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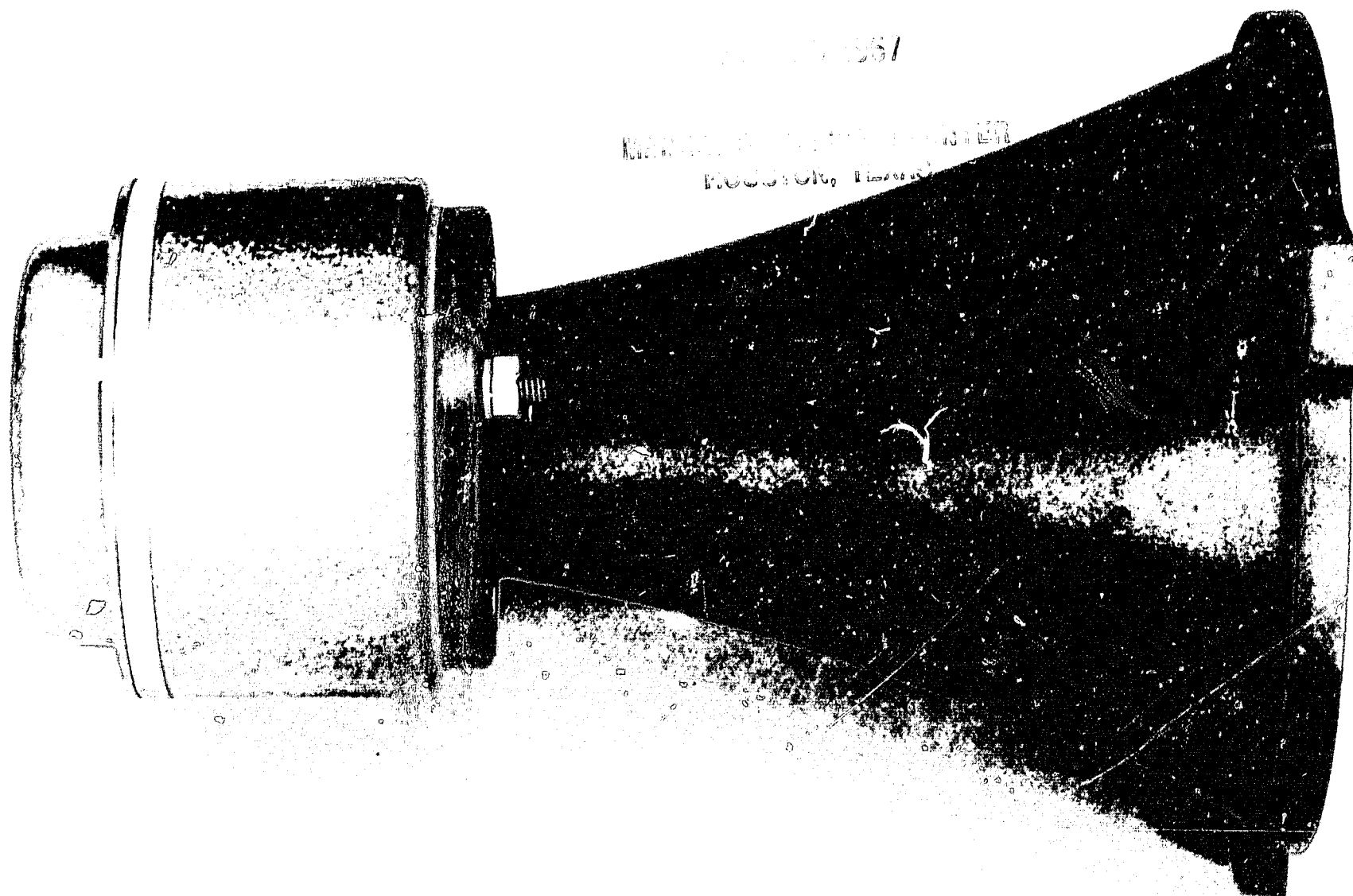
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JET PROPULSION LABORATORY
HIGH-INTENSITY ACOUSTIC TEST SYSTEM



JPL TECHNICAL MEMORANDUM 33-349

JET PROPULSION LABORATORY HIGH-INTENSITY ACOUSTIC TEST SYSTEM

**JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA**

June 15, 1967

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Preface

The Jet Propulsion Laboratory, located in Pasadena, California, is operated for the National Aeronautics and Space Administration by the California Institute of Technology. This memorandum describes the high level noise generation system available at JPL for acoustic testing of spacecraft systems and components.

The information contained herein was obtained and prepared by Mr. Charles D. Hayes and Mr. Michael D. Lamers of the Environmental and Dynamic Testing Section.



E. L. Sheldon, *Manager*
Environmental and Dynamic Testing Section

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General Description of the Acoustic Test System

The high-intensity acoustic test system was developed in order to provide high-intensity, broadband acoustic environments under both reverberant and progressive wave conditions, for the performance of acoustic environmental tests. The system is used for both developmental and flight qualification tests of NASA/JPL spacecraft and their components (and, under certain circumstances, for testing by government agencies and other organizations), as well as for research and development studies. It consists of both reverberation and progressive wave test chambers, with an input capability of broadband noise and discrete frequency signals. The reverberation chambers are designed to provide maximum sound diffusion — i.e., a very nearly uniform spatial energy distribution throughout a major portion of the volume of the chamber — and the system has maximum spectrum-shaping capabilities as well as very accurate control of input test signals.

System Description and Capabilities

This section outlines the various units which make up the acoustic test system, along with their capabilities, and gives the combinations that may be used to perform a given acoustic test.

Description

Acoustic Test Chambers (Figures 1, 2, and 3)

1. 1000-cubic-foot pentagonal reverberation

The proportion of the chamber that can be used for reliable acoustic testing is a function of (1) the test article geometry and (2) the test article size. A ratio of 10:1 between the test chamber volume and the test article volume represents a convenient, functional limiting factor. The actual dimensions of the chamber (given in a later section) result in a usable test volume as defined by a right-circular cylinder 12 feet high by at least 5 feet in diameter.

2. 7-cubic-foot pentagonal reverberation

3. 1 × 1-foot (square) progressive wave tube

4. 7 × 7-inch (square) progressive wave tube

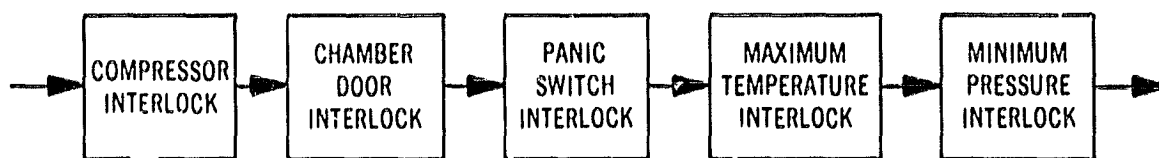
5. 2-inch-diameter plane progressive wave tube

Noise Generator System

The noise generator system consists of the following components (Fig. 4):

1. One 200-horsepower Gardner-Denver Air Compressor (Fig. 5), which supplies four electropneumatic transducers with 300 standard cubic feet of air per minute at 40 psig.
2. One Bruel & Kjaer Model 1402 random noise generator
3. One Ampex Model 311R 1/2-inch magnetic tape recorder
4. One Bruel & Kjaer Model 1022C audio beat frequency oscillator
5. One Allison Model ESD 21 1/3-octave band equalizer and noise generator
6. One Allison Model 348 1-octave band equalizer and noise generator
7. One Bruel & Kjaer Model 1612S 36-channel 1/3-octave band equalizer
8. One Bruel & Kjaer Model 2416 RMS voltmeter
9. One Hewlett-Packard Model 522 five-digit counter
10. One Weston Model 310 wattmeter
11. One Ling SMP-100 transducer monitor panel
12. Two Ling Model AM-10-30 preamplifiers
13. Five Ling Model 100-A amplifiers
14. One Ling Model TP-300 amplifier
15. The appropriate number and type of noise transducers for the particular chamber

16. Safety interlocks and interconnect switching for the above equipment when used with the 1000-cubic-foot chamber. The series arrangement for the system interlocks is shown below.



This arrangement is for system operation with the electropneumatic transducers. Temperature, pressure, and compressor interlocks are bypassed when electrodynamic transducers are used.

The noise generators employed and their respective capabilities are shown in Table 1. The generators may be operated separately or in any combination up to four.

Table 1. Noise generators

Type	Manufacturer	Acoustic power, w	Frequency response limits, Hz	Number available
Electrodynamic	Ling H ² T-20	7.2	1000-9600	5
Electrodynamic	Ling 20801	7-10	300-8000	5
Electropneumatic	Ling EPT-94A	2000	HCO ^a -1500	1
Electropneumatic	Ling 6786	2000	HCO ^a -1500	4
Electrodynamic	Altec 515-B	30	20-1000	4
Electrodynamic	Altec 802-D	5	500-22,000	2

^aHorn cutoff.

Acoustic Horns

The acoustic horns employed in the system are listed in Table 2, and their use with each of the chambers is specified.

Table 2. Acoustic horns

Type	Number	Cutoff frequency, Hz	Number used with each chamber				
			1000-ft ³	7-ft ³	1 × 1-ft	7 × 7-in.	2-in.-dia
Exponential	4	100	4	1	0	1	0
Exponential	4	50	4	1	0	1	0
Hyperbolic	1	50	1	1	0	1	0
Hyperbolic	1	25	1	1	0	1	0
Hyperbolic	4	440	4	4	4	0	0
Hyperbolic	3	100	1 ^a	1	0	1	0
Altec 511-B ^b							
Horn connector	2	500	2	0	0	0	0

^aHorn is cast into one wall of the 1000-cubic-foot chamber.
^bConnectors are designed to be used exclusively with the Altec 802-D electrodynamic transducer.

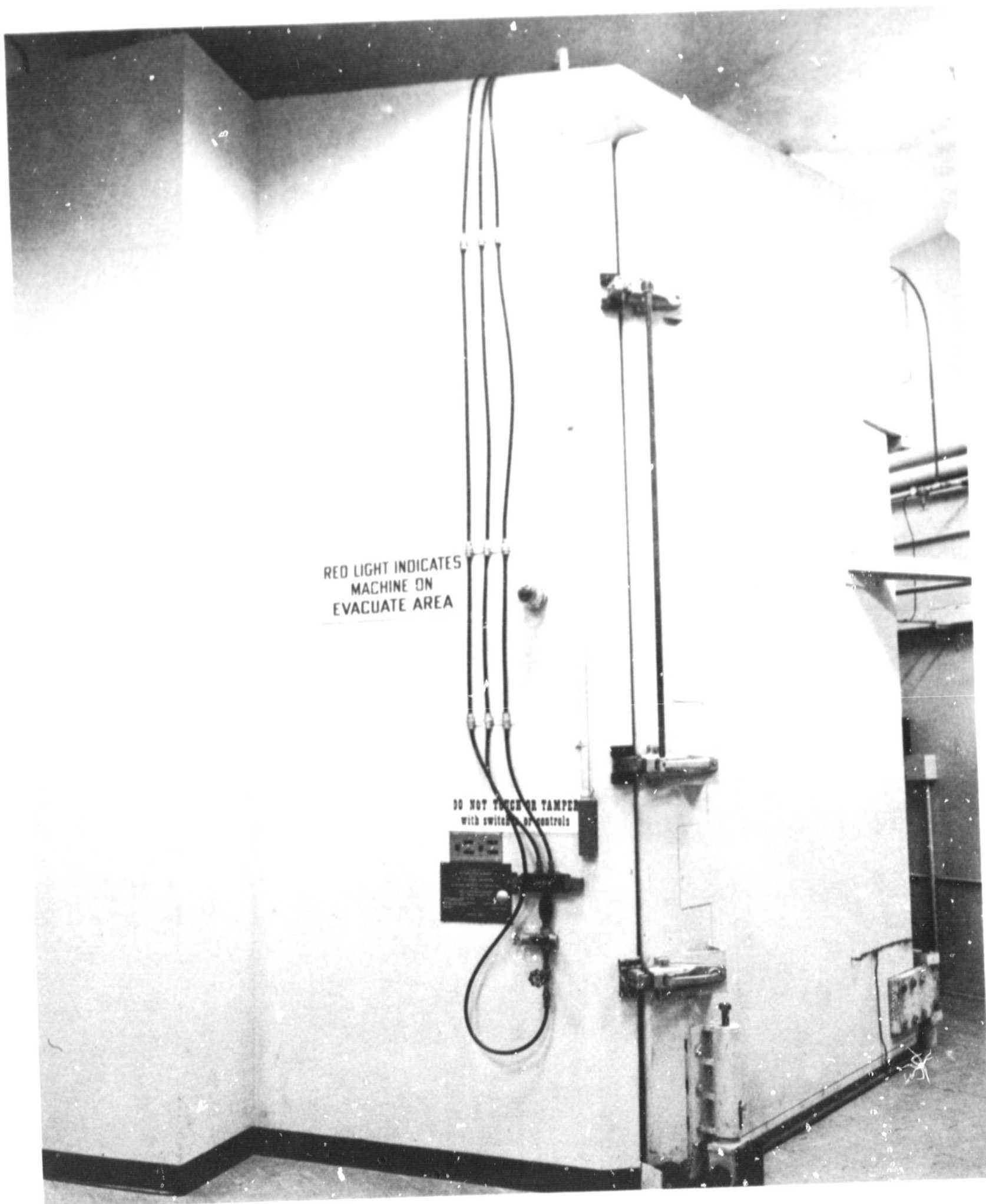


Fig. 1. 1000-cubic-foot pentagonal reverberation test chamber (external view)

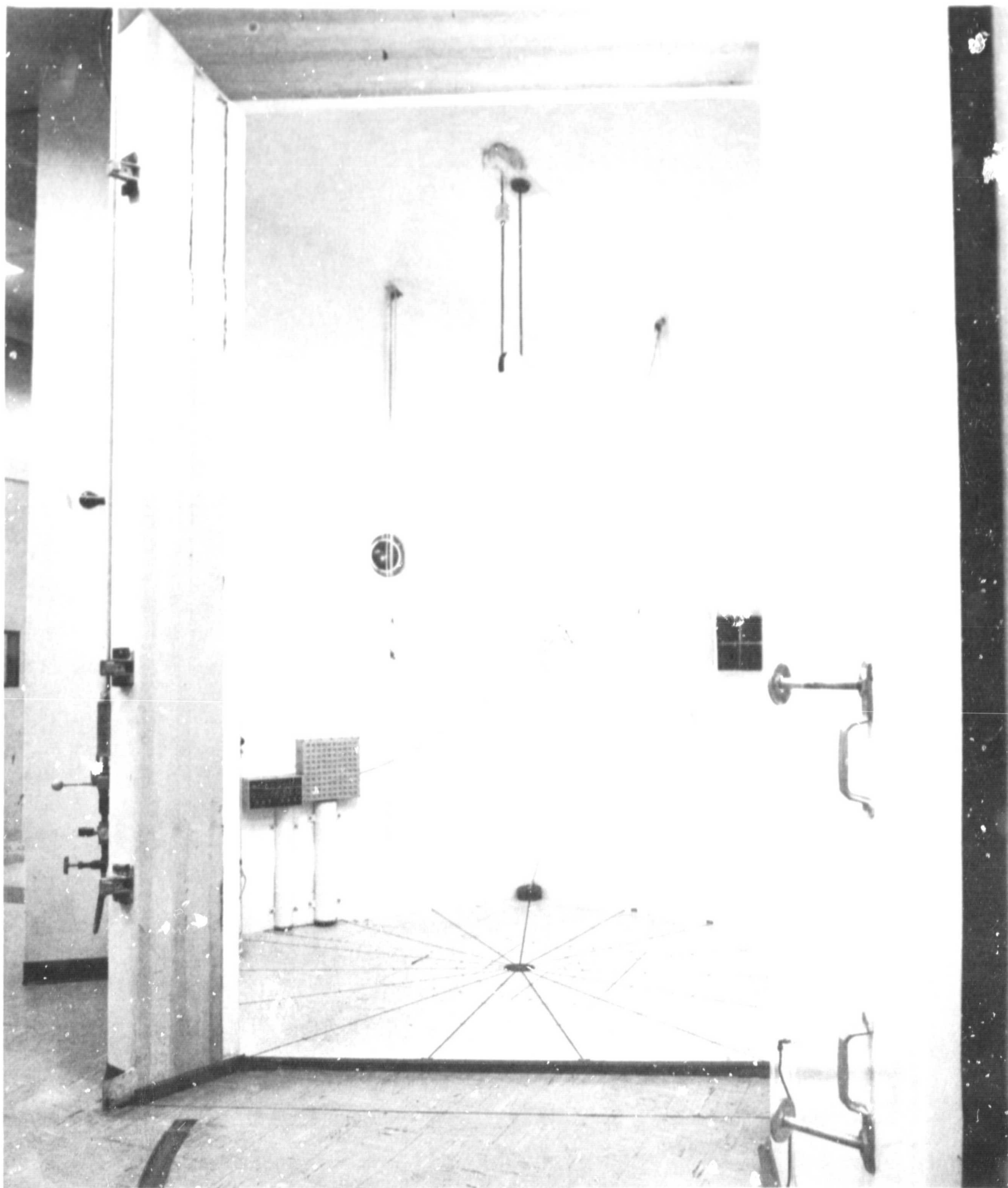


Fig. 2. 1000-cubic-foot pentagonal reverberation test chamber (internal view)

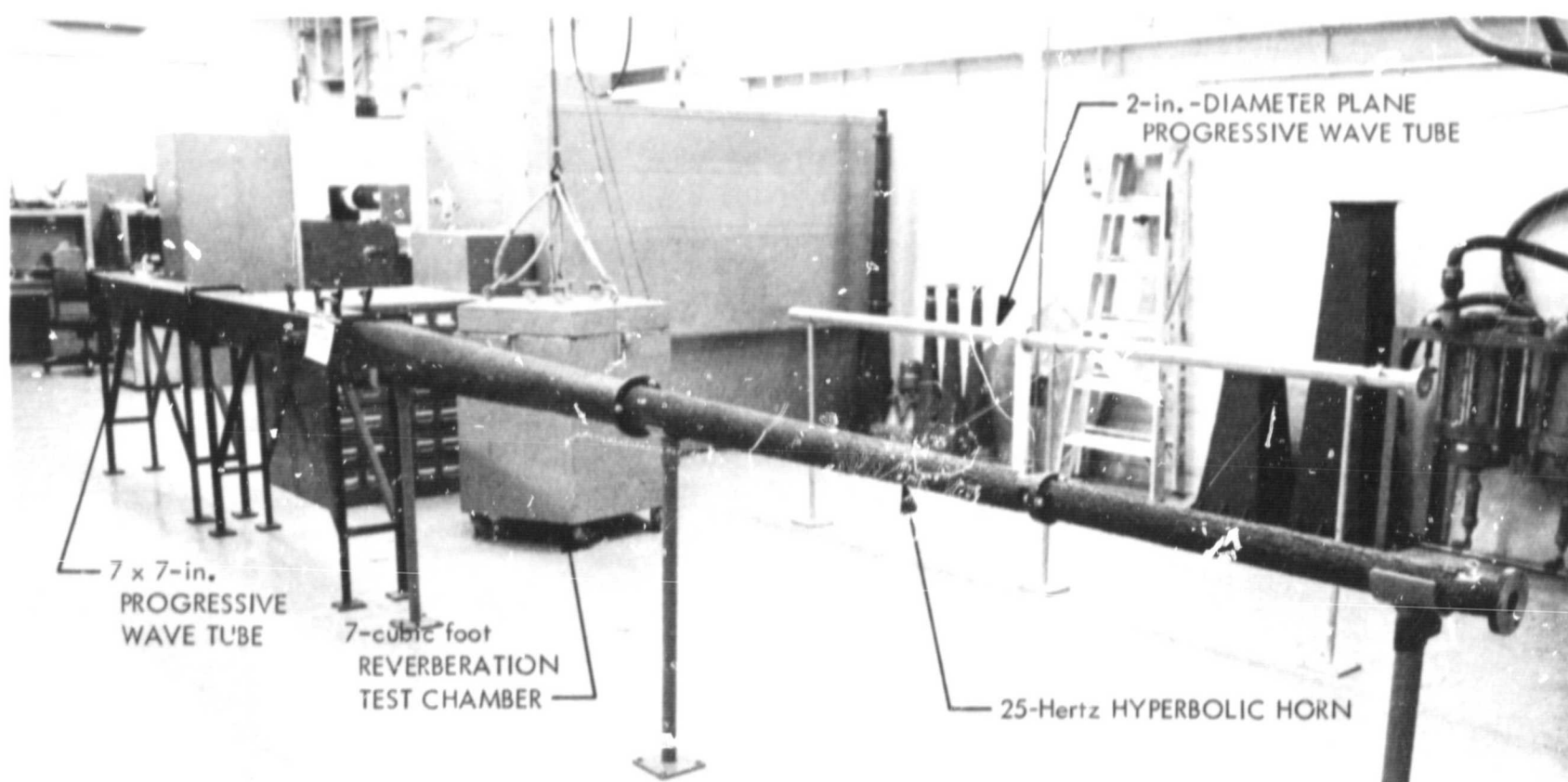


Fig. 3. Acoustic test system equipment

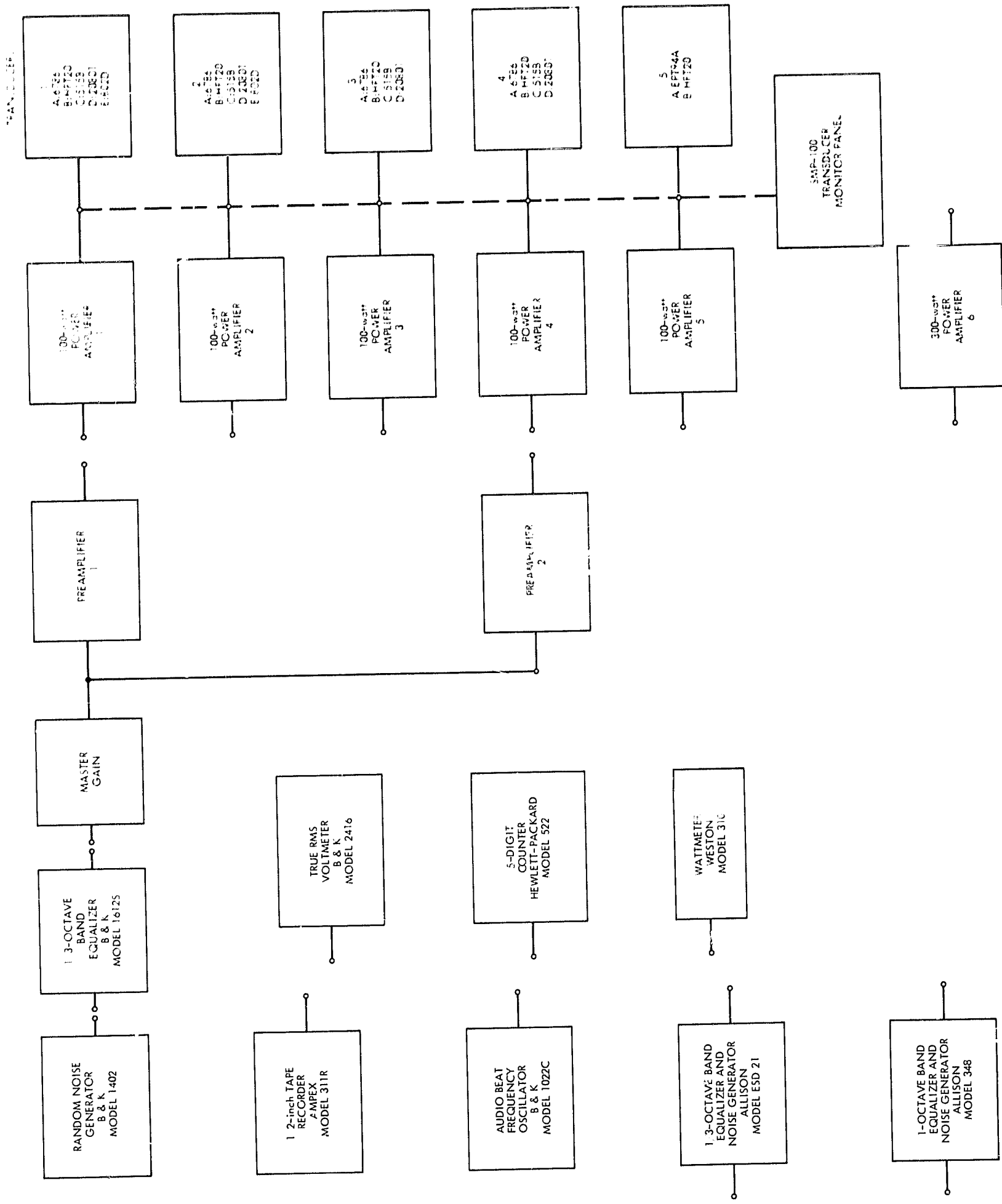


Fig. 4. Input select and electronic power for acoustic test system

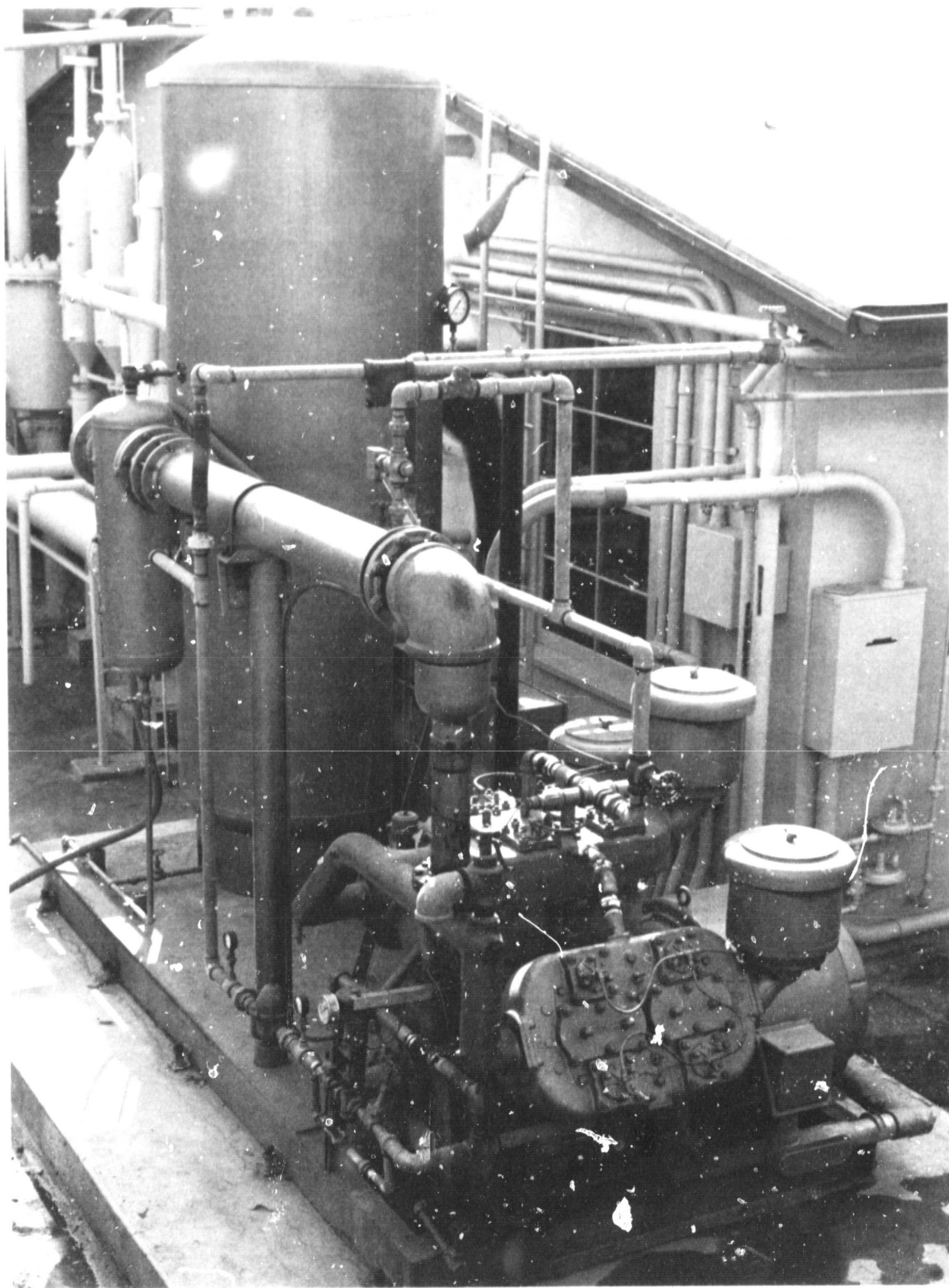


Fig. 5. 200-horsepower Gardner-Denver air compressor

Control and Monitoring System

The control and monitoring system consists of the following components (see Figures 6 and 7):

1. Condenser microphones

Three Bruel & Kjaer Model 4132 (1-inch), with dynamic range of 15 – 146 decibels

Eight Bruel & Kjaer Model 4134 ($\frac{1}{2}$ -inch), with dynamic range of 32 – 160 decibels

Four Bruel & Kjaer Model 4136 ($\frac{1}{4}$ -inch), with dynamic range of 70 – 180 decibels

One Chesapeake Model 135, with dynamic range of 85 – 200 decibels

One Photocon Model 524, with dynamic range of 105 – 182 decibels

2. Microphone cathode followers (all Bruel & Kjaer)

One Model 2612 (for Model 4132 microphone)

Two Model 2613 (for Model 4132 microphones)

Two Model 2614 (for Model 4134 and 4136 microphones)

Eight model 2615 (for Model 4136 microphones)

3. Condenser microphone power supplies

One eight-channel JPL

Two Bruel & Kjaer Model 2801

4. Microphone calibrators

One Bruel & Kjaer Type 4220 pistonphone (fixed frequency)

One Bruel & Kjaer Type 4240 random noise source

One Photocon Model PC-125 high-intensity pistonphone (variable frequency)

One Bruel & Kjaer Model 4215 artificial voice

One Neumann Model DK-2A pistonphone (variable frequency)

One Bruel & Kjaer Type 4142 reciprocity and electrostatic actuator calibrator

5. Other equipment

One Bruel & Kjaer Model 2112 audio-frequency spectrometer

One Bruel & Kjaer Model 2305 graphic level recorder

One Bruel & Kjaer Model 130 servo drive

One Bruel & Kjaer Model 3921 turntable

One Tektronix Model 502A dual-beam oscilloscope

One Allison Model 540 visual $\frac{1}{3}$ -octave audio-frequency spectrometer

Two Bruel & Kjaer Model 2416 RMS voltmeters

One Acton Model 331 AP precision digital phasemeter

One Bruel & Kjaer Model 4408 two-channel microphone selector

One Spectral Dynamics Model SD 101-A tracking filter with sine reject
(with 2-, 5-, 10-, 20-, and 50-cycle narrow-bandwidth filters)

Complete complement of microphone accessories

One Bruel & Kjaer Model 160 probability density analyzer

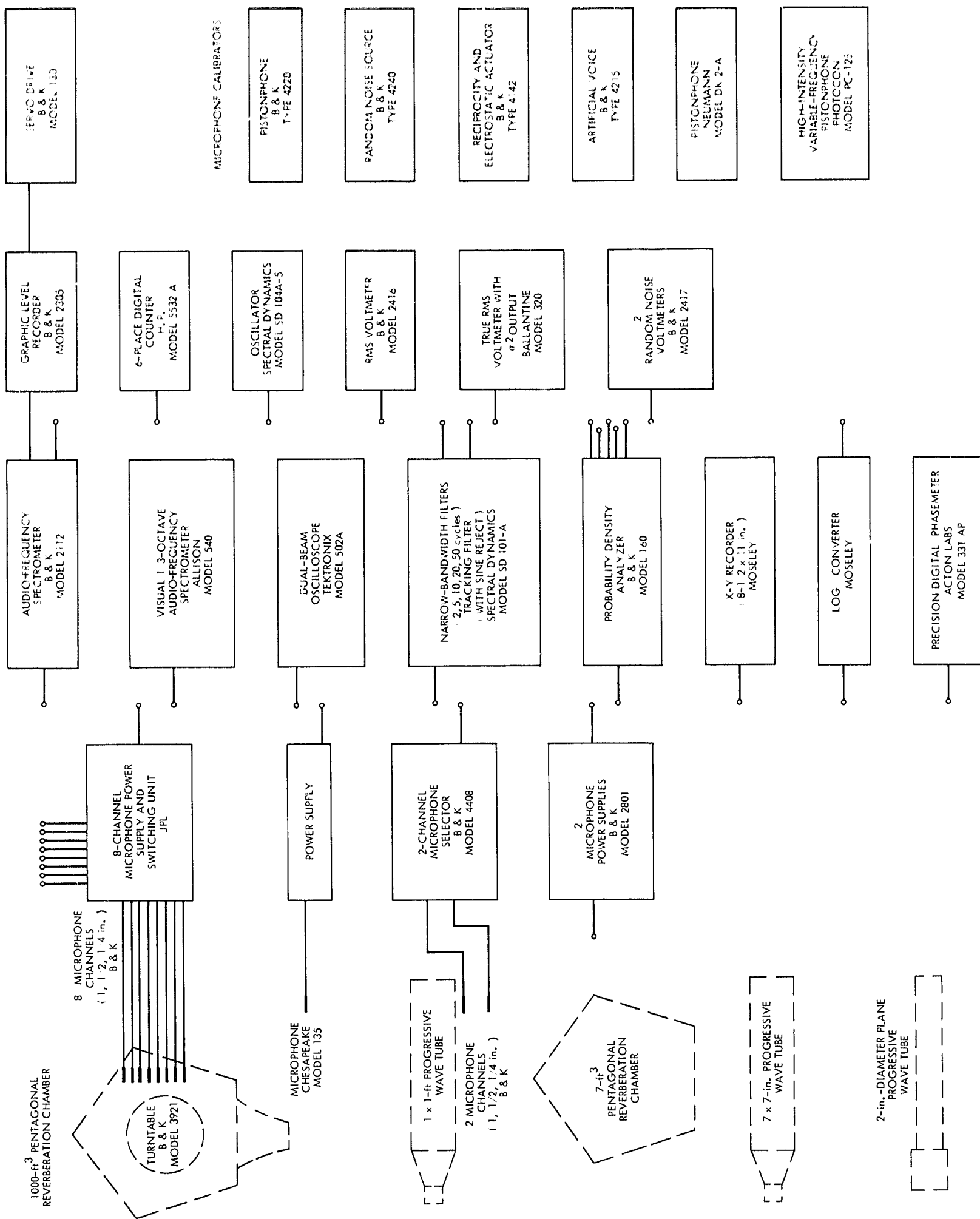


Fig. 6. Control and monitor block diagram



Fig. 7. Monitor and control console

One Moseley X-Y recorder ($8\frac{1}{2} \times 11$ inches)
 One Moseley Model 60 D log converter
 One Hewlett-Packard Model 5532A six-place digital counter
 One Spectral Dynamics Model SD 104A-5 sweep oscillator
 One Ballantine Model 320 true RMS voltmeter (with σ^2 output)
 Two Bruel & Kjaer Model 2417 random noise voltmeters

Capabilities

Utilizing the equipment described above, the acoustic test systems have the following capabilities:

1. 1000-cubic-foot reverberation chamber

Test volume: Right equilateral pentagonal cylinder, circumscribed on a 54-inch-diameter circle. The ceiling is V-shaped, with two 15-degree slopes. The minimum top-to-bottom internal clearance is 12 feet; the maximum top-to-bottom internal clearance is 13 feet.

Horn: Hyperbolic horn with 100-Hertz cutoff frequency. (See Table 2 for other horn configurations.)

Acoustic energy sources

a. Four Altec Type 6786 electropneumatic transducers

Frequency range: Random, flat from 125 to 1600 Hertz (as determined by $\frac{1}{3}$ -octave analysis), with minimum low-frequency rolloff 4 decibels/octave. This spectrum can be shaped by $\frac{1}{3}$ -octave spectrum shaping from 80 to 8000 Hertz. [Note: Transducer response is from 5 to 8000 Hertz ($\frac{1}{3}$ -octave) for random noise.]

Maximum overall sound pressure level (ref. 0.0002 microbar): Random, 158 decibels.

b. Four Ling HFT-20 electrodynamic drivers

Frequency range: Discrete from 800 to 9600 Hertz; random, flat from 1000 to 7000 Hertz ($\frac{1}{3}$ -octave), with rolloff on both sides.

Maximum overall sound pressure level (ref. 0.0002 microbar): Random, 138 decibels; sine (100 to 9600 Hertz), 130 decibels.

c. Four Altec 515-B low-frequency (20 to 1000 Hertz) electrodynamic drivers (mount inside chamber)

d. Four Altec Type 20801 transducers

Frequency range: Discrete from 400 to 8000 Hertz; random, flat from 500 to 1000 Hertz ($\frac{1}{3}$ -octave).

Maximum overall sound pressure level (ref. 0.0002 microbar): Random, 140 decibels; discrete, 132 decibels.

2. 7-cubic-foot reverberation chamber

Test volume: Right equilateral pentagonal cylinder, circumscribed on a 24-inch-diameter circle. The floor is V-shaped, with two 15-degree slopes. The minimum internal clearance (top to bottom) is $19\frac{1}{4}$ inches.

Acoustic energy source: Four Altec Type 20801 transducers

Frequency range: 400 to 8000 Hertz.

Maximum overall sound pressure level (ref. 0.0002 microbar): Random, 145 decibels; discrete, 150 decibels.

3. 1×1 -foot progressive wave acoustic test tube

Test volume: $1 \times 1 \times 1$ foot

Acoustic energy source: Four Altec Type 20801 transducers

Frequency range: Discrete from 400 to 5000 Hertz; random from 4000 to 8000 Hertz.

Maximum overall sound pressure level (ref. 0.0002 microbar): Random, 145 decibels; discrete, 145 decibels.

4. 7×7 -inch progressive wave acoustic test tube

Test volume: $7 \times 7 \times 12$ inches

Horn: Hyperbolic horn with low-frequency cutoff of 25 Hertz. (See Table 2 for other horn configurations.)

Acoustic energy sources

a. One Ling EPT-94A electropneumatic transducer

Frequency range: Sine from 25 to 4000 Hertz; random from 25 to 8000 Hertz.

Maximum overall sound pressure level (ref. 0.0002 microbar): Random, 167 decibels; sine, 157 decibels.

b. One Ling HFT-20 electrodynamic transducer

Frequency range: Sine from 800 to 9600 Hertz; random, flat from 1000 to 7000 Hertz ($\frac{1}{3}$ -octave), with rolloff on both sides.

Maximum overall sound pressure level (ref. 0.0002 microbar): Random, 140 decibels; sine, 130 decibels.

5. Plane progressive wave test tube

Test volume: 2-inch diameter $\times$ 6-inch length

Acoustic energy sources

a. One Ling EPT-94A electropneumatic transducer

Frequency range: Sine from 20 to 4000 Hertz; random from 20 to 20,000 Hertz.

Maximum overall sound pressure level (ref. 0.0002 microbar): Random, 181 decibels; sine, 171 decibels.

b. One Ling HFT-20 electrodynamic transducer

Frequency range: Sine from 800 to 9600 Hertz; random, flat from 1000 to 7000 Hertz ($\frac{1}{3}$ -octave), with rolloff on both sides.

Maximum overall sound pressure level (ref. 0.0002 microbar): Random, 155 decibels; sine, 145 decibels.

6. Instrumentation and data-acquisition capabilities

100 data-acquisition channels, which may comprise combinations of

- a. Accelerometer channels
- b. Strain gage channels
- c. Microphone channels

(This capability includes all of the required transducer, signal-conditioning, and recording equipment.)

Some Major Tests Performed Using the Acoustic Test System

The high-intensity acoustic test system is used principally for testing JPL spacecraft and components; however, other organizations may also employ this facility when the capabilities required for a specific test are not available commercially. The following figures illustrate some of the tests that have been performed using the acoustic test system; Figures 8-14 show tests of JPL spacecraft and components, and Figures 15 and 16 present tests run for other organizations.

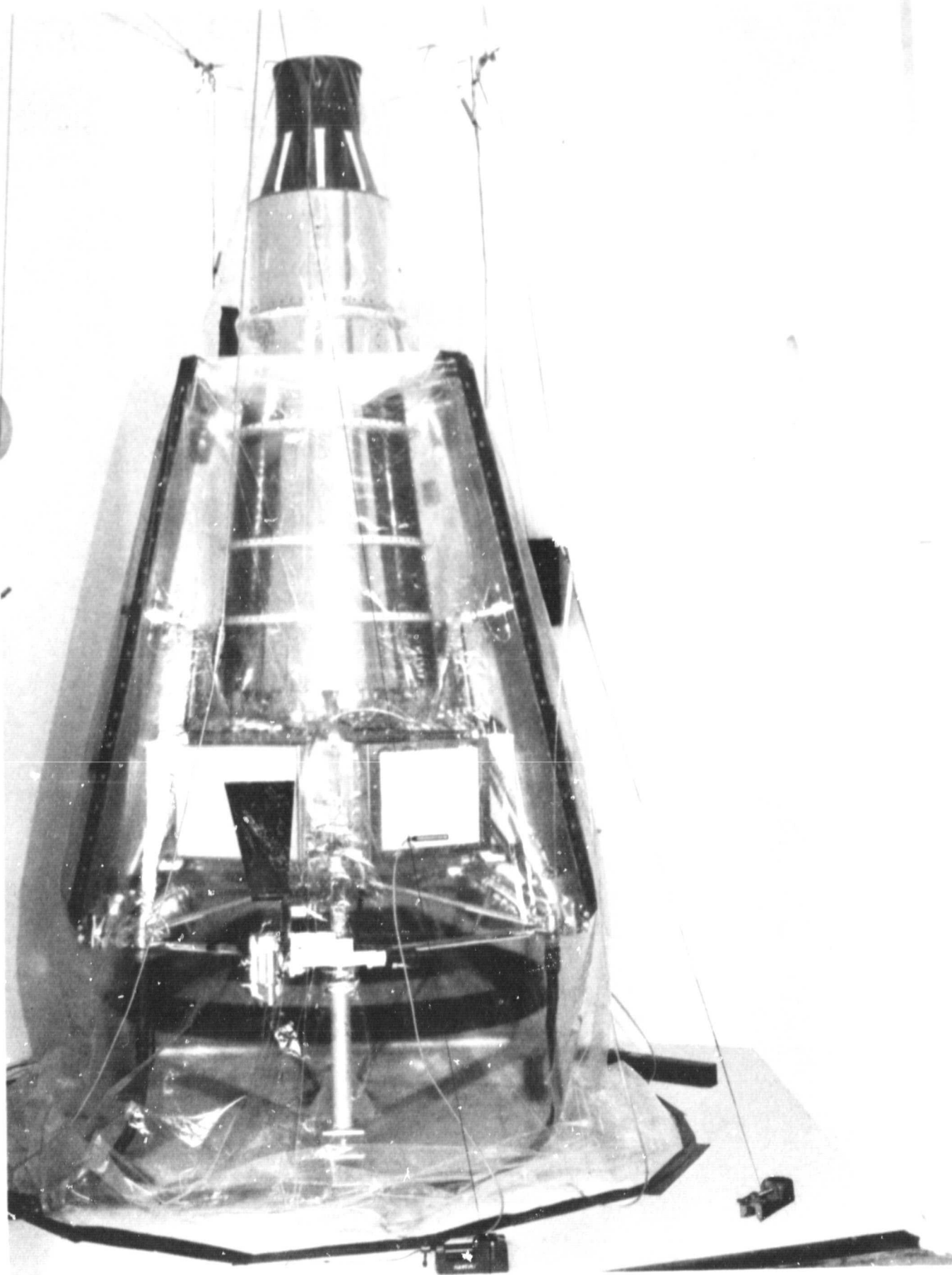


Fig. 8. Ranger Block III proof test model

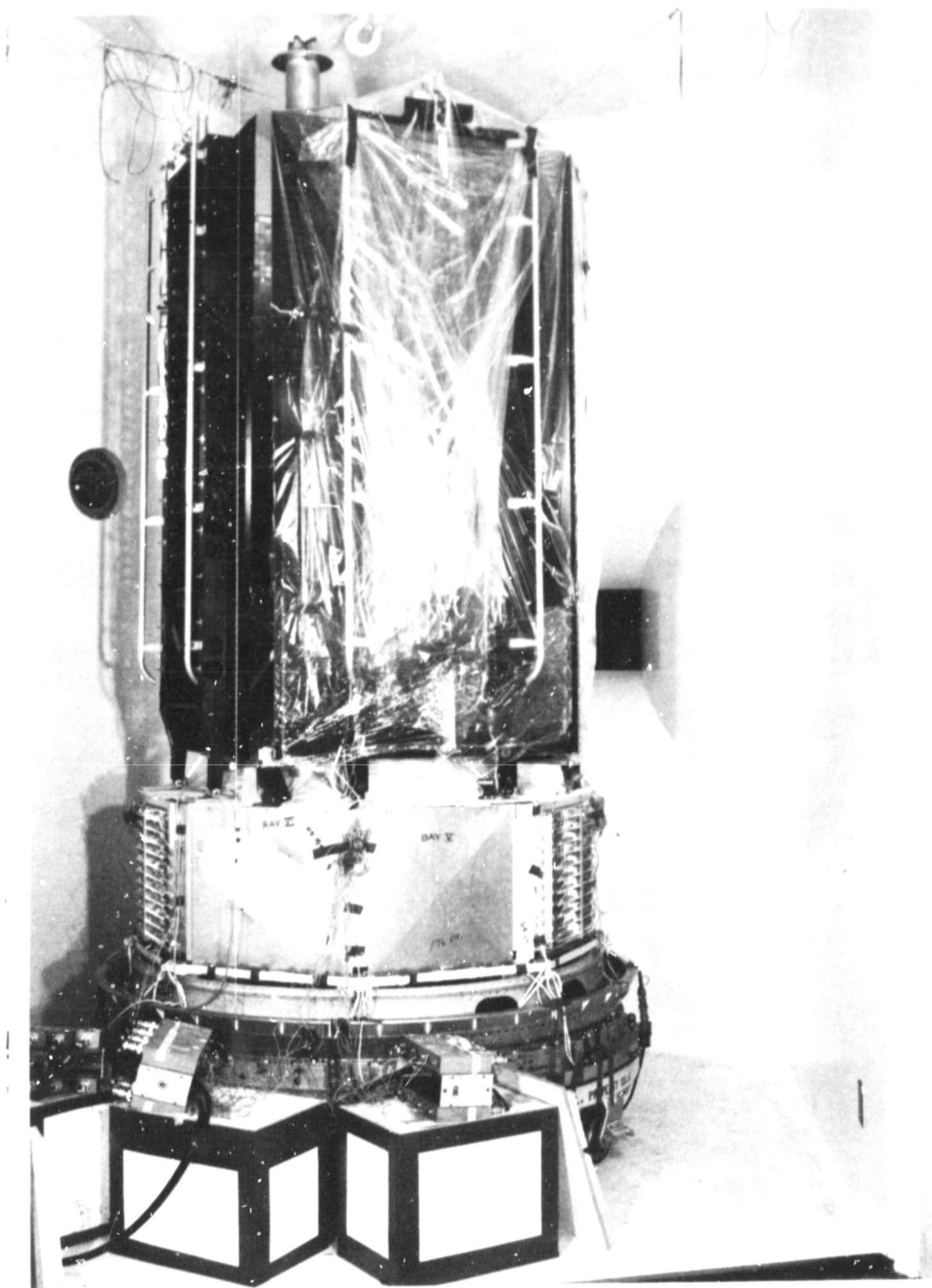


Fig. 9. Mariner Mars 1964 proof test model

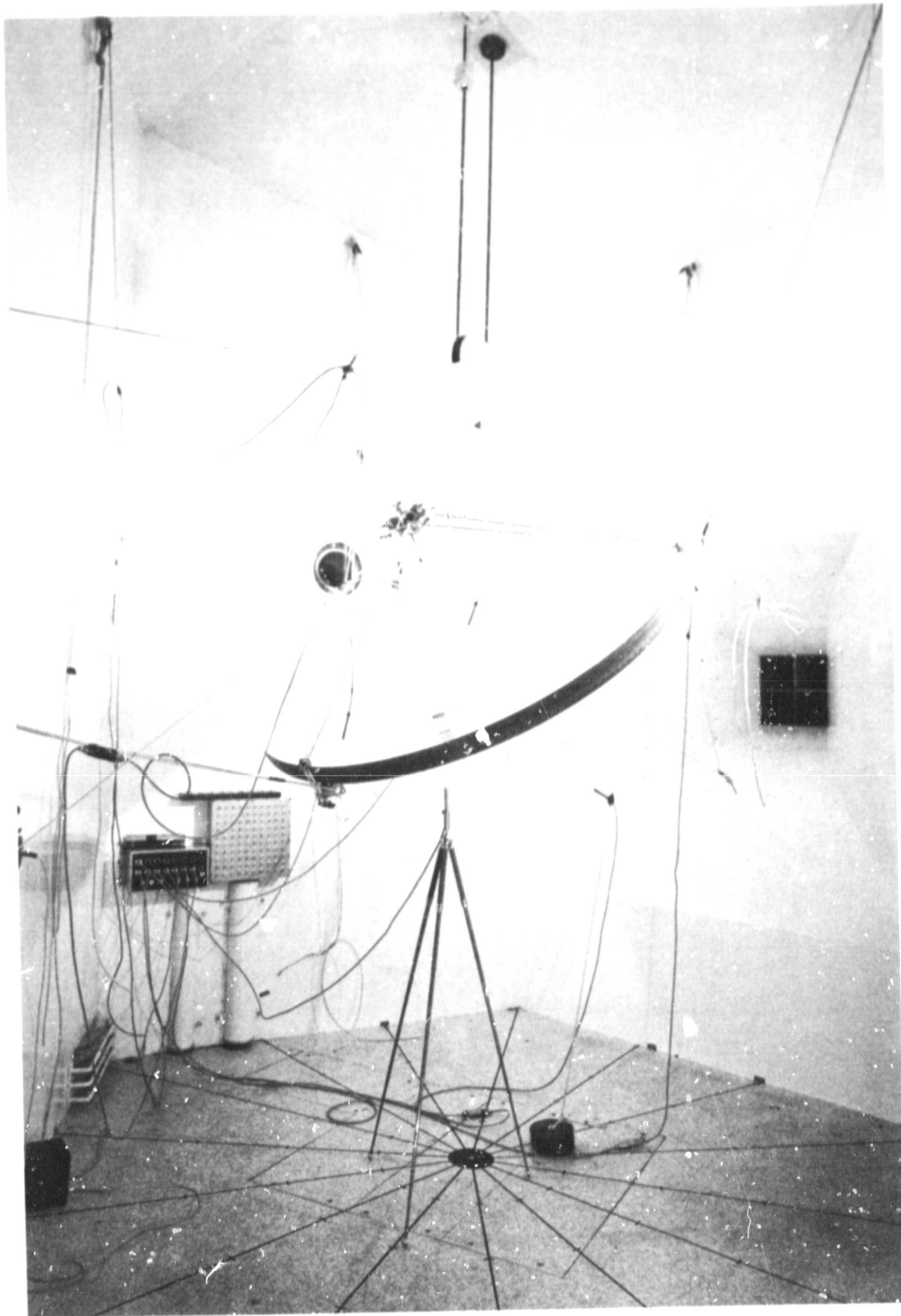


Fig. 10. Solar thermionic generator system

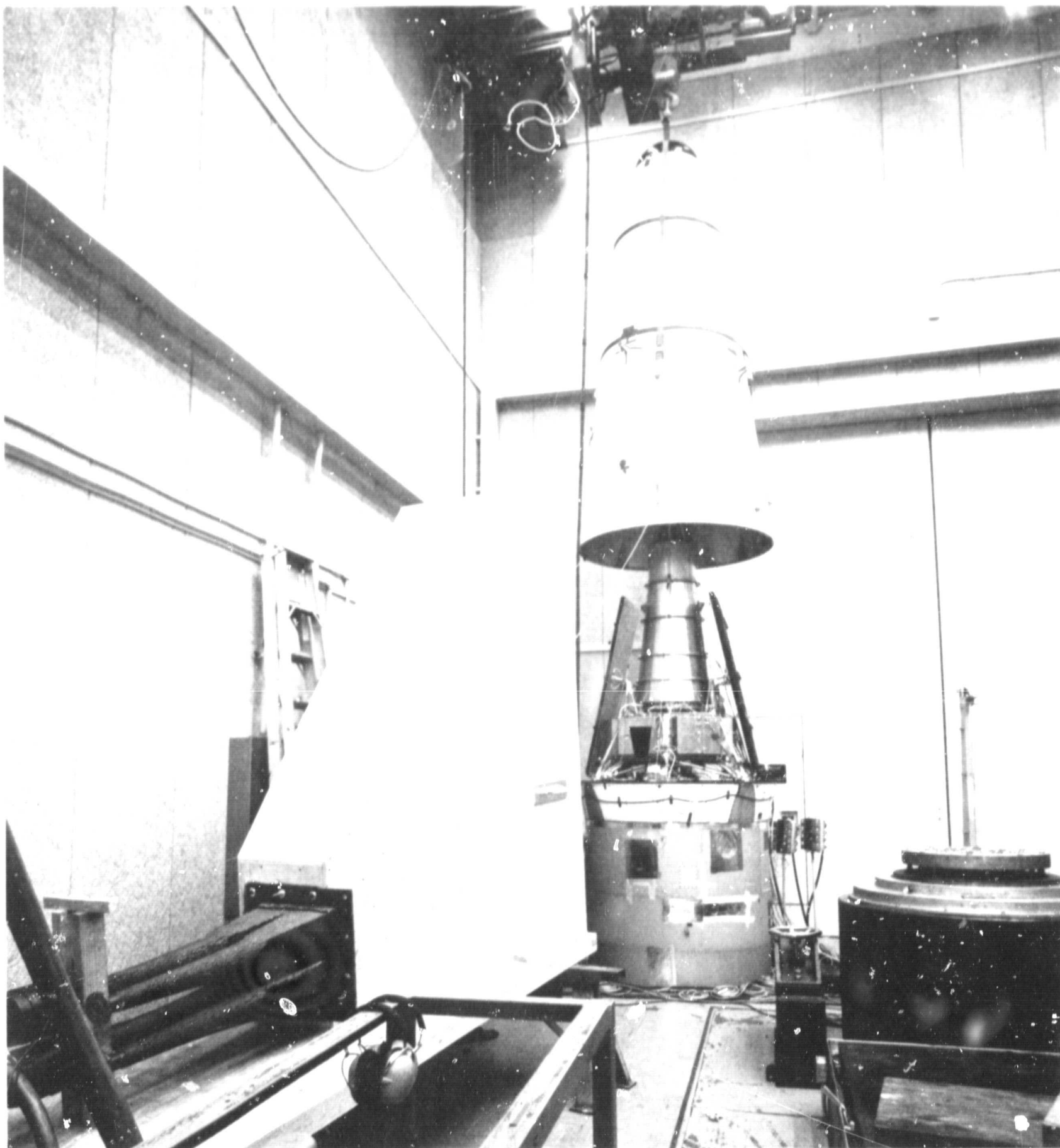


Fig. 11. Transmissibility test of Ranger Block III structural test model and shroud

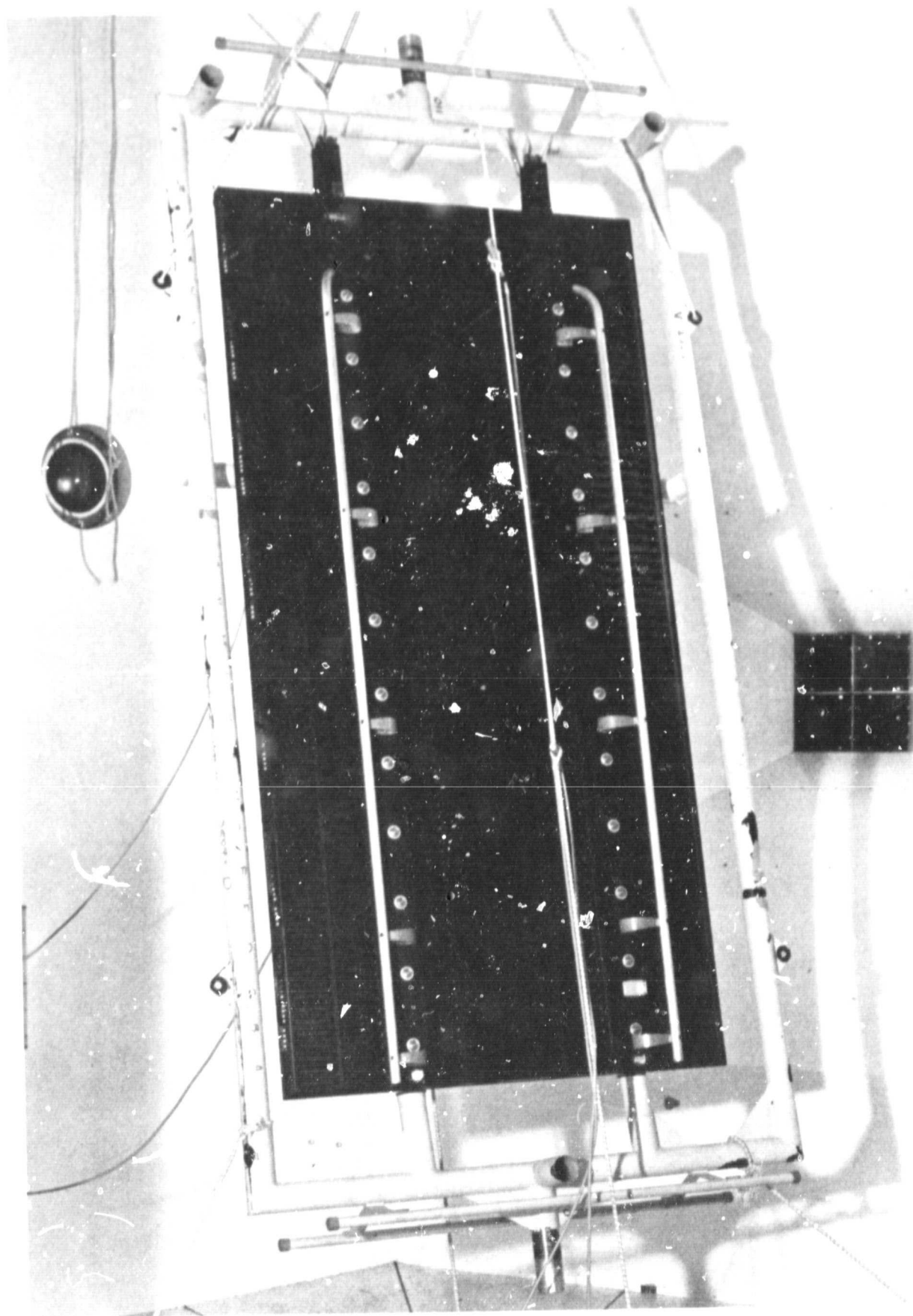


Fig. 12. Mariner Mars 1964 structural test model solar panel

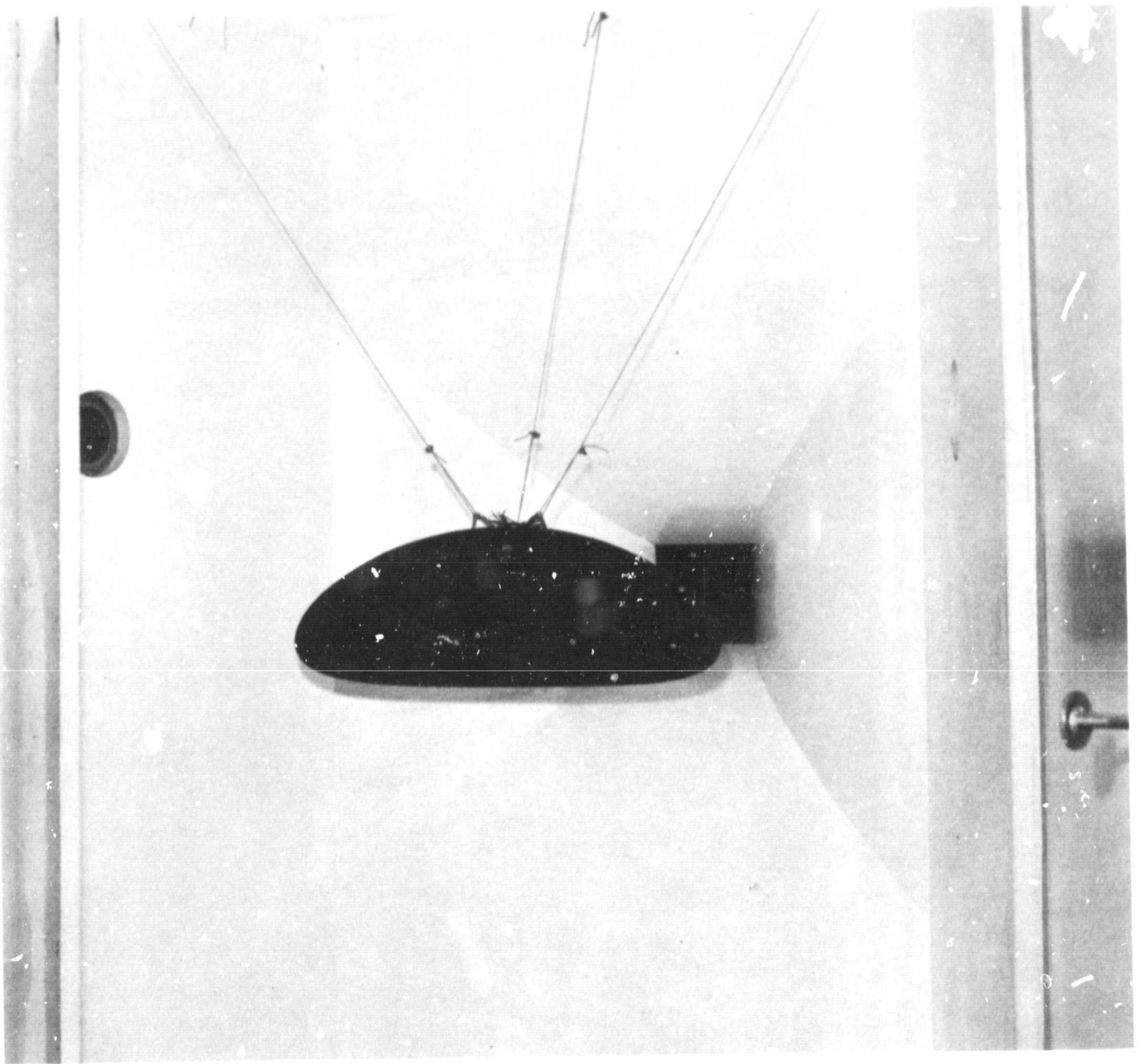


Fig. 13. Mariner Mars 1964 high-gain antenna

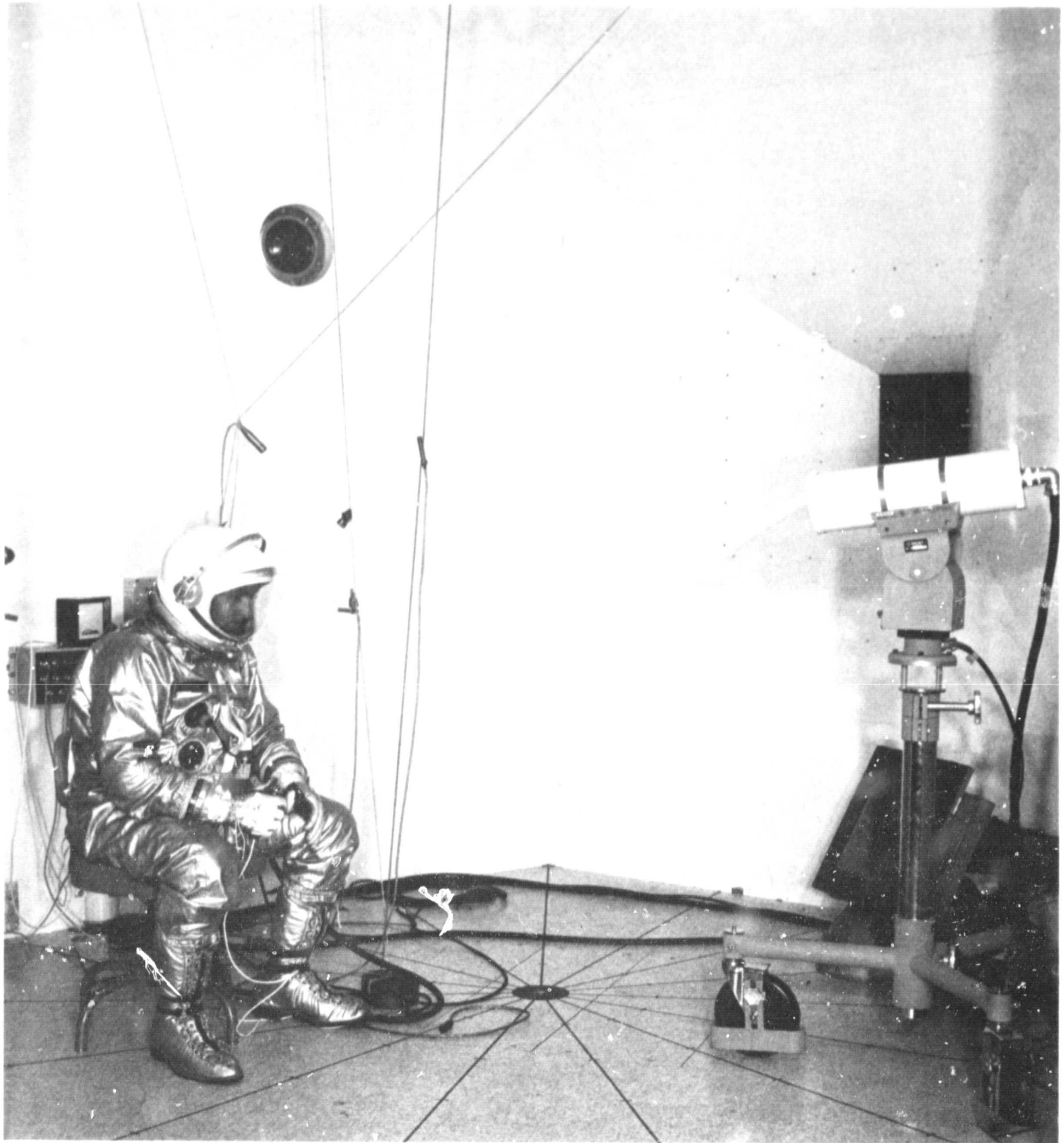


Fig. 15. Command signal-detection acoustic test of Apollo space suit

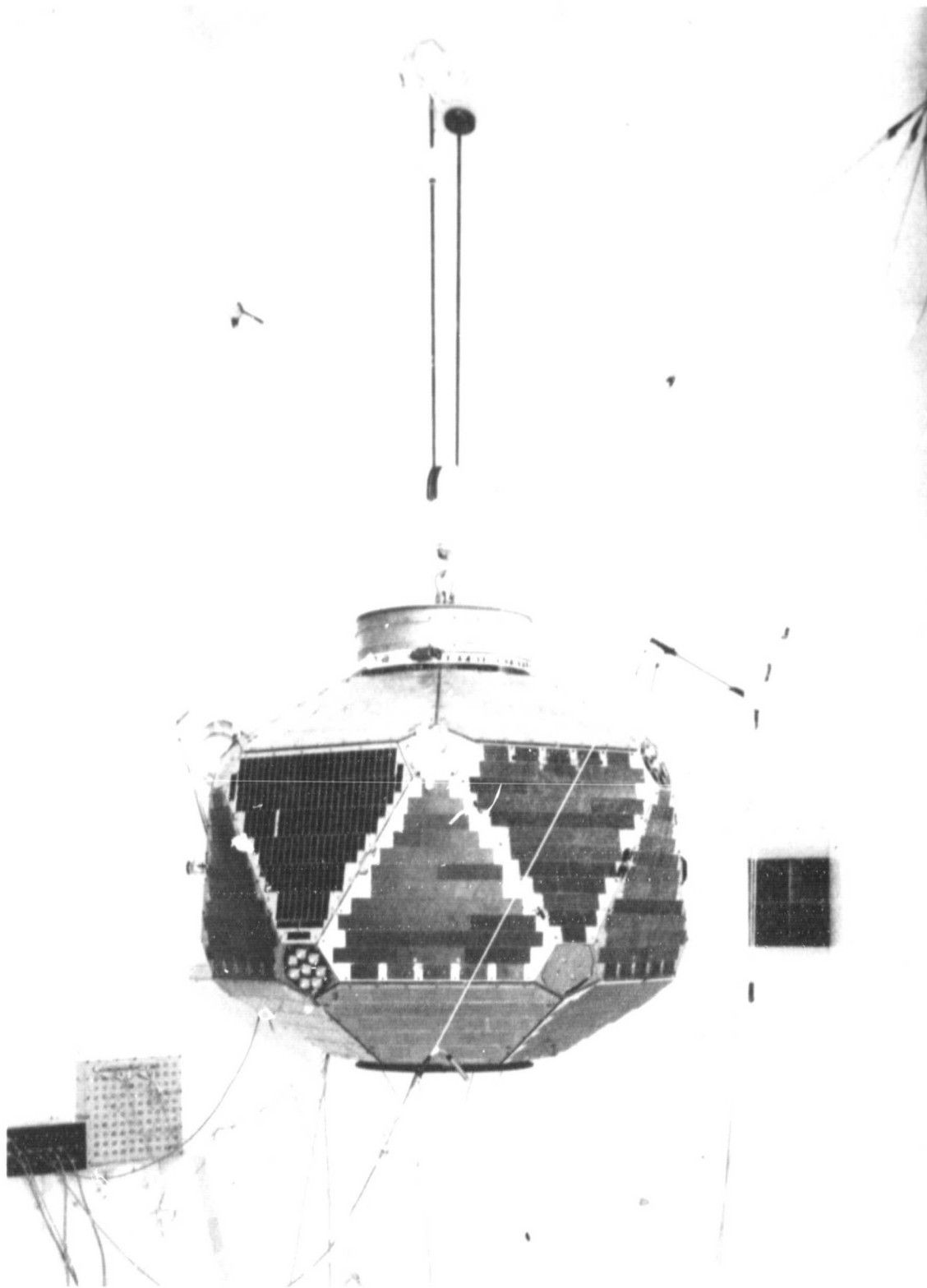


Fig. 16. Acoustic qualification test of Vela "nuclear detection" spacecraft
(photograph courtesy TRW Systems)