Report 1918

NOMINAL 36,000-BTU/HR, COMPACT, HORIZONTAL, AIR-CONDITIONING UNITS

by

Roy Peterson

December 1967

U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

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NOMINAL 36,000-BTU/HR, COMPACT, HORIZONTAL, AIR-CONDITIONING UNITS

Task 1M643303D54503

December 1967

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The Commanding Officer
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SUMMARY

This final report covers the engineering design testing of two nominal 36,000-Btu/hr, compact, horizontal, air-conditioning models. These are through the wall-mounted, air-cooled, monochlorodifluoromethane refrigerant (R-22)-charged, electric-motor-driven, 208-volt, 3-phase, 60-hertz (Model MC40HAL6-208); and 208-volt, 3-phase, 400-hertz (Model MC40-HAL4-208) units.

The report concludes:

a. The models meet the design objectives of compact, lightweight construction.

b. The units meet the capacity requirements in both heating and cooling and have demonstrated advantageous airflow characteristics.

c. The units are suitable for applications which require large cooling capacities in a small, compact envelope.

d. Both models have desirable sound characteristics when properly applied in a system enclosure.

e. The units are sufficiently durable to withstand hard military usage in world-wide climates.

NOTE: Failures occurred during humidity tests. Initial modification was inadequate, but it is believed that those units which are modified subsequently will meet requirements.

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FOREWORD

Authority for the design, development, and testing of the two air conditioners covered by this report is contained in Task 1M643303D54503, "Environmental Control Equipment." Coordinated Military and Technical Characteristics titled "Air Conditioner, 36,000-BTUH Compact Horizontal - Performance Characteristics; Physical Characteristics; and Maintenance Characteristics," 30 June 1966, are outlined in Section II of this report.

This air-conditioner project was the responsibility of the Environmental Equipment Division, R. F. Bartelmes, Chief. The development and tests were accomplished under the supervision of Darald C. Frink, Chief, Development Branch; Charles W. Lester, Chief, Evaluation Engineering Branch; and Jerry L. Wilson, Senior Project Engineer, Development Branch. Roy Peterson, Project Engineer, wrote the report.

The air-conditioning units used for the engineering design tests described in this report were developed under Contract DA-44-009-AMC-833(T), 30 September 1964, with the Stratos Division of Fairchild Hiller Corporation, Bay Shore, Long Island, New York, in coordination with the Environmental Equipment Division, Mechanical Technology Laboratory, USAMERDC (formerly USAERDL), Fort Belvoir, Virginia.

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NOMINAL 36,000-BTU/HR, COMPACT, HORIZONTAL,

AIR-CONDITIONING UNITS

I. INTRODUCTION

1. Subject. This final report covers the engineering design testing of two compact, horizontal, air-conditioning units each with a nominal cooling capacity of 36,000 Btu/hr. These two models comprise the second largest size units of the family of compact, horizontal air conditioners being developed by the Environmental Control Division, Mechanical Technology Laboratory, USAMERDC (formerly USAERDL), Fort Belvoir, Virginia. The objective of this task is to develop compact air conditioners which provide simple operation, durability, reliability, maximum interchangeability of parts with minimum weight and bulk, and which have ability to operate satisfactorily in world-wide climates for extended periods with a minimum amount of maintenance.

2. Background and Previous Investigation. The success of military agencies in providing miniature and smaller categories of portable electronic systems resulted in the requirement for lightweight, compact air conditioners capable of being easily transported and operated in extreme climatic conditions. A study was made to determine the best general design and configuration to satisfy the overall military requirements. The study concluded that lightweight, compact air conditioners could be developed by using aluminum-alloy cabinets, dual-speed fans, and lightweight components.

II. DEVELOPMENT REQUIREMENTS

3. Coordinated Military and Technical Characteristics. These requirements are set forth for the 36,000-Btu/hr-capacity models in the compact, horizontal family of air conditioners.

a. Performance Characteristics.

(1) Total cooling capacity of 36,000-Btu/hr unit (with dehumidification).

(2) Heating capacity of 28,600 Btu/hr.

(3) Minimum conditioned airflow of 1,125 cfm when unit is operating against zero external resistance.

(4) Temperature-sensing device to respond within $\pm 4^{o}$ of any preset temperature between 60^{o} and 90^{o} F.

(5) Provisions for introducing at least 140 cfm of fresh air for personnel.

(6) Maximum total power requirement not greater than 12 kw (11 kw desired).

(7) Automatic safety controls to protect against overpressure, overheating, and electrical overcurrent.

(8) Compatibility in operation with external chemical-biological (CB) protection devices.

(9) Life expectancy of 4,000 hours before overhauling unit, as is shown in the list in paragraph 3c of this report.

(10) Continuous operation mission reliability of not less than 0.95 for a mission time of 24 hours, as is shown in the aforementioned list.

(11) Combat ready rate of 95 percent, as is shown in the same list.

(12) Capability of withstanding storage and transit conditions specified in paragraphs 7.1; 7.1.a; 7.1.b; and 7.1.d; of AR 705-15 (1)*.

(13) Operation satisfactory under conditions specified in paragraphs 7.a.(1)(a)1 and 7.d.(1)(a)2 of AR 705-15.

(14) Operation in the cooling mode in outdoor temperatures to a low of -25^{o} F and in the heating mode to a low of -50^{o} F.

(15) Environmental conditions of rain, humidity, fungus, salt fog, sand and dust, shock, and vibration met as specified in U. S. Army Mobility Equipment Research and Development Center (formerly

* Numbers in parentheses refer to entries in Literature Cited.

U. S. Army Engineer Research and Development Laboratories), Fort Belvoir, Virginia, Standard Test Procedures.

(16) Separate units for operation on the following power sources:

208 volts, 3 phase, 60 hertz
208 volts, 3 phase, 400 hertz

(17) Operation of the 60-hertz unit on 50-hertz current at rated voltage with a capacity reduction of not more than 30 percent.

(18) Operation from a power source ranging from 95 percent to 110 percent of the rated voltage.

(19) Degradation of reliability per year of depot or field storage not more than 4 percent.

(20) Provisions for minimizing electrical surges while the unit is operating on thermostatic control.

(21) Noise level in conditioned area of a properly engineered installation not to exceed Curve NC-70 (NC-60 desired) as indicated in ASHRAE Guide and Data Book (2) when used in conjunction with proper external sound treatment.

(22) Condenser side noise level not to exceed the maximum steady state noise level for Army Materiel Command equipment as specified in Table 2 of USAHEL Standard S-1-63B (3), June 1965.

(23) Radio frequency interference requirements of Specification MIL-E-55301 (4) for tactical noncommunication electronic (CE) equipment met with exemptions stated in paragraph 3.4.

b. Physical Characteristics.

(1) Units suitable for starting, stopping, and temperature control by one man. Operator maintenance will be limited to minor tasks of lubrication, cleaning, replacement of filters, replacement of power cable, and cleaning condenser and evaporator coils.

(2) Units to be designed toward meeting a maximum volume requirement of 22 cubic feet and a maximum weight

requirement of 500 pounds (350 pounds desired). Desired maximum dimensions, 27 inches high, 34 inches deep, and 38 inches wide.

(3) Access panels or removable covers for ease of maintenance.

(4) Compliance with safety requirements of applicable ASA, UL, and Military Standards.

(5) Components and parts same as those used in other military air-conditioning units to the extent practicable.

c. Maintenance Characteristics.

(1) Requirement for a minimum of operational and in-storage maintenance. Repair by replacement-type components will be used to the maximum extent practicable.

(2) Requirement for the minimum of man-hours and skill to accomplish maintenance.

(3) Utilization, to the maximum extent practical, of major components that are maintenance free throughout the service life.

(4) Ease of accessibility and restricted use of components that require special skills or tools for maintenance will be stressed.

A list of the air-conditioning components and parts maintenance required on the basis of 24-hour-day operation for 30 days follows:

Maintenance Requirements

Mission Time (t) (hr)	24
Reliability for (t) (%) (MBTF); Derived Value	95
Mean Time between Failures (90% Confidence)	480
Combat Ready Rate (%)	95
Availability (%)	95
Mean Time to Repair (hr)	
Operator-Crew and Organizational	4
Direct Support	8
General Support	24

Mean Time between Maintenance (hr)	
Operator-Crew and Organizational	250
Direct Support	1,000
General Support	4,000

III. INVESTIGATION

4. Description. The 36,000-Btu/hr, compact, horizontal, air-conditioning unit (Figs. 1 through 3) is 38.0 inches wide, 34.8 inches long, 27.0 inches high (the volume is 20.6 cubic feet), and the maximum weight of the unit, charged and ready to operate, is 425 pounds.

The external casting of the cabinet is a structurally rigid, block-shaped aluminum shell with rounded corners. Access panels, internal separations, brackets, and component supports are also aluminum. The fan motors and the compressor are each provided with suitable elastomer mounts which minimize shock, vibration, and noise.

The top is a three-piece cover. The center cover is approximately 3 inches wide (to accommodate the wall thickness of a standard shelter). This allows the front (evaporator) cover, the rear (condenser) cover, or both to be removed while the unit remains mounted in the wall of a shelter. Access for inspection and service is thus provided.

The power input and control circuit breakers can be seen in the upper left corner when one faces the front of the unit. Below these is the control module which contains the compressor circuit breaker, mode selector switch, temperature selector (thermostat), and evaporator fan motor speed selector switch.

Figure 3 shows the control module removed from the unit. The control module permits remote control of the air conditioner when connected with a special distant cable. The unit thermostat is part of the control module, and the location of the thermostat sensing bulb determines the control point for air temperature. Generally, the control module remains in the unit control panel with the sensing bulb located in the return-air stream. Directly below the control module is the manual high-pressure reset switch. The outlet grille, located at the top, is finger adjustable in the vertical and horizontal planes. This provides some selection in the distribution pattern and direction of outlet air. The ventilation air-adjusting device (vent knob) is the knurled knob recessed in the left front edge of the unit. The knob closes the damper when turned to the right and opens it when turned to the

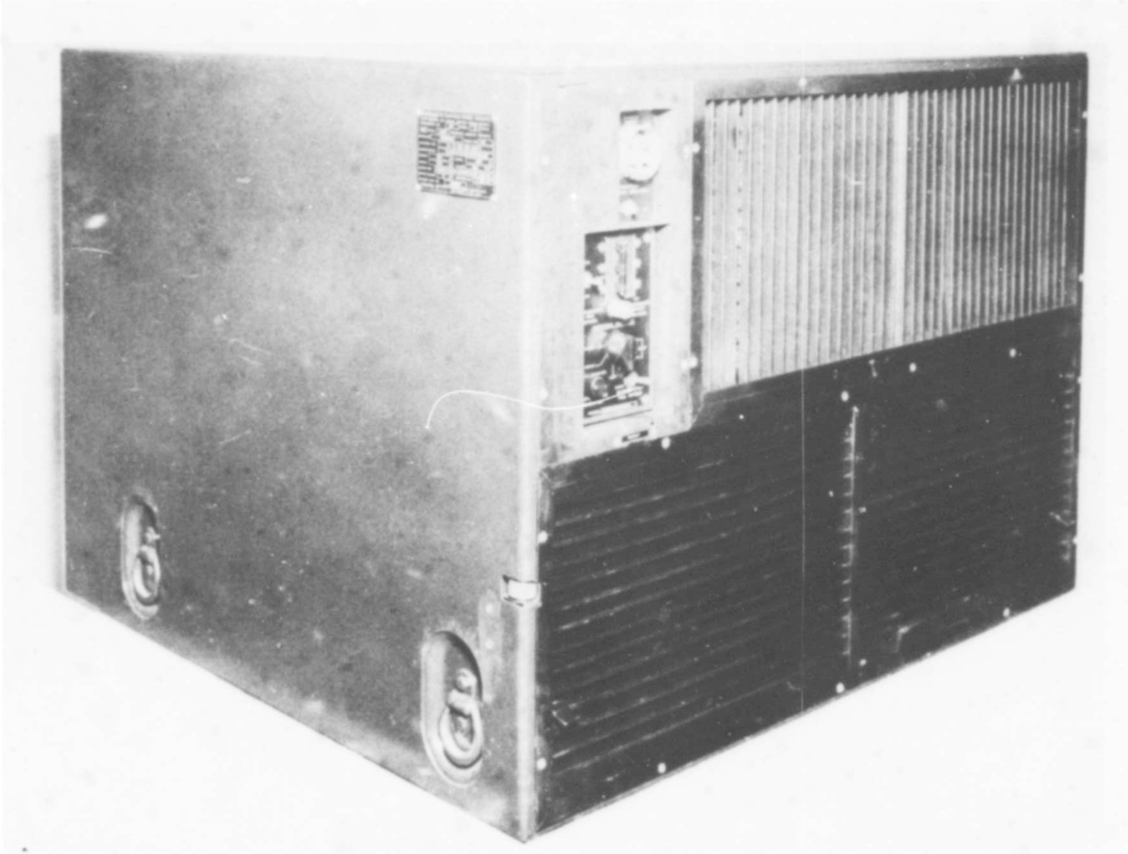

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Fig. 1. Front and left side of 36,000-Btu/hr, compact, horizontal, air-conditioning unit.

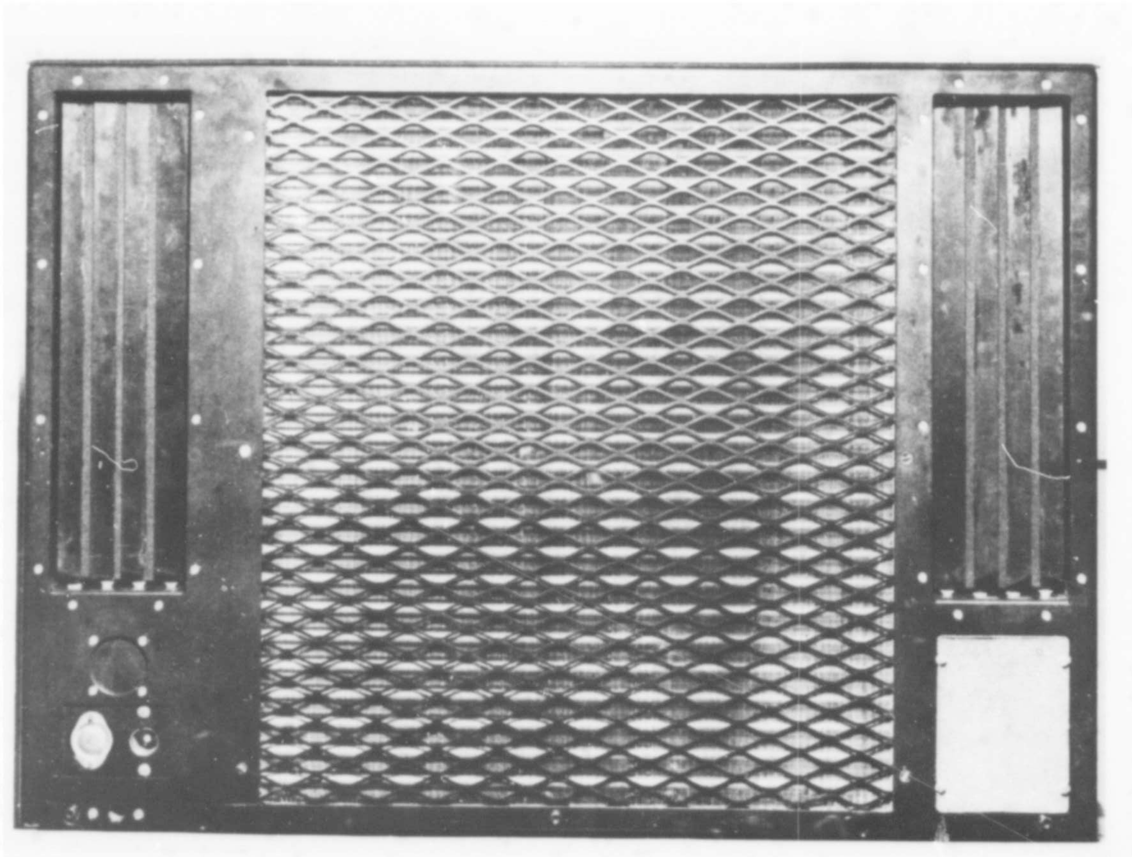

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Fig. 2. Rear of 36,000-Btu/hr, compact, horizontal, air-conditioning unit.

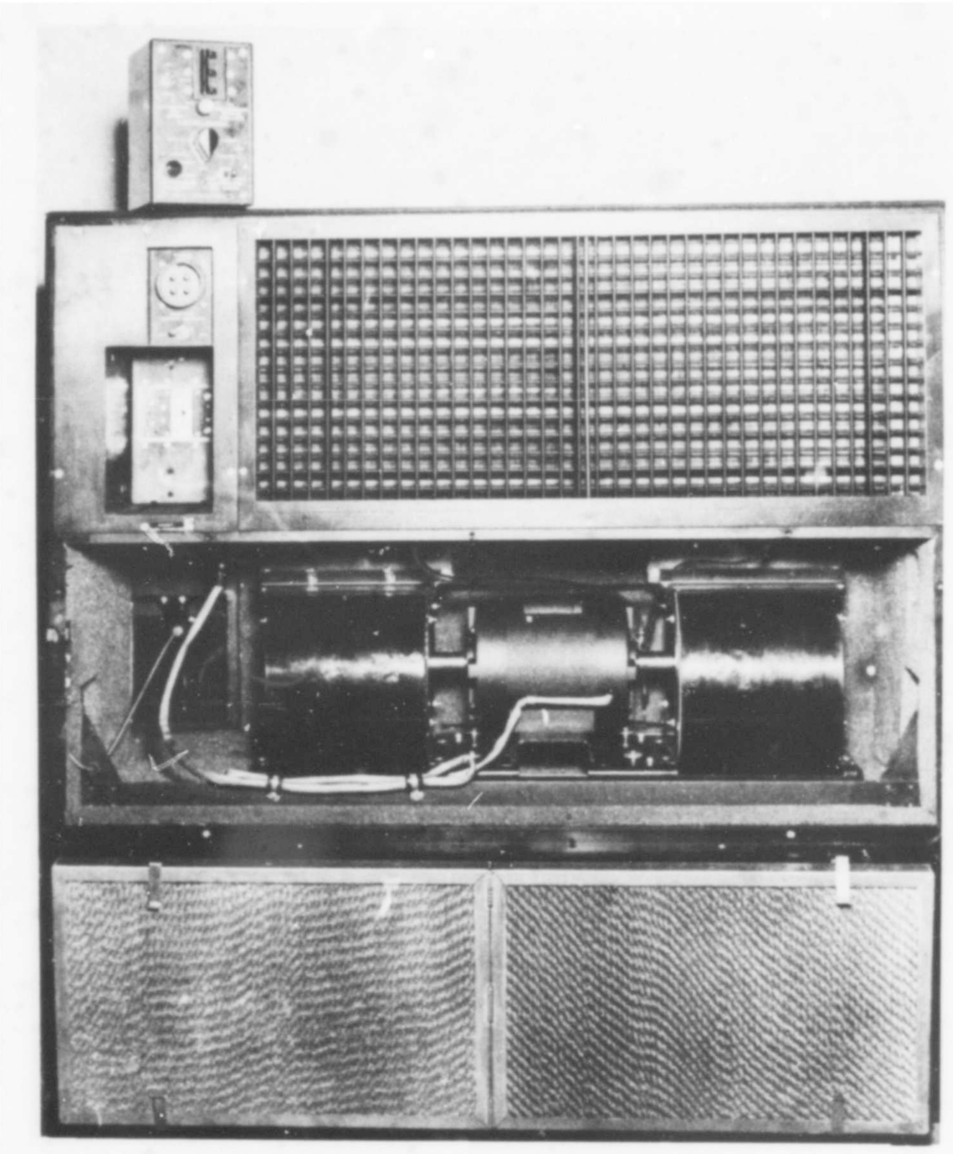

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Fig. 3. Front of 36,000-Btu/hr, compact, horizontal, air-conditioning unit, with return-air grille and control module removed.

left, by means of a flexible cable. The lower portion of the front contains the inlet grille and filter assembly. The inlet grille is finger adjustable from fully open to fully closed. This adjustment, in conjunction with the ventilation damper control, can provide some selection in the degree of simultaneous ventilation and cooling; but the maximum internal cooling occurs with the inlet grille fully open and the ventilation damper fully closed. The inlet grille and filter can be removed simultaneously, and the filter can be separated for cleaning and servicing. Application of a filter fluid after each cleaning is indicated.

A transformer and rectifier provide for the electrical control components of the unit to operate on 24-volt direct current. The direct-current control system is used for either the 60-hertz or the 400-hertz unit. Major portions of the control components are interchangeable among units of different electrical characteristics as well as other units of the compact, horizontal family. The electrical controls consist of the following components: Wiring, selector switch, thermostat, electric heater contactor, compressor contactor, condenser fan motor contactors, compressor circuit breaker, control circuit breaker, transformer, rectifier, time delay relay, temperature protectors, pressure protectors, a phase sequence protector, and an evaporator fan motor speed selector switch. Each wire is number coded and can be traced by reference to the wiring diagram. The selector switch, located in the control panel with a knob extending through the front access panel, has five modes or positions: HI-HEAT, LO-HEAT, OFF, VENTILATE or VENT, and COOL. The OFF mode electrically disconnects all power from the control circuit. (The compressor is equipped with an electrically energized, thermostatically controlled crankcase heater. The heater circuit opens at crankcase temperatures between 115° F and 125° F and closes at crankcase temperatures between 100° F and 110° F. This controlled heat application keeps the crankcase oil sufficiently free from refrigerant. The heater circuit is energized, regardless of the switch position, provided that the unit is electrically connected to a power source.) The LO-HEAT mode provides thermostatic operation of one-half the heaters and continuous evaporator fan operation. The HI-HEAT mode provides constant operation of the remaining heaters in addition to the LO-HEAT functions. The VENT mode provides continuous evaporator fan operation without any cooling or heating. The COOL mode provides continuous compressor, evaporator fan, and condenser fan operation. The cooling function of the unit is controlled by the adjustable thermostat, located in the control panel next to the selector switch. The thermostat controls the refrigerant liquid line solenoid valve in response to the return-air temperature. This causes the refrigerant system to be either in the cooling cycle or in the bypass cycle of operation. When the compressor stops operating (for any reason), a normally open solenoid valve allows the suction and head pressures to equalize. The thermostat, which has an adjustment range of 60° F to 90° F, has a remote sensing bulb located in the evaporator return-air plenum. In the COOL mode, higher return-air temperatures than the thermostat setting will cause the unit to cool the air by the normal cooling cycle. Lower return-air temperatures than the thermostat setting will cause the unit to be in the bypass cycle and therefore not perform any cooling function.

Recessed lifting rings are located in the lower sides. The data plate appears on the right side, and the access panels are on the left side.

The condenser or outside ambient air inlet opening is at the rear of the unit. The condenser air-discharge louvers are on each side of this opening. The fresh-air (or CB) inlet opening (at the lower right) is covered by a screen behind which the fresh-air filter is mounted. Directly below the left-hand discharge louver is the access for an auxiliary power connector below which the condenser fan speed control thermostat, and the sight glass (refrigerant) are located. The open holes in the bottom flange are for condensate drainage.

An interior wall or divider separates the front (evaporator section) from the rear (condenser section). This divider is provided with air-tight openings for refrigerant piping, connectors for power distribution, and insulation to minimize noise and heat transfer.

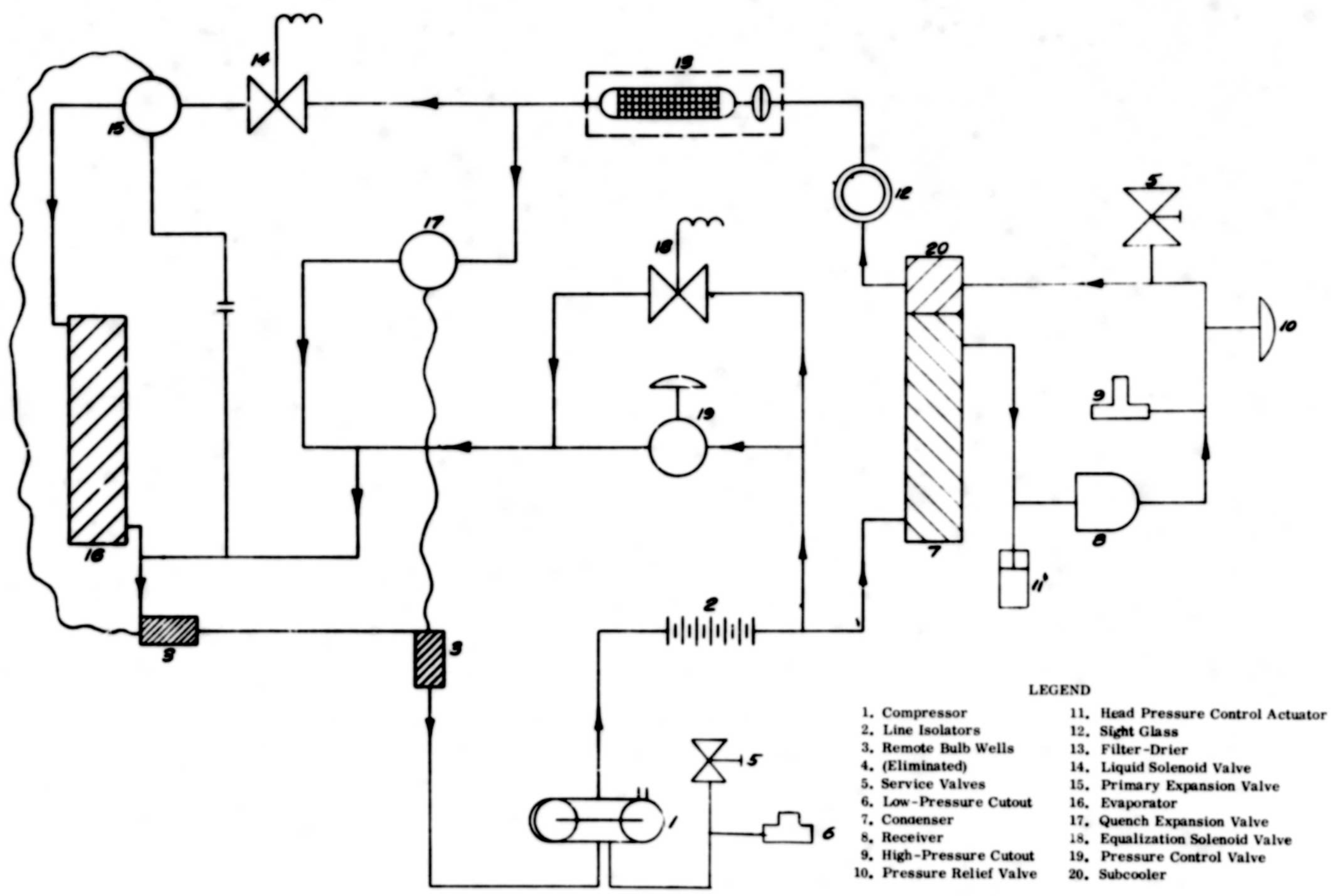
The evaporator section contains the control module (previously described), circuit components (time delay relay, transformer, rectifier, control circuit breaker, contactors, high- and low-pressure cutouts, terminal strips, phase sensing relay, and the main power receptacle), the evaporator fan assembly, the heaters, and that portion of the refrigerant circuit which contains the evaporator and the thermoexpansion valve (TEV). The two evaporator air impellers are double, forward curved centrifugal fan wheels mounted on the motor shaft and inclosed in fiber glass-lined shrouds. The return airflow is controlled by thumb latches on the return-air grilles, and the ventilation air damper is controlled by the thumb knob as has been described. The evaporator fan motor speed (high or low) is controlled by a toggle switch on the control panel. The fans pull air through the inlet grille-filter combination, the fresh-air filter, or both. This air is pushed over the heaters, through the evaporator coil, and from the unit through the outlet grille.

The rear or condenser section contains the bulk of the refrigerant circuit and controls as well as the two condenser fan assemblies.

The drivers for the propeller fan wheels are identical two-speed motors. The fans are the same diameter, but one has four blades and the other five. This difference provides quieter operation. The fan housings are volute shrouds, and louvers are at the discharge of each housing. Condenser airflow is automatically controlled by the speed of the fan motors and the amount of discharge louver opening. An outdoor thermostat automatically controls the fan motor speed. The motors are in high speed at ambients above 100° F and are in low speed at ambients below 100° F. The degree of louver opening is controlled by the actuator or head-pressure controller in the high-pressure side of the refrigerant circuit. Link-cable mechanisms between the actuator and the louvers cause increased louver opening as refrigerant pressure rises and decreased louver opening as this pressure falls. The actuator is fully extended (louvers fully open) at head pressures of 250 psig or higher, and it is completely retracted (louvers closed) at pressures at or below 165 psig.

The refrigerant employed is R-22 which is circulated through a closed fluid circuit as illustrated schematically on Fig. 4. The compressor pumps the refrigerant through this circuit by first drawing low-pressure superheated vapor through the suction line and then discharging the vapor at condensing pressure and high superheat.

When the unit is cooling (mode selector switch cool, thermostat cooler) all the refrigerant flows into the condenser. The condenser fans force sufficient ambient air over the condenser surfaces to condense the refrigerant. Flow continues to the receiver which separates any vapor, and allows only liquid refrigerant to flow into the subcooler (the condenser and subcooler are contained in a common heat exchanger assembly). Between the receiver and the subcooler four functional components are branched into the piping. Two are safety devices; the high-pressure cutout and the pressure relief valve. The others are a service valve used for the addition or removal of refrigerant; and a head pressure control actuator which controls the ambient air delivery rate. The condition of the refrigerant can be observed as it flows through the sight glass (flush with the rear face of the unit). Later, the filter-drier removes any moisture and solid contaminants, and the clean liquid flows through the liquid solenoid valve and into the thermoexpansion valve. The TEV adjusts the refrigerant flow to the cooling load by the interaction of the temperature control and the pressure control embodied in the valve. The temperature control consists of a long flexible tube reaching from the valve to the remote bulb located in a well near the evaporator. The pressure equalizer is a tube connecting the valve pressure chamber with the refrigerant line near the remote bulb well. The valve throttles the liquid refrigerant to the suction pressure. As the fluid passes



LEGEND

1. Compressor
2. Line Isolators
3. Remote Bulb Wells
4. (Eliminated)
5. Service Valves
6. Low-Pressure Cutout
7. Condenser
8. Receiver
9. High-Pressure Cutout
10. Pressure Relief Valve
11. Head Pressure Control Actuator
12. Sight Glass
13. Filter-Drier
14. Liquid Solenoid Valve
15. Primary Expansion Valve
16. Evaporator
17. Quench Expansion Valve
18. Equalization Solenoid Valve
19. Pressure Control Valve
20. Subcooler

Fig. 4. Refrigerant system schematic.

through the evaporator, the evaporator fans blow return air over the evaporator surfaces. The heat rejected by the air causes the liquid to evaporate and acquire a predetermined slight superheat. Downstream from the evaporator a service valve identical to that already described, and a low-pressure (safety) cutout are branched into the line. The superheated vapor flows through the suction line and into the compressor, thus completing the circuit. Under extremely rigorous conditions (full cooling may not be possible), the quench valve located in a line reaching from a point downstream from the filter-drier to a point near the thermoexpansion valve bulb well, maintains suction line temperature. The sensing bulb for the quench valve, located in a bulb well downstream from the thermoexpansion valve remote bulb well, can sense excess superheat. If sufficient flow cannot be provided by the thermoexpansion valve, the quench valve will allow flow of sufficient liquid to relieve this condition. A pressure control valve in a line reaching from a point upstream from the condenser to the quench valve output line can allow flow of sufficient high-pressure vapor to relieve any low-pressure situation beyond the capability of the thermoexpansion valve.

When the unit is in BYPASS (mode selector switch COOL, thermostat warmer) the liquid solenoid valve is closed, and all the refrigerant flow is divided between the pressure control line, and the quench valve line. The functions of these valves have just been described.

When the unit is turned off, the equalization solenoid valve (which parallels the pressure control valve) opens, thus equalizing the suction and discharge pressures. After restart of the unit in the COOL mode the equalization solenoid valve closes, and the suction and discharge pressures being equal allow the compressor to start with a minimum current surge.

The fan motors have two speeds, sealed bearings, and require no lubrication. The majority of the control components are interchangeable between the two models, as well as other units of the compact, horizontal family.

5. Test Objectives, Methods, and Results. Tests were initiated on the initial prototype unit. Tests not conducted at USAMERDC (formerly USAERDL) by USAMERDC personnel were supervised or monitored by the Senior Project Engineer. During initial testing all deficiencies were corrected. Final testing followed, and the findings in this report represent the tests on the final prototype air conditioners.

a. Cooling Capacity. The cooling capacity tests were conducted to determine the net cooling capacities at specific test conditions (Table I).

Table I. Cooling Capacity Test Conditions

Test Condition*	Fan Speed, Evaporator-Condenser	Air Temperature on Condenser (°F)	Air Temperature on Evaporator (°F)		Sensible Heat Factor (%)	External Static Pressure (in. of water)
			Dry Bulb	Wet Bulb		
1**	HI/HI	120	90.0	75.0	65-80	0
2***	HI/HI	120	90.0	75.0	65-80	0
3	HI/HI	120	90.0	67.5(max)	100	0
4	HI/HI	120	90.0	67.5(max)	100	0.125
5	HI/HI	120	90.0	67.5(max)	100	0.250
6	HI/HI	95	80.0	67.0	65-80	0
7	HI/LO	95	80.0	67.0	65-80	0
8	LO/LO	95	80.0	67.0	65-80	0
9	HI/HI	95	80.0	58.0(max)	100	0
10	HI/LO	95	80.0	58.0(max)	100	0

* Conditions 1, 2, 3, 5, 7, and 8 are used in the cooling capacity tests described in paragraph 5a in this report.

** Section II, Development Requirement cited in paragraph 3a(1) in this report.

*** Applies to 60-Hz (50-Hz input frequency) Model MC40HA L6-208 air conditioner, only.

The Technical Characteristics require a cooling capacity of 36,000 Btu/hr under test condition 1, and each model unit was so tested. Because of design similarity, no unit was subjected to all ten test conditions, but sufficient tests were completed on both models to determine adequacy. The cooling capacity tests were conducted using the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 37-60, Methods of Testing for Rating Unitary Air Conditioning Equipment (5) modified to incorporate military test requirements. The tests were run in a psychrometric test chamber (Fig. 5) where the air enthalpy method was employed. The cooling capacity measuring apparatus utilized code testers attached to both the evaporator air-discharge opening and the condenser air-discharge openings. Each code tester consisted of a mixing section, a sampling tree section, a nozzle section, a fan discharge section, and an adjustable damper section mounted in an insulated rectangular duct. Stable room conditions were obtained before data were recorded for the specific test conditions. Primary test runs were made under all the specific test conditions with the condenser side in free blow (without outside room ductwork attached). The evaporator side was adjusted to maintain zero differential pressure between the evaporator discharge and evaporator return. The air-conditioner capacity was then calculated from the evaporator air side, and differential pressures were measured across the code tester nozzles. The electrical power data supplied to the air conditioner were recorded and were to be used for calculating unit capacity from the condenser side. Refrigerant head pressures, which were to be used for setting the condenser discharge pressure during secondary runs, were recorded. The secondary runs were made after the primary runs were completed. The outside room code tester was attached to the condenser air discharge. After stable room conditions were obtained, the condenser air discharge was varied until the refrigerant head pressure became identical to the head pressure recorded during the primary run. The evaporator discharge and return air were kept at zero static pressure. Both evaporator capacity and condenser capacity were then calculated from the air temperatures and differential pressures which had been measured across the code tester nozzles. The calculated condenser capacity less the air-conditioner power gave an evaporator cooling capacity check. In order to be considered acceptable runs, the difference between the evaporator side capacity and the condenser side capacity as measured during the secondary run, divided by the calculated capacity, must be within a 6 percent balance.

For the test, the air conditioner was mounted in the outside room with the evaporator air side flush with the inside room surface of the separating wall. Cloth tape and foam rubber insulating strips were used around the side panels to prevent leakage between the two rooms. The

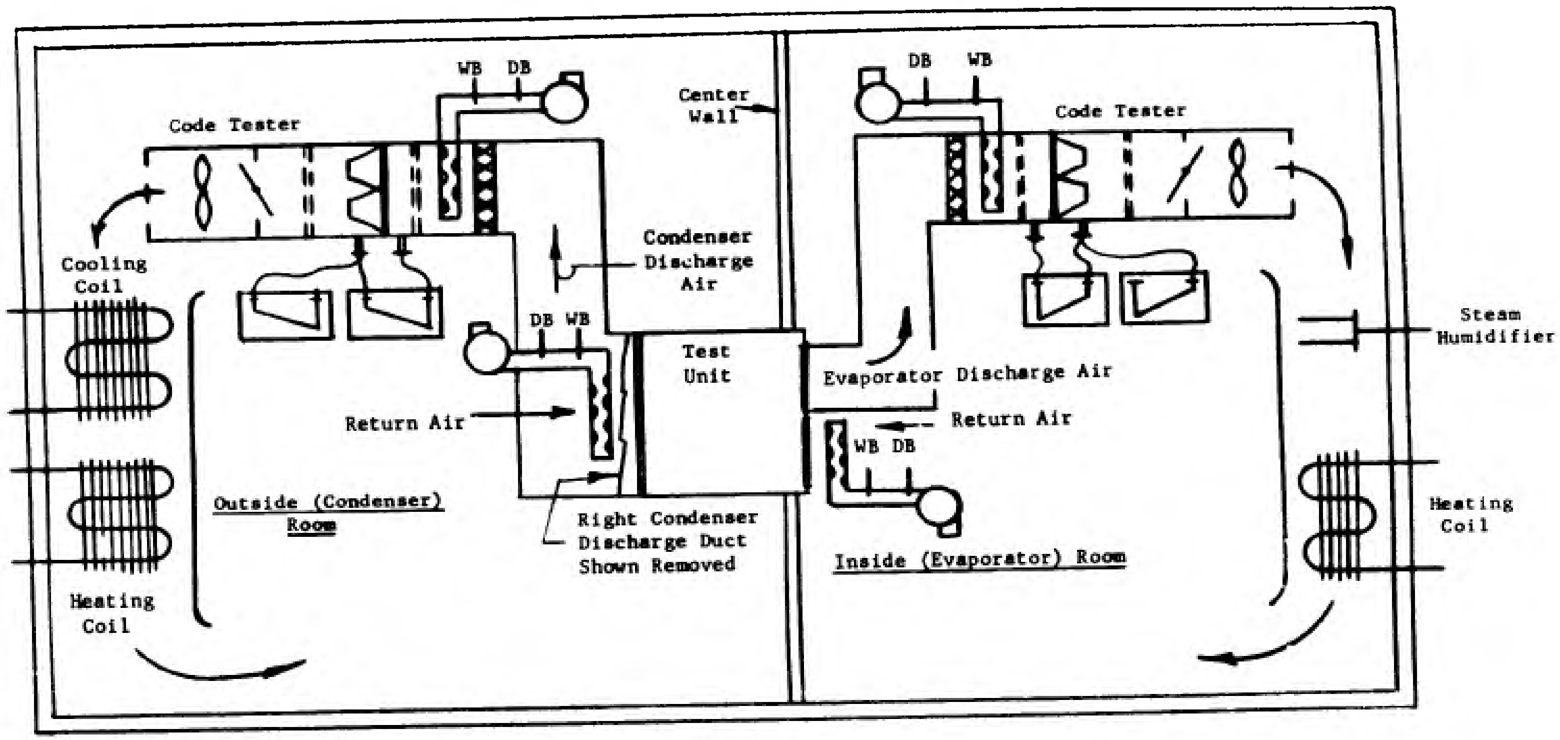


Fig. 5. Psychrometric test chamber.

ductwork attached to the evaporator discharge and condenser discharge was well-insulated to minimize temperature rise or fall in the duct. The test unit controls were set for maximum cooling with the ventilation air damper closed. Condition of the refrigerant was evaluated by visual observation of a moisture-content- and refrigerant-charge-indicating sight glass. Electrical characteristics were continuously recorded and evaluated during each operational test by use of accurately calibrated instruments.

Results of the cooling capacity tests are presented in Tables II and III.

b. Heating Capacity. The heating capacity tests were conducted to determine the total net heating capacities and the electrical characteristics of the units in this mode of operation. Because the air-conditioner heaters are electrical-resistance-type tubular strips, the heating capacities were determined by the thermal equivalents of the power inputs. Previous test experience revealed that the difference between this equivalent and the value obtained by airflow and psychrometric analyses is negligible.

Results of the heating capacity tests are presented in Table IV.

c. Evaporator Airflow. The evaporator airflow test was conducted to determine the standard airflow (scfm) rate of the evaporator fan when operating at external static pressures which ranged from 0 to 1.0 inch of water.

Airflow tests were conducted and flow rates were calculated in accordance with ASHRAE Standard 37-60 modified to incorporate military test requirements. The tests were run in the psychrometric test chamber.

The airflow measuring apparatus (code tester) consisted of a mixing section, a sampling tree section, a nozzle section, a fan discharge section, and an adjustable damper section fitted into an insulated duct. The mixing section consisted of a series of vanes arranged to divide the airflow into a number of small streams and then divert the streams across each other. The condition of the air was determined by wet-bulb and dry-bulb temperature readings as recorded through the sampling tree section. Static-pressure taps were located before and after the nozzles for determinations of pressure drop across the nozzles. The adjustable damper section consisted of an adjustable iris which could be closed to

Table II. Results of Cooling Capacity Test, Model MC40HA L6-208

Measurement	Test Condition					
	1	2	3	5	7	8
Capacity (Btu/hr)						
Total	42,800	36,600	41,400	40,000	40,600	35,700
Latent	11,600	0	0	0	8,200	12,900
Sensible	31,200	36,600	41,400	40,000	32,400	22,800
Sensible Heat Factor (%)	73.0	100	100	100	79.5	63.9
Coefficient of Performance (Btu/hr/watt)	4.55	4.88	4.50	4.40	5.47	5.91
Air Temperatures (°F)						
Entering Evaporator, Dry Bulb	90.1	90.0	90.2	90.1	79.9	80.1
Entering Evaporator, Wet Bulb	74.9	59.1	59.1	59.1	66.9	66.9
Leaving Evaporator, Dry Bulb	67.0	47.6	48.3	47.1	58.7	49.1
Outside Room Temperature (°F)	120.5	120.2	119.3	120.4	94.9	94.9
Evaporator Airflow (scfm)	1,210	1,230	1,430	1,340	1,380	660
Refrigerant Temperatures (°F)						
Superheat at Bulb	12	27	29	28	21	30/24
Subcooling at Condenser	5	10	10	9	20	18/19
Discharge Pressure (psig)	378	376	376	377	367	329/340
Suction Pressure (psig)	96.4	86.0	84.5	84.0	79.0	65.0/68.0
Electrical Characteristics						
Average Voltage	208	208	208	208	208	208
Average Amperage	29.0	27.5	28.8	28.7	23.5	19.4
Total Wattage	9,400	7,250	9,160	9,100	7,440	6,030
Power Factor (%)	86.0	75.8	88.2	87.9	87.9	86.3

Table III. Results of Cooling Capacity Test, Model MC40HAL4-208

Measurement	Test Condition				
	1*	3	5	7	8
Capacity (Btu/hr)					
Total	45,700	44,800	44,100	44,700	39,600
Latent	8,100	0	0	8,300	14,700
Sensible	37,600	44,800	44,100	36,400	24,900
Sensible Heat Factor (%)	82.3	100	100	81.4	63.0
Coefficient of Performance (Btu/hr/watt)	3.98	3.96	3.86	4.45	4.89
Air Temperatures (°F)					
Entering Evaporator, Dry Bulb	89.9	89.8	89.9	80.1	80.0
Entering Evaporator, Wet Bulb	74.8	65.0	64.6	67.1	67.1
Leaving Evaporator, Dry Bulb	68.5	64.9	64.1	59.2	49.2
Outside Room Temperature (°F)	125.1	120.2	120.3	95.5	94.9
Evaporator Airflow (scfm)	1,480	1,575	1,515	1,545	710
Refrigerant Temperatures (°F)					
Superheat at Bulb	4	11	11	3/11	5/7
Subcooling at Condenser	15	7	8	20	21
Discharge Pressure (psig)	392	368	367	357	320
Suction Pressure (psig)	94.2	86.0	85.0	79.0	67.0
Electrical Characteristics					
Average Voltage	208	208	208	207	209
Average Amperage	47.3	46.7	46.4	40.7	35.2
Total Wattage	11,730	11,540	11,460	10,020	8,080
Power Factor (%)	68.8	68.6	68.5	68.6	63.4

* Outside room temperature 125.1° F (5° F above standard test).

Table IV. Results of Heating Capacity Tests

Measurement[a]	Model			
	MC40HA L6-208		MC40HA L4-208	
	HI-HEAT	LO-HEAT	HI-HEAT	LO-HEAT
Capacity (Btu/hr)	32,900	18,700	36,600	21,900
Air Temperatures (^{o}F), Dry Bulb				
Entering Evaporator	70	70	75	72
Leaving Evaporator	88	81	95	84
Electrical Characteristics				
Average Voltage	209	209	208	208
Average Amperage	27.1	15.3	29.9	18.5
Total Wattage	9,660	5,470	10,730	6,420
Power Factor (%)	98.6	98.9	99.7	96.3
Evaporator Airflow (scfm)[b]	1,470	1,470	1,630	1,630
Fan Speed (rpm)	3,390	3,380	3,780[c]	3,780[c]

Notes: (a) External static pressure (in. of water) was 0 for both air-conditioner models.

(b) The airflow values for both models were obtained from the evaporator airflow test (paragraph 5c).

(c) The fan speed values for Model MC40HA L4-208 were also obtained from the evaporator airflow test.

increase the static pressure. The test was conducted with a dry evaporator coil and return air entering the evaporator section at zero static pressure or atmospheric conditions. The test was started with an external static pressure of 0 inch of water at the evaporator discharge and then varied from 0 to 1.0 inch of water.

Results of the evaporator airflow tests are given in Table V.

Table V. Results of Evaporator Airflow Tests

Measurement	External Static Pressure (in. of water)				
	0	0.25	0.50	0.75	1.00
Model MC40HAL6-208					
Airflow (scfm)	1,470	1,370	1,280	1,200	1,130
Filter Face Velocity (fpm)	490	457	428	399	377
Electrical Characteristics					
Average Voltage	208	208	208	208	208
Average Amperage	3.6	3.5	3.7	3.3	3.2
Total Wattage	1,190	1,150	1,100	1,040	1,000
Fan Speed (rpm)	3,430	3,440	3,440	3,450	3,460
Model MC40HAL4-208					
Airflow (scfm)	1,630	1,550	1,480	1,410	1,320
Filter Face Velocity (fpm)	545	517	492	471	440
Electrical Characteristics					
Average Voltage	207	206	208	208	208
Average Amperage	8.1	7.9	7.7	7.6	7.3
Total Wattage	1,860	1,810	1,760	1,700	1,620
Fan Speed (rpm)	3,780	3,750	3,780	3,780	3,800

Note: Entering evaporator air temperature was approximately 80^{o} F dry bulb, 57^{o} F wet bulb for each airflow test.

d. Condenser Airflow. The condenser airflow test was conducted to determine the airflow (cfm) rate of the condenser fan during operation at external static pressures that ranged from 0 to 0.5 inch of water.

Airflow tests were conducted and flow rates were calculated in accordance with ASHRAE Standard 37-60 modified to incorporate military test requirements.

The airflow measuring apparatus (code tester) consisted of a mixing section, a sampling tree section, a nozzle section, a fan discharge section, and an adjustable damper section fitted into an insulated duct. The mixing section consisted of a series of vanes arranged to divide the airflow into a number of small streams and then divert the streams across each other. The condition of the air was determined by wet-bulb and dry-bulb temperature readings as recorded through the sampling tree section. Static-pressure taps were located before and after the nozzles for determinations of pressure drop across the nozzles. The adjustable damper section consisted of an iris which could be closed to increase statis pressure. The test was conducted with a dry condenser coil and cooling air entering the condenser section at zero static pressure or atmospheric conditions. The test was started with an external static pressure of 0 inch of water at the condenser discharge and then varied from 0 to 0.5 inch of water. The test unit was operated in the COOL mode during the test. Both total electrical power input and condenser fan power input were recorded. The test results are presented in Table VI.

e. Ventilation. The ventilation test was conducted to determine the quantity of fresh air in standard cubic feet per minute supplied through the fresh-air inlet.

The entire evaporator face of each test unit was connected to the receiving end of a portable code tester via a short length of duct. Readings of velocity pressures across the nozzles and wet- and dry-bulb temperatures of the air were recorded at different combinations of box-static pressures and return-air damper positions. Ventilating rates were computed from these data, and the results are shown in Table VII.

f. Air Recirculation. The air recirculation test was conducted to determine the effect of air recirculated or short cycled between the evaporator air discharge and the evaporator air return and between the condenser air discharge and the condenser air intake.

Table VI. Results of Condenser Airflow Tests

Measurement(a)	External Static Pressure (in. of water)				
	0	0.125	0.250	0.375	0.500
MC40HA L6-208					
Airflow (scfm)	2,130	2,070	2,000	1,960	1,910
Coil Face Velocity (fpm)	570	565	550	535	520
Air Temperatures (°F), Dry Bulb Entering Condenser	118.8	119.3	119.1	120.0	120.3
Electrical Characteristics					
Average Voltage	208	-(b)	-	-	-
Average Amperage	6.02	-	-	-	-
Total Wattage	1,790	-	-	-	-
Fan Speed (rpm), Left	3,460	3,460	3,470	3,460	3,450
Right	3,440	3,450	3,450	3,450	3,440
MC40HA L4-208					
Airflow (scfm)	2,740	2,650	2,610	2,520	2,420
Coil Face Velocity (fpm)	730	725	715	690	660
Air Temperatures (°F), Dry Bulb Entering Condenser	120.1	121.4	120.4	119.6	120.8
Electrical Characteristics					
Average Voltage	212	-	-	-	-
Average Amperage	11.1	-	-	-	-
Total Wattage	2,520	-	-	-	-
Fan Speed (rpm), Left	3,790	3,800	3,780	3,780	3,780
Right	3,800	3,780	3,760	3,780	3.780

Notes: (a) All electric values were computed. Unit was operational during tests of both models.
(b) Hyphens signify that no data were taken.

Table VII. Results of Ventilation Airflow Tests

Measurement	Fresh-Air Damper Full Open Return-Air-Grille Position Open	 Closed
Model MC40HA L6-208		
Airflow (scfm)	72	163
Evaporator Fan Speed (rpm)	3,410	3,390
Model MC40HA L4-208		
Airflow (scfm)	85	188
Evaporator Fan Speed (rpm)	3,720	3,740

Notes: 1. Entering ventilation air temperature was approximately 75° F dry bulb, and approximately 55° F wet bulb for both tests.

2. Chamber pressure was zero for both tests.

This test was conducted in the psychrometric test chamber with the outside room temperature at 120° F and the inside room at 90° F dry conditions. After stable thermal equilibrium was reached in the rooms with the air conditioner in the maximum cooling mode, temperature and pressure readings were recorded. A baffle plate was then placed between the air-return openings and air-discharge openings on the evaporator side in order to eliminate short cycling. Readings were taken at 10-minute intervals. The test on the evaporator side required that air recirculated between the evaporator air discharge and evaporator air return should not cause the compressor refrigerant suction pressure to increase more than 2 psig with the evaporator baffle plate installed. A baffle plate was then placed between the air-return openings and air-discharge openings on the condenser side in order to eliminate short cycling. The test on the condenser side required that air recirculated between the condenser air return and condenser air discharge should not cause the compressor refrigerant discharge pressure to increase more than 3 psig from that measured with the condenser baffle plate installed.

Results of the air recirculation tests are given in Table VIII.

Table VIII. Results of Air Recirculation Tests

Measurement	Evaporator		Condenser	
	No Baffle	Baffle	No Baffle	Baffle
Model MC40HAL6-208				
Air Temperatures (^oF), Dry Bulb				
Inside Room	90	90	90	90
Outside Room	120	120	120	120
Entering Evaporator	90.4	89.9	90.4	90.4
Leaving Evaporator	68.5	69.4	68.5	68.3
Entering Condenser	120.3	120.2	120.3	120.7
Leaving Condenser	145.2	144.9	145.2	146.5
Discharge Pressure (psig)	374	375	374	378
Suction Pressure (psig)	84.0	83.5	84.0	83.5
Average Voltage	208	208	208	209
Average Amperage	29.1	28.5	29.1	28.9
Total Wattage	9,340	9,285	9,340	9,260
Model MC40HAL4-208				
Air Temperatures (^oF), Dry Bulb				
Inside Room	90	90	90	90
Outside Room	120	120	120	120
Entering Evaporator	90.1	89.8	90.1	89.8
Leaving Evaporator	68.5	68.8	68.5	68.0
Entering Condenser	119.6	119.6	119.6	119.6
Leaving Condenser	149.6	150.0	149.6	149.5
Discharge Pressure (psig)	373	375	373	371
Suction Pressure (psig)	87.5	88.5	87.5	86.5
Average Voltage	208	208	208	208
Average Amperage	46.8	46.9	46.8	46.7
Total Wattage	11,600	11,600	11,600	11,480

g. Chemical Biological. The units are provided with an opening for attaching ductwork from an external CB filtering device. Examination by Defense Development Engineering Laboratories (DDEL) personnel indicates that the design is compatible with CB mode operation. The unit has a blowthrough evaporator which reduces the negative pressure at the suction of the air-conditioner evaporator fan. This arrangement requires the least output from the CB filter fan to maintain a positive pressure at the suction of the air-conditioner evaporator fan.

Tests were conducted to determine the evaporator air leakage rate and the static pressure at the collective protection system at various vent airflow rates.

(1) A blowthrough airflow meter was installed at the ventilation air inlet. The evaporator air inlet and outlet were completely sealed. The evaporator compartment was kept at a static pressure of 1.0-inch water gage by applying sufficient air at adequate pressure. Leakage readings were taken with the condensate drain open and closed. The comparative results of the leak test are presented in Table IX.

Table IX. Results of Evaporator Leak Test

Measurement	Drain Open	Drain Closed
Nozzle Pressure Drop (in. of water)	0.57	0.54
Airflow (scfm)	16	16
Air Temperatures (^{o}F)		
Entering Nozzle, Dry Bulb	81.8	82.3
Entering Nozzle, Wet Bulb	64.8	64.3
Static Pressure (in. of water)	1.00	1.00
Nozzle Factor	5.85	5.85

(2) The unit was operated free from any enclosure in the VENT mode with the return air and ventilation damper fully open (an enclosure static pressure of 0-inch water gage was simulated) and with the evaporator fan at high speed. A blowthrough air meter was used to establish ventilation airflow rates of 100, 200, and 300 cfm. The static pressure at the connection of the collective protection system to the air conditioner was recorded. The results are given in Table X.

Table X. Results of Static Pressure Test

Measurement	Nominal Air Delivery (cfm)		
	100	200	300
Nozzle Pressure Drop (in. of water)	1.34	1.06	2.38
Airflow (scfm)	102	203	306
Air Temperatures (^{o}F)			
Entering Nozzle, Dry Bulb	93.1	83.2	88.0
Entering Nozzle, Wet Bulb	66.6	63.8	65.9
Static Pressure (in. of water)	-0.16	-0.05	+0.14
Nozzle Factor	23.50	53.00	53.00

These results just given are plotted on Fig. 6.

In order to determine the requirements for a collective protection delivery system for an airflow rate between 100 and 300 cfm, find the static pressure corresponding to the required airflow from Fig. 6. Add to this the sum of the shelter pressure required plus the pressure drop in the collective protection system for this rate. The required characteristics of the collective protection fan wheel can then be determined.

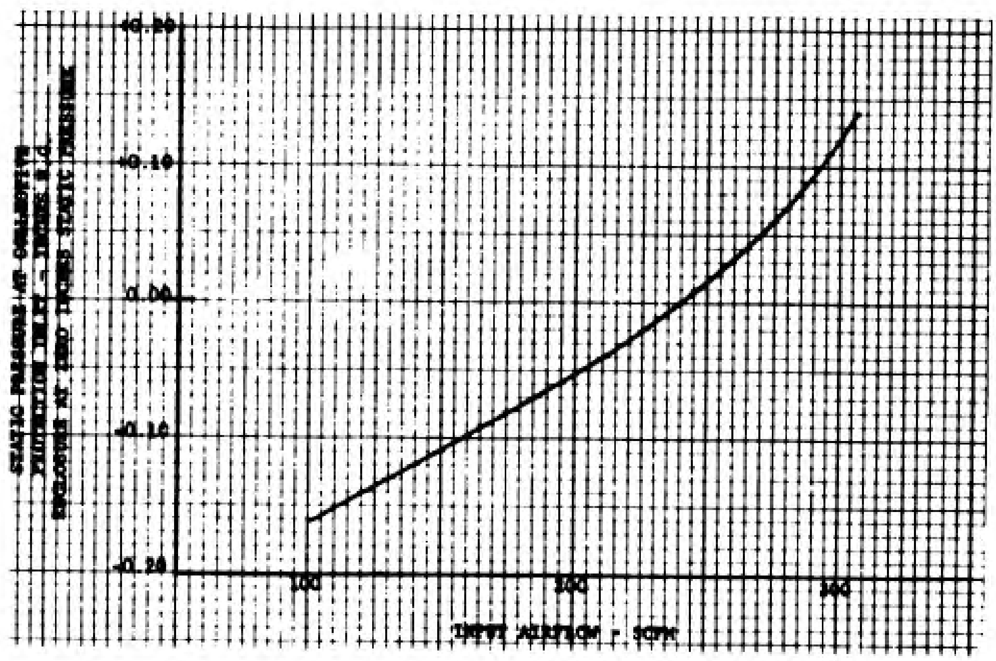


Fig. 6. Collective protection inlet static pressures vs input air delivery rates (enclosure static pressure of 0-in. water).

h. Operating Controls. Tests of the operating controls were conducted to verify thermostat and selector switch operation in each position or mode.

(1) Thermostat. The thermostat test was conducted to determine if the thermostat functioned properly and in accordance with design specifications. Tests A through D were conducted by the Development Branch (formerly the Instrumentation Division), USAMERDC (formerly USAERDL). The thermostat was tested by submerging the bulb of the power element assembly into a water bath. The temperature of the water was raised by a submerged electrical heater with variable control. The temperature was lowered with dry ice. Throughout the bath, even temperatures were maintained with a circulating pump. A low direct-current voltage was applied to the electric terminals of the thermostat in conjunction with a buzzer to determine the making and breaking of the contacts. The temperature of the water bath was measured by a calibrated, laboratory-type thermometer. The ambient temperature surrounding the test assembly was controlled as shown in Table XI. The ambient temperature was measured by a calibrated laboratory-type thermometer. Three new thermostats identified as 1, 2, and 3 were employed for Tests A, B, and C, respectively. Three old thermostats identified as 302, 303, and 304 were used for Test D.

All phases of the tests were repeated four times, and the data obtained were averaged for report purposes. All tests were conducted at an ambient temperature of 72° F unless indicated otherwise.

(a) Test A, Operating Range. The operating range test was conducted in two steps:

Step 1, Low Setting. The thermostats were set to the maximum decrease temperature position. The water bath temperature was lowered with dry ice, and temperatures were recorded as the thermostats were actuated. The water bath temperature was raised until the thermostat contacts were opened, and the temperatures were recorded.

Step 2, High Setting. The thermostats were set to the maximum increase temperature position, and the water bath temperature was raised until the thermostats were

Table XI. Results of Thermostat Test

TEST A

Operating Range at +72° F Ambient Temperature

Setting	New Thermostats No. 1	No. 2	No. 3	Average
Low	40.5	37.0	39.9	39.1
High	90.9	91.5	89.9	90.4

TEST B

Operating Differential at +72° F Ambient Temperature

Thermostat	Setting in °F 40	50	60	70	80	90	Average
1	1.8	3.3	2.3	2.0	1.9	2.4	2.3
2	2.4	2.5	2.5	2.9	1.9	2.2	2.4
3	2.9	2.0	2.3	2.3	2.2	3.2	2.5

TEST C

Effect of Ambient Temperature on Operating Range

Setting	72° F Ambient	150° F Ambient	150° F Ambient + 160° F Preheat
Low	39.9	38.9	40.6
High	89.9	86.2	87.8

Table XI (cont'd)

Effect of Ambient Temperature on Differential

Ambient Temperature	Setting in °F						Average	
	40	50	60	70	80	90	Total	Operating±
72° F	2.9	2.0	2.3	2.3	2.2	3.2	2.5	1.3
150° F	2.5	2.4	2.7	2.6	2.4	3.1	2.5	1.3
150° F + 160° F Preheat	2.5	-	-	2.1	-	2.5	2.4	1.2

TEST D

Deterioration - Operating Range at +72° F Ambient Temperature

Setting	Old Thermostats				New Thermostats
	No. 302	No. 303	No. 304	Average	Average
Low	33.3	49.1	47.4	43.3	39.1
High	94.8	--	93.0	93.9	90.4

Deterioration - Operating Differential at 72° F Ambient Temperature

Thermostat	Setting in °F						Average	Total Average
	40	50	60	70	80	90		
302	7.9	6.9	5.2	6.1	4.9	5.0	6.0	3.6
303	4.1	2.7	1.9	2.1	2.2	2.2	2.5	3.6
304	2.5	2.3	2.2	1.8	2.0	2.3	2.1	3.6

Note: Hyphens signify that no data were taken.

actuated. Temperatures were recorded, and the operation was reversed and repeated as in Step 1.

(b) Test B, Operating Differential. The thermostats were tested at the following settings: 40°, 50°, 60°, 70°, 80°, and 90° F. The procedure followed was similar to that used in Test A, Step 1.

(c) Test C, Effect of Ambient Temperature on Thermostat. The test conducted to determine the effect of ambient temperature on thermostat operating range and differential was as follows:

Step 1. The body of the thermostat was maintained at 150° F as compared to 72° F for the preceding tests, and Tests A and B were repeated.

Step 2. The entire thermostat assembly (body and sensing bulb) was subjected to an ambient temperature of 160° F for 2 hours. The sensing bulb was then immersed in the water bath, the body of the thermostat was lowered to 150° F, and Tests A and B were repeated at 40° F, 70° F, and maximum setting.

(d) Test D, Deterioration. Thermostats 302, 303, and 304 were subjected to Tests A and B and compared with thermostats 1, 2, and 3.

From this comparison, the effects of prolonged operation and rough usage upon the operation of the thermostats can be evaluated in terms of degrees Fahrenheit operation. Thermostats 302, 303, and 304 were removed from air conditioners which had been subjected to a variety of tests including: Operational, airflow, capacity, refrigerant charge, fungus, shock and vibration, and endurance. Each thermostat had an average of 1,500 hours of operation prior to these tests.

(2) Selector Switch and Fan Speed Controls. Tests of the selector switch and fan speed controls were conducted to determine if the controls and components were functioning properly and in accordance with design specifications. With rated power applied, this test was conducted at ambient temperatures between 65° F and 125° F.

Table XII. Selector Switch and Control Requirements

Selector Switch Position	Mode	Evaporator Return-Air Thermostat Setting	Ambient Temperature (°F)	Compressor Crankcase Heater	Compressor	Evaporator Fan Motor[a]	Condenser Fan Motor	Thermostatically Controlled Bank of Heaters (3 heater elements)	Remaining Bank of Heaters (3 heater elements)	Quantitative Test Results (cf. table numbers in this column)
OFF	OFF	Optional	Optional	Energized	OFF	OFF	OFF	OFF	OFF	-[b]
VENT	VENT	Optional	Optional	Energized	OFF	ON	OFF	OFF	OFF	XIII
COOL	BYPASS	Above	Above 100	OFF	ON	ON	ON High Speed	OFF	OFF	XIV
COOL	BYPASS	Above	Below 100	OFF	ON Low Speed	ON	ON Low Speed	OFF	OFF	-
COOL	COOL	Below	Above 100	OFF	ON	ON	ON High Speed	OFF	OFF	XV
COOL	COOL	Below	Below 100	OFF	ON	ON	ON Low Speed	OFF	OFF	-
LO-HEAT	LO-HEAT	Above	Optional	Energized	OFF	ON	OFF	ON	OFF	XVI
LO-HEAT	LO-HEAT	Below	Optional	Energized	OFF	ON	OFF	OFF	OFF	-
HI-HEAT	HI-HEAT	Above	Optional	Energized	OFF	ON	OFF	ON	ON	XVII
HI-HEAT	HI-HEAT	Below	Optional	Energized	OFF	ON	OFF	OFF	ON	-

Notes: (a) High or low speed can be selected by means of the toggle switch on the control panel.

(b) Hyphens signify that no data were taken.

The mode selector switch is a five-position rotary switch, and the control selection modes are: OFF, VENT, COOL, LO-HEAT, and HI-HEAT. The condenser fan speed selector is a thermostat which calls for high speed at ambient temperature of 100° F or higher and low speed at ambient temperatures lower than 100° F. The evaporator fan speed (high speed or low speed) control is a manually operated switch located on the control panel.

In these tests, power was applied and the selector switch was set in each position several times to establish proper functioning as indicated in Table XII. The function of the compressor crankcase heater (described in Section III, paragraph 4) is also included in this table.

The controls functioned as shown in Table XII. Data were recorded in the VENT, BYPASS, COOL, LO-HEAT, and HI-HEAT modes. Quantitative test results are presented in Tables XIII through XVII.

Table XIII. Results of VENT Mode Tests

Measurement	Model	
	MC40HA L6-208	MC40HA L4-208
Air Temperatures (°F), Dry Bulb		
Entering Evaporator	89	90
Leaving Evaporator	92	92
Electrical Characteristics		
Average Voltage	208	208
Average Amperage	3.50	8.24
Total Wattage	1,150	1,960
Power Factor (%)	91.4	65.8
Fan Speed (rpm)	3,380	3,780

Table XIV. Results of BYPASS Mode Tests

Measurement	Model MC40HA L6-208	Model MC40HA L4-208
Air Temperatures (°F)		
Entering Evaporator, Dry Bulb	90	90
Entering Evaporator, Wet Bulb	64	68
Leaving Evaporator, Dry Bulb	93	94
Entering Condenser, Dry Bulb	119	119
Leaving Condenser, Dry Bulb	128	128
Refrigerant Temperatures (°F)		
Discharge Line	258	274
Condenser Outlet	127	126
Subcooler Outlet	127	126
TEV Inlet	113	111
Suction at TEV Bulb	66	66
Suction at Compressor	72	70
Suction Pressure Regulating Valve Outlet	213	222
Quench Outlet	36	39
Equalization Solenoid Outlet	192	108
Subcooling at Subcooler	0	1
Superheat at Compressor	44	45
Compressor Skin Temperature (°F)	98	-
Discharge Pressure (psig)	287	283
Suction Pressure (psig)	52	49
Electrical Characteristics		
Average Voltage	208	208
Average Amperage	24.0	42.2
Total Wattage	7,450	9,790
Power Factor (%)	86.5	64.5
Evaporator Fan Speed (rpm)	3,360	3,700
Condenser Fan Speed (rpm)		
Left Side	3,400	3,790
Right Side	3,410	3,770

Note: Hyphen signifies that no data were taken.

Table XV. Results of COOL Mode Tests

Measurement	MC40HAL6-208 120° F Ambient	MC40HAL6-208 125° F Ambient	MC40HAL4-208 120° F Ambient	MC40HAL4-208 125° F Ambient
Air Temperatures (°F)				
Entering Evaporator, Dry Bulb	90	90	90	90
Entering Evaporator, Wet Bulb	65	66	62	68
Leaving Evaporator, Dry Bulb	68	68	70	68
Entering Condenser, Dry Bulb	120	125	121	125
Leaving Condenser, Dry Bulb	150	156	149	154
Refrigerant Temperatures (°F)				
Discharge Line	257	265	267	268
Condenser Outlet	152	157	150	156
Subcooler Outlet	141	146	140	141
TEV Inlet	141	146	140	141
Suction at TEV Bulb	67	68	61/66	62
Suction at Compressor	73	75	70	69
Suction Pressure Regulating Valve Outlet	149	150	145	122
Quench Outlet	149	151	145	61
Equalization Solenoid Outlet	150	154	146	139
Subcooling at Subcooler	12	10	11	14
Subcooling at TEV	12	10	11	14
Superheat at TEV Bulb	14	17	cycling	12
Superheat at Compressor	21	22	20	18
Compressor Skin Temperature (°F)	102	106	108	106
Discharge Pressure (psig)	394	414	388	406
Suction Pressure (psig)	88.0	89.0	83.5	85.0
Electrical Characteristics				
Average Voltage	209	208	208	208
Average Amperage	29.6	30.3	46.7	47.3
Total Wattage	9,470	9,510	11,960	12,180
Power Factor (%)	93.6	89.0	70.9	71.6
Evaporator Fan Speed (rpm)	3,390	3,410	3,760	3,760
Condenser Fan Speed (rpm)				
Left Side	3,410	3,440	3,820	3,840
Right Side	3,430	3,470	3,800	3,820

Table XVI. Results of LO-HEAT Mode Tests

Measurement	Model	
	MC40HA L6-208	MC40HA L4-208
Air Temperatures (°F), Dry Bulb		
Entering Evaporator	87	81
Leaving Evaporator	98	91
Electrical Characteristics		
Average Voltage	210	208
Average Amperage	15.1	18.3
Total Wattage	5,310	6,150
Power Factor (%)	96.6	93.3
Evaporator Fan Speed (rpm)	3,390	3,750

Table XVII. Results of HI-HEAT Mode Tests

Measurement	Model	
	MC40HA L6-208	MC40HA L4-208
Air Temperatures (°F)		
Entering Evaporator, Dry Bulb	88	81
Leaving Evaporator, Dry Bulb	106	98
Electrical Characteristics		
Average Voltage	209	208
Average Amperage	26.9	29.4
Total Wattage	9,650	10,280
Power Factor (%)	99.4	97.1
Evaporator Fan Speed (rpm)	3,390	3,740

i. Coil Frost. The coil frost tests were conducted on both models (MC40HA L6-208 and MC40HA L4-208) to determine the ability of these air conditioners to operate under low load (high latent conditions) and low ambient conditions without the evaporator coil freezing over.

Each model was tested in accordance with ASHRAE Standard 37-60. Installation was flush with the indoor barrier wall, and a metal duct was attached to the evaporator air outlet opening.

Each test unit was operated for 12 hours with air entering the evaporator at 67° F dry bulb and 57° F wet bulb and air entering the condenser at 55° F dry bulb. To complete this test successfully, sufficient frost or ice shall not form or collect on the cooling coil to decrease the airflow to less than 95 percent of rated delivery.

The evaporator airflow at the outset and completion of each 12-hour test showed no reduction, and inspections indicated no frost. Initial and terminal results are shown in Table XVIII.

j. High-Temperature Cooling Operations. Two different tests were conducted on each model (MC40HA L6-208 and MC40HA L4-208) to determine the ability of the air conditioners to withstand and operate against the adversities of high temperatures (125 ± 3° F ambient and 125 ± 3° F return air). The first test implied a high-temperature, steady state condition and was followed by a high-temperature "pull down" test. Each unit was installed in the dividing wall of the psychrometric chamber, and the test was performed as follows:

(1) Operated the unit in the COOL-cooler mode to assure proper unit operation.

(2) Shut off the unit and increased the air temperatures (ambient and return air) to 125° F.

(3) Applied sufficient heat during a 2-hour period to stabilize these temperatures at 122° F minimum.

(4) Started the unit and operated it for a 1-hour period.

(5) Stopped the unit and made a restart test after a 5-minute period.

Table XVIII. Results of Coil Frost Tests

Measurement	Start	Finish (12 hr)
Model MC40HAL6-208		
Air Temperatures (°F)		
Entering Condenser, Dry Bulb	56.7	55.1
Entering Evaporator, Dry Bulb	67.0	66.8
Entering Evaporator, Wet Bulb	56.9	57.0
Leaving Evaporator, Dry Bulb	46.8	46.5
Air Velocity (fpm)	540	540
Airflow Rate (scfm)	1,320	1,320
Refrigerant Temperatures (°F)		
Suction at Compressor	41-65	40-65
Suction Pressure Regulating Valve Outlet	135	138
Discharge Pressure (psig)	180-200	198-214
Suction Pressure (psig)	52-60	53-60
Model MC40HAL4-208		
Air Temperatures (°F)		
Entering Condenser, Dry Bulb	55.5	54.8
Entering Evaporator, Dry Bulb	67.0	66.8
Entering Evaporator, Wet Bulb	57.5	57.0
Leaving Evaporator, Dry Bulb	47.5	47.1
Air Velocity (fpm)	650	650
Airflow Rate (scfm)	1,600	1,600
Refrigerant Temperatures (°F)		
Suction at Compressor	38-54	38-55
Suction Pressure Regulating Valve Outlet	135	139
Discharge Pressure (psig)	200	198
Suction Pressure (psig)	59	58

(6) Started the unit and operated it for a 15-minute period.

(7) Stopped the unit for a 5-minute period (this concluded the high-temperature, steady-state portion of the test).

(8) Restarted the unit and allowed it to operate for 1 hour during which time the unit was allowed to decrease or pull down the return-air temperature.

Data were taken during the entire test, and the results are presented in Tables XIX and XX.

k. <u>High-Temperature Storage</u>. The high-temperature storage test was conducted to determine the effects of high-temperature conditions (155° F) upon the air conditioner with respect to deterioration of components or structure and to determine if the high temperature had any effect on the operational characteristics of the air conditioner.

This test was conducted in the climatic test chamber (Fig. 7). The unit was stored in a 155° F ambient for 48 hours and then operated in the VENT, COOL, and HI-HEAT modes. The test units were inspected for any malfunctions or deteriorations. Malfunctions inspected for included rupture of refrigerant piping and control components, binding of motors caused by breakdown of winding insulation or bearing lubrication, and binding of parts or components caused by metal expansion. Deterioration inspected for included discoloration, cracking, shrinking, bulging, checking, or crazing of gaskets, insulation sheets and strips, fabrication material, and paint; breakdown of insulation adhesives; and permanent setting of gaskets and packings. A detailed visual examination of the test units after exposure to this test revealed no deterioration or damage.

Results of the high-temperature storage test are presented in Table XXI.

l. <u>Low-Temperature Cooling Operation</u>. The low-temperature cooling operation test was conducted to verify air-conditioner operation in the COOL and BYPASS modes under stable conditions of ambient temperatures as low as -25° F.

The units were installed in the climatic test chamber as shown in Fig. 7. Temperature conditions of 95° F ambient and 70° F return air were obtained. The return-air temperature was maintained at

Table XIX. Results of High-Temperature Operation Test, Model MC40HA L6-208

Measurement	Time				
	Steady State Operation 1 Hr	Stop 5 Min	Steady State Operation 15 Min	Stop 10 Min	Temperature Pull Down at Close of Hour Period
Air Temperatures (^oF)					
Entering Evaporator, Dry Bulb	125		125		90
Entering Evaporator, Wet Bulb	83		83		70
Leaving Evaporator, Dry Bulb	94/101		96/103		68
Entering Condenser, Dry Bulb	122		126		124
Leaving Condenser, Dry Bulb					
Left-Side Discharge	154		157		156
Right-Side Discharge	153		155		154
Refrigerant Temperatures (^oF)					
Discharge Line	279		278		266
Condenser Outlet	155		156		156
Subcooler Outlet	138		140		144
TEV Inlet	138		140		144
Suction at TEV Bulb	53/117		50/116		67
Suction at Compressor	69/81		66/115		74
Suction Pressure Regulating Valve Outlet	126		128		150
Quench Outlet	49/81		47/86		150
Equalization Solenoid Outlet	127		131		153
Compressor Skin Temperature (^oF)	119		121		107
Discharge Pressure (psig)	405/422		396/426		408
Suction Pressure (psig)	82/103		75/104		89
Electrical Characteristics					
Average Voltage	210		210		209
Average Amperage	29.7		29.4		29.5
Total Wattage	9,640		9,550		9,340
Power Factor (%)	89.2		89.8		87.4

Table XX. Results of High-Temperature Operation Test, Model MC40HAL4-208

Measurement	Time				
	Steady State Operation 1 Hr	Stop 5 Min	Steady State Operation 15 Min	Stop 10 Min	Temperature Pull Down at Close of Hour Period
Air Temperatures (^{o}F)					
Entering Evaporator, Dry Bulb	123		122		90
Entering Evaporator, Wet Bulb	81		81		66
Leaving Evaporator, Dry Bulb	88		87		68
Entering Condenser, Dry Bulb	123		122		123
Leaving Condenser, Dry Bulb					
Left-Side Discharge	158		157		152
Right-Side Discharge	157		156		151
Refrigerant Temperatures (^{o}F)					
Discharge Line	290		287		267
Condenser Outlet	159		159		155
Subcooler Outlet	143		143		139
TEV Inlet	144		143		139
Suction at TEV Bulb	106		105		62
Suction at Compressor	108		107		69
Suction Pressure Regulating Valve Outlet	137		137		136
Quench Outlet	71		72		68
Equalization Solenoid Outlet	146		146		143
Compressor Skin Temperature (^{o}F)	133		131		107
Discharge Pressure (psig)	429		420		408
Suction Pressure (psig)	108		107		85
Electrical Characteristics					
Average Voltage	207		209		209
Average Amperage	49.4		49.6		47.9
Total Wattage	12,840		12,460		12,140
Power Factor (%)	72.5		72.4		70.4

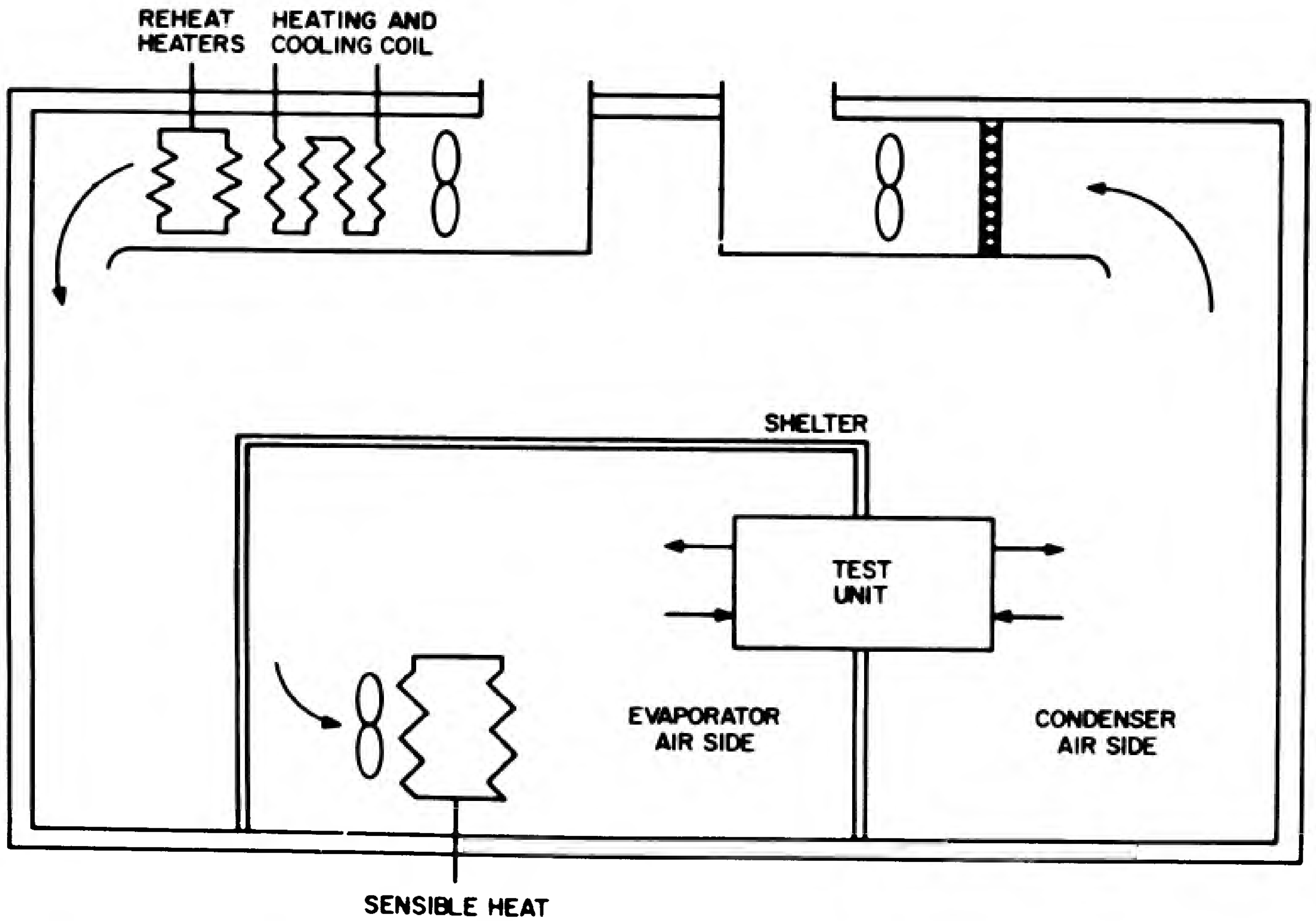


Fig. 7. Climatic test chamber.

Table XXI. Results of High-Temperature Storage Test (preoperational and postoperational), Model MC40HA L6-208

Measurement	Mode									
	COOL		BYPASS		LO-HEAT		HI-HEAT		VENT	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Air Temperatures (°F)										
Entering Evaporator, Dry Bulb	90	89	92	86	87	87	88	89	91	84
Entering Evaporator, Wet Bulb	64	64	64	59						
Leaving Evaporator, Dry Bulb	68	68	95	89	98	98	106	107	93	87
Entering Condenser, Dry Bulb	121	120	119	118						
Leaving Condenser, Dry Bulb	151	150	128	127						
Refrigerant Temperatures (°F)										
Discharge Line	258	256	254	254						
Condenser Outlet	153	152	127	126						
Subcooler Outlet	142	142	126	126						
TEV Inlet	142	142	114	112						
Suction at TEV Bulb	66	67	68	66						
Suction at Compressor	72	73	72	71						
Suction Pressure Regulating Valve Outlet	150	148	210	209						
Quench Outlet	149	147	36	36						
Equalization Solenoid Outlet	152	151	190	19						
Subcooling	11	10	1	1						
Superheat at Compressor	20	21	41	43						
Compressor Skin Temperature (°F)	104	104	96	99						
Discharge Pressure (psig)	398	393	284	285						
Suction Pressure (psig)	87.5	89.0	57.0	53.0						
Electrical Characteristics										
Average Voltage	208	209	209	210	210	210	209	209	211	211
Average Amperage	29.4	29.5	23.6	23.7	15.1	15.3	26.9	26.9	3.4	3.5
Total Wattage	9,320	9,340	7,280	7,340	5,310	5,470	9,650	9,600	1,130	1,130
Power Factor (%)	88.2	87.5	85.5	85.3	96.6	98.2	99.4	98.8	90.2	89.2

Note: Blank areas indicate data were not applicable.

70° F at each operation portion of the test. The ambient temperature was reduced to -25° F in 20° F decrements. At each of these ambient values the unit conditions were stabilized for 30 minutes, and data were recorded in the COOL and BYPASS modes. The unit was shut off, both inside and outside ambient temperatures were stabilized at -25° F, and the unit was soaked at this temperature for 10 hours. Then, power was applied to the unit with all switches off (compressor crankcase heaters energized), and the inside room temperature was increased to 70° F. After 30 minutes, the unit was started, and data were recorded in the COOL and BYPASS modes after thermal stability was obtained.

The temperatures were raised to the initial 95° F ambient, and 70° F return air and data were recorded.

Both models were subjected to this test. Cooling operation, COOL mode results are presented in Tables XXII and XXIII, and cooling operation, BYPASS mode results are given in Tables XXIV and XXV.

As the outside ambient temperature lowers, the refrigerant discharge pressure decreases progressively. As this pressure decreases, the actuator (head pressure controller) causes the condenser air-discharge louvers to close commensurately. The decreased louver opening, in turn, causes decreased condenser airflow, and at extremely low ambient temperatures, this airflow can be negligible.

The thermocouples for measuring the temperature of the air entering the condenser were arranged on a grid approximately 1 inch from the condenser. With progressively decreasing ambients combined with negligible condenser airflow, these thermocouples became progressively more subject to radiated and converted heat from the condenser. Therefore, the temperature of the air entering the condenser (Tables XXII through XXV) became progressively greater than the ambient temperature as the ambient temperature decreased.

m. Low-Temperature Storage. The low-temperature storage test was conducted to determine the effects of low-temperature conditions (-65° F) upon the air conditioner with respect to deterioration of components or structure and to determine if the low-temperature conditions had any effect on the operational characteristics of the air conditioner.

This test was conducted in the climatic test chamber where the temperature was maintained at -65° F for 48 hours. At the completion of the 48-hour storage period, the test unit was examined visually

Table XXII. Results of Low-Temperature Cooling Operation Test, COOL Mode, Model MC40HA L6-208

Measurement	Outside Ambient Temperature (°F)								
	95	75	55	35	15	-5	-25	-25	95
Air Temperatures (°F), Dry Bulb									
Entering Condenser	92	73	54	36	16	-2	-22	-21	92
Leaving Condenser, Left-Side Discharge	138	120	100	84	69	53	33	33	139
Leaving Condenser, Right-Side Discharge	135	117	96	80	63	50	38	43	137
Entering Evaporator	70	70	70	70	71	70	68	70	70
Leaving Evaporator	52	51	50	50	49	48	48	49	53
Refrigerant Temperatures (°F)									
Discharge Line	246	215	186	175	170	165	166	172	250
Condenser Outlet	141	124	106	98	96	92	94	98	141
Subcooler Outlet	118	100	79	68	60	56	52	57	118
TEV Inlet	118	100	78	69	63	57	56	60	118
Suction at TEV Bulb	40	52	55/34	56/33	56/32	56/32	32/55	54/32	52/41
Suction at Compressor	52	53	54/34	53/33	53/32	53/32	31/52	51/32	57/53
Suction Pressure Regulating Valve Outlet	166	154	138	132	128	125	126	130	137
Quench Outlet	156	144	128	122	118	116	116	120	135
Equalization Solenoid Outlet	162	148	132	124	118	116	118	121	141
Subcooling at Subcooler	24	25	29/25	33/29	39/34	38/35	39/44	44/0	23/22
Superheat at TEV Bulb	0	16	21/0	24/1	22/0	24.0	23/0	20/0	18/2
Superheat at Compressor	12	17	20/0	21/1	19/0	21/0	20/0	17/0	18/14
Discharge Pressure (psig)	344	279	221/209	200/188	190/178	180/170	184/172	198/190	343/339
Suction Pressure (psig)	68	63	61/59	60/57	61/58	59/56	60/56	61/58	67
Compressor Skin Temperature (°F)	90	78	68	64	61	60	58	61	90
Electrical Characteristics									
Average Voltage	211	208	208	208	208	208	205	208	208
Average Amperage	21.6	20.4	18.3	18.4	18.1	17.5	18.0	18.2	22.1
Total Wattage	6,890	6,430	5,950	5,710	5,610	5,450	5,520	5,680	7,020
Power Factor (%)	87.7	87.5	87.7	86.6	86.0	86.4	85.2	86.8	82.3

Note: Selector switch, cool. Thermostat, cooler.

Table XXIII. Results of Low-Temperature Cooling Operation Test, COOL Mode, Model MC40HAL4-208

Measurement	Outside Ambient Temperature (°F)								
	95	75	55	35	15	-5	-25	-25	95
Air Temperatures (°F)									
Entering Condenser	96	78	57	35	18	4	-18	-14	94
Leaving Condenser, Left-Side Discharge	141	122	102	82	75	62	49	51	137
Leaving Condenser, Right-Side Discharge	139	121	101	80	68	51	37	39	135
Entering Evaporator	70	68	70	70	71	69	72	70	70
Leaving Evaporator	56	52	51	50	51	49	50	49	55
Refrigerant Temperatures (°F)									
Discharge Line	237	214	192	178	182	168	174	116	210
Condenser Outlet	144	126	107	96	100	92	93	94	142
Subcooler Outlet	117	98	78	62	60	50	44	62	118
TEV Inlet	118	100	79	64	63	54	50	64	118
Suction at TEV Bulb	43	38	36	35	35	34	35	34	42
Suction at Compressor	42	37	34	33	33	32	32/34	32	42
Suction Pressure Regulating Valve Outlet	110	130	130	128	128	122	124	76	11
Quench Outlet	49	44	40	36	37	36	37	38	17
Equalization Solenoid Outlet	126	124	114	108	110	102	104	86	124
Subcooling at Subcooler	26	28	29	35	41	43	50	31	23
Superheat at TEV Bulb	5	3	4	4	4	4	5	3	4
Superheat at Compressor	4	2	2	2	2	2	4/2	1	4
Discharge Pressure (psig)	350	282	217	188	198	175	178	177	342
Suction Pressure (psig)	66	61	57	56	57	55	54/57	56	66
Compressor Skin Temperature (°F)	80	71	64	62	60	54	58	36	56
Electrical Characteristics									
Average Voltage	209	210	210	209	209	208	208	208	207
Average Amperage	39.7	38.8	37.8	37.1	37.3	36.7	36.7	36.7	39.8
Total Wattage	9,320	8,850	8,360	8,010	8,160	7,820	7.860	7,940	8,380
Power Factor (%)	64.9	62.8	60.9	59.6	60.5	59.2	59.6	60.1	65.9

Note: Selector switch, cool. Thermostat, cooler.

Table XXIV. Results of Low-Temperature Cooling Operation Test, BYPASS Mode, Model MC40HA L6-208

Measurement	Outside Ambient Temperatures (°F)								
	95	75	55	35	15	-5	-25	-25	95
Air Temperatures (°F)									
Entering Condenser	90	73	55	39	24	-5	-14	-16	92
Leaving Condenser, Left-Side Discharge	102	85	70	55	40	18	2	-11	102
Leaving Condenser, Right-Side Discharge	102	84	76	56	37	16	3	-5	101
Entering Evaporator	93	68	71	72	71	70	70	68	71
Leaving Evaporator	94	72	74	75	73	70	70	68	74
Refrigerant Temperatures (°F)									
Discharge Line	221	206	194	178	158	136	129	130	226
Condenser Outlet	102	91	84	72	52	28	8	7	102
Subcooler Outlet	101	90	83	72	52	27	9	11	101
TEV Inlet	98	89	87	79	66	45	34	32	90
Suction at TEV Bulb	65	57	58/54	52	52	46	33	31	60
Suction at Compressor	64	58	58/55	50	49	38	20	19	62
Suction Pressure Regulating Valve Outlet	190	175	166	153	138	118	112	103	194
Quench Outlet	31	27	26	23	19	8	-6	-7	30
Equalization Solenoid Outlet	174	155	146	133	118	97	80	81	176
Subcooling at Subcooler	1	1	1	1	3	3	0	2	1
Superheat at Compressor	41.4	39.9	41/38	37	40	37	34	33	27
Discharge Pressure (psig)	203	172	154	128	92	55	32	32	203
Suction Pressure (psig)	46	41	39	36	32	25	14	14	44
Compressor Skin Temperature (°F)	84	75	73	67	61	46	37	37	82
Electrical Characteristics									
Average Voltage	211	208	208	208	208	208	207	208	208
Average Amperage	17.0	16.3	15.7	15.1	13.9	12.8	11.9	11.9	17.3
Total Wattage	5,240	4,960	4,800	4,540	4,090	3,600	3,210	3,210	5,330
Power Factor (%)	84.6	84.6	85.0	83.3	81.5	77.9	75.1	75.1	85.5

Note: Selector switch, cool. Thermostat, warmer.

Table XXV. Results of Low-Temperature Cooling Operation Test, BYPASS Mode, Model MC40HA L4-208

Measurement	Outside Ambient Temperature (°F)								
	95	75	55	35	15	-5	-25	-25	95
Air Temperatures (°F)									
Entering Condenser	94	78	57	37	25	9	-7	-12	92
Leaving Condenser, Left-Side Discharge	106	92	76	57	44	29	10	4	104
Leaving Condenser, Right-Side Discharge	105	91	78	56	40	26	-4	-4	102
Entering Evaporator	83	70	71	69	70	69	73	70	70
Leaving Evaporator	85	74	74	72	72	71	74	71	74
Refrigerant Temperatures (°F)									
Discharge Line	242	231	221	202	190	173	158	140	238
Condenser Outlet	105	98	90	70	60	40	19	10	103
Subcooler Outlet	105	98	90	66	57	39	14	11	103
TEV Inlet	96	92	92	80	74	61	52	42	88
Suction at TEV Bulb	63	56	58	82/20	50	64/38	37	31	56
Suction at Compressor	62	57	58	37/28	48	49/36	27	18	58
Suction Pressure Regulating Valve Outlet	204	193	185	172	161	146	128	107	200
Quench Outlet	34	32	30	25	24	18	6	-4	32
Equalization Solenoid Outlet	155	140	134	120	108	92	73	57	152
Subcooling at Subcooler	0	0	0	8/2	3	3/1	8	2	0
Superheat at Compressor	43	40	43	25/20	41	44/31	34	33	40
Discharge Pressure (psig)	208	188	170	129/118	102	72/68	47	36	203
Suction Pressure (psig)	42	40	38	35/31	30	29/26	19	13	41
Compressor Skin Temperature (°F)	87	81	80	76	68	62	47	35	85
Electrical Characteristics									
Average Voltage	210	210	210	210	209	208	208	208	208
Average Amperage	35.9	35.7	35.4	34.5	34.2	33.4	32.6	32.4	35.7
Total Wattage	7,420	6,250	7,030	6,590	6,300	5,870	5,360	5,030	7,390
Power Factor (%)	57.0	48.2	54.7	52.6	51.0	49.0	45.7	43.2	59.8

Note: Selector switch, cool. Thermostat, warmer.

for any deterioration or damage as a result of differential contraction of dissimilar metal parts; loss of resiliency of insulation and gaskets; congealing of lubricants; breakdown of adhesives; binding of motors caused by breakdown of winding insulation or bearing lubrication; discoloration cracking, shrinking, bulging, checking, or crazing of gaskets and insulation, fabrication materials, and paint; and permanent setting of gaskets and packing.

Operation of the test units in the VENT, COOL, LO-HEAT, and HI-HEAT modes before and after low-temperature storage indicated no adverse effects were incurred during storage tests. A visual examination of the units after exposure to this test revealed no deterioration or damage.

Results of the low-temperature storage test (preoperational and postoperational) are presented in Table XXVI.

n. Low-Temperature Heating Operation. The low-temperature heating operation test was conducted to determine the ability of the heaters and the evaporator fan to start and operate at low-temperature conditions (-50° F).

Each model unit was tested in the VENT and HI-HEAT modes under normal temperatures. The low-temperature test was conducted in the climatic test chamber with the chamber temperature maintained at -50° F. After a 2-hour soak period the unit was switched to the VENT mode, was operated for 5 minutes, and data were recorded. The unit was then switched to the HI-HEAT mode and operated for 1 hour during which time data were recorded. The unit was switched back to the VENT mode, was operated for 5 minutes, and data were recorded. The unit was then returned to normal temperature conditions and postoperational test data on the VENT and HI-HEAT performance were secured.

Results of the low-temperature heating operation tests are found in Table XXVII.

o. Voltage Variation. The voltage variation test was conducted to determine the ability of the air conditioner to operate under temperature conditions of 120° F ambient and 90° F return air, with the rated supply voltage varying from -5 to +10 percent.

The voltage variation test was conducted in the psychrometric chamber. The air conditioner was mounted in the same manner as described in the cooling capacity test. The test was conducted in accordance

Table XXVI. Results of Low-Temperature Storage Test (preoperational and postoperational), Model MC40HA L6-208

Measurement	Mode									
	COOL		BYPASS		LO-HEAT		HI-HEAT		VENT	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Air Temperatures (°F)										
Entering Evaporator, Dry Bulb	89	90	86	92	87	82	89	84	84	80
Entering Evaporator, Wet Bulb	62	68	59	68	-	-	-	-	-	-
Leaving Evaporator, Dry Bulb	68	68	89	94	98	92	107	102	87	82
Entering Condenser, Dry Bulb	120	120	118	118						
Leaving Condenser, Dry Bulb	150	149	127	127						
Refrigerant Temperatures (°F)										
Discharge Line	256	256	254	253						
Condenser Outlet	152	152	126	125						
Subcooler Outlet	142	141	126	125						
TEV Inlet	142	141	112	114						
Suction at TEV Bulb	67	67	66	67						
Suction at Compressor	73	72	71	71						
Suction Pressure Regulating Valve Outlet	148	140	209	206						
Quench Outlet	147	143	36	36						
Equalization Solenoid Outlet	151	146	190	187						
Subcooling	11	11	1	1						
Superheat at Compressor	21	21	43	40						
Compressor Skin Temperature (°F)	104	102	99	97						
Discharge Pressure (psig)	393	381	285	281						
Suction Pressure (psig)	89	86	53	56						
Electrical Characteristics										
Average Voltage	209	210	210	211	210	210	209	209	211	209
Average Amperage	29.5	29.3	23.7	23.4	15.3	15.3	26.9	26.7	3.5	3.6
Total Wattage	9,340	9,230	7,340	7,270	5,470	5,500	9,600	9,630	1,130	1,180
Power Factor (%)	87.5	86.7	85.3	85.1	98.2	98.5	98.8	99.6	89.2	91.0

Note: Hyphens signify that no data were taken.
Blank areas indicate data were not applicable.

Table XXVII. Results of Low-Temperature Heating Operation Tests

Measurement	Preperformance VENT	Preperformance HI-HEAT		Low-Temperature Test VENT 5 Min	Low-Temperature Test HI-HEAT 0	Low-Temperature Test HI-HEAT 15 Min	Low-Temperature Test HI-HEAT 30 Min	Low-Temperature Test HI-HEAT 45 Min	Low-Temperature Test HI-HEAT 60 Min	Low-Temperature Test VENT 5 Min		Postperformance VENT	Postperformance HI-HEAT
					MC40HALC-208								
Air Temperatures (°F), Dry Bulb			Cold Soaked for 2 Hr								Restored to Normal Temperature		
Entering Evaporator	85	-88		-53	-50	-50	-50	-50	-51	-53		79	85
Leaving Evaporator	87	105		-51	-39	-37	-36	-35	-36	-50		80	102
Electrical Characteristics													
Average Voltage	208	208		209	208	208	208	208	208	208		209	210
Average Amperage	3.5	27.0		4.8	28.4	28.2	28.2	28.2	28.2	4.8		3.6	26.9
Total Wattage	1,140	9,760		1,620	10,190	10,070	10,060	10,070	10,130	1,570		1,170	9,650
Power Factor (%)	90.6	100		92.6	99.6	99.2	99.3	99.4	99.7	91.6		90.7	98.7
					MC40HAL4-208								
Air Temperatures (°F), Dry Bulb													
Entering Evaporator	67	71		-50	-50	-50	-49	-50	-50	-50			
Leaving Evaporator	69	95		-50	-50	-32	-30	-32	-31	-46			
Electrical Characteristics													
Average Voltage	207	207		208	207	207	207	207	207	207			
Average Amperage	8.6	29.9		15.9	34.6	31.7	31.0	31.7	31.7	10.7			
Total Wattage	1,960	10,330		3,010	11,430	10,860	10,840	10,880	10,870	2,610			
Power Factor (%)	63.8	96.5		52.8	92.1	94.0	97.5	95.7	95.7	68.5			

Note: Blank spaces indicate data were not available.

with the Air Conditioning and Refrigeration Institute (ARI) Standard 210-62, Standard for Unitary Air Conditioning Equipment (6) modified to incorporate military requirements. Stable thermal equilibrium in the two test rooms was achieved at the specific test conditions with the test unit operating in the cooling cycle at nameplate rated voltage and frequency. After stable thermal equilibrium was obtained at the specific test conditions (120° F ambient, 90° F return air), the supply voltage to the unit was increased to 10 percent above nameplate rated voltage, while the frequency remained at nameplate rated frequency. The unit was required to operate continuously for at least 30 minutes under these conditions. The unit was then turned OFF for approximately 2 minutes, then was restarted at the high-voltage condition and operated for at least 30 minutes. Data were recorded at the end of the 30-minute period.

When this phase of the test had been completed, the voltage was returned to rated nameplate voltage. After stable thermal equilibrium conditions were obtained, the supply voltage to the test unit was decreased to 5 percent below rated voltage, while the frequency remained at rated frequency. The unit was required to operate continuously for at least 30 minutes at this test condition. All power to the air conditioner was then cut off. The unit was restarted at the low-voltage condition and operated for at least 30 minutes. Data were recorded at the end of the 30-minute period.

During the entire test, the air conditioner was required to operate without damage to the motors or other electrical components or wiring as a result of overheating and without injury to any other component. The air-conditioner motors were required to operate continuously under the conditions specified in this test without tripping of the motor-overload protective devices.

Results of the voltage variation test are given in Tables XXVIII and XXIX.

p. Refrigerant Charge. The refrigerant charge test was conducted at the maximum design condition (120° F ambient, 90° F return air) to determine the optimum refrigerant charge and the amount of allowable variation from the optimum charge.

This test was conducted in the performance test chamber at the rated voltage and frequency of the test item. The air conditioner was mounted in the test cell in the same manner as described in the cooling capacity test (Section III, paragraph 5a). After the refrigerant system was

Table XXVII. Results of Voltage Variation Tests, Model MC40HA L6-208

Measurement		Duration 20 Min		Duration 30 Min		Duration 1 Hr 10 Min
Electrical Characteristics	Started unit. Input set at 208 volts 60 cycles.		Raised input to 229 volts. Shut down unit as required. Restarted unit.		Changed input to 197 volts. Shut down unit as required. Restarted unit.	
Average Voltage		208		228		199
Average Amperage		29.2		28.2		32.6
Total Wattage		9,140		9,320		10,040
Power Factor (%)		87.2		83.6		89.6
Discharge Pressure (psig)		380		380		370
Suction Pressure (psig)		85		84		85
Air Temperatures (°F), Dry Bulb						
Entering Evaporator		91		91		91
Leaving Evaporator		67		67		67
Entering Condenser		121		120		122
Leaving Condenser		147		148		149

Table XXIX. Results of Voltage Variation Tests, Model MC40HA L4-208

Measurement		Duration 30 Min		Duration 30 Min		Duration 30 Min
Electrical Characteristics	Started unit. Input set at 208 volts.		Input set at 229 volts. Shut down unit as required. Restarted unit.		Input set at 197 volts. Shut down unit as required. Restarted unit.	
Average Voltage		208		229		198
Average Amperage		46.8		48.2		47.2
Total Wattage		11,820		12,280		11,840
Power Factor (%)		70.2		64.4		73.2
Discharge Pressure (psig)		387		391		383
Suction Pressure (psig)		83		83		83
Air Temperatures (°F), Dry Bulb						
Entering Evaporator		90		91		90
Leaving Evaporator		66		67		67
Entering Condenser		120		121		120
Leaving Condenser, Left-Side Discharge		149		150		149
Leaving Condenser, Right-Side Condenser		148		149		148

purged it was evacuated for 1 hour (at an ambient of 77° F) with a vacuum pump to remove all refrigerant, noncondensible contaminants, and moisture. The unit was then charged with 100 ounces of refrigerant and operated in the COOL mode. The dry bulb temperatures were stabilized at 120° F ambient and 90° F return air, and data were recorded. Similar tests were made with progressively increased charges. These tests progressed under wet coil conditions because it was impossible to maintain a suitably low wet bulb temperature. The evaporator dry bulb temperature drop was reasonably constant over a wide range of charges, but refrigerant pressure and input power data indicate the possibility of widely varied latent loads.

The test results of the maximum design condition (120° F ambient, 90° F return air) are presented in Table XXX and Fig. 8. In order to determine performance under conditions of lower ambient and return-air temperatures, the unit was tested under various conditions with a similar range of refrigerant charges.

The results of these proof tests are presented in Table XXXI.

Table XXX shows the optimum refrigerant charge to be 175 ounces (approximately 11 pounds). This value is indicated on Fig. 8 (refrigerant charge test results).

For field-charging procedure the unit may be purged and evacuated as described in the procedure just given. The data in Table XXXI indicate that the sight glass will show clear at ordinary temperatures (90° F dry bulb ambient 80° F dry bulb return air) when the refrigerant charge is 108 ounces (6.75 pounds). With the recommended (optimum) charge of 175 ounces, the unit will operate satisfactorily at any ambient ranging from -25° F to 125° F. Therefore, the unit has a charge variation capability of approximately 3 pounds of refrigerant. This allows for small leakage without any change in performance and permits adequate field charging under less than ideal or laboratory conditions.

q. <u>Radio Frequency Interference (RFI)</u>. The radio frequency interference tests were conducted to determine if the test items (MC40HAL6-208 and MC40HAL4-208) were adequately suppressed to prevent electrical disturbances (radiated, conducted, or both) that may be detrimental to operation of electronic equipment. The criteria used were as follows:

(1) The items should not radiate electromagnetic energy beyond the broadband limits specified in Table I of Specification

Table XXX. Results of Refrigerant Charge Test, Model MC40HA L4-208 (120° F Dry Bulb Ambient, 90° F Dry Bulb Evaporator Return Air)

Measurement	Charge (oz)											
	100	110	115	120	125	135	145	155	165	175	185	195
Air Temperatures (°F),												
Dry Bulb												
Entering Evaporator	89	90	90	91	91	91	91	90	90	90	90	90
Leaving Evaporator	72	70	70	70	69	69	69	67	68	68	68	68
Entering Condenser	120	119	120	120	120	120	120	120	120	121	120	120
Leaving Condenser, Left-Side Discharge	150	150	152	152	152	152	151	151	151	152	151	151
Leaving Condenser, Right-Side Discharge	145	145	147	147	147	147	147	146	147	148	148	147
Refrigerant Temperatures (°F)												
Discharge Line	286	265	260	260	260	263	265	263	265	266	266	268
Condenser Outlet	148	150	152	152	152	154	154	153	153	153	152	145
Subcooler Outlet	147	147	148	143	140	137	134	131	131	132	131	129
TEV Inlet	145	147	148	143	140	137	134	132	132	133	131	130
Suction at TEV Bulb	88	70	67	66	65	65	61	61	60	60	60	59
Suction at Compressor	94	75	72	71	70	70	69	69	68	68	68	68
Suction Pressure Regulating Valve Outlet	125	127	129	130	129	129	129	128	128	129	128	128
Quench Outlet	57	61	62	62	62	62	61	61	61	61	60	60
Equalization Solenoid Outlet	136	137	139	139	139	139	140	138	138	139	138	138
Subcooling at subcooler	0	2	3	8	12	17	20	23	23	23	24	27
Superheat at TEV Bulb	42	19	15	14	13	14	10	10	9	10	10	9
Superheat at Compressor	48	24	20	19	18	19	18	18	17	18	18	18
Compressor Skin Temperature (°F)	122	109	107	107	106	106	106	106	106	106	105	106
Discharge Pressure (psig)	368	376	384	387	390	398	402	402	404	404	405	408
Suction Pressure (psig)	78	86	88	88	87	86.5	86	85	85	84	84	84
Sight Glass	Bubble	Bubble	Bubble	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Electrical Characteristics												
Average Voltage	208	208	208	208	208	208	208	208	208	208	208	208
Average Amperage	45.4	46.5	46.9	47.0	46.8	47.0	46.9	46.7	46.8	46.8	46.8	46.8
Total Wattage	11,460	11,910	12,050	12,040	12,010	12,030	12,030	11,970	11,980	11,990	11,980	11,940
Power Factor (%)	70.0	71.0	71.3	71.1	71.2	71.1	71.2	71.1	71.0	71.1	71.1	70.9

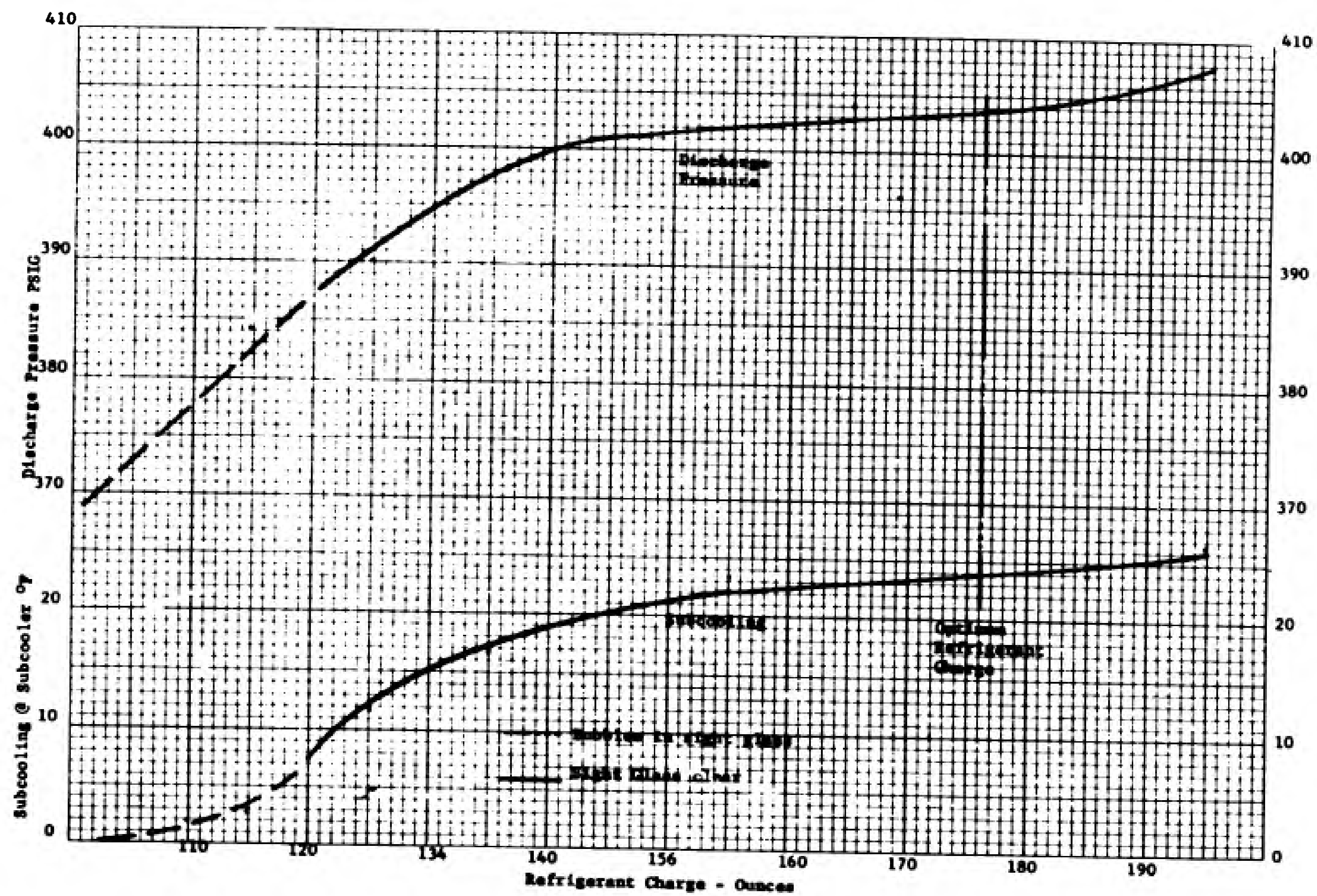


Fig. 8. Refrigerant charge test results, Model MC40HA L6-208 (120° F dry bulb ambient, 90° F dry bulb evaporator return air).

Table XXXI. Results of Refrigerant Charge Test, Model MC40HA L4-208 Under Various Conditions

Measurement	Charge (oz)												
	100	102	104	106	98	158	195	195	100	102	175	175	175
Air Temperatures (°F), Dry Bulb													
Entering Evaporator	84	85	85	85	85	85	85	80	74	75	75	90	90
Leaving Evaporator	63	64	64	64	64	62	62	58	59	59	59	68	69
Entering Condenser	89	90	90	90	90	90	90	80	80	81	80	120	125
Leaving Condenser, Left-Side Discharge	142	144	145	145	144	146	144	138	131	133	134	151	156
Leaving Condenser, Right-Side Discharge	135	137	138	138	137	139	137	132	124	126	127	147	151
Refrigerant Temperatures (°F)													
Discharge Line	257	257	253	247	247	254	254	237	234	232	232	263	269
Condenser Outlet	139	141	142	143	142	147	132	125	131	132	136	153	157
Subcooler Outlet	137	139	140	140	138	115	110	114	128	127	104	131	136
TEV Inlet	136	138	139	140	137	116	110	115	127	126	105	132	136
Suction at TEV Bulb	71	70	65	57	56	50	48	45	54	49	46	61	61
Suction at Compressor	75	73	68	62	62	58	55	45	58	56	46	68	70
Suction Pressure Regulating Valve Outlet	116	118	119	119	117	118	115	112	105	108	109	127	131
Quench Outlet	54	55	56	56	55	54	52	50	50	51	51	60	62
Equalization Solenoid Outlet	127	129	130	130	128	130	127	123	115	117	120	138	141
Subcooling at Subcooler	1	1	1	1	4	34	38	29	2	4	26	23	22
Superheat at TEV Bulb	27	24	19	10	10	4	4	5	12	7	4	11	10
Superheat at Compressor	31	27	22	15	16	12	11	5	16	14	4	18	19
Compressor Skin Temperature (°F)	105	104	101	96	95	94	92	84	90	88	84	104	107
Discharge Pressure (psig)	329	339	342	343	344	375	374	348	296	300	328	400	420
Suction Pressure (psig)	75	77	73	79	78	77	74	69	72	72	72	84	86
Sight Glass	Bubble	Bubble	Bubble	Bubble	Clear	Clear	Clear	Clear	Bubble	Clear	Clear	Clear	Clear
Electrical Characteristics													
Average Voltage	208	208	208	208	208	208	208	208	208	208	208	208	208
Average Amperage	39.3	40.1	44.3	40.4	40.3	40.5	40.4	39.6	39.3	39.3	39.5	46.6	47.0
Total Wattage	9,600	9,760	9,820	9,830	9,820	9,900	9,800	9,520	9,310	9,310	9,460	11,920	12,020
Power Factor (%)	67.0	67.6	61.5	67.5	67.7	67.7	67.5	66.8	65.8	65.7	66.7	71.6	71.1

MIL-E-55301, with Amendment No. 1 for a frequency range of 0.15 to 1,000 megacycles.

(2) The items should not emit conducted energy beyond the broadband limits specified in Table III of Specification MIL-E-55301, with Amendment No. 1 for a frequency range of 1.5 to 65.0 megacycles.

These tests were performed by the USATECOM at the Aberdeen Proving Ground.

The air conditioners and test equipment were set up in an area with low ambient noise. The air conditioners were positioned on an earth-grounded metal ground plane. A filtron-type FSR-702SC line impedance stabilization network was inserted in each power lead to the air conditioners. Each network was bonded to the ground plane and was loaded with a 50-ohm resistive termination at the type-N connector.

Tests for radiated interference were made over the frequency range of 0.15 through 1,000 megacycles with the antenna of the test equipment being located 5 feet from the front of the air conditioners.

Tests for conducted interference were made on each of the input lines to the impedance stabilization network over the frequency range of 1.5 through 65.0 megacycles.

Orientation of the test equipment, condition of units, test site, and permissible limits of interference for these tests were in accordance with the requirements outlined in Specification MIL-E-55301.

Radio interference measuring set, AN/URM-85, was used throughout the investigation. In addition to measuring radio interference at predetermined frequencies, the frequency spectrum between them was scanned for peaks of interference.

The radiated measurements at 0.15 and 0.35 megacycle were not made of any of the units because the ambient levels were too high.

As far as could be determined, both units were within the levels for radiated and conducted energy outlined in Specification MIL-E-55301, with Amendment No. 1.

Data sheets of RFI tests on Models MC40HA L6-208 and MC40HA L4-208 are given in Report No. DPS-2493 (7).

These results are presented in Tables XXXII through XXXV.

Table XXXII. Results of Radio Frequency Interference Test, Broadband, Radiated, Model MC40HA L6-208

Frequency (mc)	Interference (db > 1.0 μv/mc)			
	Ambient Noise Level	Passing Limit MIL-E-55301(EL)	Measurement COOL	Measurement HI HEAT
0.15	*	86	*	*
0.35	*	86	*	*
1.5	57	66	a	a
3	55	66		
5	56	60		
8	52	60		
12	53	60		
16	51	60		
20	47	54		
24	34			
28	32			
30	32			
35	28			
38	31			
40	28			
45	31			
50	26			
55	28			
60	34		↓	↓
65	26		36	28
70	28		38	38
75	31		33	40
80	32		42	43
85	32		49	43
90	32		48	46
95	31		50	51
100	34		a	a
110	b			
	↓			
950	b	↓	↓	↓
1,000	43	54	a	a

Note: Letter a indicates interference level at or below ambient level.
Test was continued as follows:
40 to 100 in increments of 5
100 to 200 in increments of 10
200 to 300 in increments of 20
300 to 1,000 in increments of 50
Ambient remained below specification requirement.
Letter b indicates ambient noise level of less than 46 db.
* Ambient background was above specification limit; valid reading could not be obtained.

Table XXXIII. Results of Radio Frequency Interference Test, Broadband, Radiated, Model MC40HA L4-208

Frequency (mc)	Interference (db > 1.0 μ v/mc)		
	Ambient Noise Level	Passing Limit MIL-E-55301(EL)	Measurement COOL
0.15	*	86	*
0.35	*	86	*
1.5	57	66	a
3	55	66	↓
5	57	60	↓
8	48	60	↓
12	50	60	↓
16	53	60	↓
20	47	54	↓
24	35	↓	45
28	33	↓	41
30	33	↓	38
35	34	↓	43
38	34	↓	38
40	29	↓	a
45	33	↓	34
50	35	↓	36
55	35	↓	36
60	32	↓	37
65	b	↓	a
↓	↓	↓	↓
950	↓	↓	↓
1,000	37	54	a

Note: Letter a indicates interference level at or below ambient level.
Test was continued as follows:
40 to 100 in increments of 5
100 to 200 in increments of 10
200 to 300 in increments of 20
300 to 1,000 in increments of 50
Ambient remained below specification requirement.
Letter b indicates ambient noise level of less than 42 db.

*Ambient background was above specification limit; valid reading could not be obtained.

Table XXXIV. Results of Radio Frequency Interference Test, Broadband, Conducted, Model MC40HAL6-208

Frequency (mc)	Ambient Noise Level	Passing Limit MIL-E-55301	Line A COOL	Line A HI HEAT	Line B COOL	Line B HI HEAT	Line C COOL	Line C HI HEAT	Line D COOL	Line D HI HEAT
1.5	36	83	71	58	70	60	61	61	67	58
3	40	83	63	57	56	61	59	58	53	51
5	39	80	58	60	55	55	62	54	63	51
8	38	80	63	56	58	59	60	50	66	57
12	38	74	68	62	56	62	64	56	68	60
16	37		69	65	55	42	55	50	65	61
20	37		63	63	51	45	58	50	60	55
24	37		61	62	53	53	53	51	58	57
28	38		64	62	61	62	59	60	61	66
30	37		66	61	63	52	61	55	59	60
35	30		69	68	64	49	65	46	60	61
38	31		70	65	65	51	65	63	64	62
40	31		71	57	64	53	64	61	67	62
45	32		70	52	51	46	45	54	60	54
50	32		62	42	59	44	62	60	65	56
55	32		64	49	56	49	64	49	64	51
60	32		66	60	61	54	63	52	63	49
65	32	74	69	57	61	50	63	56	65	50

Interference (db > 1.0 μv/mc)

Table XXXV. Results of Radio Frequency Interference Test, Broadband, Conducted, Model MC40HAL4-208, COOL Mode

Frequency (mc)	Interference (db > 1.0 μv/mc)					
	Ambient Noise Level	Passing Limit MIL-E-55301	Line A	Line B	Line C	Line D
1.5	37	83	40	43	41	48
3	41	83	a	a	a	a
5	39	80	48	45		41
8	36	80	a	a		37
12	36	74				48
16	39					48
20	39					40
24	38					42
28	37					40
30	38					a
35	31			38		
38	32			a		
40	32				38	
45	32				a	
50	33					
55	32					
60	32					
65	32	74				

Note: Letter a indicates interference level at or below ambient level.

r. Blocked Condenser Fan Inlet. The blocked condenser fan inlet test was conducted to determine if the air conditioner was adequately protected in the event the airflow inlet to the condenser became blocked.

This test was conducted under temperature conditions of 120° F ambient and 90° F return air. The unit was operated in the COOL mode until stable thermal equilibrium was obtained in the test cell. The inlet airflow to the condenser was blocked (evaporator not blocked); hence, this condition caused the high-pressure safety device to actuate and stop the unit. This condition was repeated a minimum of nine times.

The high-pressure safety device actuated at 437 psig on the 60-hertz unit, and 443 psig on the 400-hertz unit.

s. Blocked Evaporator Fan Inlet. The blocked evaporator fan inlet test was conducted to determine the effect on the air conditioner in the event the airflow to the evaporator became blocked.

This test was conducted under temperature conditions of 120° F ambient and 90° F return air. The unit was operated in the COOL mode until stable thermal equilibrium was obtained in the test cell. After stable conditions were obtained, the airflow to the evaporator was blocked, and the unit was allowed to operate. The necessary data were taken in order to determine whether the fan motors and compressor operated under these conditions without any adverse effects for 1 hour.

Results of the blocked evaporator fan inlet test are given in Table XXXVI.

t. Fungus. The purpose of the fungus test was to determine the fungus resistance of the compact, horizontal air conditioners. As all models of this family are similar in mechanical construction and identical in materials and finishes, the test findings on Model MC11HAL6-230 are sufficient for the entire family.

The Model MC11HAL6-230 conditioner was placed in the USAMERDC (formerly USAERDL) Tropical Testing Chamber (TTC) where simulated tropical conditions prevail. The chamber atmosphere was heavily charged with spores of various species of fungi (those fungi specified as test organisms in Method 508, "Fungus," in Military Standard MIL-STD-810A, Environmental Test Methods for Aerospace and Ground Equipment (8) were included) and provides continuous inoculation of the test unit with the fungi. Some 80 different species are present and thriving in the chamber

Table XXXVI. Results of Blocked Evaporator Fan Inlet Test, Model MC40HA L6-208

Measurement	Before Test	Duration (min)				After Test
	0	15	30	45	60	
Air Temperatures (^oF), Dry Bulb						
Leaving Evaporator	88	93	93	92	91	88
Entering Condenser	121	121	121	121	121	121
Leaving Condenser	152	139	138	138	137	151
Refrigerant Temperatures (^oF)						
TEV Inlet	143	135	136	135	136	142
Suction at TEV Bulb	65	27/60	36/58	36/58	36/58	71
Suction at Compressor	71	44/64	42/64	42/66	43/63	78
Quench Outlet	149	182	182	182	182	147
Compressor Discharge	258	248	247	246	245	258
Leaving BPRV	150	198	197	197	197	148
Compressor Skin Temperature (^oF)	103	95	93	93	91	103
Discharge Pressure (psig)	398	329	325	326	325	398
Suction Pressure (psig)	86	63	64	63	63	88
Electrical Characteristics						
Average Voltage	209	210	210	210	209	208
Average Amperage	29.4	23.9	23.9	23.9	23.9	29.9
Total Wattage	9,290	7,330	7,300	7,260	7,280	9,420

Note: During this test, the inside room temperature was 90^o F dry bulb, and the outside room temperature was 120^o F dry bulb.

among which those in the following list are typical:

- Acremonium alternatum
- Ascotricha xylina
- Aspergillus flavus
- Aspergillus niger
- Aspergillus oryzae
- Aspergillus terreus
- Aspergillus versicolor
- Chaetomium bostrychodes
- Chaetomium indicum
- Chaetomium globosum
- Coniothyrium sp.
- Curvularia sp.
- Fusarium sp.
- Memnoniella echinata
- Mucor sp.
- Myrothecium verrucaria
- Nigrospora sphaerica
- Penicillium citrinum
- Penicillium luteum
- Penicillium purpurogenum
- Penicillium stoloniferum
- Pullularia sp.
- Rhizopus nigricans
- Spicaria sp.
- Stachybotrys atra
- Trichoderma viride

After an exposure period of 44 days, the air conditioner was temporarily removed from the TTC and checked for signs of biodeterioration and for performance. It was found free of signs of corrosion and fungus growth and in good operating condition. After a total exposure time of 90 days, the top was removed from the air conditioner, and the outside and inside, as far as possible were rechecked for biodeterioration. The insulating tape over the foam rubber insulation was slightly tacky. The aluminum bolt on the service valve was slightly corroded, and the solenoid valve had a powdery appearance on the surface. The powder which appeared to be some deposit of aluminum salts, could easily be wiped off.

Operational data were taken before and at the completion of the fungus tests. The results are presented in Table XXXVII.

u. Physical Characteristics and Safety. Initial inspection of each test unit included size, weight, freedom from sharp edges, ease of handling, and protective devices for thermal, pressure, and current overload. In addition, inspections for safety and simplicity of operation were made during the functional, operational, and environmental tests.

Both models are 34.8 inches long, 38.0 inches wide, and 27.0 inches high. The 400-hertz unit weighs 415 pounds, and the 60-hertz unit weighs 425 pounds.

Throughout the tests the units were found to have:

Table XXXVII. Operational Results Before and After Fungus Test, Model MC11HAL6-230

Measurement	Before	After
Air Temperatures (°F)		
Entering Evaporator, Dry Bulb	90	90
Entering Evaporator, Wet Bulb	67	72
Leaving Evaporator, Dry Bulb	67	65
Entering Condenser, Dry Bulb	120	120
Leaving Condenser, Dry Bulb	141	139
Refrigerant Temperatures (°F)		
Discharge Line	196	214
Condenser Outlet	148	155
Subcooler Outlet	137	143
TEV Inlet	136	141
Suction at TEV Bulb	49-55	52-57
Suction at Compressor	49-54	66
Quench Outlet	68-77	86
Equalization Solenoid Outlet	162	172
Precooler Inlet	215	234
Precooler Outlet	185	202
Subcooling at Subcooler	12	12-13
Subcooling at TEV	13	14-15
Superheat at TEV Bulb	2-8	4-8
Superheat at Compressor	2-7	8-17
Compressor Skin Temperature (°F)	188	203
Discharge Pressure (psig)	376-380	406-409
Suction Pressure (psig)	79-81	80-83
Electrical Characteristics		
Average Voltage	228	230
Average Amperage	12.2	12.6
Total Wattage	2,645	2,728
Power Factor (%)	94.9	94.0

Note: These data are also applicable to Model MC40HAL4-208.

(1) Suitable features for starting, stopping, and temperature control by one man.

(2) Access panels or removable covers for ease of maintenance.

(3) Safety devices compliant with requirements of ASA, UL, and military standards.

(4) Same components and parts as those used in other military environmental control units to the extent practicable.

(5) Carrying handles, tiedown fittings, and mounting provisions.

(6) Standard refrigerants and standard lubricants.

(7) Access limited to front, top, and back to permit side-by-side multiple installation.

(8) High-pressure cutout safety device which operates at 437 psig for the 60-hertz unit, and 443 psig for the 400-hertz unit.

(9) Heater control which cuts off at 220° F at the most severe condition.

(10) Pressure equalization valve which equalizes the compressor discharge and suction pressures within 8 psi within 20 seconds should the compressor stop for any reason. Testing showed that after the compressor was shut off, the compressor discharge pressure of 400 psig decreased to 232 psig, and the suction pressure of 90 psig increased to 224 psig 20 seconds after shutdown. This feature protects the compressor by minimizing the starting load and starting current surge.

(11) In addition to tests for complete units, certain component testing was accomplished during development. Results of tests of five random samples of the pressure relief valve (Table XXXVIII) follow:

Table XXXVIII. Results of High-Pressure Relief Valve Test

Sample	Initial Test Pressure (psig)			Final Test Pressure (psig)		
	Leak	Crack	Reset	Leak	Crack	Reset
1	560	505	505	530	540	505
2	565	580	520	540	540	520
3	560	580	525	540	540	520
4	520	530	470	500	500	480
5	605	605	510	530	550	520

If the high-pressure cutout safety device fails, then the high-pressure relief valve will relieve at approximately 60-psi additional pressure.

Some adjustments were required to realize safe and simple operation. At the conclusion of tests, no evidence of features which would constitute a hazard to personnel was noted. In addition, these units were suitably provided with protective devices to prevent undue damage.

v. Phase Reversal. The phase reversal test was conducted to determine the ability of the air conditioner to operate with two phases interchanged without damaging the system.

The electrical service to the test unit service connection was such that two legs of the 3-phase system were interchanged. The air conditioner was required to be free from damage to the motors or compressor for 30 minutes.

The compressor motor, condenser fan motor, and evaporator fan motor are protected by a phase sequence relay. No component operation was possible until the correct phase sequence was established.

w. Heater High-Limit Cutout. The heater high-limit cutout test was conducted on the Model MC40HAL4-208 unit to determine if the device functioned properly. The unit was instrumented for reading temperatures at the thermal protector and the airspace above the top heater to obtain data in the HI-HEAT and LO-HEAT modes with the fan motor in low or high speed and the return-air inlet blocked or in the HI-HEAT and LO-HEAT modes with the return-air inlet open and the fan motor disconnected. These conditions were equivalent to a badly clogged filter or a fan motor failure.

During the test, smoke was being discharged from the evaporator air discharge. The unit was shut down, and investigation showed that the foam insulation on the back of the blower air outlet compartment was singed and slightly melted. The heater thermal protector support bracket was moved from the original position of 0.350 inch above to 0.175 inch above the top heater element. (The sensing face of the protector was 0.250 inch from the top heater.)

In addition to the functional tests, the unit successfully completed a 24 hour on and off cycling test with the fan motor disconnected. The time from starting to cutout was approximately $1\frac{1}{4}$ minutes and from cutout to restarting the unit was approximately 42 minutes.

Results of the heater high-limit test of Model MC40HAL4-208 follow:

(1) Fan Running: Low-Speed, HI-HEAT - Warmer Mode, Evaporator Air Inlet Open, 102^{o} F Air Temperature at Protector, Operations Continual

(2) Fan Running: Low-Speed, HI-HEAT - Warmer Mode, Blocked Evaporator Air Inlet, 162^{o} F Air Temperature at Protector (Cutout)

(3) Fan Disconnected: HI-HEAT - Warmer Mode, Evaporator Air Inlet Open, 195^{o} F Air Temperature at Protector (Cutout)

(4) Fan Disconnected: LO-HEAT - Warmer Mode, Evaporator Air Inlet Open, 220^{o} F Air Temperature at Protector (Cutout)

With the fan motor disconnected the cut-in temperature varied between 109^{o} F and 113^{o} F during the 24-hour cycling test.

x. Starting Current. The starting current test was conducted to determine the maximum starting and steady-state running current of the air conditioner in the COOL mode of operation.

The test was conducted at nameplate rated voltage and frequency, and the unit was charged with the optimum refrigerant charge. Specific test conditions of 120° F dry-bulb outside room and 90° F dry-bulb dry-coil inside room were maintained throughout the test. A stable thermal equilibrium balance was obtained in the test cells at the specific test conditions with the unit operating in the maximum cooling cycle before testing. An oscilloscope was connected to the electrical power input leads of the test unit. A camera was attached to the oscilloscope to photograph the readouts on the oscilloscope graph. The following transients were recorded:

(1) OFF to COOL (fans only).

(2) OFF to COOL (compressor).

(3) OFF to VENT.

(4) VENT to COOL (fans only).

(5) VENT to COOL (compressor).

(6) BYPASS to COOL (thermostat operation).

(7) COOL to BYPASS (thermostat operation).

When current or voltage spikes of short duration, of large amplitude, or both were apparent, the scale size and selected time of the oscilloscope were adjusted to record and photograph the spikes properly so that accurate duration periods could be determined, and root mean square current values computed.

Current transients were observed in the first five functions just listed. No measurable current surge occurred during the last two functions given.

The results of this test are presented in Table XXXIX and in Figs. 9 and 10.

y. Frequency Variation. The frequency variation tests were conducted to determine the ability of the air conditioners to operate at adverse frequencies under temperature conditions of 120° F ambient and 90° F return air.

Table XXXIX. Results of Starting Current Test

Switch Position Changes	Test Model			
	MC40HAL6-208		MC40HAL4-208	
	Transient Current (calculated in rms, amp)	Duration of Transient (calculated in msec)	Transient Current (calculated in rms, amp)	Duration of Transient (calculated in msec)
(1) OFF to COOL (fans only)	29.6	1,235	41.7	1,294
(2) OFF to COOL (compressor)	98.0	44	89.7	397
(3) OFF to VENT	18.6	25	17.1	1,024
(4) VENT to COOL (fans only)	27.5	1,047	-(a)	-(a)
(5) VENT to COOL (compressor)	102.2	44	88.6	441
(6) BYPASS to COOL (thermostat operation)	(b)	(b)	(b)	(b)
(7) COOL to BYPASS (thermostat operation)	(b)	(b)	(b)	(b)

Notes: (a) Hyphens signify that no data were taken.
(b) The power requirement for the COOL mode is only slightly greater than that for the BYPASS mode. No "spikes" occurred.

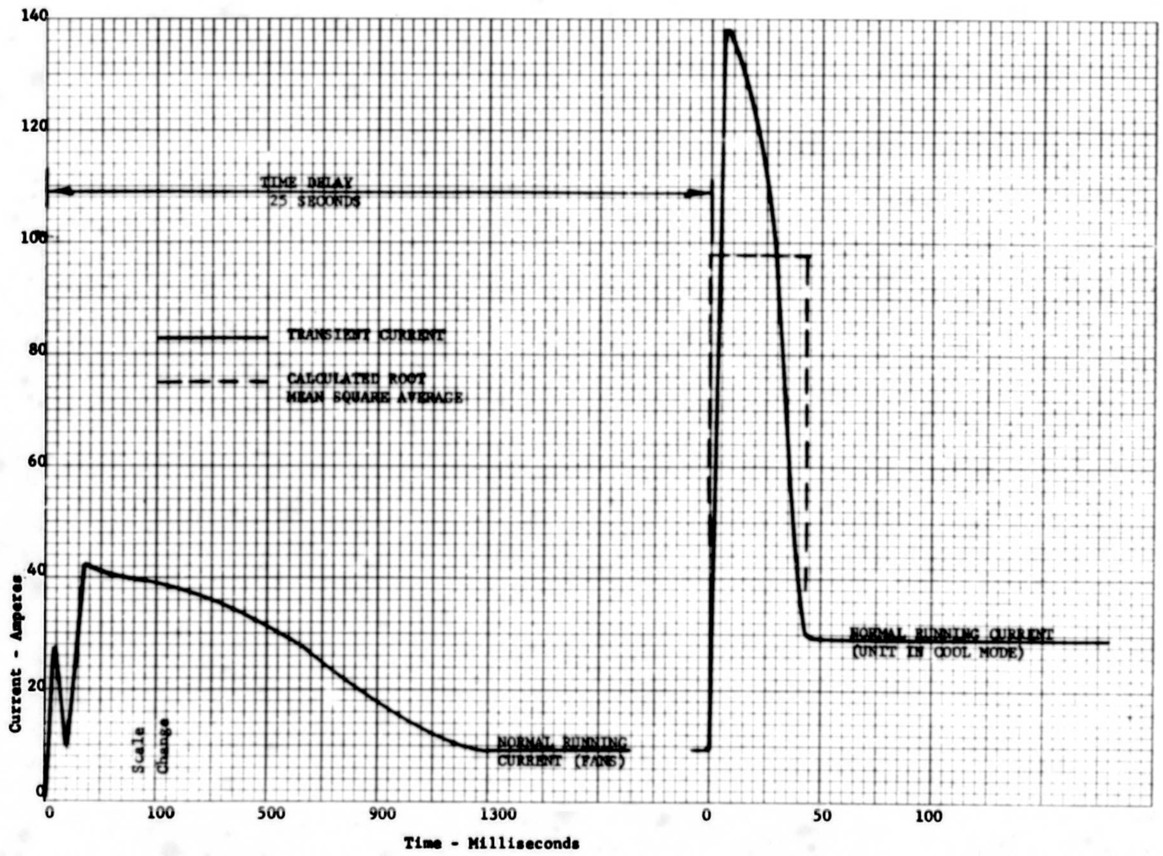


Fig. 9. Results of starting current test, Model MC40HA L6-208.

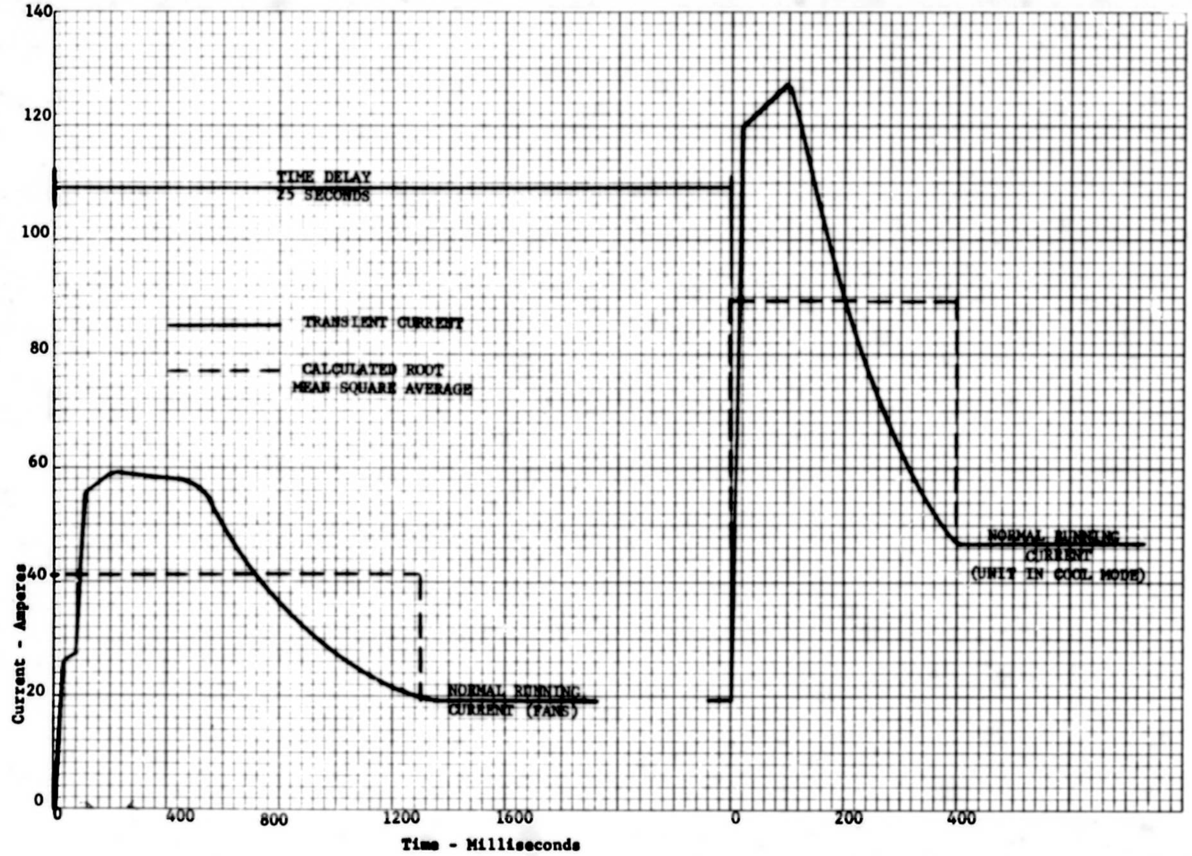


Fig. 10. Results of starting current test, Model MC40HAL4-208.

Tests were conducted under the following frequency and voltage conditions:

(1) 60-Hz Unit

(a) 63 Hz at 197 volts

(b) 63 Hz at 218 volts

(c) 50 Hz at 197 volts

(d) 50 Hz at 218 volts

(2) 400-Hz Unit

(a) 420 Hz at 197 volts

(b) 420 Hz at 218 volts

(c) 380 Hz at 197 volts

(d) 380 Hz at 218 volts

The 60-hertz unit operated under all conditions except (1)(d). Under the conditions, that is, 218 volts, 60 hertz, the unit operated for 10 minutes. The condenser fan motors then "tripped" on their overload protective device and, immediately following this, the compressor tripped on its high-pressure cutout device. After a 15-minute delay, the compressor high-pressure cutout was reset. The unit then operated for 5 minutes and again tripped in the same sequence as stated p:eviously.

The 400-hertz unit operated only under condition (2)(c), that is, 197 volts, 380 hertz. In the three other tests, the 400-hertz unit would operate for extremely short periods and would require shutting down and restarting because the motor protective devices would open prematurely or the compressor circuit breaker protection switch would tri·.

z. Condensate Disposal. The condensate disposal test was conducted to determine the effectiveness of the air conditioner condensate disposal system. This test was conducted with the air conditioner mounted in the psychrometric test chamber with the unit tilted 5 degrees from the horizontal-evaporator side low. During a 2-hour test, an occasional drop of water was emitted with the evaporator air discharge, and a steady stream of water was flowing normally from the condensate drain.

The unit was then installed at a 5-degree tilt toward the left (control box) side of the unit. As the test progressed a steady drip of water was observed leaking from the lower left corner of the evaporator air discharge grill, and less than half of the normal drainage was flowing. After 1 hour, the unit was stopped.

Investigation and analysis showed that the height of the drain pan lip must be increased, the drain holes must be closer to the ends of the drain pan, and the number of drain holes must be increased.

aa. Sand and Dust. The sand and dust test was conducted to determine the ability of the test unit to withstand an atmosphere of blowing sand and dust particles.

The requirements demand acceptable performance [illegible]er applicable storage and operating climatic conditions established by AR 705-15, Cl.

The unit tested, Model MC40HAL4-208, was inspected and operated before the sand and dust exposure. No deficiencies were found. The measurements taken during the operation are listed as follows:

Operation Before Sand and Dust Exposure

Measurement	Result
Evaporator Air Intake Temperature (°F)	45
Evaporator Air Discharge Temperature (°F)	35
Condenser Air Intake Temperature (°F)	59
Condenser Air Discharge Temperature (°F) Right Side	95
Condenser Air Discharge Temperature (°F) Left Side	94
Compressor Suction Pressure (psig)	50
Compressor Discharge Pressure (psig)	185
Average Voltage	207
Average Amperage	36.1
Total Wattage	8,100

The test item was installed in the rear of a van with the condenser section outside and the evaporator section 10 inches inside the van. The unit was caulked and sealed at the wall of the van. A mixture of sand and dust which contained particle sizes from very fine earth up to the largest size listed in AR 705-15, C1, paragraph 7a(8), was blown at the condenser end at a wind speed of 15 mph. The air conditioner was exposed to these conditions for 4 hours with the unit operating in the COOL mode, the condenser fan speed switch on automatic (speed was low), the thermostat set for cooling, the fresh-air damper closed, and the evaporator fan speed high.

During the exposure, the inside of the van and the unit were observed for evidence of sand and dust particles passing through the unit into the van. After 3½ hours of exposure, the operational parameters mentioned were measured again and after the exposure, the unit was inspected for detrimental effects.

Inspection of the unit after the sand and dust exposure revealed the following:

(1) Sand and dust piled up in the fins at the bottom of the condenser coil to a height which ranged from 1 to 2 inches.

(2) Sand and dust covered the bottom of the condenser section up to a height of 4 inches.

During the sand and dust exposure, no evidence was found of particles passing through the unit into the van.

The measurements taken during the last 1/2 hour of operation of the unit in sand and dust are listed as follows:

Sand and Dust Operation

Measurement	Result
Evaporator Air Intake Temperature (^oF)	52
Evaporator Air Discharge Temperature (^oF)	39
Condenser Air Intake Temperature (^oF)	68
Condenser Air Discharge Temperature (^oF) Right Side	101
Condenser Air Discharge Temperature (^oF) Left Side	100
Compressor Suction Pressure (psig)	57
Compressor Discharge Pressure (psig)	215
Average Voltage	208
Average Amperage	36.7
Total Wattage	8,300

bb. Performance and Power Characteristics. These tests were conducted immediately upon receipt of the air conditioners from the contractor. These performance and power characteristics data were used as bases for comparison of operation of the test unit after each test throughout the test program.

The controls tests were coordinated with the performance and power characteristics tests, and the results are presented in Tables XIII through XVII in Section III, paragraph 5h(2).

cc. Endurance. The endurance tests are being conducted to determine the durability and reliability of the air conditioners. Reports of equipment failure, cause of failure, repair data, and equipment operation are utilized in setting up reliability factors.

The endurance test chamber (Fig. 11) is a test facility that consists of two rooms, an indoor room and an outdoor room. The indoor room has means for supplying heat and moisture to maintain the required evaporator-side conditions. The outdoor room has equipment for heat control to maintain the condenser-side ambient at the required temperature.

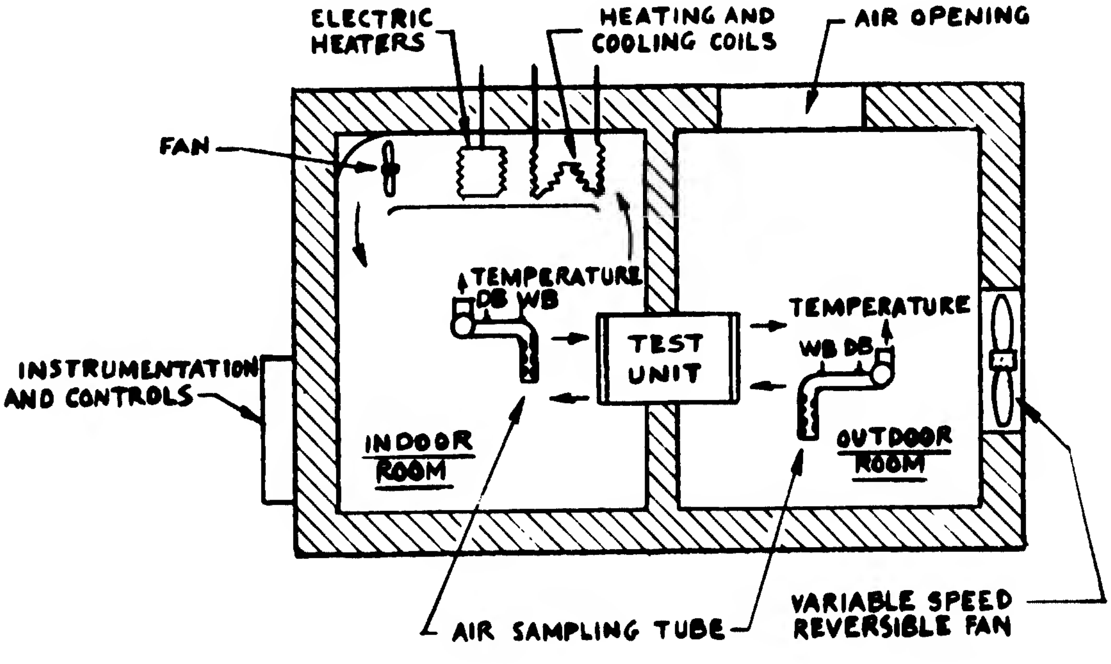


Fig. 11. Endurance test chamber.

The following procedure is used where cycling is required in this test:

(1) Switch On-Off Cycles. The air conditioner is cycled on and off by means of the air-conditioner switch. A time clock device operates this switch automatically.

(2) Thermostat Cycles. A control device heats and cools the thermostat sensing bulb at 15-minute intervals. The air conditioner then responds to the command of the thermostat.

The air conditioner was mounted in a manner similar to normal installations with provisions for removal of evaporator condensate.

The test goals for each unit were a minimum of 500 hours under HI-HEAT mode conditions and 4,000 hours under COOL and BYPASS mode conditions.

The 60-hertz unit has completed all the tests under the COOL and BYPASS modes, and has completed 33 percent of the test time under the HI-HEAT mode. The 400-hertz unit has completed over 75 percent of the tests under the COOL and BYPASS modes, but no testing in the HI-HEAT mode has yet been accomplished on this model. At present, both units are running in the endurance test chamber.

Table XV shows the actual time to date on the respective units. The test will continue until the prescribed time has been accomplished.

dd. Humidity. The humidity test was conducted to determine whether the units had sufficient protection for all components to satisfy the humidity test requirements of MIL-STD-810.

The tests were conducted at the Aberdeen Proving Ground by USATECOM personnel.

The test items were installed in a humidity chamber where the chamber temperature ranged between 68° F and 100° F. In 2 hours, the chamber temperature and humidity were raised to 155° F and $95 {}^{+5}_{-0}$ percent, respectively. These conditions were maintained for 6 hours. Then, in 16 hours, the temperature was lowered to 100° F, while the humidity was kept at $95 {}^{+5}_{-0}$ percent. This cycle was repeated ten times for a total exposure of 240 hours. Before and after the exposure, the unit was given a detailed inspection. All covers and grilles (except the condenser grille) were removed,

Table XL. Results of Endurance Tests

Condition	Selector Switch Position	Thermostat	Outdoor Ambient Temperature (°F), Dry Bulb	Return-Air Temperature (°F), Dry Bulb	Unit Function	Time (hr)[a] MC40HAL6-208	Time (hr)[a] MC40HAL4-208
A	COOL	Cycled See paragraph cc(2)	105-120	85-90	COOL or BYPASS	3,679	1,095
B	COOL	Cycled See paragraph cc(2)	90-105	75-80	COOL or BYPASS	3,176	1,678
C	COOL	Cycled See paragraph cc(2)	90 or below	65-75	COOL or BYPASS	1,544	-[b]
D	COOL	Unsatisfied	105-120	85-90	COOL	1,106	192
E	COOL	Unsatisfied	80-105	75-80	COOL	578	114
F	COOL	Satisfied	105-120	85-90	BYPASS	117	114
G	COOL	Satisfied	80-105	85-90	BYPASS	117	115
H	Cycled OFF to COOL See paragraph cc(1)	Unsatisfied	105-120	85-90	OFF or COOL	155	336
I	Cycled OFF to COOL See paragraph cc(1)	Satisfied	80-105	75-80	OFF or BYPASS	123	-
J	HI-HEAT	Cycled See paragraph cc(2)	Any	65-85	LO-HEAT or HI-HEAT	167	-
K	Cycled OFF to HI-HEAT See paragraph cc(1)	Unsatisfied	Any	65-85	OFF or HI-HEAT	-	-

Notes: (a) Time data do not necessarily imply any limits or failures. Units are currently operating in the endurance chamber (13 Oct 66).
(b) Hyphens signify that no data were taken.

and evidence of damage or corrosion was noted. In addition, prior to the exposure, the unit was operated, all controls were checked, and any evidence of improper operation was noted. With the unit in the cooling mode and the thermostat set for cooling, measurements of the following parameters were made:

(1) Evaporator air intake and discharge temperatures.

(2) Condenser air intake and discharge temperatures.

(3) Compressor suction and discharge pressures.

(4) Voltage input, current draw, and power input.

The first model tested was MC40HA L6-208, serial No. 434. The prehumidity inspection and operational check revealed no deficiencies. A list of the measurements taken during the prehumidity operational check follows:

Operation Before Humidity Exposure

Measurement	Result
Evaporator Air Intake Temperature (^{o}F)	69
Evaporator Air Discharge Temperature (^{o}F)	47
Condenser Air Intake Temperature (^{o}F)	76
Condenser Air Discharge Temperature (^{o}F) Right Side	116
Condenser Air Discharge Temperature (^{o}F) Left Side	115
Compressor Suction Pressure (psig)	60.5
Compressor Discharge Pressure (psig)	245
Average Voltage	207
Average Amperage	19.9
Total Wattage	6,140

The measurements just given were taken with unit cooling, with the evaporator fan switch in high and the condenser fan switch in automatic (speed was low), and with wet coil conditions.

After 10 minutes of operation during the posthumidity operational test, a loud pop was heard and a puff of smoke was emitted from the left condenser air discharge. The unit was cooling with the condenser fan speed switch in automatic (the speed was low). The left condenser fan was found to be inoperative in the slow speed mode and one phase of the low-speed winding was open when checked with an ohmmeter. With the condenser fan speed switch in high, the unit was turned on again and sparks were seen in the vicinity of the control box. Investigation revealed a burned area at the head of the mounting screw for a barrier strip. This same screw was used to ground the neutral wire from the power receptacle. Traces of anodizing were found in the countersink where the screw head was mounted.

The posthumidity inspection revealed the following corrosion:

(1) The diaphragm cover of the quench expansion valve was covered with rust.

(2) The diaphragm cover of the main expansion valve was covered with rust.

(3) The right condenser louvre cable was rusted at either end where it protruded from its casing.

(4) Spots of rust occurred throughout in screw slots, tops of screw threads, and various other places.

The second model tested was MC40HAL6-208 unit No. 432. The prehumidity inspection revealed no deficiencies. A list of the measurements taken during the prehumidity operational check is as follows:

Operation Before Humidity Exposure

Measurement	Result
Evaporator Air Intake Temperature (°F)	74
Evaporator Air Discharge Temperature (°F)	56
Condenser Air Intake Temperature (°F)	76
Condenser Air Discharge Temperature (°F) Right Side	135
Condenser Air Discharge Temperature (°F) Left Side	133
Compressor Suction Pressure (psig)	78
Compressor Discharge Pressure (psig)	300
Average Voltage	202
Average Amperage	22.4
Total Wattage	7,800

The measurements just given were taken with unit cooling, with the evaporator fan switch in high and the condenser fan switch in automatic (speed was low), and with wet coil conditions.

After 5 minutes of operation during the posthumidity operational test, a loud pop was heard and the air stream from the left condenser discharge louvres stopped. The unit was cooling with the condenser fan speed switch in automatic (the speed was low). Upon investigation, it was determined tnat the left condenser fan motor would operate only in the high-speed mode. To obtain readings, the condenser fan speed was turned to high, and the readings shown in the following list were taken.

Operation After Humidity Exposure

Measurement	Result
Evaporator Air Intake Temperature (°F)	73
Evaporator Air Discharge Temperature (°F)	54
Condenser Air Intake Temperature (°F)	75
Condenser Air Discharge Temperature (°F) Right Side	122
Condenser Air Discharge Temperature (°F) Left Side	120
Compressor Suction Pressure (psig)	71
Compressor Discharge Pressure (psig)	243
Average Voltage	203
Average Amperage	26.3
Total Wattage	8,300

The posthumidity inspection revealed the following corrosion:

(1) The diaphragm cover of the quench expansion valve was covered with rust.

(2) Miscellaneous screws and other small items had spots of rust on them.

(3) The diaphragm cover of the main expansion valve was covered with rust.

ee. Vibration. The mechanical vibration test was conducted to determine the ability of the air conditioner to withstand dynamic stresses which result from extremely hard usage in military service.

Vibration tests were conducted in accordance with USAERDL Vibration Test No. 514. This test procedure consists of a table vibration at a 1.6-g level for a minimum of 80 minutes in each of three mutually perpendicular planes. This 80-minute test period in each plane is equivalent to 4,000 miles of vehicular transport. One-sixth the total vibration time was at each of four points of resonance in each plane. The remaining time was spent sinusoidally cycling from 5 Hz to 50 Hz.

The three mutually perpendicular directions for the air conditioner were designated and defined as:

Vertical
Perpendicular to the top and bottom surfaces.

Transverse (side to side)
Perpendicular to the side surfaces on which the handles were mounted.

Longitudinal (front to back)
Perpendicular to the front panel.

For transverse direction testing, the air conditioner was bolted to two steel channels (1/2 inch by $2\frac{1}{2}$ inches by 4 inches) which had been bolted to a magnesium "slippery" plate supplied by USAMERDC (formerly USAERDL). The slippery plate was driven by a horizontally positioned Ling Model A300B vibration exciter. For longitudinal direction testing, two additional similar steel channels were added as well as two 1-inch-thick aluminum plates. The position of drive application was raised above the top surface of the steel channels to permit excitation closer to the center of gravity of the air conditioner and fixture. For vertical direction testing, the same fixture was bolted to a steel I beam which had been bolted to the test surface of a vertically positioned Ling Model A300B vibration exciter.

For determining resonances, piezoelectric accelerometers were cemented to the major components of the air conditioners as selected by the USAMERDC (formerly USAERDL) representatives. Before proceeding to the next direction, the test operator realigned the sensitive axis of each accelerometer so that it would coincide with the direction of excitation.

A piezoelectric accelerometer was mounted near each of the four corners of the unit for monitoring the input acceleration level. The outputs of these accelerometers were connected into an electronic network which averaged the four inputs into a single reading on a direct-current vacuum tube voltmeter; thus, the operator could control the unit from indications on one meter.

The outputs of all accelerometers were connected through cathode followers and amplifiers to a Consolidated Electrodynamics oscillograph. Oscillograms of the accelerations transduced by each accelerometer were recorded during each resonance search. The paper speed was 0.25 inch per second.

The air conditioner and fixture were observed under frequency-synchronized stroboscopic light to assist in determining resonances. Transparent Plexiglas covers permitted observation of the internal components.

A resonance search was performed with the use of a logarithmic frequency sweep with the time regulated to traverse the frequency range from 5 Hz to 50 Hz in 7.5 minutes. Oscillograms were recorded during the search.

After the oscillograms were evaluated, major resonances were selected with the assistance of the USAMERDC representatives. A 13-1/3-minute resonant dwell period was performed at each major resonance selected. The input acceleration level for each resonant dwell period was 1.6 g's (average).

The remainder of the specified 80 minutes of vibration time for each direction was devoted to cycling from 5 Hz to 50 Hz and returning to 5 Hz at the same sweep rate and input level employed during the resonance search.

Test results in each of the three planes follow:

(1) Transverse Direction. Major resonances were selected from the evaluation of the oscillograms recorded during the resonance search. The resonant frequencies are given in Table XLI.

Table XLI. Resonant Frequencies of Model MC40HAL6-208, Transverse Direction

Location	Frequency (Hz)	Acceleration (g)
Center Partition	43	22
Right Condenser Fan Motor	33	14
Evaporator Fan Motor	27	10
Compressor	24	44

A 13-1/3-minute resonant dwell was performed at each of the frequencies just given. The visual examination after conclusion of vibration along this direction disclosed the following defects:

(a) The condenser intake grille welds fractured along the right side and at the upper left corner. The grille was removed prior to continuation of tests.

(b) The condenser coil mounting bracket fractured on both sides near the top mounting screw. Steel plates were installed to reinforce both fractures to permit continuation of testing.

(c) The nuts on two of the heating element terminals had worked loose. These nuts were tightened before continuation of testing.

(d) One bolt had worked loose and a second had worked completely out of the head pressure control support bracket. This hardware was replaced and tightened before continuation of testing.

The failures which occurred during vibration tests in the transverse direction did not render the unit inoperative. It was evident that no further damage would occur in these areas if the test were continued. On the basis of this engineering judgment, no further retesting at this condition was believed necessary.

(2) Longitudinal Direction. Major resonances were selected from the evaluation of the oscillograms recorded during the resonance search. The resonant frequencies are given in Table XLII.

Table XLII. Resonance Frequencies of Model MC40HAL6-208, Longitudinal Direction

Location	Frequency (Hz)	Acceleration (g)
Head Pressure Central Bracket	43	20
Condenser Fan Motor	18	20
Evaporator Fan Motor	24	26
Compressor	10	24

A 13-1/3-minute resonant dwell period was performed at each of the frequencies just given. The visual examination after conclusion of the vibration test along this direction did not disclose any apparent defects.

(3) Vertical Direction. Major resonances were selected from the evaluation of the oscillograms recorded during the resonance search. The resonant frequencies are given in Table XLIII.

Table XLIII. Resonant Frequencies of Model MC40HA L6-208, Vertical Direction

Location	Frequency (Hz)	Acceleration (g)
Back-Pressure Regulating Valve	50	14
Left Condenser Fan Motor	40	4
Evaporator Fan Motor	35	4
Piping	22	*

* Determined from observation with stroboscopic light.

A 13-1/3-minute resonant dwell was performed at each of the frequencies just given. The visual examination after conclusion of the vibration test along this direction did not disclose any apparent defects.

Operational tests were performed before and after the vibration tests. These operational results are presented in Tables XLIV and XLV.

ff. Lifting Ring Tests. The lifting ring tests were conducted on the Model MC40HA L6-208 air-conditioning unit to determine the following:

(1) If the lifting rings are located so that the air conditioner can be moved with ordinary rigging methods.

(2) If the lifting rings have sufficient strength to withstand the forces and shocks that may be experienced during movement.

(3) If the air conditioner is distorted or in any way damaged during lifting operations.

Table XLIV. Results of Previbrational and Postvibrational Cooling Operation Test, Model MC40HA L6-208

Measurement	COOL	
	Previbrational Operation	Postvibrational Operation
Air Temperatures (^{o}F)		
Entering Evaporator, Dry Bulb	90	91
Entering Evaporator, Wet Bulb	70	61
Leaving Evaporator, Dry Bulb	68	68
Entering Condenser, Dry Bulb	120	121
Leaving Condenser, Dry Bulb	146	147
Refrigerant Temperatures (^{o}F)		
Discharge Line	265	264
Condenser Outlet	148	148
Subcooler Outlet	138	138
TEV Inlet	139	139
Suction at TEV Bulb	72	70
Suction at Compressor	76	74
Suction Pressure Regulating Valve Outlet	141	142
Quench Outlet	116	125
Equalization Solenoid Outlet	144	146
Subcooling at Subcooler	11	11
Subcooling at TEV	10	10
Superheat at TEV Bulb	21	19
Superheat at Compressor	25	23
Compressor Skin Temperature (^{o}F)	107	105
Discharge Pressure (psig)	378	377
Suction Pressure (psig)	86	86
Electrical Characteristics		
Average Voltage	208	208
Average Amperage	30.0	30.0
Total Wattage	9,510	9,510
Power Factor (%)	88.4	88.3
Evaporator Fan Speed (rpm)	3,360	3,410
Condenser Fan Speed (rpm)	3,380	3,420

Table XLV. Results of Previbrational and Postvibrational Ventilation Test, Model MC40HAL6-208

Measurement	VENT	
	Previbrational Operation	Postvibrational Operation
Air Temperatures (°F), Dry Bulb		
Entering Evaporator	92	91
Leaving Evaporator	95	93
Electrical Characteristics		
Average Voltage	208	208
Average Amperage	3.44	3.54
Total Wattage	1,116	1,170
Power Factor (%)	90.2	91.8
Evaporator Fan Speed (rpm)	3,360	3,410

The unit was subjected to static lift and shock tests. For the static lift test the unit was firmly strapped to the floor, and hoisting cables were attached to the lifting rings. The cables were attached to scales by a chain. The scales were lifted by a crane hoist to a reading of 1,100 pounds and held at this stress for 1 hour. The angle of the lift cable was 30 degrees with the horizontal during the static lift and the shock tests.

For the shock test the cable was attached to a quick release bar with a chain. The chain slack was 12 inches. The unit was dropped from the release bar and caught by the chain six times.

The unit underwent the static lift test with no apparent damage.

The lifting ring mounts moved 1/8 inch on the first shock as a result of oversized bolt holes. No further movement was observed during the remainder of the test. As a result of the third shock, the cabinet and the rear cover were bent slightly where the cables made contact. A piece of wood was placed in order to prevent further damage to this area. No more damage resulted from the last three shocks.

The lifting ring test was conducted improperly with the lifting cables only 30 degrees from horizontal. Had this angle been greater than 60 degrees, probably no damage to cover or cabinet would have occurred.

gg. <u>Acoustical Noise (Sound)</u>. The acoustical noise tests were conducted to determine sound pressure levels of the Model MC40HAL6-208 and Model MC40HAL4-208 air conditioners and to compare these noise levels with ASHRAE noise curves NC60, NC65, and NC70. These tests were conducted at the Aberdeen Proving Ground by USATECOM personnel.

The air conditioners were rigidly mounted in the rear door opening of the modified M242 fire control van. Plywood paneling 5/8 inch thick was used to block the rest of the opening, and this plywood was covered with 2 inches of fiber glass insulation. The evaporator section protruded 10 inches into the van, and the top of the air conditioner was at the top of the opening giving a height of 32-3/4 inches from the floor of the van to the bottom of the air conditioner. The inside van area (Fig. 12) was 248 inches by 87 inches by 74 inches high.

Three microphones were located on an arc 48 inches from the center of each air conditioner where it was mounted in the wall and 46 inches above the trailer floor. No. 1 microphone was at 30 degrees right, No. 2 was at zero degrees, and No. 3 was at 30 degrees left.

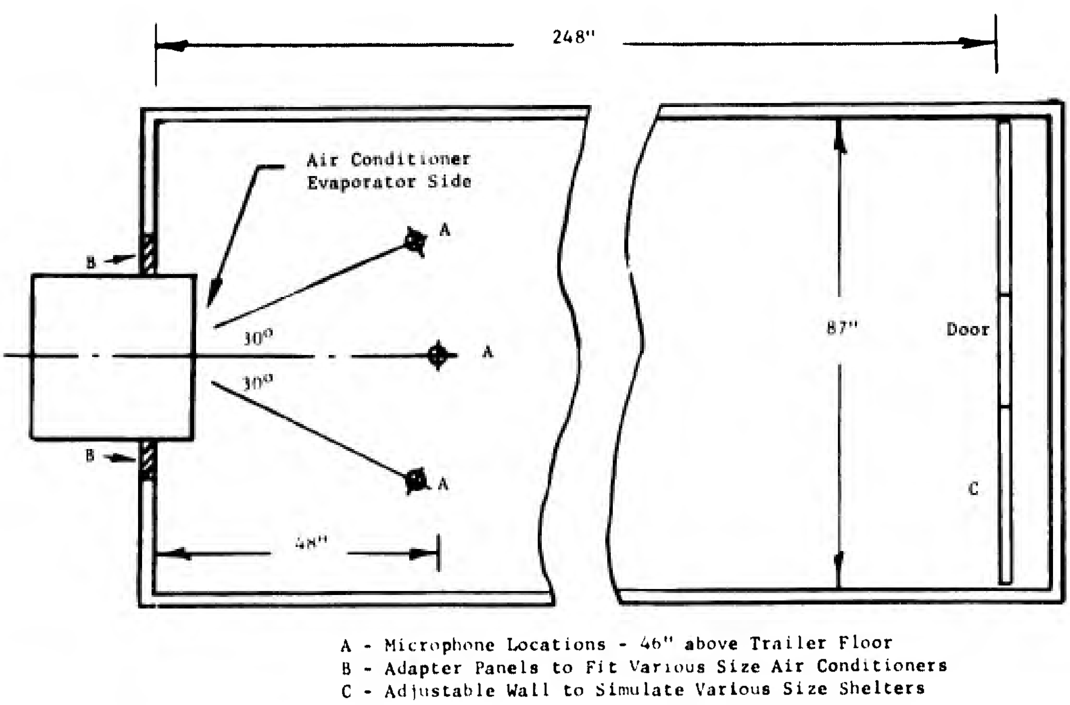


Fig. 12. Air-conditioner and microphone locations in modified M242 fire control van-type trailer for sound level tests.

The selector switch was set to COOL; the thermostat was set to maximum cooling throughout both tests.

Electrical resistance heating was utilized inside the van to provide an adequate cooling load on each air conditioner during the tests.

An octave band analysis was made covering the eight bands from 37.5 Hz to 9,600 Hz at the microphone positions shown in Fig. 12. Readings at the three microphone locations were averaged for each band. Readings were taken with the evaporator fan speed high and the condenser fan speed switch in both the high and low positions and also with the evaporator fan speed low and the condenser fan speed switch in both the high and low positions.

Ambient noise levels (with all frequencies passed) were 58 decibels at the start and 56 decibels at the conclusion of the test of the Model MC40HAL4-208 air-conditioning unit. Ambient noise levels (with all frequencies passed) were 56 decibels at the start and 54 decibels at the conclusion of the test of the Model MC40HAL6-208 air conditioner.

The results of the sound level tests are presented in Tables XLVI and XLVII. Figures 13 and 14 show the averages of the noise values in the COOL-cooler mode under high-speed and low-speed fan operations. These can be compared with the ASHRAE standard noise curves.

The outside noise tests were conducted at the Stratos Division, Fairchild Hiller Corporation. The microphone positions were similar to those for the inside noise tests (Fig. 15). The A position was directly outward from the rear center of the unit, and the B and C positions were 45 degrees to the right and left, respectively. All three positions of the microphones were 48 inches from the center of the air conditioner and 68 inches from the ground. Sound data were taken, and the average value was computed for each frequency.

The outside noise level test results for the Model MC40HAL6-208 are presented in Table XLVIII.

Table XLVI. Octave Band Noise Measurements in Decibels (Re 0.0002 Microbar) for Air Conditioner, Compact, Horizontal, 36,000 Btu/Hr, 3 Phase, 208 Volts, 60 Hert· Model MC40HAL6-208

Microphone Location	37.5 75	75 150	150 300	300 600	600 1,200	1,200 2,400	2,400 4,800	4,800 9,600	All Pass
	Evaporator Fan Speed on High - Condenser Fan Speed on High								
1	82	82	81	79	73	70	67	64	88
2	81	77	83	78	74	70	66	65	85
3	88	82	79	76	72	70	67	65	89
	Evaporator Fan Speed on Low - Condenser Fan Speed on High								
1	79	84	79	73	66	61	59	62	88
2	79	80	79	74	67	60	59	58	86
3	84	82	77	73	67	60	58	60	87
	Evaporator Fan Speed on Low - Condenser Fan Speed on Low								
1	79	83	80	76	65	60	58	61	86
2	77	78	80	71	67	60	58	60	86
3	82	82	77	72	65	59	57	59	86
	Evaporator Fan Speed on High - Condenser Fan Speed on Low								
1	78	82	81	79	73	70	66	64	89
2	79	79	81	77	73	70	66	64	87
3	85	81	76	75	72	70	66	64	88

Table XLVII. Octave Band Noise Measurements in Decibels (Re 0.0002 Microbar) for Air Conditioner, Compact, Horizontal, 36,000 Btu/Hr, 208 Volts, 3 Phase, 400 Hertz, Model MC40HA LA-208

Microphone Location	37.5 75	75 150	150 300	300 600	600 1,200	1,200 2,400	2,400 4,800	4,800 9,600	All Pass
	Evaporator Fan Speed on High - Condenser Fan Speed on High								
1	90	82	83	78	75	70	67	68	92
2	78	78	83	78	75	70	67	68	86
3	90	81	81	79	74	70	68	69	92
	Evaporator Fan Speed on Low - Condenser Fan Speed on High								
1	90	82	80	75	70	63	63	65	91
2	78	77	79	75	70	62	60	64	84
3	89	78	78	78	70	63	63	68	90
	Evaporator Fan Speed on Low - Condenser Fan Speed on Low								
1	91	82	75	73	69	62	64	71	92
2	69	76	75	71	69	61	58	61	83
3	90	79	73	73	70	61	58	60	91
	Evaporator Fan Speed on High - Condenser Fan Speed on Low								
1	91	73	77	76	75	70	68	71	92
2	72	69	79	76	74	69	68	70	84
3	89	71	77	78	74	70	69	71	91

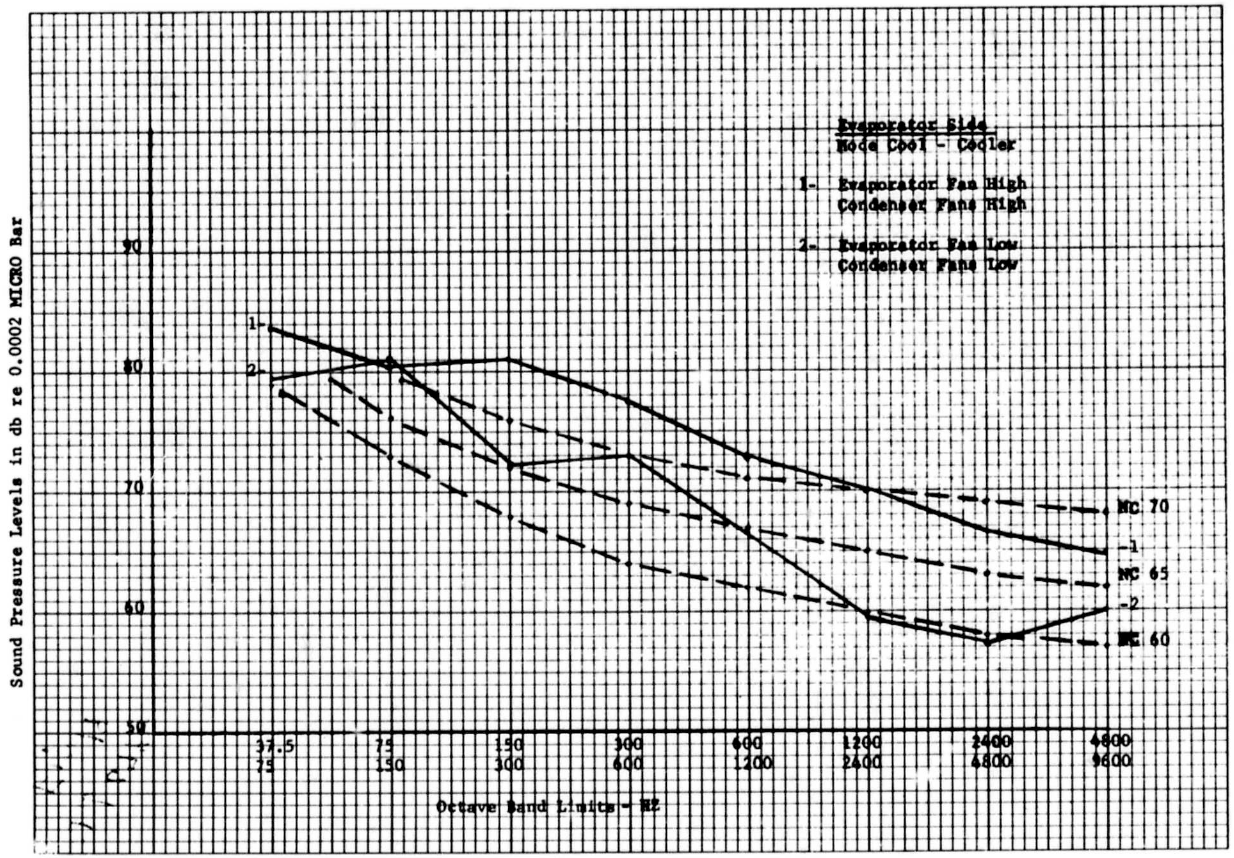


Fig. 13. Results of sound level tests, Model MC40HA L6-208.

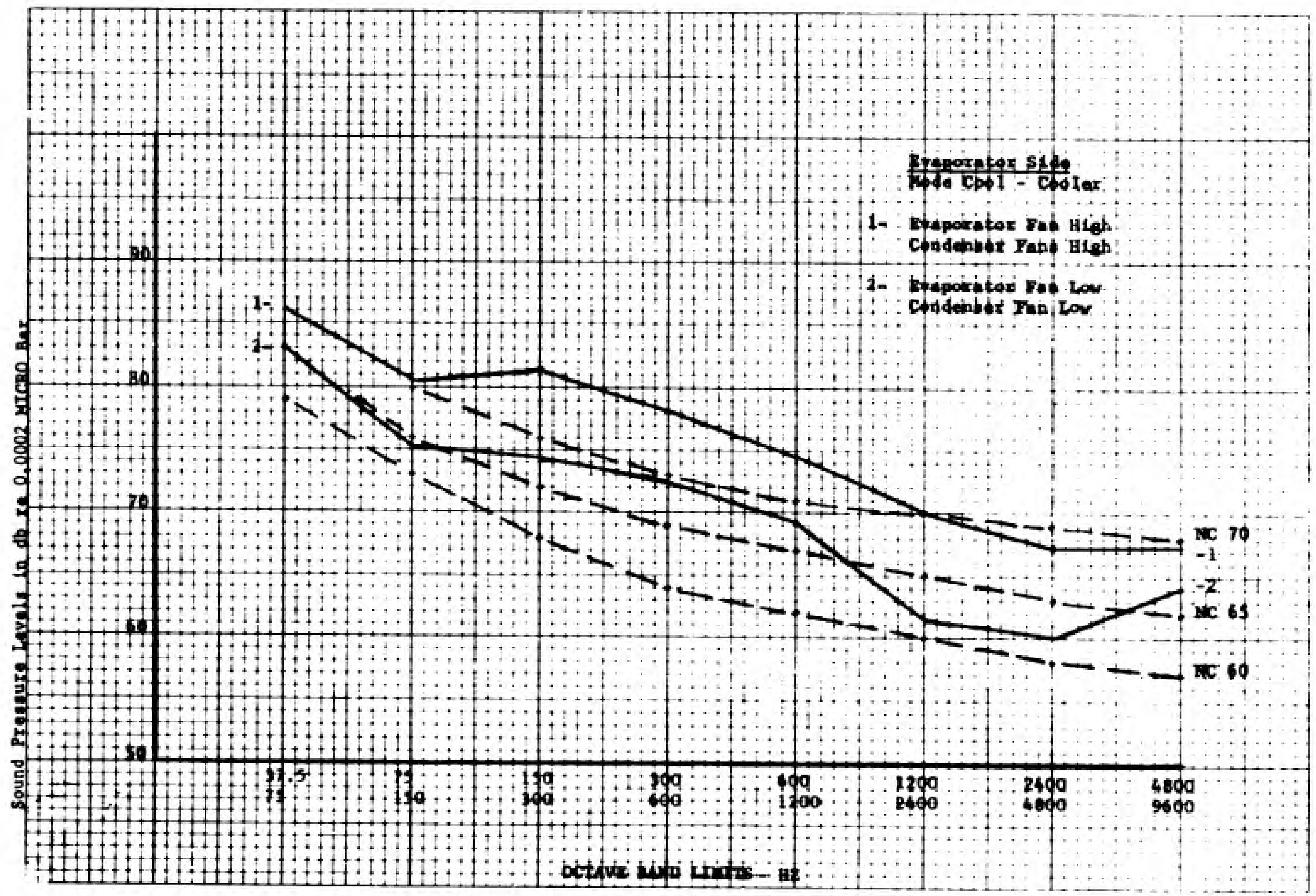


Fig. 14. Results of sound level tests, Model MC40HA L4-208.

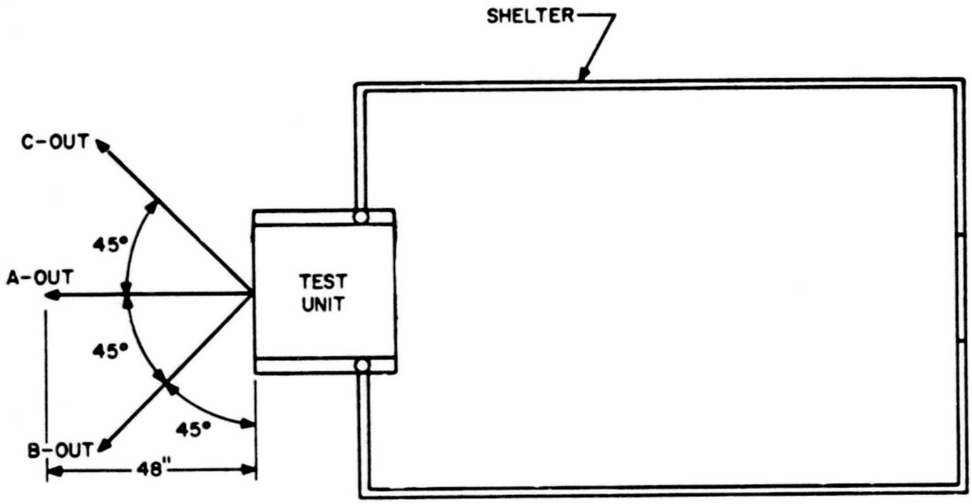


Fig. 15. Air conditioner and microphone locations for outside noise level tests.

Table XLVIII. Results of Outside Noise Level Tests, Model MC40HA L6-208

Frequency Range (Hz)	Average Sound Level (db)	Maximum Allowable Sound Level (db)*
37.5 - 75	63.5	120
75 - 150	67.3	115
15 - 300	81.3	109
300 - 600	83.3	101
600 - 1,200	80.6	93
1,200 - 2,400	80.5	89
2,400 - 4,800	78.1	89
4,800 - 9,600	67.5	91

*HEL Standard S-1-63B, Table I.

hh. Rain. The rain test was conducted to determine if the unit would be undamaged and function properly after exposure to rain environment. This test was conducted on Model MC40HA L4-208.

The unit was installed in an S-141 shelter. An operational check showed normal performance. The unit was tested under three different modes (storage or OFF, VENT, and COOL) and under conditions of varying rainfall rate and wind velocity.

(1) Storage or OFF. This portion of the rain test was run with the switch in the OFF position, the condenser weather cover rolled up, all drains open, and the fresh-air damper closed (Table XLIX). Rain was applied in the following sequence:

Table XLIX. Application of Precipitation and Wind Velocity in Storage Test

Condition	Duration (hr)	(min)	Rain Rate (in./hr)	Wind Speed (knots)
1	5	0	2	5-35
2	2	0	4	5-35
3	0	10	12	5-35
4	0	1	21	5-35
5	4	50	2	5-35

After completion of this phase of the test the unit was opened and examined. The condenser section components were wet, but no water accumulated in the base. The junction box, the control module, and the evaporator air plenum were dry; but a small amount of water accumulated in the blower air inlet section. This water did not enter the shelter.

A postoperational test in all modes and fan speeds showed normal performance.

(2) Ventilation. This portion of the rain test was run with the unit in the VENT mode, the condenser weather cover raised, evaporator fan adjusted for high speed, and the fresh-air damper open (Table L). Rain was applied in the following sequence.

Table L. Application of Precipitation and Wind Velocity in Ventilation Test

Test	Duration (hr)	Duration (min)	Rain Rate (in./hr)	Wind Speed (knots)
1	2	30	2	5-35
2	1	0	4	5-35
3	0	5	12	5-35
4	0	0.5	21	5-35
5	2	30	2	5-35

At the completion of this phase, the unit was inspected and the same conditions were noted as in storage. Before proceeding with the test, the test operator adjusted the seal between the unit and shelter, as it was suspected that the small amount of water observed was entering through this seal.

Under conditions prevailing at the end of the vent phase of the rain test, the unit performed normally in all modes and fan speeds.

(3) Cooling. During this portion of the rain test the unit was set in the COOL mode, the evaporator fan at high speed, the condenser fan on automatic, and the fresh-air damper closed (Table LI). Rain was applied in the following sequence.

Table LI. Application of Precipitation and Wind Velocity in Cooling Test

Test	Duration (hr)	Duration (min)	Rain Rate (in./hr)	Wind Speed (knots)
1	2	30	2	5-35
2	1	0	4	5-35
3	0	5	12	5-35
4	0	0.5	21	5-35
5	2	30	2	5-35

Inspection of the unit after completion of the cooling phase revealed no water anywhere in the evaporator side of the unit. A small amount of water collected in the bottom of the condenser; however, tnis amount of water in no way impaired operation of the unit.

At the close of the rain tests, the unit operated normally in all modes and at all fan speeds.

Pretest and posttest operational results are presented in Table LII.

ii. Salt Fog. The salt fog test was conducted to determine the resistance of the air conditioner to the effects of a salt atmosphere.

This test was conducted by the Development and Proof Services Department, TECOM.

Model MC40HAL4-208 was used in the salt fog test. The inspection and operational test before exposure revealed no deficiencies in the unit.

MIL-STD-810A was used as a guide for performing the salt fog test in a salt fog chamber. The evaporator return-air grille, discharge-air grille, and operating controls of the unit were covered to prevent exposure to the salt fog environment. The chamber temperature was maintained at 92° F to 97° F for 48 hours in the salt atmosphere which consisted of 20 ± 2 parts (by weight) of sodium chloride and 80 parts (by weight) of distilled water. After this exposure, the test unit was removed from the chamber and inspected for corrosion and deterioration.

The inspection after the salt fog exposure uncovered only a few minor spots of corrosion on screws and other small items. The test unit was operated in the LO-HEAT, HI-HEAT, and COOL modes at normal room temperature.

Performance results before and after the salt fog exposure tests are presented in Tables LIII and LIV.

Table LII. Results of Prerain and Postrain Operational Test
Model MC40HA L6-208

Measurement	COOL		VENT		HI-HEAT	
	Pretest Operation	Posttest Operation	Pretest Operation	Posttest Operation	Pretest Operation	Posttest Operation
Air Temperatures (°F)						
Entering Evaporator, Dry Bulb	80	79	89	77	86	92
Entering Evaporator, Wet Bulb	63	64				
Leaving Evaporator, Dry Bulb	59	58	91	80	105	101
Entering Condenser, Dry Bulb	82	81				
Leaving Condenser, Dry Bulb	131	133				
Refrigerant Temperatures (°F)						
Discharge Line	233	246				
Condenser Outlet	134	140				
Subcooler Outlet	110	113				
TEV Inlet	110	114				
Suction at TEV Bulb	42	45				
Suction at Compressor	42	52				
Suction Pressure Regulating Valve Outlet	105	113				
Quench Outlet	47	50				
Equalization Solenoid Valve Outlet	115	124				
Subcooling at Subcooler	25	27				
Subcooling at TEV	25	26				
Superheat at TEV Bulb	1	3				
Superheat at Compressor	1	10				
Compressor Skin Temperature (°F)	83	80				
Discharge Pressure (psig)	316	338				
Suction Pressure (psig)	70	72				
Electrical Characteristics						
Average Voltage	208	208	208	208	208	208
Average Amperage	39.5	39.6	8.3	8.3	29.6	29.5
Total Wattage	9,260	9,500	2,010	2,020	10,360	10,330
Power Factor (%)	65.3	66.4	67.6	68.6	97.3	97.1

Note: Blank spaces signify data were not applicable.

Table LIII. Results of Cooling Operation Before and After Salt Fog Exposure Test, MC40HAL4-208

Measurement	Results	
	Before	After
Air Temperatures (^{o}F)		
Evaporator Air Intake	74	70
Evaporator Air Discharge	46	48
Condenser Air Intake	81	75
Condenser Air Discharge (right)	123	113
Condenser Air Discharge (left)	122	113
Pressure (psig)		
Compressor Suction	63	61
Compressor Discharge	260	240
Electrical Characteristics		
Average Voltage	206	209
Average Amperage	38.2	38.2
Total Wattage	9,000	8,900

Note: The evaporator fan switch was on high; and the condenser fan switch was on automatic (speed was low).

Table LIV. Results of Heating Operation Before and After Salt Fog Exposure Test, MC40HAL4-208

Measurement	Results			
	Before		After	
	High	Low	High	Low
Electrical Characteristics				
Average Voltage	208	209	211	213
Average Amperage	39.9	28.4	40.0	28.4
Total Wattage	10,600	6,200	10,800	6,400

Note: The evaporator fan switch was on high.

IV. DISCUSSION

6. Analyses of Test Methods. As many tests as practical were conducted in accordance with established standard test methods and criteria and, where necessary, these were modified to incorporate military development requirement conditions. Cooling capacity tests were conducted with ASHRAE Standard 37-60 being used as a guide. The heating capacity was computed from the input power to the heating elements. The evaporator and condenser airflow rates were also measured and calculated in accordance with ASHRAE Standard 37-60. Environmental tests were conducted to include the minimum test requirements established by MIL-STD-810A. Several of the electrical and safety tests were conducted according to or similar to tests delineated in ARI Standard 210-62. Some deviations from this standard were necessary in order to accommodate development requirements (paragraph 3a) and MIL-STD-810A criteria. Radio frequency tests were conducted in accordance with MIL-E-55301(EL) with the test units classified as Tactical Equipment.

The remaining tests were conducted in accordance with criteria established by the Environmental Equipment Division, USAMERDC (formerly USAERDL), from experience and knowledge in the field of military air conditioning. This group of tests was generally not used to rate the air conditioners but was intended for use in performance estimates for applications of the units.

Throughout the test program, measurements were recorded from recently calibrated instruments with scales and ranges commensurate with the requirements of tolerance and accuracy. (The individual tests in paragraph 5 of this report show any differences between the actual test procedure and the standard procedures previously mentioned.)

Other tests planned but not formally conducted or not completed are condenser fan motor locked rotor and single phasing; evaporator fan motor locked rotor and single phasing; and endurance.

Two units are now undergoing endurance testing. A 4,000-hour continuous operation is required for each unit. One unit has completed the test. These units have suitable instrumentation and equipment for determining pressure, temperature, and power conditions; and these operational characteristics are checked regularly.

In addition to these, further frequency variation tests may be desired on Model MC40HAL4-208, the 400-hertz unit.

Some of the features in the tests just mentioned were partly covered in other tests. Nevertheless, the findings of any further development testing are to be ccvered in a future report.

7. Analyses of Test Results. The results of each test were analyzed and compared with the requirements delineated in Section II, paragraph 3.

a. The required cooling capacity of the 36,000-Btu/hr air conditioner (with dehumidification) was exceeded by both test units. The excess ranged between 19 and 27 percent, with the 60-hertz unit showing the lower, that is, 42,800-Btu/hr capacity. The 60-hertz units passed the 50-hertz tests. Capacity at 50 hertz was 11 percent below the 60-hertz capacity. The losses at this condition were well below the 30 percent maximum allowed.

b. The required heating capacity (28,600 Btu/hr) was exceeded by both test units. The excess was between 11 and 28 percent.

c. The evaporator airflow tests conducted at USAMERDC (formerly USAERDL) and USAETL showed that the required minimum of 1,130 cfm (against zero external resistance) was exceeded by 30 to 45 percent.

d. The condenser airflow tests conducted at USAMERDC (formerly USAERDL) and USAETL showed airflow which ranged from 2,130 to 2,740 cfm. This airflow meets the requirement for high outdoor ambient temperatures, and the fan motors operate at half speed at low outdoor ambients.

e. The minimum fresh-air (ventilation) requirement of 140 cfm was exceeded by at least 16 percent.

f. Air recirculation tests conducted at USAETL show that refrigerant pressure and temperature changes did not vary beyond the tolerance limits.

g. Examination of the unit revealed no adverse conditions, and no normal operating condition could cause unwanted contaminated air. Tests were performed to determine air leakage rates and to establish criteria for collective protection performance requirements.

h. The units passed the operational controls test. The thermostats function within ± 4° F of any preset temperature between 60° F and 90° F, and the selector switch works properly. Numerous data from USAMERDC (formerly USAERDL) and USAETL prove operational adequacy, and all safety controls to protect the unit against overpressure, overheating, and electrical overcurrent, are sufficient.

i. The units passed the coil frost test. A reduction to 95 percent of rated return airflow is permissible, and the tests conducted at USAETL showed that the air delivery loss, if any, is negligible.

j. Under high-temperature operating conditions the units proved their ability: (1) to operate under conditions of constant high temperature where sufficient heat is added in order to maintain a return-air temperature of 125° F; and (2) to reduce the temperature within the enclosure from 125° F to 90° F with the outside ambient at 125° F.

k. The units were able to withstand the duress of high-temperature storage. USAMERDC (formerly USAERDL) tests showed that pretest and posttest operations were practically identical.

l. The units met the low-temperature cooling operation requirement. They were able to perform in the cooling mode down to -25° F and to start and operate in the cooling mode at -25° F.

m. The units passed the low-temperature storage tests conducted at USAERDL.

n. The units met the test requirement of low-temperature heating operation. Tests conducted at USAMERDC (formerly USAERDL) proved that these units were able to start and heat at a temperature as low as -50° F.

o. The units proved able to operate under temperature conditions of 120° F ambient and 90° F return air with supply voltage varying from -5 to +10 percent.

p. The refrigerant charge test showed that a clear sight glass and reasonably constant power and cooling performance prevailed with refrigerant charges between 7.5 and 12 pounds when the units were operating under conditions of 120° F ambient and 90° F return air. The optimum charge is 11 pounds.

q. The radio interference tests performed by USATECOM show that the measured energy from each of the units was below the radiated and conducted energy limits outlined in Specification MIL-E-55301, with Amendment No. 1. Both test models satisfied the requirements for tactical non-communication equipment.

r. The results of the blocked evaporator fan air inlet or condenser fan air inlet tests show that the units can be operated or protected in spite of the difficulties imposed by a blocked air passage.

s. The test unit (MC11HAL6-208) proved to be fungus resistant in all important parts under simulated tropical conditions prevailing in the tropical testing chamber.

t. The physical characteristics and safety test results show that the requirements of size limit, weight limit, adaptability, safety, and reliability have been met.

u. The phase sequence relay provides inherent protection from the conditions of phase reversal.

v. The heater high-limit cutout tests were conducted at USAMERDC (formerly USAERDL). The heater high-limit cutout deenergized the heaters under conditions simulating fan motor failure or a clogged air filter. Under the high heat-fan off condition, the unit passed a 24-hour test period. Because neither damage nor loss was sustained in performance, the units have passed this test.

w. The starting current tests were conducted at USAETL. Oscilloscope photographs were taken on gridded film, and the root mean square current requirements were computed. The critical demand is made by switching from OFF to COOL. The unit must go through the VENT mode first. Therefore, the evaporator fan motor starts first. The contact is made to the condenser fan motor almost instantly, after switching to COOL. There is a 25-second time delay before the compressor motor starts. Rather than one great initial surge, there are at least two surges of smaller magnitude. The test results should be reviewed to determine generator power requirements.

x. The 60-hertz unit passed all the voltage and frequency variation tests except for the 219-volt, 50-hertz application. The 400-hertz unit failed under all but one (197 volt, 380 hertz) application when tested at voltage and frequency varying 5 percent from nameplate values. Analysis of the failures indicated problems with the fan motor protectors which would not allow proper completion of the tests, and the compressor circuit breaker opened prematurely. Design changes in the motors, the motor protective devices, or both have been accomplished. It is believed that the final units (ET/ST version) will meet all of the test requirements.

y. The small amount of condensate water emitted with the evaporator and discharge was found to be within tolerable limits.

Satisfactory redesign has been accomplished on the drain pan, and the revised drawings reflect this. It is believed that the final units (ET/ST version) will meet the condensate drainage requirements.

z. The results of the sand and dust tests prove that the units are able to meet the requirements.

aa. The performance characteristics were found to be adequate and, in many respects, actually exceeded the requirements. The power requirements were well within the required limits.

bb. The endurance test results indicate sufficient durability and reliability. This is shown in Table LV.

Table LV. Comparison of Required and Actual Reliability Results

Factor	Test Value	Derived Value (90% confidence)	Required Value (minimum)
Mean Time between Failures (hr)	5,163[(a)]	2,390	480
Mean Time to Repair (hr)	2.3[(a)]	-[(b)]	(c)
Reliability for 24-Hr Mission	0.995	.989	0.95

Notes: (a) The test values in the preceding table are based on total actual operating time, to 10 December 1967, for two test units, of 15,489 hr with three failures and a total of 7 man-hr to repair these failures. The derived values are based on the test values, modified in accordance with the standard reliability formula ($R = e^{\frac{24}{MTBF}}$) to predict average performance of a large group of units of the same design as the test units.

Table LV (cont'd)

(b) Hyphen signifies that no data were taken.

(c) Necessary repairs are listed as follows:
  (1) Condenser fan failure - required 1 hr to exchange at organizational support level.
  (2) Refrigerant line and condenser fan failure - required 4 hr to repair at direct support level.
  (3) Circuit breaker failure - required 2 hr to exchange at organizational support level.

These repairs just mentioned were at direct support maintenance level or lower, allowance for which is 8 hours at intervals of 1,000 hours of operating time.

cc. During the humidity tests, condenser fan failures occurred. Inspection revealed that the internal motor cooling fan moved along the shaft sufficiently to cause damage to the windings. Investigation is now in progress to determine a solution to this problem.

Corrosion on the quench expansion valve was attributed to inadequate protective finish. A suitable finish of cadmium plating is now specified for the valve diaphragm.

dd. During the vibration tests some failures occurred. The unit design was modified accordingly, and the ET/ST version is expected to meet the vibration test requirements. None of the failures during this test rendered the unit inoperative; therefore, no retesting of the unit was attempted.

ee. The mounting holes for the lifting rings were oversized. The size of these mounting holes was reduced to preclude reoccurrence on ET/ST units.

The damage caused by the cables probably would have been avoided had the cables been at an angle greater than 60 degrees from horizontal.

ff. The noise level test results for the conditioned area show the requirements are exceeded by 5 decibels or less in the frequency range of 75 hertz to 100 hertz. The requirements were met for the condenser-side noise level limits.

gg. The results of the rain test show adequate pretest and post-test results. Careful examination during all phases of this test revealed no shortcomings.

hh. Results of the salt fog test were satisfactory.

8. Evaluation of Units. The 60-hertz and 400-hertz compact, horizontal air conditioners, Models MC40HAL6-208 and MC40HAL4-208, are approximately the same volume as their respective compact, vertical models, and fit into approximately 16 percent less space than does the 36,000-Btu/hr standard military model. Cooling capacity and power draw compare favorably with the compact, vertical units. Power draw is approximately 12 percent greater and cooling capacity 14 percent greater than those of the conventional military units.

Because of the high sensible cooling capacities and capability of cooling with or without external ducting, these units are highly desirable for use in military vans or shelters where cooling for electronic equipment is a primary requisite. The evaporator fan wheels are a centrifugal type with forward-inclined blades best suited for added external static resistance.

The condenser fan wheels are the propellor type which normally becomes overloaded with increased static resistance: however, being shrouded by a volute casing precludes this problem. One fan has four blades, and the other has five blades. This minimizes noise.

The refrigerant cycle is equipped with a pressure-regulating valve (hot-gas bypass) system which eliminates on and off cycling of the air conditioner. By automatically energizing and deenergizing the appropriate solenoid-operated valves, the air conditioner goes from cooling to bypass which, in turn, prevents severe current surges or radio interference.

These units are part of a family development program which provides for maximum interchangeability of components and minimum supply costs. Also, personnel trained to perform maintenance operations on one of the units in the family can perform the same functions on other units in the family with a minimum of training required.

As explained in the Analyses of Test Results, some portions of the prototype air conditioners were improved during these tests. In addition, the following modifications were made to the test units during the engineering design test phase in order to complete the tests successfully.

a. Required structural modifications which occurred during vibration testing.

b. Provision for more adequate sealing around the center partition.

V. CONCLUSIONS

9. Conclusions. It is concluded that:

a. The models meet the design objectives of compact, lightweight construction.

b. The units meet the capacity requirements in both heating and cooling and have demonstrated advantageous airflow characteristics.

c. The units are suitable for applications which require large cooling capacities in a small, compact envelope.

d. Both models have desirable sound characteristics when properly applied in a system enclosure.

e. The units are sufficiently durable to withstand hard military usage in world-wide climates.

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13. ABSTRACT

This final report covers the engineering design testing of two nominal 36,000-Btu/hr compact, horizontal, air-conditioning models. These are through the wall-mounted, air-cooled, monochlorodifluoromethane refrigerant (R-22)-charged, electric-motor-driven, 208-volt, 3-phase, 60-hertz (Model MC40HAL6-208); and 208-volt, 3-phase, 400-hertz (Model MC40HAL4-208) units. The report concludes:

a. The models meet the design objectives of compact, lightweight construction.

b. The units meet the capacity requirements in both heating and cooling and have demonstrated advantageous airflow characteristics.

c. The units are suitable for applications which require large cooling capacities in a small, compact envelope.

d. Both models have desirable sound characteristics when properly applied in a system enclosure.

e. The units are sufficiently durable to withstand hard military usage in world-wide climates.

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Air conditioner: Compact, Horizontal, Lightweight Environmental Control Heating and Air Conditioning for Prefabricated Structures, Vans, Shelters, and Missile Systems						

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