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TECHNICAL AND OPERATIONAL FEASIBILITY STUDY ON HUMIDITY CONTROL WITHIN THE U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

Aircraft service shelter is an integral part of the F-16 maintenance complex

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The technical and operational feasibility of humidity control within the U.S. Air Fo Aircraft Service Shelter has been evaluated. Feasible humidification, dehumidificat and humidity control equipment has been tested and appropriate equipment modificatio recommended. It is recommended that the existing shelter heat pump be used for dehumidification, the Dri Steem model VM2 be used for humidification and the Honeywell models H46C and H46D and Abbeon Cal model 4703-602 be used for humidity control and continuous monitoring of shelter relative humidity. KeywoRDS: Air Force Pla Air Force Depots; Humidifiers; Dehumidifiers

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SUMMARY

The ensuing report represents the entire effort of engineering support, prototyping, documentation and testing services provided by VSE Corporation on Task 0024 under Contract DAAK70-86-D-0023. The Task required VSE to establish equipment which will confo to a stabilized shelter design and will be used for Government evaluation t establish the technical and operational feasibility for humidity control within the U.S. Air Force Aircraft Service Shelter.

Commercial humidifiers and humidity control equipment were procured as a result of a market survey. No dehumidifiers were procured as it was determined that the existing shelter heat pump could be used for all dehumidification requirements. The equipment was evaluated and tested to determine suitability for use and to recommend equipment modifications resulting from deficiencies exposed.

The report recommends use of the shelter heat pump with minor control circuitry modifications to provide for shelter dehumidification requirements. The Dri Steem model VM2 humidifier is recommended to provide for the shelter humidification requirements. This humidifier must be modified to reduce the size of the cabinet and to improve response time. Honeywell humidity controls models H46C and H46D are recommended for control of dehumidification and humidification equipment. The Abbeon Cal model 4703-602 humidity control is recommended for continuously monitoring shelter relative humidity and to control extreme relative humidity alarms.

Other documentation generated under Task 0024 and included in the appendices of this report are the "Market Survey of Humidity Control Equipment for use in the U.S. Air Force Aircraft Service Shelter" in Appendix A, "Test Plan for Humidification, Dehumidification and Humidity Control Equipment" in Appendix B, "Test Report for Humidity Control Equipment" in Appendix C, "Test Report for Humidification Equipment" in Appendix D and "Test Report for Dehumidification Equipment" in Appendix E.

Appendix F contains summaries of significant telephone conversations which occurred during the compilation of this report.

PREFACE

This technical and operational feasibility report was prepared under Contract No. DAAK70-86-D-0023, Task Order No. 0024, for the Belvoir Research, Development and Engineering Center (BRDEC), Fort Belvoir, Virginia. Mr. Robert A. Rhodes served as the BRDEC Contracting Officer's Technical Representative, telephone no. (703) 664-6031.

The technical and operational feasibility report represents the Final Report of the humidity control work and services to be provided under Task Order No. 0024. The required effort contained in the task order statement of work is quoted below.

> "The contractor shall perform engineering support, prototyping, documentation and testing services to establish equipment which will conform to a stabilized shelter design and will be used for Government evaluation to establish technical and operational feasibility for humidity control within the U.S. Air Force Aircraft Service Van."

TECHNICAL AND OPERATIONAL FEASIBILITY STUDY ON HUMIDITY CONTROL WITHIN THE U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

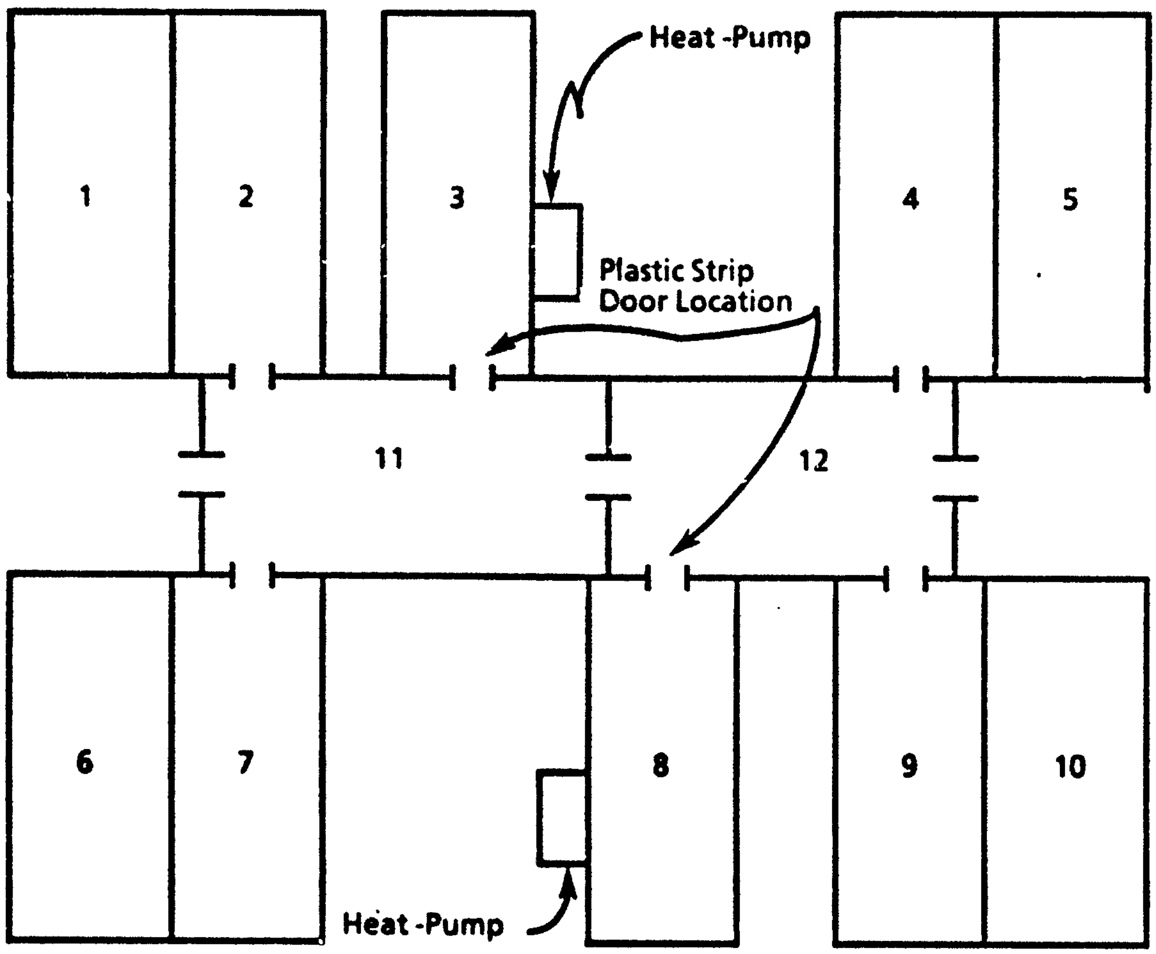
I. INTRODUCTION

1. SUBJECT

This report provides pertinent information concerning the technical and operational feasibility analysis performed on commercially available (off-the-shelf) humidity control equipment for potential installation in a U.S. Air Force Aircraft Service Shelter. Specifically, this means humidity controls, humidification and dehumidification equipment necessary to maintain indoor relative humidity at 45% $\pm$10%, required by sensitive electronic equipment located in the service shelter, under worst hypothesized operational scenarios.

2. BACKGROUND

On 14 July 1986, the Tactical Shelter Systems Development Office, HQ Electronics System Division, Department of the Air Force at Hanscom Air Force Base, Massachusetts, through the U.S. Army Belvoir Research, Development and Engineering Center, tasked VSE Corporation to provide engineering support, prototyping, documentation and testing services in evaluating humidity control equipment for potential use within the U.S. Air Force Aircraft Service Shelters. The Aircraft Service Shelters are an integral part of the F-16 maintenance complex. Twelve Navy International Standards Organization (ISO) shelters comprise the F-16 aircraft maintenance complex (Figure 1). Eight of the shelters are arranged in four groups of two, which are designated as "work stations". Two more shelters are centrally located and serve as work bench equipped corridors. The two remaining shelters (3 and 8 in Figure 1) are used for maintenance of electronic devices and storage of electronic components. Because these two shelters contain equipment and processes that are humidity sensitive, humidity within the shelters must be controlled. Currently, heating and cooling in each shelter are provided by a nominal 3-ton heat pump. The maintenance shelters are partially sealed from the corridor shelters by plastic strip doors.



NOTE: Nos. 3 and 8 are maintenance shelters requiring humidity control.

Figure 1. F-16 Maintenance Complex

II. DISCUSSION

1. MARKET SEARCH FOR HUMIDITY CONTROL EQUIPMENT

The market survey report which was previously transmitted to Fort Belvoir is enclosed in this final report as Appendix A. The market survey report presents the results and findings of the VSE investigation of commercial humidity control equipment. Criteria provided by the Tactical Shelter Systems Development Office, Hanscom Air Force Base for selecting humidity control equipment as well as engineering analyses upon which final equipment selection for testing and evaluation were based, are provided in the market survey report.

Three basic designs of humidifiers are commercially available. The three designs consist of the wetted element-type, the atomization-type and the steam generator-type. The wetted element-type humidifier was excluded from consideration for requiring hardware much too large for practical use within the service shelter. The atomization-type humidifier was excluded from consideration due to its inherent dusting potential. Problems associated with dusting of equipment located within the service shelter are discussed in part 6, paragraph (4) of Section II. The exclusion of atomizing humidifiers represents an exception taken to recommendations of the market survey report. It was originally intended to procure an atomizing humidifier for testing however, information obtained subsequent to publishing the market survey report reversed this decision. Reasons for excluding the atomization-type humidifier are discussed in part 6, paragraph (4) of Section II.

Two basic dehumidifier designs are commercially available. The two designs consist of the refrigeration-type and the desiccant impregnated element-type. Both dehumidifier designs were rejected due to the extremely large equipment size required. However, it was found that all dehumidifier needs of the service shelter can be adequately addressed with the existing shelter heat pump provided for heating and cooling. Minor modifications to the heat pump control circuitry enable its use as a dehumidifier.

Humidity controls (humidistats) are commercially available using nylon, hair, paper, electrical resistance and electro-optics to sense changes in relative humidity. Due to cost considerations and the relatively wide allowable control range, four humidity controls with nylon sensing elements were selected and procured for testing.

2. DESIGN CRITERIA

Some design criteria provided by the Air Force proved difficult if not impossible to comply with using commercial equipment. A sheet of supplementary specifications (Figure 2) were provided by the Air Force and several of these specifications proved unrealistic. The size of the humidification, dehumidification and humidity control equipment will greatly exceed the 17" width by 27" height by 23" depth allowed. The unit is required to possess a self contained water storage tank with sufficient size to sustain

SPECIFICATION-HUMIDIFIER/DEHUMIDIFIER

1. Must have separate humidification and dehumidification modes of operation.

2. Must have high/low humidity alarm lamps with adjustable settings.

3. Unit must create and maintain a stable environment of 48% +7 or -13 relative humidity within four (4) hours after activation within an 8x8x20 van or 1280 cu. ft. of interior space.

4. Unit must not exceed 17" W by 27" H by 23" D and be provided with rack adapters for mounting in standard 19" racks. Unit must also be capable of floor mounting.

5. Power requirement must be 120 VAC + or - 10%, single phase, 50/60 Hz. Unit must be fully efficient at 50 Hz.

6. Unit must be equipped with an AN type fitting for the condensate drain connection.

7. Unit must have a filtered air inlet with a removable/washable filter element.

8. Unit must have an adjustable, direct reading humidistat.

9. Unit must have a self contained water storage tank, with low water alarm, sufficient in size to sustain a minimum of eight (8) hours of humidification at rated capacity.

Figure 2. Supplementary System Specifications

a minimum of eight hours of humidification at rated capacity. For the rated humidification system capacity of 5.4 lb water/hr, a 5.2 gallon self contained tank is necessary. The specified size envelope is unattainable with commercial equipment. The proposed system does lessen the impact of equipment space required by making use of the existing shelter heat pump for all dehumidification requirements. However, no commercial humidifiers investigated in our capacity range had a self contained water tank of the required volume, and the proposed humidification equipment will exceed the specified space envelope. VSE has performed this study on the basis that, as long as no single piece of equipment in the humidification control system exceeds the 17" x 27" x 23" envelope, total system volume is not critical.

The 120 volt input power requirement proved difficult to comply with. Few steam generation humidifiers in the required capacity were available which use 120 volt power. The necessary electrical power required to attain our capacity is significant. Use of 120 volts requires relatively high currents for operation. Most steam generation humidifiers in our capacity range use a 208 volt power supply.

Exception has been taken to the requirement for an air filter on the humidification control equipment. The commercial humidifiers investigated are not equipped with filters. The inlet air to the heat pump/dehumidifier is already filtered. VSE understands that a non air filtered humidifier is acceptable.

3. SYSTEM OPERATION SCENARIOS

(1) General. To provide a properly engineered humidity control system for the service shelter the outside ambient conditions which the shelter will encounter must be predicted. The most extreme conditions provided the basis for determining the design humidification and dehumidification capacity requirements. VSE understands that the service shelter may be deployed worldwide. Thus, the extreme environmental conditions specified in AR 70-38 were used to determine required capacities. The design conditions are discussed in the following paragraphs.

The humidification and dehumidification load calculations are based on an air infiltration rate of 120 cu. ft. per minute. This rate determination is shown in Appendix A (page F-2 of the market survey report). The variable in this determination is the shelter plastic strip door. Very little usable information was received from several plastic strip door manufacturers concerning uncontrollable moisture infiltration through the inherent gaps between the strips. However, VSE believed that the strip door should not present a major moisture infiltration problem if outside air is continually brought in through the heat pump so that there is always a positive air flow out through the plastic strip doors, and if the plastic strip doors are installed properly. There should be at least a 25% strip overlap, no gaps at the top and sides, and minimum floor clearance. This will require a change from the door installation viewed during a trip by VSE and BRDEC personnel, to Medley Tool and Model Co., Philadelphia, PA, the system assembler.

(2) High Temperature, High Humidity. Table 2-3 of the AR 70-38 is entitled "Hot Climatic Design Type; Hot-Humid Daily Cycle of Temperature, Solar Radiation, and Humidity." This table shows that at a maximum ambient temperature of 105°F, relative humidity as high as 59% can be experienced. As shown in Appendix A (page F-4 of Market Survey Report) a dehumidification load of 9 lb water/hr is calculated. Test data provided by Fort Belvoir on the ECU Inc. heat pump indicates that the unit has a dehumidification ability of 8.9 lb/hr at 105°F outside and 80°F, 51% RH inside conditions as shown in Appendix A (page F-6 of the market survey report). The heat pump operating in the cooling mode will provide adequate dehumidification capacity in all but the most extreme ambient conditions. The psychrometric process for the high temperature, high humidity condition is shown in Figure 3.

Figure 3 shows ventilation air entering the shelter at 105°F, 59% RH. This air is proportionately mixed with inside air at the design condition of 76°F, 45% RH. The resulting air inlet condition to the evaporating coil is 79°F, 51% RH. Based on Fort Belvoir heat pump test data, the air leaving the evaporating coil will be dehumidified to a dew point of approximately 56°F. The air is then warmed back to the design condition of 76°F, 45% RH.

(3) High Temperature, Low Humidity. Table 2-2 of AR 70-38 is entitled "Hot Climate Design Type; Hot-Dry Daily Cycle of Temperature, Solar Radiation, and Humidity." This table shows that at a maximum ambient temperature of 120°F a relative humidity of 3% can be expected. The shelter indoor design condition that was used in the market survey report to calculate required humidification capacity at this condition has been modified to more closely reflect the specified shelter ambients. A high temperature condition of 85°F and 48% RH is used in the market survey report to calculate capacity. VSE had inquired concerning the possibility of raising the heat pump thermostat cooling set point to above its current setting of 76°F to reduce the dehumidification capacity requirement. The Air Force has stated the 76°F thermostat set point will not be altered. The task order stated an allowable relative humidity range of 48% $\pm$8%. Specifications stated by the Air Force stated an allowable relative humidity of 45% $\pm$10%. The less severe 45% $\pm$10% RH is assumed for final capacity calculations. The revised load calculation shown below is based on a design condition of 76°F, 45% RH. The following equation is used to calculate capacity:

$$M = \frac{Q\,(W_2 - W_1)}{V}$$

where:

M = mass flow rate, lb water/hr

Q = flow rate of outside air, cu. ft./hr (assume fresh air flow rate of 7200 cu. ft./hr per market survey report, page F-2).

V = specific volume of air, cu. ft./lb dry air

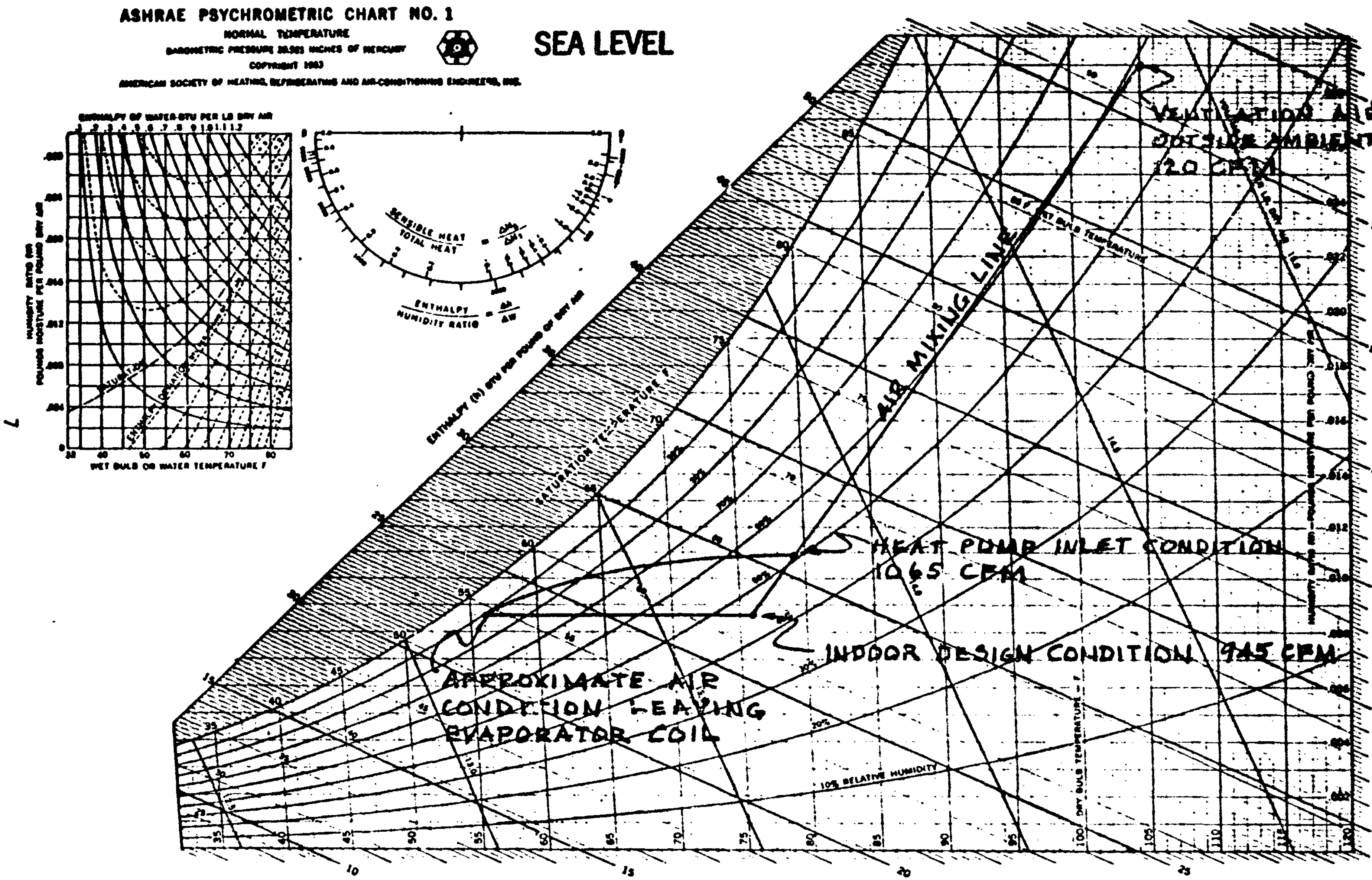


Figure 3. High Temperature, High Humidity Psychrometric Process

W_1 = humidity ratio of inside air, lb water/lb dry air

W_2 = humidity ratio of outside air, lb water/lb dry air

To obtain the capacity required for the high temperature, high humidity condition, the following parameter values were used. V, W_1 and W_2 values were obtained from ASHRAE Psychrometric Chart No. 1 for the assumed conditions of outside and inside air.

M_1 = mass flow rate at high temperature, high humidity condition.

Q_1 = 7200 cu. ft./hr.

V = 14.7 cu. ft./lb dry air for outside air at 120°F and 3% RH.

W_1 = .0086 lb water/lb dry air for inside air at 76°F and 45% RH.

W_2 = .0020 lb water/lb dry air for outside air at 120°F and 3% RH.

$$\text{Therefore, } M_1 = \frac{7200\ (.0086 - .0020)}{14.7}$$

= 3.23 lb water/hr.

However, the humidifier must possess a "pull down" capability so that the entire service shelter space (1,280 cu. ft.) is conditioned within 4 hours. This additional capacity, as calculated below, was added to the high temperature, high humidity load. The following new parameter values were used.

M_2 = mass flow rate for 4 hour "pull down" flow rate

$$Q_2 = \frac{1{,}280 \text{ cu. ft.}}{4 \text{ hr}} = 320 \text{ cu. ft./hr}$$

$$\text{Therefore, } M_2 = \frac{320\ (.0086 - .0020)}{14.7}$$

= .14 lb water/hr

And the necessary maximum capacity at the high temperature, high humidity condition is:

$M_3 = M_1 + M_2$

= 3.23 + .14

= 3.4 lb water/hr.

The psychrometric process for the high temperature, low humidity condition is shown in Figure 4. Figure 4 shows ventilation air entering the shelter at 120°F, 3% RH. This air is proportionately mixed with inside air at the design

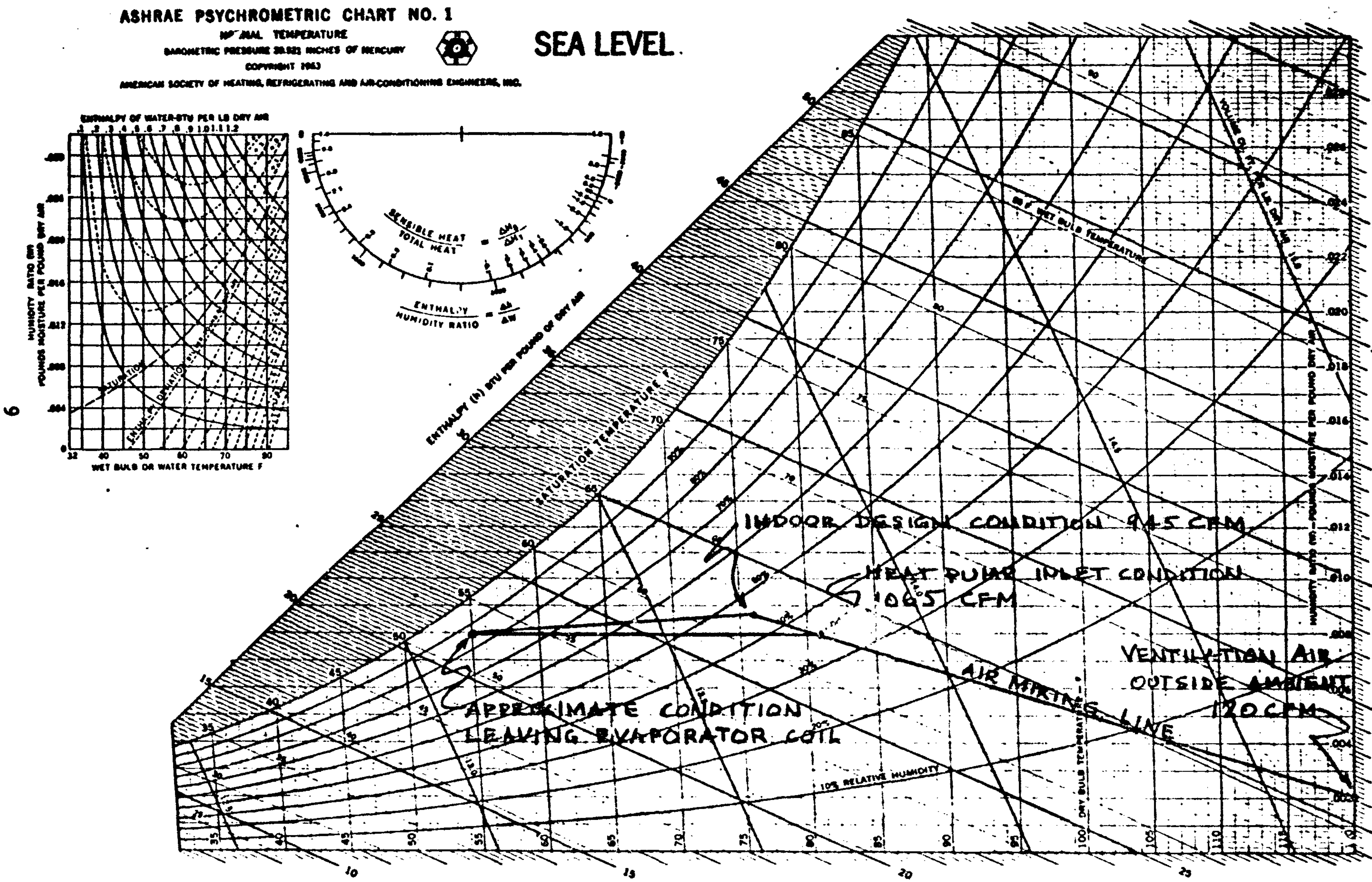


Figure 4. High Temperature, Low Humidity Psychrometric Process

condition of 76°F, 45% RH. The resulting air inlet condition to the evaporating coil is 81°F, 35% RH. Based on Fort Belvoir heat pump test data, the air leaving the evaporating coil will be cooled to approximately 55°F. The air is then warmed and humidified back to the design condition of 76°F, 45% RH.

(4) Moderate Temperature, High Humidity. Table 2-4 of AR 70-38 is entitled "Basic Climate Design Type; Constant High Humidity Daily Cycle of Temperature, Solar Radiation, and Humidity." This table shows that at a temperature of 75°F a relative humidity of 100% can be experienced. A dehumidification load of 5.4 lb/hr is required during this condition as calculated on page F-6 of the market survey report. The moderate temperature, high humidity condition must be investigated since the heat pump must operate in the cooling mode in order to dehumidify, but will not operate in the cooling mode below 76°F, as presently controlled. The heat pump thermostat set points are such that heating occurs at 72°F and below and cooling occurs at 76°F and above. A dead zone exists between 72 and 76°F. In order to provide dehumidification capability at moderate temperatures the control circuitry of the heat pump must be modified. The psychrometric process for the moderate temperature, high humidity condition is shown in Figure 5.

Figure 5 shows ventilation air entering the shelter at 75°F, 100% RH. This air is proportionately mixed with inside air at the design condition of 75°F, 45% RH. The resulting air inlet condition to the evaporating coil is 75°F, 51% RH. Based on Fort Belvoir heat pump test data and assuming dehumidification is called for, the air leaving the evaporating coil will be dehumidified to a dew point of approximately 55°F. The air will then enter the supplementary heaters where it will be heated to slightly above the shelter ambient.

(5) Low Temperature. Table 2-8 of the AR 70-38 is entitled "Cold Climatic Design Type; Daily Cycle of Temperature, Humidity, and Solar Radiation." This table shows that at a minimum temperature of -50°F a relative humidity tending towards saturation can be expected. The shelter indoor design condition that was used in the market survey report to calculate required humidification capacity at this condition has been modified to more closely reflect the specified shelter ambients. Low temperature conditions of 70°F and 48% RH indoor and -25°F, 0% RH outdoor were used in the market survey report to calculate capacity. The revised load calculations shown below are based on an indoor design condition of 72°F, 45% RH and an outdoor design condition of -50°F, 100% RH.

To obtain the capacity required for the low temperature condition, the following parameter values were used. V, W_1, and W_2 values were obtained from ASHRAE Psychrometric Charts No. 1 and 2. Q_1 remained the same as in all other conditions.

M_4 = mass flow rate at low temperature condition.

Q_1 = 7200 cu. ft./hr.

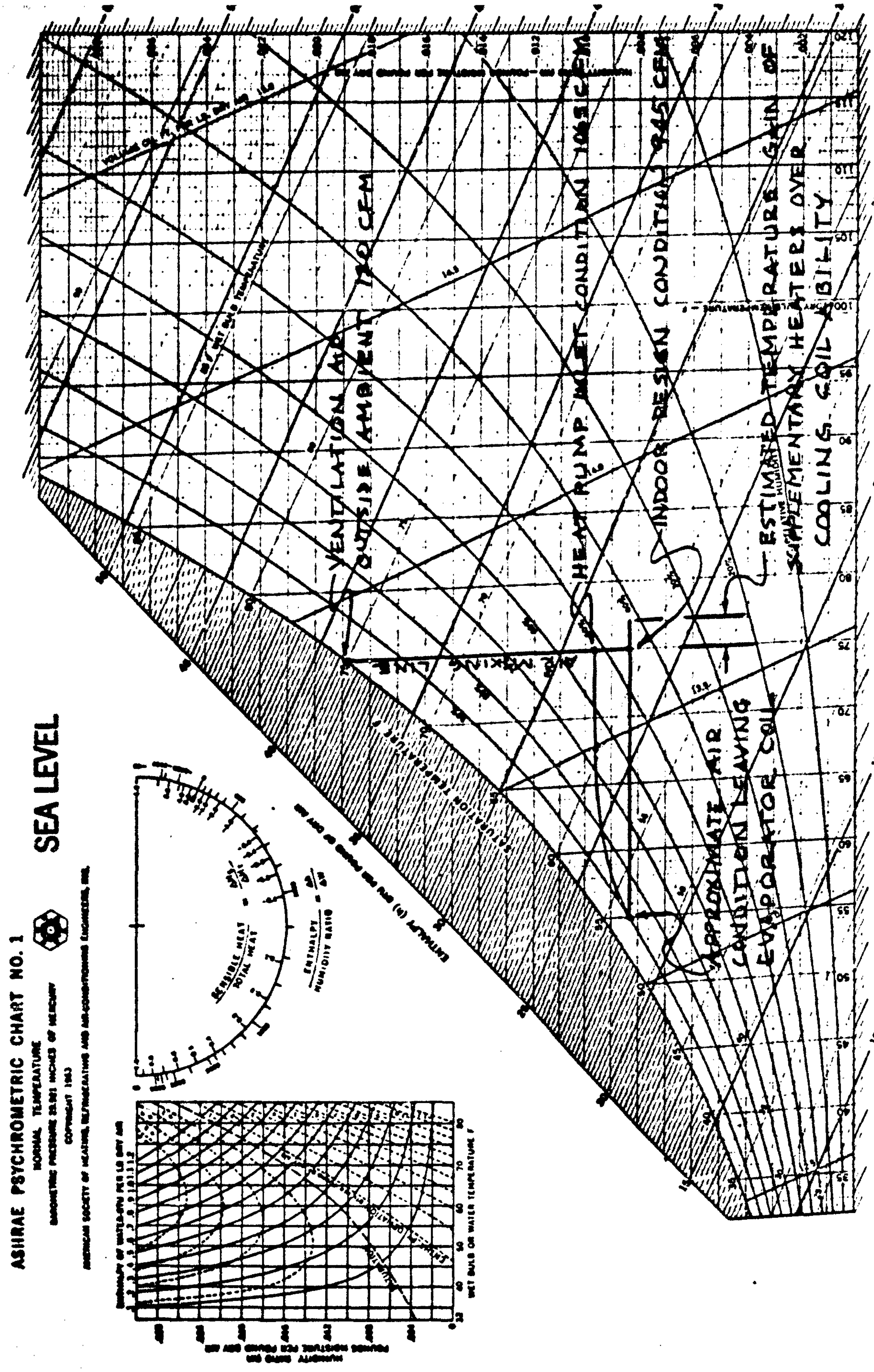


Figure 5. Moderate Temperature, High Humidity Psychrometric Process

V = 10.3 cu. ft./lb dry air for outside air at -50°F and 100% RH.

W_1 = .0075 lb water/lb dry air for inside air at 72°F and 45% RH.

W_2 = .0001 lb water/lb dry air for outside air at -50°F and 100% RH.

Therefore, $M_4 = \frac{7200\ (.0075 - .0001)}{10.3}$

$= 5.17$ lb water/hr.

However, the humidifier must possess a "pull down" capability so that the entire service shelter space (1,280 cu. ft.) is conditioned within 4 hours. This additional capacity, as calculated below, was added to the low temperature load. The following new parameter values were used.

M_5 = mass flow rate for 4 hour "pull down" flow rate

$Q_2 = \frac{1,280 \text{ cu. ft.}}{4 \text{ hr}} = 320$ cu. ft./hr

Therefore, $M_5 = \frac{320\ (.0075 - .0001)}{10.3}$

$= .23$ lb water/hr

And the necessary maximum capacity at the low temperature condition is:

$M_6 = M_4 + M_5$

$= 5.17 + .23$

$= 5.4$ lb water/hr.

The psychrometric process for the low temperature condition is shown in Figure 6.

Figure 6 shows ventilation air entering the shelter at -50°F, 100% RH. This air is proportionately mixed with inside air at the design condition of 72°F, 45% RH. The resulting air inlet condition to the evaporating coil is 58°F, 64% RH. The air is then reheated by the supplementary heaters to approximately 110°F, (based on testing performed at VSE). The air is then cooled and humidified back to the design condition of 72°F, 45% RH.

4. DEHUMIDIFICATION - USE OF EXISTING HEAT PUMP

(1) Basis of Decision. The environmental control unit used to control temperatures within the Aircraft Service Shelter is a model MHP 36K208/60/3 36,000 BTUH nominal heat pump manufactured by A.R.E. Manufacturing Company. Through analysis of capacity test data provided by Fort Belvoir on a similar heat pump to that manufactured by A.R.E., a decision to use the existing heat

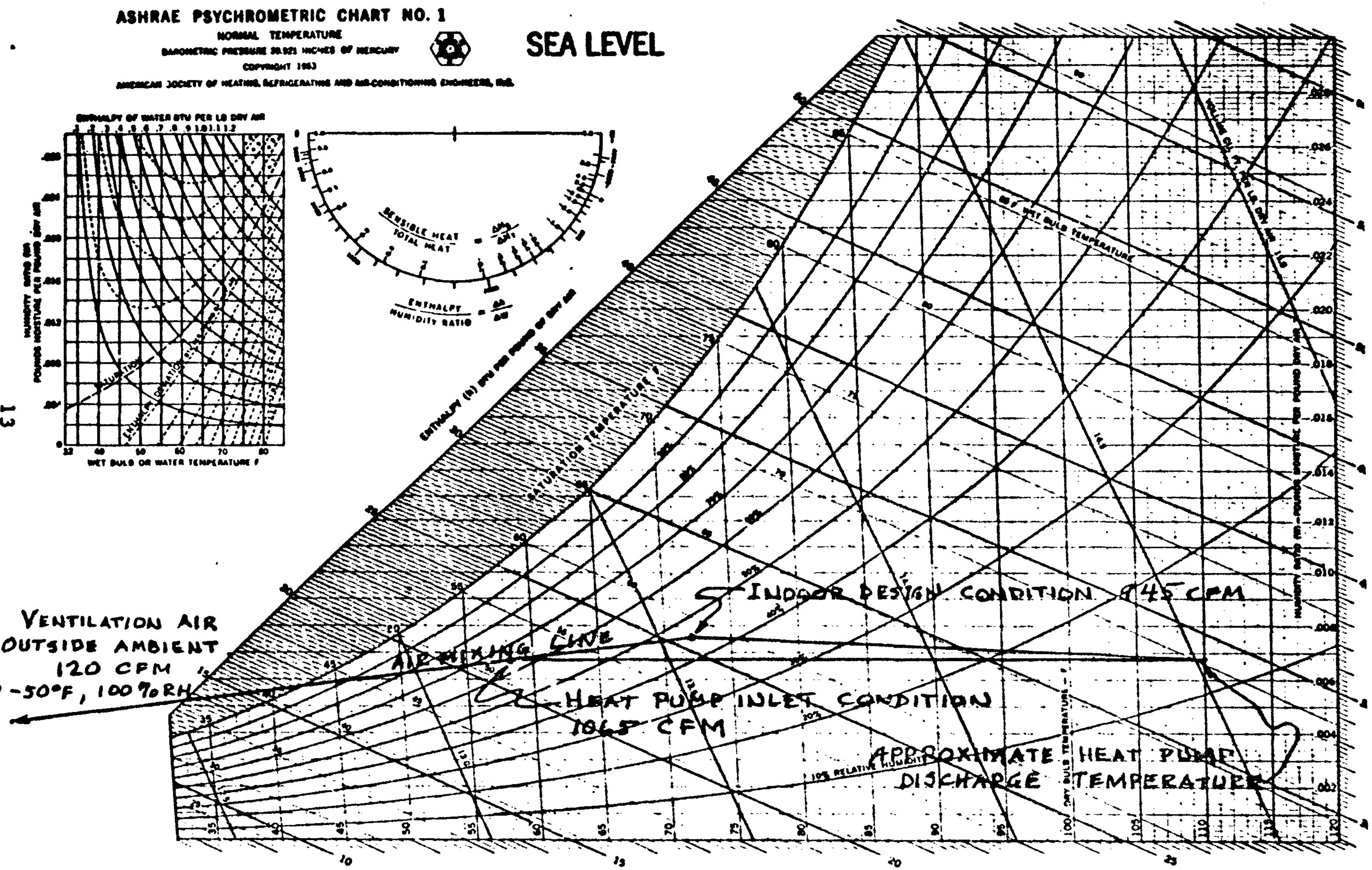


Figure 6. Low Temperature Psychrometric Process

pump for dehumidification purposes was made. The latent cooling capacity together with the inclusion of auxiliary booster heaters in the heat pump design enable its use as a dehumidifier. Since the size of a separate dehumidifier in the capacity range required would be large indeed, the use of the existing heat pump is the only logical choice.

(2) Available Capacity of Existing Heat Pump. Capacity data used in this analysis is based on testing performed by Electric Testing Laboratory (ETL) on a heat pump manufactured by ECU Inc. It is believed the A.R.E. heat pump and the ECU heat pump were manufactured from the same technical data package with no essential differences and that capacity data for the A.R.E. heat pump will closely approximate the ETL test results. Capacity test data is available at outdoor temperatures of 95°, 105°, 120°, and 125°F with indoor condition at 80°F, 51% RH throughout.

Two dehumidification scenarios were considered in this investigation. These occur at high temperature, high humidity (105°F, 59% RH) outside ambient conditions and at moderate temperate, high humidity (75°F, 100% RH) outside ambient conditions. The capacity at the moderate temperature condition was determined to be the most critical, or worst case dehumidification condition since the heat pump does not normally cool, and thus dehumidify, at moderate temperatures. Air Force personnel specified that a 4-hour "pull down" capability be included which added slightly to the total dehumidification capacity. Calculations showing the heat pumps ability to meet the dehumidification needs are shown in Appendix A (Market Survey Report, Appendix F, page F-6).

(3) Heat Pump Modifications Required. The A.R.E. heat pump is equipped with an Accustat model LHP-AH22 thermostat manufactured by PSG Industries. The thermostat provides for single stage cooling and two stage heating capability. Specifically, the non-adjustable thermostat set points call for cooling at 76°F and above. When the shelter indoor ambient temperature reaches 76°F the heat pump operates in a normal air conditioner cycle. When the shelter indoor ambient drops to 72°F and below, a reversing valve energizes which reverses the normal air conditioner cycle and allows the heat pump to heat the shelter space. When the shelter indoor ambient drops to 68°F and below, second stage heating initiates, consisting of electrical resistance heaters. Between 72°F and 76°F a "dead zone" exists where the heat pump is de-energized. It is desirable to provide dehumidification over the widest range possible. The thermostat and heat pump control circuitry can be modified to allow dehumidification to occur in the "dead zone". Modifications required consist of circuit changes on the thermostat printed circuit (PC) board and the addition of two relays with appropriate wiring changes to the heat pump 24V control circuitry. Figure 7 shows the heat pump control circuit modification.

The Accustat thermostat consists of a printed circuit board with five wires normally brought out to heat pump terminal board connections. The modification entails opening a circuit on the PC board and bringing out two additional wires to heat pump control circuitry connections. Figure 8 shows detail of the thermostat PC board modification.

NOTES: 1. HEAVY LINES INDICATE CHANGES TO EXISTING HEAT PUMP SCHEMATIC.
2. DASHED LINE DENOTES POINT ON PRINTED CIRCUIT BOARD WHERE CONDUCTOR MUST BE BROKEN.

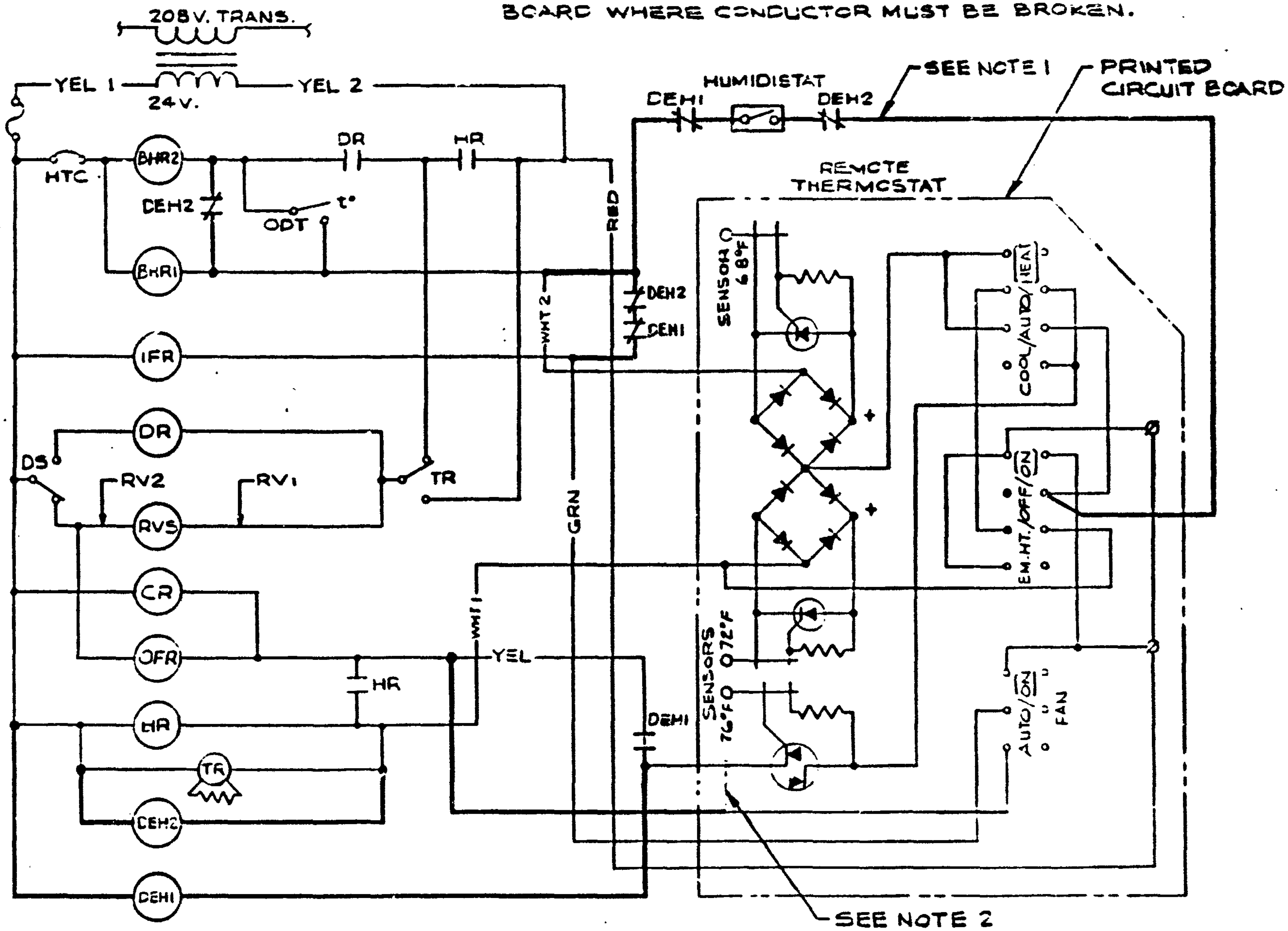
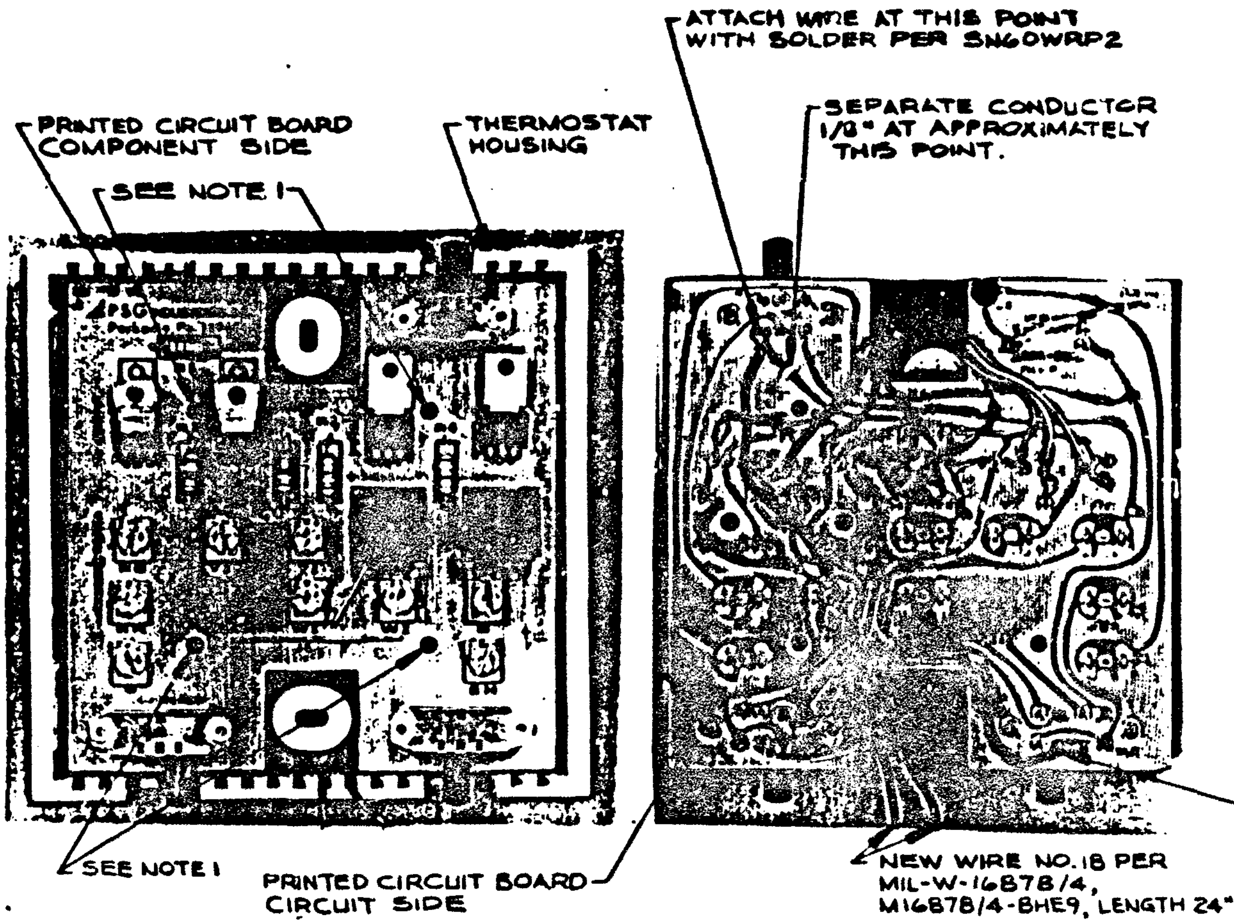


Figure 7. Electrical Schematic Modification, Heat Pump



NOTES:

1. TO PERFORM THE REQUIRED MODIFICATION TO THE CIRCUIT SIDE OF PC BOARD, CUT AWAY TABS AT 4 PLACES SO THAT PC BOARD CAN BE SEPARATED FROM THERMOSTAT HOUSING. FOLLOWING MODIFICATION REINSTALL PC BOARD IN ORIGINAL POSITION AND SEAL TABS (4 PLAC WITH EPOXY ADHESIVE PER MMM-A-134, TYPE I.

Figure 8. PC Board Modification, Thermostat

Heat pump control circuitry modifications involve the addition of two 3-pole, double throw Potter and Brumfield model KUP14A55-24 relays. The additional relays add to the current load of the circuit. The Accustat thermostat has a maximum current load rating of 2.5 amps. During operation of the modified heat pump, only one of the additional two relays will be operating at any one time. This will increase the current loading by approximately .11 amps. Measurements of the maximum loading through the thermostat in the normal configuration was 1.3 amps. The additional .11 amps is not expected to cause an overload problem.

The current requirements for the heat pump will increase as a result of the modification. When dehumidifying in the "dead zone," the unit will be operating in the cooling mode with both supplementary heaters operating simultaneously. Currents as high as 40 amps were recorded during VSE testing. This represents an approximate 29% increase over the maximum current draw of the unmodified heat pump. The additional current is not expected to adversely affect the heat pump. Only a single terminal board within the heat pump carries the higher current.

(4) Design Limitation. There are many advantages to using the existing heat pump for dehumidification purposes. By far the most important advantage is the space savings afforded. However, there is a limitation with this concept. No dehumidification capability is available when the heat pump is operating in the heating mode. During heating, the indoor heat exchanger coil is rejecting heat. Thus, there is no cool surface on which to condense moisture. It is anticipated that dehumidification will rarely be needed below 72°F. Generally, dehumidification will not be required at lower ambients due to the decreased ability of air to absorb moisture at lower temperatures. A psychrometric chart will show that at ambient temperatures of 55°F and below with 100% RH, the moisture load would not be enough to exceed our indoor maximum allowable RH limit of 55% at 72°F. However, it is possible to experience outside ambients between 55°F and 72°F with high RHs. At these conditions the heat pump must first satisfy the thermostat's call for heat (indoor space heated to 72°F) before the heat pump will operate in the dehumidification mode. The process of heating the shelter air will naturally reduce relative humidity. The operation logic for dehumidification is charted below:

Modified Heat Pump Function at Various Temperature Conditions

Below 72°F	Between 72 and 76°F	Above 76°F
Heat pump operates in heating mode. Heating of air naturally reduces RH.	Heat pump will operate in cooling mode with supplementary heaters operating simultaneously. Air is dehumidified by the cooling coil and then reheated to minimize effect on shelter air temperature.	Heat pump operates in cool mode. Air is dehumidified by cooling coil.

5. HUMIDIFICATION EQUIPMENT

(1) General. The two steam generator humidifiers procured for testing and evaluation present a sharp contrast in their design. The Vapormist model VM2 manufactured by the Dri Steem Humidifier Company is a relatively sophisticated humidifier with many auxiliary features designed into the unit. The unit is of heavy duty construction, has electronic water level control, automatic skimming and draining features, low water protection and distribution blower. The unit is specifically designed with maintenance in mind. The Autoflo model L-1011-K, manufactured by American Metal Products Company, is designed with simplicity in mind. The unit basically consists of a water reservoir with heating element, float controlled water inlet valve, float controlled switch and distribution blower.

(2) Dri Steem Humidifier. The Dri Steem humidifier contains a Teflon coated 18 gauge stainless steel evaporation chamber. Water supply and drain lines to the chamber are both provided with solenoid valves. The supply inlet is 1/4" NPT and the drain line is 3/4" SW. A skimmer port/overflow drain is provided which is intended to skim off chamber surface water following each fill cycle. During normal operation dissolved minerals tend to concentrate at the surface. Skimming off surface water will increase the period between servicing. A single 2 kW electric resistance element is provided for heat transfer. Evaporator pan water level is sensed by a three prong conductivity sensor which cycles the solenoid operated fill valve and the heating element. The unit possesses a drain/flush feature also designed to increase time between servicing. An internal control module contains an integral electronic timer which accumulates the humidifier "ON" time. When accumulated "ON" time reaches the timer set point, the drain/flush cycle begins. The unit will simultaneously fill and drain for 10 minutes.

The Dri Steem humidifier is housed in a 20 gauge steel cabinet, the floor of which constitutes a drip pan, provided with a 1/2" NPT drain connection. The cabinet is provided with two removable panels for access to internal components. Panels are secured in place with key locks. The evaporator chamber is slide mounted for ease of access. Pilot lights on the housing front annunciate the ready water mode, the fill mode and the drain/flush mode.

The unit's electrical compartment contains a 120V/24VAC transformer, a power relay, timer printed circuit board, water level control printed circuit board, power block for connecting power lines and terminal board for humidistat connection.

The unit is equipped with a separately wired fan distribution unit which sits on top of the humidifier. The unit houses a 265 cfm blower with a steam dispersion tube mounted downstream of the blower. The blower is controlled with a thermal switch located adjacent to the metal steam tubing.

The entire humidification unit is 34" high x 24" wide x 16" deep and weighs approximately 118 lb operating. It costs approximately $1200 complete.

(3) Dri Steem Humidifier - Test Result Summary. The following tests were performed to determine the units suitability for use in the Aircraft Service Shelter:

- o Human Factors Evaluation
- o Sound Level
- o Tilted Operation
- c Variable Voltage and Frequency
- o Vibration
- o Capacity
- o High Temperature Storage
- o Low Temperature Storage
- o Electromagnetic Interference

The Dri Steem humidifier possesses a significant burn hazard. The steam distribution tube located downstream of the blower is exposed. The tube temperature during operation is approximately 180°F. Removing the front access panel will expose the evaporator chamber which is also 180°F during operation. No warning labels are provided. Operating weight of the humidifier and blower assembly is 118 lb. No handles are provided for safe lifting.

The humidifier demonstrated very low sound levels. Levels are well below the dB(A) criteria of category F in Table 2 of MIL-STD-1474. Category F requirements are imposed in shelters where frequent telephone or radio use or frequent direct communication at distances up to 5' is required.

The humidifier will not function properly when tilted 5° in certain directions. The maximum allowable tilt is 2°.

The humidifier operated satisfactorily during variable input power tests. The tested voltage and frequency combinations were 132V-60Hz, 132V-50Hz, 108V-60Hz and 108V-50Hz.

No damage resulted during the simulated transportation vibration test.

Capacity testing demonstrated that the unit could not meet the minimum 5.4 lb/hr steaming rate. This deficiency is due to the evaporating chamber refill mode which is cyclic. The refill mode occurs approximately every hour. During refill the heating element de-energizes resulting in no steam emission for 17 minutes.

The humidifier was undamaged and functioned properly following the high and low temperature storage tests. These tests were performed at +160°F and -60°F.

The humidifier was below the conducted and radiated EMI emission level limits imposed by methods CE03 and RE02 of MIL-STD-461, Part 4 for steady state conditions. The unit exceeded the limits for transients, however all transient durations were much less than the 1 second duration allowable for military standard air conditioners.

Following all testing the unit was inspected for general appearance. Minor corrosion had begun to occur on the exterior of the cabinet at the seam between the base panel and the side panels. Very minor pitting corrosion had begun to occur on the interior of the evaporator chamber. Minor corrosion had begun on the heating element.

(4) Autoflo Humidifier. The Autoflo humidifier consists of a 22 gauge stainless steel reservoir contained within a sheet metal housing. Reservoir is equipped with a 1.4 kW electric resistance heating element. A stainless steel and bronze float valve maintains the proper water level within the reservoir through a 1/8" inlet port. A stainless steel and bronze float switch provides low water protection. Should the water level drop too low for safe operation, a microswitch will shut off power to the heating element. The reservoir is equipped with two 3/4" threaded ports for manual flushing. A drain line may be connected to the upper port to provide for overflow protection. Steam dispersion is accomplished with a fan assembly. A simple shaded pole electric motor with a plastic axial fan is mounted in a sheet metal housing. A thermal switch adjacent to the water reservoir operates the fan.

The unit junction box contains a power relay, a 120V/24VAC transformer, thermal switch and microswitch, and necessary terminal boards. An external terminal board is provided for humidistat connection. A pilot light affirms that the unit is operating. The entire humidification unit is 16" high x 14" wide x 14" deep and weighs approximately 35 lb operating. It costs approximately $340 complete.

(5) Autoflo Humidifier - Test Result Summary. The following tests were performed to determine the units suitability for use in the Aircraft Service Shelter:

- Human Factors Evaluation
- Sound Level
- Tilted Operation
- Variable Voltage and Frequency
- Vibration
- Capacity
- High Temperature Storage
- Low Temperature Storage
- Electromagnetic Interference

The Autoflo humidifier possesses a significant burn hazard. The unit has an unguarded back which allows the possibility of coming in contact with the heated water and the rotating fan. The sheet metal work is relatively poor, with sharp corner edges which are not radiused or buffed.

The humidifier demonstrated very low sound levels. Levels are well below the dB(A) criteria of category F in Table 2 of MIL-STD-1474.

Tilting the unit 5^{o} in certain directions impairs proper operation. The maximum allowable tilt is 1^{o}.

The humidifier operated satisfactorily during variable input power tests. The tested voltage and frequency combinations were 132V-60Hz, 132V-50Hz, 108V-60Hz and 108V-50Hz.

The unit was not damaged during the simulated transportation vibration test.

Capacity testing demonstrated that the unit could not meet the minimum 5.4 lb/hr steaming rate. Two humidifiers would be required for the service shelter application.

The humidifier was undamaged and functioned properly following the high and low temperature storage tests. These tests were performed at +160°F and -60°F.

Humidifier operation proved to be below the conducted and radiated EMI emission level limits imposed by methods CE03 and RE02 of MIL-STD-461, Part 4 for steady state conditions. The unit exceeded the CE03 limits for transients, however all transient durations were much less than the 1 second duration allowable for military standard air conditioners.

Following all testing the unit was inspected for general appearance. Minor pitting corrosion had begun to occur on the interior of the heating reservoir.

6. HUMIDIFIER SUPPLY WATER

(1) Water Hardness - General. In order for humidification equipment to operate, water must be introduced into the system prior to dispersion within a conditioned space. For the Aircraft Service Shelter humidification system it is assumed potable supply water will be used. It is also assumed that distilled or demineralized water will not be available for system use. The hardness of the water, or the mineral content, can have a significant impact on the maintenance requirements and life expectancy of a humidifier.

The water for the Aircraft Service Shelter is anticipated to be from surface water sources such as reservoirs, lakes, rivers, treated sea water or ground water wells. Concern for water hardness primarily centers around ground water sources since water which filters down through the ground to water tables has a much greater likelihood of coming in contact with minerals and thereby dissolving these minerals into the water. The F-16 maintenance complex can be deployed worldwide. Therefore, water found anywhere in the world may be used in this humidification system.

Information on water hardness proved difficult to obtain. Organizations such as the U.S. Geological Survey, Environmental Protection Agency, American Water Works Association, World Health Organization, Organization of Economic Cooperation and Development and Geraghty and Miller Inc. (ground water consultants) were contacted. Very general information on hardness in the U.S. was obtained. No information on water hardness worldwide was obtained.

It was determined that designing for a "worst case" water hardness is virtually impossible and very impractical. Water hardness may be expected to vary from less than 5 grains/gallon to over 110 grains/gallon. Water hardness is a transient condition. Local water hardness may change significantly over a period of time. Treatment methods for reducing water hardness are discussed in the following paragraph.

(2) Water Treatment Methods Investigated. Water hardness is primarily composed of calcium and magnesium salts dissolved as positive ions (cations) in solution.

Water hardness can present many problems for humidification systems. Atomization-type humidifiers distribute water including all its dissolved solids into the conditioned space. Upon evaporation of the water, the solid minerals settle as a fine dust over all items contained within the space. Introducing this dust into electronic equipment internals can impair the equipment's operation. Maintenance of the atomization-type equipment is relatively low since the dissolved minerals do not accumulate. The potential problem of dust accumulation on equipment within the shelter was eliminated by ruling out use of atomization-type humidifiers. The only practical method for humidifying the service shelter is the use of steam generation equipment. Maintenance of steam generation humidifiers is a major concern. Steam generator maintenance is greatly dependent on the hardness of the water since dissolved minerals do accumulate in the humidifier. Allowing hardness scale to build up on humidifier internals will reduce unit life. Several water treatment methods exist which reduce water hardness. Among those investigated were water softeners, demineralizers, reverse osmosis equipment, magnetic inhibitors and chemical treatment.

Water softeners remove calcium and magnesium cations from solution by an ion exchange process. This process requires a resin tank and a brine tank. The resin tank contains resin beads with an affinity for cations. Initially brine (sodium chloride) is educted into the resin tank where the resin separate sodium cations from the sodium chloride molecule and attracts the cation to the resin surface. Raw water is then flowed through the sodium saturated resin tank where ion exchange takes place. Calcium and magnesium cations exchange on the resin beads and displace sodium cations into the water stream. Eventually the resin is saturated with hardness ions and must be regenerated with brine. The brine tank contains enough sodium chloride for several regenerations. This method does not address the problem of scale build up on humidifier internals. Sodium merely replaces calcium and magnesium in the water and, therefore, a sodium scale will accumulate.

Deionizers or demineralizers use an ion exchange process to remove all ions in solution. Deionizers use two ion exchange resins to remove both cations and anions from the raw water. Hardness such as calcium carbonate ($Ca^+CO_3^-$) and magnesium sulfate ($Mg^+SO_4^-$) are exchanged on the resin beads and replaced in the water stream with hydrogen (H^+) and hydroxyl (OH^-) ions which combine to form water. Following depletion of the resins, regeneration with a strong acid and strong base is required to restore the ion exchange capability. Deionization delivers water of extremely high quality. The regeneration process is cumbersome. Usually a purchaser of this type equipment will also contract for periodic replacement of the resins. Resins are then returned to a facility for regeneration. Deionizers are available with disposable cartridges. Deionizer drawbacks include the size of equipment needed and inlet water pressure needed for efficient operation. Inlet water pressure is not necessarily required for deionizers however, water which is fed by gravity will tend to channel through the unit thereby reducing demineralizer capacity. Additional pressure drop through a deionizer may adversely impact the water flow to the humidifier.

Osmosis is a natural phenomena which is the passage of a liquid through a semi-permeable material or membrane where the liquid flows from a state of low concentration of impurities to a state of higher concentration. Reverse osmosis equipment reverses this natural phenomena by forcing pure water through a specially designed membrane and the dissolved solids or hardness remain on the feed side of the membrane. This process requires a high pressure water supply. An auxiliary pump would be necessary. Again, the size alone for this equipment precludes its use.

Magnetic-type deionizers are available for removing suspended ions. A magnetic field is established through which the raw water flows. Positively charged ions are drawn to the walls of the water tubing towards the magnet. As the ions accumulate on the walls, the water passage narrows. Among the water treatment equipment vendors contacted the general consensus was that magnetic deionizers are not effective due to insufficient contact time.

Chemical additives can be used to treat hard water. Calcium and magnesium have a molecular structure which allows these molecules to fit into the microscopic crevices of a humidifier. Additional calcium and magnesium build upon those preceding until a hard scale forms. Chemical additives can be used to keep this building process from occurring. A crystal scale distorter, such is a polyphosphate, actually distorts the molecular structure of calcium and magnesium such that these molecules do not adhere to the sides of the humidifier. The minerals remain fluidized and tend to form a sludge at the bottom of the evaporator pan. The sludge can easily be flushed out.

(3) Water Supply Equipment. Pressurized water is not available in the Aircraft Service Shelter. For this reason a gravity flow feedwater system to the humidification equipment is proposed. Hanscom Air Force Base has imposed a requirement for eight hours of continuous operation for the humidity control equipment at rated capacity without operator attention. Since our maximum capacity is 5.4 lb/hr water for the humidifier, a storage tank capacity of just over five gallons is required. Since gravity flow is required, the tank should be mounted high, close to the shelter ceiling. Plastic tubing will connect the tank to the humidifier inlet. Hanscom AFB requires a low water alarm for the water supply tank. A float switch wired to an annunciating lamp will alert shelter operators to a low supply water condition.

Aetna Plastics Corporation manufactures equipment which appears adequate for this application. A seven gallon square tank part no. 14300-0010 is 12" x 12" x 12". The tank is open for easy refilling and provided with a cover. The tank is fabricated from a cross linked polyethylene which should provide adequate rigidity. This polyethylene material is capable of withstanding temperatures of 225°F to -140°F. Drainage will be from the side, just above the tank bottom. A 1/2" CPVC bulkhead fitting with a 1/2" compact ball valve will provide for on/off flow control. A 1/2" elbow will direct flow downward. 1/2" plastic Tygon tubing, R-3603, can be routed from the tank to the humidifier. The tubing has a temperature range of +165°F to -58°F.

The low water level alarm requirement can be satisfied with a Compac Engineering series 15-650 side mounted magnetic float switch which will be wired to an annunciating lamp. The lamp requirement can be satisfied with a General Instrument Corporation socket part no. 5100-822, incandescent bulb part no. CM757 and a red fluted dome part no. 25P-326R (identical lamps can be used for warning of extreme high or low humidity conditions).

A potential problem with a water storage tank is the growth of microorganisms. Control of bacteria can be accomplished with the use of a biocide such as Biocide 20 manufactured by Okite Products. No organic growth will occur in an operating steam generating humidifier due to the high temperatures.

(4) Equipment Environment (Dust). During the market survey investigation it was determined that two basic humidifier designs could technically provide the necessary humidification within a reasonable space envelope. The steam generation and atomization-type humidifiers were chosen for further evaluation. Subsequent information from the manufacturer of equipment used in the Aircraft Service Shelter indicated that atomization-type humidifiers should be excluded from consideration. Atomizers have the inherent problem of discharging water, with all its dissolved minerals, into the conditioned space. Upon evaporation, the minerals settle out and accumulate on equipment surfaces within the shelter. Discussions with personnel from General Dynamics who designed the Aircraft Service Shelter indicated that disk drives used within the shelter, Hewlett-Packard models 7905 and 7906, may be susceptible to a dust laden environment.

Hewlett-Packard was contacted regarding their 7905 and 7906 disk drives. Models 7905 and 7906 contain electronic heads which interact with the disk media to store or recall magnetic signals that are eventually translated into usable data. The heads are of an aerodynamic design which allows them to float or ride an air cushion over the disk media. The air gap width is approximately 30 microns. For comparison, smoke particles are in the 250 micron diameter range. The relative speed of the disk media to the head is approximately 150 mph. Any contact between the two can be very damaging. Contact between the head and the disk media which is called "crashing" can destroy the head and/or the media.

These units are indeed very susceptible to dust particles. These disk drives are equipped with a double filter and blower assembly. The first stage filter is basically a furnace type filter for trapping very large particles. The second stage filter is a very fine paper which filters down to particle diameters of three microns. The blower provides for cooling and maintaining a positive pressure within the disk drive. Operation of the disk drives in a dusty environment will clog the filters very quickly. Clogged filters will not allow the blower to maintain an internal positive pressure, thus permitting dust particles to infiltrate and obstruct the head/media interface. Clogged filters will not allow proper cooling which will increase internal temperatures and reduce internal air density. The rarified air will impair the operation of the aerodynamic head by reducing its lift characteristics and thus the head rides closer and closer to the disk media. Air of sufficiently low density will allow the head to "crash".

Hewlett-Packard recommended the use of an atomization type humidifier only if the water supply is deionized.

No information was obtained on the dust susceptibility of F-16 components which may pass through the service shelter.

7. HUMIDITY CONTROLS

(1) General. The humidity controls chosen for testing all sense the moisture content of the air by use of nylon sensing elements. Nylon can be fabricated to possess hygroscopic properties. The humidistat industry is tending more and more to use nylon elements as opposed to hair or paper elements for basic humidity controllers. Nylon has a reputation for good precision, although accuracy is difficult to control during the fabrication process.

The response time for nylon increases with decreasing temperature. The ability of nylon to absorb moisture is hindered at lower ambients. Generally, nylon element humidistats should not be used at temperatures below 60°F.

Honeywell humidistat models H46C and H600A, Barber Colman model HC101 and Abbeon Cal model 4703-602 were procured for testing. Only the Abbeon Cal humidity control is capable of controlling both a humidifier and a dehumidifier. The other models would require two controls for both a humidifier and dehumidifier. Each humidity control was subjected to the following tests:

- Human Factors Evaluation
- Initial Controls Performance Test
- Vibration
- High Temperature Storage
- Low Temperature Storage
- Final Controls Performance Test
- Electromagnetic Interference

(2) Honeywell Humidity Control (Model H46C). The Honeywell model H46C contains a single pole, single throw snap switch which controls a dehumidifier. Unit is provided with a 20-80% RH adjustable dial and positive on/off setting positions for manual operation of the controlled equipment. The unit possesses a 5% RH differential, which closes the switch at the set point and will open the switch at the set point minus the differential. The unit is enclosed in a molded plastic case 4-21/32" x 2-15/16" x 1-3/8" and includes an adapter plate for vertical switch box mounting. The humidistat has lead wire connections suitable for up to 240V use. Model H46D is similar in operation and will control a humidifier.

(3) Honeywell Humidity Control (Model H46C) - Test Result Summary. The initial controls performance test indicated that this model had an inaccuracy of approximately 3% RH upon reception from the equipment supplier. The unit was recalibrated.

The human factors evaluation indicates that the height of the rotating adjustment knob is not per MIL-STDS. Labeling of the unit lacks in bolding and is not per MIL-STDS. Indicator scale is in increments of 10% RH. It is, therefore, difficult to accurately adjust the unit.

The humidity control endured the vibration, high temperature storage and low temperature storage tests with no apparent damage.

The final control performance test revealed that the model H46C maintained its accuracy better than the other candidates. The unit was inaccurate by approximately 1% RH.

EMI testing indicated that the humidity control was within the radiated emission level limits imposed by method RE02 of MIL-STD-461, Part 4 for transients.

(4) Honeywell Humidity Control (Model H600A). The Honeywell model H600A contains a single pole, double throw switch which can be used to control either a humidifier or dehumidifier. Unit is provided with a 20-80% RH adjustable dial and has a 5% RH differential. It is enclosed in a molded plastic case 5-3/4" x 3-3/4" x 2-3/16", and includes a metal adapter plate for switch box mounting. The humidistat has lead wire connections suitable for up to 240V use.

(5) Honeywell Humidity Control (Model H600A) - Test Result Summary. The initial controls performance test indicated that the H600A was inaccurate by approximately 14% RH upon reception from the equipment supplier. The unit was recalibrated.

The human factors evaluation indicates that the height and the diameter of the rotating adjustment knob is not per MIL-STDS. Knob is removable, thus easily lost. Adjustment knob and scale are located on top of unit requiring mounting of lower than eye level for viewing. This would place the unit in height area susceptible to damage by bumping from personnel. Mounting unit at eye level would make the indicator scale difficult to read. The indicator scale is in increments of 10% RH, making it difficult to accurately adjust the unit. Generally this was the most difficult humidity control to adjust.

The humidity control successfully completed the vibration, high temperature storage and low temperature storage tests with no apparent damage.

The final controls performance test revealed that the model H600A was inaccurate by approximately 3% RH.

EMI testing indicated that the humidity control was within the radiated emission level limits imposed by method RE02 of MIL-STD-461, Part 4 for transients.

(6) Barber Colman Humidity Control. The Barber Colman model HC101 contains a single pole, double throw switch which can be used to control either a humidifier or dehumidifier. The unit is provided with a 10-90% RH adjustable dial, and possesses a 5% RH differential. It is enclosed in a molded plastic case 4-3/8" x 2-7/8" x 1-5/8". Two screw holes are provided in a plastic backplate for mounting. The humidistat has lead wire connections suitable for up to 240V use.

(7) Barber Colman Humidity Control - Test Result Summary. The initial controls performance test indicated that the unit was inaccurate by approximately 5% RH upon reception from the equipment supplier. The unit was recalibrated.

The human factors evaluation revealed that the height of the adjustment knob is not per MIL-STDS. Reference indicator and knob are the same color, thus contrast requirements of MIL-STDS are not met. The indicator scale is in increments of 10% RH, making it difficult to accurately adjust the unit.

The humidity control endured the vibration, high temperature storage and low temperature storage tests with no apparent damage.

The final controls performance test revealed that the unit was inaccurate by approximately 9% RH.

EMI testing indicated that the humidity control exceeded the radiated emission level limits imposed by method RE02 of MIL-STD-461, Part 4 for transients.

(8) Abbeon Cal Humidity Control. The Abbeon Cal model 4703-602 is manufactured by Lufft of Germany. This unit indicates the ambient RH on a 0-100% RH face plate. The RH indicator or pointer is used as the switch. Two additional pointers which are manually adjustable are used to open or close control circuits in conjunction with the RH indicator. The unit will control both a humidifier and dehumidifier within any range. The unit does not possess a %RH differential. It is enclosed in a metal case 6" diameter and 1-1/2" deep with a glass face plate. Three screw holes are provided in the flanged metal case for mounting. The unit includes three screw terminals for wire connections and is only suitable for 24V use.

(9) Abbeon Cal Humidity Control - Test Result Summary. The initial controls performance test indicated that the unit was inaccurate by approximately 12% RH upon reception from the equipment supplier. The unit was recalibrated.

This is the only humidity control tested which visibly indicates the ambient relative humidity. The height of the adjustment knob is not per MIL-STDs. The indicator scale is in increments of 2% RH and the unit can be easily and accurately adjusted. This unit is superior to the other humidity controls tested as far as human factors in concerned.

The humidity control endured the vibration, high temperature storage and low temperature storage tests with no apparent damage.

The final controls performance test revealed that the unit was inaccurate by approximately 5% RH.

EMI testing indicated that the humidity control exceeded the radiated emission level limits imposed by method RE02 of MIL-STD-461, Part 4 for transients.

8. LOCATION OF HUMIDIFICATION EQUIPMENT AND CONDITIONED AIR DISTRIBUTION THROUGHOUT THE SHELTER

(1) Dehumidifier. In the proposed humidity control system the existing heat pump will be used for all dehumidification requirements. The heat pump will remain as originally installed in the service shelter with its discharge air distributed throughout the shelter by the existing duct work. Condensate will drain to the outside through existing drain tubing.

(2) Humidifier and Water Storage Tank. The exact location of the humidification equipment within the shelter has not been determined. Generally, in order for a gravity feed water system to operate, the source of water must be located above recipient equipment. The available space in the service shelter is very limited with the floor to ceiling distance being eight feet. The water storage tank must be located as close to the ceiling as possible while still allowing access to the tank top for refilling. Mounting the tank bottom approximately 22 inches from the ceiling should provide adequate access. To obtain a minimal inlet pressure, the humidifier should be located as low in the shelter as possible and directly beneath the storage tank. Floor mounting the humidifier will provide for just over 2 psi inlet water pressure to the unit. Drain tubing must be provided to the humidifier for overflow protection and the drain/flush cycle as required.

Distribution of steam within the shelter will be accomplished with the humidifier's internal blower. The blower will discharge into free space. Ideally, use of the existing duct system with the heat pump blower would provide the best distribution, but potential problems associated with use of the duct work eliminated it from consideration. Dumping steam into the heat pump discharge duct would allow condensate accumulation inside the duct when both cooling and humidification are required simultaneously. This is obviously unacceptable as water would drip uncontrollably over equipment and personnel. Introducing steam into the heat pump intake duct would greatly reduce humidification capacity and increase the latent cooling load of the heat pump. It is believed that distributing steam with a separate blower is the only viable alternative.

Care must be taken when locating and orienting the humidifier blower. Obstacles in the blower discharge area will provide surfaces on which condensate may accumulate. As an example, Dri Steem recommends that no solid objects be within four feet from the VM2 discharge horizontally (assuming 40% RH) and no solid object should be within three feet of the discharge vertically. The discharged steam should be directed down the length of the service shelter. Discharging steam into the aisle may result in an uncomfortable situation for personnel.

(3) Humidity Controls and Alarm Lamps. The humidity controls for the humidifier, dehumidifier, high humidity alarm, low humidity alarm and lamps for high and low humidity and low water storage tank level should be located on a vertical wall four to five feet above the floor. Humidity controls should be placed as far away as possible from the discharge of the equipment they control. This should allow proper distribution of conditioned air throughout the shelter and prevent short circuiting. Optimally, all sensors and alarm lamps can be located together for convenience. A general arrangement sketch of the entire humidification control system is shown in Figure 9.

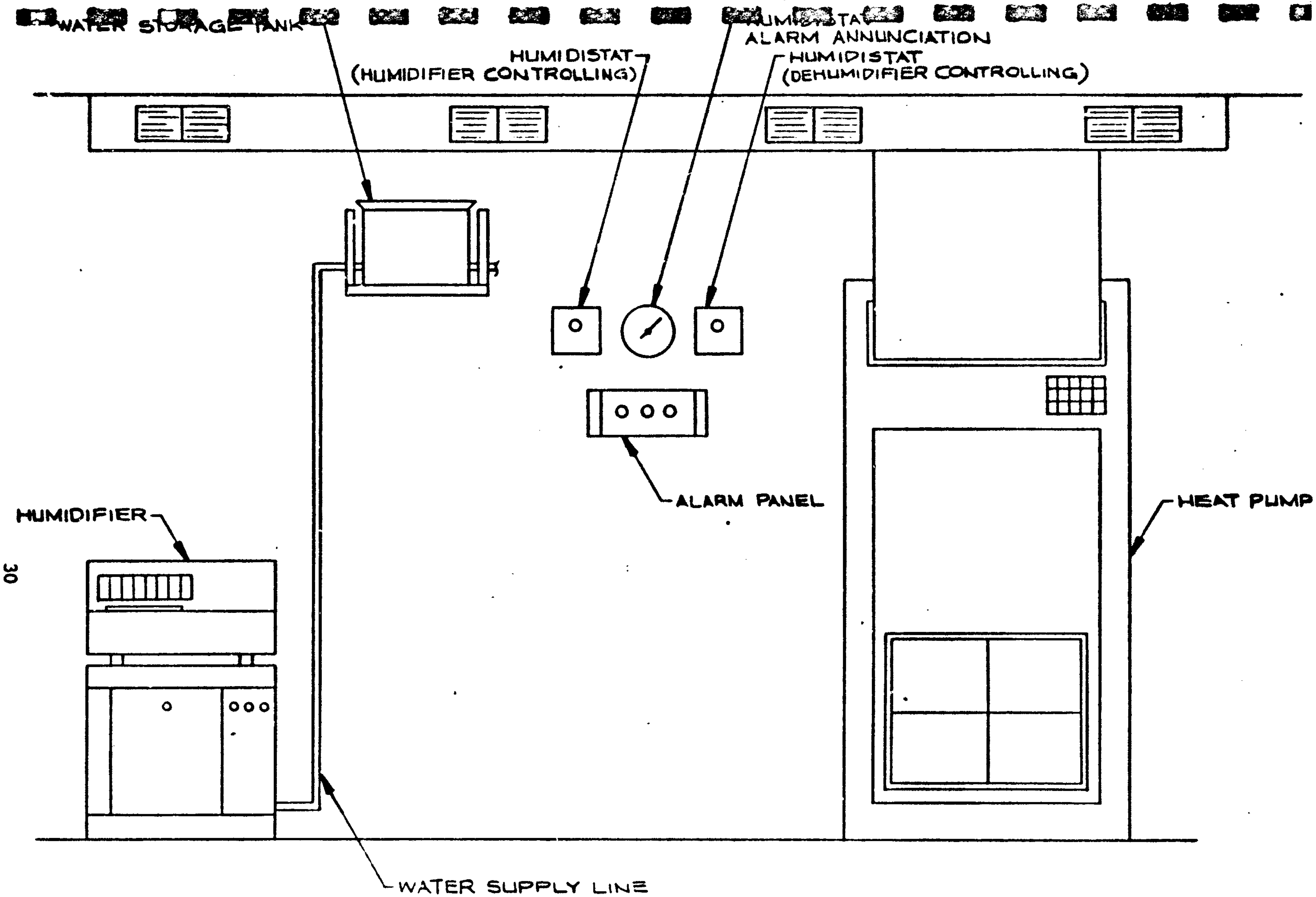


Figure 9. General Arrangement of Humidification Control System

III. CONCLUSION

VSE believes it is technically and operationally feasible to develop a workable humidification control system using commercial equipment for application in the Aircraft Service Shelter. A workable system will include compromises regarding the original design criteria for the humidity control system. A working humidity control system will involve significant modifications to the proposed commercial humidifier to be used and also some changes to existing shelter equipment. However, the modifications needed are practical and will permit the use of commercial equipment for this application. Of course, modifying off-the-shelf equipment will necessitate increased procurement costs. However, the modification costs would prove minuscule compared to the costs associated with a full scale design and development program.

The series of tests performed on the evaluated commercial equipment has demonstrated that the items should survive in a military environment.

Areas of concern which may impact the development of a satisfactory humidification control system are space required and the response time of the humidifier equipment. Discussions with the manufacturer of the proposed humidifier indicate the manufacturer's willingness to work with VSE to overcome the space and response problems. The manufacturer has proposed modifications to their equipment which would comply with our requirements.

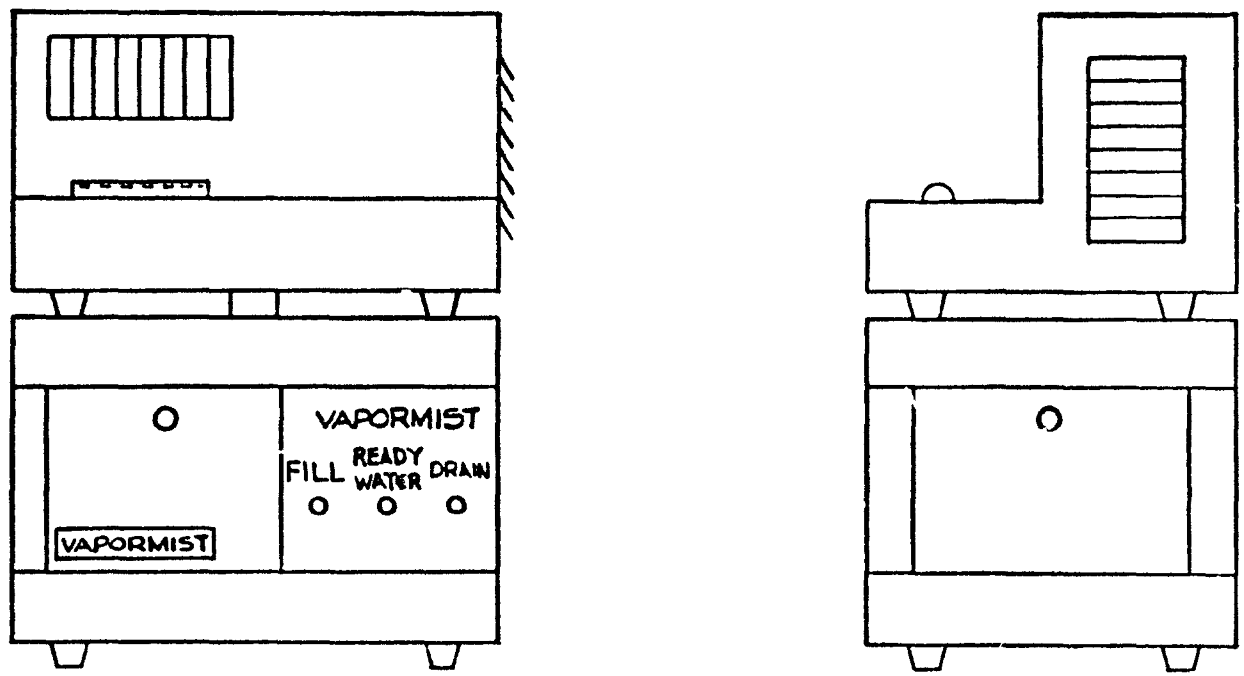


Figure 10. Dri Steem Humidifier Model VM2

Figure 11. Honeywell Humidistat Model H46C

Figure 12. Abbeon Cal Humidistat Model 4703-602

IV. RECOMMENDATION

1. GENERAL

It is recommended that the following major components be used to comprise the Aircraft Service Shelter humidification control system:

- o Existing shelter heat pump, modified as required, to provide for shelter dehumidification requirements.
- o Dri Steem humidifier model VM2, modified as required, to provide for shelter humidification requirements (Figure 10).
- o Honeywell humidistats models H46C and H46D to provide control for the dehumidification and humidification equipment respectively (Figure 11).
- o Abbeon Cal humidistat model 4703-602 to provide continuous indication of shelter ambient relative humidity and to provide for high and low relative humidity condition alarm (Figure 12).

2. EQUIPMENT MODIFICATIONS

(1) Dehumidification. The existing heat pump would be modified as discussed in part 4, paragraph (3) of Section II. Level I drawings have been provided under this task which depict electrical modifications to the 24V heat pump control circuitry and to the thermostat printed circuit board. During the developmental phase of this project, consideration must be given to the heat pump input power lines. The proposed modifications will require input currents approximately 29% higher than present needs. The power supply system must be capable of carrying the increased current.

(2) Humidification. The Dri Steem humidifier must be modified to comply with the 27" height x 17" width x 23" depth requirement. Excess space does exist within the cabinet of the humidifier. Dri Steem Humidifier Company personnel have proposed fabricating an entirely new cabinet. The new cabinet would be composed of an aluminum angle frame with aluminum panels. The new cabinet can be fabricated to comply with the 27" x 17" x 23" space envelope.

The humidifier response time must be improved. The lag time from initial unit start up to steam emission and the lag time during and following the refill mode is significant. Dri Steem personnel have suggested modifications which will decrease the non steam emitting periods. The initial heating period during unit start up can be reduced by decreasing the volume of water in the evaporator chamber. This can be accomplished by extending the three conductivity probes deeper into the chamber. Less water would be needed to fill the chamber. The skimming port would also be lowered accordingly. The lag time during and following the refill mode can be reduced by allowing the resistance heater to remain "ON" during refill. This can be accomplished by rewiring such that the cycling fill valve circuit is divorced from the low water protection circuit. The evaporator chamber itself would complete the lower water protection circuit as opposed to one of the three conductivity sensor probes. The first and second probes would cycle the fill valve as necessary while the third probe and the evaporator chamber would de-energize the heating element at low water level. The proposed circuitry is currently used on other model humidifiers manufactured by Dri Steem. Dri Steem has proposed to change the current 1/4" solenoid fill valve to a 1/2" solenoid valve. The larger port will increase the flow rate from the gravity fed water supply.

Human factors considerations may require that the exposed steam distribution tube be guarded to reduce the burn hazard. Since a new cabinet is proposed, handles for proper lifting could easily be incorporated. The humidifier annunciating lights are not provided in the colors dictated by MIL-STDs. The light colors can be easily changed.

The unit exceeded the EMI limits for transients. It is not recommended that the humidifier be modified to eliminate the transient spikes since the spike durations are only a fraction of a second.

The humidifier 24V control circuitry would be modified to provide power to the extreme RH alarm lamps and to the water storage tank low level alarm lamp. These lamps require very low currents and should not adversely impact humidifier operation.

It is recommended that the slide mounted evaporator chamber be packaged such that the chamber cannot contact the front and back panels during transportation.

(3) Humidity Controls. No modifications are necessary to the humidity controls selected for use. However, all humidity controls should be recalibrated prior to installation in the shelter. The allowable relative humidity extremes are 35% and 55%. Below 35% and above 55% alarm lamps will annunciate. Due to the apparent lag time for the Abbeon Cal humidistat on falling RH, it is recommended the alarm set points be 40% and 55%. The Honeywell humidistat set points must be within this range.

3. EQUIPMENT MAINTENANCE

The humidity controls are maintenance free. No additional maintenance will be required for the heat pump/dehumidifier (other than maintenance presently required).

Maintenance will be necessary for the humidifier. The amount of maintenance will be directly related to the hardness of the supply water. It is recommended that chemical additives be used as required to impede the formation of a hard mineral scale on the humidifier internals. Oakite Enprox 355NC or an equivalent polyphosphate should be adequate for this purpose. The remaining sludge residue must be periodically flushed from the evaporator chamber before the sludge accumulates to the level of the heating element. The Dri Steem automatic surface water skimming feature and the automatic flush cycle probably will not be adequate to remove the sludge. The gravity fill arrangement will not provide pressure with which to agitate sediments in the evaporator chamber and drain them away.

Should problems with bacteria arise in the water storage tank and the water supply tubing, it is recommended that a biocide additive such as Oakite Biocide 20 be used for eliminating the microorganisms.

4. DEVELOPMENTAL WORK REQUIRED

Work remaining to arrive at a complete and operationally suitable humidification control system involves determining the exact interfaces of the system and the shelter. The interfaces and final equipment used should be documented with level 2 drawings. The operational suitability should be demonstrated by outfitting one or more Aircraft Service Shelters with the humidification control system and operating for a period of time under various ambient conditions requiring humidification and dehumidification.

APPENDIX A

MARKET SURVEY OF HUMIDITY CONTROL EQUIPMENT FOR THE U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

MARKET SURVEY OF HUMIDITY CONTROL EQUIPMENT FOR THE U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

Prepared For:

U.S. ARMY BELVOIR RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
FORT BELVOIR, VIRGINIA 22060

Contract DAAK70-86-D-0023

5 December 1986

Report No. VSE/ASG/0024-86
Task 0500.0024

Market Survey of Humidity Control Equipment for the U.S. Air Force Aircraft Service Shelter

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SUMMARY

The purpose of this report is to present findings resulting from a market survey to select commercially-available humidity control equipment (humidifier, dehumidifier and humidity controls) for installation in the U.S. Air Force service shelter, which is an integral part of the F-16 maintenance complex. The humidity control system is necessary to control the humidity at 48% ± 8% required by sensitive equipment located in the service shelter. Initially, a list of 107 potential manufacturer's or their representatives was compiled from available industrial catalogues and directories. A survey letter requesting technical, cost and delivery information about their product was sent to each of the listed manufacturers. Out of the 107 solicitations sent, 33 (about 31%) responded - 27 provided technical data and 6 could not meet the requirements.

An evaluation of the data received indicated that three types of humidifiers (wetted element, atomization, and steam generation), two types of dehumidifiers (refrigeration and desiccant impregnated element) and various types of humidity controls with sensing elements ranging from nylon or human hair to state-of-the-art electro-optics were available. However, out of the three types of humidifiers available, only one out of ten of the atomization type evaluated and two out of nine of the steam generation type evaluated were selected for further evaluation and study. The wetted element was not chosen because it would require an auxiliary heating unit that would be too large for the allocated service shelter space. Both types of dehumidifiers were excluded from further evaluation because the size required would be too large to fit into the allocated service shelter space and because the existing shelter environmental control unit (heat pump) is capable of being modified to provide the necessary dehumidification by rewiring the units control circuitry to allow dehumidification operation when thermostat is satisfied.

Four of 12 humidity controls evaluated were selected for further evaluation and study. All use nylon sensing elements and were chosen because they had the required characteristics and were relatively inexpensive compared to other types of humidistats.

Thus, the single atomization-type humidifier, two steam generation-type humidifiers, and four humidity controls will be procured for further evaluation and testing. The existing heat pump will be evaluated to determine what modifications are necessary, and be tested after incorporation of the modifications.

PREFACE

This market survey report was prepared under Contract No. DAAK70-86-D-0023, Task Order No. 0024, for the Belvoir Research, Development and Engineering Center (BRDEC), Fort Belvoir, Virginia. Mr. Robert A. Rhodes served as the BRDEC contracting officers technical representative at (703) 664-6031.

The market survey effort was part of the total humidity control work and services to be provided under Task Order No. 0024. The required effort contained in the task order statement of work is quoted below.

> "Perform a market survey of commercial equipment such as humidity controls, humidifying equipment and dehumidifiers. From information acquired from this market survey, select the best candidates for use in the van. Purchase sample items of equipment for test and evaluation."

MARKET SURVEY OF

HUMIDITY CONTROL EQUIPMENT FOR THE

U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

I. INTRODUCTION

1. SUBJECT

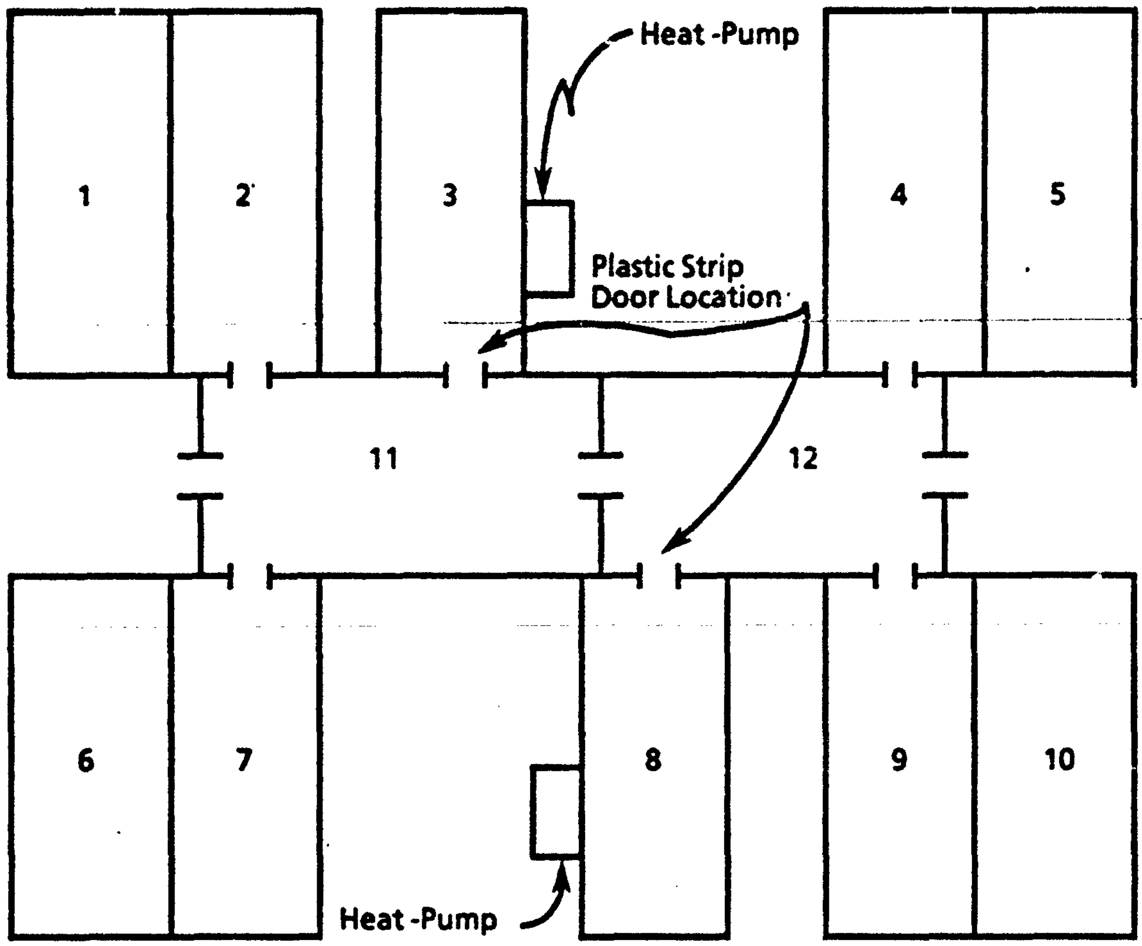
This report provides information concerning the market survey effort to obtain manufacturer's technical data for evaluation of commercially available (off-the-shelf) humidity control equipment for potential installation in a U.S. Air Force Service Shelter. Specifically, this means humidity control equipment that would maintain indoor humidity at 48% ± 8% required by sensitive electronic equipment located in the service shelter.

The selection of potential humidity control equipment such as humidity controls, humidifying equipment and dehumidifiers was based on the following.

- Obtaining technical data from manufacturers or their representatives about their off-the-shelf humidity control equipment.
- Obtaining manufacturer's price and delivery time after receipt of order.
- Evaluation of data received to select potential candidates for further evaluation.

2. BACKGROUND

On 14 July 1986, the Tactical Shelter Systems Development Office, HQ Electronics System Division, Department of the Air Force at Hanscom Air Force Base, Massachusetts, through the Belvoir Research, Development and Engineering Center, tasked VSE to provide engineering support, prototyping, documentation and testing services in evaluating humidity control equipment for potential use within the U.S. Air Force service shelters. These 12 Navy International Standards Organization (ISO) shelters comprise the F-16 aircraft maintenance complex (Figure 1). Eight of the shelters are arranged in four groups of two, which are designated as "work stations". Two more shelters are centrally located and serve as work bench equipped corridors. The two remaining shelters (3 and 8 in Figure 1) are used for maintenance of electronic devices. Because these two shelters contain equipment and processes that are humidity sensitive, humidity within the shelters must be controlled. Currently, heating and cooling in each shelter are provided by a nominal 3-ton heat pump.



NOTE: Nos. 3 and 8 are maintenance shelters requiring humidity control.

Figure 1. F-16 Maintenance Complex

II. DISCUSSION

1. MARKET SEARCH FOR HUMIDITY CONTROL EQUIPMENT CANDIDATES

Initially, the following documents were searched to compile a list of potential humidity control manufacturers to be surveyed.

- American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), 1979 Equipment Volume.
- American Refrigeration Institute (ARI) Unitary Directory dated July 1 - December 31, 1985.
- Thomas Register of American Manufacturers dated 1986.

A list of 107 potential manufacturers or representatives was compiled (Appendix A). The survey letter (Appendix B) requesting information about their product was then sent to each of these manufacturer's or representatives. Out of the 107 solicitated, 33 (about 31%) responded. Twenty-seven provided technical literature about their humidity control equipment candidates while the remaining six stated they could not meet the requirements. No responses were received from the remainder. A brief summation of the technical information received from 27 manufacturers about their humidifiers, dehumidifiers, and humidity controls is presented in Appendix C, D, and E, respectively. Results of the investigation are presented in Section III.

2. SELECTION OF HUMIDITY CONTROL EQUIPMENT CANDIDATES FOR FURTHER EVALUATION

a. <u>Criteria for evaluating candidates.</u> The criteria listed below were provided by the Tactical Shelter Systems Development Office, Hanscom Air Force Base, for evaluating the off-the-shelf humidity control equipment. The humidity control system must:

- Have separate humidification and dehumidification modes of operation.
- Have high/low humidity alarm lamps with adjustable settings.
- Create and maintain a stable environment of 48% ± 8% relative humidity within 4 hours after activation within an 8 X 8 X 20 foot shelter or 1,280 cubic feet of interior space.
- Not exceed dimensional envelope of 17 inch width by 27 inch height by 23 inch depth and be provided with rack adapters for mounting in standard 19-inch racks. Must also be capable of floor mounting.
- Be powered by 120 vac ± 10%, single phase, 50/60 Hz electric power. Must be fully efficient at 50 Hz.
- Have a filtered air inlet with a removable/washable filter element.
- Have an adjustable, direct reading humidistat.
- Have a self-contained water storage tank with low water alarm, sufficient in size to sustain a minimum of 8 hours of humidification at rated capacity.

In conjunction with design, capacity, size and electrical characteristics, cost was used to evaluate potential equipment candidates.

b. Humidifier candidates. Review of the manufacturer's technical information received indicated that three basic types of humidification equipment (Figure 2) were available:

- Wetted Element
- Atomization
- Steam Generation (Heated Pan)

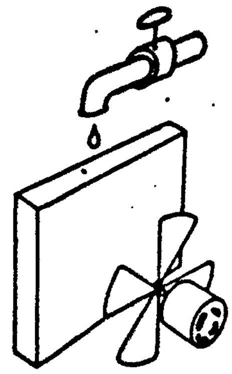
Of these three types, atomization and steam generation seemed to be the most promising, as indicated in the following description and evaluation of each type.

(1) Description

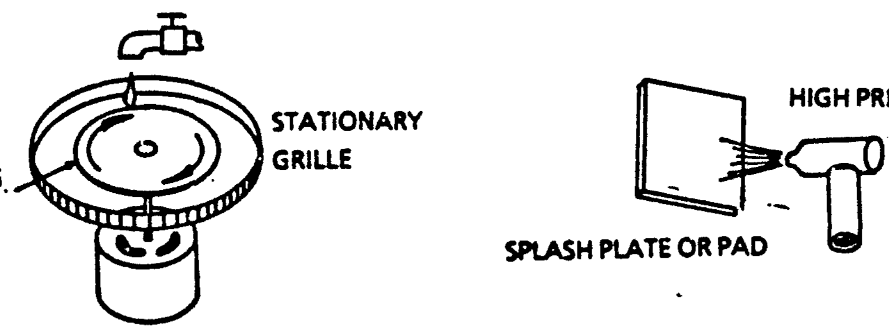
(a) Wetted element humidifiers. As shown in Figure 2, the wetted element humidifier uses a wetted media through or over which air is circulated to evaporate water.

Wetted element humidifier capacities are greatly dependent upon conditions of the surrounding air or water supply. For evaporation to occur at an appreciable rate, in a wetted element humidifier, either the supply water or forced air must be heated to an elevated temperature. Elements generally employ materials that have a high surface area for a given volume and are configured to facilitate evaporation in a forced air stream. Common off-the-shelf designs for wetting the element surface include supplying water continuously to the top of an element pad. The water is then evenly dispersed along the length and width of the element. Supply water then trickles down the element by gravity while coming in contact with the forced air. Water that is not evaporated helps to flush minerals through the system drain. A buildup of minerals in the media is one drawback of this type of humidifier. It generally also has to be quite large to provide enough wetted surface for the required capacity. Another off-the-shelf wetted element design uses an electric motor to slowly rotate a cylindrical element through a water pan and into the forced air stream.

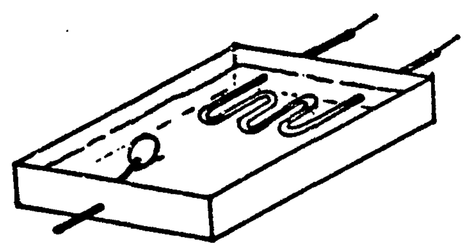
(b) Atomization humidifiers. Atomization humidifiers are not dependent on the temperature conditions of the surrounding air or water supply like the wetted element humidifiers. Most of the off-the-shelf designs use the centrifugal force of a rotating disc (Figure 2) to distribute a water film evenly on the disc edge. Water then leaves the rotating disc edge and impacts a grille which



WETTED ELEMENT TYPE



ATOMIZATION TYPES



STEAM GENERATION (HEATED PAN) TYPE

NOTE: Any of the above types may have fans to distribute the moisture.

Figure 2. Humidifier Types

breaks the water up into small droplets. These water droplets are entrained into an air stream generated by an internal blower, and the air stream then distributes the droplets throughout the conditioned space. Inherently a rotating disc will distribute moisture in a 360° spread. The discharge can be blanked off to provide a discharge spread, as required, to avoid nearby obstructions.. Other off-the-shelf designs rely on high pressure water supplied to a nozzle (Figure 2) which disperses the water droplets throughout the conditioned space. Another off-the-shelf design is an ultrasonic atomizer which involves flowing a controlled amount of water over a surface which is vibrated at a high frequency. The vibrations produce capillary waves in the water. Finely atomized droplets are sheared off the wave peaks and are then projected a short distance before falling due to gravity or are entrained in the air stream of an internal blower. All atomizing units have the inherent potential of "dusting" the humidified space, i.e., hard water or water containing a high concentration of calcium or magnesium salts in solution will dust (precipitate) these talcum fine minerals over all equipment within the conditioned space. Deposits will also form on the internals of the humidification equipment itself. Proximity of the mist spray to surfaces within the conditioned space is critical since improper location may cause moisture accumulation on nearby equipment. Atomizers which make use of water reservoirs possess the potential for growth of biological organisms. Atomizers, as well as wetted element types, inherently will remove sensible heat from the conditioned air space through the evaporative cooling effect. Approximately 1000 BTU is absorbed per pound of water evaporated.

(c) Steam generation humidifiers. Steam generation humidifiers are also not dependent on the temperature conditions of the surrounding air or water supply like the wetted element humidifiers. The off-the-shelf design uses electric heating elements in a water reservoir. This heated pan design (Figure 2) eliminates the dusting drawback of atomizer humidifiers since generated steam is mineral free. However, minerals in hard water must precipitate somewhere and for steam generators this is a lime formation (calcium and magnesium salts) on the sides of the water reservoir, heating elements and float valves. This scaling tendency indicates that steam generation requires comparatively high maintenance. Steam generators inherently add heat to the conditioned space during their operation, though experience shows that this heat is not significantly more than the latent heat of vaporization.

(2) Evaluation. All three of the humidifier designs have shortcomings as to shelter application. However, only in wetted element humidifiers is this a significant drawback.

(a) Wetted element humidifiers. Wetted element humidifiers require the use of heated supply air or water for efficient operation. Most of the off-the-shelf humidifiers were designed for installation in the hot air duct of a house furnace where a ready supply of hot air (about 120°F) is available for accelerating the evaporation process. Other off-the-shelf humidifiers are intended for industrial use where supply water heated up to 140°F is already available. Neither heated air nor water at higher temperatures is available in the service shelter. An auxiliary unit to heat the water or air would have to be installed. The heating unit would be an unnecessary system complication and would require additional space. In addition, the wetted media retains minerals from the water and may rapidly accumulate a buildup which would block air flow. Therefore, the wetted element humidifier was eliminated as a candidate for further analysis and testing. Other details about wetted element humidifiers are presented in Appendix C.

(b) Atomization humidifiers. Atomization humidifier equipment may require significant maintenance due to calcium or magnesium salt depositing in the reservoir. This maintenance will be less frequent than for steam generation humidifiers due to the atomization humidifier nonmineral concentrating design. However, additional maintenance may be required for other equipment located in the conditioned space within the shelters due to "dusting" (mineral deposit). Scaling can be reduced by neutralizing or removing mineral ions in the supply water. This may be accomplished by chemical additives or use of a demineralizer. However, water treatment methods would merely slow the scaling process. The size of the water treatment equipment may preclude their use. The simplest solution to reduce scaling would be to use distilled or demineralized supply water. However, this "pure" water may not be available at all military locations. Internal scaling can be removed by scraping off excess deposits followed by an acid bath. The frequency of cleaning would depend on the hardness of the supply water, which will vary from location to location. Mineral deposits due to "dusting" may be reduced by installing a filter-eliminator, which would have to be cleaned or replaced periodically. Atomizer shortcomings do not eliminate further evaluation of this type of humidifier for use in the service shelter. Alternate water treatments would be evaluated to determine whether internal scale cleaning can be eliminated or periods between scale removal could be lengthened. As noted in Appendix C, 10 off-the-shelf candidates were evaluated as to capacity, size, and electrical power requirements. Nine candidates were rejected as noted under the "Remarks" column. Information about the candidates not rejected is also contained under the "Remarks" column. The single candidate selected for further evaluation and testing is presented in Table 1.

(c) Steam generation humidifiers. Steam generation humidifiers will require relatively high maintenance due to calcium or magnesium salt depositing on the inside of the equipment. Most steam generators combat scaling by periodically self-flushing. Flushing is initiated by a preset internal timer, which opens a solenoid

Table 1. Humidifiers Recommended for Testing

Manufacturer & Model No.	Basic Design	Specifications/Remarks
American Metal Co. Autoflo L-1011-K	Steam Generation	Capacity approximately 4.6 lb/hr, convection discharge or directional forced air. Ball valve water inlet. No self-flushing capability, pan size 8" high x 13" wide x 12" deep, double height for added blower. Input power: 1.4kw, 120v/1 ph/6OHz. Price: $770 ea., two required. Delivery: 7-12 days after order. Test Units Required: 1
Flakt Bahnson EIA	Atomization (Rotating Disc)	Capacity approximately 12.5 lb/hr. 360° Discharge unless shielded. Dimensions 14" high, 18" Diameter. Unit should be mounted high and away from surfaces for evaporation; should not be mounted near ceiling due to top fan inlet. Input power: approximately 230 watts, 115 v/1ph/60Hz Operating weight: 40 lb Price: $890 Delivery: 2-3 days after order. Test Units Required: 1.

Table 1. Humidifiers Recommended for Testing (Cont'd)

Manufacturer & Model No.	Basic Design	Specifications/Remarks
Shafer, Troxell & Howe Inc. Dri Steem Humidifier Co. VM2	Steam Generation	Capacity 6 lb/hr. Unit can be equipped w/ a blower assembly or dispersion tube for duct mounting. Dimensions of base unit are 21" high X 24" wide X 16" deep, and optional blower assembly dimensions are 12" high X 24" wide X 16" deep. Unit possesses automatic flush capability requiring approximately 1/2 gal. Requires a minimum water conductivity and therefore a water hardness of at least 2 gr/gal for operation of internal water level sensor. Input power: 2 kw, 120v/1ph/60Hz. Operating weight: 118 lb with blower assembly Price: $1500 Delivery: 2-3 weeks after order. Test Units Required: 1.

operated drain valve. Other measures used to combat scaling include chemically treating supply water or installing a demineralizer. As in the atomizer humidifier, preliminary demineralizer investigation indicates that equipment of appreciable size would be needed. Both these water treatment methods would merely slow the scaling process. The size of the water pre-treatment equipment may preclude their use. The simplest solution to reduce scaling would be to use distilled or demineralized supply water. However, this "pure" water may not be available at all military locations. Regardless of the method used, evaporation pans and heating elements would have to be cleaned periodically. Scaling would be removed by scraping off excess deposits followed by an acid bath. The frequency of cleaning would depend on the hardness of the supply water, which will vary from location to location. As in the case of the atomization humidifiers, this shortcoming does not eliminate using and further evaluating steam generation humidifiers for use in the service shelter. Alternate water treatments will be evaluated if treated water is deemed necessary for application. As noted in Appendix C, 10 off-the-shelf candidates were evaluated as to capacity, size, and electrical power requirements. Eight candidates were rejected as noted under the "Remarks" column. The two candidates selected for further evaluation are presented in Table 1.

c. Dehumidifier candidates. Review of the manufacturer's technical information received indicated that two types of off-the-shelf dehumidifiers were available:

- Refrigeration
- Desiccant Impregnated Element

However, as indicated in Appendix A, all of the available candidates, in order to produce the required dehumidification, would be very large. Most of the space allocated in the service shelter would already be occupied by the humidifier. Indications are that the dehumidification requirement of 5.43 lb/hr can be met with the existing environmental control unit (ECU). Results of ECU capacity tests presented in Report No. 466303 rendered to U.S. Army MERADCOM, Tests of a Model ECU 36 HP 36000 BTU/HR, 208/230 volts, 60 Hz, 3 phase Heat Pump in Accordance with ASHRAE Standard 37-1978, dated 27 December 1984, indicate a latent cooling capacity of 9350 BTUH. The heat pump tested (fabricated by ECU Inc.) did not contain the identical compressor as the heat pump (fabricated by ARE Manufacturing Co.) deployed in the aircraft service shelter, however, it is believed test results would be similar. The 9350 BTUH capacity equates to a dehumidification capability of approximately 9 lb/hr which is almost twice that required by the service shelter. Ambient test conditions of 80°F and 51% RH approximate the service shelter's design condition. It appears that minor modifications to the control circuitry of the ECU would provide the required dehumidification. Since the ECU is a heat pump with electrical booster heaters, dehumidification in the temperature comfort range ambients can be readily achieved by operating heat pump in cooling mode with booster heaters operating simultaneously. By modifying the existing ECU to provide controlled dehumidification and eliminating the need for a separate dehumidifier, cost savings in both materials and labor would results. Other benefits would produce savings in servicing, space, weight and handling.

d. Humidity controls. Review of the manufacturer's technical information received indicates that a wide variety of humidity controls are available. Sensing elements used in the controls varied from nylon or human hair to state-of-the-art electro-optics. The more conventional controls used hygroscopic materials which expand or contract with humidity changes. The expansion or contraction, in turn, mechanically opens or closes a set of electrical contacts. Currently, the industrial trend is toward using the less expensive nylon as the sensing element. Nylon has a reputation for good precision, but manufacturing techniques may not produce consistent accuracy. Therefore, it may be necessary to calibrate each control upon receipt. Solid state controls use sensors that detect changes in electrical resistance and are relatively expensive. Electro-optic controls use a photosensor to detect moisture formation on a chilled mirror. Dew point changes are interpreted by a microprocessor which then sends signals to a humidifier, dehumidifier or other similar equipment. Consideration must be given to the internal switch mechanism of the controls, which must have the ability to operate both the humidifier and dehumidifier with a dead band between the two control points. However, it may prove to be less expensive to install two separate controls, one for humidification and one for dehumidification. Controls are available for either low or line voltage. As noted in Appendix D, 12 off-the-shelf candidates were evaluated. Eight candidates were rejected as noted under the "Remarks" column. The four candidates selected for further evaluation are presented in Table 2.

Table 2. Humidity Controls Recommended for Testing

Manufacturer & Model No.	Sensing Element	Specifications/Remarks
Abbeon Cal 4703-602	Durotherm (Nylon Derivative)	Will control humidifier and dehumidifier at two separate set points. Maximum 24v input. Adjustable dead band. Dimensions: 6" Diameter. Approximate Differential % RH: 3. Price: $140.
Barber-Colman HC 101	Nylon	Will control a humidifier or dehumidifier, SPDT. Accepts low or line voltage. Dimensions: 4-1/2" X 3" X 1-1/2". Approximate Differential % RH: 5. Price: $55.
Honeywell H600A	Nylon	Will control a humidifier or dehumidifier, SPDT. Accepts low or line voltage. Adjustment knob is removable. Dimensions: 5-3/4" X 3-3/8" X 2-3/16". Approximate Differential % RH: 5. Price: $64.

Table 2. Humidity Controls Recommended for Testing (Cont'd)

Manufacturer & Model No.	Sensing Element	Specifications/Remarks
Honeywell H46C, D	Nylon	Unit is supplied with the Airflow Co. model DEH-34-250 dehumidifier, which is designed for military applications. Accepts low or line voltage, single switch (SPDT). Dimensions: 4-3/4" X 3" X 1-3/8". Approximate Differential % RH: 5. Price: $33.

III. CONCLUSIONS

The market survey and subsequent evaluation of the off-the-shelf humidity control equipment resulted in the following conclusions about the humidifier, dehumidifier and humidity control equipment.

1. HUMIDIFIER EQUIPMENT

Of the three types of humidifier equipment available (wetted element, atomization and steam generation), the atomization and steam generation type have the potential of providing the humidification required by the service shelter. One of the nine atomization type evaluated and two of the ten steam generation type evaluated were chosen as candidates (see Table 1) for further evaluation and testing because they closely approximate requirements specified by the government. The five wetted element types were excluded from further evaluation because the size of an auxiliary unit needed to heat incoming air or supply water would be too large to fit into the allocated service shelter space.

2. DEHUMIDIFIER EQUIPMENT

Both types of dehumidifiers available (refrigeration and desiccant impregnated element) were excluded from further evaluation and testing. Exclusion was based on the fact that the size required would be too large to fit into the allocated service shelter space. In lieu of using an auxiliary dehumidifier, results of a preliminary investigation indicate that the existing ECU with modified controls is capable of providing the dehumidification required.

3. HUMIDITY CONTROLS

Of the various types of humidity controls available with sensing elements ranging from nylon or human hair to state-of-the-art electro-optics, the most promising candidates (see Table 2) are four with nylon sensing elements.

IV. RECOMMENDATIONS

It is recommended that the three atomization and the two steam generation humidifiers in Table 1 be procured, evaluated and tested for use in the Air Force service shelter to determine which candidate could best provide the required humidification. Additionally, it is recommended that the four humidity controls in Table 2 be procured, evaluated and tested. However, procurement of dehumidifiers for further evaluation and testing is not recommended because the existing ECU (heat pump) can provide the necessary dehumidification. Therefore, it is also recommended that the ECU be evaluated to determine what modifications are necessary for its use as a dehumidifier and that it be tested following the modification.

APPENDIX A

LIST OF 107 PROSPECTIVE MANUFACTURERS CONTACTED

1. Airflow Co.
295th Bailes Ln.
Frederick, MD 21701

2. American Hofer Sub. of Kahn & Co., Inc.
Goff & Wells Roads
Wethersfield, CT 06109

*3. Barnebey-Cheney Co.
P.O. Box 2526
Columbus, OH 43216

4. Bry-Air, Inc.
P.O. Box 269
Sunbury, OH 43074

*5. Cargocaire Engineering Corp./Craig
Bill Kennedy
6 Chestnut Street
Amesbury, MA 01913

6. Airtek Division
Compressed Air Components
757 E. Ferry Street
Buffalo, NY 14211

*7. Dryomatic, Div. of Airflow Co.
Airport Industrial Center
Gaithersburg, MD 20879

8. Eagle Chemical Co., Inc.
P.O. Box 107
Mobile, AL 36601

*9. Electro Impulse, Inc.
116 Chestnut Street
Red Bank, NJ 07701

*10. General Cable Corp., Apparatus Div.
500 W. Putnam Avenue
Greenwich, CT 06830

11. Kahn & Co.
Goff & Wells Roads
Wethersfield, CT 06109

12. Kathabar Systems Ross Air Sys. Div.
20600 Chagrin Blvd.
Cleveland, OH 44122

13. Lectrodryer Div., Ajax Magnethermic Corp.
Overland at Larchmont
Warren, OH 44482

14. McIntire Co.
33 River Street
Thomaston, CT 06787

*15. Niagara Blower Co.
673 Ontario Street
Buffalo, NY 14207

*16. Pall Corporation Pneumatics Prod. Corp.
Tony Quilon
4647 Southwest 39th Ave.
Ocala, FL 32674

17. Rainville Co., Inc.
200 Clay Avenue
P.O. Box 640
Middlesex, NJ

*18. Tate Temco, Inc./Tate Andale, Inc.
1941 Lansdowne Road
Baltimore, MD 21227

*19. Universal Dynamics Corp.
13614 Dawson Beach Road, E.
Woodbridge, VA 22191

*20. Addison Products Co.
Addison, MI 49220

*21. Amana Refrigeration, Inc.
Amana, IA 52204

*22. Antar Industries, Inc.
350 5th Ave., Empire State Bldg.
New York, NY 10118

23. Dayton Electric Mfg. Co./W.W. Grainger's
Lynn McBride
7400 Boston Blvd.
Springfield, VA 22153

24. Ebco Mfg. Co.
265 N. Hamilton Road
Columbus, OH 4312

*25. Electrohome Ltd.
809 Wellington Street
N. Kitchner, Ontario, Canada
N2G4J6

26. Fedders Corporation
4429 James Place
Melrose Park, IL 60160

27. General Cold Corp.
Empire State Building
New York, NY 10118

28. Heat Controller, Inc.
1900 Wellworth at Losey
Jackson, MI 49203

*29. Kelvinator International Corp.
4248 Kalamazoo Ave., S.E.
Grand Rapids, MI 49508

30. Marlow Industries, Inc.
10451 Vista Park Road
Dallas, TX 75238

31. Oasis Water Coolers
265 N. Hamilton Road
Columbus, OH 43213

32. Singer Co., The Climate
Control Div.
401 Randolph Street
Red Bud, IL 62278

33. Valad Electric Heating Co.
161 Wildey St., P.O Box 577
Tarrytown, NY 10591

34. Whirlpool Corp., Commercial
Refrigeration Division.
2000 U.S. 33N
Benton Harbor, MI 49022

35. White-Westinghouse
Appliance Co.
930 Fort Duquesne Blvd.
Pittsburgh, PA 15222

36. Air & Refrigeration Corp.
P.O. Box 10127
Dallas, TX 75207

*37. Abbeon Cal, Inc.
Susan Reed
123 Gray Avenue
Santa Barbara, CA 93101

38. Aeronca, Inc., Buensod/Agitatir
Div.
200 Rodney Street
Pineville, NC 28134

39. Air Conditioning, Inc.
P.O. Box 800396-TR
Houston, TX 77280

40. Air Dynamics, Inc.
1918 N. Potrero Avenue
P.O. Box 3666
South El Monte, CA 91733

41. Air-Heet Products
10134 Pacific Avenue
Franklin Park, IL 60131

*42. Armstrong Machine Works
8091 Maple Street
Three Rivers, MI 49093

*43. Autoflo Co., Div. Masco Corp.
American Metal Products
Stella
6100 Bandini Blvd.
Los Angeles, CA 90040

*44. Flakt Inc. Products Division
Bahnson, Ind. Air Quality Div.
Envirotech
200 Lowery Street
Winston-Salem, NC 27101

45. Bete Fog Nozzle, Inc.
324 Wells Street
P.O. Box 311
Greenfield, MA 01302

46. Binks Mfg. Co.
9201 W. Belmont Avenue
Franklin Park, IL 60131

*47. Brod & McClung-Pace Co.
9800 S.E. McBrod Avenue
Portland, OR 97222

48. Bryant, Day & Night, Payne/BDP Co.
7310 W. Morris Street
Indianapolis, IN 46231

49. Buffalo Force Co.
465 Broadway
Buffalo, NY 14240

50. Cranes Co. Div. of Wehr Corp.
10201 W. Lincoln Avenue
Milwaukee, WI 53227

51. Century by Heat Controller, Inc.
1900 Wellworth at Losey
Jackson, MI 49203

52. Clark-Reliance Corp.
15900 Industrial Pky.
Cleveland, OH 44135

53. Clermont Engineering Co.
1304 N. Ninth Street
Philadelphia, PA 19122

54. Contempo Engineering Co.
555 Riverdale Drive
Glendale, CA 91204

55. Day & Night/Bryant/Payne Brands/BDP
7310 W. Morris Street
Indianapolis, IN 46231

56. Dornback Industries Div. Dornback Furnace & Foundry Co.
33220 Lakeland Blvd.
Eastlake, OH 44094

57. Dri-Steem Humidifier Co.
P.O. Box 621
Hopkins, MN 55343

58. Electrodome Ltd.
809 Wellington Street
N. Kitchener, Ontario, Canada
N2G4J6

59. Emerson-Chromalox Div. Emerson Electric Co.
8000 W. Florissant Avenue
St. Louis, MO 63136

60. General Filters, Inc.
43802 Grand River Avenue
Novi, MI 48050

*61. Herrmidifier Co., Inc.
1770 Hempstead Road
Lancaster, PA 17601

62. Humid-Aire Corp.
156-A N. Jefferson
Chicago, IL 60606

*63. Johnson Controls, Inc.
1250 E. Diehl Road
Naperville, IL 60540

64. Lau Industries, Div. of Phillips Industries, Inc.
4801 Springfield Street
Dayton, OH 45401

65. Leigh Products, A Div. of Leigh Products, Inc.
411 64th Avenue
Coopersville, MI 49404

*66. Lennox Industries, Inc.
400 Norris Glen Road
Etobicoke, Ontario, Canada
M9C1HS

67. Liebert Corporation
1050 Dearborn Drive
Columbus, OH 43229

68. Lobb Humidifier Co.
3080 Oakley Park Road
Walled Lake, MI 48088

69. Maid-O-Mist
3217 N. Pulaski Road
Chicago, IL 60641

70. Mountain States Equipment Co.
1975A S. Navajo Street
Denver, CO 80223

71. Nu-Air Humidifier Corp.
405 S. Center Street
P.O. Box 1145
Bloomington, IL 61701

72. Paashe Airbrush Co.
7440 W. Lawrence Ave.,
Dept 99B
Harwood Heights, IL 60656

73. Parks-Cramer Co.
P.O. Box 2200
Fitchburg, MA 01420

74. Permatron Corp.
10134 Pacific Avenue, Dept. T
Franklin Park, IL 60131

75. Pneumafil Corp.
4500 Chesapeake Drive
Box 16348
Charlotte, NC 28216

*76. Research Products Corp.
1017 E. Washington Avenue
Madison, WI 53701

77. Sarco Co., Inc.
Spirax Sarco
P.O. Box 119, 1951 26th St., S.W.
Allentown, PA 18105

78. Skuttle Mfg. Co.
Route 1
Marietta, OH 45750

79. Sonic Development Corp.
305 Island Road
Mahwah, NJ 07430

80. Southwark Metal Mfg.
S.W. Cor. 16th & Washington Ave.
Philadelphia, PA 19146

81. Spra-Kleen Co.
Lou Dinsmore
1242 Easy Street
Woodbridge, VA 22191

*82. Spray Engineering Co./Spraco, Inc.
P.O. Box 3800
2 Spit Brook Road
Nashua, NH 03061

83. Spraying Systems Co.
North Avenue
Wheaton, IL 60188

84. Standard Engineering Works
289 Roosevelt Avenue
Pawtucket, RI 02860

*85. Steinen Mfg. Co.
29 E. Halsey Road
Parsippany, NJ 07054

*86. Tempmaster Corp.
1222 Ozark Street
North Kansas City, MO 64116

*87. Atkins Technical, Inc.
3333 S.W. 40th Blvd.
Gainesville, FL 32608

88. Barber-Colman Co./Environmental Control Div.
1354 Clifford Avenue
P.O. Box 2940
Loves Park, IL 61132

*89. EG&G Environmental Equip. Div.
151 T. Bear Hill Road
Waltham, MA 02154

90. Hydro-Temp Controls, Inc.
Fort Washington, PA 19034

91. Hygrometrix, Inc.
7800 MacArthur Blvd.
Oakland, CA 94605

92. ITT General Controls
801 Allen Avenue
Glendale, CA 91201

93. Johnson Controls, Inc.
5757 N. Green Bay Ave.
P.O. Box 591
Milwaukee, WI 53201

94. Penn Division, Johnson Controls, Inc.
P.O. Box 11248
5740 Gen. Wash. Drive
Alexandria, VA 22312

95. Trane Co.
6200 Troop Hwy.
Tyler, TX 75701

*96. Twinoak Products, Inc.
Debbie Mareuki
12127 B Galena Road
Plano, IL 60545

*97. Walton Laboratories, Inc.
1 Carol Place
Moonachie, NJ 07074

98. Water Cooling Corp.
P.O. Box 56
Rosedale, NY 11422

99. American Instrument Co.
Div. of Travenol Laboratories, Inc.
Washington Blvd.
Savage, MD 20863

100. Phys-Chemical Research Corp.
36-A W. 20th Street
New York, NY 10011

101. Ranco Controls Division
8115 U.S. Route 42 N.
Plain City, OH 43064

*102. Robertshaw Controls Co.
P.O. Box 26544
Richmond, VA 23261

*103. Shafer, Troxell & Howe, Inc.
203 Brookes Avenue
P.O. Box 118
Gaithersburg, MD 20877

*104. Mitsubishi International Corp.
520 Madison Avenue
New York, NY 10022

*105. Honeywell, Inc.
1885 Douglas Drive North
Minneapolis, MN 55422

*106. Rotromic Instrument Corp.
7 High Street, Suite 207
Huntington, NY 11743

*107. Dument Refrigeration Corp.
P.O Box 148
Monmouth, ME 04259

APPENDIX B

SURVEY LETTER

1234K

August 15, 1986
0500.0024

Attention: Sales Manager

Subject: Humidifiers, Dehumidifiers and Humidity Controls

Dear Sir/Madam:

VSE is performing a market survey to evaluate the performance of commercially available humidifiers, dehumidifiers and humidity controls under contract to the U.S. Army Belvoir Research, Development and Engineering Center. This equipment is expected to be used in a U.S. Air Force Aircraft Service Van. It has been brought to our attention that the capabilities sought might exist in your line of humidity controlling equipment.

We are requesting catalogs and/or specification sheets describing your equipment's physical form, performance capabilities, power requirements, etc., especially that which meets the flowing criteria: 1) Humidify up to 28 gals/day; 2) Dehumidify up to 24 gals/day. Also important is information on cost and delivery time ARO.

The information you provide will be used to facilitate our evaluation of the Air Force's need for this equipment and the suitability of your systems to satisfy those needs. This request is for information only. Your response shall not constitute any contractual arrangement with VSE Corporation and it is to be done completely without cost to VSE.

Please direct replies and information packages as well as questions you might have to Harry L. Johnson at the above address within two (2) weeks.

Your help and cooperation is greatly appreciated.

Very truly yours,

VSE CORPORATION

H. L. Johnson, Resources Coordinator
Army Systems Group

R. R. Caldwell, Manager
Army Systems Group

HLJ/RRC:lam

APPENDIX C

SUMMARY OF MARKET SURVEY FOR HUMIDIFIERS

SUMMARY OF MARKET STUDY FOR HUMIDIFIERS

Manufacturer	Model No.	Basic Design	Capacity	Dimensions (Approximate)	Remarks
Abbeon Cal Inc.	A 500U	Atomization (Mist)	2 lb/hr	12" Height 12" Diameter	Rejected due to low capacity.
	910	Wetted element	30 lb/hr @75°F, 30% RH	36" x 25" x 21"	Rejected due to input voltage requirement of 208 VAC and internal 10 kw heater
Airflow Co. (Dryomatic)	SCF	Steam Generation	18 lb/hr	6" X 23" X 23"	Rejected due to input voltage requirement of 208 VAC.
American Metal Products Co. (Autoflo)	244D	Wetted Element (Duct Mounted)	Up to 9.7 lb/hr		Rejected because unit is designed for installation in the hot air duct of a home furnace.
	L-1011-k	Steam Generation	4.6 lb/hr	13" X 12" X 16"	Dimensions include optional blower. Two units would be required for the application.
	X-15B	Steam Generation	6.6 lb/hr	13" X 12" X 8"	Rejected due to input voltage requirement of 220 VAC.

SUMMARY OF MARKET STUDY FOR HUMIDIFIERS (Cont'd)

Manufacturer	Model No.	Basic Design	Capacity	Dimensions (Approximate)	Remarks
	550-1	Steam Generation	4.6 lb/hr		Rejected because unit is designed for installation in a duct.
	300B	Atomization (Spray)	4.2 lb/hr		Rejected because unit is designed for installation in a hot air duct.
Armstrong	EHU-600	Steam Generation	4.5 lb/hr	18" X 23" X 12" optional blower 17" x 13" x 13"	Rejected due to low capacity and large size.
EKW Appliances Inc.	EHR Series	Wetted Element	Manufacturer claims unit humidifies up to 3500 ft^2 based on a tight house	28" X 15" X 25"	Rejected due to low capacity design.
Flakt (Bahnson)	EIA	Atomization (Rotating Disc)	12.5 lb/hr	14" Height 18" Diameter	Discharge of 360° can be shielded as required.
Herrmidifier	Herricane CS-1	Steam Separator	3-800 lb/hr @ 2-60 psig Steam		Rejected due to requirement for a steam supply.

SUMMARY OF MARKET STUDY FOR HUMIDIFIERS (Cont'd)

Manufacturer	Model No.	Basic Design	Capacity	Dimensions (Approximate)	Remarks
	Herr-itronic	Steam Generation	0 to 50 lb/hr adjustable	25" X 43" X 15"	Rejected due to inlet water pressure required and minimum input voltage requirement of 208 VAC.
	300	Steam Generation	0 to 30 lb/hr adjustable	20" X 40" X 16"	Rejected due to inlet water pressure required and minimum input voltage requirement of 208 VAC.
Lennox	WSI-18 Humidi-spray	Atomization	6.2 lb/hr		Rejected unit Designed for installation in a hot air duct of a home furnace.
	WDI-15 Humidi-wheel	Wetted Element	6.2 lb/hr		Rejected unit Designed for installation in a hot air duct of a home furnace.

SUMMARY OF MARKET STUDY FOR HUMIDIFIERS (Cont'd)

Manufacturer	Model No.	Basic Design	Capacity	Dimensions (Approximate)	Remarks
Research Products Corp. (Aprilaire)	1120	Wetted Element	22 lb/hr	26" X 26" X 16"	Rejected due to requirement of 25 gph supply water @ 140°F.
Shafer Troxell & Howe Inc. Dri Steam Humidifier Co.	VM2	Steam Generation	6 lb/hr	21" X 24" X 16" Optional Blower Assembly 12" X 24" X 16"	3 probe conductivity sensor requires water w/ 2gr/gal. Drain line required for automatic flush cycle, 1/2 gallon required. Operating weight of 118 lb w/blower assembly. Dispersion tube option.
Spraco	66-1000-6056	Atomization (Ultrasonic)	4.2 lb/hr	Nozzle 4" Height 1-1/2" Diameter Oscillator 7" X 4" X 2"	Rejected due to low capacity.
	66-1000-6262	Atomization (Ultrasonic)	Up to 108 lb/hr	Nozzle 6" Height 2-1/2" Diameter Oscillator 9-1/2" X 8" X 8"	Rejected due to cost - Oscillator $1,700, Nozzle $1,100. Both are required for operation.

SUMMARY OF MARKET STUDY FOR HUMIDIFIERS (Cont'd)

Manufacturer	Model No.	Basic Design	Capacity	Dimensions (Approximate)	Remarks
The Field Controls Co.	Thermo-mist 80	Atomization	6.2 lb/hr	Small	Rejected because unit is designed for installation in a hot air duct of a home furnace.
Walton	SF-10	Atomization (Mist) Rotating Disc	10 lb/hr	13-1/2" Height 17-3/4" Diameter	Rejected due to minimum inlet water pressure of 10 psig.
	WJ-228	Atomization (Mist)	12 lb/hr	20" X 17" X 18"	Rejected because unit is duct mounted which may allow moisture accumulation due to high capacity.
	G0050BS	Steam Generation	17 lb/hr	8" X 28" X 19"	Rejected due to input voltage requirement of 208 VAC.

APPENDIX D

SUMMARY OF MARKET SURVEY FOR DEHUMIDIFIERS

SUMMARY OF MARKET STUDY FOR DEHUMIDIFIERS

Manufacturer	Model No.	Basic Design	Capacity	Dimensions (Approximate)	Remarks
Addison Products Co.	DHF41	Refrigeration System	1.8 lb/hr @ 80°F 60% RH	23" X 13" X18"	All Dehumidifiers are rejected due to excessive equipment size required for necessary capacity. Existing heat-pump w/booster heater capability will allow its use as a dehumidifier even in lower ambients.
Airflow Co. (Dryomatic)	DEH-34-250	Refrigeration System	2.2 lb/hr @ 80°F 60% RH	29" X 18" X 13"	
Cargocaire	M-85-L	Rotating Desiccant Wheel	.9 lb/hr @ 80°F 60% RH	17" X 16" X 24"	
	MD-08	Rotating Desiccant Wheel	3.6 lb/hr @ 80°F 60% RH	30" X 17" X 34"	
	GC-150	Rotating Desiccant Wheel	2-4 lb/hr	24" X 22" X 39"	
EKW Appliances Inc.	EDQ 36	Refrigeration System	1.6 lb/hr @ 80°F	21" X 14" X 16"	
General Cable Co. (Apparatus)	HF Series	Multiple bed solid absorption			

SUMMARY OF MARKET STUDY FOR DEHUMIDIFIERS (Cont'd)

Manufacturer	Model No.	Basic Design	Capacity	Dimensions (Approximate)	Remarks
Kelvinator International Co.	KD-3800	Refrigeration System	1.6 lb/hr @ 80°F 60% RH		
Tate Andale Inc.	HP Series	Multiple bed desiccant		41" X 19" X 76" Smallest	
Universal Dynamics Corp.	A220	Multiple bed solid absorption	32 lb/hr @ 80°F 75% RH	101" X 82" X 40"	

APPENDIX E

SUMMARY OF MARKET SURVEY FOR HUMIDITY CONTROLS

SUMMARY OF MARKET SURVEY FOR HUMIDITY CONTROLS

Manufacturer	Model No.	Sensing Element	Switch Action	Diff. % RH Approx.	Dimensions Approximate	Remarks
Abbeon Cal Inc.	4720 or 4721	Duro-therm (TM)	1 Switch	3		Will control a single piece of equipment. Line power is connected to hygrostat.
	4723	Duro-therm (TM)	2 Switch	3		Rejected because unit equipped w/extended sensor for insertion in mediums other than air.
	4703-602	Duro-therm (TM)	2 separate set points	3	6" Diameter	Maximum 24v input.
American Metal Products Autoflo	052000	Nylon				Rejected because unit designed to control a humidifier only and relatively narrow range of operation 10-60% RH.

SUMMARY OF MARKET SURVEY FOR HUMIDITY CONTROLS (Cont'd)

Manufacturer	Model No.	Sensing Element	Switch Action	Diff. % RH Approx.	Dimensions Approximate	Remarks
EG & G Environmental Equipment	200	Electro-optic				Rejected because this is a humidity transmitter which must be used in conjunction with microprocessor for control purposes. Transmitter alone costs $1,300.
Flakt (Bahnson)	MBE-1	Hygro-scopic paper	SPDT	2-3	2-5/8" X 2-7/8" X 10-3/4"	Rejected due to cost. Unit price is $270, two would be required.
Honeywell	H600A	Nylon	SPDT	5% nominal	5-3/4" X 3-3/8" X 2-3/16"	Accepts low or line voltage. Minimum operating temperature of 60°F.
	H46C-F	Nylon	SPST	5%	4-3/4" X 3" X 1-3/8"	Unit is supplied with the Airflow Co. model DEH-34-250 dehumidifier, which is designed for military applications.

SUMMARY OF MARKET SURVEY FOR HUMIDITY CONTROLS (Cont'd)

Manufacturer	Model No.	Sensing Element	Switch Action	Diff. % RH Approx.	Dimensions Approximate	Remarks
Barber Colman Co.	HC101	Nylon	SPDT	5%	4-1/2 X 3" X 1-1/2"	Unit is being used to control humidity equipment manufactured by Keco Industries for military application. Unit is depicted on a US Army drawing.
Johnson Controls	W42 AA-1	Human Hair	SPDT	4	2" X 4"	Rejected due to element material. Human hair elements are considered very accurate but become brittle with age.
	W50 DG-1	Solid state electrical resistance		4 to 20	4-1/2" X 5" X 1-7/8"	Rejected due to cost, unit capable of controlling humidifier and dehumidifier within specified band. Must control humidification equipment through 24 VAC contactors.
Mitsubishi Int'l Corp.	HS-5 or HS-6	Solid state electrical resistance				Rejected because these are absolute humidity sensors which must be used with microprocessor.

APPENDIX F

DETERMINATION OF REQUIRED HUMIDIFICATION AND DEHUMIDIFICATION CAPACITIES

To determine the actual humidification and dehumidification capacities required, the following assumptions were initially made to obtain the flow rate of outside air being continuously supplied to service shelter.

- Three persons would occupy the service shelter.
- Induced fresh air flow rate required by paragraph 5.8.1.2 of MIL-STD-1472C is 60 CFM (20 CFM per person).
- To account for moisture from the three occupants and unknown factors introduced by the plastic strip door at the service shelter entrance, a safety factor of 2 was used.

As a result, a fresh air flow rate of 120 CFM (60 CFM X 2) was used in all calculations. Calculation results showed that the service shelter required a maximum humidification capacity of 5.33 lb water/hr and a maximum dehumidification capacity of 5.43 lb water/hr.

1. HUMIDIFICATION MAXIMUM CAPACITY DETERMINATION

The humidification capacity was first determined by using the following equation to calculate the capacity required at the extreme high and low temperature conditions. Then to the highest capacity required at these temperature extremes, the capacity required for 4-hour "pull down" was added to determine maximum humidification capacity needed.

Equation: $$M = \frac{Q_1 (W_2 - W_1)}{V}$$

Where:

M = mass flow rate, lb water/hr.

Q_1 = flow rate of outside air, cu. ft./min.

V = specific volume of air, cu. ft./lb dry air.

W_1 = humidity ratio of inside air lb water/lb dry air.

W_2 = humidity ratio of outside air, lb water/lb dry air.

To obtain the capacity required for the worst high temperature condition, the following parameter values were used. V, W_1 and W_2 values were obtained from ASHRAE Psychometric Chart No. 1 for the assumed conditions of outside and inside air. Q_1 of outside air was assumed as discussed previously.

M_1 = mass flow rate at worst high temperature condition.

Q_1 = 120 cu. ft./min.

V = 14.7 cu. ft./lb dry air for outside air at 120°F and 3% RH.

W_1 = .0124 lb water/lb dry air for inside air at 85°F and 48% RH.

W_2 = .0020 lb water/lb dry air for outside air at 120°F and 3% RH.

Therefore, $M_1 = \frac{120\,(.0124 - .0020)}{14.7}$

= .085 lb water/min.

= 5.1 lb water/hr.

To obtain the capacity required for the worst low temperature condition, the following parameter values were used. V, W_1, and W_2 values were obtained from ASHRAE Psychometric Chart No. 1. Q_1 remained the same.

M_2 = mass flow rate at worst low temperature condition.

Q_1 = 120 cu. ft./min.

V = 11.0 cu. ft./lb dry air for outside air at -25°F and 0% RH.

W_1 = .0076 lb water/lb dry air for inside air at 70°F and 48% RH.

W_2 = 0 lb water/lb dry air for outside air at -25°F and 0% RH.

Therefore, $M_2 = \frac{120\,(.0076 - 0)}{11.0}$

= .083 lb water/min.

= 5.0 lb water/hr.

However, since the humidifier must possess a "pull down" capability so that the entire service shelter space (1,280 cu. ft.) is conditioned within 4 hours, this additional capacity, as calculated below, was added to the worst high temperatur condition. The following new parameter values were used.

M_3 = mass flow rate for 4 hour "pull down" flow rate

$$Q_2 = \frac{1{,}280 \text{ cu. ft.}}{4 \text{ hr}} = 320 \text{ cu. ft./hr}$$

$$\text{Therefore, } M_3 = \frac{320\,(.0124 - .0020)}{14.7}$$

$$= .23 \text{ lb water/hr}$$

And the total maximum capacity at the worst high temperature condition neede is:

$$M_4 = M_1 + M_3$$

$$= 5.1 + .23$$

$$= 5.33 \text{ lb water/hr.}$$

2. DEHUMIDIFICATION MAXIMUM CAPACITY DETERMINATION

The dehumidification capacity was determined by using the assume infiltration rate shown in the first paragraph of this appendix to calculate th capacity required at extreme high humidity, high temperature condition and a high humidity, moderate temperature condition. The capacity at the moderat temperature condition was determined to be the most critical, or worst cas dehumidification condition since the heat pump does not cool, and thu dehumidify, at moderate temperatures. To those capacities, the additional capaci required for 4-hour "pull down" was added to determine maximu dehumidification capacity needed.

To obtain the capacity required for the high temperature condition (durin which time the heat pump will normally be operating), the following paramet values were used. V, W_1, and W_2 were obtained from ASHRAE Psychrometric Cha No. 1. Q was the same as used previously. The assumed inside air condition is 80

51% RH as opposed to the 85F, 48% RH design point used to evaluate humidification requirements. This was done to allow direct comparison with capacity data available for the heat pump.

M_5 = mass flow rate at high temperature condition

Q_1 = 120 cu. ft./min

V = 14.9 cu. ft./lb dry air assuming outside air is at 105°F anc 59% RH

W_1 = .0112 lb water/lb dry air assuming inside air is at 80°F 51% RH

W_2 = .0290 lb water/lb dry air assuming outside air is at 105° 59% RH

$$\text{Therefore, } M_5 = \frac{Q_1 (W_2 - W_1)}{V}$$

$$= \frac{120\,(.0290 - .0112)}{14.9}$$

$$= .143 \text{ lb water/min}$$

$$= 8.6 \text{ lb water/hr.}$$

However, since the dehumidifier must possess a "pull down" capability so t the entire service shelter space (1,280 cu.ft.) is conditioned within four hours, additional capacity, as calculated below, was added. The following new parame were used. W_1 and W_2 remain the same.

M_6 = mass flow for four hour "pull down"

Q_2 = $\frac{1280 \text{ cu. ft.}}{4 \text{ hr}}$ = 320 cu. ft./hr "pull down" flow rate

$$\text{Therefore, } M_6 = \frac{320\,(.0290 - .0112)}{14.9}$$

$= .4$ lb water/hr.

and the total maximum dehumidification capacity needed is:

$$M_7 = M_5 + M_6$$

$$= 8.6 + .4$$

$$= 9.0 \text{ lb water/hr}$$

A determination must be made of the dehumidifying capability of the existing heat pump. Fort Belvoir has capacity test data performed on an ECU Inc. heat pump from which the following information was extracted:

Capacity test conditions:

- 105°F outdoor temperature
- 80°F indoor temperature, 51% RH
- .25 in. W. G. indoor static pressure

Achieved latent cooling capacity:

9,350 BTU/hr

Enthalpy of saturated liquid and saturated vapor/@80°F:

1048.3 BTU/lb water

Heat pump dehumidification capability

$$\frac{9{,}350}{1{,}048.3} = 8.9 \text{ lb water/hr}$$

At extreme high humidity and high temperature condition the dehumidification capability of the heat pump and the system requirement are within 1.5%.

To obtain the capacity required for the moderate temperature condition the following parameter values were used. V, W_1, W_2 were obtained from ASHRAE Psychometric Chart No. 1. Q_1 was the same as used previously.

M_8 = mass flow rate at moderate temperature condition.

Q_1 = 120 cu. ft./min.

V	=	13.8 cu. ft./lb dry air assuming outside air is at 75°F and 100% RH.
W_1	=	.0088 lb water/lb dry air assuming inside air is at 75°F and 48% RH.
W_2	=	.0188 lb water/lb dry air assuming outside air is at 75°F and 100% RH.

$$\text{Therefore, } M_8 = \frac{Q_1 (W_2 - W_1)}{V}$$

$$= \frac{120\,(.0188 - .0088)}{13.8}$$

$$= 5.2 \text{ lb water/hr.}$$

However since the dehumidifier has to possess a "pull down" capability so that the entire service shelter space (1,280 cu. ft.) is conditioned within 4 hours, this additional capacity, as calculated below, was added. The following new parameters were used. W_1, and W_2 values remained the same.

M_9	=	mass flow for 4-hour "pull down".
Q_2	=	$\frac{1{,}280 \text{ cu. ft.}}{4 \text{ hr.}} = 320$ cu. ft./hr "pull down" flow rate.

$$\text{Therefore, } M_9 = \frac{320\,(.0188 - .0088)}{13.8}$$

$$= .23 \text{ lb water/hr}$$

And the total maximum dehumidification capacity needed is:

$$M_{10} = M_8 + M_9$$

$$= 5.2 + .23$$

$$= 5.43 \text{ lb water/hr}$$

APPENDIX B

TEST PLAN FOR HUMIDIFICATION, DEHUMIDIFICATION AND

HUMIDITY CONTROL EQUIPMENT

TEST PLAN
FOR
HUMIDIFICATION, DEHUMIDIFICATION
AND HUMIDITY CONTROL
EQUIPMENT

9 January 1987

Contract No. DAAK70-86-D-0023
Task Order 0024

TEST PLAN

FOR

HUMIDIFICATION, DEHUMIDIFICATION

AND HUMIDITY CONTROL

EQUIPMENT

Contract No. DAAK70-86-D-0023
Task Order 0024

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TEST PLAN
FOR
HUMIDIFICATION, DEHUMIDIFICATION
AND HUMIDITY CONTROL
EQUIPMENT

Prepared For:

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1.0 PURPOSE

The purpose of this test program is to ascertain performance data with which to evaluate the operational feasibility of selected humidification, dehumidification and humidity control equipment. Testing will be conducted on three humidifiers, one dehumidifier (modified heat pump) and four humidity controls.

2.0 APPLICABLE DOCUMENTS

Statement of work and services dated 14 July 1986. Task Order 0024 - Contract No. DAAK70-86-D-0023.

MIL-STD-45662; Calibration System Requirements.

MIL-STD-461; Electromagnetic Emission and Susceptibility Requirements for the control of Electromagnetic Interference.

MIL-STD-462; Electromagnetic Interference Characteristics, Measurement of.

MIL-STD-810; Environmental Test Methods and Engineering Guidelines

MIL-STD-1472; Human Engineering Design Criteria for Military Systems, Equipment and Facilities.

MIL-STD-1474; Noise Limits for Army Materiel.

AR 70-38; Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.

3.0 ITEM DESCRIPTION

3.1 Humidification Equipment

3.1.1 Steam Generators

Two steam generators will be tested. These units consist of water pans or reservoirs which are heated with electrical resistance heaters. Units will be connected to a ten gallon water tank so as to allow gravity flow of supply water. Water level in the pans is maintained by a float valve or electrical sensor with a solenoid valve. Units contain internal blowers which distribute the vaporized moisture into the conditioned space.

The DRI STEEM model VM2 is approximately 34" high X 24" wide X 16" deep, with a 6 lb/hr capacity, weighs 118 lb operating and requires input power of 2kW. Unit possesses a teflon coated steel vaporizing chamber with incoloy sheathed immersion heaters. Water level is sensed by a three-pronged electrical probe which makes or breaks electrical circuits through the water. A solenoid valve is actuated appropriately. A minimum water hardness is required for sensor operation. An internal timer initiates a periodic chamber flush cycle to reduce rate of mineral build-up. Generated steam rises from the vapor chamber, through a vapor hose to a dispersion tube. The dispersion tube is mounted down stream of a centrifugal blower. Forced air passing over the dispersion tube distributes vapor into the conditioned space.

The alternate steam generator to be tested is the AUTOFLO model L-1011-K. This unit has a capacity of 4.5 lb/hr, necessitating two units for final application. A single unit is approximately 16" high X 13" wide X 12" deep, weighs 30 lb. operating and draws 1.4kw. Unit possess a steel vaporizing pan with a single incoloy immersion heater. Pan water level is maintained by a steel and bronze float valve. Rising vapor is distributed in the conditioned space by an axial fan.

3.1.2 Atomizers

A single atomizer will be tested. The BAHNSON type EIA atomizes water by means of centrifugal force. Water at a specific flow rate is provided to the center of a rotating disc. The water then flows out by centrifugal force to the edge of the disc. Water leaves the disc and contacts a grille which breaks the water into small droplets. Unit contains an internal blower which distributes the mist into the conditioned space. The type EIA is 14" high and 18" in diameter, with a 12 lb./hr.

capacity, weighs 40 lb operating and draws approximately 230 watts. Moisture is normally discharged 360° but can be shielded to desired spread.

3.2 Dehumidification Equipment

The only dehumidifier to be tested consists of the existing shelter heat pump with auxiliary booster heaters. The heat pump is intended for heating and cooling the conditioned space. The heat pump control circuitry must be modified to allow use as a dehumidifier. A humidistat is wired-in so that dehumidification can be accomplished in the temperature range requiring neither cooling nor heating.

3.3 Humidity Controls

Four humidity controls will be tested. The four controls are Honeywel model H46C and model H600A, Barber-Colman model HC101 and Abbeon Ca model 4703-602. Each control contains a nylon element which senses relative humidity. Nylon is a hygroscopic material which expands or contracts depending upon moisture content. The expansion and contraction mechanically actuates an electrical switch depending upon the unit set point.

4.0 TEST LOCATION

All testing delineated in this test plan will be performed, in part, at one of the following facilities:

- VSE Corporation
  2550 Huntington Avenue
  Alexandria, VA
- National Technical Systems (NTS)
  Route 748
  Hartwood, VA
- E-Systems, Melpar Division
  7700 Arlington Boulevard
  Falls Church, VA

5.0 TEST EQUIPMENT

5.1 VSE Facilities and Hardware

Extreme temperature tests shall be performed in a chamber manufactured by Thermotron. Chamber volume is 38" X 38" X 38" with a temperature range of +265° F to -90°F.

Gravity feed water supply apparatus will consist of a 10 gallon plastic laboratory tank. Water supply is required for humidifier capacity test and other testing requiring humidifier operation verification. The tank will be supported by a wooden structure, elevated sufficiently to allow gravity flow to humidifiers. Tygon tubing with clamps will be used to connect supply water to humidifier.

Equipment fixtures required for vibration testing shall consist of aluminum brackets, braces, metal bands, etc. which will simulate the anticipated mounting within a military van.

Sound testing will be accomplished in a local field or open area which approaches a free field environment.

5.1.1 VSE Instrumentation

All instrumentation used during testing will be maintained under the following calibration control. The equipment shall be cleaned, inspected, and calibrated to manufacturers specifications, National Technical Systems (NTS) calibration procedures, Melpar calibration procedures, or VSE standards as required. The definitions for measuring equipment, test equipment, and standards, as listed in MIL-STD-45662, apply to this procedure. All VSE reference measurement standards will be calibrated by commercial firms using standards traceable to the National Bureau of Standards. All VSE test equipment will be calibrated using VSE reference standards or calibrated by commercial firms using standards traceable to the National Bureau of Standards. Reference standards will be used by calibration personnel only. All standards tested by outside sources must be returned with the following information:

- Certificate of Calibration stating that the calibration standards used by the outside source are traceable to the National Bureau of Standards.
- Certification that the subcontractor's system is in conformance with MIL-STD-45662.
- Serial numbers of equipment used on calibration and the date of certification of the equipment.
- Data sheets or other records showing accuracy and environmental conditions of the instrument calibrated.

If equipment size and usage permits, calibration data, such as date of calibration, the initials of the calibrator, and the date of next calibration shall be indicated on a suitable tag or label attached to each piece of equipment. A Calibration Record Card (see Figure 1.), will be kept on each piece of test or inspection equipment and standard. The card will list the equipment description, serial number, calibration interval, general use, each calibration and recall date, and any repairs made or standards used. It will also be signed by the person performing the calibration or reference the calibration source, if performed outside VSE. Each card will be retained in the QC Department.

5.1.2 Temperature

Temperatures will be measured using copper-constantan thermocouples with an accuracy of ± 1°F. Dry bulb and wet bulb temperatures will be measured with a sling psychrometer with an accuracy of ± 1°F.

5.1.3 Water Weight

Water weight will be measured using an Accu-Weigh model 12ETDX/L weight scale having 125 lb. capacity and .05 lb. resolution.

Affix tab and mark block corresponding to Cal. Interval

30 DAYS	60 DAYS	90 DAYS	6 MOS	12 MOS

CALIBRATION RECORD

Calibration Interval: ______________________ VECO Serial No. Q.C. ________

Item Description: ______________________________________

Use: ______________________________________

Date Calibrated	Calibrated By	Remarks (repair)	Calibration Due Date

Q.C.-8 3/4/68

Figure 1. Calibration Record Card

5.1.4 Time

Time measurement will be made with a Seiko wrist watch.

5.1.5 Voltage AC

Voltage will be measured with a Weston volt meter.

5.1.6 Amperage

Amperage will be measured with a Weston ammeter.

5.1.7 Frequency

Frequency will be measured with Dynascan 1851 frequency meter.

5.1.8 Wattage

Wattage will be measured with a Weston watt meter.

5.1.9 Continuity

Circuit continuity will be determined with a Simpson 260 multimeter.

5.1.10 Sound Level

Sound levels will be measured with a GenRad sound level meter.

5.2 NTS Facilities

Variable power input testing will be accomplished by a 15kW motor driven alternator manufactured by Kato.

Vibration test will be performed with an MB Electronics C210, 28,000 force-pound vibration machine.

5.3 Melpar Facilities

Melpar shall make use of test equipment in accordance with MIL-STD-462 capable of measuring conducted and radiated EMI. A list of equipment and their accuracies will be provided by Melpar and included in the final test report.

6.0 TESTING

6.1 General

The following is a list of tests to be performed on the humidification equipment:

- Controls Performance
- Dehumidification Operation
- Capacity
- EMI
- Variable Voltage and Frequency
- High Temperature Storage
- Low Temperature Storage
- Vibration
- Sound Level
- Tilted Operation
- Human Factors Evaluation

Capacity testing for atomizer and steam generator humidifiers is not dependent on ambient air conditions. Regardless of temperatures or relative humidities within the conditioned space, these type humidifiers will discharge moisture at a given rate. Special attention will be given to atomizer capacity at 50 Hz input. Slower operation will reduce capacity and may affect droplet size.

Extreme temperature tests reflect the worst anticipated storage temperatures the equipment will encounter world-wide. High and low temperatures (+160°F and -60°F) and storage duration periods (4 hrs and 12 hrs respectively) reflect data compiled in AR 70-38.

Control tests will be performed on the humidity controls upon reception of equipment for baseline data. This test will verify controls set point and differential accuracies. Following completion of all other humidity control testing, a final controls test will be performed to determine what loss of accuracy, if any, has occurred.

Humidifiers shall be tested to ensure operation at variable voltage and frequency conditions. Military generators used to provide power may not be adjusted to correct voltage settings during initial start-up. It is assumed that the generator settings will be corrected with 15 minutes of start-up. It is assumed the system will be deployed in countries making use of 50 or 60 Hz frequencies. No variation from the specified frequencies will be tested.

The vibration test specified in this test plan is categorized as basic transportation. This test simulates equipment shipped as secured cargo by land, sea or air on common carriers. Test levels are established from land transport stress levels since these are higher than air and sea stresses. All air and sea transport scenarios include prior or subsequent land transportation.

Humidifiers will be tested for both conducted and radiated electro-magnetic interference (EMI) in the transient and steady state modes. EMI will be tested to the requirements of CEO3 and REO2 in accordance with MIL-STD-461B, part 4. The heat pump installed in the aircraft service shelter, has been tested to identical requirements. Humidity controls will be tested for transient radiated (REO2 requirements) emissions since only this scenario presents any potential problem.

Sound levels for humidification equipment are not anticipated to be significant. Humidifiers will be tested to ensure the expected low levels are achieved.

Humidifiers and humidity controls shall be examined and evaluated for human factors. Equipment should be compatible with requirements of MIL-STD-1472. Special design emphasis shall be given, but not limited to, paragraphs 4 (General Requirements), 5.5 (Labeling), 5.9 (Design for Maintainability), and 5.13 (Hazards and Safety), of MIL-STD-1472, as applicable.

A dehumidification operation test shall be performed to ensure that the circuit modifications made on the heat pump will allow operation as intended and that the primary heating and cooling modes are not affected. Dehumidification cannot be accomplished below 72°F. Below 72°F the heat pump is operating in the heat mode which does not provide for a cool indoor coil surface on which to condense moisture. It is anticipated that at indoor temperatures below 72°F, the outdoor temperature will be significantly lower to overcome heat gains from equipment and personnel within. Thus, heating the cool high humidity outside air will tend to provide air with decreased RH's in the indoor space. It is believed dehumidification will rarely be needed below 72°F. Should dehumidification be needed in this range, the heat pump must first satisfy the thermostat before dehumidification can take place. The conditioned space must be warmed to 72°F which will take the heat pump out of the heat mode. The evaporator coil can then be used for dehumidification (cooling) in conjunction with both booster heaters.

Humidifiers will be operated in tilted orientations to simulate possible military shelter location on other than level ground.

6.2 CONTROLS PERFORMANCE - VSE Performed

Purpose of Test: To determine if manufacturer's specified operation of humidity controls is achieved and to recalibrate controls if specified operation is not achieved. Control set points and % RH differentials will be evaluated. Two control tests will be performed. The first control test will be performed upon reception of the controls and the second test will be performed following the high and low temperature storage tests and the vibration test. Results of the initial controls test will provide baseline data with which to compare to results of the second controls test. Any degradition in performance will be recorded.

Application Requirement: Humidity controls shall possess an electrical switch which will close or open depending upon sensed relative humidity. Separate switches are required to actuate a humidifier and a dehumidifier. Humidifier humidity controls shall close their switch at the control RH set point and below. Dehumidifier humidity controls shall close their switch at the controls RH set point and above.

Test Equipment:

- Chamber lined with plastic to impede moisture loss. Chamber shall be provided with a view port and will allow access to equipment within without affecting internal conditions.
- Humidifier
- Continuity tester
- Wire extensions necessary to test controls outside chamber
- Psychrometer with blower
- Time clock

Test Procedure: Set the control knob for each of the four controls at 50% RH. Place humidity controls, humidifier and psychrometer/blower assembly in chamber (see Figure 2.). The chamber shall then be conditioned as closely as possible to 50% RH. Current ambient RH's are usually well below 50% so only humidification capability should be required in the chamber. Chamber RH will be verified with psychrometer/blower assembly (see Figure 3.). Blower will insure a necessary air velocity over thermometers. Humidity controls shall be soaked at 50% RH for 30 minutes. Determine accuracy of controls by rotating control knob from the 50% RH set point until each unit's internal switch opens or closes as required. (e.g.., a dehumidifier control whose switch has not yet closed at 50% RH shall have its control knob rotated above the 50% setting until the switch does close.) Switch actuation will be determined with a continuity tester. The difference between the knob setting at switch actuation and the chamber RH will be recorded. Should the difference between the knob setting at switch actuation and chamber RH exceed 1/2% RH the control will then be recalibrated. Recalibration involves rotating the control knob back to 50%. The housing of the control will then be removed to expose the calibration screw. The calibration screw will be adjusted until the control switch opens or closes as required at 50% RH.

Recorded Data:

- Record chamber db and wb temperatures every 10 minutes throughout test.
- Record the difference between the control knob setting at switch actuation and chamber RH prior to recalibration.
- Record recalibration condition, % RH.

SAMPLE DATA SHEET

CONTROLS PERFORMANCE TEST

Time (min)	db (°F)	wb (°F)	% RH	Remarks
0				
10				
20				
30				
40				
50				
60				

Humidity Control	Δ between chamber % RH and control set point at switch actuation (% RH)	Recalibration Required (Yes, No)	Recalibration Condition (% RH)
Honeywell H46C			
Honeywell H600A			
Barber-Coleman HC101			
Abbeon Cal 4703-602			

Figure 2. Controls Test Set Up

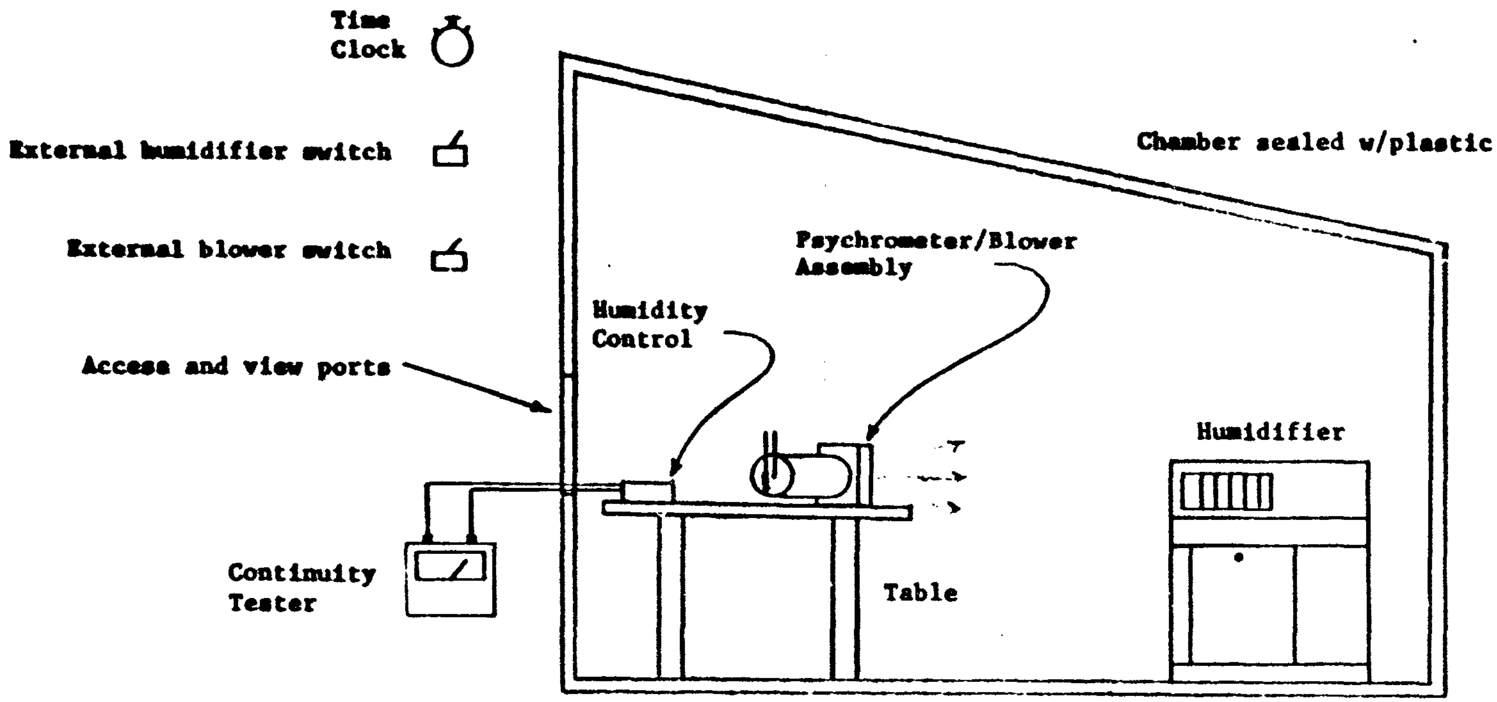
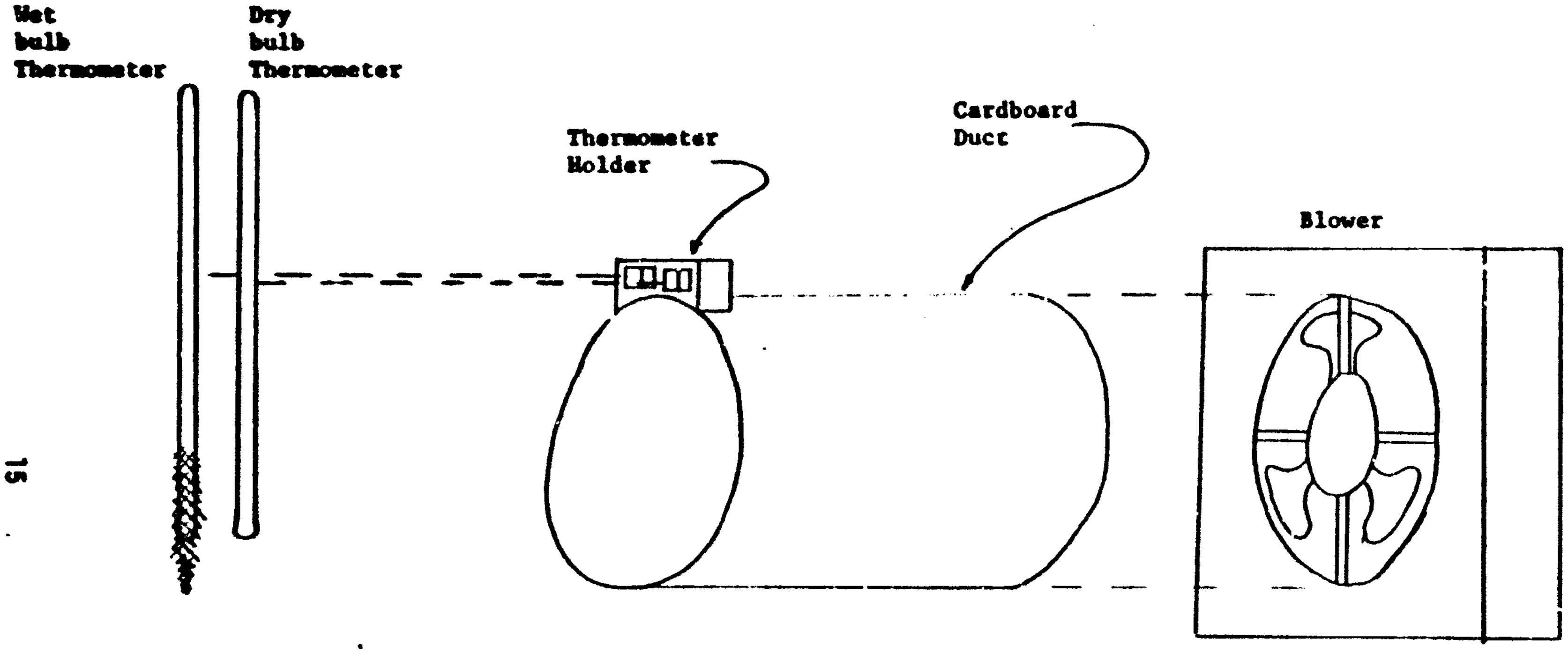


Figure 3. Psychrometer/Blower Assembly



6.3 DEHUMIDIFICATION OPERATIONS - VSE Performed

Purpose of Test: To ensure modifications to the control circuitry of heat pump will allow operation as a dehumidifier without unintended equipment consequences (see Figure 4.).

Background: The heat pump is equipped with three selector switches to control unit operation. The selector switches are listed below:

Switch	Positions
Unit	EMERGENCY HEAT/OFF/ON
Mode	COOL/AUTO/HEAT
Fan	AUTO/ON

A separate ON/OFF switch has been added to the heat pump control circuitry which simulates a humidistat for test purposes. The temperature set points provided with the heat pump thermostat are as follows:

- cooling called for @ 76°F and above
- First stage heating called for @ 72°F and below
- Second stage heating called for @ 68°F and below

Thermostat contacts can be selectively shorted to simulate ambient temperature conditions.

Application Requirement: The heat pump operating modes discussed below are based on unit switch in "ON" position, fan switch in "AUTO" position and the dehumidification simulator switch (DSS) in "ON" position. The modified heat pump will operate in the cool mode at ambient temperatures of 76°F and above, with the mode selector switch in the "COOL" or "AUTO" positions. The modified heat pump will operate in cool mode with both booster heaters energized between ambient temperatures of 72°F and 76°F. Mode selector switch may be in "COOL", "AUTO", or "HEAT" position. Modified heat pump will operate in heat mode at ambient temperatures of 72°F and below, with the mode selector switch in the "HEAT" or

"AUTO" positions. A single booster heater will energize at temperatures of 68°F and below.

Fan shall operate continuously with fan selector switch in "ON" position.

A single booster heater will operate with the unit selector switch in "EMERGENCY HEAT" position.

Test Equipment:

- Heat pump manufactured by ARE
- ON/OFF switch which simulates a humidistat w/necessary wiring
- Thermocouple
- Two thermocouple grids
- Volt meter
- Ammeter
- Frequency meter
- Watt meter

Test Procedure: With heat pump in an indoor ambient environment, jumper the heat pump thermostat contacts W1, W2 and Y1 (see Figure 5). This will simulate operation above 76°F. Turn unit selector switch to "ON" position and turn mode selector switch to "COOL" position. Fan selector switch shall be in "AUTO" position. Turn DSS to "ON" position. Allow a 3 minute stabilization period. Ensure heat pump is operating in cooling mode and that the booster heaters are not operating. Move mode sector switch to "AUTO" position. Again, ensure heat pump is operating in cooling mode and that the booster heaters are not operating following a 3 minute stabilization period. Remove jumper wire on thermostat Y1 contacts to simulate an ambient temperature between 72°F and 76°F. Allow a 10 minute stabilization period. Ensure that the heat pump is operating in the cooling mode with the booster heaters operating simultaneously. Turn DSS off, stabilize for 3 minutes and verify booster heater and compressor de-energize. Remove jumper wire on thermostat W1 contacts to simulate an ambient temperature between 72°F and 68°F. Stablize for 10 minutes. Ensure heat pump is operating in heat mode with booster heaters de-energized. Turn DSS on, stabilize for 3 minutes and ensure heat pump is operating in heat mode with booster heaters de-energized. Move mode selector switch to "HEAT" position and stabilize for 3 minutes. Again ensure heat pump is operating in heat mode with booster heaters de-energized. Remove jumper wire on W2 contacts to simulate an ambient temperature below 68°F. Stabilize for 10 minutes. Ensure a single booster heater has energized.

Recorded Data:

- Verification of intended operation

Record the following data at the start and finish of each stabilization period delineated in the test procedure:

- Ambient Temperature
- Heat pump intake and discharge temperatures
- Volts
- Amps
- Frequency
- Watts

SAMPLE DATA SHEET

DEHUMIDIFICATION OPERATION TEST

Time (min)	Heat Pump Intake Temp. (°F)	Heat Pump Discharge Temp. (°F)	Voltage (Volts)	Current (Amps)	Frequency (Hz)	Power (Watts)

SAMPLE DATA SHEET

DEHUMIDIFICATION OPERATION TEST (con't)

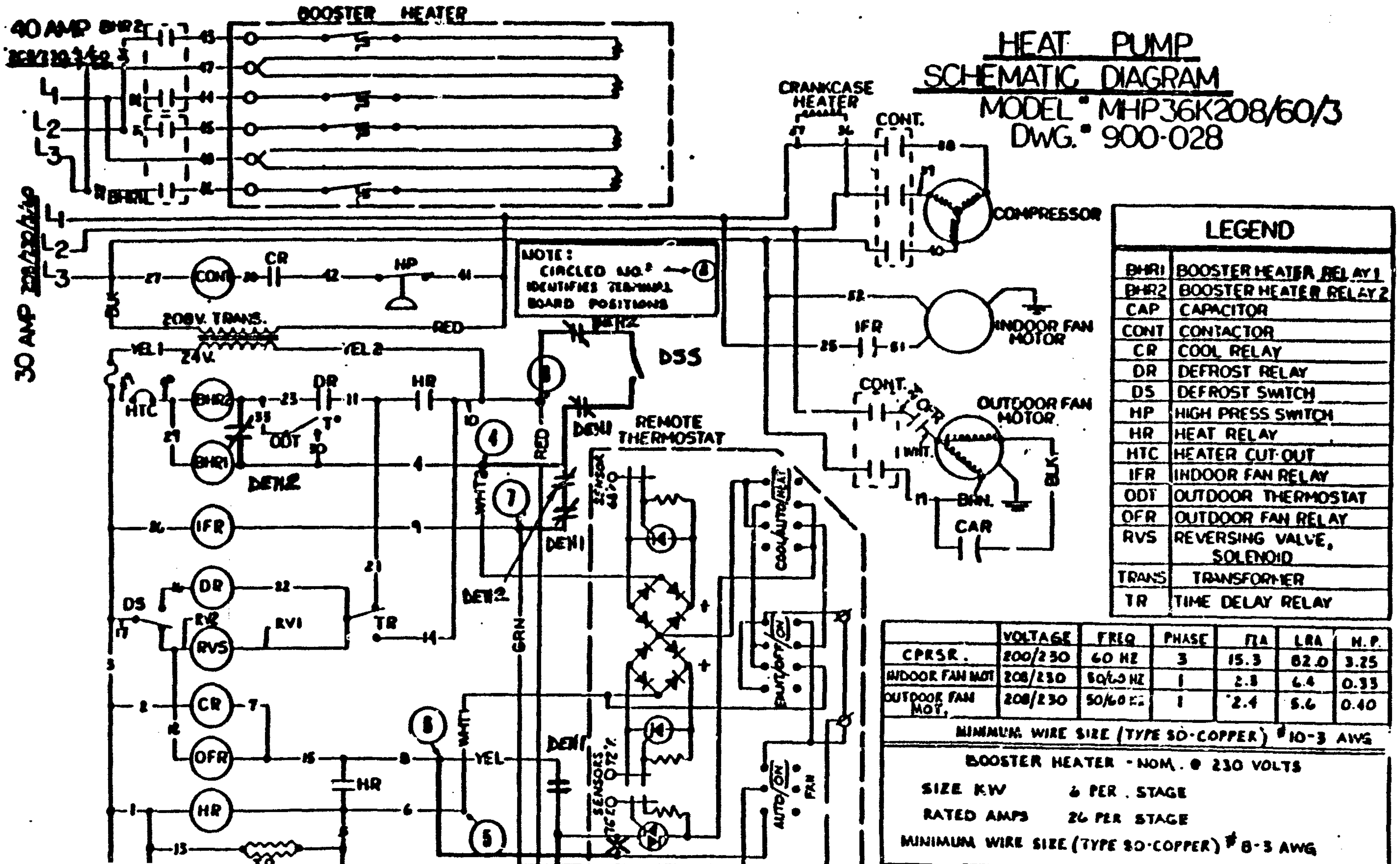
Time (min)	Switch Positions				Contacts Jumpered	Remarks-Verification of intended operation
	Unit	Mode	Fan	DSS		

Figure 4. Heat Pump Circuit Modifications

- Modifications are shown in bold lines and lettering

A.R.E. Manufacturing Co., Inc. Environmental Control Unit (ECU)
U.S. Navy Model A/32C-45

- Two additional relays are required.
  DEH1 2PNC, 1PNO
  DEH2 3PNC



LEGEND	
BHR1	BOOSTER HEATER RELAY 1
BHR2	BOOSTER HEATER RELAY 2
CAP	CAPACITOR
CONT	CONTACTOR
CR	COOL RELAY
DR	DEFROST RELAY
DS	DEFROST SWITCH
HP	HIGH PRESS SWITCH
HR	HEAT RELAY
HTC	HEATER CUT-OUT
IFR	INDOOR FAN RELAY
ODT	OUTDOOR THERMOSTAT
OFR	OUTDOOR FAN RELAY
RVS	REVERSING VALVE, SOLENOID
TRANS	TRANSFORMER
TR	TIME DELAY RELAY

	VOLTAGE	FREQ	PHASE	RLA	LRA	H.P.
CPRSR.	200/230	60 HZ	3	15.3	82.0	3.25
INDOOR FAN MOT	208/230	50/60 HZ	1	2.8	6.4	0.33
OUTDOOR FAN MOT.	208/230	50/60 HZ	1	2.4	5.6	0.40

MINIMUM WIRE SIZE (TYPE SO-COPPER) #10-3 AWG

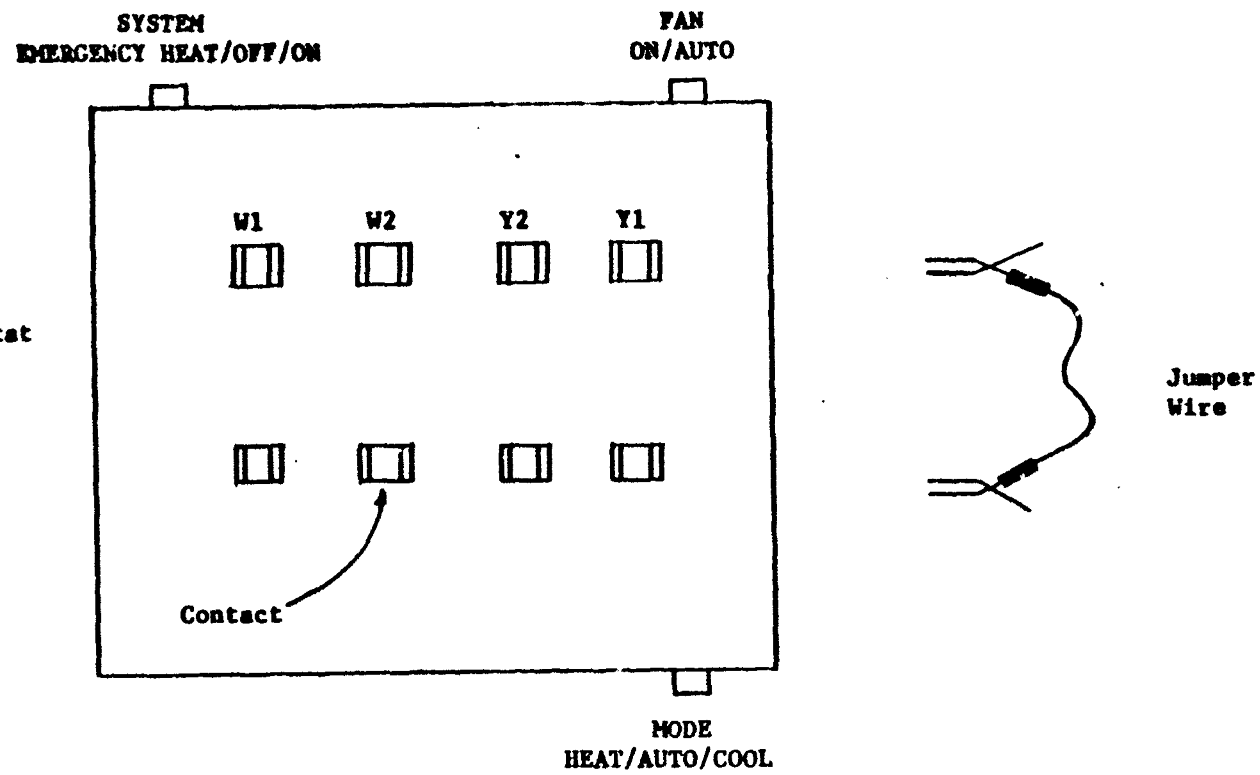
BOOSTER HEATER - NOM. @ 230 VOLTS

SIZE KW 6 PER STAGE

RATED AMPS 26 PER STAGE

MINIMUM WIRE SIZE (TYPE SO-COPPER) #8-3 AWG

Figure 5. Thermostat



6.4 CAPACITY - NTS Performed

Purpose of Test: To determine water discharge capacity of humidifiers and to determine if a single unit will satisfy application requirement.

Application Requirement: Humidifier shall have a minimum humidification capability of 5.3 lb/hr water. Unit shall be capable of specified performance at both 50 and 60 Hz operation.

Test Equipment:

- Generator Set
- Water reservoir (10 gal.)
- Weight scale
- Volt meter
- Ammeter
- Frequency meter
- Watt meter
- Sling psychrometer
- Time clock

Test Procedure: Place humidifier in an indoor ambient environment. Connect humidifier water inlet to water reservoir in such a way as to allow gravity feed of supply water. Operate humidifier a minimum of 15 minutes before starting test. Just prior to actual test period weigh water supply reservoir. Continue operation of humidifier undisturbed for one hour. Immediately following the one hour period reweigh the water supply reservoir. Should the humidifier capacity exceed the reservoir capacity it will be necessary to add measured amounts of make-up water to the reservoir, during test.

Two tests shall be performed; the first at 120V, single phase, 60 Hz and the second at 120V, single phase, 50 Hz.

Recorded Data: Record weight of water reservoir before and after one hour test period.

The following measurements shall be recorded at test initiation and at 15 minute intervals for a total of 5 readings:

- Ambient db and wb temperatures
- Voltage
- Current
- Frequency
- Watts

SAMPLE DATA SHEET

CAPACITY TEST

50 or 60 Hz Operation

Humidifier:

Time (min)	Ambient Temperatures db (°F)	wb (°F)	Voltage (Volts)	Current (Amps)	Frequency (Hz)	Power (Watts)	Remarks

Weight of Water Reservoir @ Test Initiation ________

Weight of Water Reservoir @ Test Conclusion ________

6.5 ELECTROMAGNETIC INTERFERENCE (EMI) - Melpar Performed

Purpose of Test: To evaluate humidifiers and humidity controls for EMI (Emissions) in accordance with MIL-STD-461.

Application Requirement: Conducted and radiated emissions must be within limits imposed by methods CE03 and RE02 of MIL-STD-461, Part 4.

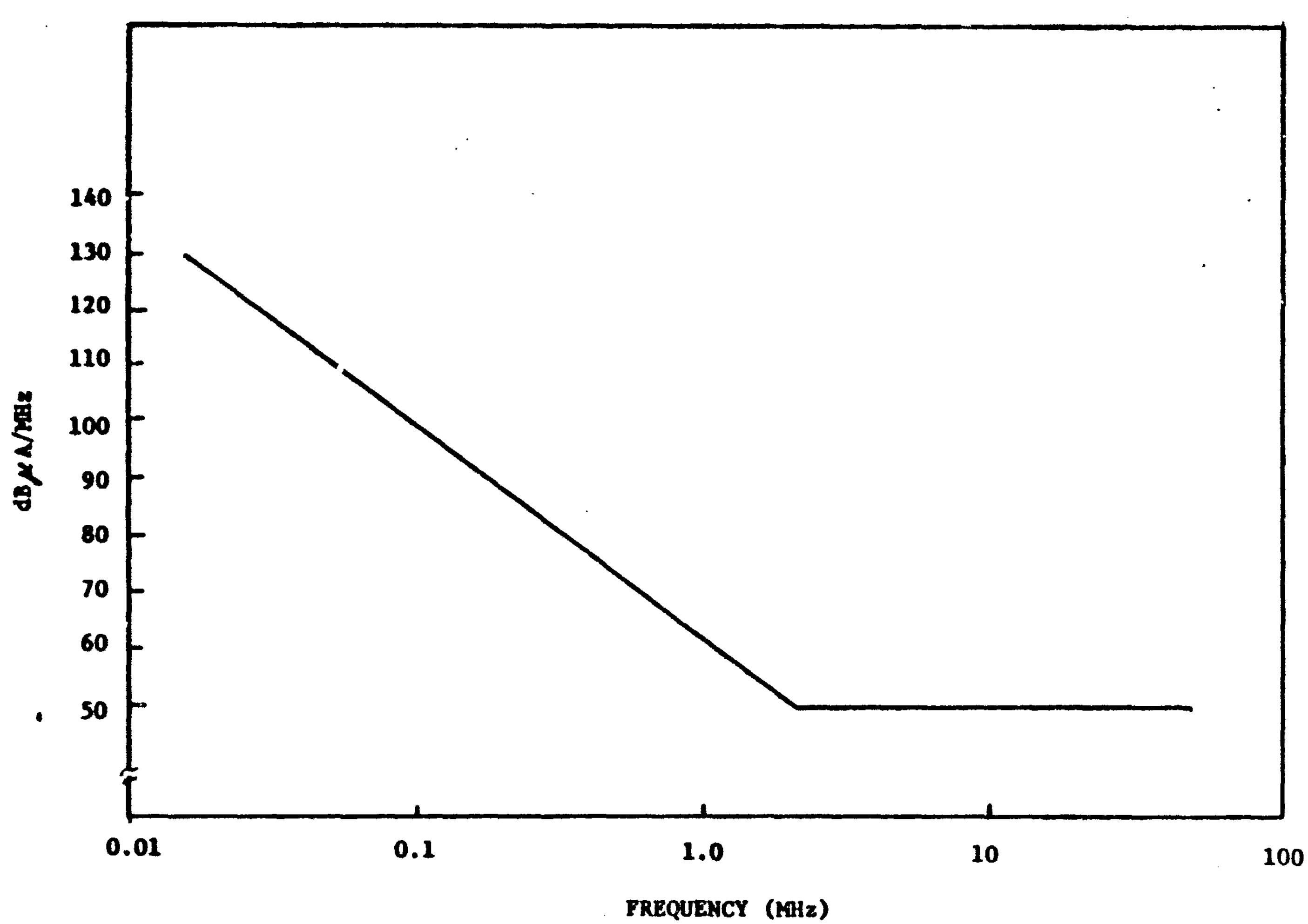
Test Equipment: Equipment required in MIL-STD-462.

Test Procedure: Using equipment and test procedures in MIL-STD-462, the humidifiers shall be evaluated in accordance with method CE-03, Part 4 of MIL-STD-461. Humidifiers and humidity controls shall be evaluated in accordance with method RE-02, Part 4 of MIL-STD-461. Only broadband conducted and radiated emissions need be measured. Humidifiers shall be tested for steady state and transient operations. Humidity controls shall be tested for transients only.

Recorded Data: Each different test mode shall be stated and provided with corresponding graphical results.

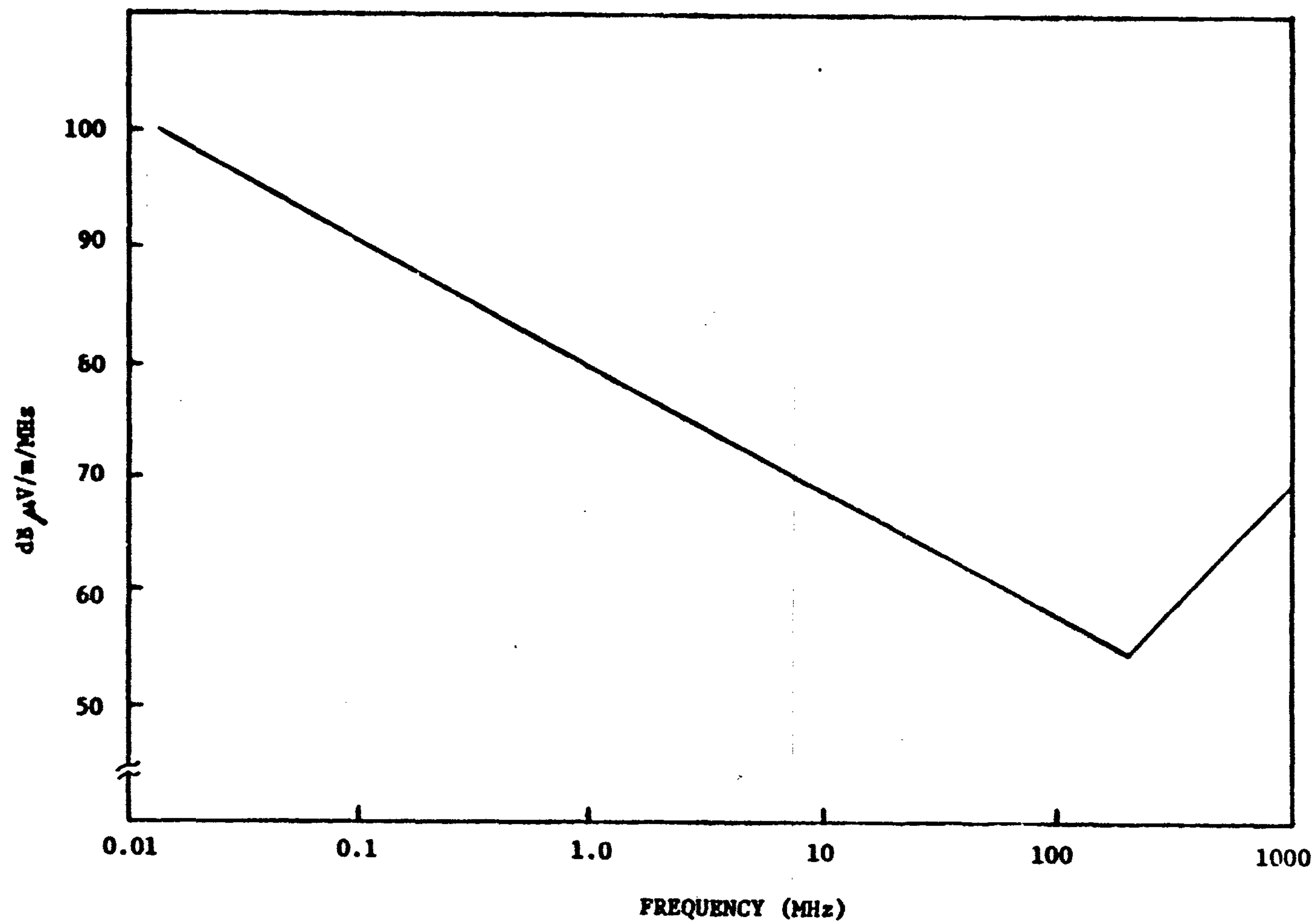
SAMPLE DATA SHEET

Limit for CE03 Broadband Emissions



Limit for RE02 Broadband Emissions

SAMPLE DATA SHEET



6.6 VARIABLE VOLTAGE AND FREQUENCY - NTS Performed

Purpose of Test: To determine if humidifiers will operate at various input power conditions.

Application Requirement: Humidifier shall start and operate continuously for 15 minutes on variable input power conditions described below:

Test	Voltage Condition	Frequency Condition	Voltage VAC ± .5V	Frequency Hz ± 2Hz
1	High	High	132	60
2	Low	Low	108	50
3	Low	High	108	60
4	High	Low	132	50

Test Equipment:

- Generator set
- Volt meter
- Ammeter
- Frequency meter
- Watt meter
- Thermo couple
- Water reservoir
- Time clock

Test Procedure: Maintain water supply to humidifier under test to insure continuous operation (see Figure 6.). Begin with test 1 power conditions and operate unit continuously for 15 minutes. Following 15 minute test period allow humidifier to soak for 1 hour minimum at ambient conditions. Following soak period operate humidifier at test 2 power conditions for 15 minutes. Each 15 minute test will be followed by a 1 hour soak period until all four tests are completed.

Recorded Data: The following measurements shall be recorded at each test initiation and at 5 minute intervals during each 15 minute test:

- Volts
- Current
- Frequency
- Watts
- Ambient temperature

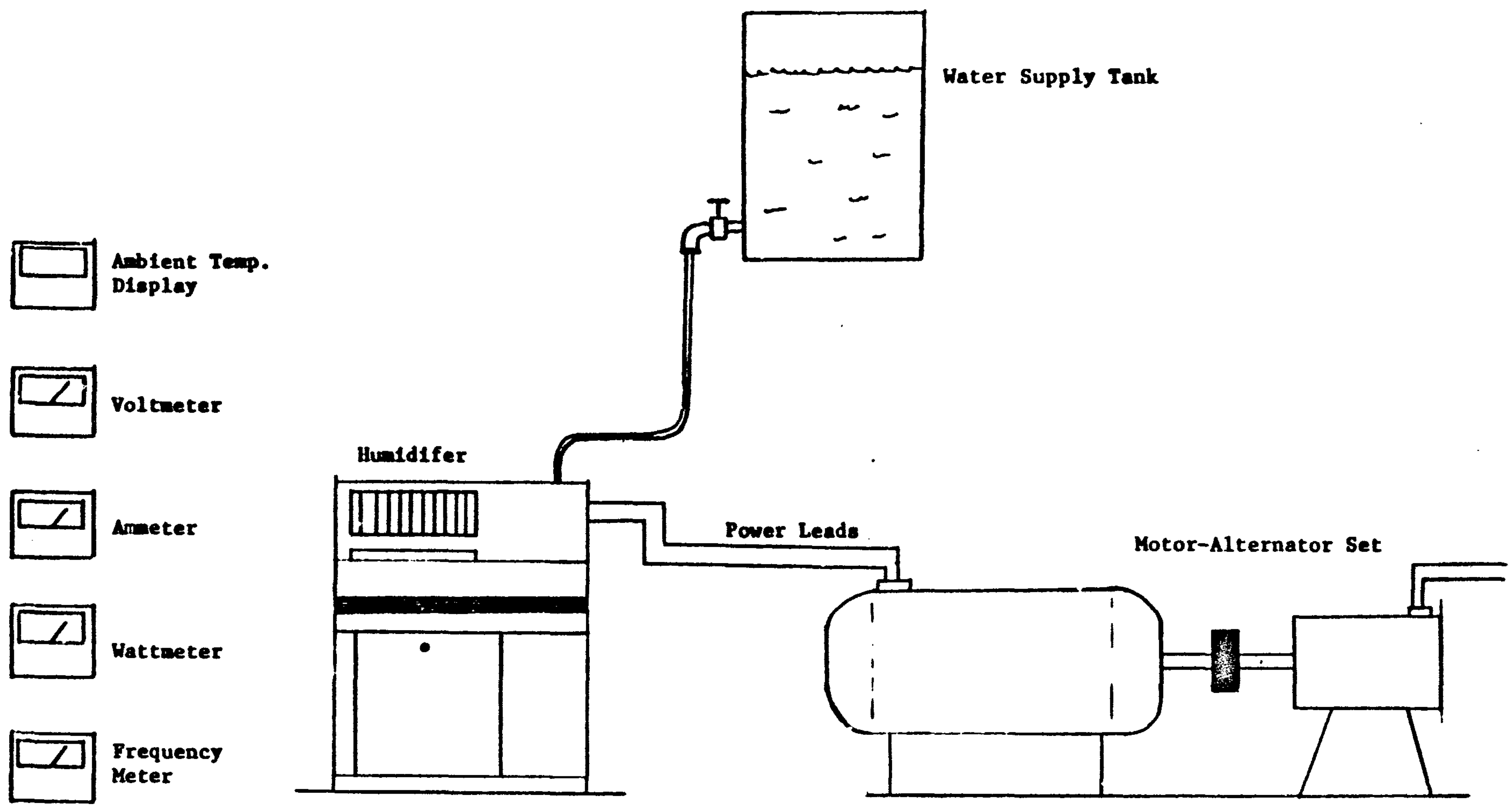
SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: Frequency condition: Humidifier:

Time (min)	Ambient Temp. (^{o}F)	Voltage (Volts)	Current (Amps)	Frequency (Hz)	Power (Watts)	Remarks

Figure 6. Variable Voltage and Frequency Test Set Up



6.7 VIBRATION - NTS Performed

Purpose of Test: To determine effect of simulated transportation vibration on humidifiers and humidity controls.

Application Requirement: Humidifier and humidity controls shall show no evidence of structural damage or abnormal vibration during operation, following vibration in accordance with MIL-STD-810, Method 514.3, Table 514.3-I, category 1, test procedure I, Figure 514.3-1 through 3. Equipment shall be vibrated in three planes (longitudinal, transverse, vertical) for a duration of 30 minutes per plane. Test items shall be mounted in their normal operating position throughout vibration test. Vibration inputs shall be monitored by averaging responses of four accelerometers located in four corners of base fixture. Test items shall not be operated during vibration. See Figure 7. for typical equipment mounting.

Test Equipment:

- Vibration machine
- Fixtures necessary to securely mount humidifier and controls to vibration machine.
- Water reservoir
- Voltmeter
- Ammeter
- Frequency meter
- Watt meter
- Time clock
- Continuity tester
- Capability to produce a humidified or dehumidified atmosphere as required.

Test Procedure: Ensure water has been drained from humidifier water reservoirs. Mount fixtured humidifier and controls on vibration machine. Vibrate equipment in all three planes. Following test, inspect equipment for damage. Note any fractures, misalignment, etc. Connect water supply and operate humidifier for 15 minutes. Note any abnormal operation. Verify humidity controls still function by placing unit in a humidified or dehumidified atmosphere and insuring switch opens or closes as required with continuity tester.

Recorded Data:

- Vibration machine data to verify input at each of the three planes
- Results of physical examinations
- Record volts, amps, frequency and watts at start and finish of 15 minute operation.
- Results of continuity test

SAMPLE DATA SHEET

VIBRATION TEST

Humidifier or
Humidity Control:

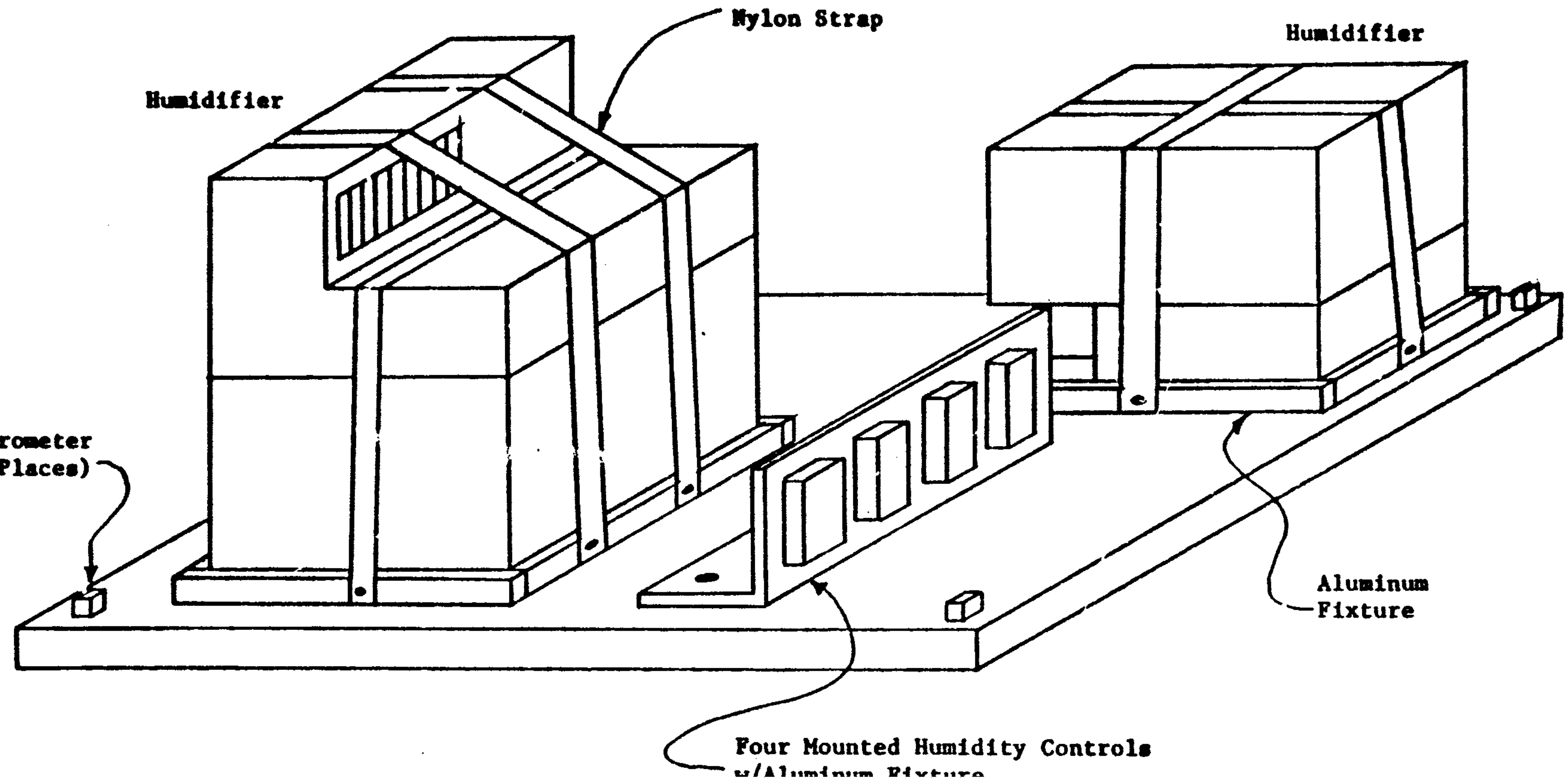
Results of Physical Examination:

15 Minute Operation

Time	Voltage (Volts)	Current (Amps)	Frequency (Hz)	Power (kW)	Remarks

Switch Mechanism Verification (Continuity Test):

Figure 7. Equipment Mounting for Vibration Test



6.8 HIGH TEMPERATURE STORAGE - VSE Performed

Purpose of Test: To determine effect of extreme high temperature on humidifiers and humidity controls.

Application Requirement: Humidifiers and humidity controls shall not be damaged and operation shall not be impaired by storage at an ambient temperature of 160°F as derived from AR 70-38.

Test Equipment:

- Hot chamber
- Thermocouples
- Water reservoir
- Continuity tester
- Time clock
- Capability to produce a humidified or dehumidified atmosphere as required.

Test Procedure: Place humidifier and humidity controls in test chamber and subject them to 160 ± 5°F temperature for a continuous period of 4 hours. After exposure period remove test samples from chamber and examine for deterioration and damage. Following examination, soak test samples at room temperature for 1 hour. Operate humidifiers for 30 minutes. Verify humidifier controls still function by placing unit in a humidified or dehumidified atmosphere and ensuring switch opens or closes as required with continuity tester.

Recorded Data:

- Monitor chamber temperature at beginning of 4 hour soak period and once very hour thereafter. Record ambient temperature following 1 hour soak period.
- Results of physical examinations
- Results of 30 minute operation
- Results of continuity test

SAMPLE DATA SHEET

HIGH TEMPERATURE STORAGE TEST

Humidifier or
Humidity Control:

Time	Chamber Temp. °F	Ambient Temp. °F	Remarks

Results of Physical Examination:

Results of 30 minute operation:

Results of Continuity Test:

6.9 LOW TEMPERATURE STORAGE - VSE Performed

Purpose of Test: To determine effect of extreme low temperature on humidifiers and humidity controls.

Application Requirement: Humidifiers and humidity controls shall not be damaged and operation shall not be impaired by storage at an ambient temperature of -60°F as derived from AR 70-38.

Test Equipment:

- Cold chamber
- Thermocouples
- Water reservoir
- Continuity tester
- Time clock
- Capability to produce a humidified or dehumidified atmosphere as required.

Test Procedure: Ensure water has been drained from humidifier water reservoirs. Place humidifiers and humidity controls in test chamber and subject them to -60 ± 5°F temperature for a continuous period of 12 hours. After exposure period remove test samples from chamber and examine for deterioration and damage. Following examinations, soak test samples at room temperature for 1 hour. Operate humidifiers for 30 minutes. Verify humidifiers controls still function by placing unit in humidified or dehumidified atmosphere and ensuring switch opens or closes as required with continuity tester.

Recorded Data:

- Monitor chamber temperature at beginning of 12 hour soak period and once every hour thereafter. Record ambient temperature following 1 hour soak period.
- Results of physical examinations

- **Results of 30 minute operation**
- **Results of continuity test**

SAMPLE DATA SHEET

LOW TEMPERATURE STORAGE TEST

Humidifier or
Humidity Control:

Time	Chamber Temp. °F	Ambient Temp. °F	Remarks

Results of Physical Examination:

Results of 30 minute operation:

Results of Continuity Test:

6.10 SOUND LEVEL - VSE Performed

Purpose of Test: To determine sound level of humidifiers during operation.

Application Requirement: Humidifier shall have a dB(A) criteria of no more than 75dB per Table 2, Category E of MIL-STD-1474.

Test Equipment:

- Open field
- Sound level meter
- Water reservoir
- Volt meter
- Ammeter
- Watt meter

Test Procedure: Humidifier shall be placed in an open area which simulates a free field environment. Test should be conducted in the early morning to avoid excessive background noise levels caused by automobile traffic, birds chirping, etc. Connect water supply and operate humidifier. Locate sound level meter at the same level as humidifier discharge and 36" away from humidifier vertical center line (see Figure 8.).

Recorded Data: Record sound levels at specified active band frequencies of MIL-STD-1474. Record volts, amps and watts at test initiation.

SAMPLE DATA SHEET

Sound Level Test

Humidifier:

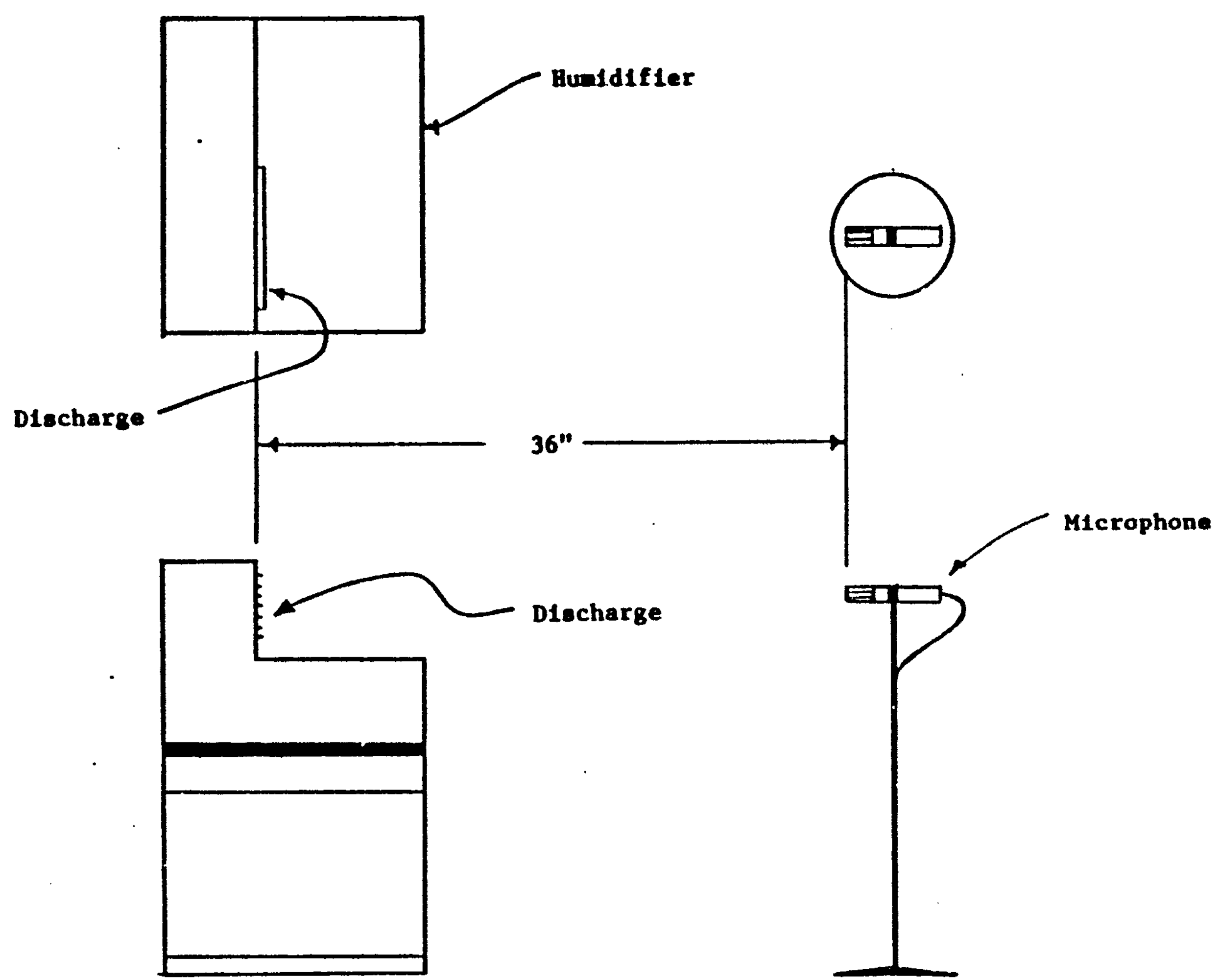
@ Test Initiation

Time	Voltage (Volts)	Current (Amps)	Frequency (Hz)	Power (Watts)

Octave band center frequencies - Hz	Background (db Max)	Operational Humidifier Discharge (db Max)
63		
125		
250		
500		
1000		
2000		
4000		
8000		

Remarks:

Figure 8. Sound Level Testing



6.11 TILTED OPERATION - VSE Performed

Purpose of Test: To determine affect of a 5° tilted orientation on humidifiers or to determine maximum allowable tilt for satisfactory operation if less than 5°.

Application Requirement: Water shall not discharge from humidifier other than through intended ports.

Test Equipment:

- Wood wedge or some type of block with which to impart a tilt to test samples
- Protractor to measure degree of tilt
- Water reservoir

Test Procedure: With humidifier non operational, observe unit to be tested for worst anticipated tilt directions (see Figure 9.). Observe whether or not water will leak from pan, or heating elements (if applicable) will be exposed when tilted 5°. Observe operation of float valve or level sensor. Partial disassembly may be required. Determine degree of tilt which allows satisfactory operation. Block humidifier to this degree of tilt and operate. Observe function.

Recorded Data: Record observations of tilted condition.

SAMPLE DATA SHEET

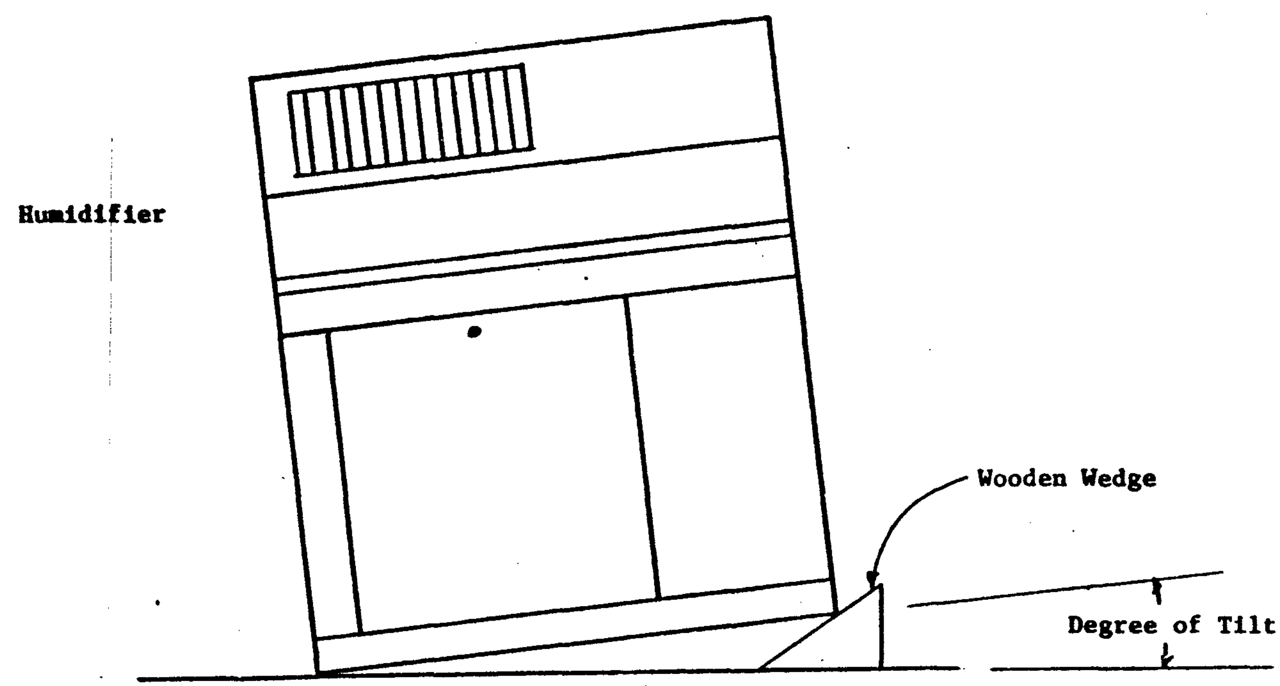
Tilted Operation Test

Humidifer:

Results of 5^{o} tilt observations:

Results of operation at maximum (up to 5^{o}) tilt angle which allows satisfactory operation:

Figure 9. Tilted Operation Test



6.12 HUMAN FACTORS EVALUATION - VSE Performed

Purpose of Test: To determine compatibility of humidifiers and humidity controls with MIL-STD-1472.

Application Requirement: Humidifiers and humidity controls should be, to the greatest extent possible, compatible with requirements of MIL-STD-1472. Deviations from prescribed standards shall be documented.

Test Procedure: Humidifiers and humidity controls will be evaluated by a human factors engineer to determine conformance to Human Factors Engineering Design Criteria as described in MIL-STD-1472. Special design emphasis shall be given, but not limited to, Paragraphs 4 (General Requirements), (5.5 Labeling), 5.9 (Design for Maintainability), and 5.13 (Hazards and Safety), of MIL-STD-1472, as applicable.

Recorded Data: All comments, observations and recommendations of the human factors engineer will be documented and prescribed in the form of an (HFEA) Human Factors Engineering Analysis.

7.0 TEST SCHEDULE

Test Order	Humidifier	Humidity Controls	Dehumidifier	Test	Performed by
1		x		Controls Performance	VSE
2			x	Dehumidification Operation	VSE
3	x			Tilted Operation	VSE
4	x			Sound level	VSE
5	x	x		Human factors Engineering	VSE
6	x	x		EMI	Melpar
7	x	x		High Temp. Storage	VSE
8	x	x		Low Temp. Storage	VSE
9	x			Capacity	NTS
10	x			Variable Voltage & Frequency	NTS
11	x	x		Vibration	NTS
12		x		Controls Performance	VSE

APPENDIX C

TEST REPORT FOR HUMIDITY CONTROL EQUIPMENT

VSE/ASG/0024-87/02RD

TEST REPORT
FOR
HUMIDITY CONTROL EQUIPMENT
EVALUATED FOR USE IN THE
U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

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11 February 1987

Final Report for Period 9 January 1987 - 11 February 1987

Prepared For:

U.S. Army Belvoir Research, Development
and Engineering Center
Environmental Control Division
Fort Belvoir, Virginia 22060

TEST REPORT
FOR
HUMIDITY CONTROL EQUIPMENT
EVALUATED FOR USE IN THE
U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

Testing Performed By:

VSE Corporation and Subcontractors

Testing Initiated: 9 January 1987
Testing Completed: 11 February 1987

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Four commercial humidity controls were tested to determine their suitability for use within the Aircraft Service Shelter. Humidity controls received from suppliers are inaccurate; controls used in the service shelter must be recalibrated prior to installation. Humidity controls endured vibration, high and low temperature storage test. Units exceeded radiated EMI limits for transients. It is recommended Honeywell models H46C and H46D and the Abbeon Cal model be used in the shelter.

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APPENDICES

1.0 REASON FOR TESTING - GENERAL

The reason for the test series described herein was to ascertain performance data with which to evaluate the technical and operational feasibility of selected humidity control equipment for use in the Air Force Aircraft Service Shelter. The Aircraft Service Shelter is an integral part of the F-16 maintenance complex. The approved test plan on which the ensuing testing is based, is provided in Appendix D.

2.0 APPLICABLE DOCUMENTS

Statement of Work and Services dated 14 July 1986, Task Order 0024, Contract No. DAAK70-86-D-0023.

MIL-STD-461; Electromagnetic Emission and Susceptibility Requirements for the control of Electromagnetic Interference.

MIL-STD-462; Electromagnetic Interference Characteristics, Measurement of.

MIL-H-1759; Human Factors Engineering Design for Army Materiel.

MIL-STD-810; Environmental Test Methods and Engineering Guidelines.

MIL-STD-1472; Human Engineering Design Criteria for Military Systems, Equipment and Facilities.

AR 70-38; Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.

3.0 DESCRIPTION OF TEST SAMPLES

3.1 General. All humidity controls tested are commercial off-the-shelf equipment. Samples were chosen as a result of a market survey using criteria provided by the Tactical Shelter Systems Development Office, Hanscom Air Force Base.

3.2 Honeywell Humidity Control (Model H46C). The Honeywell model H46C contains a single pole, single throw snap switch which closes on a rise in relative humidity (RH) above the set point. Unit is provided with a 20-80% RH adjustable dial and positive on/off setting positions for manual operation of controlled equipment. Unit possesses a 5% RH differential, which closes the switch at the set point and will open the switch at the set point minus the differential. Unit is enclosed in a molded plastic case 4-21/32" x 2-15/16" x 1-3/8" and includes an adapter plate for vertical switch box mounting. The humidistat has lead wire connections suitable for up to 240V use.

3.3 Honeywell Humidity Control (Model H600A). The Honeywell model H600A contains a single pole, double throw switch which can be used to control either a humidifier or dehumidifier. Unit is provided with a 20-80% RH adjustable dial. Unit possesses a 5% RH differential. Unit is enclosed in a molded plastic case 5-3/4" x 3-3/8" x 2-3/16" and includes a metal adapter plate for switch box mounting. The humidistat has lead wire connections suitable for up to 240V use.

3.4 Barber Colman Humidity Control. The Barber Colman model HC101 contains a single pole, double throw switch which can be used to control either a humidifier or dehumidifier. Unit is provided with a 10-90% RH adjustable dial. Unit possesses a 5% RH differential. Unit is enclosed in a molded plastic case 4-3/8"x 2-7/8"x 1-5/8". Two screw holes are provided in a plastic backplate for mounting. The humidistat has lead wire connections suitable for up to 240V use.

3.5 Abbeon Cal Humidity Control. The Abbeon Cal model 4703-602 is manufactured by Lufft of Germany. This unit indicates the ambient RH on a 0-100% RH face plate. The indicator or pointer which responds to RH changes is used as one contact of the switch. Two additional pointers which are manually adjustable are used to open or close control circuits in conjunction with the RH indicator. The unit will control both a humidifier and dehumidifier within any RH range. Unit does not possess a %RH differential. Unit is enclosed in a metal case with a glass face plate. Unit is 6" in diameter across the flange and 1-1/2" deep. Three screw holes are provided in the flanged metal case for mounting. Unit includes three screw terminals for wire connections and is only suitable for 24V use.

4.0 DISPOSITION OF TEST SAMPLES

All four humidity controls tested will be kept at VSE Corporation until completion of task, at which time they will be transmitted to the Environmental Equipment Division at Fort Belvoir.

5.0 ABSTRACT, CONCLUSIONS AND RECOMMENDATIONS

Four commercial humidity controls were tested to determine their technical and operational feasibility for use as part of a humidity control system in the Aircraft Service Shelter. The humidity controls were subjected to the following tests:

- Human Factors Evaluation
- Initial Controls Performance
- Vibration
- High Temperature Storage
- Low Temperature Storage
- Final Controls Performance
- Electromagnetic Interference (EMI)

The initial controls performance test exposed the poor accuracy of all the humidity controls in the "as received" condition from the equipment supplier. Any humidity control chosen for the service shelter application must first be recalibrated prior to installation.

Generally, the humidity control most compatible with the military specification MIL-H-759 and military standard MIL-STD-1472 regarding human factors is the Abbeon Cal unit. This unit possess a large, easily read and understandable dial with an easily adjustable knob.

All units endured the vibration and extreme high and low temperature storage tests with no apparent damage.

The final controls performance test indicated that the Honeywell model H46C maintained its accuracy better than the other candidates.

The Barber Colman and the Abbeon Cal humidity controls exceeded the radiated EMI emission level limits imposed by method RE03 of MIL-STD-461, Part 4 for transients. However all transient durations were much less than the 1 second duration allowable for military standard air conditioners.

Based on the test results it is recommended that the Honeywell model H46C be used to control the Aircraft Service Shelter dehumidification equipment and that its sister unit, the Honeywell model H46D be used to control the humidification equipment. The task requires that a continuous reading RH indicator be provided in the shelter. It is recommended that the Abbeon Cal unit be used for this purpose and to actuate high and low humidity alarm lamps.

6.0 FACTUAL DATA - TESTING

6.1 Human Factors Evaluation

6.1.1 Reason for Test. The human factors evaluation was performed to determine the compatibility of humidity controls with MIL-STD-1472.

6.1.2 Description of Test Apparatus. No other apparatus was required to perform the evaluation.

6.1.3 Test Procedure. Humidity controls were evaluated by a human factors engineer to determine conformance to Human Factors Engineering Design Criteria as described in MIL-STD-1472. Special design emphasis shall be given, but not limited to, Paragraphs 4 (General Requirements), 5.5 (Labeling), 5.9 (Design for Maintainability), and 5.13 (Hazards and Safety), of MIL-STD-1472, as applicable.

6.1.4 Test Results and Analysis. Each humidity control was assessed in accordance with standards set forth in MIL-STD-1472, paragraph 5.4 Controls, and other sections as applicable.

6.1.4.1 Honeywell Model H46C

Controls

a. "ON/OFF" knob is a circular fingertip grasp type. Smooth (not serrated) plastic with detect mark for identifying setting/position.

b. Height of control is 3/10". It does not meet the standard of 1/2" minimum.

c. Diameter is 1". This falls within established specifications.

d. Torque values were not assessed but seem to be enough to prevent accidental movement, or vibration-induced movement.

e. Not sufficient for use with gloved or mittened hand.

f. The knob is a rotating type with a fixed scale, and a pointer/marker on the knob edge for noting setting/position.

g. The knob is colored so as to contrast with face plate decal background and the position indicator is of such contrast to the knob and scale background to make control position obvious.

Control Functions

To take advantage of previous learning, maximize transfer of training, and minimize error, the control functions should be standardized:

a. The "ON" direction of movement (i.e. clockwise) is in accordance with MIL-STDS-1472 and 759.

b. The "OFF" direction (i.e. counterclockwise) is in accordance with MIL-STDS-1472 and 759.

c. To increase the amount of humidity the knob is turned counter clockwise. This is in direct conflict with MIL-STDS, i.e. to increase, movement should be to right and decrease to left.

d. The control increments range from 20 to 80 in increments of 10 with no tenths divisions.

General

a. Labeling of humidity increments is high contrast but lacks in boldness. Not in accordance with MIL-STD-1472, Paragraph 5.5.5 Design of Label/Letter Characteristics.

b. Control is mounted vertically with displays facing front. Easily read and accessed.

6.1.4.2 Honeywell Model H600A

Controls

a. Control knob is rotating type with fixed scale beneath. No reference mark or setting indicator is provided on knob.

b. The control knob is a serrated finger grasp type, circular. The dimensions (diameter 1/2", height 1/4") do not meet established standards. Not adequate for gloved/mittened hand.

c. Torque values were not assessed but seem to be sufficient to prevent accidental movement or movement by vibration.

d. Knob is color contrasted with label background.

e. Knob is two part, with finger grasp portion detaching from a larger circular rotary knob located beneath the control box cover. The reference mark for determining what humidity value has been selected is located on the lower knob. However, the reference mark is difficult to see when the finger grasp knob is in place.

The removable finger grasp knob may be a valid concept for preventing tampering with preset controls but it does not (1) allow visual reference when setting the controls to a particular humidity setting and (2) it will be lost, thus encouraging use of other than proper equipment to set humidity values.

Control Functions

a. There are no "ON" "Off" control functions evident. This may be a result of lack of labeling or automated "ON-OFF" controls incorporated into the unit.

b. To decrease the humidity setting the control knob is turned clockwise. To increase the RH setting, the control knob is rotated counterclockwise. This is in direct conflict with MIL-STDS-1472/759 as clockwise is to increase and counter clockwise is to decrease.

c. The humidity increments range from 20 to 80 in increments of 10, no tenths markings are present.

General

a. The humidity setting indicator label is on top of the control unit. Thus:

1) The unit must be mounted lower than eye level so personnel can locate and operate the control knob. This effectively places the equipment in a height area extremely susceptible to damage by bumping from personnel equipment, tools, etc.

2) If mounted at "eye level", the control setting label cannot be seen at all by 5th percentile individual and with varying degrees of parallax by 95th percentile personnel.

b. The removable finger grasp knob is plastic and fits into a flanged plastic receiver in the lower knob. Repeated removal/replacement ultimately will knurl the turning knob shaft and render it useless.

c. Humidity setting labeling is inadequate for visual acuity and positioning. Location of setting label is not in the optimum position. Lettering characteristics of label not in accordance with MIL-STD-1472.

6.1.4.3 Barber Colman Model HC101

Controls:

a. Control knob is circular, finger grasp type with serrated front.

b. Diameter of knob is 1 1/2" and is in accordance with MIL-STDS-1472/759. Height of knob is 1/4", not in accordance with MIL-STDS-1472/759.

c. Reference indicator is a plastic line, slightly raised above the knob surface and protruding outward slightly from the knob's edge.

d. Reference indicator is the same color as the knob, thus, lacking in contrast and not in accordance with MIL-STDS-1472/759.

e. Torque values were not assessed but seem to be adequate to prevent accidental movement or movement by vibration.

f. Knob is difficult to grasp due to extremely thin configuration. Not adequate for use with gloved or mittened hand.

Control Functions

a. No apparent "ON" "OFF" control capability.

b. To decrease the humidity the control knob is rotated counterclockwise; to increase clockwise. This is in accordance with MIL-STDS-1472/759.

c. The humidity increments range from 10 to 90 in increments of 10. No tenths markings are present.

General

a. Labeling of humidity increments is high contrast to background.

b. Numerical figures are bold type and can be read easily.

c. Control is mounted with humidity increments facing front.

6.1.4.4 Abbeon Cal Model 4703-602. This is the only humidistat of the sample group which has an integral, controllable limiting capability. There are lower and upper limiting pointer switches on the control, as well as a pointer which indicates ambient humidity on the fixed readout scale.

Controls:

a. The control knob is centered on the unit. It is 3/4" in diameter, with serrated edges and meets MIL-STDS. The height is 3/8" and does not meet standards.

b. This is a multi-function knob. By merely turning the knob, either clockwise or counterclockwise the upper limit pointer switch can be adjusted. By pressing in on the knob and turning it, the lower limit pointer switch can be adjusted higher or lower.

Control Functions:

a. To increase the upper/lower limiting pointers switches, the control knob is turned clockwise, and decreased by turning counterclockwise. This is in accordance with MIL-STDS-1472/759.

b. The control is a fixed-scale moving-pointer indicator type with the numerical progression increasing clockwise. Also, all humidity indicator numbers are oriented in the upright position. This is in accordance with MIL-STDS-1472/759.

General Information

a. The "ON" "OFF" function is controlled by limiting pointer switches which, when contacted by the humidity indicator pointer, completes an electrical circuit and turns the controlled equipment "ON". When contact between the limiting pointer switch and indicator pointer is broken, the controlled equipment is deactivated. Thus, all "ON" "OFF" functions are controlled automatically.

b. Labeling is black on white providing high contrast. Numbers are large, bold and not visibly restricted by any pointers. This meets MIL-STDS.

c. This is the only humidistat of the sample group which has a method by which actual ambient humidity can be determined visibly.

6.2 Controls Performance - Initial

6.2.1 Reason for Test. The initial controls performance test was performed to determine the accuracy of humidity control upon receipt from supplier. All units displayed inaccuracies to various degrees. Units were recalibrated so the effect of vibration, high temperature and low temperature storage tests could be evaluated during the final controls performance test.

6.2.2 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the controls performance test:

- Wooden Chamber 7' x 9' x 7-1/2'lined with sheet plastic to impede moisture loss. Chamber was provided with a view port and an access port through which test samples within could be handled with minimal effect on inside conditions.
- Humidifier, Autoflo model L-1011-K, 4.61 pound per hr capacity.
- Continuity tester, multi meter, Microna model 22-204C.
- Mercury filled thermometer, Miller and Weber Inc., 50-87^oF range, S/N 8L4236, calibrated 7/1/86, recalibration required 6/26/87, with woven wick for wet bulb temperature reading.
- Mercury filled thermometer, SGA Co., 50-87^oF range, S/N 100, calibrated 6/30/86, recalibration required 6/25/87.
- Cardboard duct.
- Water reservoir, styrofoam cup.
- Blower, Dayton Electric Mfg., model 4C548, 55 cfm.
- Air velocity meter, Sierra Instruments model 441, 0-6000 fpm range, I.D. no. 2280, calibrated 9/10/86, recalibration due 3/10/87.
- Purified water, Great Bear Spring Co.
- Wrist watch, Seiko.
- Psychrometric chart, ASHRAE psychrometric chart no. 1, sea level, normal temperature.

6.2.3 Test Procedure. Assembled mercury thermometers, cardboard duct, water reservoir and blower such that an air flow of approximately 600 fpm is induced over bulbs of thermometers as measured by air velocity meter. This served as a psychrometer assembly. Place humidity controls, humidifier, continuity tester and psychrometer assembly in plastic lined chamber. Initiated humidifier and increased chamber RH to above 50%. Shut down humidifier and allowed chamber RH to stabilize or gradually decrease. Testing must be accomplished within a 35%-55% RH range.

A 30 minute chamber RH stabilization period was observed where the rate of RH decrease was gradual for 30 minutes. A gradual RH decline resulted since the plastic lined chamber was not 100% air tight. Humidity control circuit trip points were then determined, and their proximity to the actual chamber condition. Circuit trip points were determined by rotating the humidity control adjusting knob so that the control switch just closes as verified by continuity tester. The control adjusting knob RH setting was then compared to the actual chamber RH as determined by the psychrometer assembly and the psychrometric chart. Control differentials were determined by rotating adjusting knob in the opposite direction until control switch just opens its internal circuit as verified by continuity tester. The Abbeon Cal control was tested by observing the RH indicated by its direct reading dial and comparing with actual condition. The difference between the various control knob settings at switch actuation (or direct reading dial) and the chamber RH were recorded. When this difference exceeded 1/2% RH the control was recalibrated. Recalibration involved rotating the RH adjusting knob to the ambient RH condition. The housing of the control was then removed to expose the calibration screw. The calibration screw was adjusted until the control switch closed at the actual chamber RH. The Abbeon Cal control was recalibrated by adjusting its calibration screw, until the RH indicated on its dial corresponded to ambient condition.

6.2.4 Test Results and Analyses. It should be noted that the humidity controls RH setting scales were divided into increments of 10%. It is therefore very difficult to accurately judge what the RH set point is. The Abbeon Cal unit is the exception since this units scale is divided into 2% RH increments.

All four humidity control set points differed from the actual RH condition by more than 1/2% RH as visually perceived by test personnel. All were recalibrated. Recalibration requires the use of an 1/8" hex head to adjust the calibration screw of the Honeywell H46C and H600A units. The Barber Colman unit requires a 1/16" allen head to adjust its calibration screw. The Abbeon Cal unit requires a small straight edge screw driver. The results of the test are summarized in Table 1. It is very apparent that all the humidity controls were inaccurate upon receipt. Should any of the tested humidity controls be used in the Aircraft Service Shelter, they must first be recalibrated before being installed. Effect of vibration, high temperature storage and low temperature storage on units accuracy will be determined in the final controls performance test. Data sheet for this test is provided in Appendix A.

Table 1. Initial Control Performance Test Summary

Humidity Control	Actual Ambient % RH	Control Set Point at Switch Closing % RH	Control Error % RH	Control Differential % RH
Abbeon Cal 4703-602	49	61 (Indicator Reading)	12	N/A
Honeywell H600A	48	34	14	2
Honeywell E46C	47	50	3	3
Barber Colman HC101	47	52	5	4

6.3 Vibration

6.3.1 General. The actual vibration test was performed at National Technical Systems (NTS) in Hartwood, Virginia. The operation check out following vibration was performed at VSE.

6.3.2 Reason for Test. Vibration test was performed to determine the effect of simulated transportation vibration on humidity controls.

6.3.3 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the vibration test:

- Vibration Exciter, MB Electronics, model C210, ID no. D 6306 D (NTS Equipment).
- Vibration Control System, Hewlett-Packard, ID no. D 6054 D, calibrated 6/5/86, recalibration due 6/5/87 (NTS Equipment).
- Accelerometer, PCB, ID no. D 6155 D, calibrated 12/2/86, recalibration due 6/2/87 (NTS Equipment).
- Power Supply, PCB, ID no. D 6093 D, calibrated 11/11/86, recalibration due 5/11/87 (NTS Equipment).
- Fixture, aluminum base plate and aluminum angle for mounting humidity controls.
- Continuity tester, multi meter, Microna model 22-204C.

6.3.4 Test Procedure. Fixtured humidity controls were mounted on vibration machine. Equipment was then vibrated in accordance with MIL-STD-810, Method 514.3, Table 514.3-1, Category 1, Test Procedure 1, Figures 514.3-1 through 3. Equipment was vibrated in three planes (longitudinal, transverse, vertical) for a duration of 30 minutes per plane. Humidity controls were mounted in their normal operating position throughout vibration test. Vibration inputs were monitored by averaging responses of four accelerometers located in four corners of base plate fixture. Verified humidity controls still functioned following vibration by rotating control knobs and insuring switches opened and closed as required with continuity tester. Observed units for any evidence of damage.

6.3.5 Test Results and Analyses. All humidity controls endured the vibration test without mishap. No physical damage to the controls could be detected. The continuity tests proved that the internal switch of each control still functioned properly. Data sheet is provided in Appendix A.

6.4 High Temperature Storage

6.4.1 Reason for Test. High temperature storage test was performed to determine the effect of extreme high temperature on humidity controls.

6.4.2 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the high temperature storage test:

- o Environmental chamber manufactured by Thermotron. Chamber volume is 38" x 38" x 38" with a temperature range of +265°F to -100°F.
- o Thermocouple indicator, Thermo Electric, 18 channel.
- o Thermocouple, copper-constantan.
- o Continuity tester, multi meter, Microna model 22-204C.

6.4.3 Test Procedure. Humidity controls were placed in test chamber and the chamber then stabilized at 160 $\pm$5°F. Chamber temperature was verified with thermocouple. Controls were soaked at 160 $\pm$5°F for a minimum continuous period of 4 hours. After exposure period, test samples were removed from chamber and examined for deterioration and damage. Following examination, test samples were soaked at room temperature for 1 hour. Humidity control function was verified by rotating control knobs and insuring switches opened and closed as required with continuity tester.

6.4.4 Test Results and Analyses. All humidity controls endured the high temperature storage test without mishap. No physical damage or deterioration could be detected. The continuity tests proved that the internal switch of each control still functioned properly. Initially it appeared that the Abbeon Cal unit was damaged following this test. The unit appeared not to respond to the ambient humidity several hours following test. However, unit appeared to track humidity normally the following day. Data sheet is provided in Appendix A.

6.5 Low Temperature Storage

6.5.1 Reason for Test. Low temperature storage test was performed to determine the effect of extreme low temperature on humidity controls.

6.5.2 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the low temperature storage test:

- Environmental chamber manufactured by Thermotron. Chamber volume is 38" x 38" x 38" with a temperature range of +265°F to -100°F.
- Thermocouple indicator, Thermo Electric, 18 channel.
- Thermocouple, copper-constantan.
- Continuity tester, multi meter, Microna model 22-204C.

6.5.3 Test Procedure. Humidity controls were placed in test chamber and the chamber then stabilized at -60 $\pm$5°F. Temperature was verified with thermocouple. Controls were soaked at -60 $\pm$5°F for a minimum continuous period of 12 hours. After exposure period, test samples were removed from chamber and examined for deterioration and damage. Following examination, test samples were soaked at room temperature for 1 hour. Humidity control function was verified by rotating control knobs and insuring switches opened and closed as required with continuity tester.

6.5.4 Test Results and Analyses. All humidity controls endured the low temperature test without mishap. No physical damage or deterioration could be detected. The continuity tests proved that the internal switches of each control still functioned properly. Data sheet is provided in Appendix A.

6.6 Controls Performance - Final

6.6.1 Reason for Test. Final control performance test was performed to evaluate the impact of vibration, high temperature storage and low temperature storage tests on accuracy of humidity controls.

6.6.2 Description of Test Apparatus. The test apparatus used was identical to that used for the initial controls performance test (see section 6.2.2).

6.6.3 Test Procedure. The test procedure was identical to the test procedure followed for the initial controls performance test with the exception that the controls were not recalibrated (see section 6.2.3).

6.6.4 Test Results and Analyses. It should be noted that the humidity controls RH setting dials were divided into increments of 10%. It is therefore very difficult to accurately judge what the RH set point is. The Abbeon Cal unit is the exception since this units scale is divided into 2% increments.

The results of the final controls performance test are summarized in Table 2. The humidity control that maintained the best accuracy was the Honeywell H46C. The unit differed from the actual RH by only 1% RH. The Barber Colman control was the least accurate as it differed from the actual RH by 9% RH. This inaccuracy may be explained by the proximity of its calibration screw to one of its mounting screws. The units were mounted and unmounted many times during the course of testing. One could not help but contact the Barber Colman calibration screw during mounting. This may have affected its accuracy. The Honeywell H600A was off by 3% RH and the Abbeon Cal control was off by 5% RH.

Prior to the final control performance test, data was recorded on the response of the Abbeon Cal unit. Approximately 90 minutes of data was recorded. The unit appeared to track increases in RH relatively well. The unit appeared to lag decreasing RH by approximately 5% RH. Data sheet is provided in Appendix A.

It was noted that each of the four humidity controls were inaccurate on the high side. That is, each indicated a higher RH than the ambient. This may be due to the controls response time coming into play. The chamber conditions were kept as stable as possible however the ambient RH was gradually falling at a rate of approximately 3-1/3% RH per hour. Data sheet for this test is provided in Appendix A.

Table 2. Final Control Performance Test Summary

Humidity Control	Actual Ambient % RH	Control Set Point at Switch Closing % RH	Control Error % RH	Control Differential % RH
Abbeon Cal 4703-602	38	43 (Indicator Reading)	5	N/A
Honeywell H600A	39	42	3	2
Honeywell H46C	39	40	1	5
Barber Colman HC101	38	47	9	4

6.7 Electromagnetic Interference (EMI)

6.7.1 General. The EMI test was performed by the Honeywell Signal Analysis Center in Annapolis, Maryland.

6.7.2 Reason for Test. EMI testing was performed on humidity controls to evaluate the equipments electromagnetic transient emissions in accordance with MIL-STD-461. Transient radiated emissions were compared with limits imposed by method RE02 of MIL-STD-461, Part 4.

6.7.3 Description of Test Apparatus. The equipment and instrumentation used by Honeywell to conduct the EMI test are listed in Appendix C.

6.7.4 Test Procedure. The humidity controls were wired in series with a 120/24V transformer and a 10 ohm resistor which simulated the power relay coil in the humidifier 24V control circuit. The humidity controls were tested in accordance with test procedures specified in MIL-STD-462. The humidity controls were tested for transient emissions and compared with limits imposed by method RE02 for radiated emissions of MIL-STD-461, Part 4. Antenna equipment was oriented at one meter distance from test unit.

6.7.5 Test Results and Analyses. The transient emissions for Barber Colman and the Abbeon Cal humidity controls exceeded the radiated limits imposed by RE02. Military standard air conditioners are allowed transients which exceed RE02 limits only if the transients are less than 1 second in duration. The observed transients for the humidity controls were less than 1 second in duration. EMI testing performed by the Belvoir RD&E Center on the heat pump used in the Aircraft Service Shelter demonstrated that this unit also exceeds the RE02 limits for transients. VSE believes the transient emissions for the humidity controls will not pose a problem in the service shelter and that equipment modifications are unnecessary. Data sheets are provided in Appendix C.

APPENDIX A

VSE TEST DATA SHEETS

DATA SHEET

DATE: 1/9/87
TEST PERFORMED BY: M. Baker

INITIAL CONTROLS PERFORMANCE TEST

Time	Db(°F)	Wb(°F)	%RH	Remarks
13:25	74.5	62.5	52	Soak Period begins (30 m
13:35	74.8	62.4	51	
13:45	74.9	62.3	50	
13:55	74.8	61.9	49	
14:05	74.8	61.9	47	Abbeon Cal unit is recalibr
14:15	75.2	62.0	48	Honeywell H600A is "
14:25	75.3	62.1	48	
14:35	74.8	61.4	47	Honeywell H46C is "
14:45	74.7	61.2	47	Barber Colman unit is "
14:55	74.9	61.3	47	

Humidity Control	Recalibration Required (Yes, No)	Ambient %RH	Control Set Point at Switch Closing %RH	Control Set Point at Switch Opening %RH
Honeywell H46C	Yes	47	50	47
Honewell H600A	Yes	48	34	36
Barber-Colman HC101	Yes	47	52	36
Abbeon Cal 4703-602	Yes	49	61 (Indicator Reading)	N/A

Units were recalibrated to actual ambient RH

DATE: 1/22/87
TEST PERFORMED BY: M. Baker

DATA SHEET

VIBRATION TEST

__Results of Physical Examination:__

Honeywell H46A	No visible damage
Honeywell H600A	" " "
Barber Colman HC101	" " "
Abbeon Cal 4703-602	" " "

__Switch Mechanism Verification (Continuity Test):__

Honeywell H46C	Switch mechanism checks out OK
Honeywell H600A	" " "
Barber Colman HC101	" " "
Abbeon Cal 4703-602	" " "

DATE: 1/23/87
TEST PERFORMED BY: M. Baker

DATA SHEET

HIGH TEMPERTURE STORAGE TEST

Time	Chamber Temp (^{o}F)	Ambient Temp (^{o}F)	Remarks
10:20	163		Begin 4 hour soak
11:20	163		
12:20	163		
13:20	164		
14:20	164		End 4 hour soak
15:45		65	Observe units for dam and tested

Results of Physical Examination:

Honeywell H46A	No apparent damage was observed
Honeywell H600A	" " "
Barber Colman HC101	" " "
Abbeon Cal 4703-602	Unit appears stuck at extremely low RH

Switch Mechanism Verification (Continuity Test):

Honeywell H46C	Switch functions OK
Honeywell H600A	" "
Barber Colman HC101	" "
Abbeon Cal 4703-602	" "

DATE: 1/26/87
TEST PERFORMED BY: M. Baker

DATA SHEET

LOW TEMPERTURE STORAGE TEST

	Time	Chamber Temp (°F)	Ambient Temp (°F)	Remarks
1/26	17:00	-64		Begin 12hr soak
1/27	7:15	-64		End 12hr soak
	13:00		70	units observed for da and tested

Results of Physical Examination:

Honeywell H46A	No visible damage or deterioration
Honeywell H600A	No visible damage or deterioration
Barber Colman HC101	No visible damage or deterioration
Abbeon Cal 4703-602	No visible damage or deterioration

Switch Mechanism Verification (Continuity Test):

Honeywell H46C	Switch	Functions	Ok
Honeywell H600A	"	"	"
Barber Colman HC101	"	"	"
Abbeon Cal 4703-602	"	"	"

DATA SHEET

DATE: 1/30/87
TEST PERFORMED BY: M. Baker

FINAL CONTROLS PERFORMANCE TEST

Time	Db(°F)	Wb(°F)	%RH	Remarks
15:10	75.8	60.3	40	Begin soak period (30 mins)
15:20	75.7	59.9	39	
15:22	75.4	59.8	40	
15:25	75.2	59.6	39	
15:30	75.1	59.5	39	
15:33	75.1	59.4	39	
15:40	75.3	59.3	39	Honeywell H46C & H600A are compared w/ ac
15:45	75.6	59.3	38	Abbeon Cal & B-C units are compared w/ actual
15:50	75.5	59.2	38	

Humidity Control	Ambient %RH	Control Set Point at Switch Closing %RH	Control Set Point at Switch Opening %RH
Honeywell H46C	39	40	35
Honewell H600A	39	42	44
Barber-Colman HC101	38	47	51
Abbeon Cal 4703-602	38	43 (Indicator Reading)	N/A

DATA SHEET

RECORDER: M. Bak

Abbeon Cal Response Data

Time	Db (°F)	Wb (°F)	%RH	Abbeon Reading
8:40	75.8	63.3	51%	55%
8:45	75.9	64.2	54%	55
8:55	76.0	65.0	56%	56
9:10	76.0	65.6	58%	5

Movement of Abbeon Cal control quickly increased RH reading to 57%

Time	Db (°F)	Wb (°F)	%RH	Abbeon Reading
9:15	76.6	65.7	57%	57
9:30	76.8	658	57%	57

Opened chamber door

Time	Db (°F)	Wb (°F)	%RH	Abbeon Reading
9:55	76.1	63.7	50%	54
10:00	76.2	63.7	50%	54
13:25	74.6	59.8	43%	47

Movement of Abbeon Cal control quickly decreased RH reading to 46%

Time	Db (°F)	Wb (°F)	%RH	Abbeon Reading
13:35	74.8	60.5	45%	46.
13:45	75.2	61.9	47%	48
13:47	75.7	62.8	49%	4
13:49	75.7	63.0	50%	5
13:51	75.8	63.4	51%	5
13:59	76.2	64.1	52%	5

APPENDIX B

NATIONAL TECHNICAL SYSTEMS

TEST DATA SHEETS

GENERAL LOG SHEET

TEST Random Vibration W/O 553-2053
CUSTOMER VSE DATE 1-19-87
TEST ITEM Humidifiers & Controllers P/N SEE BELOW S/N SEE BELOW
SPECIFICATION MIL-STD-810D Meth 514.3 TABLE 514.3-1 Cat 1 Proc 1

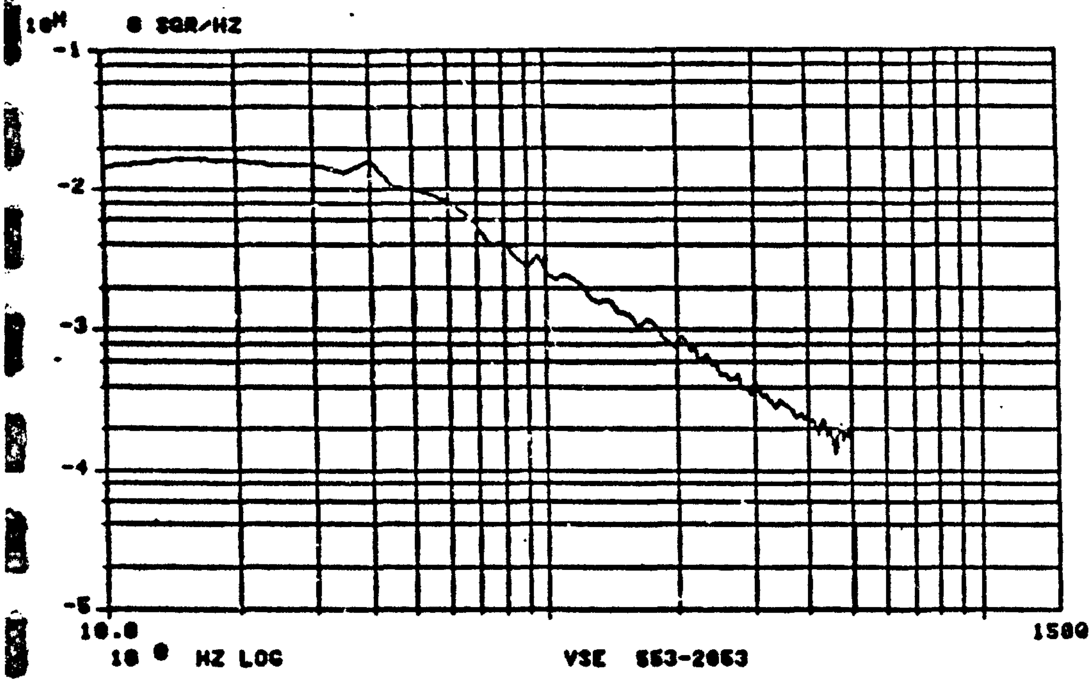
DATE	TIME	LOG ENTRIES	INITIAL
1-19-87	1400	Run Transverse axis	VB
	1700	Run Vertical axis	VB
1-20-87	1000	Run long axis	VB
		TEST ITEMS	
		HUMIDIFIER: Autoflo Mod/ L-1011-K	
		" Vapormist " VM2	
		CONTROLLER Honeywell " H600	
		" " " H46C	
		" Allbeon " 4703-602	
		" BarberColman " HC101	VS

PAGE 1 OF 1

TEST BY SBrown DATE 1-20-87
INSP [illegible] GOVT QAR Acc

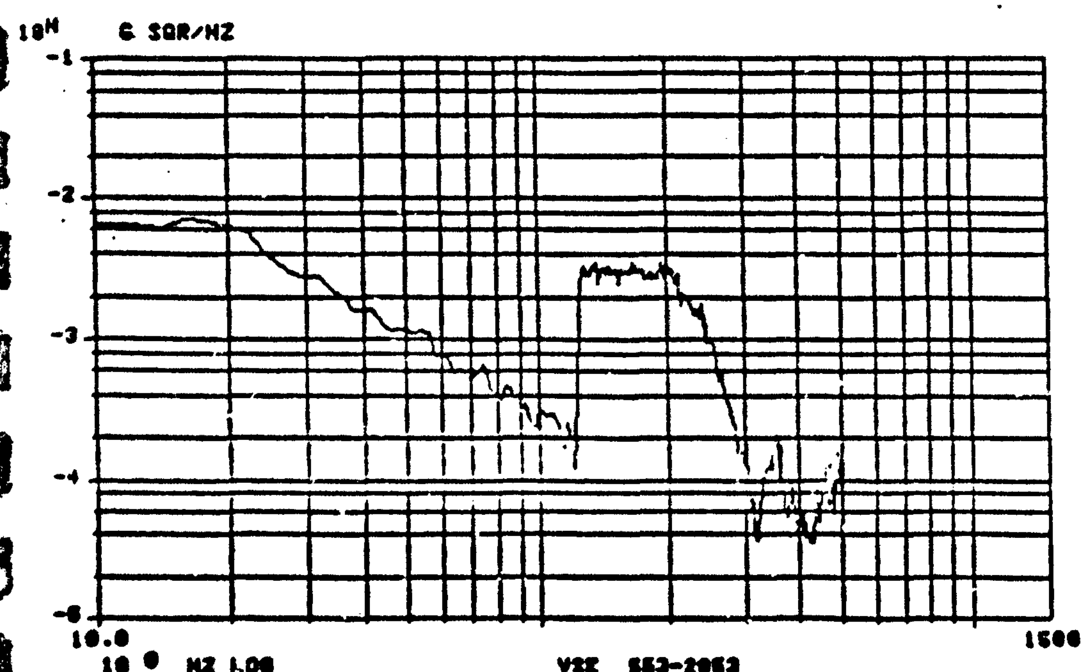
VERTICAL AXIS
CONTROL: POST TEST
RMS LEVEL = 1.049 G'S

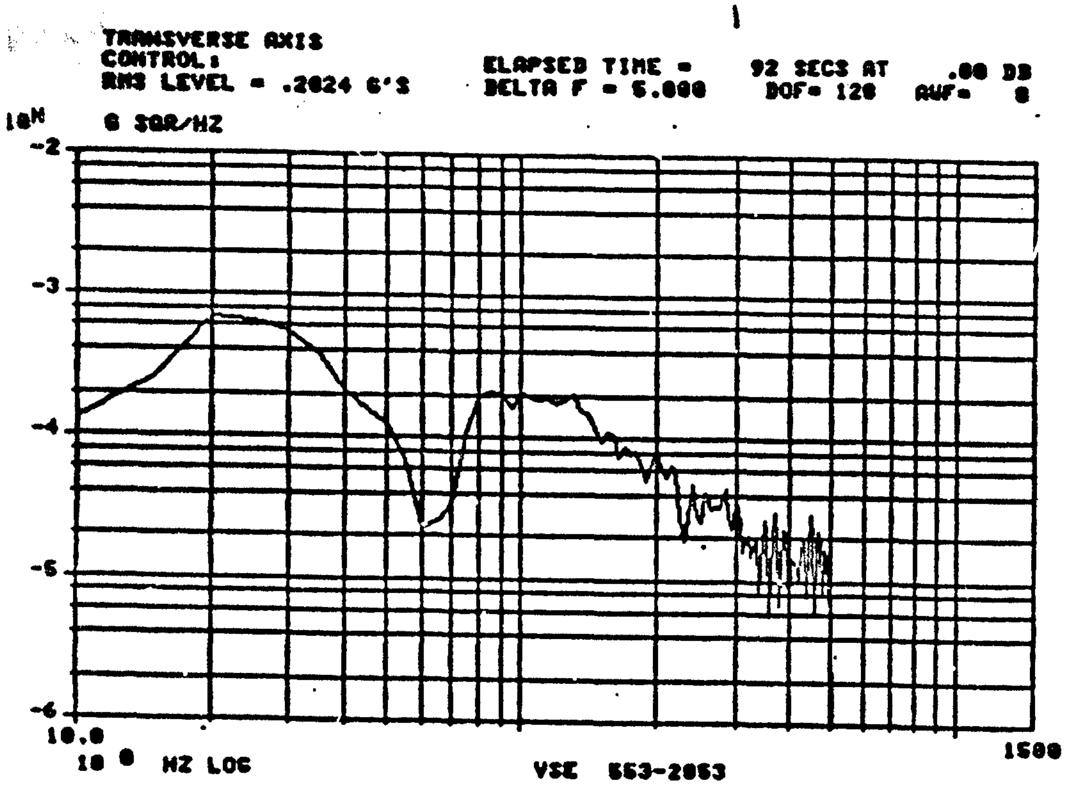
ELAPSED TIME = 1620 SECS AT .00 DB
DELTA F = 5.000 DOF= 0 AVF= 0



LONGITUDINAL AXIS
CONTROL:
RMS LEVEL = .7359 G'S

ELAPSED TIME = 70 SECS AT .00 DB
DELTA F = 2.000 DOF= 119 AVF= 0





TRANSVERSE AXIS
CONTROL:
RMS LEVEL = .2024 G'S
ELAPSED TIME = 92 SECS AT .00 DB
DELTA F = 5.000 DOF= 120 AVF= 8
10N G SQR/HZ
-2
-3
-4
-5
-6
10.0
10 0 HZ LOG
1500
VSE 553-2053

APPENDIX C

HONEYWELL SIGNAL ANALYSIS CENTER

TEST DATA SHEETS

Test Equipment List

NOMENCLATURE	MANUFACTURER	MODEL NUMBER	PROPERTY NUMBER	CALIBRATION DUE DATE
Spectrum Analyzer	HP	8568B	6372	20 FEB 87
Disc Drive	HP	82901M	6385	20 FEB 87
Monitor	HP	216	6386	20 FEB 87
Plotter	HP	7475A	6356	20 FEB 87
Bicon Antenna	EMCO	3104	5313	24 MAR 87
Rod Antenna 40"	Honeywell	2825	4602	10 AUG 87
Log Spiral Antenna	EMCO	3101	5398	10 OCT 87
Current Probe	Stoddard	91550-1	0252	24 OCT 87
Preamp	Avantek	AWL-500B	5438	23 DEC 87
Preamp	ASI	8375	6197	3 DEC 87
Attenuator	HP	8496B	6244	3 JUL 87

Honeywell SIGNAL ANALYSIS CENTER

TEST DATA Sheet____ of ____

TEST NO. ________ TEST REO2 BB TRANSIENT TEST INST. ________

DATE 2/11/87 ENG. LEE SERIAL NO. ________

LOCATION LAB 7 WITNESS BAKER ANT/PROBE ________

REMARKS HONEYWELL CONTROLLER M/N H46C

BW (HZ)		FREQ (HZ)		SIGNAL LEVEL (dBμV)	ATT db	IBW FACTOR dB	PROBE/ ANT FACTOR dB					CORR LEVEL dBμV/m/MHZ	LIMIT dBμV/m/MHZ	REMARKS PULSE DURATION
1K		14K		34	20	-55.2	6					4.8	120	1mS
10K		200K		48.9		-35.5						39.4	87.5	280μS
30K		1.2m		41.5		-26.2						41.3	79	120μS
30K		14.8M		31.2		-26.2						31.1	67	100μS
300K		400M		23.3		-5.8	18.5					43.5	61.5	100μS

Data Sheet A-5. Honeywell Controller M/N H46C Test Results, RE02, BB.

Honeywell SIGNAL ANALYSIS CENTER

RE02 BB.

TEST DATA Sheet____of____

TEST NO. ______ TEST TRANSIENT TEST INST. ______
DATE 2/11/87 ENG. LEE SERIAL NO. ______
LOCATION Lab 7 WITNESS BAKER ANT/PROBE ______
REMARKS HONEYWELL CONTROLLER M/N H600A

BW		FREQ (HZ)		SIGNAL LEVEL (dBuV)	ATT db	IBW FACTOR dB	PROBE/ANT FACTOR dB					CORR LEVEL dBuV/m/MHZ	LIMIT dBuV/m/MHZ	REMARKS
														Pulse DURATION
1K		14K		58.7	20	-55.2	6					29.5	100	1mS
10K		200K		58.4		-35.5						48.9	87.5	200uS
30K		1.2M		47.1		-26.2						47	79	100uS
30K		14.8M		40.4		-26.2						40.2	67	100uS
300K		400M		23		-5.8	18.5					55.7	61.5	100uS

Data Sheet A-6. Honeywell Controller M/N H600 A Test Results, RE02, BB

APPENDIX D

TEST REPORT FOR HUMIDIFICATION EQUIPMENT

APPENDIX D

TEST PLAN FOR HUMIDIFICATION, DEHUMIDIFICATION AND HUMIDITY CONTROL EQUIPMENT

Report No. VSE/ASG/0024-87/04RD

TEST REPORT FOR HUMIDIFICATION EQUIPMENT EVALUATED FOR USE WITHIN THE U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

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Prepared by:

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2550 Huntington Avenue
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11 February 1987

Final Report for Period 9 January 1987 - 11 February 1987

This document has been approved for public release and sale; its distribution is unlimited.

Prepared for:

U. S. Army Belvoir Research, Development
and Engineering Center
Environmental Control Division
Fort Belvoir, Virginia 22060

TEST REPORT
FOR
HUMIDIFICATION EQUIPMENT
EVALUATED FOR USE WITHIN THE
U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

Test preformed by:

VSE Corporation and Subcontractors

Testing Initiated: 9 January 1987

Testing Completed: 11 February 1987

The citation of trade name and names of manufacturers in this report is not to be construed as official endorsement or approval of commercial products or services referenced herein.

The views, opinions, and/or findings contained in the report are those of the authors and should not be construed as an official Department of the Army position, policy, or decision, unless designated by other documentation.

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Two commercial off-the-shelf steam generating humidifiers were tested to determine suitability for use in the Aircraft Service Shelter. The Dri Steem humidifier model VM2 is recommended for the application. In order for the unit to perform satisfactorily, modifications must be incorporated to improve response time and reduce overall dimensions.

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22a. NAME OF RESPONSIBLE INDIVIDUAL: Mr. Robert A. Rhodes, Jr.

22b. TELEPHONE (Include Area Code): (703) 664-6031

22c. OFFICE SYMBOL: STRBE-FE

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.
All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Appendices

1.0 REASON FOR TESTING - GENERAL

The reason for the test series described herein was to ascertain performance data with which to evaluate the technical and operational feasibility of selected humidification equipment for use in the Air Force Aircraft Service Shelter. The Aircraft Service Shelter is an integral part of the F-16 maintenance complex. The approved test plan upon which the ensuing test is based, is provided in Appendix D.

2.0 APPLICABLE DOCUMENTS

Statement of Work and Services dated 14 July 1986, Task Order 0024, Contract No. DAAK70-86-D-0023.

MIL-STD-461; Electromagnetic Emission and Susceptibility Requirements for the control of Electromagnetic Interference.

MIL-STD-462; Electromagnetic Interference Characteristics, Measurement of.

MIL-P-514; Plates, Identification, Instruction and Marking, Blank.

MIL-H-759; Human Factors Engineering Design for Army Materiel.

MIL-STD-810; Environmental Test Methods and Engineering Guidelines.

MIL-STD-1472; Human Engineering Design Criteria for Military Systems, Equipment and Facilities.

MIL-STD-1473; Standard General Requirements for Color and Marking of Army Materiel.

AR 70-38; Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.

3.0 DESCRIPTION OF TEST SAMPLES

3.1 General. Two steam generator humidifiers were procured for testing as a result of a market survey and selection criteria provided by the Tactical Shelter Systems Office at Hanscom Air Force Base.

3.2 Dri Steem Humidifier Model VM2. The Dri Steem humidifier is a steam generation unit with a rated capacity of 6 pounds per hour. The humidifier possesses a stainless steel evaporating chamber with a single 2kW heating element. Evaporating chamber water level is sensed by a three probe conductivity sensor which cycles on and off, a solenoid operated fill valve and the heating element. The unit possesses a drain/flush feature designed to increase time between servicing. An internal control module contains an integral electronic timer which accumulates humidifier "ON" time. When accumulated "ON" time reaches the timer set point, the drain/flush cycle operates for 10 minutes. The unit contains a 265 cfm blower which distributes the emitted steam throughout the conditioned space. Evaporating chamber, junction box and blower assembly are housed within a heavy gauge steel cabinet. The unit is 120V, single phase, 60Hz and weighs 118 pounds operating.

3.3 Autoflo Humidifier Model L-1011-K. The Autoflo humidifier is a steam generation unit with a rated capacity of 4.6 pound per hour. The humidifier possesses a stainless steel heated pan with a single 1.4kW heating element. The pan water level is controlled by a float valve and low water protection is provided by a float switch. Steam dispersion is accomplished with a fan assembly. A simple shaded pole electric motor with a plastic axial fan is mounted in a sheet metal housing. The unit is 120V, single phase, 60Hz and weighs 35 pounds operating.

4.0 DISPOSITION OF TEST SAMPLES

The two humidifiers tested will be kept at VSE Corporation until task completion, at which time they will be transmitted to the Environmental Equipment Division at Fort Belvoir.

5.0 ABSTRACT, CONCLUSIONS AND RECOMMENDATIONS

Two commercial steam generation humidifiers were tested to determine their technical and operational feasibility for use as part of a humidity control system in the Aircraft Service Shelter. The humidifiers were subjected to the following tests:

- Human Factors Evaluation
- Sound Level
- Tilted Operation
- Variable Voltage and Frequency
- Capacity
- Vibration
- High Temperature Storage
- Low Temperature Storage
- Electromagnetic Interference (EMI)

The human factors evaluation revealed that a significant burn hazard exists with both humidifiers. The Dri Steem unit has an exposed steam distribution tube. The Autoflo unit has an unguarded back which allows the possibility of coming in contact with the heated water and the rotating fan. The Dri Steem unit is a two man lift. No handles are provided for safe lifting. The potential for lacerating personnel exists with the Autoflo unit since corner edges of the housing are not radiused or buffed.

Both humidifiers demonstrated very low sound levels.

Neither humidifier will function properly when tilted 5° in certain directions. The maximum allowable tilt for the Dri Steem unit is 2°, and the maximum allowable tilt for the Autoflo unit is 1°.

Both humidifiers operated satisfactorily during each of the four combinations of variable voltage and frequency tested.

The humidifiers were undamaged and functioned properly following the vibration test.

Capacity tests demonstrated that neither humidifier met the 5.4 pounds per hour minimum acceptable capacity. Two Autoflo units would be necessary to meet minimum capacity, or use of a single 208 Volt version of the unit. The Dri Steem unit possesses a cycling refill mode which greatly reduces the effective rate of humidification. The method for refill must be modified to make this unit acceptable. Another option is to use the 208V version which has twice the rated capacity.

The humidifiers were undamaged and functioned properly following the high and low temperature storage tests.

Both humidifiers were below the conducted and radiated EMI emission level limits imposed by methods CE03 and RE02 of MIL-STD-461, Part 4 for steady state conditions. The units exceed the limits for transients, however all transient durations were much less than the 1 second duration allowable for military standard air conditioners.

Based on the test results it is recommended that the Dri Steem model VM2 be used to humidify the air within the Aircraft Service Shelter. Use of the VM2 will require modifications for achieving the necessary capacity and other modifications deemed necessary for human factors compatibility, etc.

6.0 FACTUAL DATA - TESTING

6.1 Human Factors Evaluation. The human factors engineering (HFE) assessment of the two humidifiers was performed using established military standards and guidelines as documented in MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment and Facilities and MIL-H-759, Human Factors Engineering Design for Army Materiel.

6.1.1 Reason for Evaluation. The humidifiers were assessed for human factors to determine their compatibility with MIL-STD-1472 and MIL-H-759.

6.1.2 Description of Evaluation Apparatus. The following equipment and instrumentation were used during this evaluation:

- Thermocouple indicator, Thermo Electric, 18 channel
- Thermocouple, copper-constantan
- Common screwdriver

6.1.3 Evaluation Procedure. The humidifiers were evaluated by a human factors engineer to determine conformance to Human Factors Engineering principles and practices as described in MIL-STD-1472 and MIL-H-759. Special design emphasis was given, but not limited to, Paragraphs 4 (General Requirements), 5.5 (Labeling), 5.9 (Design for Maintainability), and 5.12 (Hazards and Safety), of MIL-STD-1472, as applicable.

6.1.4 Evaluation Results and Analyses

6.1.4.1 Dri Steem Model VM2. The unit electrical rating is 120VAC, 1 phase, 60Hz, 20amp. Unit is two part with the fan distribution section weighing 35 pounds and the humidifier section weighing 83 pounds. Total operating weight is 118 pounds.

a. **Unit is a two person lift minimum.** There are no handles for lifting.

b. Distance between bottom of cabinet and floor is inadequate for gripping and lifting, and even if adequate would put undue strain on lifting personnel due to awkward positioning. Also, sections are not secured together and could separate while being lifted.

c. Exterior cover is smooth, providing no gripping/lifting capability.

d. Unit has no wheels, thus mobility/transportability is limited.

e. Exterior finish unknown. No tests were completed to determine ability to withstand oils, lubricants, fuels, cleaners etc.

f. The two flat surfaces on the exterior top of the unit sections provide an area to rest tools, parts etc. This may be acceptable, however, the steam dispersion manifold on the humidifier sections presents a distinct burn hazard when reaching for articles resting on the top.

g. Metalwork on cabinets is adequate to eliminate/reduce cutting, snagging of personnel/clothing.

The unit is composed of a humidifier section and a fan distribution section. Evaluation of each is presented respectively.

h. Humidifier Section

- Caution sign not in accordance with MIL-STD-1472/MIL-P-514/MIL-STD-1473.
- Terminal block not labeled J1, J2, etc.
- Hot wires not labeled (all are colored red).
- Lead/terminal connections to PC boards are color coded, not labeled.
- Hot wires have no connectors, just bare wire.
- Instruction placard on side of electrical wiring bulkhead should be a caution. A separate instruction placard should be attached in an area unobstructed by other components.
- A strain relief should be used for main lead-in wires.

- There is ample area for accessing components.

- Has water outlet to provide for drainage and overflow protection.

i. Fan Distribution Section

- Labels inadequate; not positioned to be obvious to personnel; not in accordance with MIL-STD-1472 for character configuration and color.

- Electrical terminals inadequately labeled.

- Cabinet finish is adequate.

- Interior cabinet flanges should be radiused (.03 min) to prevent snagging/cutting of personnel/clothing.

- Steam distribution tube is open and accessible from exterior of cabinet. This is a burn hazard. The surface temperature of the tube is 180°F as measure with thermocouple. No protective guard is present.

- No warning label on/around steam distribution tube warning of excessive temperature.

j. Front Panel

- Panel lights are positioned as follows:

  Color of light is in ( )

Fill	Ready	Drain
(Yellow)	(Green)	(Red)

- Color of lights and their associated functions are not in accordance with MIL-STD-1472, i.e. a red light indicates malfunction, failure, system damage, etc. Lights should be green or white. Any fault detections should be red/yellow.

6.1.4.2 Autoflo Model L-1011-K. The unit electrical rating is 120VAC, 1 phase, 60Hz, 15amp. Unit is single piece which is capable of being separated into the fan distribution section and humidifier section. Total operating weight is 35 pounds which is well within single person lift capability. No handles, but unit is small enough and light enough to be carried by one person.

a. Water Holding and Heating Section

- Encompasses lower part of the unit.

- Has water inlet to allow water reservoir to fill to a specific level. Water level controlled by a float valve.

- Has water outlets to provide for drainage and overflow protection.

- Both inlet and outlet are standard 3/4" nominal pipe.

- Cover caps for inlet/outlet are not captive, thus increasing possibility of loss.

- Fill tank is stainless steel to prevent corrosion.

- Electrical control unit is attached to front of unit, covered with a removable panel attached by several screws.

- Water holding tank and heating element are exposed from the rear of the unit. The operating temperature of the water is 212°F as measured with thermocouple. This presents a definite burn hazard. No labels are posted anywhere on the unit warning of this danger.

- The holding tank is separated from the outer cabinet skin, thus reducing unit exterior temperature to a non-hazardous level.

b. Electrical Controls

- Wires are color coded, however, terminals are not identified.

- Accessibility to electrical connections/components is good, once cover is removed.

- Cover is secured with six screws thus reducing potential for accidental removal.

c. Dispersion Fan and Housing Section

- Housing fits atop water holding and heating section.

- Intake fan is located at front of unit, drawing in air and pushing it across heated (boiling) water.

- Rear of housing is totally open - possibly to allow attachment of ductwork, but if no duct is present, boiling water and resistance coils are accessible.

- Corner edges of housing are not radiused nor buffed, creating cutting/snagging/puncture hazards.

- From the rear of the unit the fan has no guard over the rotating blades. Blades are plastic with honed edges. Fan is not accessible from front of unit as it is covered with an inlet grill/guard.

6.2 Sound Level

6.2.1 Reason for Test. Test was performed to determine sound level of humidifiers during operation.

6.2.2 Description of Test Apparatus. The following instrumentation was used to conduct the sound level test:

- Sound level meter, GenRad model 1988, 0-140 dB range, ID no. 005633, calibrated 10/13/86, recalibration due 4/13/87.

6.2.3 Test Procedure. Humidifier was placed in a large quiet room. The background noise level was measured. The "A" weighted decibel levels were recorded at 36" and 1" distances from the humidifiers in the front, left side, right side, and rear positions. Readings were taken in the octave band center frequencies with the sound level meter positioned 36" from the humidifier's discharge.

6.2.4 Test Results and Analyses. Neither humidifier is an appreciable source of noise. Measured sound levels at 36" fall well below the dB(A) criteria of category F in Table 2 of MIL-STD-1474. Category F requirements are imposed in shelters where frequent telephone or radio use or frequent direct communication at distances up to 5' is required. Data sheets are provided in Appendix A.

6.3 Tilted Operation.

6.3.1 Reason for Test. Test was performed to determine affect of a 5° tilted orientation on humidifiers and to determine maximum allowable tilt for satisfactory operation if less than 5°.

6.3.2 Description of Test Apparatus. The following equipment was used to conduct the tilted operation test:

- Level indicator, bubble type, adjustable
- Wood wedge used to impart tilt to humidifiers

6.3.3 Test Procedure. Humidifiers were tilted 5° on each of the unit's four sides (front side up, back side up, right side up, and left side up). Units were observed for detrimental consequences. The worst case tilt direction for each unit was determined. Units then were operationally tested in the worst direction to determine what degree of tilt is permissible for satisfactory operation.

6.3.4 Test Results and Analyses. The tests revealed that neither of the humidifiers will operate properly if tilted 5° in the wrong direction. The Dri Steem humidifier allows water from the evaporator chamber to drain through the skimmer port when the unit is tilted with the back side up or the left side up as viewed from the unit discharge side. When tilted in either of these orientations the unit will continuously fill and drain simultaneously. The humidifier then was operated in the worst case orientation (left side up) to determine what degree of tilt, if any, is acceptable. Unit was found to fill properly without draining though the skimmer port at 2° tilt.

The Autoflo humidifier also had problems with filling and draining simultaneously when tilted. The Autoflo unit allows water from the reservoir to drain through to overflow port with the back side up or the right side up as viewed from the unit intake side. The humidifier then was operated in the worst case orientation (back side up) to determine what degree of tilt, if any, is acceptable. The unit was found to fill properly without draining through the overflow port at 1° tilt. The float valve stem may be adjusted to overcome positional problems by bending stem.

Neither unit experienced a problem with water discharging from the respective water reservoirs (other than through drain ports). There were no exposed heating elements to cause overheating. Data sheets are provided in Appendix A.

6.4 Variable Voltage and Frequency

6.4.1 General. The variable voltage and frequency test was performed at National Technical Systems (NTS) in Hartwood, Virginia.

6.4.2 Reason for Test. Humidifiers were operated at various input power conditions to insure 15 minute continuous operation at other than design electrical characteristics.

6.4.3 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the variable voltage and frequency test.

- Motor driven alternator, Kato Co., 15kW (NTS Equipment)
- Voltmeter, Weston, ID no. E 6024 D, calibrated 8/8/86, recalibration due 2/8/87 (NTS Equipment)
- Ammeter, Weston, ID no. E 6242 D, calibrated 8/8/86, recalibration due 2/18/87 (NTS Equipment)
- Frequency meter, Weston, ID no. E 6220 D, calibrated 8/18/86, recalibration due 2/18/87 (NTS Equipment)
- Sling psychrometer, Bacharach code 12-7012
- Wrist watch, Seiko

6.4.4 Test Procedure. Humidifiers were subjected to the following input power conditions:

Test	Voltage Condition	Frequency Condition	Voltage VAC ± .5V	Frequency Hz ± 2Hz
1	High	High	132	60
2	Low	Low	108	50
3	Low	High	108	60
4	High	Low	132	50

Test began with test 1 power conditions on the first humidifier. The humidifier was powered 15 minutes and observed for continuous operation. The humidifier then was allowed to soak at ambient conditions for 30 minutes. Following soak period the humidifier was operated at test 2 power conditions for 15 minutes. Each 15 minute test was followed by a 30 minutes soak until all four tests were completed on both humidifiers.

6.4.5 Test Results and Analyses. The Dri Steem and the Autoflo humidifiers both operated satisfactorily during all variable voltage and frequency testing. The blower thermal switch for each humidifier was jumpered to observe continuous operation of blowers. After initiation of testing it was discovered that a significant voltage drop existed between the motor driven alternator and the humidifier input connections. The 132V, 60Hz condition for both units had to be rerun due to an approximate 11 volt drop through the power lines for the Dri Steem unit and an approximate 6 volt drop through the power lines for the Autoflo unit. Data sheets are shown in Appendix A.

6.5 Capacity

6.5.1 General. The 50Hz capacity test was performed at NTS in Hartwood, Virginia using their 15kW motor driven alternator. The 60Hz capacity test was performed at VSE using house power.

6.5.2 Reason for Test. Capacity test was required to insure a minimum humidification rate of 5.4 pounds per hour. Capacity test was also required to determine the steam discharge rate of humidifiers at both 50Hz and 60Hz operation.

6.5.3 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the capacity test:

- Motor driven alternator, Kato Co., 15kW (NTS Equipment)
- Voltmeter, Weston, ID no. E 6024 E, calibrated 8/8/86, recalibration due 2/8/87 (NTS Equipment)
- Ammeter, Weston, ID no. E 6242 D, calibrated 8/8/86, recalibration due 2/18/87 (NTS Equipment)
- Frequency meter, Weston, ID no. E 6220 D, calibrated 8/18/86, recalibration due 2/18/87 (NTS Equipment)
- Voltmeter, Weston Model 341, 0-300 volt range, S/N 1480
- Ammeter, Weston Model 904, 0-5 amp range, ID No. 3313
- Frequency counter, Dynascan Corp. model 1851, 0-520 MHz range, ID No. 4151
- Current transformer, Weston Model 461, S/N 1497
- Current transformer, Weston Model 461, S/N 1501
- Sling psychrometer, Bacharach code 12-7012
- Water reservoir, 10 gallon plastic tank
- Weight scale, Accu-Weigh model 126TDX/L, 0-125 pound range with .05 pound resolution
- Wrist watch, Seiko

6.5.4 Test Procedure. The humidifier was placed in an indoor ambient environment. The humidifier water inlet was connected to water reservoir in such a way as to allow gravity feed of supply water. Humidifier was operated a sufficient time prior to actual test to insure unit was up to normal operating temperature. Water reservoir was weighed at test initiation. The unit then was allowed to operate undisturbed for one hour. Immediately following the one hour period the water reservoir was reweighed. Two tests were performed on each humidifier, one at 120V, single phase, 50Hz and the second at 120V, single phase, 60Hz.

6.5.5 Test Results and Analyses Neither the Dri Steem nor the Autoflo humidifiers emitted steam at the minimum allowable rate of 5.4 pounds per hour. This fact would necessitate the use of two units to achieve the minimum required steam rate, or the use of a unit of higher capacity, or modifying tested equipment to increase capacity.

The cyclic water refill function on the Dri Steem unit made accurate capacity testing difficult. The Dri Steem humidifier was gravity filled until the "ready water" signal was given, at which time the inlet water solenoid valve closed. The weight of the water reservoir was recorded at this time. The unit emitted steam until the low water sensor activated which de-energized the heating elements and opened the inlet water solenoid valve to refill the humidifier. The weight of the water reservoir was recorded for the second time. The difference between the first and second reservoir weights, minus the water that drained through the units skimmer port, represented the moisture steamed into the air. The unit is wired such that the heating element shuts down during the refill mode. Gravity fed make up water required approximately 7 minutes to refill the unit. Following refill, the heating elements energized requiring approximately 10 minutes before steam again emanated from the unit. This sequence of events resulted in a 17 minute lag time with no steam generation on each refill cycle. Unit refills approximately once an hour.

The effective capacity for the Dri Steem unit at 120V-50Hz was 4.4 pounds per hour. However, the unit emitted 4.4 pounds into the air in 44 minutes. Assuming the unit can be modified to allow the heating element to remain on during refill, the effective capacity should increase to approximately 6.0 pounds per hour as proportioned below:

4.4 pounds is to 44 minutes as X pounds is to 60 minutes

$X = 6.0$

The effective capacity at 120V-60Hz was 5.3 pounds per hour. The skimmer port was plugged during this test to alleviate the necessity to measure drain water. The unit emitted 5.3 pounds per hour into the air in 55 minutes. Assuming the heating element circuitry is modified, the effective capacity should increase to approximately 5.8 pounds per hour as proportioned below:

5.3 pounds is to 55 minutes as X pounds is to 60 minutes

$X = 5.8$

The difference between the expected capacities at 50 and 60 Hz is probably due to the 8 Volt drop through the power lines during the 60 Hz test.

The Autoflo humidifier possesses a float valve which allows continuous refilling. The unit capacity was below 5.4 pounds per hour. The 50 Hz test capacity was 4.2 pounds per hour. The 60 Hz capacity was 3.6 pounds per hour.

The difference between the two tests may be attributable to the 6 Volt drop through the power lines during the 60 Hz test. No voltage drop was experienced at the unit during the 50 Hz test at NTS since the power supply was adjustable.

It appears that the alternatives for achieving minimum humidification capacity from the Dri Steem humidifier are (1) modify the unit such that the heating element remains on during the refill cycle or (2) use of the Dri Steem model VM4 which has double the rated capacity (12 pounds per hour). The alternative for the Autoflo unit would be use of the Autoflo X-15B which has a rated capacity of 6.6 pounds per hour. The higher capacity units both require 208 Volts. Data sheets are provided in Appendix A.

6.6 Vibration

6.6.1 General. The actual vibration test was performed at NTS in Hartwood, Virginia. The operation check out following vibration was performed at VSE.

6.6.2 Reason for Test. This test was performed to determine the effect of simulated transportation vibration on humidification equipment.

6.6.3 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the vibration test.

- Vibration Exciter, MB Electronics model C210, ID no. D 6306 D (NTS Equipment)

- Vibration Control System, Hewlett-Packard, ID no. D 6054 D, calibrated 6/5/86, recalibration due 6/5/87 (NTS Equipment)

- Accelerometer, PCB, ID no. D 6155 D, calibrated 12/2/86, recalibration due 6/2/87 (NTS Equipment)

- Power Supply, PCB, ID no. D 6093 D, calibrated 11/11/86, recalibration due 5/11/87 (NTS Equipment)

- Fixtures, aluminum base plate with metal banding to secure humidifiers to base plate. (NTS Equipment)

- Voltmeter, Weston model 341, 0-300 volt range S/N 1480.

- Ammeter, Weston model 904, 0-5 amp range ID no. 3313.

- Current transformer, Weston model 461, S/N 1497.

- Current transformer, Weston Model 461, S/N 1501.

- Frequency counter, Dynascan Corp. model 1851, 0-520 MHz range, ID no. 4151

6.6.4 Test Procedure. Fixtured humidifiers were mounted on vibration machine. Equipment was vibrated in accordance with MIL-STD-810, Method 514.3, Table 514.3-1, Category 1, Test Procedure 1, Figures 514.3-1 through 3. Equipment was vibrated in three planes (longitudinal, transverse, vertical) for a duration of 30 minutes per plane. Humidifiers were mounted in their normal operating position throughout vibration test. The two float valves in the Autoflo humidifier were packed with newspaper to prevent contact with heating elements. The slide mounted evaporating chamber in the Dri Steem humidifier was packed with newspaper to prevent contact with housing. Vibration inputs were monitored by averaging responses of four accelerometers located in four corners of base plate fixture. Humidifiers were operated following vibration. Units were observed for any evidence of damage.

6.6.5 Test Results and Analyses. Both humidifiers endured the vibration test without mishap. No physical damage to the humidifiers could be detected other than minor deformation of the Autoflo blower housing which resulted from tightening the metal banding supports. The functional test proved that the humidifiers operated satisfactorily following vibration. Data sheet is provided in Appendix A.

6.7 High Temperature Storage

6.7.1 Reason for Test. High temperature storage test was performed to determine the effect of extreme high temperature on humidifiers.

6.7.2 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the high temperature storage test:

- Environmental chamber manufactured by Thermotron. Chamber volume is 38" x 38" x 38" with a temperature range of +265°F to -100°F.
- Thermocouple indicator, Thermo Electric, 18 channel.
- Thermocouple, copper-constantan.
- Voltmeter, Weston model 341, 0-300 volt range, S/N 1480.
- Ammeter, Weston model 904, 0-5 amp range, ID No. 3313.
- Current transformer, Weston model 461, S/N 1497.
- Current transformer, Weston model 461, S/N 1501.
- Frequency counter, Dynascan Corp. model 1851, 0-520 MHz range, ID No. 4151
- Wrist watch, Seiko.

6.7.3 Test Procedure. The humidifiers were placed in test chamber and the chamber then stabilized at 160 ± 5°F. Chamber temperature was verified with a thermocouple. Humidifiers were soaked at 160 ± 5°F for a minimum continuous period of 4 hours. After exposure period, test samples were removed from chamber and examined for deterioration and damage. Following examination, test samples were soaked at room conditions for 1 hour. The units were operated 15 minutes following 1 hour soak to verify function.

6.7.4 Test Results and Analyses. Both humidifiers endured the high temperature storage test without mishap. No physical damage or deterioration could be detected. The humidifiers functioned properly during the operational check out. Data sheet is provided in Appendix A.

6.8 Low Temperature Storage

6.8.1 Reason for Test. Low temperature storage test was performed to determine the effect of extreme low temperature on humidifiers.

6.8.2 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the low temperature storage test:

- Environmental chamber manufactured by Thermotron. Chamber volume is 38" x 38" x 38" with a temperature range of +265°F to -100°F.
- Thermocouple indicator, Thermo Electric, 18 channel.
- Thermocouple, copper-constantan.
- Voltmeter, Weston model 341, 0-300 volt range, S/N 1480.
- Ammeter, Weston model 904, 0-5 amp range, ID No. 3313.
- Current transformer, Weston model 461, S/N 1497.
- Current transformer, Weston model 461, S/N 1501.
- Frequency counter, Dynascan Corp. model 1851, 0-520 MHz range, ID no. 4151
- Wrist watch, Seiko.

6.8.3 Test Procedure. The humidifiers were placed in test chamber and the chamber then stabilized at -60 $\pm$ 5°F. Temperature was verified with a thermocouple. Humidifiers were soaked at -60 $\pm$ 5°F for a minimum continuous period of 12 hours. After exposure period, test samples were removed from chamber and examined for deterioration and damage. Following examination, test samples were soaked at room conditions for 1 hour. The units were operated 15 minutes following 1 hour soak to verify function.

6.8.4 Test Results and Analyses. Both humidifiers endured the low temperature storage test without mishap. No physical damage or deterioration could be detected. The humidifiers functioned properly during the operational check out. Data sheet is provided in Appendix A.

6.9 Electromagnetic Interference (EMI)

6.9.1 General. The EMI test was performed by the Honeywell Signal Analysis Center in Annapolis, Maryland.

6.9.2 Reason for Test. EMI testing was performed on humidifiers to evaluate the equipment's electromagnetic steady state and transient emissions in accordance with MIL-STD-461. Conducted and radiated emissions were compared with limits imposed by methods CE03 and RE02 of MIL-STD-461, Part 4.

6.9.3 Description of Test Apparatus. The equipment and instrumentation used by Honeywell to conduct the EMI test are listed in Appendix C.

6.9.4 Test Procedure. The humidifiers were connected to 120V/1 phase/60Hz power for all testing. The humidifier blower motor thermal switches were jumpered to ensure blower operation during all testing.

The humidifiers were tested in accordance with test procedures specified in MIL-STD-462. The humidifiers were tested for steady state and transient emissions and compared with limits imposed by methods CE03 for conducted emissions and RE02 for radiated emissions of MIL-STD-461, Part 4.

The conducted emissions were measured through the frequency range of 15 KHz to 50 MHz for broadband interference on power input leads. The radiated emissions were measured through the frequency range of 14 KHz to 1 GHz for broadband emissions. Antenna equipment was oriented at one meter distance from test unit. The Honeywell H46C humidity control was wired to each humidifier in order to cycle the units on and off.

6.9.5 Test Results and Analyses. It should be noted that the EMI emissions for the Honeywell H46C humidity control were included with the emissions of the humidifiers during transient testing. The steady state emissions for the Dri Steem and Autoflo humidifiers were well below the limits imposed by CE03 and RE02. The units generate low level noise and emit no strong signals. Both humidifiers exceeded the CE03 and RE02 limits for transients. However, Military Standard air conditioners and related equipment are allowed transients which exceed the CE03 and RE02 limits if the transients are less than 1 second in duration. The observed transients for the humidifiers were considerably less than 1 second in duration. EMI testing performed by the Belvoir RD&E Center on the heat pump used in the Aircraft Service Shelter demonstrated that this unit also exceeds the RE02 limits for transients. VSE believes the transient emissions for the humidifiers will not pose a problem in the service shelter and that equipment modifications are unnecessary. Data sheets are provided in Appendix C.

APPENDIX A

VSE TEST DATA SHEETS

DATA SHEET

DATE: 1/15/87

TEST PERFORMED BY: L. Lawrence

M. Baker

SOUND LEVEL TEST

Background sound level dB(A) - 46.9

[illegible] Steam Humidifier

Distance from unit →	36"	1"
Measurement Position	dB ~~[illegible]~~ (A)	dB ~~[illegible]~~ (A)
Front (discharge)	57.8	78.7
Left Side	54.5	63.7
Right Side	55.7	74.7
Rear	52.9	59.9

Octave Band Center Frequencies - Hz	[illegible]
63	65.2
125	60.1
250	56.4
500	55.8
1000	51.9
2000	50.4
4000	45.9
8000	42.2

Microphone was positioned "30" above floor

Autoflo Humidifier

Distance from unit / Measurement Position	36" dB (A)	1" dB (A)
Front (discharge)	51.6	69.4
Left Side	51.0	56.0
Right Side	51.4	56.7
Rear	51.1	65.2

Octave Band Center Frequencies - Hz	Humidifier Discharge at 36" distance (dB)
63	53.5
125	55.2
250	55.5
500	47.9
1000	45.3
2000	38.1
4000	33.2
8000	27.4

Microphone was positioned 30" above floor

DATA SHEET

DATE: 1/12/87
TEST PERFORMED BY: M. Buker

TILTED OPERATION TEST

Humidifier: Dri Steem

Results of 5° Tilt Observations:

Right side tilt up - no apparent effect

Front side tilt up - no apparent effect

Back side tilt up - Water drains thru skimmer port

worst case → Left side tilt up - water drains thru skimmer port

Tilting the back up and front up evaporator chamber contacts side of housing

Determination of Maximum Allowable Tilt for Satisfactory Operation

check refill ability with left side tilted up.

@ 3° tilt - Unit can not fill to conductivity sensor due to skimmer port. Unit fills and drains simultaneously.

@ 2° tilt - unit fills properly.

Humidifier: Autoflo

Results of 5° Tilt Observations:

Left side tilted up - Water level float valve will allow additional water into pan. No adverse effects.

Right side tilted up - Water level is such that the water would continuously discharge thru overflow port during normal operation. Low water level float switch remains on.

Back side tilted up - water level is such that the water would continuously drain thru overflow port.

Front side tilted up - slightly less water is allowed into pan with no adverse effects.

Determination of Maximum Allowable Tilt for Satisfactory Operation

Worst case tilt condition is back side tilted up. By observing at what point water would begin draining ~~into~~ thru overflow port, it was determined that the unit can be tilted no more than 1° before simultaneous filling and draining began. Float valve may be adjusted by bending stem to compensate for tilted orientation.

DATE: 1/19/87

SAMPLE DATA SHEET

Blower [illegible] continuous blower operation during all testing.

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 132 Frequency condition: 60 Humidifier: [illegible]

	Time (min)	Ambient Temp. (^oF)	Voltage (Volts)	Current (Amps) x 2	Frequency (Hz)	Remarks
Preliminary	9:50	61°	120	8.4	60	Everything checks a OK
	9:54	61	132	9.15	60	Begin [illegible]
	9:59	61	132	9.15	60	
	10:04	62	132	[illegible]	[illegible]	
	10:09	62	132	9.15	60	End [illegible] test

All data above was recorded using NTS instrumentation

An approximate 11 volt drop existed in power lines — Test was rerun

DATE: 1/19/87

Blower thermal switch jumpered
ensure continuous blower operat
during all testing.

SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 132 Frequency condition: 60 Humidifier: [illegible]

	Time (min)	Ambient Temp. (°F)	Voltage (Volts)	Current (Amps) X2	Frequency (Hz)	Remarks
Preliminary	10:27	62	120	5.75	60	Baseline Data.
	10:29	62	132	6.3	60	Begin 132V, 60Hz [illegible]
	[illegible]	62	132	[illegible]	60	
	10:39	63	132	6.25	60	
	10:44	63	132	6.25	60	End test

All data above was recorded using NTS instrumentation
An approximate 6 volt drop existed in power lines - test was rerun

SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 108 Frequency condition: 50 Humidifier: Di stea

Time (min)	Ambient Temp. (^{o}F)	Voltage (Volts)	Current (Amps) X 2	Frequency (Hz)	Remarks
10:53	63	108	7.55	50	
10:58	[illegible]	108	7.5	50	
11:03	62	[illegible]	[illegible]	[illegible]	
11:08	62	108	7.5	50	An 11 volt drop thr power lines is discon this test was not rerun since conditions were actually 97V-5

SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 108 Frequency condition: 50 Humidifier: [illegible]

Time (min)	Ambient Temp. (°F)	Voltage (Volts)	Current (Amps)x2	Frequency (Hz)	Remarks
11:11	62	108*	5.15	50	
11:16	62	108*	5.15	50	
11:21	62	108.	5.32	50	
11:26	62	108	5.35	50	

* A 6 volt drop thru power lines is discov voltage is corrected for the 11:21 and 11:26 ..

SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 108 Frequency condition: 60 Humidifier: Dr[illegible]

Time (min)	Ambient Temp. (^{O}F)	Voltage (Volts)	Current (Amps) x 2	Frequency (Hz)	Remarks
11:33	62	108	8.15	60	
11:38	62	108	8.20	60	
11:43	62	108	8.15	60	
11:48	62	108	8.15	60	

SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 105 Frequency condition: 60 Humidifier: Auto

Time (min)	Ambient Temp. (°F)	Voltage (Volts)	Current (Amps) x 2	Frequency (Hz)	Remarks
11:58	62	108	5.30	60	
12:03	62	108	5.35	60	
12:08	62	108	5.35	60	
12:13	62	105	5.40	60	

SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 132 Frequency condition: 50 Humidifier: Dis

Time (min)	Ambient Temp. (°F)	Voltage (Volts)	Current (Amps) X4	Frequency (Hz)	Remarks
~~12:18~~ 12:24	62	132	5.0	50	
12:29	62	134	5.5	50	
12:34	62	132	5.0	50	
12:39	62	132	5.0	50	

SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 132 Frequency condition: 50 Humidifier: Auto

Time (min)	Ambient Temp. (^oF)	Voltage (Volts)	Current (Amps) x 4	Frequency (Hz)	Remarks
12:43	62	132	3.25	50	
12:48	62	132	3.20	50	
12:53	62	132	3.20	50	
12:58					

SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 132 Frequency condition: 60 Humidifier: Dri Steem

Time (min)	Ambient Temp. (^{o}F)	Voltage (Volts)	Current (Amps) x4	Frequency (Hz)	Remarks
13:06	62	132	5.0	~~50~~60	This test is a rerun of previous test
13:11	62	132	5.0	60	
13:16	62	132	5.0	60	
13:21	62	132	4.95	60	

SAMPLE DATA SHEET

VARIABLE VOLTAGE AND FREQUENCY TEST

Voltage condition: 132 **Frequency condition:** 60 **Humidifier:** Auto/lo

Time (min)	Ambient Temp. (°F)	Voltage (Volts)	Current (Amps) x4	Frequency (Hz)	Remarks
13:24	62	132	3.20	60	This test is a rerun of previous test
13:29	62	132	3.20	60	
13:34	62	132	3.20	60	
13:39	62	132	3.20	60	

DATA SHEET

DATE: 1/19/87
TEST PERFORMED BY: NTS person
M. Luker

CAPACITY TEST

50 or 60 Hz Operation

Humidifier: Dri Steem

Time	Ambient db(°F)	Temperatures wb(°F)	Voltage (Volts)	Current (Amps) x4	Frequency (Hz)	Remarks
14:04	66	53	120	4.50	50	begin capacity test @ 50Hz
14:19	63	54	120	4.50	50	
14:34	66	56	120	4.55	50	
14:48						Unit initiates refill cycle
14:55						Fill cycle complete

~ 1 lb water was collected in drain during test

Calculate capacity

$$\begin{array}{r} 21.0 \\ -15.6 \\ \hline 5.4 \end{array}$$

subtract drain water

$$\begin{array}{r} 5.4 \\ -1.0 \\ \hline 4.4 \end{array}$$

Approx. 4.4 lb is effective capacity in lb/hr

		Initial	21.0
			15.6
		d	

DATA SHEET

DATE: 1/19/87
TEST PERFORMED BY: NTS Personnel
M. Baker

CAPACITY TEST

50 or 60 Hz Operation

Humidifier: Autoflo

Time	Ambient db(°F)	Temperatures wb(°F)	Voltage (Volts)	Current (Amps)X4	Frequency (Hz)	Remarks
15:07	67	55	120	3.00	50	Begin capacity test @ 50 Hz
15:22	67	57	120	2.90	50	
15:37	68	56	120	2.90	50	
15:52	68	55	121	2.90	50	
16:07	67	56	120	2.90	50	Complete test

Calculate capacity 24.2
$-$ 20.0
4.2 lb/hr

Weight of Water Reservoir @ Test Initiation 24.2

Weight of Water Reservoir @ Test Conclusion 20.0

~~Weight of Water Reservoir @ Test Initiation~~

~~Weight of Water Reservoir @ Test Conclusion~~

DATA SHEET

DATE: 1/23/87
TEST PERFORMED BY: M. Crier

Dri Steam Humidifier

CAPACITY TEST

50 or 60 Hz Operation

Time	Ambient db(°F)	Temperatures wb(°F)	Voltage (Volts)	Current (Amps) X5	Frequency (Hz)	Remarks
8:12	70	54	115	4.20	60	- Skimmer port is plugged
8:27	70	54	115	4.20	60	- An approximate 8V drop is experienced thru power lines
8:42	71	55	115	4.20	60	
8:57	71	55	115	4.20	60	
9:07	71	55	115	4.20	60	unit begins refill mode, refill complete in ~ 7 minutes Unit begins steaming 10 minutes after refill is complete.

Weight of Water Resevior @ Test Initiation 25.6 lb

Weight of Water Resevior @ Test Conclusion 20.2 lb

Weight of Water Resevior @ Test Initiation ______

Weight of Water Resevior @ Test Condulsion ______

DATA SHEET

DATE: 1/22/87
TEST PERFORMED BY: M. Kaler

Hulaflo Humidifier

CAPACITY TEST

50 or 60 Hz Operation

Time	Ambient db(°F)	Temperatures wb(°F)	Voltage (Volts)	Current (Amps)X5	Frequency (Hz)	Remarks
16:40	69	53	117	2.90	60	- Unit was operated approx. 45 mins prior to test
16:55	69	54	117	2.90	60	
17:10	69	54	117	2.85	60	- Blower guard used
17:25	70	54	117	2.85	60	An approximate 6V drop is experienced thru power lines
17:40	69	54	117	2.85	60	

Weight of Water Resevior @ Test Initiation 18.1 lb

Weight of Water Resevior @ Test Conclusion 14.8 lb

Weight of Water Resevior @ Test Initiation ______

Weight of Water Resevior @ Test Conclusion ______

Dristeem – The slide mounted evaporation chamber was packed w/ newspaper to prevent contact with front and back panels during vibration.

DATA SHEET

Autoflo – Float valve and float switch were packed with newspaper to prevent contact with heating elements during test

DATE: 1/22/87

TEST PERFORMED BY: NTS [illegible]

M. Linker

VIBRATION TEST

Results of Physical Examination

Dri Steem — No visible damage to unit

Autoflo — No visible damage to unit

45 Minute Operation

Time	Voltage (Volts)	Current (Amps) x5	Frequency (Hz)	Remarks
15:00	114	4.25	60	Begin check out test on Dri Steem unit
15:05	114	4.25	60	
15:10	114	4.20	60	
15:15	114	4.20	60	
15:40	117	2.90	60	Begin check out test on Autoflo unit
15:45	117	2.90	60	
15:50	117	2.90	60	
15:55	117	2.90	60	

DATA SHEET

DATE: 1/23/87
TEST PERFORMED BY: M. Baker

HIGH TEMPERATURE STORAGE TEST

Time	Chamber Temp (°F)	[illegible] Temp (°F)	
10:20	163		Begin 4 hour [illegible]
11:20	163		
12:20	163		
13:20	164		
14:20	164		End 4 hour [illegible]
15:15		65	Begin physical Examination

Results of Physical Examination:

Dri Steem Unit — No visible damage to unit

Autoflo unit — No visible damage to unit

Results of 15 minute operation:

	Time	Voltage (Volts)	Current (Amps) x5	Frequency (Hz)
Dri Steem	15:35	115	4.30	60
	15:50	115	4.25	60
Autoflo	15:55	117	2.90	60
	16:10	117	2.90	60

DATA SHEET

DATE: 1/26 - 27

TEST PERFORMED BY: M. Baker

LOW TEMPERATURE STORAGE TEST

	Time	Chamber Temp (°F)	Ambient Temp (°F)	[illegible]
1/26	17:00	-64		Begin 12 hr soak [illegible]
1/27	7:15	-64		End soak [illegible]
	14:15		70	Begin Physical Exam

Results of Physical Examination:

Dri Steem Unit No visible damage to unit

Autoflo Unit No visible damage to unit

Results of 15 minute operation:

	Time	Voltage (volts)	Current (Amps) X5	Frequency (Hz)
Dri Steem	14:35	114	4.30	60
	14:40	114	4.30	60
	14:45	114	4.30	60
	14:50	114	4.30	60
Autoflo	15:10	117	2.95	60
	15:15	117	2.95	60
	15:20	117	2.95	60
	15:25	117	2.90	60

APPENDIX B

NATIONAL TECHNICAL SYSTEMS

TEST DATA SHEETS

UNTES

GENERAL LOG SHEET

TEST VARIABLE Voltage & Frequency W/O 555 8053
CUSTOMER VSE DATE 1-19-87.
TEST ITEM DRI-STEAM & AutoFlow STEAM P/N SEE RECEIVER S/N SEE RECEIVER
SPECIFICATION Per Cust PAR — NA

DATE	TIME	LOG ENTRIES	INITIAL
1-19-87	0950	STARTED DRI-STEAM up TO Check out at	CB
		60 HZ 120 volts 17 Amps TEST #1	CB
	0954	High voltage 132 60HZ Amps 9.15 X 2	CB
	0959	voltage 132 60 HZ Amps 9.15 X 2	CB
	1004	" 132 60 HZ " 9.15 X 2	CB
	1009	" 132 60 HZ " 9.15 X 2	CB
	1021	AUTOFLO STEAM HUMIDIFIER was run at 120 volts 60HZ	CB
	1029	High voltage 60HZ TEST #1	CB
	1029	volts 132 60HZ Amps 6.3 X 2	CB
	1034	" 132 60HZ " 6.25 X 2	CB
	1039	" 132 60HZ " 6.25 X 2	CB
	1044	" 132 60HZ " 6.25 X 2	CB
		DRI-STEAM HUMIDIFIER TEST #2	CB
	1053	volts 108 50HZ Amps 7.55 X 2	CB
	1058	" 108 50 HZ " 7.5 X 2	CB
	1103	" 108 50 HZ " 7.5 X 2	CB
	1108	" 108 50 HZ " 7.5 X 2	CB
		AUTOFLO STEAM TEST #2	CB
	1111	Volts 108 50HZ Amps 5.15 X 2	CB
	1116	" 108 50HZ " 5.15 X 2	CB
	1121	" 108 50HZ " 5.35 X 2	CB
	1126	" 108 50HZ " 5.35 X 2	CB

PAGE 1 OF 4.

TEST BY CB DATE 1-19-87
ENGR. [signature] GOV'T QAR ACC

ABB PTG 211-81

WYLE

GENERAL LOG SHEET

TEST VARIABLE VOLTAGE & FREQUENCY   M/O 555 2053
CUSTOMER VSE   DATE 1-19-87
TEST ITEM DRI-STEAM & AUTOFLOW   P/N SEE RECEIVER   S/N SEE RECEIVER
SPECIFICATION Per Cust   PAR NA

DATE	TIME	LOG ENTRIES			INITIAL
1-19-87		DRI-STEAM TEST #3			
	1133	Volts 108	60 HZ	Amps 8.15 x 2	CB
	1138	" 108	60 HZ	" 8.2 x 2	CB
	1143	" 108	60 HZ	" 8.15 x 2	CB
	1148	" 108	60 HZ	" 8.15 x 2	CB
		AUTOFLOW TEST #3			
	1158	Volts 108	60 HZ	Amps 5.3 x 2	CB
	1203	" 108	60 HZ	" 5.35 x 2	CB
	1208	" 108	60 HZ	" 5.35 x 2	CB
	1213	" 108	60 HZ	" 5.4 x 2	CB
		DRI-STEAM TEST #4			
	1224	Volts 132	50 HZ	Amps 5.0 x 4	CB
	1229	" 134	50 HZ	" 5.5 x 4	CB
	1234	" 132	50 HZ	" 5.0 x 4	CB
	1239	" 132	50 HZ	" 5.0 x 4	CB
		AUTOFLOW TEST #4			
	1243	Volts 132	50 HZ	Amps 3.25 x 4	CB
	1248	" 132	50 HZ	" 3.2 x 4	CB
	1253	" 132	50 HZ	" 3.2 x 4	CB
	1258	" 132	50 HZ	" 3.2 x 4	CB

PAGE 2 OF 4   TEST BY CB   DATE 1-19-87
ENGR. C Whitaker   GOV'T QAR ACL

WYLE FTG 211-R1

GENERAL LOG SHEET

TEST VARIABLE Voltage & Frequency M/O 555 2053

CUSTOMER YSF DATE 1-19-87.

TEST ITEM DRI-STEAM & AutoFlow P/N 528 RECEIVER S/N 528 RECEIVER

SPECIFICATION Per Client PAR NA

DATE	TIME	LOG ENTRIES			INITIAL
1-19-87		DRI-STEAM RETEST #1			
	1306	VOLTS 132	60HZ	AMPS 5.0 x4	CR
	1311	" 132	60 HZ	" 5.0 x 4	CR
	1316	" 132	60 HZ	" 5.0 x 4	CR
	1321	" 132	60 HZ	" 4.95 x 4	CR
		AutoFlow RETEST #1			
	1324	Volts 132	60 HZ	Amps 3.2 x 4	CR
	1329	" 132	60 HZ	" 3.2 x 4	CR
	1334	" 132	60 HZ	" 3.2 x 4	CR
	1339	" 132	60 HZ	" 3.2 x 4	CR

PAGE 3 OF 4

TEST BY CB DATE 1-19-87

ENGR. C H Wheeler GOV'T QAR ACC

AAN PTG 211-R1

GENERAL LOG SHEET

TEST Capacity M/O 555 2053

CUSTOMER VSE DATE 1-19-87

TEST ITEM Autoflow + DRI-STEAM Humidifier P/N SEE RECEIVER S/N SEE RECEIVER

SPECIFICATION Per Cust PAR NA

DATE	TIME	LOG ENTRIES	INITIAL
1-19-87		Autoflow Steam Humidifier 50HZ 120 volts	CB
	1404	Volts 120 50HZ Amps 4.5 x 4	CB
	1419	" 120 50HZ " 4.5 x 4	CB
	1434	" 120 50HZ " 4.55 x 4	CB
	1448	" 120 50HZ " 4.5 x 4	CB
	1448	UNIT had used a TANK of WATER in 45 min.	CB
		IT Took unit 7 min. To fill TANK END of TEST	CB
		DRI-STEAM 50HZ 120 volts	CB
	1507	Volts 120 50HZ Amps 3.0 x 4	CB
	1522	" 120 50HZ " 2.9 x 4	CB
	1537	" 120 50HZ " 2.9 x 4	CB
	1552	" 121 50HZ " 2.9 x 4	CB
	1607	" 120 50HZ " 2.9 x 4	CB
	1608	Shut unit Down used 4.2 LB of water	CB
		in one hour	CB

PAGE 4 OF 4

TEST BY CB DATE 1-19-87

ENGR. C H [illegible]

GOV'T QAR HCE

ADS PTG 211-R1

NTS

GENERAL LOG SHEET

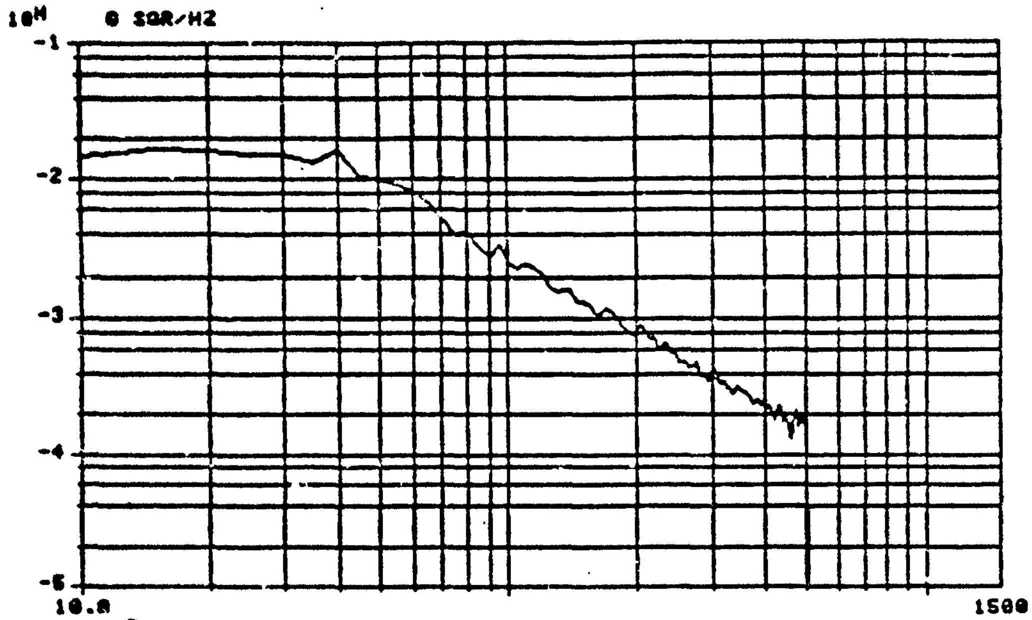
TEST Random Vibration W/O 553-2053
CUSTOMER VSE DATE 1-19-87
TEST ITEM Humidifiers & Controllers P/N SEE BELOW S/N SEE BELOW
SPECIFICATION MIL-STD-810D Meth 514.3 TABLE 514.3-1 Cat 1 Proc 1

DATE	TIME	LOG ENTRIES	INITIAL
1-19-87	1400	Run Transverse axis	VB
	1700	Run Vertical axis	VB
1-20-87	1000	Run long axis	VB
		TEST ITEMS	
		HUMIDIFIER Autoflo Mod/ L-1011-K	
		" Vapormist " VM2	
		CONTROLLER Honeywell " H600	
		" " " H46C	
		" Absheon " 4703-602	
		" BarberColman " HC101	VB

TEST BY STB-mey DATE 1-20-87

VERTICAL AXIS
CONTROL: POST TEST
RMS LEVEL = 1.049 G'S

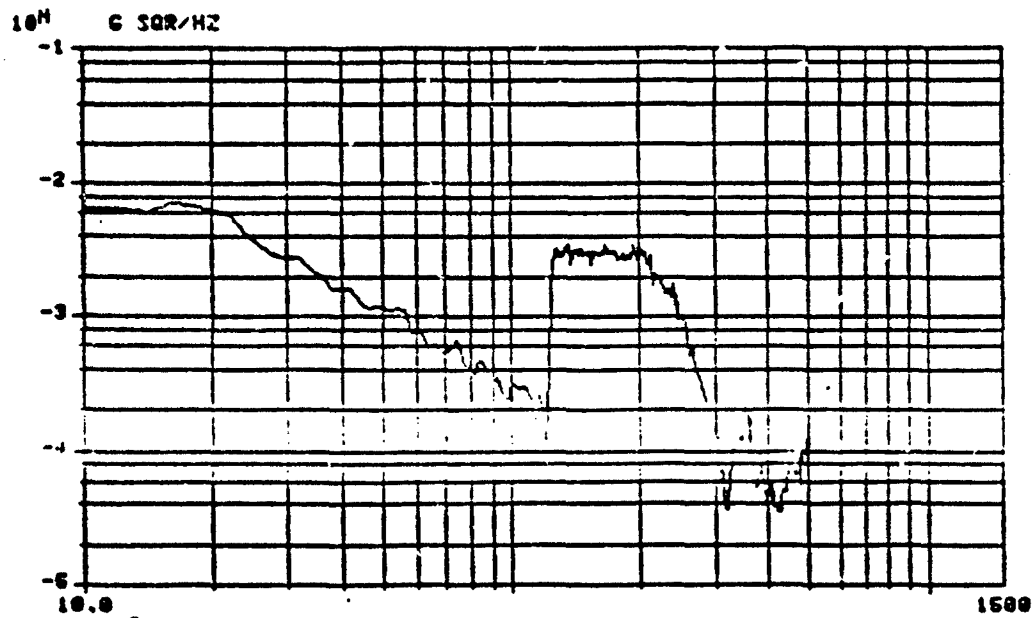
ELAPSED TIME = 1620 SECS AT .00 DB
DELTA F = 5.000 DOF= 0 AVF= 0



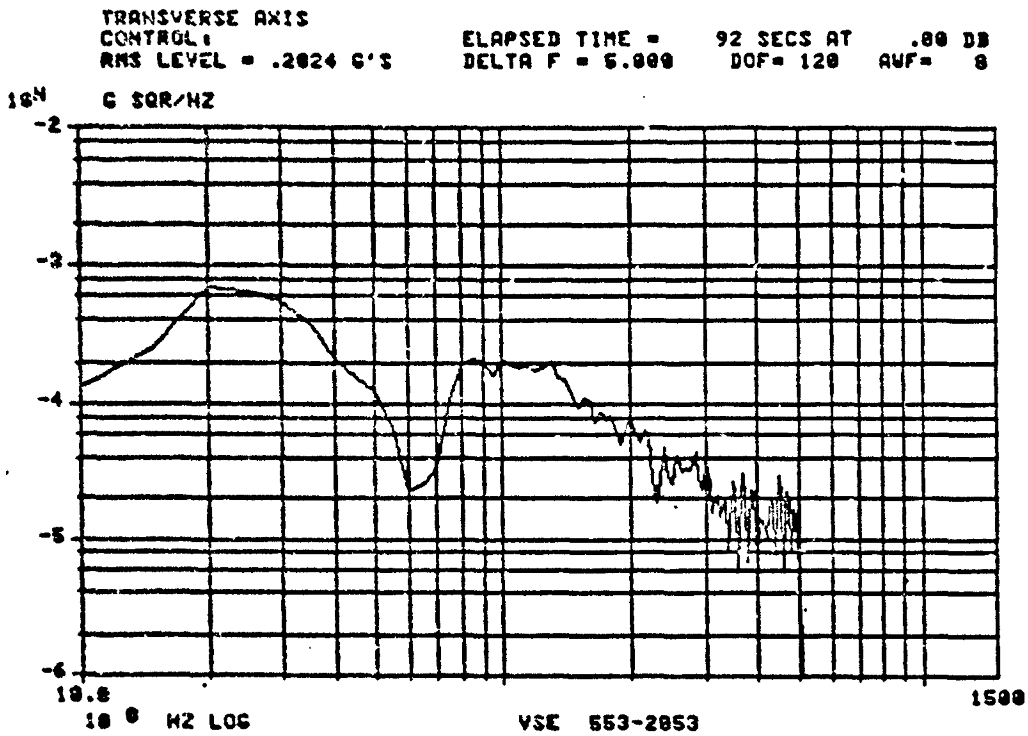
VSE 553-2053

LONGITUDINAL AXIS
CONTROL:
RMS LEVEL = .7359 G'S

ELAPSED TIME = 78 SECS AT .00 DB
DELTA F = 2.000 DOF= 119 AVF= 8



VSE 553-2053


TRANSVERSE AXIS
CONTROL:
RMS LEVEL = .2024 G'S
ELAPSED TIME = 92 SECS AT .00 DB
DELTA F = 5.000 DOF= 120 AVF= 8
10^N G SQR/HZ
-2
-3
-4
-5
-6
10.0
1500
10^0 HZ LOG
VSE 553-2053

APPENDIX C

HONEYWELL SIGNAL ANALYSIS CENTER

TEST DATA SHEETS

Test Equipment List

NOMENCLATURE	MANUFACTURER	MODEL NUMBER	PROPERTY NUMBER	CALIBRATION DUE DATE
Spectrum Analyzer	HP	8568B	6372	20 FEB 87
Disc Drive	HP	82901M	6385	20 FEB 87
Monitor	HP	216	6386	20 FEB 87
Plotter	HP	7475A	6356	20 FEB 87
Bicon Antenna	EMCO	3104	5313	24 MAR 87
Rod Antenna 40"	Honeywell	2825	4602	10 AUG 87
Log Spiral Antenna	EMCO	3101	5398	10 OCT 87
Current Probe	Stoddard	91550-1	0252	24 OCT 87
Preamp	Avantek	AWL-500B	5438	23 DEC 87
Preamp	ASI	8375	6197	3 DEC 87
Attenuator	HP	8496B	6244	3 JUL 87

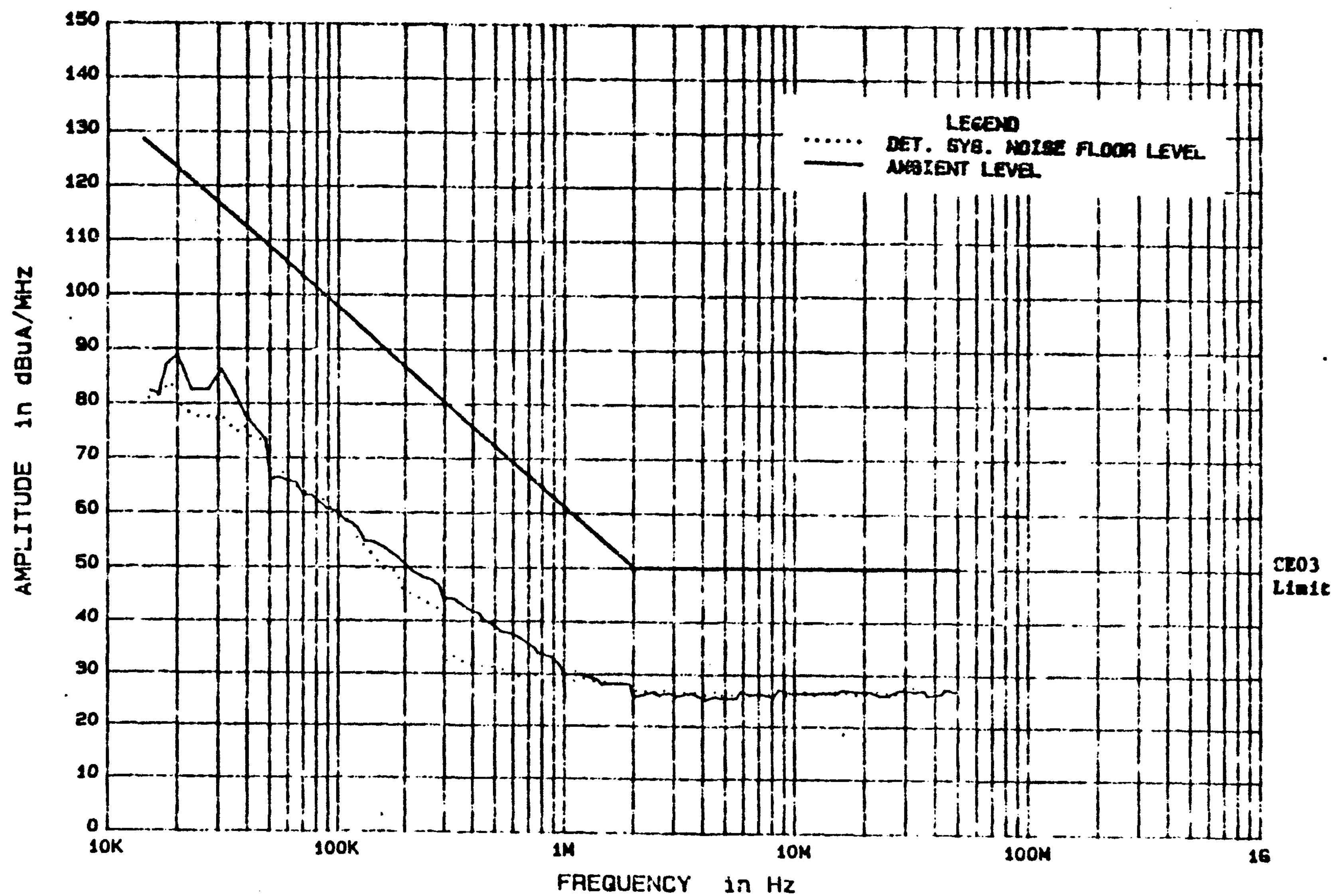


Figure A-1. Auto Flo Humidifier Test Results, CE03, BB, Low Side.

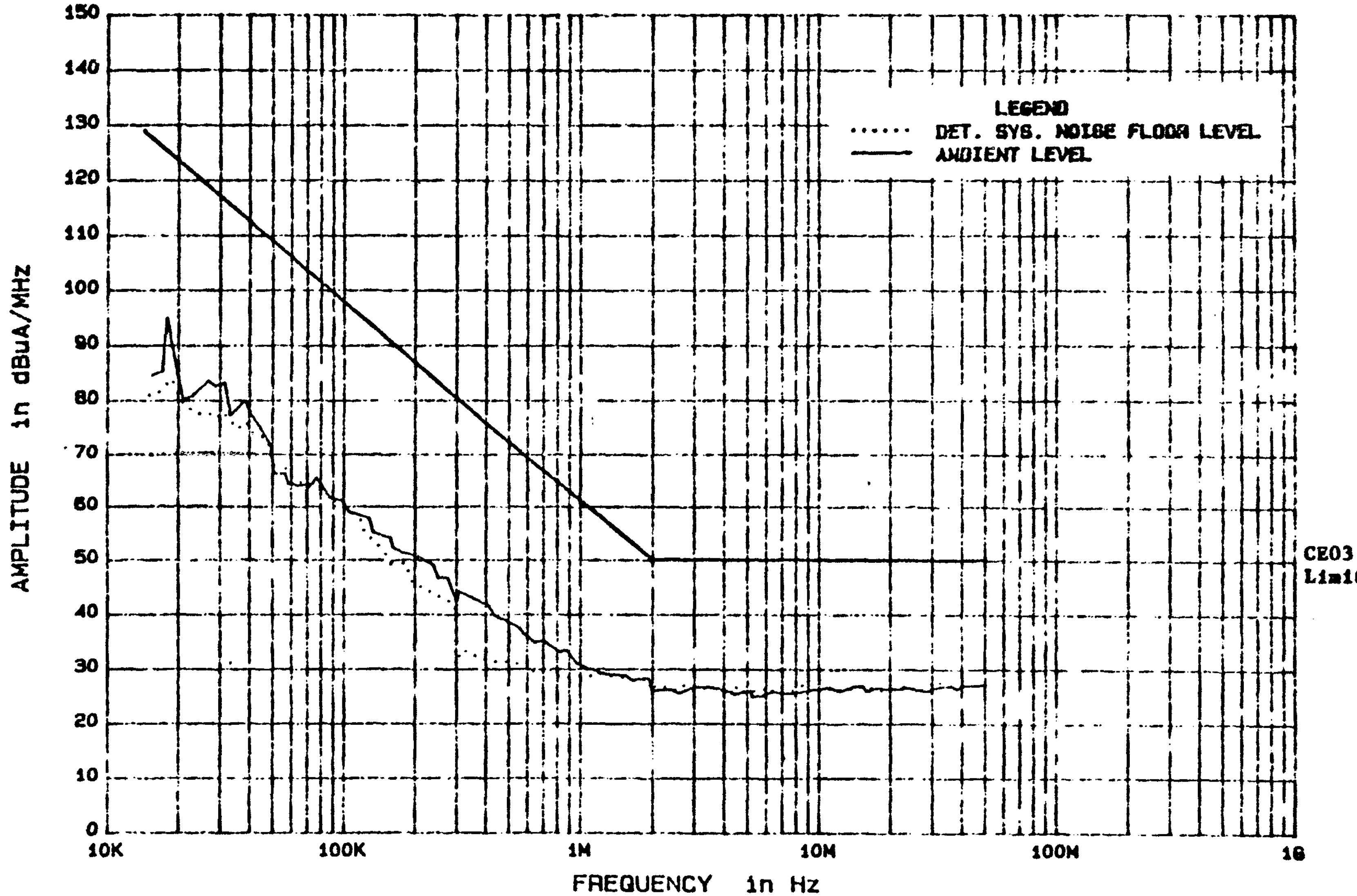


Figure A-2. Auto Flo Humidifier Test Results, CE03, BB, High Side.

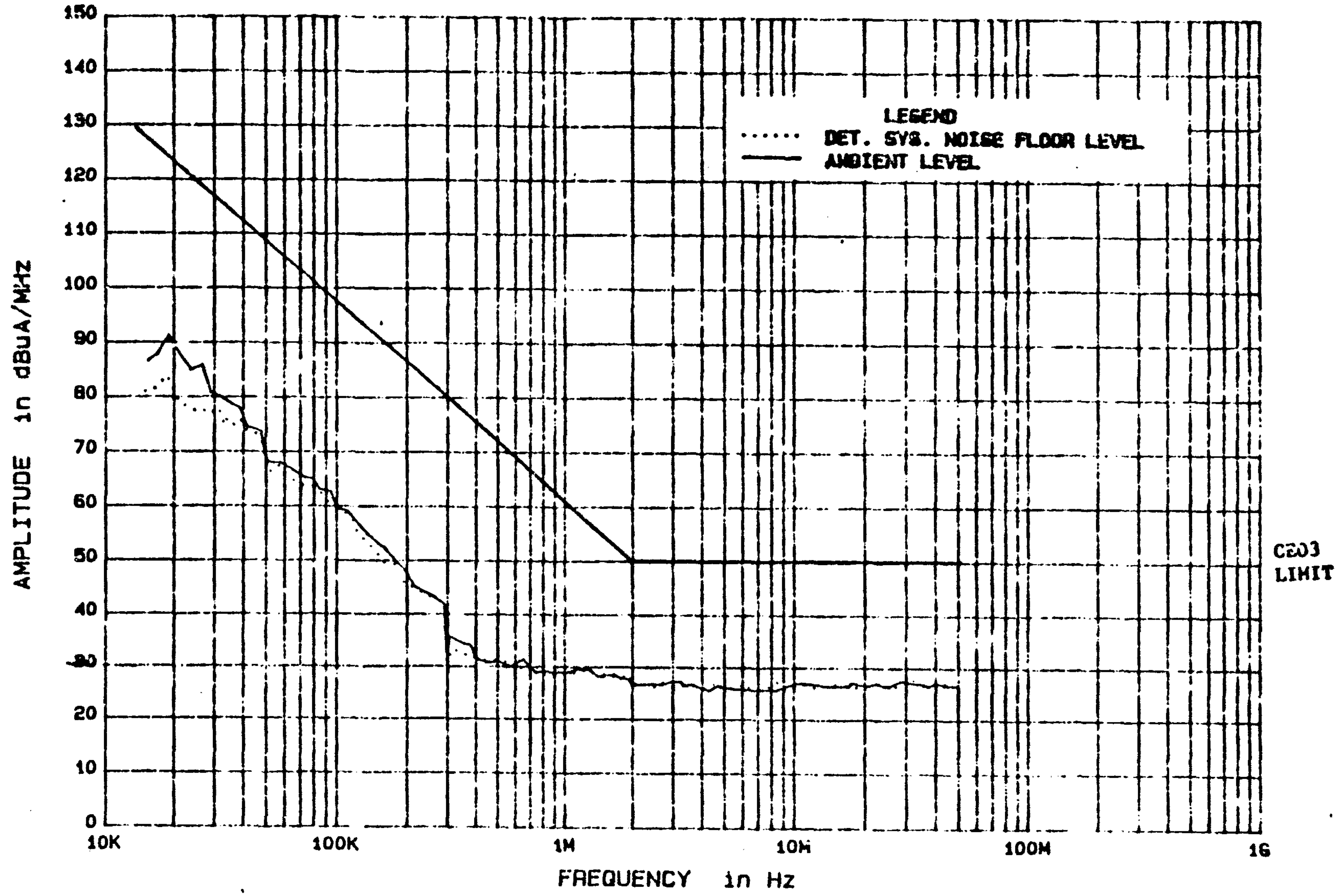


Figure A-3. Dri Steem Humidifier Test Results, CE03, BB, Low Side.

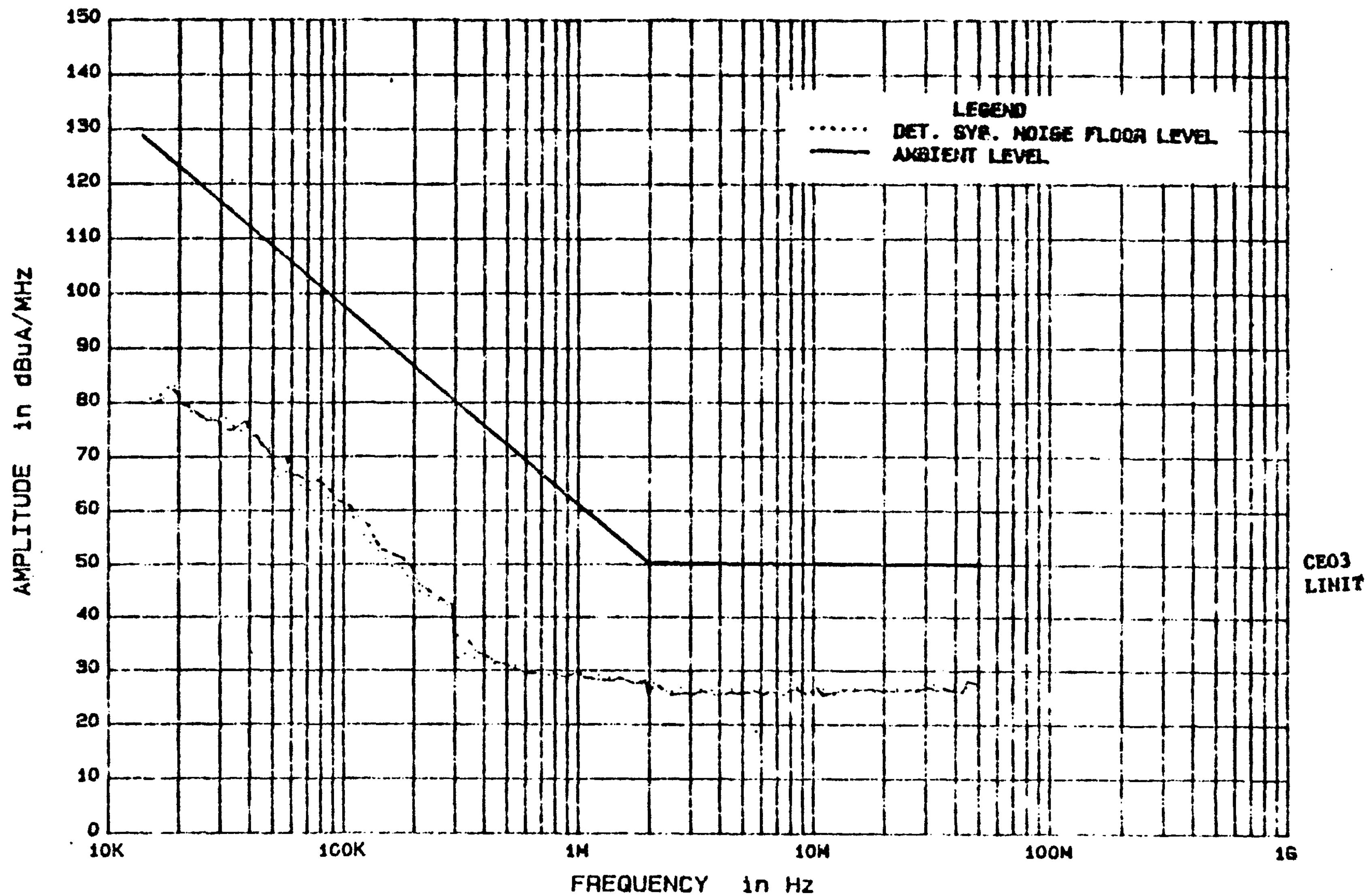


Figure A-4. Dri Steem Humidifier Test Results, CE03, BB, High Side.

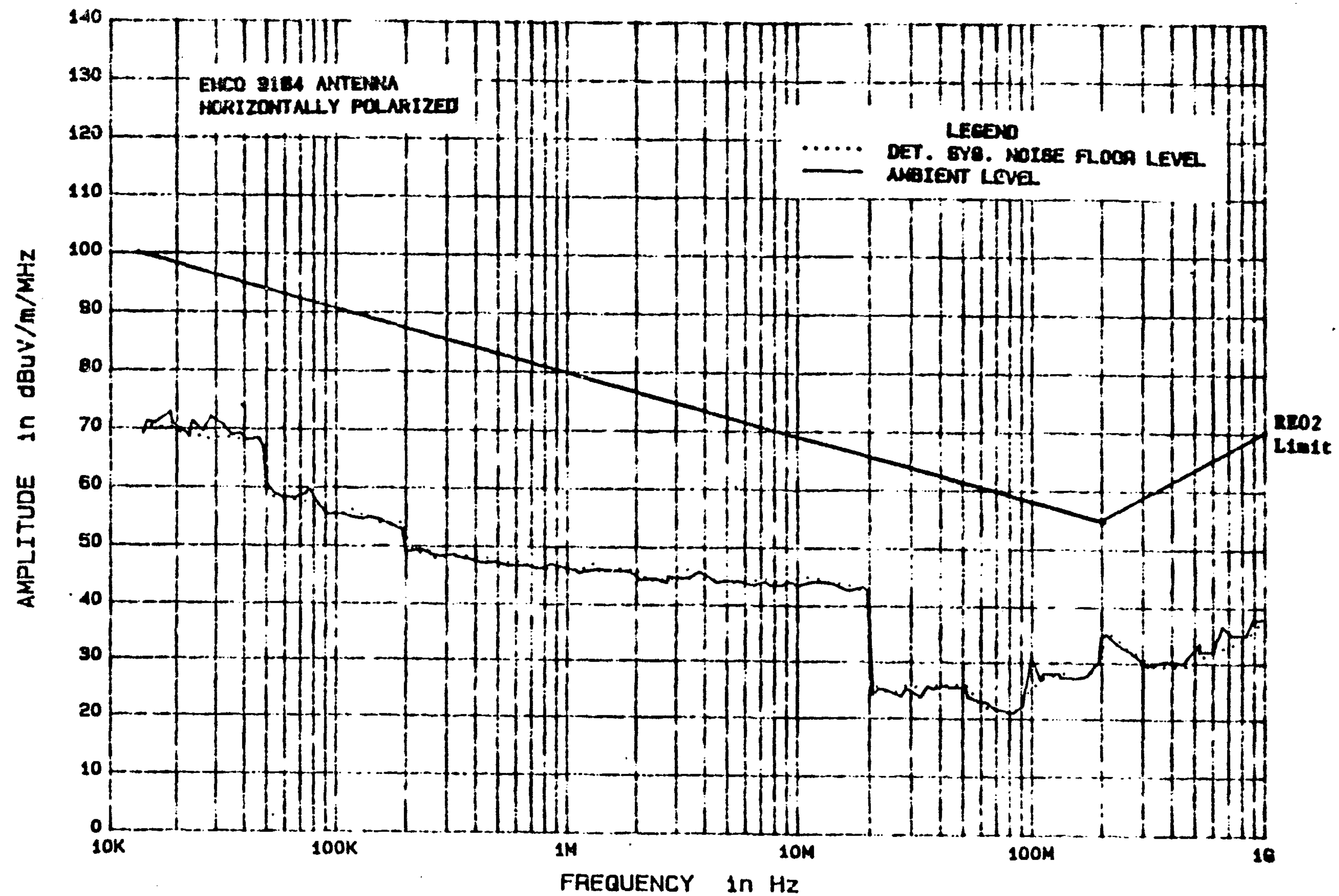


Figure A-5. Auto Flo Humidifier Test Results, RE02, BB, Horizontal Polarization.

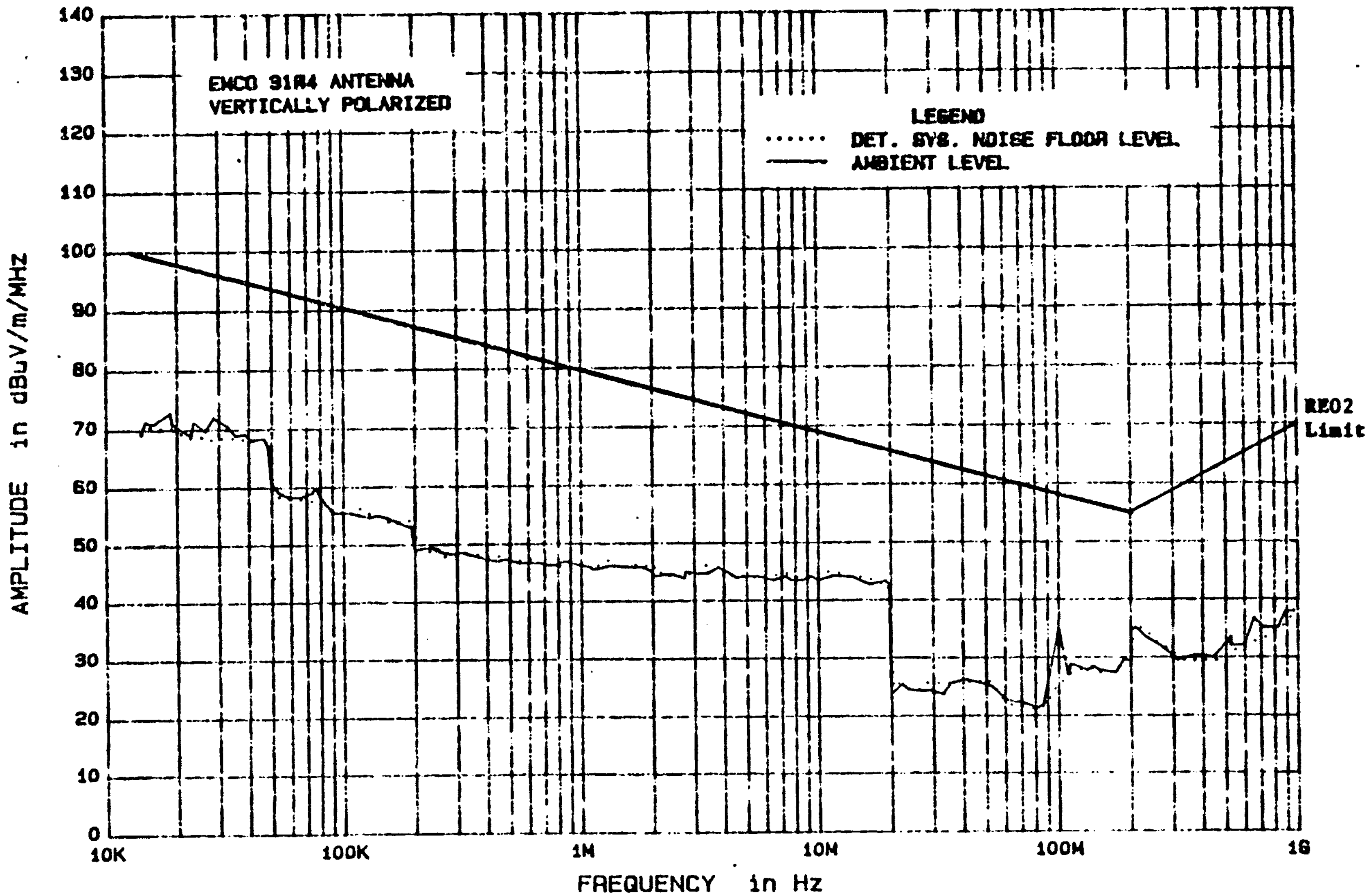


Figure A-6. Auto Flo Humidifier Test Results, RE02, BB, Vertical Polarization.

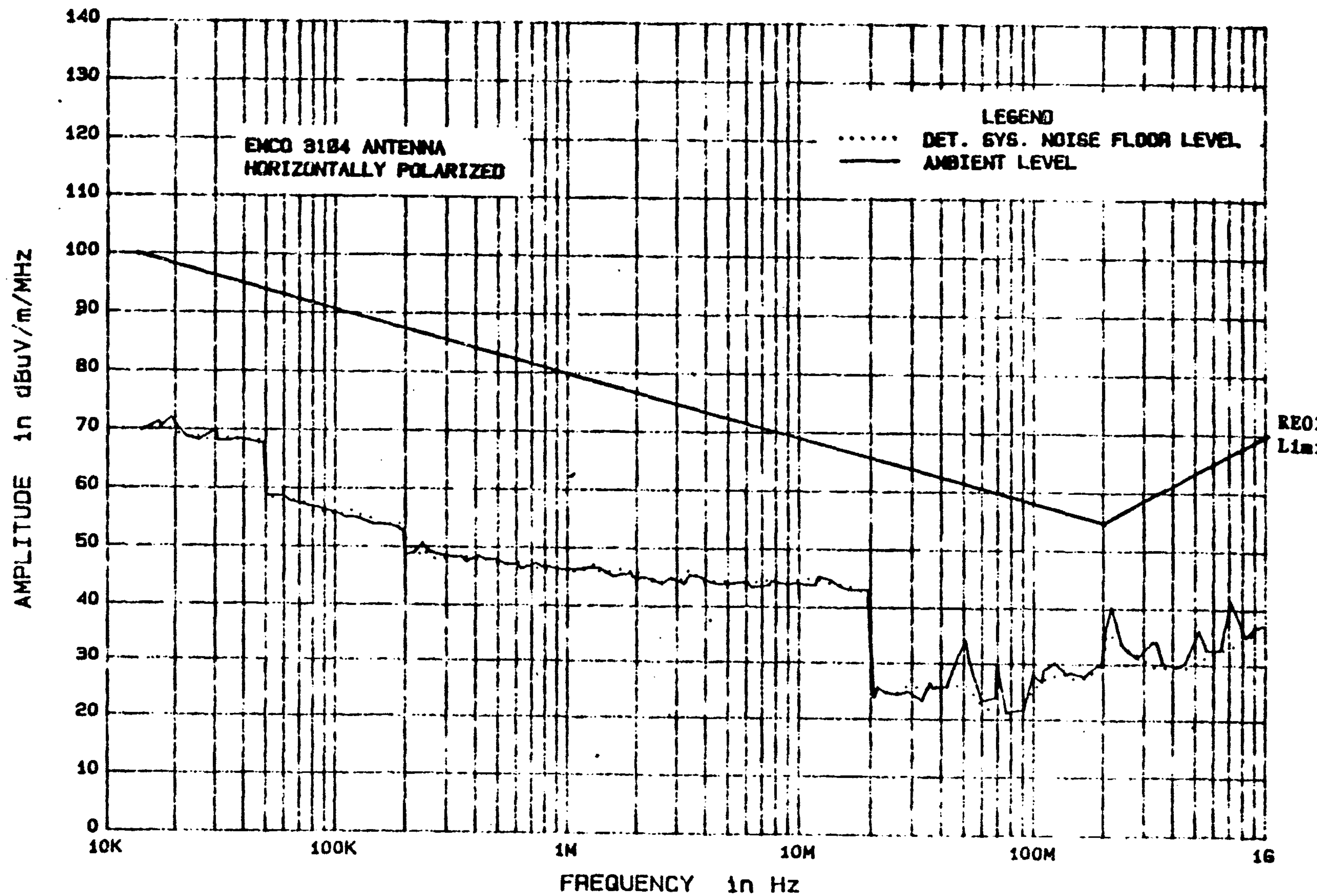


Figure A-7. Dri Steem Humidifier Test Results, RE02, BB, Horizontal Polarization.

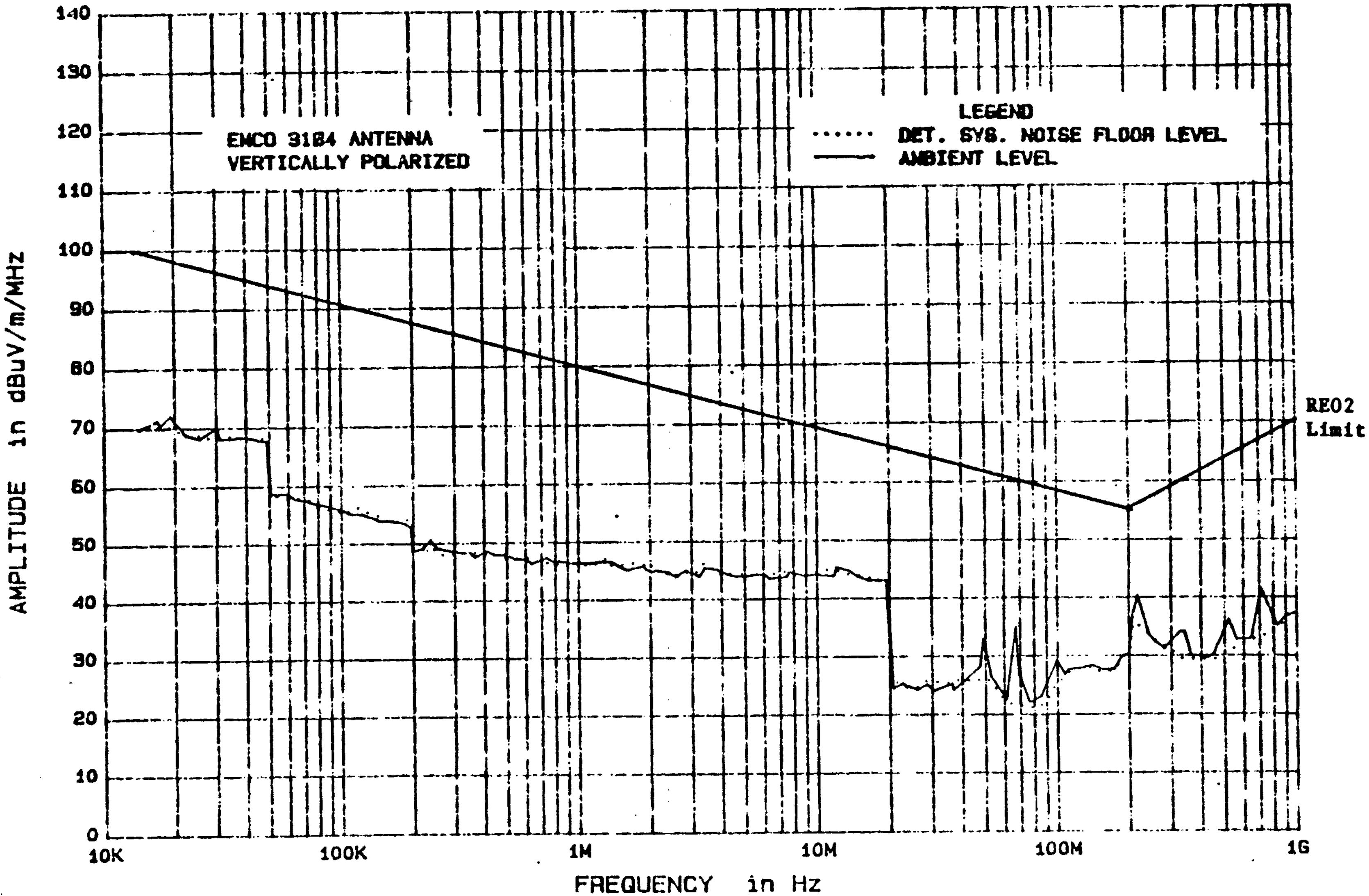


Figure A-8. Dri Steem Humidifier Test Results, RE02, BB, Vertical Polarization.

Honeywell SIGNAL ANALYSIS CENTER

TEST DATA Sheet ___ of ___

CE03 BB

TEST NO. ______ TEST TRANSIENT TEST INST. ______

DATE 2/10/87 ENG. LEE SERIAL NO. ______

LOCATION LAB 7 WITNESS BAKER ANT/PROBE ______

REMARKS AUTO FLO HUMIDIFIER M/N L-1011-K

BW	POWER LINE	FREQ (HZ)		SIGNAL LEVEL dBuV	ATT db	IBW FACTOR	PROBE/ ANT. FACTOR					CORR LEVEL dBuA/MHz	LIMIT dBuA/MHz	REMARKS Pulse duration
30K	LOW	800K		45.1	20	-26.2	-12					26.9	32	1.6mS
		8m		42.4			-15					21.2	20	3mS
		25m		29.3			-15					28.1	20	600uS
30K	HIGH	800K		69.4	20	-26.2	-12					51.2	32	2mS
		8m		45.9			-15					24.7	20	3mS
		25m		36.5			-15					15.3	20	1mS

Data Sheet A-1. Auto Flo Humidifier Test Results, CE03, BB, Transient Measurements

Honeywell SIGNAL ANALYSIS CENTER

CE03 BB

TEST DATA Sheet___of___

TEST NO. ____ TEST TRANSIENT TEST INST. ____
DATE 2/10/87 ENG. LEE SERIAL NO. ____
LOCATION LAB 7 WITNESS BAKER ANT/PROBE ____
REMARKS DRI STEAM HUMidiFIER MIN VM2

BW (HZ)	POWER LINE	FREQ (HZ)	SIGNAL LEVEL (dBuV)	ATT db	IBW FACTOR dB	PROBE/ANT FACTOR dB	CORR LEVEL dBuA/MHz	LIMIT dBuA/MHz	REMARKS Pulse DURATION
30K	LOW	800K	90	20	-26.2	-12	11.8	32	2mS
		8M	45.8			-15	24.6	20	520uS
		25M	39.6			-15	18.4	20	100uS
30K	HIGH	800K	68	20	-26.2	-12	49.8	32	620uS
		8m	48.4			-15	27.2	20	2.3mS
		25m	42.3			-15	21.1	20	640uS

Data Sheet A-2. Dri Steem Humidifier Test Results, CE03, BB, Transient Measurements.

Honeywell SIGNAL ANALYSIS CENTER

TEST DATA Sheet ___ of ___

TEST NO. ______ TEST REO2 BB TRANSIENT TEST INST. ______

DATE 2/10/87 ENG. LEE SERIAL NO. ______

LOCATION LAB 7 WITNESS BAKER ANT/PROBE ______

REMARKS AUTO FLO HUMIDIFIER M/N L-1011-K

BW	FREQ (HZ)	SIGNAL LEVEL (dBuV)	ATT db	IBW FACTOR dB	PROBE/ANT FACTOR dB	CORR LEVEL dBuV/m/MHz	LIMIT dBuV/m/MHz	REMARKS PULSE DURATION
1K	14K	67.3	20	-55.2	6	38.1	100	3ms
10K	200K	70.8		-35.5	6	61.3	67.5	400us
30K	1.2M	70.8		-26.2	6	70.6	79	400us
30K	14.8M	57.2		-26.2	6	57	67	100us
300K	400M	29.2		-5.8	18.5	49.4	61.5	100us

Data Sheet A-3. Auto Flo Humidifier Test Results, REO2, BB, Transient Measurements.

Honeywell SIGNAL ANALYSIS CENTER

TEST DATA Sheet____ of ____

RE02 BB

TEST NO. ______ TEST TRANSIENT TEST INST. ______

DATE 2/10/87 ENG. LEE SERIAL NO. ______

LOCATION ______ WITNESS BAKER ANT/PROBE ______

REMARKS DRI STEEM HUMIDIFIER M/N VM2

BW (HZ)		FREQ (HZ)		SIGNAL LEVEL (dBuV)	ATT db	IBW FACTOR dB	PROBE/ ANT FACTOR dB					CORR LEVEL dBuV/m/M		LIMIT dBuV/m/MHZ		REMARKS PULSE DURATION
1K		14K		63.4	20	-55.2	6					34.2		100		2ms
10K		200K		50.7		-35.5	6					41.2		87.5		1.4ms
30K		1.2M		45.1		-26.2	6					44.9		79		2ms
30K		14.8M		35.5		-26.2	6					35.3		67		1ms
300K		400M		32.6		-5.8	18.5					65.3		61.5		400uS

Data Sheet A-4. Dri Steem Humidifier Test Results, RE02, BB, Transient Measurements.

APPENDIX D

TEST PLAN FOR HUMIDIFICATION, DEHUMIDIFICATION AND HUMIDITY CONTROL EQUIPMENT

APPENDIX E

TEST REPORT FOR DEHUMIDIFICATION EQUIPMENT

Report No. VSE/ASG/0024-87/09RD

TEST REPORT FOR DEHUMIDIFICATION EQUIPMENT EVALUATED FOR USE WITHIN THE U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

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Prepared by:

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11 February 1987

Final Report for Period 6 February 1987 - 9 February 1987

Prepared for:

U.S. Army Belvoir Research, Development
and Engineering Center
Environmental Control Division
Fort Belvoir, Virginia 22060

TEST REPORT
FOR
DEHUMIDIFICATION EQUIPMENT
EVALUATED FOR USE WITHIN
THE U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

Test preformed by:

VSE Corporation

Testing Initiated: 06 February 1987

Testing Completed: 09 February 1987

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Heat pump model MHP36K208/60/3 manufactured by ARE Manufacturing Co. was modified by VSE Corporation to allow operation as a dehumidifier. The heat pump provides for heating and cooling within the Aircraft Service Shelter and a modified unit will also provide controlled dehumidification. Modifications involve minor rewiring to the heat pump control circuitry and thermostat. The modified heat pump was tested to verify satisfactory operation.

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DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

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1.0 REASON FOR TESTING - GENERAL

The reason for testing described herein was to ascertain performance data with which to evaluate the technical and operational feasibility of modified environmental control equipment for use in the Air Force Aircraft Service Shelter. The Aircraft Service Shelter is an integral part of the F-16 maintenance complex. The approved test plan upon which the ensuing test is based, is provided in Appendix B.

2.0 APPLICABLE DOCUMENTS

Statement of Work and Services dated 14 July 1986, Task Order 0024, Contract No. DAAK70-86-D-0023.

3.0 DESCRIPTION OF TEST SAMPLE

The item tested is a nominal 36,000 BTUH single package heat pump model no. MHP36X208/60/3, serial no. MWM-119 manufactured by ARE Manufacturing Co., Inc. The ARE unit has 208-230V/3phase/60 Hz electrical characteristics and a maximum input power of 16,030 watts. The unit has a reversible refrigeration cycle with an approximate cooling capacity of 33,000 BTUH and an approximate heating capacity of 35,000 BTUH. Unit is equipped with two banks of supplementary heaters which provides for 41,000 BTUH of electrical resistance heating. Unit volume is 72-1/2" high x 39-1/4" wide x 15" deep and unit weight is 450 pounds.

The ARE heat pump is equipped with an Accustat model LHP-AH22 thermostat manufactured by PSG Industries. The thermostat settings are fixed by three mercury filled sensing bulbs and are non-adjustable. The sensing bulbs provide for single stage cooling and two stage heating. Set points are such that cooling is called for from 76°F and above. First stage heating is called for from 72°F and below. Second stage heating is called for from 68°F and below. The thermostat has a maximum allowable current rating of 2.5 amps.

4.0 DISPOSITION OF TEST SAMPLES

The ARE heat pump, the PSG Industries Accustat thermostat and relays required for system modification will be kept at VSE Corporation until task completion, at which time they will be transported to the Environmental Equipment Division at Fort Belvoir.

5.0 ABSTRACT, CONCLUSIONS AND RECOMMENDATIONS

The dehumidification operation test was performed successfully. The modified heat pump will operate in the cooling mode with both supplementary heaters operating simultaneously, as intended, when the ambient temperature is between 72°F and 76°F. Circuit modifications will not adversely affect normal heat pump heating and cooling modes of operation. Adequate space exists within the heat pump junction box to locate the two additional relays. The additional relays in the control circuit did not overload the 2.5 amp maximum thermostat. The Accustat rewiring modification is simply done. The only area of concern brought out by the test is the heat pump current draw when the unit is operating in cooling with both banks of supplementary heaters operating simultaneously. Currents as high as 40 amps were recorded on the L_3 power leg. This represents an approximate 29% increase over the maximum current draw of the unmodified heat pump.

It is recommended that the heat pump, modified as shown in Figure 1, be used to provide for dehumidification requirements of the Aircraft Service Shelter. Application of the modified heat pump should, however, take into consideration the increased current necessary.

6.0 FACTUAL DATA - TESTING

6.1 Dehumidification Operation

6.1.1 Reason for Test. The dehumidification operation test was performed to ensure that modifications made to the heat pump control circuitry would allow operation as a dehumidifier without unintended or detrimental equipment consequences.

6.1.2 Description of Test Apparatus. The following equipment and instrumentation were used to conduct the dehumidification operation test:

- Thermocouple indicator, 18 channel, Thermo Electric model 31620-1000, S/N A339748-21433, calibrated 08/26/86.
- Ten Thermocouples, copper-constantan
- Ammeter, clamp-on induction type, Amprobe Co., 0-6 amp, 0-15 amp, 0-40 amp, 0-100 amp ranges.
- Wrist watch, Seiko

6.1.3 Test Procedure

Background

The heat pump is equipped with three selector switches to control unit operation. The selector switches are listed below:

Switch	Positions
Unit	EMERGENCY HEAT/OFF/ON
Mode	COOL/AUTO/HEAT
Fan	AUTO/ON

A separate ON/OFF switch has been added to the heat pump control circuitry which simulates a humidistat for test purposes. This switch is

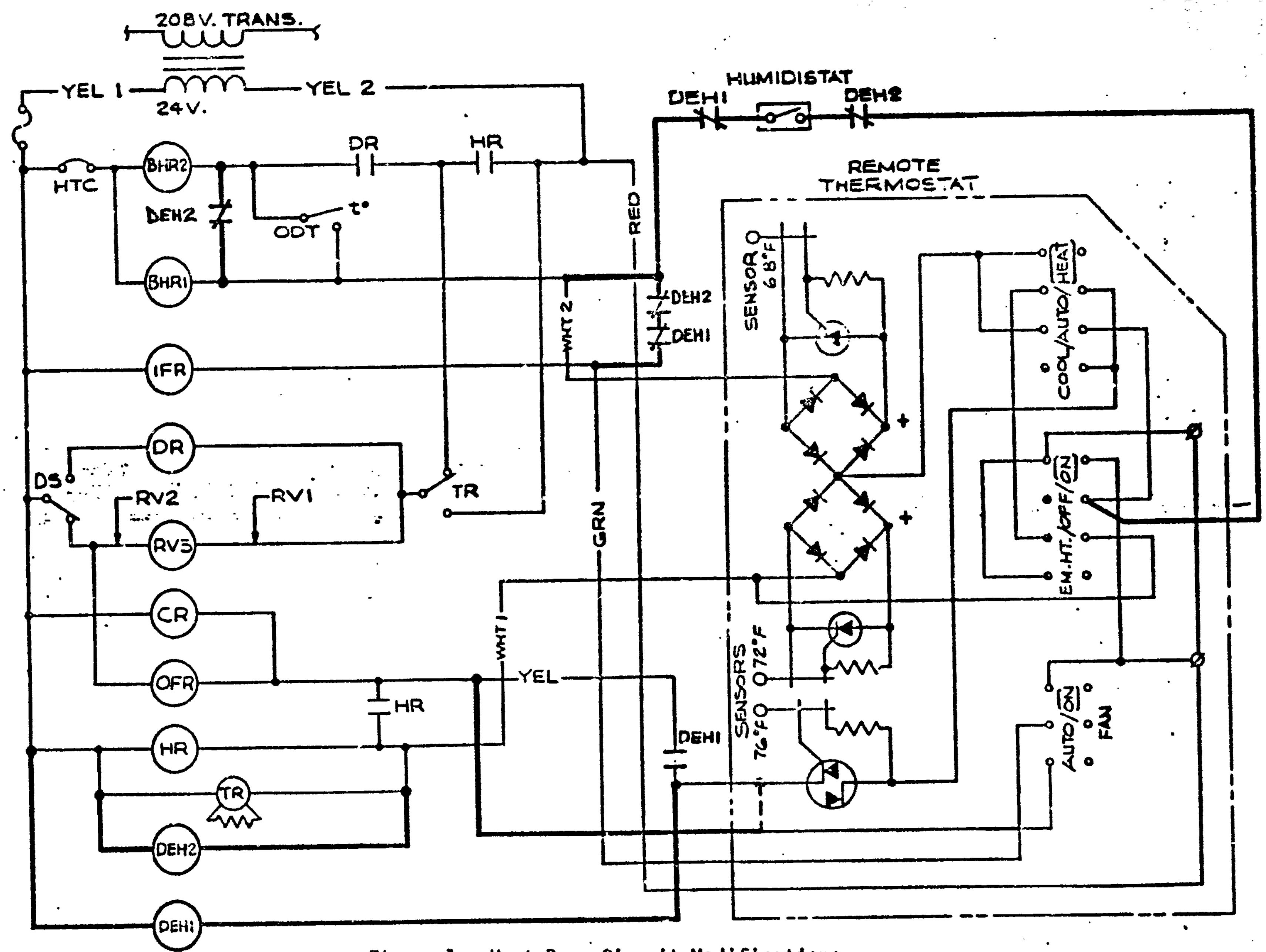

Figure 1. Heat Pump Circuit Modifications
(Modifications are shown in bold)

later referred to as the Dehumidification Simulation Switch (DSS). The temperature set points provided with the heat pump thermostat are as follows:

- Cooling called for @ 76°F and above
- First stage heating called for @ 72°F and below
- Second stage heating called for @ 68°F and below

Thermostat contacts can be selectively shorted to simulate ambient temperature conditions.

Procedure

The unit function during each operational mode tested was verified with a current meter and unit discharge temperatures.

The heat pump was initially operated with an unmodified control circuitry so baseline data could be recorded. Current draw and evaporator inlet and discharge temperatures were recorded for the cooling, low heat and high heat modes of operation. The heat pump was then modified as shown in Figure 1. The heat pump was placed in an ambient environment. Thermostat contacts were jumpered as necessary to simulate different ambient temperature ranges as described below:

- Cooling, Operation Above 76°F

Thermostat contacts W1, W2 and Y1 were jumpered to simulate operation above 76°F. The DSS was turned to "ON" position, fan switch was in "AUTO" position and mode selector switch was in "COOL" position. Heat pump was initiated by turning the unit selector switch to "ON" position. A three (3) minute stabilization period was observed. It was verified that the unit was operating in the cool mode and that the supplementary heaters were not energized. The DSS switch was turned to the "OFF" position to verify no impact on heat pump operation. The mode selector switch was then moved to the "AUTO" position. Again it was verified that the unit was operating in the cooling mode and that the supplementary heaters were not energized. DSS switch in either the "ON" or "OFF" positions had no effect on heat pump operation.

- Thermostat Dead Zone, Operation Between 72°F and 76°F

Jumper wire on thermostat Y1 contacts was removed to simulate an ambient temperature between 72°F and 76°F. The DSS was moved to the "ON" position. The mode selector switch remained in the "AUTO" position. A ten (10) minute stabilization period was observed. It was verified that the heat pump was operating in the cooling mode with both supplementary heater banks operating simultaneously. The DSS was then moved to the "OFF" position and stabilized for three (3) minutes. It was verified that the compressor and supplementary heaters were de-energized.

- First Stage Heating, Operation Between 68°F and 72°F

Jumper wire on thermostat W1 contacts was removed to simulate ambient temperatures between 68°F and 72°F. The mode selector switch remained in the "AUTO" position. A ten (10) minute stabilization period was observed. It was verified that the heat pump was operating in the heating mode with supplementary heaters de-energized. Mode selector switch was then moved to the "HEAT" position to verify no change in unit operation. Positioning the DSS to "ON" or "OFF" had no effect on unit operation.

- Second Stage Heating, Operation Below 68°F

Jumper wire on thermostat W2 contacts was removed to simulate ambient temperatures below 68°F. A ten (10) minute stabilization period was observed with the mode selector switch in the "AUTO" position. It was verified that the heat pump was operating in the heating mode with one bank of supplementary heaters energized. The mode selector switch was moved to the "HEAT" position to verify no impact on unit operation. Positioning the DSS to "ON" or "OFF" had no impact on unit operation.

Following the above testing the unit was again operated in the cooling, dead zone, first stage heating and second stage heating modes. In each case the unit switch was moved from the "ON" to the "OFF" position to ensure that modified heat pump did indeed de-energize. During each test mode the current through the heat pump thermostat was measured to ensure that additional relays did not exceed allowable thermostat current.

6.1.4 Test Results and Analyses. The heat pump did not function as intended with the original specified system modifications incorporated. The unit functioned properly while operating in all modes of operation, however, when the unit selector switch was moved to the "OFF" position in the cooling and heating modes, several relays chattered on and off continuously. It was discovered that if the heat pump was turned off while the DSS was in "ON" position, an improper short circuit was established. This problem was easily corrected by wiring one leg of the DSS switch to the unit on/off switch as opposed to terminal board position 8 as originally specified. This modification involves soldering in additional wire to the Accustat (thermostat) printed circuit board at the unit selector switch and routing the wire to a normally closed contact of relay DEH2.

When the ambient temperature is in the thermostat dead zone (72°F-76°F) and dehumidification is required, the heat pump compressor and both banks of supplementary heaters are operating simultaneously. This scenario represents the maximum current draw condition. During the test, when the unit operated with the compressor, supplementary heaters and blower motors functioning, the heat pump ran approximately three (3) minutes before a 30 amp house power circuit breaker tripped. The measured currents were L_1 - 37 amps, L_2 - 29 amps, and L_3 - 40 amps. These currents were measured with an uncalibrated ammeter. It is believed the additional currents will have no impact on the heat pump electrical system. The added current is only carried through a single terminal board in the unit.

The current through the thermostat did not exceed the 2.5 amp maximum allowable. Data sheets are provided in Appendix A.

APPENDIX A

VSE TEST DATA SHEETS

DATA SHEET

DATE: 2/6/87
TEST PERFORMED BY: M. Baker

DEHUMIDIFICATION OPERATION TEST – Unmodified Control Circuitry

		Operation Mode		
	Cool	Low Heat	High Heat	Remarks
L_1 Current (Amps)	11.0	13.25	31	
L_2 Current (Amps)	11.0	13.5	21	
L_3 Current (Amps)	12.5	15.0	25	
Discharge Temp. (°F)	41	112	119	
Inlet Temp (°F)	60	70	66	
Ambient Temp (°F)	62	68	64	Ambient temps. fluctuate due to nearby doors opening periodically.
Accustat Current (Amps)	.5	.9	1.3	
Time Start	14:55	15:30	15:23	
Time Finish	15:00	16:10	15:28	

DATA SHEET

DATE: 2/9/87
TEST PERFORMED BY: M. Baker

DEHUMIDIFICATION OPERATION TEST – Modified Control Circuitry

	Operation Mode							
	Cooling		Dead Zone Selector in "AUTO"		Low Heat		High Heat	
	*Selector in "Cool"	*Selector in "AUTO"	DSS in "ON"	DSS in "OFF"	*Selector in "AUTO"	*Selector in "HEAT"	*Selector in "HEAT"	*Selector in "AUTO"
L_1 Current (Amps)	11.0	11.0	37	0	13.0	13.0	31	31
L_2 Current (Amps)	11.0	11.0	29	0	12.75	12.75	21	21
L_3 Current (Amps)	12.5	12.5	40	0	14.5	14.5	25	25
Discharge Temp. (°F)	43	43	68	70	105	105	126	125
Inlet Temp (°F)	63	63	66	68	69	69	70	68
Ambient Temp (°F)	64	64	66	67	64	65	66	64
Accustat Current (Amps)	Negligible	Negligible	1.1	0	1.0	1.0	1.3	1.3
Time	13:35	13:40	13:43	13:50	14:13	13:57	14:00	14:08

Several relays chattered on/off when unit selector switch was turned "off" both in cooling and heating modes. Minor rewiring alleviated the problem.

* DSS in "ON" or "OFF" position had no effect.

APPENDIX B

TEST PLAN FOR HUMIDIFICATION, DEHUMIDIFICATION AND HUMIDITY CONTROL EQUIPMENT

APPENDIX F

RECORD OF SIGNIFICANT TELEPHONE CONVERSATIONS

TELECON

JOB NO.: 0024 TITLE: Humidification Control Project

DATE: 11/13 TIME:

CALLER: Mark Baker

CALLED: PERSON: Richard Ingram

COMPANY: Culligan

ADDRESS: 352 Maple Ave. Vienna

PHONE: 938-73[illegible]

SUBJECT: Methods of reducing water hardness

SUMMARY OF CALL: Richard relayed data on demineralizer that Culligan offers:

- A 4500 grain capacity is 8"Dia x 36"L. When unit attains capacity the cartridge is removed and taken to a regeneration [illegible]
- A 630 grain capacity for laboratory applications is 10"x24"x7" and has disposable cartridges cost is $800.

Mr. Ingram informed me that water softeners are as bad as hard water. In softeners the minerals are replaced w/ salt which will precipitate just as minerals.

DISTRIBUTION:

JOB NO.: 0024 TITLE: Humidification Control Project

DATE: 12/3 TIME:

CALLER: Mark Baker

CALLED: PERSON: Dan Hager

COMPANY: Rain Soft

ADDRESS: Stafford, VA

PHONE: 690-1821

SUBJECT: Different methods for reducing water hardness.

SUMMARY OF CALL: Mr. Hager pushed a Reverse Osmosis water purification system. He mentioned an R.O. system which treats 18 gallons per day, is 14"x16"x13" w/ a 3.5"D x 6"L semipermiable membrane, requires 40-60psi inlet water pressure and costs $1095. A 3gal/day version costs $795.
Mr. Hager discussed a cheatallating agent (chemical [illegible]) of polymer phosphate @ $32/gal. The agent combines w/ the ions in solution and keeps them suspended. Mr. Hager stated that magnetic inhibitors do not work do to lack of contact time. Mr. Hager did not like demineralizer do to regeneration requirements.

DISTRIBUTION:

JOB NO.: 0024 TITLE: Humidification Control Pro[illegible]

DATE: 12/5 TIME: 10:00

CALLER: Mark Baker

CALLED: PERSON: Salesperson

COMPANY: Compu-Dynamics Inc.

ADDRESS: 6332 Richmond Hwy

PHONE: 660-9550

SUBJECT: Impact of dusting on computer equipment resulting from use of atomization type humidifiers.

SUMMARY OF CALL: The sales person did not recommend the use of atomization type humidifiers at all. Compu-Dynamics, which constructs facilities for computers, never uses atomizers. They use steam systems or pan type humidifiers heated w/ infrared light. The salesman suggested I contact hardware manufacturers.

DISTRIBUTION:

JOB NO.: 0024 TITLE: Humidification Control

DATE: 12/11 TIME: 3:00

CALLER: Bob Sharly, Mark Parker

CALLED: PERSON: Jerry Russell Electronics Engineer

COMPANY: General Dynamics

ADDRESS: Ft. Worth TX

PHONE: (817) 777-8241

SUBJECT: Any problems w/ dusting of electronic equipment by an atomization humidifier?

SUMMARY OF CALL: Jerry informed us that they attempt to keep the military shelters as dust free as possible. This is desirable to insure proper operation of the computer disks and the disk drives. The hard disks used are semi-open and dust accumulates on/in disks when stored in the shelters. Dust then impedes proper operation of discs in the drives. He believes floppy disks aren't as susceptable.

For more specific information on processes with the F-16 maintenance shelter Jerry gave us a POC Sgt Sonny Sorles who is a resident @ Medley Tool and Model Co. in

DISTRIBUTION:

JOB NO.: 0024 TITLE: Humidification Control Project

DATE: 12/12 TIME: 9:00

CALLER: Mark Baker

CALLED: PERSON: Bernie Morton

COMPANY: Dri Steem Co.

ADDRESS:

PHONE: (612) 935-6986

SUBJECT: Impact of dusting on computer equipment resulting from use of atomization type humidifiers.

SUMMARY OF CALL: Mr. Morton heads the humidification committee of ASHRAE. He knows of no application where computer facilities employed other than evaporative humidifiers. Mr. Morton could not talk in detail regarding specific reasons why atomizers are detrimental to computer equipment. Mr Morton mentioned a study by a Mr. Sterling in British Columbia which investigated cold water humidifiers and how they harbor the growth of disease germs. Mr. Morton knew of a hospital which banned the use of cold water humidifiers because of the spread of germs.

DISTRIBUTION:

JOB NO.: 0500.0024 TITLE: Humidification Control System

DATE: 1/23/87 TIME: 5:00

CALLER: Mark Baker

CALLED: PERSON: Gene Williams

COMPANY: Hewlett - Packard

ADDRESS: Boise, Idaho

PHONE: (208) 323-2930

SUBJECT: H-P disk drives models 7905 and [illegible] used in Air Force Aircraft Service Shelter

SUMMARY OF CALL: H-P disk drive models 7905 and 7906 require an extremely clean environment in which to operate. These units are equipped with a prefilter and an absolute filter. The prefilter is for very large particles and basically resembles a furnace filter. The absolute filter consists of fine filter paper which filters down to [illegible] microns. Units fan/filter arrangement is such that a positive pressure is maintained within the drives. The primary reason for maintaining a pure environment within the drives is to avoid "crashing the head." Crashing head means that the head comes in contact with the disk media which can destroy both the head and the media. Using these disk drives in a dirty environment is not recommended by Mr. Williams.

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Mr. Williams stated that use of an atomizing humidifier is acceptable ~~&~~ only if if deionized water is provided to the humidifier.

Models 7905 and 7906 H-P disk drives [illegible] aerodynamic head designs. ~~and~~ the heads tend to "fly" or in other words, they ride a cushion of air over the disk media. The air cushion is approximately 20 microns. Smoke particles for instance are in the 250 micron diameter range. The relative speed of the disk media to the head is approximately 150 mph. Any contact between the two is very damaging. Use of the disk drives in a dusty environment will tend to clog the drives filters very quickly. Two basic problems occur when the filters become clogged. First the positive pressure within the equipment is lost allowing external particles to infiltrate and bridge the gap between the head and drive. Clogged filters will also reduce the cooling capability of the internal blower. Warmer air within the disk drive will decrease the air density resulting in the aerodynamic head to loose lift and thus ride closer and closer to the disk media. Air of sufficiently low density will allow the head to "crash."

I discussed with Mr. Williams the project with the Air Force in general. Mr. Williams stated that electrostatic discharge can be controlled by maintaining proper humidity, which is expensive, or by the use of conductive floor tiles or carpet. High humidity conditions can result in fungus growth within the equipment.

TELECON

JOB NO.: 0024 TITLE: Humidity Control Proj[illegible]

DATE: 12/24/86 TIME: 9:30

CALLER: Mark Baker

CALLED: PERSON: Jim Wohlford

COMPANY: Honeywell

ADDRESS: [illegible]

PHONE: (612) 542-3359 (612) 542-[illegible]

SUBJECT: How does Honeywell test its H46 and H600A Humidity Controls?

SUMMARY OF CALL: Jim stressed that these Hu[illegible] controls are not precise control equipment. He does feel they are adequate to maintain RH within 48% ± 8% however. Honeywells procedure for manuf[illegible] controls is first to condition the nylon to rem[illegible] mechanical stresses and memory. Controls are then placed in a low humidity chamber which [illegible]creased to a high humidity condition to [illegible] that the internal switches function (make & break) [illegible] required. Honeywell ~~the~~ makes no attempt to deter[illegible] precise points when ~~the~~ switches actuate. Controls used with humidifiers are then placed [illegible] chamber whose condition is closely controlled at [illegible]0% RH ± ½%. Temperature is controlled at ± [illegible]°F.

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The controls are then calibrated for 50% R[illegible]
Controls used with dehumidifiers are placed
in a chamber at 50% RH and calibrated.
Controls are soaked for 24 hours prior to
calibration.

Jim stated that virtually all control manufacturers obtain their nylon from BSF in Germany. Honeywell controls intented for residential use are fabricated with [illegible] thicker nylon then ~~the~~ Honeywell competitors. Thicker nylon increases response time. Low temperatures (~50°F) will increase response time.

TELECON

JOB NO.: 0500.0024 TITLE: Humidification Control Project

DATE: 1/29/87 TIME: 14:00

CALLER: Mark Baker

CALLED: PERSON: Dan Zwart

COMPANY: Dri Steem Humidifier Co.

ADDRESS: Hopkins, Minnesota

PHONE: 1-800-328-4447

SUBJECT: Modifications to the Humidifier model VMZ to improve response and reduce cabinet size.

PRECIS OF CALL: I informed Dan of our intended use of the model VMZ humidifier. I informed him that the humidifier cabinet must comply with a 37"H x 17"W x 23"D space envelope. Unit must be responsive, must be capable of providing steam for [illegible] periods of time than presently capable. Dan then discussed possible modifications. Ample space exists within the humidifier to allow use of a smaller frame. It was suggested that the current cabinet design be done away with completely and substituted with an aluminum angle frame to which aluminum panels can be mounted. The initial warm up period can be decreased by reducing the water volume in the evaporator chamber. This can be accomplished

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by lengthening the water level conductivity probes. The non steaming period during refill cycle can be reduced by rewiring the unit such that its heating element remains "on" during refill. This can be accomplished by making the metal evaporation chamber the "common" for the low water protection circuit as opposed to the longest of the three conductivity probes. The low water protection and refill circuits are thus separated.

Lengthening the conductivity probes to reduce initial response time will require repositioning the skimmer/overflow drain port to accomodate the lower water level. A lower water level will not adversely affect the resistance heater. Only the horizontal run of element is energized.

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