571)	
AR	AR		58		M22759/11-26-9	WIRE (MIL-W-22759)	
18	18		57		MS35649-224	NUT, #2-56	
8	8		56		MS35338-136	WASHER, LOCK #6	
28	28		55		MS35338-134	WASHER, LOCK #2	
30	30		54		MS35338-135	WASHER, LOCK #4	
AR	AR		53		.063 NAT	THERMOFIT KYNAR	08795
AR	AR		52		.125 NAT	THERMOFIT KYNAR	08795
25	25		51		NAS620C2	WASHER, FLAT # 2	
38	38		50		NAS620C4L	WASHER, FLAT #4	
18	18		49		MS15795-802	WASHER, FLAT #2	
8	8		48		MS51957-38	SCREW, 6-32 X 2" LG PH	
4	4		47		MS51957-121	SCREW, 4-40 X 1 1/8 LG PH	
4	4		46		MS51957-23	SCREW, 4-40 X 1 1/2 LG PH	
4	4		45		MS51959-5	SCREW - 2-56 X 3/8 LG FH	
4	4		44		MS51957-7	SCREW, 2-56 X 1/2 LG PH	
2	2		43		MS51957-3	SCREW, 2-56 X 1/4 LG PH	
22	22		42		MS51957-4	SCREW, 2-56 X 5/16 LG PH	
16	16		41		MS51957-13	SCREW, 4-40 X 1/4 LG PH	
8	8		40		MS51957-14	SCREW, 4-40 X 5/16 LG PH	
1	1	RT1	39		6834PZ	THERMISTOR	15801
2	2	HR1, HR2	38		E/F111689	HEATER	85932
REF	REF		37	150-496		ASSY PROCEDURE	
REF	REF		36	C150-644		SCHEMATIC DIAGRAM	
REF	REF		35	151-012		TEST PROCEDURE	
4	4		34	C150-536-02		PILLAR, MTG	
4	4		33	C150-536-01		PILLAR, MTG	
4	4		32	B150-537-04		SPACER	
4	4		31	B150-537-03		SPACER	
4	4		30	B150-537-02		SPACER	
8	8		29	B150-537-01		SPACER	
1	1		28	B150-755		SPACER, CONNECTOR	
2	2		27	C150-865		INSULATOR #1-E. C.	
2	2		26	C150-864		INSULATOR #2-SWEEP & MHVPS	
2	2		25	D150-876		BRACKET, MTG-WIRING BOARD	
2	2		24	C150-855		BAR, MTG - CONNECTOR	
1	1		23	B150-756		STRAP - CABLE	
2	2		22	D150-854		BRACKET, MTG-WIRING BOARD	
1	1		21	E150-787		RADIATOR PLATE	
1	1		20	D150-757-03		CABLE ASSY-SIDE PWB ASSY.	
1	1		19	D150-762		CABLE ASSY -INTERFACE	
1	1		18	D150-758		CABLE ASSY -INTERCONNECT	
1	1		17	D150-759		CABLE ASSY - MHVPS	
1	1		16	D150-757-02		CABLE ASSY - SIDE PWB ASSY	
1	1		15	D150-757-01		CABLE ASSY - SIDE PWB ASSY	
1	1		14	D150-760		CABLE ASSY - EMISSION CONT.	
1	1	A2	13	D150-660		PWB ASSY-THERMAL CONT.	
1	1	A6	12	D150-814		LVPS ASSY	
1	1	W2	11	D150-783		PWB ASSY - CABLE ASSY	
1	1	W1	10	D150-780		PWB ASSY - CABLE ASSY	
–	1	A10	9	D150-813-01		PWB ASSY - HOUSEKEEPING MULT.	
2	2	A8, A9	8	D150-754		PWB ASSY - CNTG & DATA COMP	
1	1	A3	7	D150-713		PWB ASSY - DIG. SWP. CONT. CKT	
1	1	A5	6	D150-770		PWB ASSY - SHVPS	
1	1	A11	5	D150-816		PWB ASSY - MHVPS	
1	1	A4	4	D150-667		PWB ASSY - SIGNAL COND.	
1	1	A12	3	B150-786		PWB ASSY - EMISSION CONTROL	
1	1	A1	2	D150-745		SWITCHING PRE-REG. ASSY	
1	1	A7	1	E150-721		PREAMP, DISC, & PRESCALER ASSY	

LIST OF MATERIAL

SOUTHWEST CENTER FOR ADVANCED STUDIES DALLAS, TEXAS

ELECTRONIC SUBASSEMBLY A1

MATERIAL: SEE L/M

FINISH: NONE

E 150-761 D

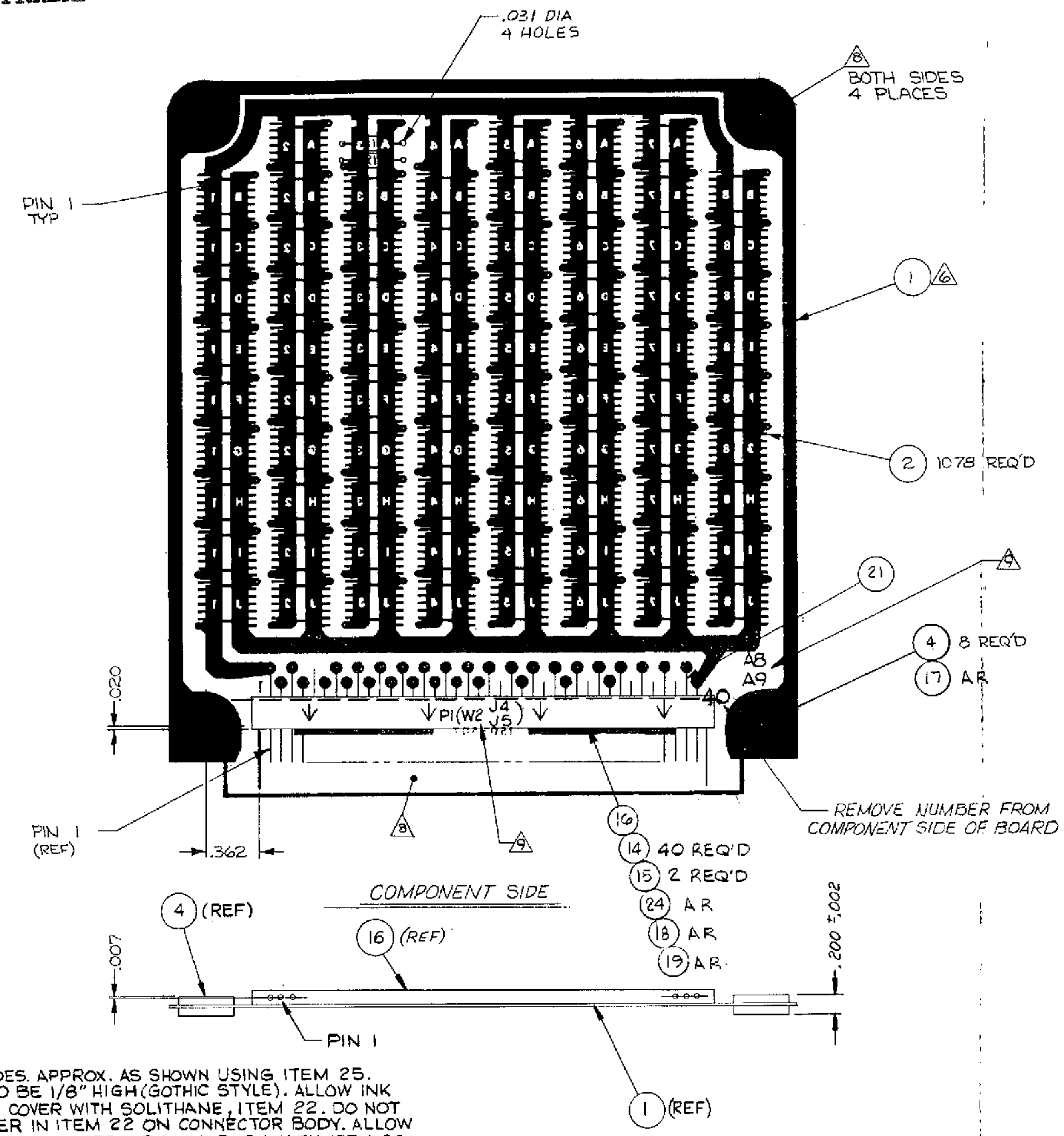
SCALE 1/1

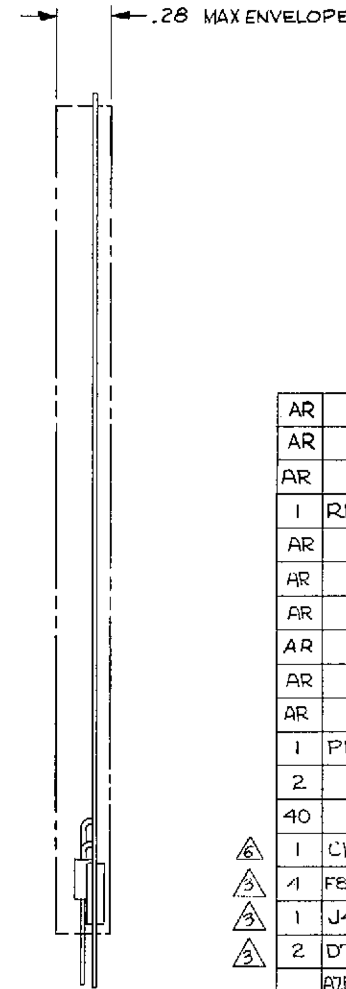
Figure 2-6. Electronics Assembly

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL
A	REVISED PER DCN 94	5/5/70	
B	REVISED PER DCN 166	6/8/70	
C	REVISED PER DCN 279	7-11-70	
D	REVISED PER DCN 311 7-23-70	7-29-70	
E	REV PER ECO 1660-456 11/23/70	11/23/70	

FOLDOUT FRAME 2





	AR		26		DC1201	RTV PRIMER	71984
	AR		25		73X	INK, BLACK	12744
	AR		24		SCOTCH 75	TAPE	76381
	1	R1	23		RCR07G102JS	RESISTOR	01121
	AR		22		SOLITHANE 113/300	CONFORMAL COATING	78731
	AR		21		26AWG, TYPE S	BUS WIRE (QQ-W-343)	
	AR		20		SN63	SOLDER (QQ-S-571)	
	AR		19		VERSAMID V25	CURING AGENT	86961
	AR		18		EPON 828	RESIN	86961
	AR		17		DELTA BOND 152	ADHESIVE	05820
	1	P1	16		221-2242	CONNECTOR	29587
	2		15		221-504	GUIDE PIN	29587
	40		14		220-530-02	CONTACT	29587
6	1	C1	13		CKR12BX103KR	CAPACITOR	04222
3	4	F8, G4, I7, J1	12		U3I900251XUNQ 1/2/3/4/5	INTEGRATED CIRCUIT	07263
3	1	J4	11		HL 10461	INTEGRATED CIRCUIT	07263
3	2	D7 & E7	10		HL 10459	INTEGRATED CIRCUIT	07263
3	16	A7, B3, B7, C3, C7, D3, E3, F3, F4, F7, G3, G7, G8, H4, I4, I8	9		HL 10460	INTEGRATED CIRCUIT	07263
3	52	A2, A5, A6, B1, B2, B4-B6, B8, C1, C2, C4-C6, C8, D1, D2, D4-D6, D8, E1, E2, E4, E5, E6, E8, F1, F2, F5, F6, G1, G2, G5, G6, H1, H2, H3, H5-H8, I2, I3, I5, I6, J2, J3, J5-J8	8		HL 10455	INTEGRATED CIRCUIT	07263
3	1	I1	7		U3I900151X	INTEGRATED CIRCUIT	07263
	REF		6	A150-763		WIRE LIST	
	REF		5	R150-636		SCHEMATIC DIAGRAM	
	8		4	B150-655		FLANGE	
	AR		3	A150-680		WIRE-PUR COATED NICKEL	
	1078		2	B150-624		TERMINAL PINS	
	1		1	D150-507		PRINTED WIRING BOARD	
	QTY REQ'D	REF DES	ITEM	SCAS PART NO	MFGR PART NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED TOLERANCES ON: ANGLES ±1/2° DECIMALS .XXX ±.005 .XX ±.020	AUTHENTICATION: DRN. 4/17/70; CHK. 4/27/70; DSGN. 4/20/70; APP. 4/21/70; APP. 4/21/70; NASA 4/20/70
MATERIAL: SEE L/M	SOUTHWEST CENTER FOR ADVANCED STUDIES OF THE GRADUATE RESEARCH CENTER OF THE SOUTHWEST... DALLAS, TEXAS
APPLIED FINISH: NOTED	PRINTED WIRING BOARD ASSY-COUNTING & DATA COMPRESSION A1A8, A1A9
CONTRACT NO. NAS 9-10410	D 150-754 REV E; SCALE 2/1; WT; SHEET 1 OF 1

QTY	NEXT ASSY	QTY	USED ON
2	E150-761	2	R150-500

APPLICATION

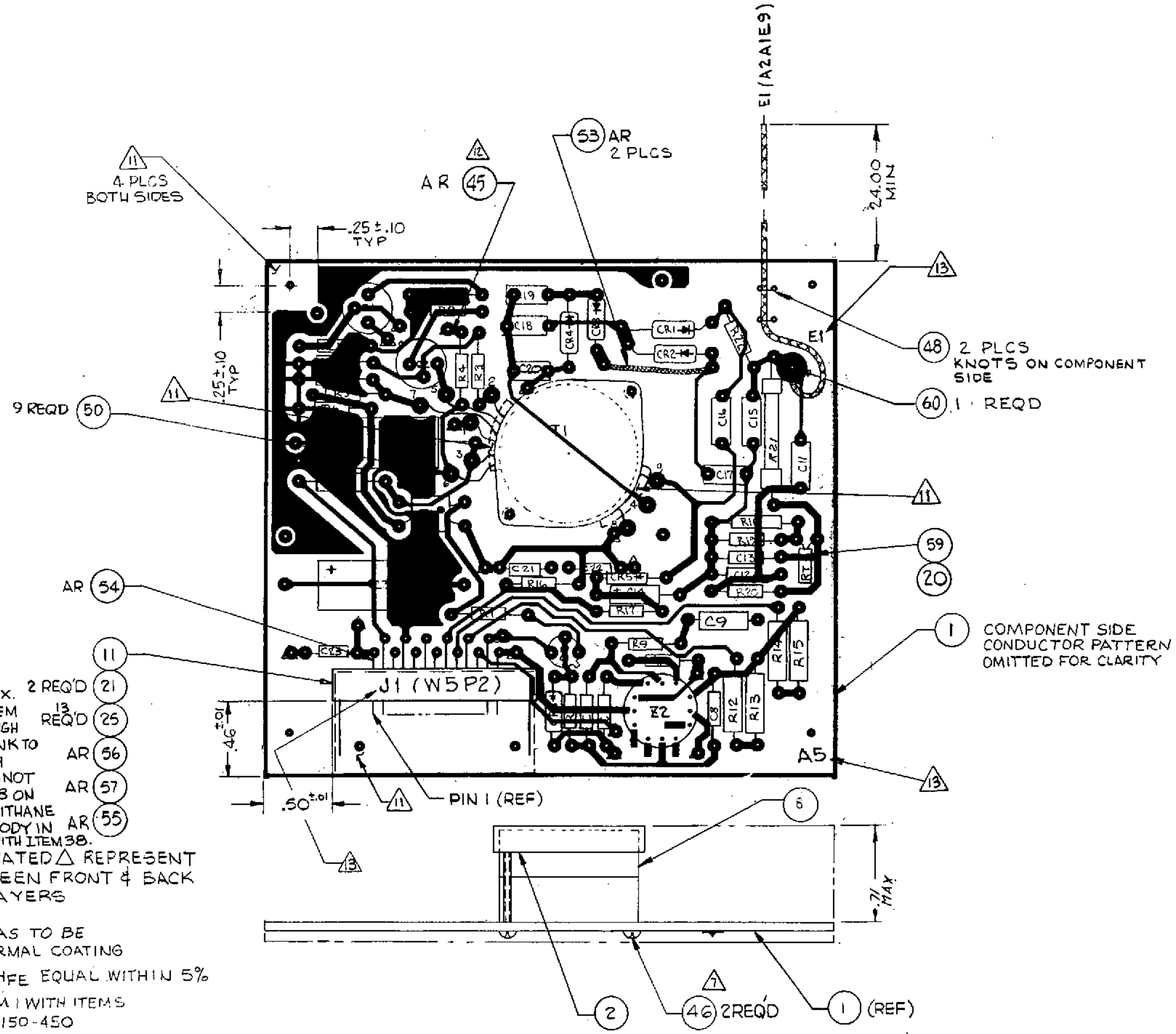
NOTES: UNLESS OTHERWISE SPECIFIED:

1. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN: FOR COMPLETE DESIGNATION PREFIX *WITH NUMBER AND ASSEMBLY DESIGNATIONS*
2. ITEMS NOT IDENTIFIED IN FIELD OF DRAWING ARE IDENTIFIED BY REFERENCE DESIGNATION IN LIST OF MATERIALS OR IN ASSEMBLY SPECIFICATION UTD NO. 150-434
3. (△) LOCATION DESIGNATION NUMBERS USED INSTEAD OF REFERENCE DESIGNATION NUMBERS FOR INTEGRATED CIRCUITS
4. ON COMPONENT SIDE, CONDUCTOR PATTERN OMITTED FOR CLARITY
5. ASSEMBLE PER UTD NO. 150-434
6. (△) REMOVE TERMINAL AREAS FOR CONNECTOR PINS 5, 22, 26, 30, 34, 36 & 38 PRIOR TO INSTALLATION OF CONNECTOR
7. TEST PER UTD NO. 150-472
8. (△) AREAS INDICATED ARE TO BE FREE OF CONFORMAL COATING
9. (△) MARK REF. DES. APPROX. AS SHOWN USING ITEM 25. LETTERS TO BE 1/8" HIGH (GOTHIC STYLE). ALLOW INK TO DRY AND COVER WITH SOLITHANE, ITEM 22. DO NOT USE THINNER IN ITEM 22 ON CONNECTOR BODY. ALLOW SOLITHANE TO CURE. PRIME CONN. BODY WITH ITEM 26 IN AREA TO BE MARKED

Figure 2-7. Typical Polywire Board Assembly

FOLDOUT FRAME 1

FOLDOUT FRAME 2



13. MARK REF DES. APPROX. AS SHOWN USING ITEM 37. LETTERS TO BE 1/8" HIGH (GOTHIC STYLE). ALLOW INK TO DRY AND COVER WITH SOLITHANE, ITEM 58. DO NOT USE THINNER IN ITEM 58 ON CONNECTOR. ALLOW SOLITHANE TO CURE. PRIME CONN. BODY IN AREA TO BE MARKED WITH ITEM 38.
12. LOCATIONS INDICATED △ REPRESENT JUMPERS BETWEEN FRONT & BACK CONDUCTOR LAYERS
11. INDICATED AREAS TO BE FREE OF CONFORMAL COATING
10. MATCHED PAIR. H_{FE} EQUAL WITHIN 5%
9. BOND ITEM 13 TO ITEM 1 WITH ITEMS 56 AND 57 PER UTD 150-450
8. VALUE TO BE DETERMINED DURING FUNCTIONAL TEST
7. TORQUE SCREWS TO 3 IN.-LBS
6. CONFORMAL COAT PER UTD 150-439
5. SLEEVE ALL DIODES WITH ITEM 20
4. TEST ASSY PER UTD 150-469 PRIOR TO CONFORMAL COATING & UTD 150-480 AFTER
3. ASSEMBLE PER UTD 150-434
2. ITEMS NOT IDENTIFIED IN FIELD OF DRAWING ARE IDENTIFIED BY REFERENCE DESIGNATION IN LIST OF MATERIALS OR IN UTD 150-434
1. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN: FOR COMPLETE DESIGNATION PREFIX WITH UNIT NUMBER WITH ASSEMBLY DESIGNATION

NOTES: UNLESS OTHERWISE SPECIFIED

QTY	REF DES	ITEM	SCAS PART NO	MFG'R PART NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT
1		60		3653-2-05	TERMINAL	71279
1	RT1 (△8)	59		GB----	THERMISTOR	02606
AR		58		SOLITHANE 113/300	CONFORMAL COATING	78731
AR		57		VERSAMID V25	CURING AGENT	86961
AR		56		EPON 828	RESIN	86961

LIST OF MATERIAL

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	REVISED PER DCN 190	9/8/70	
B	REVISED PER DCN 270 7-18-70	7-18-70	
C	REV PER DCN 323 8-2-70	8/4/70	
D	REV PER ECO 1660-447 11/20/70 RR	11/21/70	

QTY	REF. DESIGNATOR	ITEM	SCAS PART NO	MFG'R PART NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT
AR		55		SCOTCH 75	TAPE	76381
AR		54		26AWG, TYPE S	BUS WIRE (QQ-W-343)	
AR		53		M22759/9-24-?	WIRE (MIL-W-22759C)	
AR		52		SN63	SOLDER (QQ-S-571)	
1	L1	51		1537-742	INDUCTOR	99800
9		50		2085-2	TERMINAL	71279
AR		49		RTV 11	SILASTIC	01139
AR		48		TEMP LACE 256	LACING CORD	82110
1	Z1	47		MCT1	PHOTOTRANSISTOR	29083
2		46		MS51957-19	SCREW-4-40X3/4 LG P.H.	
AR		45		22AWG TYPE S	BUS WIRE (QQ-W-343)	
1	R21	44		MOX-750-200MEGOHM	RESISTOR	63060
1	R20	43		RCR07G474JS		01121
1	R19 (△8)	42		RCR07---JS		01121
1	R18	41		PME66T2.1M		03888
1	R17	40		RCR07G104JS		01121
1	R16	39		RCR07G753JS	RESISTOR	01121
AR		38		DC1201	RTV PRIMER	71984
AR		37		73X	INK, BLK	12744
2	R13, R15 (△8)	36		RCR07G...JS	RESISTOR	01121
2	R12, R14 (△8)	35		PME60T-.---		03888
1	R22	34		RCR07G225JS		01121
1	R10 (△8)	33		RNC55H....FR		80031
1	R9	32		RCR07G680JS		01121
1	R8	31		RCR07G103JS		01121
1	R7	30		RCR07G471JS		01121
1	R6	29		RCR07G222JS		01121
1	R5	28		RCR07G223JS		01121
2	R3, R4	27		RCR07G472JS		01121
2	R1, R2	26		RCR07G150JS	RESISTOR	01121
13		25		220-830-02	CONTACT	29587
1	C20	24		DD30-470	CAPACITOR	71590
5	C15-C19	23		DD30-101	CAPACITOR	71590
1	C14	22		CSR13G105KM	CAPACITOR	13606
2		21		220-504	GUIDE PINS	29587
AR (△5)		20		NO. 10 NAT	SLEEVING (MIL-I-22129)	
1	C11	19		DD30-100	CAPACITOR	71590
1	C8	18		CKR12BX101KR	CAPACITOR	16546
1	Z2	17		2404BG	OPERATIONAL AMPLIFIER	15818
3	C21-C23	16		C30C104K	CAPACITOR	16546
2	C7, C13	15		C10B271K	CAPACITOR	16546
3	C5, C6, C9	14		CKR12BX103KR		04222
2 (△9)	C3, C4	13		CLR65B.680KGM		13606
3	C1, C2, C12	12		CKR12BX561KR	CAPACITOR	04222
1	J1	11		221-2219	CONNECTOR	29587
2	CR5, CR6	10		JANTX1N914	DIODE	01295
4	CR1-CR4	9		S030G	DIODE	12040
1	T1	8	A150-850		TRANSFORMER	
1	Q3	7		JANTX2N2222A	TRANSISTOR	04713
2 (△10)	Q1, Q2	6		S2N2102	TRANSISTOR	49671
		5				
		4				
REF		3	D150-623		SCHEMATIC DIAGRAM	
1		2	C150-753-02		MOUNT, TRANSFORMER	
1		1	D150-769		PRINTED WIRING BOARD	

LIST OF MATERIAL

QTY	NEXT ASSY	QTY	USED ON
1	E150-761	1	R150-500

APPLICATION

UNLESS OTHERWISE SPECIFIED TOLERANCES ON: ANGLES ±1/2° DECIMALS .XXX ±.010 .XX ±.020

MATERIAL: SEE L/M

APPLIED FINISH: NOTED

AUTHENTICATION

	NAME	DATE
DRN.	J. Hall	5/2/70
CHK.	[illegible]	4/12/70
DSGN.	J.M. Younce	5/12/70
APP.	R. Hurong	5/12/70
APP.	D. R. [illegible]	19 May 70
	J. Corfore	5-14-70

CONTRACT NO. NAS 9-10410

SOUTHWEST CENTER FOR ADVANCED STUDIES OF THE GRADUATE RESEARCH CENTER OF THE SOUTHWEST... DALLAS, TEXAS

PRINTED WIRING BOARD ASSY-SWEEP HIGH VOLTAGE

A1A5

D 150-770 REV D

SCALE 2/1 WT SHEET OF

Figure 2-8. Typical High-Voltage Assembly

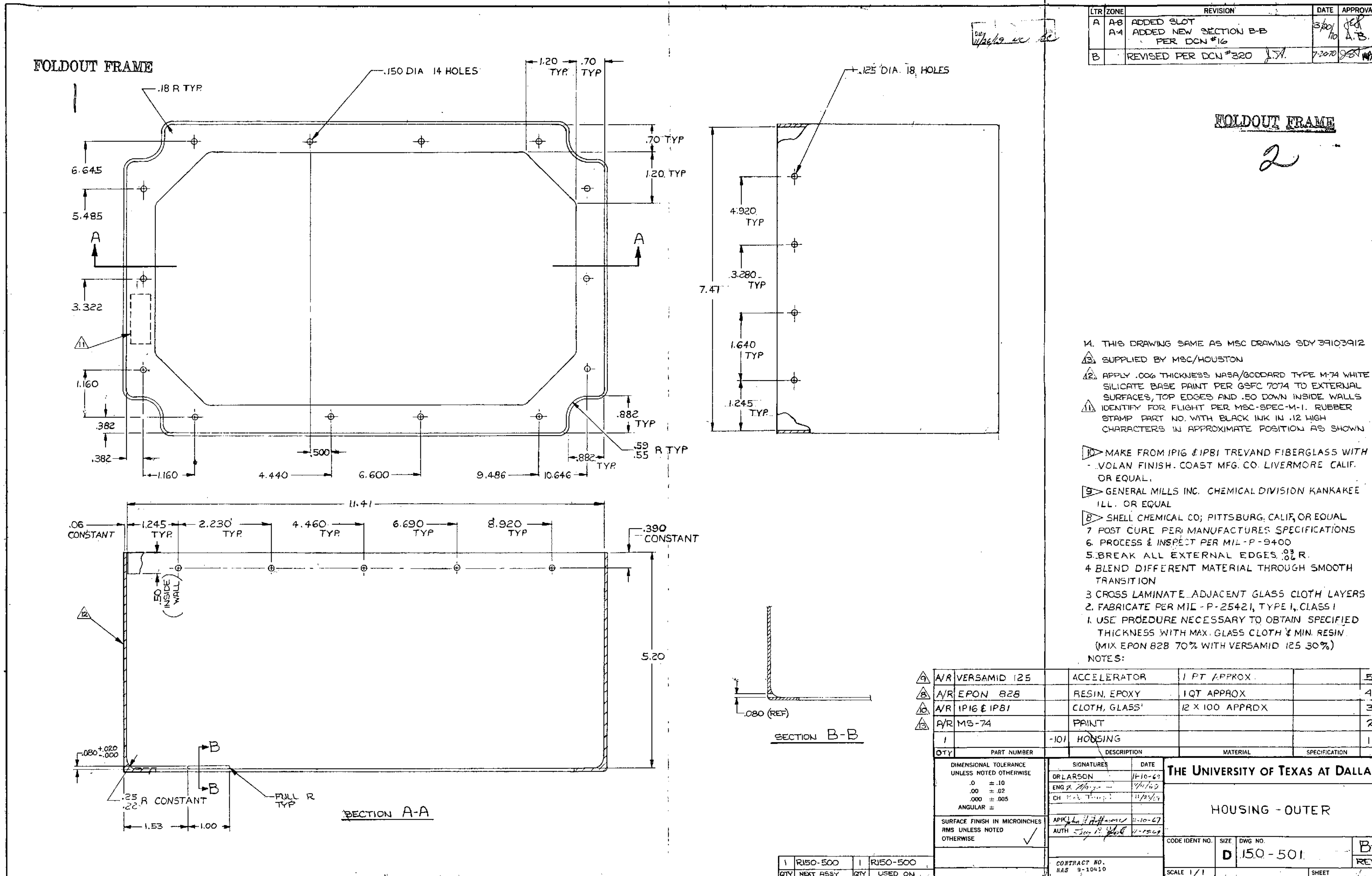
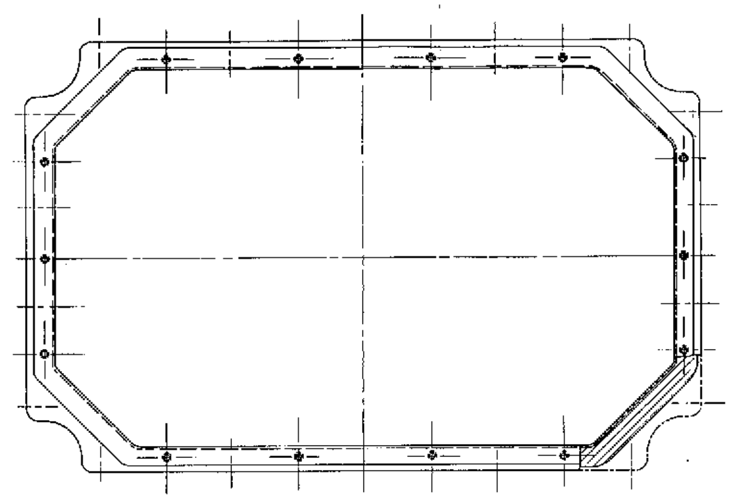


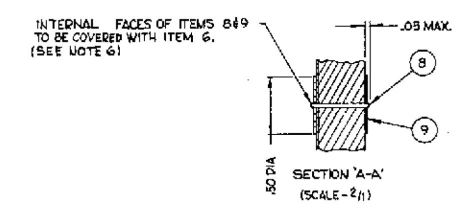
Figure 2-9. Outer Housing Assembly

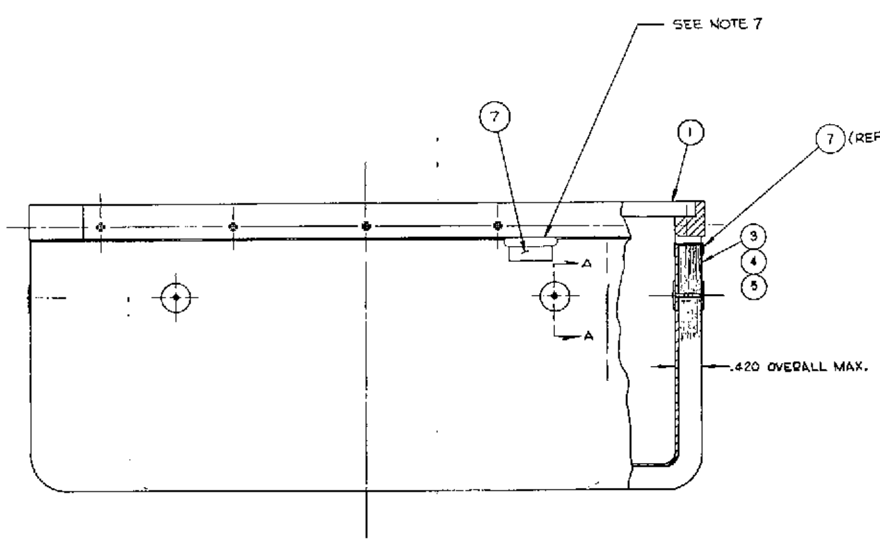
FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL
A	REVISED PER DCN 231		
B	REV PER DCN 319		
C	ITEM 7 WAS "7452, TAPE - ALUMINUM FOIL" PER DCN 39_	9/21/70	

FOLDOUT FRAME 2







NOTES: UNLESS OTHERWISE SPECIFIED:

1\. SUPPLIER: G.T. SCHJELDAHL, NORTHFIELD, MINN.

2\. SUPPLIER: PALLFLEX INC., PUTNAM, CONN.

3\. SUPPLIER: E.I. DUPONT DE NEMOURS & CO., WILMINGTON, DELAWARE

4\. SUPPLIER: PERMACELL PRODUCTS DALLAS, TEXAS

5\. GENERAL CONSTRUCTION OF TERMAL BAG:- THE BAG IS TO BE CONSTRUCTED OF ALTERNATING LAYERS OF, ITEMS 3&4, STARTING & FINISHING WITH A LAYER OF, ITEM 3. THE OUTSIDE LAYER OF, ITEM 3, SHALL THEN BE COVERED WITH A LAYER OF, ITEM 5, WITH THE ALUMINIZED SIDE (BLUISH-TINGED SIDE) ON THE INSIDE, FACING, ITEM 3.

6\. ASSEMBLY OF THERMAL BAG TO INNER SHELL:- THE THERMAL BAG IS TO BE ATTACHED TO THE INNER SHELL, (ITEM 1), BY MEANS OF MONOFILAMENT, (ITEM 8) & SECURING BUTTONS, (ITEM 9), AS SHOWN IN SECTION 'A-A'. ITEM 9 TO BE SECURED BY DEFORMING THE ENDS OF, ITEM 8, BY APPLYING HEAT. THE INSIDE FACES OF, ITEMS 8&9. ARE TO BE COVERED WITH, ITEM 6. A MINIMUM OF 6 ATTACHMENTS ARE TO BE USED (I.E. 1 EACH END & 2 EACH SIDE MIN.), LOCATED NEAR THE FLANGED TOP OF, ITEM 1.

7\. CUT SLOTS IN THERMAL BAG CORRESPONDING TO SLOTS IN INNER SHELL. TAPE THERMAL BAG TO INNER SHELL THRU SLOTS TO PREVENT TEARING

8\. SUPPLIER: MYSTIC TAPE CO.

DESIGN SPECIFICATIONS - THERMAL BAG

1\. WEIGHT OF THE THERMAL BAG (ITEMS 3,4,5,8&9) SHALL NOT EXCEED .45 LBS (I.E. EXCLUSIVE OF ITEM 1)

2\. PRESSURE:- 14.7 P.S.I.A. MAX.
10^{-14} TORR MIN.
RATE OF CHANGE OF PRESSURE = 14.5 P.S.I./MIN.

3\. HEAT LEAK:- SHALL NOT EXCEED 4.5 WATTS UNDER THE FOLLOWING CONDITIONS-
PRESSURE = 10^{-14} TORR

CONDITIONS		TEMP AT INNER FACE OF INNER SHELL (ITEM 1)	TEMP AT OUTER FACE OF THERMAL BAG.	ΔT
A	LUNAR DAY	+158°F	+300°F	142°F
B	LUNAR NIGHT	-4°F	-350°F	346°F

4\. ACCELERATION, SHOCK & VIBRATION:- THE FOLLOWING ARE NON-OPERATING ENVIRONMENTAL CONDITIONS (QUAL. LEVELS). THE AXIS REFERRED TO ARE THE 3 MUTUALLY PERPENDICULAR AXES OF THE THERMAL HOUSING:-

ACCELERATION:- $14G^{\pm 1G}$ FOR A PERIOD OF 1 MINUTE MINIMUM PER AXIS.

SHOCK:- $20G^{\pm 1G}$, 11 MS. SAWTOOTH (10 MS RISE & 1 MS. DECAY) EACH AXIS

VIBRATION:-
SINUSOIDAL (EACH AXIS)

FREQUENCY (HZ) RANGE	'G' LEVEL (O-PEAK) (1 OCTAVE/MIN. WITH INCREASING & DECREASING FREQUENCY.)
5-15	.42 D.A.
15-30	3.2±.5
30-60	7.8±1.0
60-100	10.4±1.0

RANDOM (EACH AXIS)
TIME-8 MINS.

FREQUENCY (HZ) RANGE	P.S.D. LEVEL (G^2/HZ)
25-55	12db/OCTAVE±1db INCREASING.
55-120	.46
120-480	12db/OCTAVE±1db DECREASING.
480-1000	.00185

QTY REQD	QTY REQD	QTY REQD	ITEM	SCAS PART NO	MFGR PART NO	NOMENCLATURE OR DESCRIPTION
			10			
		A/R	9			.010 THK SHEET STOCK 'TEFLON'
		A/R	8			.018 DIA MONOFILAMENT 'TEFLON'
		A/R	7		7341	TAPE - MYLAR
		A/R	6		EE6600	TAPE - ALUMINIZED MYLAR
		A/R	5		G.102900	2 MIL. THK ALUMINIZED 'KAPTON'
		A/R	4		TYPE 60-6	TISSUE GLASS
		A/R	3		GSM-59	¼ MIL DOUBLE ALUMINIZED MYLAR (I.E. ALUMINIZED 2 SIDES)
			2			
		1	1	150-502		INNER SHELL & MOUNTING RING - THERMAL HSG.

LIST OF MATERIAL

NEXT ASSY	QTY	FINAL ASSY
150-500	1	150-500

APPLICATION

UNLESS OTHERWISE SPECIFIED TOLERANCES ON ANGLES ±1/2° DECIMALS .XXX ±.005 .XX ±.020

MATERIAL: SEE L/M

APPLIED FINISH

AUTHENTICATION: DRN LAUGHLIN

CONTRACT NO. NAS 9-10410

SOUTHWEST CENTER FOR ADVANCED STUDIES DALLAS TEXAS

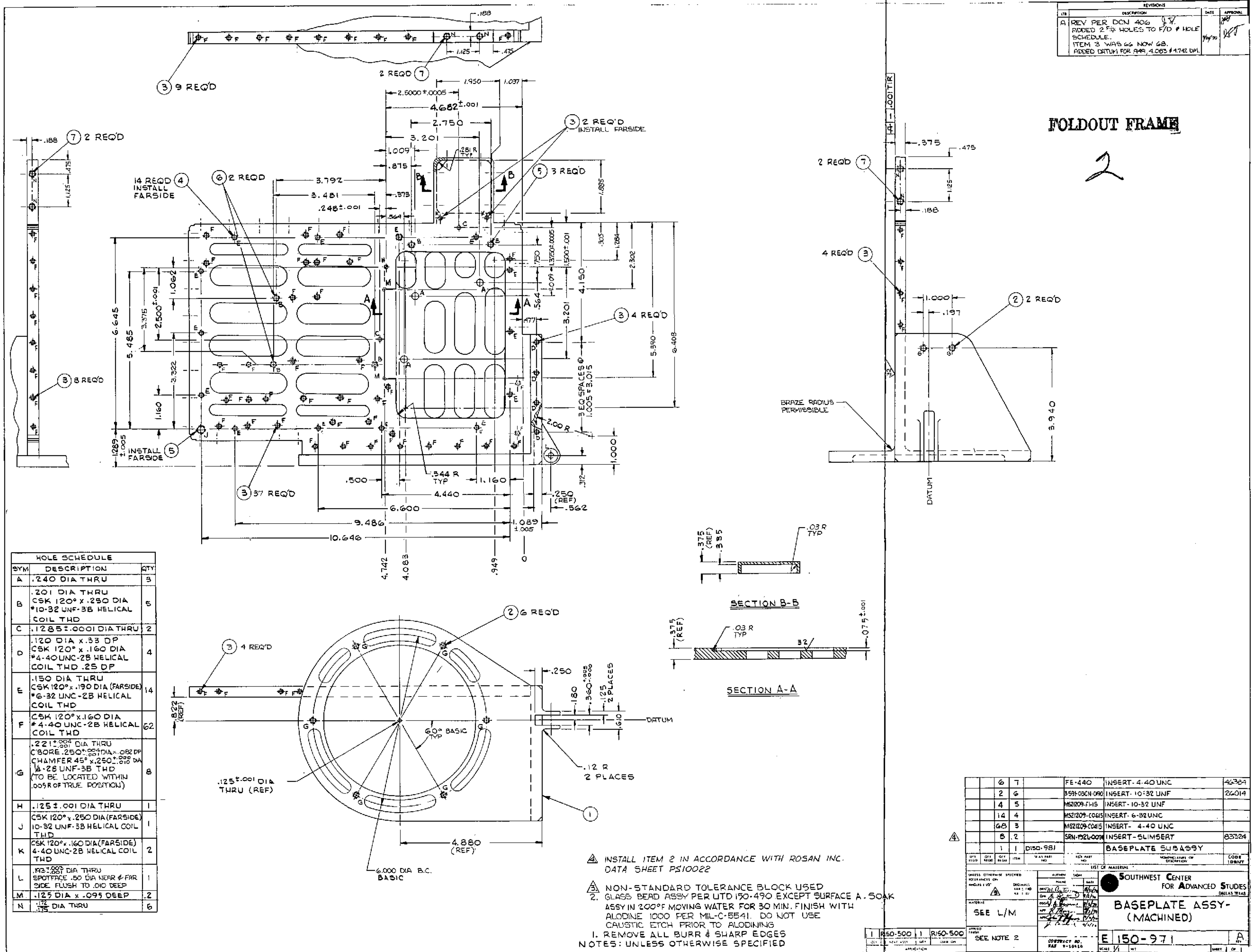
THERMAL HOUSING ASSEMBLY

E | 150-577 | C

SCALE 1/1 SHEET 1 OF 1

Figure 2-10. Thermal Housing Assembly

FOLDOUT FRAME 1



HOLE SCHEDULE		
SYM	DESCRIPTION	QTY
A	.240 DIA THRU	3
B	.201 DIA THRU CSK 120° x .250 DIA #10-32 UNF-3B HELICAL COIL THD	5
C	.1285±.0001 DIA THRU	2
D	.120 DIA x .33 DP CSK 120° x .160 DIA #4-40 UNC-2B HELICAL COIL THD .25 DP	4
E	.150 DIA THRU CSK 120° x .190 DIA (FARSIDE) #6-32 UNC-2B HELICAL COIL THD	14
F	CSK 120° x .160 DIA #4-40 UNC-2B HELICAL COIL THD	62
G	.221 +.004/-.001 DIA THRU C'BORE .250 +.004/-.001 DIA x .082 DP CHAMFER 45° x .250 +.000/-.010 DIA 1/4-28 UNF-3B THD (TO BE LOCATED WITHIN .005 R OF TRUE POSITION)	8
H	.125±.001 DIA THRU	1
J	CSK 120° x .250 DIA (FARSIDE) 10-32 UNF-3B HELICAL COIL THD	1
K	CSK 120° x .160 DIA (FARSIDE) 4-40 UNC-2B HELICAL COIL THD	2
L	.193 +.003/-.001 DIA THRU SPOTFACE .50 DIA NEAR & FAR SIDE FLUSH TO .010 DEEP	1
M	.125 DIA x .095 DEEP	2
N	.172/.175 DIA THRU	6

4\. INSTALL ITEM 2 IN ACCORDANCE WITH ROSAN INC. DATA SHEET PS10022

3\. NON-STANDARD TOLERANCE BLOCK USED

2\. GLASS BEAD ASSY PER UTD 150-490 EXCEPT SURFACE A. SOAK ASSY IN 200°F MOVING WATER FOR 30 MIN. FINISH WITH ALODINE 1000 PER MIL-C-5541. DO NOT USE CAUSTIC ETCH PRIOR TO ALODINING

1\. REMOVE ALL BURR & SHARP EDGES

NOTES: UNLESS OTHERWISE SPECIFIED

QTY REQD	QTY REQD	QTY REQD	ITEM	SCAS PART NO	FSCM PART NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT
		6	7		FE-440	INSERT-4-40 UNC	46384
		2	6		3591-03CN-090	INSERT-10-32 UNF	24014
		4	5		MS21209-F1-15	INSERT-10-32 UNF	
		14	4		MS21209-C0615	INSERT-6-32 UNC	
		68	3		MS21209-C0415	INSERT-4-40 UNC	
		8	2		SRN-1921-0070	INSERT-SLIMSERT	83324
		1	1	D150-981		BASEPLATE SUBASSY	

LIST OF MATERIAL

MATERIAL: SEE L/M

APPLIED FINISH: SEE NOTE 2

SOUTHWEST CENTER FOR ADVANCED STUDIES, DALLAS TEXAS

BASEPLATE ASSY-(MACHINED)

CONTRACT NO. NAS 9-10410

E 150-971 REV A

SCALE 1/1

NEXT ASSY R150-500

FOLDOUT FRAME 2

Figure 2-11. Baseplate Assembly

2.5 THERMAL DESIGN

Environmental conditions and thermal control dictated the thermal design effort. Thermal consideration during trans-lunar/trans-earth environment, lunar orbit environment, and during RCS burns with the SIM door off were analyzed. Passive and active control measures were then designed to ensure proper operation in the varying thermal environments.

2.5.1 ENVIRONMENT

Worst case environments with the instrument in several CSM attitudes were investigated and determined to be as follows:

a. Hottest Environment

Instrument deployed

CSM in a +45 degree Lunar Inclincation Orbit

Instrument Electronics ON

Heaters operating

CSM in ALEM attitude with SIM bay directed toward the Lunar surface with the mass spectrometer boom assembly mounted 31 degrees clockwise looking forward from the SIM bay centerline.

b. Coldest Environment (Four-hour cold bias contingency)

Instrument boom retracted

SIM door off

No external flux to the instrument

SIM bay temperatures as specified in North American Document MH01-12664-434

Heaters active using a set point of 32°F

Instrument electronics OFF

Using the worst case environmental conditions, maximum and minimum temperatures for the individual components were calculated. A thermal math model was developed by The Boeing Company and implemented in North American's overall SIM thermal math model. Table 2- 1 lists the predicted temperatures with maximum operating and survival temperatures. Measured temperatures on instrument hardware proved to be well within predicted worst case limits.

Temperatures predicted for the SIM bay structural elements for all flight conditions are well documented in NR Document MH01-12664-434 and will not be repeated in this report.

TABLE 2-1. . SUMMARY OF PREDICTED MAXIMUM AND MINIMUM TEMPERATURES

COMPONENT	TEMPERATURES (°F) HOTTEST ENVIRONMENT MAXIMUM	TEMPERATURES (°F) COLDEST ENVIRONMENT MINIMUM	MAX. OPERATIONAL TEMPERATURE LIMIT	MIN. SURVIVAL TEMPERATURE LIMIT
Multiplier H. V.	108	- 7	149°F	- 58°F
Low Voltage P.S.	93	-10		
PreAmp & PreScaler	98	1		
Counter & Data Compressor	95	6		
Counter & Data Compressor	94^{+13}_{-9}	5^{+13}_{-9}		
Housekeeping	88	- 5		
Switch PreReg.	92^{+13}_{-9}	-10^{+13}_{-9}		
Thermal Control	86^{+13}_{-9}	10^{+13}_{-9}		
Digital Sweep	98^{+13}_{-9}	-2^{+13}_{-9}		
Signal Conditioner	86^{+30}_{-0}	-5^{+30}_{-0}		
Sweep High Volt.	101	- 7		
Emission Control	103^{+13}_{-9}	-7^{+13}_{-9}	149°F	- 58°F
Multiplier H.M.	0^{+15}_{-9}	-37^{+15}_{-9}	160	-200
Multiplier L.M.	0^{+15}_{-9}	-37^{+15}_{-9}	160	-200
Magnet	0	-40	190	<<-40

2.5.2 THERMAL CONTROL TECHNIQUES

To adequately perform in all thermal environments, it was determined that both passive and active control was required.

The mass spectrometer is logically divided into two thermal sections. One, the analyzer section consists of the analyzer tube, magnet assembly, electron multipliers ion source, and ion source heater power supply. The second section contains 95% of the electronic circuitry and is associated with counting, data compressing and housekeeping functions. The analyzer section contains few temperature sensitive elements, whereas the electronics have typical electronic circuits which must be temperature compensated for optimum performance. Only passive control is used in the analyzer section, maintaining this section at temperatures of from -80°F to +80°F. Both passive and active control are used for the electronics section, maintaining temperatures from 0°F to +130°F.

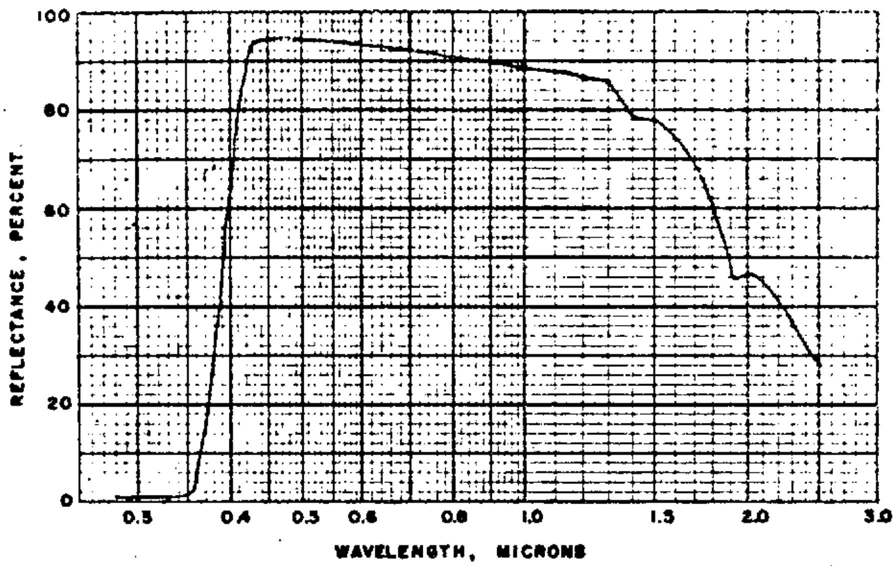
2.5.2.1 ANALYZER CONTROL

Data from thermal vacuum tests of a previous study program had shown that the analyzer section could survive wide temperature excursions without degraded performance. The main components of the analyzer section are thermally coupled to the main baseplate of the system and as a coupled unit exhibits considerable thermal inertia. As a result, with the proper choice of thermal finishes, control can be maintained by passive means only.

A study of the response of the analyzer using thermal finishes as a parameter resulted in the selection of a white silicate coating. developed by Dr. Shutte at the Goddard Space Flight Center and identified as MS-74. This finish is very stable under exposure to solar radiation. After 144 hours exposure to the equivalent of 1 solar ultraviolet spectrum in a pressure of 10^{-6} torr, solar absorptance changed only from 0.22 to 0.25. Normal emittance is 0.95 and insensitive to ultraviolet radiation. The spectral ultraviolet degradation is thus negligible as shown in detail in Figure 2-12.

This finish is thus the primary thermal control finish for the analyzer section. The finish is applied to all exterior surfaces of the analyzer cover, a .020" thick nickel-iron alloy, which encloses five sides of the analyzer. Although the cover itself has low thermal inertia and can change rapidly under varying thermal input conditions (-150°F to +80°F over a lunar orbit), the inertia of the analyzer assembly keeps the analyzer close to the average cover temperature. Using this combination of white paint and thermal inertia, the analyzer temperature is cold biased compared to the electronics. Maximum analyzer temperature never exceeds 80°F and minimum temperatures of -80°F can be experienced during extended periods of no solar exposure.

An active heater element is present in the analyzer section and is located on the Ion Source. However, this heater is for local heating of the Ion Source for bakeout purposes and not for thermal control of the analyzer. The heater dissipates 10 watts and is activated by command from the astronaut. Ion Source temperatures in excess of 400°F are obtained at the Ion Source using this heater. The heater does not significally change the thermal response of the remainder of the analyzer.



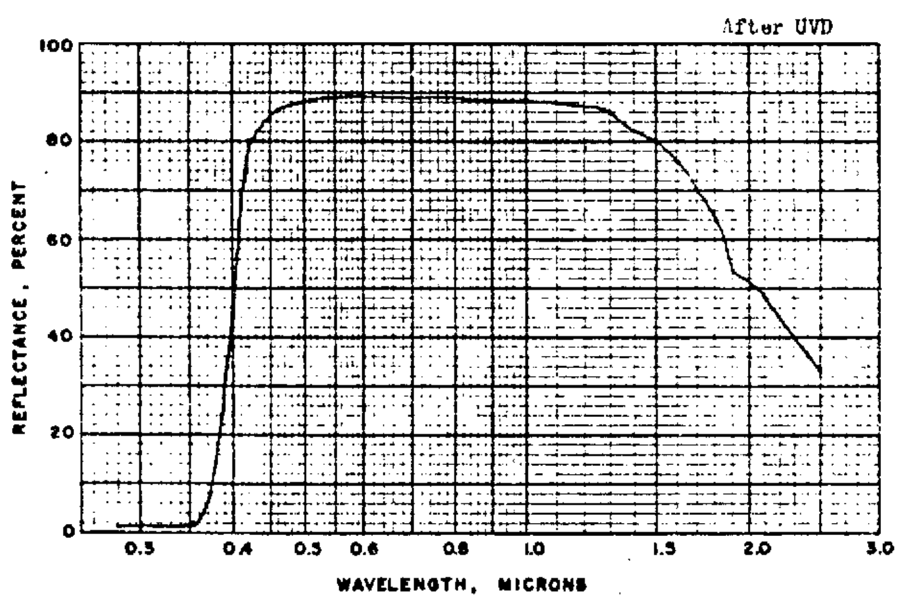


Figure 2-12. Ultraviolet Degradation of MS74

2.5.2.2 ELECTRONICS CONTROL

The electronics assembly consisting of 12 printed circuit boards, are mounted with spacers to an aluminum plate which is 6" by 10" by .090" and is referred to as the radiator plate. The size of this plate is dictated by general system outline constraints. This plate is the primary thermal control surface for the electronics and is coated with MS 74 which acts as an efficient heat radiator and solar reflector when the electronics are full on (dissipation $\sim$13 watts) during the worst case hot environment.

Since no other external surface is required for thermal control during the hot condition, the remaining five sides of the electronics are insulated to prevent heat loss during the worst case cold condition. This insulation is provided by use of a multi-layer, metalized kapton foil-fiberglass blanket. The blanket is enclosed in a two-walled structure. An inner fiberglass shell is used to protect the blanket whenever the electronics assembly is removed and replaced, and also provides a mounting ring for the radiator plate. An outer fiberglass shell mounts to the baseplate of the system and provides mechanical support and thermal insulation between the electronics and the baseplate, which acts as the basic support structure of the system. The outer surface of the outer housing is also coated with MS 74.

Analysis showed that with this configuration during the worst case cold condition, with the electronics off, the temperature of the electronics could fall below acceptable levels (-20°F). Reserve energy is therefore provided by means of heater pads attached to the radiator plate. These pads provide 10 watts of heat and are activated by a control circuit that is full on whenever the radiator plate falls below 32°F and full off whenever the radiator plate exceeds 47°F. In normal orbital operations, with the electronics on, the heater pads are off and all control is supplied by the electrical dissipation of the electronics themselves.

On the individual printed circuit boards, hot spots are controlled by spreading the heat dissipating elements as uniformally as possible over the boards and by using thermal joint compounds such as silicon grease and conducting epoxies to heat sink power transistors and resistors to the boards. The hottest board is the Emission Control Board, dissipating 1.5 watts, and the hottest elements on the board are two silicon power transistors, each dissipating approximately .5 watts each. Gradients between these transistors and the radiator plate are less than 30°F.

Using the techniques described above the temperatures of the electronics are controlled within the range of 0°F to 130°F for all mission profiles.

2.5.3 THERMAL ANALYTICAL MODEL

The thermal analysis and predictions cited in the above paragraphs were performed using a mathematical model of the system. This model was created by the Boeing Company, Aerospace Group, Southeast Division, Houston, Texas, and is documented in Boeing D2-118302-1A.

In summary, the model consists of a segmentation of the system into 43 thermal nodes, each node representing a physical part of the system; that is, a printed circuit board, a section of the baseplate, etc. The nodes are given the thermal properties of the physical section which they represent and are coupled by conduction and radiation, resulting in a system of 43 simultaneous equations. This set of equations is then solved using a high speed computer. The computer program employed in the input of data to the computer and in the actual specification of computational steps is the NASA sponsored CINDA-3G program. For a detailed description of the mathematical model refer to the Boeing document D2-118302-1A. For a detailed description of the CINDA-3G program, consult Chrysler Corporation Space Division Document TN-AP-67-287.

To verify the accuracy of the mathematical model, predictions were made on the thermal response of the system to the thermal vacuum tests as described in Section 7.0 of this document. As a result of the actual thermal vacuum tests on the Prototype Unit, some changes were made in the model to obtain agreement between predictions and test results. The final correlation between the model and thermal vacuum tests showed agreement to within ±15°F. It was with this revised model that all the analysis referenced in the preceeding paragraphs were made.

The final thermal model was incorporated in the overall North American thermal model of the SIM bay.

SECTION 3

ELECTRICAL DESIGN

3.1 ELECTRICAL CHARACTERISTICS

Electrical design objectives were directed toward meeting the following requirements for each of the component subassemblies, and subsystem performance.

3.1.1 SWITCHING PRE-REGULATOR SUBASSEMBLY A1

a. Input Voltage: 27.5 $\pm$ 2.5 volts

b. Transients: 21 to 32 volts with recovery to steady state within 1 second.

c. Overvoltage Spike: 50 volt spike superimposed to d-c power.

d. Ripple: 1 volt p-p maximum.

e. Output Voltage: 20 $\pm$ 0.25 Volts.

f. Efficiency: $\geq$85% @ 750 mA.

g. Output Current: 800 mA, maximum.

h. Output Ripple: $\leq$0.25 Volts p-p.

i. Noise Feedback: Noise Feedback on power line to comply with NAR Document #MC999-0002C, Titled: "Electromegnetic Interference Control for the Apollo Space System".

3.1.2 THERMAL CONTROL AND MONITORING SUBASSEMBLY A2

a. Thermal Control Sensing Circuit

1. Low temperature turn-on point to be 0 $\pm$ 2°C and remain on to -35°C.

2. Circuit to be operated from CSM power source (+27.5 $\pm$ 2.5 volts). Circuit must be able to withstand +50 Volt spike of about 10 microseconds.

b. Electronics Temperature Monitor Circuit

1. Circuit must be able to cover the temperature range from -50°C to +100°C.

2. Output Level: 0 to +5 volts, maximum.

c. Mass Spectrometer Temperature Monitor Circuit

1. Circuit must be able to cover the temperature range from -160°C to +250°C.

2. Output Level: 0 to +5 volts, maximum.

d. Instrument Current Monitor

1. Circuit must be able to cover the current range from 0 to 1.5 amperes.

2. Output Level: 0 to +5 volts, maximum.

3.1.3 DIGITAL SWEEP CONTROL CIRCUIT SUBASSEMBLY A3

a. Input Specifications

1. Sync Pulse - 10 pps.

2. Amplitude - 0 to 4 volts min.

3. Pulse Width - 10 $\pm$ 1.0 microsecond.

4. Rise time and fall time $\leq$1.0 microsecond.

b. Output Specifications

1. Pedestal gate, 0 to 4 volts min.

2. D/A output, 0 to -10 volts (w/40K load on ladder).

3. First linearization, 400 steps; second linearization, 190 steps; background, 30 steps.

4. Sweep Start Gate; 0 to 4 volts min.; positive level for 590 steps.

5. Internal calibrate gate ; 0 to 4 volts min.; positive level for 15 steps.

3.1.4 SIGNAL CONDITIONING SUBASSEMBLY A4

a. Input:

Command voltage of +28 Volts from spacecraft on six lines

b. Output:

1. Switching control on four signal lines.

2. Switching control of +20 volts with vacuum lock-out at altitudes below 60,000 feet (54.24 torr).

3.1.5 SWEEP HIGH VOLTAGE POWER SUPPLY SUBASSEMBLY A5

a. Input Specifications:

1. Input Voltage: 20 ± 0.25 volts.

2. Input Ripple: ≤0.25 volts p-p.

3. Input Noise: ≤0.25 volts p-p.

4. Digital Sweep Control Voltage: 0 to -10 volts.

b. Output Specifications:

1. Output Voltage: 0 to -1560 volts
± 30 volts @ -1560 volts

2. Pedestal -620 volts ±15 volts
First linearization, 400 steps @ 1.2 volts/step;
Second linearization, 190 steps @ 2.4 volts/step;
Background, 30 steps @ 0 volts/step.

3. Step change response time ≤10 ms.

4. Load ≥200 megohms.

5. Output Noise and Ripple: 0.1 volts p-p.

6. Sweep Monitor: 0 to +5 volts.

3.1.6 LOW VOLTAGE POWER SUPPLY SUBASSEMBLY A6

a. Input Specifications:

Input Voltage: 20 ± 0.25 volts.

Input Ripple: ≤0.25 volt p-p.

Noise: ≤0.25 volt P-P

Output Specifications:

Output Voltage	Tolerance	Output Current	Noise P-P
+15 volts unregulated	±1 V	≤ 10 mA	≤ 0.3 V
+12 volts regulated	±0.1 V	≤ 50 mA	≤ 0.04 V
-12 volts regulated	±0.1 V	≤ 50 mA	≤ 0.04 V
-15 volts reference	±0.015 V	≤ 2.8 mA	≤ 0.015 V
-25 volts filtered	±1 V	≤ 15 mA	≤ 0.3 V
+ 5 volts filtered	±0.25 V	≤ 485 mA	≤ 0.3 V
- 5 volts filtered	±0.25 V	≤ 20 mA	≤ 0.15 V

c. Efficiency: ≥60 percent at 80 percent load.

3.1.7 PRE-AMPLIFIER, DISCRIMINATOR AND PRE-SCALER SUBASSEMBLY A7

a. General Specifications: The following subsystem consisting of sensor, high voltage power supply, pre-amplifier, discriminator and pulse shaper must operate within specs over a temperature range of -25°C to 65°C. Variances in the gain of the sensor and pre-amplifier along with high voltage changes must be considered when designing this subsystem.

1. Sensor: Bendix Electron Multiplier Model M310. Gain $\geq 10^6$ tolerance to be determined.

2. High Voltage Power Supply: 1400 - 1800 volts adjustable with regulation ±75 volts.

b. Pre-amplifier: Gain to be matched to sensor. Overload pulse limiter required to minimize deadtime.

Maximum counting rate expected - 5 mHz.

Voltage Avail: ±12 volts ± 0.1 volts
- 5 volts ± 0.1 volts
+ 5 volts ± 0.25 volts

c. Discriminator and Pulse Shaper: Pulse Width - 50 ns ± 5 ns. Pulse Amplitude - 0 to 4 V. min. Discriminator to be a two level controlled by relay contacts. Must be able to drive a Fairchild 9001 flip-flop.

d. Pre-scaler: Fairchild 9001 Flip-flop (to be included in package).

e. Signal Injection: Pre-amplifier must be able to accept an internal calibrate signal and an external signal from the BTE.

3.1.8 COUNTING AND DATA COMPRESSION SUBASSEMBLY A8, A9

a. Input Specifications:

Input Voltage: +5 to 0.25 volts logic level.

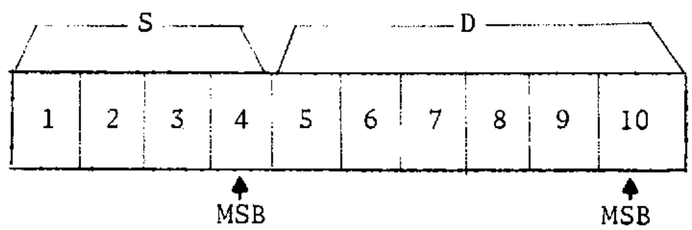
Input Signal: Output of Fairchild 9001, Flip-flop - 5 mH_z max.

b. Output Specifications:

Output from data compressor to be serial shiftout. The output will be buffered by a Fairshild 9002 Gate. Must be able to drive 70 feet of cable.

Output Levels: "0" $\leq$ + 0.5 volts
"1" $\geq$ + 3.6 volts

Output Signal: 6 most significant bits of data counter.
4 bits of shift counter, as follows:



Where:

S = Number of Shift Pulses
D - Six most significant bits

Number of Counts = (D + 64) (2^{14-S}) When S<15

= D when is S = 15

3.1.9 HOUSEKEEPING MULTIPLEXER SUBASSEMBLY A10

a. Multiplexer and Output Buffers

Multiplex 16 analog voltage levels (0 to +5 Volts). Use 1 PPS signal (0 V. to 4 V. min.) for multiplexing rate. Output buffers must be capable of driving 70 feet of cable. Two buffers are required for isolation. Generate 1 Hz Sync Pulse

b. Input Characteristics

Load impedance - 100 ohms

Source impedance - Logical "1" 100 ± 20 ohms

Logical "0" <5K ohms

Pulse amplitude: 0 to +4 ± 1 volts

D.C. offset: 200 mV maximum

Rise time: <500 ns

Fall time: <500 ns.

Duty cycle: 50% ± 10%

c. Sync pulse will drive a Fairchild U3I900251X gate

d. +5 volt monitor

Monitor output impedance to be 2.5K ohms.

+2.50 volts monitor voltage represents +5.00 volts actual.

e. +12 volt monitor

Monitor output impedance to be 2.5K ohms.

+4.00 volts monitor voltage represents +12.00 volts actual.

3.1.10 ELECTRON MULTIPLIER HIGH VOLTAGE POWER SUPPLY A11

a. Input Specifications:

Input Voltage: 20 ± 0.25 volts

Input Ripple and Noise: ≤0.25 volts p-p

b. Output Specifications:

Output Voltage: 1400 to 1800 Volts adjustable
2-level control by relay contacts

Output Current: 100 microamperes, maximum

Output Voltage Monitor: 0 to 4 volt signal. Goes to
50K telemetry load.

Output Ripple & Noise: 50 millivolts P-P

Output Regulation: ±75 volts

3.1.11 EMISSION CONTROL SUBASSEMBLY A12

a. Input:

+20 VDC current drain not exceeding 200 mA

+ 5 VDC current drain not exceeding 10 mA

b. Voltage Output (based upon 3% mil Rhenium filament)

+45 VDC	45 ±2	Volts for ion source filament biasing
-80 VDC	-80 ±4	" " " " " "
+13 VDC	+13 ±1	" for internal circuitry
-13 VDC	-13 ±1	" " " "
+ 5 VDC	+5 ±0.5	" " " "

c. Regulated Filament Current Output

The Emission Control circuitry shall be capable of delivering 1 Ampere at 2 Volts RMS to the filaments. The filament current should be regulated such that the emission current is at a preselected value (50µA - 300µA).

d. Automatic Filament Switching

The Emission Control circuitry shall detect the failure of the functioning filament in lieu of the emission current. When there is no emission detected, the circuit shall generate an energizing signal, between 5 and 10 seconds after the detection, to switch to and to properly bias the other filament.

e. Manual Filament Switching

The Emission Control circuitry shall provide a test line such that when this line is connected to signal ground it will simulate the failure of a filament and cause a switchover to the other filament in the same manner as described in 6.1.4. Ground signal must be 5 to 7 seconds from duration.

f. Sweep potential divider

A resistive voltage divider shall be included in the Emission Control circuitry such that the total load on the sweep high voltage is 200 +10 megohm and that 3 voltages are produced to bias the following: following:

Draw out	0-1/2% down from sweep potential
J plate 1	20% max. down from sweep potential
J plate 2	20% max. down from sweep potential

These three voltages shall vary with respect to the ion source used, but the variation should be within the range specified above.

g. Monitor Lines

Three monitor lines shall be provided with their specifications stated below:

Filament 1 Monitor:

To indicate current flowing in filament 1 represented by a voltage of 0 to 5 volts.

Filament 2 Monitor:

To indicate current flowing in filament 2 represented by a voltage of 0 to 5 volts.

Emission Monitor

To indicate emission current represented by a voltage of 0 to 5 volts.

h. High Voltage Isolation:

The input voltages and their directly coupled components shall be isolated electrically from the ion source driving circuitry. The ion source driving circuitry shall withstand and be operative at a floating potential equivalent to the sweep potential.

3.1.12 ELECTRICAL POWER REQUIREMENTS

a. D-C Power

The Mass Spectrometer uses CSM power which is a 27.5 ±2.5 volts dc. The input regulator is designed to accept ±50 volt spikes. Ripple up to 1.0 volt peak-to-peak is acceptable.

The current load on the CSM power buss is nominally 0.6 ampere. Current varies with the selected instrument operating mode.

b. AC Power - None

3.1.13 DATA OUTPUT CHARACTERISTICS

Two data channels (Data A and Data B) has the following interface characteristics:

a. Voltage Magnitude:

Logical "zero": 0.0 ±1.0 volt

Logical "one" : 4.5 ±1.5 volts

b. Rise Time: 5.0μs maximum (10% to 90%)

c. Fall Time: 5.0μs maximum (10% to 90%)

d. Bit Time : 15.625μs (nominal)

e. Source Impedance: 300 ohms maximum shunted by 100 picofarads maximum capacitance.

f. Input Impedance: 3,000 ohms minimum shunted by 6,200 picofarads maximum capacitance.

3.1.14 TELEMETRY SYSTEM

The Scientific Data System 64 K-bit telemetry system is used to transmit all experiment data to earth. The system format is an 80 x 100 matrix with 8,000 8-bit words per second capacity. Reference: Electrical ICD, MH01-12662-234. The specific words containing the Mass Spectrometer data are:

a. Data A - Low Mass

1. Words 71 and 72

2. Frames 2, 12, 22, 32, 42, 52, 62, 72, 82, and 92

b. Data B - High Mass

1. Words 71 and 72

2. Frames 4, 14, 24, 34, 44, 54, 64, 74, 84, and 94

c. Data C - Sweep Start Flag

1. Word 72 (bit 8)

2. Frames 7, 17, 27, 37, 47, 57, 67, 77, 87, and 97

d. Housekeeping Analog

1. Word 53

2. Frames 6, 16, 26, 36, 46, 56, 66, 76, 86, and 96

3.2 SYSTEM PERFORMANCE REQUIREMENTS

3.2.1 GENERAL

The Mass Spectrometer instrument is designed to measure the types and abundances of gas molecules in the ion source regime in the mass range from 12 to 66 amu which is scanned simultaneously in two ranges, 12 to 28 amu and 28 to 66 amu by varying the ion accelerating voltage in a step-wise manner approximating an exponential wave form. Figure 3-1 is a functional block diagram of the system.

Ionization is by electron bombardment of the gas molecules in the source region. Detection of the ion currents is by counting the number if ions traversing pre-selected paths through the ion optical system. Two Bendix magnetic electron multipliers, one for each channel, mounted behind collector slits, act as pulse amplifiers transmitting a pulse of charge into a pre-amplifier and counter system for each ion detected. Data is telemetered to earth via the SDS 64-kilobit telemetry system. Figure 3-1 shows the configuration of the mass spectrometer.

The ion-accelerating voltage is varied in a step-wise manner from approximately 620 volts to 1,560 volts in 590 steps. Dwell time on each step (the counting period) is not critical, but has been set at 100 milli-seconds. Counts are accumulated for this period and stored in a 21-bit accumulator in each channel. An enable pulse from the SIM Scientific Data System triggers the counting period, and steps the ion accelerating voltage.

Immediately following the enable pulse, the data is compressed and stored in 10-bit buffer registers to be sampled by the telemeter system within the next 100 millisecond period following the data accumulation.

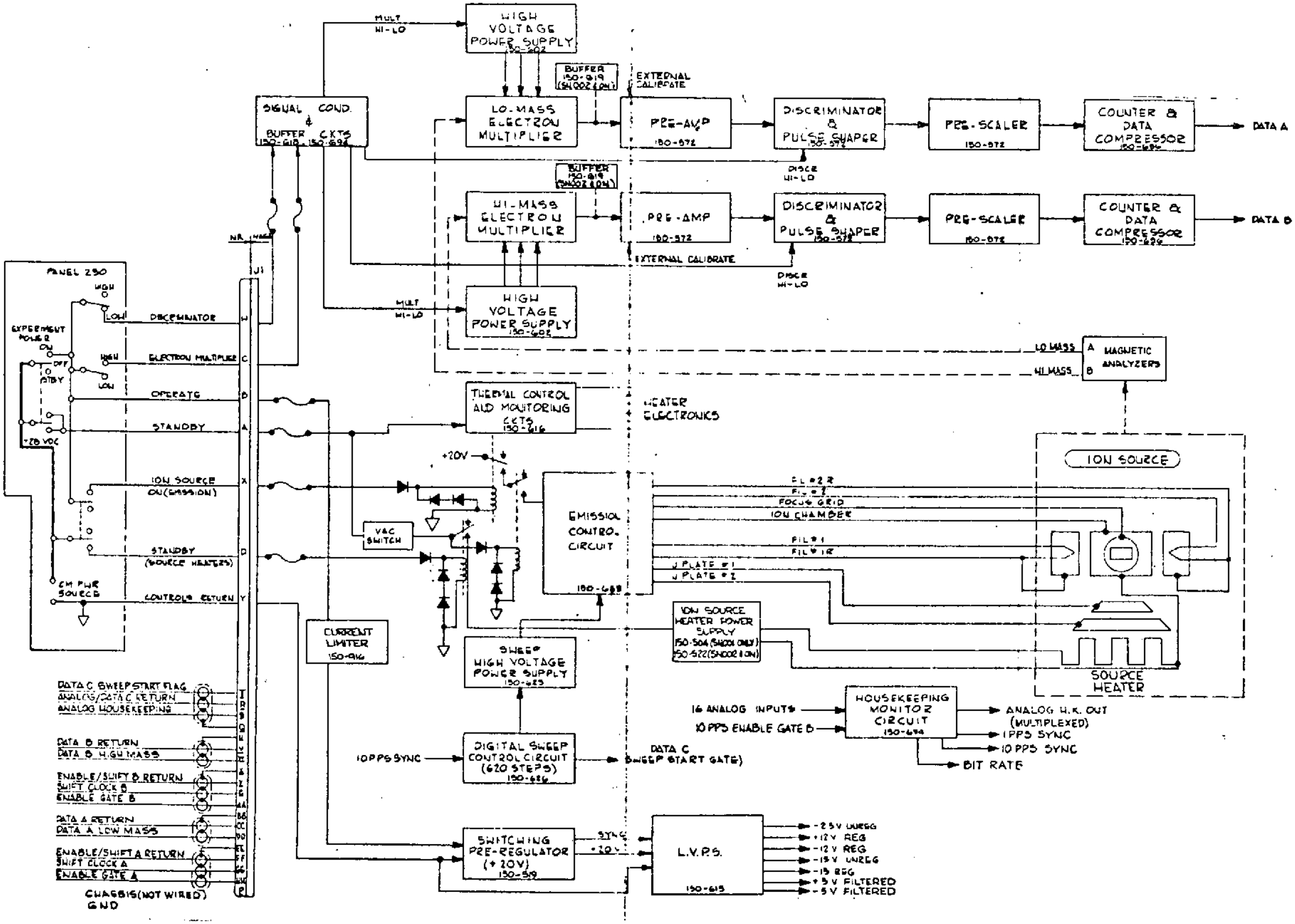


Figure 3-1. Mass Spectrometer Block Diagram

Meanwhile, count accumulation for the next voltage step occurs. Enable Gates A and B are received during each 100 millisecond period.

The voltage step is determined by counting from step one, which is indicated by a sweep start flag called Data C. The mass number of the ion being detected is determined by counting the number of voltage steps from step one (the start of the sweep).

The ion accelerating voltage sweep is generated by varying the voltage in a series of 620 steps from 620 volts to 1,560 volts according to the following plan: 400 steps at 1.2 volts per step, 190 steps at 2.40 volts per step, 15 steps at zero volts for background counting, and 15 steps at zero volts for a 32 kHz calibration frequency. Sweep start flag (Data C) will indicate data or background, the flag being high (logic 1) for the data mode and low (logic 0) for the background calibrate mode, and serves as a marker for the start of each sweep.

Maximum range of the 1,560-volt end of the sweep is ±30 volts; maximum range of the 620 volt end of the sweep is ±15 volts, depending on the magnetic field value. The minimum number of steps between adjacent mass peaks below mass 54 is 12 and the mass resolution is such that at mass 39 amu there is less than 0.3 percent contribution from the mass 40 peak. At a dwell time of 100 milliseconds per step, the partial pressure sentivitivy of the instrument is on the order of 10^{-13} torr. Response time of the high voltage step change is less than 10 milliseconds.

Internal calibration occurs after each sweep of the mass spectrum during the 30 zero-volt background and calibration steps by applying an internal clock output to the counter inputs for the last 15 steps of this period.

3.2.2 TELEMETER FORMAT

The SIM Scientific Data System format contains 8000 8-bit words repeated each second. Ten sets of 8-bit words for each channel (Data A and Data B) per 100 millisecond period contain the mass spectrometer data; a single discrete bit is the data-background flag (Data C). In addition, a single zero-to-five analog housekeeping channel is sampled once per second. Sixteen instrument parameters are monitored, commutated internally to the instrument and outputed sequentially on this channel. The housekeeping monitors are shown in the Table 3-1 with MIN and MAX values of the data.

Table 3-1. Housekeeping Parameters

PARAMETER	MIN VOLTS	MAX VOLTS
+12 volts	3.85	4.15
+ 5 volts	2.20	2.80
-12 volts	2.85	3.15
-15 volts	4.67	4.83
Emission current	Note 1	
Filament #1 current	Note 1	
Filament #2 current	Note 1	
Electron multiplier voltage (low mass)	Note 1	
Electron multiplier voltage (high mass)	Note 1	
Sweep high voltage monitor	Note 2	
Temperature 1 (Electronics)	Note 1	
Temperature 2 (Ion Source)	Note 1	
Status flags (Multiplier HI-LO)	-0.1	4.4
Status flags (Discriminator HI-LO)	-0.1	3.2
Instrument current	Note 1	
Marker	5.00	6.00

Note 1: Calibration data supplied with each instrument.

Note 2: Sweep monitor varies from 0 to 5 volts as sweep cycles.

Summary of telemetry requirements:

20 pairs of 8-bit words/second

1 discrete flag bit/second

1 sample/second housekeeping channel (analog input)

Commanding of the experiment is by toggle switches in the Command Module. No automatic uplink commands are available. Special tests are achieved through voice communication with the Command Module pilot. The functions requiring adjustment are the electron multiplier high voltage level HIGH/LOW, ion source ON/OFF/STANDBY (source heater) and instrument power ON/OFF/STANDBY disc level.

Four switches in the Command Module (CM) operate these functions by applying Spacecraft power directly to the Spectrometer in the case of Operate/Standby and ion source heater modes, but operate relays in the Spectrometer to control all other functions. Real time data displays are required to monitor the settings of these functions. Vacuum switches are used as interlocks to prevent operations of the ion source heaters and the ion source (emission) control circuitry at atmospheric pressure below 60,000 feet (54.24 torr).

3.3 SUBSYSTEM PERFORMANCE REQUIREMENTS

For purposes of description relating to functional subsystem levels, the Mass Spectrometer is divided into the Data Subsystem, Ion Source and Control Subsystem, Sweep High Voltage Subsystem, Power Converter Subsystem, and the Thermal Control, Housekeeping Monitor, and Signal Conditioning Subsystem. Refer to Figures 3-2 through 3-7 for subsystem block diagrams.

3.3.1 DATA SUBSYSTEM

The Data Subsystem consists of the high voltage power supply, electron multiplier, pre-amplifier, discriminator and pulse shaper, pre-scaler, and counter and data compressor. See Figure 3-2.

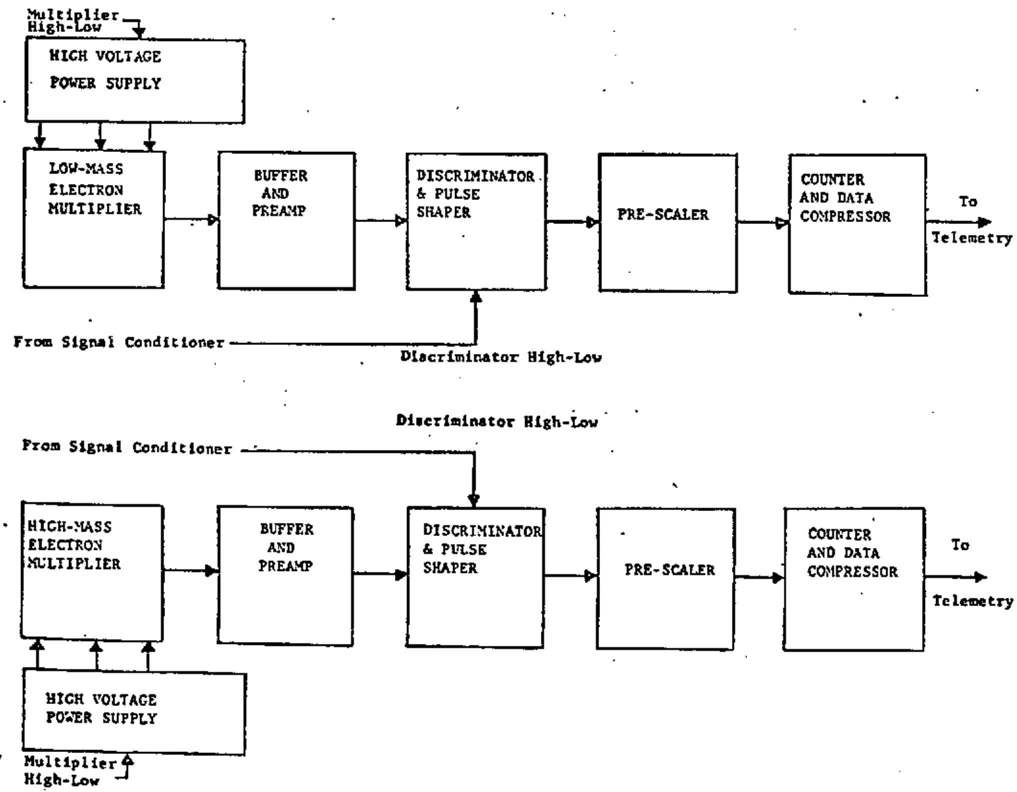


Figure 3-2. Data Subsystem Block Diagram

The electron multiplier high voltage power supply requires voltage inputs of -12 volts, +12 volts, and +20 volts in addition to the multiplier gain control voltage. It supplies nominal output voltages of -160 volts, -1,150 volts, and -1,600 volts, which are used in the electron multiplier. The correct voltage levels must be selected for each electron multiplier to maximize its gain.

The electron multiplier (ion collector) has a charge gain of 10^6 and functions as collector for the ions which pass through the magnetic analyzer. Two electron multipliers are required in the Spectrometer, one for each mass range channel. Each ion striking the multiplier cathode produces an output pulse which is counted.

The buffer is used as an impedance-matching device thus producing an increased voltage pulse at the input to the pre-amplifier. Basically, the pre-amplifier amplifies the pulse to a useable level for the discriminator and pulse shaper.

The input reference level of the discriminator is controlled by command. This command can set the discriminator's sensitivity level at one of two values such that a noise pulse will not trigger the discriminator. A pulse amplitude exceeding the preset cutoff level of the discriminator will cause the discriminator to conduct and will produce a pulse output to the pre-scaler.

The pre-scaler is a divide-by-two counter which selects every other pulse for output to the counter and data compressor.

The counter and data compressor converts a 21-bit number into 10-bits for readout. Steps in which the data are compressed are as follows (refer to Figure 3-3 for a typical data compressor output):

a. The data number is transferred from a 21-bit counter to a 21-bit shift register.

b. Shifting of the data number begins. A shift counter is used to count each shift pulse.

c. The shifting process stops when the most significant one bit (MSB) of the data number is detected in the last stage of the shift register.

d. The six bits following this MSB are saved for readout. This number is called "D".

e. The number of shifts is transferred to the four stages in the shift register immediately behind the number "D". This shift count is called "S".

f. A maximum of 21-7 = 14 shifts is allowed. These 14 shifts will position the six lowest significant bits so they will be equal to "D".

g. Shift count 14 stops the shifting process whether MSB is equal to 1 or 0. The counter will increment to 15 if MSB = 0. If MSB = 1, the shift counter will remain at 14. The 6-bit number "D" will be read out first starting with the most significant bit.

"S" follows with its most significant bit first. The equation for reconstructing the value of the 10-bit register is:

$$(D + 64)\ 2^{14-S}, \text{ if } S \leq 15$$
$$D\ , \text{ if } S = 15$$

When the shift count $S \leq 14$, the MSB is always equal to 1. Therefore, the value 64 must be added to obtain the correct data value. When S = 15 the MSB = 0, and no correction to "D" is required.

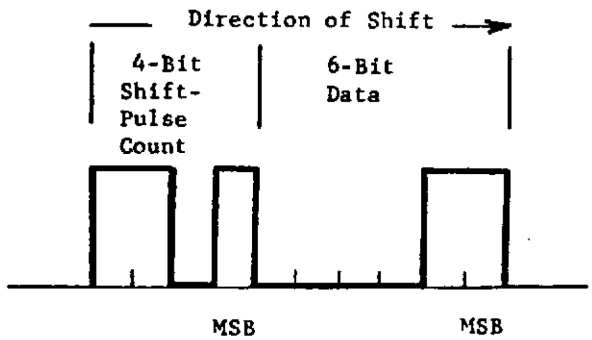


Figure 3-3. Typical Data Compressor Output

3.3.2 ION SOURCE AND CONTROL SUBSYSTEM

The Ion Source and Control Subsystem consists of the emission control circuit, and the ion source. Two filaments are available for redundancy. The following paragraphs provide a discussion of subsystem performance characteristics. See Figure 3-4.

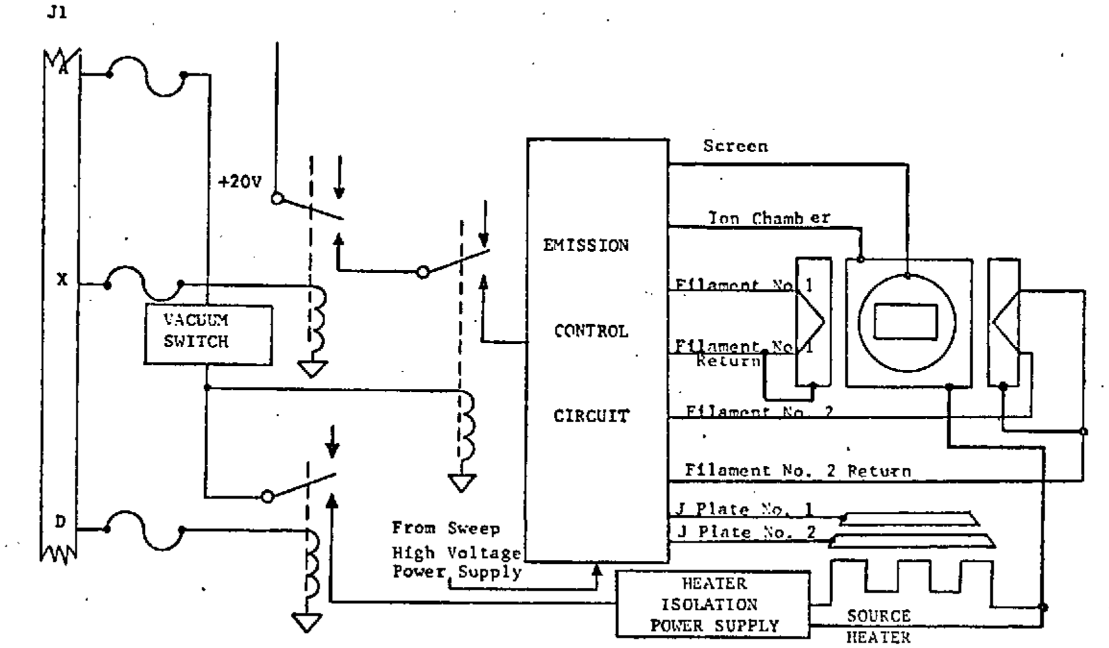


Figure 3-4. Ion Source and Control Subsystem Block Diagram

The emission control circuit is used to control and switch the filament voltages in case of failure of the operating filament. The operating filament, requiring approximately 1.6 amps, is at a potential of -80 volts with respect to the ionization chamber, and the standby filament, which serves as an electron trap, is maintained at a +45 volts referenced to sweep voltage.

Additional functions include application and control of voltages on the focus grid, ion chamber, and J-plates numbers 1 and 2. The potential on the focus grid is -3 volts referenced to sweep voltage, and the ion chamber has the ion accelerating sweep voltage applied to it. This sweep voltage, which is a series of voltage steps, provides the Mass Spectrometer's ability to scan the ion spectrum.

The ion source performs the function of ionization by electron bombardment of the atmospheric gas molecules, accelerating these ions and forming a collimated beam directed into the magnetic analyzer.

3.3.3 SWEEP HIGH VOLTAGE SUBSYSTEM

The Sweep High Voltage Subsystem consists of the sweep high voltage power supply and the digital sweep control circuit. See Figure 3-5.

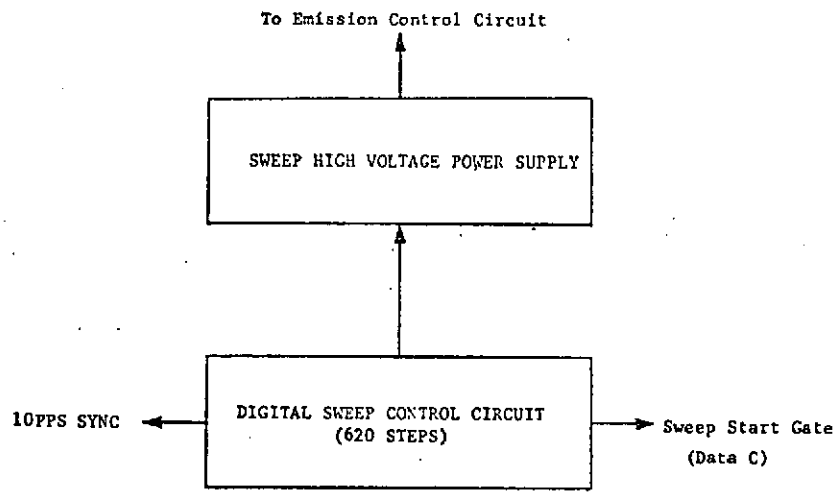


Figure 3-5. Sweep High Voltage Subsystem Block Diagram

The sweep high voltage power supply develops the high voltage level on which the ion source rides. The circuit obtains +20 Volts from the switching pre-regulator, and the two control signals (sweep and pedestal) from the digital sweep control circuit. This combination provides an output voltage which sweeps from 0 volts to 1560 volts in the following manner:

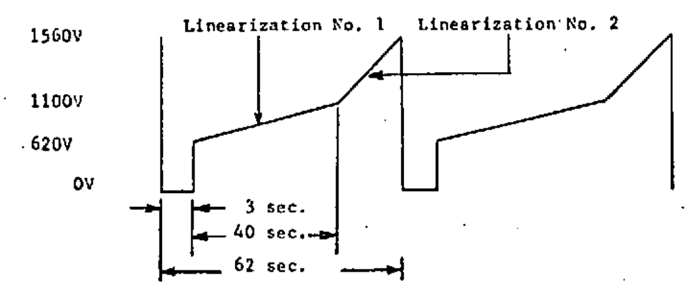


Figure 3-5a

After operating in the background/calibrate count mode (0 volts) for three seconds during which the background counting rate is determined for 1.5 seconds and an internal calibrate frequency (32 KHz) is read, also for 1.5 seconds, the output begins to advance along linearization line No. 1. The output takes 400 steps at 1.2 volts/step which brings it to 1100 volts. At 0.1 second/step, the time required to advance along linearization No. 1 is 40 seconds. The output then advances along linearization curve No. 2 where the output taken 190 steps at 2.4 volts/step. In an additional 19 seconds the output is at its peak voltage of 1560 volts. The output now returns to zero volts and the sweep cycle starts over.

Digital control develops a sweep output and a pedestal output. Together these two outputs control the sweep high voltage power supply. These outputs are referenced to the 10 PPS input (10 steps/sec. or 0.1 sec/step). Sweep output consists of two straight lines which approach an exponential as shown in Figure 3-5b. Linearization No. 1 consists of 400 steps while linearization No. 2 consists of 190 steps. Pedestal voltage is at zero volts for 30 steps and -15 volts for 590 steps as shown in Figure 3-5c.

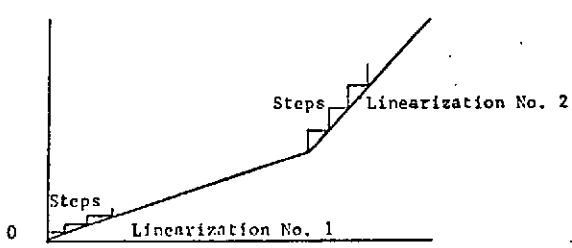


Figure 3-5b

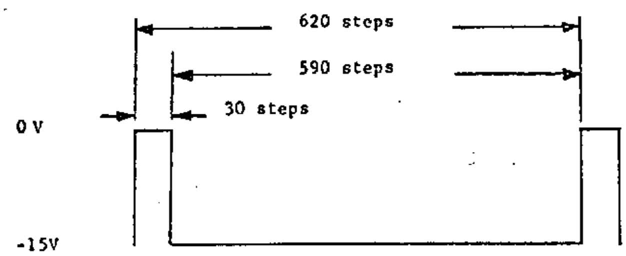


Figure 3-5c

3.3.4 POWER CONVERTER SUBSYSTEM

The Power Converter Subsystem consists of the switching pre-regulator and the low voltage power supply. See Figure 3-6.

The switching pre-regulator obtains +27.5 ±2.5 volts from the Command Module and provides a regulated +20 volts to ±.25 volts output, at more than 85 percent efficiency. This output is used for the low voltage power supply, the sweep high voltage power supply, the multiplier high voltage power supply, and the emission control circuit. Operated as a driven regulator, drive oscillator develops a 50-KHz signal which is scaled to 25-KHz and used to externally drive the regulator supplying 0.6 amps of current in normal operation. In the event the output is shorted or overloaded, the circuit will operate in the current limit mode and will drain less current from the CM than in the normal mode. The input is also designed to accept rather large voltage spikes (50 V) on the CM input lines.

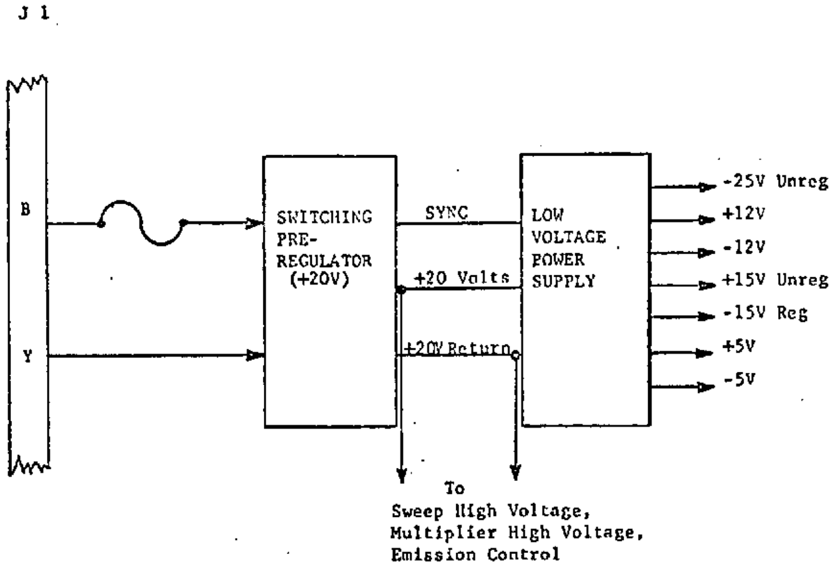


Figure 3-6. Power Converter Subsystem

The low voltage power supply accepts the +20 volts from the switching pre-regulator and develops -25 volts, +12 volts, -12 volts, -15 volts, -15 volts reference, +5 volts and -5 volts. These voltages are used throughout the instrument. The circuit is driven at 12.5 KHz from the same drive oscillator as the switching pre-regulator at one-half the frequency of the switching pre-regulator to obtain a well balanced power system.

3.3.5 THERMAL CONTROL, HOUSEKEEPING MONITOR, AND SIGNAL CONDITIONING SUBSYSTEM

This Subsystem consists of thermal control, housekeeping monitor, and signal conditioning circuits installed on printed circuit boards. See Figure 3-7.

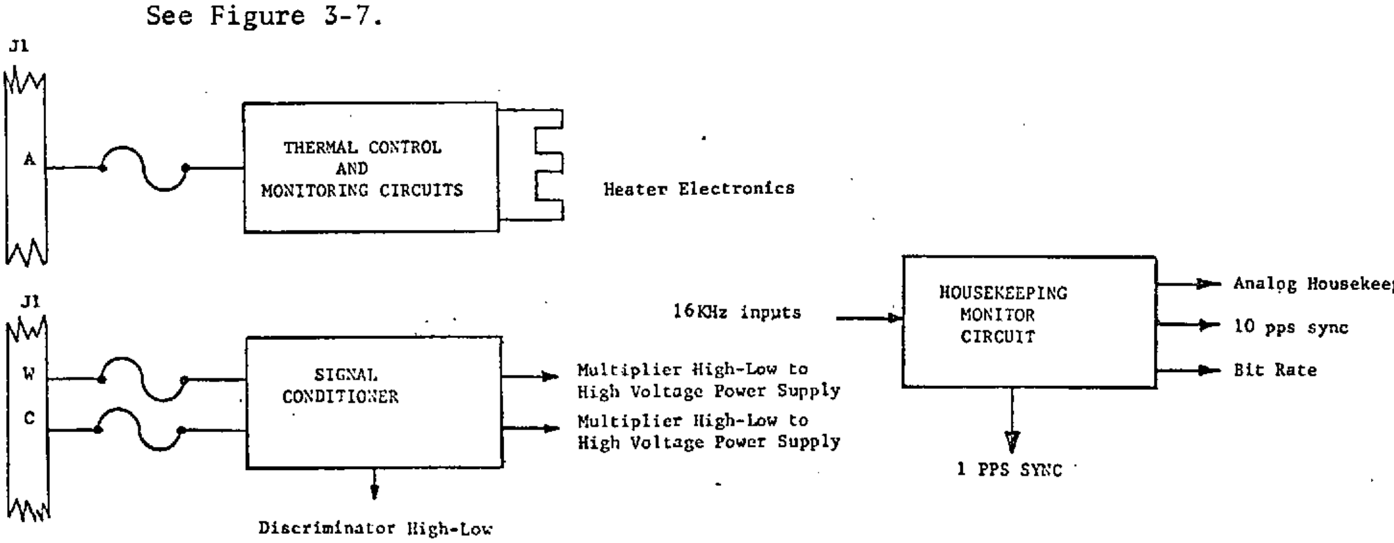


Figure 3-7. Thermal Control, Housekeeping Monitor, and Signal Conditioner Subsystem Block

The thermal control circuitry consists of a -12 volt monitor, -15 volt reference monitor, instrument current monitor, mass spectrometer temperature monitor, electronic temperature monitor, and thermal control. It performs its function of regulating Spectrometer temperature by utilizing these reference, monitor, and control circuits to switch on and off a pair of patch heaters.

Housekeeping and monitor circuits consist of multiplexer, output buffers, two 32 KHz oscillators, and a divide-by-ten counter. The multiplexer samples 16 analog monitors at the rate of one per second, and the information is sent by separate voltage followers to the spacecraft and to the diagnostic connector, to ensure minimum deterioration due to cable loss. One of the 32 KHz oscillators is used to provide, through a monostable multivibrator, 50-nanosecond internal calibration pulses to the preamp-discriminator. It also provides a 32 KHz pulse stream to the high-mass data compressor.

The other 32 KHz oscillator provides a 32 KHz pulse stream to the low-mass data compressor, and to the instrument current monitor circuit. The divide-by-ten counter receives the buffered 10 PPS from the spacecraft and generates a 1 Hz pulse stream which is used in the multiplexer, and a sync pulse for the diagnostic BTE.

Signal conditioning circuitry consists of five BR16 nonlatching Babcock relays and four Carmac vacuum switches. One set of contacts of relay K1 is used to switch gains of the high-mass discriminator, and the other set of contacts is used to switch gains of the low-mass discriminator. One set of contacts of relay K2 is used to control the gain of the electron multipliers. The other set serves to provide an electron multiplier flag. Only one set of contacts is used on relay K3. These are used to switch +20 volts to the emission control. Only one set of contacts of relay K4 is used. These are used to switch the vacuum-switched standby power to the source heaters. Relay K3 obtains +20 volts from the only operating set of contacts of relay K5. In the interest of safety, four of the Carmac vacuum switches are connected in series-parallel configuration. (These vacuum switches will close at 60,000 feet altitude, thus ensuring that the source heaters will not be turned on below 60,000 feet.) Relay K4 receives its standby power from these switches.

3.4 COMPONENT PERFORMANCE REQUIREMENTS

Component level treatment of the Mass Spectrometer consists of dividing the PC boards and other components into separate and discrete functional entities that meet the requirements outlined in Paragraph 3.1. Block diagrams of the PC boards are provided to illustrate the individual component. See Figures 3-8 through 3-18.

3.4.1 MULTIPLIER HIGH VOLTAGE POWER SUPPLY

The power supply outputs identical voltage outputs to Channels A and B. Discrete circuits of the multiplier high voltage power supply (Figure 3-8) consist of the following:

a.	DC to DC converter	Converts CM output for Spectrometer use
b.	Control loop op amps	Referenced at -15 volts
c.	Output filter	
d.	Diode voltage divider networks	Constant level outputs
e.	Voltage monitor	

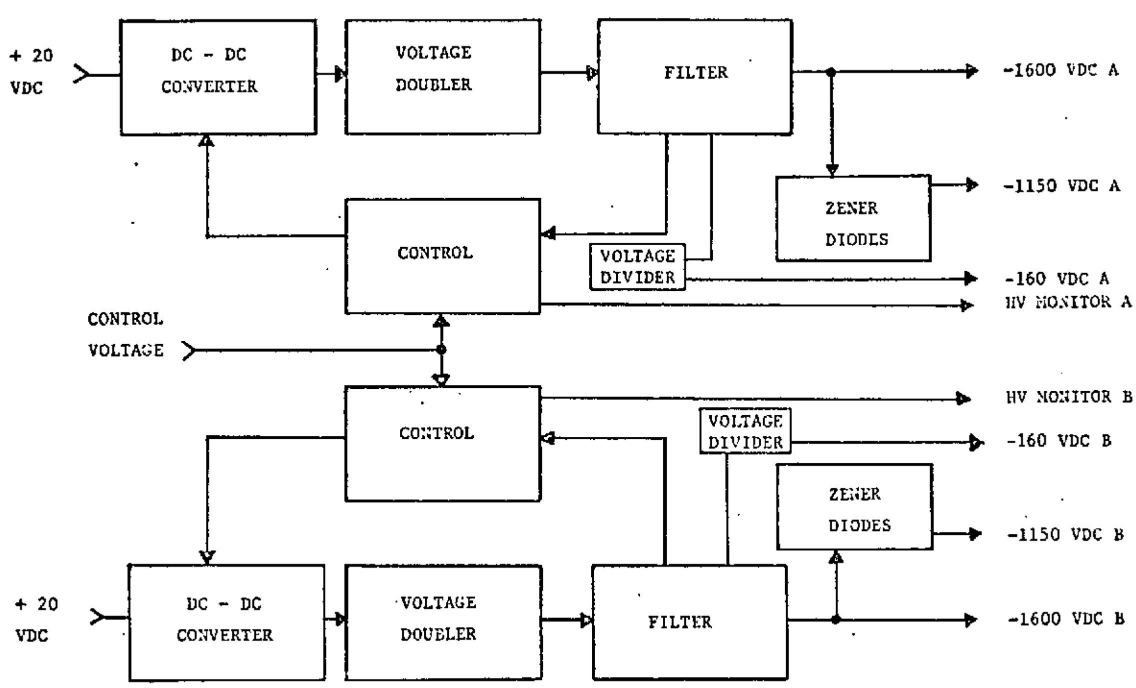


Figure 3-8. Multiplier High Voltage Power Supply Block Diagram

3.4.2 ELECTRON MULTIPLIER

The electron multiplier is reduced to separate components as follows:

	Component	Characteristics
a.	Dynode strip	Cathode attached
b.	Field strip	Separated from Dynode by 0.1 inch
c.	Anode	Opposite cathode between ends of two strips. Collects signals
d.	Permanent magnets	Field strength 550 gauss

3.4.3 PRE-AMPLIFIER

The pre-amplifier (Figure 3-9) is basically a straight-forward ac amplifier. There is one each pre-amplifier in Channels A and B.

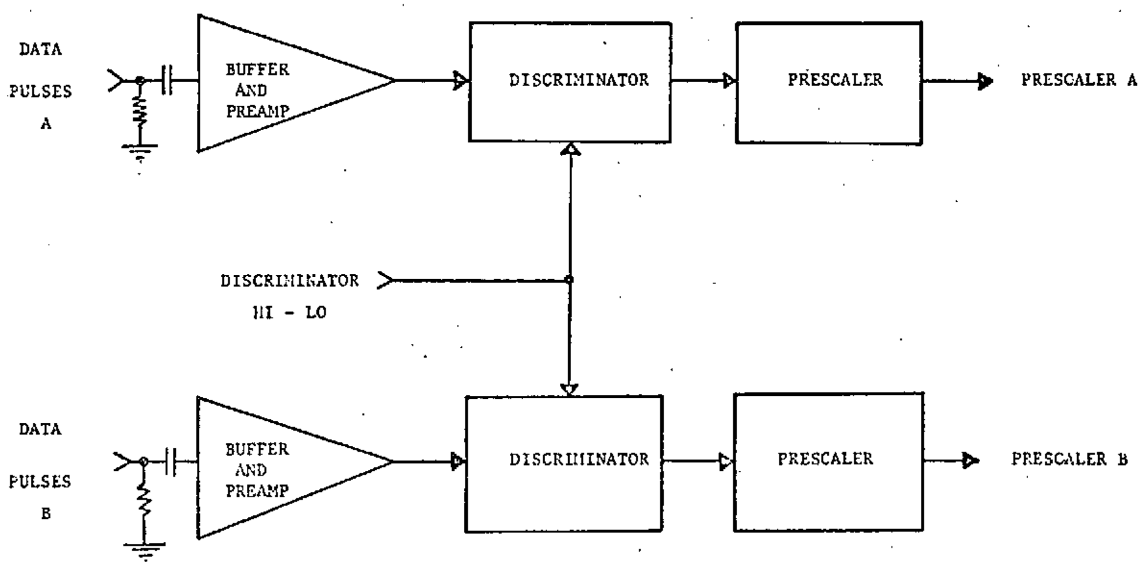


Figure 3-9. Pre-amplifier, Discriminator, and Pre-Scaler Block Diagra

3.4.4 DISCRIMINATOR AND PULSE SHAPER

These two circuits are divided down to their lowest functional level and their titles describe their function. There is one each discriminator and pulse shaper in Channels A and B.

3.4.5 PRE-SCALER

The pre-scaler is a divide by two counter which selects every other pulse for output to the counter and data compressor. There is one each pre-scaler in Channels A and B.

3.4.6 COUNTER AND DATA COMPRESSOR

There is one each counter and data compressor in Channels A and B. Circuit delination of the counter and data compressor (Figure 3-10) is as follows:

Circuit	Characteristics
a. Timing and control	Reference
b. 21-bit counter	Counts each input pulse
c. 21-bit shift register	Data compression
d. Shift pulse counter	Counts each shift pulse

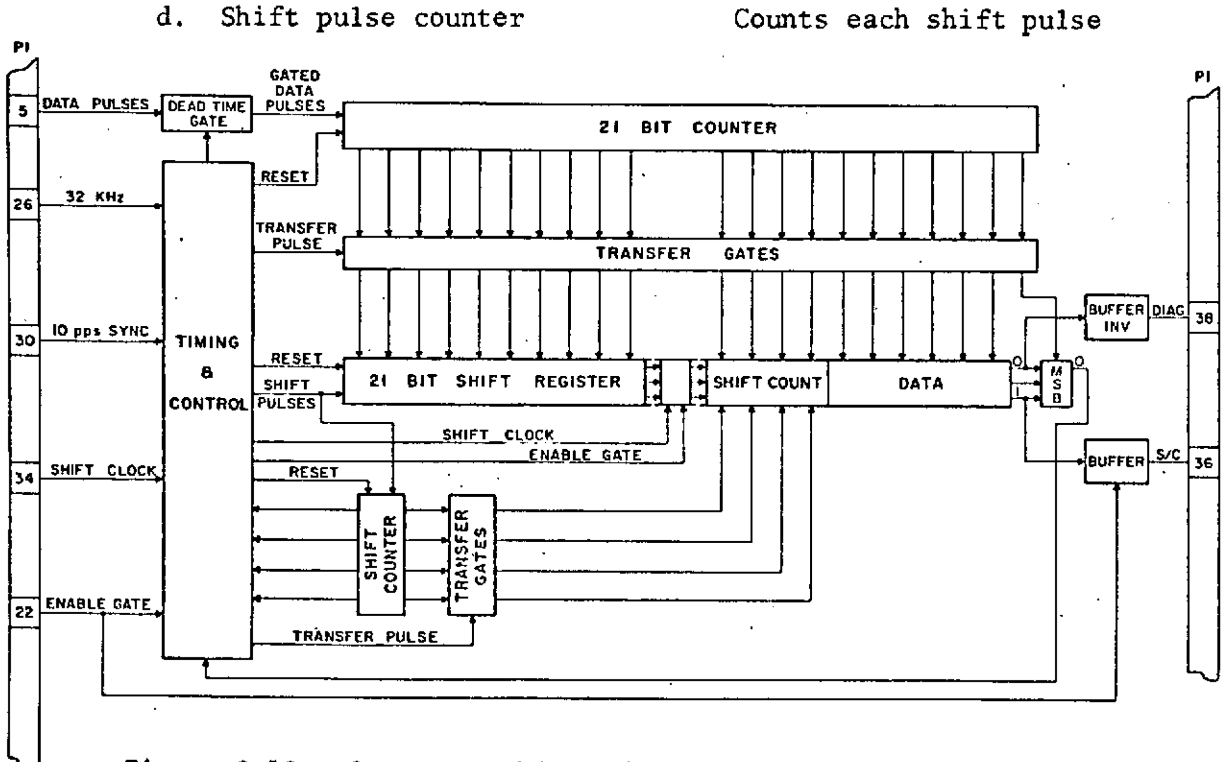


Figure 3-10. Counter and Data Compressor Block Diagram

3.4.7 EMISSION CONTROL

The emission control selects and controls the alternate filament which is used for the ion source in case of failure of the operating filament. See Figure 3-11. Discrete circuits are as follows:

	Circuit	Characteristics
a.	DC-to-DC converter	T1 designed with 1600 volts isolation
b.	Emission I detector (Module EM-1)	Filament fails, 5 second delay, 30 msec one-shot pulse output
c.	Bistable (Flip-flop) multivibrator (Module EM-2)	Triggered by 30 msec pulse

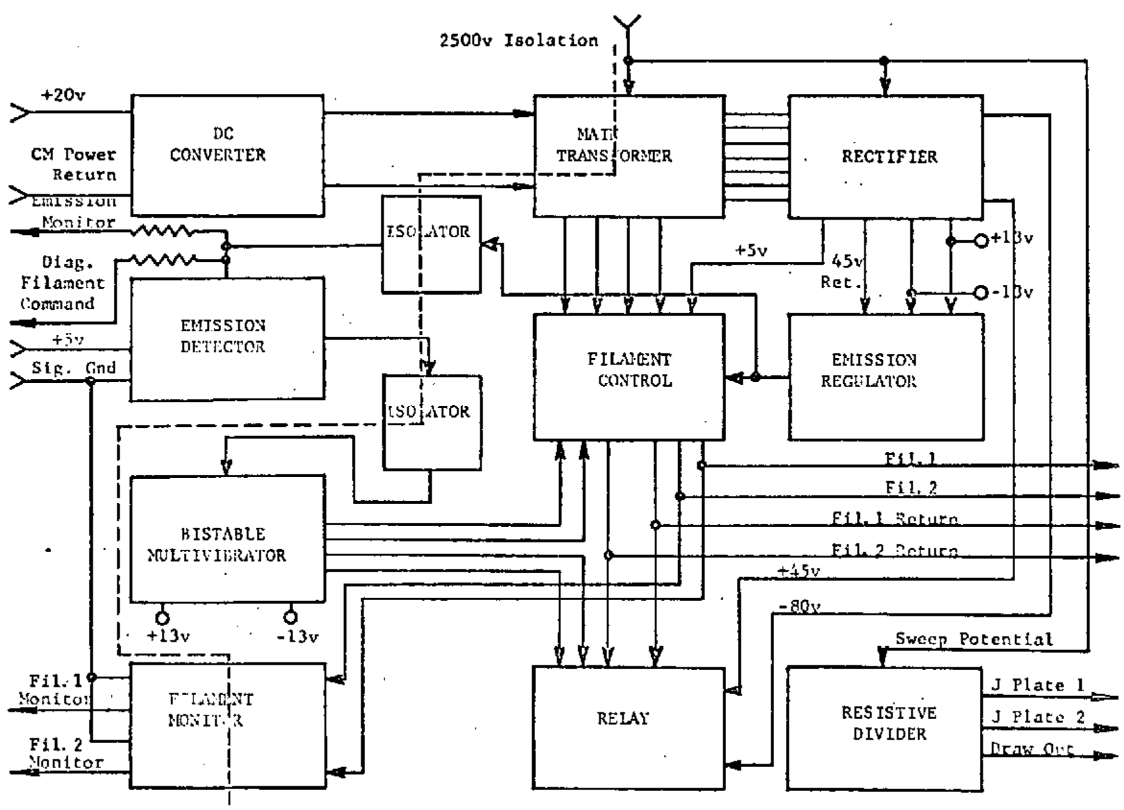


Figure 3-11. Emission Control Block Diagram

d.	Emission current regulator	Emission current at constant level
e.	Filament monitor	T4 and T7 sense current in filaments
f.	Sweep voltage dropping network	Provides voltage for drawout and plates J1 and J2

3.4.8 SWEEP HIGH VOLTAGE POWER SUPPLY

The following list shows the circuits contained within the sweep high voltage power supply (Figure 3-12).

	Circuit	Characteristics
a.	Input Filter	
b.	DC-to-DC inverter	Converts CM output for use in Spectrometer
c.	Cockroft-Walton quadrupler	Voltage multiplier
d.	Op amp	Provides control
e.	Photo-sensitive transistor	Control

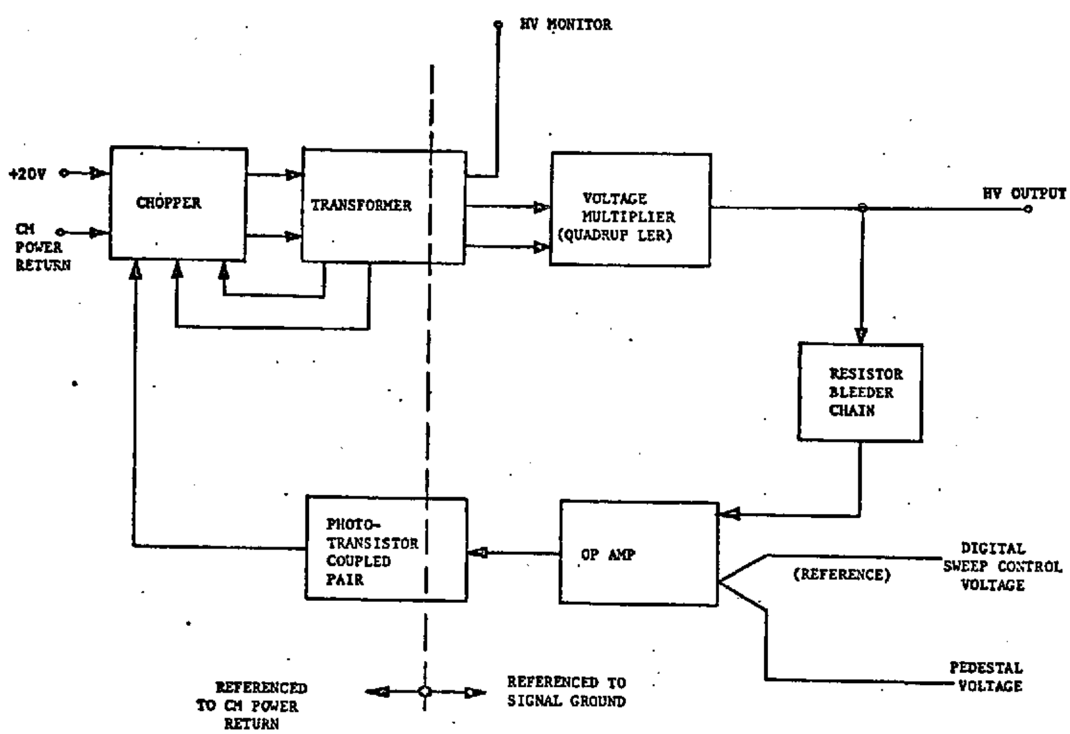


Figure 3-12. Sweep High Voltage Power Supply Block Diagram

3.4.9 DIGITAL SWEEP CONTROL

The digital sweep control (Figure 3-13) consists of the following circuits:

Circuit	Characteristics
a. Binary counters	These circuits are used to develop a sweep and pedestal output for control of the sweep high voltage
b. Logic circuits	
c. Digital/analog converter	

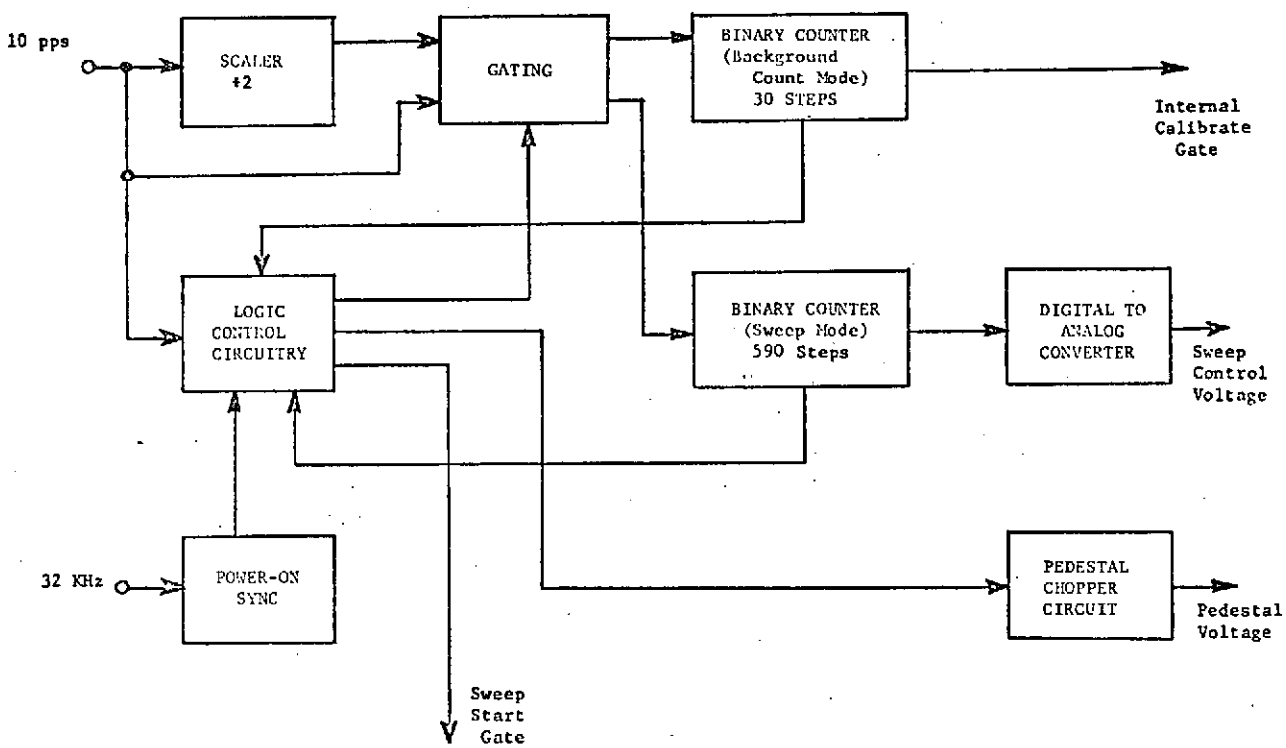


Figure 3-13. Digital Sweep Control Block Diagram

3.4.10 SWITCHING PRE-REGULATOR

The switching pre-regulator (Figure 3-14) consists of the following:

Circuit	Characteristics
a. Input filter	Input designed to accept voltage spikes of 50 volts.
b. Pre-regulator	0.6 amps current (normal)
c. Blocking oscillator	Provide operation in case of failure in normal mode
d. Scales (Flip-flop)	Scales 50 KHz to 25 KHz
e. Fold-back current limiter	
f. Output filter	

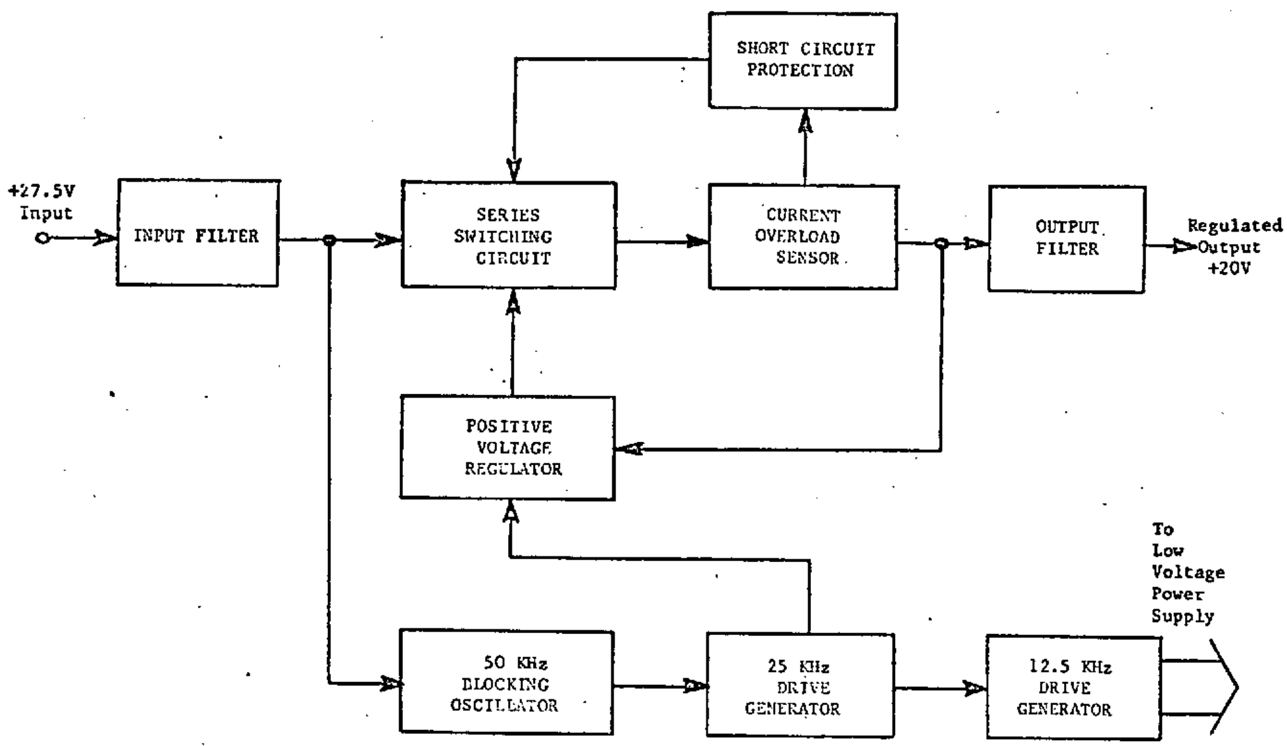


Figure 3-14. Switching Pre-Regulator Block Diagram

3.4.11 LOW VOLTAGE POWER SUPPLY

Discrete circuits contained in the low voltage power supply (Figure 3-15) are as follows:

Circuit	Characteristics
a. Input filter	Filter and isolation
b. Inverter drive	
c. DC-to-DC converter	Converts CM output for use in Spectrometer
d. Low voltage regulator	Regulates output
e. Failure mode	Self-oscillation provides power at reduced efficiency

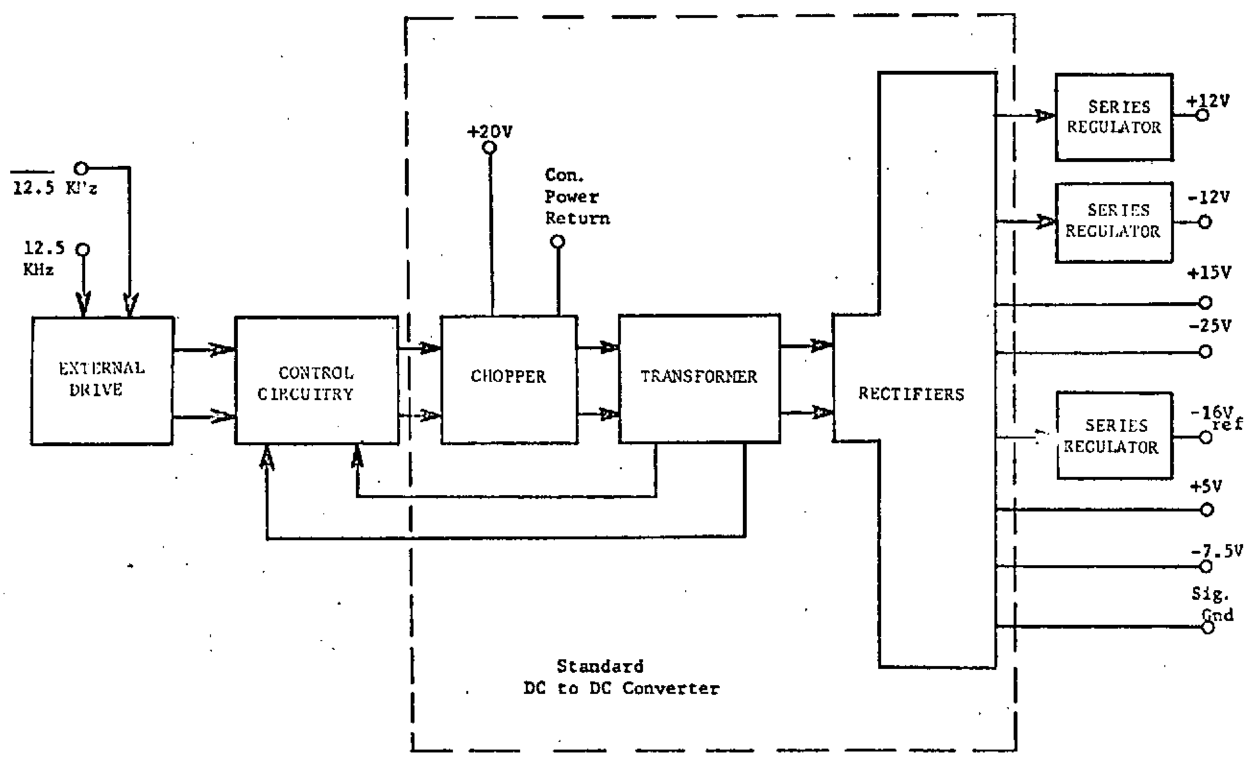


Figure 3-15. Low Voltage Power Supply Block Diagram

3.4.12 THERMAL CONTROL

Thermal control circuits (Figure 3-16) are contained in the following list:

Circuit	Characteristics
a. -12 volt monitor	Utilizes the reference, monitor, and control circuits to switch on and off a pair of patch heaters
b. -15 volt monitor	
c. Instrument current monitor	
d. Mass Spectroemter temperature monitor	
e. Electronic temperature monitor	
f. Thermal control	

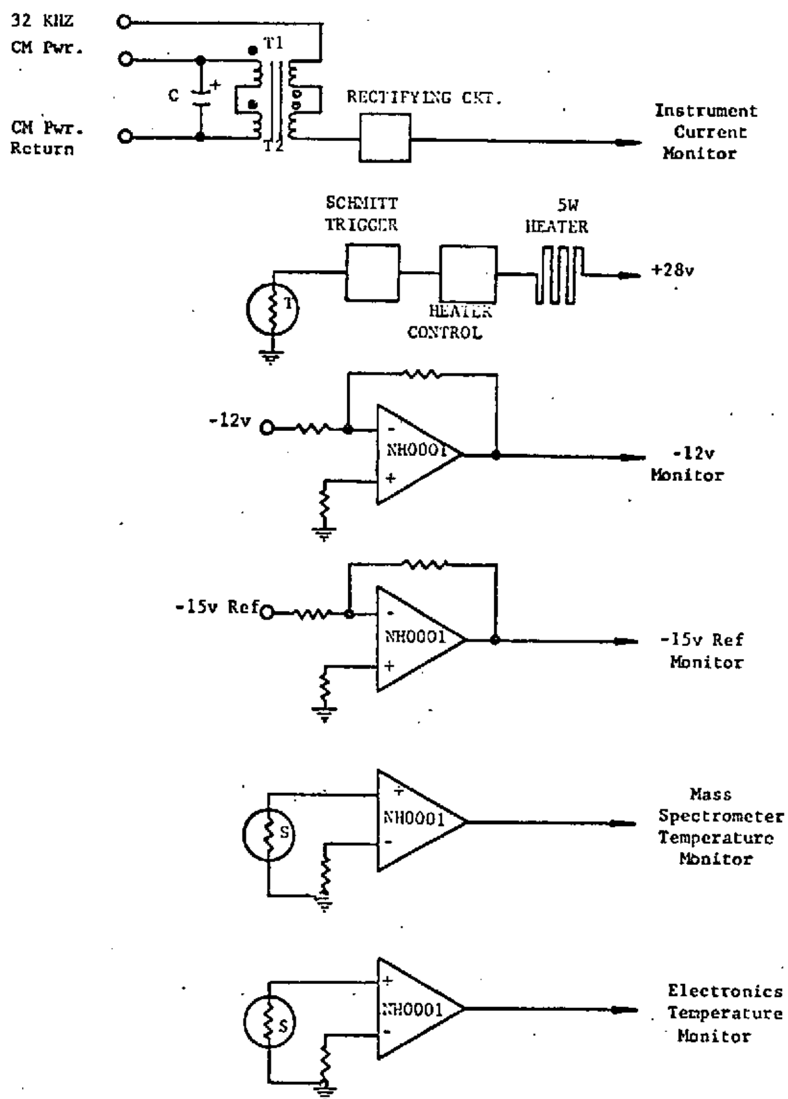


Figure 3-16. Thermal Control Block Diagram

3.4.13 HOUSEKEEPING MONITOR

Housekeeping monitor circuits (Figure 3-17) are listed as follows:

Circuit	Characteristics
a. Multiplexer	Samples 16 analog monitors
b. Output buffers	Ensure minimum deterioration of signal
c. 32 KHz oscillators (2)	One provides 50-nanosecond internal calibration pulses to preamp-discriminator and a 32 KHz pulse stream to high-mass data compressor. The other provides 32 KHz pulse stream to the low-mass data compressor, and to the instrument current monitor.
d. Divide-by-ten counter	Receives buffered 10 PPS from CM, and generates 1 Hz pulse stream for multiplexer and sync pulse for diagnostic BTE.

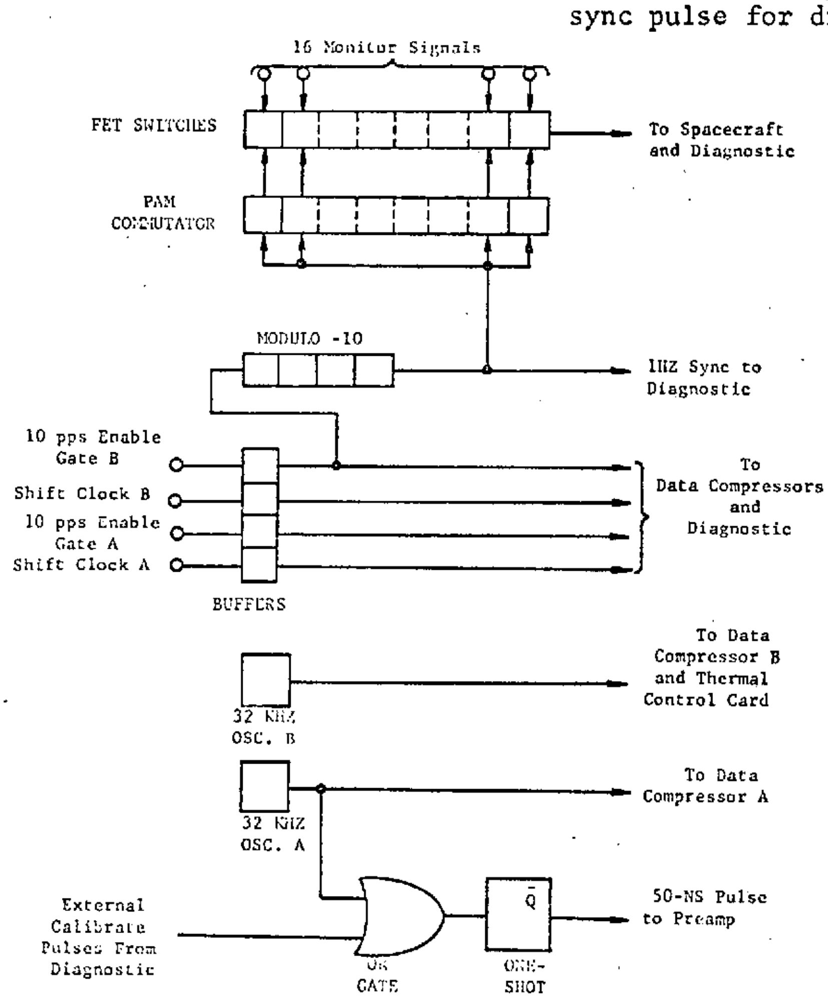


Figure 3-17. Housekeeping Multiplexer Block Diagram

3.4.14 SIGNAL CONDITIONING

Signal conditioning (Figure 3-18) consists of the following:

	Circuit	Characteristics
a.	Five Babcock BR16 non-latching relays	Switch gains for high and low mass
b.	Four Carmac vacuum switches	Safety, prevents turn-on of source heaters below 60,000 feet

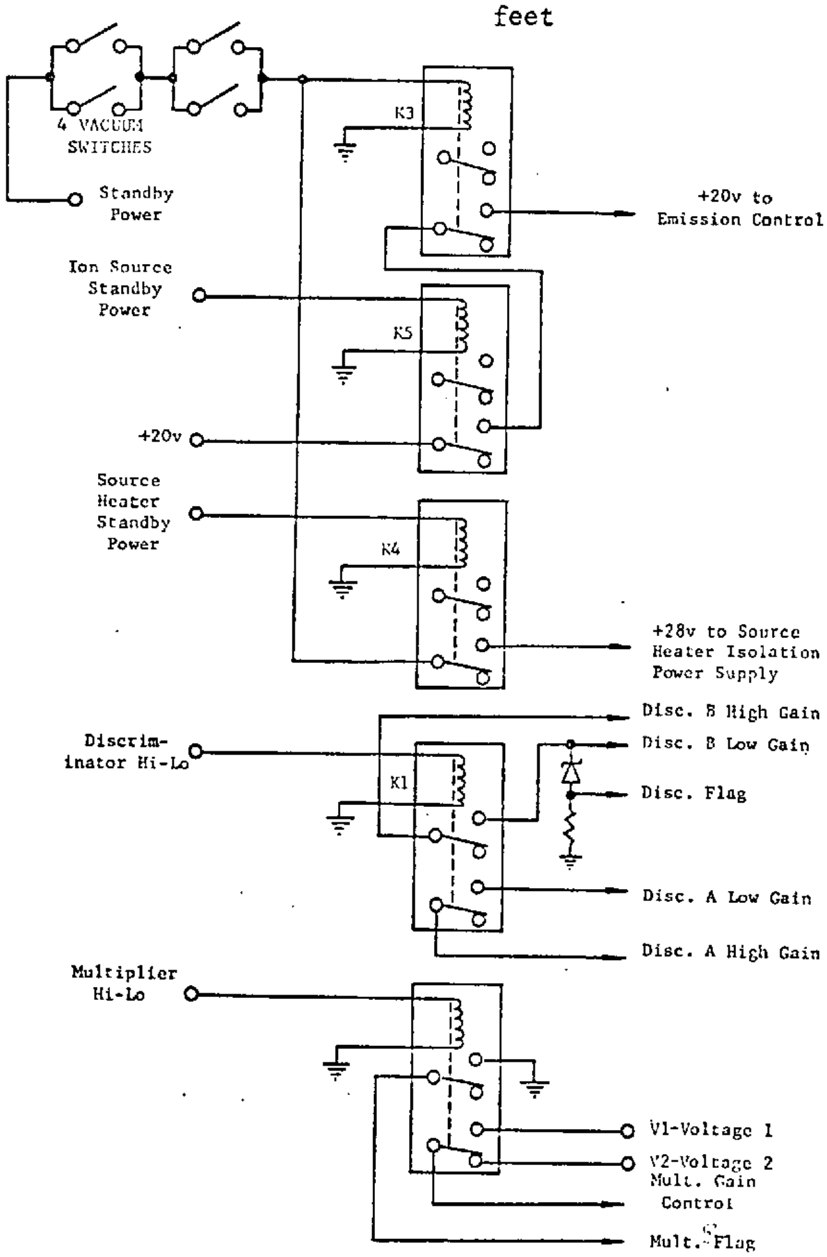


Figure 3-18. Signal Conditioning Block Diagram

3.4.15 HEATER AND SENSOR CIRCUITS

Temperature control of the mass spectrometer is performed by three circuits as shown in Figure 3-19.

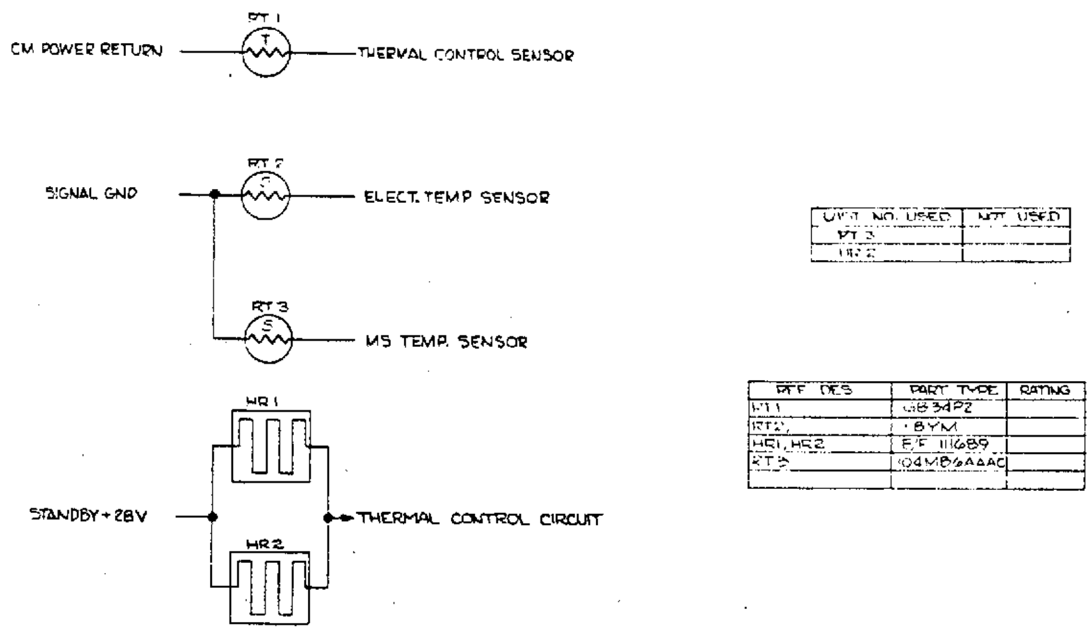


Figure 3-19. Heater and Sensor Circuits

3.5 COMMAND AND CONTROL

Operational modes of the mass spectrometer are controlled by switches external to the instrument. Figures 3-1 and 3-18 illustrate the control functions and switch operations. Table 3- lists the control operations and the associated circuit requirements.

TABLE 3- . COMMAND AND CONTROL OPERATIONS

OPERATION	CIRCUIT REQUIREMENT
Experiment STANDBY	Apply CM power to thermal control of electronics unit heaters
Ion Source STANDBY	Apply CM power to Ion Source heater
Experiment OPERATE	Apply CM power to Switching Pre-regulator and Low Voltage Power Supply

TABLE 3 . COMMAND AND CONTROL OPERATIONS (continued)

OPERATION	CIRCUIT REQUIREMENT
Ion Source OPERATE	Activate Emission Control relays to apply +20 Volts to Emission Control filament circuits
DISCRIMINATOR HIGH/LOW	Apply CM power to Signal Conditioner relays to change discriminator level
MULTIPLIER HIGH/LOW	Apply CM power to Signal Conditioner relays to change multiplier high voltage

3.6 CABLING AND INTERFACE

Point-to-point wiring of the instrument is shown on UTD Drawing 151-116 and instrument cable routing is shown on Figure 3-20. Connection to the spacecraft is through receptacle J1 and connection to the Console BTE is through the diagnostic connector J2. A dust cap is provided for J2 in the flight configuration.

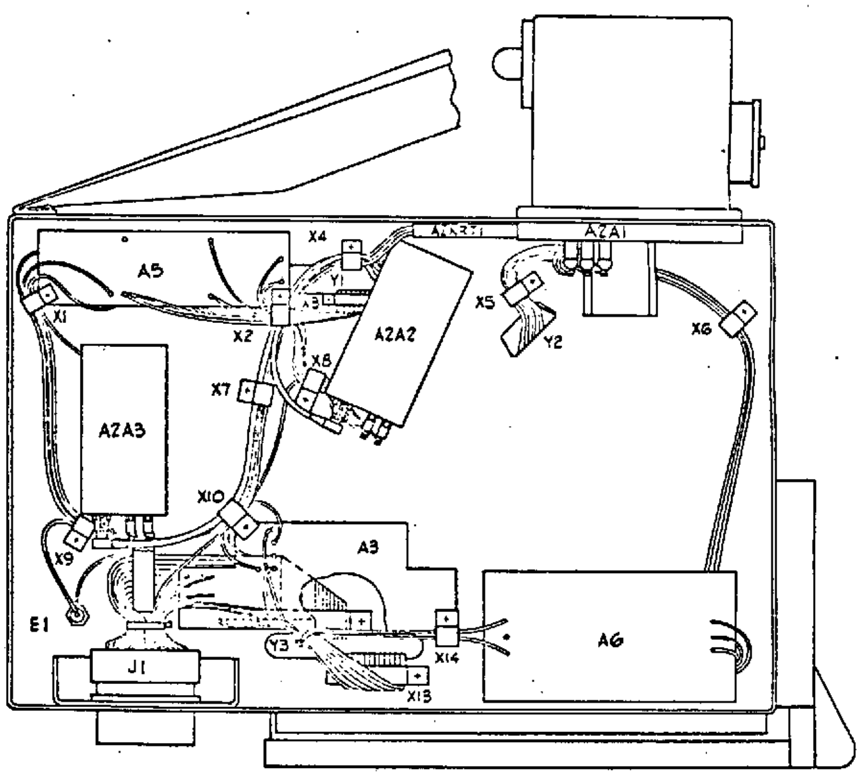


Figure 3-20. Instrument Cabling

SECTION 4

ENVIRONMENTAL PARAMETER DESIGN

4.1 MECHANICAL

Design of the instrument was such that the mechanical, thermal and partial pressure environmental parameters are in excess of those required for ground handling and flight. Successful testing to the standards delineated in Section 7 of this report verified the integrity of the environmental parameter design. Design objectives are summarized in the following paragraphs.

4.2 NATURAL ENVIRONMENTS

The functional performance of the Mass Spectrometer will not be affected upon exposure to the following natural environments.

4.2.1 TRANSPORTATION, GROUND HANDLING, AND STORAGE ENVIRONMENTS

The Mass Spectrometer performance will not be affected after exposure, in a non-operating condition, to the following environments encountered prior to flight:

a. Temperature: -40° to +120°F at pressures shown in b.

b. Pressure: 30.0 inches of Hg (Sea Level) to 1.6 inches of Hg (35,000 ft).

c. Humidity: 0 to 60 percent relative humidity.

d. Fungus: As experienced in Florida climate.

4.2.2 FLIGHT ENVIRONMENTS

The Mass Spectrometer performance will not be affected during operation in the following flight environments:

a. Temperature: See Paragraph 3.1.5.10, Induced Environments.

b. Pressure: Less than 10^{-6} mm of Hg.

c. Electromagnetic Radiation: As defined in Paragraph 3.1.2.4.2.2 of SD-69-315.

d. Meteroid Flux: As defined in Paragraph 3.1.2.4.2.2 of SD-69-315.

e. Nuclear Radiation: As defined in Paragraph 3.1.2.4.2.2 of SD-69-315.

4.3 INDUCED ENVIRONMENTS

The functional performance of the Mass Spectrometer will not be affected upon exposure to the following induced environments.

4.3.1 TRANSPORTATION, GROUND HANDLING, AND STORAGE ENVIRONMENTS

The Mass Spectrometer performance will not be affected upon exposure, in a non-operating condition, to the following environments prior to flight:

a. Shock: As encountered by being dropped from heights no greater than 21 inches while packed in its special handling shipping container.

b. Vibration: 0.75 g's peak, 5 to 2,000 Hz

4.3.2 FLIGHT ENVIRONMENTS

The Mass Spectrometer performance will not be affected upon exposure to the following environments:

4.3.2.1 ASCENT (NON-OPERATING SYSTEM)

The following environmental factors encountered during ascent will not affect the Mass Spectroemter:

a. Temperature: +55° F to +120°F

b. Pressure: 30.0 inches of Hg to 12.5 inches of Hg.

c. Vibration: As defined in MH01-12664-434.

d. Acoustics: As defined in Paragraph 3.1.2.8.2.1 of SD-69-315.

e. Acceleration: As defined in Paragraph 3.1.2.8.2.1 of SD-69-315.

4.3.2.2 EARTH PARKING ORBIT, TRANSLUNAR INJECTION, TRANSLUNAR COAST, AND LUNAR ORBIT INSERTION (NON-OPERATING SYSTEM)

The Mass Spectrometer will not be affected by the following environments:

a. Temperature: -15°F to +130°F

b. Shock: As defined in Figure 16 of SD-69-315.

4.3.2.3 LUNAR ORBITAL OPERATION (OPERATING SYSTEM)

The following environment will not affect functional performance of the Mass Spectrometer during Lunar Orbit:

a. Temperature: Temperature extremes as determined by the thermal characteristics of the Mass Spectrometer in an environment of combined solar and lunar thermal inputs, and exposure to the cold sink of space. Predicted extremes for the Electronics section is from -12°F to +139°F. For the Analyzer section, temperatures to -71°F are anticipated.

4.3.2.4 SPACECRAFT INDUCED ENVIRONMENT

The spacecraft induced environment, when the Mass Spectrometer is in operating position on the extended boom, is specified in the Environmental ICD, MH01,12664-434.

4.4 ENVIRONMENTAL PROTECTION

To prevent filament burn-out, vacuum switches were included in the design to prevent inadvertent filament operation at Earth altitudes of less than 60,000 feet.

SECTION 5

MANUFACTURING AND R&QA STANDARDS

5.1 FABRICATION

Applicability of manufacturing process specifications, production standards, and assembly procedures were identified on the appropriate manufacturing drawings and changed by Engineering Change Orders (ECO) under the same control as described by Paragraph 5.4. The following documents governed manufacturing procedures.

UTD Document No.	Title
150-426-20	Welding Procedure
150-431	Fabrication Control Procedure
150-432	General Specification for Printed Wiring Board Fabrication
150-439	Process Specification for Conformal Coating with Solithane 113/300
150-443	Procedure for Outgassing Ci-Coil Cable Assemblies
150-446	Material Procurement Procedure
150-447	Manufacturing Planning Procedure
150-448	Process Specification for RTV 11 Silastic
150-449	Process Specification for Bonding w/Delta Bond 152
150-450	Process Specification for Bonding w/Epon 828/Versamid V25
150-451	General Specification for Torquing
150-452	Silver Braxing Process Specification
150-453	Lava Firing Process Specification
150-455	Molded Cables, Technical Specifications
150-483	Assembly Procedure for Mass Spectrometer
150-485	Handling and Cleaning Procedure for MS 74 Thermal Control Silicote Coating Parts, Components, and Assemblies
150-488	Transformer Core Selection

UTD Document No.	Title
150-490	Glass Bead Peening Process Specification
150-492	Magnetization Procedure
150-496	Assembly Procedure for Electronic Subassembly
150-497	Binary Ladder Networks Specification
150-987	Assembly Procedure for Ion Source Subassembly
150-988	Assembly Procedure for Ion Source Heater and Filament Subassembly
150-991	Magnetizing Procedure for Yoke and Magnet Assembly
150-992	Assembly Procedure for Yoke and Magnet Assembly
150-994	Assembly Procedure for Strip Connectors and Crimp Contacts on W1 and W2 Printed Wiring
150-996	General Specification for Contamination Control

5.2 PARTS PROGRAM

Materials, parts, and processes used in the experiment hardware were of the highest quality compatible with specified technical requirements. NASA, Air Force-Navy (AN), Military Standards (MS) or joint Air Force-Navy (JAN) standard parts were used where applicable and maximum economic standardization of parts and components was provided. Where identical or similar functions are performed in more than one application within the system, effort was made to use only one item design for all system applications.

Parts were selected from the following source/types with the highest listed category having preference.

CATEGORY	SOURCE/TYPE
A	Established Rel (ER) MIL SPEC Example: (RNR, CKR, etc.)
B	JAN-TX (Testing Extra) MIL STD 701 Example: (Jan Only) (MIL-S-19500)
C	Other Military Spec + Screen & Burn-In Example: (MIL-R11) + Screen & Burn-In
D	Industry Spec + Screen & Burn-In Example: (Programs) (UNIQUE, SHURE) + Screen & Burn-In
E	Supplier Specs + Screen & Burn-In Example: (mfg-or labs) + Screen & Burn-In
F	User Specification (Unique Parts) + Screen & Burn-In Example: (UTD Designed) + Screen & Burn-In

5.2.1 TESTING OF COMPONENTS

Screen and burn-in specifications were prepared for items in categories C, D, E and F. Screen and burn-in operations were performed by an independent testing laboratory. MSCM 5320 was used as a guide in preparing screen and burn-in specifications.

5.2.2 PARTS APPLICATION AND DERATING

A parts application analysis (UTD 150-) for all circuits was prepared as required by the contract. The analysis was used to determine if sufficient parts deratings had been used. Appendix B of MSCM 5320 as used as a guide in parts derating.

5.3.3 FAILURE MODE, EFFECT ANALYSIS (FMEA)/SINGLE FAILURE POINT SUMMARY (SFPS)

A failure mode, effect analysis and Single Failure Point Summary (UTD 150-437) of the interface circuits and major subassemblies was prepared early in the design program as a tool for reliability evaluation.

5.3.4 RELIABILITY REQUIREMENTS

In summary, the reliability requirements fully complied with the provisions of NPC250-1 Reliability Program for Space Systems Contractor, as set forth in UTD 150-428, Reliability Plan for Mass Spectrometer Experiment.

5.3 QUALITY ASSURANCE CRITERIA

The provisions of NHB5300.4(1B), Quality Program Provisions for Space System Contractors were complied with as set forth in UTD 150-429, Quality Assurance Plan QAP-100-1 for Mass Spectrometer Experiment, and in UTD 150-426, Reliability and Quality Assurance Procedures. Component specifications of 150-426 are as follows.

SPECIFICATION NUMBER	TITLE
150-426-01	Corrective Action Procedure
150-426-03	Use of Fabrication Inspection Discrepancy Record
150-426-04	Use of Discrepant Material Tag
150-426-06	Control of Government Equipment
150-426-08	Weekly Inspection Record Sheet Procedure
150-426-09	Packing, Packaging, and Shipping Procedure
150-426-10	Use and Control of Inspection and Certified Operator Stamps
150-426-12	Control of Manufacturing Tooling
150-426-15	Receiving Inspection Procedure
150-426-16	Subcontractor and Vendor Control Procedure
150-426-17	Control of Raw Materials, Parts and Assemblies Procedure
150-426-23	Reliability and Quality Assurance Procedure for Fabrication of Printed Wiring Board
150-426-29	Procedure for use of MSC Form No. 2174 FIAR

5.4 CONFIGURATION MANAGEMENT

Configuration control was directed by the Configuration Control Supervisor who reported to the Program Manager. It was the responsibility of the Configuration Control Supervisor to establish configuration change control and ensure that the contractural configuration management requirements were adopted.

UTD configuration control procedures 151-033 and 151-034 designated responsibilites for Configuration Control implementation and provided for uniformity of implementation. These procedures are in general accordance with NASA Apollo Configuration Management Manual NPC 500-1 (NHB 8040.2) and Manned Spacecraft Center Configuration Management Requirements document MSC-02436.

Preparation for formal design reviews (PDR and CDR), recording UTD CCB activities, preparation of Acceptance Data Packages and data/documentation control were administrered and regulated under the requirements of the Configuration Control Management.

Configuration Control provided a systematic approach to the identification, control, and accounting of the configuration of the delivered Contract End Item (CEI) and component parts. Seven basic Configuration Control functions were used to achieve the systematic approach.

a. Design Documentation Control

b. Product Identification

c. Configuration Change Control

d. Configuration Assurance

e. Configuration Status Reporting

f. Engineering Release Control

g. Deviations and Waivers

5.4.1 CONFIGURATION CHANGE CONTROL

5.4.1.1 DEFINITION

Configuration Change Control was the formal system by which proposed Class I and II changes were analyzed before being authorized for implementation.

Formal change control was required on the contractually negotiated established baseline design specifications from contract go-ahead; on additional contractual design specifications and interface requirements subsequent to PDR (Requirements Baseline); and drawings from CDR (Drawing Baseline).

Formal changes were submitted to the cognizant MSC Project Engineer and then formally to the Contracting Officer.

Informal change control without the use of the UTD CCB was utilized prior to the PDR for design requirement and prior to CDR for drawings. Advance and experimental releases were utilized for the Experiment Test Equipment (ETS), breadboard and engineering model documentation and drawings. Standard releases were utilized for the Prototype, Qualification, Flight Units, and Flight Spares as critical deliverable items. Informal change control as a minimum consisted of Engineering Releases, Master Change Verification Record (See Paragraph 5.4.3) and Engineering Change Orders.

5.4.1.2 PROCEDURES

All Class I and II changes were handled in general accordance with NASA MSC-02436 and NASA NPC 500-1, being used as guides as directed by the Configuration Control Board.

5.4.1.3 UTD CONFIGURATION CONTROL BOARD (CCB)

A Configuration Control Board was convened at the call of the Program Manager to review and rule on all proposed Engineering Change Orders (ECO) requiring formal control after design freeze of the Contract End Item Specification and following drawing baseline freeze.

The CCB consisted of the following persons or their designated representatives:

Project Scientist (as required)

Program Manager and/or Assistant Program Manager - (Chairman)

Electrical Engineering Manager (as required)

Mechanical Engineering Manager (as required)

Reliability and Quality Assurance Manager

Manufacturing Manager

Materials Procurement (as required)

Configuration Control Manager (secretary)

Production Control Coordinator (as required)

5.4.1.4 CHANGE ADMINISTRATION

Class I and Class II engineering changes required an ECO and were processed as shown in Figure 5-1. All Class I changes subsequent to CDR required approval via ECP in accordance with UTD Doc. 151-034. Class II changes subsequent to CDR were reported to the customer for information and review on a monthly basis.

5.4.1.4.1 CLASS I CHANGES

A change was determined to be Class I when one or more of the following was affected:

a. Contract specifications, contract price or fee, contract weight, contract guarantees, contract delivery, or contract test schedules.

b. Contract reliability and/or contract maintainability.

c. Performance as stated either in definite terms or goals; or as experienced in items in service use.

d. Interchangeability, substitutability, or replaceability. The definitions of "interchangeable item", "substitute item", and "replaceable item" in MIL-STD-721B apply.

e. Safety.

f. Electrical interference to communications-electronic equipment or electromagnetic radiation hazards.

g. Ground Support Equipment (GSE), trainers, training devices or Government Furnished Equipment (GFE).

h. Preset adjustments or preset schedules to the extent that (1) new identification must be assigned, or (2) operating limits are affected.

i. Systems, equipments, or facilities produced by other contractor(s) to the extent that the affected other contractor(s) must accomplish an engineering change to maintain compatibilty at the interface(s).

j. Operational computer programs.

k. A change of vendors, i.e., a different or new source, applicable at the removable repairable level or higher assemblies.

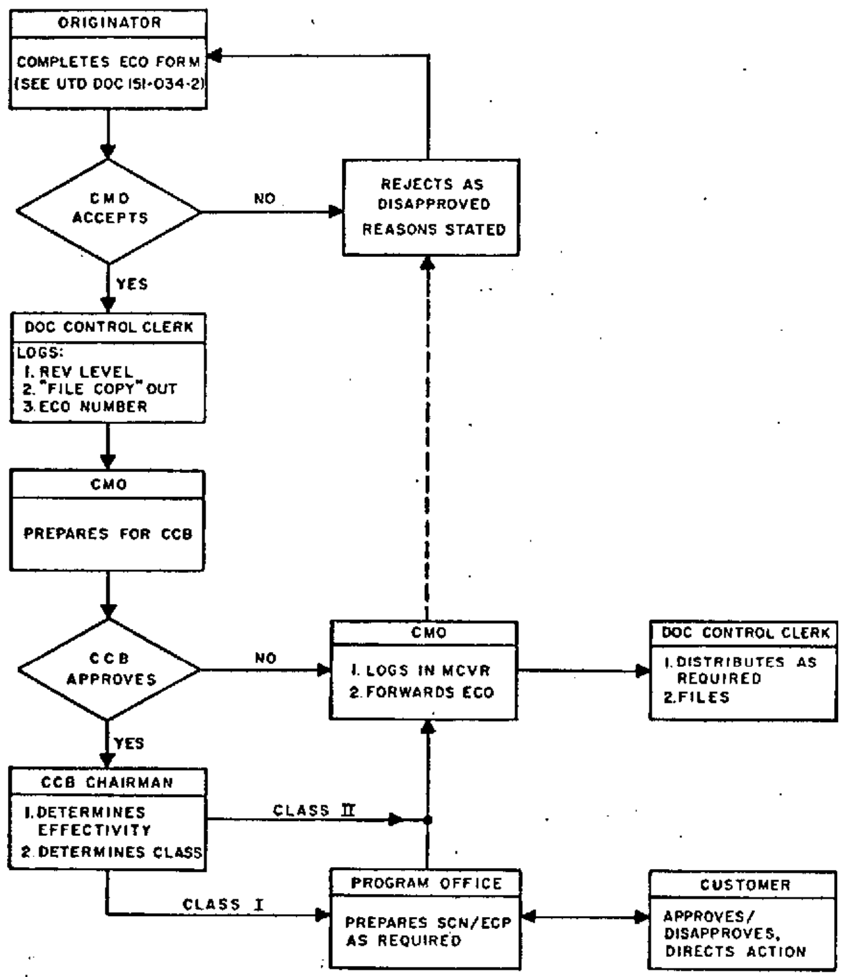


Figure 5-1. Change Control Flow Diagram

5.4.1.4.2 CLASS II CHANGE

A change was determined to be Class II when it did not fall within the parameters of Paragraph 5.4.1.4.1. Examples of Class II changes were:

a. Record changes (correction of minor drafting errors, addition or clarifying views or notes, etc.).

b. A change in hardware which did not affect any factor of Paragraph 5.4.1.4.1.

5.4.2 ACCEPTANCE DATA PACKAGE (ADP)

An Acceptance Data Package was accumulated for each CEI in accordance with Paragraph 3.3.1 of Exhibit C of the Contract, and presented at the Acceptance Review. Each ADP was assembled under configuration management requirements and included all pertinent, quality inspected, data concerning the appropriate CEI. Each ADP was maintained and updated as required.

5.4.3 MASTER CHANGE VERIFICATION RECORD

The Configuration Control Supervisor maintained a Master Change Verification Record (MCVR) for each deliverable Contract End Item to enumerate documentation and record all changes, effectivity, priorities, CCB approvals and disapprovals. (See Figure 5- An abbreviated Change Control System was maintained for the Engineering Model based on advance and experimental releases and informal change control.

5.4.3.1 CONFIGURATION ASSURANCE

Configuration of the CEI and its component parts was assured by the following methods:

a. The documentation history was traced by the engineering drawings specifying all procedures, tests, and applicable specifications to be used for all levels of manufacturing.

b. Each serialized item through all levels of assembly, inspection, test, and final integration was physically traced.

c. Configuration verification was accomplished by comparing the CEI and its component parts to the applicable engineering documentation to verify that each item reflected the approved configuration and authorized changes as recorded on the MCVR.

MASTER CHANGE VERIFICATION RECORD

PROGRAM:					UNIVERSITY OF TEXAS AT DALLAS / DASS / P.O. BOX 30365, DALLAS, TEXAS 75230								UNITS EFFECTED									
ECO		DWG/DOC NO.	REV.	TITLE	CHANGE CONTROL BD.				AUTHORITY FOR CHANGE													
											APPROVAL											
NO.	DISTR DATE				NO.	DATE	CLASS	ACTION	ECP	SCN	NO.	DATE										

EFFECTIVITY LEGEND: 1. TO COMPLY WITH ECO 2. USE AS IS 3. REWORK TO ECO 4. SCRAP AND REBUILD 5. RECORD CHANGE ONLY

070-035

Figure 5-2. Master Change Verification Record (MCVR)

5.4.3.2 CONFIGURATION ACCOUNTING

The Manufacturing Planning Sheets (MPS) were used to provide physical traceability control and configuration verification. A separate MPS was prepared for each engineering drawing in accordance with UTD Doc. 150-447.

a. A separate MPS was prepared for each item which contained serialized parts or subassemblies and for each item which contained parts to be selected in test.

b. A "rework" MPS was prepared upon receipt of a revised engineering drawing or ECO, unless the change was a record change only which did not affect hardware.

c. Manufacturing support personnel performed this function.

SECTION 6

GROUND SUPPORT EQUIPMENT

6.1 GENERAL

Two types of ground support equipment was supplied: Console Bench Test Equipment and Portable Ground Support Equipment. The Console BTE provides all power and stimuli necessary for test and checkout of the instrument during manufacture, calibration, acceptance testing, and pre-installation testing. The Portable GSE is used after the instrument is installed on the spacecraft to monitor and evaluate instrument performance.

6.2 CONSOLE BENCH TEST EQUIPMENT

The Console BTE is housed in a single console as shown in Figure 6-1. Operational functions and data reacout are monitored on binary and decimal displays with a printout of data available from a high speed printer. The console is equipped with four eye hooks to facilitate freight handling. Normal weight of the console is 465 pounds and 6-inch casters facilitate moving the console from room to room. Console dimensions are 61 inches high, 21 inches wide, and 25.5 inches deep.

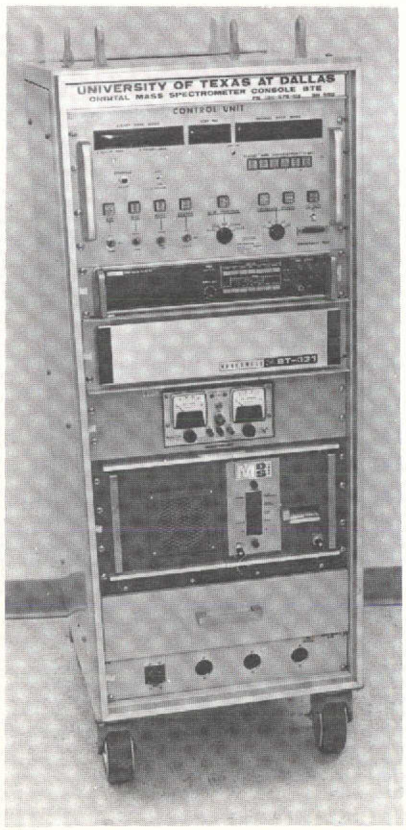


Figure 6-1. Console BTE

6.2.1 FUNCTIONAL DESCRIPTION

Functional capabilities of the Console BTE are summarized as follows:

a. Command and Control

b. Data Display

c. Data Processing

d. Housekeeping Data Readout

e. Data Printing

f. Instrument Power Supply

6.2.2 COMMAND AND CONTROL

Command and control operations utilize eight switches located on the Control Unit. Power is applied to the console and all functions are enabled when the Console power switch is operated (Circuit Breaker CB701 must be on).

Instrument power to the Mass Spectrometer Experiment is controlled by the EXP switch with lamp indication of status. A 3-position switch enables selection of Experiment Power ON, Power OFF, or STANDBY.

Selection of discriminator sensitivity is accomplished with the DISC switch. A 2-position switch enables selection of either HIGH or LOW discriminator sensitivity. Lamp indication of status verifies the level in use.

Selection of electron multiplier high-voltage levels is made with a 2-position switch enables selection of either HIGH or LOW discriminator sensitivity. Lamp indication of status verifies the level in use.

Selection of electron multiplier high-voltage levels ia made with a 2-position switch labeled MULT. Either HIGH or LOW level voltage may be commanded and lamp indication of status shows the level in use.

Control of the Ion Source filament and heater is provided by the SOURCE switch. A 3-position switch enables selection of filament power ON, OFF, or STANDBY. In STANDBY position, a heater is energized instead of the filament. Lamp indication of the status shows the selected condition.

Diagnostic monitoring and calibration functions are controlled by three switches. The DVM FUNCTION switch selects analog data for decimal display on the digital voltmeter and for printout by the printer. When positioned to FL HK, the digital voltmeter displays the housekeeping functions that are telemetered during flight (from the Flight Connector J1). In VOLT and AMP positions, instrument power is monitored. The MANUAL position disconnects the digital voltmeter from instrument data lines and permits use of the digital voltmeter for general use. In the DIA HK position, housekeeping data present on the diagnostic cable lines are displayed.

Accuracy of the Mass Spectrometer, pre-amp discriminator, ion counting and data compression circuits are checked with the CALIBRATE STATUS switch. In the INT position, normal operation is enabled and the status is indicated by the INTERNAL lamp indicator. In positions F1, F2, F3, and F4, signals are connected to the instrument preamplifier test input to simulate data inputs from the electron multiplier. Predetermined ion counts will be displayed on the DECIMAL DATA WORD indicators for each of the four calibrate positions. Lamp indications of the selected calibration frequency is provided. These signals and readouts are as shown in Table 6-1.

TABLE 6-1. CALIBRATE FREQUENCIES

Switch Position	Oscillator Frequency	Decimal Readout
F1	8 MHz	400,000 ± 20,000
F2	4 MHz	200,000 ± 10,000
F3	1 MHz	50,000 ± 2,500
F4	128 KHz	6,400 ± 400*
INT	32 KHz	1,600 160*

*Plus Background

CAUTION

Filament Test is effective only under hard vacuum conditions. When the Console BTE is connected to a Mass Spectrometer unit, do not operate the Filament Test switch to the ON position except in accordance with UTD approved procedures.

Switchover to the Standby filament of the Ion Source is accomplished by operation of the FIL TEST switch to the ON position for 7 seconds and then back to OFF immediately after the 7 seconds has elapsed. A lamp indicator shows that filament switchover operation has been commanded. An aural alarm sounds while this switch is in the ON position. Unless the FIL TEST is returned to OFF, the filaments will alternate each five seconds. A bypass switch is available for the audible alarm on the rear of the Control Unit.

6.2.3 DATA DISPLAY AND STATUS MONITOR

Both decimal and binary display of data words from the Mass Spectrometer are provided. Analog data is displayed by the digital voltmeter as selected. Operational status is displayed by lamp indicators with markings to denote status information.

Binary data is displayed in 10-bit format on the BINARY DATA WORD display. The display consists of two readouts. The upper readout displays the contents of the A-REGISTER which may be commanded to accept either high-mass data or low-mass data. The A-REGISTER HIGH/LOW switch is used to select the desired data. The A-REGISTER data display is updated once per second.

Both high-mass and low-mass data are displayed on the lower display, and are sequentially updated 20 times per second. This display provides a dynamic indication of data changes; accurate data information can be obtained with a printed output by the printer.

Binary data words are displayed in the same serial format as the data word output of the Mass Spectrometer (see Figure 6-2). The first six bits, from the left of the display, are the data bits with the bit on the extreme left being the most significant bit (MSB). The remaining four bits are the shift-code bits with the fourth bit from the extreme right being the most significant bit.

Decimal values of the data word are displayed by the DECIMAL DATA WORD display. Six digits from 000000 to 999999 and the letters H and L are displayed.

Bit Number	1	2	3	4	5	6	7	8	9	10
	MSB					LSB	MSB			LSB
	DATA						SHIFT CODE			

Figure 6-2. Binary Data Word Format

High-mass data are identified with the letter H and low-mass data with the Letter L.

Mass Spectrometer operations are monitored with the 3-digit STEP NUMBER display. Background noise values are read from the data word displays when the STEP NO. indicates steps 1 through 15. Internal calibration readouts occur when STEP NO. indicates steps 16 through 30. Ion counts appear in the data word when the DATA C SWEEP indicator is lighted and STEP NO. indicates 1 through 590.

Status and verification of the Mass Spectrometer operational configuration are monitored with STATUS and VERIFICATION FLAGS displayed with lamp indicators. DATA C SWEEP is indicated when the instrument is sweeping throug the normal operating steps of 1 through 590. DATA C BKGND is indicated when the instrument is on the background and internal calibration steps. These indicators are also used in conjunction with the STEP No. indication to identify the significance of steps 1 through 30 as these step numbers are common to both the background and operation sweep steps.

Mass Spectrometer power status is displayed with two indicators. Placing the EXP ON/OFF/STDBY switch to STDBY applies standby power to the instrument and the Standby status is indicated by the FLAG 1 STANDBY indicator. During instrument standby, the binary, decimal, and housekeeping function of the BTE are inoperative. Placing the switch to EXP ON applies operational power to the instrument and a return signal verifying that power is applied is displayed with the POWER VERIFIED lamp indicator. Ion Source heater operation is verified when the SOURCE ON/OFF/STDBY switch is placed to STDBY and the FLAG 2 SOURCE HEATER VERIFIED indicator is lighted. A signal return from the Mass Spectrometer over the diagnostic cable activates the BTE indicator.

Filament operation is verified when the SOURCE ON/OFF/STDBY switch is placed to ON and the FLAG 2 SOURCE EMISSION VERIFIED indicator is lighted. A signal return from the Mass Spectrometer over the diagnostic cable activates the indicator.

Verification of data validity is displayed by the DATA GOOD/DATA BAD indicator. A DATA BAD indication will be displayed when the bits of the data word contain a "1" bit position 11 through 16.

Cable connections are verified by the FLIGHT CABLE/DIA CABLE indicators. Disconnecting either cable will cause the associated indicator to fail to illuminate. Color coding of the Status monitor indicators readily shows standby or abnormal conditions. These conditions displayed by read indicators are as follows:

a. Standby power to the Mass Spectrometer.

b. Standby power to the Ion Source.

c. Filament test.

d. Calibration with F1, F2, F3, or F4.

e. Bad Data.

6.2.4 DATA PROCESSING AND CONTROL

The Console BTE provides all of the digital logic signals to the Mass Spectrometer in the same manner as the spacecraft. This logic provides the following functions:

a. Data Word Enable Gate - Two gates (Enable Gate A, Enable Gate B) are provided to enable the 257.8 usec (16.5 bits) data word period. Enable Gate A starts to T_0 and enables the low-mass data word output. Enable Gate B starts 20 ms later and enables the high-mass data word output. These gates have a repetition rate of 100 ms and appear on separate lines to the Mass Spectrometer. The enable gates are logic "1" during the enable time and logic "0" at all other times.

b. Data Shift Clock - A data shift clock is provided synchronous with each enable work gate. Each series of shift clock pulses contains 15 shift pulses. The shift pulse coincident with the first bit is omitted, causing the first shift to occur at the start of the second bit period. The shift clock operates at a 64-kbs rate. The bit period is 15.625 μ/sec.

c. Data Decompression - Conversion logic converts the compressed 10-bit data word from each ion counter channel into four code bits and siz data bits. Each 10-bit data word is converted to binary coded decimal and loaded into an output register. From this register the BCD data is interfaced to the printer and to the Decimal Data Word display. The decompression circuits perform the function $C = (D + 64)\ (2^{14-S})$ when $S < 15$ and the function $C = D$ when $S = 15$. D is the decimal equivalent of the 6-bit data code. S is the decimal equivalent of the 4 shift code bits. D and S are determined as follows:

$$D = B1 \times 2^5 + B2 \times 2^4 + B3 \times 2^3 + B4 \times 2^2 + B5 \times 2^1 + B6 \times 2^0$$

$$S = B7 \times 2^3 + B8 \times 2^2 + B9 \times 2^1 + B10 \times 2^0$$

or

$$D = B1 \times 32 + B2 \times 16 + B3 \times 8 + B4 \times 4 + B5 \times 2 + B6 \times 1$$

$$S = B7 \times 8 + B8 \times 4 + B9 \times 2 + B10 \times 1$$

where B1 through B10 are the binary bits of the data word under consideration.

6.2.5 HOUSEKEEPING DATA READOUT

Readout of analog housekeeping data can be observed on the digital voltmeter and printed by the printer. Positioning the DVM VUNCTION switch to either FL HK or DIA HK connects to the digital voltmeter. The DVM provides a BCD data output to the printer. Table 6-2 lists the housekeeping data by sub-commutated segment number, function and nominal analog value. Data voltage output from the Mass Spectrometer is quantized between 0 and 5 volts. Nominal values listed in Table 6-2 are typical and actual values must be obtained from data supplied with each Mass Spectrometer. The housekeeping segments are used to monitor operating parameters within the Mass Spectrometer instrument. Individual segments may be observed to verify the instrument status. The housekeeping segments and BTE flags together verify the instrument spacecraft interface.

TABLE 6-2. ANALOG HOUSEKEEPING DATA FORMAT (NOTE 6)

Analog H.K. Segment #	Function	Range	Nominal Reading	Note 3 Min.	Max.
1	+12 Volts	0 to 15 V.	4.00 V.	3.85	4.15
2	+ 5 "	0 to 10 V.	2.50 V.	2.20	2.80
3	-12 "	0 to 20 V.	3.00 V.	2.85	3.15
4	-15 "	0 to 15.8 V.	4.75 V.	4.67	4.83
5	Emission Current	0 to 500 uA NOTE 1, 5	0.00	-0.10	+0.20 V.
6	Fil. #1 Current	0 to 1.25 amp			
	ON		3.50	3.00	5.00
	OFF	Note 1, 5	0.00 V.	-0.10	+0.20
7	Fil. #2 Current	0 to 1.25 amp			
	ON		3.50	3.00	5.00
	OFF	Note 1, 5	0.00 V.	+0.10	+0.20
8	Low Mass Mult H.V. Monitor	0 to 3 KV			
	LOW		3.1 V.	2.80	3.30
	HIGH		3.5 V.	3.1	4.0
9	High Mass Mult H.V. Monitor	0 to 3 KV			
	LOW		3.1 V	2.8	3.3
	HIGH		3.5	3.1	4.0

TABLE 6-2. ANALOG HOUSEKEEPING DATA FORMAT (NOTE 6) continued

Analog H.K. Segment #	Function	Range	Nominal Reading	Note 3 Min.	Note 3 Max.
10	Sweep H.V. Monitor	0 to 3 KV	NA	Note 4	
11	Temp #1 (Elec)	-100°C to +125°C	2.70 V.	Note 2	
12	Temp #2 (Source)	-200°C to +150°C	2.10 V.	Note 2	
13	Multiplier				
	HIGH	FLAG	4.00 V.	3.60	4.40
	LOW	"	0.00 V.	-0.10	+0.20
14	Discriminator				
	HIGH	FLAG	0.00 V.	-0.10	+0.20
	LOW	"	2.8 V.	2.4	3.2
15	Inst. Current (Normal Operation)	0 to 1.5 amps T > 6°C 0.28±.1 amp	2.00 V.	Note 2	
16	Marker	FLAG	5.65 V.	5.00	6.00

Note 1: Emission, Fil #1 and Fil #2 will be OFF during all KSC tests. Ion Source Operation is locked out by the vacuum switches.

Note 2: This measurement will vary unit to unit. A calibration curve will be supplied with each deliverable unit.

Note 3: These MIN-MAX values include all end to end accuracies and 8-bit analog to digital conversion.

Note 4: This is a changing voltage. Used only to verify sweep operation.

Note 5: The MIN-MAX values and nominal reading are valid for atmospheric pressures. During vacuum tests use calibration curves.

Note 6: All information contined in Table 1-5.is for general reference use only. All test and checkout data requirements should be obtained from the pertinent test documents and calibration curves.

6.2.6 DATA PRINTING

Printout of processed data is provided, on command, at a rate of 20 lines per second. Maximum printing speed of the printer is 30 lines per second; however, the Bench Test Equipment logic is designed to operate the printer at the slower rate. Data to be printed in the housekeeping column 1-5 is selected by the DVM Function switch on the Control Unit. Sixteen colums, on paper tape, are available and the programmed format is as shown in Table 6-3 and illustrated in Figure 6-3.

TABLE 6-3. PRINTER FORMAT

Column	Information
Cols 1-5	(2.56B) Three digits with decimal and blank column. This number will be outputted to the printer from the DVM via the data processor. The number will represent the Analog H.K..signal
Cols 6-9	(128B) A three-digit number followed by a blank space. This number will represent the sweep step.
Cols 10-16	(999999L) of (999999H) A six-digit number followed by either an ~ or an *. The number represents the decimal output from the data word corresponding to the experiment ion counters. The ~ indicates low-mass while the * indicates high-mass.

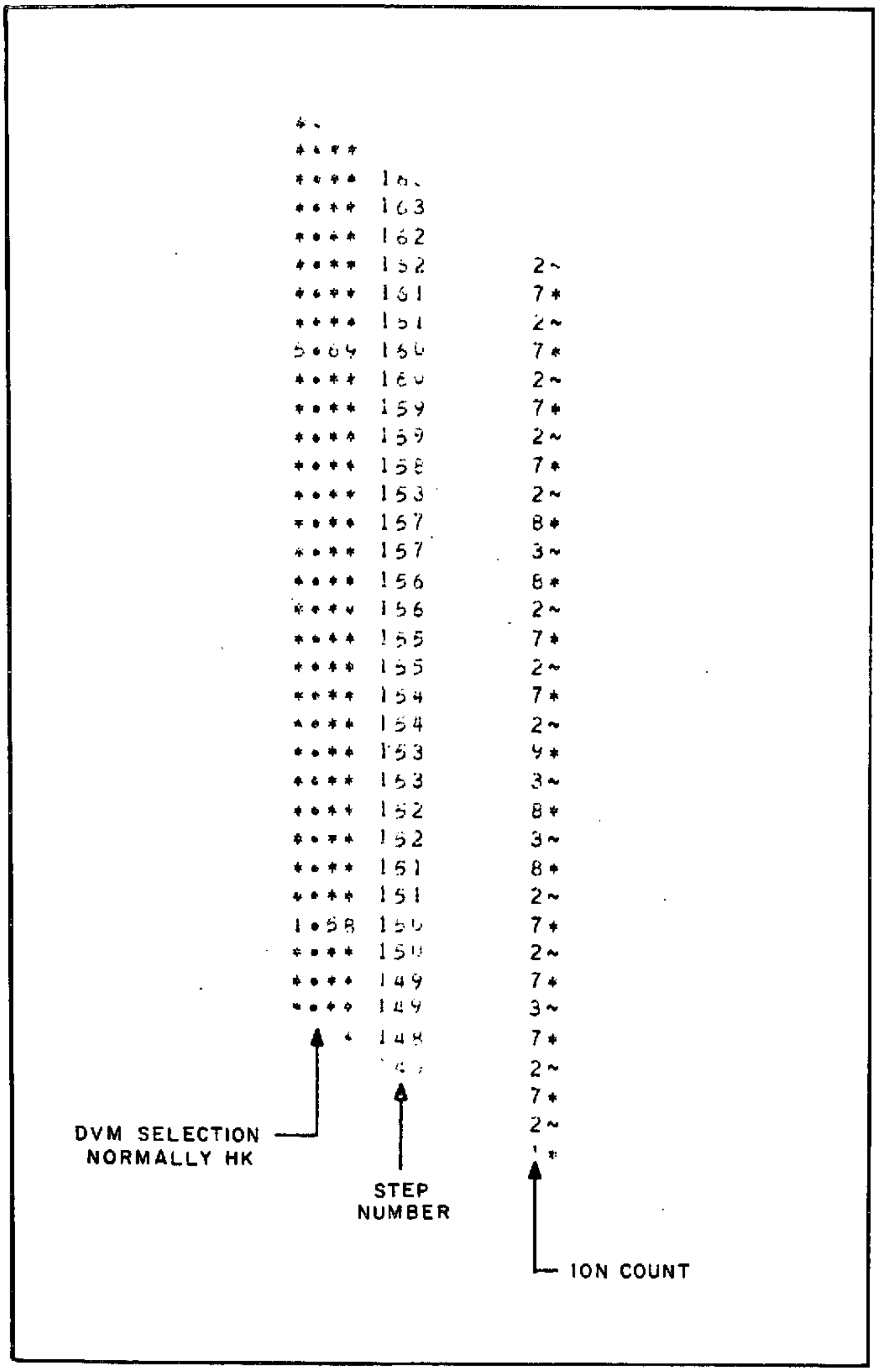


Figure 6-3. Printer Format

6.2.7 INSTRUMENT POWER SUPPLY

Power for the Mass Spectrometer is supplied by the Instrument Power Supply Assembly. Over-current and over-voltage protection is provided. Nominal output to the Mass Spectrometer is 27.5 volts, 500 milliamps, with voltage regulation of less than 0.01 percent. Current limiting is set at 1.2 amperes. The over-voltage protector is an assembly mounted on the rear of the power supply and is equipped with a circuit breaker which must be reset manually when an over-voltage condition occurs. Instruction manuals on the power supply and over-voltage protector are included in Section 5.0.

6.2.8 TECHNICAL DESCRIPTION

The Console BTE operation can be explained by following the signal flow of Figure 6-4. An exchange of signals with the Mass Spectrometer Experiment takes place via the Flight Cable J1 and the Diagnostic Cable J2. The signal lines from the cable are terminated on the AC and Signal Distribution Unit of the Console BTE. From this panel the lines are distributed to either the Logic Unit or the Control Unit according to the functional requirement.

The Logic Unit receives the digital data lines from the Signal Distribution Unit. The Enable Gates A and B, along with the shift clock signals, are generated in the Logic Unit and sent via the Flight Cable J1 to the Mass Spectrometer Unit. The digital data from the Mass Spectrometer is received at the Logic Unit Data register from both the Diagnostic Cable and the Flight Cable. If both cables are connected, the data received and processed is that from the Flight Cable. If the Flight Cable is not connected, the data received and processed is that carried by the Diagnostic Cable. An interlock recognition logic determines which set the data is processed by the Logic Unit.

Whenever the Console BTE is not controlling the Mass Spectrometer via the Flight Cable, the Mass Spectroemter must be powered and controlled from the spacecraft or some simulator in order to utilize the Diagnostic Cable as an instrument monitoring system.

The Logic Unit derives its basic timing from a 256 KHz crystal clock oscillator. The Enable Gates, shift clocks, and other timing signals are logically derived by counting down from the basic clock frequency. Figures 6-5 and 6-6 provide some of the more important relationships of the Logic Unit.

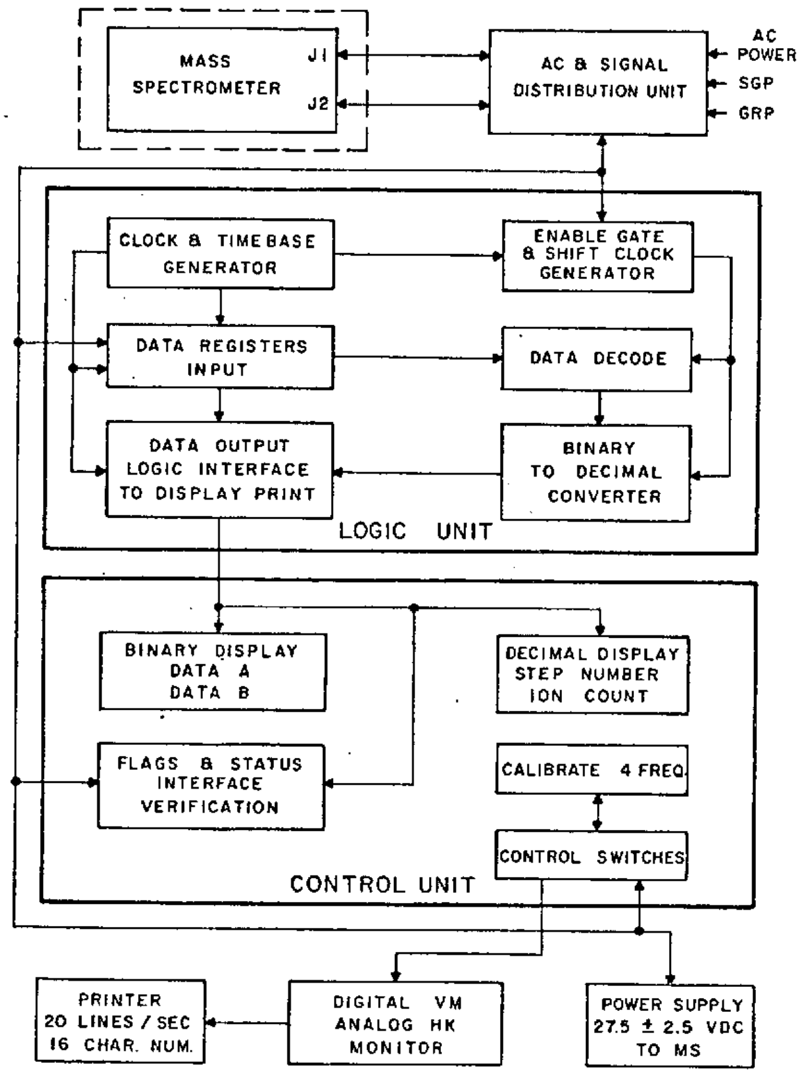


Figure 6-4. Console BTE Simplified Block Diagram

The received binary data word has been compressed by the Mass Spectrometer from a 21-bit binary number into a compressed binary code of 10-bits. The first six bits are data bits and the last four are the shift code bits. The Logic Unit converts the compressed 10-bit data word into a decimal equivalent. The binary to decimal conversion is performed using a serial conversion technique similar to that described by J. F. Couleur.[1] The BCD register also serves as the output register for the data assigned to the printer and the Decimal Display of the Control Unit.

The logic section is made up of Honeywell μ-PAC logic cards mounted in a single drawer. The drawer may be extended and rotated to the vertical for servicing and testing.

The Control Unit interfaces with the logic unit input data in such a way as to provide binary display of the received data word. The auxillary data register word is displayed and updated at a slower than real-time rate to enhance the visual reading of binary data. Either A or B data may be read by proper switch selection.

The four switches at the lower left of the Control Unit simulate the spacecraft 230 Panel functions for the Mass Spectrometer.

The oscillator which provide the four external calibrate frequencies for verifying the Mass Spectrometer counting capability are contained on the PC card in the Control Unit.

The visual status indicators contain front release mechanism which allow lamp bulbs to be changed from the front of the Control Unit. A lamp test feqture is included to verify all segments of the 7-segment lamps used for Step Number and for Count Data Word.

The digital voltmeter inputs are controlled by the Control Unit DVM FUNCTION selection switch. The DVM samples under control of the Logic Unit at a 1 pps rate.

The Instrument Power Supply, a KEPCO Model CK36-1.5M, provides the primary power to the Mass Spectrometer under control of the switches or the Control Panel. The unit is equipped with current limiting and over-voltage protection. The over-voltage trips point is set for 30 VDC. The current limit is set at 1.2 amperes. The voltage and current are monitored by the DVM through switch selection in the Control Unit.

---

[1] J. F. Couleur, "BIDEC - A Binary-to-Decimal or Decimal-to-Binary Converter," IRE Transactions on Electronic Computers, Vol. EC-7, No. 4, December 1958, page 313.

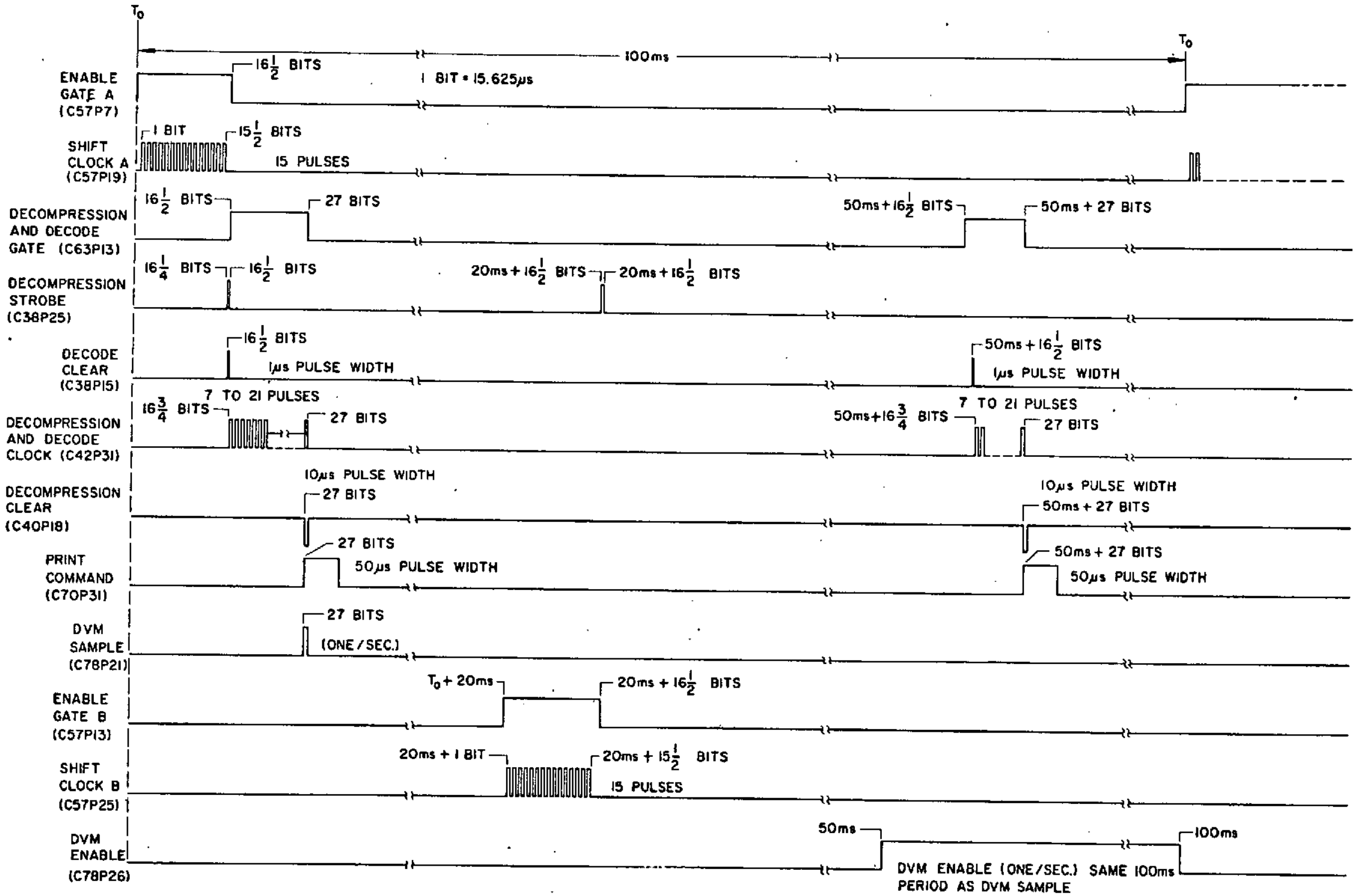


Figure 6-5. Timing Waveform (Sheet 1)

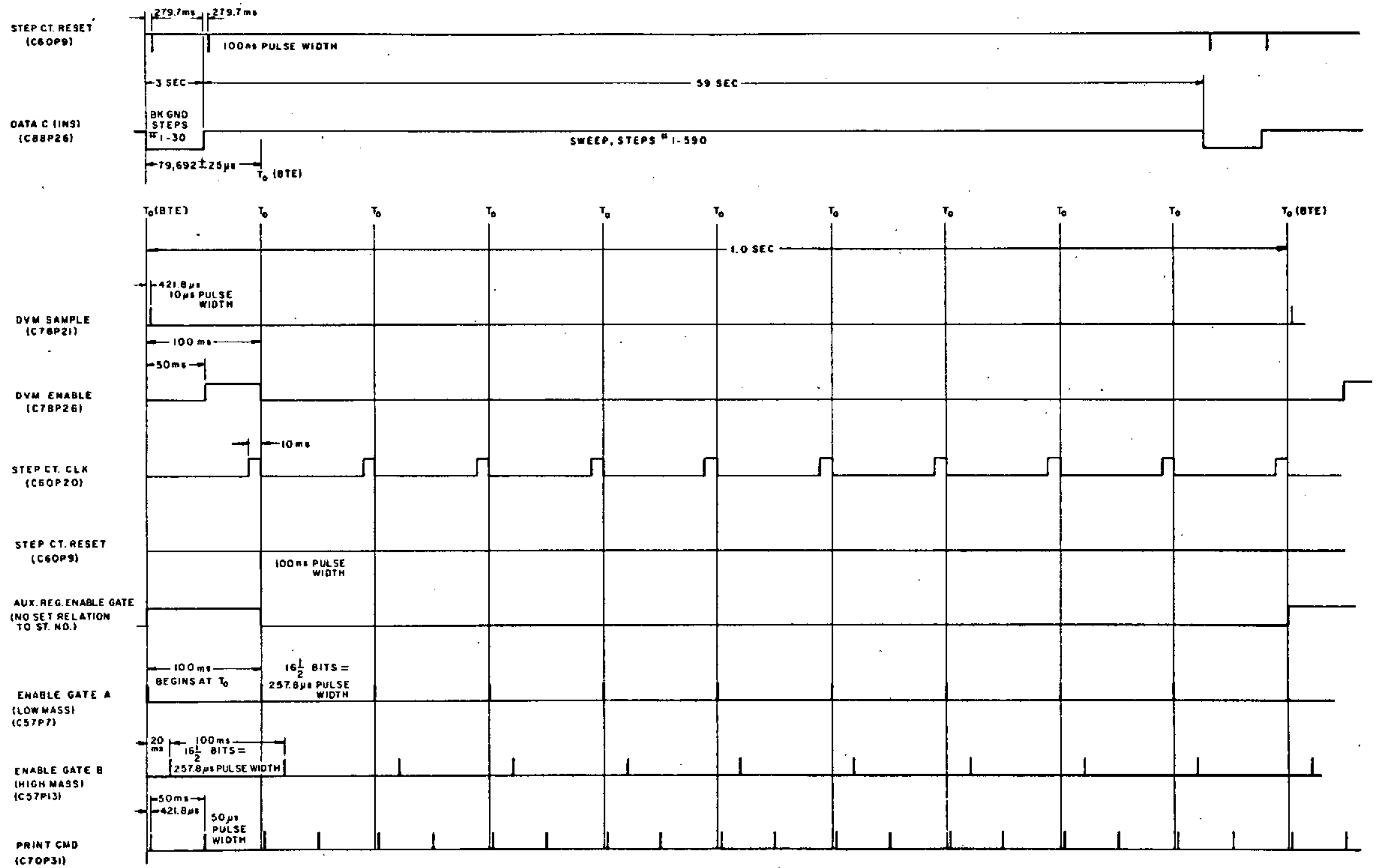


Figure 6-5. Timing Waveform (Sheet 2)

The Console ON/OFF switch on the Control Unit activates a relay which applies AC power to all Console BTE subassemblies. The Console is protected by an "instant trip" type AC Circuit Breaker. Three AC outlets are provided on the front of the Console for associated test equipment powering.

6.2.9 CONSOLE BTE CABLE CONNECTIONS

Interconnection of the Console BTE and the mass spectrometer instrument is as shown in figure. All necessary cables are furnished with the Console BTE.

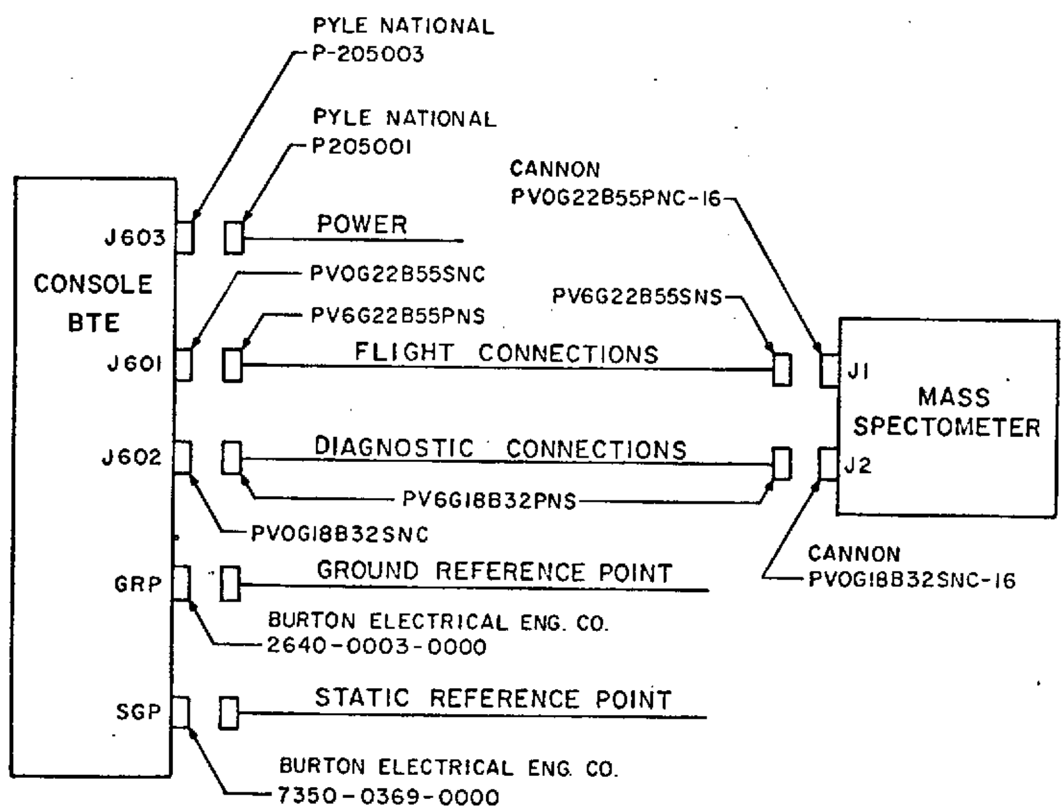


Figure 6-6. Cable Connections

6.3 PORTABLE GROUND SUPPORT EQUIPMENT

The Portable GSE is contained in an industrial type aluminum case similar to a suitcase. See Figure 6-7. A removable cover is installed on the case which provides a water-tight seal, when in place, for storage or shipping. Provisions are made in mounting the components in the case to minimize shock and vibration normally encountered in air shipment and in-service handling.

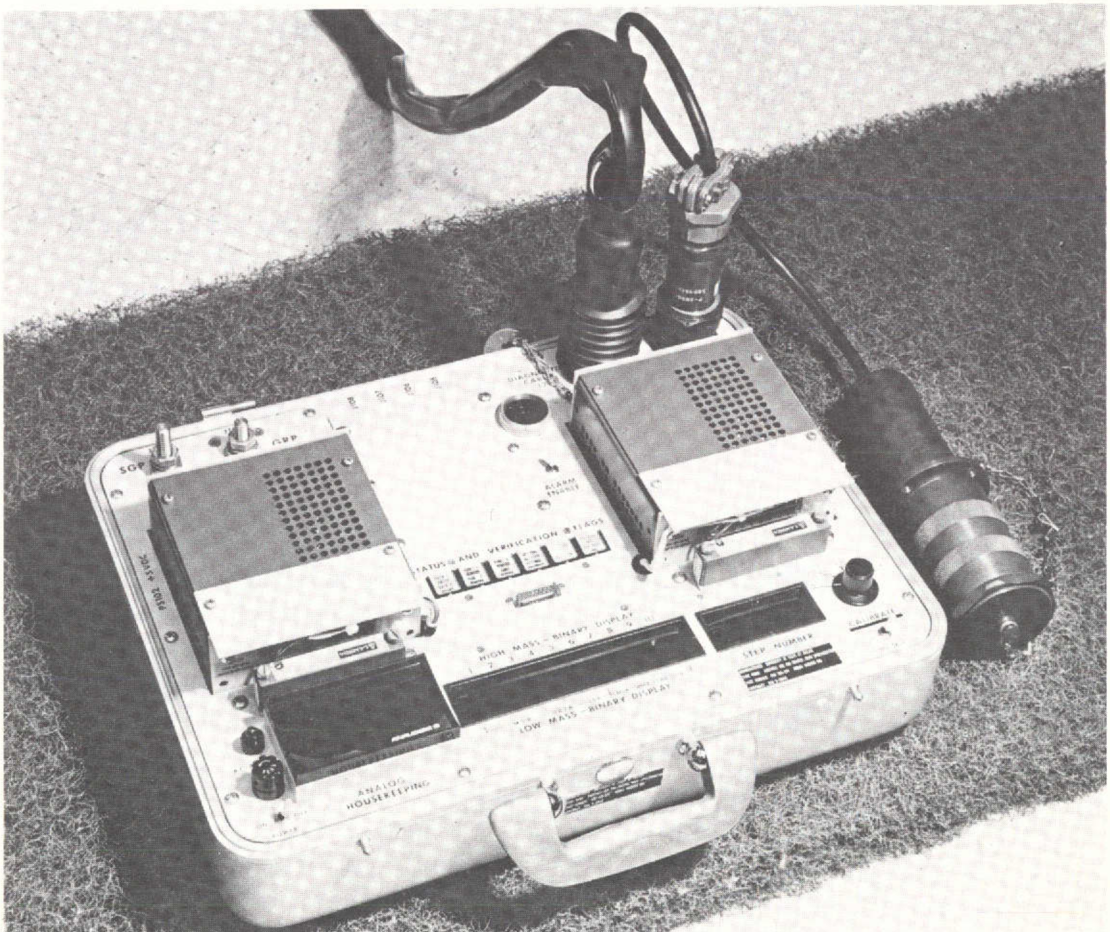


Figure 6-7. Portable GSE

Physical dimensions of the Portable GSE, in carrying configuration, are 14 inches high, 18 inches wide and 6 inches deep. Total weight is 35 pounds.

6.3.1 FUNCTIONAL DESCRIPTION

Functional operation of the Portable GSE is controlled and displayed by potentiometer type controls, switches, and display indicators. Primary functions are as follows:

a. Analog Housekeeping Monitor - The housekeeping functions are monitored on a digital panel meter at a 1-Hz rate. Test points are provided to allow an external strip chart recorder to be connected to the housekeeping signal.

b. Binary Data - Two 10-bit binary data words are displayed by two rows of light indicators. Logic 1 is indicated by a lighted indicator.

c. Step Counter - A three digit decimal counter is provided to indicate the sweep or background step number.

d. Calibrate Function - The portable GSE provided four discrete frequencies as inputs to the instrument for calibration of the Mass Spectrometer. The four frequencies are 8 MHz, 4 MHz, 1 MHz, and 128 KHz; F1, F2, F3, and F4, respectively.

e. Status and Verification Display - Interface verification is provided by lamp display.

6.3.2 CONTROLS AND INDICATORS

The controls and indicators for the Portable GSE are mounted on the front panel and consist of the POWER ON/OFF switch and indicator, alarm enable switch, status and verification flag indicators, binary display, step number indicator, calibrate switch, and filament test switch.

6.3.2.1 POWER ON/OFF SWITCH AND INDICATOR

A.C. Power is applied to the Portable GSE through the POWER ON/OFF switch and power application is shown by the red power-on indicator.

6.3.2.2 ALARM ENABLE SWITCH

The ALARM ENABLE switch is used to enable or disable the audible alarm for the filament test circuit. This switch should normally be on the ON position.

6.3.2.3 STATUS AND VERIFICATION FLAG INDICATORS

Status and verification of the Mass Spectrometer operational configuration are monitored with STATUS and VERIFICATION FLAGS and are displayed with lighted lamp indicators. Table 6-4 describes the function of each indicator.

TABLE 6-4. STATUS AND VERIFICATION FLAG INDICATORS

Name	Function
DATA C SWEEP/DATA C BKGND	Indicates whether sweep or background steps are displayed on STEP NO. display.
FLAG 1 VERIFIED	Indicates standby power is applied to the Mass Spectrometer.
FLAG 2 VERIFIED	Indicates power is applied to source heater.
FLAG 3 VERIFIED	Indicates Experiment power is applied to instrument and Ion Source voltage is present.
INTERNAL CALIBRATE	Indicates instrument is on internal calibration frequency.
EXTERNAL CALIBRATE	Indicated external F1, F2, F3, or F4 frequency has been selected.
F1, F2, F3, F4	Indicates which external calibration frequency has been selected.
FIL TEST OFF/FIL TEST ON	Indicates filament test conditions as selected by FILAMENT TEST switch.

6.3.2.4 DATA DISPLAY

Binary data are displayed with two 10-bit readouts, one displaying high mass data and the other displaying low mass data. Analog data are displayed by a digital voltmeter.

6.3.2.5 BINARY DATA

Binary data words are displayed in the same serial format as the data word output of the Mass Spectrometer and as described for the Console BTE. The first six bits, from the left of the display, are the data bits with the bit on the extreme left being the most significant bit (MSB). The remaining four bits are the shift-code bits with the fourth bit from the extreme right being the most significant bit.

6.3.2.6 HOUSEKEEPING DATA READOUT

Readout of analog housekeeping data can be observed on the digital voltmeter. Table 6-2 lists the housekeeping data by sub-commutated segment number, function and nominal analog value, which are the same as for the Console BTE. Data voltage output from the Mass Spectrometer is quantized between 0 and 5 volts. Nominal values listed in Table 6-2 are typical and actual values must be obtained from data supplied with each Mass Spectrometer. The housekeeping segments are used to monitor operating parameters within the Mass Spectrometer instrument.

SECTION 7

TEST AND CALIBRATION

7.1 SUMMARY

Test and calibration operations were developed to demonstrate the ability of the Mass Spectrometer to perform mission requirements with safety, reliability and operational efficiency. Test categories are as follows:

a. Subassembly Functional Tests

b. Initial Calibration

c. Developmental Tests

d. Qualification Testing

e. Acceptance Testing

f. Final Calibration

g. ATEE Test at NAR, Downey

Table 7-1 lists the test specifications used to ensure the integrity of the units. Abbreviated titles are shown.

TABLE 7-1. TEST SPECIFICATIONS

NUMBER	TITLE
150-402	Test Plan for Absolute Calibration
150-403	Functional Test Procedure for Absolute Calibration
150-444	Test Procedure for Absolute Calibration
150-489	Certification Test Specification
150-491	Qualification Test Plan
150-494	Full Functional Acceptance Test Procedure
150-495	Calibration Test Procedure for Mass Spectrometer Analyzer Subsystem
150-499	Abbreviated Function Acceptance Test Procedure
151-001	Acceptance Test Plan for Prototype Mass Spectrometer

TABLE 7-1. TEST SPECIFICATIONS (Cont)

NUMBER	TITLE
151-002	Prototype Master Test Sequence
151-003	Acceptance Test Plan for Qualification and Flight Mass Spectrometer
151-004	Pre-Integration Test Procedure
151-005	KSC Pre-Installation Test Procedure
151-006	Thermal Soak Test Procedure for Pre-Test Evaluation
151-007	Electromagnetic Interference Test
151-048	General Specification for Plotting Analog Housekeeping Data
151-058	Flight Preparation Procedure for Ion Source Assembly

Figure 7-1 illustrates the test sequence of the developmental, qualification and acceptance testing. EMI testing was performed on the Qualification Unit following acceptance testing.

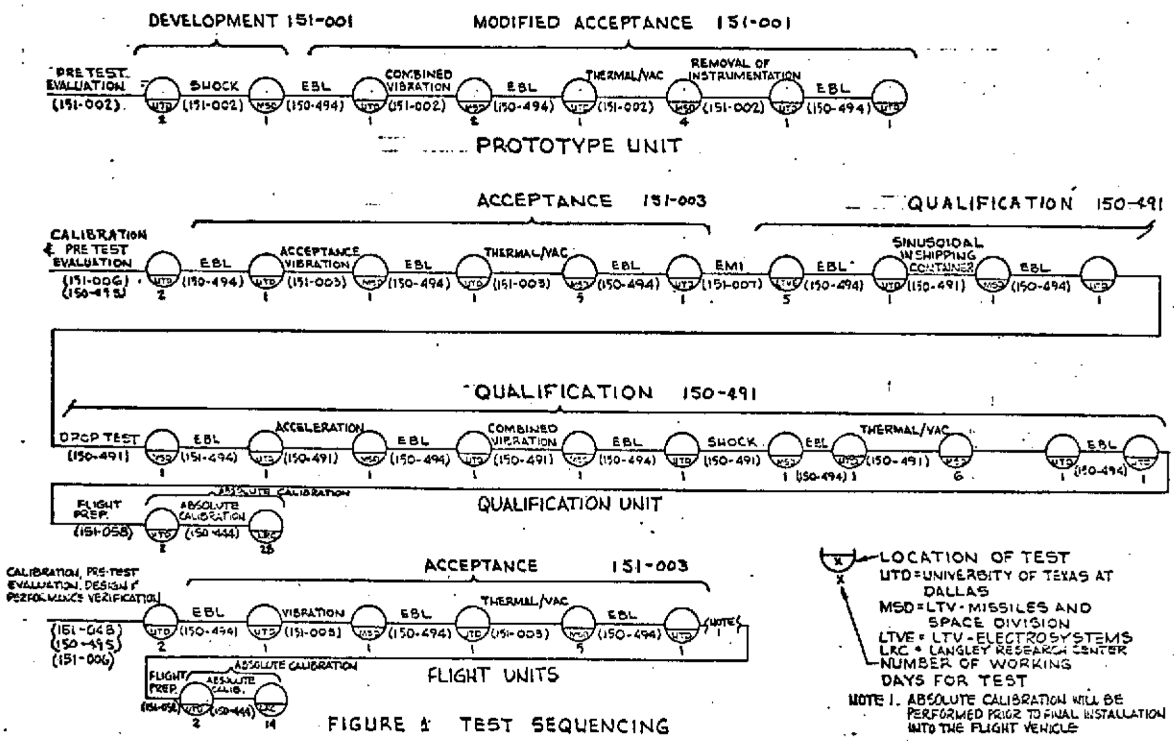


Figure 7-1. Test Sequence

7.2 SUBASSEMBLY FUNCTIONAL TEST

Full functional acceptance tests were performed on all component parts before installation in a next higher assembly. Proper operation at temperature extremes was demonstrated. These tests established design integrity and ensured that there were no workmanship deficiencies. Test fixtures for modules and printed wiring boards supplied the necessary voltages and signals.

7.2.1 MODULE TEST

Module tests were performed in accordance with the following specifications:

UTD 150-479	Acceptance Test Procedure for Low Voltage Power Supply Regulator Module
UTD 150-990	Acceptance Test Procedure for Emission Control Modules EM1, EM2, EM3, and EM4

Cordwood-module construction techniques were qualified using an Emission Control Subassembly as a motherboard in a thermal cycle environment from -30°C to +70°C. Sixty cycles were performed allowing 30-minutes for transition from one temperature extreme to the other with a 15-minute soak at each extreme. Test data is contained in UTD 150-493, Cordwood Module Thermal-Cycle Data Report.

7.2.2 PRINTED WIRING BOARD SUBASSEMBLIES

Each printed wiring board subassembly (PWB) was tested under the supervision of a Quality Control Inspector. Temperature extremes of -25°C and +65°C as well as room ambient temperature were employed. During these tests, housekeeping data were recorded and plotted in accordance with UTD 151-048, General Specification for Plotting Analog Housekeeping Data. Table 7-2 lists the acceptance test procedure (ATP) specifications used in testing printed wiring board subassemblies.

TABLE 7-2. PWB ACCEPTANCE TEST PROCEDURES

NUMBER	TITLE
150-465	ATP for Switching Pre-Regulator Subassembly A1
150-466	ATP for Thermal Control Subassembly A2
150-467	ATP for Digital Sweep Control Subassembly A3

TABLE 7-2. PWB ACCEPTANCE TEST PROCEDURES (Cont)

NUMBER	TITLE
150-468	ATP for Signal Conditioning Subassembly A4
150-469	ATP for Sweep High Voltage Power Supply Subassembly A5
150-470	ATP for Low Voltage Poser Supply Subassembly A6
150-471	ATP for Preamplifier Discriminator, and Pre-Scaler Subassembly A7
150-472	ATP for Counting and Data Compression Subassembly A8 and A9
150-473	ATP for Housekeeping Multiplexer Subassembly A10
150-474	ATP for Multiplier High Voltage Power Supply Subassembly A11
150-475	ATP for Emission Control Subassembly A12
150-476	ATP for Fuse Board Subassembly B3
151-027	ATP for Impedance Matching Buffer

7.2.3 ELECTRON MULTIPLIERS

Extensive testing was done on Electron Multipliers for the Analyzer Unit. Test objectives were to obtain sufficient data to enable selection of optimum voltages which would result in the highest gain with the least supply voltage differential between the two multipliers. Initial selection was made on the basis of information contained in the data sheets furnished with each unit. The following procedure was used as a guide in initial multiplier selection.

a. Study Dynode Strip Input Voltage (DSIE) figures listed in the manufacturer's test data.

b. Compare ion count and anode current for similar DSIE values of approximately 1,500 to 1 800 volts.

c. Select two multipliers having the highest gain with the least voltage and the least voltage differential.

d. Designate the multiplier having the highest gain of the two as the high-mass multiplier A2A3.

e. Designate the other multiplier and the low-mass multiplier A2A2.

f. Furnish the designated serial numbers to Manufacturing Planning for entry on the Manufacturing Planning Sheet.

After the multipliers have been installed in an analyzer unit further testing was carried out to optimize the multiplier gain. Details of these tests are described in UTD 151-026, Process Specification, Analyzer Magnet and Multiplier Adjustments. Final tests are made using neon for low-mass channels measurements and argon for high-mass channel measurements. Figures 7-2 and 7-3 illustrate typical pulse-height distribution curves at various multiplier voltage combinations.

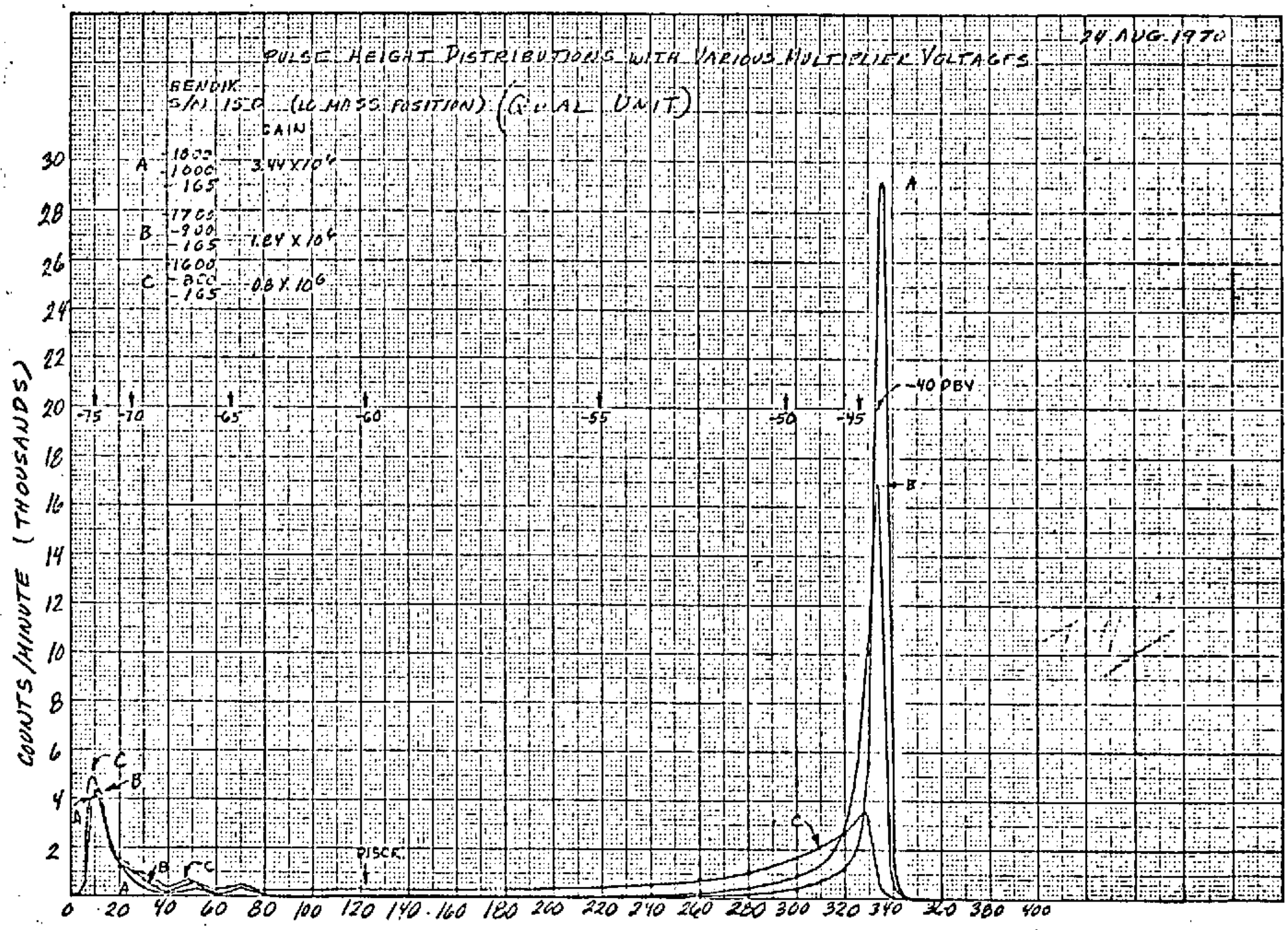


Figure 7-2. Low-Mass Pulse-Height Distribution

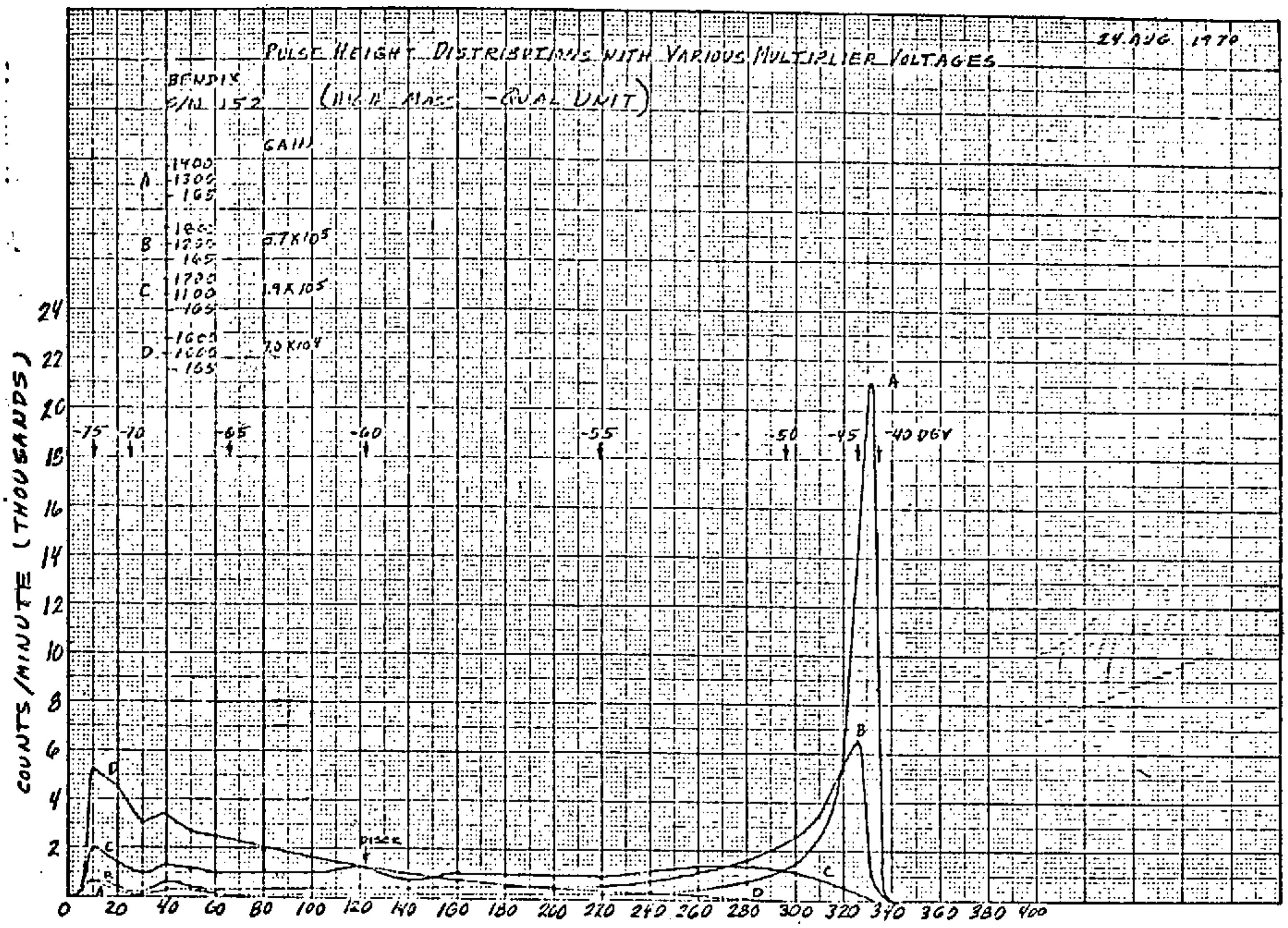


Figure 7-3. High-Mass Pulse-Height Distribution

7.2.4 MAGNET AND YOKE

Magnet position and flux density required vacuum chamber tests to establish operating conditions commensurate with the electronics design. Magnet position is critical within ±0.010 inch and flux density was varied 16 Gauss per 10 volts at 28 amu. Figure 7-4 illustrates a recording of the high-mass channel at a partial pressure of 10^{-6} torr.

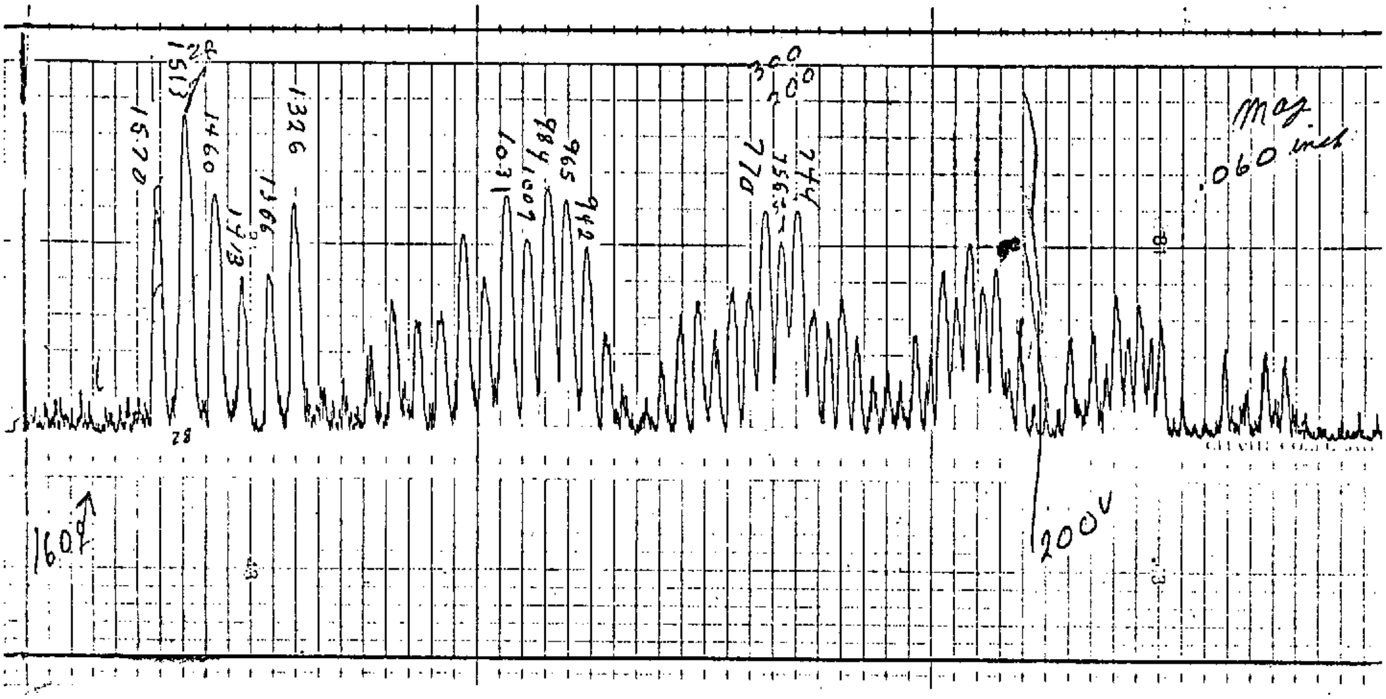


Figure 7-4. Analyzer Recording

Improper magnet position results in a spectrum recording with very wide peaks, a low peak-to-valley ratio, and the baseline failing to return to zero. An initial magnet clearance of 0.060 inch clearance is used during the first test and adjustments of ±0.010 inch are made until an optimum position is found.

Proper flux density is determined by manually adjusting the sweep high voltage power supply for 1500 volts and determining exactly the required voltage to obtain the 28 amu peak. When the peak is at less than 1,490 volts, the flux density must be increased and if the peak is indicated at a voltage greater than 1510 volts, the flux density must be decreased.

Figure 7-5 illustrates the power supply connections to the vacuum chamber and analyzer for multiplier, magnet and Ion Source tests.

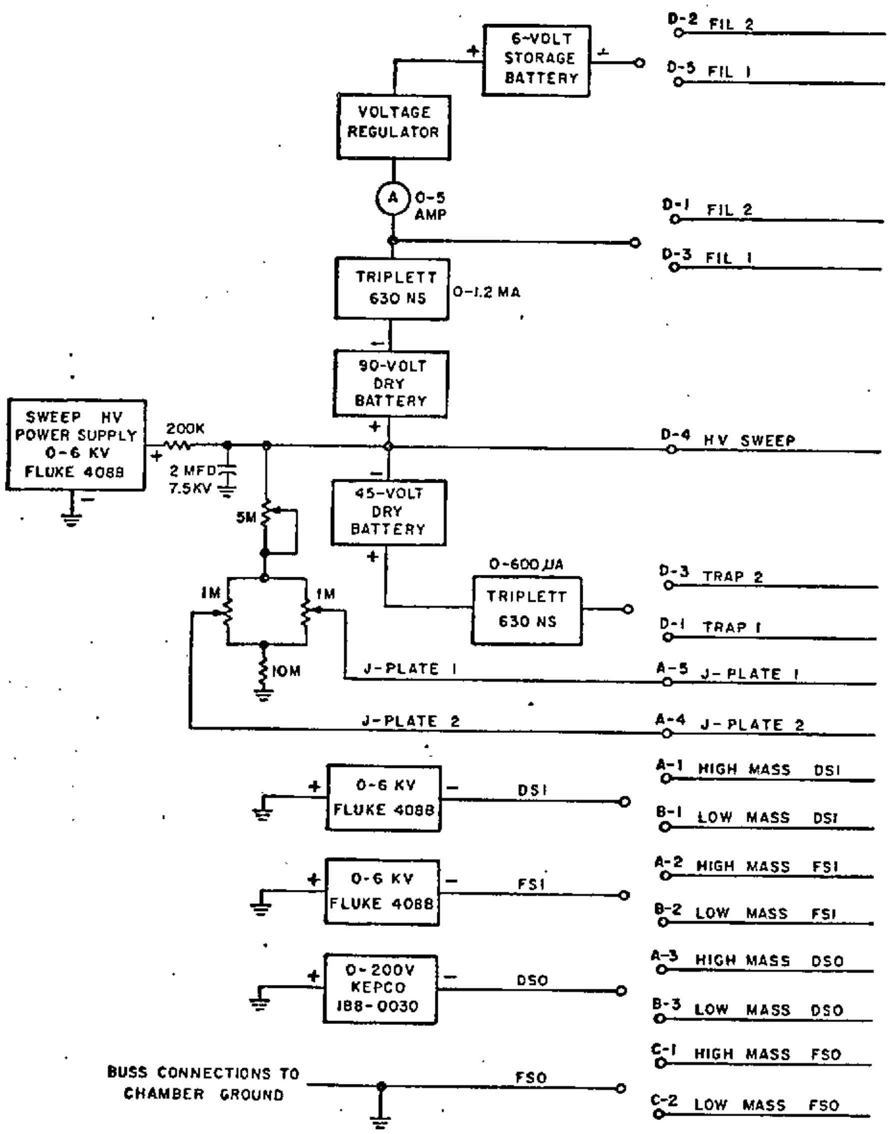


Figure 7-5. Vacuum Chamber Power Connections

7.2.5 ION SOURCE SUBASSEMBLY

Two select-in-test operations are performed with the Analyzer Unit in the vacuum chamber. One test determines the value of the control resistor that limits the Ion Source emission and at the same time tests the quality of the filaments. The other test determines optimum J-plate voltages.

The value of the emission current control resistor is determined by using a test fixture which simulates the Emission Control Subassembly. A potentiometer on the fixture is varied until emission current reaches 250 uA and the ability of the filament to hold regulation at that current is observed. If it does not hold regulation, the filament must be replaced. After testing the filament, current is reduced to 220 uA and the value of the potentiometer resistance is taken as the required value of the control resistor.

Tests to determine optimum J-plate voltages are made to minimize variations between source filaments 1 and 2. The test is performed by adjusting test fixture J-plate potentiometers for peak output of the analyzer while operating on filament no. 1, then repeating the operation while operating on filament no. 2. The J-plate voltage is then readjusted to minimize the difference between electrometer indications for each filament and a variation of greater than 50 percent was cause for readjustment or rejection of the source assembly.

UTD 151-026, Process Specification - Analyzer Magnet and Multiplier Adjustments describes the details of these tests.

7.3 INITIAL CALIBRATION

Initial calibration testing was performed to determine the sensitivity, dynamic range, linearity, resolution and mass discrimination properties of the Analyzer Unit. For this test, the Analyzer Unit and Electronics Unit are separate with the Analyzer Unit in the vacuum chamber and the Electronics Unit connected to it through flange connections on the chamber. Figure 7-6 illustrates the test connections. Sweep high voltage was supplied with a manually operated power supply, as shown in figure 7-5, when discrete voltages were required.

7.3.1 RESIDUAL GAS SPECTRA TEST

As this is the first time the Analyzer Unit and Electronic Unit are operated together, a residual gas spectra test is run. The purpose of this test is to determine that an ion beam is actually traversing

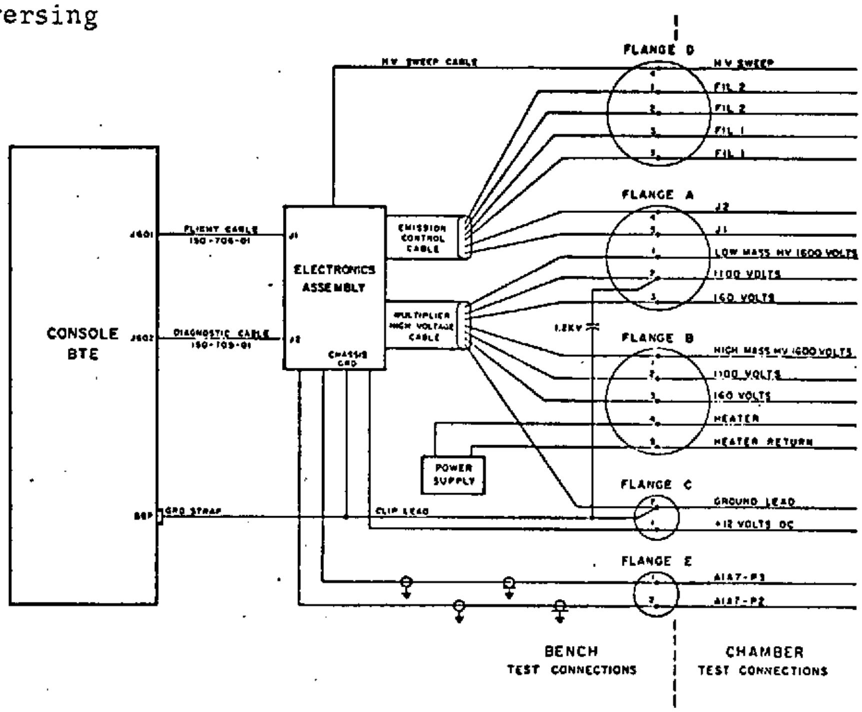


Figure 7-6. Initial Calibration Test Connections

the magnet analyzer and is being detected. This test also demonstrates that the mass spectrometer is scanning the proper mass range in the specified time. Data from this test are used in subsequent tests when the "residual" amount of a particular mass must be known.

7.3.2 LINEARITY AND DYNAMIC RANGE TEST

Linear response of the mass spectrometer was verified over a partial pressure range from 10^{-10} to approximately 10^{-8} torr. Correction factors for partial pressures above 10^{-8} were established, and partial pressures above 10^{-8} were established, and partial pressure response of four orders of magnitude were demonstrated. Table 7-3 lists the pertinent steps of the test procedure.

TABLE 7-3. LINEARITY AND DYNAMIC RANGE TEST SUMMARY

STEP	OPERATION
1.	Adjust sweep high voltage to 20, 21 and 22 AMU peaks (approximately 900, 850 and 820 volts in succession).
2.	Operate printer five seconds for each peak position (20, 21, 22 AMU).
3.	Record amplitude of Mass 20 AMU peak.
4.	Record amplitude of Mass 21 AMU peak.
5.	Record amplitude of Mass 22 AMU peak.
6.	Introduce Neon into the chamber with $\Delta P = 5 \times 10^{-9}$ torr.
7.	Record amplitude of Mass 20 AMU peak.
8.	Record amplitude of Mass 21 AMU peak.
9.	Record amplitude of Mass 22 AMU peak.
10.	Subtract 3 from 7.
11.	Subtract 4 from 8.
12.	Subtract 5 from 9.
13.	Repeat steps 7 through 12 for $\Delta P = 1 \times 10^{-8}$ torr, $\Delta P = 2 \times 10^{-8}$ torr, $\Delta P = 5 \times 10^{-8}$ torr, and 1×10^{-7} torr.
14.	Plot net amplitude of mass 20, 21 and 22 peaks as function of ΔP on a log scale. Deviation from linear relationship should be less than 20% for $\Delta P < 2 \times 10^{-9}$ torr, and correction factor to linear function shall be determined for $\Delta P > 2 \times 10^{-9}$ torr.

TABLE 7-3. LINEARITY AND DYNAMIC RANGE TEST SUMMARY (Cont)

STEP	OPERATION
15.	Verify that partial pressure response of four orders of magnitude is visible on the graphs of step 14.

7.3.3 MASS RESOLUTION TEST

Resolution capabilty of the instrument was demonstrated by measuring the tail of the mass 40 peak at the 39-1/2 and 38-1/2 positions in the spectrum. The resolution ratio of 40/39-1/2 was greater than 100, and the ratio of 40/38-1/2 was greater than 1,000. Table 7-4 summarizes the resolution test procedure.

TABLE 7-4. MASS RESOLUTION TEST SUMMARY

STEP	OPERATION
1.	Determine high voltage sweep voltages for mass 36, 38, 38-1/2, 39-1/2 and 40 AMU (approximately 1159, 1098, 1085, 1060, and 1044 volts).
2.	Inhibit low mass display on Console BTE.
3.	Operate printer five seconds for each peak position (36, 38, 38-1/2, 39-1/2 and 40 AMU).
4.	Record amplitude of mass 36, 38, 38-1/2, 39-1/2 and 40 AMU peaks.
5.	Introduce Argon into the chamber with $\Delta P = 5 \times 10^{-9}$ torr.
6.	Record amplitude of mass 40 AMU peak.
7.	Subtract residual amplitude of step 4 from peak amplitude for each mass number.
8.	Record ratio of Ar^{40}/39-1/2 AMU net and Ar^{40}/38-1/2 AMU net.
9.	Repeat steps 5, 6, 7, and 8 for $\Delta P = 1 \times 10^{-8}$, 2×10^{-8}, 5×10^{-8} and 1×10^{-7} torr. Omit step 8 for 1×10^{-7} torr.

7.3.4 MASS DISCRIMINATION TEST

Mass discrimination testing determined the mass discrimination capability of the Analyzer Unit. Mass discrimination is also known as the Voltage Effect. The discrimination factors are the deviations from true isotopic abundance ratios. Three primary areas were tested.

a. Measurement of two different mixtures of neon/argon and comparison of the data to the certification data of the gas mixture.

b. Calculation of the mean discrimination factors for both neon and argon isotopes.

c. Calculation of the error in the mean discrimination factors.

Table 7-5 lists typical data taken on Qualification and Flight Units, and Table 7-6 summarizes the test procedure.

TABLE 7-5. MASS DISCRIMINATION TEST DATA

TEST OPERATION	TEST RESULTS			
	QUALIFICATION UNIT	FLIGHT NO. 1	FLIGHT NO. 2	FLIGHT NO. 3
Calculated ratio of measured deviation from certification data on neon/argon mixture	17%	4%	12%	6%
Mean discriminator factor for Ne21/Ne22	12%	4.9%	7.4%	27%
Calculated error	13%	4.5%	3.0%	5.3%
Mean discriminator factor for Ar38/Ar36	9%	4.7%	4.2%	3.4%
Calculated error	6%	0.0%	3.7%	1.3%

TABLE 7-6. MASS DISCRIMINATION TEST SUMMARY

STEP	OPERATION
1.	Introduce Neon/Argon mixture No. 1 into chamber with $\Delta P = 5 \times 10^{-8}$ torr.
2.	Operate printer five seconds for peak positions for Mass 36 and 22 AMU peaks.
3.	Record amplitude of Mass 36 AMU peak.
4.	Record amplitude of Mass 36 AMU peak from Step 4 of Table 7-3.
5.	Subtract Step 4. from Step 3.
6.	Repeat Steps 4., 5., 6.,for Mass 22 AMU peak (in Step 4., use Mass 22 AMU peak amplitude from Step 5 of Table 7-3).
7.	Record ratio Ar^{36}/Ne^{22} x 28.6.
8.	Calculate percent deviation of Step 7. from calculated ratio using certification data on gas mixture.

TABLE 7-6. MASS DISCRIMINATION TEST SUMMARY

STEP	OPERATION
9.	Repeat Steps 1. through 8. with gas mixture No. 2.
10.	Using the data from Step 13., Table 7-3, record the ratio Ne^{21}/Ne^{22} for $\Delta P = 1 \times 10^{-8}$, 2×10^{-8}, and 5×10^{-8} torr.
11.	Calculate the percent deviation of these ratios from .028.
12.	Calculate the mean discrimination factor.
13.	Calculate the error in the mean discrimination factor.
14.	Using the data from Step 4., Table 7-4, record the ratio of Ar^{38}/Ar^{36} for $\Delta P = 2 \times 10^{-8}$ torr, 5×10^{-8} and 1×10^{-7} torr.
15.	Calculate the percent deviations from 0.19.
16.	Calculate the mean discrimination factor.
17.	Calculate the error in the mean discrimination factor.

7.3.5 SENSITIVITY TEST

Partial pressure sensitivity of the mass spectrometer was demonstrated to be greater than 5×10^{-6} Ampere/torr. Typical test results for both neon and argon are as follows:

Qualification Unit: 1×10^{-5} Ampere/torr

Flight Unit No. 1 : 2.8×10^{-5} Ampere/torr

Flight Unit No. 2 : 2.7×10^{-5} Ampere/torr

Flight Unit No. 3 : 3.3×10^{-5} Ampere/torr

Table 7-7 summarizes the sensitivity test procedure.

TABLE 7-7. SENSITIVITY TEST SUMMARY

STEP	OPERATION
1.	Using the data from Step 14. of Table 7-3, determine the slope of the Ne = F (ΔP) curve up to ΔP = 2×10^{-8} torr.
2.	Multiply the slope factor by the ion gauge sensitivity coefficient for Neon (3.5).
3.	Convert units to Ampere/torr (e = 1.6×10^{-19} coulomb).
4.	Using the data from Table 7-4, determine the Ar = F (ΔP) slope.
5.	Multiply the sope factor by the ion gauge sensitivity coefficient for Argon (0.8).
6.	Convert units to Ampere/torr.

7.4 DEVELOPMENT TESTS

Development tests were performed on the Prototype Unit for the purpose of establishing pre-qualification confidence, obtaining engineering information, detecting workmanship deficiencies, and establishing the adequancy of functional procedues. Figure 7-7 illustrates the development and acceptance test sequence for the Prototype Unit.

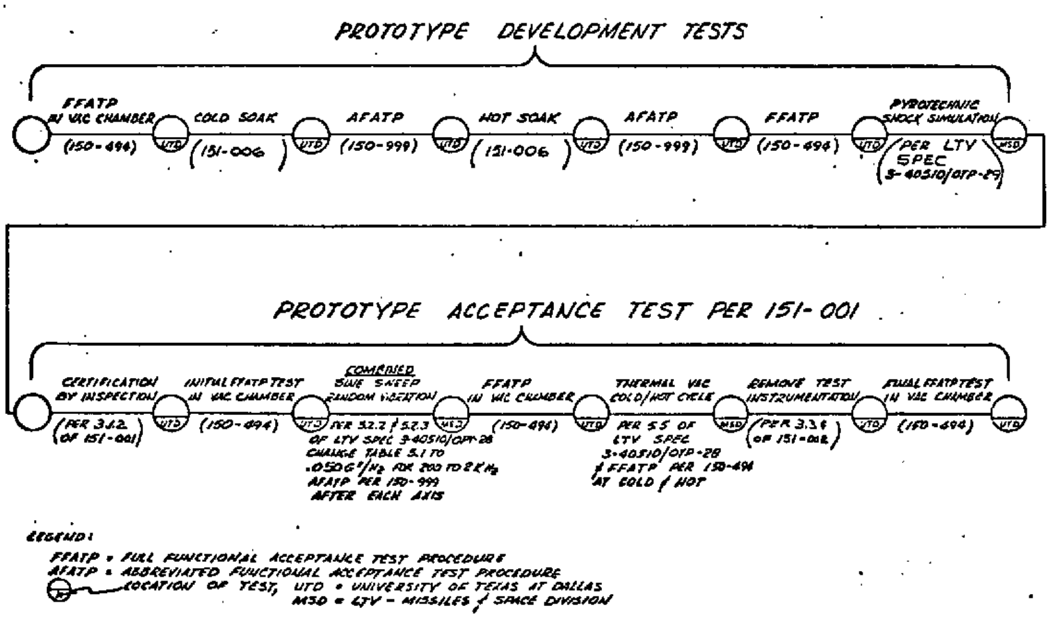


Figure 7-7. Prototype Test Sequence

Development tests consisted temperature soaks at -40°F and at +120° F in accordance with UTD 151-006, Thermal Soak Test Procedure; and, shock tests. Shock tests used pyrotechnic simulation to achieve 3,000 g response at the mounting interface in a direction parallel to the axis of the support boom. Functional tests were performed before each test phase, between test phases, and at the conclusion of the development tests.

Following the temperature soaks and shock tests, acceptance testing included vibration and thermal-vacuum to further demonstrate the integrity of the design and workmanship. Vibration consisted of five minutes of sinusoidal vibration followed by five minutes of random vibration in each of three mutually perpendicular axes. The following levels were employed

a. Sinusoidal: 0.75 g peak amplitude, 5 to 2,000 Hz with logarithmic sweep from lower to upper limit.

b. Random: Increase spectral density at the rate of 3 dB/octave from 20 to 200 Hz; constant spectral density of 0.05 g^2/Hz from 200 to 2,000 Hz.

Thermal-vacuum test with solar simulation was performed at 20°F below minimum flight temperatures and 20°F above maximum flight temperature. One cold and one hot cycle were performed.

Functional tests were performed as shown in Figure 7-7.

7.5 QUALIFICATION TESTING

On 23 November 1970, the Qualification Unit underwent the Final Electrical Baseline Test in the UTD vacuum chamber. The test was performed without incident thus completing the Qualification Test sequence.

In summary, the Qualification Tests were accomplished with 15 total test deviations, 2 Retest Plans and a total of 8 FIAR's. Four of the FIAR's were officially closed with the remaining four being considered closed by NASA authorization TWX JC931/T229-70/88. Only one minor design change was required as a result of the test sequence, that the change in lengths of the screws which were loosened during vibration. Instrument design is considered to be more than adequately for all flight performance objectives.

In addition, quantitative and qualitative investigations of the paint flaking problem strongly indicated that the phenomenon is not serious enough to warrant any further investigation regarding stripping of the present finish and repainting with a new finish.

Qualification Test levels were established to stress the system beyond expected flight levels to ensure mechanical and electrical integrity of the flight units. Baselines were confirmed and system design was frozen following Qualification Acceptance Review. Testing was performed in the following categories:

a. Functional Baseline Tests

b. Electromagnetic Interference

c. Shock

d. Vibration

e. Thermal/Vacuum

f. Solar/Lunar Simulation

Qualification testing was carried out in accordance with UTD 150-491, Qualification Test Plan. Detailed test results are contained in UTD 151-055, Qualification Data Package and a summary report is contained in UTD 151-053, Qualification Test Report Summary.

7.5.1 FUNCTIONAL BASELINE TESTS

Functional baselines constitute the operational parameters as defined by UTD 150-440, End Item Specifications for Apollo Lunar Orbital Mass Spectrometer. From these parameters, detailed test operations were designed to demonstrate instrument performance within specified tolerances. UTD 150-494, Full Functional Acceptance Test Procedure for Mass Spectrometer 150-500, was approved as the electrical baseline test. An abbreviated version of this test was approved to be conducted at room pressure and performed between axis tests and at other specified times to partially verify functional operation. The abbreviated version is UTD 150-999, Abbreviated Functional Acceptance Test.

7.5.2 ELECTROMAGNETIC INTERFERENCE TESTS

7.5.2.1 TEST LEVELS AND OBJECTIVES

Objectives of the EMI tests were to determine if the instrument was compatible with the overall Apollo system in terms of susceptibility of the unit to impressed EMI from other Apollo experiments and determine whether or not the instrument was a source of EMI of sufficient magnitude to compromise other experiments. Susceptibility criteria was established by UTD to impressed levels specified by North American Rockwell, Downey. Allowable interference levels were established by UTD from North American Rockwell requirements. These criteria are given in UTD 151-007, Electromagnetic Interference Test Plan.

7.5.2.2 TEST DEVIATIONS

Prior to the EMI tests, upon final review of the EMI functional test procedures (151-011 and 151-038), it was determined that the planned use of the diagnostic cable was unnecessary. The procedures were modified to reflect this change. During the test, deviation 151-024-01 had to be generated to cover this change to the overall test procedure. It was also found during the actual tests that the effects of the lack of the diagnostic cable on some of the data items had not been completely reflected in the final approved 151-038 test procedure. Deviations 151-038-01, 02, 03, and 04 were generated as a result of this oversight.

7.5.2.3 TEST SEQUENCE

Initial setup for the EMI radiated tests took place on 20 October 1970 at the LTV Electrosystems facilities and radiated susceptibility tests were performed on the same day. As required, UTD test procedure 151-038 was utilized to determine susceptibility sensitivity during the application of the RF signals. No out-of-tolerance anomalies were observed.

On 21 and 22 October, radiated interference tests were performed and out-of-tolerance conditions were observed. Mr. Ted Pumphries of North American Rockwell, Downey, was informed of the out-of-tolerance values and upon his request preliminary copies of all available interference data were sent to him.

RF conducted tests were performed with the unit installed in the UTD vacuum chamber on 23 October, with the tests concluding in the early morning of 24 October. UTD functional test procedure 151-011 was utilized for determining susceptibility sensitivity.

In the conducted susceptibility test one out-of-tolerance sensitivity was observed and during the conducted interference test out-of-tolerance conditions were observed, especially above .60 mHz, with a high peak occurring at 1.5 mHz.

Mr. Ted Pumphries was informed of the conducted results by phone on 26 October. Mr. Pumphries said that he would have to conduct other sub-contractors before any judgment could be made on the levels observed. On 27 October, after talking with the other contractors involved and after reviewing both the radiated data which had been sent to him and the conducted data as described to him over the phone, Mr. Pumphries suggested a retest with certain changes in the test conditions. The retest was intended to answer two major questions, these being:

a. In the radiated interference tests, were the out-of-tolerance levels emanating primarily from the test instrument or from the cables? If the levels were results of the test instrument then the remove location of the instrument in flight on its 24-foot boom would provide an attenuation of the levels by approximately -40dB as measured in the vicinity of the next closest instrument on the Apollo Mission. These levels would then be acceptable.

b. Would any tests be conducted at the complete system level which would provide adequate test conditions to produce the conducted interference levels observed? These system tests could then provide the data to determine the sensitivity of the rest of the system to the conducted interference produced by the UTD instrument. No data were presently available to determine this.

In addition Mr. Pumphries requested that the LISC's which had been installed during the tests be removed for the retest.

To provide the answers to a. and b. above Retest Plan 151-038-1 was initiated. The retest required the following steps:

1. Removal of the LISC's from the cables.

2. Repeating part of the radiated interference tests with the power cable shielded and then with the test instrument shielded from the measuring instruments.

3. Repeating the conducted interference test over the range of 500 kHz to 5 mHz with the instrument installed in the screen room at ambient pressure.

On 27 October, radiated interference retests were performed per Retest Plan 151-038-01. It was observed that the primary source of narrow band radiated interference was the test instrument rather than the cables, and that the instrument was also the primary source of broadband interference from 0.01 to 1.00 MC. It is believed that this result answers question a. above in the affirmative.

On 28 October, conducted interference retests were begun per Retest Plan 151-038-01. Preliminary results indicated a significant difference in levels between the new tests and the comparable tests performed in the UTD vacuum chamber on 23 October. Investigation of the results indicated that the difference might be due to the fact that the Console BTE being used for the retest (S/N 003) was not the same as was used for the first test (S/N 001).

Retest Plan 151-038-02 was initiated to answer this question. When the Console BTE's were compared under the same test conditions it was found that Console 003 was generating a considerable higher noise level than 001. Console 003 was therefore replaced with 001 and the conducted tests completed. To form a comparable baseline the tests were performed both with and without the LISC's, as shown.

Results of the conducted interference tests also answered question b. above in the affirmative. The results show that comparable conducted interference levels are produced whether the instrument is operated in a vacuum environment or at room ambient conditions.

7.5.2.4 TEST RESULTS AND CONCLUSIONS

During the EMI tests four FIAR's were written due to suspected out-of-tolerance conditions.

022 - Written during radiated susceptibility test. Segment No. 12 (T2) of the Analog Housekeeping data showed a marked change in voltage at 120 mHz with a threshold of .25 V/meter. However, this segment has an allowable tolerance of from 0 to 5 volts and was not out-of-tolerance. It is considered that this FIAR should be voided as inapplicable.

023 - Written during radiated interference test as a result of the out-of-tolerance levels measured. Retest Plans 1 and 2 were performed to better define these levels. The final results of these retests were relayed to Mr. Al Copeland via EMI Test Deviation Report, SMOG-OL-278, 24 November 1970, and it is considered that this report together with NASA authorization, TWX JC 931/T229-74/88, closed this FIAR.

024 - Written during conducted interference tests, as a result of the out-of-tolerance levels measured. Retest Plans 1 and 2 were also performed to better define these levels. Final results were included in SMOG-OL-278. This FIAR was also closed per the discussion of FIAR 023.

025 - Written during conducted susceptibility tests (in UTD vacuum chamber). The Mass 18 data counts varied by more than 50 percent at the conducted frequency of 6 MHz. Threshold was established at 0.025 VRMS. No corrective action was taken as it was considered that the criticality of this failure is low.

026 - During the initial radiated interference tests the Console BTE being used initially (S/N 001) malfunctioned. Console S/N 001 was replaced with S/N 003 and the test continued. The Console was subsequently repaired by replacement of Card C81 and the Console re-certified.

Because of the positive results of retests 1 and 2 in regards to defining the levels as requested by Mr. Ted Pumphries of North American Rockwell and by virtue of the authorization given by TWX JC931/T229-74/88, no design changes were considered to be necessary for the instrument.

As a result of the EMI tests, EMI requirements for the Mass Spectrometer as documented in MH01-12662-234, paragraph 3.2.1 and 3.2.2 and revised by IRN No. 8050, were updated to reflect these results and the general conclusions reached.

Detailed test results are contained in UTD 150-055, Qualification Data Package.

7.5.3 TRANSPORTATION VIBRATION

7.5.3.1 TEST LEVELS AND OBJECTIVES

The purpose of the transportation vibration test was to determine whether or not the test item, installed in its shipping container, can be shipped by normal air freight or ground transportation without incurring damage. The input test levels are sinusoidal motions from 5 Hz to 500 Hz with levels increasing from 1.3 g's at 5 Hz to 5 g's at 52 Hz and constant at 5 g's to 500 Hz. Thirty minute dwells are required at any detectable resonances over the 5 to 500 Hz frequency range.

There were no test deviations during the transportation vibration test.

7.5.3.2 TEST SEQUENCE

On 5 November at the LTV/MSD Facilities, the Qualification Unit, installed in the special shipping container, was subjected to the required transportation vibration levels input to the mounting interface of the shipping container in the X, Y and Z axis of the instrument. A triaxial accelerometer was mounted to one of the latch plates of the inner container to monitor the response of the foam shock insulators and the inner container. The observed (on deduced) resonances and performed dwells and listed in Table 7-8.

TABLE 7-8. TRANSPORTATION VIBRATION TEST SUMMARY

AXIS	RESONANCE (Hz)	AMPLIFICATION	COMMENT
X	4	3:1	Primary resonance of foam - no dwell since frequency is below lower limit requirement.
	12	3:1	30 minute dwell.
	95	2.6:1	30 minute dwell - this resonance is probably a resonance of the inner housing, rather than the foam.
Y	8	1.8:1	Primary resonance of foam - 30 minute dwell.
	20	1.8:1	30 minute dwell.
	65	3:1	30 minute dwell.
Z	11	2:1	Primary resonance of foam - 30 minute dwell.

TABLE 7-8. TRANSPORTATION VIBRATION TEST SUMMARY (continued)

AXIS	RESONANCE (Hz)	AMPLIFICATION	COMMENT
	51	1.2:1	30 minute dwell.
	95	1.8:1	30 minute dwell - inner housing resonance.

7.5.3.3 TEST RESULTS AND CONCLUSIONS

Functional tests per UTD 150-999 were conducted between each axis and per UTD 150-494 upon the conclusion of the test. No anomalies were observed nor FIAR's written on the instrument; the test objectives were fu lly met.

During the test, FIAR 027 was written due to a malfunction of the Console BTE (S/N 003) being used for the test. A contaminated pin on connector J302 caused incorrect decimal read-out on the control panel. The test was continued since data was being correctly printed and the Console was repaired upon the conclusion of the transportation vibration test.

The instrument was mounted within the inner shipping container during the test except when it was necessary to remove the unit while performing the functional tests between axis. Some paint flakes were found in the inner container between each axis. Samples were collected and marked.

7.5.4 TRANSPORTATION DROP

7.5.4.1 TEST OBJECTIVES AND LEVELS

The purpose of the transportation drop test is to demonstrate that the unit, installed in its shipping and handling container, can withstand the handling abuse that could be expected of a package of its size when shipped by commercial carrier. Test levels are 21-inch drops to a hard concrete floor onto each of the eight corners of the outer container.

There were no test deviations during the transportation drop tests.

7.5.4.2 TEST SEQUENCE

The Qualification Unit, installed in the special shipping container, was subjected to the required transportation drop tests on 6 November 1970 at the LTV/MSD Facilities. The response of a triaxial accelerometer, mounted identical as during vibration testing, was recorded on polaroid film.

7.5.4.3 TEST RESULTS AND CONCLUSIONS

Responses for all drops were consistant, showing an approximate +30g and -60g response with a frequency of approximately 100 Hz. In comparing this frequency with those found during the transportation vibartion test, it is most probable that this frequency represents the response of the inner container at the location of the monitor accelerometer. Actual input to the instrument would be less than these levels due to its mounting configuration within the inner container. In each drop, the corner of the outer container was indented indicating that the container outer structure absorbs much of the energy of the shock without transmitting it through the shock mounts. Indentation of all corners was consistant showing an overall uniform response of the container.

Following the eight drops, the required functional tests per UTD 150-999 and UTD 150-494 were conducted on the unit without incident. No FIAR's were written during the test. It was concluded that the shipping container will protect the unit adequately and that all test objectives were met.

Upon removal of the unit from the inner container following the eight drops the inner container was examined for paint flakes or other contamination. None was found.

7.5.5 ACCELERATION TEST

7.5.5.1 TEST OBJECTIVES AND LEVELS

The purpose of the acceleration test was to prove that the unit could withstand constant body force loads which will be imposed as a result of the launch accelerations. The test levels (±6 g's in each axis) and durations (5 minutes for each test) are in excess of actual flight levels to provide an adequate safety margin.

There were no test deviations during the acceleration test.

7.5.5.2 TEST SEQUENCE

The Qualification Unit was installed on the LTV/MSD Schauvitz Centrefuge and subjected to the required acceleration test levels. All required levels were met without incident.

7.5.5.3 TEST RESULTS AND CONCLUSIONS

Functional tests per UTD 150-999 were conducted on the unit between axis and per UTD 150-494 upon the conclusion of the test. No anomalies were observed. No FIAR's were written as a result of the test sequence and all test objectives were met.

The unit was enclosed in a clean plastic during the test sequence and no accumulation of paint nor other contamination was observed during the test.

7.5.6 COMBINED VIBRATION TEST

7.5.6.1 TEST OBJECTIVES AND LEVELS

The purpose of the combined vibration test were: (1) to demonstrate that the instrument will withstand the effects of induced sinusoidal and random vibration in a launch environment and, (2) to exhibit a fatigue resistance to exposure to five times the duration of a normal acceptance vibration test at 1.69 times the level of the acceptance vibration test. Test levels and durations per axis are as follows:

SINSOIDAL LEVELS

Freq (Hz)	Level (Peak g)
4-5	.95
5-35	1.5

Duration: Sweep from 4Hz to 35Hz to 4Hz at a rate of 3 OCT/Min.

RANDOM LEVELS

Freq (Hz)	Level (g^2/Hz)
20-180	Increase at +3db/octave
180-1000	.068
1000-2000	Decrease at -6db/octave

Duration: 225 seconds at the shown level (5 x ATP x 1.69).

80 seconds at +1db above the shown level (Launch).

10 seconds at +2.7db above the shown level (Max. Q).

7.5.6.2 TEST DEVIATIONS

Test Deviation 151-020-01 resulted due to an inconsistancy of the test sequence as imposed by UTD 150-491. Combined vibration was required before pyrotechnic shock.

Test Deviations 150-489-01, 150-491-02 and 151-020-02 resulted due to the requirements of Qualification RID 03 for the collection and labeling of contamination resulting from combined vibration.

7.5.6.3 TEST SEQUENCE

The Qualification Unit was exposed to the required combined vibration levels at the LTV/MSD Facilities on 12 November 1970. All required levels were met without incident.

7.5.6.4 TEST RESULTS AND CONCLUSIONS

Functional tests per UTD 150-999 were conducted on the unit between axis. Upon conclusions of the test a functional test per UTD 150-494 was conducted. No electrical anomalies were observed.

Upon visual examination of the unit one screw had backed out of the radiator plate. A test of all remaining external screws revealed that four more screws had loosened in the same area. FIAR 029 was written. The corrective action taken was to increase the length of the screws in question in order to provide positive engagement of the screw threads with the locking insert. No other FIAR's were written.

The Qualification Unit was enclosed in a clean plastic bag throughout the test sequence and upon completion of the test all contamination collected in the beg was transferred to either a small bag or into a bottle of distilled water as required by UTD 151-047. The samples were labeled and shipped to NASA/MSC with cover letter SMOG-OL-263, 13 November 1970.

7.5.7 PYROTECHNIC SHOCK SIMULATION TEST

7.5.7.1 TEST OBJECTIVES AND LEVELS

The purpose of the pyrotechnic shock simulation test was to demonstrate that the unit would not be damaged by exposure to a shock environment which simulates the shock created by jettisoning the SIM bag door. Response levels produced by this test are specified as being 3000 g's from 3000 Hz to 10,000 Hz, dropping to 10 g's at 200 Hz. Three shocks were required in the X-axis. Figure 7-8 illustrates these levels.

No deviations were written during the performance of the pyrotechnic shock simulation test.

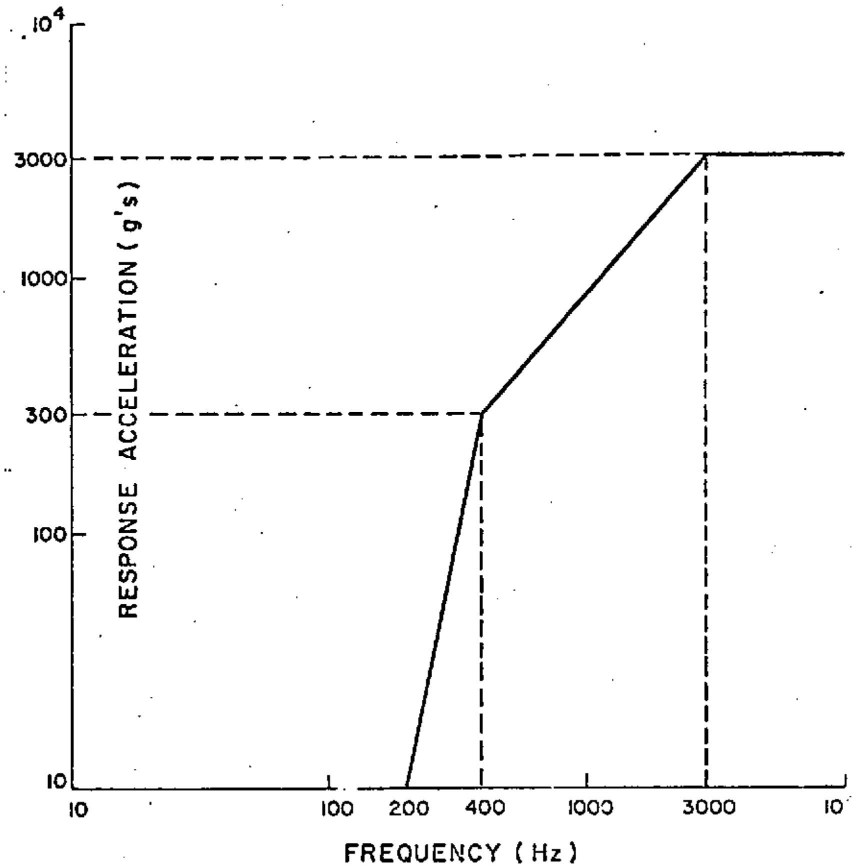


Figure 7-8. Shock Response Levels

7.5.7.2 TEST SEQUENCE

Prior to the application of the required shocks to the actual unit, LTV/MSC test lab tested the shock-test procedure using a mass mockup of the test item as required by UTD 150-491. Some adjustment of the shock fixture was required before an acceptable spectrum was obtained. The final test spectrum was approved via SMOG-0L-258. Shock test of the actual Qualification Unit then proceeded on 13 November 1970.

7.5.7.3 TEST RESULTS AND CONCLUSIONS

Functional tests per UTD 150-999 were performed between each shock. Upon the conclusion of the test a functional test per UTD 150-494 was performed. No anomalies were observed and no FIAR's written showing that all test objectives were met.

A problem with the diagnostic cable, interconnecting the unit with the Console BTE, was detected prior to the test. The cable was temporarily repaired and the test completed. Final repairs were made to the cable after the test.

The unit was visually monitored during each shock for evidence of paint flaking. None was observed.

7.5.8 THERMAL/VACUUM-SOLAR SIMULATION

7.5.8.1 TEST LEVELS AND OBJECTIVES

The objective of the thermal/vacuum test with solar simulation was to prove that the performance of the test item would not be degraded upon exposure of thermal/vacuum conditions that produced component temperatures in excess of those worst case values expected during flight. Environmental levels of the test were determined from the results of acceptance thermal/vacuum testing of the Prototype and Qualification Units which were performed at flight extremes. The actual required levels are documented in UTD test plan 150-491.

7.5.8.2 TEST DEVIATIONS

The following test deviations resulted before or during the thermal/vacuum tests:

150-489-02 - Location of the functional test required to be performed before the thermal vacuum test was changed from UTD to MSD vacuum chamber. This change was due to a conflict with Flight Unit No. 1 on using the UTD vacuum facilities. It was decided that the MSC chamber could support the test adequately.

150-491-01 - During the Acceptance Data Review, the Scientific Group Meeting requested that additional thermocouple monitoring of the instrument in the vicinity of the Ion Source Assembly be provided to obtain information of gas temperature in this area. The test plan was changed by this deviation to provide three additional monitor points.

150-491-03 - Same as 150-489-02, but required for complete documentation of the deviation.

150-020-03 - Test Procedure Deviation to incorporate test plan deviation 150-491-03.

150-020-04 - Test procedure deviation to incorporate test plan deviation 150-491-01.

151-020-05 - During the first cold cycle, thermocouple monitor point No. 9 (Electron Multiplier) fell below the minimum allowed limit as specified in the test procedure. The solar light duty cycle was increased from 40 percent to 50 percent to provide heating. After review the lower limit of this item was lowered and the solar light duty cycle returned to 40 percent.

150-020-06 - During the first hot cycle, thermocouple monitor point No. 13 (Baseplate) exceeded its maximum allowed limit. The radiator plates were reduced from +170°F to 150°F for 30 minutes. A quick review of the other monitor points showed no other anomalies. It was deduced (and later confirmed upon removal of the instrument) that monitor point No. 13 had been mis-located. The radiator plates were returned to +170°F and the test continued.

7.5.8.3 TEST SEQUENCE

The Qualification Unit was installed in the LTV/MSD vacuum chamber on 13 November 1970 following the completion of the pyrotechnic shock tests. Figure 7-9 illustrates the test geometry. Pump down began at 8:00 a.m., 16 November. The first cold cycle was completed at 7:45 a.m., 17 November; the first hot cycle completed 9:15 p.m., 17 November; the second cold cycle completed 9:30 a.m., 18 November and the final hot cycle at 9:05 p.m., 18 November. The unit was removed from the chamber at 1:00 p.m., 19 November 1970 completing the thermal/vacuum test. No major problems were encountered in meeting all required levels.

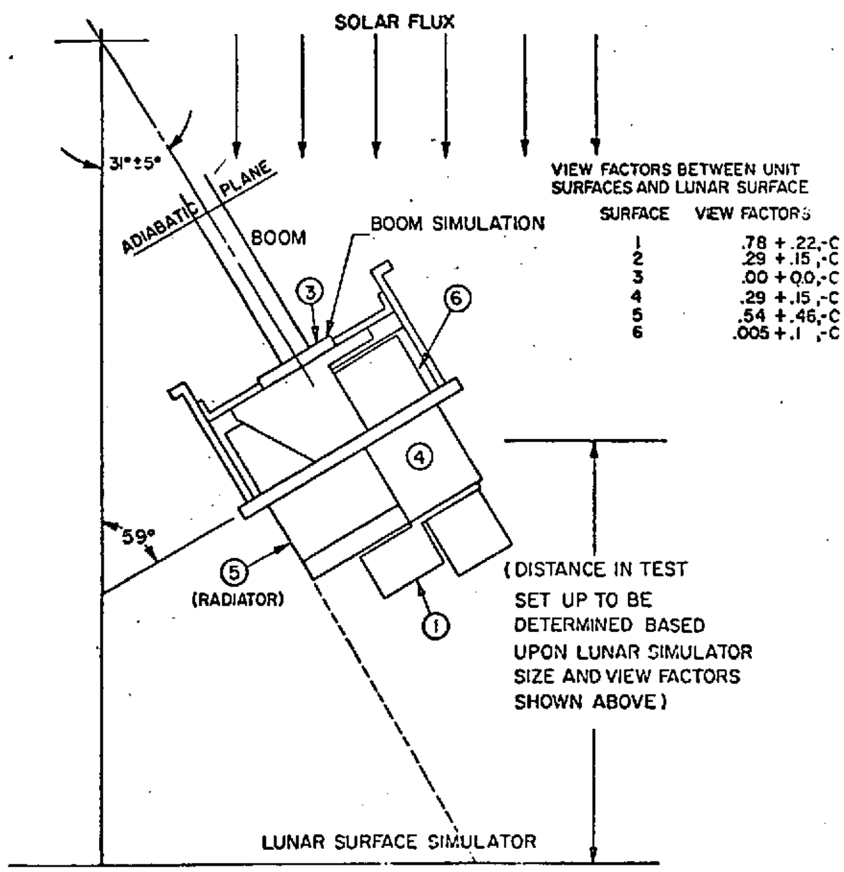


Figure 7-9. Thermal/Vacuum with Solar/Lunar Simulation

7.5.8.4 TEST RESULTS AND CONCLUSIONS

The Table 7-9 shows the response of the unit compared with response during the comparable acceptance test performed earlier on the unit.

TABLE 7-9. THERMAL/VACUUM TEST RESULTS

T/C NO.	COLD RESPONSE (°F)			HOT RESPONSE (°F)		
	ACCEPT. TEST	QUAL TEST (2nd Cold Cycle)	STRESS	ACCEPT. TEST	QUAL TEST (1st Hot Cycle)	STRESS
1	- 5.5	-13.8	- 8.3	+105.5	+124.7	+19.2
2	+ 5.0	- 6.2	-11.2	+117.0	+126.7	+ 9.7
3	+13.5	+ 3.8	- 9.7	+119.0	+133.7	+14.7
4	+ 2.0	- 8.7	-10.7	+117.5	+126.7	+ 9.2
5	+12.5	+ 1.8	-10.7	+120.5	+135.4	+14.9
6	+17.0	+ 5.8	-11.2	+127.0	+139.9	+12.9
7	+ 5.0	- 5.7	-10.7	+125.0	+135.8	+10.8
8	+ 6.0	- 4.7	-10.7	+111.5	+122.1	+10.7
10	+ 3.5	- 5.7	- 9.2	+119.0	+138.7	+19.7
11	+ 3.5	- 6.2	- 9.7	+117.5	+137.0	+19.5
14	+ 6.5	- 4.2	-10.7	+110.0	+125.5	+15.5
15	+ 6.5	- 4.2	-10.7	+111.5	+126.7	+15.2

Comparisons of the temperatures show that all test objectives were met.

Transient responses of three additional thermocouples (T/C) mounted to the Ion Source flange and Plenum chamber wall showed the following response during a 20-minute Ion Source Heater Test (Lst Hot Cycle).

TABLE 7-10. TRANSIENT RESPONSE OF ION SOURCE ASSEMBLY

TIME	T/C 16 (Ion Flange Inside)	T/C 17 (Ion Flange Outside)	T/C 18 (Plenum Chamber)
8:19pm	53.8°F	55.6°F	77.8°F
8:22	56.0	56.5	79.0
8:25	60.1	59.2	81.1
8:28	64.5	62.8	83.1
8:31	68.9	66.3	84.7
8:34	72.8	70.2	87.1
8:37	76.1	72.8	88.6
8:40	78.6	74.9	89.0
8:43	78.6	75.7	88.6

During the thermal vacuum test T/C No. 16 was used to determine the proper calibration curve for housekeeping Segment 12 (T2) since this segment had shown inconsistant results when correlation was attempted after the acceptance thermal/vacuum test on the Qualification Unit.

It was noted that during the performance of deviation 150-020-1 (EBL in MSC, SES Chamber) that cryogene pumping of the argon test gas resulted due to the temperature required on the MSD inner shroud to obtain the necessary pressure. Although this pumping is acceptable during the FFT's performed in the normal thermal vacuum test sequence, its presence during the EBL is undesirable and it was decided that further EBL's in the MSD chamber should be avoided, whenever possible.

7.6 FINAL CALIBRATION

From 26 February to 26 March 1970, absolute calibration tests were conducted on the Qualification Unit at the Langley Research Center. Tests were performed in the Molecular Beam Facility described in NASA TND-5308. UTD Test Plan 150-402, Test Plan for Absolute Calibration of the LOMSE Qualification Unit at the Langley Research Center, was utilized as a guide for conducting the test. In the actual test sequence, the test procedure (UTD 150-403) was considerably modified to arrive at the desired results. Quality Control was maintained to ensure proper documentation of all test activities.

7.6.1 TEST GASES

Originally nitrogen and neon were to be the test gases. However, in the initial calibration and -5° pitch calibration tests, it was found that the background counts for the nitrogen peak were excessive and resulted in switching to Argon and Neon as the final test gases. Using these gases, partial pressures ranging from 10^{-12} to 10^{-9} torr were obtained in the molecular beam facility. Subsequent tests with the Flight Units also utilized Argon and Neon.

7.6.2 SENSITIVITY

Preliminary test results show a sensitivity at -5° pitch to argon and approximately 4.4 counts/0.1 sec at 10^{-13} torr and to neon of approximately 1.3 counts/0.1 sec at 10^{-13} torr. Response of the unit was essentially linear over the test pressure range for both gases. No degradation of sensitivity was observed between the tests conducted at -5° pitch on 18 March and the tests conducted at +5° pitch on 26 March. All differences in readings could be accounted for by the differences in putch angles.

7.6.3 ION SOURCE FLIGHT PREPARATION

A substantial improvement was exhibited in the response of the instrument after the ion source preparation on 6-10 March following the initial calibration tests on 3 March. Improvement was of such a magnitude that approval was given in a test review meeting held at NASA/MSC on 21 March to incorporate UTD 151-058, Ion Source Flight Preparation Procedure for all flight units.

7.6.4 ANGULAR RESPONSE OF FLIGHT SCOOPS

The tests performed to show the angular response of the flight scoope (UTD Part No. 151-118) produced results in general agreement with theory. The test data was used to establish that scoop 151-118 was an acceptable configuration. This scoop was subsequently approved for all flight units.

7.6.5 GENERAL PERFORMANCE OF THE TEST CHAMBER

Although the test chamber was not able to achieve the ultimate total pressure which had been specified in the test plan ($<10^{-13}$ torr), by using partial pressures of Argon 36 and Neon 22 isotopes all test objectives were met. The chamber adequately supported the calibration tests. Figure 7-10 shows the instrument installed in the chamber and Figure 7-11 illustrates the geometry of the scoop and the molecular beam.

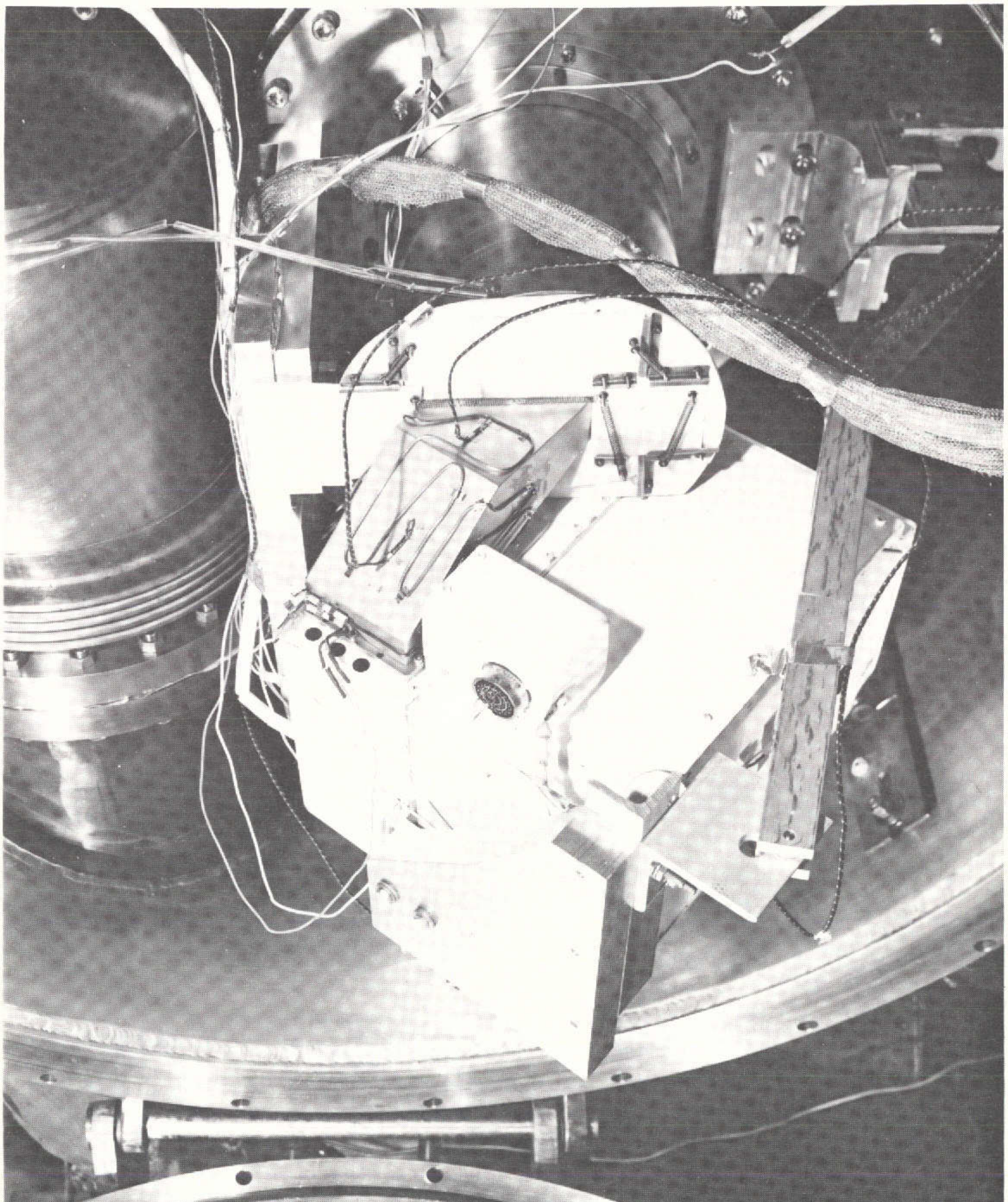


Figure 7-10. Test Chamber Installation

7.6.6 TEST RESULTS

Tables 7-11 through 7-16 and Figures 7-12 through 7-15 summarize the calibration tests.

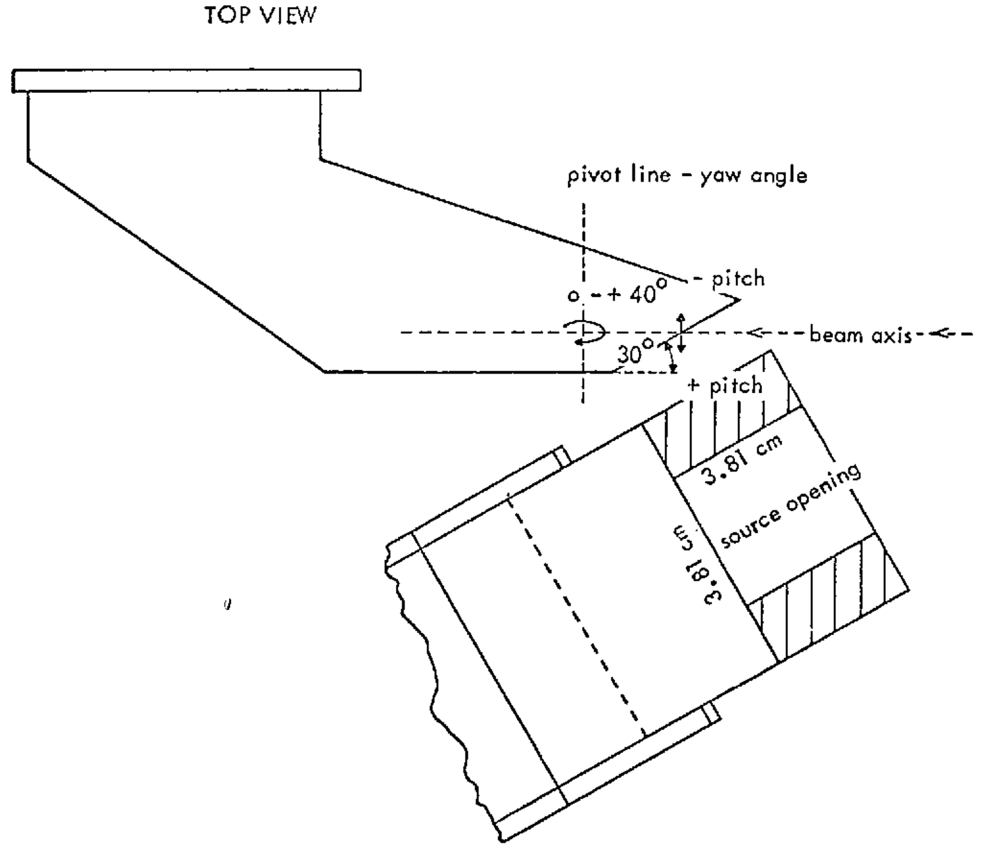


Figure 7-11. Scoop Mounting Geometry

TABLE 7-11. TEST CONDITIONS

Pitch Angle	Test Gas	Yaw Angles	Source Pressures
-5°	Nitrogen	0°, 20°, 40°	.78, 3.0, 30.0 PSI
-5°	Argon	0°, 20°, 40°	1.0, 3.0, 30.0 PSI
-5°	Neon	0°, 20°, 40°	3.0, 25.0 PSI
+5°	Argon	0°, 20°, 30°, 40°	3.0, 10.0, 30.0, 50.0 PSI
+5°	Neon	0°, 20°, 30°, 40°	1.0, 3.0 10,0, 30.0, 50.0 PSI

TABLE 7-12. TEST POINT VALUES FOR 0° YAW PLOTS

(-5° Pitch Reading/+5° Pitch Reading)

Source Pressure PSI	Argon 40 Net (Counts/0.1 sec)	Argon 36 Net (Counts/0.1 sec)	Neon 20 Net (Counts/0.1 sec)	Neon 22 Net (Counts/0.1 sec)
1.0	209 ± 10/ *	** / *	* /61 ± 30	* /6 ± 2
3.0	522 ± 30/377 ± 60	** / **	200 ± ?[1]/155 ± 5	32 ± ?[1]/15 ± 2
10.0	* /1212 ± 40	** / **	* /505 ± 15	* /55 ± 5
25.0	* / *	* / *	1680 ± 30/ *	165 ± 8/ *
30.0	5083 ± 30/3601 ± 120	24 ± 2/14 ± 2	* /1615 ± 5	* /155 ± 3
50.0	* /5887 ± 100	* /23 ± 4	* /2642 ± 20	* /257 ± ?[1]

NOTES:

* - This pressure not run for this test combination.

** - Background too high for meaningful reading.

1.0 - Only one reading taken. Probably minimum deviation of ±1%.

-5° PITCH and +5° PITCH CORRELATION (0° YAW)

Counts as shown above.

Where no deviation is shown, a minimum deviation in counts of ± 1 percent was taken. This does not include the 6 percent possible error in the settings of the beam pressure.

COS 55° = 0.574 (-5° Pitch)

COS 65° = 0.422 (+5° Pitch)

Predicted difference: $\text{Counts}_{-5° \text{ Pitch}} = 1.36 \times \text{Counts}_{+5° \text{ Pitch}}$

Actual Ratios:

Counts	Ratio	Deviation
522/377	1.38	±.36
200/155	1.29	±.03
5083/3601	1.40	±.04
24/14	1.71	±.24

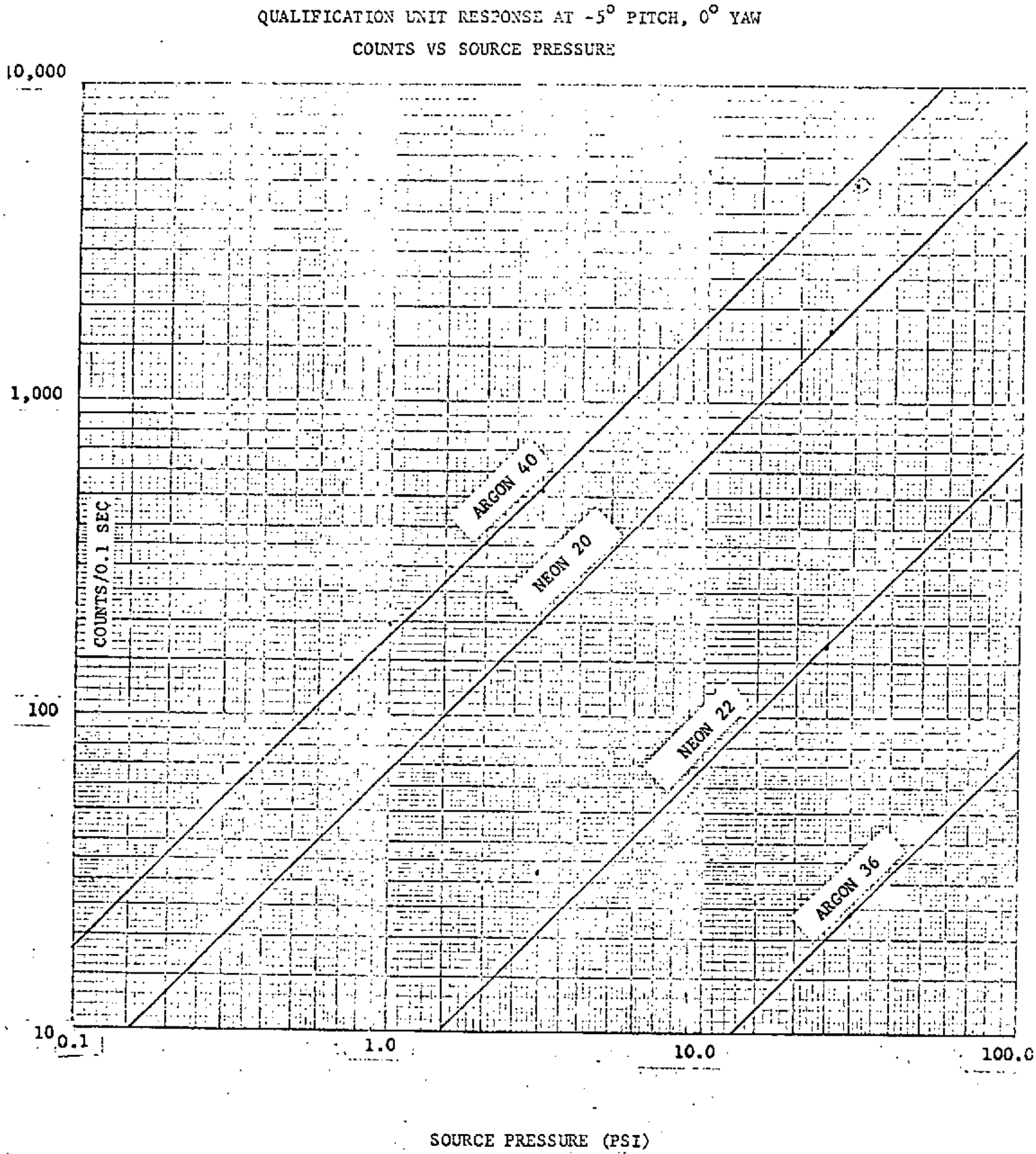


Figure 7-12. Counts vs Source Pressure at -5° Pitch

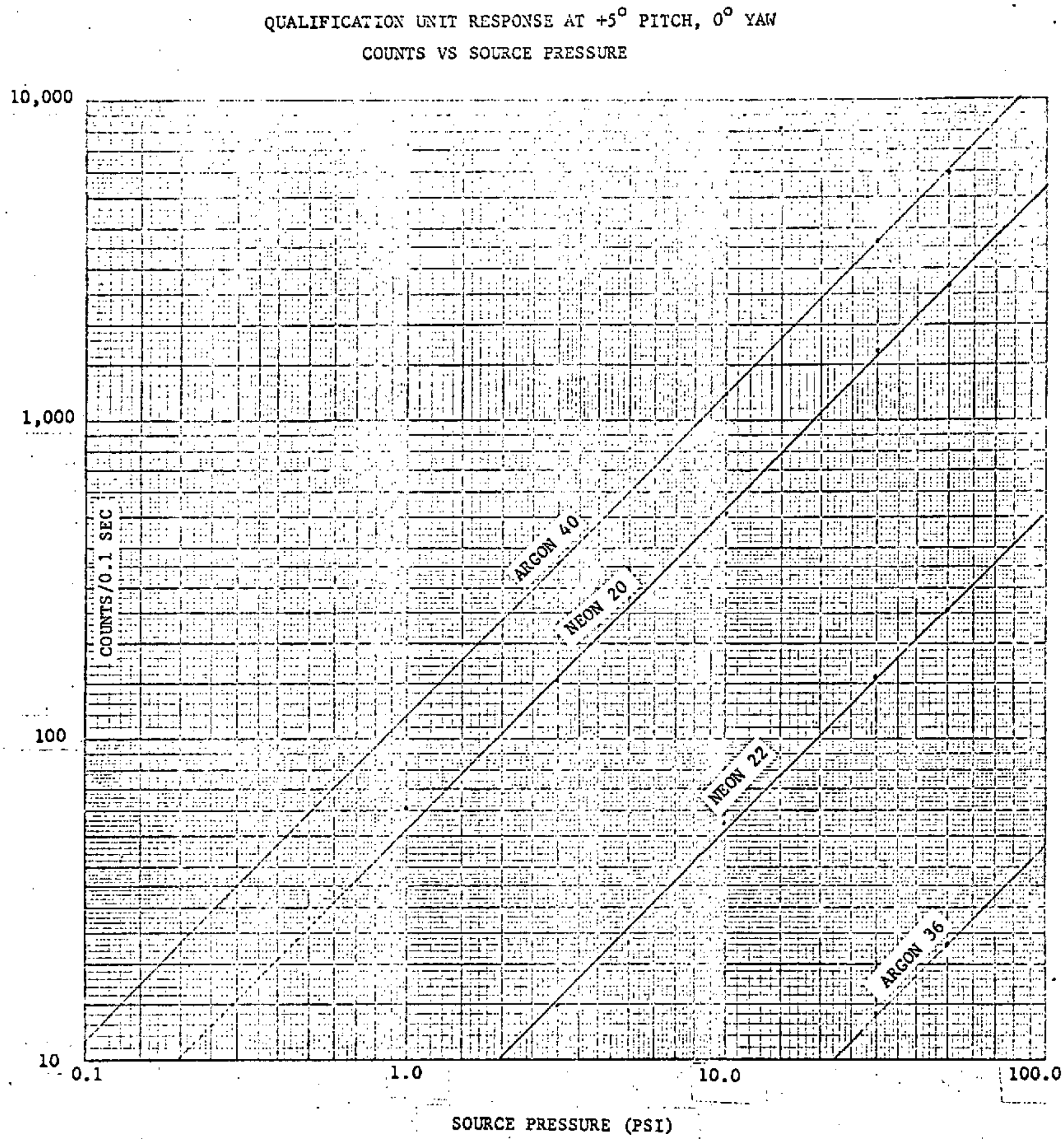


Figure 7-13. Counts vs Source Pressure at +5° Pitch

TABLE 7-13. SOURCE PRESSURE/GAS PARTIAL PRESSURE CORRELATION

Source Pressure (PSI)	Argon Beam[1] Total Pressure (Torr)	Argon 40[2] Partial Pressure (Torr)	Argon 36[3] Partial Pressure (Torr)	Neon Beam[4] Total Pressure (Torr)	Neon 20[5] Partial Pressure (Torr)	Neon 22[6] Partial Pressure (Torr)
1.0	8.16×10^{-12}	8.16×10^{-12}	2.76×10^{-14}	1.15×10^{-11}	1.04×10^{-11}	1.04×10^{-12}
3.0	2.45×10^{-11}	2.45×10^{-11}	8.25×10^{-14}	3.45×10^{-11}	3.12×10^{-11}	3.12×10^{-12}
10.0	8.16×10^{-11}	8.16×10^{-11}	2.76×10^{-13}	1.15×10^{-10}	1.04×10^{-10}	1.04×10^{-11}
25.0	--	--	--	2.88×10^{-10}	2.59×10^{-10}	2.59×10^{-11}
30.0	2.45×10^{-10}	2.45×10^{-10}	8.25×10^{-13}	3.45×10^{-10}	3.12×10^{-10}	3.12×10^{-11}
50.0	4.08×10^{-10}	4.08×10^{-10}	1.37×10^{-12}	5.75×10^{-10}	4.20×10^{-10}	5.20×10^{-11}

NOTES:

1. Plug conductance - 1.14×10^{-6} liters/sec
2. Abundance: 99.6%
3. " : .34%
4. Plug conductance - 1.61×10^{-6} liters/sec
5. Abundance: 90.0%
6. " : 9.0%

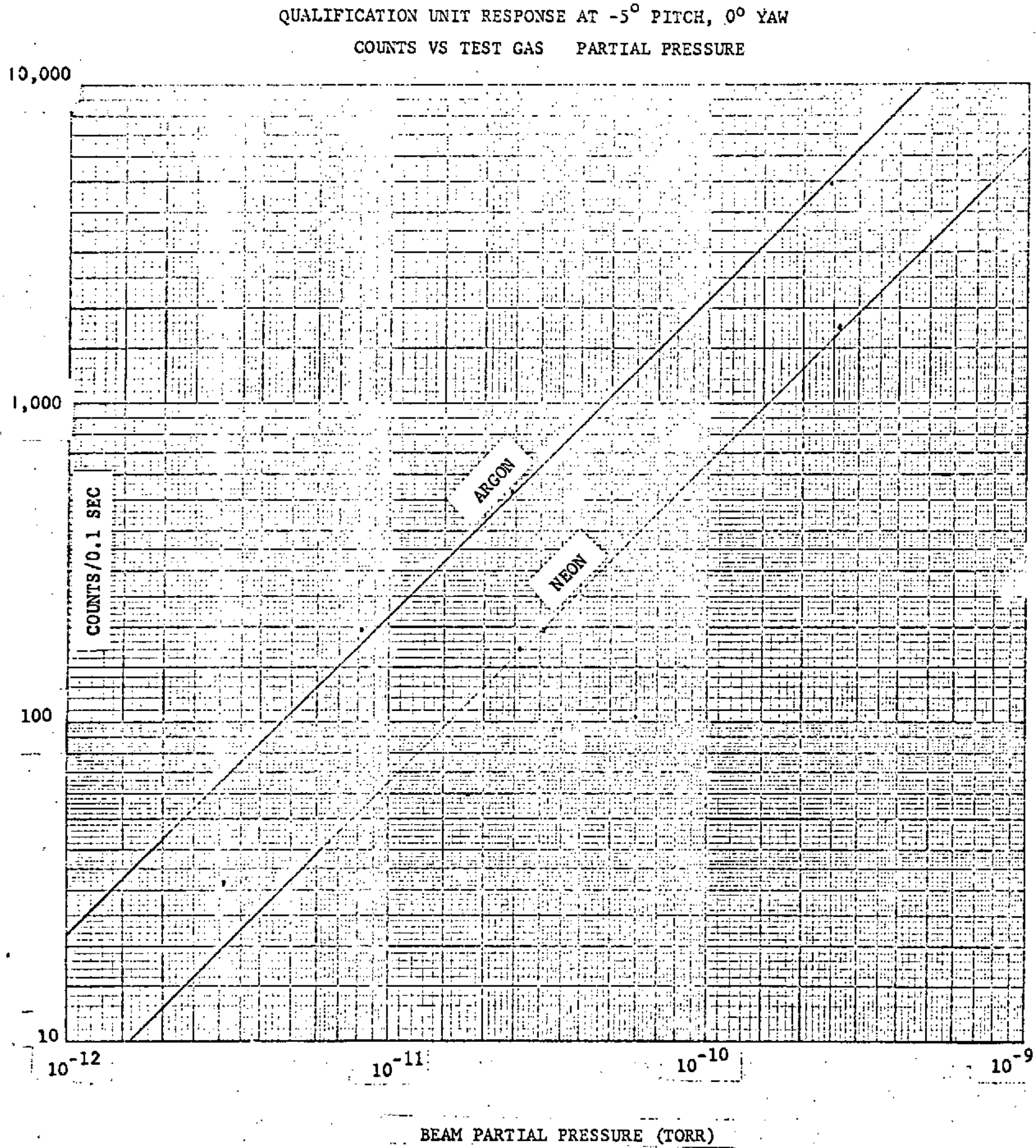


Figure 7-14. Counts vs Test Gas Partial Pressure at -5° Pitch

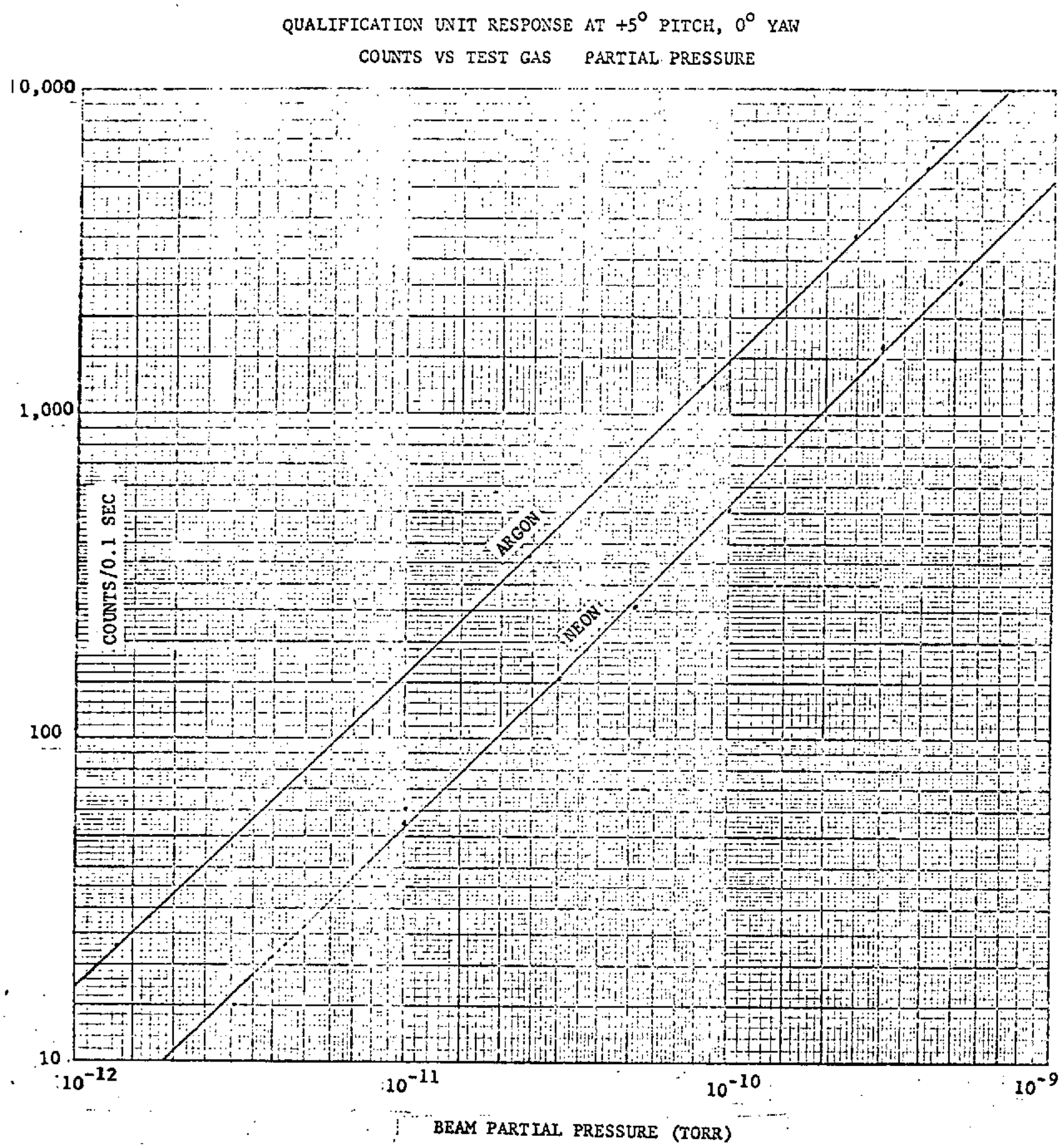


Figure 7-15. Counts vs Test Gas Partial Pressure at +5° Pitch

TABLE 7-14. SENSITIVITIES TO MOLECULAR BEAM

Condition	Argon	Neon	Ratio
-5° Pitch, 0° Yaw	2.2 counts/10^{-13} Torr[1]	.65 counts/10^{-13} Torr[1]	2.95
0° Pitch, 0° Yaw	2.0 counts/10^{-13} Torr[2]	.63 counts/10^{-13} Torr[2]	--
5° Pitch, 0° Yaw	1.7 counts/10^{-13} Torr[1]	.54 counts/10^{-13} Torr[1]	3.17

NOTES:

1.0 Measured Value

2.0 Calculated from $\text{counts}_{0°} = \frac{\cos 60°}{\cos 65°} \times \text{counts}_{+5°}$

3.0 Actual analyzer sensitivity is twice the above values (see 1.3.2)

TABLE 7-15. ANGULAR RESPONSE OF 151-118 SCOOP AT -5° PITCH

Gas	Source Pressure (PSI)	Counts at Yaw Angle		
		0°	20°	40°
Argon 40	30.0	5083	4900	3616
Neon 20	25.0	1680	1413	1354
Argon 40	3.0	522	510	351
Neon 20	3.0	200	170	--
Argon 40	1.0	209	196	157
Neon 22	25.0	165	--	--
Neon 22	3.0	32	27	20

TABLE 7-16. ANGULAR RESPONSE OF 151-118 SCOOP at +5° PITCH

Gas	Source Pressure (PSI)	Yaw Angle Counts/0.1 sec			
		0°	20°	30°	40°
Argon 40	50.0	5924	5508	4900	4132
Argon 40	30.0	3574	3344	2970	2480
Argon 40	10.0	1248	1104	1098	960
Neon 20	10.0	520	500	450	370
Neon 20	3.0	159	133	115	115
Neon 22	10.0	50	49	42	29
Argon 36	50.0	25	22	18	15
Neon 22	3.0	16	13	9	9
Neon 22	1.0	6	--	5	4

7.7 ATEE TESTS AT NAR, DOWNEY

7.7.1 OBJECTIVE

ATEE tests were performed in the Apollo Telecommunication Engineering Evaulation (ATEE) laboratory at North American Rockwell Corporation, Downey, California and were designed to ensure compability of a full SIM experiment complement with all affiliated CSM systems. It was intended to verify that no experiment-to-experiment interaction nor interference to other CSM systems would occur due to the operation of the scientific experiments. Successful completion of the test program would ensure compatibility of all SIM systems.

Primary objectives of the ATEE test program were to:

a. Demonstrate compatibility of the prototype mass spectrometer with the Spacecraft Control System.

b. Demonstrate compatibility of the prototype mass spectrometer with the Scientific Data System.

c. Demonstrate compatibility of the mass spectrometer in an integrated flight configuration.

d. Verify all pre-installation, installation and operational procedures through their use during all ATEE testing.

e. Familiarize Downey and KSC personnel in the installation and operation of the equipment.

7.7.2 TEST PHASES

Test phases performed as part of this compatibility test program are as follows:

a. Pre-Installation Test - Designed to verify proper functioning of the Mass Spectrometer prior to the installation of the instrument into the SIM.

b. Sequence I - Experiment/Experiment - Designed to establish the operational effect of one experiment upon the others with the outputs of the various experiments monitored on the respective BTE consoles.

c. Sequence IA - Experiment/SDS - Designed to establish the systems operational baseline between the instrument and the SDS. Data from one experiment is transmitted via the SDS to the telemetry ground station (TGS) and subsequently computer processed. Data output is also monitored by the BTE Console.

d. Sequence II - Designed to establish the systems operational baseline between all experiments and the SDS. Data is computer processed via TGS and compared with data monitored by the BTE Console.

e. Sequence III - An integrated test designed to establish effects between experiments and all associated CSM systems during a typical lunar mission. Data is processed via TGS only.

f. Special Test II - Designed to ensure CSM wire harness/mass spectrometer compatibility. The test is performed with the flight saver cable removed and the CSM wire harness connected directly to the instrument. Data is processed via TGS only.

7.7.3 PRE-INSTALLATION

The Pre-Installation Test (PIT_ was performed per UTD Document 151-004, and was performed with both Diagnostic Connector Saver and Flight Connector Saver removed.

7.7.3.1 ANOMALIES

There were no anomalies observed during the PIT test.

7.7.3.2 CONCLUSIONS

Tapes and data sheets from the PIT test were carefully examined and no anomalies were observed. UTD and NR have jointly concluded that the Mass Spectrometer was functioning properly and within all design specifications.

7.7.4 SEQUENCE I - EXPERIMENT TO EXPERIMENT

This phase of the testing was performed with the Mass Spectrometer mounted in the SIM Mock-up using the Control Interface Verification Procedure. The BTE was used as a passive monitor only. The Mass Spectrometer was controlled by the 230 control panel switches and power supplied by the spacecraft. Data was taken using the BTE. A diagnostic Connector Saver was used in all BTE monitoring.

7.7.4.1 ANOMALIES

There were no anomalies of the Mass Spectrometer observed during this phase of the testing for those modes of operation of the other experiments. The data presented by the UTD Console BTE was incorrect in the HIGH MASS word output.

7.7.4.2 CONCLUSIONS

The Mass Spectrometer functioned properly and within all design specifications during the entire Sequence I phase of testing. There were no anomalies or failures of the instrument. The Mass Spectrometer was compatible with all other experiments for those modes of operation exercised during this test phase and showed no incompatibility with the SDS based upon UTD review of the specific resultant results of the tests conducted.

7.7.5 SEQUENCE IA - EXPERIMENT TO SCIENTIFIC DATA SYSTEMS

This phase of the testing was performed using the Console BTE as a passive monitor. The data from the Mass Spectrometer was transmitted via the SDS to the Telemetry Ground Station (TGS) and subsequently computer processed.

7.7.5.1 ANOMALIES

No anomalies of the Mass Spectrometer were observed during this test phase.

7.7.5.2 CONCLUSIONS

The Mass Spectrometer functioned properly during the Sequence IA Test Phase. Computer printout was examined by UTD personnel to verify correct Data Printout Format. The following recommendations were requested by UTD of the NR ADPL computer program output format which NR provided:

a. Add step number to Analog Housekeeping data.

b. The High Mass and Low Mass words were reversed in labeling.

c. Analog channel program must be changed to 20 mV per step instead of 19 mV per step.

7.7.6 SEQUENCE II

The Sequence II test phase was performed under the Control of the NR Test Director using applicable ATEE Lab Test Procedures. The instrument was turned on and a baseline established for all modes of operation. Subsequent to establishing a baseline the other experiments were energized in the sequence indicated and run through their various operation modes. The data was monitored real time via the BTE Console in addition to being transmitted to TGS via the SDS for later analysis. Selected time intervals were computer processed by TGS and analyzed for problem areas and cross correlated with the test data obtained via the BTE Console.

7.7.6.1 ANOMALIES

There were no anomalies observed nor failures occurring during this portion of the test program. The data reviewed for selected time intervals indicated operation of other experiments produced no adverse effects upon the Mass Spectrometer.

7.7.6.2 CONCLUSION

The Mass Spectrometer functioned within acceptable limits during the entire Sequence II test phase. Values obtained via TGS closely correlated with those from the BTE Console. There was no evidence of interference caused by the operation of any of the other experiments in any of their different modes of operation. The instrument appeared compatible with all other experiments plus the associated CSM systems and proceeded to the next test phase.

7.7.7 SEQUENCE III - EXP-SDS-CDS-TGS (INTEGRATED TEST)

The Sequence III phase of the testing was performed with all experiments on the data outputs received by TGS via SDS. Various modes of operation were exercised during the testing and selected time intervals were computer processed to be analyzed at a later time.

7.7.7.1 ANOMALIES

Computer printouts of the selected time intervals were carefully scrutinized for any anomalies by North American Rockwell Corporation and by the UTD Test Engineer. No anomalies were observed for those modes of operation exercised during this test phase.

7.7.7.2 CONCLUSIONS

The Mass Spectrometer functioned properly during this test phase and appeared compatible with all other experiments and CSM systems.

7.7.8 SPECIAL TEST II

Special Test II was performed with the flight saver cable and the SIM wire harness connected directly to the instrument. A short operational test was performed to ensure SIM wire narness/instrument compatibility and verify no adverse effect after removal of the saver cable. The instrument functioned within limits during this test phase.

7.7.8.1 ANOMALIES

There were no anomalies observed during this portion of the test program.

7.7.8.2 CONCLUSION

The Mass Spectrometer functioned properly during this test phase. The instrument appeared compatible with the SIM wire harness and no adverse effects were detected during operation of the instrument with the saver cable removed.

7.7.9 TEST SET-UP PROBLEMS

7.7.9.1 UTD CONSOLE BTE HIGH MASS READOUT

Data presented by the UTD Console BTE was incorrect in the High Mass Word output. This difficulty was traced to a difference in the timing of the Enable Gate B signals generated by the Scientific Data System and the same gate signal generated within the Console BTE.

Serial PCM data word assignments for the Mass Spectrometer are spaced 20 milliseconds apart. These words then repeat every 100 milliseconds. The Console BTE was slaved to the SDS by resetting and synchronizing with Enable Gate A from the SDS. The Console BTE is reset each 100 milliseconds by SDS Enable Gate A. It then runs on a internal clock until the next Enable Gate A is received at which time a reset occurs.

The Mass Spectrometer reads out data through the Spacecraft connector and through the BTE connector under the control of the SDS enable gates. The prototype SDS operating in the ATEE test program is generating enable gates from a clock of 64.05 kbs. The separation of the Enable Gates A and B from the SDS was measured to be 19,982 microseconds (18 microseconds less than 20 milliseconds). The separation of the Enable Gates A and B from the UTD Console BTE was found to be 20,003 microseconds. The BTE 64 kbs clock is operating at 64.001 kbs.

The data output errors from the BTE were found to be a result of the 21 microsecond (18 + 3) timing difference. A single bit period is 15.625 microseconds. A difference of greater than 7.8 microseconds will result in a one bit shift in the data and the loss of the leading serial bit.

This error can only appear when the Console BTE is operated in the slaved mode. The slaved mode of operation is not presently programmed for the Console BTE at KSC. The Portable GSE, UTD 150-574-01, is designed for use as the monitor in this type configuration.

Sometime during the time measurement of the gates of the Console BTE, a malfunction of the binary to decimal converter occurred. This malfunction caused a 6 to appear in the high order position of the decimal display unit. The problem was determined to be a bad BR335 card in position C21 of the logic drawer. A BR335 card was borrowed from the ATEE Lab and temporarily substituted for the bad card.

The logic drawer was closed and a short test was performed on the Mass Spectrometer. All outputs were proper, except that for the DATA B Shift due to the timing discrepancy of 64.058 kbs.

7.7.9.2 DIAGNOSTIC CABLE CONNECTIONS

Mating and unmating of the in-line connectors of the adapter cable to the test cable was considered by NR to be difficult enough to warrant investigation. A UTD representative traveled to ITT Cannon Corporation in Los Angeles to discuss possible solutions to this problem and also the possibility of reducing the mating and unmating torque requirements for this size connector.

The opinion of ITT Cannon Corporation's Engineering was to use connector pliers to assist in mating and unmating the in-line connectors.

The unmating torque of this size connector (#18) could be reduced by removal of one of the two ring springs which holds the coupling nut against the locking tabs. This reduction in torque is under investigation by UTD Engineering.

The torque requirements for the Dust Cap cannot be easily reduced. A rubber gormmet is used to obtain the force necessary to hold the cap against the locking tabs. This does not however present any foreseeable problem in the installation of the dust cap at KSC.

7.7.10 TEST RESULTS

Data obtained from the above tests was carefully analyzed by UTD for possible errors or anomalies. The baseline determined per UTD 151-004 for the initial ATEE Test Program agrees in all respects with that previously determined during acceptance testing per UTD 150-003. The initial test data from UTD 151-004 was compared item by item with the data from the acceptance test previously performed at the UTD and establishes the reference baseline for all subsequent ATEE test sequences. Functional performance of the Lunar Orbital Mass Spectrometer is ascerttained by four basic output indicators. Those four data outputs from the Mass Spectrometer are:

a. Data A - The number of counts from the A channel analyzer preamplifier.

b. Data B - The number of counts fromthe B channel analyzer preamplifier.

c. Data C - A d-c voltage level change which indicates the start of the High Voltage Sweep, sweep time and background time.

d. Analog - A 16-segment multiplexed output which is advanced once per second. The outputs are used to determine the operating status of the instrument.

Tolerances for each of these outputs are listed in the UTD 151-004 data sheets. All items were carefully compared by UTD personnel and found to be within all specified tolerances.

Conclusions reached concerning the Lunar Orbital Mass Spectrometer performance were based upon the successful operations as illustrated by comparisons of these four basic data outputs for the various test sequence configurations against the baseline duties.

Integration and interconnection configurations which were tested during the ATEE operations demonstrated compatibility of the Lunar Orbital Mass Spectrometer with the other experiments to the extent that their operational modes were jointly exercised.

SECTION 8

FLIGHT CHECK-OUT

8.1 GENERAL

Flight check-out and testing of the Mass Spectrometer instrument was performed at Kennedy Space Center by North American Rockwell, the Integrating Contractor. Each instrument was delivered to NR for incoming and receiving inspection. Following this inspection, NASA R&QA inspected the instrument and Acceptance Data Package for contractual completeness. Instruments and data packages were then returned to J-Mission Bond Room for storage.

8.2 TEST SERIES

A series of 10 tests was developed by NR/NASA to verify proper operation of each instrument, its compatibility with other instruments, and its compatibility with the spacecraft. The test series ensured instrument performance would meet the standards of Test Requirements and Specification Documents (TRSD). Table 8-1 lists the individual tests.

TABLE 8-1. KSC TEST SERIES

SEQUENCE NUMBER	TEST DESIGNATION	ABBREVIATED TITLE
1	TCP-UTD-151-005	Pre-Installation Test
2	K-0070	Combined Systems Test
3	TPS-055	Experiments Retest
4	K-8241	High Gain Antenna Test
5	K-0005	Integrated Systems Test
6	K-0028	Lightning Test
7	K-0028	Flight Readiness Test
8	K-0052	Lightning Retest
9	K-0007	Countdown Demonstration Test
10	Countdown	Countdown Status Check

8.2.1 PRE-INSTALLATION TESTING (PIT)

PIT test TCP-UTD-151-005 was developed by UTD to verify proper operation of the instrument prior to installation in the spacecraft, or after any transportation, or long storage period. This test was performed in the lab of the J-Missions Operations and Control Building. Console Bench Test Equipment 150-575-01 and associated cables, manufactured by UTD and delivered to KSC, were used to perform the PIT.

Mass Spectrometer instruments S/N 102, 103, 104, and 105 successfully passed all PIT tests.

8.2.2 COMBINED SYSTEMS TEST

Test objectives of Combined Systems Test K-0070 were to verify that each of the Apollo 15 scientific instruments was compatible with the CSM and there was no mutual interference. Each instrument was first individually tested with the CSM; then, the instruments were turned on until all instruments were fully operational and formed a combined system. Mass Spectrometer instrument S/N 103 was used for this test and performed satisfactorily. The instrument was removed from the CSM following completion of the test.

8.2.3 EXPERIMENT RETEST

Test TSP-055 was developed and performed to verify that the thermal modifications to the new CSM had no adverse effects on instrument operation. Testing was accomplished in preparation for the High Gain Antenna Test K-8241. All instruments were tested individually and then as a combined system to ensure that there were no deviations from the K-0070 test results.

Mass Spectrometer instrument S/N 102 was used for this test and performed with any anomalies.

8.2.4 HIGH GAIN ANTENNA TEST

Test K-8241 was performed to verify that no interference existed as a result of high gain antenna radiation. All experiments were configured in their various mission modes to verify non-susceptibility. Test results showed that Mass Spectrometer instruments neither caused interference nor was affected by high gain antenna radiation.

Instrument S/N 102 was used for this test and removed from the CSM following the test to facilitate removal and inspection of the boom assembly. A boom-drive motor had failed during installation of the Mass Spectrometer instrument.

8.2.5 INTEGRATED SYSTEMS TEST

The K-0005 Integrated Systems Test was performed on the launch pad after the CSM had been mated to the Saturn V in the Vehicle Assembly Building, and transportated to the launch pad. Test objectives were to verify operation of the CSM and J-Mission experiments in an integrated configuration with the entire spacecraft.

Mass Spectrometer instrument S/N 104 was installed prior to this test and a solo test did not reveal any anomalies in instrument performance. During the K-0005 testing, the boom cable jammed while extending the boom and the Mass Spectrometer instrument was extended only 30 inches during the test.

8.2.6 LIGHTNING RETEST

Prior to the start of the K-0028 Flight Readiness Test, series of lightning strikes occurred on the gantry. These strikes were considered serious enough to schedule a retest to verify the K-0005 test results. This test was similar to the K-0005 Integrated Systems Test. Mass Spectrometer test results were normal and showed no indications of damage or degradation.

8.2.7 FLIGHT READINESS TEST

Test objectives of the K-0028 Flight Readiness Test were to verify flight readiness of the spacecraft and all instruments in an integrated system prior to launch. All instruments were powered in a simulated flight configuration to verify that no interference existed between instruments and that all instruments were operating normal before declaring each one ready for flight. The Mass Spectrometer instrument operated without any anomalies.

8.2.8 LIGHTNING RETEST

The K-0052 Lightning Retest was developed following a second lightning strike which followed the Flight Readiness Test. Each instrument was powered individually and tested for damage and degradation. Test results on the Mass Spectrometer instrument showed no damage nor degradation of data.

8.2.9 COUNTDOWN DEMONSTRATION TEST

Test objectives of Countdown Demonstration Test K-0007 were to demonstrate each instrument's ability, and the system's ability, to perform an operational status check during a simulated countdown. Each J-mission instrument was tested solo and with minimum operating mode changes. The Mass Spectrometer instrument test results were normal and within all tolerances and specifications.

8.3 COUNTDOWN STATUS CHECK

A status check was made of all J-mission instruments starting at approximate T minus 110 hours. The Mass Spectrometer instrument status check required approximately 10 minutes. All outputs were normal and within all tolerances and specifications.

SECTION 9

GROUND DATA HANDLING

9.1 DATA PROCESSING

LOMSE data were sent by the scientific data down-link telemetry system to the Manned Spacecraft Center where experimenter tapes are prepared. Data analysis and final formatting were accomplished with computers on the UTD campus. Figure 9-1 illustrates the processing sequence.

9.2 DATA STORAGE

Upon completion of data analysis and scientific studies, the data were recorded on both microfilm and magnetic data tapes for storage at the National Space Sciences Data Center located at Goddard Space Flight Center, Greenbelt, Maryland.

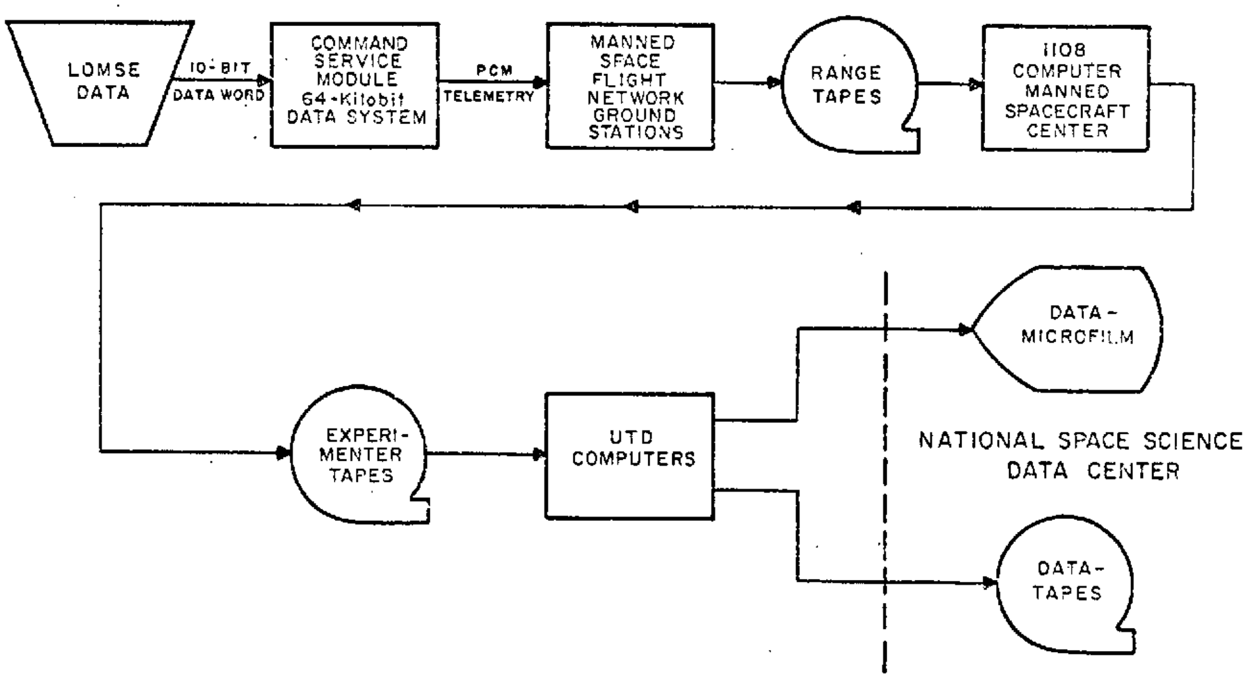


Figure 9-1. Data Processing Sequence

SECTION 10

PROGRAM HISTORY

The LOMSE program encompassed a rather unique episode in a University environment, but had a somewhat typical chronology for a major one-time, single-objective space project for research and development of a scientific experiment with a tight schedule in aero-space programs.

This program was unique to the UTD in that it was the first major program at UTD which required the full disciplines of design documentation, configuration control, and environmental qualification testing; all governed by reliability and quality controls in accordance with NASA manned space flight standards. It was a typical program in aerospace experiences. With an initial learning period, UTD met and solved the characteristic requirements normally associated with Apollo projects. These requirements included: extremely short schedules, tight management controls for technical and financial performance, plus the vigorous regimentation of reliability, quality control and documentation demands.

The history of the NAS9-10410 contract is presented beginning with the previous project and the various proposals as the prologue to the Lunar Orbital Mass Spectrometer Experiment (LOMSE). Internal to UTD, the NAS9-10410 project was known as the "SMOG Program" under the institutional account number "E1660." The program was completed on 30 September 1973 with a contract cost and value of $2,015,180.

10.1 PRELIMINARY RESEARCH

10.1.1 GALA Project

The Gas Analyzer for the Lunar Atmosphere project (GALA) was conducted jointly by The University of Texas at Dallas and the Space Physics Division of NASA/MSC to determine the feasibility of instrument design. Work was performed under NASA Contract No. NAS9-7591 in 1968 and 1969. The instrument developed was a small (2-1/2 inch radius) magnetic-deflection mass spectrometer with a dual-filament ion source and three ion-counting detector systems which simultaneously measured the concentrations of ambient atmospheric gas species in three mass ranges. These ranges were 1 to 4 amu, 12 to 48 amu, and 40 to 160 amu. The mass spectrum was scanned by varying the ion-accelerating voltage in a step-wise manner and counting the number of ions impinging on each detector per voltage step. Count magnitude determined the concentration of each constituent of the gas sample in the ion source, and the voltage step number identifies the molecular weight of the species. With a dwell time of 1 second per voltage step, the instrument sensitivity was 10^{-14} torr.

A fully functional prototype model of the GALA mass spectrometer was jointly manufactured by UTD and NASA/MSC. It was packaged in a format suitable for use as an ALSEP experiment. The electronics were housed in a temperature controlled environment with a mirrored radiator plate on top and a thermal bag insulator surrounding the other five sides. The electronics package was mounted above the base plate which bisects the package. The magnetic analyzer which was below the base plate, contained the ion source, magnet, electron multipliers and analyzer tube, and ALSEP cable reel.

LOMSE was a modified second generation GALA instrument. Modifications were due to difference in telemetry format, mechanical interface, and design experience gained in the development of the GALA instrument.

Overall packaging of the LOMSE was similar. The radiator plate did not require mirrors but was painted with white thermal paint (M74) instead. The ALSEP cable reel was replaced with a connector for compatibility with the boom cable and the baseplate had a boom mounting flange added to interface with the boom supplied in the Scientific Instrument Module (SIM) BAY of the Apollo Service Module.

The radiator plate used in the LOMSE was the same one piece construction as GALA, both of which were fabricated and supplied by MSC. Likewise the fiberglass thermal housing with the mylar layer thermal bag was supplied by MSC from Lockheed for the electronics section for both projects.

Electrical design of the LOMSE incorporated many of the circuit designs used in GALA. Counting and data compression circuits were identical except for telemetry timing. The housekeeping multiplexer circuit was the same although no A/D converter was necessary in the LOMSE because an analog telemetry channel was available in the CM telemetry.

Telemetry interface and command control was entirely different due to differences between the ALSEP and Apollo COMMAND MODULE Telemetry Systems.

Thermal control, emission control, low voltage power supplies, high voltage power supplies, digital sweep control, and switching pre-regulator were basically the same design as GALA. Design improvements were incorporated where possible to insure greater reliability of the circuits.

10.1.2 Proposal, UTD #2769

A chronological explanation of the various proposals that ultimately lead into the NAS9-10410 Contract is presented in this section. A summary of these various proposals and submittals is presented in Table 10-1.

The University of Texas at Dallas (UTD) was established by the Texas State Legislature in September 1969 beginning with the nucleus of personnel and facilities that had for over 10 years been known as the Southwest Center for Advanced Studies (SCAS).

As a direct result of the SCAS activities in the GALA development program, an unsolicited proposal was submitted to NASA Headquarters, in March 1969. This proposal presented scientific definitions for a lunar orbital mass spectrometer experiment, proposed to be flown on the Apollo 17 and 18 missions, and a description of a resultant data analysis program for mass spectra measurements of the composition and distribution of the lunar atmosphere.

On 25 April 1969, SCAS submitted a technical proposal and a business-cost proposal #2769 and #2869 to NASA Headquarters in response to interest expressed by NASA for a lunar orbital mass spectrometer experiment. (Item 2, Table 10-1).

On 10 October 1969, UTD resubmitted the technical proposal and business cost proposal #2769 to NASA/MSC in direct response to the NASA RFP #BG-931-89-0-40P with a cost of $939,760. (Item 3, Table 10-1). This increased amount included a mass mock-up, Hi-Fi mock-up, a 3rd Test Set, plus integration and Flight Test Support services.

TABLE 10-1

SUMMARY OF PRECONTRACT HISTORY

Item No.	Date	Proposal	Scope	Schedule	$Amount	Status/Remarks
1	28Mar69	Phase I unsolicited Proposal	12-28, 28-66 amu 1 Prototype 1 Qual 2 Flight 1 Flight Spare 2 Test Sets No PI Supporting Studies No Data Analysis No Field Engineering Weight - 20 lbs. Size: 7.5" x 9" x 15" 20 ft. S/C Boom at rear 18 watts max.	1Apr69-1Apr70	$675K	First unsolicited proposal to NASA/HDQT
2	25Apr69	Phase II unsolicited Proposal #2769	Same as item 1 except size 8 1/2" x 11 1/2" x 9"	1Oct69-1Jan71	$750K	Second unsolicited Proposal to NASA/HDQT; NASA letter of receipt 27May69
3	13Oct69 10Oct69	#2769 Rev. for RFP #BG931-89-0-40P (T) & (B)	Same as item 2 plus: Mass Mock-up Hi-Fi Mock-up 1 Test Set (3rd) Integration & Flight Test Support Services	1Nov69-1Sept72	$939,760	First UTD response to NASA/MSC RFP #BG 931-89-0-40P
4	31Oct69	#2769 (T)	Same as #3 + R & QA Plan	1Nov69-1Sept72	$1,059,280	+ Technical Points of Clarification 2nd Revision

Item No.	Date	Proposal	Scope	Schedule	$Amount	Status/Remarks
5	12Nov69	#2769 (PI) (T&B) Addendum	PI Services	Feb71-Jan73	$110,570	Addendum to #2769, Original PI proposal
6	12Nov69	NASA/DC letter	UTD Mass Spec selected			Letter from John E. Naugle
7	24Nov69	#2769 (PI) (T&B) Addendum	PI Activities plus Theoretical Supporting Study	Dec69-Jan73	$182,035	Addendum to #2769, 1st Rev., PI proposal
8	24Nov69	#2769 (PI) (T&B) Addendum	Same as 6, less 20Nov negotiations	Dec69-Jan73	$168,979	Addendum to #2769 2nd Rev., PI proposal Reduced Data Analyst
9	25Nov69	#2769 (B)	Same as 4	1Nov69-1Sept72	$1,059,280	Same as 4
10	5Dec69	#2769 (B)	Same as 4 less 11/26/69 negotiations	1Nov69-1Sept72	$981,460	Revised Costs for Negotiated Hardware + PI proposal #2769
11	12Dec69	#2769 + PI addendum	Final negotiations with NASA/MSC	27Oct-Jan73	$968,600	Combined hardware and PI Contract
12	28Jan70	NASA/MSC letter	Acceptance of M/S & PI			Letter from Col. James A McDivitt
13	28Jan70	NAS9-10410	Contract awarded	27Oct69-Jan73	$968,600	Contract including SOW Exhibit A & B

After fact-finding conferences in mid October, UTD revised the proposal. On 31 October 1969, UTD submitted technical clarifications plus a detailed Reliability and Quality Control Plan, SRQA100-1 to define the increased R & QA requirements. (Item 4, Table 10-1). The total proposed revised cost was $1,059,280 with a schedule of 1 November 1969 to 1 September 1972. (Item 9, Table 10.1).

On 12 November 1969, UTD prepared the original Principal Investigation (PI) technical and business proposal for support of the previously proposed hardware program. This was submitted as an addendum to the UTD proposal #2769 (Item 5, Table 10.1). In mid-November 1969, Dr. John H. Hoffman was notified that the UTD mass spectrometer had been selected for the Apollo lunar orbital mission Nos. 17 and 18 (Item 6, Table 10.1). At the request of NASA, design and development activities were started by UTD including Interface Control Definition(ICD) meetings with North American Rockwell, in Downey, California.

On 24 November 1969, UTD resubmitted the PI technical and business proposal in response to the NASA/MSC requests to combine the Theoretical Supporting Study of the proposal #2769 and the original PI's proposal (Item 7, Table 10.1). This combination was submitted as an addendum to proposal #2769 and provided additional elaboration of the PI's role, including the Theoretical Supporting Study, as well as requirements for data analysis. This addendum was the first revision of the PI proposal which resulted with an increase to proposal #2769 of $182,035 with a schedule extension from December 1969 to January 1973. The 24 November 1969 PI proposal was revised a second time to incorporate the 20 November 1969 negotiations which reduced the data analyst activities.(Item 8, Table 10.1). This revised PI proposal was also submitted as an addendum to the previously submitted proposal #2769 (Item 4 and 9, Table 10.1), with a revised amount of $168,979 in lieu of $182,035 (Item 7, Table 10.1).

During the 26 November 1969 negotiations at NASA/MSC, UTD was advised that the total cost for the hardware program and the supporting PI activities must be in the order of $885,801. NASA requested cuts plus more detail breakdown and definition of costs spreads for the schedule.

This resulted with a revised DD-633 dated 5 December 1969 which was transmitted with a revised price of $981,460 (Item 10, Table 10.1). During the 12 December negotiations, the total price was cut back to $968,600 (Item 11, Table 10.1). The University was in a position to accept this figure or not realize any contract funding. These two unrealistic and large reductions in cost below what the University had originally proposed later proved to be reflected as a large contributing factor in the ten per cent overrun of the project. It was agreed by NASA to reimburse UTD as a non-profit institution for costs incurred from 27 October 1969 because work had already been requested by NASA and was underway by the University including preliminary ICD meetings with North American Rockwell in California.

A resultant, NAS9-10410 Contract was made on 28 January 1970 for $968,600 with a schedule of 27 October 1969 to January 1973 (Items 12 and 13, Table 10.1).

10.2 CONTRACT AWARD & CHANGES

10.2.1 Original NAS9-10410 Contract

On 28 January 1970 the NAS9-10410 contract was mutually accepted by UTD and NAS/MSC in the amount of $968,600. The schedule was effective 27 October 1969 through 31 January 1973. This contract included for Exhibits A, B, C, and D in conjunction with the "Contract Schedule":

Exhibit	Title & Date
A	Statement of Work Mass Spectrometer, August 22, 1969
B	Technical specifications for Mass Spectrometer, September 2, 1969
C	Documentation Requirements Lunar Orbital Science Experiments
D	Specifications for High Fidelity Mock-Up

Much of the confusion and many of the difficulties that the University experienced initially in not being responsive to the NASA/MSC technical monitor were a direct result of the failure of this contract to accurately define the NASA requirements for the contractor. The primary examples of these shortcomings in the original NAS9-10410 contract were:

1. Major conflicts between exhibits A, C, and the Contract Schedule for data and documentation requirements, as well as environmental design requirements.

2. Failure to fully define the reliability and quality assurance requirements for the contractor especially as they related to the prototype mass spectrometer and ground support equipment.

3. Failure to properly define an environmental acceptance test and qualification test program requirements for the flight hardware as well as the prototype and qualification unit.

4. Failure to define the requirements for documentation and configuration control until late in the program when hardware was well advanced in fabrication and assembly.

5. Failure to properly define the inter relationships between the contractor NASA, and the spacecraft contractor (North American Rockwell) for interface control definition requirements between the mass spectrometer, the boom, and the spacecraft.

6. Failure to define the science requirements documentation, responsibilities, of the Principal Investigator and scientific support activities.

7. Failure to define the extremely generalized statement of .."as required and requested by NASA" for the KSC and MSC field and mission support.

The University initially in 1969 was inexperienced in contracting for scientific experiments with increased reliability and quality assurance requirements for Apollo Manned space flight hardware compared to previous rocket type experiments. Upon recognition by NASA of the inexperience of the University and the inadequacy of the original contract to properly define the basic requirements, five major corrective actions were sequentially taken in early 1970 which resolved the problems:

1. NASA provided a full time management consultant from North American Rockwell who was assigned to the University. In January 1970, Mr. Don Beaman, who had extensive background and experience in the aero-space industry, assisted and guided the management and spacecraft interface activities at UTD during 1970.

2. UTD employed a fulltime Program Manager in February 1970 with extensive background and experience in the aero-space industry to take over the management and reorganization of the contract for the university. This included the establishment of a completely separate Reliability/Quality Assurance group, a Manufacturing group, and a Support Operations group in addition to the existing Mechanical and Electrical Engineering groups.

3. A part time environmental and test engineer was provided by NASA/MSC during mid 1970, Mr. Buster Keaton was very instrumental in establishing the environmental design and test requirements as well as the acceptance and qualification test program criteria.

4. In July 1970, NASA/MSC agreed to completely rewrite the NAS9-10410 contract to properly and accurately present the requirements for the University.

5. Whereas the original contract failed to delineate the necessary requirements throughout 1970, UTD submitted Engineering Change Proposals (ECP's) as an interim corrective action to properly define the contractual requirements with the resultant cost and schedule adjustments.

10.2.2 Revised NAS9-10410 Contract

On 25 November 1970, following major negotiations for ECP's 3, 4, 5, 6, 7, 9, 10, 11 and 12A at NASA/MSC on 23 and 24 November 1970, the first of a series of reviews and conferences for revision of the NAS9-10410 began between the NASA/MSC Contracting Specialist, Technical Monitor, R & QA representative, Apollo Program Office representative and the UTD Program Manager. In February and March 1971 a completely revised NAS9-10410 contract was circulated for review and negotiation. During 1970 and early 1971 most of the hardware on the contract had been delivered in accordance with requirements established by UTD ECP's and NASA CCA's rather than per the original erroneous contract which by the necessity of time was temporarily abandoned in favor of the correct requirements.

These contractual inadequacies were resolved in April 1971 when the new NAS9-10410 contract (Modification 12S) was mutually accepted by NASA/MSC and UTD. The revised contract contained the previously negotiated ECP's, CCA's, and $200,000 overrun, which increased the value of the contract to $1,508,935. The revised schedule was effective 27 October 1969 through one year following receipt of Apollo 16 mission data.

Exhibit	Title
A	Scope of Work Mass Spectrometer, February 22, 1971
B	Technical Specification for Mass Spectrometer, February 22, 1971
C	Statement of Work for Science Support Requirements

This revised NAS9-10410 contract established a much needed base line from which all subsequent change traffic was referenced to. Contract administration activities were significantly improved between UTD and NASA/MSC following the establishments of the revised contract.

10.2.3 Contract Changes and ECP's

It was necessary to conduct the NAS9-10410 contract throughout 1970 and early 1971 based upon contractual definitions and requirements almost exclusively per the numerous UTD Engineering Change Proposals (ECP's) and NASA Contract Change Authorization (CCA's).

Table 10-2 reflects the change order log for the NAS9-10410 contract. The revised contract was a new base line which reflected the previous changes.

The cost of the NAS9-10410 contract changes may be summarized from Table 10-2 as follows:

1.	Basic Contract, Estimated Cost at Contract Award (28 Jan 1970)	$968,600
2.	ECP-12A Negotiated for KSC & MSC Field Mission Support (Considered Overrun by MSC, but considered increase in scope by UTD)	$102,000
3.	Negotiated ECP's through ECP-32	$728,608
	TOTAL ECP's	$830,608
4.	Overrun Proposal Negotiated	$215,972
	Total Contract value at close of Contract (30 Sept 1973)	$2,015,180

Table 10-2 UTD ECP LOG for NAS9-10410 5 March 1973

ECP NO	TITLE	UTD OL NUMBER	UTD DATE OUT	NASA APP'L	NASA DATE	NASA/MSC AUTHORITY	AMOUNT $
							Negotiated "N" Proposed "P"
1	DATA OUTPUT CHANGE					/	No Cost
2	REVISED MASTER SCHEDULE	(150-993 Rev. A)	31 Aug 70				No Cost
3	ENVIRONMENTAL TESTING FOR LOMSEP	195	9/1/70		5/70	CCA#3	$ 225,285 N
4	PORTABLE GROUND SUPPORT EQUIPMENT	195	9/1/70		5/70	CCA#1	$ 33,453 N
5	MSCM 8080	214	9/9/70		5/70	JC93/L422-70/T88	$ 6,100 N
6	SD69-315 P&I SPECIFICATION PLUS SCN's 48 through 55	226	9/25/70		5/70	JC931/L299-70/T94	$ 10,557 N
7	ATEE TESTING SUPPORT	195	9 /1/70	Per SMOG OC-251	7/70	JC931/L529-70/T88 CCA #5	$ 13,985 N
8	MASTER SCHEDULE PSCN #8	211	9/9/70				No Cost
9	45 FOOT CABLES TO SUPPORT ATEE TESTING	195	9/1/70		7/21/70	C931/T178-70/88 CCA#4	$ 2,168 N
10	RELOCATION OF BTE CONNECTORS	226	9/25/70		3/70	JC931/L591-70/T88 CCA #2	$ 2,150 N
11	CONFIGURATION MANAGEMENT PER MSC-02436 REVISION A	226	9/25/70		4/70	NASA MSC-02436 Rev. A	$45,000 N
12	KSC FIELD SUPPORT (See ECP 12A)	256	11/2/70				WITHDRAWN VOID
12A	KSC FIELD SUPPORT	270	11/21/70		12/7/70	JC341/L795-70/L88 CCA #8	$102,000 N
13	J-MISSION M/S END ITEM ABSOLUTE CALIBRATION	259	11/10/70		12/70	JC341/L792-70/L88 CCA #7	$18,500 N
14 A & C	SUSTAINING ENGINEERING FOR KSC LAUNCH SUPPORT	272	11/23/70	1C-550	1/1/71	18,943 CCA15 & CCA 15-R1	$141,865N
15	SEPT. 29 MEETING AT KSC	545	12/10/70		9/70	CCA #6 S/A #12S	$ 1,637 N
16	DESIGN STANDARDS 121, 125, 128, 129, 133, 134	321	Not Submitted				VOID
17	REVISE DOCUMENTS 150-003, 494, & 489	296	11/23/70			Disapproved	NO COST
18 Opt B Revised	LOMSE PROPOSED ENTRANCE SCOOP DESIGN AND RETROFIT	304 Revised 357	1/6/71		1/29/71 3/31/71	BC341/T27-71/L86 & BC341/T78-71/L8 CCA #9	(B) 17,571 N
19	ADDITIONAL WIRING FOR LOGIC CHANGE TO PORTABLE GSE	307	1/15/71		2/16/71	JC341/T48-71/L88 (CCBD 1J0009)	NO COST
20	EMI TEST OF PORTABLE GSE	329	2/17/71	Per SMOG 1C-410	3/24/71	JC341/T65-71 L88 CCA #12	$5,469 N
	N = Negotiated with NASA/MSC						

Table 10-2 (Contd)   UTD ECP LOG FOR NAS9-10410

ECP NO.	TITLE	UTD OL NUMBER	UTD DATE OUT	NASA APP'L	NASA DATE	NASA/MSC AUTHORITY	AMOUNT
21	SUPPORT PDR AND CDR AT NR	319	2/10/71		CCA #11 1/29/71	EF-71-T30	$1,483N
22	THERMAL PROTECTION	334	2/18/71			JC341/T26-71/ L86/0J0137	VOID
22A Part II	THERMAL PROTECTION	339	3/1/71		CCA #10 1/29/71	"	$12,000N
23	DOCUMENT REVISION	338	2/25/71		5/7/71	BC341/L404-71/L88	NO COST
24	SCOOP FOR NORTH AMERICAN	340	3/4/71		4/1/71 CCA#14	BC341/L316-71/L88	$1,977 N
25 Revised	LOMSE FLIGHT PREPARATION FOR ION SOURCES, AND ABSOLUTE CALIBRATION	Revised 356	4/22/71		CCA #13 3/31/1 & CCA #9	BC341/T77-71/L88 dated 3/31/71	$28,100N
26A	REFURBISHMENT & RETEST OF FLIGHT UNITSNO. 1, 3 and QUAL	417	10/5/71		CCA #16	BC341/T221-71/L88 Dated 9/20/71	$78,100N
27	SPACE CRAFT CONTAMINATION STUDY & MEASUREMENT	418	10/5/71			Disapproved	VOID
28	PROVIDE ANGLE SEALING RCS PLUME COVER FOR LOMSEP QUALIFICATION MODEL, FLIGHT UNIT #1 AND FLIGHT UNIT #3	454	12/6/71	3/1/73			$2,524 N
29	UTD SUPPORT TO CHANGE IN APOLLO 16 LAUNCH DATE (Superceded by ECP-29A)	456	12/6/71		Superceded by ECP- 29A ($20,375)		VOID
29A	EXTENSION OF P.I. EFFORT FOR APRIL APOLLO 16 LAUNCH (IN LIEU OF ECP-29)	482	1/24/72				$31,000 N
30	KSC LAUNCH SUPPORT EXTENSION	468	12/21/71		Withdrawn by UTD ($10,187)		VOID
31	EXTENSION OF SUSTAINING ENGINEERING FOR APOLLO 16 APRIL LAUNCH	483	1/24/72				$15,000 N
32	OVERHEAD ADJUSTMENT	514	10/13/72	3/1/73			$34,684 N
33	EXTENSION OF PI DATA ANALYSIS	528	2/28/73			Disapproved	$52,313 P
151-0511	OVERRUN PROPOSAL	274	11/23/70	3/1/73			$215,972 N
	SUMMARY						
	ORIGINAL BASIC CONTRACT						$968,600
	TOTAL NEGOTIATED ECP's (THRU 32)						$830,608 N
					TOTAL.		$2,015,180

10.3 PROGRAM SCHEDULES

10.3.1 Program Master & Internal Schedules

A master program schedule was established from the contractual delivery dates for all hardware and software end items. Throughout the history of the program the master program schedule was used as a reporting media to reflect the status and progress of all activities with NASA.

Detail schedules in the form of PERT sequence event flow diagrams were successfully utilized for UTD internal management-control plus quantitative percentage-completion status for each major milestone.

The chronology of program events and status was well documented in the monthly progress reports. Internal PERT schedules were updated on a weekly basis for internal control. The scheduling structure centered around the following major categories, i.e. contract end items and major milestones:

Mechanical Design and Drawings

Electrical Design and Drawings

Procurement

Mass Mock-up

Prototype

Flight Unit #1

Qualification Unit

Flight Unit #2

Flight Unit #3

GSE (BTE and Portable)

Hi-Fi Mock-up

Documentation

10.3.2 Schedule Performance

Notwithstanding the contractual difficulties that existed, the UTD schedule performance was excellent through-out the project including the several configuration changes that were incorporated late in the manufacturing sequence.

Table 10-3 summarizes the contractual delivery dates and the actual delivery dates. In all cases UTD was able to deliver the end items to NASA without subsequently delaying NASA or any other NASA contractor or subcontractor for testing and installation of the LOMSE for the Apollo 15 and 16 missions.

Table 10-3

NAS9-10410 HARDWARE CONTRACT END ITEM

MASTER SCHEDULE SUMMARY

Contract End Items	Delivery Date @Contract Award in Jan 1970	Delivery Date Contract Revision (Per ECP's in 1970 & early 1971)	Actual Delivery by UTD			Configuration Changes and Retrofits			
			Date	DD-250 UTD-	Location ("now"-Sept 1973)	ECP#	Schedule Dates and Delivery Planned	Actual	DD-250 UTD
1. Mass Mock-up	12 March 1970	12 March 1970	3 Mar 1970	UT 0001	Shipped to NR				
2. Prototype	19 June 1970	31 July 1970	31 July 1970	004	Shipped to NR now at UTD				
3. BTE #1	17 June 1970	17 June 1970	1 July 1970 31 July 1970	100% 006	Used at UTD now at UTD				
4. BTE #2 (with proto)	17 June 1970	31 July 1970	6 July 1970 31 July 1970	100% 005	Shipped to NR, Used at KSC, now at UTD				
5. Flight #1	7 Aug 1970	4 Dec 1970	8 Dec 1970	011	Shipped to KSC, (Apollo 16)	13, 18B, 22 for-03 26A for-04	24 May 1971 31 Oct 1971	13 May 1971 7 Nov 1971 (-04 Flown on Apollo 16)	011A 011B
6. Qual	1 Sept 1970	23 Nov 1970	16 Oct 1970	010	Tested at UTD now at NASA/JSC	26A for-04	9 Dec 1971	10 Dec 1971	010A
7. Flight #2	18 Dec 1970	5 Feb 1971	4 Mar 1971	012	Shipped to KSC, (Apollo 15)	13, 18B, 22 for-03	7 May 1971	6 May 1971 (-03 Flown on Apollo 15)	012A
8. High-Fi Mock-up	15 Jan 1971	15 Sept 1970	3 Sept 1970	008	Shipped to NASA/MSC				
9. Flight #3	1 Feb 1971	26 Mar 1971	29 June 1971	015	Shipped to KSC now at UTD	13, 18B, 22 for-03 26A for-04	1 July 1971 8 Dec 1971	(-03 Stop Work) 29 Nov 1971	015A
10. BTE #3	1 Feb 1971	23 Nov 1970	29 July 1970 31 July 1970	100% 007	Used at UTD now at UTD				
11. Portable GSE	N/A	1 Oct 1970	18 Sept 1970	009	Shipped to KSC, now at UTD				
12. ATEE Test Cables	N/A	10 Aug 1970	31 July 1970	006	Shipped to NR				

10.4 CHRONOLOGY OF EVENTS

The NAS9-10410 Project Chronology of events as presented in this section has been taken from the other sections of this report and summarized chronologically below for the overall program by major milestones:

No.	Date	Major Milestones
1	28 Mar 69	Unsolicitied Proposal to NASA Headquarters
2	10 Oct 69	NASA RFP #BG-931-89-0-40P
3	13 Oct 69	UTD Proposal #2769 submitted
4	27 Oct 69	UTD started work on contract & experiment definition
5	12 Nov 69	UTD Proposal #2769 for PI activities submitted
6	12 Dec 69	Final negotiations with NASA/MSC
7	28 Jan 70	NAS9-10410 Contract Award, all design, development, & procurement, fabrication & assemblies activities initiated.
8	28 Feb 70	UTD employed Program Manager and initiated reorganization
9	3 Mar 70	Mass Mock-up completed & shipped to North American Rockwell 12 March 1970
10	30 Apr 70	Electrical design 100% complete, mechanical design 100% complete, drawings 90% complete
11	12-16 May 70	Critical Design Review at UTD
12	16 May 70	Stop work on prototype re-design in accordance with RID's
13	May 70	One portable GSE added to contract via CCA#1
14	31 May 70	Approximately 98% of initial procurement of materials was complete
15	30 June 70	Electrical & Mechanical Design 99% complete, drawings 98% complete, Re-designs 99% complete
16	1 July 70	Bench Test Equipment #1 100% complete
17	6 July 70	Bench Test Equipment #2 100% complete
18	29 July 70	Bench Test Equipment #3 100% complete
19	31 July 70	Design 100% complete, drawings 100% complete
20	31 July 70	ATEE cables completed & shipped to NR
21	31 July 70	Prototype 100% complete through manufacturing & testing

No.	Date	Major Milestones
22	6-7 Aug 70	Acceptance Review at UTD for prototype & BTE #2
23	7 Aug 70	Shipped BTE #2 to NR
24	10 Aug 70	Shipped prototype to NR
25	26 Aug 70	Acceptance Review at UTD for BTE #1 & 3
26	31 Aug 70	All materials received
27	3 Sept 70	Hi-Fi Mock-up 100% complete
28	4 Sept 70	Acceptance Review for Hi-Fi Mock-up
29	14 Sept 70	Shipped Hi-Fi Mock-up to NASA/MSC
30	18 Sept 70	Portable GSE 100% complete
31	22 Sept 70	Acceptance Review for Portable GSE, stored in bonded stock room at UTD
32	Sept 70	Major Test Documents submitted to NASA/MSC: a. End Item Specification b. Acceptance Test Plans c. Acceptance Test Procedures d. Qualification Test Specifications e. Qualification Test Procedure
33	9 Oct 70	Acceptance Testing of Qualification Unit complete, no failures
34	13-16 Oct 70	Acceptance Review of Qualification Unit at UTD
35	30 Oct 70	EMI testing of Qualification Unit complete, test deviation required.
36	23 Nov 70	Qualification Environmental Testing complete
37	24 Nov 70	Assembly & manufacturing of Flight #1, 100% complete
38	4 Dec 70	Acceptance & Environmental test of Flight #1, 100% complete
39	7 Dec 70	Qualification Test Report complete
40	8 Dec 70	Flight #1 accepted by NASA
41	9-11 Dec 70	Acceptance Review at NASA/MSC for Flight #1 & Qual Unit
42	Jan 71	CCA#9, ECP-18, presented NASA/MSC solutions for NR Boom Twist Problem, New scoop design approved for UTD
43	22 Jan 71	Established UTD field engineering office at NASA/KSC
44	29 Jan 71	Began new scoop design at UTD for new configuration and retrofit of LOMSE Qual & Flight Units

No.	Date	Major Milestones
45	3 Feb 71	Flight #1 (151-500-02, S/N 103) Shipped from UTD to NASA/KSC
46	11-19 Feb 71	Pre-integration Tests of Flight #1 at KSC
47	15 Feb 71	BTE #3 Shipped from UTD to NASA/LRC.
48	15 Feb 71	Portable GSE received at NASA/KSC from UTD.
49	18 Feb 71	Qual Unit retrofitted with new 151-118 scoop for new 151-500-03 configuration.
50	19 Feb 71	Calibration Re-acceptance Test of portable GSE completed at KSC.
51	25-26 Feb 71	Flight #1 was mounted in Apollo 15 at KSC.
52	27 Feb 71	Portable GSE returned to UTD for integration testing with Flight #2.
53	28 Feb 71	Flight #2 Environmental & Acceptance Testing completed.
54	Feb 71	2-TV-2 tests completed at NASA/MSC using prototype.
55	Mar 71	Prototype returned to NR from NASA/MSC.
56	3 Mar 71	Portable GSE shipped to NASA/KSC second time.
57	4 Mar 71	Calibration and reacceptance of portable GSE at NASA/KSC.
58	5 Mar 71	Acceptance Review at NASA/MSC for Flight #2, 150-500-02, S/N 103.
59	16 Mar 71	1. Shipped Qual Unit to NASA/LRC for calibration testing.
		2. Flight #1 removed from Apollo 15 Spacecraft. Portable GSE & Flight #1 returned to UTD.
60	17-27 Mar 71	Absolute Calibration Testing of 150-500-03 Qual Unit conducted at NASA/LRC.
61	29 Mar 71	Returned Qual Unit to UTD from LRC.
62	12 Apr 71	Old scoop removed and new scoop installed on Flight #2 for 150-500-03, S/N 104.
63	15 Apr 71	Old scoop removed and new scoop installed on Flight #1, for 150-500-03, S/N 103.
64	19 Apr 71	Shipped Qual Unit & Portable GSE to NASA/KSC from UTD.
65	22 Apr 71	Shipped Flight #2 to NASA/LRC from UTD.

No.	Date	Major Milestones
66	23-30 Apr 71	Absolute Calibration of Flight #2 at LRC.
67	29-30 Apr 71	Qual 150-500-03, S/N 102 was installed in Apollo 15 SIM Bay, performed TCP-055 test.
68	29 Apr 71	Completed Retrofit & shipped Flight #1 to LRC.
69	3-11 May 71	Absolute Calibration of Flight #1 at LRC.
70	3 May 71	Completed K 8341 Test on Qual Unit at KSC, removed Qual MS from spacecraft.
71	10 May 71	Shipped Flight #2 to NASA/KSC.
72	14 May 71	Shipped Flight #1 to NASA/KSC (back-up unit).
73	19 May 71	PIT TCP-150-005 performed at KSC on Flight #2.
74	22 May 71	Acceptance Test of Flight #3 complete & retrofits started.
75	26 May 71	Ship Flight #3 to NASA/LRC.
76	30 May 71	Flight #2, 150-500-03 S/N 104, was installed in Apollo 15 SIM bay at KSC, Pad 39.
77	2-3 June 71	PIT performed at KSC on Flight #1.
78	June 71	MS Boom cable problem during Apollo 15 close-out.
79	2 June 71	Returned Flight #3 to UTD from NASA/LRC. (Aborted test)
80	11 June 71	Flight Readiness Review complete at KSC for Flight #2 on Apollo 15.
81	14 June 71	Rework of Flight #3 completed at UTD.
82	15-16 June 71	Lightning struck Pad 39A at KSC, no problems with LOMSE.
83	16 June 71	Qual Unit shipped to UTD from KSC, stored at UTD.
84	23 June 71	Reworked Flight #1 at KSC for cable clamp problem. Flight #1 returned to UTD for Vacuum Functional Test per DR 0009.
85	24-25 June 71	Acceptance Review at NASA/MSC for Flight #3, 150-500-03, S/N 105.
86	29 June 71	Completed Functional Retest of Flight #1 at UTD, shipped to NASA/KSC.
87	29 June 71	Shipped Flight #3 to NASA/LRC from UTD.

No.	Date	Major Milestones
88	1-12 July 71	Absolute Calibration of Flight #3 at NASA/LRC.
89	13 July 71	Shipped Flight #3 to NASA, KSC.
90	26 July 71	Apollo 15 launch from KSC Pad 39A.
91	29 July- 7 Aug 71	Flight #2 operated during Apollo 15 lunar orbital & transearth coast portion of Mission.
92	20 Aug 71	NASA approved Retrofit & Retest of Flight #1 & 3 plus Qual to 150-500-04 configuration per CCA#16 for addition of thermally controlled inner scoop.
93	26 Aug 71	PIT performed on Flight #3.
94	3 Sept 71	Installed LOMSE Flight #3 150-500-03 S/N 105 into Apollo 16 spacecraft at KSC.
95	18 Sept 71	Returned Flight #1 & 3 to UTD from KSC.
96	22 Sept 71	Started retrofit of Flight #1 for CCA#16, -04 configuration.
97	28 Sept 71	Started retrofit of Qual Unit for CCA#16, -04 configuration.
98	29 Sept 71	Returned portable GSE to UTD from KSC.
99	30 Sept 71	Shipped Prototype to NR, Downey, California for special boom test.
100	1-6 Oct 71	Special boom test at NR with prototype.
101	1-20 Oct 71	EMI testing of portable GSE at LTV/E, Garland, Texas
102	25 Oct 71	Shipped portable GSE to NASA/LRC from UTD.
103	4 Nov 71	Complete Retrofit & Retesting of Flight #1 150-500-04, S/N 103.
104	4-5 Nov 71	Acceptance Review at NASA/MSC for Flight #1.
105	8 Nov 71	Shipped Flight #1 to KSC from UTD.
106	9 Nov 71	1. An anomaly during PIT at KSC on Flight #1. 2. Flight #1 returned to UTD from KSC.
107	10 Nov 71	Stopped testing on Qual & shipped to KSC.
108	11 Nov 71	Qual MS mounted on prototype boom at KSC, performed K-0070 tests.

No.	Date	Major Milestones
109	11-18 Nov 71	Failure analysis, rework, & retest of Flight #1 at UTD.
110	17-18 Nov 71	NR Scoop Seal Definition (ECP-28) at Downey, California conference.
111	24 Nov 71	1. Modified outer scoop per ECP-28 & Retest of Flight #3. 2. Returned Qual MS to UTD from KSC.
112	29 Nov 71	Acceptance Review at NASA/MSC for Flight #3.
113	1 Dec 71	Shipped Flight #3 to LRC from UTD.
114	2-10 Dec 71	Absolute Calibration of Flight #3 at LRC.
115	6 Dec 71	Shipped Flight #1 to LRC from UTD.
116	8 Dec 71	Completed modification of outer scoop per ECP-28 & retest for Qual MS, stored at UTD.
117	10 Dec 71	Returned Flight #3 to UTD from LRC.
118	10-18 Dec 71	Absolute Calibration of Flight #1 at LRC.
119	13 Dec 71	Shipped Flight #3, 150-500-04, S/N 105 to KSC from UTD.
120	13 Dec 71	Shipped Qual MS, 150-500-04, S/N 102 to NASA/MSC from UTD for Acceptance Review.
121	14 Dec 71	Qualification MS Acceptance Review at NASA/MSC.
122	15 Dec 71	Qual MS returned to UTD from MSC, placed in storage at UTD.
123	18 Dec 71	Returned Flight #1 to UTD from LRC.
124	20 Dec 71	Shipped Flight #1 to KSC from UTD.
125	7 Jan 72	Flight #1 installed in Apollo 16, SC 113 at KSC.
126	Jan 72	NR Boom retraction & spacecraft thermal shield problems with Flight #1 interfaces. Removed Flight #1 from S/C.
127	18 Feb 72	NR Boom modified with proximity switch. Removed Flight #1 from spacecraft.
128	22-24 Feb 72	Flight Readiness Review for Apollo 16 at KSC.
129	29 Feb 72	Flight #1 reinstalled into Apollo 16 spacecraft.
130	1 Mar 72	Installed new thermal shield on spacecraft at KSC for LOMSE.
131	22 Mar 72	K-0007 countdown test with portable GSE & Flight #1 at Pad 39A.

No.	Date	Major Milestones
132	16 Apr 72	Apollo 16 launch from KSC, Pad 39A @ 12:54 p.m.(EST).
133	18-25 Apr 72	Lunar Orbital operation of Flight #1 from NASA/MSC.
134	24 Apr 72	Flight #3 returned to UTD from KSC for data evaluation.
135	25 Apr 72	Boom failed to complete retract, Flight #1 LOMSE jettisoned into lunar orbit just prior to TEI.
136	15 May 72	KSC field engineering office closed.
137	30 May 72	Qualification MS 150-500-04, S/N 102 shipped to NASA/MSC from UTD for display in lobby of Building #15.
138	13 July 72	Transferred residual inventories from NAS9-10410(E1660) to NAS9-12999(E1308).
139	15 July 72	Received microfilm reader/printer for quick-look data analysis of mass spectra data at UTD.
140	19 Aug 72	BTE #1 was returned to UTD from LRC.
141	1972&1973	1. Data reduction & data analysis 2. Numerous scientific papers published

10.5 CRITICAL DESIGN REVIEW

A very thorough and exhaustive formal Critical Design Review was conducted at the University on May 12, 13, 14, and 15, 1970 for the NAS9-10410 mass spectrometer. The design review was attended by approximately 35 to 50 personnel from NASA, ONR, and UTD.

There were initially individual detailed design task team meetings on 12, 13 and 14 May for the following subsection of the design review:

1) Electrical Design

2) Electrical Interface and Data

3) Mechanical Design

4) GSE Design

5) Reliability and Quality Assurance

6) Science and Management

On 15 May a formal Review Item Disposition (RID) Review Board was chaired by Mr. Enoc Jones of NASA/MSC. A total of 98 RID's were written by NASA/MSC based upon the review of printed circuit board assemblies of the prototype unit and review of designs, assembly drawings, schematics, block diagrams, science objectives, mission requirements, QA inspection criteria, and procedures presented in the End Item Specification:

Task Team/Area	No. of RIDS
GSE	None
Electrical	18
Mechanical	17
Science and Management	16
R & QA	47
TOTAL	98

The CDR resulted in a 30 day stop work on the prototype unit with redesign of most printed circuit boards and major subassemblies primarily for weight reduction and quality assurance inspection and assembly tehcniques such as strain relief of components, heat sinking, and conformal coating of assemblies.

One item under review of particular interest was printed circuit module construction utilizing straight lead components without crimps. UTD was able to demonstrate through subsequent special tests and thermal cycling that it was not necessary to crimp axial lead devices within the printed circuit modules, nor was it necessary to pot these modules.

A major weight reduction program was undertaken to reduce the original design weight of 25 pounds to 22.8 pounds.

Many manufacturing and R & QA operations were subsequently corrected and improved for such items as:

1) High reliability screening and burn-in of components
2) Failure modes and effects analysis
3) Material Review Board activities
4) Non-metallic material review
5) Purchase order control
6) Receiving inspection of components
7) Batch, lot, and date codes for all flight materials
8) Controlled stock room
9) Traceability of parts and materials
10) Independent inspection stations for electrical and mechanical subassemblies
11) Configuration control of all end items
12) Process and assembly procedures
13) Improved inspection criteria
14) Control of solithane 303 conformal coating on all electrical assemblies.

In retrospect this CDR was the major turning point in the NAS9-10410 contract at UTD even though at the time it was a very painful setback in the program. All corrective action was taken to satisfy the 98 RID's.

The corrective action taken by UTD from the CDR resulted in an engineering design, configuration, control, manufacturing, testing, and reliability and quality assurance program for the project that ultimately in every way met the full manned space flight criteria and requirements of the NASA for the Apollo program.

10.6 ACCEPTANCE REVIEWS

Formal Acceptance Reviews (AR) with NASA were conducted for all end items based upon a very extensive Acceptance Data Package prepared for each. These acceptance reviews typically took place at NASA/MSC with detailed reviews of the Acceptance Data Package information for one or two days prior to the formal Acceptance Review. The AR's and data packages were based upon the requirements of MSC-02436 Rev. A.

The manufacturing planning, inspection records, test data, deviations, defective or discrepant materials, configuration records, serial numbers, part numbers, weight and balance data were very carefully reviewed by UTD, NASA, and ONR Reliability and Quality Assurance personnel for compliance to the requirements and drawings. The formal acceptance Review was concluded with the execution of a DD-250 and a Certificate of Flight Worthiness. The reviews were typically attended by approximately 15 to 20 UTD, ONR, and NASA/MSC personnel. An acceptance review report was prepared for each such meeting.

The summary of the Acceptance Reviews for NAS9-10410 is presented in Table 10-4.

10.7 ORGANIZATION AND MANAGEMENT

A program organization was established in March, 1970 utilizing a Program Manager as the focal point for administration and control of the financial and technical implementation of the project. The Principal Investigator served as the Program Director, Project Scientist, and Principal Engineer for the analyzer.

The UTD internal organization was under the direction of the program Manager who was also the central point for all interfaces with the NASA/MSC via appropriate contractual and administrative offices. The overall managerial functions, communication, channels, and liason operations were organized as shown in Figure 10-1. The internal program personnel and relationship to UTD management was organized as shown in Figure 10-2.

Beginning in January 1971 a UTD field engineering office was established at the Kennedy Space Center with a full time field engineer. The UTD field engineer performed liaison, tests, and assistance for installation of the Mass Spectrometer for the Apollo 15 and 16 flights in conjunction with the UTD base personnel and integrations contractor personnel.

TABLE 10-4. SUMMARY OF ACCEPTANCE REVIEWS

AR DATE	AR LOCATION	END ITEM ACCEPTED	ACCEPTANCE REVIEW DATA PACKAGE (RELEASE DATE)	ACCEPTANCE REVIEW REPORT (W/ CONFIGURATION)	REVIEW
6 & 7 Aug 70 6 & 7 Aug 70	UTD UTD	Prototype BTE #2	151-009 (7-31-70) 151-008A (7-31-70)	SMOG-OL-172 SMOG-OL-164	1
26 Aug 70	UTD	BTE #1 BTE #3	151-016 151-017	151-037	2
4 Sept 70	UTD	Hi-Fi Mockup	151-030 (9-2-70)	SMOG-OL-219 151-041	3
22 Sept 70	UTD	Portable GSE	151-032 (9-18-70)	SMOG-OL-224	4
15&16 Oct 70	UTD	Qualification MS	151-039 (10-12-70)	(-03) SMOG-OL-246 SMOG-OL-262	5
9&11 Dec 70	NASA/MSC, BLDG. 15	Flight #1	151-052 (12-2-70) 151-052A (5-13-71)	(-02) SMOG-OL-298 (-03) SMOG-OL-386	6
5 Mar 71	NASA/MSC, BLDG. 15	Flight #2	151-061 (2-9-71) 151-061A (5-6-71)*	(-02) SMOG-1L-344 (-03) SMOG-1L-395*	7
24&25Jun 71	NASA/MSC, BLDG. 15	Flight #3	151-064 (4-15-71) 151-064A (7-15-71)	(-02) SMOG-1L-400 (-03) SMOG-1L-404	8
4 & 5 Nov 71	NASA/MSC, BLDG. 15	Flight #1	151-052B (11-5-71) 151-052C (12-20-71)**	(-04) SMOG-1L-442 (-04CAL) ECO-1660-623**	9
29 Nov 71	NASA/MSC, BLDG. 15	Flight #3	151-064B (11-19-71) 151-064C (12-10-71)	(-04) SMOG-1L-455 (-04CAL) SMOG-1L-466	10
14 Dec 71	NASA/MSC, BLDG. 15	Qualification MS	151-039A (12-10-71) 151-039B (1-4-72)	(-04) SMOG-1L-466 (-04CAL) ECO-1660-625	11

NOTES: *Flown on Apollo 15 Mission
**Flown on Apollo 16 Mission
CAL=After Absolute Calibration

FOLDOUT FRAME 1

FOLDOUT FRAME 2

SMOG ORGANIZATIONAL CHART
15 OCTOBER 1970

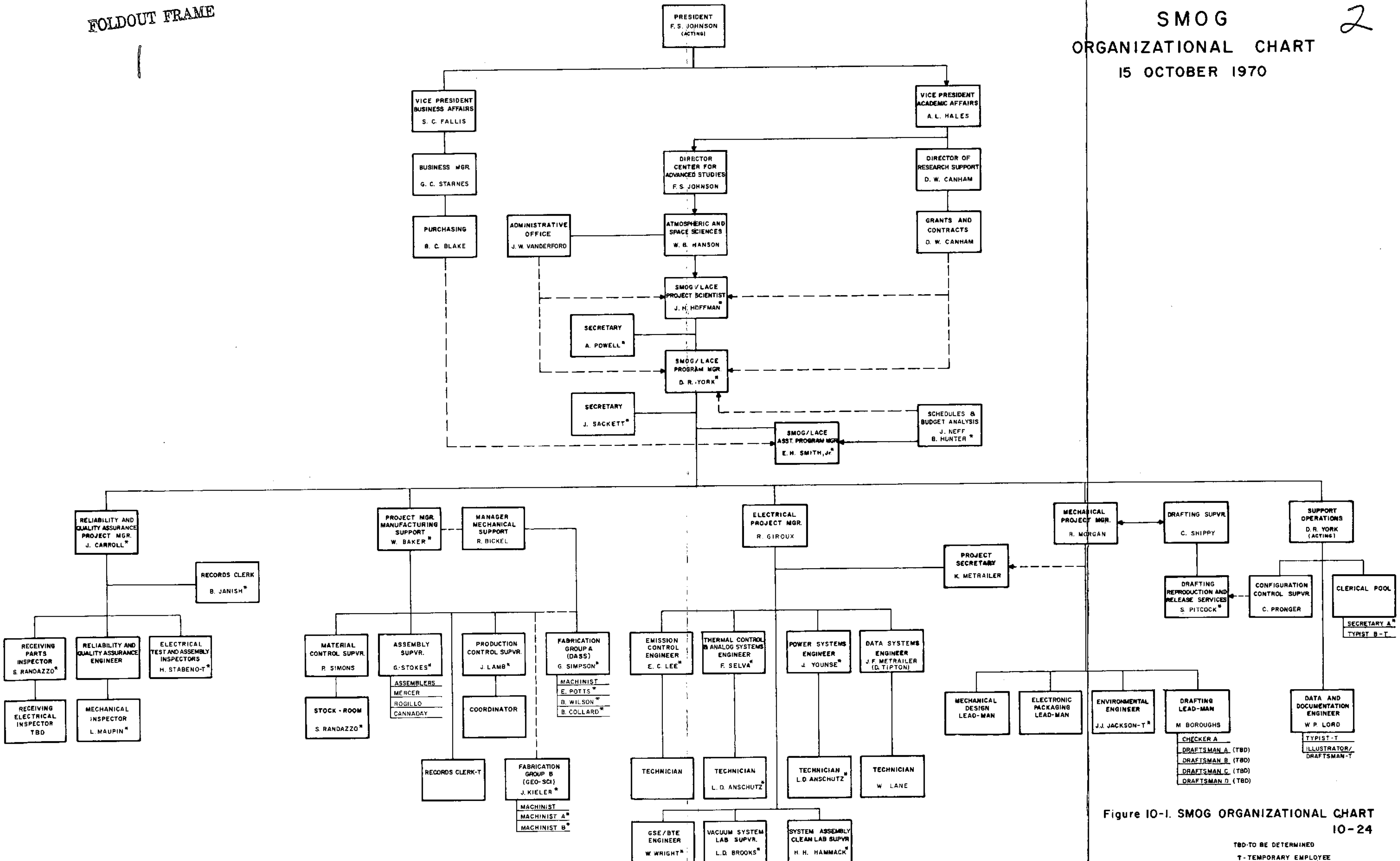
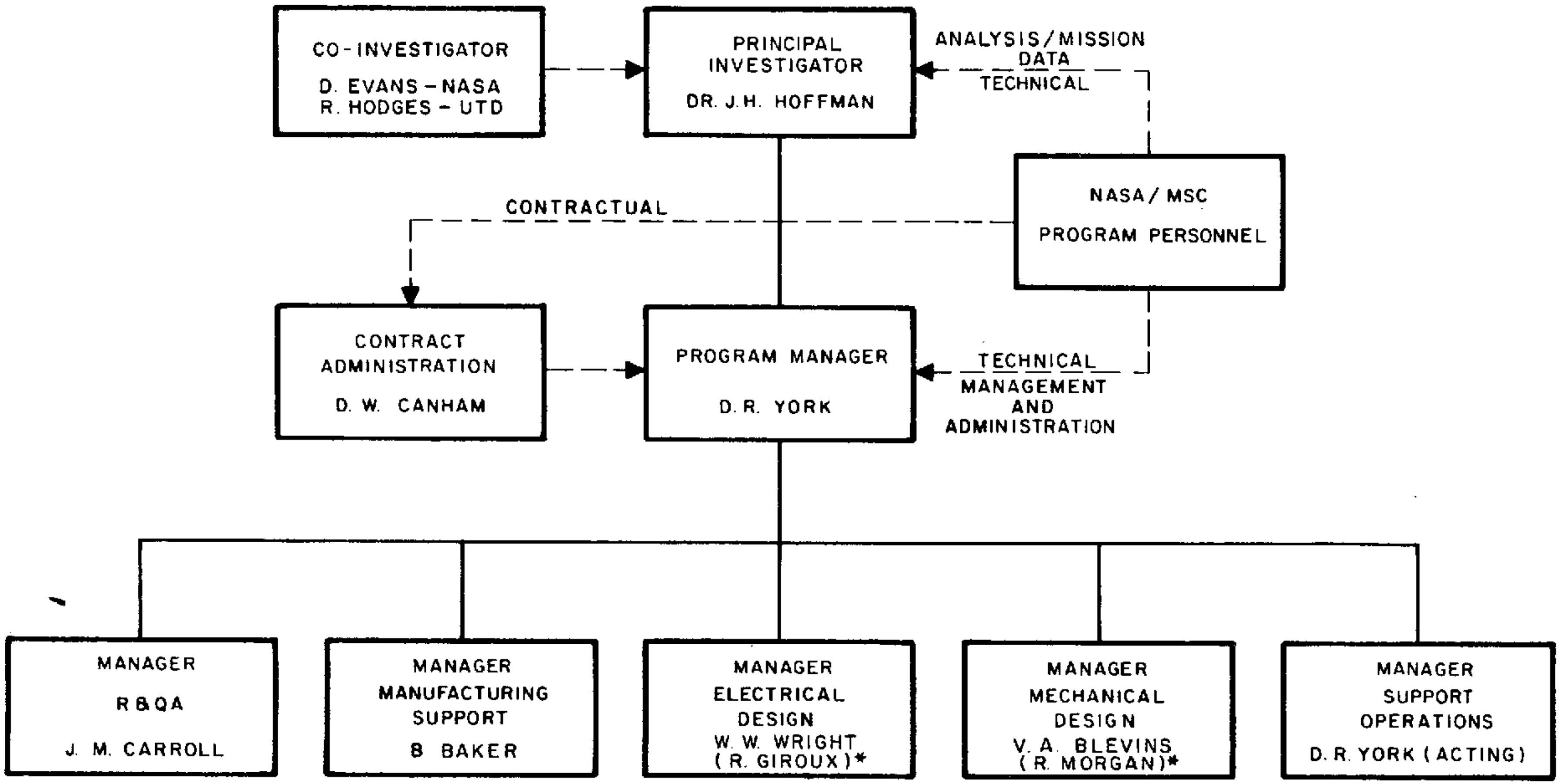


Figure 10-1. SMOG ORGANIZATIONAL CHART

TBD-TO BE DETERMINED
T-TEMPORARY EMPLOYEE
*-TIME SHARED WITH OTHER CONTRACTS



NOTES:
* INITIAL STAFFING
- - - MANAGEMENT INFORMATION FLOW
—— STAFFING CHANGE-OF-COMMAND AND INFORMATION FLOW

Figure 10-2 UTD Management Flow for NAS9-10410

10.8 COSTS PER TASKS AND SUBTASKS

Beginning in March 1970, a matrix system of cost accumulation was utilized to maintain cost control visibility and to develop historical cost data. This matrix system was superimposed on the standard University accounting system and is presented in the Table 10-5.

The matrix system of cost control resulted from the necessary program reorganization that took place in early 1970 to maintain management visibility and control of the overall project. The resultant matrix is based upon the project work-breakdown structure of tasks and subtasks, using major deliverable hardware groups or major end items and activities as the basis for the task groups within the overall NAS9-10410 contract. The matrix cost control was a very key element in managing and monitoring the NAS9-10410 program at UTD both technically and financially to ensure that the dollar constraints were met and were compatible with the schedules, budgets, technical objectives as well as the system and contractual requirements. The internal account number was E1660 with a suffix of two alpha characters for task and subtask plus standard institutional expense code plus a concluding budget alpha character. This enabled the accumulation of costs for each task, subtask, expense code, and budget assignments, which were provided in detailed computer print-outs each month.

The total contract value for NAS9-10410 upon close out on 30 September 1973 was $2,015,180.00. According to the matrix of task and subtasks this total cost was distributed as presented in Table 10-6 and 10-7.

The total cost was distributed according to the UTD expense codes as presented in Table 10-8 and by budget assignments per Table 10-9.

Table 10-5

MATRIX OF TASKS & SUBTASKS FOR SMOG PROGRAM

EFFECTIVE: 1 APRIL 1970 D.R. YORK

REV D 7 JULY 1971

SUBTASK LABOR & MATL GROUPS 2ND → / TASKS 1ST ↓		UTD LABOR (SALARIES & WAGES) GROUPS (51XX)														MATERIALS GROUP					TASK REPORTS FROM COMPUTER
		ENGINEERS, ELEC., DESIGNERS	ENGINEERS, MECH., DESIGNERS	ENGINEERS, R&QA	DRAFTSMEN	TECHNICIANS	ASSEMBLERS (ELEC)	MACHINISTS & FABRICATORS	INSPECTORS, QA	CLERICAL/ SECRETARY	SUPPORT OPER. PERSONNEL	SUPERVISORS	PROJECT MGR.	PROJECT SCIENTIFIC PERSONNEL	PROGRAM MGR	SUBCONTRACT LABOR PURCHASE SERV (6330)	MATERIALS FOR MS & GSE (6310) (6320)	PERMANENT EQUIP. COSTS (7341 & 7342)	OPERATIONAL & SUPPORT COST (6950) (6912) (6310, 6350, 6370, 6380, 6420, 6430, 6440, 6503 ...)	TRAVEL & SUBSISTENCE (9410)	
		XA	XB	XC	XD	XE	XF	XG	XH	XJ	XK	XL	XM	XN	XP	XQ	XR	XS	XT	XU	
DESIGN TASK	AX	AA	AB		AD	AE	AF	AG				AL				AQ	AR		AT	AU	→ AØ
MOCK-UPS TASK	BX		BB		BD	BE		BG	BH							BQ	BR			BU	→ BØ
PROTOTYPE TASK	CX	CA	CB		CD	CE	CF	CG	CH							CQ	CR			CU	→ CØ
QUAL MODEL TASK	DX	DA	DB		DD	DE	DF	DG	DH							DQ	DR			DU	→ DØ
FLIGHT UNITS TASK	EX	EA	EB		ED	EE	EF	EG	EH							EQ	ER		ET	EU	→ EØ
GSE TASK	FX	FA	FB		FD	FE	FF	FG								FQ	FR			FU	→ FØ
DOCUMENTATION INCL. DESIGN REVIEWS TASK	GX	GA	GB	GC	GD	GE				GJ	GK	GL	GM	GN	GP	GQ			GT	GU	→ GØ
FLIGHT SUPPORT TASK [13]	HX	HA	HB			HE				HJ	HK		HM	HN		HQ	HR		HT	HU	→ HØ
PROGRAM ADMIN. TASK	JX									JJ	JK	JL	JM	JN	JP	JQ			JT	JU	→ JØ
SUB C/CONSULTANT & SUSTAINING ENGR. [14]	KX	KA	KB	KC	KD	KE	KF		KH	KJ	KK	KL	KM	KN	KP	KQ	KR		KT	KU	→ KØ
OTHER DIR. COST TASK	LX	LA				LE	LF	LG								LQ		LS	LT	LU	→ LØ
R.I. EFFORT TASK	MX				MD					MJ	MK			MN		MQ	MR		MT	MU	→ MØ
R & QA TASK	NX			NC		NE	NF		NH	NJ			NM			NQ		NS	NT	NU	→ NØ
SUB-TASK REPORTS FROM COMPUTER		ØA	ØB	ØC	ØD	ØE	ØF	ØG	ØH	ØJ	ØK	ØL	ØM	ØN	ØP	ØQ	ØR	ØS	ØT	ØU →	1660-ØØ TOTAL PROGRAM REPORT FROM COMPUTER

NOTES:

1.) MAKE UP OF CHARGE NO: E1660 - TASK SUB-TASK - STANDARD EXPENSE CODE - BUDGET ASSIGNMENTS - WORK ORDER OR BLANK

XXXXX -X X -XXXX- X- XXX

- XXXXX: FIXED CONTR. NO.
- X X: USE ABOVE MATRIX TABLE
- XXXX: TO BE ASSIGNED BY J. VANDERFORD
- X: USE TABLE 2 (F=SUSTAINING ENGR. ECP 14) (T=THERMAL ANALYSIS ECP-22A, E=EMI PORTABLE GSE ECP 20) (C=CARROLL, G=GIROUX, H=HOFFMAN, M=MORGAN, Y=YORK, S=SOUTHERN ECP-12A, L=LANGLEY ECP-13, D=SCOOP ECP-10B)
- XXX: TO BE ASSIGNED BY ESCHOL CABLE/J. VANDERFORD

2.) BUDGET ASSNMT REPORTS FROM COMPUTER

→C, →D, →G, →H, →M, →Y, →S, →L: TOTAL TASK & SUBTASK REPORT PER BUDGET ASSIGN., →T, →E

TABLE 10-6.

NAS9-10410 COST BY TASKS

UTD ACCOUNT E1660

TASK		MAN HOURS	TOTAL COST
A.	Design and Development	17,501	$197,311.
B.	Mock-Up Units (2)	286	3,302.
C.	Prototype Unit	8,145	116,355.
D.	Qualification Unit	9,075	137,107.
E.	Flight Units (3)	17,034	332,136.
F.	GSE Units (4)	3,964	91,027.
G.	Documentation, Configuration Control, and Design Review	9,377	130,525.
H.	Flight Support (KSC Offsite Activities only)	5,070	85,909.
J.	Program Administration, Overall Tasks (Including PI & Secretaries)	25,151	314,402.
K.	Subcontracts, Consultants, and Sustaining Engineering (Including Environmental Testing)	10,780	206,205.
L.	Miscellaneous Other Direct Costs (Including Permanent Equipment)	1,247	77,541.
M.	PI Effort and Data Analysis (Science)	13,924	230,489.
N.	R & QA Engineering	8,240	92,871.
	TOTAL BY TASKS	HRS 129,794	$2,015,180.

TABLE 10-7.

NAS9-10410 COST BY SUBTASKS

SUBTASK	MAN HOURS	TOTAL COST
A. Electrical Engineers (UTD)	17,076	$ 210,547.
B. Mechanical Engineers (UTD) *	1,268	17,441.
C. R & QA Engineers (UTD)	3,239	40,514.
D. Draftsmen (UTD)*	4,320	37,418.
E. Technicians (UTD)*	17,793	155,244.
F. Electrical Assemblers (UTD)	6,487	41,557.
G. Machinist & Fabricators (UTD)	3,229	25,213.
H. R&QA Inspectors (UTD)*	3,206	28,676.
J. Clerical/Secretarial (UTD)*	12,481	66,016.
K. Support Operations Personnel (UTD)*	11,283	119,196.
L. Supervisors (UTD)*	4,391	46,691.
M. Project Managers (Lead Engineers)(UTD)**	10,288	148,549.
N. Project Scientists (UTD)	5,323	95,515.
P. Program Manager (UTD)	3,088	54,443.
Q. Subcontract Labor and Purchase Service*	26,322	299,260.
R.1. Materials of Mass Spectrometers & GSE (End Items)	N/A	312,345.
2. Environmental Tests for End Items, Subcontracted	N/A	94,352.
S. Permanent Equipment	N/A	42,575.
T. Operational Support	N/A	106,746.
U. Travel	N/A	72,882.
TOTAL BY SUBTASK	129,974 HRS	$2,015,180.

NOTE *1. Purchased and Subcontract labor (26,322 Hours) was used primarily in Subtasks B, D, E, H, J, K and L and are not separated into the appropriate subtask categories.

TABLE 10-7 (CONTD).

It is estimated that purchased labor of 26,322 hours should be distributed with addition to the above subtasks in manhours as follows:

SUBTASK		ADD		UTD HOURS	TOTAL HOURS
B	-	8,657	+	1,268	= 9,925 Hours
D	-	6,655	+	4,320	= 10,975 Hours
E	-	1,600	+	17,793	= 19,393 Hours
H	-	3,068	+	3,206	= 6,274 Hours
K	-	5,862	+	11,283	= 17,145 Hours
L	-	480	+	4,391	= 4,871 Hours
		26,322			

NOTE **2. All labor cost includes 77.9% indirect charges except for Subtask M which contains $35,953 total labor at 49.8% indirect for KSC offsite.

TABLE 10-8.

NAS9-10410 COST BY UTD STANDARD EXPENSE CODES

UTD EXPENSE CODES	DESCRIPTION	MAN HOURS	TOTAL COST
100	UTD Labor	103,472H	$ 614,820
	Labor Overhead		472,200
	Subtotal	103,472H	$1,087,020
310	Materials & Supplies		326,244
320	Subcontracts		94,352
330	Purchased Services	(Est. 26,322H)	299,260
340	Permanent Equipment		42,575
360	Postage & Freight		3,164
370	Communications,(Telephone & TWX)		10,225
380	Reproduction Service (Xerox)		31,376
410	Travel		72,882
430	Internal Computer Service		31,016
440	Meetings & Conferences(Coffee)		7
520	Page Cost (Technical Papers)		807
902	Rearrangements & Alterations		19
903	Repairs & Service Calls		6,399
911	Uniforms, Cleaning & Laundry Service		195
912	Rental of Equipment/Gas Bottle Demurrage		1,648
950	Lease Payments		3,364
960	External Computer Service		4,627
	TOTAL	129,974 HRS	$2,015,180

TABLE 10-9.

NAS9-10410 COST BY BUDGETS

BUDGETS	TOTAL COSTS
C - R & QA Manager	$ 143,183.
E - EMI Testing, UTD Support for	2,720.
F - Sustaining & Support Engineering	114,526.
G - Electrical Engineering Manager	686,997.
H - Principal Investigator Activities (Science & Hardware)	358,849.
L - LRC Activities	57,192.
M - Mechanical Engineering Manager	398,455.
S - KSC Offsite Activities	85,909.
T - Thermal Analysis	10,317.
Y - Program Administration Activities	157,032.
	$2,015,180.

SUMMARY OF SCIENTIFIC RESULTS FROM THE APOLLO 15 AND APOLLO 16 LUNAR ORBITAL MASS SPECTROMETER

R. R. HODGES, JR.

A major goal of the Apollo 15 and Apollo 16 lunar orbital mass spectrometer experiments was to verify the theory of production of a lunar atmosphere from neutralized solar wind ions which have impacted the moon. Analyses of early returned lunar soil samples had showed that amounts of the major solar wind elements, hydrogen, helium, carbon, nitrogen, neon and argon, entrapped in soil grains were substantially less than would be expected if the total solar wind influx had been implanted over geologic time. The most reasonable explanation of the missing solar wind elements is that they have left the moon via atmospheric escape processes. A present state of balance of solar wind accretion and escape seems to require the existence of a tenuous atmosphere.

Sizing of the experimental parameters for detection of atmospheric gases by an orbiting mass spectrometer was based largely on the predictions of lunar atmosphere composition reported by Johnson (1971) and on the theory of planetary exospheric equilibrium of Hodges and Johnson (1968) and Hodges (1972, 1973a). It was thought that thermal escape of hydrogen and helium precluded formation of detectable amounts of atmosphere, and that neon should be a dominant constituent of solar wind origin. To allow for detection of carbon and nitrogen compounds arising from the solar wind influx, as well as discovery of volcanic gases, the mass range chosen for the orbital experiments was 12 amu to 66 amu. Given the benefit of hindsight, specifically from the results of the Apollo 17 lunar surface mass spectrometer, it would have been extremely useful to have included 4 amu (helium).

Hodges and Johnson had showed that a gas like neon, which does not escape thermally, and which is not adsorbed by the cold nighttime lunar surface, should be 30 to 40 times more abundant at night than in daytime. This is because exospheric lateral transport tends to distribute gases so as to equalize $nT^{5/2}$ over the lunar surface. Most species, however, were expected to be adsorbed at night. Their sudden release from the rapidly warming surface just to the east of the advancing sunrise terminator was predicted to form a sunrise pocket of atmosphere which would extend into nighttime a distance of several scale heights.

The natural nighttime excess of noncondensable gases complemented a fortuitous feature of neutral gas mass spectrometers: That instrumental background contamination levels are less in nighttime conditions when outgassing from cold spaceflight hardware is low. However, the retrograde Apollo orbits resulted in day-to-night crossings of the sunrise terminator, resulting in mass spectra that were cluttered by the daytime contaminant artifacts, masking the natural sunrise pocket of atmospheric gas formed by release of adsorbed molecules from the lunar surface.

In addition, the contaminant background in lunar orbit included an unexpectedly large amount of water vapor. The detected amount was more than an order of magnitude greater than could be accounted for if degassing of spaceflight hardware were the source and if the most optimistic assumptions are made. It may be that the water vapor resulted from evaporation of orbiting ice crystals formed in water dumps from the CSM. The principal ions of water formed in the mass spectrometer ion source include O^+, OH^+, H_2O^+, H_3O^+, and $H_2{}^{18}O^+$, at masses 16 through 20 amu.

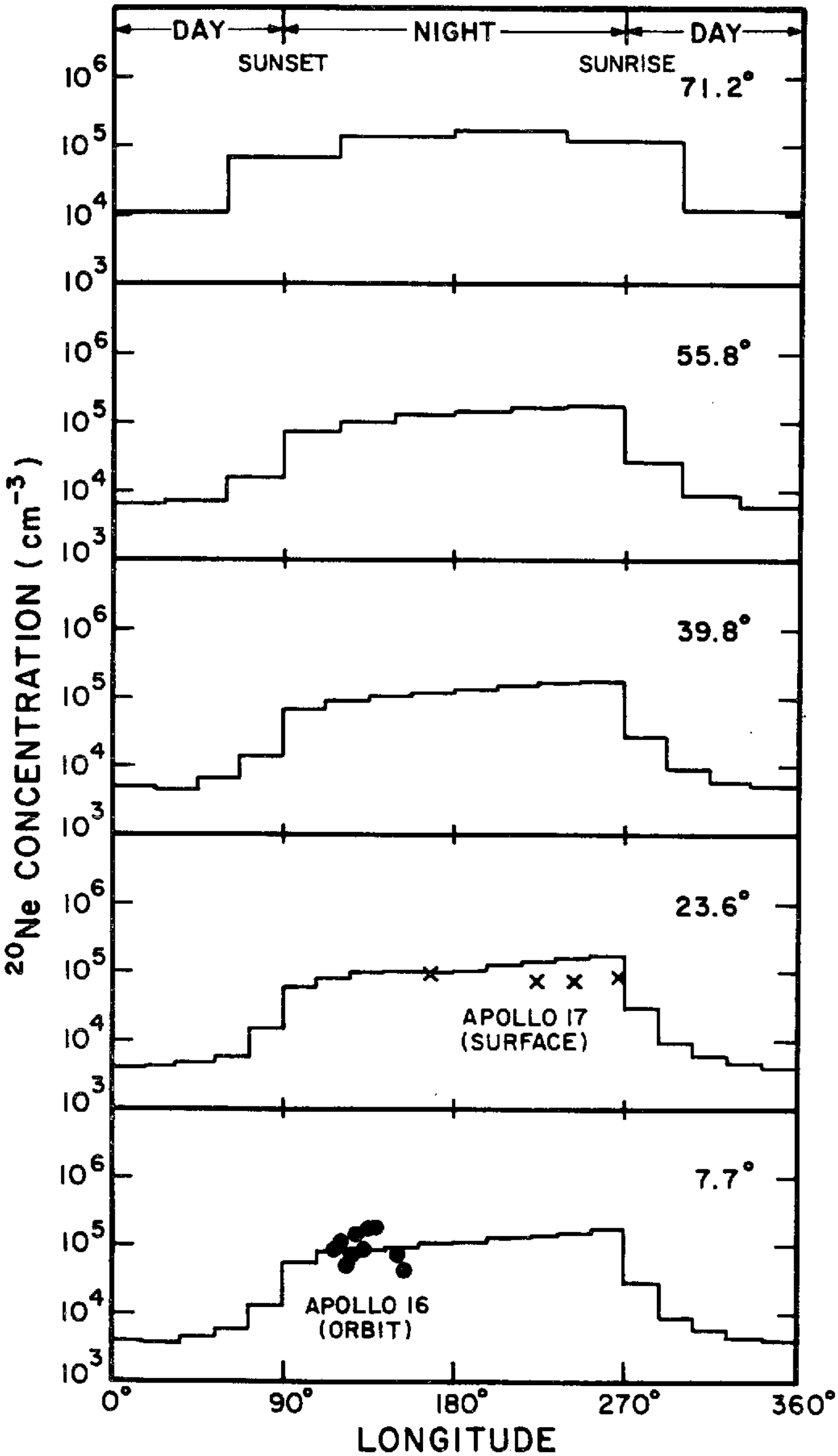
The fragments O^+ and OH^+ precluded detection of lunar CH_4 and NH_3 (At 16 and 17 amu, respectively), while the $H_2{}^{18}O$ severely hampered the detection of ^{20}Ne (Hodges et al., 1972a).

Dispite the contamination problems, the major goals of the orbital mass spectrometry program were accomplished. The amount of neon detected in the nighttime lunar atmosphere is in good agreement with theoretical models based on total conversion of the solar wind influx into atmospheric gas. In addition, one transient event detected by the Apollo 15 instrument probably was of volcanic origin. Operational aspects of these experiments have been reported by Hoffman et al. (1972a,b) and by Hodges et al. (1972b). Details of scientific results are given by Hodges et al. (1972a, 1973a, b). Summaries of the neon results, the volcanic event, and a synopsis of cumulative knowledge of lunar atmosphere gained from the Apollo program are included in subsequent discussion.

NEON

Calculations by Hinton and Taeusch (1964), Johnson (1971), Johnson et al. (1972), and Hodges et al. (1973 a, b) have shown ^{20}Ne to be the most probable dominant gas of solar wind origin on the moon, although successive refinements of theory have resulted in a significant decrease in the expected amount. At present there is a fairly good agreement of theory and experimental results.

Figure 1 (from Hodges et al., 1973b) is a superposition of a theoretical global model distribution of ^{20}Ne and the existing experimental results. The paucity of data points reflects the difficulties that have plagued attempts to measure neon. Data shown on the 7.7° latitude graph are surface values extrapolated from the Apollo 16 orbital mass spectrometer measurements at latitudes between 7° and 10°. These points are the only data in which


DAY
SUNSET
NIGHT
SUNRISE
DAY
71.2°
55.8°
39.8°
23.6°
7.7°
APOLLO 17
(SURFACE)
APOLLO 16
(ORBIT)
^{20}Ne CONCENTRATION (cm^{-3})
LONGITUDE
0°
90°
180°
270°
360°
10^{3}
10^{4}
10^{5}
10^{6}

the spectral peak at mass 20 amu was not overwhelmed by $H_2{}^{18}O$ arising from a spacecraft source of water. Scatter of the points is well within the large statistical uncertainties of the data that result from subtraction of about a 90% water contribution from the mass 20 amu measurements.

Available measurements from the Apollo 17 mass spectrometer at 20° N (Hoffman et al., 1973) are shown on the computed graph for 23.6° latitude. Each point was obtained by a complex process in which the instrument was turned off and allowed to cool sufficiently to condense a significant mass 20 amu contaminant, HF, which is produced in the ion source, probably from decomposition of vestiges of contaminant halogen and hydrogen compounds ingrained in materials from which the source was constructed. These measurements also provide an isotopic abundance ratio of ^{20}Ne to ^{22}Ne of about 14.2, which is in reasonable agreement with the solar wind ratio of 13.7 measured by Geiss et al. (1972).

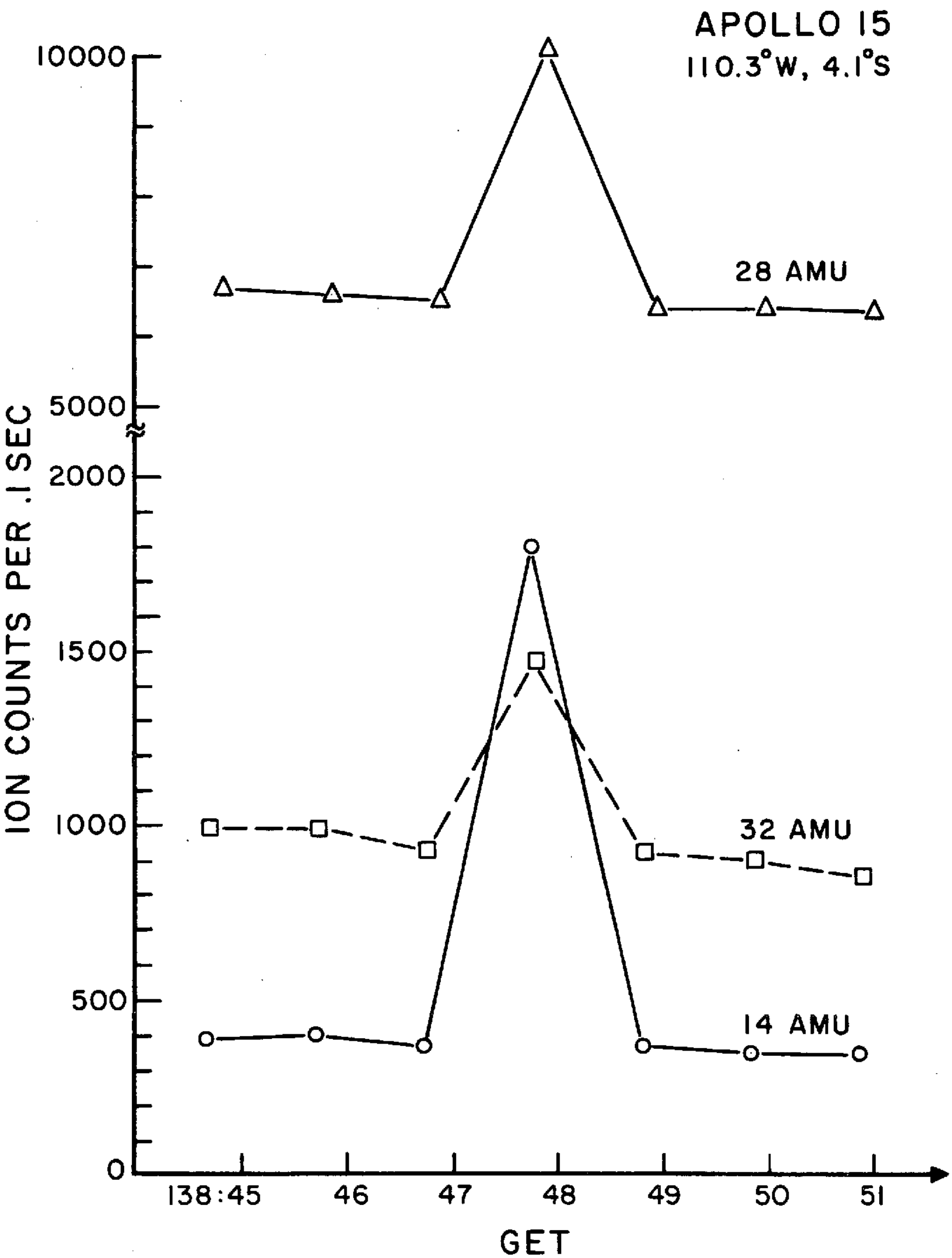
The theoretical model was obtained by application of the Monte Carlo technique of Hodges (1973b). It employs the assumption of no surface adsorption and complete conversion of the solar wind influx of neon ions to neutral, atmospheric atoms. A solar wind flux of 2.4×10^4 $cm^{-2}sec^{-1}$ was adopted on the basis of the measurements by Geiss et al. (1972), which show the ratio of ^4He to ^{20}Ne in the solar wind to be about 570. This flux has been corrected for the fraction of time the moon spends in the geomagnetic tail, and hence not in the solar wind, about four days per lunation. It has also been assumed that the dominant loss mechanism for atmospheric neon is photoionization with a lifetime of 6×10^6 sec, as suggested by Manka (1972). These photoions are accelerated by the $\vec{v} \times \vec{B}$ field of the solar wind so that about half escape while the other half impact the moon and are subsequently recycled into the atmosphere.

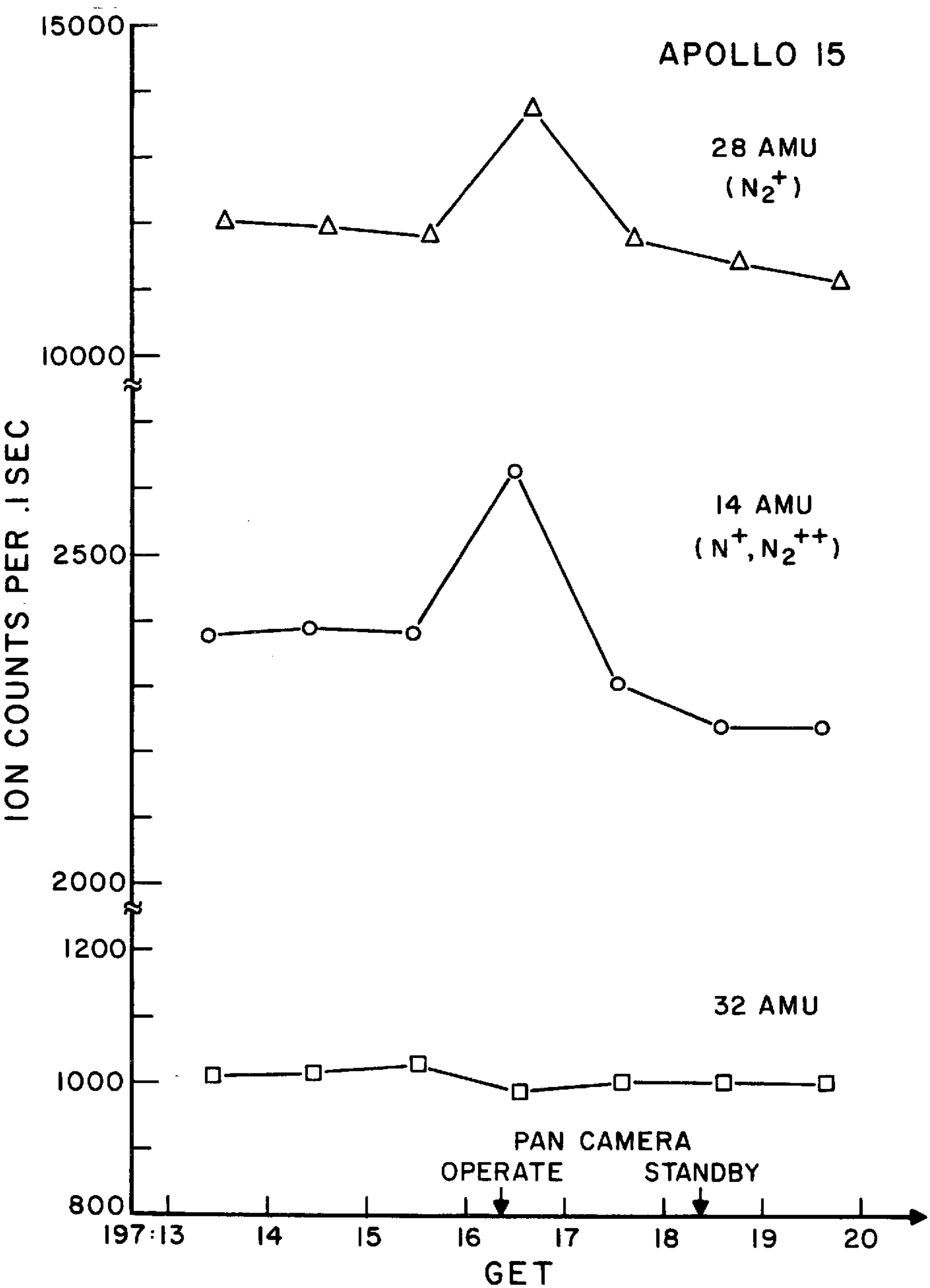
Close agreement of theory and experiment suggests that the assumptions of the model are essentially correct. The failure of the Apollo 17 data to rise late in the night may be interpreted as an indication of a very slight amount of surface adsorption. Comparison with argon calculations (Hodges et al., 1973b) indicates that the fraction of surface encounters which result in adsorption is probably the order of 10^{-4}.

Evidence of lunar volcanism

In all of the data from the orbital mass spectrometers on Apollo 15 and Apollo 16, and preliminary data from the Apollo 17 lunar surface instrument, only one probable volcanic event has been discovered. Figure 2 shows measurements at masses 14, 28 and 32 amu from the Apollo 15 orbital mass spectrometer. The sudden excursions of these three masses occurred at 0822 hours GMT on August 6, 1971, as the spacecraft passed over 110.3° W, 4.1°S (i.e. northwest of Mare Orientale and in lunar night). No coincident change occurred at any other mass in the spectrum from 12 to 67 amu. Excursions with amplitudes similar to that at 32 amu would have been detected at all masses except 16, 17, 18 and 44 amu, which were dominated by large contaminant levels (Hodges et al., 1972a). The absence of other substances in this event may be a temporal artifact, caused by a short lived disturbance that did not span the entire duration of one sweep of the mass spectrum (62 seconds).

It is practical to rule out some conjectured causes of this event. There is no evidence of recurrence of this pattern of gas release that would suggest a spacecraft origin. The lone crew member was asleep when the event occurred, and all monitors of spacecraft operation were nominal. A similar type of perturbation of only 14 and 28 amu shown in Figure 3 was produced by the release of a large quantity of N_2 from the panoramic camera whenever its control was switched (by the crewman) to "operate."


APOLLO 15
110.3°W, 4.1°S
ION COUNTS PER .1 SEC
10000
5000
2000
1500
1000
500
0
28 AMU
32 AMU
14 AMU
138:45
46
47
48
49
50
51
GET


APOLLO 15
28 AMU
(N_2^+)
14 AMU
(N^+, N_2^{++})
32 AMU
ION COUNTS PER .1 SEC
15000
10000
2500
2000
1200
1000
800
PAN CAMERA
OPERATE
STANDBY
197:13
14
15
16
17
18
19
20
GET

The panoramic camera produced no effect at 32 amu, while the ratio of 28 amu to 14 amu was typical of the cracking pattern of N_2, and different from that of the supposed volcanic event of Figure 2. Thus accidental release of N_2 from the camera is not a plausible explanation of the event.

While the above comparison seems to indicate that the volcanic gas at 28 amu was not entirely N_2, the absence of a large effect at 12 amu seems to rule out the dominance of CO as well. A mixture of N, N_2 and a small amount of CO would be plausible, however. Mass 32 amu could have been O_2, or possibly SO_2 if the duration of the event were short enough to have dissipated by the time the instrument measured 64 amu (about 20 sec after the 32 amu measurement).

In a word, the event shown in Figure 2 asks more questions than it answers. The origin of its component gases is difficult to explain in terms of volcanism. Certainly N and O_2 are unlikely constituents. On the positive side, the rate of gas release necessary to have produced this event can be extrapolated from the work of Hodges et al. (1972a) to be the order of 1 kg/sec, or about 20 kg total, which is small in volcanic terms, albeit a significant contribution to the lunar atmosphere.

SYNOPSIS OF LUNAR ATMOSPHERE MORPHOLOGY

A summary of the present knowledge of lunar atmospheric constituents is given in Table 1. Amounts of helium, ^{20}Ne and ^{36}Ar, which are known from Apollo 16 and Apollo 17 mass spectrometer data (Hodges et al., 1973a; Hoffman et al., 1973 respectively), are in balance with the solar wind influxes of these species. (Hodges, 1973b, and Hodges et al., 1973b). The lack of a large accumulation of hydrogen in the lunar soil suggests that the solar wind influx of protons is similarly converted to a neutral gas, presumably H_2, to equalize rates of accretion and escape of hydrogen.

TABLE 1

SUMMARY OF LUNAR ATMOSPHERE PARAMETERS

		H	H_2	^{4}He	^{20}Ne	^{36}Ar	^{40}Ar
Solar wind influx(ions/sec)		2.8×10^{25}		1.3×10^{24}	2.2×10^{21}	8.0×10^{19}	-
Lunar venting (atoms/sec)		-	-	-	-	-	8.7×10^{20}
Photoionization time (sec)		10^7	10^7	10^7	6×10^6	1.6×10^6	1.6×10^6
Residence time (sec) §		1.2×10^3	7×10^3	8×10^4	4×10^7	10^7	10^7
Concentration (cm^{-3}):							
Theory	day	(6×10^2)‡	2×10^3	1.7×10^3	4×10^3	1.3×10^2	1.6×10^3
	night	(1.6×10^3)‡	1.2×10^4	4×10^4	1.8×10^5	3×10^3†	4×10^4†
Experiment*	day	$<10^1 cm^{-3}$	$< 6 \times 10^3$	2×10^3	-	-	-
	night	-	$<3.5 \times 10^4$	4×10^4	10^5	3×10^3†	4×10^4†

§ Hydrogen and helium escape thermally, while photoionization controls lifetimes of the other gases.

* Daytime upper bounds on H and H_2 are Apollo 17 orbital ultraviolet spectrometer results (Fastie et al.,1973) while the remaining data are from Apollo mass spectrometer experiments.

† Sunrise terminator maxima are given for argon. Surface adsorption removes most of the nighttime argon.

‡ Amounts that would be present if released in atomic rather than molecular form.

By analogy, it is reasonable to expect that the carbon and nitrogen influxes from the solar wind are also balanced by atmospheric escape. The molecular forms in which these elements appear remain to be established, but probably these are CH_4 and NH_3.

The presence of excess amounts of ^{40}Ar trapped in returned lunar samples has been recognized as evidence of ^{40}Ar as an atmospheric gas (Manka and Michel, 1971). More recently, ^{40}Ar has been identified in the lunar atmosphere by the Apollo 17 mass spectrometer (Hodges et al., 1973a, b Hoffman et al., 1973). Since the only known source of ^{40}Ar is radiogenic decay of ^{40}K within the moon, its presence in the atmosphere is evidence of a venting process which may involve other gases. The alpha particle experiments on Apollo 15 and Apollo 16 have shown evidence of atmospheric ^{222}Rn and its long lived daughter ^{210}Po on the moon (Bjorkholm et al., 1973; Gorenstein et al., 1973). One interpretation of an imbalance of radon and polonium in the alpha particle data is that sporadic venting of other gases may cause spatial and temporal fluctuations in the rate of effusion of radon. Whether venting rates of ^{40}Ar and ^{222}Rn are related is speculative at this time.

DATA AVAILABILITY

Data from the Lunar Orbital Mass Spectrometer experiments conducted on Apollo 15 and 16 missions will have been deposited in the National Space Science Data Center (NSSDC) in the form of SD4060 microfilm plots of mass spectra and peak summaries by the time this Final Report is distributed. These films are on 10 standard microfilm reels and are labeled according to date and time when the data were recorded. Similar data are available on magnetic tape.

The NSSDC is located at Goddard Space Flight Center, Greenbelt, Maryland.

Bjorkholm, P., L. Golub, and P. Gorenstein, Detection of radon emanation from the lunar regolity during Apollo 15 and 16 (abstract), in Lunar Science IV, edited by J. W. Chamberlain and Carolyn Watkins (Lunar Science Institute, Houston, Texas), 78, 1973.

Fastie, W. G., P. D. Feldman, R. C. Henry, H. W. Moos, C. A. Barth, G. E. Thomas, and T. M. Donahue, A search for far ultraviolet emissions from the lunar atmosphere, submitted to Science, 1973.

Geiss, J., F. Buehler, H. Cerutti, P. Eberhardt, Ch. Filleux, Solar wind composition experiment, Apollo 16 Preliminary Science Report, NASA SP-315, 14-1, 1972.

Gorenstein, P., L. Golub, and P. Bjorkholm, Spatial nonhomogeneity and temporal variability in the emanation of radon from the lunar surface: interpretation (abstract), in Lunar Science IV edited by J. W. Chamberlain and Carolyn Watkins (Lunar Science Institute, Houston, Texas) 307, 1973.

Hinton, F. L., and D. R. Taeusch, Variation of the lunar atmosphere with the strength of the solar wind, J. Geophys. Res., 69, 1341, 1964.

Hodges, R. R., Applicability of a diffusion model to lateral transport in the terrestrial and lunar exospheres, Planet. Space Sci., 20, 103, 1972.

Hodges, R. R., The differential equation of exospheric lateral transport and its application to terrestrial hydrogen, J. Geophys. Res., in press, 1973a.

Hodges, R. R., Helium and hydrogen in the lunar atmosphere, J. Geophys. Res., in press, 1973b.

Hodges, R. R., and F. S. Johnson, Lateral transport in planetary exospheres, J. Geophys. Res., 73, 7307, 1968.

Hodges, R. R., J. H. Hoffman, T. T. J. Yeh, and G. K. Chang, Orbital search for lunar volcanism, J. Geophys. Res., 77, 4079, 1972a.

Hodges, R. R., J. H. Hoffman and D. E. Evans, Lunar orbital mass spectrometer experiment, Apollo 16 Preliminary Science Report, NASA SP-315, 21-1, 1972b.

Hodges, R. R., J. H. Hoffman, F. S. Johnson, and D. E. Evans, Composition and dynamics of lunar atmosphere, Proc. Fourth Lunar Sci. Conf., (Pergamon), in press, 1973a.

Hodges, R. R., J. H. Hoffman, and F. S. Johnson, Lunar atmosphere, (paper in preparation), 1973b.

Hoffman, J. H., R. R. Hodges, and D. E. Evans, Lunar orbital mass spectrometer experiment, Apollo 15 Preliminary Science Report, NASA SP-315, 19-1, 1972a.

Hoffman, J. H., R. R. Hodges, and D. E. Evans, Lunar orbital mass spectrometer experiment, Proc. Third Lunar Sci. Conf., Geochim. Cosmochim Acta, Suppl. 3, Vol 3, 2205, 1972b.

Hoffman, J. H., R. R. Hodges, and D. E. Evans, Lunar atmospheric composition results from Apollo 17, Proc. Fourth Lunar Sci. Conf., (Pergamon), in press, 1973.

Johnson, F. S., Lunar atmosphere. Rev. Geophys. Space Phys., 9, 813, 1971.

Johnson, F. S., J. M. Carroll, and D. E. Evans, Lunar atmospheric measurements, Proc. Third Lunar Sci. Conf., Geochim Cosmochim Acta, Suppl. 3, Vol. 3, 2231, 1972.

Manka, R. H., Lunar atmosphere and ionosphere, Ph.D. Thesis, Rice University, 1972.

Manka, R. H., and F. C. Michel, Lunar atmosphere as a source of lunar surface elements, Proc. Second Lunar Sci. Conf., Geochim Cosmochim Acta, Suppl. 2, Vol 2, 1717, 1971.