2296

NATIONAL BUREAU OF STANDARDS REPORT

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PERFORMANCE OF A DEVELOPMENT MODEL 3HP YORK CONSOLE AIR CONDITIONER FOR VANS AND PREFABRICATED BUILDINGS

by

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NBS PROJECT		NBS REPORT
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PERFORMANCE OF A DEVELOPMENT MODEL 3HP CONSOLE AIR CONDITIONER FOR VANS AND PREFABRICATED BUILDINGS

manufactured by
York Corporation

by

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Heating and Air Conditioning Section
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To

Engineer Research and Development Laboratories
Fort Belvoir, Virginia.

NBS

Performance of a Development Model 3HP York Console Air Conditioner for Vans and Prefabricated Buildings

Abstract

Performance tests were made of a development model of a 3HP sectional console air conditioner, for vans and prefabricated buildings, manufactured by York Corporation of York, Pa. As received, the total net cooling capacity of the specimen was about 9000 Btu/hr at ASRE standard rating conditions. The capacity was unnecessarily low because misadjustment of the expansion valve caused liquid refrigerant to pass through the evaporator into the compressor, because of a number of serious air leaks into the cabinet and between cabinet sections, because there was no insulation between evaporator and condenser sections, and because conditioned air was short circuited between outlet and inlet of the evaporator section. After correcting these and other faults, comparisons were made of the capacity of the unit when mounted inside the conditioned space, when mounted outside the conditioned space, and when divided into two parts with the condenser section outside and the evaporator section inside the conditioned space. Under ASRE standard rating conditions the total net cooling capacity ranged from 13,040 Btu/hr for the inside installation to 15,600 Btu/hr for the divided installation. The outside mounting produced 9 percent higher capacity than the inside mounting primarily because of air leakage into the condenser section of the cabinet from the conditioned space for the inside installation. The divided installation produced 10 percent higher capacity than the outside mounting chiefly because non-useful heat transmission through the cabinet of the evaporator section was eliminated. The performance factor of the unit in Btu/hr per watt was lower than required by the Federal Specification for self-contained air conditioners whereas the net sensible heat ratio was higher than required by this Federal Specification.

I. INTRODUCTION

In accordance with a request from the Engineer Research and Development Laboratories, Fort Belvoir, Virginia, dated September 28, 1951, tests of development models of two multi-section, package-type air conditioning units were made to determine their performance as a basis for developing air conditioning equipment for vans and prefabricated buildings for Theater-of-Operation use. The two units were designed for capacities in the range from 18,000 to 22,000 Btu/hr. This report presents the results obtained on a specimen manufactured by York Corporation of York, Pennsylvania. Tests were made to determine net cooling capacities, the quantity of conditioned air circulated, the quantity of air circulated through the condenser, and the starting current of the unit.

Capacity tests were requested at standard rating conditions of the American Society of Refrigerating Engineers with outdoor temperatures of 95°F dry bulb, 75°F wet bulb, and indoor temperatures of 80°F dry bulb, 67°F wet bulb, and also at high outdoor ambient temperature conditions of 125°F dry bulb, 85°F wet bulb with indoor temperatures of 90°F dry bulb, 80°F wet bulb.

II. DESCRIPTION OF TEST SPECIMEN

The specimen air conditioning unit was identified as follows:

(NBS Test Specimen 82-52)
York Corporation, York, Pa.
Model V-80 SC
P.O. No. 1R 781

The air conditioning unit was built for operation on alternating current, 208 volts, 3-phase, 60 cycle. The sectional construction of the unit permitted operation in three different ways: the entire unit within the space to be cooled, with ducts to the condenser section; the entire unit on the outside of the space to be cooled, with ducts to the evaporator section; or the unit divided into two parts with the evaporator section placed inside the cooled space and the condenser section placed outside the cooled space. The sectional construction is evident in Figures 1 to 4. The bottom section contained the condenser and the condenser fan; the second section contained the hermetic motor-compressor assembly; the third section contained the evaporator coil and the evaporator fan, while the fourth or top section acted as a plenum chamber for the air discharged into the space to be cooled. The two lower sections were not built for ready separation, and the condenser air entered the unit through the second section and was blown out through two outlets in the bottom section of the unit. The second and third sections were separated from each other by a piece of sheet aluminum approximately 3/16 inch thick. The evaporator air entered the unit through the third section and was blown out through the top section. Figure 4 is a view of the air conditioning unit with all the face panels removed, and the four different sections of the unit can be seen very clearly.

The electrical controls for operation of the air conditioning unit were mounted on the right side of the third section, as viewed in Figures 1 and 3, underneath a small face plate, which could be removed by unscrewing two wing bolts. The controls consisted of a three-position selector switch, which was marked "Fan", "Off", and "Cool". When the selector switch was turned to the "Fan" position, only the evaporator fan would operate: if turned to the "Cool" position, both of the fans and compressor would operate, with the thermostat regulating the operation of the compressor according to the temperature at the inlet of the evaporator. The thermostat adjusting knob was located directly below the selector switch. The unit was not equipped with any means such as dampers, etc. for introducing outside air into the cooled space.

Two centrifugal fans were used to circulate air through the condenser, the fan wheels being mounted on opposite ends of the shaft of the driving motor. A similar arrangement was employed for air circulation through the evaporator. These assemblies can be seen in Figure 4. A thermostatic expansion valve was used as the refrigerant flow control.

Figure 1 is a front view of the unit from the room side. Figure 2, a rear view of the unit, shows the condenser air inlet in the second section and the two outlets in the bottom section of the unit. A front view with all panels removed is shown in Figure 3, whereas Figure 4 shows a rear view with all panels removed.

The physical dimensions, weight, and the electrical data for the unit were as follows:

Height, inch	55
Width, inch	42
Depth, inch	15-1/2
Weight, lbs.	500
Compressor Motor, HP	3
Condenser Fan Motor, HP	3/4
Evaporator Fan Motor, HP	1/6
Refrigerant Charge, lbs. Freon-12	6

The unit was equipped with an air filter made of expanded aluminum mesh at the evaporator inlet. All framing and panels of the unit were made of aluminum.

III. TEST PROCEDURE

Circular No. 16-R, published by the American Society of Refrigerating Engineers, entitled "Methods of Rating and Testing Air Conditioners", was used as a general guide for the procedure to be used in determining the capacity of the air conditioning unit. This ASRE circular states that the capacity rating of self-contained air conditioning units shall be the net total room cooling effect in British Thermal Units per hour. The following apparatus was used to determine this net room cooling capacity.

A portable, 600 cu. ft. warehouse normally used for the refrigerated storage of various materials was used as a calorimeter for the first series of tests. The air conditioning unit was mounted in the opening normally used for the refrigerating unit for the warehouse. It was placed on the inside of the warehouse-calorimeter flush with the outside wall. The calorimeter was then sealed in such a manner that only the openings for the condenser air circuit communicated with

the outside space. For the second series of tests the air conditioning unit was placed entirely on the outside of the calorimeter and short ducts were used on the evaporator air circuit into the calorimeter. For the third series of tests, the evaporator section of the air conditioning unit was separated from the condenser section and was placed on the inside of the calorimeter whereas the condenser section was placed on the outside of the calorimeter. The calorimeter was sealed so that there was no communication other than the refrigerant lines between inside and outside.

For each series of tests, the warehouse, with the air conditioning unit in place, was calibrated to determine the heat transmission per degree of temperature difference between the inside and outside, since this heat constituted part of the sensible heat load. Electric heaters were placed on the inside of the calorimeter to provide the remainder of the sensible heat load for the air conditioning unit. A humidifier consisting of an electric heating element immersed in water was also placed inside the calorimeter to provide the necessary humidity, and provision was made to weigh the amount of water evaporated. The calorimeter was made as airtight as was considered necessary, and provisions were made to measure the amount of air which was introduced into or exhausted from the calorimeter by the air conditioning unit during operation. This was done by removing air from or introducing air into the calorimeter through a pipe by means of a blower. The air quantities were measured by a pitot tube placed inside of the pipe. The amount of air flowing through the pipe was regulated by a throttling valve so that the pressure difference between the inside and the outside of the calorimeter was zero ± 0.002 in. W.G. Calibrated watthour meters were used to measure all electric energy consumption. Temperatures were measured by means of calibrated thermocouples using an electronic, constant-balance type potentiometer. Humidity measurements were made utilizing calibrated lithium-chloride-coated elements in conjunction with a micro-ammeter. Humidity measurements observed with the electric hygrometer were checked regularly with a 24" mechanical psychrometer. The condensate drained from the evaporator coil was collected as a check against the amount of water evaporated by the humidifier.

Measurements of the quantities of air circulated by the evaporator and condenser fans were made by means of a pitot tube located inside a smooth, round duct during separate tests with the air conditioning unit removed from the calorimeter. This duct was connected to the outlet of the evaporator or condenser air circuit by means of a plenum chamber and an exhaust blower was attached to the other end of the duct. The air flow through the duct was regulated by a throttling device so that the static pressure at the evaporator or condenser outlet opening in the cabinet was zero ±0.002 in. W.G. with respect to the pressure in the test room to determine the free-air delivery of the fans.

IV. TEST RESULTS

A. Cooling Capacity

The unit, as received for tests, produced a total net cooling capacity of 9000 Btu/hr under conditions of 95°F DB, 75°F WB condenser ambient and 80°F DB 67°F WB evaporator ambient with the assembled unit within the conditioned space. The capacity was found to be unnecessarily low because certain features of design, workmanship, and control adjustment needed improvement. These features were modified during the course of several preliminary tests in cooperation with representatives of the manufacturer after which the test results hereinafter reported were obtained. The defects in the unit and the modifications made are described in the section entitled "Design and Workmanship".

Determinations of the total net cooling capacity of the unit were made for two different sets of indoor and outdoor temperature and humidity conditions, for each of three different positions of the unit with respect to the calorimeter. Tests numbered 1a and 1b were made with the unit entirely within the calorimeter, tests numbered 2a and 2b were made with the unit on the outside of the calorimeter, and tests numbered 3a and 3b were made with the unit divided as described previously. The enthalpy difference between outdoor and indoor temperature conditions for any air that leaked through the air conditioner into or out of the conditioned space was not credited to the total net cooling capacity of the unit. The desired test conditions, the average temperatures maintained during the tests, and the results are summarized in Table 1.

A comparison of capacities observed for the three methods of mounting the air conditioner shows that the lowest capacity can be expected when the unit is mounted wholly within the cooled space. Using the indoor location as a base for comparison, the capacity was increased 9.1 and 15.8 percent with the unit mounted on the outside of the cooled space, and was increased 20.3 and 36.6 percent with the unit divided, for the lower and higher ambient temperatures, respectively. The difference in capacity between inside and outside mounting was probably due chiefly to the fact that the unit exhausted some air from the calorimeter when mounted entirely inside and this air was replaced with ambient air, whereas there was no air movement into or out of the calorimeter when the unit was mounted on the outside of the calorimeter.

The differences in capacity between Tests 2a and 3a and between Tests 2b and 3b represent with reasonable precision the non-useful heat gain of the evaporator section (through the frame, panels, etc.) from the ambient air in the two cases since the evaporator section was outside the calorimeter for tests 2a and 2b and inside for tests 3a and 3b and there was no measurable air leakage to or from the calorimeter in either case. These capacity differences amounted to 1450 Btu/hr for an ambient temperature of 95°F (Tests 2a and 3a) and 2490 Btu/hr for an ambient of 125°F (Tests 2b and 3b).

Table 1

Performance of York Corporation Air Conditioner
Model V-80SC, NBS Specimen 82-52

Desired Test Conditions

Ambient Air Conditions		
Dry Bulb Temp., °F	95	125
Wet Bulb Temp., °F	75	85
Relative Humidity, %	40	20
Air Conditions at Evaporator Inlet		
Dry Bulb Temp., °F	80	90
Wet Bulb Temp., °F	67	80
Relative Humidity, %	51	65

Observed Test Conditions

Test No.	1a	2a	3a	1b	2b	3b
Ambient Air Conditions						
Dry Bulb Temp., °F	96.4	94.8	95.9	126.1	124.6	126.0
Wet Bulb Temp., °F	76.3	74.6	76.8	86.9	86.0	87.5
Relative Humidity, %	40.5	39.0	43.0	22.0	22.0	22.5
Air Conditions at Condenser Inlet						
Dry Bulb Temp., °F	99.8	95.3	98.2	128.3	125.5	128.2
Wet Bulb Temp., °F	77.3	74.8	77.4	87.4	86.2	88.3
Relative Humidity, %	37.3	38.8	39.5	20.4	21.5	21.0
Air Conditions at Condenser Outlet						
Dry Bulb Temp., °F	109.7	106.4	110.2	140.0	139.1	142.0
Air Conditions at Evaporator Inlet						
Dry Bulb Temp., °F	81.7	79.9	79.7	90.2	90.0	91.0
Wet Bulb Temp., °F	68.3	66.9	66.9	80.1	80.0	80.7
Relative Humidity, %	51.0	50.8	51.0	65.2	65.0	65.2
Air Conditions at Evaporator Outlet						
Dry Bulb Temp., °F	68.0	66.1	67.4	80.6	81.4	81.5
Wet Bulb Temp., °F	62.0	63.2	64.4	76.5	77.4	77.5
Electrical Data						
Power Consumption, watts						
Compressor Motor	2206	2135	2166	2868	2835	2886
Evap. Fan Motor	206	230	231	201	223	221
Cond. Fan Motor	541	622	612	521	586	573
Total	2953	2987	3009	3590	3644	3680
Current Used, amps						
Compressor Motor, rated 9.3amps	6.5	6.3	6.3	7.9	7.8	7.9
Evap.Fan Motor, rated 1.5 amps	1.6	1.5	1.6	1.6	1.5	1.5
Cond.Fan Motor, rated 4.9 amps	3.6	3.4	3.4	3.5	3.3	3.3
Terminal Voltage	209	209	208	209	208	208

Table 1 - continued

Test No.	1a	2a	3a	1b	2b	3b
Moisture Load, lbs/hr						
Evaporated at humidifer	1.13	1.38	2.13	5.5	5.44	5.75
Collected off evaporator	2.25	1.15	2.38	5.75	5.47	6.0
Head Pressure, psig	185	173	183	275	272	286
Suction Presure, psig	38.7	36.0	36.0	55.1	53.3	53.5
Net Sensible Cooling Capacity, Btu/hr	11,840	12,760	13,410	6150	8120	10,270
Net Dehumidifying Capacity, Btu/hr	1200	1460	2260	5830	5760	6100
Total Net Cooling Capacity, Btu/hr	13,040	14,220	15,670	11,980	13,880	16,370
Sensible Heat Ratio, %	90.9	89.8	85.6	51.6	58.5	62.7
Performance Factor, Btu/hr/watt	4.4	4.8	5.2	3.3	3.8	4.4

Computations of the net sensible heat removal from the conditioned space based on the air circulation rate of the evaporator fan and the increase in dry-bulb temperature between the evaporator section outlet and inlet openings do not agree well for every test with the values of net sensible cooling capacity reported in Table 1. A part of this discrepancy is accounted for in tests 1a and 1b by the sensible heat of the air forced into the calorimeter by the auxiliary blower to replace that exhausted by the air conditioner. Some error is probable in all tests because it is impossible to obtain a true weighted average temperature of a stream of air when discharged in confined conditions with several sudden changes of direction as was the case for the test specimen. Furthermore, the air circulation rate of the evaporator fan was not determined during each capacity test, but was measured in a separate test with the unit outside the calorimeter.

The electric power consumption of the test specimen was rather high for the total net cooling capacity observed, as shown in Table 1 by the low performance factor in Btu/hr/watt. For tests made at ASRE standard rating conditions (ambient conditions 95 DB, 75 WB; room air inlet 80 DB, 67 WB), Federal Specification OO-A-372, covering self-contained air conditioning units requires a minimum performance factor of 6.0 Btu/hr/watt for console-type air conditioners with air-cooled condensers such as this one. The performance factor for the test specimen ranged from 4.4 to 5.2 Btu/hr/watt for tests 1a, 2a, and 3a.

Table 1 shows that the sensible heat ratio was from 85 to 90 percent for the tests at ASRE standard rating conditions with 51 percent relative humidity in the conditioned space (Tests 1a, 2a and 3a). This result indicates that this unit could only remove a limited amount of moisture from a space at a humidity level of 51 percent. The Federal Specification for self-contained air conditioning units requires that the sensible heat ratio be within the range from 70 to 80 percent for these room conditions.

By contrast, the sensible heat ratio was reduced to the range from 52 to 63 percent for tests 1b, 2b, and 3b in higher ambient temperatures for which the relative humidity of the room was maintained at 65 percent. For these tests the dehumidification load seriously reduced the sensible cooling capacity of the unit. For the conditions prevailing during tests 1b, 2b, and 3b the dew point temperature of the outdoor air was 72°F whereas it was 76.5°F for the indoor air. Thus an exchange of air between indoors and outdoors would remove moisture from the conditioned space. During actual use in ambient conditions of 125 DB and 85 WB, this air conditioning unit would probably reduce the indoor relative humidity below the 65 percent level in all applications except those where an unusually large amount of moisture (5 or 6 pounds per hour) was released in the conditioned space.

B. Air Circulating Capacity

Determinations of the air circulating capacity were made for both the evaporator and condenser fans. The results of these measurements are summarized in Table 2. The Federal Specification OO-A-372 for self-contained air conditioners requires a minimum air circulation rate of 30 cfm per thousand Btu/hr of rated capacity for this type unit. The observed air circulation rates of the test specimen exceeded this value considerably for both the evaporator and condenser fans based on the observed capacities.

Table 2

Air Circulating Capacity of York Unit

	Air Capacity cfm	Temp. of Air, °F During Test DB	WB
Evaporated Fan	840	87	66
Condenser Fan	1597	96	66

As pointed out earlier in the report, some air was exhausted from the calorimeter by the unit during tests 1a and 1b when the condenser section was mounted inside the calorimeter. This leakage amounted to 23 to 30 cfm, respectively, for tests 1a and 1b, and probably occurred around some of the removable panels of the condenser section of the cabinet in such manner that the condenser fans exhausted air from the calorimeter. The evaporator section of the cabinet was apparently leak-tight because no leakage occurred during the tests with only the evaporator section in the calorimeter. It should be noted that some of the modifications described in Section D of Test Results of this report directly affected the amount of air leaking through the cabinet sections.

C. Electrical Tests

A Brush oscillograph was used to measure the starting current of the complete unit and of the two fans. The highest instantaneous starting current observed for the complete unit was 66.8 amperes, and for the two fans, 46 amperes. The time of starting was 0.117 seconds for the compressor and 0.51 seconds for the fans.

The unit was equipped with a timer which prevented the fans and compressor from starting simultaneously.

D. Design and Workmanship

As a result of attempts to determine reasons for the low capacity observed for the unit as received, certain construction features were noted which required modification or adjustment.

It was noted that if the assembled unit was set on an uneven floor the frame could be distorted sufficiently to cause the condenser blower wheels to rub against the scroll sides. Apparently this was caused by the softness of the particular aluminum used for framing and by the further weakening of the angle base framing (see Figure 4) resulting from relief notching of this angle at the condenser fan discharge openings. A representative of the manufacturer stated that 3S-1/2 H or 3S-H-14 aluminum was used for the prototype under test and that in production of this item 52-S-H-14 aluminum, more suitable for the purpose, would be used.

Figure 3 shows that the base angle of the second section, to which the compressor base rails are attached is bent outward. The opposite angle, as can be seen in Figure 4 was bent inward. Representatives of the manufacturer stated that this could have occurred in transit and was aggravated by the softness of the aluminum used.

As delivered for tests, a very poor fit between cover panels and the frames of the sections was noted. The panels were of sheet aluminum, were not equipped with gaskets, and were each attached by means of 4 threaded aluminum fasteners. The resulting poor fit permitted considerable air exchange between the unit sections and the surrounding ambient. These openings were sealed before the tests were made since the representative of the manufacturer stated that in production gaskets would be provided between sections and cover panels and between sections.

Some of the threaded aluminum fasteners used to fasten the panels to the section frames were stripped at the time of receipt of the unit and others became stripped during the removal and replacement of panels during the tests.

The bottom and end portions of each section were welded. Cracks were observed on some of these welds and in Figure 4 two of the cracked welds can be clearly seen, one in the lower right corner of the top section, the other in the lower left corner of the compressor section. At least three other such welds were also cracked.

No evaporator or discharge air louver or grill was supplied with the unit. As can be seen in Figure 1 the return air opening to the evaporator is directly beneath the evaporator discharge opening. In order to prevent serious short-circuiting of the evaporator air during tests it was necessary to install a baffle projecting from between the two top sections.

Preliminary runs made prior to testing indicated serious flooding of refrigerant from the evaporator to the compressor. A representative of the manufacturer made several adjustments to the expansion valve and shifted the position of the bulb for the thermostatic expansion valve before correcting the flooding condition. He cut an access opening in the end of the evaporator fan section (see Figure 4, right hand side of the third section) to permit adjustment of the expansion valve while the unit was operating and in position for test. The manufacturer's representative discharged, evacuated and recharged the system with 6 lbs. of dichlorodifluoromethane, after correcting the flooding condition, in an attempt to lower the head pressure observed during the preliminary runs.

Various openings between sections for electric lines, refrigerant tubing, etc., were not sealed when the unit was received. A representative of the manufacturer stated that these openings, which would permit exchange of air between evaporator and condenser, would be sealed in production. These openings in the unit under test were then sealed with a mastic-type material before testing.

V. DISCUSSION AND CONCLUSIONS

The tests of this development model air conditioner showed that a considerable gain in capacity was obtained by separating the evaporator and condenser sections of the unit, installing the former in the cooled space and the latter outside the space to be cooled, as compared to mounting the entire unit either inside or outside the space. This increase in capacity amounted to 20 percent as compared to the inside installation and 9 percent as compared to the outside installation for ASRE standard rating conditions indoors and outdoors. The advantage of dividing the unit was even greater for higher outdoor temperatures.

The performance factor of the unit in Btu/hr of total net cooling capacity per watt of electrical energy input was considerably below the value of 6.0 required by Federal Specification, OO-A-372, for self-contained air conditioners. The unit was shown to have a limited capacity for dehumidification at relative humidities near 50 percent by the relatively high sensible heat ratio observed under ASRE standard rating conditions.

As received the capacity of the unit was seriously reduced by air leaks around the cabinet panels, recirculation of conditioned air from evaporator outlet to inlet and improper adjustment of the refrigerant control device. Attention should be given to improving these features in any future development.

FIG. 1

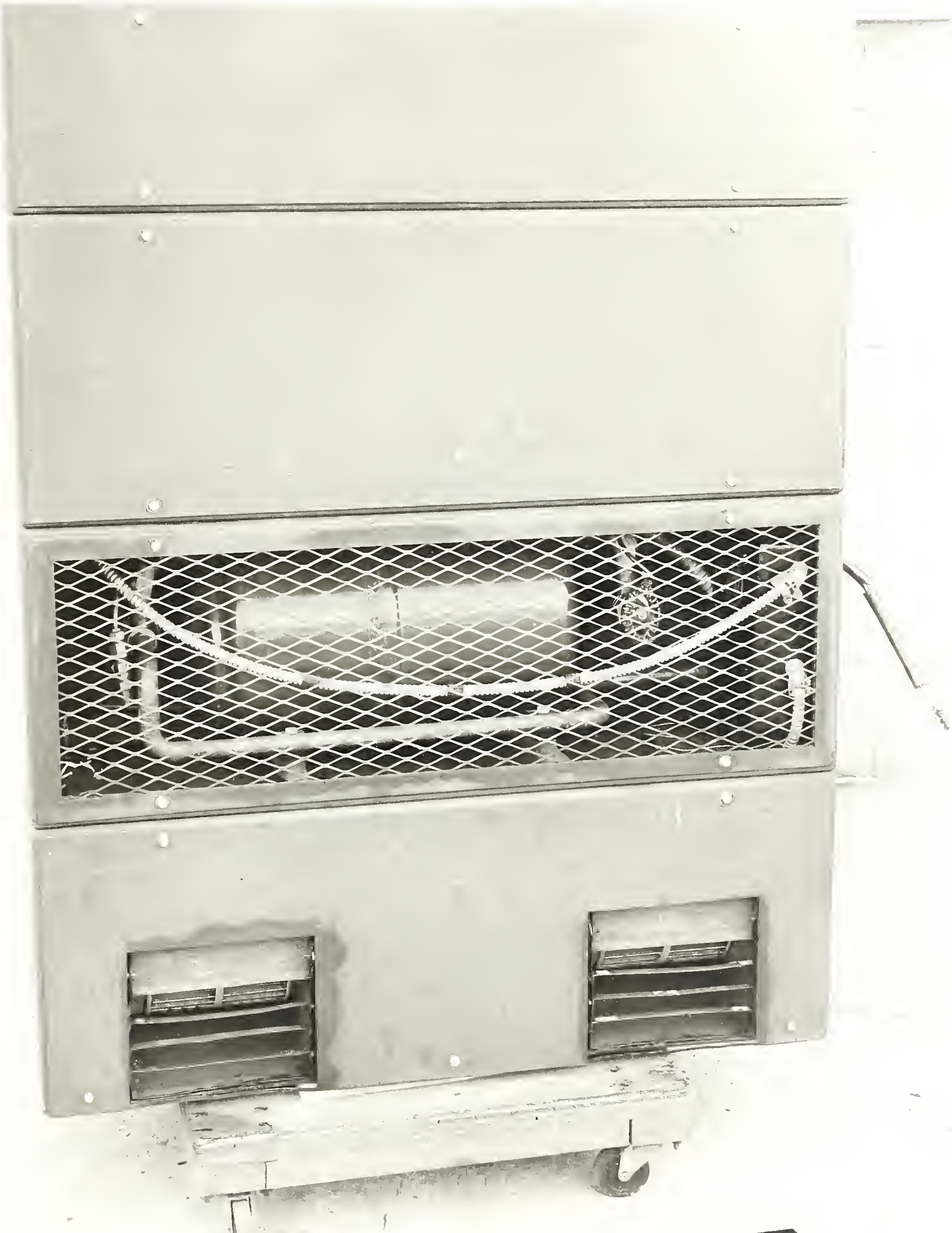

FIG. 2

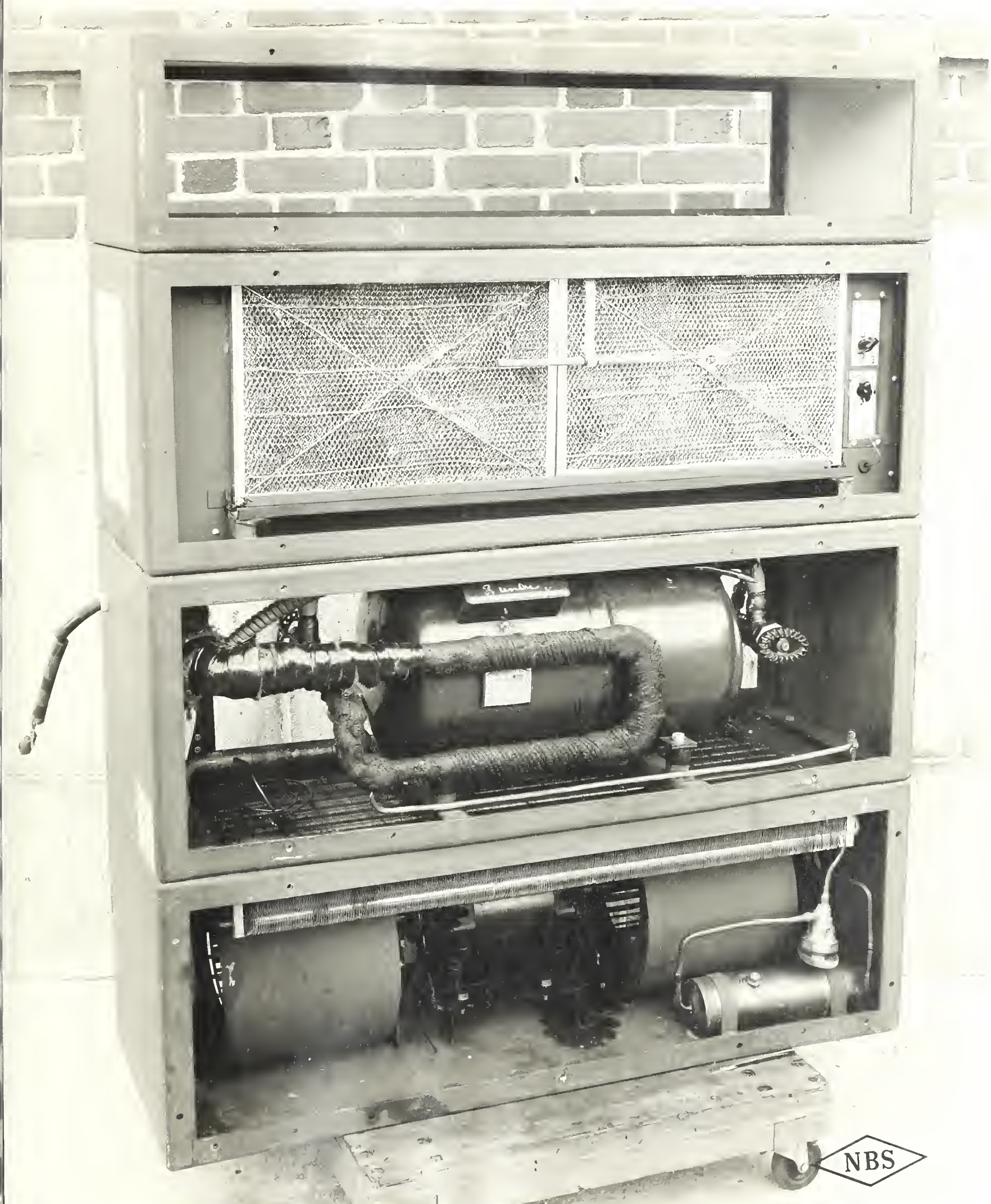

FIG. 3

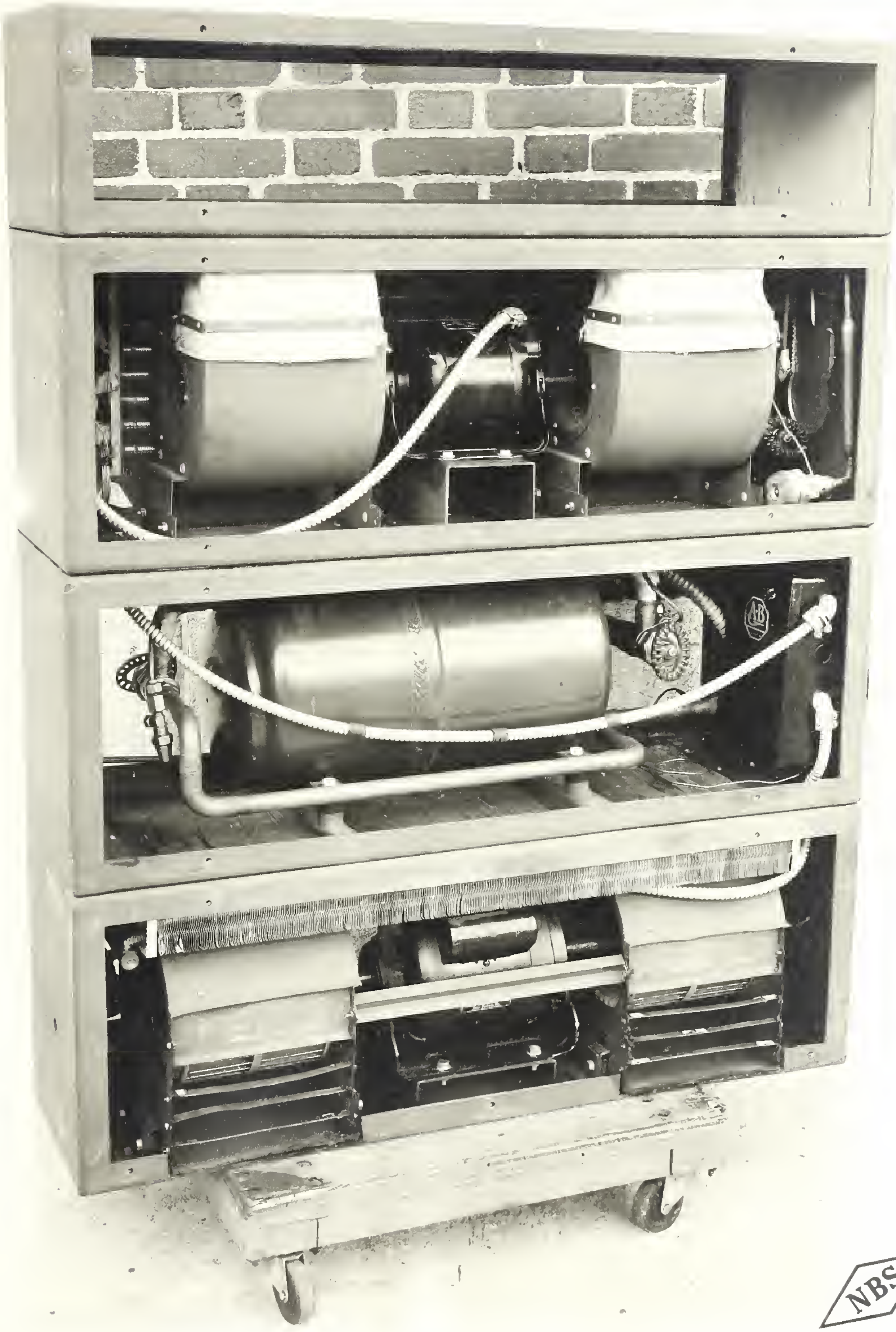

FIG. 4

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