NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-319

Preliminary Description of the Modified JPL 25-ft Space Simulator

Maurice J. Argoud

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

February 1, 1967

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-319

Preliminary Description of the Modified JPL 25-ft Space Simulator

Maurice J. Argoud

Approved by:

George G. Goranson

George G. Goranson, Manager
Space Simulators
and Facility Engineering Section

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

February 1, 1967

Technical Memorandum 33-319

Prepared Under Contract No. NAS 7-100
National Aeronautics & Space Administration

CONTENTS

I. Introduction 1

II. Facility Description 1

A. Vacuum System 4

B. Cryogenic System 8

C. Solar Simulator System 11

III. Supporting Systems 14

A. Electrical Power 14

B. Emergency Power 14

C. Cooling Water 14

D. Pneumatic System 15

E. Hydraulic System 16

F. Air Conditioning and Ventilation 16

IV. Test Item Installation 17

V. Facility Instrumentation Systems 17

A. Pressure 17

B. Temperature 17

C. Solar Radiation 20

D. Vibration 24

E. Spacecraft Power Cutoff System 24

VI. Test Item Instrumentation System 24

A. Data Acquisition 27

B. Data Conditioning 27

C. Data Reduction 28

D. Data Presentation 28

E. Temperature Control 28

CONTENTS (contd)

VII. Facility Design Criteria 29

A. Vacuum System 29

B. Cryogenic System 30

C. Solar Simulation System 32

References 33

Bibliography 34

TABLES

1. Allowable floor loads, 25-ft space simulator 4

2. Pumpdown sequence 6

FIGURES

1. JPL space simulator facility 2

2. JPL 25-ft space simulator 3

3. Site plan, 25-ft space simulator 5

4. Pumpdown curve, 25-ft space simulator (estimated) 7

5. Vacuum system schematic diagram (simplified) 9

6. Cryogenic system schematic diagram (simplified) 10

7. Solar system schematic diagram (simplified) 12

8. Ranger spacecraft in the 25-ft space simulator 18

9. Ranger spacecraft in the 25-ft space simulator 19

10. Eppley Mark I radiometers 21

11. Eppley Mark IV filter radiometer and control console 23

12. Eppley Mark VII radiometer for measuring light beam divergence 25

13. Main floor trench layout 26

ABSTRACT

A description is presented of JPL's 25-ft space simulator, which is designed for environmental testing of unmanned spacecraft under simulated interplanetary conditions of extreme cold, high vacuum, and intense solar radiation.

PRELIMINARY DESCRIPTION OF THE MODIFIED JPL 25-FT SPACE SIMULATOR

I. INTRODUCTION

The Jet Propulsion Laboratory's 25-ft space simulator is designed for environmental testing of unmanned spacecraft under simulated interplanetary conditions of extreme cold, high vacuum, and intense solar radiation. Typical tests include heat balance and temperature distribution studies, investigations of subsystem interactions, tests of attitude-control equipment and sensors, and acceptance tests of flight spacecraft. Figure 1 shows a cross section of the test facility. Figure 2 shows a cross section of the 25-ft space simulator.

II. FACILITY DESCRIPTION

The simulator chamber is a stainless-steel vessel 27 ft in diameter and 85 ft high, having a 15 ft wide by 25 ft high side-opening door for entry and test item loading. The chamber has an ultimate pressure of 5×10^{-6} torr, and the walls and floor are lined with aluminum shrouds capable of a temperature range of -320 to +250°F. A 276-in.-diameter (23 ft) collimating mirror is installed under the top head of the chamber to reflect solar energy down to the test specimen. The mirror is internally cooled through a temperature range of -100 to +200°F.

The test volume of the simulator is 20 ft in diameter by 25 ft high above the chamber floor. This test volume can be irradiated from above by a 15-ft-diameter beam (130 W/ft^2) of simulated solar energy. The spectrum is that of xenon compact arc lamps modified by the simulator optics. The uniformity is ±5% using a 1 cm^2 detector and the maximum beam divergence is 1 deg from vertical. A 30,000-force-lb shaker may be installed in the chamber for vibration testing. Six hard points rated at 10,000 lb vertical load are installed at floor level and at the 36 and 52 ft elevations for spacecraft support. These are oriented for 3 or 4 cable symmetrical support (90 or 120 deg spacing of hard points). A ring will be available later at the 36- or 52-ft elecation for any cable orientation.

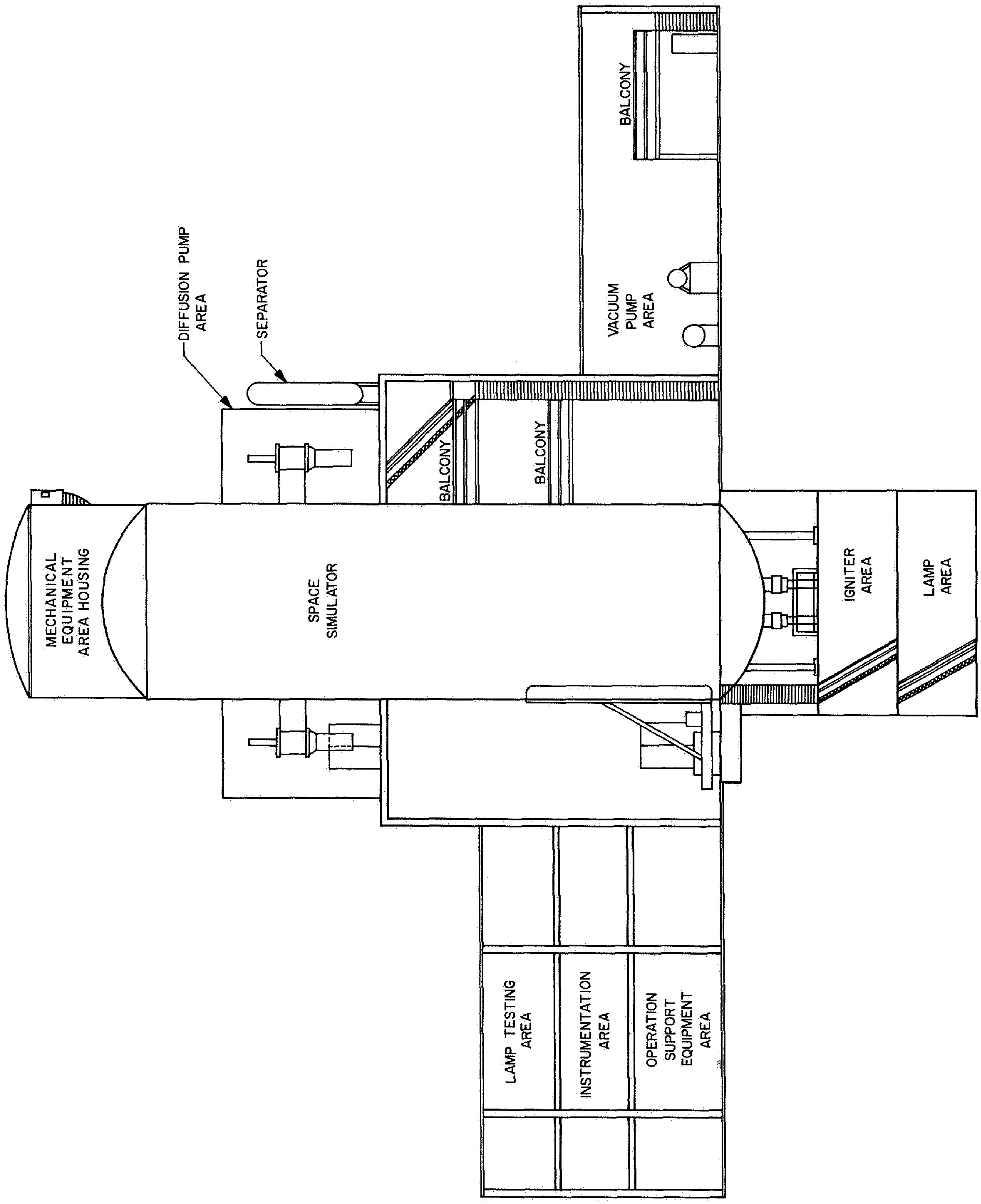

Figure 1. JPL space simulator facility

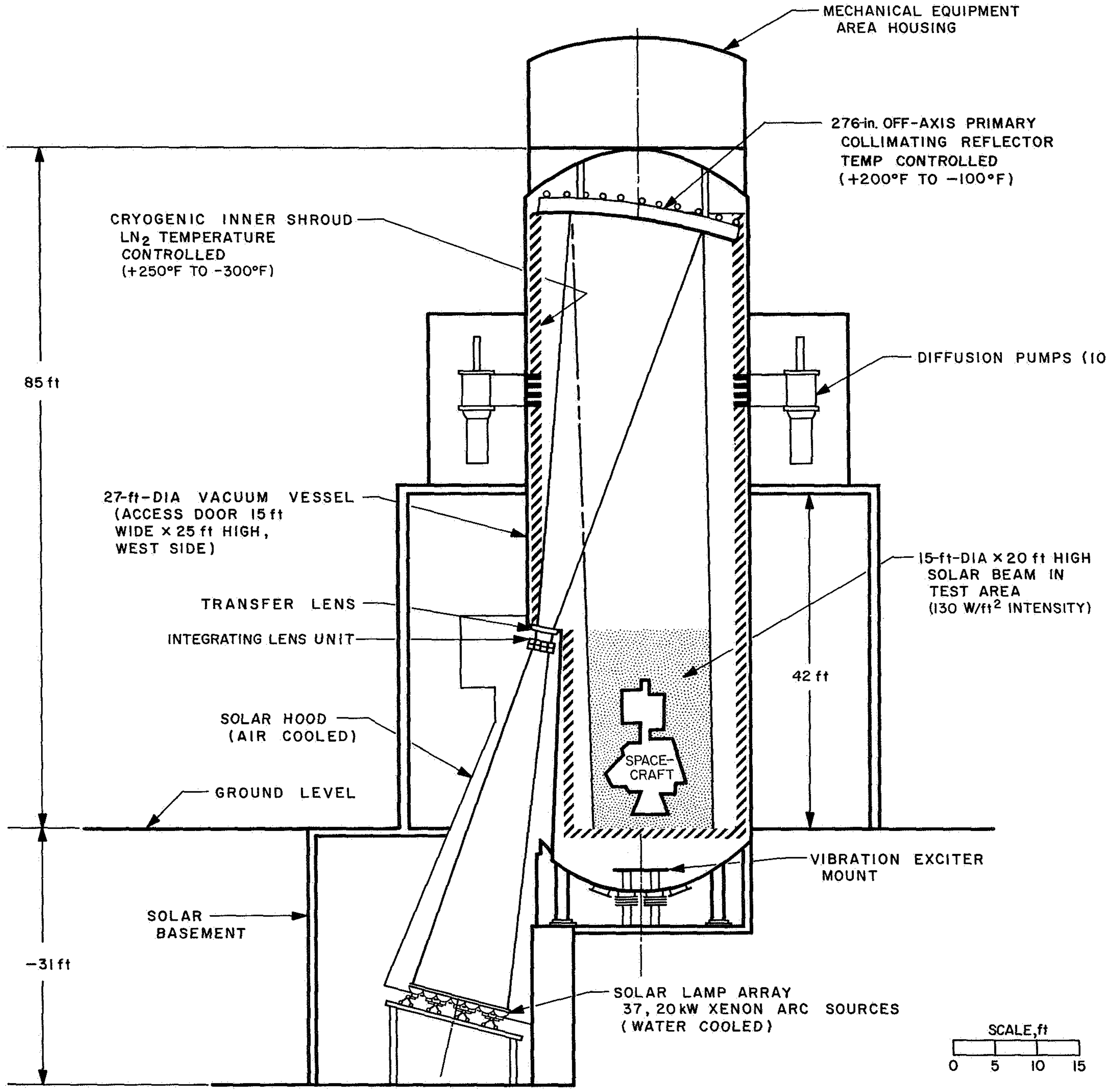

Figure 2. JPL 25-ft space simulator

The entire facility is housed in a partially air-conditioned, pressurized building with separate areas for mechanical equipment, spacecraft preparation, test monitoring equipment, and operations control. All operations of the facility are monitored and controllable from a graphic control console. Figure 3 shows the first floor plan layout; Table 1 presents the allowable floor loads for the entire facility.

Table 1. Allowable floor loads, 25-ft space simulator

Location	Live load maximum, lb/ft^2
Optics Laboratory (Rm. 301)	75
Instrumentation area (Rm. 201)	75
OSE area (Rm. 102)	1500
Spacecraft handling high-bay area (Rm. 104)	1500
Rooms 202, 203, 204 south	50
Rooms 303, 309, 310 north	50
Rooms 308, 309, 310 south	50
Console (Rm. 100)	1500
Mechanical pump room (Rm. 102)	1500
Storage balcony mechanical room	100
Roof loads	20
Diffusion pump room (floor)	20
Diffusion pump roof	30
Simulator balcony 1st floor	100
Simulator balcony 2nd floor	100
Space simulator chamber floor (no safety factor)	100
Alpine scaffold	2000/cable

A. Vacuum System

The vacuum chamber is located in the simulator room (Fig. 3). Its outside diameter is 27 ft, inside diameter (area bounded by wall shroud) 25 ft, and overall height 85 ft. The volume of the chamber is approximately 52,000 ft^3. The west wall of the chamber contains a hydraulically operated, 16-ton door, 25 ft high by 15 ft wide. A 6-ft high by 25-ft wide hand-operated personnel access door is provided at the center of the large door. A tier of 10 diffusion pump ports, 42 in. in diameter,

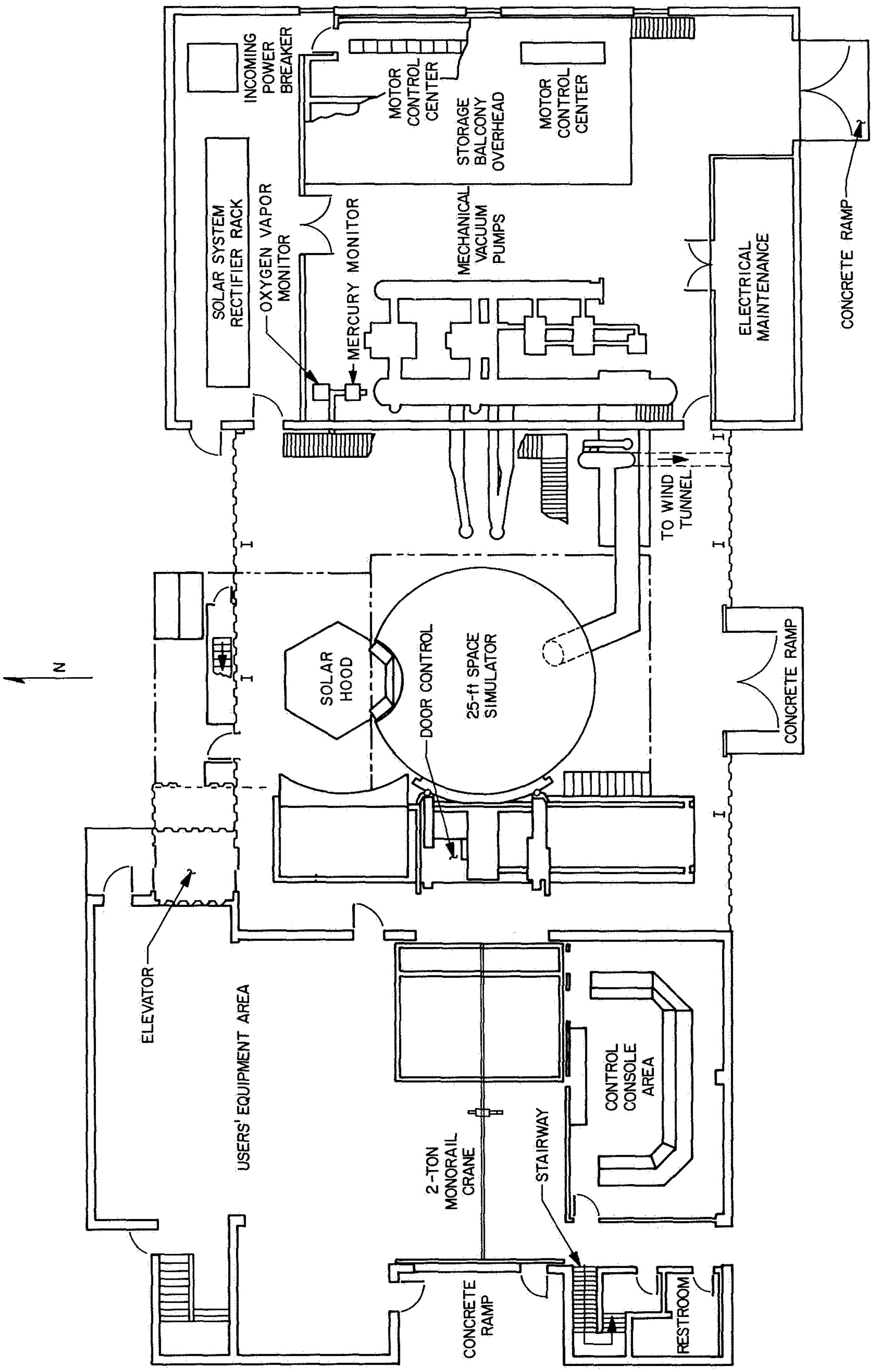

Figure 3. Site plan, 25-ft space simulator

rings the chamber at a height of 54 ft (to centerline) from the floor level. These ports open to large right-angle gate valves attached to cryogenic baffles and the diffusion pumps. A middle and bottom tier of similar pump ports, presently blanked, are placed 29 ft 5 in. and 10 ft 5 in. above the floor. The bottom head of the chamber contains a 36-in.-diameter port which connects to the roughing line.

The vacuum system equipment consists of the following:

10 CVC (Consolidated Vacuum Corp.) 50,000-liter/sec diffusion pumps (using Convoil 20)

2 Stokes No. 1713 blowers rated at 6370 ft^3/min

2 Stokes No. 1711 mechanical pump/blower combinations rated at 300/1250 ft^3/min

1 Stokes No. 412-H mechanical holding pump rated at 300 ft^3/min

In addition to this equipment, a 20-in. pipe line connects the simulator to the JPL wind tunnel compressor plant for "roughing down" the chamber. This plant provides four stages of compression going from 82,000 ft^3/min at atmospheric pressure to 1075 ft^3/min at 2 torr. It can evacuate the chamber from atmospheric pressure to 6 torr in 10 min (Table 2), thereby offering useful launch-profile test capabilities as well as providing an extremely fast roughing system for normal testing. Figure 4 shows a pressure profile for fast pumpdown.

Table 2. Pumpdown sequence

Phase 1	
Wind tunnel compressors	Chamber reaches 6 mm Hg in 10 min
Phase 2	
Mechanical pumps	Chamber reaches 2.5×10^{-2} mm Hg in 35 min
Phase 3	
Diffusion pumps	Chamber reaches 5×10^{-6} mm Hg in 4.5 hr

This same line is used for backfilling the chamber with dry air. Air is passed through the wind tunnel air driers and can be delivered at a maximum rate of 10,000 ft^3/min with a dewpoint of -30°F.

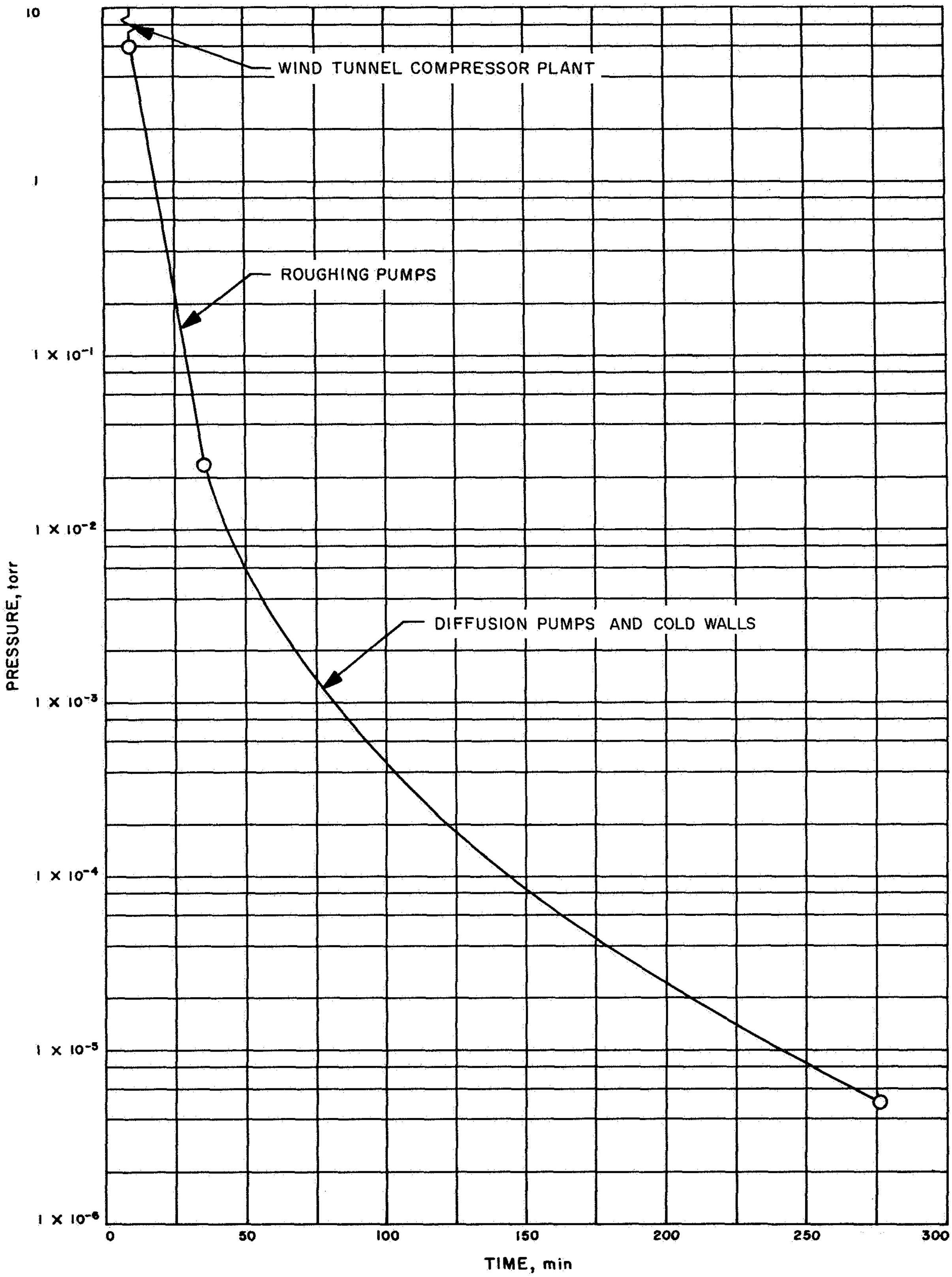

Figure 4. Estimated pumpdown curve, 25-ft space simulator

High vacuum valves are installed at the inlets of all diffusion pumps, and each pump is equipped with a liquid nitrogen (LN_2) baffle to reduce oil backstreaming. All exterior vacuum system piping is made of mild steel. Figure 5 is a schematic diagram of the vacuum system.

B. Cryogenic System

The cryogenic system (Fig. 6) operates either with LN_2 to approximately -320°F or with gaseous nitrogen (GN_2) at between -250 to +250°F. All shrouds and associated piping inside the chamber are made from extruded aluminum. Other portions of the system including the blowers, pumps, heaters, and exterior piping are made of stainless steel. All surfaces of the shrouds facing a test vehicle are coated with Cat-a-lac* flat black paint (No. 463-1-8) for high absorptivity. The shroud surface facing the chamber wall and the inside surface of the chamber wall have high reflecting surfaces to minimize radiant heat transfer.

The major components of the cryogenic system have individual thermal control capabilities. These components are listed as follows:

(1) Wall shrouds. These shrouds comprise five sections, including the door shroud and a "washer" shroud section at the diffusion pump ports. Gaseous nitrogen may be used with a chiller/600-kW heater and blower rated at 165,000 lb/hr at 90 psig and 100°F (37,200 ft^3/min).

(2) Floor shrouds. These shrouds consist of an inner and outer section. Gaseous nitrogen may be used with a heater and blower rated at 21,300 lb/hr at 90 psig and 100°F (4800 ft^3/min).

(3) Mirror cooling equipment (GN_2 only). This equipment consists of an array of cooling passages welded to the back of the mirror with a chiller/300-kW heater and blower rated at 32,000 lb/hr at 90 psig and 200°F (7200 ft^3/min).

(4) Contamination plates. This equipment consists of two stainless-steel-plate coil panels, each approximately 12 ft^2 in area. A 2.5-kW heater is available for warm-up.

(5) Diffusion pump baffles. This equipment comprises 10 stainless-steel, chevron-type baffles integrally mounted in the top of each diffusion pump.

*Trade name of two-element polymerizing epoxy paint made by Finch Paint and Chemical Co., Torrance, California.

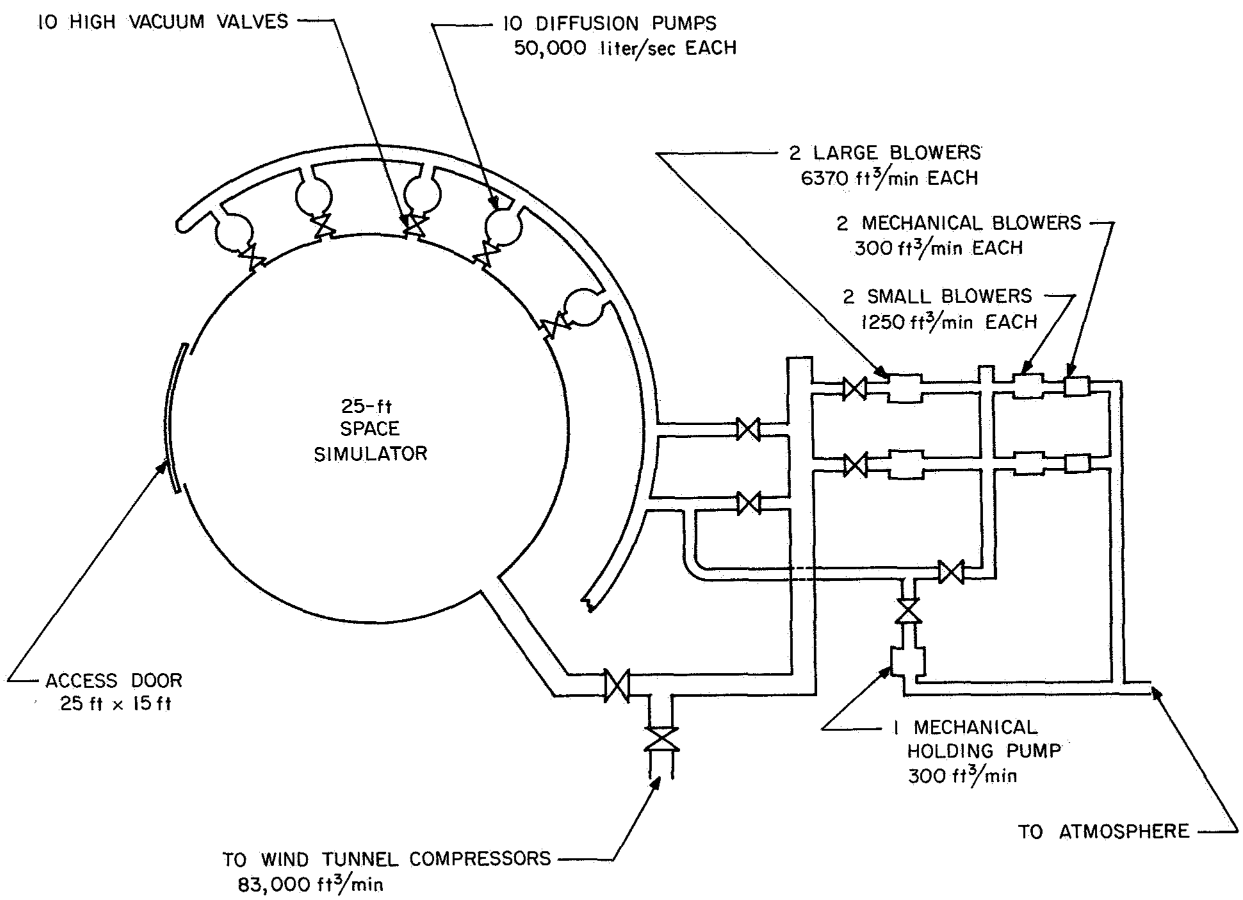

Figure 5. Vacuum system schematic diagram (simplified)

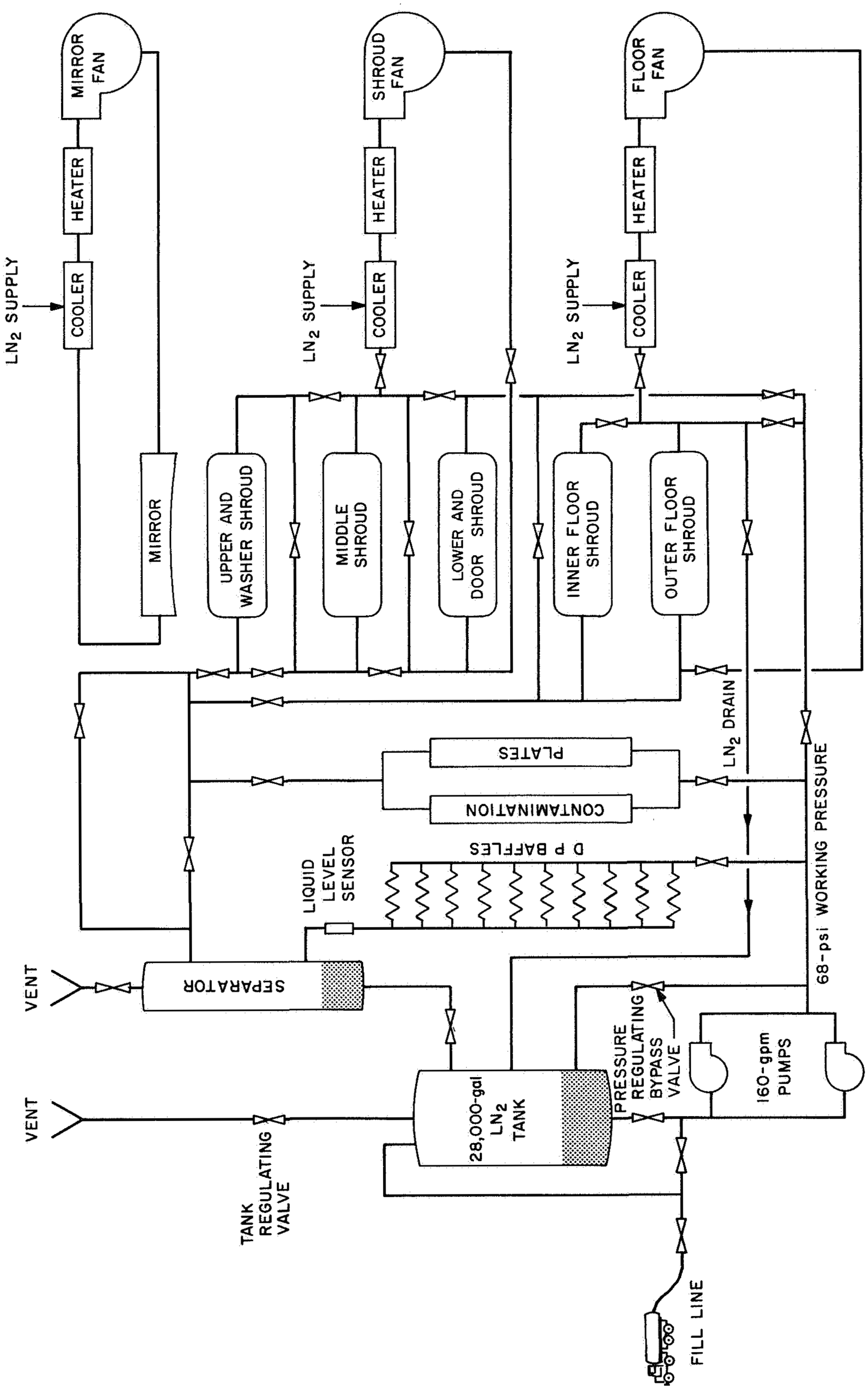

Figure 6. Cryogenic system schematic diagram (simplified)

During liquid phase operations (except at cool-down), the LN_2 system operates as a fully flooded, single-phase system from a head/separator tank located on the roof of the facility. Cool-down time from ambient to LN_2 temperature is approximately 1 hr.

All LN_2 is supplied to this chamber from a 28,000-gal LN_2 storage tank used in common with the JPL 10-ft space simulator. The GN_2 is obtained from a 2000-psi, Laboratory-wide distribution system. Shroud temperatures are monitored at multiple points on the wall and floor shrouds.

C. Solar Simulator System

The installed system (Fig. 7) is capable of producing an illuminated slightly barrel-shaped cylinder with a diameter of 15 ft. Its useful height is 25 ft. This is established by uniformity consideration and direct infrared radiation from the solar penetration window. The major components of the solar simulator system are as follows:

(1) Lamp array. This array comprises a hexagonal grouping of 37 20-kW compact xenon arc lamps mounted in ellipsoidal reflectors (26 3/4-in. diameter, 4-in. F_1, 544-in. F_2, 116-deg capture angle, cast aluminum, water-cooled) and operating at 450 A and 45 Vdc with a water-cooled cathode and anode. Capacitor discharge-spark-gap-type igniters are included in each lamp circuit and furnish a 50-kV pulse to establish the arc.

(2) Mixing lenses. This equipment consists of an entrance lens assembly and an exit lens assembly, each approximately 20 in. in diameter and made up of 19 hexagonal lenses. The entrance (condensing) lenses are mounted in a water-cooled copper frame; the exit (transfer) lenses are mounted in an air-cooled stainless-steel frame. The mixing lens spacing is adjustable to optimize focusing and to permit adjustment of the beam size. All lenses are plano-convex and are made from fused silica. The mixing lenses are mounted outside the chamber, in front of a 27-in.-diameter lens having a 750-in. focal length. This lens is the solar window into the tank and acts as a vacuum seal.

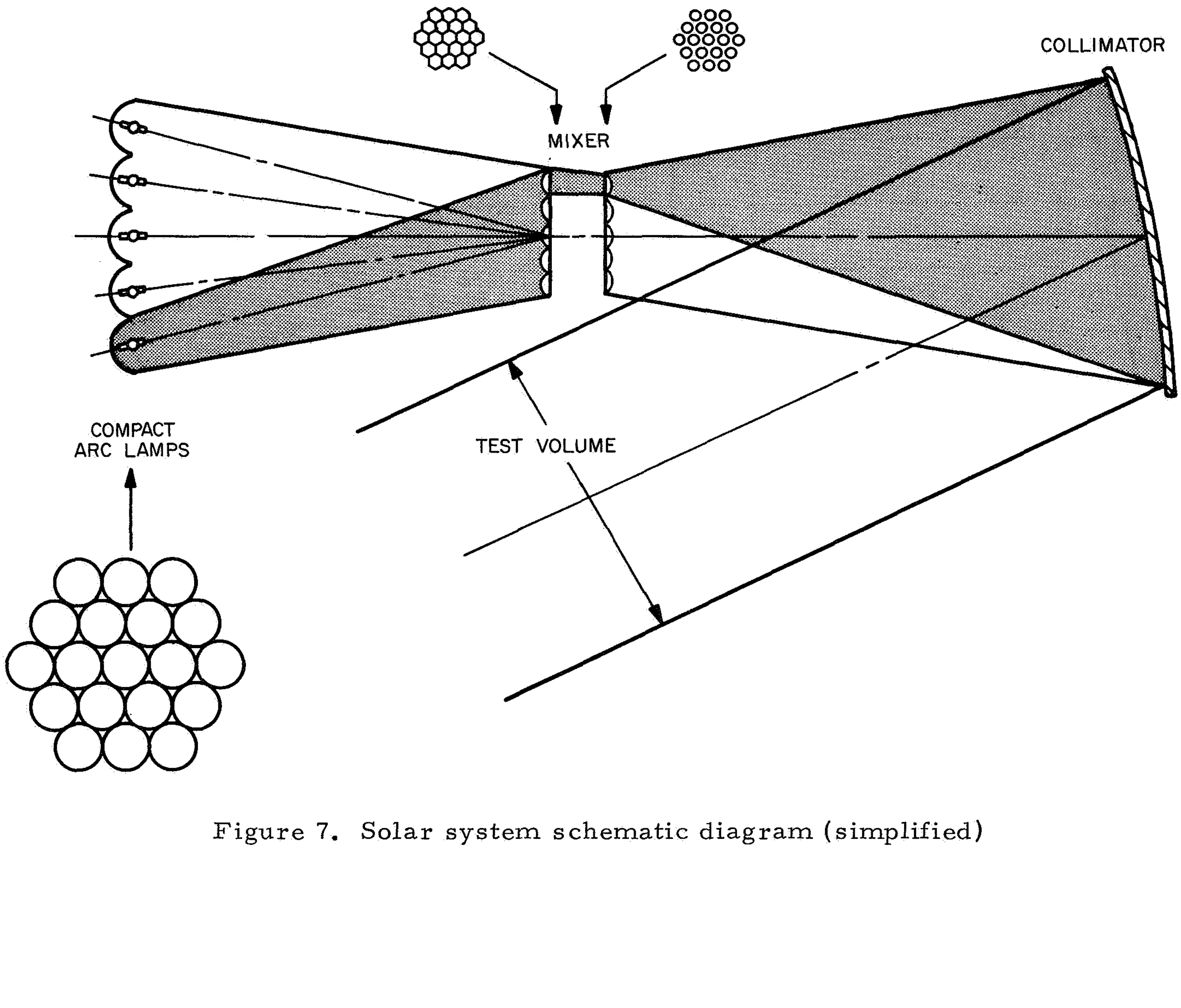

Figure 7. Solar system schematic diagram (simplified)

(3) Collimator. This is a 276-in.-diameter aluminum weldment having a nominal thickness of 2 in. It is reinforced with 14-in. ribs at the perimeter and in a diamond pattern over the back surface. The front surface is machined and polished to a spherical radius of 1200 in. Electrodeposited nickel with a nominal thickness of 0.020 in. is the substrate for the aluminized surface, which is 700 to 1000 Å thick. The mirror is hung from the top head of the tank by a whiffletree suspension system which connects to the chamber head at only three points. The mirror perimeter has 12 equally spaced attachments to the whiffletree. Internal cooling with GN_2 is provided.

(4) Power source. This equipment comprises 111 200-A rectifiers connected in parallel groups of three which furnish power to the lamps through a 4 x 4 x 0.5-in.-thick water-cooled copper bus.

(5) Scaffold hoist. This component is a ring scaffold suspended from four cables which can raise and lower a platform inside the chamber for equipment maintenance. The surface of the mirror will be coated from an electron-beam gun supported on this hoist.

(6) Solar hood. This component is a sheet-metal enclosure for the solar beam. It is located between the solar basement, where the lamp array is located, and the solar window in the vacuum vessel. Cooling is provided by a filtered recirculating air system containing a heat exchanger for temperature control and activated charcoal filters for ozone removal.

Light from the hexagonal grouping of 37 20-kW compact xenon arc lamps, modified by the mixing lens, passes through the window lens into the vacuum vessel. The light impinges on the one-piece collimating mirror, which reflects a collimated beam of light into the test area as an "off-axis" beam.

The solar simulator will be able to provide a stable light intensity level at any point between 0 and 250 W/ft^2. The intensity level can be controlled by the number of lamps in use and by the power (current) supplied to each lamp. Thermopiles in the test volume of the chamber measure the intensity of the radiation.

III. SUPPORTING SYSTEMS

A. Electrical Power

The power supply is a 2500-kVA, three-phase, 2400-V (Δ) transformed to 480-V/277-V (Y). From switch gear located in the rectifier room, this power is distributed to four solar simulator system rectifier power panels (PRA, PRB, PRC, PRD), three motor control centers (PB, PC, PD), the shroud heater control panel (PM), and the wall shroud blower. The motor control centers in turn provide power to a secondary distribution system of eight panels for lighting, controls, and small power applications.

Motor control center PD furnishes power to a cross section of equipment, controls, and lighting circuits selected so as to allow nominal operation or controlled, orderly shutdown of the facility. In the event of power failure, an automatic transfer switch connects the control center to an emergency generator, and operations may continue by manual resetting of equipment. Restart of lighting in control room and equipment areas is automatic.

B. Emergency Power

A 400-kW, three-phase 480-V diesel-powered generator is automatically connected to a motor control center from which nominal operations of the facility may be continued in the event of power failure. A 2-1/2-day fuel supply is stored underground. A 75-kW, three-phase, 480-V generator powered by natural gas provides standby power which is transformed to 120/208 V (Y) and is supplied to the outlet circuits which supply power to the spacecraft command and monitoring equipment in the system test complex.

C. Cooling Water

Treated, filtered water is furnished in a closed-loop system having 8-in. supply and return lines. Two 75-hp pumps (one of which is normally on standby) provide 680 gpm at 150 psig each. Water from an updraft cooling tower is used as a heat-exchange medium in the two cooling coils of this system. The rated capacity of the system is as follows:

Cooling coil capacity	1600 gpm
Outlet temperature	95°F
Inlet temperature	107.7°F
Cooling capacity	1800 kW
Wet bulb (maximum)	72°F

Cooling water is piped to the following areas, where a regulated supply is manifolded to individual equipment.

	Inlet pressure, psig
Vacuum pumps and blowers	24
Air-conditioning system	50
Solar lamp reflectors	50
Solar lamps and copper bus heat exchanger	50
Mixer lens holder and light douser	100
Solar hood cooling coil	50
Diffusion pumps	50

City water is available for system use in the event of an emergency.

D. Pneumatic System

Air is obtained from a Laboratory-wide, 115-psi distribution system. In the event the supply pressure drops below 85 psi, a 10-hp emergency compressor starts automatically to supply air to the facility. This air supply is used for valve controls, air hoists, overhead crane pin actuators, utility outlets, and, in emergencies, for breathing.

Gaseous nitrogen is obtained from a 2250-psi, Laboratory-wide distribution system reduced to 100 psi for distribution in the facility. The GN_2 is used (1) to drain the shrouds and baffles of LN_2, (2) as the "fluid" for operating the shrouds between -250 and +250°F, (3) for cooling the mirror, (4) for chamber backfill, (5) for mechanical pump gas ballast, (6) for pressurizing the Perlite insulation of the LN_2 storage tank, and (7) for valve controls.

E. Hydraulic System

A hydraulic system is mounted on the carriage which operates the 15- x 25-ft side-opening chamber door. This system consists of a 12-gpm (at 1000-psi) pump, a 60-gal tank, and a 5-gal accumulator with piping to the following actuators:

Carriage traverse motors
Main door retracting cylinders
Drawbridge lifting cylinders
Personnel door latch cylinders

A stationary hydraulic unit is installed in the vacuum vessel basement for actuating the main door wedge locks and seal clamps. The unit consists of a 19-gpm (at 500-psi) pump, a 60 gal tank, and a 5-gal accumulator.

F. Air Conditioning and Ventilation

The 25-ft space simulator facility is divided into three separate zones of air control. The west end of the building, which contains three floors of offices, shops, the control room, and the system test complex area, is completely air conditioned. Cooling is supplied from two 29-ton refrigeration units; heating is supplied by a gas-fired boiler having an input of 900,000 Btu/hr. The center section of this building, containing the simulator chamber, is ventilated by four roof-mounted fans rated at 10,000 ft^3/min. Air is discharged through shuttered wall louvers at the floor line. A 3/4-hp fan is installed in the tank basement, with inlet openings at basement floor level and an outside discharge for dissipating nitrogen gas which may accumulate in the basement from leaks or spilled LN_2. A 1/2-hp fan is similarly installed in the solar simulator basement. Two 3,300-ft^3/min unit heater/fans are connected to the boiler, and supply heat to Room 101, the simulator room.

The mechanical equipment room to the east has three 1/2-hp roof-mounted exhaust fans for ventilation and two gas-fired radiant space heaters. A 30-hp fan is mounted on the roof above the power supply racks in the rectifier room to cool the units and ventilate the room.

IV. TEST ITEM INSTALLATION

In general, the spacecraft or test item is hung by cables or hard-mounted from the chamber floor structure (Figs. 8,9). A hard-mounting technique can be used to minimize spacecraft motion, thus eliminating saturation of certain gyros in the attitude control system. A systems test operations area is provided in the central portion of the control room opposite the large entrance door. It is used for operating space for handling and checkout of test models. This area is serviced by a 3-ton bridge crane covering a span of 15 x 26 ft with a hook height of 28 ft. The hoist travels at two speeds, 3 and 10 ft/min and 8 and 40 ft/min with 5-step control. A 2-ton monorail traveling beam crane is utilized for test item mounting inside the chamber.

V. FACILITY INSTRUMENTATION SYSTEMS

A. Pressure

1. One atmosphere to 10^{-3} torr. Pressure profiles are measured and recorded by two Baratron* measuring systems. Each system consists of two measuring heads. One head ranges from 0 to 10^{3} torr full scale; the other ranges to 10 torr full scale. With the 10-torr head, it is possible to measure pressures down to 10^{-3} torr.

2. Pressures below 10^{-3} torr. Varian ion gage systems are used for vacuum measurements below 10^{-3} torr. The ion gages are mounted close to the test item; redundant gages are used in case of gage or controller failure.

B. Temperature

The following equipment is available for temperature measurements:

(1) Thermocouple transducers

Capacity	1000 data channels
Thermocouple types	chromel constantan copper constantan
Temperature range	-320 to +1800°F

*Baratron is the tradename of a diaphragm-type differential vacuum measuring system using a variable-capacitance pickup as an element of an ac bridge and manufactured by MKS Instruments, Inc., 45 Middlesex Twinpike, Burlington, Massachusetts.

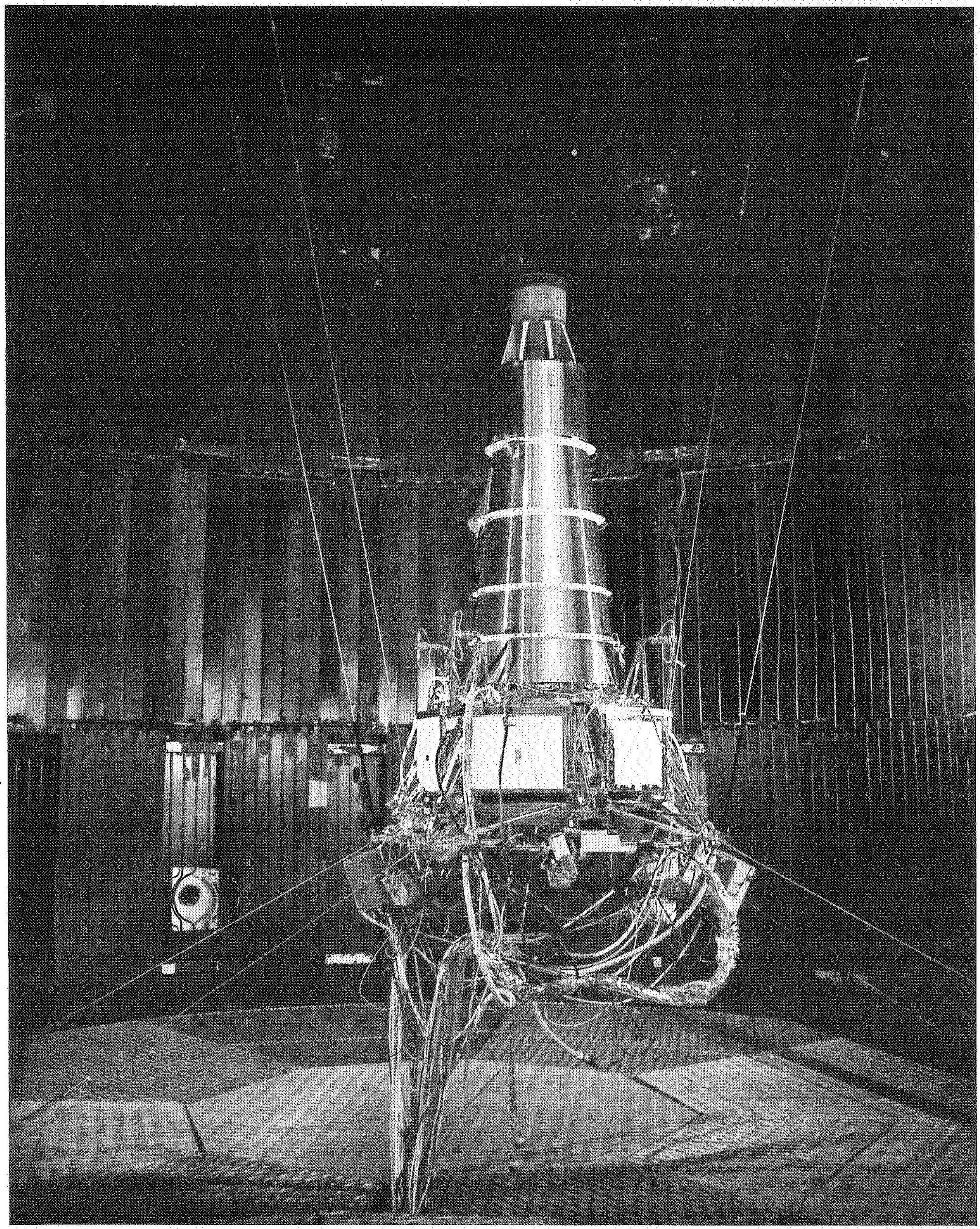

Figure 8. Ranger spacecraft in the 25-ft space simulator

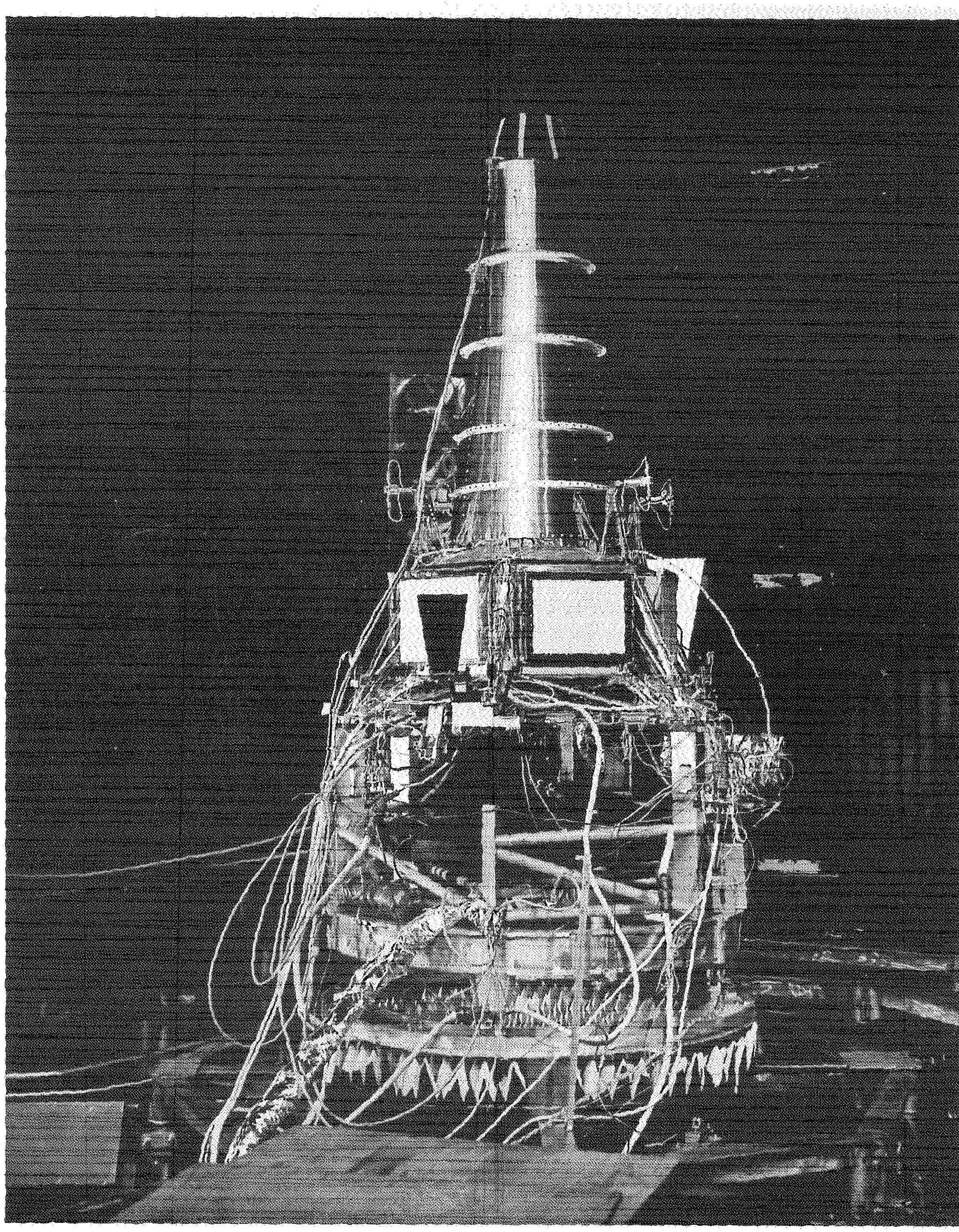

Figure 9. Ranger spacecraft in the 25-ft space simulator

(2) Resistance temperature sensors

Capacity . . . . 12 channels of excitation

C. Solar Radiation

The Eppley Mark I radiometer, of which JPL has two, is used to set the solar intensity and monitor it throughout each test. It consists of a 15-junction, bismuth-silver thermopile radiometer for use in vacuum or air at irradiance levels up to 300 mW/cm^2 (about 280 W/ft^2).

The instrument is linear in air at atmospheric pressure; a non-linear calibration curve is used in vacuum. The sensitivity is about 0.45 $mV/W/ft^2$ in vacuum and 0.22 $mV/W/ft^2$ in air. Response time is approximately 5 sec in air and approximately 15 sec in vacuum.

The Mark I electrical output is normally recorded on a Speedomax H recorder with AZAR (adjustable zero and range), which allows a ±2- to ±100-mV span and a 0-, 10-, 20-, 30-, or 40-mV zero suppression. If additional radiometers are used, their outputs are simply read from a digital millivoltmeter or fed into the Datex recording system. The Speedomax H accuracy is 0.3% of full scale. The digital millivoltmeter accuracy is 0.1% of the reading ±1 digit, and its sensitivity is 10 μV.

Figure 10 shows four Mark I radiometers on a device used to sequentially position the instruments in the same location in the simulator for comparative purposes.

The Eppley Mark I radiometers at JPL incorporate a 7-deg acceptance angle, water-cooled, baffled, blackened collimation tube. This reduces the zero-irradiance (solar simulation off) reading to an insignificant amount making the instruments direct-reading. These instruments have also been calibrated in air at Table Mountain, near Wrightwood, California, against two Eppley angstrom pyrheliometers, which also have 7-deg acceptance angles. No windows are used in air; the collimation tube eliminates wind and convective current problems experienced in the past. These radiometers can also be used in a hemispherical mode if desired.

Newer Eppley Mark I radiometers using wire-wound and plated thermopiles are on order and will be evaluated in the near future. These are much more rugged and should be more reliable and stable and less subject to damage than the bismuth-silver thermopiles.

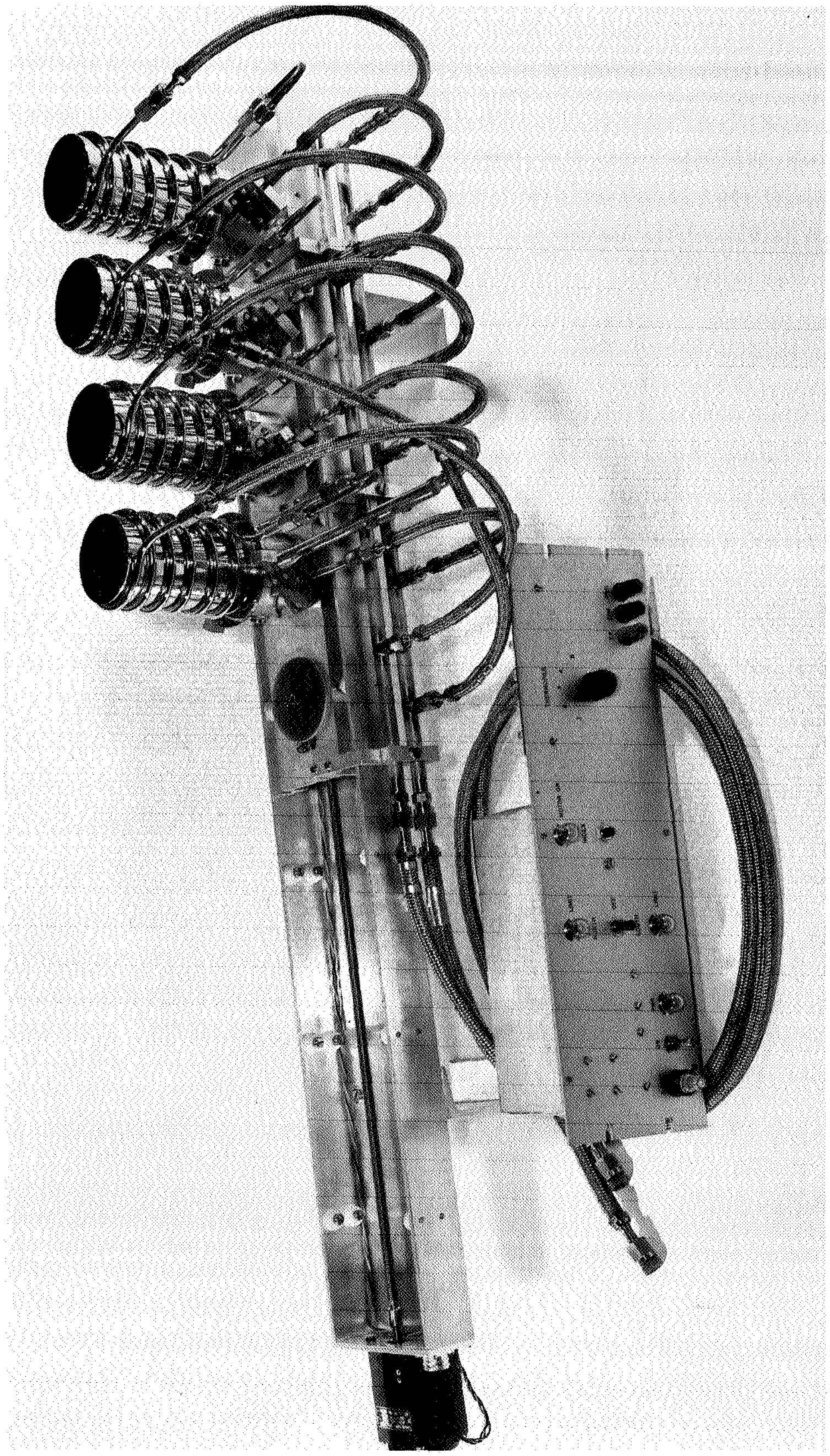

Figure 10. Eppley Mark I radiometers

Four Hy-Cal Model 8400 radiometers are also available. These are water-cooled and may be used with or without quartz windows. They employ the Hy-Therm principle, with thermopile junctions on both sides of an insulating wafer which is irradiated on one side and attached to a heat sink on the other. This results in conductively dominated heat transfer and the response is thus the same in air or vacuum. The output is linear to several solar constants. The sensitivity is 0.043 mV/W/sq ft. Response time ($1/\epsilon$), is 1/4 sec. No collimation tube or aperture limit is currently employed. Zero-irradiance readings must therefore be taken during vacuum operation.

The JPL Instrumentation Section (371) in conjunction with the Applied Mechanics Section (353) has developed a cone radiometer described in Refs. 1 and 2. This device employs a nickel wire-wound cone inside a guard heater. The nickel wire acts as a highly sensitive resistance thermometer as well as a heating element. The guard is maintained at a preset constant temperature determined by the irradiance range desired. The cone temperature is slaved to the guard temperature by using the nickel wire as a heater element. In the vacuum environment of cold, black space, the electrical power into the cone would be all radiated out the cone following the formula $A\sigma T_r{}^4$, where A is the cone aperture area, σ is the Stephan-Boltzmann constant, and T_r is the cone temperature. No heat transfer between the cone and guard occurs, since they are at the same temperature. If the cone is now irradiated, less electrical power will be needed to maintain its temperature. This electrical power difference is a measure of the irradiance. Note that it is useful only in vacuum; thermal equilibrium is required and therefore the effective time constant (including the human operator needed in the present configuration) is long, on the order of minutes. The theoretical accuracy is reported to be better than 1%. The instrument is still under development.

The Eppley Mark IV filter radiometer (Fig. 11) measures irradiation at the test location as a function of wavelength. It employs 12 narrow-band filters, which are remotely positioned one at a time over the radiometer from controls at a small, remote console. Each filter is selected for appropriate bandwidth according to the source used, different sets of filters being employed for mercury-xenon, xenon, carbon-arc and tungsten filament lamps. Aperture openings in 1-deg steps from 5 to 15 deg are provided. A suitable opening is selected to accommodate the light beam divergence in the chamber. A remotely rotatable shutter reduces solarization of the

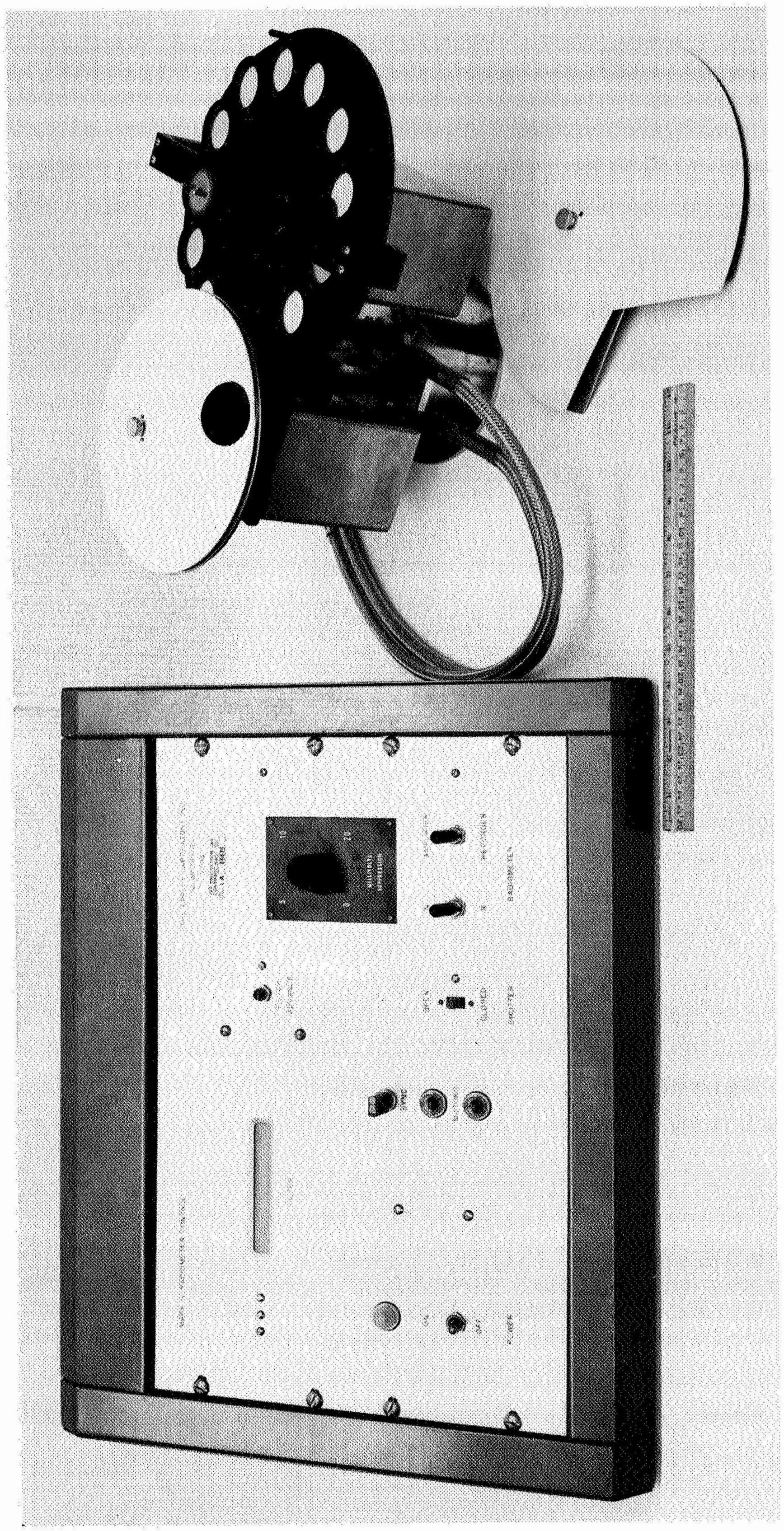

Figure 11. Eppley Mark IV filter radiometer and control console

filters; cooling-water coils permit temperature control of the thermopile assembly. The instrument will operate satisfactorily at 10^{-6} torr under cold-wall conditions. A quartz window is provided for use at atmospheric pressure. Sensitivity is 0.04 $mV/W/ft^2$ in air and 0.13 $mV/W/ft^2$ in vacuum. Response times to 98% of steady-state value, for air and vacuum, respectively, are 3 and 10 sec.

The Eppley Mark VII radiometer (Fig. 12) employs remotely positioned aperture discs in order to determine irradiance as a function of light beam divergence over a range of 2 to 20 deg total angle in 1-deg steps.

D. Vibration

A vibration system of 30,000 force-lb can be installed at floor level inside the space simulator. All vibrations generated by the vibration system are isolated from the space simulator structure.

E. Spacecraft Power Cutoff System

The power cutoff system consists of three Varian ion gages and a control unit. Its purpose is to turn off spacecraft power in the event of an uncontrolled increase in chamber pressure. In order to actuate the shutdown circuit, all three ion gages must sense the pressure increase.

VI. TEST ITEM INSTRUMENTATION SYSTEM

The instrumentation recording area is located on the second floor north of the high bay in Building 150. This area contains much of the data conditioning, data presentation, and temperature control equipment. The raw data signals from the test item are hard-lined through the bottom of the space simulator to the recording area. These signals are conditioned, reduced to engineering units, and displayed for use. Also located on the second floor is a technician work area for the cognizant temperature control personnel. Figure 13 shows the trench layout for all electrical conductors required for testing.

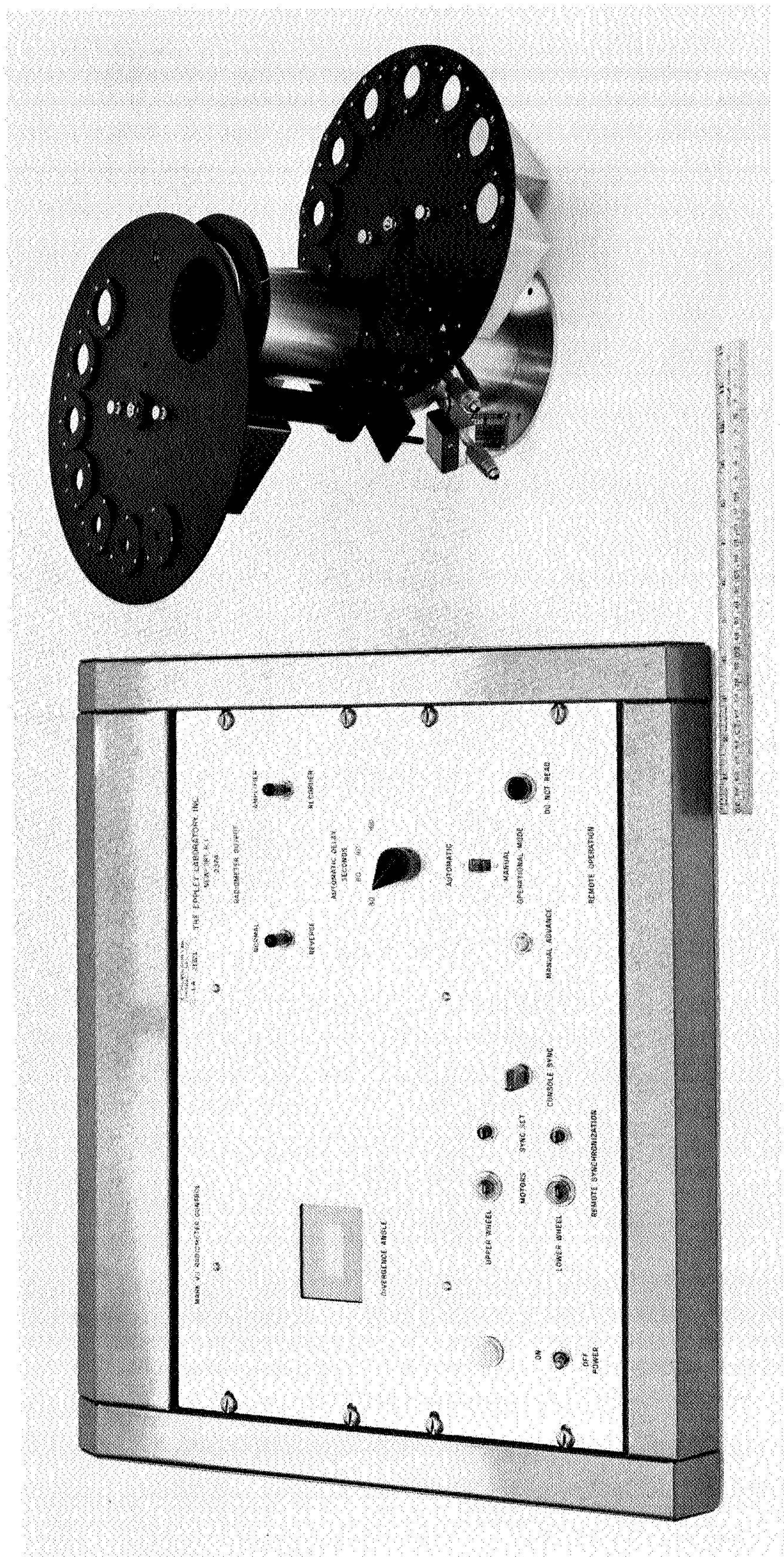

Figure 12. Eppley Mark VII radiometer for measuring light beam divergence

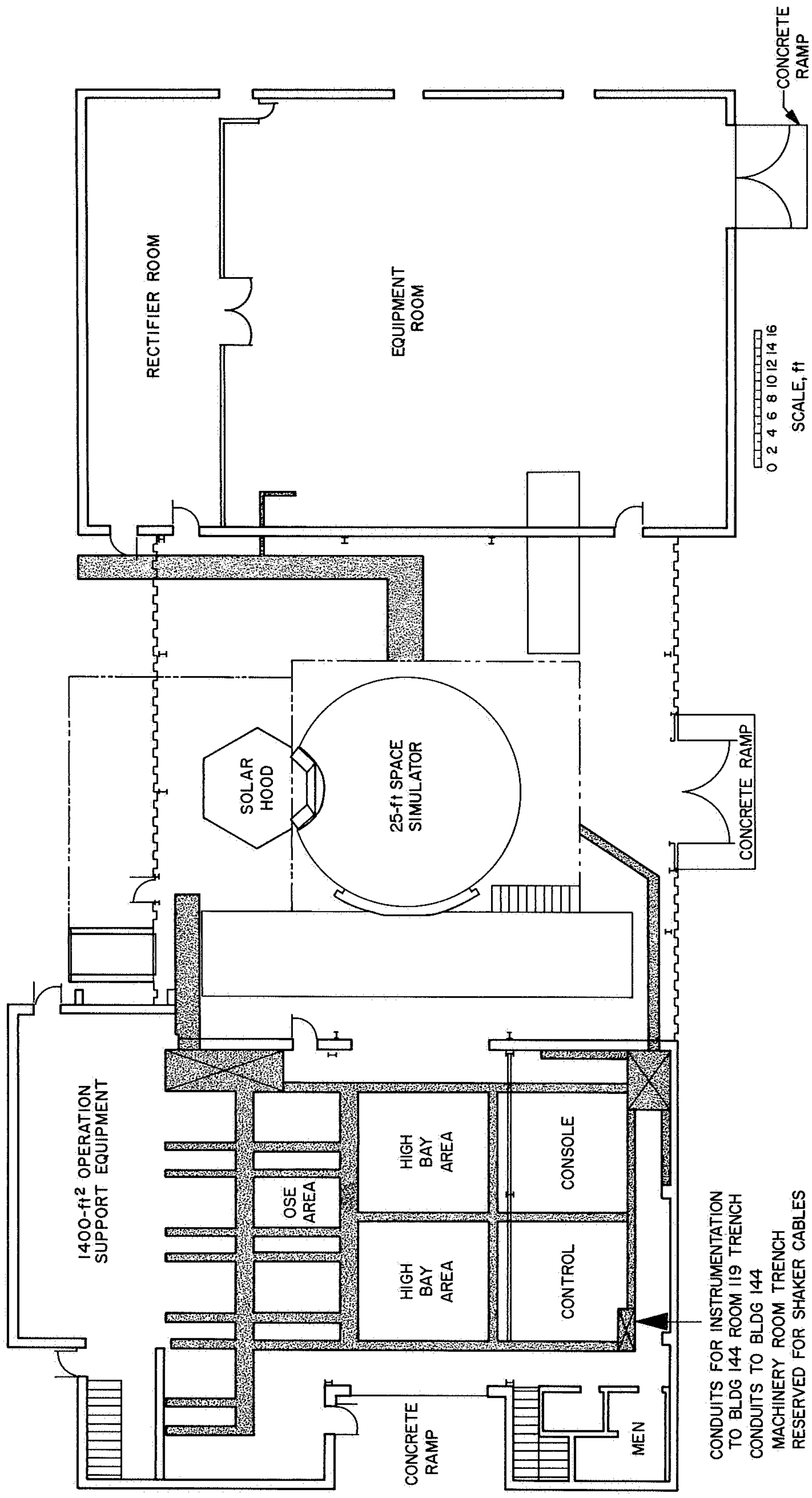

Figure 13. Main floor trench layout

A. Data Acquisition

1. Temperature. The system is designed to accept 1000 channels of either chromel constantan or copper constantan thermocouples. The thermocouple input connectors (Deutsch tri-cam lock) each contain 55 sockets. This system can be altered to accept other input configurations when necessary.

2. Vibration. This data acquisition gear is not normally installed in the space simulator. It is available and can be supplied on demand.

3. Facility measurements. Representative channels of temperature, pressure, and solar radiation levels will be selected from the environmental control console and recorded as part of the test record.

4. Miscellaneous measurements. Input lines for 50-mV signals are available inside the space simulator. Provisions for operating 12 strain-gage-type transducers are also available.

B. Data Conditioning

1. Thermocouple referencing. The reference is an isothermal cavity constructed in an equipment rack and located in the pit beneath the space simulator. An accurate measurement is taken of the cavity temperature and applied in the data reduction equations.

2. Multiplexing. The multiplexer and its controls are located in the recording area. There are presently 640 channels. This number will be expanded to 1000. Of the input data channels, 800 will go directly from the space simulator to the multiplexer and 200 will go to the patch panel and can there be patched into the multiplexer. The multiplexer has a maximum scanning rate of 50 channels/sec and can be remotely controlled by computer. Once a scan is initiated during normal operation, the multiplexer will scan all channels and stop; during setup it will be possible to address each channel individually. The output of each channel from the multiplexer is amplified and converted to a frequency proportional to the input analog level. This signal is available for data reduction.

In the recording area there are dc amplifiers, filters, and galvanometer attenuation panels available for use when necessary.

C. Data Reduction

The frequency signal output of the multiplexer is transmitted over CRS cabling to Building 125 (Central Recording Center). There a PDP-4 computer with magnetic tapes is available for receiving the signal and converting it to degrees Fahrenheit or centigrade. The reduced data is stored on digital magnetic tapes for future access and is also transmitted back to the recording area for real-time operation.

D. Data Presentation

1. Digital printout. A high-speed printout device is located in the recording area to record the result of the reduced scan.

2. Digital magnetic tapes. These tape units are located in the CRS room in Building 125. The data stored on these tapes can be programmed through the IBM 7094 computer for further data reduction or plotting.

3. Analog recording. Both Leeds and Northrup, and Moseley single- and double-pen strip charts are used in the recording area. In addition, one 36-channel CEC direct-write oscillograph is available when needed.

4. Analog magnetic tapes. Presently there are no analog tapes in Building 150, but there are 50 interconnecting channels to the recording room in Building 144 where tape recorders are available on short notice.

5. Light banks. Digital light banks can be located in the user area for displaying environmental parameters representing conditions in the space simulator.

6. Printout in OSE. Selected environmental parameters can be transmitted to the central recorder in the operational support equipment (OSE). These signals will be conditioned and isolated before transmission.

E. Temperature Control

1. Heater controllers. The system has 100 variable voltage transformers each capable of an output of 300 W.

2. Power transducers. The system has 50 power transducers each rated at 60 W maximum. These transducers have a millivolt output proportional to the power input which can be recorded as part of the test data.

3. DC voltage supplies. There are six dc voltage supplies available together with precision shunts and meters for making accurate low-power measurements.

VII. FACILITY DESIGN CRITERIA

The following facility design criteria have been established.

A. Vacuum System

(1) The working fluid is assumed to be air at 70 °F.

(2) The vessel is 27 ft in diameter and 85 ft high with spherical heads. It has a volume of approximately 52,000 ft^3 and a surface area of approximately 9400 ft^2.

(3) The vessel design features shall be consistent with its expected ultimate pressure of 5×10^{-7} torr.

(4) The vacuum capability shall be 5×10^{-6} torr in not more than 240 min with the chamber empty, cold walls filled with liquid nitrogen, and diffusion pumps operating. Figure 4 shows a typical pumpdown curve for the chamber.

(5) All valves, pressure controllers, regulators, motors, and other equipment normally required to operate the vacuum pumping system shall be controlled from, and indicated on, the main console.

(6) The high vacuum plant will be designed to maintain full operation with one Stokes No. 1711 mechanical pump/blower functioning.

(7) A holding pump shall be installed to back the diffusion pumps while the main roughing system is pumping down the chamber.

(8) All valve operations shall be pneumatic with operating pressures not to exceed 80 psi of air or GN_2.

(9) Position and interlock devices shall be integrated with the unit served.

(10) No component or portion of the vacuum system shall be located outside the building enclosure.

(11) Vacuum piping operating at 10^{-3} torr and higher may be mild steel.

(12) Main distribution lines for house and control air or GN_2 shall be steel.

(13) Pneumatic equipment control connections may be copper tubing.

Cryogenic System

(1) The shroud temperature range will be from -320 to +250°F.

(2) The working fluid shall be LN_2 at saturation pressure/temperature (approximately -320°F). GN_2 is used between -250 and +250°F.

(3) Cool-down time from ambient to LN_2 temperature shall be 1 hr maximum.

(4) LN_2 shall be drained from the shroud system in 30 min and returned to storage with a GN_2 blowback system.

(5) With the shrouds filled with LN_2, the rate of change of temperature from -320 to +100°F shall be sufficient to make the change in 1 hr.

(6) The design pressure shall be 100 psig; normal operating pressure shall be 75 psig.

(7) The shrouds shall be designed to provide a thermally opaque test volume 20 ft in diameter and 25 ft high above the chamber floor.

(8) The floor heat load shall be assumed as 275 W/ft^2 over a 20-ft-diameter circle. No point on the shrouds shall be warmer than -275°F when operating with LN_2.

(9) Temperature regulation shall be as follows:

±5°F from set point between -175 and +250°F

±10°F from set point between -175 and -250°F

No steady-state operations between -250°F and LN_2 temperature.

(10) The wall shrouds shall be made of weldable 3003 aluminum alloy, suitable for -320 to +250°F service, and of 1/8-in minimum thickness. Tubes containing pressure shall have a minimum wall thickness of 5/32 in.

(11) All shroud surfaces facing the chamber wall shall be polished, and all surfaces seen from the test volume shall be painted black to have a solar absorptivity higher than 0.90 in the 0.2- to 3.0-micron band.

(12) The floor shroud shall be covered with a removable structural floor made from aluminum honeycomb panels designed for a live load of 100 lb/ft^2. A 12-ft-diameter, separately removable center section shall be provided in the floor to accommodate an exciter installation. Supports for the floor shall be 304 stainless steel.

(13) Two circulating pumps rated at 160 gpm at 200-ft head pressure shall supply LN_2 to the system. Each pump shall be provided with an

automatically controlled, manually adjustable bypass valve to insure operation under fixed conditions without loss of prime.

(14) Relief valves shall be installed in each isolatable portion of piping or section of shroud. Venting shall be outside the building.

(15) All valves required to operate the system shall have pneumatic operators. They shall be controlled and indicated at the console.

(16) An LN_2 separator tank shall be installed on the roof of the building at the high point of the system to maintain a head on the system during liquid-phase operations and to provide shroud venting and regulated GN_2 blowoff to the atmosphere.

(17) Each shroud section shall have a remotely operated inlet valve. Thermocouple readouts shall be provided on a multiple point recorder.

(18) All external piping shall be insulated. All cryogenic penetrations in the vacuum vessel will be isolation-type insulators.

(19) The heater and blower for the floor shroud shall serve as the emergency warmup unit for the entire cold-wall system in the event of power failure and be so piped.

(20) All heaters are to operate at full power to within 20°F of set point, at which time 80% of the power shall be cut out and the remaining 20% regulated by a saturable core reactor controlled by a proportional controller. Maximum sheath temperature of heaters shall be 1000°F.

(21) Shroud ducts shall be designed so that the temperature increment between inlet and outlet of any section shall not exceed 50°F during warm-up.

(22) Shroud temperatures between ambient and -250°F will be obtained by LN_2 evaporation and blowdown from within the circuit. Pressures shall be automatically controlled to any set point within the design limit by pressure-controlled modulating valves.

(23) The wall shroud blower shall be piped so that the floor shroud can be operated at the same temperatures and pressures as the wall shrouds.

(24) The floor shrouds shall be operable in gas phase temperatures while the wall shrouds are in liquid phase. The converse is not required.

(25) The collimating mirror cooling system shall be designed for a heat load of 20,000 lb of aluminum with an estimated cooling requirement of 15 kW. GN_2 shall be used as the working fluid regulated to ±10°

from -100 to +200°F with a rate of change of 200°F/hr. The design pressure shall be 50 psig; operating pressure shall be 25 psig.

C. Solar Simulation System

(1) The solar beam shall be as follows:

Size . . . . 15-ft diameter
Intensity . . . . 130 W/ft^2 (earth constant)
Uniformity . . . . ±5% throughout the test volume
Collimation . . . . 1 deg half angle
Spectrum . . . . that from xenon arc lamps

(2) Compact xenon arc lamps shall be used in a quantity to provide a 30% margin for lamp degradation and a 10% reserve energy level.

(3) The test volume to be irradiated will be 15 ft in diameter and 25 ft high, located on the centerline of the chamber.

(4) The collimating mirror shall be internally cooled with GN_2 between -100 and +200°F at a design pressure of 50 psig.

(5) The solar basement, lamp array structure, and power source installation shall be designed to permit the addition of lamps at a future time to produce a 20-ft-diameter earth constant.

(6) The solar hood shall be gastight and designed for 1-in. internal water pressure and a temperature range of 80 to 140°F.

REFERENCES

1. Proceedings of the Third Conference on Solar Simulation Research, July 14-15, 1965, Office of Advanced Research and Technology, NASA Headquarters, Washington, D. C.

2. Space Programs Summary No. 37-35, Vol. IV, Jet Propulsion Laboratory, Pasadena, Calif., October 31, 1965 (pp. 66-69).

BIBLIOGRAPHY

Strong, H. D., "Design and Initial Operation of the JPL 25-ft Simulator," IAS Paper No. 62-122, presented at the IAS National Summer Meeting, Los Angeles, California, June 19-22, 1962.

Riise, H. N., "Modifications to the Solar Simulation System of the JPL 25-ft Space Simulator," Space Programs Summary No. 37-19, Vol. IV, pp. 94-101, Jet Propulsion Laboratory, Pasadena, California, February 28, 1963.

Bartera, R. E., and Barnett, R. M., Development of the Jet Propulsion Laboratory Solar Simulator Type A, Technical Report 32-638, Jet Propulsion Laboratory, Pasadena, California, July 15, 1964.

Section 375 Staff, "25-ft Space Simulator Standard Procedures," Jet Propulsion Laboratory, Pasadena, California.

Goranson, G. G., Comments on the Operation of the JPL 25-ft Space Simulator, Technical Report 32-885, Jet Propulsion Laboratory, Pasadena, California, January 25, 1965.

Space Simulator Staff, Space Simulator Facilities at the Jet Propulsion Laboratory, Technical Memorandum 33-197, Jet Propulsion Laboratory, Pasadena, California, March 1, 1965.