9570

# NATIONAL BUREAU OF STANDARDS REPORT

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## CAPACITY TESTS OF FOUR REMOTE FORCED CIRCULATION REFRIGERATION EVAPORATORS

Manufactured by

Kramer Trenton Company
Trenton, New Jersey

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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# NATIONAL BUREAU OF STANDARDS REPORT

**NBS PROJECT**
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**NBS REPORT**
9570

## CAPACITY TESTS OF FOUR REMOTE FORCED CIRCULATION REFRIGERATION EVAPORATORS

Manufactured by

Kramer Trenton Company
Trenton, New Jersey

by


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National Bureau of Standards




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# CAPACITY TESTS OF FOUR REMOTE
# FORCED CIRCULATION REFRIGERATION EVAPORATORS

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## 1.0 Introduction

This report presents results of capacity tests of four remote, forced circulation refrigeration evaporators, of the same class and of four different sizes listed in QMR&E IP/DES S-9-8 "Interim Purchase Description, Refrigeration Evaporators, Forced Circulation, for Use with Dichlorodifluoromethane (F-12)", dated January 31, 1958. All four were manufactured by the Kramer Trenton Company, Trenton, New Jersey.

The four evaporators were:

1. Class A Size 1
   Copper Tubes, Aluminum Fins
   NBS Specimen No. 188-59

2. Class A Size 2
   Copper Tubes, Aluminum Fins
   NBS Specimen No. 189-59

3. Class A Size 3
   Copper Tubes, Aluminum Fins
   NBS Specimen No. 190-59

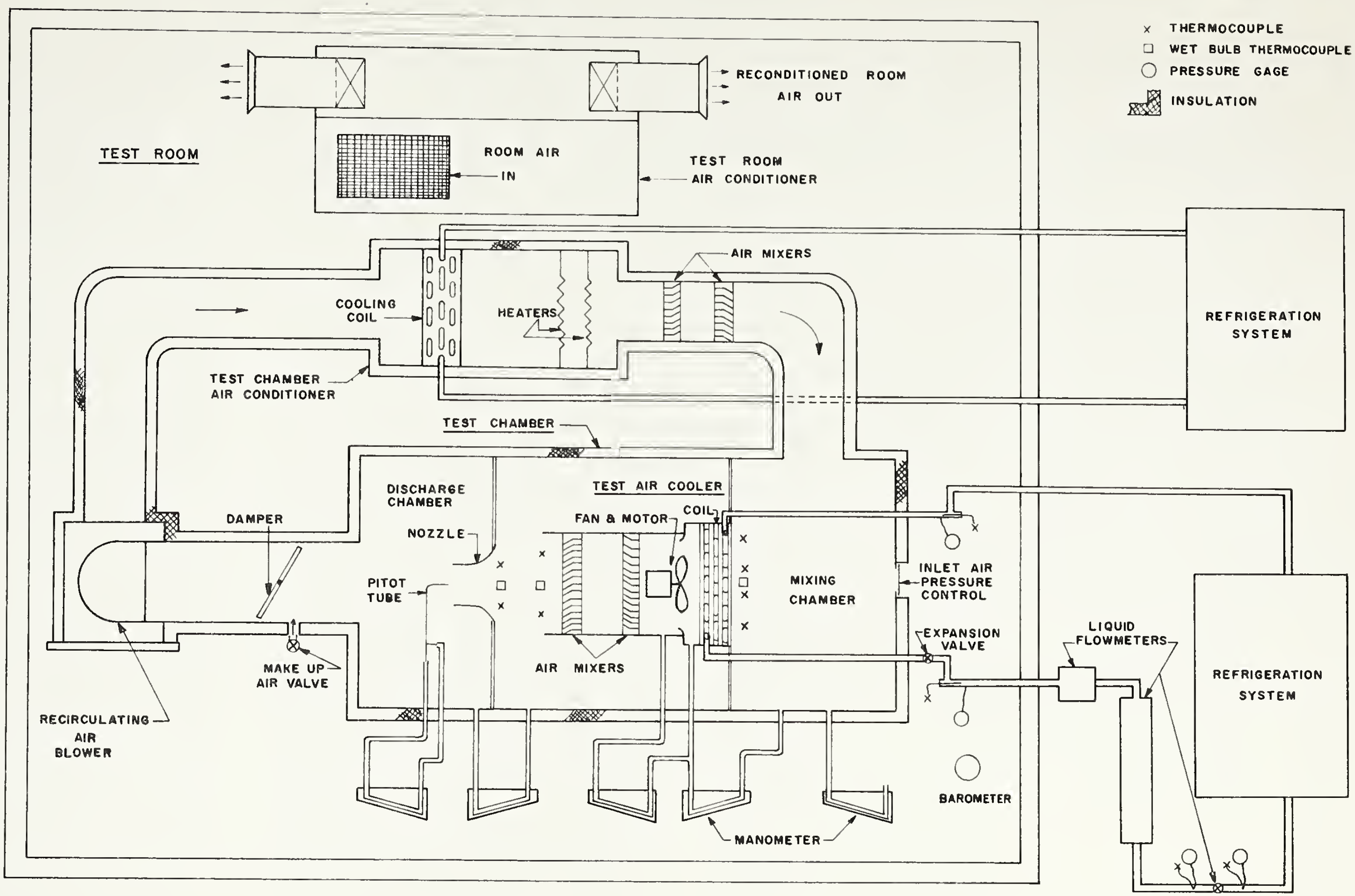
4. Class A Size 4
   Copper Tubes, Aluminum Fins
   NBS Specimen No. 191-59

All specimens were procured under contract No. DA 19-129-QM-1235.

## 1.1 Background

This report is one of three presenting test data on the performance of forced circulation refrigeration evaporators. Each of the other two reports in this series presents test data on the performance of four evaporators of the same military sizes as this report, but constructed by different manufacturers.

The test apparatus used for this series of tests was constructed by modifying an apparatus previously developed at NBS for U.S. Army Natick Laboratories for the testing of remote air-cooled refrigeration condensers in accordance with ASRE (American Society of Refrigerating Engineers) Standard PS-2.4. The apparatus was modified and developed in two stages to conform to ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers) Standard 25-56,"Method of Rating Air Coolers for Refrigeration", between March and October 1962 and between October and December 1964. Tests were run on the twelve coils, four of which are reported here, between December 1964 and August 1966. To accommodate other investigations of higher priority to QMR&E, this project was deferred for approximately one year between the two stages. Subsequent to implementation of the project, a revision of ASHRAE 25-56 has been proposed. The primary change between the original standard and its revision is the elimination of capacity determination using the psychrometric (air side) measurement and substitution of the measurement of the refrigerant flow with two independent flow meters. The apparatus as used is shown schematically in figure 1. Provision was retained for measurement of capacity by air side measurement; however, it was found necessary




PSYCHROMETRIC CALORIMETER FOR AIR COOLER TESTS

Figure 1

to provide air mixers both at the inlet and outlet of the test coil for stable, repeatable air temperature measurements.

ASHRAE Standard 25 was prepared for the testing of entire air cooler units including fans, expansion valves, heat exchangers, casings, etc. For these tests, ASHRAE 25-56 was used as a guide to determine the conformance of the test coils with the requirements of IP/DES S-9-8 which deals primarily with the evaporators. A principal objective of the investigation was to determine the interchangeability (from the standpoint of capacity) of the various manufacturers' evaporators.

The expansion valve supplied with each coil was removed before testing and replaced with a specially selected valve which would permit comparison of the performance of the evaporators without consideration of the performance of different thermostatic expansion valves.

Although IP/DES S-9-8 requires draw-through fans all evaporator coils were supplied with blow-through fans. New blades of the draw-through type identical to the original blades except for air flow direction were procured from the Torrington Company, manufacturer of all the original blades. After the correct fan blades were substituted the fan and motor units were then mounted on the downstream side of their coils so that the air flow over the coil surfaces was not reversed in direction from the manufacturer's original design.

QMR&E Interim Purchase Description, "Refrigeration Evaporators, Forced Circulation, for Use with Dichlorodifluoromethane (F-12)" dated January 31, 1958, set forth the following capacity requirements. At a refrigerant saturation temperature of -10 °F, corresponding to the pressure at the suction outlet of the evaporator, and an inlet air dry bulb temperature

of 0 °F, the minimum capacities for the four sizes of evaporators are:

| | |
|---|---|
| Size I | 4500 Btu/hr |
| Size II | 6500 Btu/hr |
| Size III | 10,000 Btu/hr |
| Size IV | 13,000 Btu/hr |

Capacities have been determined at these conditions and also at the following conditions as suggested in ASHRAE 25-56:

| Dry Bulb Temp. °F | Wet Bulb Temp. °F | Nominal RH, % | Refrigerant Temp. °F |
|---|---|---|---|
| 50 | 45 | 70 | 35 |
| 30 | - | - | 18 |
| -10 | - | - | -22 |

ASHRAE 25-56 suggests a fourth rating condition at -30 °F dry bulb temperature and -40 °F refrigerant temperature. The refrigeration capacity of the test apparatus was not adequate to pull the test chamber temperature down to the level this test requires.

## 2.0 Test Apparatus and Procedures

Tests were run in general conformance with requirements of ASHRAE Standard 25-56, "Method of Testing for Rating Air Coolers for Refrigeration."

Because ASHRAE Standard 25-56 is intended primarily for testing of entire air coolers whereas these tests were primarily concerned with comparative evaporator performance, and for other reasons, certain deviations were made from the standard in conducting tests. A few points of non-conformance are discussed below.

1) The requirement in Section 4.1.2 of ±0.1 deg F accuracy of absolute temperature measurements is unrealistic. For normal laboratory quality measuring systems ±0.2 deg F is more realistic, and test results reported were based on measurements approaching this degree of accuracy.

2) The thermostatic expansion valves which were supplied with the coils were replaced with specially selected thermostatic expansion valves with a changeable maximum coil pressure setting. Two of these valves, of 1 and 1 1/2 ton nominal sizes, were used to cover the range of coil sizes tested. The same valve was used for all coils of appropriate size.

ASHRAE Standard 25-56 describes a test procedure for air cooler units incorporating fans and expansion valves as well as evaporators. It was desired in the series of tests to compare evaporators (principally) with the variability of valve performance removed from the test. It was also found that some normal expansion valves were not sufficiently stable in performance to enable easy maintenance of steady-state test conditions.

3) In the ASHRAE Standard 25-56 test method, the air flow rate over the coil is established by the fan and motor as supplied with the assembled air cooler. Military Interim Purchase Description S-9-8 specifies minimum

air flow rates for the different size coils for the 0 $^{o}$F entering air -10 $^{o}$F refrigerant test as follows:

| Mil. Std. Evap. Size | Minimum Air Quantity, CFM |
|---|---|
| I | 750 |
| II | 1100 |
| III | 1500 |
| IV | 2200 |

As described earlier the units were fitted and tested with draw-through fans identical otherwise to the blow-through fan supplied and selected by the evaporator manufacturer to provide the required minimum air flow capacity. With the fan running, the minimum required air flow rate was obtained for each test by adjusting the dampers on the auxiliary blower in the psychrometric calorimeter to produce a suitable pressure downstream from the fan in the test unit.

4) The superheat of the refrigerant was controlled in the range from 3 deg F to 8 deg F. A thermocouple was soldered to the underside of the suction line to detect liquid refrigerant flowing along the bottom of the coil outlet tube.

The two independent measuring systems are shown schematically in figure 1 and can be described briefly.

1) Air-side or Psychrometric. The test evaporator was mounted in an insulated, closed-loop, air duct apparatus with temperature and humidity controlled at the specified evaporator entering air conditions.

Figure 2 shows a test coil during installation in the psychrometric calorimeter. The discharge test duct and air mixer can be seen in the foreground. The apparatus was enclosed in a test room with controlled ambient conditions. The air was drawn through the evaporator by its fan mounted directly on the unit and by a large auxiliary blower with an

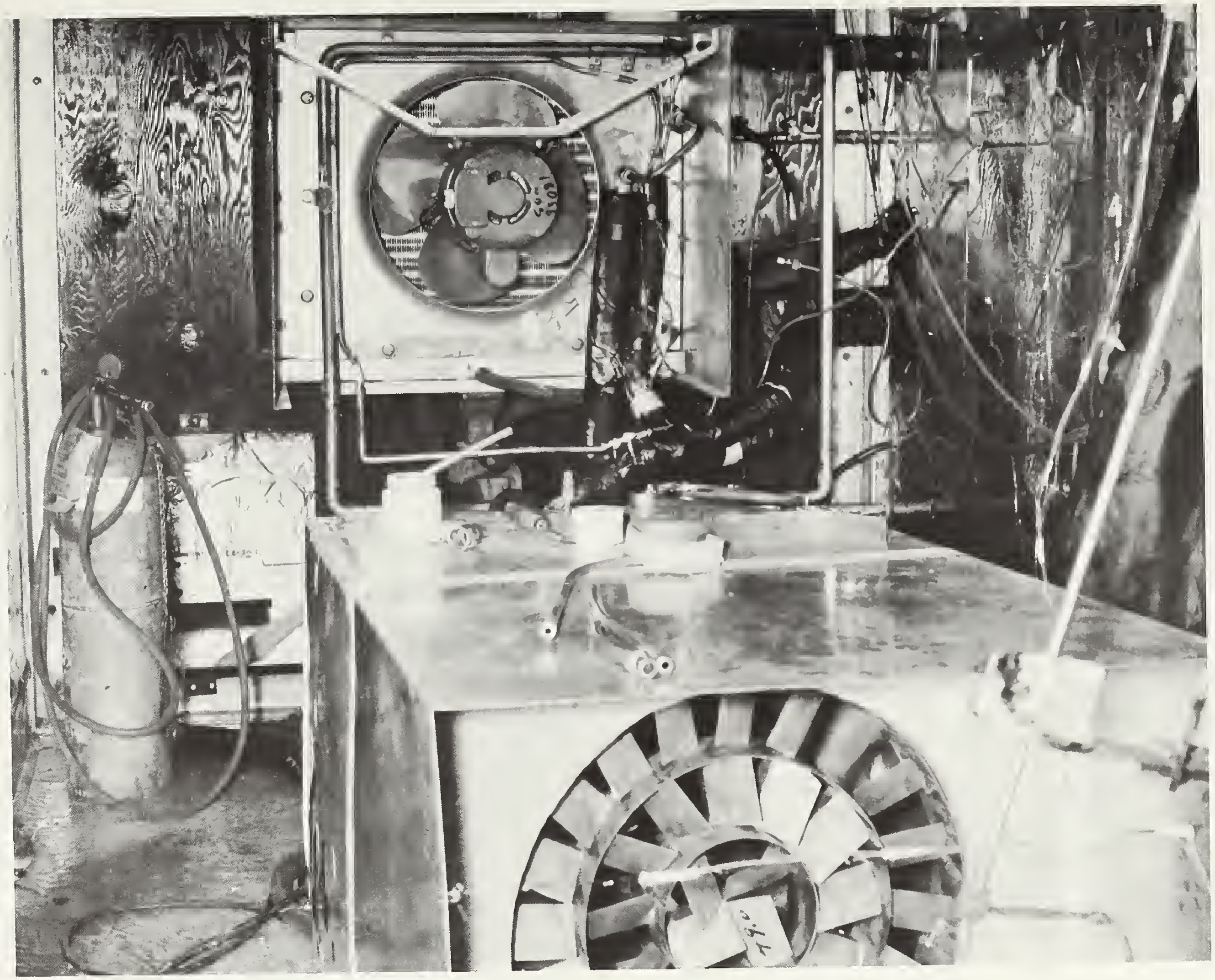


Figure 2. Test coil during installation in psychrometric calorimeter. Note discharge test duct and air mixer in foreground.

adjustable damper which was used to control the air flow rate and system pressure at the specified values. Evaporator heat absorption capacity was determined by measuring air quantity and enthalpy change and correcting for fan motor energy input. Air quantity was measured with an ASME long radius nozzle.

2) Liquid refrigerant flowmeter. The subcooled condensed liquid refrigerant was metered by means of a totalizing (integrating) piston-type positive displacement flowmeter, and heat absorption capacities were determined from refrigerant mass flow and enthalpy change. A variable head meter was read and used as a flow check during steady-state periods. A cylindrical tank, built and instrumented by the NBS Fluid Meters Section, which showed the quantity of refrigerant contained by the position of a piston which formed one of its ends was installed in the system and used as a calibration device.

The required conditions of inlet air temperature were determined by a multiple grid arrangement of calibrated thermocouples and a precision potentiometer. Inlet humidity (for the 50 °F test) was measured with calibrated thermocouple psychrometers. The absolute suction pressure, from which the required refrigerant temperature was determined, was measured with a calibrated, precision grade, aneroid absolute pressure gage. Other temperatures were read using calibrated thermocouples and an electronic potentiometer. Air pressures in the fan circuit were measured with calibrated slope gages referenced to a calibrated aneroid barometer.

## 3.0 Test Specimens

3.1 Four Class A Kramer Trenton forced circulation refrigeration evaporators were tested. As furnished, each was mounted in a metal casing with a blow-through fan, fan motor, and flat fan orifice. For the tests an otherwise identical draw-through fan was used, and the coil was reversed to provide the original direction of air flow. All units were supplied with thermostatic expansion valves and none had integral heat exchangers. Table 1 gives the related physical data for the four units.

The aluminum fin and copper tube assembly was similar for all units (except for numbers of tubes and rows) and is shown in figures 3 and 4. The 5/32 in. slots shown in the plate fin in figure 4 permitted the flattened integral return bend to be inserted through the fins during coil assembly. The flattened sections were expanded hydraulically, after assembly, in the same operation which expanded the tube into the fin collars. All coils except the Size IV has a crisscross arrangement for the tube rows at mid-height of the coil which minimized the significance of air flow direction through the coil. Final expanded diameter of the tubes was approximately 0.39 in. All coils had tubes arranged in-line in the direction of air flow.

TABLE 1. PHYSICAL CHARACTERISTICS

KRAMER TRENTON AIR COOLERS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| QMR & E Size | | I | | II | | III | | IV | |
| QMR & E Class | | A | | A | | A | | A | |
| NBS Specimen No. | | 188-59 | | 189-59 | | 190-59 | | 191-59 | |
| COIL TUBE CHARACTERISTICS | | | | | | | | | |
| MATERIAL | | Copper | | Copper | | Copper | | Copper | |
| Number of Rows Deep | | 4 | | 5 | | 6 | | 4 | |
| Number of Tubes High | | 20 | | 20 | | 18 | | 40 | |
| Number of Circuits in Parallel | | 4 | | 5 | | 6 | | 10 | |
| Number of Tubes per Circuit | | 20 | | 20 | | 18 | | 16 | |
| Tube Diameter, O.D., in. | | 0.386 | | 0.386 | | 0.386 | | 0.386 | |
| Tube Diameter, I.D., in. | | .339 | | .339 | | .339 | | .339 | |
| Tube Wall Thickness, in. | | .024 | | .024 | | .024 | | .024 | |
| Tube Return Bend Diameter, O.D., in. | | 3/8 | | 3/8 | | 3/8 | | 3/8 | |
| Vapor Outlet Diameter, O.D., in. | | 7/8 | | 7/8 | | 1 1/8 | | 1 1/8 | |
| Liquid Inlet Diameter, O.D., in. | | 1/2 | | 5/8 | | 5/8 | | 5/8 | |
| Vertical Spacing of Tubes, in. | S | 1 | | 1 | | 1 | | 1 | |
| Horizontal Spacing of Rows, in. | | 1 | | 1 | | 1 | | 1 | |
| Integral Heat Exchanger | | None | | None | | None | | None | |
| COIL FIN CHARACTERISTICS | | | | | | | | | |
| MATERIAL | | Aluminum | | Aluminum | | Aluminum | | Aluminum | |
| Type of Fin | | Plate | Slotted & embossed | Plate | Slotted & embossed | Plate | Slotted & embossed | Plate | Slotted & embossed |
| Fin Spacing, Fins per inch | | 6 | 136 Fins | 6 | 135 Fins | 6 | 183 Fins | 6 | 179 Fins (top), |
| Fin Thickness, in. | | 0.0135 | | 0.0135 | | 0.0135 | | 0.0135 | 178 (bottom) |
| COIL DIMENSIONS | | | | | | | | | |
| Finned Height, in. | K | 20 | | 20 | | 18 | | 39 7/8 | |
| Finned Width, in. | F | 23 | | 23 | | 31 1/4 | | 30 1/4 | |
| Finned Depth, in. | V | 4 | | 5 | | 6 1/8 | | 4 | |
| Coil Height, in. | H | 19 | | 19 | | 17 | | 39 | |
| Coil Width, in. | W | 24 7/8 | | 25 | | 33 | | 31 15/16 | |
| Coil Depth, in. | D | 3 | | 4 | | 5 | | 3 | |
| Face Area, Sq. Ft. | | 3.09 | (23 1/4" x 19 1/8") | 3.03 | (23 1/4" x 18 3/4") | 3.70 | (31 1/4" x 17 1/16") | 8.23 | (30 3/8" x 39") |
| SURFACE AREAS | | | | | | | | | |
| Primary Area, Sq. Ft. | | 1.27 | | 1.59 | | 2.33 | | 3.34 | |
| Secondary Area, Sq. Ft. | | 10.28 | | 12.75 | | 19.16 | | 26.90 | |
| Total Area, Sq. Ft. | | 11.55 | | 14.34 | | 21.49 | | 30.24 | |
| Width, in. | A | 27 1/4 | | 26 7/8 | | 35 1/4 | | 36 | |
| Width, Shroud, in. | B | 23 1/4 | | 23 1/4 | | 31 1/4 | | 30 3/8 | |
| Height, in. | C | 20 1/8 | | 20 1/8 | | 20 1/8 | | 43 5/8 | |
| Depth, in. | E | 15 | | 9 1/4 | (Not including fan housing) | 15 | | 15 | |
| Fan Orifice Diameter, in. | X | 14 13/16 | | ------ | (Nominal for 16 in. fan) | 18 3/4 | | 22 3/4 | |
| Fan Orifice Radius, in. | R | None | | None | | None | | None | |

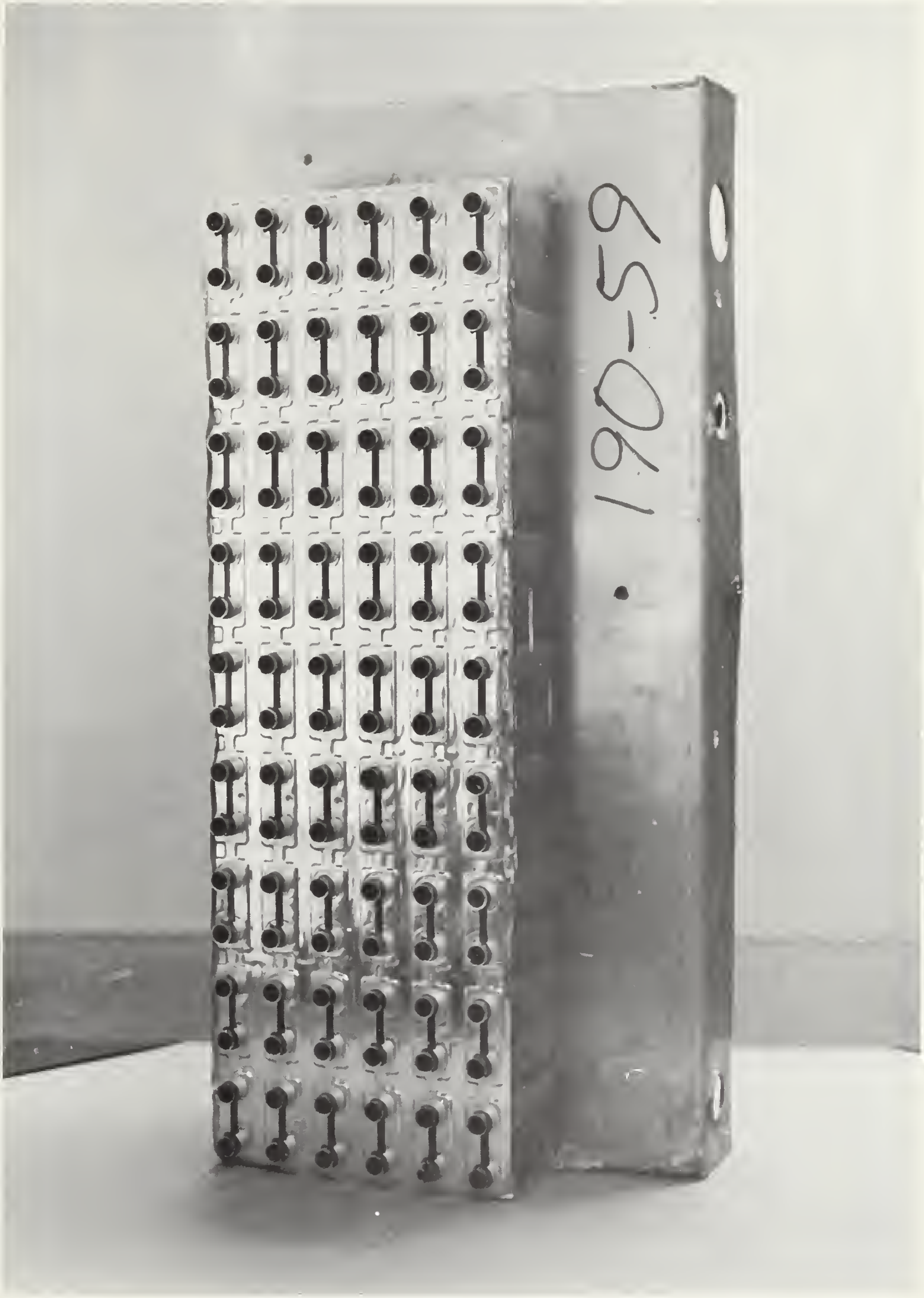



Figure 3. Section of typical Kramer Trenton coil showing fin and tube assembly.

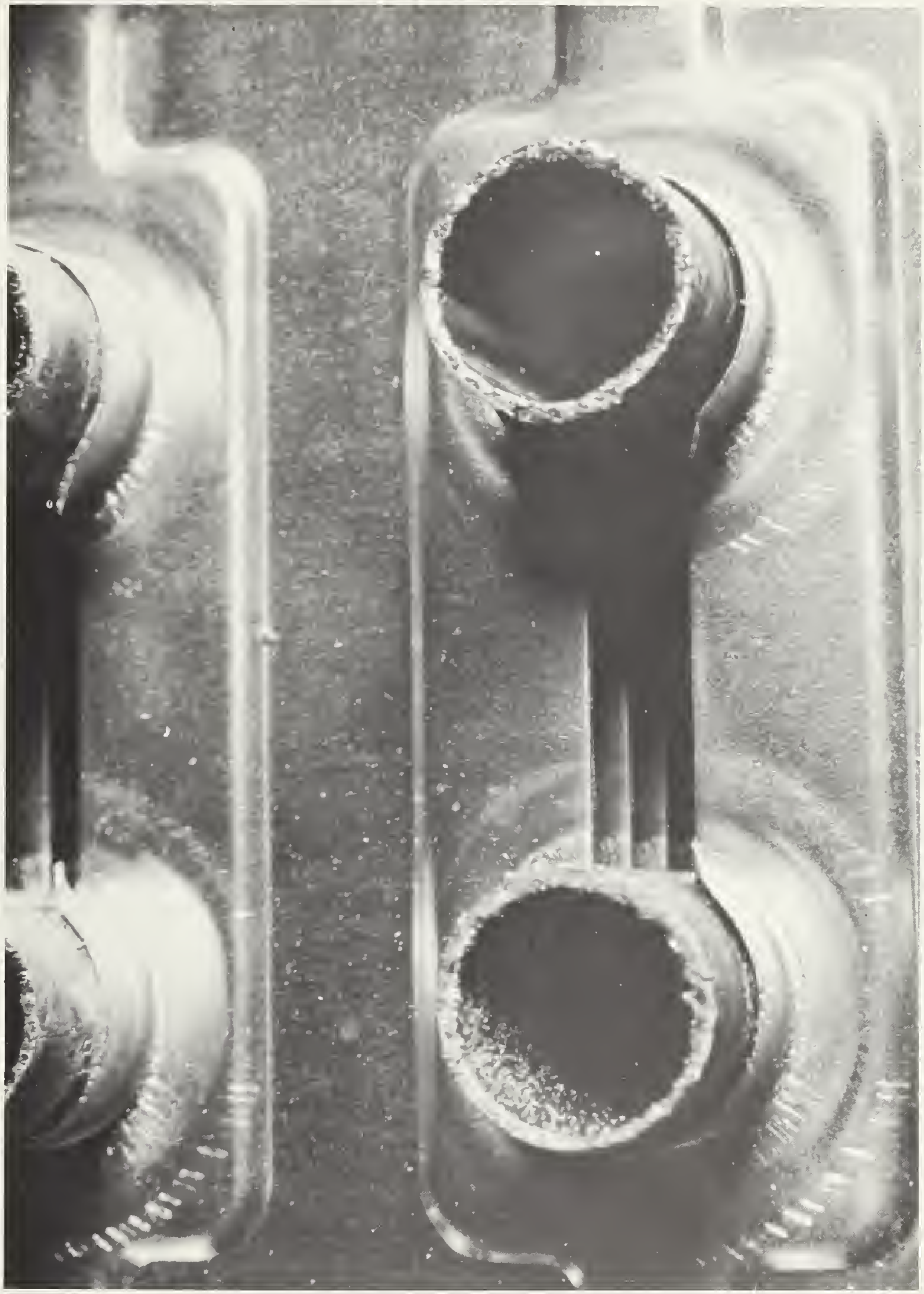


Figure 4. Typical Kramer Trenton fin collar and tube assembly.

3.1.1 NBS Specimen No. 188-59 was a Size I Class A evaporator with copper tubes and aluminum fins. Figures 5 and 6 are, respectively, right and left views of the unit as mounted for test. Note the flat shape of the fan orifice typical to the four Kramer Trenton Units (fan and motor not shown). Figure 7 is a schematic drawing of the general configuration of this unit and the related physical data are given in table 1. The criss-cross arrangement of the tube rows, shown in figure 5, minimizes the significance of air flow direction through the coil. Note that none of the Kramer Trenton units was equipped with an integral heat exchanger. The hot gas defrosting connection at the refrigerant distributor can be seen in figure 5.

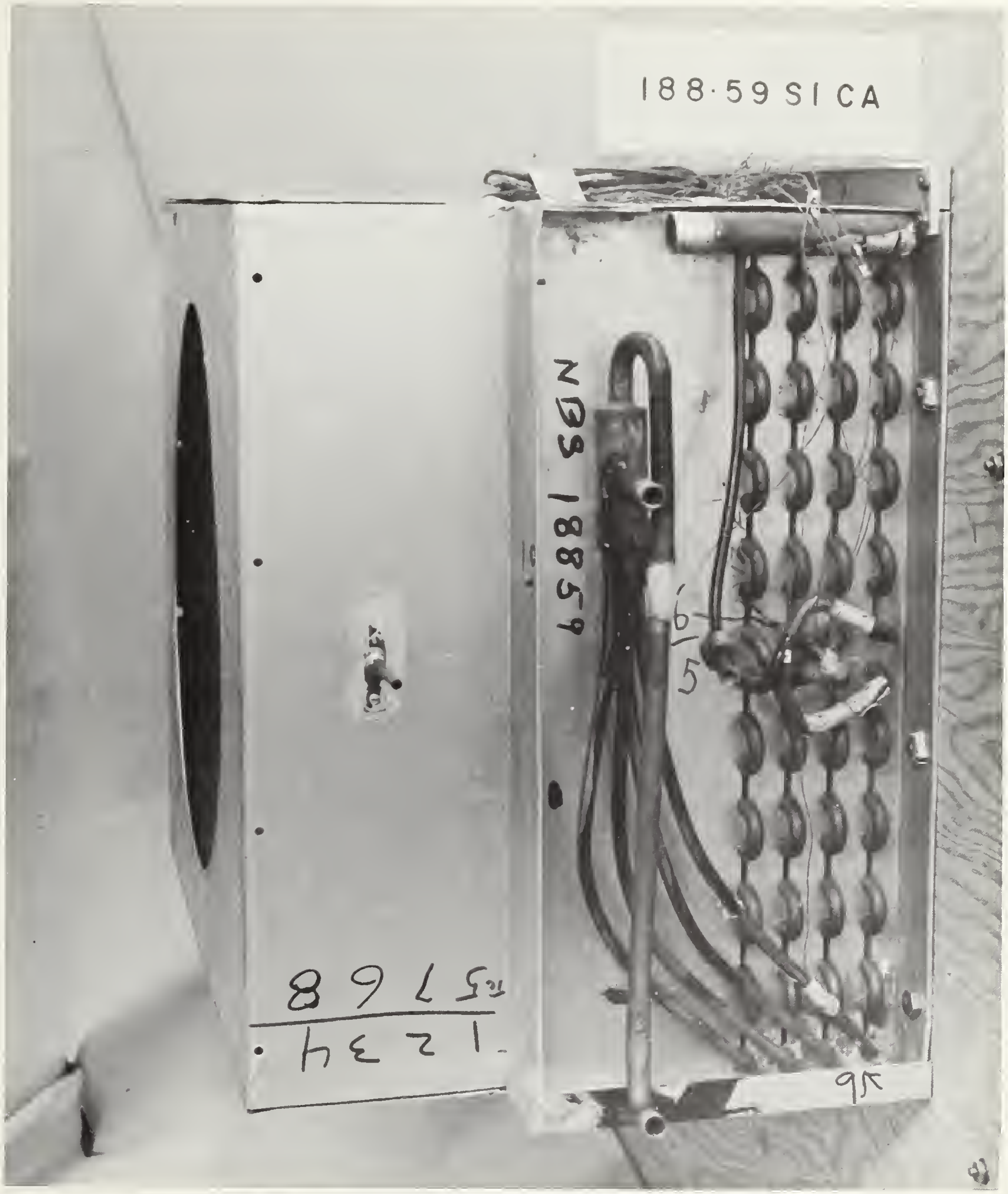



Figure 5. Right end of Size I evaporator (NBS No. 188-59) as mounted for test.

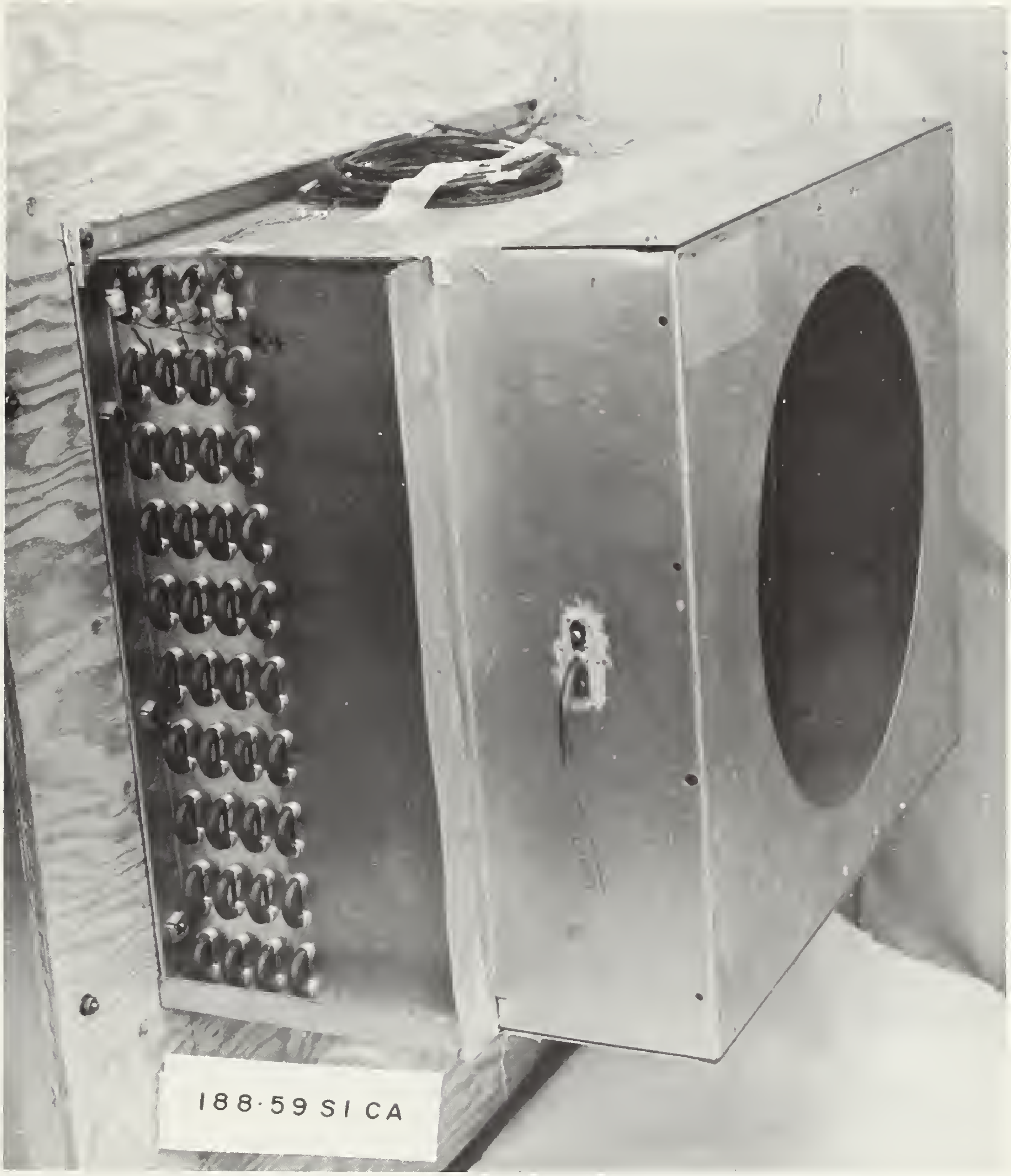



Figure 6. Left end of Size I evaporator (NBS No. 188-59) as mounted for test.

EVAPORATOR SPECIMEN

KRAMER TRENTON NBS NO. 188-59 SIZE I CLASS A

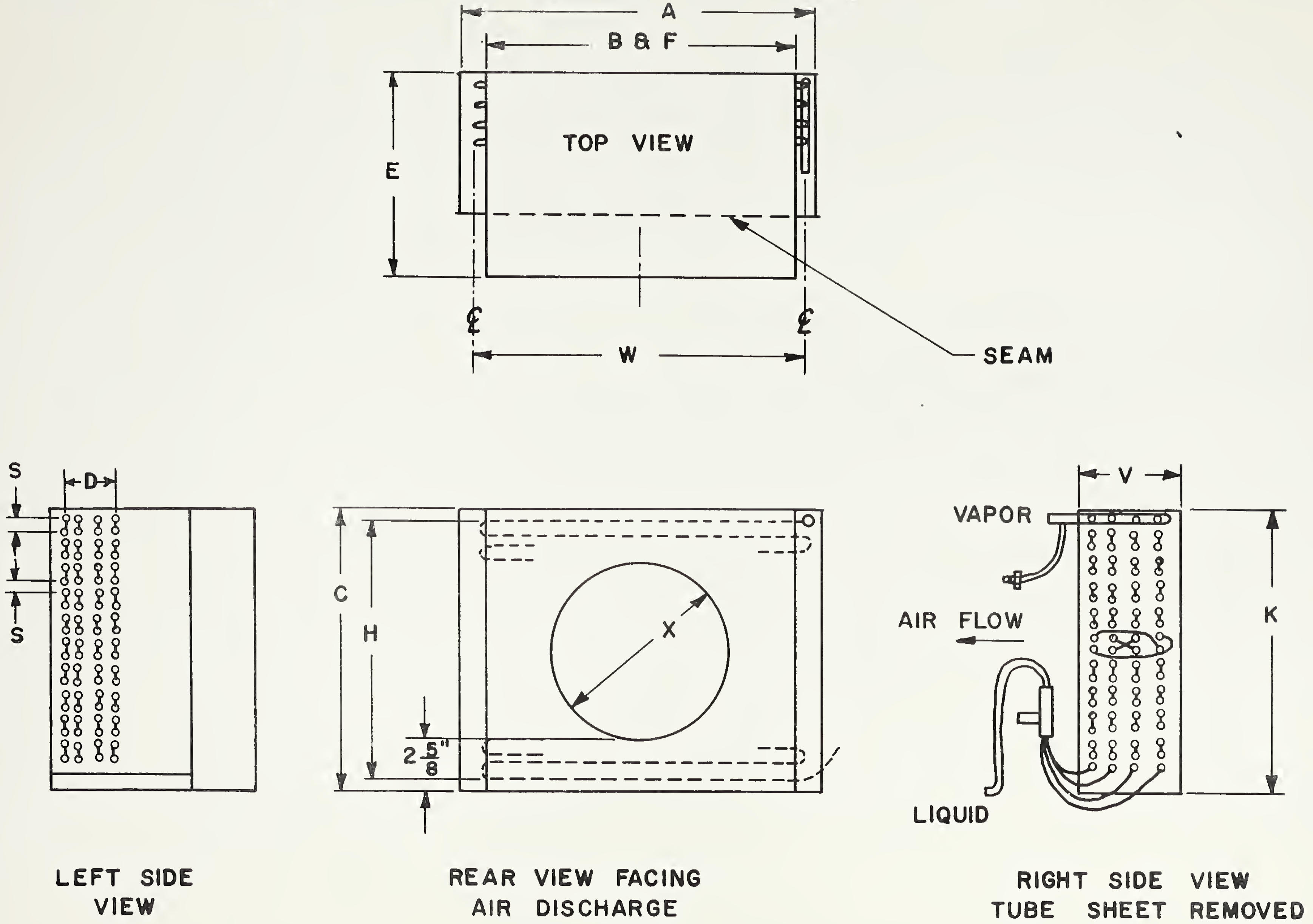



Figure 7

3.1.2 NBS Specimen No. 189-59 was a Size II Class A evaporator and figures 8 and 9 are, respectively, right and left views with the fan orifice, fan and motor removed. The bottom-feed distributor tube arrangement typical to all four Kramer Trenton coils is clearly shown in figure 8. Thermocouples attached to each coil row outlet to determine refrigerant temperatures in the test can be seen in figure 8. Figure 10 is a schematic drawing of this unit and the related physical data are given in table 1.

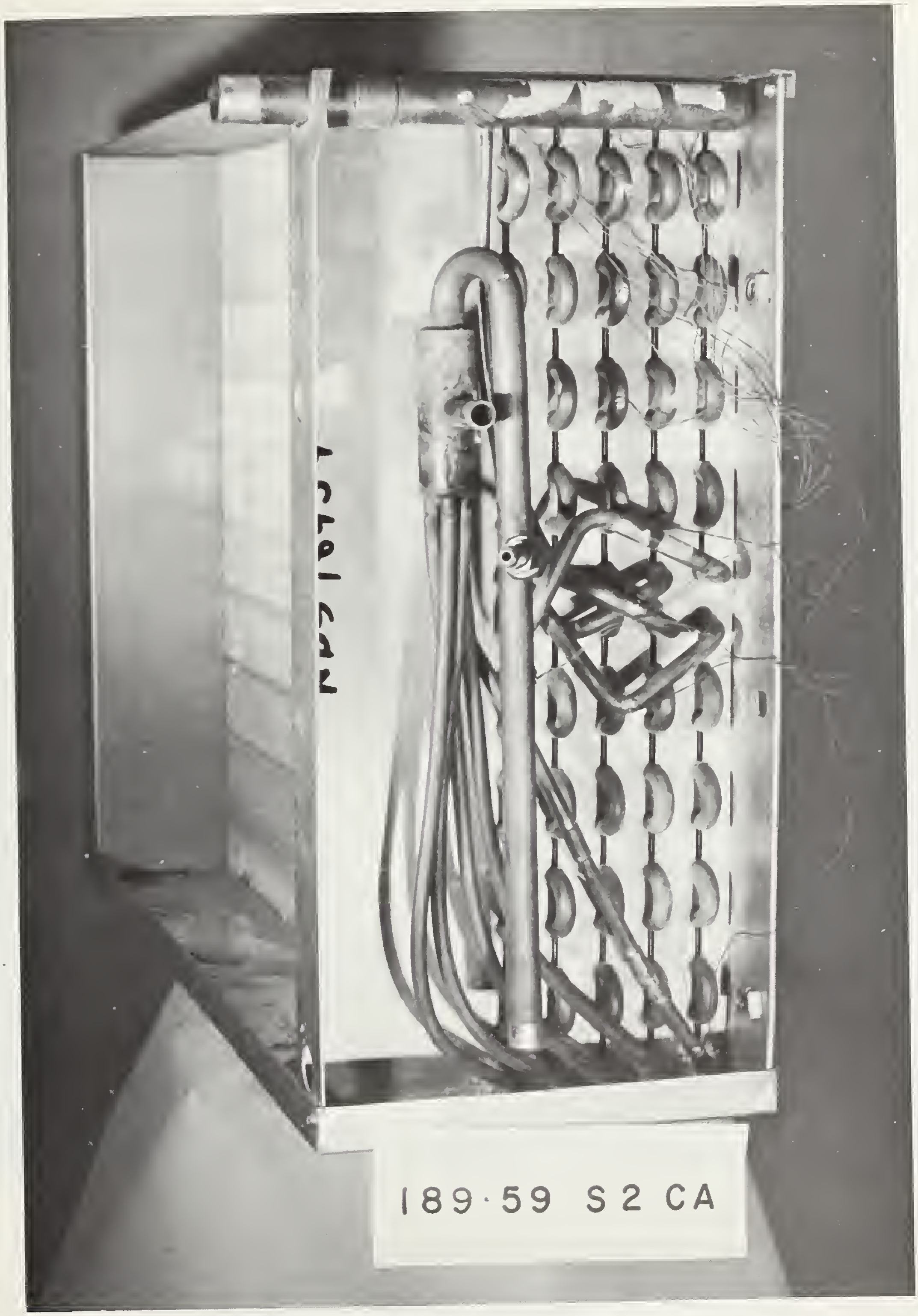



Figure 8. Right end of Size II evaporator (NBS No. 189-59).


Figure 9. Left end and air discharge side of Size II evaporator (NBS No. 189-59).

EVAPORATOR SPECIMEN

KRAMER TRENTON NBS NO. 189-59 SIZE II CLASS A

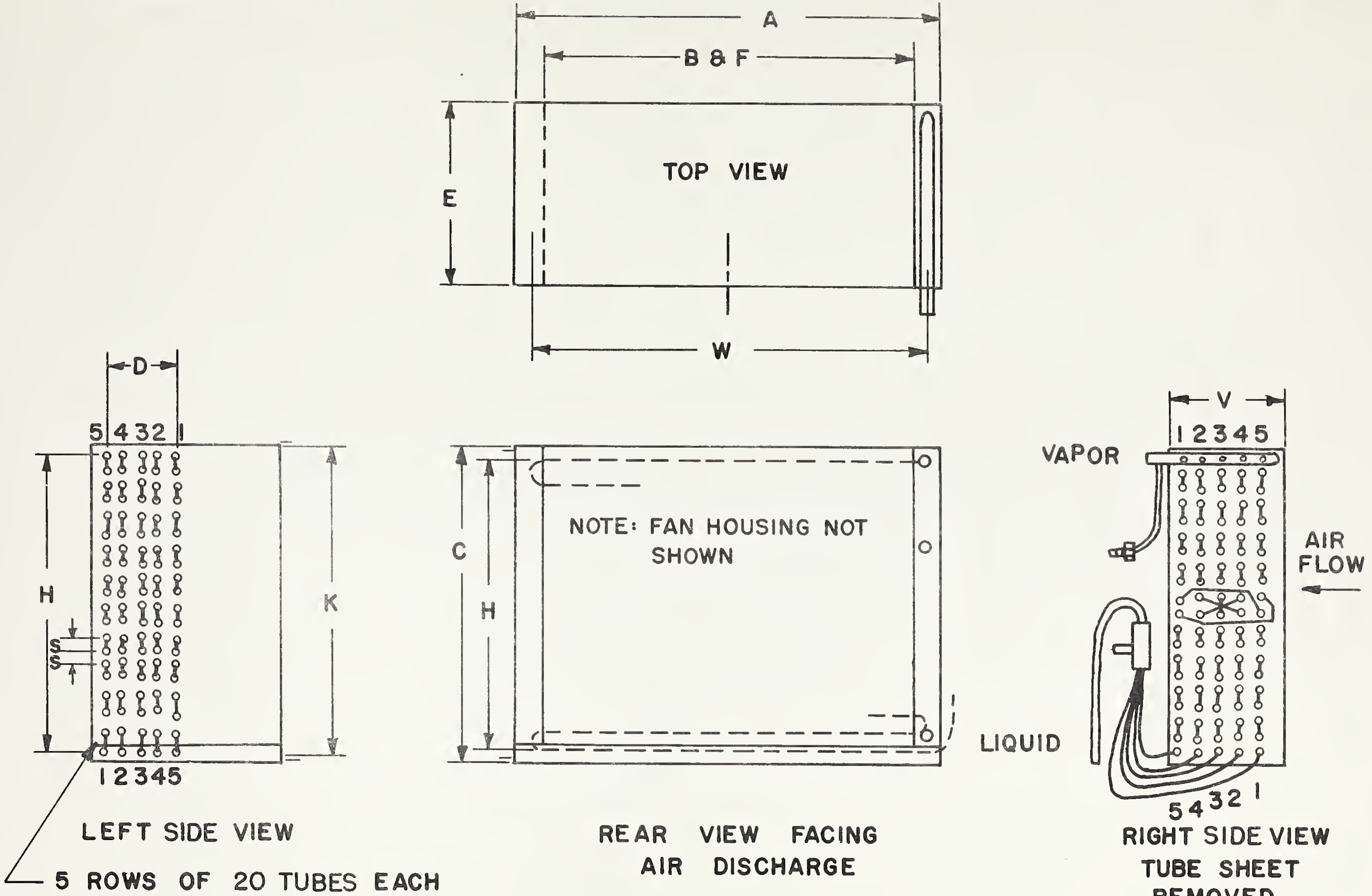



Figure 10

3.1.3 NBS Specimen No. 190-59 was a Size III Class A evaporator. Figures 11 and 12 are, respectively, front (air discharge side) and rear views of this unit as supplied. Note in figure 12 the blow-through fan. Figures 13 and 14 show, respectively, right and left ends of this unit as mounted for test (fan and motor not shown). Figure 15 is a schematic drawing of this unit and related physical data are given in table 1.

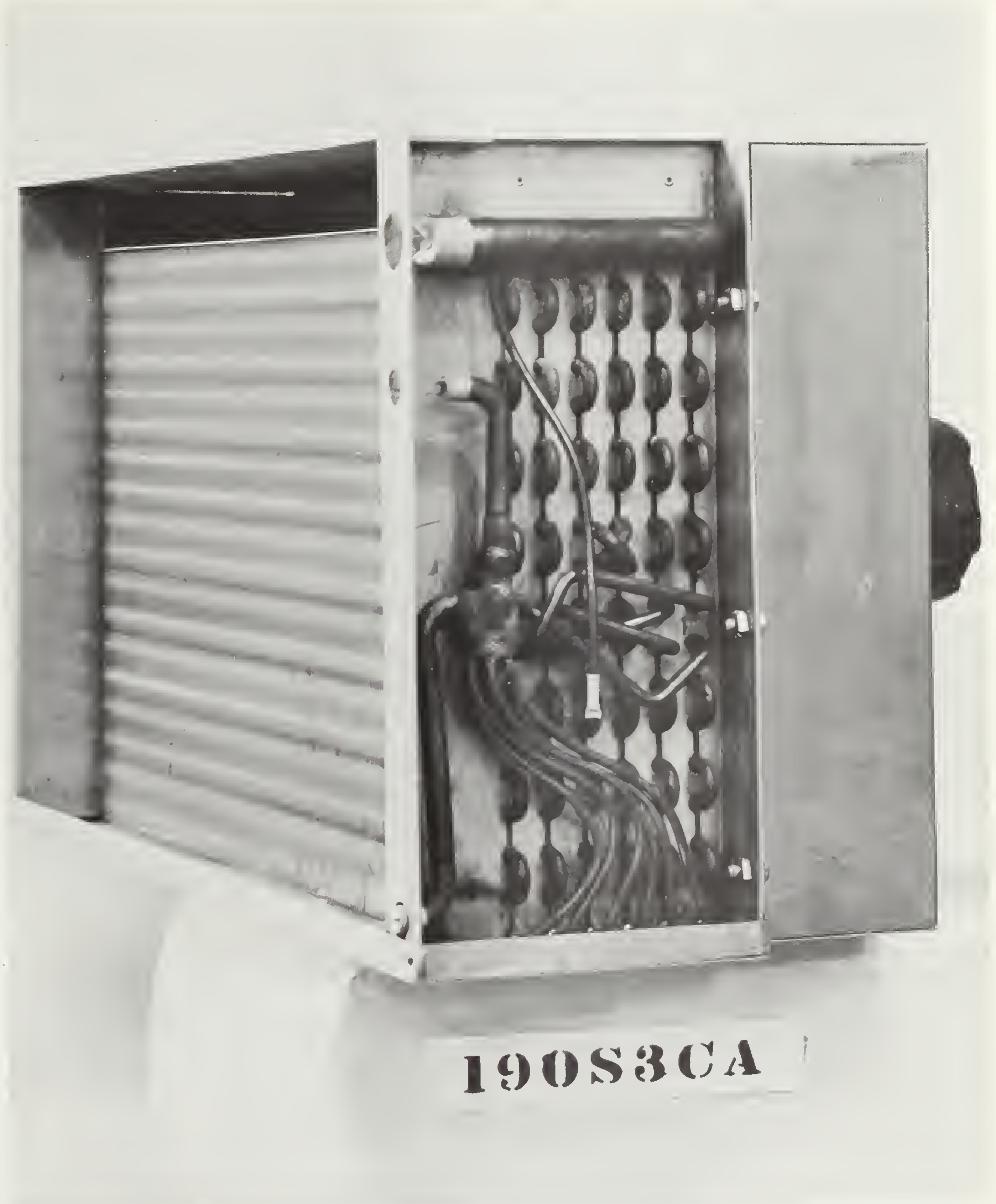



Figure 11. Air discharge side and right end of Size III evaporator (NBS No. 190-59) as supplied.


Figure 12. Size III evaporator (NBS No. 190-59) and fan assembly as supplied.

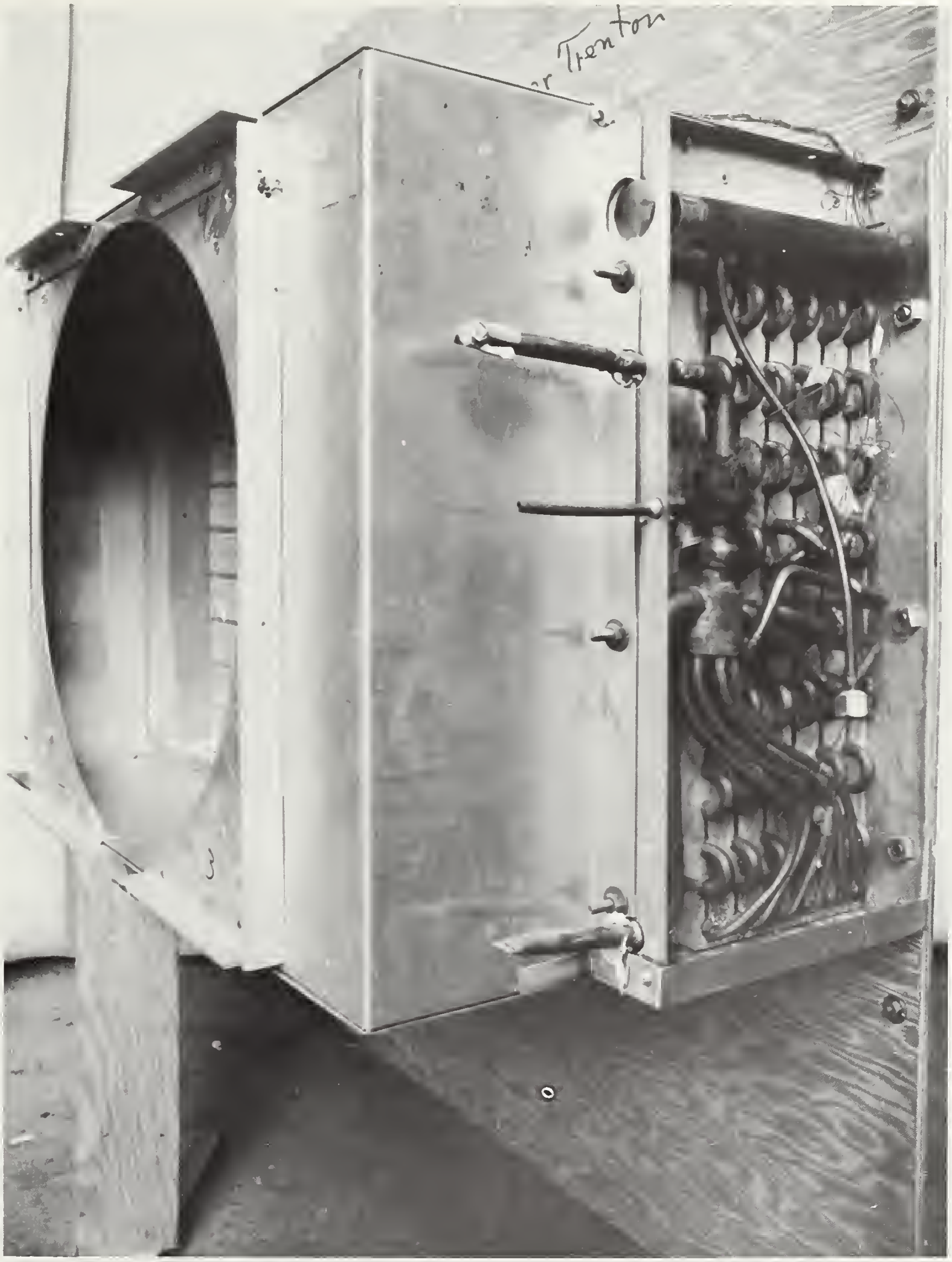



Figure 13. Air discharge side and right end of Size III evaporator (NBS No. 190-59) as mounted for test.

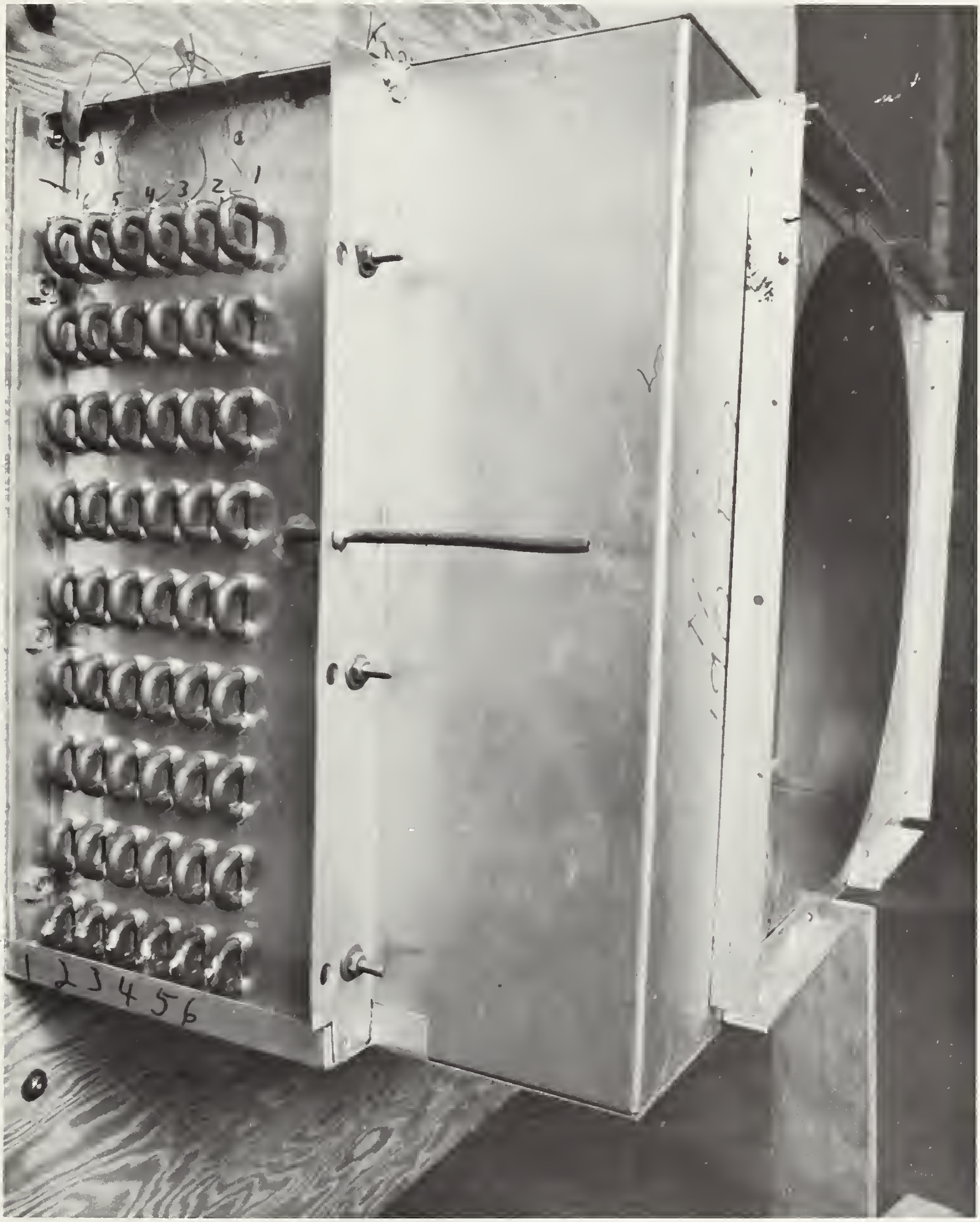



Figure 14. Left end of Size III evaporator (NBS No. 190-59) as mounted for test.

EVAPORATOR SPECIMEN

KRAMER TRENTON NBS NO. 190-59 SIZE III CLASS A

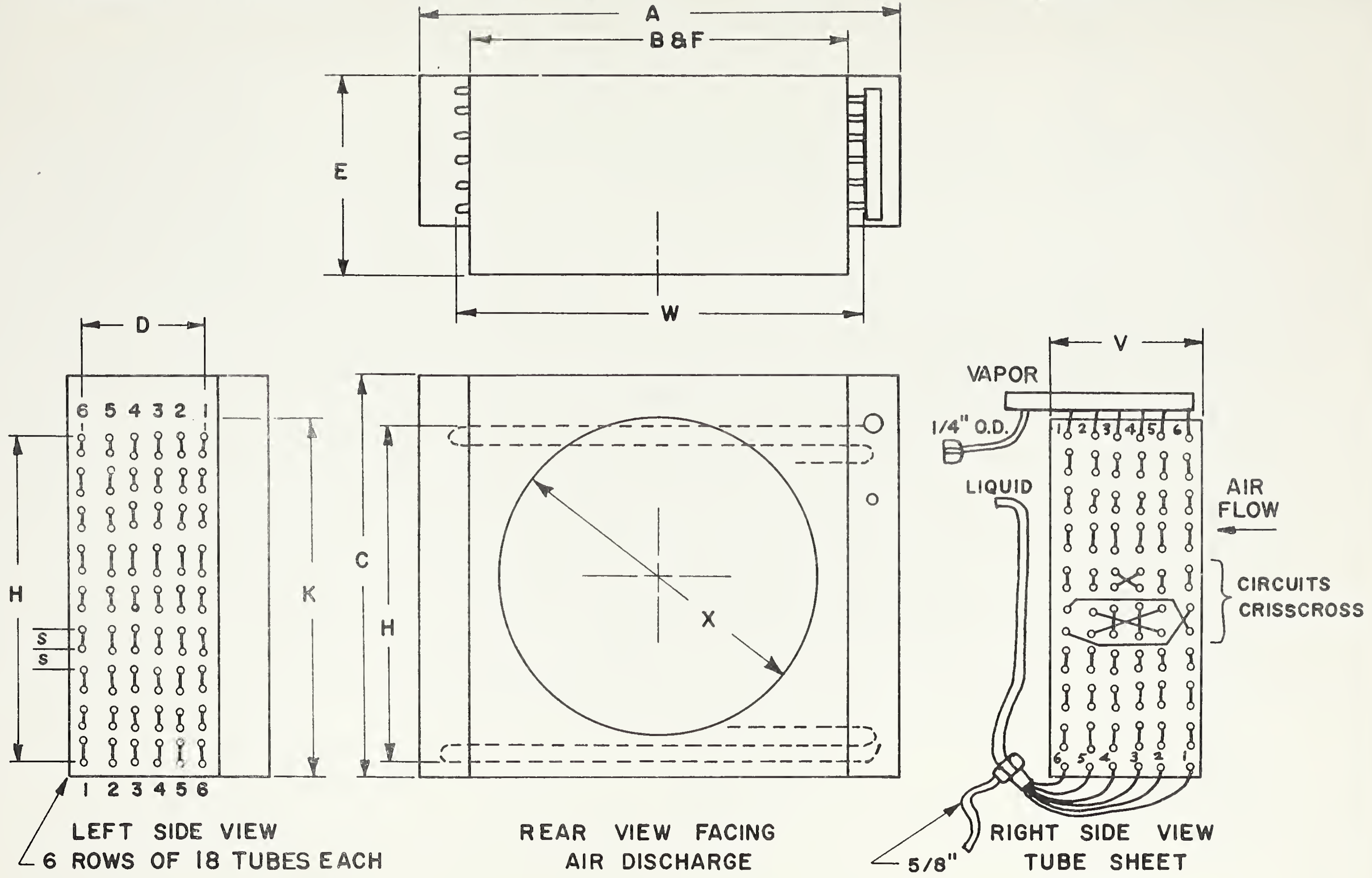



Figure 15

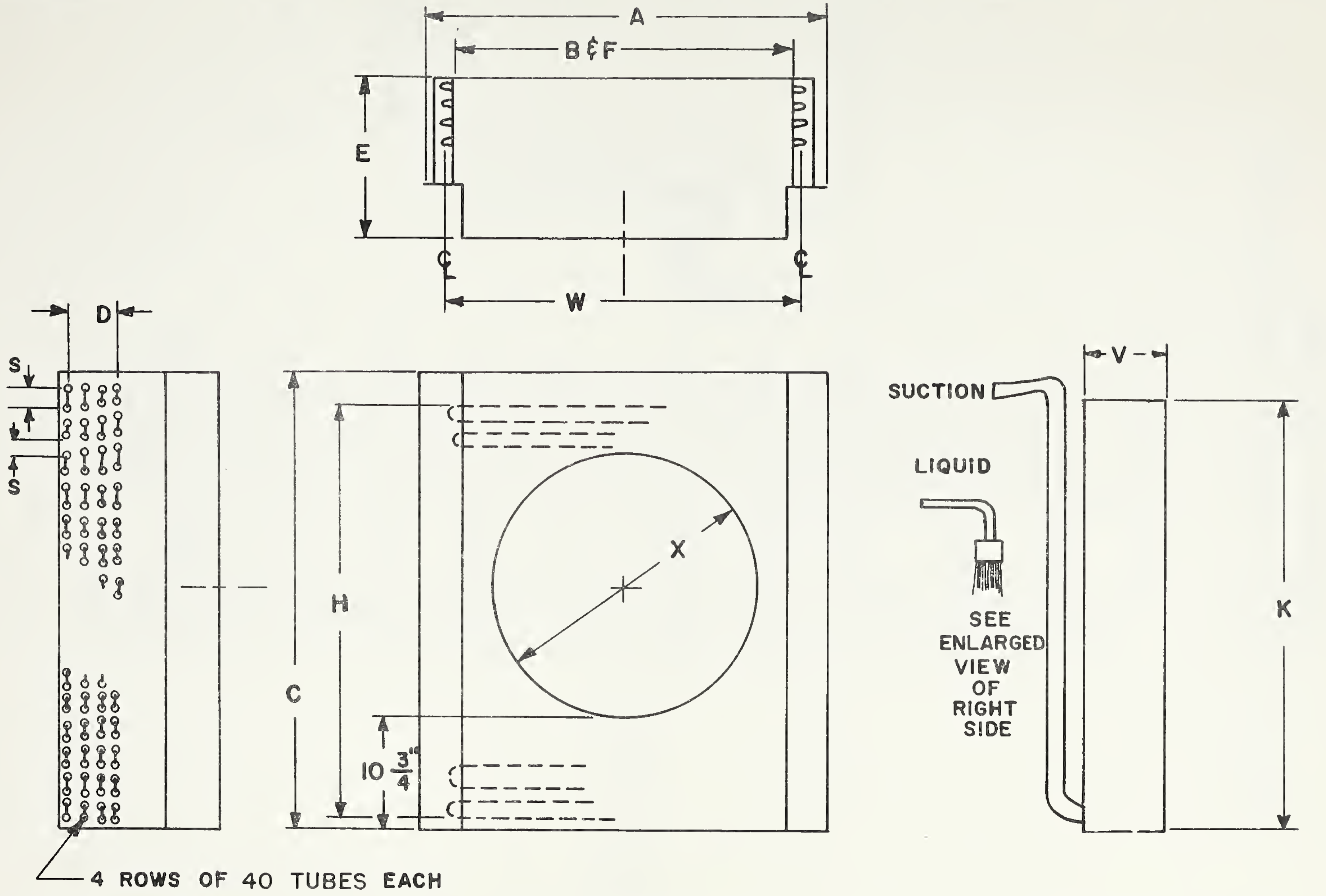
3.1.4 NBS Specimen No. 191-59 was a Size IV Class A evaporator. Figure 16 shows the right end and air inlet side of this unit as supplied, and figure 17 is a view of the air inlet side and left end of the unit as installed for tests. Figures 18 and 19 show schematic arrangement and table 1 gives related physical data for this unit.

Figure 16. Size IV evaporator (right end) and fan assembly (NBS No. 191-59) as supplied.

Figure 17. Air inlet and left end of Size IV evaporator (NBS No. 191-59) as mounted for test.

EVAPORATOR SPECIMEN

KRAMER TRENTON NBS NO. 191-59 SIZE IV CLASS A




LEFT SIDE VIEW

BACK VIEW FACING AIR DISCHARGE

RIGHT SIDE VIEW WITH SHROUD REMOVED

Figure 18

NBS NO. 191-59

ENLARGED RIGHT SIDE VIEW

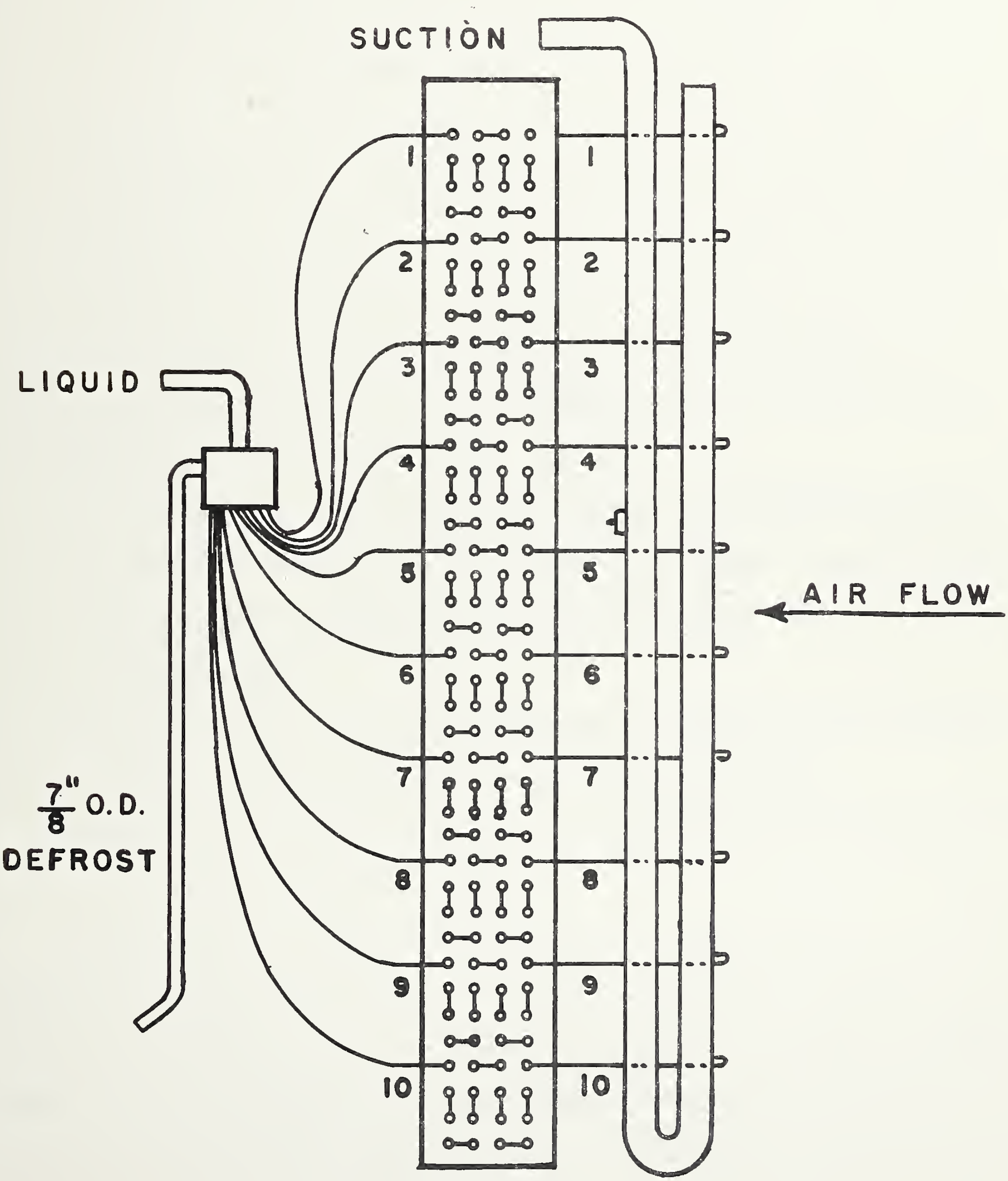



Figure 19

## 4.0 Data and Results

Each evaporator was studied at four different sets of standard conditions as previously described. Each test required control of refrigerant inlet subcooling and temperature, air inlet temperature and pressure, cubic feet per minute of air flow, and refrigerant outlet pressure and superheat. The variables which fluctuated with capacity were the refrigerant flow rate and the air outlet temperature. Although each evaporator was supplied with its own blow-through fan and fan motor, tests were made using selected draw-through fans identical to those furnished except for the direction of air flow and with an auxiliary blower to adjust the air flow rate to the desired test values. The determination of primary, secondary, and total surface areas were based on the following conditions:

1. Primary area = Number of tubes x length x $\pi$ x (measured diameter plus twice the fin collar thickness), minus area covered by fins based on fin thickness. Note that fin collars were included as primary area.
2. Area of open slots and tube openings was deducted from total fin area, taking into account both surfaces of each fin.
3. End sheets and tube area through and beyond end sheets and exposed fin edges were not included.

At the bottom of figure 2 is shown the air mixing duct which was attached to the downstream side of the coil. It was found to be nearly impossible to obtain consistent satisfactory agreement (to within 6 percent) between air and refrigerant side capacity measurements before this mixer was installed in the apparatus ahead of the downstream temperature

measurement thermocouples.

Table 2 summarizes the test data and results for the four Kramer Trenton air cooler evaporators.

TABLE 2

CAPACITY TEST DATA

KRAMER TRENTON CLASS A AIR COOLER EVAPORATORS

| | | Nominal Test Conditions | | | Actual Test Conditions | | | Superheat, Deg F[b] | | Coil Air Pressure Drop, In.W.G. | Capacity BTU/H | | Results | | | | Capacity Adjusted to QMR&E Conditions, BTU/H[f] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | Size | Air In, °F | Refr., °F[a] | Air Flow, CFM | Air In, °F | Refr., °F[a] | Air Flow, CFM | Evap. Outlet | Air Cooler Outlet | | Air Side | Refr. Side | % Diff.[d] | Air Out, °F | Refr. Flow lb./Hour | Fan Power Watts[e] | |
| 131 | I | 0 | -10 | 750 | 0.6 | -10.1 | 740 | c | 7.0 | 0.02 | 3070 | 3020 | -1.7 | -2.3 | 58 | 135 | 2830 |
| 133 | I | 50,70% RH | 35 | 750 | 49.8,63% | 35.0 | 760 | c | 6.1 | .01 | 5270 | 5070 | -3.9 | 44.1 | 91 | 121 | |
| 132 | I | 30 | 18 | 750 | 29.9 | 17.9 | 750 | c | 7.3 | -- | 3730 | 3400 | -9.7 | 26.2 | 62 | 123 | |
| 130 | I | -10 | -22 | 750 | -9.8 | -22.1 | 730 | c | 8.0 | .02 | 4060 | 3970 | -2.3 | -13.7 | 78 | 144 | |
| 134 | I | -20 | -30 | 750 | -18.9 | -30.4 | 710 | c | 6.6 | .02 | 3570 | 4000 | 10.8 | -22.2 | 76 | 145 | |
| 201 | II | 0 | -10 | 1100 | 0.2 | -10.1 | 1110 | c | 7.3 | 10 | 4100 | 4160 | 1.4 | -2.2 | 83 | 241 | 4038 |
| 203 | II | 50,70% RH | 35 | 1100 | 50.2,68% | 35.0 | 1100 | c | 7.6 | .08 | 7900 | 8400 | 6.0 | 44.6 | 136 | 237 | |
| 207 | II | 30 | 18 | 1100 | 30.2 | 18.0 | 1100 | c | 4.0 | .08 | 5620 | 5940 | 5.4 | 26.5 | 115 | 237 | |
| 205 | II | -10 | -22 | 1100 | -11.1 | -23.4 | 1090 | c | 9.2 | .14 | 4800 | 5030 | 4.6 | -13.9 | 85 | 253 | |
| 903 | III | 0 | -10 | 1500 | 0.4 | -10.1 | 1480 | c | 4.2 | .18 | 8770 | 8640 | -1.5 | -3.7 | 164 | 308 | 8220 |
| 901 | III | 50,70% RH | 35 | 1500 | 50.3,68% | 35.6 | 1500 | c | 7.1 | .12 | 13080 | 14310 | 8.6 | 43.3 | 255 | 271 | |
| 902 | III | 30 | 18 | 1500 | 30.7 | 17.9 | 1490 | c | 4.1 | .13 | 11110 | 11490 | 3.3 | 24.7 | 214 | 273 | |
| 904 | III | -10 | -22 | 1500 | -8.5 | -22.6 | 1480 | c | 6.9 | .21 | 10170 | 10680 | 4.8 | -13.3 | 215 | 302 | |
| 1003 | IV | 0 | -10 | 2200 | 0.7 | -10.4 | 2240 | c | 4.8 | .08 | 11910 | 12700 | 6.2 | -3.1 | 252 | 352 | 11430 |
| 1001 | IV | 50,70% RH | 35 | 2200 | 50.0,71% | 35.1 | 2250 | c | 4.7 | .08 | 17500 | 18300 | 4.4 | 43.5 | 331 | 329 | |
| 1002 | IV | 30 | 18 | 2200 | 29.8 | 17.7 | 2210 | c | 3.4 | .08 | 13930 | 13540 | -2.9 | 24.9 | 254 | 345 | |
| 1004 | IV | -10 | -22 | 2200 | -10.2 | -22.9 | 2190 | c | 3.2 | .12 | 13260 | 14010 | 5.4 | -14.5 | 286 | 377 | |

a. Refrigerant temperature corresponding to pressure at suction outlet.
b. ASHRAE Standard 25-56 recommends 5 to 8 deg F superheat at the evaporator outlet.
c. Kramer Trenton air coolers not equipped with integral heat exchangers.
d. $\frac{\text{Refr. Side} - \text{Air Side}}{\text{Refr. Side}} \times 100$
e. Air pressure drop across fan adjusted to produce required air flow; power not indicative of free air delivery.
f. Measured capacity adjusted to QMR & E nominal condition = $\frac{0 - (-10)}{T_{\text{Air In}} - T_{\text{Refrigerant}}} \times$ Measured Capacity

## 5.0 Discussion and Conclusions

The tests covered in this report were part of a series intended to provide a comparison of the cooling capacities of refrigeration evaporators produced by three manufacturers for use in military forced circulation air coolers. This report covers results of tests of evaporators manufactured by the Kramer Trenton Company, purchased under the QMR&E Interim Purchase Description, IP/DES S-9-8, dated January 31, 1958.

To provide a meaningful comparison of coil performance leading to interchangeability of evaporators under conditions where the air flow rate will be a function of the performance of a suitably-selected military standard fan, all coils in this series were tested at the minimum air flow rate specified in IP/DES S-9-8, even though the fans supplied with each evaporator would deliver a different air flow rate under the normal free air delivery conditions. It is likely that the cooling capacities obtained with the minimum air flow rate were less than the capacities which would be obtained if the free air delivery rate were greater than the minimum. As described earlier the minimum air flow rate was obtained by varying the air pressure downstream of the fan.

To remove from the tests the variability of different thermal expansion valves, a specially-selected valve was used to test all coils of the same size. In addition these special test valves were set to maintain essentially steady-state refrigerant flow conditions as opposed to the hunting characteristic of normal thermal expansion valves. It is to be expected that higher

cooling capacities are obtained with steady-state operation, other conditions being equal. This was confirmed by a preliminary test of one of the coils in this series.

Use of integral liquid-suction heat exchangers can be a factor where interchangeability is concerned. The Kramer Trenton coils covered in this report were not equipped with heat exchangers, and the other coils in the test series were so equipped. This should be considered in preparation of the military standard for such units. As discussed under Test Procedures the refrigerant superheat requirement of 5 to 8 deg F specified in ASHRAE Standard 25, the capacity test method prescribed in IP/DES S-9-8, had to be modified for use with the evaporators equipped with integral heat exchangers. It should be noted that ASHRAE Standard 25 describes test methods for fully assembled air coolers whereas the principal interest in these tests was directed to the evaporators in such units.

As shown in Table 2 capacity tests of each coil were made at several conditions in addition to the IP/DES S-9-8 required conditions of -10 °F refrigerant and 0 °F entering air. The performance of the four Kramer Trenton evaporators in relation to the QMR&E required capacities was as follows:

| | Capacity, Btuh | | |
|---|---|---|---|
| Size | Measured | Required | Percent of required capacity |
| I | 2830 | 4500 | 63 |
| II | 4040 | 6500 | 62 |
| III | 8220 | 10000 | 82 |
| IV | 11430 | 13000 | 88 |

The average measured capacities in Btuh, for the three makes of coils tested, at the QMR&E conditions, were; Size I 3030, Size II 4010, Size III 7620, and Size IV 9710.

Two coefficients related to coil capacity which outline relative performance are

$$(1)\ \frac{\text{Btuh}}{(\text{Face area,ft}^2)(\text{deg F})} \quad \text{and} \quad (2)\ \frac{\text{Btuh}}{(\text{Total surface area,ft}^2)(\text{deg F})}.$$

For the QMR&E conditions, the comparisons of the Kramer Trenton coils with the other makes tested were:

| | Btuh / (Face area,ft$^2$)(deg F) | | Btuh / (Total surface area,ft$^2$)(deg F) | |
|---|---|---|---|---|
| Size | Kramer Trenton | Range of 3 makes | Kramer Trenton | Range of 3 makes |
| I | 91 | 76-165 | 24 | 19-38 |
| II | 133 | 106-190 | 28 | 18-32 |
| III | 222 | 157-222 | 38 | 28-38 |
| IV | 139 | 97-139 | 38 | 26-38 |

One factor which may have had a significant influence on the observed variability of coil performance as indicated by these coefficients was the distribution of refrigerant in proper amounts to the several parallel circuits. In particular the method of connecting the defrost headers should be examined for possible interference with proper distribution.

In view of the fact that the units tested were of a prototype nature they were not examined in rigorous detail for dimensional or material compliance with the purchase description. Table 1 lists the physical data for each unit.

As supplied for test each of the four Kramer Trenton evaporators, contrary to the requirement as shown in sketch 5 of the purchase description, was equipped with a blow-through fan, as were each of the evaporators supplied by the other two manufacturers. The fans were corrected for test purposes as described under Test Procedure.

The change in ASHRAE Standard 25 substituting the use of a second simultaneous independent measurement of the refrigerant-side capacity for the previous psychrometric apparatus air-side measurement emphasizes the importance of valid calibration of the integrating liquid refrigerant flow meters. Experience gained in this series of tests showed that calibration of these devices using the same fluids as those to be measured is necessary for all instruments affected by pressure, lubricity or viscosity. Air-side measurements were retained in this series inasmuch as the psychrometric apparatus had been constructed prior to the change in ASHRAE Standard 25. Experience gained in this series of tests indicated the necessity for adequate mixing of the air, particularly that leaving the coil (or fan), if the temperature at that point is to be used to obtain a heat balance.

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