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NATIONAL BUREAU OF STANDARDS REPORT

6699

CAPACITY TESTS OF TWO PEERLESS HEAT PUMPS, MODELS CPA584-1A/54CPH-A AND CPA384-1A/34CPH-A

Manufactured by
Peerless Corporation
Indianapolis, Indiana

by

J. C. Davis, W. M. Ellis and P. R. Achenbach

Report to

McCoy Air Force Base
Orlando, Florida

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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J. C. Davis, W. M. Ellis and P. R. Achenbach
Air Conditioning, Heating, and Refrigeration Section
Building Technology Division

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ABSTRACT

Tests were performed to determine the heating and cooling capacity of a 5-ton and a 3-ton Peerless heat pump intended for use in the housing development at McCoy Air Force Base, Orlando, Florida. The original letter, outlining specifications and test conditions, was amended after discussions with the Contracting Officer and corroborated by letters dated October 21, 1959, and December 8, 1959. The tests were performed using a psychrometric calorimeter, as described in ASRE Standard 16-56, Standard Methods for Testing and Rating Air Conditioners. All cooling tests were performed at 95°F outdoors and 80°F DB, 67°F WB, indoors. All heating tests were performed at 30°F outdoors and 70°F indoors. For the 5-ton heat pump, the cooling capacity was 53,800 Btu/hr as compared to 53,000 Btu/hr required by specifications. The heating capacity, including the capacity of the supplementary resistance heater, was 60,700 Btu/hr as compared to a requirement of 62,000 Btu/hr. When another supplementary resistance heater of the same physical dimensions and same manufacturer, submitted at a later date, was used, the total heating capacity was 61,900 Btu/hr. For the 3-ton heat pump, the cooling capacity was 32,600 Btu/hr as compared to 30,000 Btu/hr required by specifications. The heating capacity, including the capacity of the supplementary resistance heater, was 43,100 Btu/hr as compared to a requirement of 46,000 Btu/hr. The heating capacity, using the same alternate supplementary heater mentioned above, was 44,300 Btu/hr. When the 5-ton heat pump was tested, the air flow rate across the indoor coil was close to that specified for heating, or 1850 cfm; but the air flow rate for cooling was about 95 cfm lower. Later determinations indicated that the cooling capacity for this system would probably have been 1500 Btu greater if the air flow rate had been 1850 cfm. During the tests on the 3-ton heat pump, the air flow rate was about 80 cfm greater than the 1100 cfm specified for the test. Later determinations indicated that the capacity for this system would probably have been 250 Btu/hr less if the air flow rate had been 1100 cfm.

1. INTRODUCTION

In accordance with a request from Captain Paul R. Miller, Contracting Officer, McCoy Air Force Base, Orlando, Florida, by letter dated October 19, 1959, tests were made to determine the heating and cooling capacity of two Peerless heat pumps. One, a nominal 5-ton system, was designated as CPA584-1A/54CPH-A; and the other, a nominal 3-ton system, as CPA384-1A/34CPH-A.

Contract specification requirements and test conditions were outlined in written material and drawings supplied with the letter of October 19, 1959. Following the receipt of this letter, discussions were held by telephone with Captain Miller and several amendments were made in the test conditions. These amendments were authorized by letters dated October 21, 1959, and December 8, 1959.

The specification requirements and the test conditions which applied after amendment are shown below:

SPECIFICATION CAPACITY VALUES
FOR 5-TON HEAT PUMP

Building Type	Minimum Total Cooling Requirement (Btu/hr)	Minimum Total Heating Requirement (Btu/hr)	Minimum Heating Supplied by Compressor (Btu/hr)	Minimum Heating Supplied by Supplementary Strip Heater (Btu/hr)
O-G	46,500	53,000	31,800	Difference between total heat required and amount obtained by compressor in laboratory tests.
O-H	46,000	58,000	34,800	
O-J	53,000	62,000	37,200	

TEST CONDITIONS FOR 5-TON HEAT PUMP

	Design Test Conditions Cooling (°F)	Design Test Conditions Heating (°F)	External Static Pressure on Indoor Unit (In. W. G.)	Rate of Air Flow Across Indoor Coil (CFM)
Indoors	80 DB, 67 WB	70 DB	0.4	1850
Outdoors	95 DB, 78 WB*	30 DB		

* In the NBS facility, it would have been difficult to control humidity in the air section simulating the outdoor air. Because

of this and since humidity of the air entering the outdoor coil during the cooling cycle has a negligible effect on capacity for a dry coil, no effort was made to control this atmospheric condition.

SPECIFICATION CAPACITY VALUES FOR 3-TON HEAT PUMP

Building Type	Minimum Total Cooling Requirement (Btu/hr)	Minimum Total Heating Requirement (Btu/hr)	Minimum Heating Supplied by Compressor (Btu/hr)	Minimum Heating Supplied by Supplementary Strip Heater (Btu/hr)
A-A	20,500	32,000	19,200	Difference between total heat required and amount obtained by compressor in laboratory tests.
A-B	24,500	36,000	21,600	
A-C	25,500	41,000	24,600	
O-A	26,000	40,000	24,000	
O-B	25,500	41,000	24,600	
O-C	26,000	43,000	25,800	
O-D	27,000	43,000	25,800	
O-E	29,500	46,000	27,600	
O-F	30,000	45,000	27,000	

TEST CONDITIONS FOR 3-TON HEAT PUMP

	Design Test Conditions Cooling (°F)	Design Test Conditions Heating (°F)	External Static Pressure on Indoor Unit (In. W. G.)	Rate of Air Flow Across Indoor Coil (CFM)
Indoors	80 DB, 67 WB	70 DB	0.3	1100
Outdoors	95 DB, 78 WB*	30 DB		

* In the NBS test facility, it would have been difficult to control humidity in the air section simulating the outdoor air. Because of this and since humidity of the air entering the outdoor coil during the cooling cycle has a negligible effect on capacity for a dry coil, no effort was made to control this atmospheric condition.

Inspection of drawings supplied by McCoy Air Force Base showed that the lengths of the liquid and vapor lines were specified at values ranging from about 12 ft to about 32 ft. Based on this specification, the length of each line in the test installation was 25 ft.

2. DESCRIPTION OF TEST SPECIMENS

The two heat pumps are known as "split type" or "remote type" heat pumps in which one section of the apparatus is placed outdoors and the other inside the home at a suitable place for delivering conditioned air. The 5-ton heat pump tested consisted of a Model No. CPA584-1A outdoor unit with a 54CPH-A indoor unit; and the 3-ton heat pump of a CPA384-1A outdoor unit with a 34CPH-A indoor unit. The operational features for both heat pumps were very nearly the same. These are described as follows:

During the cooling cycle, the coil of the indoor unit served as an evaporator, absorbing heat; and during the heating cycle, as a condenser, rejecting heat. This operational change was accomplished by means of a change in direction of circulation of the refrigerant through the system, using a thermostatically-controlled solenoid in a four-way valve. During the tests, the solenoid was controlled by a manually-operated switch to preclude automatic shifting from cooling to heating conditions and vice versa. Capillary tubes were used as a liquid refrigerant flow control device in both the indoor and outdoor units with a check valve in the by-pass line around the capillary tubes of the outdoor unit. No check valve was provided in the indoor unit. On the heating cycle, therefore, the refrigerant flowed through the capillary tubes in the reverse direction, since no alternate refrigerant flow path was provided. Following the new ASRE refrigerant designations, the refrigerant used was R-22.

A schematic diagram of the 5-ton heat pump system and auxiliary test instrumentation is shown in Figure 1, and of the 3-ton system in Figure 2. A list of line sizes between the indoor and outdoor units for the two heat pumps is shown below. The liquid and vapor lines were each about 25 ft long.

During the tests, the vapor line was insulated with "Armaflex," 1 in. thick, vapor sealed. Following are the sizes of the refrigerant lines used between the indoor and outdoor units:

	5-Ton	3-Ton
1. Liquid line except flowmeter manifold, in.	1/2 OD	3/8 OD
2. Lines in manifold, in.*	1/2 OD	1/2 OD
3. Vapor line, in.	3/4 OD**	3/4 OD

* Part of testing apparatus.

** Two lines, 5-ton unit. Two 3/4 in. OD lines were used to provide an acceptable gas velocity in the vapor line, and to limit the number of sizes that needed to be stocked by the manufacturer.

2.1 Indoor Units

The indoor units of both heat pumps consisted of 2 finned coils, a blower for circulating conditioned air through the duct system of the house, a motor for powering the blower, capillary tubes, and a drain pan for collecting condensate. These units also included resistance heaters to supplement compressor heating during extremes of cold weather. The supplementary strip heaters in the two heat pumps were physically interchangeable.

Figure 3 shows the indoor unit of the 5-ton heat pump and Figure 4 shows that of the 3-ton heat pump.

2.2 Outdoor Units

The outdoor unit of the 5-ton heat pump consisted of 3 finned coils, a hermetically-sealed motor-compressor, a set of capillary tubes, a check valve, a four-way valve and controls for operation and defrost. The 3-ton heat pump consisted of essentially the same components as the 5-ton heat pump except there were two coils instead of three.

The outdoor unit installed in a home also includes a defrost control system employing a temperature differential device, an outdoor thermostat, high- and low-pressure switches, and a compressor crankcase heater. All of these devices, except the high-pressure switch, were left out of the system during the tests.

Figure 5 shows the outdoor unit of the 5-ton heat pump with test equipment and Figure 6 shows the outdoor unit of the 3-ton model. Only one coil appears in Figure 5, but the unit actually has two other coils each identical to the one showing. Likewise, only one coil appears in Figure 6, but the unit has another coil identical and 90 degrees displaced from that showing. Note on both figures the five-in-one thermocouple system and the thermostat used for controlling outdoor conditions during the test.

2.3 Controls

Defrost Control (Ranco D-50) Although no defrosting controls were used during the tests, defrosting was initiated during heating operation on an increase over a set differential between the outdoor ambient temperature and the refrigerant temperature of the outdoor coil, which opened a defrost switch. Opening of the defrost switch contacts de-energized the four-way valve solenoid and also shut off the outdoor fan. The system thus was placed on the cooling cycle. Under these conditions, the outdoor coil became a condenser and the frost was melted by heat rejection.

The defrost switch consisted of a temperature sensing bulb, which sensed the refrigerant temperature of the outdoor coil; and a gas-filled ambient sensing capillary tube. The bulb and gas-filled capillary were connected to separate bellows. Both bellows acted upon a common lever connected to the switch contacts. When the coil frosted or iced up, the refrigerant temperature was reduced so that the pressure of the refrigerant sensing bulb was less than that of the capillary. This caused the switch to open, a relay de-energized the reversing valve, which caused the unit to go on the cooling cycle, also cutting off the outdoor fan. The system remained on the cooling cycle until the pressure of the refrigerant sensing bulb was great enough to overcome the pressure of the ambient sensing capillary, and the temperature differential was no greater than the set value.

During the defrost period, the suction pressure sometimes, in home operation, goes below the setting of the low-pressure cut-off switch. Stopping of the compressor during this operation was prevented, however, by means of an electrical shunt around the low-pressure switch during the defrost cycle.

High- and Low-Pressure Switches The high-pressure switch stopped the unit when the discharge pressure was too high, and the low-pressure switch stopped the unit when the pressure was too low. A table showing high- and low-pressure switch performance for the two heat pumps is given below.

5-TON HEAT PUMP

Low-Pressure Switch

1. Setting adjustable from 10-30 psig.*
2. By-passed after initiation of defrost to prevent shut-off during surges of low suction pressure. By-pass not removed from circuit until 3 minutes have elapsed after termination of defrost.
3. By-passed throughout the heating cycle to allow for low suction pressures which occur when the outdoor temperature is near 0°F.
4. Manually reset at indoor thermostat.

High-Pressure Switch

1. Factory-set at about 405 psig.
2. Manually reset at indoor thermostat.

3-TON HEAT PUMP

Low-Pressure Switch

1. Setting adjustable from 10-30 psig.*
2. By-passed after initiation of defrost to prevent shut-off during surges of low suction pressure. No time delay in removal of by-pass after termination of defrost, as was included in 5-ton unit.
3. By-passed during heating cycle to allow for low suction pressures which occur when the outdoor temperature is near 0°F.
4. Automatic reset in outdoor unit.

* Special wrench required. The Peerless Corporation representative requested that the company be consulted before adjustment is made of this control in the field.

High-Pressure Switch

1. Factory-set at about 405 psig.
2. Manually reset in outdoor unit.

Indoor thermostat (Minneapolis-Honeywell Model T 870, two stage) The first stage starts the heat pump for either heating or cooling, the solenoid in the four-way valve being energized on heating. The second stage (heating only) turns on the supplementary strip heat if the temperature drops more than one and three-fourths degrees below the setting of the thermostat. The indoor fan can be controlled manually at this thermostat even though the compressor is inoperative. In the case of the 5-ton unit, the high- and low-pressure switches can be reset at the indoor thermostat if either one stops the compressor.

Outdoor thermostat (Ranco Corp. No. A-11) This thermostat was in series with the second stage of the indoor thermostat to prevent the operation of supplementary heaters unless the outside temperature falls below a predetermined setting. The thermostat worked on about a 7-degree differential, closing at about 40°F and opening at about 47°F.

Crankcase Heater Both the 5-ton and 3-ton units were equipped with an 80-watt heater (Industrial Equipment and Engineering Co., St. Louis, Mo.), attached to the crankcase of the compressor to reduce absorption of refrigerant in the oil and to prevent excessive foaming and ebullition of the oil when starting the compressor. The heater is always in operation, but is needed only after the heat pump has been shut down either in cold weather, in a warm season when the outdoor temperature is colder than the indoor temperature, or when the system is greatly overcharged.

Material and dimensional data on the components of the indoor and outdoor units are contained in the Appendix at the end of the report.

3. METHODS OF TESTING

Except for minor deviations, the heat pumps were tested under the conditions described in ASRE Testing and Rating Standard No. 16-56. Figure 7 shows the enclosure housing the indoor unit and the 33-in. square duct attached to the outlet side of the unit. This duct housed the nozzle used for measuring the air circulation rate and the instruments for measuring temperature and humidity of the outlet air. Because the mixing baffles and mixing screen introduced considerable resistance in the outlet duct, an auxiliary blower powered by a one HP motor was provided at the downstream end of the 33-in. duct. Required adjustments of external static resistance on the units under test were made by a wooden slide-type damper at the outlet of the auxiliary blower. The air delivery rate of the indoor blower depended on the adjustment of this damper in conjunction with the adjustable pulley on the fan motor. The auxiliary blower, return air heaters, and humidifier are shown in Figure 8.

ASRE Standard 16-56 requires that two independent measuring methods be used during the test to provide greater reliability in the results. One method, known as the psychrometric method, involved measuring the mass flow of air through the indoor unit and the change in enthalpy of the air between inlet and outlet of the unit. The other method, referred to as the flowmeter method, involved determination of the rate of flow of refrigerant through the indoor coil and the change in enthalpy of the refrigerant between inlet and outlet of the indoor coil. A correction to the total enthalpy change of the refrigerant was necessary, either by adding or subtracting the heat equivalent of the electrical energy supplied to the indoor blower motor depending on whether the heating or cooling cycle was in use. Acceptable precision required that the values obtained by the two methods should not differ by more than six percent.

Mass flow rate of air in the psychrometric method was determined by measuring humidity and temperature conditions of the air entering the long-radius nozzle and the static pressure difference across the nozzle. Enthalpy change of the air was determined by measuring temperature, humidity and barometric pressure of the air entering the indoor unit, and in the duct immediately after it left the unit.

Flow rate of refrigerant was measured by means of a flowmeter in the liquid line of the system. The flowmeter was a Potter electronic type with an impeller, which generated an electrical

pulse on each revolution. A Potter Counter coupled to the flowmeter served to translate the pulses into a volume flow rate. The temperature of the liquid in the line was measured so the volume flow rate could be converted to mass flow rate. Enthalpy change of the refrigerant was determined from the temperature and pressure measurements at the inlet and outlet of the indoor coil and the refrigerant tables. For accurate measurement of capacity by the refrigerant flow method, it was necessary that there be no gas bubbles in the liquid refrigerant as it passed through the flowmeter and the point of measurement of temperature for enthalpy determination, and that all of the liquid refrigerant be evaporated in the coil.

It was possible to maintain "state" conditions for both the indoor and outdoor units during cooling and heating operation with the use of a test structure having two controlled-temperature spaces.

During the tests, the energies consumed by the indoor blower, outdoor fan and compressor were read from separate watthour meters. Simultaneous readings were also made of currents and voltages. The various watthour meters, together with the other instruments for measuring pressure, pressure difference, temperature and humidity, are shown in Figure 9.

A refrigerant charge of approximately 14 lbs, measured after all corrections were made for gages and lines, was used for the 5-ton unit. Ten pounds of refrigerant were used for the 3-ton unit. During the tests of both heat pumps, charging was done on the cooling cycle, after which the system was exposed to heating conditions and sufficiency of charge determined. No change of charge was made thereafter for the cooling tests.

Specifications required that the tests be performed using an air delivery rate over the indoor coil of 1850 cfm for the 5-ton heat pump, and 1100 cfm for the 3-ton heat pump. In either case, since the density of the air crossing the coil was different for the cooling test and the heating test, it was impossible, unless pulley adjustments were made, to perform the tests at the specified rate for both cooling and heating. It was considered advisable to perform the tests without change in the pulley adjustment between heating and cooling or vice versa, since the pulley adjustment remains the same when the heat pump is in the home.

The cooling test for the 5-ton unit was performed at the standard conditions of 95°F outdoor temperature, 80°F DB and 67°F WB inside. At these conditions, it was not possible to obtain subcooling in the liquid line entering the indoor unit. Consequently, the flowmeter method could not be used for this test. Another test was performed with the outside temperature at 91°F and with the inside conditions the same as the original test, but with artificial subcooling in the liquid line between the outdoor and indoor units. From this test, it was possible to obtain a comparison between the psychrometric and flowmeter results. This comparison resulted in a ratio of 100/97.3 for the ratio of the psychrometric value/flowmeter value, which in turn was subsequently used to determine a flowmeter value for the cooling test at the standard test conditions. This difficulty was not encountered during any other cooling or heating test for either type of heat pump. The ratio of the psychrometric value to the flowmeter value for these other tests agreed closely with 100/97.3.

Both the 5-ton and 3-ton outdoor units had vertical discharge of air from the fan as shown in Figures 5 and 6. The temperature of the air entering the outdoor coils was checked several times during the tests to be certain that there was no short-circuiting of discharge air back into the coils caused by the characteristics of the test facilities, and to give assurance that the air temperature entering each coil was the same.

Following the tests for cooling and heating capacity of the 2 heat pumps, the power consumption of the supplementary strip heater for each heat pump was measured. For this determination, 230 volts were applied to the strip heater for a period of one hour while the energy consumption was measured with a calibrated watthour meter and checked with voltage and current readings which were made every 15 minutes. The results of the 2 tests showed a lower electrical energy consumption than required by specifications. As a result, and in conformance with an authorizing letter of December 29, 1959 from Captain Miller, another strip heater was tested at the same voltage. The energy consumption, as shown under Test Results was greater.

The energy consumption of the crankcase heater for both the 5-ton and 3-ton heat pumps was measured using 230 volts and the same method of measurement as for the strip heaters. These heaters were disconnected during the tests on the heat pumps.

4. TEST RESULTS

4.1 5-ton Unit

A. Cooling Test under Standard ASRE Conditions

Details of the cooling test on the 5-ton heat pump with outdoor temperature at 95°F, and indoor conditions at 80°F DB, and 67°F WB, are given below.

Summary of Cooling Capacity Values (Btu/hr)

	5-Ton Unit	
	Test Value	Rounded Value
By psychrometric method	54,510	
By flowmeter method*	53,030	
Average	53,770	
Correction for deviation of barometric pressure from normal	0.0	
Total	53,770	53,800

* Due to inability to obtain both subcooling and superheating during the test at Standard ASRE conditions, both conditions being necessary for use of the flowmeter method, this value was calculated using the ratio of the psychrometric value/flowmeter value determined during another test in which conditions were such that both subcooling and superheating existed (See Methods of Testing).

Psychrometric Method

Air Temperatures (°F)

At inlet to enclosure around indoor unit	79.8
At outlet of indoor unit in duct	60.7
Temperature difference across indoor coil	19.1
At inlet to outdoor unit	95.0

Wet Bulb Depressions (°F)

At inlet to enclosure around indoor unit	12.9
At outlet of indoor unit in duct	3.7

Relative Humidities (%)

At inlet to enclosure around indoor unit	50.7
At outlet of indoor unit in duct	79.7

Static pressure across nozzle (in. W.G.)	0.67
Volume air flow at nozzle (cfm)	1755
Mass air flow at nozzle (lb dry air/hr)	7900
Barometric pressure (in. Hg)	29.87
Area of nozzle (sq ft)	0.544
Nozzle coefficient	0.99
Static resistance external to unit (in. W.G.)	0.39

Refrigerant Temperatures (°F)

In vapor line leaving coil of indoor unit	46.5
In liquid line entering coil of indoor unit	118.4
In discharge line of compressor	227.5
In suction line of compressor	61.7
Superheat at indoor coil outlet	3.2

Refrigerant Pressures (psig)*

Compressor discharge	273.0
In liquid line preceding flowmeter	264.0
In liquid line entering coil of indoor unit	260.5
Pressure drop across flowmeter	3.5
In vapor line leaving coil of indoor unit	74.0
In suction line of compressor	70.0

* Pressure referenced to compressor level

Motor Power Consumption (watts)

Indoor blower	730
Outdoor fan	630
Compressor	6930
Total	8290

Coefficient of performance	1.90
Motor Voltages (volts)	
Indoor blower	113.0
Outdoor fan	230.0
Compressor	230.0
Motor Current (amperes)	
Indoor blower	8.5
Outdoor fan	3.4
Compressor	30.3

B. Heating Test at 30°F Outdoor Temperature, 5-Ton Unit

Details of the heating test with the outdoor temperature at 30°F and the indoor temperature at 70°F are given below.

Summary of Heating Capacity Values (Btu/hr)

	5-Ton Unit	
	Test Value	Rounded Value
By psychrometric method	45,790	
By flowmeter method	43,980	
Average	44,885	
Correction for deviation of barometric pressure from standard barometric pressure	150	
Total	45,035	45,000

Psychrometric Method

Air Temperatures (°F)

At inlet to indoor unit	70.1
At outlet of indoor unit in duct	93.8
Temperature difference across indoor coil	23.7
At inlet to outdoor coil	30.0

Wet Bulb Depression (°F)

At outlet of indoor unit in duct	34.4

Relative Humidity (%)

At outlet of indoor unit in duct	8.7

Static pressure across nozzle (in. W.G.)	0.72
Volume air flow at nozzle (cfm)	1880
Mass air flow at nozzle (lb dry air/hr)	7990
Barometric pressure (in. Hg)	29.76
Area of nozzle (sq ft)	0.544
Nozzle coefficient	0.99
Static pressure at indoor blower outlet (in. W.G.)	0.38

Flowmeter Method

Refrigerant Temperatures (°F)

Compressor discharge	215.5
Compressor discharge after 4-way valve	175.0
At inlet to coil of indoor unit	174.5
At outlet of coil of indoor unit	91.5
Suction line at compressor	18.5
Superheating at compressor discharge	104.3*
Superheating at inlet to coil of indoor unit	64.9*
Subcooling at outlet of indoor unit	12.5*
Superheating at suction line of compressor	5.5*

* Subcooling and superheating determined using pressure at point of measurement.

Refrigerant Pressures (psig)**

Compressor discharge	232.5
In vapor line entering coil of indoor unit	230.5
In liquid line leaving coil of indoor unit	213.0
In liquid line after flowmeter	213.0
Pressure drop across flowmeter	Negligible
Suction pressure at compressor	36.0

** Referenced to compressor level.

Potter meter count for 1 minute	28.17***

*** Refrigerant flow, gal./min = $\frac{\text{count for one minute x 100}}{3404}$

Motor Power Consumption (watts)

Indoor blower	720
Outdoor fan	750
Compressor	5020
Total	6490

Coefficient of performance	2.03

Motor Voltages (volts)

Indoor blower	115.0
Outdoor fan	230.0
Compressor	230.0

Motor Current (amperes)

Indoor blower	8.3
Outdoor fan	4.0
Compressor	22.1

C. Power Consumption of Strip Heater

Readings of the energy dissipated by the strip heater which came with the 5-ton indoor unit were made every fifteen minutes for a period of one hour with the following results:

Watthour meter value (watts)	4590
Average terminal voltage (volts)	230
Average current (amperes)	20.0
Voltage times current (watts)	4600
Heat energy (Btu/hr)	15,700

D. Power Consumption of Crankcase Heater (watts)	80

4.2 3-ton Unit

A. Cooling Test under Standard ASRE Conditions

Details of the cooling test with the outdoor temperature at 95°F, and the indoor conditions at 80°F DB and 67°F WB, are given below.

Summary of Cooling Capacity Values (Btu/hr)

	3-Ton Unit	
	Test Value	Rounded Value
By psychrometric method	33,030	
By flowmeter method	32,100	
Average	32,565	
Correction for deviation of barometric pressure from normal	80	
Total	32,645	32,600

Psychrometric Method

Air Temperatures (°F)

At inlet to enclosure around indoor unit	80.0
At outlet of indoor unit in duct	60.5
Temperature difference across coil	19.5
At inlet to outdoor unit	94.7

Wet Bulb Depressions (°F)

At inlet to enclosure around indoor unit	13.1
At outlet of indoor unit in duct	3.1

Relative Humidities (%)

At inlet to enclosure around indoor unit	50.3
At outlet of indoor unit in duct	83.3

Static pressure across nozzle (in. W.G.)	1.13
Volume air flow at nozzle (cfm)	1115
Mass air flow at nozzle (lb dry air/hr)	4976
Barometric pressure (in. Hg)	29.60
Area of nozzle (sq ft)	0.268
Nozzle coefficient	0.981
Static resistance external to unit (in. W.G.)	0.31

Flowmeter Method

Refrigerant Temperatures (°F)

In vapor line leaving coil of indoor unit	49.0
In liquid line entering coil of indoor unit	110.2
In discharge line of compressor	213.5
In suction line of compressor	75.3
Superheating at indoor coil outlet	5.0
Subcooling at indoor coil inlet*	9.5

* Subcooling determined using pressure at point of measurement as determined by correction for liquid pressure drop in gage line. No correction necessary for superheating involving gage with vapor in line.

Refrigerant Pressures (psig)**

Compressor discharge	276.5
In liquid line preceding flowmeter	266.0
In liquid line entering coil of indoor unit	264.5
Pressure drop across flowmeter	2.5
In vapor line leaving coil of indoor unit	75.0
In suction line of compressor	72.0

** Pressure referenced to compressor level

Potter meter count for 1 minute 31.05***

*** $\text{Refrigerant flow, gal./min} = \dfrac{\text{count for one minute} \times 100}{3400}$

Motor Power Consumption (watts)

Indoor blower	430
Outdoor fan	350
Compressor	3850
Total	4630

Coefficient of performance 2.06

Motor Voltages (volts)

Indoor blower	115
Outdoor fan	230
Compressor	230

Motor Current (amperes)

Indoor blower	5.1
Outdoor fan	1.9
Compressor	18.4

B. Heating Test at 30°F Outdoor Temperature, 3-Ton Unit

Details of the heating test with the outdoor temperature at 30°F and the indoor temperature at 70°F are given below.

Summary of Heating Capacity Values (Btu/hr)

	3-Ton Unit Test Value	 Rounded Value
By psychrometric method	27,410	
By flowmeter method	27,320	
Average	27,365	
Correction for deviation of barometric pressure from normal	None	
Total	27,365	27,400

Psychrometric Method

Air Temperatures (°F)	
At inlet to indoor unit	70.2
At outlet of indoor unit in duct	92.5
Temperature difference across indoor coil	22.3
At inlet to outdoor coil	30.2
Wet Bulb Depression (°F)	
At outlet of indoor unit in duct	33.8
Relative Humidity (%)	
At outlet of indoor unit in duct	8.27
Static pressure across nozzle (in. W.G.)	1.21
Volume air flow at nozzle (cfm)	1180
Mass air flow at nozzle (lb dry air/hr)	5085
Barometric pressure (in. Hg)	29.97
Area of nozzle (sq ft)	.268
Nozzle coefficient	.981
Static pressure at indoor blower outlet (in. W.G.)	0.29

Flowmeter Method

Refrigerant Temperatures (°F)

Compressor discharge	198.0
Compressor discharge after 4-way valve	169.0
At inlet to coil of indoor unit	168.3
At outlet of coil of indoor unit	89.8
Suction line at compressor	15.0
Superheating at compressor discharge	79.0*
Superheating at inlet to coil of indoor unit	49.8*
Subcooling at outlet of indoor unit	21.5*
Superheating at suction line of compressor	0.0*

* Subcooling or superheating determined using pressure at point of measurement

Refrigerant Pressures (psig)**

Compressor discharge	263.0
In vapor line entering coil of indoor unit	260.0
In liquid line leaving coil of indoor unit	236.0
In liquid line after flowmeter	236.0
Pressure drop across flowmeter	Negligible
Suction pressure at compressor	38.0

** Referenced to compressor level

Potter meter count for 1 minute	17.22***

*** Refrigerant flow, gal./min = $\frac{\text{count for one minute x 100}}{3339}$

Motor Power Consumption (watts)

Indoor blower	440
Outdoor fan	390
Compressor	3030
Total	3860

Coefficient of performance	2.08

Motor Voltages (volts)

Indoor blower	115
Outdoor fan	230
Compressor	230

Motor Current (amperes)

Indoor blower	5.0
Outdoor fan	2.1
Compressor	14.7

C. Power Consumption of Strip Heater

Readings of the energy dissipated by the strip heater which came with the 3-ton indoor unit were made every fifteen minutes for a period of one hour with the following results:

Watthour meter value (watts)	4540
Average terminal voltage (volts)	230
Average current (amperes)	19.75
Voltage times current (watts)	4545
Heat energy (Btu/hr)	15,500

This same test was performed on another strip heater of the same size and manufacture supplied by the Peerless Company, at the request of Captain Miller, McCoy Air Force Base. The results are the following:

Watthour meter value (watts)	4950
Average terminal voltage (volts)	230
Average current (amperes)	21.51
Voltage times current (watts)	4950
Heat energy (Btu/hr)	16,900

D. Power Consumption of Crankcase Heater (watts)	80

5. RELATED RESULTS AND DISCUSSION

5.1 Motor Currents vs. Normal Ratings

The current used by the motors on the indoor blowers during the tests was within that allowed by the nameplate service factor; the current used by the outdoor fans was within that allowed by

the National Electric Manufacturers Standards, or 1.35 service factor times the nominal rating, even though no service factors were shown on the nameplates. The current used by the compressor motors was less than the nominal rating on the motor nameplates. Nominal ratings, allowable maximum current and the maximum readings observed during the tests are summarized below:

	Nominal Ratings, amperes	Nameplate Service Factor	Allowable Maximum Current, amperes	Maximum Current Readings, amperes
5-Ton Unit				
Outdoor blower	8.0	1.25	10.0	8.5
Outdoor fan	3.5	None	--	4.0
Compressor	31.5	None	--	30.3
3-Ton Unit				
Outdoor blower	4.5	1.35	6.08	5.1
Outdoor fan	2.0	None	--	2.1
Compressor	21.0	None	--	18.4

5.2 Temperature Drop Across 4-way Valve, Heating Tests

The listing of refrigerant temperatures for the 30°F heating test of the 5-ton unit, under Test Results, shows that the temperature decreased from the compressor discharge to the inlet of the coil of the indoor unit about 41°F. Of this total, the decrease in temperature across the four-way valve was 40 degrees. A significant decrease in temperature like this would be expected considering that the difference in temperature between the discharge gas and the suction gas entering the four-way valve was 197 degrees for this test.

The 30°F heating test for the 3-ton unit showed a temperature decrease of about 30°F from the discharge of the compressor to the inlet of the coil of the indoor unit. Twenty-nine degrees of this decrease occurred in the four-way valve.

5.3 Outdoor Thermostat

Section 20.2.8 of the Specifications for the All Electric Heat Pump System, supplied to the National Bureau of Standards by Captain Miller, required outdoor thermostats for both heat pumps.

This thermostat prevents energizing the supplementary resistance heaters unless the outdoor temperature falls below a predetermined setting. The heat pumps tested did not contain this device, but representatives of the Peerless Company advised that all 3-ton and 5-ton units would be supplied to the McCoy Air Force Base with an outdoor thermostat.

5.4 Mild-Weather Switch

The specifications do not require a mild-weather switch. This device, included in many residential air-to-air heat pump systems today, is intended to preclude compressor shut-off on high head pressure during heating operation when the outdoor weather is mild. This is accomplished by cycling the operation of the outdoor fan to reduce the amount of heat absorbed by the outdoor coil from the air. The possible need for the mild-weather switch was called to the attention of the Peerless Company representative, but he advised that the design of both the 3-ton and 5-ton units made its use unnecessary.

5.5 Effect of Deviation of Air Flow Rate over Indoor Coil from Specified Rate

5-ton Heat Pump Tests performed on the 5-ton heat pump under the National Bureau of Standards program after completing the specification tests for the United States Air Force, showed that there was a decrease in cooling capacity when the air flow rate over the indoor coil was decreased. This is clearly indicated in the following table:

Air Flow Rate (cfm)	Cooling Capacity (Psychrometric Method Only) (Btu/hr)
1630	53,500
1660	53,400
1755	54,500
1840	56,900

The specification cooling test, reported in Section 4, was performed at an air flow rate of 1755 cfm, because the air flow rate was originally adjusted for the heating test and no change in pulley adjustment was made for the cooling test. The data in this table

indicate a decrease in capacity of about 1500 Btu/hr for a 95 cfm reduction in air flow rate from 1850 cfm. It is probable, therefore, that the 5-ton heat pump would have shown a capacity about 1500 Btu/hr greater for an air flow rate of 1850 cfm than the value reported.

Deviation of the air flow rate from 1850 cfm was small during the heating test so no similar determination of capacity change with air flow rate was made for the heating condition.

3-ton Heat Pump Tests performed on the 3-ton heat pump under the NBS program also showed a direct linear change of cooling capacity with air flow rate. However, the cooling test, in this case, was performed at an air flow rate very close to the 1100 cfm specified.

Since no change in pulley adjustment was made after the cooling test was completed, the specification test for heating was performed at 1180 cfm. Heating tests performed on this unit for a range of air flow rates showed, as indicated by the table below, an increase in capacity of about 250 Btu/hr for an increase of 80 cfm from 1100 cfm. Therefore, the 3-ton heat pump would probably have shown a capacity decrease of about 250 Btu/hr when operating at 1100 cfm, as compared to the reported value in Section 4 of this report.

Air Flow Rate (cfm)	Heating Capacity Psychrometric (Btu/hr)	Heating Capacity Flowmeter (Btu/hr)	Average with Correction for Deviation in Barometric Pressure from Normal (Btu/hr)
860	26,305	26,445	26,500
930	26,555	26,660	26,800
1075	26,980	26,995	27,200
1305	27,825	27,705	27,900

6. APPENDIX

6.1 Material and Dimensional Data on Components of Indoor Unit (5-Ton Unit)

The following material and dimensional data were obtained from the manufacturer's representative, from nameplates, or from inspection or measurement of the heat pump components in the laboratory.

2 Coils, Three rows, 1/2 in. o.d. copper tubing, 11 tubes each row, 1 1/4 in. spacing center to center, 12 aluminum fins per inch of tube length. Two coils assembled in the shape of an inverted V. Overall dimensions of each coil: 15 in. high, 24 in. wide, 3 1/4 in. deep. Coil Model 54-UAF, Serial No. 014124.

Blower, (Lau Mfg. Co.), Centrifugal, 7 in. pulley, 12 in. wide, 12 in. diameter.

Blower Motor, (Marathon Electric Co., Model WFQ 124A64W), Type SCS, Frame 56-4, 1/2 HP, 1725 rpm, 1 phase, 60 cycle, 115/230 volts, F.L. amp. 8.0/4.0, cont. duty, 40°C rise, S.F. 1.25, 4 1/2 in. adjustable pulley, thermal protection, MEJ30AX Code C, requires oiling.

Capillary Tubes, Four capillary tubes, two for each coil, $0.080 \begin{smallmatrix}+.000 \\ -.001\end{smallmatrix}$ in. i.d., 36 inches long, and strainer.

Air Filter, Three glass fiber filters, throw-away type, 25 in. wide, 10 in. high, 1 in. thick.

Insulation of Cabinet, One-inch glass fiber covered with moisture-resistant cloth.

Description of Lines Inside Indoor Unit, 1/2 in. o.d. liquid line, 3/4 in. o.d. vapor line, 3/4 in. condensate drain. All lines brazed with "Sil-Fos" type of solder.

Supplementary Strip Heater, (H. W. Tuttle Co., Tecumseh, Mich.), One 5000 watt, 240 volt heater with Klixon limit switch, opens at 200°F. A second supplementary heater, furnished by the Peerless Co., was rated at 5000 watts, 230 volts. See Methods of Testing in this report.

Accumulator-Drier, (Kenmore Machine Products), 8 in. long, 2 in. diameter, with silica gel and strainer.

Housing Dimensions, 25 in. wide, 62 in. high, 30 in. deep, 0.032 in. wall thickness.

6.2 Material and Dimensional Data on Components of Outdoor Unit (5-Ton Unit)

3 Coils, Three rows, 1/2 in. o.d. copper tubing, 16 tubes each row, 1 1/4 in. spacing center to center, 8 1/2 aluminum fins per inch of tube length, average. Overall dimensions of each coil: 21 in. high, 27 in. wide, 3 1/4 in. deep. Coils are vertically placed.

Fan, (Elec. Motor & Spec.), Propeller "pull-through" type, direct driven, 6 blades, 30 in. diameter, requires oiling.

Fan Motor, (Electric Motor and Specialties, Inc., Model S-16-HG1), Type S, 1/2 HP, 630 rpm, 60 cycle, 230 volts, 3.5 amp., cont. duty, requires oiling.

Motor Compressor Unit, (Tecumseh PFB500), Hermetically sealed, 1 phase, 60 cycle, 230 volts, F.L. amp. 31.5, thermal overload.

Capillary Tubes, Three capillary tubes, one for each coil, $0.070^{+.000}_{-.001}$ in. i.d., 60 inches long, and strainer.

Check Valve, ("Magna-Chek" Watsco Co.), 1/2 in. o.d. sweat, pressure activated. This valve returns to closed position by magnetic action and is not spring-loaded.

Four-Way Valve, (Ranco V25 500 SR11), 230 volts. Solenoid energizes on heating.

Description of Lines of Outdoor Unit, Discharge line from compressor to 4-way valve, 1/2 in. o.d. Suction line from compressor to 4-way valve, 7/8 in. o.d. Vapor line, inside of unit, 7/8 in. o.d. Line from 4-way valve to outdoor coil, 3/4 in. o.d. Liquid line inside of unit, 1/2 in. o.d. All lines brazed with "Sil-Fos" type of solder.

Housing Dimensions, 37 in. square, 31 in. high, 0.0808 in. base plate thickness, 0.032 in. cabinet thickness.

6.3 Material and Dimensional Data on Components of Indoor Unit (3-Ton Unit)

2 Coils, Three rows, 1/2 in. o.d. copper tubing, 10 tubes each row, 1 1/4 in. spacing center to center, 12 aluminum fins per inch of tube length. Two coils mounted in V shape. Overall dimensions of each coil: 13 in. high, 19 in. long, 3 1/4 in. deep.

Blower, (Lau Mfg. Co.), Centrifugal, 5 in. pulley, 10 in. wide, 12 in. diameter.

Blower Motor, (Marathon Electric Co., Model WOF 48S17D 35FE), Type SS, Frame 48-5, 1/3 HP, 1725 rpm, 1 phase, 60 cycle, 115 volts, F.L. amp. 4.5, cont. duty, 40°C rise, S.F. 1.35, 3 1/4 in. adjustable pulley, thermal protection, MEH22JX, requires oiling.

Capillary Tubes, Two capillary tubes, one for each coil, $0.080^{+.000}_{-.001}$ in. i.d., 36 inches long, and strainer.

Air Filter, One glass fiber filer, throw-away type, 25 in. wide, 20 in. high, 1 in. thick.

Insulation of Cabinet, One-inch glass fiber covered with moisture-resistant cloth.

Description of Lines Inside Indoor Unit, 1/2 in. liquid line, 3/4 in. vapor line, 3/4 in. condensate drain.

Supplementary Strip Heater, (H. W. Tuttle Co., Tecumseh, Mich.), One 5000 watt, 230 volt heater with Klixon limit switch, opens at 200°F.

6.4 Material and Dimensional Data on Components of Outdoor Unit (3-Ton Unit)

2 Coils, Three rows, 1/2 in. o.d. copper tubing, 17 tubes each row, 1 1/4 in. spacing center to center, 8 1/2 aluminum fins per inch of tube length, average. Overall dimensions of each coil: 21 in. high, 27 in. wide, 3 1/4 in. deep. Coils are vertically placed.

Fan, (Elec. Motor & Spec.), Propeller "pull-through" type, direct driven, 4 blades, 24 in. diameter, requires oiling.

Fan Motor, (Electric Motor and Specialties, Inc., Model S-13-HB4), Type S, 1/3 HP, 750 rpm, 230 volts, 2 amp., 60 cycle, cont. duty, 1 phase.

Motor Compressor Unit, (Tecumseh Jo. 316-123, G1458 380079, PJE 300), Hermetically sealed, 1 phase, 50/60 cycle, 230 volts, F.L. amp. 21.0, thermal protection.

Capillary Tubes, Two capillary tubes, one for each coil, $0.064 \begin{smallmatrix}+.000\\-.001\end{smallmatrix}$ in. i.d., 60 inches long, and strainer.

Check Valve, ("Magna-Chek" Watsco Co.), 1/2 in. o.d. sweat connections, pressure activated. This valve returns to closed position by magnetic action and is not spring-loaded.

Four-Way Valve, (Ranco V30 101), 230 volts. Solenoid energizes on heating.

Description of Lines of Outdoor Unit, Discharge line from compressor to 4-way valve, 3/8 in. o.d. Suction line from compressor to 4-way valve, 3/4 in. o.d. Vapor line inside of unit, 3/4 in. o.d. Line from 4-way valve to outdoor coil, 3/4 in. o.d. Liquid line inside of unit, 1/2 in. o.d. All lines brazed with "Sil-Fos" type of solder.

Housing Dimensions, 37 in. square, 31 in. high, base plate thickness 0.0808 in., cabinet 0.032 in.

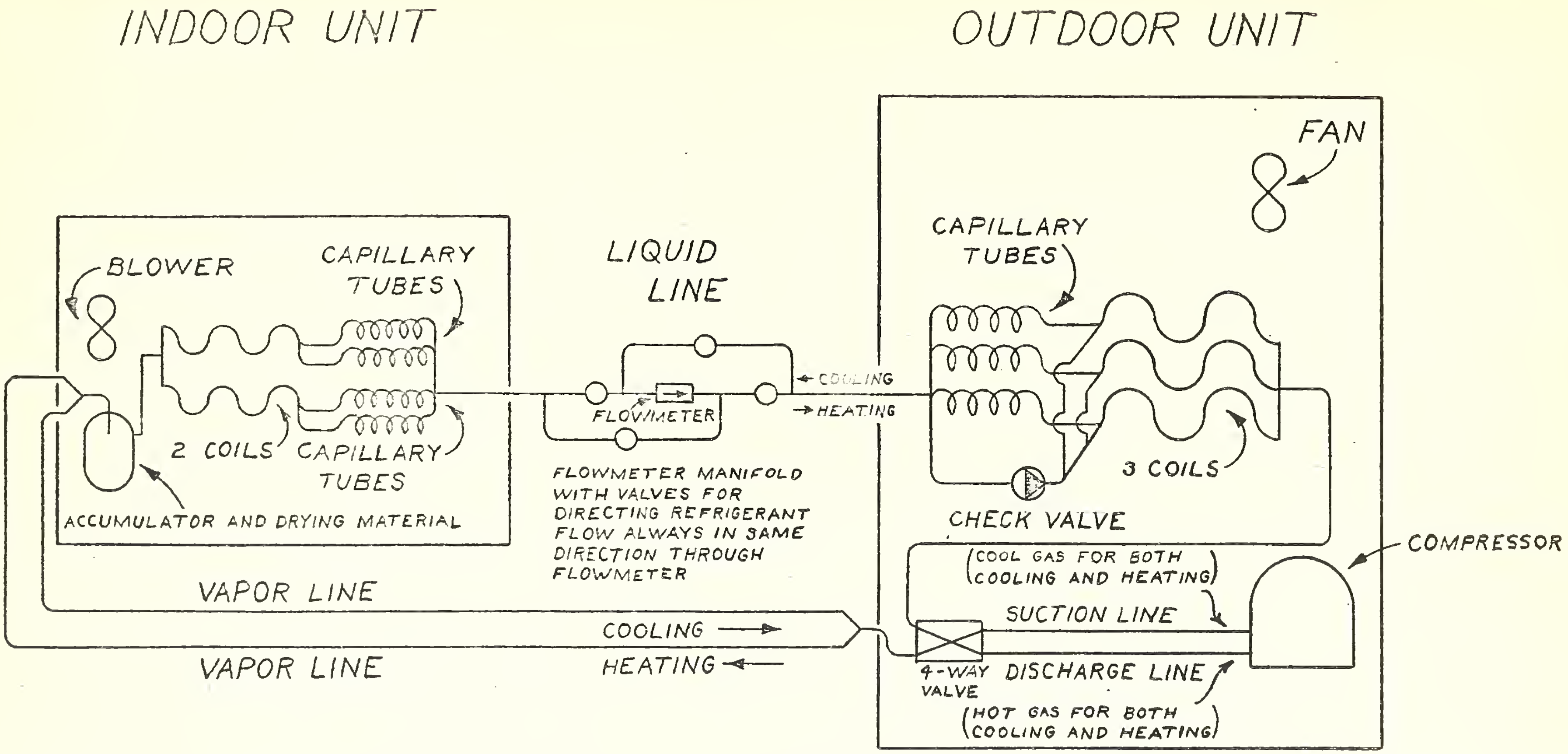

FIG. 1

PEERLESS 5-TON AIR-TO-AIR REMOTE TYPE HEAT PUMP NO. CPA584-1A WITH 54CPH-A INDOOR UNIT

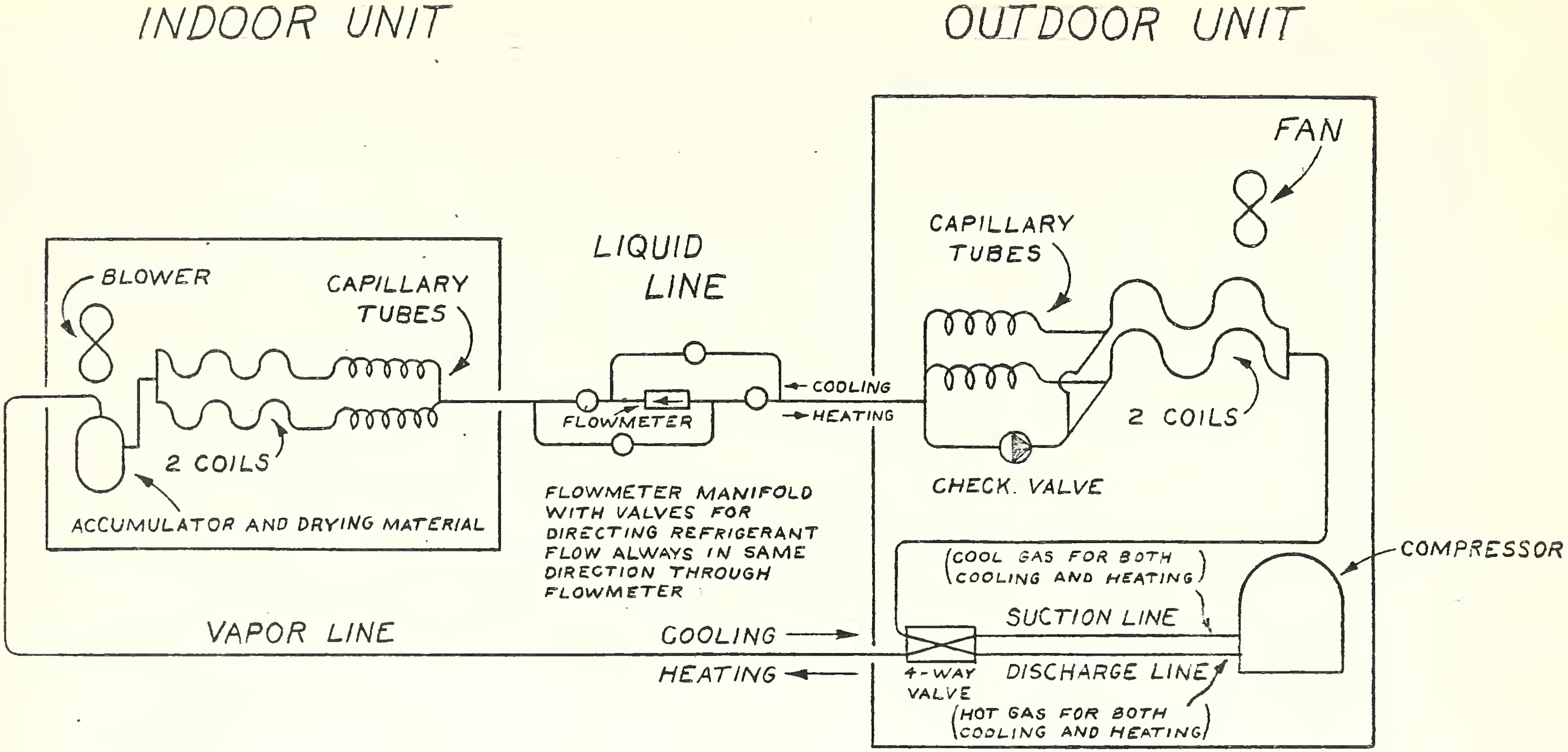

FIG. 2

PEERLESS 3-TON AIR-TO-AIR
REMOTE TYPE HEAT
PUMP NO. CPA 384-1A WITH
34 CPH-A INDOOR UNIT

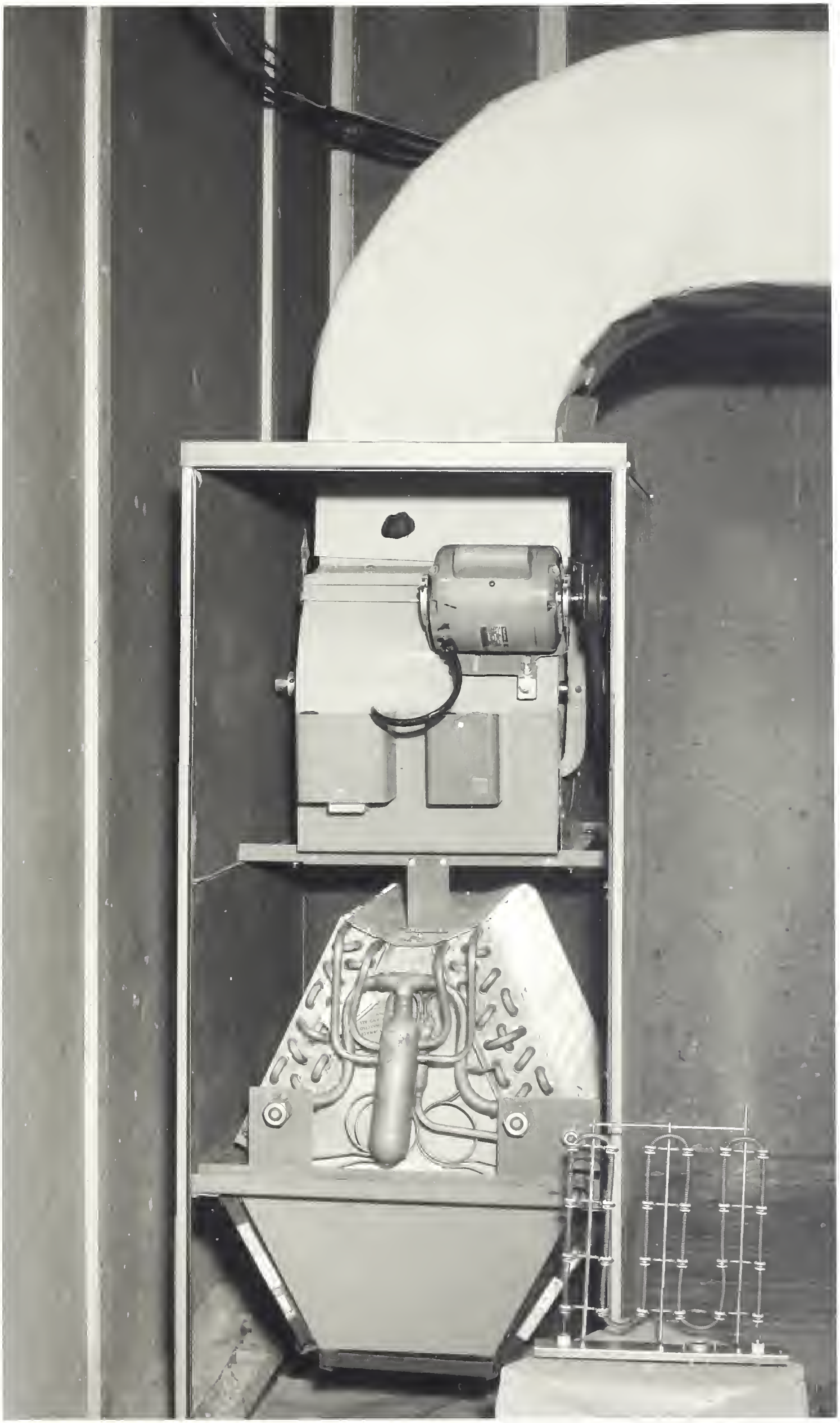

Fig. 3 INDOOR UNIT - 5-TON HEAT PUMP

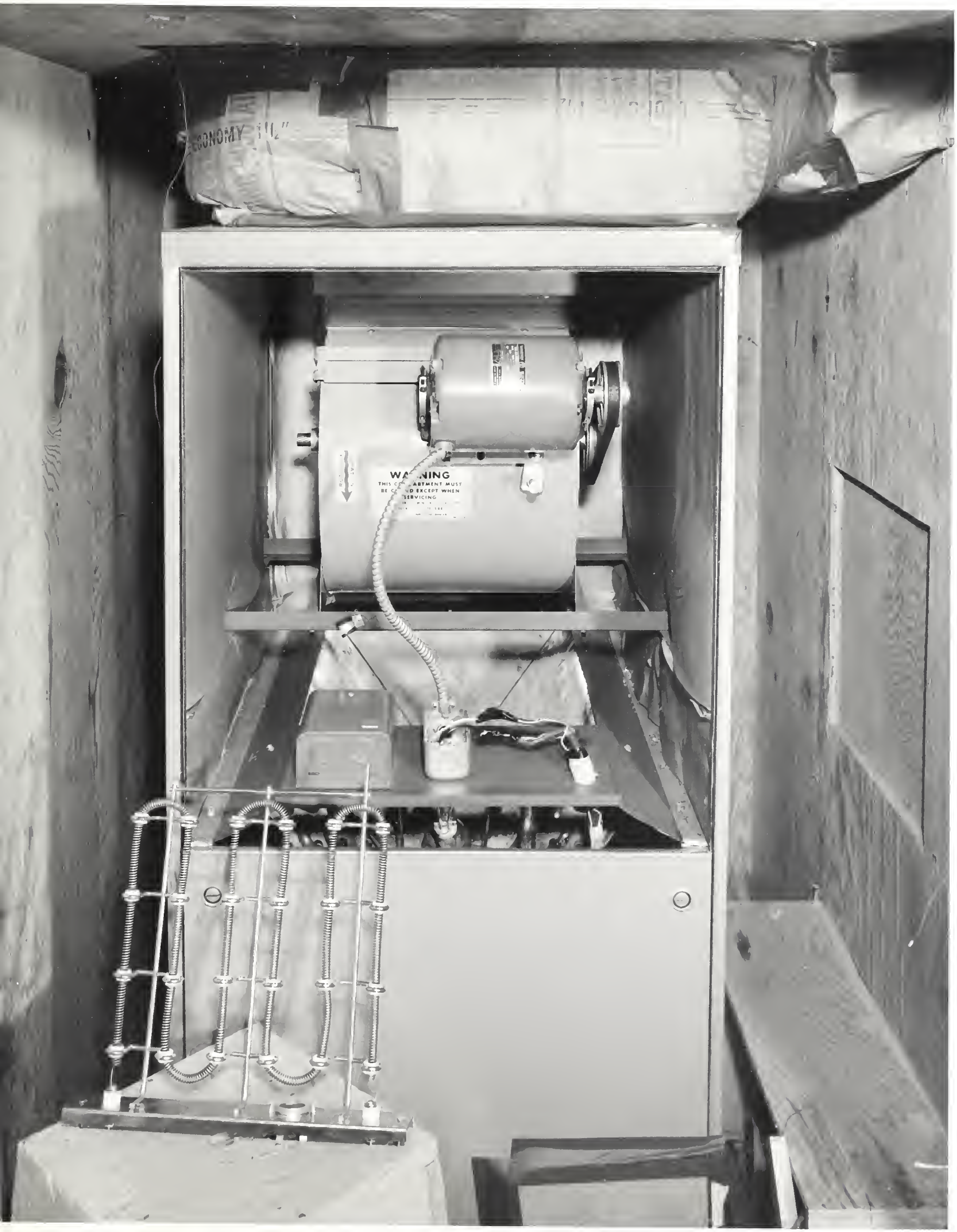

Fig. 4 INDOOR UNIT - 3-TON HEAT PUMP

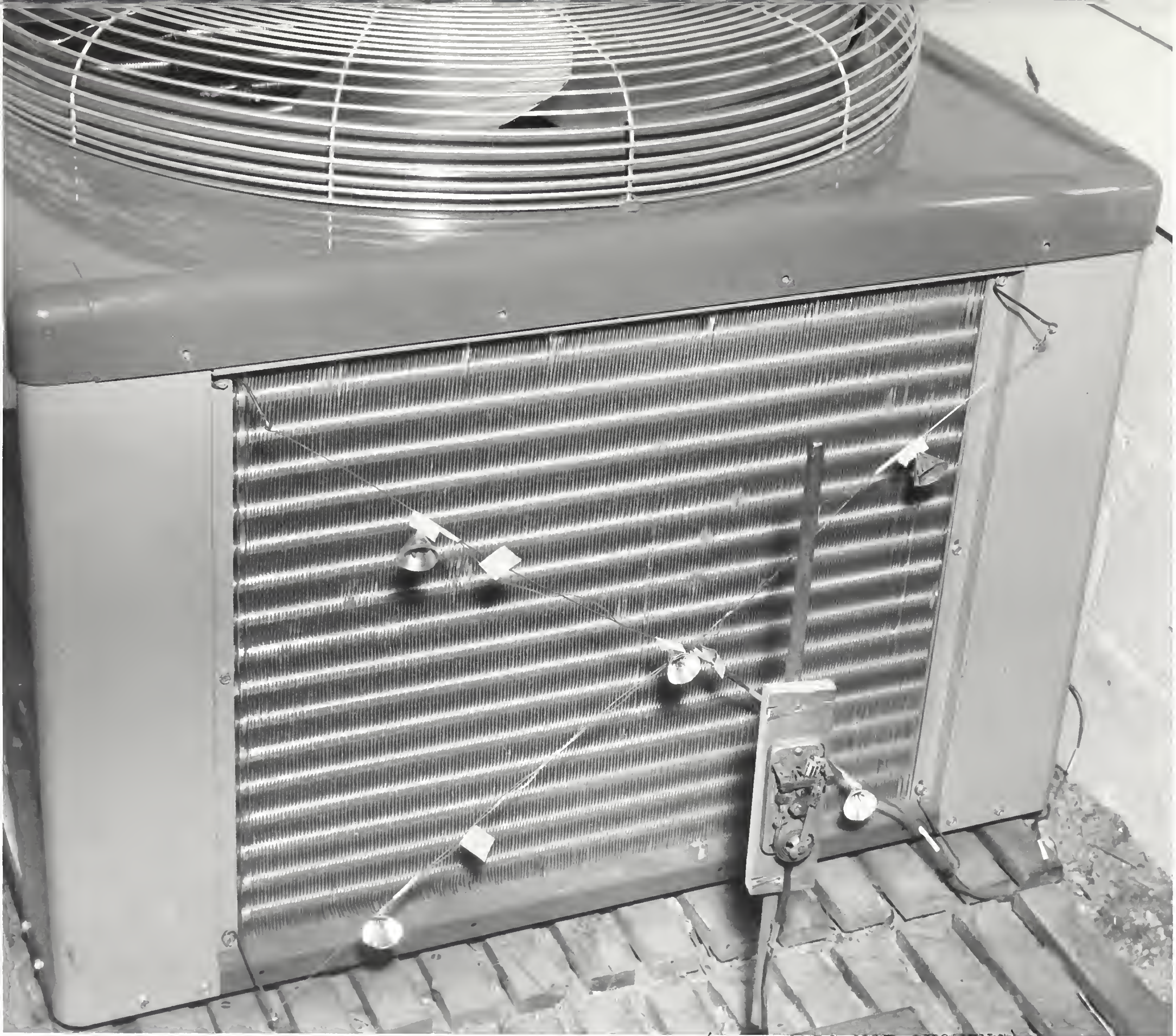

Fig. 5 OUTDOOR UNIT - 5-TON HEAT PUMP (TWO COILS NOT SHOWING)

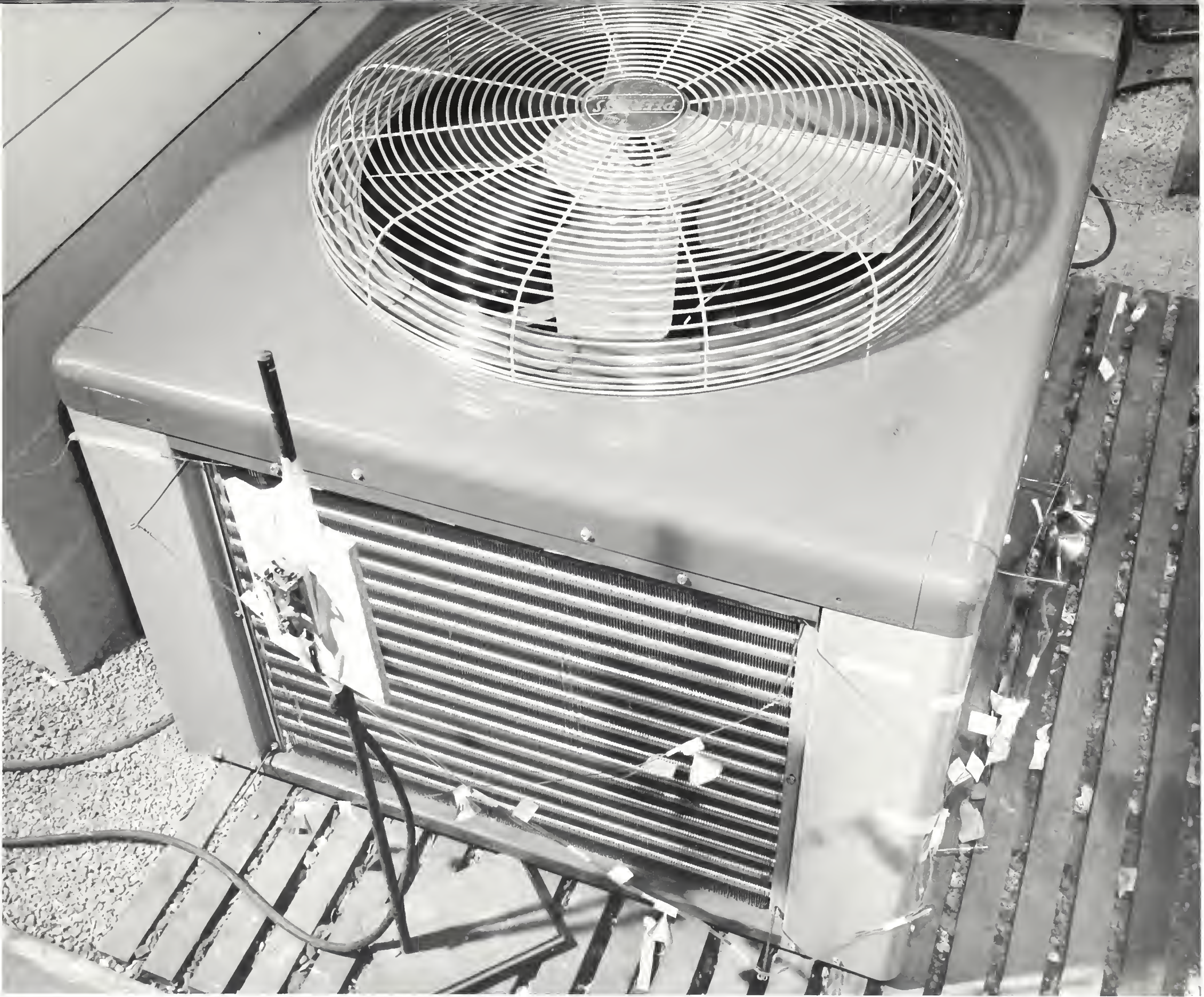

Fig. 6 OUTDOOR UNIT - 3-TON HEAT PUMP (ONE COIL NOT SHOWING)

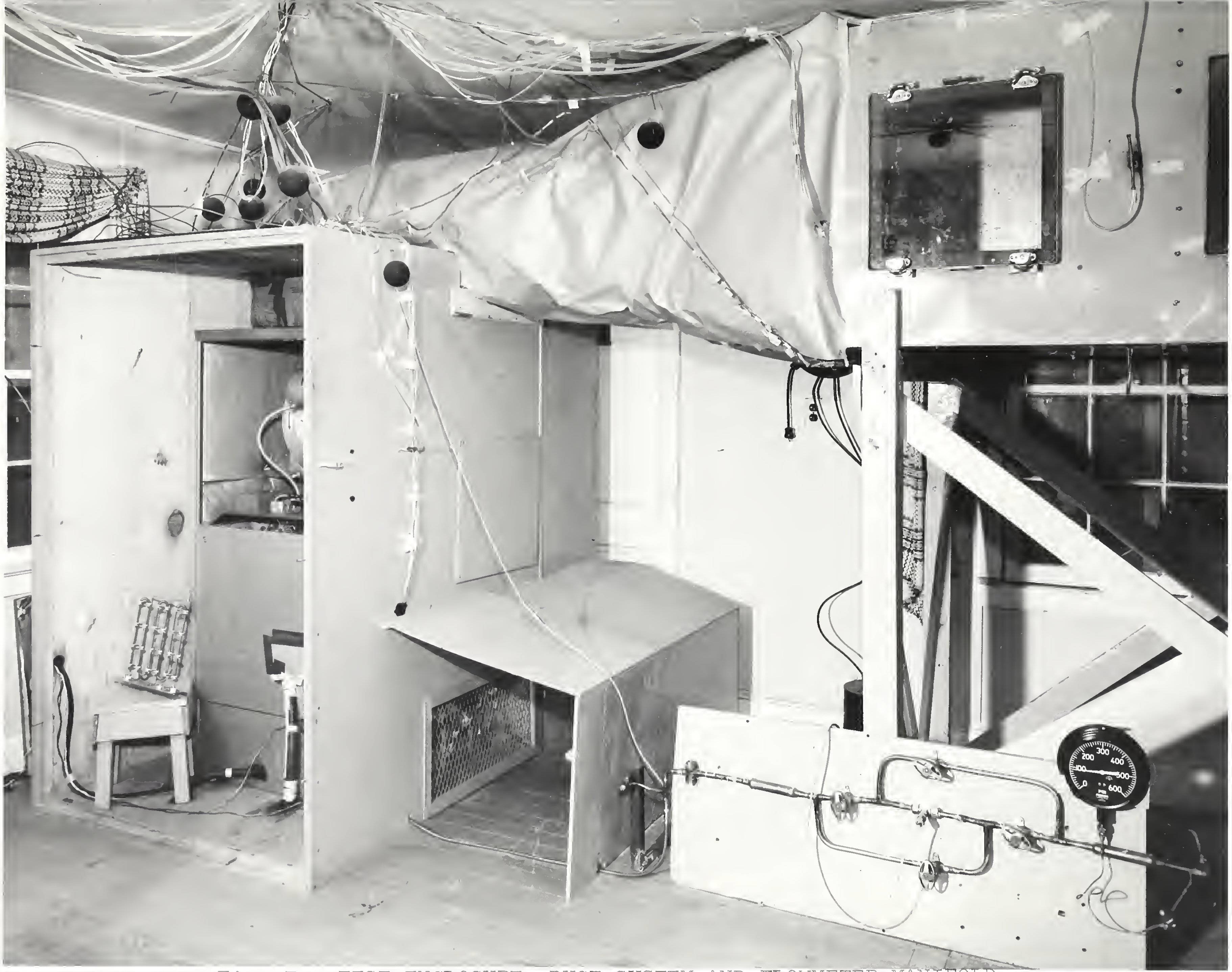

Fig. 7 TEST ENCLOSURE, DUCT SYSTEM AND FLOWMETER MANIFOLD

Fig. 8 AUXILIARY BLOWER

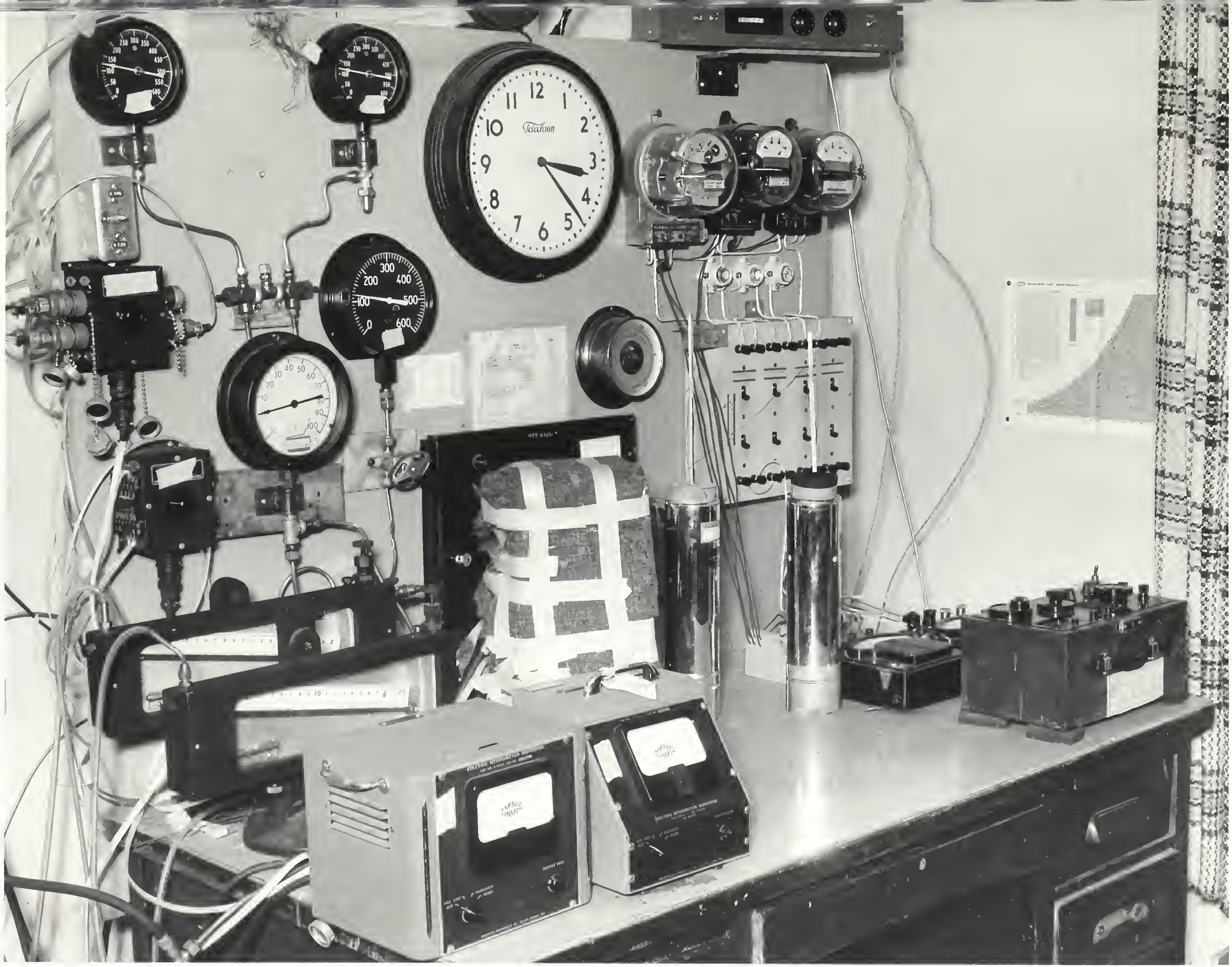

Fig. 9 TEST PANEL

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

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