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# GSFC VENUS ATMOSPHERE SIMULATOR

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### ABSTRACT

The design and preliminary testing of a Venus Atmosphere Simulation System are described. The system was designed for testing a quadrupole mass spectrometer proposed for the Pioneer-Venus Experiment. The system is capable of providing programmed temperature cycles up to 550°C, and manually controlled pressure up to 100 atmospheres.

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CONTENTS

	<u>Page</u>
ABSTRACT . . . . .	iii
OBJECTIVE . . . . .	1
AUTHORIZATION . . . . .	1
RESULTS. . . . .	1
DESCRIPTION OF SYSTEM	
Chamber . . . . .	1
Gas Transfer System . . . . .	2
Temperature Control System . . . . .	2
Thermocouple Assembly. . . . .	3
Insulation . . . . .	3
PRELIMINARY TESTING . . . . .	3
APPENDIX A   PHOTOGRAPHS OF SYSTEM . . . . .	A-1

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## ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Test Chamber Assembly . . . . .	5
2	Schematic Diagram, Gas Transfer System . . . . .	6
3	Schematic Diagram, Electrical . . . . .	7
4	Thermocouple Assembly . . . . .	8
5	Descent Temperature, Model and Result . . . . .	9
App. A	Photographs of Venus Atmosphere Simulator . . . . .	A-1

## GSFC VENUS ATMOSPHERE SIMULATOR

### OBJECTIVE

The goal of this program was to develop and construct an environmental system capable of simulating the entry conditions expected to be experienced by a proposed Pioneer-Venus experiment package. The simulation system was designed for ground-based testing of a candidate quadrupole mass spectrometer and its associated sampling mechanisms. The system is capable of simulating the anticipated temperature-time and pressure-time profiles of entry.

### AUTHORIZATION

The Engineering Services Division was authorized by Work Request No. 623-76361-0052 of October 10, 1973, submitted by the Experiment Development and Operations Branch, Laboratory for Planetary Atmospheres, to fabricate one high temperature, high pressure reaction chamber. The task also required design, engineering, and testing.

### RESULTS

Laboratory test runs indicate that the simulation system is capable of simulating the temperature-time profile anticipated in a proposed Pioneer-Venus experiment. The pressure-time profile can be maintained manually if a heated gas source is employed. Minor gas leakage problems were encountered around the main flange seal. High strength titanium bolts have been installed to provide more clamping force, but no further tests have been conducted.

### DESCRIPTION OF SYSTEM

#### CHAMBER

The heart of the Venus Atmosphere Simulation system is a specially designed stainless steel pressure vessel containing integral socketed heaters, provisions for gas flow, and accessory feedthroughs to accommodate thermocouple assemblies. The chamber is fabricated from an AISI 316 stainless steel forging per Figure 1. The main sealing flange is a Hughes Aircraft Co. non-rotatable blank flange Model VF 800-2. Two flanges are provided; one blank, for testing and calibrating the simulation system, and a similar flange modified to accept the Quadrupole Mass Spectrometer structural model. The pressure vessel is jacketed to provide for cooling using liquid nitrogen.

The pressure chamber was designed jointly by the Fabrication Technology Section, Fabrication Engineering Branch and the Experiment Development and

Operations Branch. In order to avoid time consuming developmental problems, the chamber was designed employing the following principles:

1. Avoiding mechanical feedthroughs, and minimizing gas stratification with adequate gas flow, using internal baffling where required.
2. Eliminating gas-heater contact. Hot heaters contaminate the gas, and the heaters may be chemically attacked by the hot gases.
3. Avoiding dependence upon internal insulation.
4. Avoiding hot electrical feedthroughs for heaters and thermocouples.
5. Minimizing the mass to be heated.
6. Avoiding welds in the pressure vessel.
7. Allowing maximum flexibility for other potential applications.

#### GAS TRANSFER SYSTEM

A schematic diagram of the gas transfer system is shown in Figure 2. The simulation system was designed for use with bottled carbon dioxide or mixtures of carbon dioxide and other gases. All high pressure tubing is AISI 304 stainless steel, 0.25 inch O. D., 0.065 inch wall thickness. The vacuum pump, vacuum gauge tube, and low pressure transducer are isolated from the high pressure by a manually operated valve. Exhaust gas flow rate is controlled by a high pressure micrometer needle valve. All valves and controls, with the exception of the gas bottle regulator, are mounted on the front panel; the pressure vessel and high pressure lines are located behind a safety shield.

#### TEMPERATURE CONTROL SYSTEM

The temperature control system is described schematically in Figure 3. The temperature-time profile is controlled automatically by a solid state power controller whose set point is varied by a curve-following programmer. Twelve Chromalox Model CIR-2080 cartridge heaters, inserted into sockets in the pressure vessel, are capable of supplying up to 8400 watts at 240 VAC, or 6300 watts at 208 VAC.

The temperature control system consists of a Research, Inc. Series 625, Model 6000 Thermac Controller with 60 ampere capacity integral phaser. The controller has the capability for operation in manual, set point, or program

modes. The programmer is a Data-Trak Model 5110 electrostatic curve follower with a 100 ohm potentiometric output.

The thermocouple range card installed in the controller is calibrated from  $-185^{\circ}\text{C}$  ( $-300^{\circ}\text{F}$ ) to  $650^{\circ}\text{C}$  ( $1200^{\circ}\text{F}$ ) with an iron-constantan thermocouple. Any temperature within this range may be automatically maintained in the set point mode.

#### THERMOCOUPLE ASSEMBLY

The thermocouple assembly, illustrated in Figure 4, consists of two pairs of B&S No. 24 gauge iron-constantan wire, insulated with 1.5mm O. D. glass pipet tubing, encased in a stainless steel sheath. The pressure seal was made with Hysol 151 epoxy adhesive at the end of the sheath most distant from the chamber, where the temperature remains practically ambient. The assembly was designed to permit ease of removal and replacement by disconnecting a compression fitting. Each thermocouple assembly was hydrostatically tested to 2000 psi at  $75^{\circ}\text{F}$  before installation into the simulation chamber.

#### INSULATION

External insulation was provided to reduce heat losses from the pressure vessel. The insulation was cast in two half-cylindrical sections approximately one inch thick using a mixture of powdered asbestos cement, calcined calcium sulfate (plaster of paris), and water. The two halves were clamped onto the pressure vessel outer jacket with modified worm gear clamps.

#### PRELIMINARY TESTING

Four preliminary test runs were made with a blank main flange. The first three were performed while awaiting delivery of the thermocouple range card, so automatic temperature control was not possible. Also, nickel gaskets for the main seal were not yet fabricated, so readily available copper gaskets were substituted, and some seal leakage was expected.

Run No. 1 was performed beginning at room temperature and a pressure of 100 microns of mercury. The evacuated system was backfilled to 500 psig with bottled carbon dioxide. The temperature-power controller was operated in the manual mode, and was arbitrarily set at an output current of 15 amperes. Thermocouples were located on the inner surface of the pressure vessel and in the center of the vessel. The pressure was allowed to rise naturally as the temperature increased. Both temperature locations were monitored using a Leeds and Northrup temperature potentiometer, and the pressure was read from a 0-2000 psig pressure gauge. Leaks around the copper gasket on the main seal developed as the temperature began to increase. The leaks were



stopped by tightening the flange bolts, but enough gas was lost to prevent the system from reaching the desired 100 atmospheres.

The second trial run was performed at a constant heater current of 20 amperes, using a copper gasket. The temperature-time data indicated that the heating rate at 20 amperes input more closely resembled the desired rate than the first run. Again, pressure leaks developed as the temperature began to increase. The pressure reached a maximum of 78.5 atmospheres at the end of the heating cycle.

The third run was performed under the same conditions as the second, except that the chamber was backfilled to full bottle pressure, 965 psig, before the temperature was elevated. Only small leaks developed, again around the copper gasket. No significant loss of gas occurred, and the pressure climbed to 100 atmospheres and was maintained by bleeding off excess gas through the needle valve. Leaks occurred late in the run but the pressure remained near 95 atm.

It should be noted that the pressure leaks occurred during temperature elevations; leaks occurred in all three temperature runs during the first 55°C (100°F) rise.

Test run number 4 was performed using an annealed nickel gasket instead of copper; the thermocouple range card was received and installed in the controller, permitting a programmed temperature profile for the first time. The temperature control system functioned satisfactorily, however, the temperature of the chamber remained a constant 33°C (60°F) below the apparent set point throughout the test run, indicating the need for calibration. No pressure leaks occurred and the starting bottle pressure of 64 atmospheres quickly reached 100 atmospheres, at which time the pressure was maintained by bleeding off gas through the needle valve.

A fifth test run was performed after calibration of the temperature programmer. A structural model of the quadrupole mass spectrometer housing was installed in the modified main flange. A temperature-time curve was plotted from data recorded and was compared to a target curve. Both curves are illustrated in Figure 5. A gas leak occurred early in the test and a sufficient quantity of gas was lost such that the target pressure of 100 atmospheres was not attained. If a warmed carbon dioxide bottle is employed for pressure regulation in future testing, the pressure profile can be restored as small leaks are sealed.

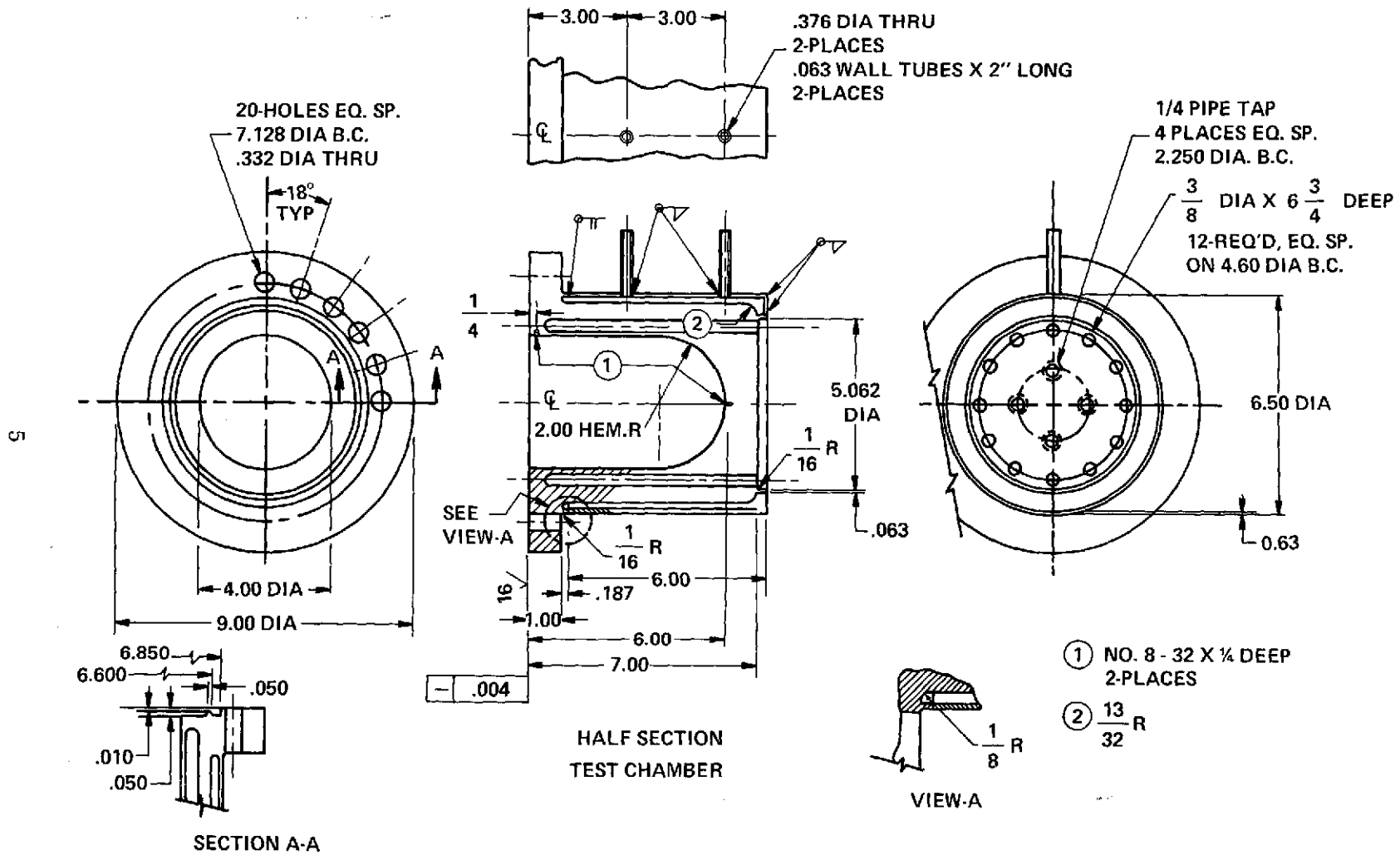


Figure 1. Test Chamber Assembly

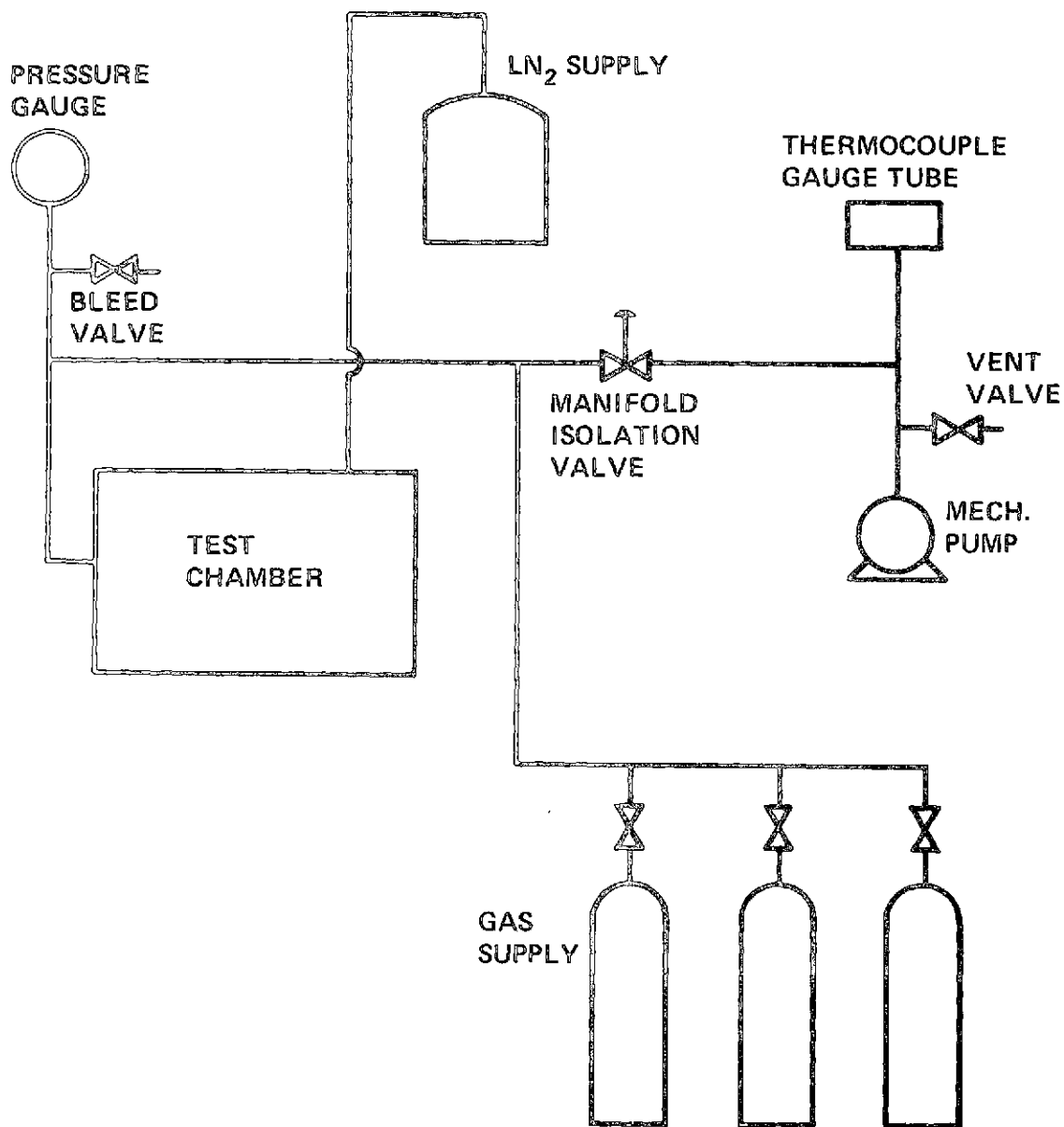


Figure 2. Schematic Diagram, Gas Transfer System

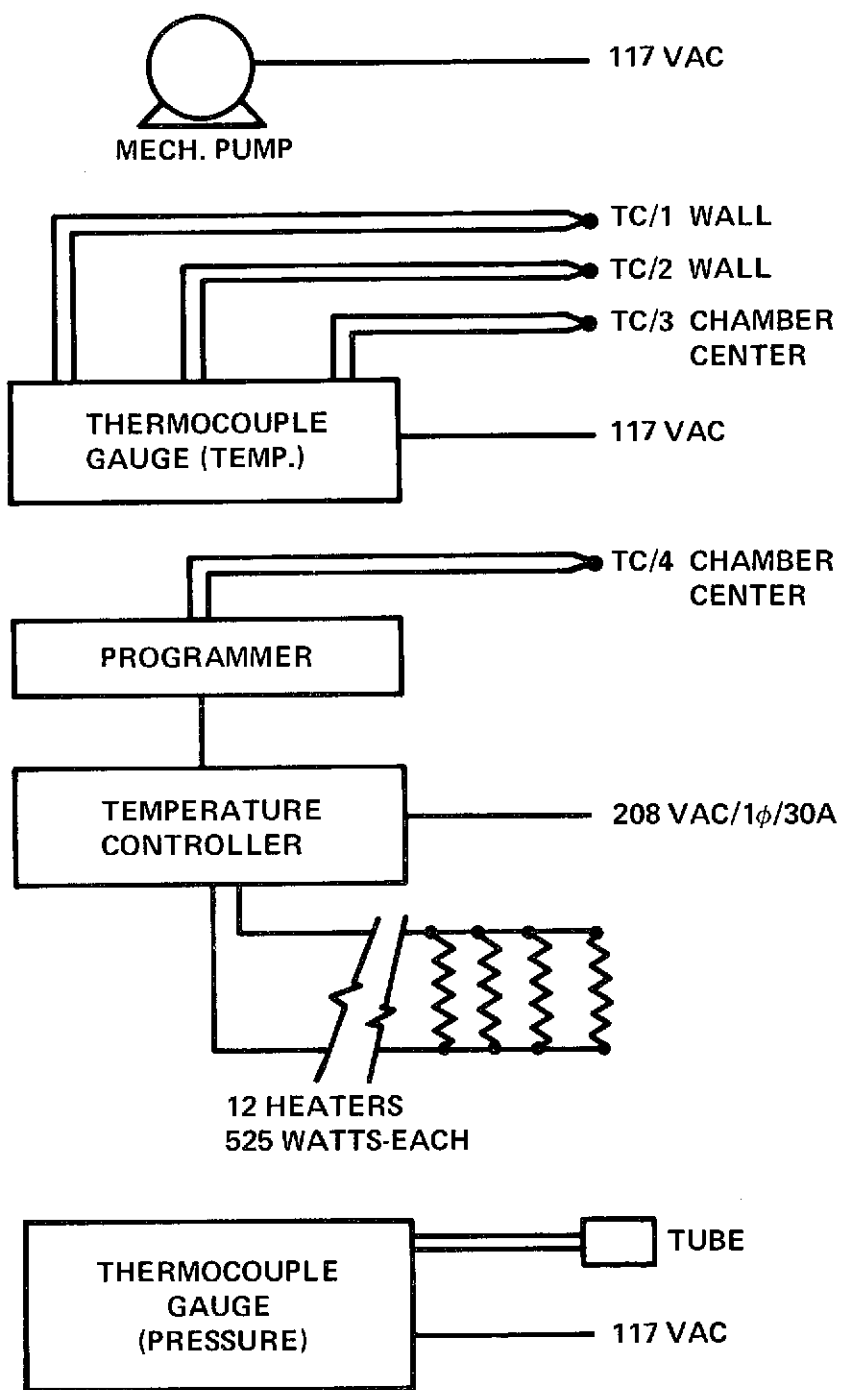


Figure 3. Schematic Diagram, Electrical

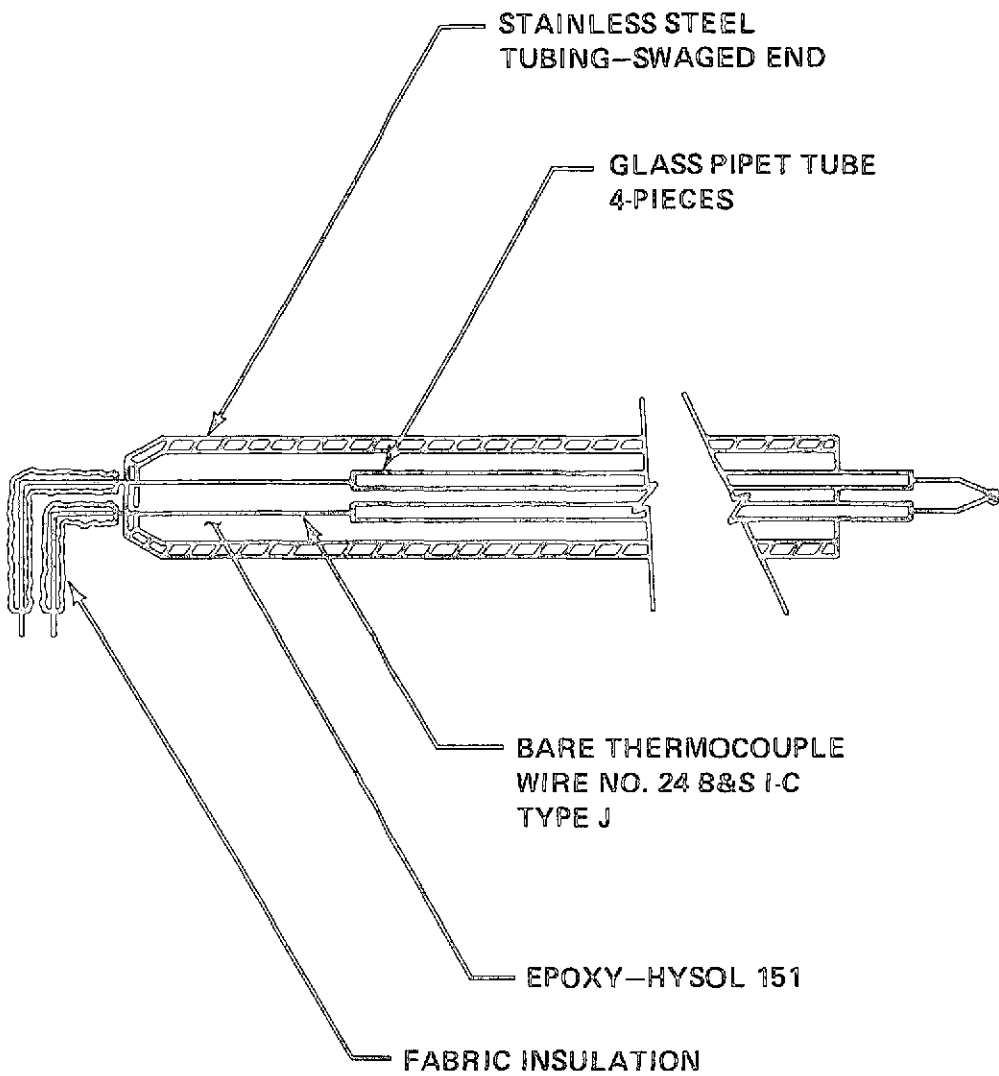


Figure 4. Thermocouple Assembly

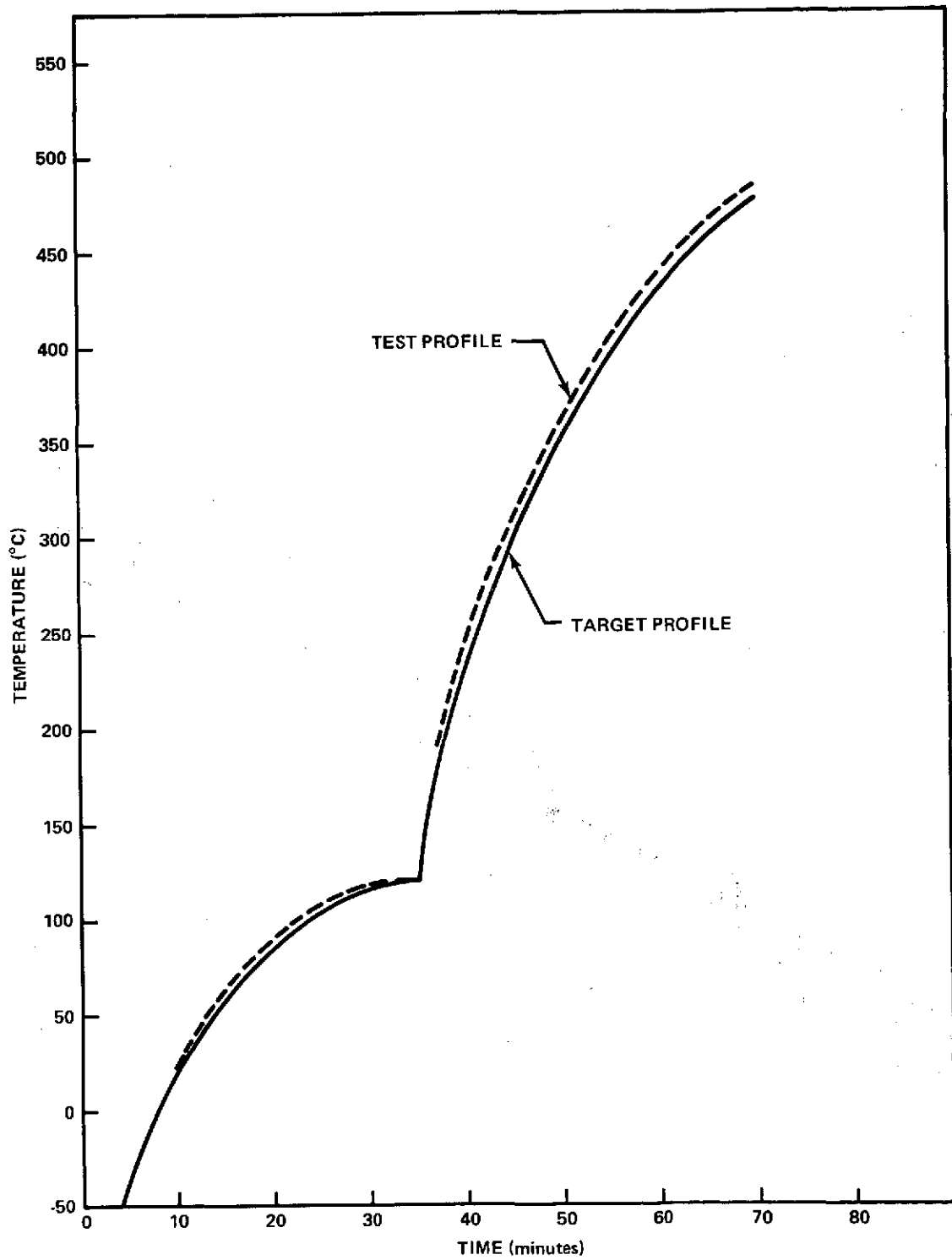
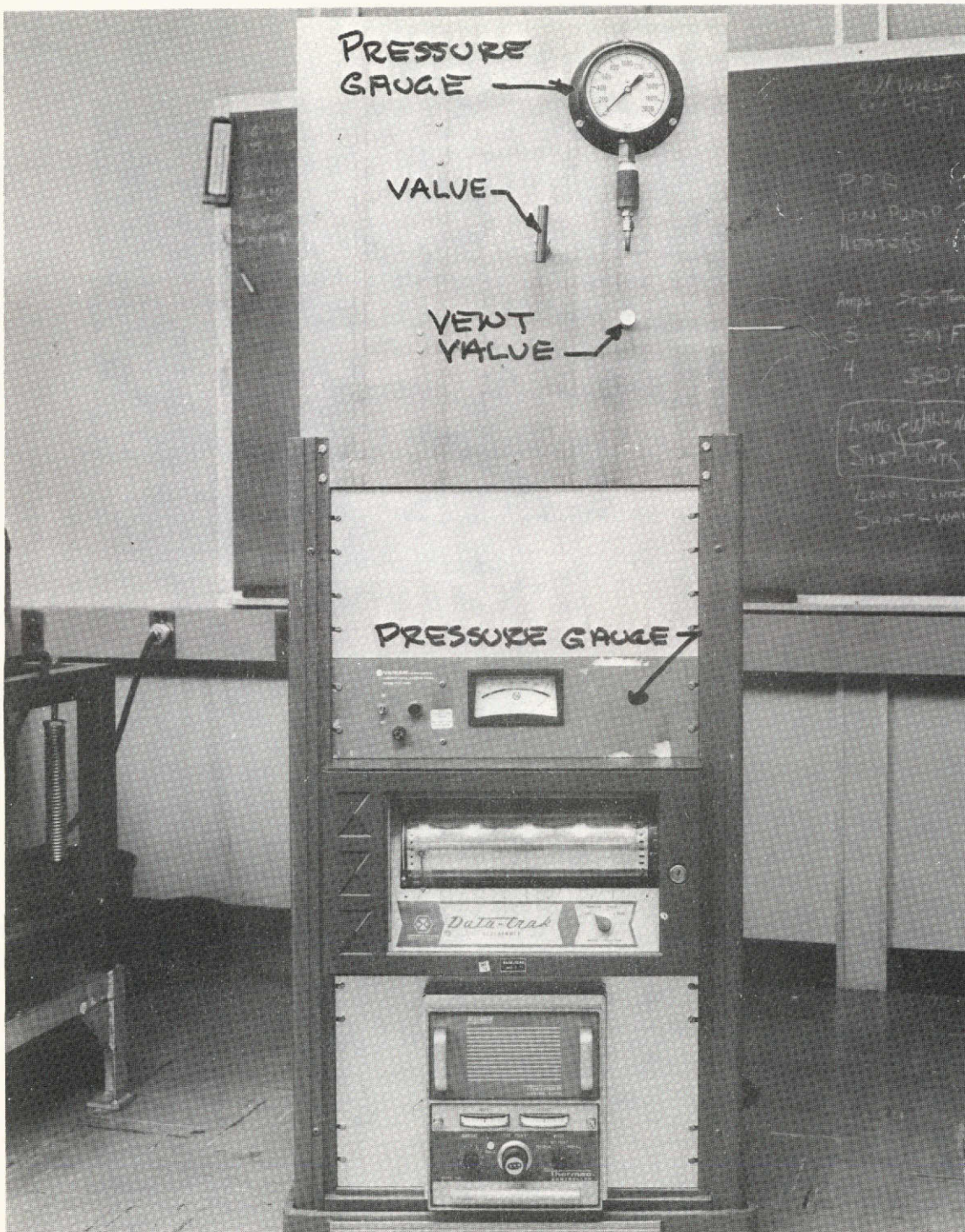


Figure 5. Descent Temperature, Model and Result

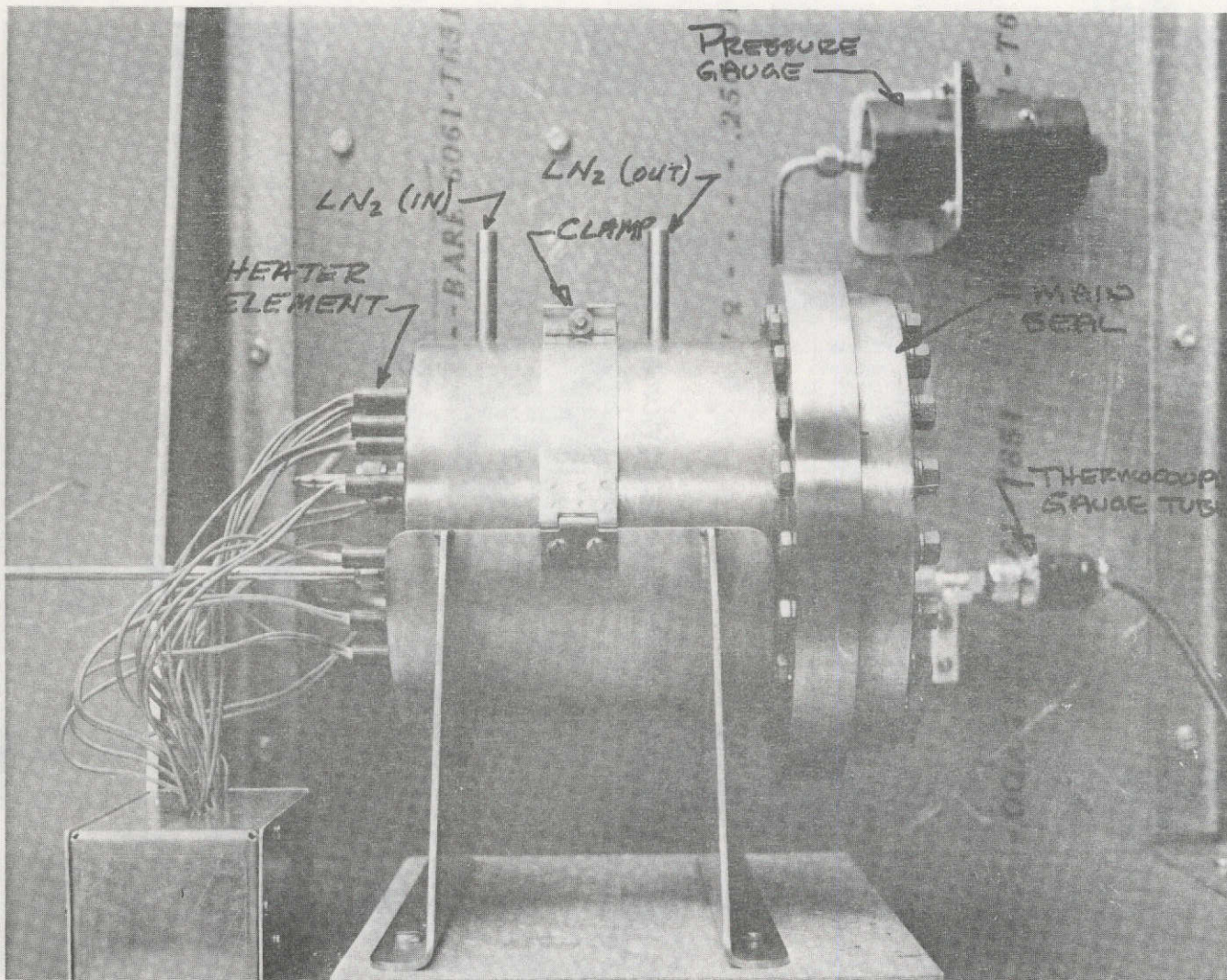
APPENDIX A

Photographs of  
Venus Atmosphere Simulator

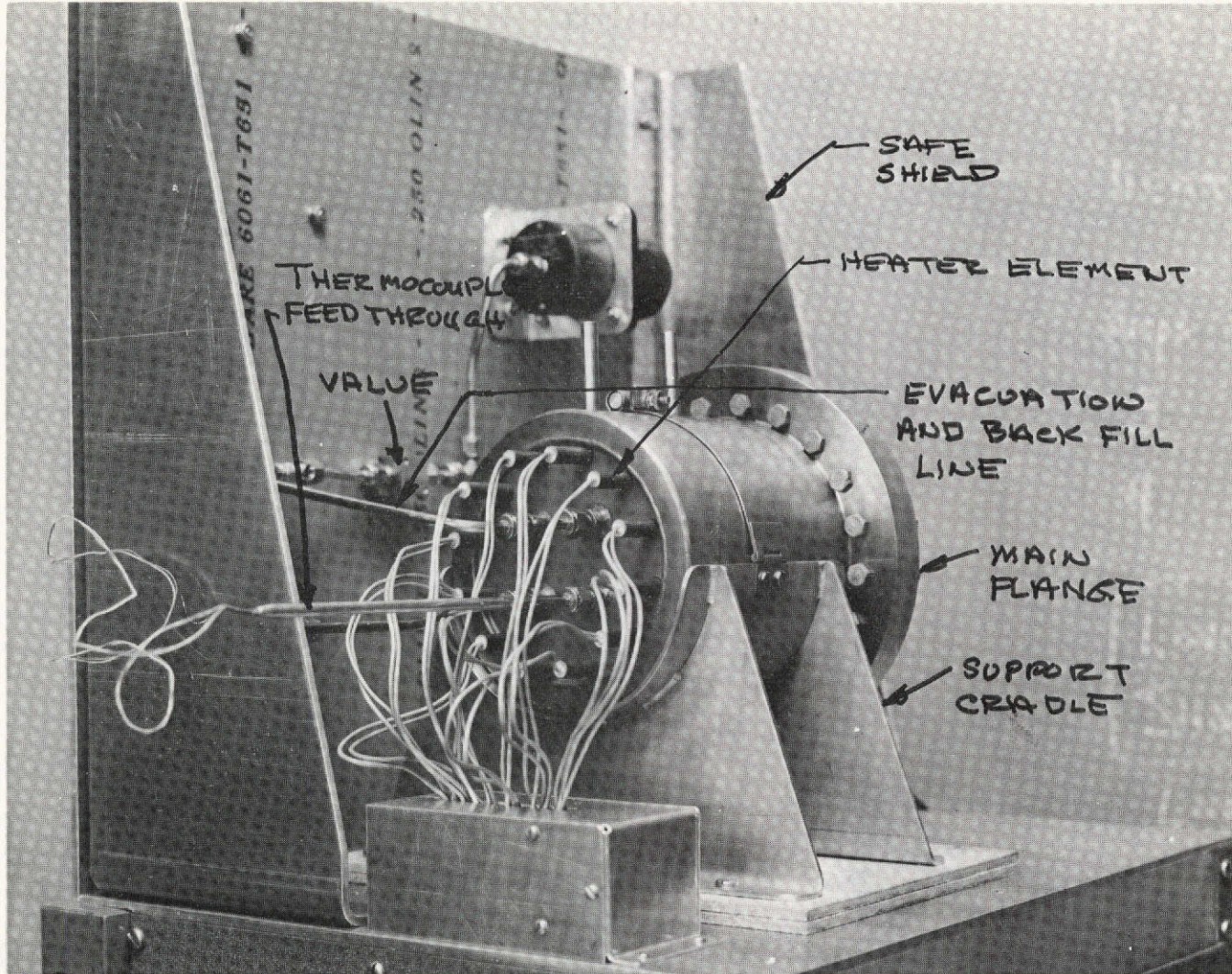


Front View





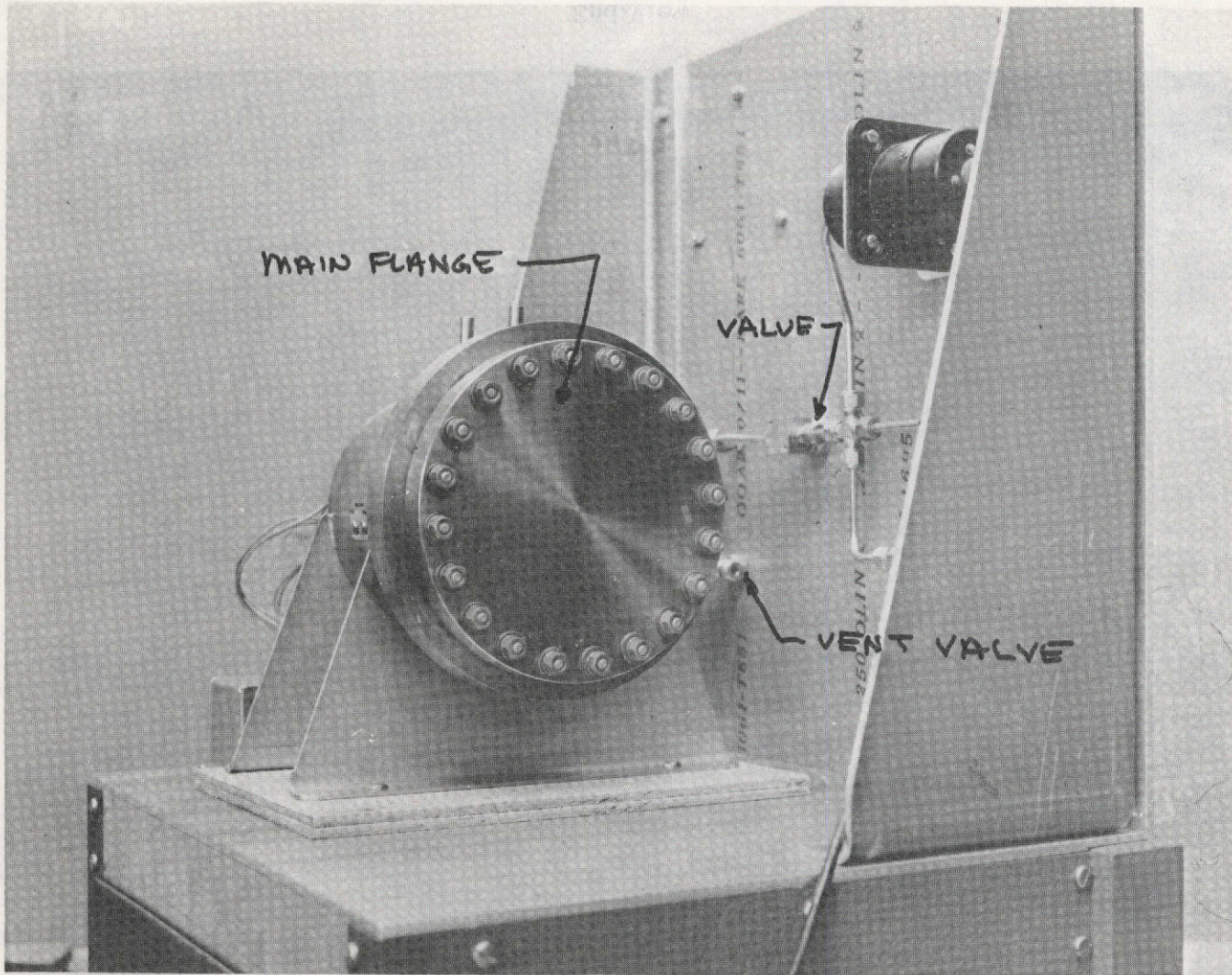
Back View



End View

A-5

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End View