2947

100

NATIONAL BUREAU OF STANDARDS REPORT

2947

AN APPARATUS FOR MEASUREMENT OF SIMULTANEOUS HEAT AND WATER VAPOR FLOW THROUGH 4x8 FT INSULATED PANELS

by

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Report to

Office of The Quartermaster General
Department of the Army

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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- Office of Basic Instrumentation
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NATIONAL BUREAU OF STANDARDS REPORT

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4x8 FT INSULATED PANELS

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Heating and Air Conditioning Section
Building Technology Division

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by

H.E.Robinson, F.J.Powlitch, M.A.Barron and P.R.Achenbach

Abstract

An apparatus designed to subject the opposite faces of large insulated panels to selected differences of temperature and vapor pressure, for the study of moisture condensation and accumulation in panels in refrigeration service, is described. Provision is made for periodic measurement of the thermal conductance of the panel and of the rates of water vapor flow into the warm side and out of the cold side of the panel. The apparatus is mounted to rotate on horizontal trunnions so that a panel can be oriented in the position of a wall, roof or floor. Because moisture accumulates slowly in panels, the equipment is designed for continuous operation for periods of weeks or months. An account is given of measurements to evaluate apparatus coefficients needed in calculating heat transfer results, and also of the results of a few tests made in the apparatus for the chief purpose of evaluating its operation and performance.

I. INTRODUCTION

A project entitled "Water Vapor Transmission in Refrigerated Warehouses" was initiated at the National Bureau of Standards in May 1952, under the sponsorship and financial support of the Office of The Quartermaster General, Department of Defense. Its chief object was to establish practical criteria for the water vapor permeances of the faces and joints of insulated panels, used in refrigerated warehouses, to avoid condensation of moisture and its accumulation in them under operating conditions. Such moisture accumulation impairs the insulating effectiveness of panels, leading to serious difficulty in maintaining desired low temperatures in the structure, and causes rapid deterioration of panels due to decay or corrosion of their components or fasteners.

The problem is basically that of preventing or minimizing vapor entrance on the warm side of the panel, and allowing, or impeding as little as possible, its exit through the cold face. Except for metal sheets, there are few materials available for panel construction, especially under war conditions, that are not to some extent permeable to water vapor. Other factors, such as leaks, methods of assembling and fastening panels, and requirements for the washability of cold side surfaces of panels, also must be taken into account.

To explore and evaluate the problem, which includes knowing the temperature and humidity or moisture conditions at which the various components of panels must operate in service, an apparatus capable of tests on full-scale panels (4x8 ft in size) was constructed, as described herein. In this apparatus, a panel is exposed to desired temperatures and vapor pressures on both sides over long periods, during which heat flow through and vapor flow into and through the panel can be periodically observed. Measurements of the heat flow, or of its changes, are for the purpose of indicating the effect of moisture accumulation on overall insulating value, as well as to indicate indirectly if moisture is accumulating in the panel. In addition, temperature and humidity measuring elements in the panel will be used for observing the ambient conditions at which various components of the panel must function in service. The latter information is essential for evaluating and selecting appropriate materials for use as components, since the vapor permeance of many applicable panel materials depends on the humidity and temperature conditions to which they are exposed.

Using permeance data for materials at appropriate conditions if they are available, or if necessary are obtained by appropriate measurements, improved designs of panel can be worked out and subjected to trial in the panel apparatus.

The orientation of a panel, that is, whether it is used as a wall, floor or ceiling of a refrigerated chamber, may markedly affect its performance, especially as regards moisture accumulation effects. To enable studies in different orientations, the test apparatus was constructed so that it can be rotated 90° in either direction, thus orienting a panel in either a wall, roof or floor position.

The apparatus was designed for warm side air temperatures up to about 150°F, with relative humidities up to about 90 percent. The cold side was designed to attain temperatures as low as 100 degrees under the room temperature, or about -30°F, and relative humidities from about 20 to 70 percent.

In the first year of the project, a bibliographical compilation on the subject was made, and the large panel apparatus was built, instrumented, and subjected to calibration and operating tests. Inasmuch as the sponsoring agency was not able to continue its expected financial support of the project at the start of this fiscal year, the following report is presented to describe the completed apparatus and the results of the tests thus far made with it.

II. DESCRIPTION OF THE APPARATUS

A schematic drawing of the apparatus, with its major elements designated by numbers, is shown in Figure 1. The main part of the apparatus was constructed as two sections of a box, which are coupled together by bolts through the angles (2) at their edges. The test panel (3), 4x8 ft in size, is installed against a gasketed stop (23) in one section, dividing the enclosure into a warm side and a cold side, which are separately maintained at the desired temperature and humidity conditions throughout a test. Insulation is packed into the space at the edges of the panel to prevent chilling of the stop (23) and possible condensation on its warm side. The assembled sections are supported on trunnions attached to the warm side section and resting on brass bearings, constituting a horizontal axis (A) about which the apparatus can be rotated 90° in either direction. A small dolly is used to support and move the cold side when it is uncoupled from the trunnion-supported warm side.

Both sections were constructed using 2x4 softwood framing with 1/4-inch plywood glued and screwed to its inner and outer faces. Framing was kept to a minimum consistent with structural requirements to reduce heat conduction through framing members. The 3-5/8 inch spaces between the plywood sheets were filled with two slightly compressed layers of 2-inch low density fiberglass thermal insulation.

Both sections were lined on the inside and covered on the outside with 0.006-inch aluminum sheet for vapor proofing. The aluminum sheet was cemented to the plywood with a rubber-base adhesive, and seams were overlapped and sealed with an adhesive-surfaced lead tape one inch wide. Heavy polyethylene sheet was substituted for aluminum sheet on the inner warm side surface at the stop and the edges of the test panel to reduce heat conduction to the cold side. All electric and other lines entering into the enclosed spaces were bunched into groups, and led through close-fitting holes packed with permagum and sealed with aluminum sheet and lead tape.

On assembly, the joint between the warm and cold side sections is made vapor-tight by four lines of rubber gasket (1), the spaces between which are filled with permagum prior to closing the joint. The test panel is installed against the stop (23), against which it is firmly pressed by means of wedges (4) bearing on the peripheral shim (21) and the removable retainers (5). A vapor-seal at the panel edges is provided by a rubber gasket flanked by permagum.

The air temperature on the warm side is maintained by small electrical resistance heaters in a cylindrical tube (6) through which air is circulated by a fan (7). Selected heaters are energized continuously, and one or two are energized intermittently under the control of an electronic time-proportioning thermostat (ref. NBS Report No. 2083) having its sensing element at the location (8) on the warm side. On the cold side, the air is cooled to a temperature slightly below the desired value, by means of the flooded direct-expansion cooling coil (9) through which air is circulated by a fan (7). An electrical strip heater (10), controlled by a second channel of the previously-mentioned thermostat, with its sensing element at (8) on the cold side, is used to raise the air temperature by the slight amount necessary to obtain the desired value. Eight fine wire (No. 30 AWG) thermocouples (11), connected electrically in parallel, are used on each side to measure the average air temperature at a distance of 3 inches from the panel. Ten individual thermocouples (12) are used to measure the temperature of each face of the panel. Leads for a number of thermocouples, and for several Dunmore-type humidity-indicating elements, are brought into the boxes for making measurements of conditions at various locations within the test panel. Sixteen differential thermocouples (13), connected electrically in series, are attached to the inside and outside plywood sheets of the warm side section under the aluminum sheet, for the purpose described below.

All electrical input to the warm side is measured by an integrating watt-hour meter with dials readable to one watt-hour. The heat thus introduced leaves the warm side box by (a) transmission through the test panel (b) transmission through the five other faces of the warm side box to the laboratory air and (c) conduction around the test panel through the inner lining of the warm side section. Item (b) is proportional to the average emf developed by the series-differential thermocouple (13), and item (c) is approximately proportional to the air temperature difference of the warm and cold sides. (Perhaps more satisfactory for evaluating item (c) would be a series-differential thermocouple similar to (13) with junctions appropriately located on the inner lining on both sides of the panel). Since the average rate of heat input to the warm side during a period of a test is known from the watt-hour meter readings, and items (b) and (c) can be evaluated from the measured thermocouple readings and constants determined by calibration tests, the average rate of heat transmission through the panel, both sensible and latent, can be calculated with reasonable accuracy. By this means, significant changes in the heat transmission of the panel can be determined as a test is continued. The procedure for determining the calibration constants to be used in evaluating items (b) and (c) is described in Section IIIA of this report.

Water vapor is generated on the warm side as needed to maintain its humidity at a desired value and to replace vapor permeating the test panel. A covered and insulated aluminum vessel (14) contains water held approximately at a desired temperature by a constant small current in an electrical resistance heater cemented to the bottom of the vessel. When an electronic humidity controller with a Dunmore-type sensing element located at (16) on the warm side calls for an increase in humidity, a small blower (15) is energized, forcing air through the hose (20) into the vessel (14), from which it is discharged carrying an increment of water vapor. The water temperature is adjusted so that the blower on and off periods are approximately equal.

The water container (14) is suspended from a cantilever scale (19) (see NBS Progress Report No. 2228 to O.Q.M.G.) by means of which the weight of water evaporated in a given period can be determined. Figures 2 and 3 show details of the construction of the cantilever scale, which is mounted on a horizontal axis with ball bearings so that it remains in a fixed plane regardless of the angular orientation of the panel and main apparatus. The deflection of the cantilever beam under load at constant temperature is linearly proportional to the load, provided the maximum stress in the cantilever does not exceed the proportional limit. Consequently loads corresponding to intermediate deflections can be calculated by interpolation between deflections for two known loads. The cantilever bar is dimensioned so that its deflection changes about 0.08 inch when the suspended container (14) is filled with water. Deflections of the cantilever within this range are indicated by a dial gage with 0.0001 inch graduations, the dial of which is viewed through the multiple double-pane window (22). A small buzzer mounted on the scale is actuated during readings to overcome frictional hysteresis in the system. Deflections can be read to within a fraction of a graduation of the dial gage, enabling calculation of load changes to within less than 1/800 of the weight of the water contents of the container. The dimensions of the cantilever bar and the capacity of the container are selected to accord with the estimated demand for vapor during a test run.

Beryllium copper was used for the cantilever beams because of the high limit of proportionality (70-80,000 psi) of its stress-strain curve, and its low hysteresis; the maximum stress occurring during use does not exceed 40,000 psi. Experimental measurements indicated that the load-deflection curves of the devices closely approximated straight lines over the working load range. A pantagraph support for the hose (20) was pro-

vided to obviate possible forces in the hose between the fixed blower (15) and the suspended load (14). Prior to a test, the load deflection characteristic of the cantilever beam in place is determined by measurements with known increments of load. A small correction factor has been evaluated to take account of changes in the elastic properties of the cantilever and its dimensions with temperature.

The relative humidity on the cold side of the panel is held constant, and vapor permeating the panel is absorbed, by means of the desiccant (17) (silica gel) spread out in eleven wire mesh trays in the external desiccant box. By means of the flexible metallic hoses (18) and the two small blowers (15), air is drawn from the cold side, passed over the desiccant, and returned to the cold side at a rate of about 4 CFM. Operation of the blowers is controlled by a humidity controller with a Dunmore-type sensing element located at position (16) in the cold box. A refrigerating coil (9) is operated in the desiccant box to keep its air temperature approximately equal to that in the cold side box. The construction and vapor-proofing of the desiccant box is like that of the other boxes; one of its sides is removable for placement of the trays of desiccant, and the joint is sealed in the same manner as the joint between the warm and cold side boxes.

The trays of desiccant are hung from a fixed cantilever scale (19), similar to but of greater capacity than that in the warm side box. As much as 80 lb. of dry desiccant can be placed in the trays, affording capacity for adsorption of 15 or more lb. of water at a low vapor pressure. The desiccant is regenerated, when necessary, by lowering the entire tray assembly into a chimney-shaped drying oven made of 4-inch foamglas blocks with a 660-watt electric cone heater at its bottom. An insulated cover is placed over the oven, and a few small apertures are left open at top and bottom for thermal ventilation of the oven. The temperature of the desiccant reaches 300°F or more at the end of the drying period, which requires from 16 to 24 hours. The desiccant is removed from the oven just prior to a test, and is transferred to the desiccant box while still quite warm, to reduce moisture pick-up during transferral.

In operation of the cold box, it is necessary to avoid condensation of vapor on its refrigerating coil (9) or on that in the desiccant box, if all the vapor permeating the panel is to be adsorbed by the desiccant. The coils must therefore be operated at temperatures above the dewpoint of the air in contact with them. For this reason, the coils (9) are large and are operated with large air circulation rates; furthermore, the coils are operated flooded with refrigerant to obtain maximum capacity with a small air to coil temperature

difference. The coil temperatures are controlled by adjustable evaporator pressure regulating valves; supply of refrigerant to each coil is governed by a thermostatic expansion valve. To keep the coil flooded, the superheat bulb of the expansion value is in thermal contact with and responsive to the temperatures of both the coil suction line and a small variac-energized electric heater by means of which an artificial superheat is produced. The voltage on the heater is adjusted so that the coil operates completely flooded, as indicated by thermocouples on its surfaces, without overflooding back to the compressor. The refrigerant and suction lines are connected to the cold box by means of flexible hoses to allow for its range of movement.

In order that the relative humidity in the cold box may be kept at a reasonably high value if this is desired during a test, and in view of the limitation on dewpoint temperature to avoid condensation on the cooling coil, the re-heat required for thermostatic control of the cold side air temperature, previously referred to, is kept as small as possible.

To indicate the performance of the arrangement described, in a test with the average cold air temperature at -23°F, the temperatures of the refrigerating coil at its entrance, center and exit were within 0.5 degree of -27.9°F. Under these conditions, condensation on the coil would not occur for cold side air relative humidities up to 75%.

Eight photographs are attached showing views of the apparatus and parts as follows:

Figure 4 - General view of apparatus with panel in horizontal plane.
Figure 5 - General view of apparatus with panel in vertical plane.
From left to right: instrument console, warm and cold side boxes, desiccant box, and oven for regenerating desiccant.
Figure 6 - Apparatus with the two boxes separated.
Figure 7 - Close-up of warm side section showing heater and centilever scale assemblies.
Figure 8 - Close-up of cold side section.
Figure 9 - Close-up of desiccant box.
Figure 10 - Refrigerating equipment and controls.
Figure 11 - Instrument console and controls.

III. APPARATUS CALIBRATION, TESTS, AND RESULTS

A. A series of tests was made to determine the calibration constants for evaluating heat losses from the warm side other than through the test panel, as previously mentioned, in order to enable calculation of heat transmission through the test panel. For this purpose, a 4x8 ft test panel was prepared with 2x4 framing with 1/16-inch aluminum sheet faces. The panel was filled full-thick with fiberglass insulation.

With the cold side held at substantially the same temperature (-23°F), three tests were conducted, of several day's duration each, with the warm side air temperatures adjusted to values a) approximately equal to room temperature, b) 25 deg. F cooler and c) 25 deg. F warmer. Heat input to the warm side was measured, and periodic readings were made of the various air and panel surface thermocouples, and of the differential thermocouple (13). During the initial stage of these measurements, it was found that the reading of thermocouple (13) varied widely with room air temperature fluctations resulting from thermostatic control of the laboratory heating system. To obviate this difficulty, the outer aluminum skin of the warm side section was covered with one inch of fiberglass duct insulation, glued to the aluminum. This reduced the amplitude of the cyclic variation of the readings of thermocouple (13) very considerably, to such extent that the average of several periodic readings showed little effect from this cause.

Using the data of the three tests, it was possible to write a heat balance equation for each test, as previously discussed, in which the unknowns were the calibration coefficient for thermocouple (13) and the equivalent thermal conductance of the panel including the heat conduction to the cold side around its edges. By simultaneous solution of these equations taken in pairs, the unknown coefficients were determined. Coefficients determined from different pairs of the heat balance equations agreed with their average value within 2.1 percent. The equivalent thermal conductance of the panel so determined included both heat flow through it, and heat flow around its edges. To estimate the latter, and a coefficient for it, the thermal conductance of the test panel was calculated using data as to the thermal conductivity of its components, and the desired coefficient was obtained from the difference between the observed equivalent conductance and the calculated conductance.

Taking the average values of the coefficients determined in this manner, the heat balance equation for calculating the average thermal conductance of a 4x8 ft panel was found to be

$$Cp \times \Delta t_{s-s} = 0.106W + 0.786\ (\pm D) - 0.0382\ \Delta t_{a-a}$$

where Cp = average thermal conductance of panel, Btu/hrft^2(deg.F)

W = average electrical input to warm side, watts

$\pm D$ = emf (millivolts) of differential thermocouple (13), with appropriate polarity

Δt_{s-s} = average surface to surface temperature difference of panel, deg.F

Δt_{a-a} = average air to air temperature difference across panel, deg. F

The validity of the above equation was shown in a test on a homogeneous foamed plastic panel described under C in this report.

B. An operational test of seven day's duration was made to observe the performance of the vapor generating and vapor absorbing systems and controls on the warm and cold sides of the apparatus. The test panel used for this purpose (see Figures 12 and 13) consisted of a frame of 2x4's on 16 inch centers and at the edges, to the warm side face of which was fastened a 4x8 ft sheet of 1/16-inch aluminum. Fiber glass duct insulation one inch thick was glued to the cold side of the aluminum sheet and, like the frame, was exposed to the cold side air. Six 1/4-inch diameter holes were drilled in the aluminum sheet along each of two horizontal lines 6 ft apart vertically, the insulation being chamfered around the holes. Under the test conditions (warm side air at 80°F and 51% R.H.; cold side air at 30°F and 66% R.H.), convective circulation of air between the warm and cold sides through these holes caused a steady net flow of vapor from the warm to the cold side.

The major findings based on the test of this panel were: (a) The cantilever weighing devices for determining vapor release and adsorption rates on the two sides of the panel performed satisfactorily, as did the operating control systems on both sides. Both cantilever scales indicated constant rates of vapor transfer; the cold side cantilever scale showed a rate of vapor adsorption twice as great as the warm side vapor release rate, which is believed to have been due to vapor entering from the laboratory air through a small leak which was later found in a connection of the flexible hose carrying air to the desiccant box.

(b) The vapor flow from the warm side through the holes in the panel was measured as equivalent to 3.4 grains per hour per square foot of panel. This is in agreement with the vapor flow that would be calculated on the basis of a coefficient of discharge of 0.78 for the holes, for convective air flow due to stack action under the conditions of the test.

(c) The vapor generating and vapor absorbing systems on the two sides of the panel had ample capacity for the vapor flow rates experienced.

(d) The heating and refrigerating systems, and their automatic controls, operated very satisfactorily throughout the seven-day test period.

C. A full-scale test of eight days' duration was made to determine the performance of the apparatus in testing a homogeneous, non-hygroscopic, test panel of low thermal conductance and moderate vapor permeance. The test panel was composed of four planks of foamed polystyrene insulation (Styrofoam 22) each 8 ft long, one foot wide and 3-1/16 inches thick, glued edge to edge to form a panel 4x8 ft in size and 3-1/6 inches thick. The three joints which were glued with a polymerizing adhesive called Weldwood were very strong, and appeared to be continuous and without leaks.

The findings of the test, which was conducted with the warm side air at 82.0°F and 55.5% R.H. and the cold side air at 32.1°F and 35.5% R.H., were as follows:

(a) The thermal conductance of the panel was determined to be 0.093 Btu/hrft^2(deg F), using the equation given previously. This compares with a calculated conductance of 0.092 Btu/hr ft^2(deg F) for the 3-1/16 inch panel based on the thermal conductivity of similar material as measured in a guarded hot plate apparatus.

(b) The average water vapor permeance of the test panel, as determined from the warm-side vapor generation rate, was 0.40 perm (grains/hr ft^2(inch Hg)), indicating an average permeability of the material of 1.22 perm-inch. Dry-cup tests of samples of the material 0.8 and 3.0 inches thick, at a uniform temperature of 73°F in an ambient at 50% R.H., yielded an average permeability of 1.5 perm-inch, which is in good agreement considering the different temperature and vapor pressure conditions.

(c) The cold side vapor adsorption rate exceeded the warm side generation rate, as in the previous test. Since there was no wood or hygroscopic material exposed in this panel, the excess moisture could be accounted for only by moisture ingress to the cold side from the humid laboratory air through a leak. A leak of considerable magnitude at one of the desiccant box hose connections was detected by introducing Freon 12 vapor into the cold side and inspecting all joints and seals with a halide torch. The leak was sealed, and further examination indicated an absence of discoverable leaks.

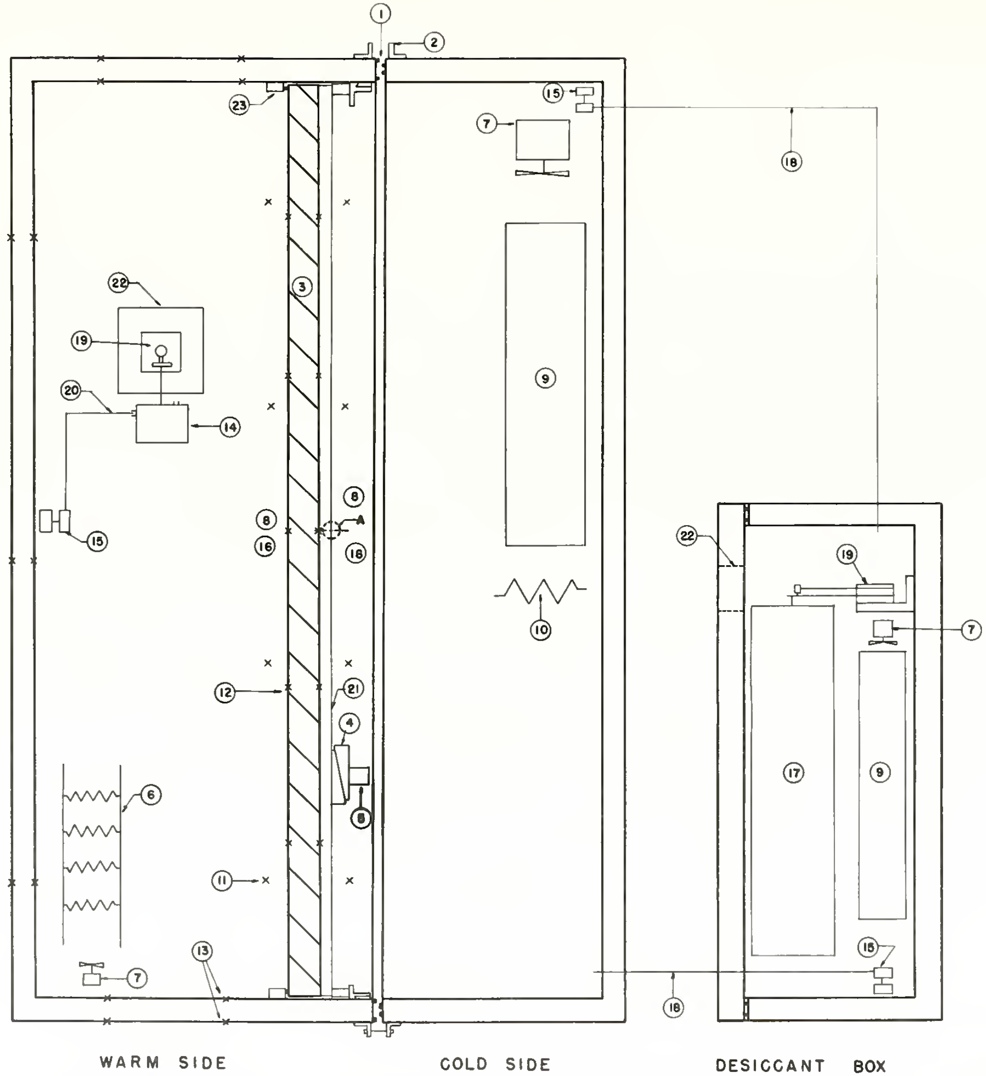
(d) The thermal conductance of the panel did not change perceptibly during the test. There was no evidence of moisture accumulation in the cells of this homogeneous, moderately permeable, panel material under the conditions of this test, based upon observation of a piece of the panel cut therefrom immediately on termination of the test. Analysis of the vapor pressure and temperature conditions in the panel material (based on the method described in BMS 63) showed that condensation in the material was unlikely under the conditions of this test. It was planned to repeat the test with the cold side at a much lower temperature to obtain conditions favoring moisture or frost accumulation in the panel material but curtailment of the project occurred before this test could be undertaken.

IV. SUMMARY

A description is given of an apparatus for making simultaneous heat and vapor transmission tests of 4x8 ft insulated panels over periods of time of weeks or months. Temperatures and relative humidities on both sides of the panel can be controlled at selected values. Check tests made on a few panels indicated that the thermal conductance and vapor permeance of panels can be measured with good accuracy.

The apparatus was constructed for the conduct of research measurements to determine criteria for the water vapor permeance of the surfaces of insulated panels to avoid moisture condensation difficulties in refrigeration service, and to study moisture accumulation and its effect in impairing the insulating effectiveness of panels as a result of improper vapor permeances, or vapor leaks, in their construction. The research program, including other phases of the work for which this apparatus was intended to serve as a guide in exploring the nature of moisture problems in panels, was originally expected to cover a period of three or more years. The essential preparatory steps to carry out the project as planned--namely, a bibliographical research and construction and operational checks of the major item of the necessary apparatus--

have been completed. Measurements of the vapor permeance of panels can therefore be undertaken at once if financial support for such measurements is provided.



A	TRUNNION AXIS
23	PANEL STOP
22	WINDOW
21	PANEL SHIM
20	HOSE TO VAPOR SOURCE
19	CANTILEVER SCALE
18	FLEXIBLE HOSE
17	DESICCANT TRAYS
18	HUMIDITY SENSING ELEMENTS
15	CENTRIFUGAL BLOWER
14	VAPOR SOURCE
13	DIFFERENTIAL THERMOCOUPLES
12	SURFACE THERMOCOUPLES
11	AIR THERMOCOUPLES
10	ELECTRIC HEATER
9	REFRIGERATION COIL
8	TEMPERATURE SENSING ELEMENTS
7	FAN
6	HEATER DUCT
5	WEDGE RETAINER
4	WEDGES
3	TEST PANEL
2	ANGLE IRON
1	BASKETS & PERMAGUM SEALERS

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HEAT & WATER VAPOR TRANSMISSION APPARATUS FOR PANELS—SCHEMATIC

FIGURE 1

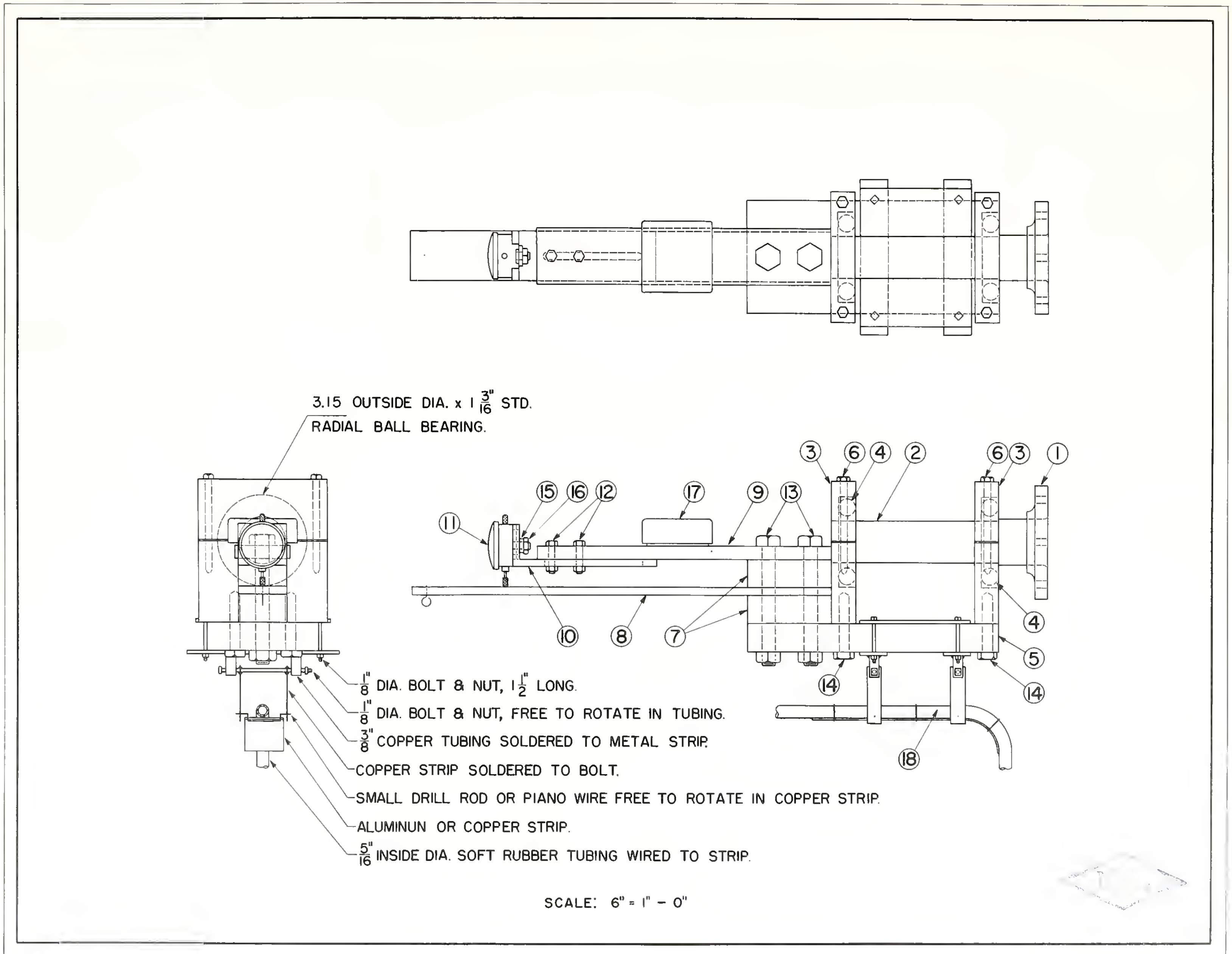
3.15 OUTSIDE DIA. x 1 3/16" STD.
RADIAL BALL BEARING.
1/8" DIA. BOLT & NUT, 1 1/2" LONG.
1/8" DIA. BOLT & NUT, FREE TO ROTATE IN TUBING.
3/8" COPPER TUBING SOLDERED TO METAL STRIP.
COPPER STRIP SOLDERED TO BOLT.
SMALL DRILL ROD OR PIANO WIRE FREE TO ROTATE IN COPPER STRIP.
ALUMINUN OR COPPER STRIP.
5/16" INSIDE DIA. SOFT RUBBER TUBING WIRED TO STRIP.
SCALE: 6" = 1" - 0"

Fig. 2

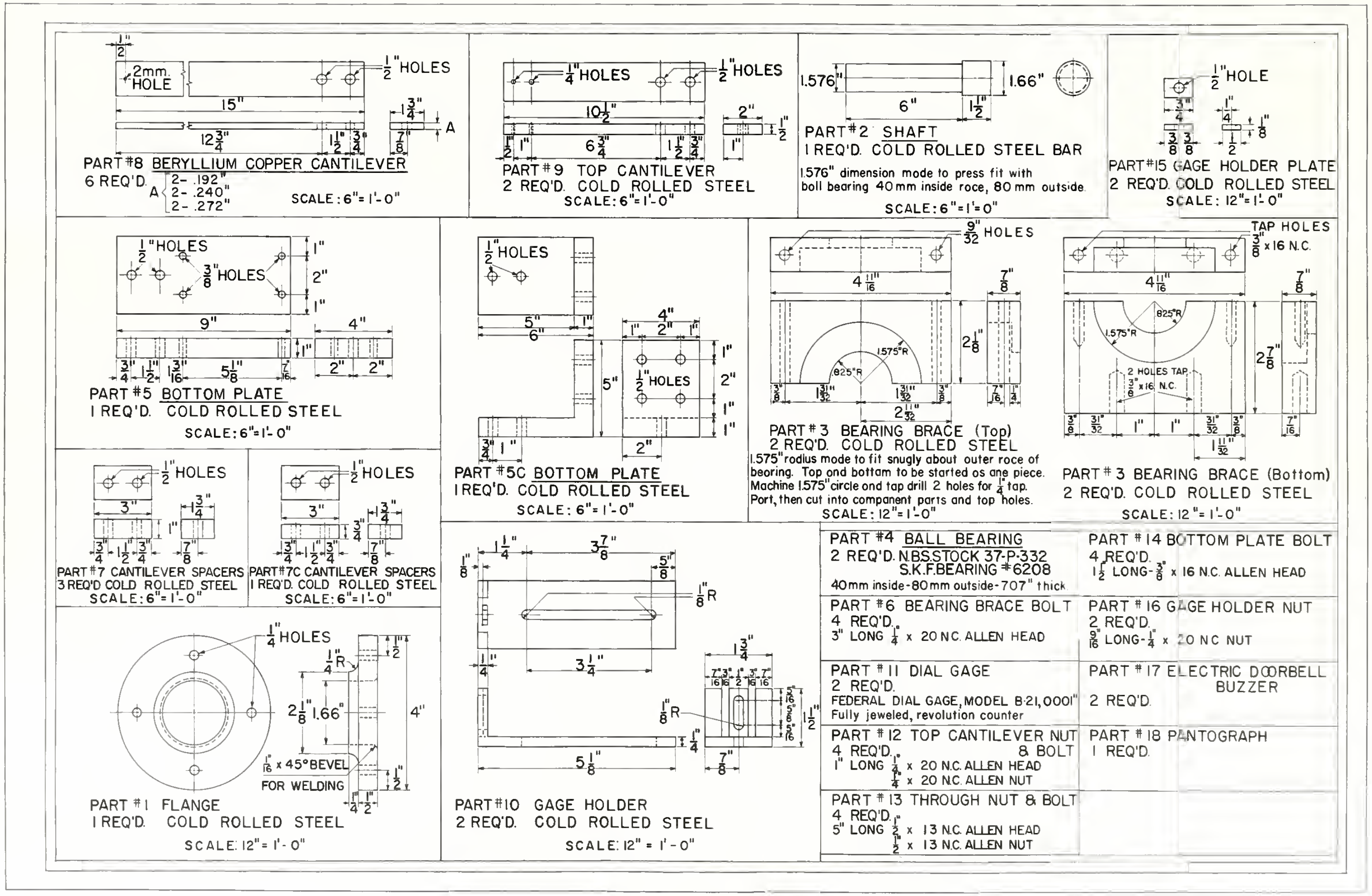
PART #8 BERYLLIUM COPPER CANTILEVER
6 REQ'D. A 2- .192" 2- .240" 2- .272"
SCALE: 6"= 1'-0"
2mm. HOLE
1/2" HOLES
PART #9 TOP CANTILEVER
2 REQ'D. COLD ROLLED STEEL
SCALE: 6"= 1'-0"
1/4" HOLES
1/2" HOLES
PART #2 SHAFT
1 REQ'D. COLD ROLLED STEEL BAR
1.576" dimension made to press fit with ball bearing 40 mm inside race, 80 mm outside.
SCALE: 6"= 1'= 0"
PART #15 GAGE HOLDER PLATE
2 REQ'D. COLD ROLLED STEEL
SCALE: 12"= 1'-0"
1/2" HOLE
PART #5 BOTTOM PLATE
1 REQ'D. COLD ROLLED STEEL
SCALE: 6"= 1'-0"
1/2" HOLES
3/8" HOLES
PART #5C BOTTOM PLATE
1 REQ'D. COLD ROLLED STEEL
SCALE: 6"= 1'-0"
1/2" HOLES
PART #3 BEARING BRACE (Top)
2 REQ'D. COLD ROLLED STEEL
1.575" radius made to fit snugly about outer race of bearing. Top and bottom to be started as one piece. Machine 1.575" circle and tap drill 2 holes for 1/4" tap. Part, then cut into component parts and tap holes.
SCALE: 12"= 1'-0"
9/32" HOLES
PART #3 BEARING BRACE (Bottom)
2 REQ'D. COLD ROLLED STEEL
SCALE: 12"= 1'-0"
TAP HOLES 3/8" x 16 N.C.
2 HOLES TAP 3/8" x 16 N.C.
PART #7 CANTILEVER SPACERS
3 REQ'D COLD ROLLED STEEL
SCALE: 6"= 1'-0"
PART #7C CANTILEVER SPACERS
1 REQ'D. COLD ROLLED STEEL
SCALE: 6"= 1'-0"
1/2" HOLES
PART #1 FLANGE
1 REQ'D. COLD ROLLED STEEL
SCALE: 12"= 1'-0"
1/4" HOLES
1/16" x 45° BEVEL FOR WELDING
PART #10 GAGE HOLDER
2 REQ'D. COLD ROLLED STEEL
SCALE: 12"= 1'-0"
PART #4 BALL BEARING
2 REQ'D. N.B.S. STOCK 37-P-332 S.K.F. BEARING #6208
40 mm inside-80 mm outside-.707" thick
PART #14 BOTTOM PLATE BOLT
4 REQ'D.
1 1/2" LONG-3/8" x 16 N.C. ALLEN HEAD
PART #6 BEARING BRACE BOLT
4 REQ'D.
3" LONG 1/4" x 20 N.C. ALLEN HEAD
PART #16 GAGE HOLDER NUT
2 REQ'D.
9/16" LONG-1/4" x 20 N C NUT
PART #11 DIAL GAGE
2 REQ'D.
FEDERAL DIAL GAGE, MODEL B-21,0001"
Fully jeweled, revolution counter
PART #17 ELECTRIC DOORBELL BUZZER
2 REQ'D.
PART #12 TOP CANTILEVER NUT & BOLT
4 REQ'D.
1" LONG 1/4" x 20 N.C. ALLEN HEAD
1/4" x 20 N.C. ALLEN NUT
PART #18 PANTOGRAPH
1 REQ'D.
PART #13 THROUGH NUT & BOLT
4 REQ'D.
5" LONG 1/2" x 13 N.C. ALLEN HEAD
1/2" x 13 N.C. ALLEN NUT

Fig. 3

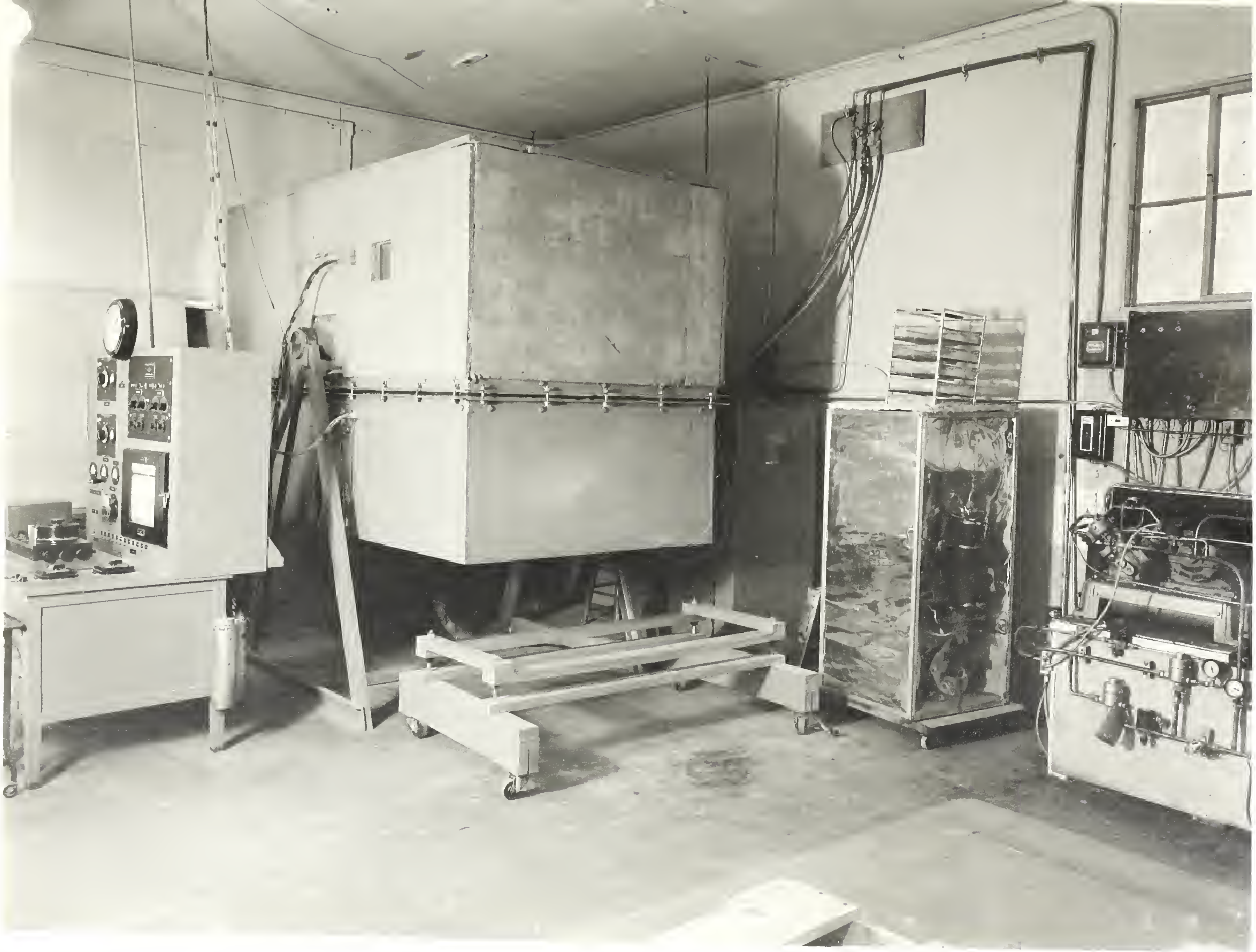

Fig. 4

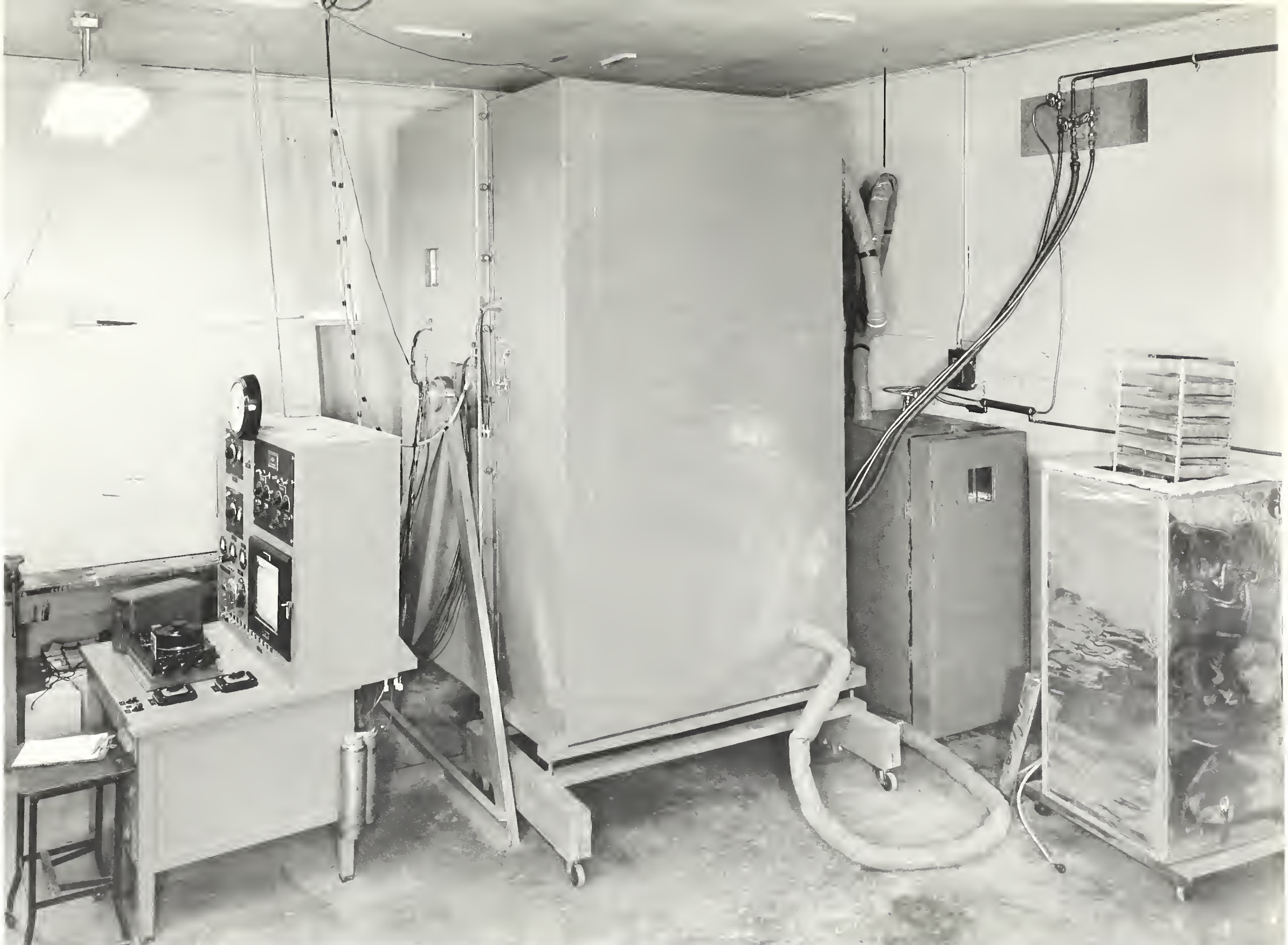

Fig. 5

Fig. 6

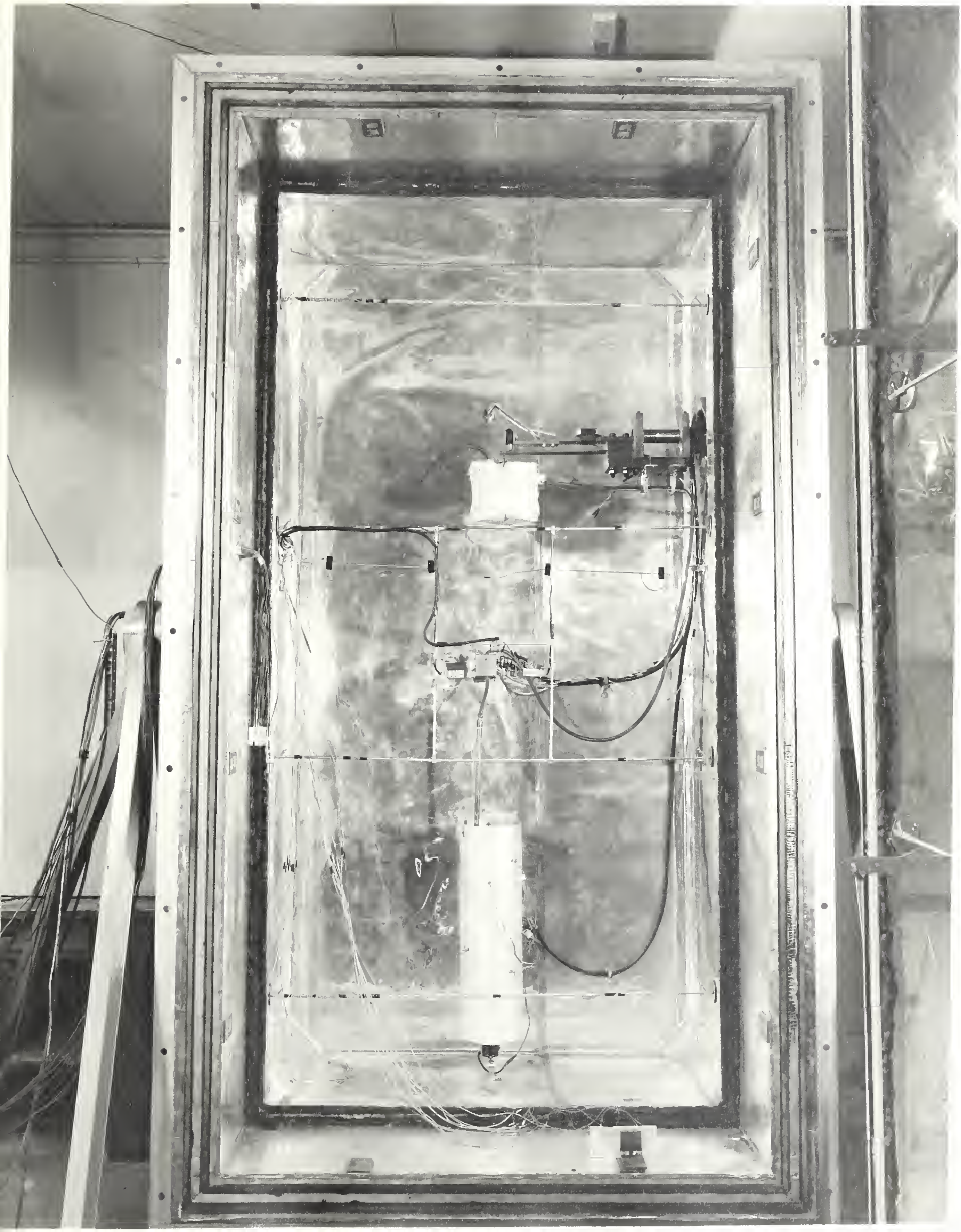

Fig. 7

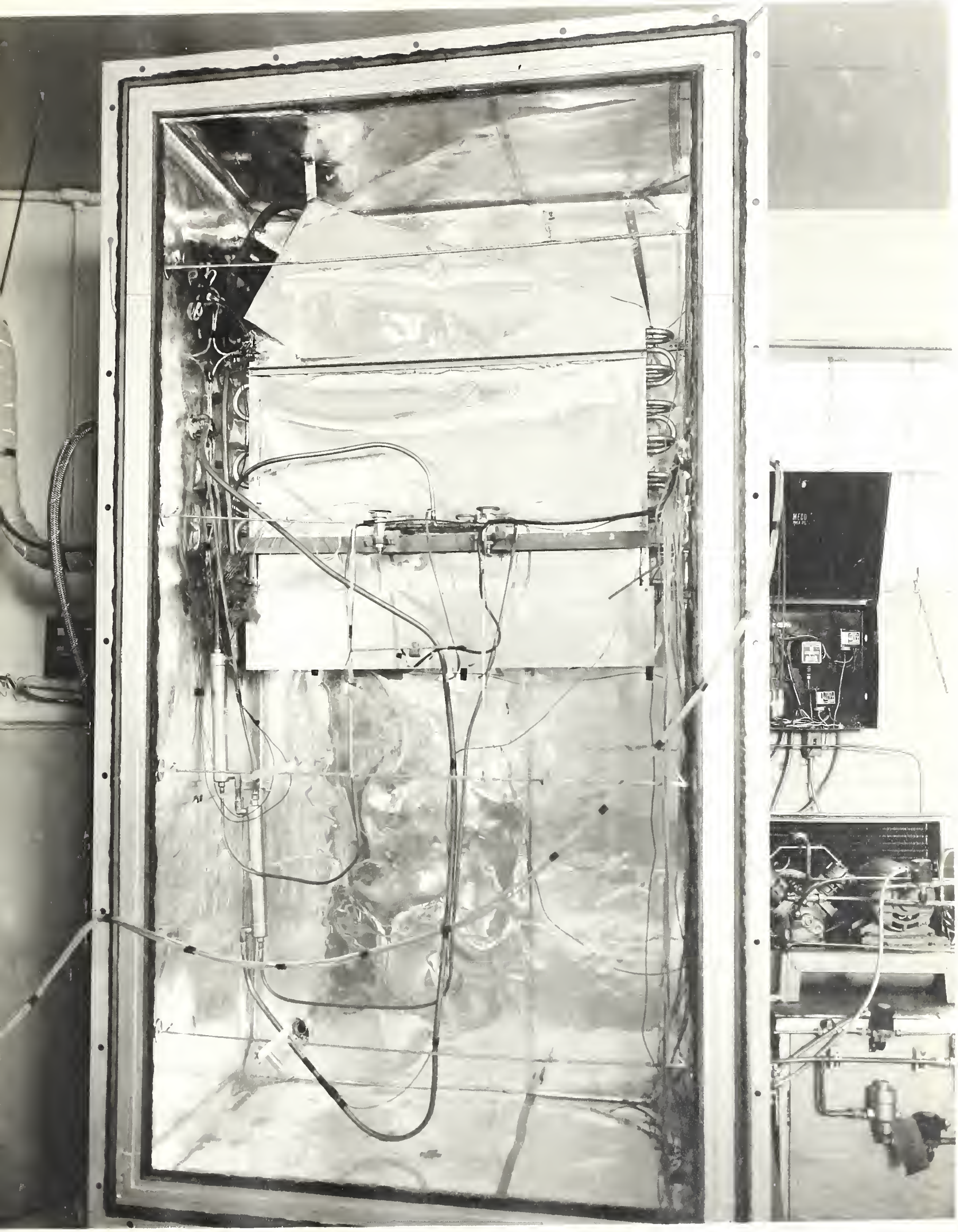

Fig. 8

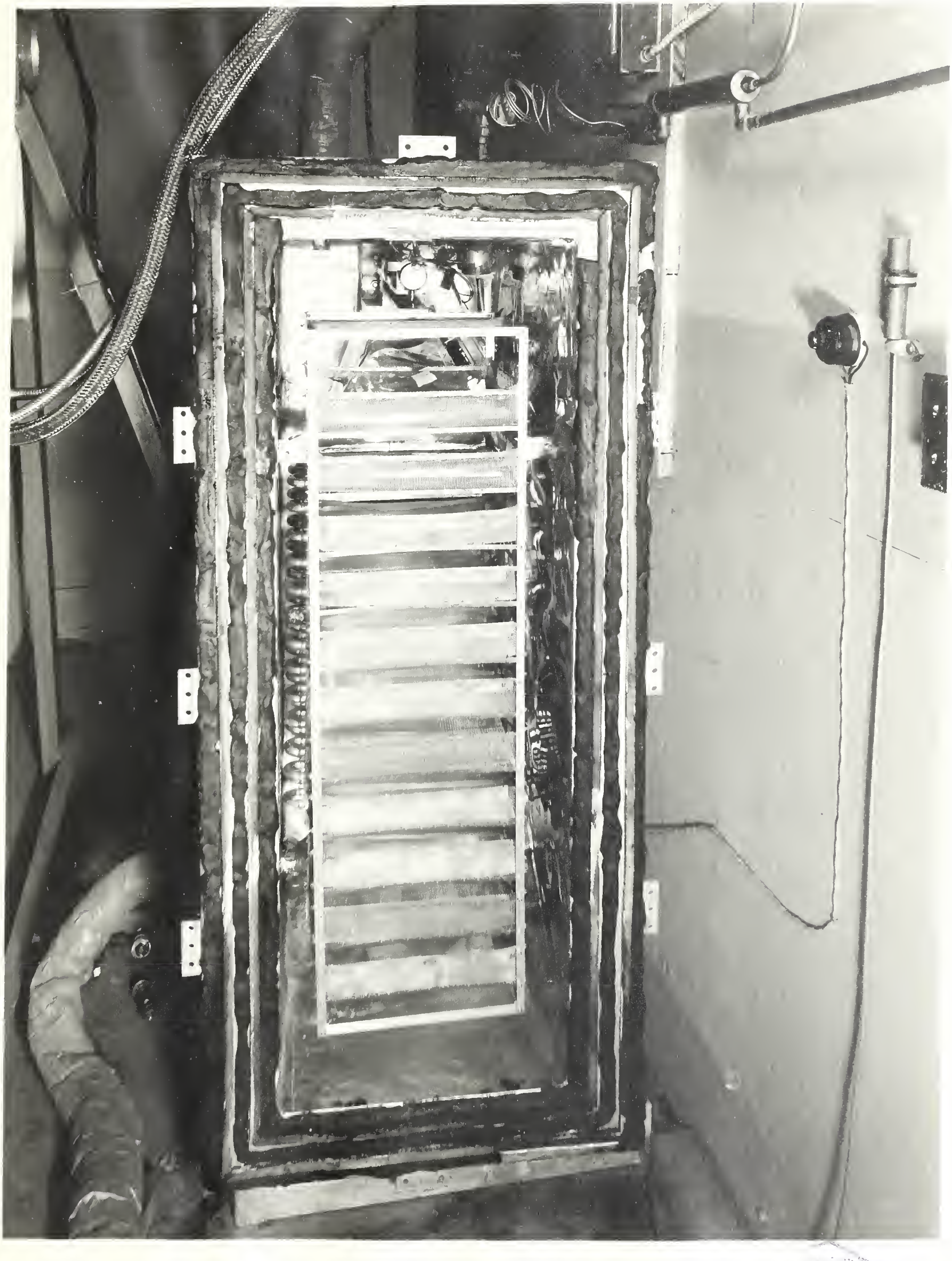

Fig. 9

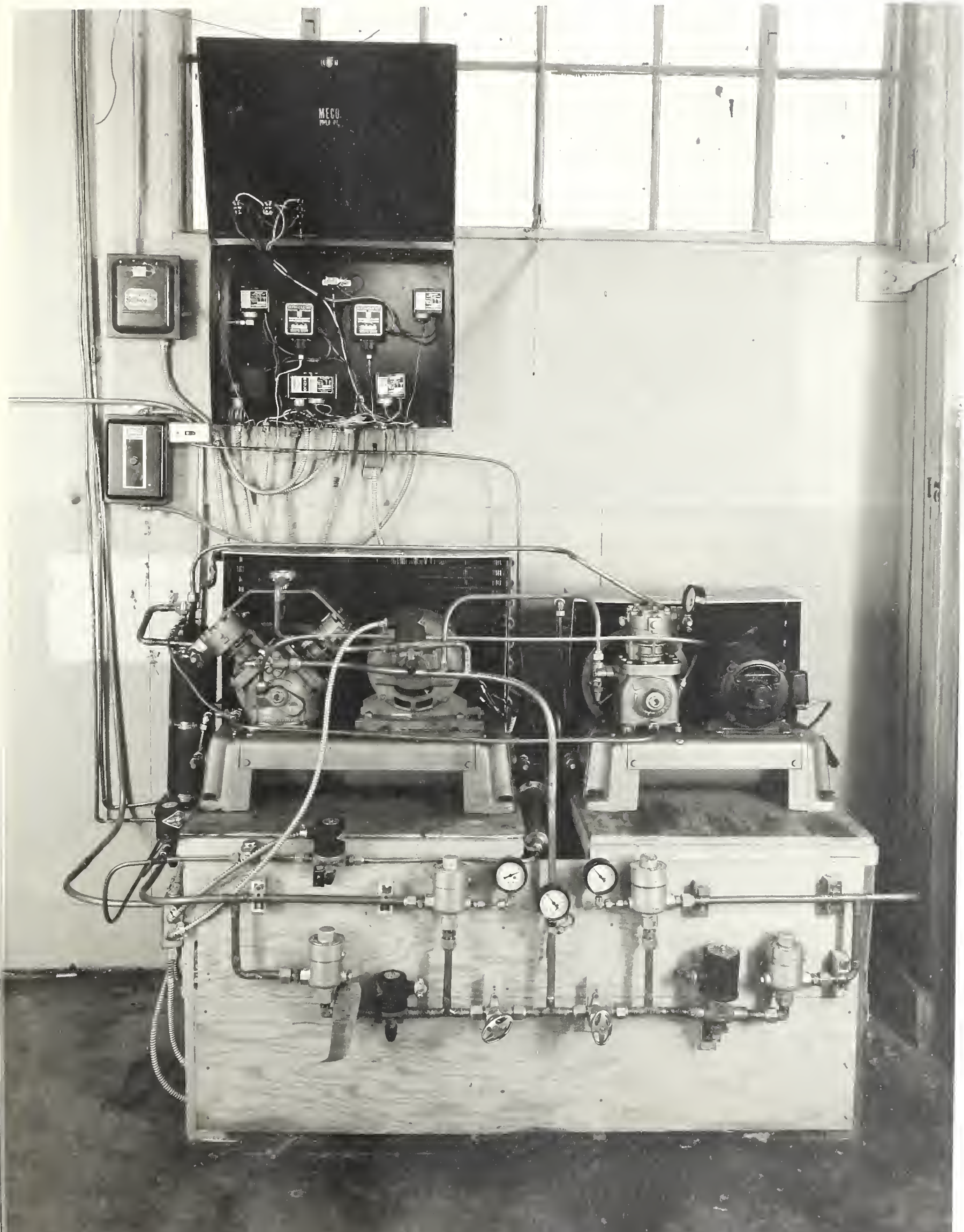

Fig. 10

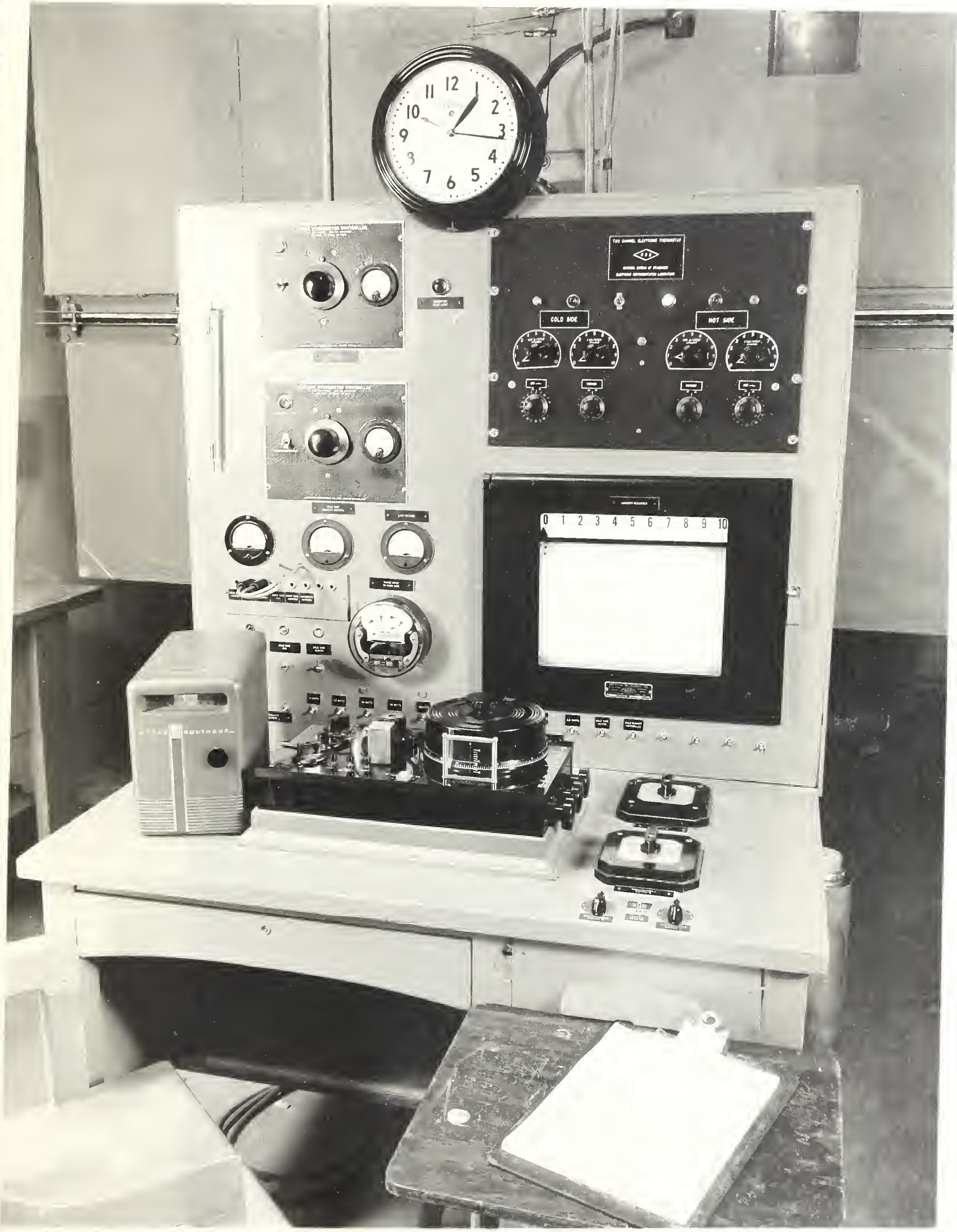

Fig. 11

Fig. 12

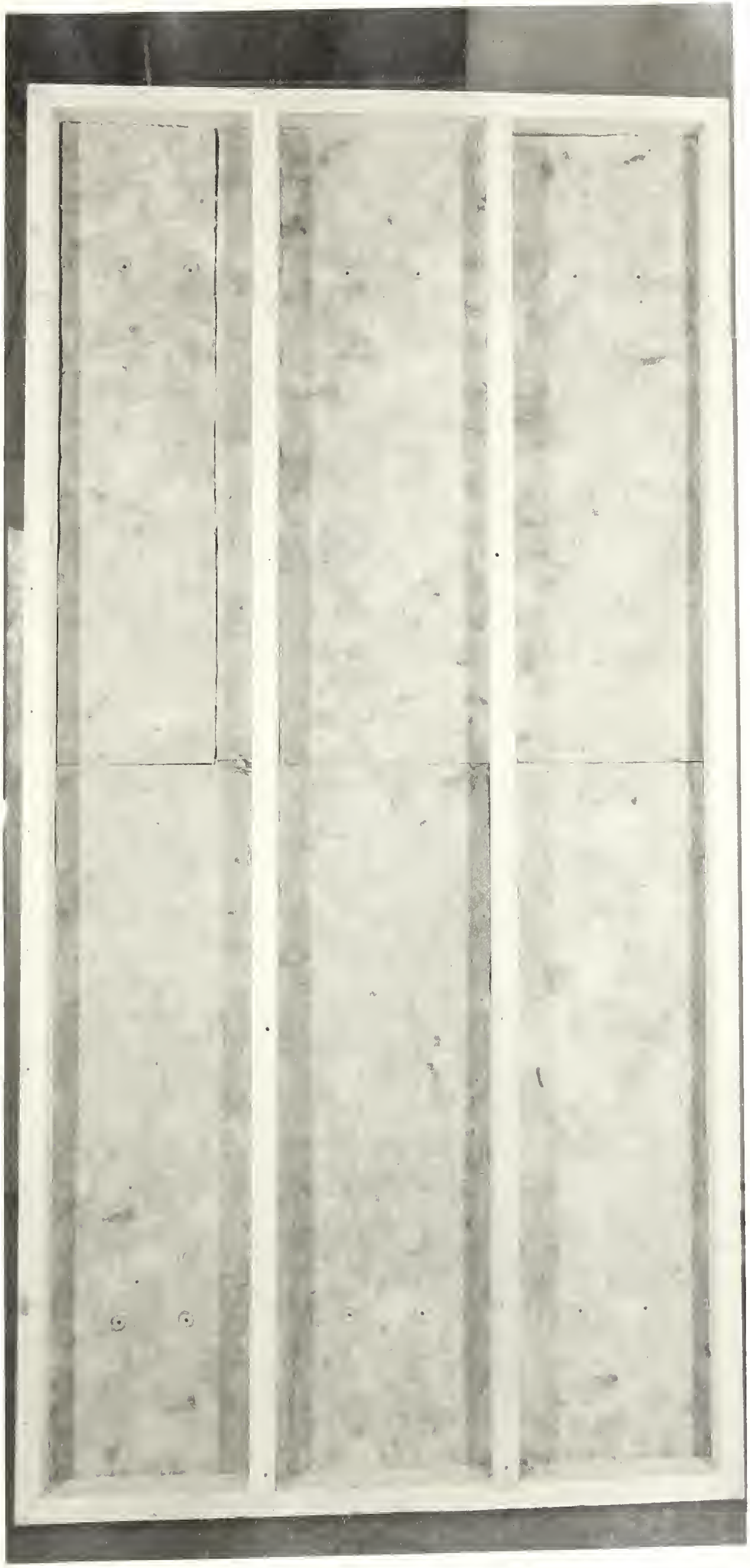

Fig. 13

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

NBS