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NATIONAL BUREAU OF STANDARDS REPORT

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CAPACITY TESTS OF TWO WESTINGHOUSE HEAT PUMPS MODELS 23 RHP AND 33 RHP

by

Joseph C. Davis
Paul R. Achenbach

Report to
Myrtle Beach Air Force Base
Myrtle Beach, South Carolina

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Air Conditioning, Heating, and Refrigeration Section
Building Technology Division

to
Myrtle Beach Air Force Base
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ABSTRACT

At the request of Captain John. F. Burket, Jr., Contracting Officer, Myrtle Beach Air Force Base, South Carolina, cooling and heating capacity tests were made of two Westinghouse air-to-air heat pumps, Models 23 RHP and 33 RHP. Before the tests began interpretation of contract specification requirements with regard to capacity values and conditions for testing were agreed upon at a meeting held on April 8, 1958, at Columbia, South Carolina between representatives of the United States Air Force, Westinghouse Corporation, and the National Bureau of Standards. The tests, except for minor deviations, were made under procedures and conditions specified by the American Society of Refrigerating Engineers Standard No. 16-56. Results of the tests showed compressor cooling capacities to be 21,000 and 33,900 Btu/hr and compressor heating capacities to be 14,700 and 20,700 Btu/hr for the 23 RHP and 33 RHP models, respectively. Thus the cooling capacity of the Model 23 RHP was slightly less than required on type C and N houses only and the cooling capacity of the Model 33 RHP exceeded the requirements on all types of houses for which it was to be used. The heating capacity of the Model 23 RHP unit ranged from 1700 to 10,000 Btu/hr less than required and that of the Model 33 RHP ranged from 3800 to 6800 Btu/hr less than required for the different house types in the project. Tests on the supplementary resistance heaters for the 23 RHP showed 6.42 KW or 21,911 Btu/hr, and for the 33 RHP, 6.49 KW or 22,150 Btu/hr. These values are in excess of those called for by specifications. The required resistance heating capacities range from 8000 to 12,000 Btu/hr for the several type homes in the Myrtle Beach project. During both specification heating tests, modulation of the expansion valve occurred, and in the case of the 33 RHP the modulation caused the flowmeter to stop several times during the test run, making it impossible to check the psychrometric measurements by the flowmeter measurements. Tests on both heat pumps were made at other "state" conditions than those called for by the specifications, but only those made on the 23 RHP are reported here, since those on the 33 RHP were not part of the test request from USAF.

1. INTRODUCTION

In accordance with a request from Captain John F. Burket, Jr., Contracting Officer, Myrtle Beach Air Force Base, South Carolina, by letter dated April 9, 1958, tests were made to determine the heating and cooling capacity of two Westinghouse heat pumps, Models 23 RHP and 33 RHP. The interpretation of the specification requirements with regard to capacity values and the design conditions for testing were agreed upon at a meeting held on April 8, 1958, at Columbia, South Carolina, between representatives of the United States Air Force, Westinghouse Corporation, and the National Bureau of Standards. Each type house under construction at Myrtle Beach Air Force Base had specific requirements for cooling and heating, based upon loads calculated by the Air Force. The capacity values agreed upon and the conditions for testing are listed below.

SPECIFICATION CAPACITY VALUES
FOR 23 RHP HEAT PUMP

For Housing Unit	Calculated Heat Gain (Btu/hr)	Compressor Cooling per Heat Pump (Btu/hr)	Calculated Heat Loss (Btu/hr)	Supplementary Resistance Heating (Btu/hr)	Compressor Heating per Heat Pump (Btu/hr)
A	19,650	19,650	24,400	8,000	16,400
B	19,650	19,650	25,400	9,000	16,400
C	22,314	22,314	30,700	6,000	24,700
M*	36,700	18,350	47,500	7,000	16,750
N*	43,250	21,625	57,200	11,000	17,600

* 2 heat pumps per house.

SPECIFICATION CAPACITY VALUES FOR 33 RHP HEAT PUMP

For Housing Unit	Calculated Heat Gain (Btu/hr)	Compressor Cooling per Heat Pump (Btu/hr)	Calculated Heat Loss (Btu/hr)	Supplementary Resistance Heating (Btu/hr)	Compressor Heating per Heat Pump (Btu/hr)
D	26,300	26,300	30,000	5,500	24,500
F	26,300	26,300	33,700	8,000	25,700
G	29,700	29,700	37,500	11,000	26,500
H	29,700	29,700	30,000	5,500	24,500
I	29,700	29,700	33,900	8,000	25,900
J	33,240	33,240	39,500	12,000	27,500
K	33,240	33,240	36,000	10,000	26,000

CONDITIONS FOR TESTING 23 RHP AND 33 RHP HEAT PUMPS

Design Test Conditions	Cooling	Heating
Outdoor dry bulb temperature	95°F	20° F
Outdoor wet bulb temperature	80°F (51.5% RH)	
Indoor dry bulb temperature	80°F	70° F
Indoor wet bulb temperature	67°F (50% RH)	

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

It was agreed at the meeting at Columbia, South Carolina, that all tests would be performed with the indoor blower delivering 800 CFM of conditioned air for the 23 RHP, and 1200 CFM for the 33 RHP. Static pressure at the outlet of the indoor unit was not specified.

2. DESCRIPTION OF TEST SPECIMEN

The models 23 RHP and 33 RHP 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 two sections will be designated hereinafter as the outside unit and the indoor unit.

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 shifting from cooling to heating and vice versa. Thermostatic expansion valves were used as the liquid refrigerant flow control device in both the indoor and outdoor units with check valves to bypass each when not needed. Following the new ASRE refrigerant designations, the refrigerant in the RHP 23 was R-12 and in the RHP 33 was R-22. A heat exchanger between the liquid line and the suction line downstream from the four-way valve served to subcool the liquid refrigerant before being pumped to the expansion valve.

A schematic diagram of the heat pump system and auxiliary test instrumentation is shown in figure 1. A list of line sizes between the indoor and outdoor units for the two heat pumps is shown below. Both liquid and vapor lines were about 30 ft.

	23 RHP	33 RHP
1. Liquid line except for flowmeter manifold (in.)	3/8 OD	3/8 OD
2. Lines in manifold (in.)	1/2 OD	1/2 OD
3. Vapor line (in.)	7/8 OD	7/8 OD

INDOOR UNIT

The indoor unit consisted essentially of a coil (used as an evaporator during cooling), a blower for circulating conditioned air through the duct system of the home, a motor for powering the blower, an expansion valve, a check valve, and two supplementary resistance heaters. A short description of the above components and of other smaller components is given below:

Coil, 23 RHP. Four rows of 1/2-in. OD copper tubing, 14 tubes each row, 1 1/4 in. apart - center to center. Ten aluminum fins per in. of tube length. Dimension of coil assembly: 17 1/2 in. high, 17 1/2 in. wide, 5 1/2 in. deep.

Coil, 33 RHP. Four rows of 1/2-in. OD copper tubing, 14 tubes each row, 1 1/4 in. apart - center to center. Ten aluminum fins per in. of tube length. Dimension of coil assembly: 17 1/2 in. high, 25 in. wide, 5 1/2 in. deep.

Blower, 23 RHP. Lau Mfg. Co., Centrifugal, 7-in.pulley, 10 in. wide, 10 in.-diameter.

Blower, 33 RHP. Lau Mfg. Co., Centrifugal, 7-in. pulley, 12 in. wide, 11-in.-diameter.

Blower Motor (both heat pumps). Single-phase, type FH, continuous operation. Westinghouse 1/3 HP, 60 cycles, 1725 RPM. Frame 56, service factor 1.35. Temperature rise 40°C. Code L. 230 volts, 2.45 amperes. Thermoguard thermal protective device, type A. Requires oiling. Adjustable pulley, 3 1/4 in. for 23 RHP and 3 3/4 in. for 33 RHP.

Expansion valve, 23 RHP. Non-adjustable, thermostatic type, Sporlan, 3/8-in. OD, sweat, type NSFE, charge G 2-ton F12. External equalizer, 1/4-in. OD line, and charged thermal bulb.

Expansion valve, 33 RHP. Non-adjustable, thermostatic type, Sporlan, 3/8-in. OD, sweat, type NSVE, 3 1/2 G 3-ton F-22. External equalizer, 1/4-in. OD line, and charged thermal bulb.

Check Valve (both heat pumps). Kerotest, 3/8-in. OD, sweat. Pressure activated.

Resistance Heaters. Two coil-type heaters in parallel which cut in simultaneously when temperature in home reaches a certain value below thermostat setting, or when the heat pump is on a defrost cycle. On defrost the air supply to the home is cooled for a short interval by the indoor coil. The coil assembly includes 2 thermal safety cut-offs to prevent overheating in case of fan failure. Name plate information: 235 V, 60 cycles, 1 phase, 6.6 KW. (Information given later in this report shows that each coil dissipated about 3.2 KW at 230 volts of test.)

Drier, RHP 23. Sporlan Catch-all, Type 1635.

Drier, RHP 33. Sporlan Catch-all, Type C 163.

Filter, RHP 23. One, spunglass type, Dust-stop Mfg., 20 in. high, 25 in. wide, 1 in. thick, throwaway type.

Filters, RHP 33. Two, mounted in same plane, glasfloss type, 16 in. high, 20 in. wide and 1 in. thick, throwaway type.

Insulation, RHP 23. One in. of glass fiber, completely foil covered

Insulation, RHP 33. One in. of glass fiber, partially foil covered.

Description of lines inside indoor unit, both heat pumps. Liquid line, 3/8-in. OD, vapor line 7/8-in. OD. Header line 7/8-in. OD. Four distributor lines, each 3/16-in. OD. All lines brazed with Sil-Fos.

Housing dimensions, indoor unit, 23 RHP. Twenty-three in. high, 36 in. wide, 25 1/2 in. deep. Wall thickness 1/32 in.

Housing dimensions, indoor unit, 33 RHP. Rwenty three in. high, 36 in. wide, 34 in. deep. Wall thickness 1/32 in.

Nameplate covering entire indoor unit, RHP 23. F12. Type RHP23F, Style 493D450G07, Ser. C1066. Test pressure 400 lb.

Nameplate covering entire indoor unit, RHP 33. F22. Type RHP 33F. Sytle 493D451G07, test pressure 400 lb.

Figure 2 shows the indoor unit ready for test inside of its enclosure.

OUTDOOR UNIT

The outdoor unit consisted essentially of a coil (used as an evaporator during heating), a blower, a motor to drive the blower, a hermetically-sealed motor-compressor, an expansion valve, a check valve, a four-way valve, and a heat exchanger in the liquid line to provide subcooling to the liquid before being pumped to the expansion valve. These components and others are described below.

Coil, 23 RHP. Three rows of 1/2-in. OD copper tubing, 18 tubes each row, 1 1/4 in. apart - center to center. Ten aluminum fins per in. of tube length. Dimensions of coil assembly: 22 1/2 in. high, 28 in. wide, 3 3/4 in. deep.

Coil, 33 RHP. Three rows of 1/2-in. OD copper tubing, 28 tubes per row, 1 1/4 in. apart - center to center. Ten aluminum fins per in. of tube length. Dimension of coil assembly: 35 in. high, 28 in. wide, 3 3/4 in. thick.

Blower 23 RHP. Preslock. Twelve in. dia., 12 in. wide. Pulley 8 in. dia.

Blower, 33 RHP. Preslock. Fourteen-in. dia., 12 in. wide. Pulley, 8 in. dia.

Blower Motor, 23 RHP. Westinghouse AC, single-phase, type FH, cont. operation, 1725 rpm, 60 cycle, 230 volts., 2.45 amp., 1/3 HP. Service factor, 1.35. Thermoguard Mfg. thermal protection. Frame 56. Ser. No. MD Code L, 40°C rise, requires oiling. Adjust. pulley 3 1/4 in. dia.

Blower Motor, 33 RHP. Westinghouse AC, single phase, type F, cont. operation, 1725 rpm, 60 cycle, 230 volts, 3.3 amp., 1/2 HP. Service factor 1.25. Thermoguard Mfg. Co. thermal protection. Frame 056. Ser. No. ND Code G, 40°C rise. Requires oiling. 3 3/4 in. dia., adjust. pulley.

Motor Compressor, 23 RHP. Westinghouse, type CLS21, #492D962G01, 230 V, air cooled, full load amp., 16. L. R. amp. 55. Ser. No. BC2802. Pressure test, 250 lbs. Spring mounted. F-12.

Motor Compressor, 33 RHP. Westinghouse type CLS, S#492D903G01, 230 V, air cooled, full load amp., 26.1, L. R. amp., 88. 1750 rpm. Spring mounted. F-22.

Expansion Valve, 23 RHP. Non-adjust., thermostatic, Sporlan, 3/8-in. OD, sweat, NSFE 2 Z, low temp. type--suction temp. 0° to -40°, F-12. External equalizer, 1/4-in. OD line, and charged thermal bulb. Line strainer before valve.

Expansion Valve, 33 RHP. Non-adjust., thermostatic, Sporlan, 3/8-in. OD sweat, Y84NRVE 2 1/2 Z, low temp. type--suction temp. 0° to -40°, F-22. External equalizer, 1/4-in. OD line, and charged thermal bulb. Line strainer before valve.

Check Valve, both heat pumps. Kerotest 3/8-in. OD, sweat, pressure-activated.

Four-Way Valve, both heat pumps. Westinghouse. Solenoid operated on low voltage.

Other Components. Both heat pumps have a muffler in the discharge line to minimize compressor noises in the home, and the heat exchanger in the suction line described previously.

Controls (a) Defrost switch for heating cycle. At low temperatures and when the outdoor atmosphere is humid, the outdoor unit coil gradually becomes frost covered. To defrost the coil the solenoid of the four-way valve is actuated by a pressure sensing device and the refrigerant flow is reversed so that the outdoor coil rejects heat (becomes a condenser) and the frost is melted. Concurrently the outdoor fan is cut off and the supplementary electric heaters of the indoor unit are placed into operation to warm up the conditioned air in the home which during the brief period of defrosting is cooled by the indoor coil.

The device actuating the solenoid of the four-way valve is a diaphragm which senses the difference between atmospheric pressure and outdoor blower suction pressure. This actuates a defrost relay. (b) The defrost limit switch operates on a preselected high value of head pressure after defrost, causing reactivation of the solenoid, change in direction of the refrigerant flow and return to normal operation. This switch "limits" the head pressure. (c) A thermally actuated device on the discharge line from the compressor stops the compressor when there is low refrigeration, mechanical failure or any situation where the compressor temperature becomes excessive. This control is manually reset in the outdoor unit and is manufactured by Thermo-guard. (d) A Hi-low pressure switch opens either when suction pressure is too low or head pressure too high to stop operation of the compressor when there is an obstruction in a line. Reset manually in home at thermostat. (e) Mild weather control on heating cycle. During mild weather with satisfactory indoor temperature of about 70°F and an outdoor temperature of about 65°, the outdoor fan is turned on and off by this control to prevent overheating of the conditioned air and excessive head pressure

Which would eventually cut off the compressor. The cycle is actuated and the fan cut off by a head pressure above a given threshold. During this period, while the fan is inoperative and with the compressor still operating, both head pressure and suction pressure decrease until a point is reached where the fan comes back into operation and the cycle is repeated. (f) The electrical overload switches on compressors and motors mentioned previously are reset manually at the thermostat inside the home.

Insulation, both units. One in. of glass fiber top and back of compressor compartment. Access doors both have the same thickness of insulation. No foil.

Description of lines inside of outdoor unit, both heat pumps. Discharge line from compressor to four-way valve, 5/8 in. OD. Suction line from compressor to four-way valve, 7/8 in. OD. Liquid line from coil, 3/8 in. OD. Line from four-way valve to coil, 7/8 in. OD. Vapor line inside of unit, 7/8 in. OD. Header line, 7/8 in. OD for 23 RHP and 1 3/8 in. OD for 33 RHP. Four distributor lines, 1/4 in. OD. All lines brazed with Sil Fos.

Housing, outdoor unit, 23 RHP. Thirty-nine in. high, 36 in. wide, 29 in. deep. Thickness 1/16 in.

Housing, outdoor unit, 33 RHP. Thirty-nine and one half in. high, 36 in. wide, 29 in. deep. Wall thickness 1/16 in.

Nameplate covering entire heat pump, 23 RHP. F-12. Type RHP 23 F. Style 493D461G01. Ser. BC 6889. ASRE rating, cooling 22,000. Heating 23,100 to 15,000 Btu.

Nameplate covering entire heat pump, 33 RHP. F-22. Type 33F Style 493D470G01, Ser. DC6296, ASRE rating, cooling 36,000 Btu, heating 37,000 to 25,000 Btu. (Representatives of the Westinghouse Corporation informed the National Bureau of Standards that the 25,000 Btu rating was placed on the nameplate in error. This rating representing capacity expected from the compressor for heating at an outdoor temperature of 20°, should have been 22,500 Btu.)

Figure 3 shows the outdoor unit with test equipment. Note the five-in-one thermocouple system and the thermostat used for controlling outdoor conditions during the test.

3. METHODS OF TESTING

Except for minor deviations, the heat pump was tested under the conditions described in ASRE Testing and Rating Standard No. 16-56. Figure 4 shows the enclosure housing the indoor unit and the 33-in. square test duct attached to the outlet side of the unit. This duct housed the nozzle used for measuring air circulation rate and the instruments for measuring temperature and humidity of the outlet air. Because the nozzle, mixing baffles, and 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. Adjustment of external static resistance when such adjustment was necessary was made by a wooden slide-type damper at the outlet of the auxiliary blower. The auxiliary blower, return air heaters, and humidifier are shown in figure 5.

ASRE Standard 16-56 requires that two independent measuring methods be used during the test, each as a check on the other. 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 across the unit. The other method involved determination of the flow of refrigerant through the indoor coil and the change in enthalpy of the refrigerant across the indoor coil. A correction to the total enthalpy change of the refrigerant is 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 is in use before comparing it with the result of the psychrometric method. Values obtained by the two methods should not differ by more than six percent.

Mass flow of air in the psychrometric method was obtained by measuring humidity and temperature conditions of the air entering the long-radius nozzle and the static pressure drop 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.

For both heat pumps the volume air flow rate was set by adjusting the blower pulley before the test with the compressor inoperative and with the indoor blower forcing dry air over the indoor coil. Thereafter the damper at the outlet to the auxiliary blower remained unchanged.

Flow of refrigerant was measured by means of a flowmeter in the liquid line of the system--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 gal-unit time. By knowing temperature of the liquid in the line, the flow was converted to mass flow. Enthalpy change was determined by temperature and pressure measurements at the inlet and outlet of the indoor coil. For accurate measurement of capacity by the refrigerant flow method it was imperative that there be no gas bubbles in the liquid refrigerant as it passed through the meter, and that the liquid refrigerant all be evaporated in the coil.

It was possible to maintain "state" conditions for both cooling and heating with the use of a test structure having two controlled temperatures.

During both tests, power consumed by the indoor blower, outdoor fan, and compressor was read from separate watthour meters. Simultaneous readings were made of currents and voltages. The various meters, together with the other instruments for measuring temperature and humidity, are shown in figure 6.

In each heat pump test, the following "state" conditions for the indoor and outdoor air were maintained during the cooling cycle in accordance with contract specifications:

95°F DB outdoors
80°F DB inside
67°F WB inside (50 percent relative humidity)

For the heating test, the following "state" conditions for the indoor and outdoor air were maintained in accordance with the contract specifications:

20°F DB outdoors
70°F DB indoors

The same refrigerant charge was used for the cooling test as for the heating test. For the 23 RHP the Westinghouse representative and the NBS project leader agreed to set this charge for optimum capacity on the cooling cycle. This charge remained constant during a number of subsequent cooling and heating tests at "state" conditions other than those specified in the contract specifications and was still the same for the test at 20° outdoors and 70° indoors. When this cold temperature was reached, however, bubbles appeared in the sight glass of the liquid line indicating a shortage of refrigerant. Although the test was completed, the Westinghouse representative thereupon requested the addition of another pound of refrigerant and both the specification heating and cooling tests were repeated. The additional tests at other "state" points were not repeated but the significance of the shortage of one pound of refrigerant on the values obtained will be discussed in paragraphs following.

In light of this experience the representative and the NBS project leader agreed to set up the charge for the 33 RHP on the heating cycle at 20°F, with the charge remaining constant through the cooling test.

Surveillance of charge was always made with the heat pump on cooling and with the outdoor temperature at 95°F, the indoor temperature at 80°F, and the indoor relative humidity at 50 percent. Checks were made for pressures, refrigerant vapor and liquid temperatures, superheating, subcooling, flowmeter count, and change in air temperature across the indoor coil. During both heating tests after the correct charge was made, the outdoor temperature was raised to 95°F as soon as possible and these check points determined.

The tests on the RHP 23 with a refrigerant shortage of one lb were made at the six "state" conditions for cooling and three "state" conditions for heating shown below.

	Cooling		Heating	
Outdoor Temp	Indoor Temp	Indoor RH	Outdoor Temp	Indoor Temp
105 °F	80 °F	50 %	50 °F	70 °F
95	80	50	35	70
85	80	50	20	70
75	80	50		
95	75	50		
85	75	50		

The tests at other than specification design conditions were made in conformance with a request from the USAF for information in addition to that required by specification.

Due to a shortage of time and the need for curtailing expense, only the two specification tests were performed on the RHP 33 under the USAF test request. Other tests at the "state" points indicated below were performed at the expense of NBS when it was not too time consuming and too expensive to perform them. These "state" points are indicated below.

Cooling			Heating	
Outdoor Temp.	Indoor Temp.	Indoor RH	Outdoor Temp.	Indoor Temp.
105 °F	80 °F	50 %	50 °F	70 °F
85	80	50	35	70

The results of the observations at these points are not reported, but are available for use by USAF, and the Westinghouse Corporation with the permission of USAF.

Before each test run, a minimum of one hour steady-state conditions was held before the data were considered valid. During most test runs, readings were taken every ten minutes for at least one hour. In each case, except the cases noted below, the hour representing the steadiest conditions was used for evaluating performance. In the specification cooling test for the 33 RHP, the best two hours were used. In the specification heating test for the 23 RHP, due to cycling of the expansion valve, readings were taken every five minutes, and data covering a period of 55 minutes were used. In the specification heating test for the 33 RHP, readings were taken every ten minutes and data covering a two-hour period were used.

4. TEST RESULTS

A. 23 RHP, Cooling Test

ASRE Standard 16-56 requires that values obtained by the psychrometric and flowmeter methods be averaged to obtain the rated capacity of the heat pump. The results obtained by the two measuring methods during the cooling test, and the total rated cooling capacity of the model 23 RHP are shown below. This capacity, it will be noted, includes a correction for deviation of barometric pressure from standard barometric pressure. This is in accordance with ASRE 16-56, which allows an increase of 0.8 percent of capacity for each inch of barometer reading below 29.92 in. of Hg during the cooling test.

Summary of Cooling Capacity Values (Btu/hr)

	Test Value	Rounded Value
By psychrometric method	21,060	
By flowmeter method	20,800	
Average	20,930	
Allowance for deviation of barometric pressure from normal	50	
Total	20,980	21,000

Following is a summary of the averages of the more significant data during the cooling test.

Psychrometric Method

Temperatures (°F)

At inlet to enclosure around indoor unit	80.0
At outlet of indoor unit in duct	61.7
Temperature difference across indoor coil	18.3
At inlet to outdoor unit	95.0

Relative humidities (%)

At inlet to enclosure around indoor unit	50.0
At outlet of indoor unit in duct	82.3

Static pressure across nozzle (In. of H_2O)	.555
Volume air flow at nozzle (cfm)	788
Mass air flow at nozzle (lb dry air/hr)	3581
Barometric pressure (In. of Hg)	29.57
Diameter of nozzle (In.)	7.009
Nozzle coefficient	.987
Static pressure at indoor blower outlet (In. of H_2O)	.023

Flowmeter Method

Temperatures (°F)

In vapor line leaving coil of indoor unit	53.7
In liquid line entering coil of indoor unit	102.7
Superheat at indoor coil outlet	10.0
Subcooling at indoor coil inlet	15.2
In discharge line of compressor	209.2
In suction line of compressor	83.8

Pressures (psig)

Compressor discharge	163.0
In liquid line entering coil of indoor unit	155.0
In vapor line leaving coil of indoor unit	40.5
In suction line of compressor	39.2

Difference in pressure across flowmeter was negligible.

Potter meter count for 10 minutes	220.7*

* Refrigerant flow, gal/min = $\frac{\text{Count for one minute x 100}}{3365.5}$

Motor power consumption (Watts)

Indoor blower	264
Outdoor blower	346
Compressor	2481
Total	3091

Coefficient of performance	1.99

Motor voltages (Volts)

Indoor blower	230.6
Outdoor blower	230.6
Compressor	230.6

Motor currents (Amperes)

Indoor blower	2.34
Outdoor blower	2.32
Compressor	12.35

B. 23 RHP, Volume Air Flow

When the volume air flow from the blower of the indoor unit was set by pulley adjustment before the cooling test without the compressor running and at an indoor temperature of about 75°F, the following results were obtained.

Volume air flow at nozzle (cfm)	806
Static pressure at indoor blower outlet (In. of H_2O)	0.08

No subsequent pulley adjustment or damper adjustment affecting static pressure was made during the cooling and heating tests on the 23 RHP.

C. 23 RHP, Heating Test

The heating test performed in accordance with the procedures described in ASRE Standard 16-56, except for minor deviations, gave the following results. The ASRE standard allows an increase of 2.0 percent of capacity for each inch of deviation below standard barometric pressure for the heating condition.

Summary of Heating Capacity Values (Btu/hr)

	Test Value	Rounded Value
By psychrometric method	14,580	
By flowmeter method	14,590	
Average	14,585	
Correction for deviation of barometric pressure during test from standard barometric pressure	80	
	14,665	14,700

Following is a summary of the averages of the more significant data observed during the heating test.

Psychrometric Method

Temperatures (°F)

At inlet to enclosure around indoor unit	69.8 DB
At outlet of indoor unit in duct	87.1 DB
Temperature difference across indoor coil	17.3
At inlet to outdoor coil	20.5 DB

Relative humidity of indoor air in duct (%)	12.3
Static pressure across nozzle (In. of H_2O)	0.56

Volume air flow at nozzle (cfm)	807
Mass air flow at nozzle (lb dry air/hr)	3496.3
Barometric pressure (In. of Hg)	29.65
Diameter of nozzle (In.)	7.009
Nozzle coefficient	.987
Static pressure at indoor blower outlet (In. of H_2O)	.080

Flowmeter Method

Temperatures (°F)

In vapor line entering coil of indoor unit	154.0
In liquid line leaving coil of indoor unit	89.5
Superheating at vapor line entering coil of indoor unit	56.9
Subcooling at liquid line leaving coil of indoor unit	7.0

Pressures (psig)

Compressor discharge	115
In vapor line entering coil of indoor unit	114
In liquid line leaving coil of indoor unit	114
In liquid line leaving flowmeter	108
Pressure difference across flowmeter	6.0

(Suction pressure not observed.)

Potter meter count for 10 minutes	561*

* Refrigerant flow, gal/min $= \dfrac{\text{Count for 1 minute} \times 100}{18133.8}$

Motor power consumption (Watts)

Indoor blower	255
Outdoor blower	426
Compressor	1728
Total	2409

Coefficient of performance	1.79

Motor voltages (Volts)

Indoor blower	229.1
Outdoor blower	229.8
Compressor	229.8

Motor currents (Amperes)

Indoor blower	2.31
Outdoor blower	2.60
Compressor	8.55

Power dissipated by supplementary resistance heaters (KW)	a. 3.23 b. 3.19

D. 23 RHP, Other Tests

As discussed previously, when the heating test at the 20° outdoor temperature was completed, another pound of refrigerant was added to the system and another heating test-run made at the same outdoor temperature. It was found that capacity increased by 700 Btu/hr with the extra lb, and the second run was used as the specification test. With the same refrigerant charge, another cooling test was performed and here again an increase of 700 Btu/hr occurred. This cooling test also served as the specification test. The results for both heating and cooling reported above on the 23 RHP heat pump were those observed after adding the pound of refrigerant.

Before the two final specification tests were performed, the total of six cooling tests and three heating tests were performed with the original low charge. Two of these, one for cooling and one for heating, were at design conditions.

The results of these tests with low refrigerant are shown graphically in figure 7 for the six cooling tests, and in figure 8 for the three heating tests.

E. 33 RHP, Cooling Test

The cooling test for the 33 RHP gave the following results.

Summary of Cooling Capacity Values (Btu/hr)

	Test Value	Rounded Value
By psychrometric method	34,960	
By flowmeter method	32,610	
Average	33,785	
Correction for deviation of barometric pressure from standard barometric pressure	70	
	33,855	33,900

Following is a summary of the more significant data observed during the cooling test.

Psychrometric Method

Temperatures (°F)

At inlet to enclosure around indoor unit	79.8 DB
At outlet of indoor unit in duct	59.8 DB
Temperature difference across indoor coil	20.0 DB
At inlet to outdoor unit	94.8 DB

Relative Humidities (%)

At inlet to enclosure around indoor unit	49.4
At outlet of indoor unit in duct	84.5

Static pressure across nozzle (In. of H_2O)	1.24
Volume air flow at nozzle (cfm)	1179
Mass air flow at nozzle (lb of dry air/hr)	5325
Barometric pressure (In. of Hg)	29.65
Diameter of nozzle (In.)	7.009
Nozzle coefficient	.99
Static pressure in indoor blower outlet (In. of H_2O)	-0.01

Flowmeter Method

Temperatures (°F)

In vapor line leaving coil of indoor unit	54.3
In liquid line entering coil of indoor unit	103.8
Superheating in vapor line leaving coil of indoor unit	11.4
Subcooling in liquid line entering coil of indoor unit	11.8
In compressor discharge line	245.5
In suction line of compressor	85.3

Pressures (psig)

Compressor discharge	267
In liquid line before flowmeter	251
In liquid line entering coil of indoor unit	249
Pressure difference across flowmeter	2
In vapor line leaving coil of indoor unit	73.9

Potter meter count for ten minutes	297.8*

Motor power consumption (Watts)

Indoor blower	358
Outdoor blower	564
Compressor	4206
Total	5128

$$* \text{ Refrigerant flow, gal/min} = \frac{\text{Count for one minute} \times 100}{3365.5}$$

Coefficient of performance	1.94
Motor voltages (Volts)	
Indoor blower	230.1
Outdoor blower	230.0
Compressor	230.0
Motor current (Amperes)	
Indoor blower	2.58
Outdoor blower	3.51
Compressor	20.21

F. 33 RHP, Volume Air Flow

When the volume air flow from the blower of the indoor unit was set by pulley adjustment before the heating test with the compressor running and at an indoor temperature of about 75°F, the following results were obtained. (The heating test was performed before the cooling test on the 33 RHP.)

Volume air flow at nozzle (cfm)	1206
Static pressure at indoor blower outlet (In. of H_2O)	0.07

No subsequent pulley adjustment or damper adjustment affecting static pressure was made during the cooling and heating tests on the 33 RHP.

G. 33 RHP, Heating Test

The heating test for the 33 RHP gave the following results.

Summary of Heating Capacity Values (Btu/hr)

	Test Value	Rounded Value
By psychrometric method	20,610	
Correction for deviation of barometric pressure from standard barometric pressure.	110	
	20,720	20,700

Because modulation of the expansion valve caused the flowmeter to stop intermittently, it was impossible to make a capacity calculation based upon refrigerant flow.

Following is a summary of the more significant data observed during the heating test.

Psychrometric Method

Temperatures (°F)

At inlet to enclosure around indoor unit	69.7 DB
At outlet of indoor unit in duct	85.8 DB
Temperature difference across indoor coil	16.1 DB
At inlet to outdoor unit	19.9 DB

Relative humidity of indoor air in duct (%)	10.2
Static pressure across nozzle (In. of H_2O)	1.28
Volume air flow at nozzle (cfm)	1220
Mass air flow at nozzle (Lb of dry air/hr)	5303.5
Barometric pressure (In. of Hg)	29.56
Diameter of nozzle (In.)	7.009
Nozzle coefficient	.99
Static pressure at indoor blower inlet (In. of H_2O)	0.070

Other temperatures (°F)

In vapor line entering coil of indoor unit	199.0
In liquid line leaving coil of indoor unit	85.4
Superheat in vapor line entering coil of indoor unit	107.4
Subcooling in liquid line leaving coil of indoor unit	6.6
In compressor discharge line	234.1
In compressor suction line	49.1

Pressures (psig)

In compressor discharge line	179
In vapor line entering coil of indoor unit	177
In liquid line leaving coil of indoor unit	177
In liquid line beyond flowmeter	172
Difference in pressure across flowmeter	5
In suction line of compressor	30

Motor power consumption (Watts)

Indoor blower	331
Outdoor blower	678
Compressor	2608
Total	3617

Coefficient of performance	1.68

Motor voltages (Volts)

Indoor blower	230.1
Outdoor blower	230.2
Compressor	230.3

Motor current (Amperes)

Indoor blower	2.45
Outdoor blower	3.99
Compressor	12.84

Power dissipated by supplementary resistance heaters (KW)

a.	3.25
b.	3.24

H. Comparison of 23 RHP operation at 230 volts and 220 volts

Following a test run on the 23 RHP for cooling, the voltage on all three motors of the system was reduced to 220 volts. This voltage was maintained for 40 minutes. During this 40-minute period, little change in the important temperature, pressure, and refrigerant flow values was noted, indicating that capacity on the heat pump should be about the same at

220 volts as at 230 volts. An increase in compressor current drain was noted, but the change in power was not significant. A comparison of data with the system operating at 230 volts and operating at 220 volts is shown below. Each set of data represents 40 minutes. Readings were taken every ten minutes. Outside temperature was 95°, inside temperature 80° and inside relative humidity 50 percent. One pound of refrigerant had been added before this test.

Temperatures (°F)	230 volts	220 volts
At inlet to enclosure around indoor unit	80.1	80.2
At outlet of indoor unit in duct	62.2	62.2
Temperature difference across indoor coil	17.9	18.0
In vapor line leaving coil of indoor unit	54.6	54.6
In liquid line entering coil of indoor unit	101.9	101.9
Potter meter count for 10 minutes	222.5	221.5

Pressures (psig)	230 volts	220 volts
In vapor line leaving coil of indoor unit	40.6	40.6
In liquid line entering coil of indoor unit	154.2	153.0
In suction line of compressor	38.1	38.1

Power consumption (Watts)		230 volts	220 volts
Indoor blower	40 min.	174	167
Outdoor blower	40 min.	229	223
Compressor	40 min.	1714	1706
	Total	2117	2096

Motor voltages (Volts)	230 volts	220 volts
Indoor blower	229.6	219.0
Outdoor blower	230.0	219.4
Compressor	229.6	219.2
Motor current (Amperes)		
Indoor blower	2.37	2.23
Outdoor blower	2.33	2.30
Compressor	12.46	12.87
Static pressure across nozzle	.055	.055

5. DISCUSSION OF TEST RESULTS

Starting with the pulley adjustment on the indoor blower motor, without the compressor running, it was found during the cooling tests that the static pressure at the blower outlet became very low in one case and slightly negative in another. This phenomenon was the result of a change of air density and an interaction of the characteristics of the indoor unit blower and auxiliary blower. At the conclusion of the cooling test RHP 33, it was demonstrated that the pulley of the indoor blower could be further adjusted to deliver the required amount of air against an external static pressure of 0.10 of H_2O or greater, such as might occur in a duct system of a house. This operation also required adjustment of the slide damper on the auxiliary blower. There was no significant rise in blower motor current.

To determine the amount of oil traveling through the lines with the refrigerant and the effect of this oil on the flowmeter registration, the refrigerant was sampled after the tests on both heat pumps. The refrigerant, taken from the line while the heat pump was operating, was discharged into special flasks pre-cooled by dry ice, and then allowed to evaporate slowly as the ice melted, leaving a residue of oil. For the 23 RHP the percentage of oil to refrigerant was 0.50 by volume, whereas for the 33 RHP the percentage was 2.0 by volume.

Throughout the cooling test on the 33 RHP, a pressure difference of 16 psi existed between the compressor discharge and the liquid line entering the coil of the indoor unit as measured by calibrated pressure gages. This difference was estimated to be six psi greater than would normally be caused by the four-way valve, the outdoor distributors, coil, check valve, etc. Of this, about two lb was brought about by the pressure drop across the flowmeter-manifold system. It was estimated that the excessive pressure drop of six lbs, whatever its cause, could cause a loss in capacity of not greater than 300 Btu/hr, and was consequently not considered serious enough by the Westinghouse representative to cause alterations and a retest. Throughout the same tests the needle of the gage measuring the pressure of the liquid going to the coil of the indoor unit, jumped to a high reading and returned instantly to the normal reading. This occurrence was repeated at undetermined intervals of two to ten minutes. The phenomenon was not occasioned by the gage.

Through the heating tests on the 33 RHP, the expansion valve fluctuated between two extremes of position with a corresponding fluctuation in vapor temperature at the coil outlet and temperature of the conditioned air from the indoor unit. The refrigerant flow varied to such an extent that the flowmeter stopped a number of times during the run. Some cycling was expected by the Westinghouse Company at an outdoor temperature of 20°, and was considered a design problem that needed further attention. The representative was somewhat surprised however, when he learned that the cycling occurred to a smaller degree at 35°F and 50°F. The stoppage of the flowmeter during the 20° test run obviated the possibility of a flowmeter calculation, and only a psychrometric value is reported. The flowmeter capacity value for the test at 50° outdoors, was about six percent lower than the psychrometric value.

After both heating tests, an analysis of the effect of the expansion valve cycling on the distribution of temperature values was made. For example, it was possible for a wave function during a period to be heavily weighted in favor of high temperature values, and a simple averaging of temperatures could not be used. In the analysis of the 33 RHP readings were made of the temperature of the vapor at the inlet to the indoor coil every three seconds for 180 seconds, and four complete almost sinusoidal cycles were obtained, indicating that there was an even distribution and the simple averaging process could be used. The same result was obtained for the 23 RHP.

Immediately preceding the taking of data on the 20° test run, the outdoor unit was defrosted. Halfway through the run, the unit frosted slightly, although the average suction pressure during the test period showed little decrease as evidence of capacity loss. The run was continued, however, rather than defrosting and losing conditions. The 23 RHP did not frost during the test.

All pressure readings where the line to the gage held liquid, were corrected for altitude difference between the gage and the point in the system where the pressure indication was desired.

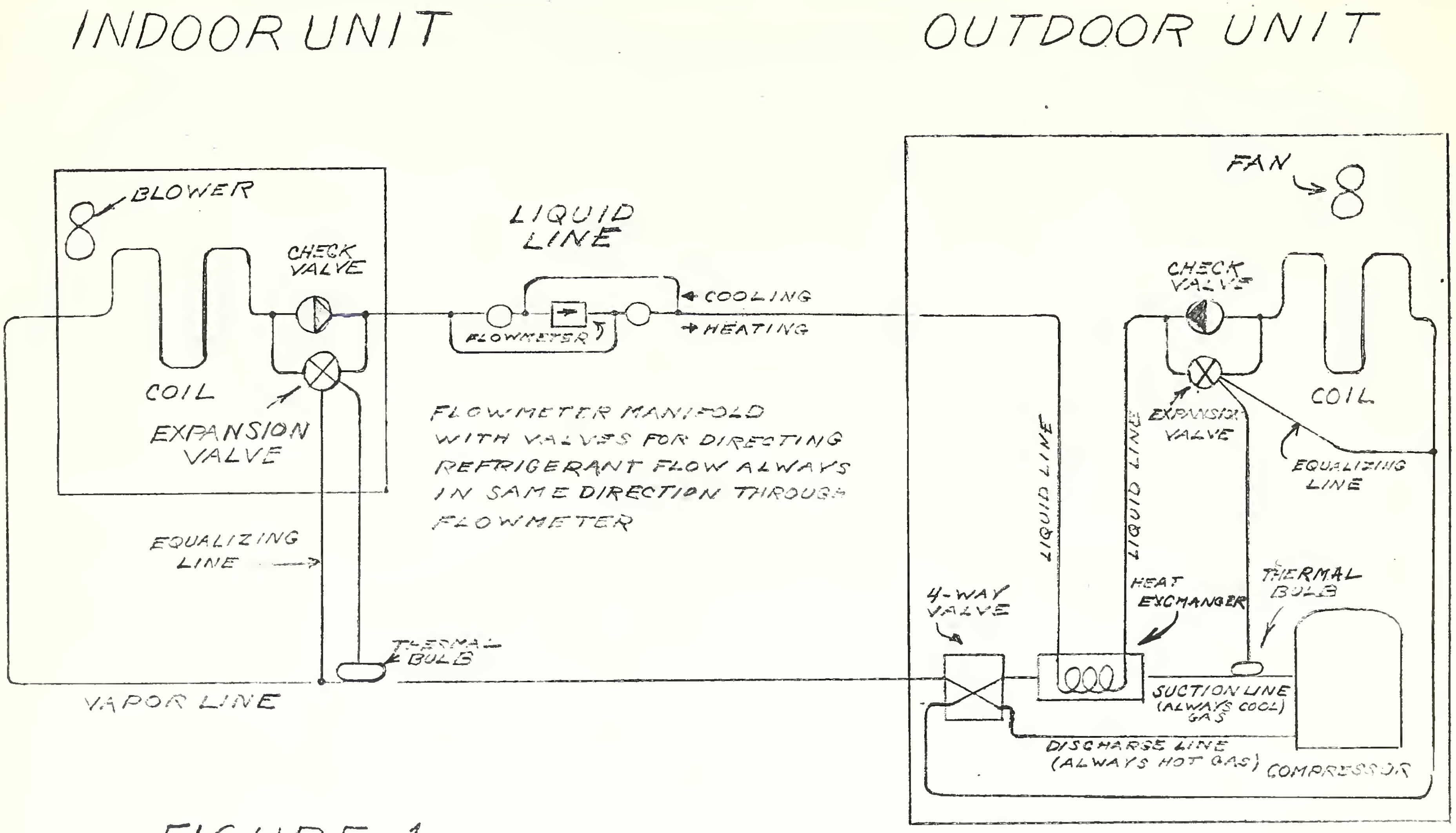

INDOOR UNIT
OUTDOOR UNIT
BLOWER
COIL
CHECK VALVE
EXPANSION VALVE
EQUALIZING LINE
THERMAL BULB
VAPOR LINE
LIQUID LINE
FLOWMETER
COOLING
HEATING
FLOWMETER MANIFOLD WITH VALVES FOR DIRECTING REFRIGERANT FLOW ALWAYS IN SAME DIRECTION THROUGH FLOWMETER
FAN
CHECK VALVE
COIL
EXPANSION VALVE
EQUALIZING LINE
LIQUID LINE
LIQUID LINE
HEAT EXCHANGER
THERMAL BULB
4-WAY VALVE
SUCTION LINE (ALWAYS COOL) GAS
DISCHARGE LINE (ALWAYS HOT GAS)
COMPRESSOR

FIGURE 1

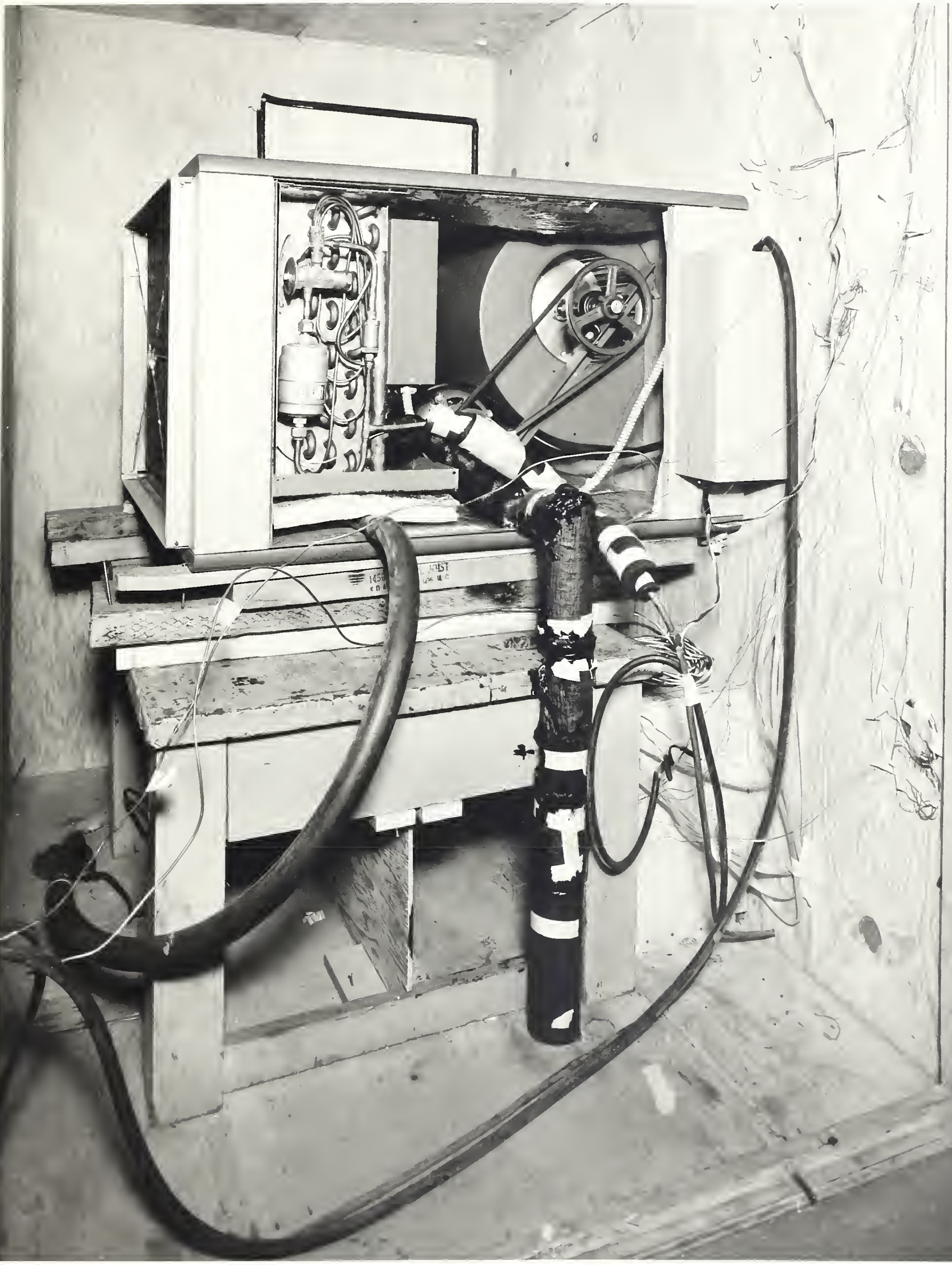


Fig. 2 RHP 33 INDOOR UNIT IN TEST ENCLOSURE

Fig. 3   RHP 33 OUTDOOR UNIT

COEFFICIENT OF PERFORMANCE

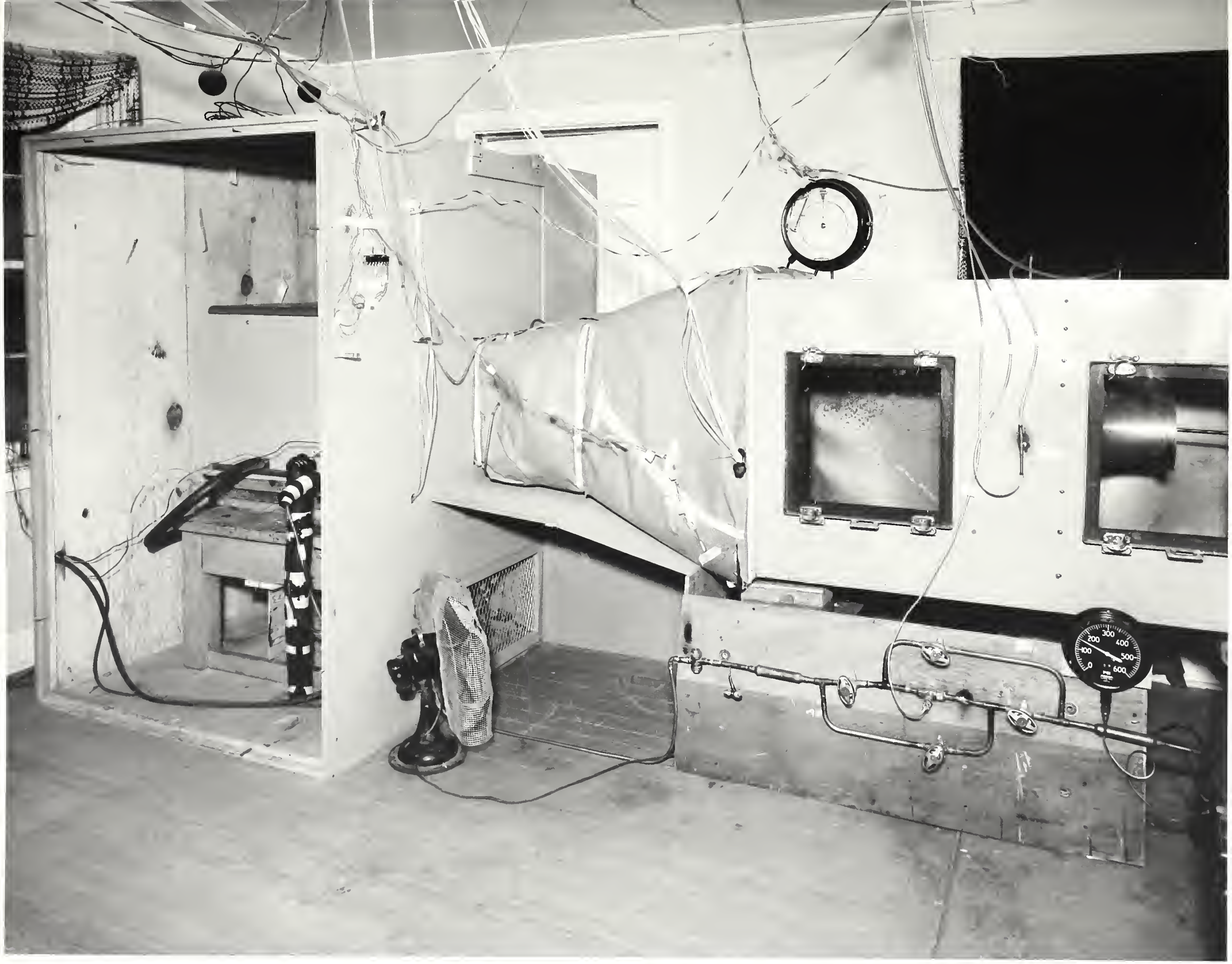
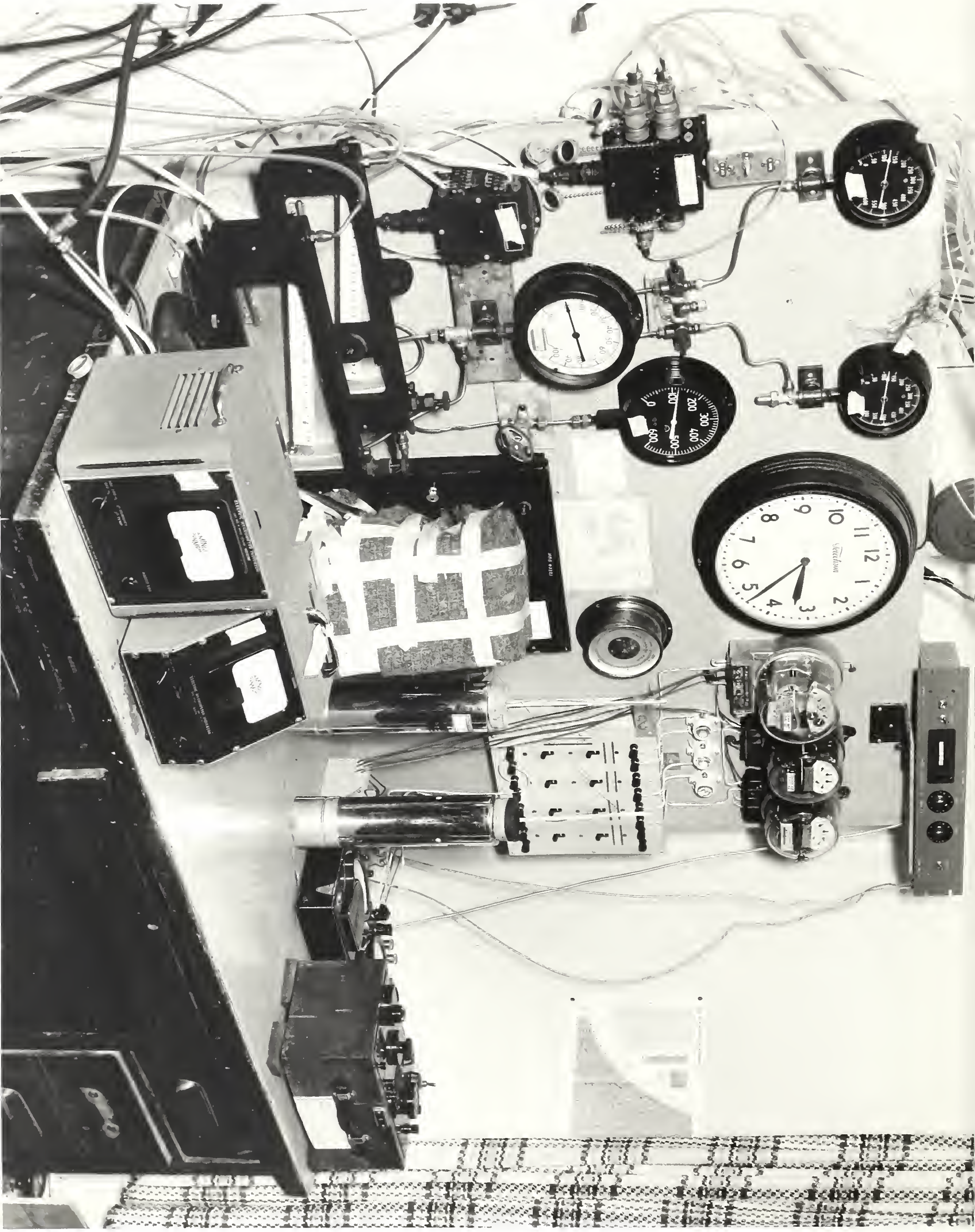


Fig. 4. TEST ENCLOSURE, DUCT SYSTEM, AND FLOWMETER MANIFOLD

COEFFICIENT OF PERFORMANCE



COEFFICIENT OF PERFORMANCE

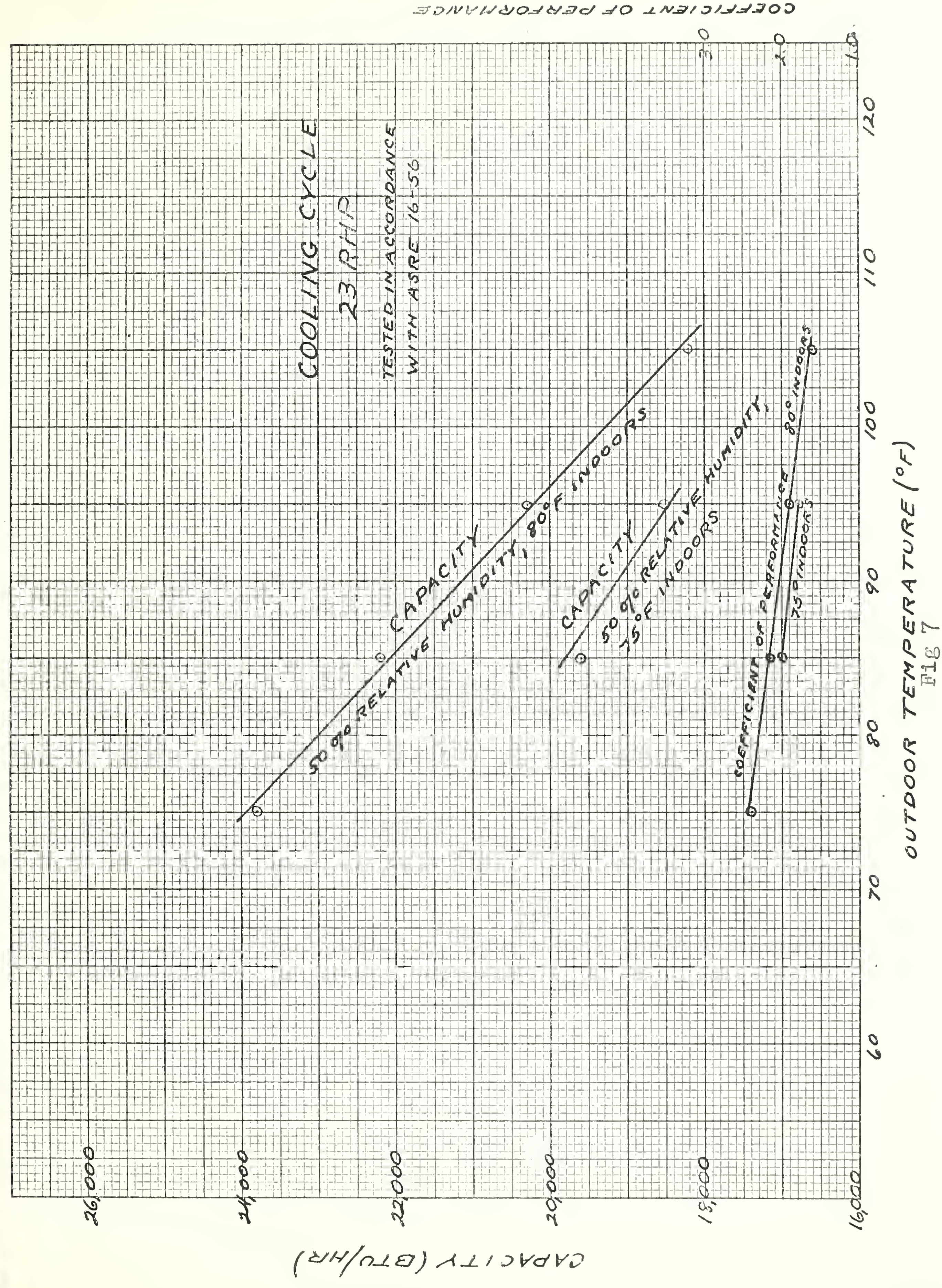

COOLING CYCLE
23 RHP
TESTED IN ACCORDANCE WITH ASRE 16-56
CAPACITY 50% RELATIVE HUMIDITY, 80°F INDOORS
CAPACITY 50% RELATIVE HUMIDITY, 75°F INDOORS
COEFFICIENT OF PERFORMANCE
80° INDOORS
75° INDOORS
COEFFICIENT OF PERFORMANCE
3.0
2.0
1.0
OUTDOOR TEMPERATURE (°F)
60
70
80
90
100
110
120
CAPACITY (BTU/HR)
26,000
24,000
22,000
20,000
18,000
16,000

Fig 7

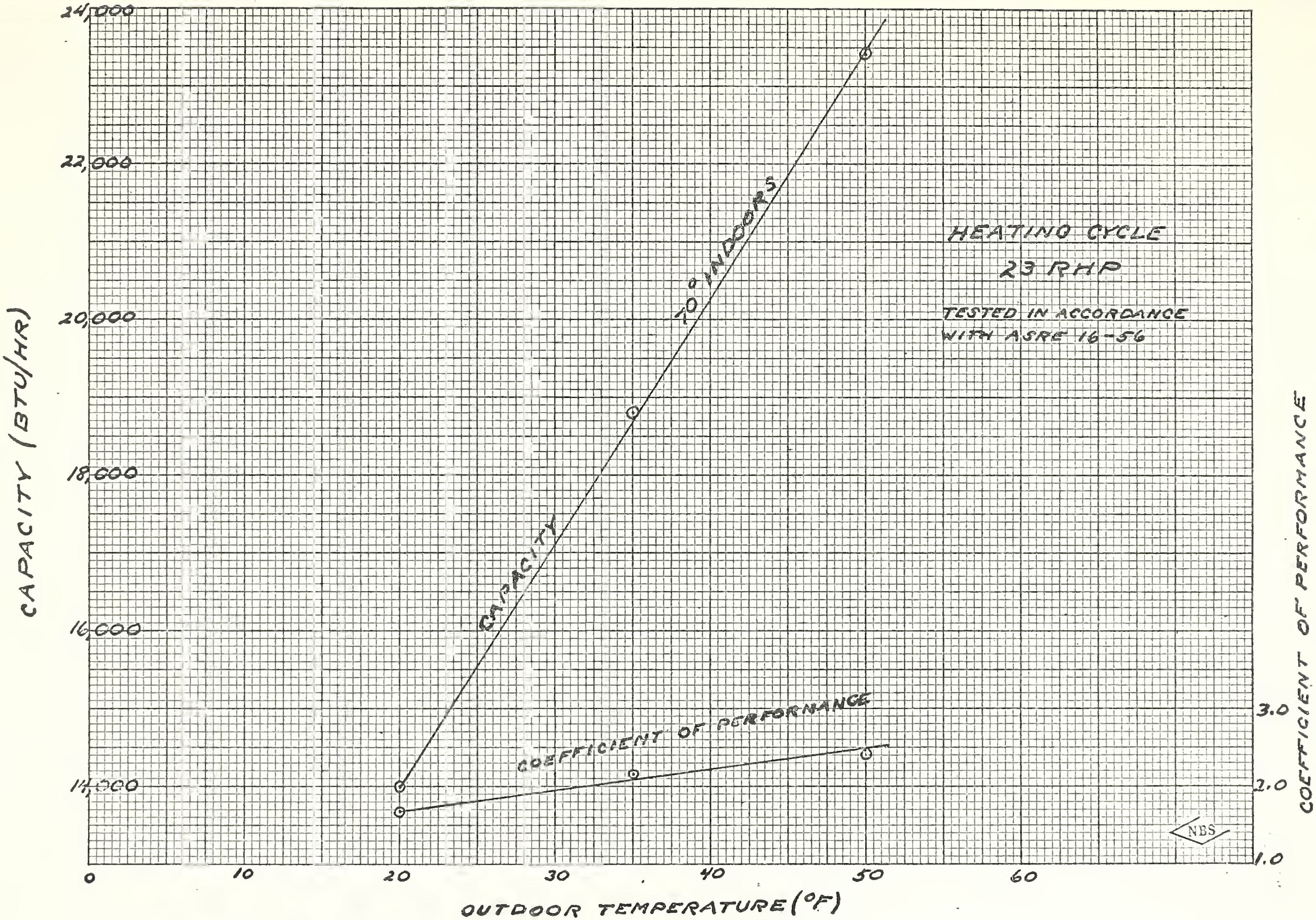

HEATING CYCLE
23 RHP
TESTED IN ACCORDANCE WITH ASRE 16-56
70° INDOORS
CAPACITY
COEFFICIENT OF PERFORMANCE
CAPACITY (BTU/HR)
24,000
22,000
20,000
18,000
16,000
14,000
COEFFICIENT OF PERFORMANCE
3.0
2.0
1.0
0
10
20
30
40
50
60
OUTDOOR TEMPERATURE (°F)
NBS

Figure 8

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

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

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major laboratories in Boulder, Colo., is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside front cover.

WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio Meteorology.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.


NBS