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NATIONAL BUREAU OF STANDARDS REPORT

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CAPACITY TESTS OF A MATHES HEAT PUMP
MODEL 38HAR-LEB-HP

by

Joseph C. Davis
Clinton W. Phillips
Paul R. Achenbach

Report to
Seymour Johnson Air Force Base
Goldsboro, North Carolina

NBS

U. S. DEPARTMENT OF COMMERCE

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Air Conditioning, Heating, and Refrigeration Section
Building Technology Division

to

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ABSTRACT

At the request of the Contracting Officer, Seymour Johnson Air Force Base, cooling and heating capacity tests were made of a Mathes air-to-air heat pump, Model 38HAR-LEB-HP, at the indoor and outdoor conditions stated in the contract specifications. The tests were made in accordance with American Society of Refrigerating Engineers Standard No. 16-56, entitled Methods of Rating and Testing Air Conditioners. Certain modifications of the unit were made during the test, and a second outdoor unit was tested after it was found that the original specimen did not have adequate cooling capacity. The Tecumseh motor-compressors in the two outdoor units bore the same model numbers, but had different full-load current ratings stamped on the nameplates. It was unknown whether the displacements of the two compressors were identical or not. The observed cooling capacity of the system with the second outdoor unit was 35,100 Btu/hr at the specified test conditions whereas the minimum required cooling capacity was 36,000 Btu/hr. The specimen did not perform satisfactorily on heating operation in that the discharge pressure of the compressor was so low that the interlocking pressure control on the indoor blower would not permit it to continue running, and the temperature rise produced by the indoor coil was inadequate. There were gas bubbles in the liquid refrigerant line between the condenser and capillary tube to the outdoor unit and the refrigerant liquid was flooding through the outdoor coil into the compressor. The indication was that the capillary tube was not restricting the refrigerant flow sufficiently. Upon arbitrarily restricting the

liquid refrigerant line a maximum heating capacity of about 22,000 Btu/hr was observed exclusive of the strip heaters. The adjustment that produced the maximum heating resulted in a slight flooding of liquid into the compressor. At rated voltage the strip heaters consumed 3.3 KW as compared to a requirement of 3.6 KW.

1. INTRODUCTION

In accordance with a request from Captain W. A. Schrontz, Contracting Officer, Seymour Johnson Air Force Base, United States Air Force, by letter dated August 22, 1957, tests were made to determine the cooling and heating capacity of a Mathes Heat Pump, Model 38HAR-LEB-HP. These tests represented the first phase of a series of tests on several models of heat pumps that will be used at this site.

Specifications supplied by Captain Schrontz, Section 27A-Heat Pumps (Alternate) of the contract specifications and drawings for homes under construction at Seymour Johnson Air Force Base require a total cooling capacity for this model of 36,000 Btu/hr and a total heating capacity of 42,786 Btu/hr. A breakdown of the capacity requirements for these two conditions follows:

COOLING CAPACITY (Btu/hr)

Sensible	Latent	Total
25,200	10,800	36,000

HEATING CAPACITY (Btu/hr)

Condenser Heat Transfer	From Auxiliary Strip Heaters	Total
35,500	12,286	42,786

The specifications also require that the minimum air circulation rate be 1,300 CFM against an external static resistance of 0.2 inches of water.

2. DESCRIPTION OF TEST SPECIMEN

The Model 38HAR-LEB-HP heat pump is known as a "split-type" unit in which one section is placed outdoors and the other inside the home at a suitable place for delivering conditioned air. The two sections involved will be designated hereinafter as the inside unit and the outdoor unit.

Some modifications of the heat pump were made by the manufacturer during the test to improve its performance. These modifications are described in a later section of the report. Tests of the heat pump system were made with two outdoor units. The second specimen was submitted when the tests showed the first had inadequate capacity. The results reported are those obtained using the second outdoor 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 test the solenoid was controlled by a manually operated switch to preclude shifting from cooling to heating or vice versa. Capillary tubes were used as the liquid refrigerant flow control device in both the indoor and outdoor units with check-valves to by-pass each when not needed. Following the new ASRE refrigerant designations, the refrigerant was R-22.

The indoor unit consisted essentially of a coil (used as evaporator during cooling), a blower for circulating conditioned air through the duct system of the home and a capillary tube-check valve assembly. The coil was a three-row coil, 30 in. wide and 20 in. high, with 13 fins per in. of tube length. A Torrington blower with a 13-in. diameter wheel was used and it was powered by a 1/3 HP single phase motor. Nameplate rating of the motor was 230 volts, 2.7 amperes, with a service factor of 1.35. The capillary tube had an ID of 0.117 inch. The housing of the indoor unit was 33 13/16 in. wide, 32 7/8 in. deep, and 27 7/8 in. high.

The outdoor unit consisted essentially of a coil (used as an evaporator during heating), a propeller fan, a hermetically-sealed Tecumseh No. PJE-300 motor-compressor, a capillary tube-check valve assembly, and a four-way valve. The fan blade assembly, 24 inches in diameter with a 40° pitch for each blade, was powered by a 1/3 HP, single phase motor. Nameplate rating of the motor was 208 - 230 volts, 2.7 amperes, with a service factor of 1.35. The capillary tube had an ID of 0.109 in. This unit with grilled panel removed is shown in Fig. 1.

Fig. 2 shows the opposite side of the outdoor unit facing the coil. Note the five-in-one thermocouple system and the thermostat used for controlling outdoor conditions during the test. The housing of the outdoor unit was 51 in. wide, 27 in. deep, and 31 in. high.

3. METHODS OF TESTING

The heat pump was tested under the conditions described in ASRE Testing and Rating Standard No. 16-56, as required by the specification. Fig. 3 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 excessive 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. By adjustment of a wooden slide-type damper at the outlet of the auxiliary blower, the static resistance imposed upon the indoor unit blower was adjusted to 0.20 inches of water. The auxiliary blower, return air heaters, and humidifier are shown in Fig. 4

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, involves 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 which cycle is under operation before comparing it with the result of the psychrometric method. Values obtained by the two methods must not differ by more than six percent in order for a test to be valid.

Mass flow of air in the psychrometric method was obtained by measuring humidity and temperature conditions of the air entering the 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.

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.

To assure substantially oil-free refrigerant at the flowmeter, an oil separator was provided in the hot gas line between the compressor and four-way valve to separate the oil. The oil was returned to the refrigerant at the inlet to the indoor coil during the cooling cycle test and to the inlet of the coil in the outdoor unit during the heating cycle 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)

Before performing the cooling test, the refrigerant charge in the system was adjusted in accordance with instructions from the Mathes Company, to produce approximately 3° of superheat at the outlet of the indoor coil under the "state" conditions specified above. Steady state conditions were maintained for more than an hour before the test. During the test, readings were taken every ten minutes for a full hour. Averages of the readings were used for determining capacity values.

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

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

4. TEST RESULTS

A. 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 unit. Since there was an 11 PSIG pressure drop across the oil separator during the test that would not normally be imposed on the compressor, an adjustment was made on the basis of a capacity vs. head pressure curve for the PJE-300 compressor furnished by the Tecumseh Products Company. This method of adjustment met with agreement from the manufacturer. The adjustment amounted to an increase of 550 Btu/hr for the observed operating conditions. The results

of the two measuring methods applied during the cooling test, and the total rated cooling capacity of the Model 38HAR-LEB-HP heat pump are summarized below.

Summary of Cooling Capacity Values (Btu/hr)

By psychrometric method	35,000
By flowmeter method	34,100
Average	34,550
Adjustment for 11 lb pressure drop across oil separator	550
Total rated cooling capacity	35,100

ASRE Standard 16-56 allows an increase of 0.8 percent for the psychrometric value of capacity for each inch of barometer reading below 29.92 in. Hg during the test. Barometric pressure in this case was 29.60 in. Hg. The correction amounted to 91 Btu/hr for this test and is included in the figures shown in the table.

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

Psychrometric Method

Temperatures (°F)

At inlet to enclosure around indoor unit	80.0 DB
At outlet of indoor unit in duct	61.2 DB
At inlet to outdoor unit	95.4 DB

Relative Humidities (%)

At inlet to enclosure around indoor unit	50.3
At outlet of indoor unit in duct	85.2

Static Pressure Across Nozzle (In. of Water)	1.45
Volume Air Flow at Nozzle (cfm)	1280
Mass Air Flow at Nozzle (lb dry air/hr)	5720
Barometric Pressure (In. of Hg)	29.60
Diameter of Nozzle (In.)	7.03
Nozzle Coefficient	.99
Static Resistance (In. of water)	.20

Flowmeter Method (Refrigerant Method)

Temperatures (°F)

In liquid line entering coil of indoor unit	106.5
In vapor line leaving coil of indoor unit	47.7

Pressures (PSIG)

In liquid line entering coil of indoor unit	257.
In vapor line leaving coil of indoor unit	45.7

Potter-Meter Count for 10 Minutes	319.5*

Other Pressures (PSIG)

Compressor discharge pressure	285
Pressure downstream of oil separator	274
Difference in pressure across oil separator	11.0

Motor Power Consumption (Watts)

Indoor blower	499
Outdoor fan	593
Compressor	3998

Motor Voltages (Volts)

Indoor blower	230.1
Outdoor fan	230.4
Compressor	230.3

Motor Current (Amperes)

Indoor blower	3.15
Outdoor fan	3.25
Compressor	18.50

*Refrigerant flow, gal/min $= \dfrac{\text{Meter count (10 min)} \times 100}{3365.5}$

B. Heating Test

No adjustment was made on the heat pump before performance of the heating test. To make certain that no refrigerant had leaked from the system during preliminary runs on the heating cycle, the "state" conditions for cooling were established prior to the heating test and it was found that refrigerant superheat at the outlet of the indoor unit was still present and less than 3°F. Thereafter, the "state" conditions for heating were established as quickly as the test apparatus permitted.

After the "state" conditions of 20° DB outdoors and 70° DB indoors had again been reached and maintained for over two hours, the heat pump was turned on for heating. Voltages and currents for the indoor blower, outdoor fan, and compressor were observed. These are shown below:

Voltages (Volts)

At indoor blower	229 to 231
At outdoor fan	
At compressor	

Currents (Amperes)

Indoor blower	3.00
Outdoor fan	Offscale, over 5
Compressor	11.00

Despite the large current drawn by the outdoor fan, the system was allowed to run. From observations made at the watthour meter, this fan alternately ran and stopped, apparently cycling on its motor-protective device, repeating the operation five to ten times. Finally, it ran continuously, drawing about 4 amperes.

The head pressures and those at the inlet and outlet of the indoor coil were low. Before ten minutes had elapsed , they decreased to such a point that the indoor blower cut off. The heat pump was turned off. After a short period it was turned

on again, but within a few minutes the indoor blower again cut off. It was impossible to obtain capacity data under these conditions because of the intermittent operation of the indoor blower. The Mathes heat pump was designed to cut off the indoor blower at low condenser pressure to preclude blowing cool air into the home after a change from the cooling to heating. The condenser inlet pressure was about 165 psig when the indoor blower stopped.

When it was obvious that the indoor blower would not operate continuously, the auxiliary blower was speeded up to obtain about the rated air flow through the indoor unit. Under these conditions a heating capacity of about 13,000 Btu/hr was observed, exclusive of the strip heaters. During this period, gas bubbles appeared in the refrigerant liquid line, and no superheat was observed at the compressor suction, the compressor discharge, or the condenser inlet.

The above data and the high and low side pressures observed suggested the need for a capillary tube with greater restriction. It was possible that the check valve in the outdoor unit leaked, but this could not be established from the observations taken.

A capillary tube with greater restriction was simulated by partially restricting a valve at a point in the liquid line downstream from the indoor unit. At first, the valve was adjusted so there was some superheat at the inlet to the compressor. Capacity values obtained under these conditions were as follows:

		Heating Capacity (Btu/hr)
Psychrometric method		20,400
Flowmeter method		20,000
	Average	20,200

The valve was then readjusted so there was no superheat at the inlet to the compressor. The capacity obtained under these conditions was as follows:

Heating Capacity (Btu/hr)	
Psychrometric method	22,000

In this case the value obtained by the flowmeter method, although not far different from 22,000 Btu/hr, is not reported since it was certain that the vapor at the inlet to the indoor coil was saturated and might have contained some liquid refrigerant.

Following the heating tests at an outdoor temperature of 20°F and an indoor temperature of 70°F, temperatures were raised to 75°F DB and 35°F DB outdoors to duplicate those used in a test made previously with another specimen by the manufacturer. Under these temperature conditions a heating capacity of about 20,000 Btu/hr was observed with no restriction in the liquid refrigerant line, and about 26,000 Btu/hr after careful adjustment of the valve in the liquid line.

Power Consumption of Strip Heaters

Readings of the energy dissipated by the strip heaters in the indoor unit was made every ten minutes for a period of 30 minutes with the following results:

Watthour meter value (Watts)	3312
Average terminal voltage (Volts)	230.2
Average current (Amperes)	14.22
Voltage times current (Watts)	3273

The contract specification requires a strip heater capacity of 3.6 KW whereas the observed power consumption averaged 3.3 KW at rated voltage.

5. SYSTEM MODIFICATIONS

Cooling tests were made using two outdoor units. With the combination of the first outdoor unit and the indoor unit used throughout, some 20 tests, including some informal determinations, were made. During the tests of the first outdoor unit, numerous adjustments were made by the manufacturer to

replace defective parts or to improve the performance of the system. The cooling capacity of the system with the first outdoor unit using ASRE Standard testing methods was 32,500 Btu/hr after all modifications were made.

The principal modifications made on the system during the tests made with both outdoor units are summarized below:

1. The capillary tube system of the indoor unit changed from multiple tube assembly to single tube system of 0.120 in. ID, nominal.

2. During the process of installing a thermocouple well in the outlet of the indoor coil, a partial restriction was found in the header common to the distribution lines from the coil. This was rectified by the Mathes representative.

3. The outdoor fan motor was changed from 1/4 to 1/3 HP on the first outdoor unit.

4. The capillary tube in the first outdoor unit was found to be made of two sections of tubing, joined, both having an ID of 0.100 in. It was replaced by a tube having ID of 0.110 in., the nominal ID finally used.

5. NBS data having shown that the indoor blower was not supplying an air flow of 1300 cfm against a static pressure of 0.20 in. WG, the Mathes Company replaced the 1/4 HP motor with a 1/3 HP motor.

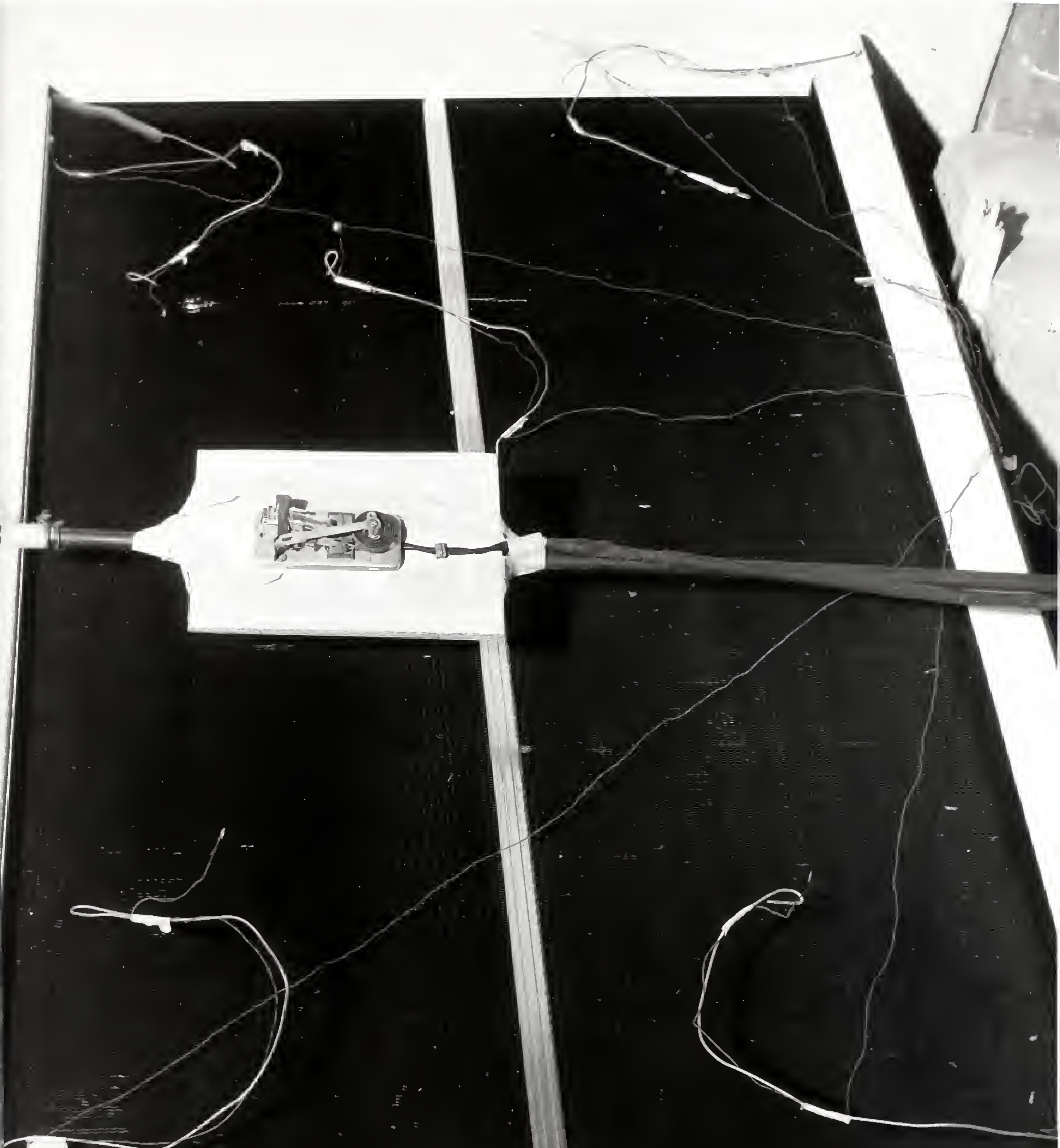
6. A two-foot piece of the hot gas line between the compressor and four-way valve was changed from 3/8 to 1/2 in. in the first outdoor unit.

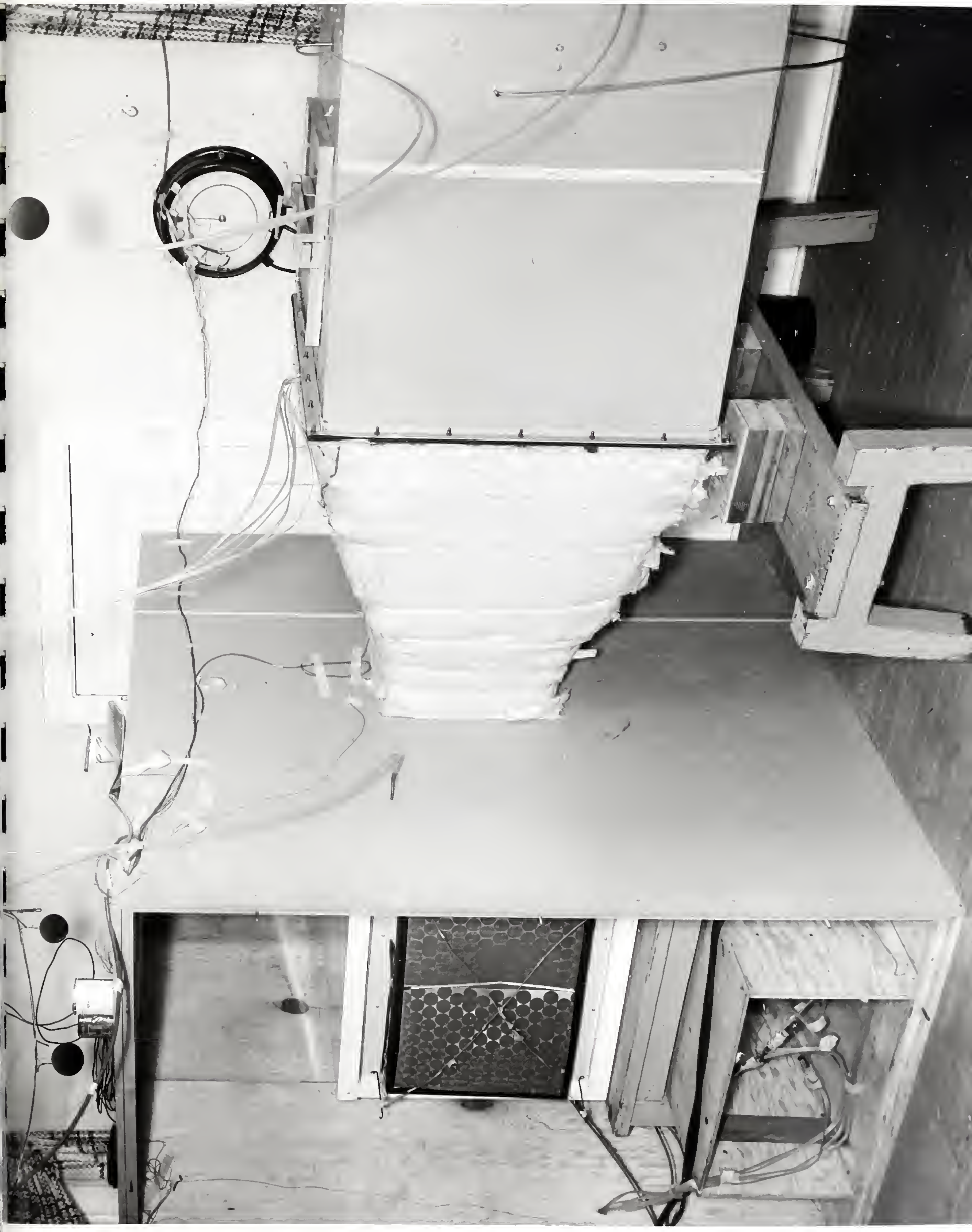
7. A new dryer was placed in the liquid line as one of several steps taken to reduce the pressure drop between the compressor and the indoor coil.

8. The outdoor fan motor pulley on the first outdoor unit was adjusted by the manufacturer to give greater fan speed prior to the final test of this unit. Stroboscopic readings showed a rotational speed of 890 rpm. This test resulted in a cooling capacity of 32,500 Btu/hr.

9. The manufacturer replaced the first outdoor unit with a complete, new unit because of the low cooling capacity of the first unit. The nameplate amperage of the second compressor was 21.0, whereas that on the first compressor was 19.5 The model numbers of the two Tecumseh motor-compressor units were the same.

10. After installing the new outdoor unit, a refrigerant leak was found in the four-way valve. The four-way valve was replaced and the capillary tube-check valve assembly, and liquid line dryer were replaced at the same time.



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