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FINAL TECHNICAL REPORT FOR HUMIDITY CONTROL IN THE U.S. AIR FORCE AIRCRAFT SERVICE SHELTER

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Prototype design, testing, documentation and manufacture of a Humidity Control System for Air Force maintenance shelters.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
A prototype Humidity Control System (HCS) were developed for use in the electrical and mechanical calibration shelters of the Air Force F-16 maintenance complex. The contractor tested, documented with Level 1 drawings and manufactured two complete working HCSs using commercial equipment modified as required. Contractor testing demonstrated the system's ability to maintain the shelter RH at 45% ± 10% as specified. Major system components included a humidifier manufactured by the Dri Steem Humidifier Co., electronic humidity controllers manufactured by Johnson Controls Co. and the existing shelter ECU, which was modified to provide dehumidification. Originally the intent of the task was to install the two prototype HCS in two fielded shelters for further testing. The Air Force has decided during the course of this task that the HCS, as manufactured, would not be used for its intended purpose.

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SUMMARY

This report represents the entire effort of engineering support, prototype manufacture, component modification, documentation and testing services for the continued development of a Humidity Control System (HCS) to interface with existing Air Force electrical and mechanical calibration shelters of the F-16 maintenance complex.

The HCS basically consists of a modified commercial humidifier, the existing shelter ECU modified to provide dehumidification capability and commercial electronic humidity controllers. The steam generator humidifier was provided by the Dri-Steem humidifier Co. The unit is equipped with an off-the-shelf vaporization chamber enclosed in a special housing fabricated to Air Force envelope dimensions. Two complete prototype HCSs were manufactured.

A mock up HCS was tested in an Army ISO shelter, identical in overall dimensions to the calibration shelters. The HCS demonstrated the ability to maintain shelter RH in the 45% ±10% range specified in the Task Order.

Other documentation generated under Task 0080 and included in the appendices of this report are the "Test Plan for Humidity Control System for use in the Air Force F-16 Maintenance Shelter" in Appendix D, "Test Report for Humidity Control System Evaluated for use within the U.S. Air Force Aircraft Service Shelter" in Appendix E, "Operation, Maintenance and Installation Instruction for the F-16 Electrical and Mechanical Calibration Shelters Humidity Control System" in Appendix B, and a complete level 1 drawing package (not included in appendices).

Appendix G contains summaries of significant telephone conversations which occurred during the course of this task.

PREFACE

This Final Technical Report was prepared under Contract No. DAAK70-86-D-0023, Task Order 0080, for the Belvoir Research, Development and Engineering Center (BRDEC), Fort Belvoir, Virginia. Mr. Robert Rhodes (retired) and Mr. Gregory Wesley served as the BRDEC Contracting Officer's Technical Representative, telephone No. (703) 664-6031. Special thanks is extended to Mr. Robert Bannan and Mr. Phil Rothsching of Medley Tool and Model Co., Philadelphia, PA for information and experience shared with VSE regarding the Air Force F-16 calibration shelters.

This report represents the final effort of the humidity control work and services to be provided under Task Order 0080. The required effort contained in the Task Order statement of work is quoted below.

> "The contractor shall provide engineering support, prototype manufacturing, component modification, documentation and testing services for the continued development of a system to interface with existing Government equipment and shelters and which will control the humidity within the U.S. Air Force F-16 Aircraft Service Shelters."

1.0 INTRODUCTION

1.1 Subject. This report provides information concerning the design and development of a Humidity Control System (HCS) capable of maintaining relative humidity (RH) at 45% ±10% in the Air Force Aircraft Service Shelter for all anticipated operation scenarios in extreme environments encountered worldwide.

1.2 Background. Humidity control for the Air Force Aircraft Service Shelters (electrical calibration shelter - ECS and mechanical calibration shelter - MCS) using commercial equipment was originally studied by VSE Corporation under Contract No. DAAK70-86-D-0023, Task Order 0024, for technical and operational feasibility. Based on the positive results of Task 0024, VSE was awarded a follow-on Task (task 0080) to design, develop, fabricate and install two prototype HCS at Shaw AFB, SC for field testing. Following completion of successful field testing, the Air Force intended to retrofit additional F-16 maintenance complexes with the HCS.

Calibration equipment used in the Shelters requires specific relative humidity (RH) ranges in which to function properly. Currently system flexibility is limited since equipment calibrations cannot be accomplished when RH is out of range.

During the course of Task 0080 the Air Force decided not to deploy the HCS in the calibration shelters due to a relaxation of the humidity control requirements. An attempt will be made to find an alternate use for the system. See correspondence from Hanscom, AFB to Fort Belvoir, provided in Appendix A. VSE was instructed by Belvoir to complete all documentation and fabrication as required under the Task Order.

2.0 DISCUSSION

2.1 General System Description. The F-16 calibration shelter HCS is comprised of the following equipment:

- Humidifier. Unit is a steam generator type with a capacity of 7.3 lb/hr. Unit weighs 137 lbs filled with water and has dimensions of 29 1/2" H x 23" W x 17" D. Input power is 208V, 3Ø, 50/60 Hz.

- Dehumidifier. Existing shelter ECU is modified to provide dehumidification.

- Control Panel. The components listed below are mounted on the control panel:

  - Humidity Controller: Controller is used to operate both the humidifier and dehumidifier. Set points are adjustable.

  - Alarm Controller: Controller is used to actuate the high and low humidity warning lights. Set points are adjustable.

  - Humidity Indicator: Unit provides a visual indication of the shelter RH.

- Circuit Breaker: A 20 amp, three pole breaker is provided for equipment protection.

- Water Storage Tank. A stainless steel storage tank provides an approximate 10 hour water supply to humidifier at full load. Tank is 1.13 ft^3 in volume and holds approximately 8 gallons of water.

- Water Transfer Pump. Pump conveys water from the storage tank to the humidifier and is controlled automatically. Design point is 3 gpm @ 7 ft head. Input power is 115V, 1Ø, 50/60 Hz.

- Power Distribution Box. Box is provided to direct power and control wiring to the pump and tank level switches. The pump relay is housed in the box.

A more detailed description of system components is discussed in Section 1.3 of the operation, maintenance and installation instruction provided in Appendix B.

2.2 Prototype Humidifier. Two prototype humidifiers were procured from the Dri Steem Humidifier Co. of Minneapolis, MN. The steam generator humidifiers contain a vaporization chamber and electrical controls within a sheet metal housing. The vaporization chamber (including heaters, valves, strainer, conductivity switch and reservoir, etc.) and electrical equipment (including relays, printed circuit board control module, terminal boards, and blower, etc.) are off-the-shelf commercial components. Only the humidifier housing is specially designed to comply with dimensional requirements of this application.

2.2.1 Humidifier Modifications

2.2.1.1 Dri Steem Humidifier Improvements. The humidifiers as received from Dri Steem were deficient regarding access for maintainability. Access to the blower and steam distribution tube was extremely difficult. Removal of the vaporization chamber was inconvenient, with access to the chamber mounting screws being obstructed and excessive time required to disconnect wires from various electrical equipment. Dri Steem provided key lock quarter-turn fasteners for the front and side panels posing a potential for lost keys.

VSE worked with Dri Steem to overcome these shortcomings. VSE specified certain changes to the humidifier unit which Dri Steem agreed to include in their humidifier drawing package. The changes were incorporated at no additional cost for future humidifiers. A listing of the VSE specified changes is provided below:

- Vaporization chamber wiring was connected to a new terminal board, located beside the chamber, to facilitate removal.

- Repositioned aquastat to allow easier access to vaporization chamber mounting screws.

- Added access cover in humidifier top panel to allow access to steam distribution tube and blower.

- Modified sheet metal of internal duct work to facilitate its removal.

- Added opening in side panel and bottom panel to facilitate power/water cable exit.

- Changed quarter turn panel fasteners from key lock type to permanent knob type to alleviate potential lost key situations.

2.2.1.2 User Modifications. Additional modifications must be performed on the Dri Steem humidifiers following their procurement. These modifications include the addition of nylon pin receptacles to the bottom panel for mounting bracket interface. A toggle switch which provides high and low humidity control must be added to the unit. A cable assembly which includes the power and water lines must be added to the unit. Two brackets around which the cable assembly is wrapped during storage must be assembled onto the unit. All hole additions, rewiring and assembly work required are depicted on VSE drawing No. 10748.

2.2.2 Humidifier Technical Data. The Dri Steem Humidifier Co. provided a technical data package for the prototype humidifiers which consisted of the following:

- General arrangement drawing showing locations of components within the unit.

- Manufacturing drawings for unit housing.

- Specification sheets for commercial components used within the unit.

- Parts list for unit.

- Generic technical manual for Dri Steem's VPC model humidifiers.

Manufacturing drawings for the humidifier housing only were provided since only the housing was designed and fabricated per Government specifications using Government funds. Other humidifier components were previously designed by Dri Steem or are commercial off-the-shelf items.

2.2.3 Letter of Intent. Dri Steem provided a "letter of intent", as requested by the Government, stating that the Dri Steem Humidifier Company does intend to provide humidifiers to the Air Force, in quantities required, through 1992 at designated unit prices in FY 88 dollars. See letter of intent provided in Appendix C.

2.3 HCS Testing. A mock up HCS was tested per the approved test plan with minor variations. See test plan provided in Appendix D. Variations to the test plan included no specific fast or slow response testing of system controls due to test impracticality. A wide range of data was collected for humidifier operation. Relatively little data was collected during dehumidifier operation due to testing occurring during the humidification season. From the HCS performance testing it was determined that the response of the nylon element Honeywell humidity controllers was inadequate to consistently maintain shelter RH within the specified range. Alternate electronic Johnson Controls humidity controllers were substituted and their response proved satisfactory.

A mineral accumulation test was performed which was not required by the test plan. The mineral accumulation test revealed accumulations forming on the steam distribution tube. This result necessitated that the steam distribution tube be included as a maintenance item in the HCS Operation, Maintenance and Installation Instruction. Complete documentation of HCS testing is provided in the test report provided in Appendix E.

2.4 HCS Equipment Locations. The locations of the major system components within the shelter were specified by the Air Force during the July 29, 1987 meeting at Medley Tool and Model Company, Philadelphia, PA. Available space in the calibration shelters is extremely limited. Therefore, the Air Force specified what areas would be made available for the humidifier, water storage tank and control panel which would minimize impact on other shelter equipment. The humidifier and water tank are mounted side by side in a leg well beneath a work surface and the control panel is end wall mounted in the ECS and side wall mounted in the MCS. See Figures 1 and 2 for HCS general arrangements in allocated spaces.

2.5 HCS/Shelter Interface

2.5.1 Shelter Modifications. Relatively minor modifications are required to the calibration shelters to accommodate the HCS. Components must be mounted to floor and walls, and electrical harnesses routed through raceway and interfacing the existing electrical system at the panelboard. Shelter modifications are based on shelter drawings provided by the Medley Tool and Model Co. Modifications for the ECS and MCS are depicted on VSE drawing no. 10749 and 10751 respectively.

2.5.1.1 Mechanical Modifications. The humidifier requires two floor mounted brackets to secure it during transportation. The rear bracket (closest to the wall) is permanently mounted while the front bracket must be removed in order to roll the humidifier into the aisle during operation. Both brackets are mounted using 1/4" rivnuts installed into the 1/8" aluminum floor. The linoleum finish flooring must be counterbored to allow proper seating of the rivnuts. A total of twelve 1/4" screws fasten the brackets to the floor.

The water storage tank is secured to the floor using three brackets. A total of eight 1/4" rivnuts are installed in the floor. Four screws are used in the pivot bracket, two in the floor lock bracket and two in the stop bracket.

The power distribution box (PDB) is mounted on a side wall behind the humidifier. The walls of the shelter are provided with a 3/4" layer of sound absorbing tile. To securely mount the PDB against the wall, a cut out must be made in the tile. Four 1/4" rivnuts are then installed through the wall and

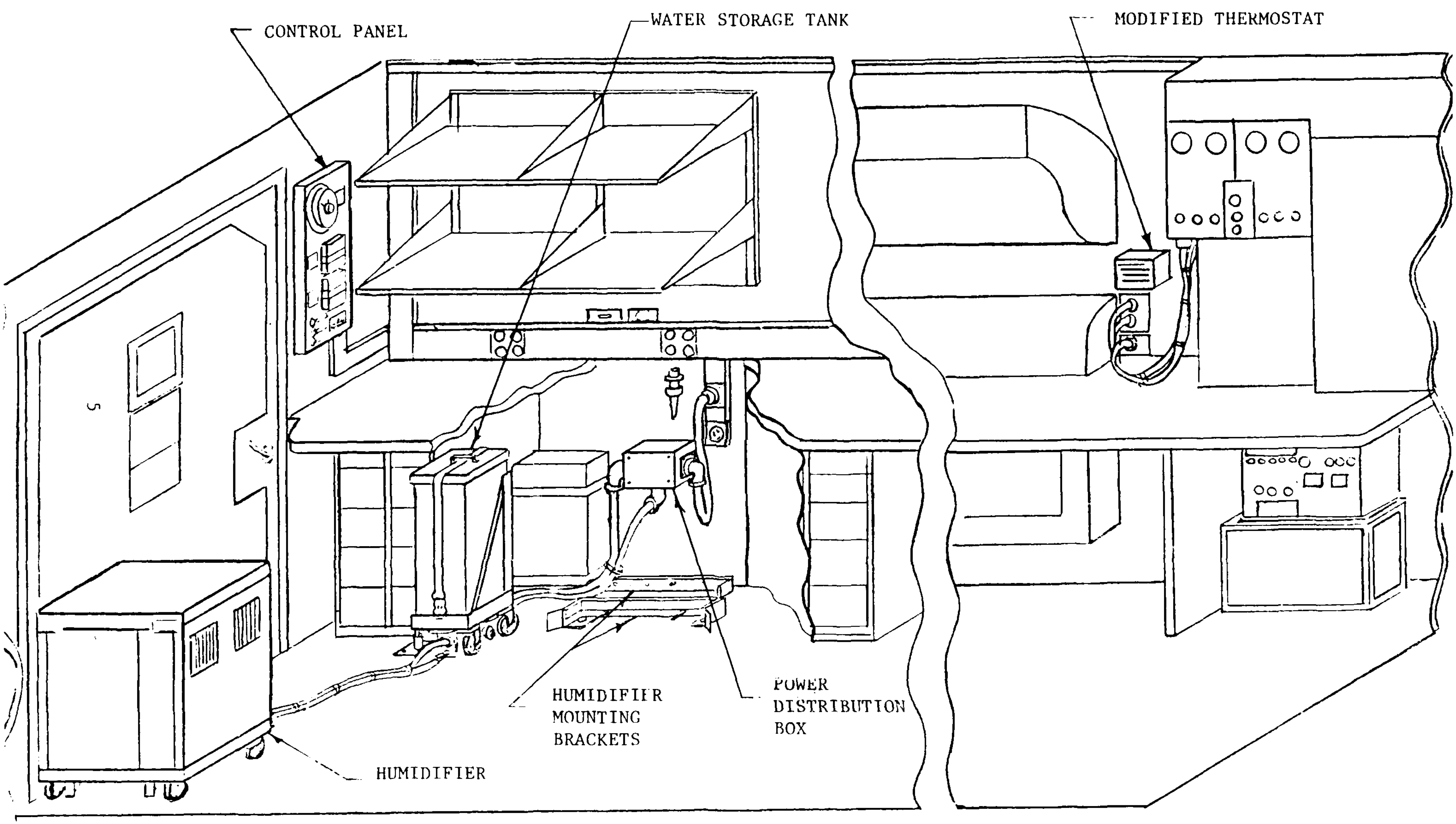

FIGURE 1. HCS General Arrangement - ECS

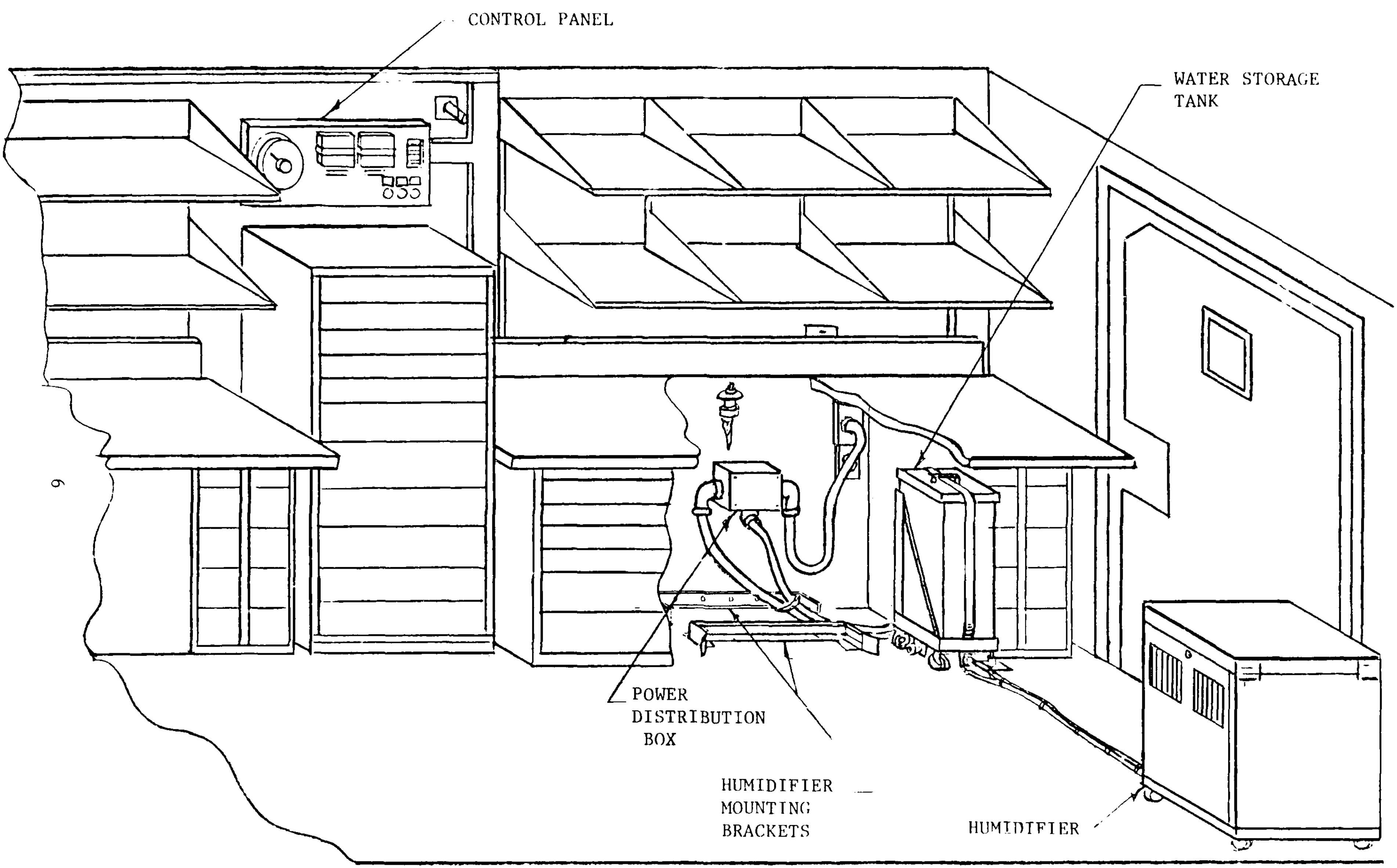

FIGURE 2. HCS General Arrangement - MCS

into the lower horizontal support structure that runs the length of the wall. Wall installed equipment must be mounted to wall support structure since thin .040" aluminum comprises the wall. PDB are mounted on roadside and curbside walls in the ECS and MCS respectively.

In the ECS the control panel is mounted on the emergency exit end wall using unistrut. Sound absorbing tile must be cut away to allow unistrut mounting. Four 5/16" rivnuts are installed in the vertical support structure that runs along the edge of the emergency door and the corner of the shelter. Tile must also be cut away for a short run of new raceway to route new wire harnesses from the existing raceway to control panel.

2.5.1.2 Electrical Modifications. The HCS requires 208V, 3Ø, 50-60 Hz power. The HCS is tapped into the shelter's existing electrical system at the panelboard, on the load side of the 100 Amp main AC circuit breaker. Power is then transmitted to the control panel via a wire harness which must be installed in existing raceway. Medley Tool and Model Co. personnel stated that adequate space exists in the shelter raceways for additional harnesses. Main system power and control power is then conveyed through existing raceway to an MS connector installed in the raceway cover just above the vacuum pump receptacle beneath the work surface. At this point, all wiring to the PDB, junction box (JB) and humidifier are exposed harness runs. An additional wiring harness routes control power between the control panel and the environmental control unit (ECU). This harness is routed through existing raceway to the power converter box. A fitting is installed in the power converter box in the vicinity of the ECU cooling and heating power cable fittings to allow the new harness to exit the converter box and connect to the ECU front panel at a new MS connector mounted in the connector plate.

2.5.2 ECU Modifications. The existing shelter ECU is modified to allow its use as a dehumidifier. The existing thermostat is replaced with a thermostat of the same model, but which has been previously modified. The addition of two relays and minor rewiring of the ECU control panel is required. Control wiring is routed from the ECU control panel to a new MS connector which is mounted in the ECU connector plate. The modifications performed on the ECU in no way affect temperature controlling operation or limit ECU operational flexibility. ECU modifications are depicted on VSE drawing No. 10174. These modifications will necessitate changes to the ECU technical manual.

2.6 HCS Structural Analysis. In accordance with Section 3.3.4 of MIL-A-8421, General Specification for Air Transportability Requirements, the humidifier and the water tank and their respective mounting structures were analyzed to determine their ability to withstand "G" loadings of 3 G's longitudinally, 1.5 G's laterally, 4.5 G's vertically downward and 2 G's vertically upward. Although it is intended that these units be transported dry, the analyses assumed that each unit was full of water.

The humidifier was subjected tc detailed finite element structural analysis using Computer Aided Structural Analysis/Graphical Interactive Finite Element Total System (CASA/GIFTS). Its mounting structure, the water tank and its mounting structure were subjected to manual structural analysis as indicated in the following paragraphs. The analyses indicate that all components maintain structural integrity when subjected to the requirements of MIL-A-8421. See Appendix F for detailed analysis data.

2.7 HCS Installation. The ECS and MCS are to be retrofitted with the HCS. Altered item shelter and ECU drawings are provided with complete dimensions, referenced from existing equipment, for locating HCS components. To facilitate field installation, it is suggested on the drawings that the equipment itself be used as templates for match drilling specific hole locations. See Section 4.0 of the Operation, Maintenance and Installation Instruction for detailed installation procedures.

2.8 HCS Operation. The HCS is intended to operate in two modes, the humidification mode and dehumidification mode. During use of the HCS, the user must insure that the ECU fresh air vent is approximately 2/3 open and that the ECU evaporator fan is in the "ON" position. These items ensure that adequate fresh air is supplied to shelter inhabitants and that adequate air circulation is maintained in the shelter for proper humidity control. Once the humidity controller is set properly for either mode, system control is automatic. Controller adjustments are required to go from one mode to the other.

To operate the HCS when humidification is required, the humidifier must be rolled out from under the work surface and in the aisle. The back of the unit is positioned against the emergency exit to allow the humidified air to discharge down the length of the aisle. Unwrap the power/water the cable assembly from side panel mounts and connect the lines to their receptacles located on the water tank stand. Ensure water storage tank is full. Adjust controller to desired settings and turn "System Power" switch to "ON" position. Observe system operation to ensure shelter RH is being controlled properly. Fine tune controller as necessary. To operate the HCS when dehumidification is required, adjust controller to desired settings and turn "System Power" switch to "ON" position. Observe system operation to ensure shelter RH is being controlled properly. Fine tune controller as necessary.

To refill the humidifier's water tank, release the tank stand from floor support by removing push pin located on side of stand. Rotate tank out from under work surface. Remove lid and fill tank. See Section 2.0 of the Operation, Maintenance and Installation Instruction for detailed operation procedures.

2.9 HCS Maintenance. The humidifier will require regular maintenance to ensure troublefree operation. Due to the nature of steam generator humidifiers, minerals suspended in supply water tend to accumulate on wetted surfaces of the unit (vaporization chamber and steam distribution tube). Excessive accumulation will result in unit failure. The rate of accumulation, and therefore the interval between maintenance, will depend on actual hours of system use and relative "hardness" of supply water. Dri Steem humidifiers are normally provided with a skim/flush system. By periodically skimming off water with high concentrations of minerals from the vaporization chamber and by completely draining and flushing the chamber automatically at preset intervals, the frequency of maintenance is reduced. The skim/flush system was not employed with the Air Force humidifier. It was determined that the advantages of the skim/flush system were outweighed by the disadvantages of installing a drain line through the shelter wall in the field. The Operation, Maintenance and Installation Instruction includes a preventive maintenance schedule in Table 4 and a troubleshooting guide in Table 5. The instruction also provides detailed maintenance procedures in Section 3.0.

3.0 CONCLUSION

The prototype Humidity Control System has demonstrated the capability of controlling shelter RH at 45% ±10%. Early problems with slow system response time were overcome by incorporating faster responding electronic humidity controllers. All electrical and mechanical system components are designed to fit in available spaces to minimize impact on existing shelter systems. Shelter modifications are minimal, requiring simple installation of rivnuts into floor and walls to mount system equipment. HCS power is tied in at the shelter panelboard with harnesses routed through existing raceway. Minor modifications are necessary to the shelter ECU to enable the unit to provide dehumidification when required. Use of the ECU to dehumidify obviates any need for dedicated dehumidifier. Shock/finite element analysis of the HCS indicate that the humidifier and water tank equipment and their mounts will withstand shock loading specified in Section 3.3.4 of MIL-A-8421.

4.0 RECOMMENDATIONS

VSE understands that at this time the Air Force does not intend to pursue further testing of the two prototype HCS developed under this task. The HCS's will not be installed in the electrical and mechanical calibration shelters of the F-16 maintenance complex at Shaw AFB as originally intended. The Air Force is however, searching for an alternate used for all or part of the HCS.

The control panel installed humidity indicator may be a source of confusion when the humidity controller is set prior to system operation. Since the indicator's response time is much slower than the controller's, it is important that the controller be adjusted without regard to the indicator's reading. HCS users could easily make this mistake. It is recommended the humidity indicator be deleted from the control panel.

APPENDIX A

TASK REDIRECTION CORRESPONDENCE

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS ELECTRONIC SYSTEMS DIVISION (AFSC)
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731-5000

APR 11 1988

REPLY TO ATTN OF: AVMS

SUBJECT: Disposition of Humidity Control System

TO: BRDC/STRBE/FED (Greg Wesley)

1. Thank you for your outstanding efforts in the development of a humidity control system for the F-16 AISMF. We have received nothing but the utmost of cooperation and engineering excellence from you organization and from your support contractor, VSE. Unfortunately, through no fault of yours, we will be unable to install the system in F-16 AISMF shelters as planned.

2. There are several reasons why we can't use your system in these shelters. The main one is that TAC has recently relaxed their humidity control requirements (20-70%, 8 hours knockdown period). These new limits translate into reduced capacity, allowing us to fulfill their requirements with a smaller unit at a reduced cost. Another major benefit of relaxed requirements is that no changes will be required to either the ECU or the ECU technical order.

3. We'll continue to seek an alternative use for your system. In the interim, we request that you ship the system to the address below.

ESD/AVMS
Bldg 1305
Hanscom AFB, MA 01731-5000
Attn: Lt Mark Reynolds
Lt Jeffrey Beecher.

4. We apologize for any inconvenience this turn of events may cause you, if we can be of any assistance, please call myself or Lt Beecher at AV 478-6429.

JEFFREY C. VALITON, Capt, USAF
Deputy Chief
AF Tactical Shelter Systems
Development Office
Airlift & Weather Systems Directorate

APPENDIX B

OPERATION, MAINTENANCE AND INSTALLATION INSTRUCTIONS FOR THE F-16 ELECTRICAL AND MECHANICAL CALIBRATION SHELTERS HUMIDITY CONTROL SYSTEM

OPERATION, MAINTENANCE AND INSTALLATION INSTRUCTIONS FOR THE F-16 ELECTRICAL AND MECHANICAL CALIBRATION SHELTERS HUMIDITY CONTROL SYSTEM

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February 1988

Contract: DAAK70-86-D-0023
Project Task No. 0080

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CAUTIONS

CAUTION: Distilled or demineralized water, or water with an electrical conductivity of less than 100 micromhos/cm (2 gr/gal) cannot be used for humidifier supply. Humidifier will not function properly without minimally conductive water.

CAUTION: Humidifier vapor chamber maintenance which is too infrequent, will allow extensive scale accumulation resulting in heater failure.

CAUTION: The direct reading humidity indicator cannot be used for calibrating the electronic humidity and alarm controllers. The humidity indicator response time is relatively slow compared with the electronic units and therefore may not be indicating actual humidity when a specific reading is taken.

CAUTION: When the system power switch is in the "OFF" position, the alarm controller AC1 remains energized with 24 VAC.

CAUTION: When the HCS is in use it is necessary that the heat pump fan be in the "ON" position in order to properly control kit.

1.0 GENERAL

1.1 Scope. This instruction provides operation, maintenance and equipment installation instructions for the humidity control system (HCS) used in the electrical and mechanical calibration shelters of the Air Force F-16 maintenance complex. The instruction addresses the primary system components such as the humidifier, dehumidifier (modified heat pump), humidity controls and water handling equipment. Equipment specifications and set-up, recommended control settings, normal operation expected, routine maintenance and system troubleshooting are discussed. A system parts list is provided. Also provided are detailed installation instructions which enable field installation of a complete and working HCS.

1.2 Purpose of Equipment. The HCS shall maintain a 45% ±10% relative humidity in the shelter at ambient temperatures maintained by the heat pump.

1.3 System Description. The F-16 calibration shelter's HCS basically consists of the following primary components:

- Humidifier
- Dehumidifier (modified heat pump)
- Water Storage Tank
- Water Transfer Pump
- Control Panel
- Power Distribution Box

Section 1.3.1 through 1.3.8 briefly describes each component and it's specifications.

1.3.1 Humidifier. The model VPC-3 humidifier is a modified commercial unit manufactured by the Dri-Steem Humidifier Co. The humidifier is a steam generation type unit, using an immersion electrical resistance heater in an internal vaporization chamber (reservoir) to generate steam. Generated steam rises from the vaporization chamber, through a vapor hose, to a dispersion tube mounted down stream of an internal blower. Forced air passing over the dispersion tube absorbs the vapor and discharges the high humidity air into the shelter. See Table 1 for humidifier specifications.

The vaporization chamber water level is maintained by use of a conductivity probe, printed circuit board with control logic, a solenoid operated valve, a relay, a water transfer pump, and an external water source. The electronic water level sensor consists of three stainless steel probes of three different lengths (upper, middle, lower) which extend through the wall of the vaporization chamber. The probes provide for electric circuits which make or break through the water. The water level is maintained between the upper and middle probes. When the water level drops below the middle probe, the solenoid fill valve opens and simultaneously, a relay energizes which initiates the water transfer pump. The water level rises until contact is made with the upper probe, at which time, the solenoid fill valve and the pump relay are deenergized. Water within the vaporization chamber is maintained in a preheated condition by an aquastat. The aquastat cycles the immersion

Table 1. Humidifier Specifications

- Manufacturer: Dri-Steem Humidifier Co.
  Model VPC-3 Serial No. *

- Dimensions: Heights 29 1/2"
  Width 18 1/4"
  Depth 23"

- Weight: Dry 115 lb
  Operating 137 lb

- Materials:

Top and Bottom Panels	carbon steel	14 gauge
Side and Interior Panels	carbon steel	18 gauge
Vaporization Chamber	304 stainless steel	12 and 14 gauge
Distribution Tube	304 stainless steel	18 gauge

- Steam Capacity:

High Humidification	7.9 lb water/hr
Low Humidification	5.3 lb water/hr

- Blower Capacity: 265 cfm

- Electrical Characteristics: Voltage - 208V
  Phase 0-3Ø
  Frequency - 50/60 Hz
  Current - 8.5A
  Power - 3 kW

Control circuitry is 24 VAC, supplied by built-in transformer

*When ordering additional humidifiers or spare parts, both the Model No. and Serial No. must be provided to the Dri-Steem Humidifier Co.

resistance heater such that the water temperature is maintained between 170-180°F. The preheated water reduces the time necessary for the humidifier to emit steam following an extended "off" period.

The humidifier is mounted on four coasters which allow the unit to be rolled from it's storage position underneath the work surface to it's operational position in the aisle of the shelter. The housing consists of a steel casing with an egg shell white finish. Two removable metal panels with quarter turn fasteners are provided for access to internal equipment. Four spring loaded handles are provided for ease of movement. A single green light is mounted on the front housing which indicates a "power-on" condition. The blower inlet and outlet are located on the front face of the unit. The outlet is provided with adjustable louvers for directing the humidifier discharge as desired.

1.3.2 Dehumidifier (modified environmental control unit). The dehumidification requirements of the shelter are provided for by use of the shelter's environmental control unit (heat pump). The unit is a model MHP 36K208/60/3 heat pump manufactured by the ARE Manufacturing Co. The heat pump employs a common refrigeration system consisting of a compressor, condenser coil, capillary tube pressure reducer and evaporator coil to provide heating and cooling to the shelter. The compressor circulates the refrigerant throughout the system in one direction for cooling and a reversing valve allows circulation of refrigerant in the opposite direction for heating. The unit is provided with electrical resistance booster heaters for use during periods of extreme cold when the heating capacity of refrigerant system is inadequate. The unit is controlled by a thermostat with three non-adjustable set points. One stage of cooling and two stages of heating are available. At 76°F and above the heat pump operates in the cooling mode. At 72°F and below the heat pump operates in the heating mode. AT 68°F and below one bank of electrical resistance booster heaters operates simultaneously with the heat pump circuit. Thermostat setpoints are based on the ARE Manufacturing Co. commercial manual. See Table 2 for dehumidifier specifications.

Maintenance shelters which are equipped with the HCS have had the control circuitry of the environmental control unit modified. This modification enables the heat pump to dehumidify between 72°F and 76°F. When the humidity controller calls for dehumidification between 72-76°F, the heat pump refrigerant circuit will operate in the cooling mode with simultaneous operation of two banks of electrical resistance booster heaters. The evaporator coil will provide a cold surface on which to cool the shelter air and condense moisture while the booster heaters downstream will reheat the air. The heating capacity is expected to slightly exceed the cooling capacity during simultaneous operation. Impact on the shelter air temperature will be minimal, with the air being slightly heated during operation. Modifications performed on the heat pump include the addition of two relays K1 and K2, alteration of the thermostat printed circuit board and necessary rewiring.

Above 76°F the heat pump functions in the cooling mode automatically, thus providing inherent dehumidification.

1.3.3. Control Panel. The control panel contains a humidity controller, an alarm controller, a humidity indicator, a circuit breaker, two relays, three alarm lamps and necessary terminal boards. The panel itself is a surface

Table 2. Dehumidifier (Modified Heat Pump)*

- Estimated water removal Capacity**: 8.9 lb water/hr

- Current (during operation between 72-76°F):
  - L1 - 38 amps
  - L2 - 30 amps
  - L3 - 39 amps

- Ventilation Air (recommended): 120 cfm

*For additional heat pump specifications see ECU Technical Manual NAVAIR 19-60-83.

**Based on cooling capacity test data @ 80 °F, 51% RH mounted 21 1/2" L x 9" W x 3" D aluminum box with black background and white lettering labels. Wiring to and from the control panel is routed through existing raceway and a new raceway extension which interfaces the control panel. The control panel wiring diagram is shown on VSE drawing No. 10720.

1.3.3.1 Humidity Controller. The humidifier and dehumidifier are controlled by a single Johnson controls solid state humidity controller model W50DG-1. The controller contains a Cellulose Acetate Butyrate (CAB) sensing element which determines RH by changes in electrical resistance. Resistance of the sensing element changes as its water content changes. The unit is housed in a steel casing. The original cover provided has been replaced with an aluminum band to allow unrestricted air circulation around the sensing element and serve as a guard.

The controller requires a 24 VAC power supply in which to operate two relays. The relays provide on/off switch action for operating the humidifier and dehumidifier. The W50DG-1 is provided with two adjustment knobs, one for the setpoint, and one for the differential. The setpoint knob is used to set the controller at the desired RH of the conditioned space. Scale range is 30 to 80% RH with 5% graduations. The differential knob is used to control the range about the setpoint in which the environment RH is to be controlled. For example, it is desired to control RH at 50% ± 5% RH. The setpoint knob is set at 50 and the differential knob is set at 10. A controller adjusted to the above settings will initiate the humidifier when shelter RH falls to 45% and initiate the dehumidifier when the shelter RH rises to 55%. In addition to the adjustable overall differential, individual equipment differentials exists which are fixed at 2% RH. See Johnson Controls bulletin No. 4051-C, Figure 6, in Appendix A for further clarification of controller operation.

The use of two relays are required to provide on/off switch action to the humidifier and dehumidifier control circuits. Potter and Brumfield model KHS-1711-24, four pole double throw, socket mounted, hermetically sealed relays are provided.

1.3.3.2 Alarm Controller. A second model W50DG-1 humidity controller is provided for actuation of extreme humidity alarm lamps. Setpoints and differentials are adjusted in the same manner as the equipment humidity controller. Each alarm lamp has push-to-test capability with dimmer and amber lens per MS25041-4. No relays are required for operation of the alarm lamps.

1.3.3.3 Humidity Indicator. The Abbeon Cal model 4703-600 humidity indicator senses RH using a nylon derivative element. Nylon is a hygroscopic material which expands or contracts depending on moisture content. The expansion or contraction mechanically displaces a pointer on a circular face plate. The unit indicates the ambient RH on a direct reading 0-100% face plate with 2% graduations. One manually adjustable contact which opens or closes a control circuit is provided with the humidity indicator. The contact is not used in the HCS. The 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.

1.3.3.4 Circuit Breaker. A Heinemann model AM3-Z29-102, 20 amp, three pole circuit breaker (CB) is provided for equipment protection. Power for the HCS is tapped off the existing 100 amp AC main CB in the existing panel board. Since the existing panel board has no positions available for a new AC CB, the HCS CB is remotely located on the control panel. The CB also serves as an on/off switch for the HCS.

1.3.4 Water Storage Tank. The water storage tank (WST) provides the humidifier an approximate 10 hour water supply without operator attention, during worst case humidification operation condition. The tank is 1.13 ft^3 in volume and holds approximately 7.7 gallons of water. The tank is fabricated of 16 gauge, 304 stainless steel. The tank is mounted in an aluminum bracket which is provided with wheels for ease of tank refilling. The tank is provided with two handles and a removable top. Two proximity type, magnetically actuated level switches are installed in the tank side. The level switches initiate a low water condition warning lamp on the control panel, and open the water transfer pump control circuit at an extremely low water level to insure the pump will not run dry. A double end shut-off quick disconnect is provided for detaching the water line. A screen mesh strainer is provided over the water port. The tank weighs 90 lbs when full and 25 lbs when empty.

1.3.5 Water Transfer Pump. A small water pump is provided to automatically transfer supply water from the storage tank to the humidifier. Specifications for the pump are provided in Table 3. The pump is a magnetically driven centrifugal which delivers 3 gpm @ 7' head pressure. The pump is mounted on the backside of the water storage tank support bracket. A 3/8" inlet and 1/4" outlet barbed brass fittings are used with screw clamps to connect to 1/4" ID polyurethane water hose to the pump. The pump must deliver water from the tank through approximately 7' of tubing to the humidifier.

1.3.6 Power Distribution Box. A power distribution box (PDB) is provided to branch off power and control wiring for the water pump and level switches to the WST assembly. Three wiring harnesses routed to the PDB are attached using MS connectors. The PDB also houses the water pump power relay. A chassis ground is provided for the PDB. The PDB wiring diagram is shown on VSE drawing No. 10720.

Table 3. Water Transfer Pump

- Manufacturer: March Manufacturing Co.
  Model No. AC-2CP-MD

- Type: Centrifugal, magnetically coupled

- Overall Dimensions: Height - 4 1/2"

  Length - 7 3/8"

  Width - 3 1/2"

- Weight: 4 1/2 lb

- Design Point: 3 gpm @ 7' head pressure

- Electrical Characteristics: Voltage - 115V
  Phase - 1Ø
  Frequency - 50/60 Hz
  Current - 1.0A
  Power - 70W
  Motor Speed - 3450 rpm

2.0 OPERATION INSTRUCTIONS

2.1 Humidifier Storage and Set Up. The humidifier is stored beneath the ECU side work surface (near the emergency exit) in the electrical calibration shelter, and beneath the work surface opposite to ECU side (near the emergency exit) in the mechanical calibration shelter. The humidifier is secured in place using two floor mounted aluminum brackets, front and back. Both brackets are fabricated with two 3/8" dia. 2 1/2" long steel pins. Four 1 1/2" x 2" rigid nylon blocks, mounted to the bottom panel of the humidifier, act as receptacles for the pins. This mounting configuration secures humidifier movement in the vertical plane. The angle brackets are located such that they butt up against the humidifier sides and the humidifier front and back. Rigid nylon is used as a liner for the brackets to eliminate metal to metal contact and therefore possible damage to the humidifier finish. The brackets secure humidifier movement in the longitudinal and lateral planes. Figure 1 shows details of the humidifier mounts.

In order to operate the HCS when humidification is required, the humidifier must be set up in the proper position. The front bracket must be removed from the floor by unscrewing the five fasteners. The humidifier can then be rolled out on it's own wheels from under the work surface and into the aisle. The just removed front bracket can then be loosely stowed behind the back bracket against the wall. At this point, the power harness and the water line must be deployed. Remove the humidifier side panel to expose the wire harness and water line assembly. Unroll the harness/line assembly from its panel bracket until the panel can be removed completely and set aside. Route the harness/line assembly through the 3/4" x 1 1/4" port located in the bottom left hand side of the panel opening. If the humidifier is being set up in the electrical calibration shelter, a harness/line assembly of additional length is provided to allow routing around the backside of humidifier. The humidifier is then rolled in place with the backside against the shelter emergency exit. The remaining length of harness/line assembly is then routed along the floor against the shelter emergency exit and in front of the Lyon cabinet and connected to receptacles mounted beneath the WST. If the humidifier is being set up in the mechanical calibration shelter, the humidifier is rolled in place with the back side against the shelter emergency exit and the harness/line assembly is routed from the 3/4" x 1 1/4" port along the floor against the shelter emergency exit and in front of the Lyon cabinet and connected to receptacles mounted beneath the WST. The receptacles consist of an MS connector and a double end shut-off quick disconnect. The MS connector should always be the first connection engaged when setting up and the last connection disengaged when breaking down to insure that any water leakage from the quick disconnect does not find its way into the electrical connector. Replace the humidifier side panel. Adjust the six vertical louvers in the unit discharge such that the emitted high humidity air does not blow on any nearby equipment, personnel, etc., and such that the emitted air is not likely to be recirculated back into the humidifier intake.

The WST must be filled with water. It is important that demineralized water is not used in the HCS. Removal of the humidifier allows access to the push pin which secures the WST in place. Remove the push pin and place in it's holder. Rotate the WST and bracket assembly on it's wheels 90° (See Figure

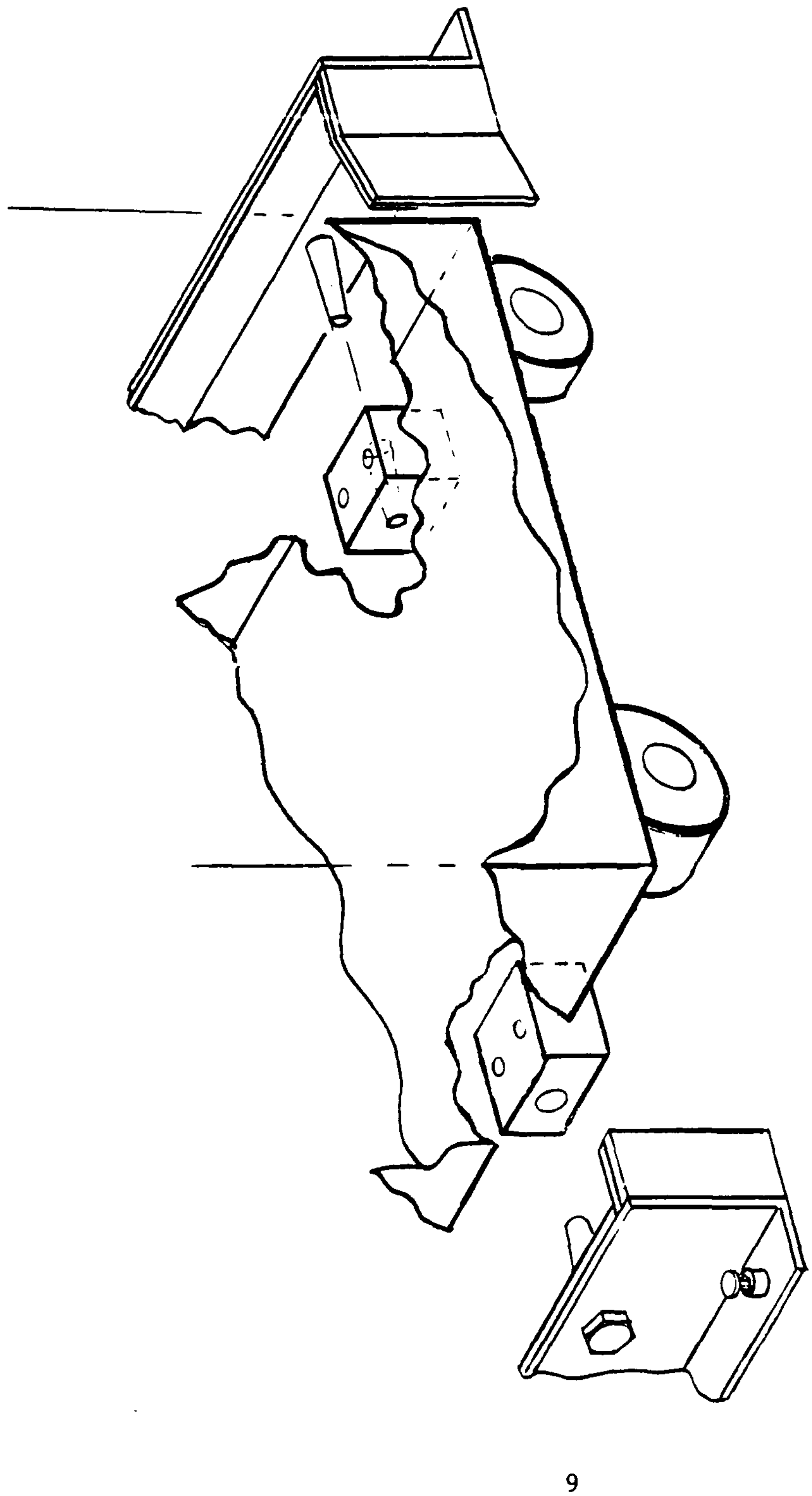

Figure 1. Front and Rear Humidifier Brackets

2). The WST is now partially exposed from beneath the work surface. Remove the 1" strap which secures the WST to the bracket by releasing the buckle. Remove the tank cover and fill the tank to not more than 3" from the top. Replace the tank cover. Resecure the strap through the cover handle and buckle in place to keep loose strap out of the way and maintain a neat appearance. Slowly rotate the WST back underneath the work surface and secure in place with push pin.

This tank filling procedure assumes that the supply water will be brought to the tank. The tank may be taken to the water source by removing the strap, disconnecting the MS connector for the tank's two level switches at the junction box, and disengaging the tank mounted double end shut-off quick disconnect. Handles are provided for lifting/carrying the tank.

2.2 Dehumidifier Storage and Set Up. The control circuitry of the environmental control unit provided for heating and cooling is modified to allow use as a dehumidifier. The ECU dehumidifier does not require any special consideration for storage or set up other than adjustment of the fresh air damper. The damper should be set midway between 1/2 and full positions in order to introduce approximately 120 cfm of outside ventilation air. When the ECU is in position for heating and cooling the unit is also ready to dehumidify. See ECU Technical Manual NAVAIR 19-60-83, Section 2 for storage and set up procedures.

2.3 HCS Controls. The HCS is designed to maintain the shelter RH within a 45% ± 10% range. The controls provided offer great flexibility with which to maintain this range. It should be noted that relative humidity is dependent on both air temperature and water content. The humidification capacity of the humidifier and the dehumidification capacity of the dehumidifier are sized for extreme weather conditions which may be encountered anywhere in the world. When moderate weather conditions exist, the most difficult control situation occurs when minimal humidification or dehumidification is required. The controller is fully adjustable for adaptability to various ambient conditions.

The humidifier is provided with two stages. A toggle switch is located internal to the unit which can be set for low humidification or high humidification. On low humidification the unit capacity is 2/3 of full capacity is available. On high humidification, full capacity if available. The dehumidifier is provided with one stage of dehumidification.

The humidity and alarm controllers are calibrated upon installation in the shelter. Controllers should be recalibrated approximately twice a year. Procedures for controller calibration are delineated in section 4.8 of this instruction.

To operate the HCS the heat pump thermostat fan switch should be placed in the "ON" position. The system circuit breaker should be switched "ON".

It is anticipated that the humidity controller (HC1) settings will require adjustment depending upon the season. For example the HC1 controller may require certain settings during a cold winter season when the need to humidify predominates, and different settings during a hot humid summer when the need

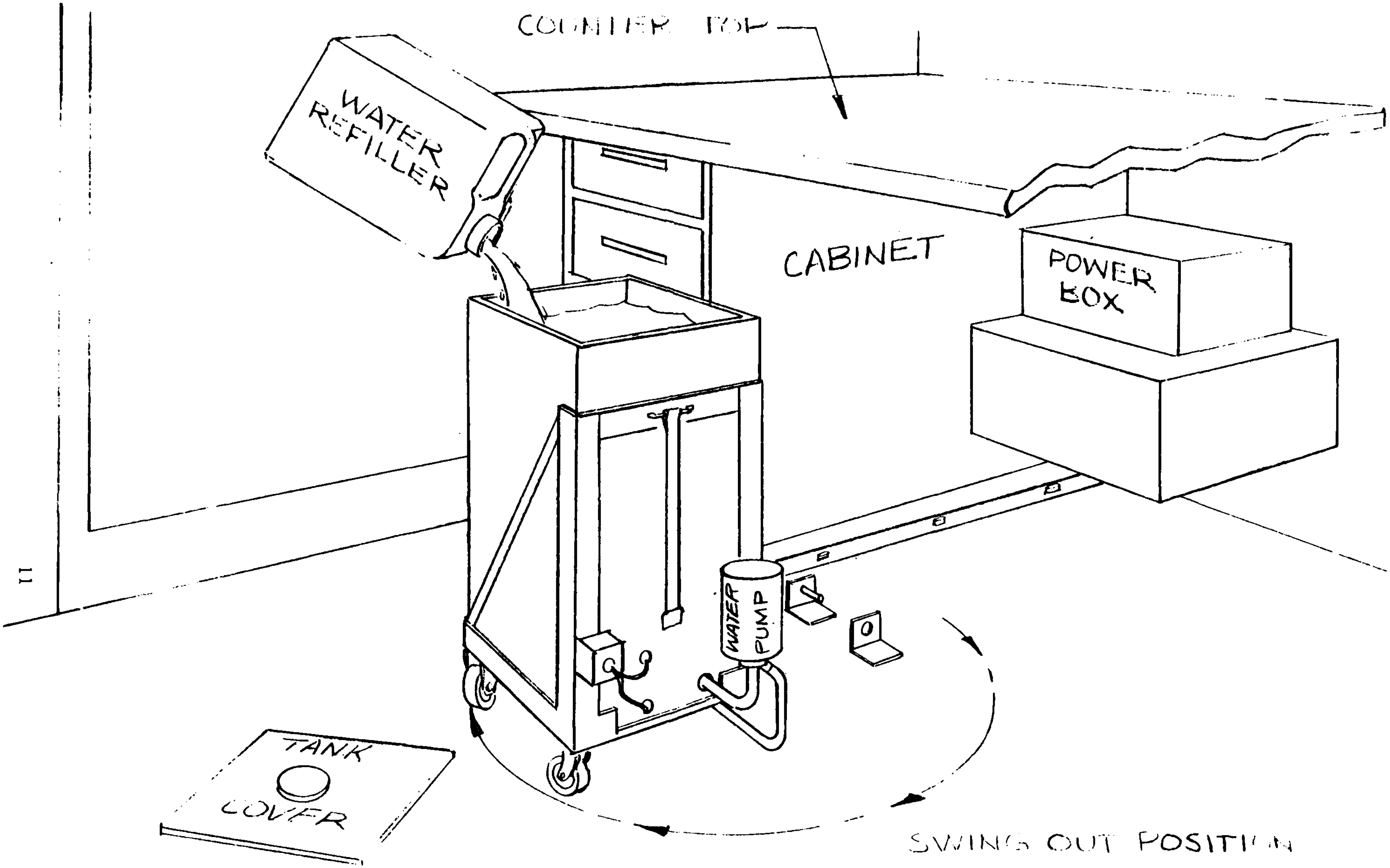

Figure 2. Water Tank in Filling Position

to dehumidify predominates. The settings for the alarm controller (AC1) should not require adjustments for either mode of operation. Generally, the HC1 settings should enable the HCS to control shelter RH without actuating either the high or low humidity alarm lamps or allowing the humidifier and dehumidifier to compete with one another. The equipment may compete if the differential is so low such that the shelter is humidified until the humidifier shuts off and system overshoot causes the dehumidifier to start. The shelter is then dehumidified until the dehumidifier shuts off and system overshoot causes the humidifier to start, etc. To begin with, it is recommended that the setpoint knob be set at 45% and the differential knob be set as low as possible, such as 5%. Remove controller guard if necessary to make adjustments. System operation should be observed for approximately 1 hour for satisfactory operation. If the humidifier and dehumidifier compete, the differential should be adjusted higher. If the low humidity alarm lamp actuates the setpoint knob should be adjusted higher. If the high humidity alarm lamp actuates the setpoint knob should be adjusted lower.

A humidity indicator is included with the HCS to provide a visual reading of the shelter RH. No adjustments are necessary for the humidity indicator and the unit should be recalibrated each time the humidity controllers are recalibrated. It should be noted that the response time of the humidity indicator is much slower than that of the controllers. Therefore the controller settings should be manipulated without regard to the humidity indicator reading. Rapid RH changes within the small volume of the shelter may cause the humidity indicator not to display the actual shelter RH.

A summary of recommended system settings is as follows:

Humidifier - Set internal switch to high or low humidification depending upon humidification load.

Dehumidifier - Set thermostat fan switch to "ON" position.

HCS Circuit Breaker - Set to "ON" position.

Humidity Controller (HC1) - Set setpoint to 45% and differential to 5%, adjust as necessary.

Alarm Controller (AC1) - Unit need only be adjusted during calibration.

3.0 MAINTENANCE INSTRUCTIONS

3.1 HCS Preventive Maintenance. Table 4 outlines a schedule for all preventive maintenance actions recommended for the HCS.

3.1.1 Humidifier Cleaning Interval. A steam generator humidifier requires regular maintenance to insure troublefree operation. The need for regular maintenance is necessitated by the fact that the supply water used in the unit contains dissolved minerals such as calcium and magnesium. The term "water hardness" refers to the relative amount of minerals dissolved in the water. In a steam generator type humidifier, the water is heated to create steam which is then blown out into the conditioned space. As the water is evaporated into steam, most of the heavier minerals are left behind in the humidifier and eventually concentrated to high levels. The minerals begin to accumulate on all wetted surfaces of the humidifier. The frequency of maintenance will vary greatly with the amount of minerals dissolved in the supply water and on the evaporation load (how often the humidifier operates). The water hardness will vary with the different water sources found worldwide. Though a minimum supply water hardness is necessary for operation of the unit, the dissolved minerals will begin to build on the sides and bottom of the vapor chamber, the three probe level sensors and the outside of the steam distribution tube due to moisture carryover.

The frequency of cleaning will be "as required" for the specific system location and environmental conditions, however it is recommended that the vaporization chamber be visually inspected following one week of operation. Visual inspection may be accomplished by unplugging the water level probe cap assembly and unscrewing the 2 1/4" phelonic hex head probe holder. Observe accumulation on probe ends. Using a flashlight observe accumulation on internal surfaces through the probe mounting port. Too infrequent maintenance will allow excess accumulation resulting in unit failure.

Mineral accumulation, at first, occurs evenly on all wetted surfaces of the vaporization chamber in the form of a hard light colored scale. When approximately 1/4 inch has accumulated on the side of the chamber, scale accumulation in excess of 1/4 inch tends to naturally flake off and drop to the bottom. Due to thermal expansion, scale build up on the heating element tends to naturally flake off and drop to the bottom. For these reasons bottom accumulation is most critical. Maintenance which is too infrequent or totally neglected will allow bottom accumulations to reach the level of the heating element. When this occurs the element becomes insulated causing overheating and burn out.

3.1.2 Humidifier Maintenance. To clean the humidifier vaporization chamber, ensure that the power to the unit is off. Roll the humidifier to a location where the water in the vaporization chamber can be conveniently drained out. Open the side panel and drain the vaporization chamber using the manual ball valve. Remove the connected wiring at the terminal board, unplugging the water level probe cap assembly, remove the two 1/4" head screws in lower corners of the chamber and slide the 2" flexible rubber hose off the upper steam distribution tube by loosening the two screw clamps. The vaporization

Table 4. HCS Preventive Maintenance

Item No.	Item to be Inspected or Serviced	Procedures	Time Interval
1	Vaporization Chamber Inspection	Remove housing side panel. Drain chamber through the ball valve. Remove conductivity probe plug and unscrew 2 1/4" hex head probe holder. With flashlight observe scale internal to chamber.	Every two weeks when in humidification mode. Adjust interval as required based on local water hardness and evaporation loads.
2	Vaporization Chamber Service	Based on inspection results, remove chamber by disconnecting all wiring at the terminal board, unscrew clamps securing flexible hose to chamber and remove two 1/4" hex head screws in lower corners of chamber. Remove vaporization chamber completely from housing. Expose chamber internals by removing eight No. 10 screws in top panel. Using a paint scraper or equivalent loosen and remove accumulated scale. All scale need not be removed down to bare metal. The tips of the conductivity probe should be brushed clean with stainless steel wool.	Clean chamber as required.
3	Steam Distribution Tube Inspection	Remove top access panel on humidifier top by removal of four No. 8 screws. Observe scale accumulation around tube nozzles.	Every two weeks during humidification season. Adjust interval as necessary.

Table 4. HCS Preventive Maintenance (Continued)

Item No.	Item to be Inspected or Serviced	Procedures	Time Interval
4	Steam Distribution Tube Service	Based on inspection results, remove tube by loosening the two hose clamps and 2" hose on bottom of tube. Remove the four No. 8 screws which secure the tube to the duct work. Remove tube from humidifier. Remove the eight black nylon inserts from the nozzles. Using a paint scraper or an equivalent loosen and remove accumulated scale.	Clean tube as required.
5	Water Storage Tank	Inspect for and remove as necessary any accumulation of dust, dirt, bacteria growth or scale. Insure strainer is free of debris. Observe free swing of level switches. Consider chemical additives if biological growth is severe.	Inspect WST along with vaporization chamber.
6	Humidity and Alarm Controllers HC1 and AC1	Recalibrate controllers (see Section 4.8 for procedure)	Twice a year.
		Replace controllers	Every two years.
7	Humidity Indicator	Recalibrate indicator	Once a year.
8	Water Line	Replace 1/4" ID plastic water line	Once a year.

chamber can then be completely removed from the housing. Access is gained to the chamber internals by unscrewing eight No. 10 pan head screws and removing the top. Using a paint scraper or some equivalent, scrape off the excess accumulation on all surfaces and dump from chamber. All scale need not be scraped off the metal, only that which is relatively easy to remove. Remove the probe holder. Flake the scale off the teflon coated portion of water level probes. The bottom 3/8 inch of the probes are uncoated and should be brushed clean with stainless steel wool. The heating element is self cleaning and should not require maintenance. Replace chamber top and reinstall probe holder with arrows up and "top" marking at the top. Replace vapor chamber in housing and reinstall the two 1/4" hex screws and the 2" flexible hose with the two screw clamps. Reconnect wiring to the terminal board and plug in the probe cap to the probe holder. When cleaning the unit at the end of a humidification season, or when it is known that humidification will not be required for a period of time, the unit should be left unfilled until which time humidification is again required.

3.1.3 Water Storage Tank. Little maintenance is required for the water storage tank and its mounting bracket. Prior to refill, visually inspect the tank for any accumulation of dust, dirt, bacteria growth or scale. To clean the tank remove the securing strap, disconnect the water line via the double shut-off quick disconnect, disconnect the electrical connector to the level switches and remove tank from bracket. Scrape free any accumulations. Rinse with fresh water. Observe level switches to insure free swing. Ensure strainer (wire mesh) at inlet to the water line is free of debris.

In some environments biological growth may become a problem in the unheated water circuit of the HCS. No microorganisms will consistently accumulate in the humidifier vapor chamber itself since the bacteria cannot survive at the high operation temperatures. Control of microorganisms may be accomplished by use of a biocide additive. The biocide used must be compatible with a steam generator humidifier.

3.1.4 Water Pump. No maintenance is necessary for the water pump. Bearings are permanently lubricated and sealed. See commercial literature in Appendix A for motor replacement.

3.1.5 Humidity and Alarm Controllers. It is recommended that the humidity controls be recalibrated twice a year and replaced every two years. See Section 4.8 for calibration procedures.

3.1.6 Humidity Indicator. It is recommended that the humidity indicator be recalibrated once a year or each time the controllers are calibrated.

3.2 Corrective Maintenance. See Table 5 for HCS troubleshooting guide and recommended corrective action.

Table 5. HCS Troubleshooting Guide

Humidifier (H1):

Problem	Control Module Lights: Power	Fill	Water	Possible Cause	Recommended Action
Green "Power ON" indicator will not light				Light	Verify voltage across terminals 6 and 7 of TB1.
				Circuit Breaker	Verify voltage across terminals L1, L2 and L3 of CB1. Inspect for loose connections at CB1.
Vaporization Chamber does not preheat	On	Off	On	Aquastat	Disconnect aquastat from terminals 8 and 9 of TB1 and insure continuity through aquastat when heating is called for.
Humidifier will not heat	Off	Off	Off	Control Transformer	Verify control voltage across terminals 6 and 7 of TB1.
	On	Off	On	Humidity Controller (HC1)	Set humidity controller to call. Verify control voltage from terminal 13 of relay K1 in control panel to ground.
				Humidity Controller Relay (K1)	Set humidity controller to call. Insure continuity between terminals 8 and 12 of K1.
				Contactor	Jumper terminals 8 and 9 of TB1 contactor should pull in.
				Control Module	Verify control voltage between terminals 6 and 8 of TB1.
				Probe Corrosion	Replace probes

Table 5. HCS Troubleshooting Guide (Continued)

Humidifier (H1): (Continued)

Problem	Control Module Lights: Power	Fill	Water	Possible Cause	Recommended Action
Humidifier will not fill	On	On	Off	Water Tank	Verify tank has water
				Water Transfer Pump	Insure pump operates when energized.
				Water Transfer Pump Relay (K1)	Verify proper operation of relay in Power Distribution Box by measuring control voltage between terminal 13 and ground.
				Solenoid Valve	Verify action of fill solenoid valve by turning control module switch from "Standby" to "Normal Operation". Audible click should be heard as solenoid operates. Also check for plugged valve.
				Strainer	Check for plugged strainers at the WST outlet and solenoid valve inlet.
				Control Module	Verify control voltage across terminals 5 and 6 of TB1.
Humidifier does not stop filling	On	On	Off	Lack of tank to probes continuity. Water conductivity 100 microhos/cm (2gr/gal) minimum	Jumper terminals 1 and 4. If water stops, verify tank ground to terminal 4; check water supply conductivity; then consult Dri Steem Humidifier Co.
				Solenoid Valve	Check valve for obstructions

Table 5. HCS Troubleshooting Guide (Continued)

Humidifier (H1): (Continued)

Problem	Control Module Lights: Power	Fill	Water	Possible Cause	Recommended Action
Humidifier short Cycles				Probes may be incorrectly wired	Confirm that unit is wired per diagram.

Dehumidifier (HP1):

Problem	Possible Cause	Recommended Action
Dehumidifier does not operate between 72 -76 F.	Humidity Controller (HC1)	Set humidity controller to call. Verify voltage from terminal 13 of relay K2 in control panel to ground.
	Humidity Controller Relay (K2)	Set humidity controller to call. Insure continuity between terminals 8 and 12 of K2.
	Field wiring of heat pump	Insure heat pump is wired per diagram.
Resistance heater operates simultaneously with cooling cycle above 76 F.	Heat pump relay (K1)	Jumper thermostat contacts W1, W2 and Y1. Insure continuity between terminals 8 and 12 of K1.
Resistance heater(s) operate simultaneously with heating cycle between 68 and 72 F.	Heat pump relay (K2)	Jumper thermostat contacts W2 and open contacts W1 and Y1. Insure continuity between terminals 8 and 12 of K2.

NOTE: For additional ECU troubleshooting guidance refer to Table 4.3 of ECU Technical Manual NAVAIR 19-60-83.

4.0 INSTALLATION INSTRUCTIONS

4.1 General. Existing electrical and mechanical calibration shelters must be retrofit with the HCS. Section 4.0 provides written instructions as well as figures to delineate the steps necessary to install a complete and functional HCS. It is noted throughout, where installation procedures differ between the two calibration shelters. See electrical and mechanical shelter modification drawing numbers 10749 and 10751 respectively.

4.2 Control Panel. Refer to Figures 3 and 4 during control panel installation. Using a sharp matt knife, cleanly cut a 9 1/8" x 21 5/8" section of wall tile for the control panel and approximately a 1 1/4" x 6" section of wall tile for the raceway extension located as shown. Using a paint scraper, remove the wall tile down to the sheet metal. Carefully scrape away all excess tile and adhesive residue until a relatively smooth surface remains for mounting the control panel. It may be necessary to sand down the wall surface. Be careful not to damage the remaining tile edges. Place control panel base in cut away section and match drill six 1/4" mounting holes. Place raceway extension in cut away and match drill three 5/16" mounting holes. In the electrical shelter the left three holes will penetrate a wall structural member and the right three holes will penetrate only .040" sheet metal. In the mechanical shelter the top three holes will penetrate a structural number and the bottom three holes will penetrate only .040" sheet metal. Install the proper length rivnuts. Mount the control panel P/N 10731-1 or -2 as applicable. Mount the raceway as shown and secure in place with 5/16" rivets. Tie in the new raceway into the existing raceway and the control panel using two No. 6 screws. The final step for control panel installation is to carefully caulk around the control panel and the new raceway to fill the gaps and present a neat appearance.

4.3 Power Distribution Box. Refer to Figure 5 during box installation. Figure 5 shows box installation in electrical calibration shelter only, however mechanical calibration shelter installation is similar. Using a sharp matt knife, cleanly cut a 6 1/8" x 9 5/8" section of wall tile located as shown. Using a paint scraper, remove the wall tile down to the sheet metal. Carefully scrape away all excess tile and adhesive residue until a relatively smooth surface remains for mounting the power distribution box (PDB). It may be necessary to sand down the wall surface. Be careful not to damage the remaining tile edges. Place PDB in cutout area and match drill four 27/64" mounting holes. The two upper most holes will penetrate a wall structural member and the two lower holes will penetrate only .040" sheet metal. Install the proper length rivnuts. Mount the power distribution box P/N 10722.

4.4 Humidifier Storage Brackets. Refer to Figure 6 during bracket installation. Figure 6 shows bracket installation in electrical calibration shelter only, however mechanical calibration shelter installation is similar. Install rear bracket P/N 10747 by locating the bracket in the proper position shown and match drilling the seven 1/4" mounting holes into the floor. Counterbore 1" Dia. holes through the finished flooring only. This will allow enough room for properly installing the rivnuts. A single rivnut will penetrate a structural member in the floor as shown. Install the proper length rivnuts. Mount the rear bracket.

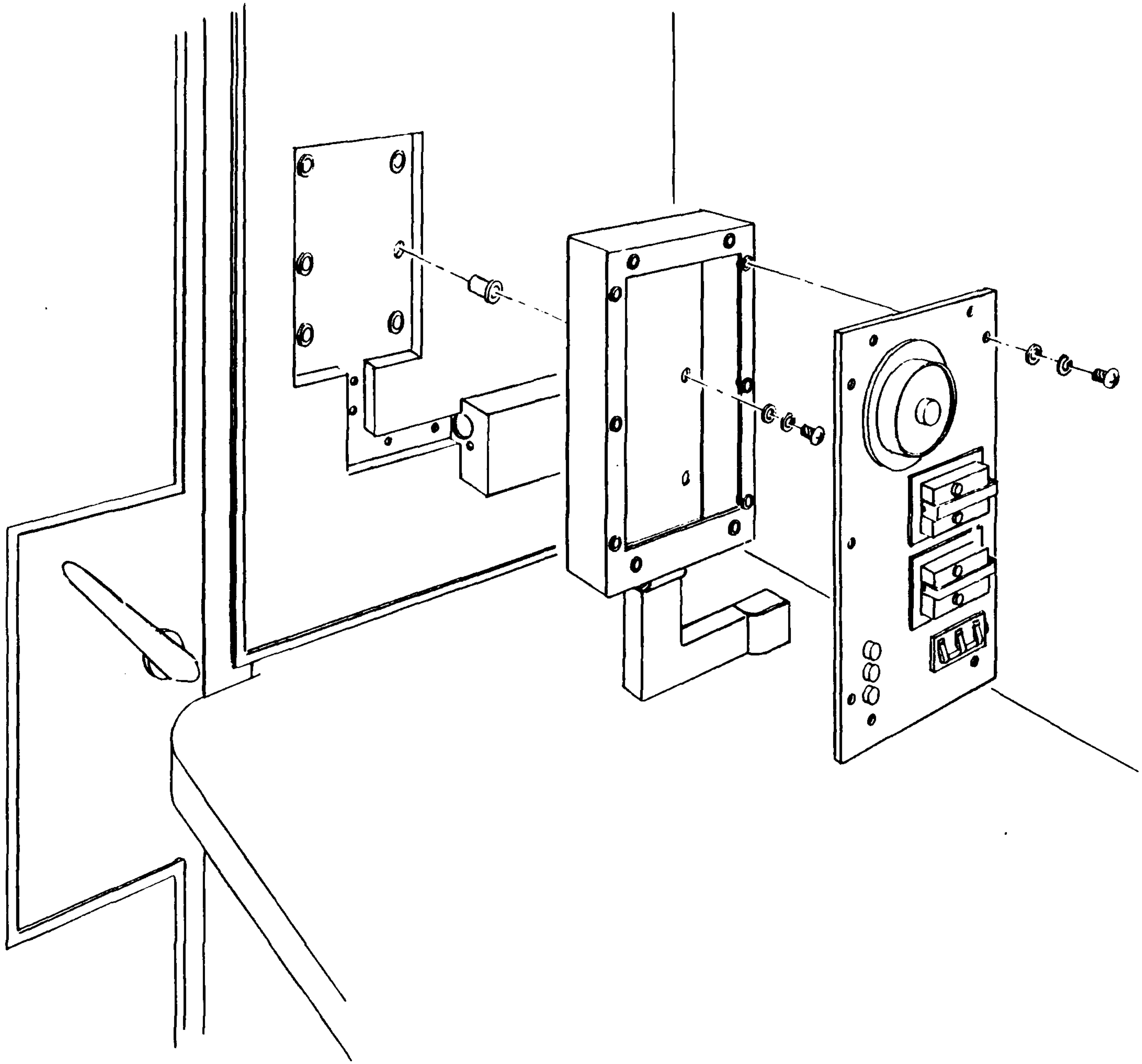

Figure 3. Control Panel Installation - Electrical Calibration Shelter

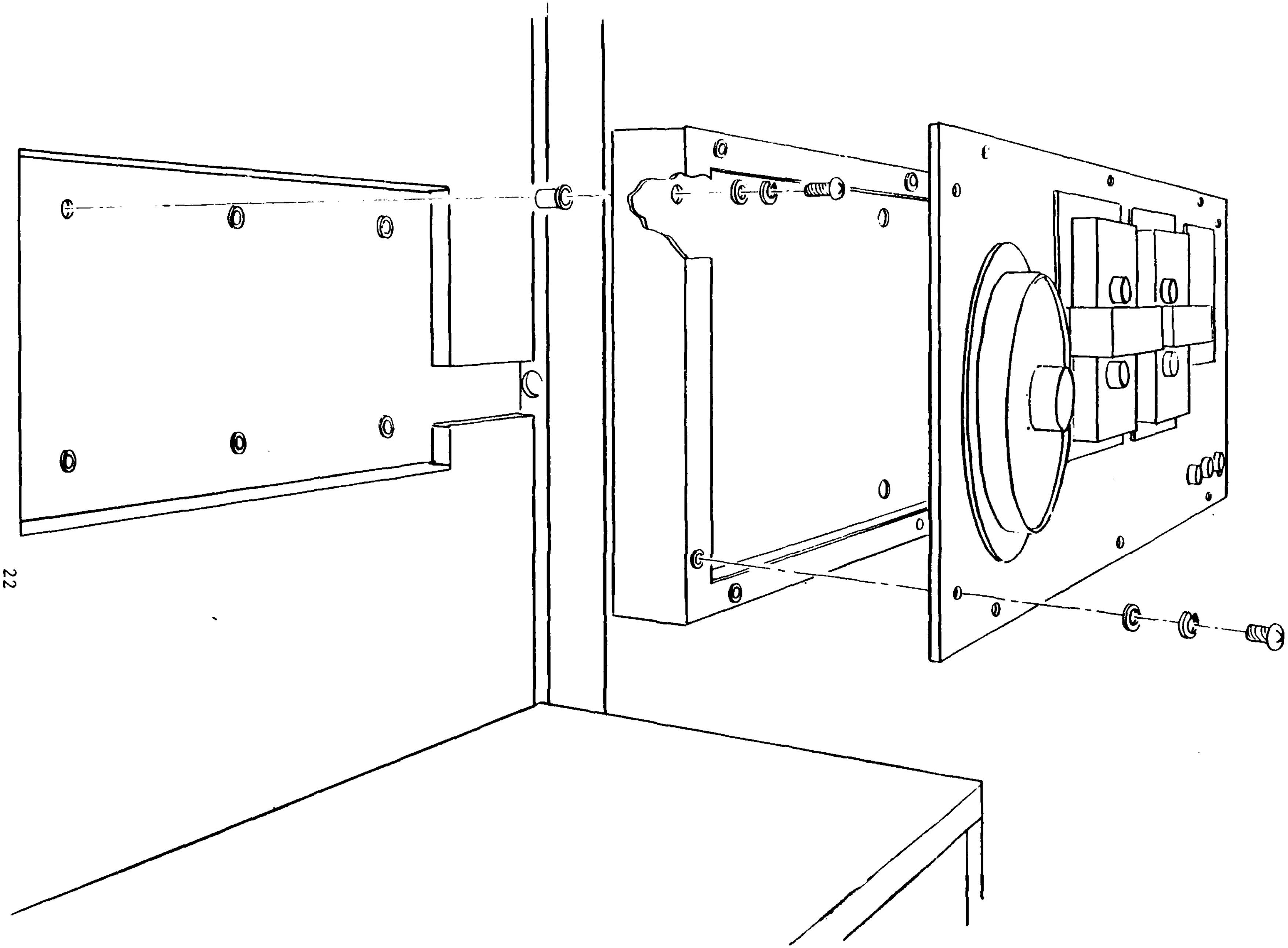

Figure 4. Control Panel Installation - Mechanical Calibration Shelter

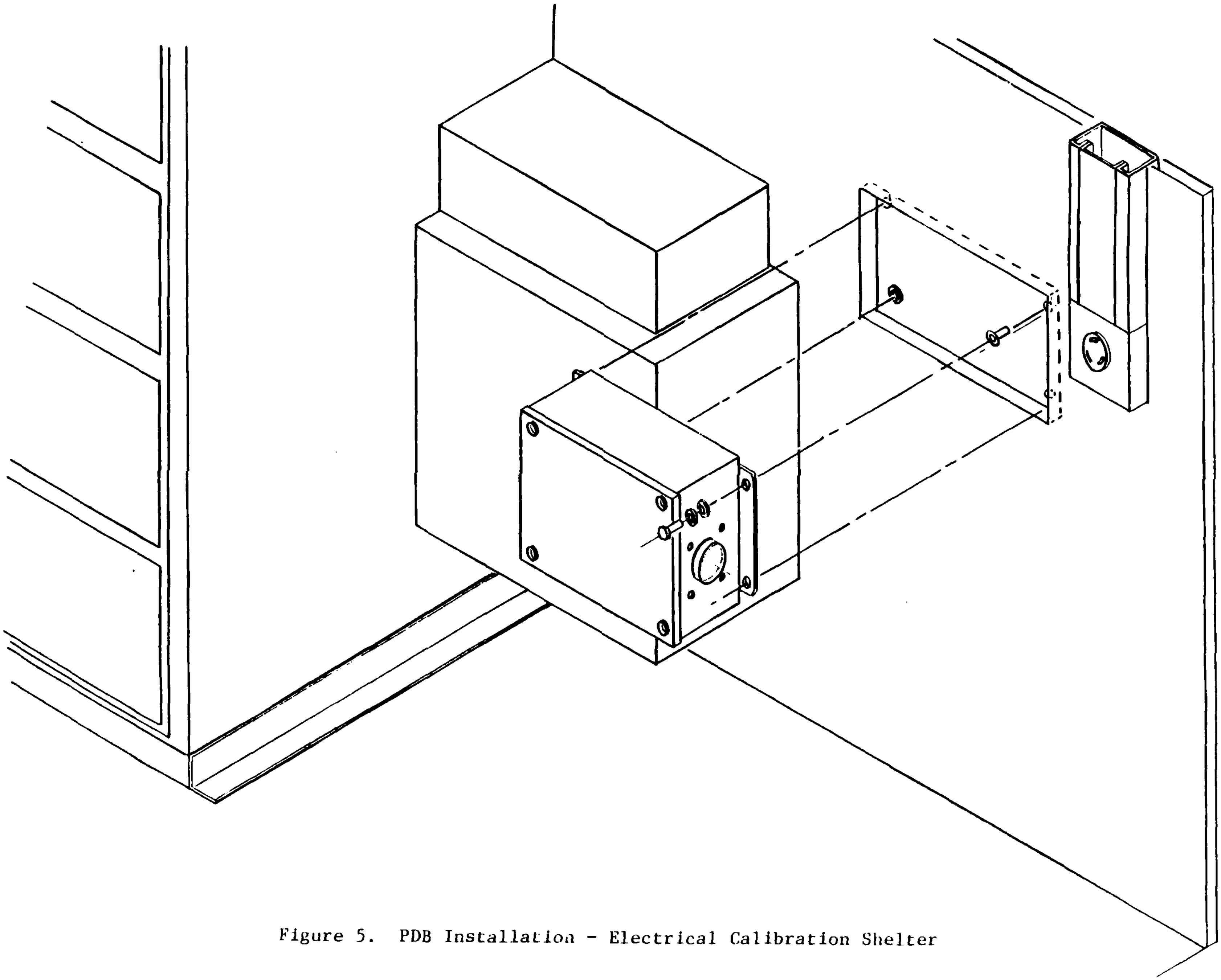

Figure 5. PDB Installation - Electrical Calibration Shelter

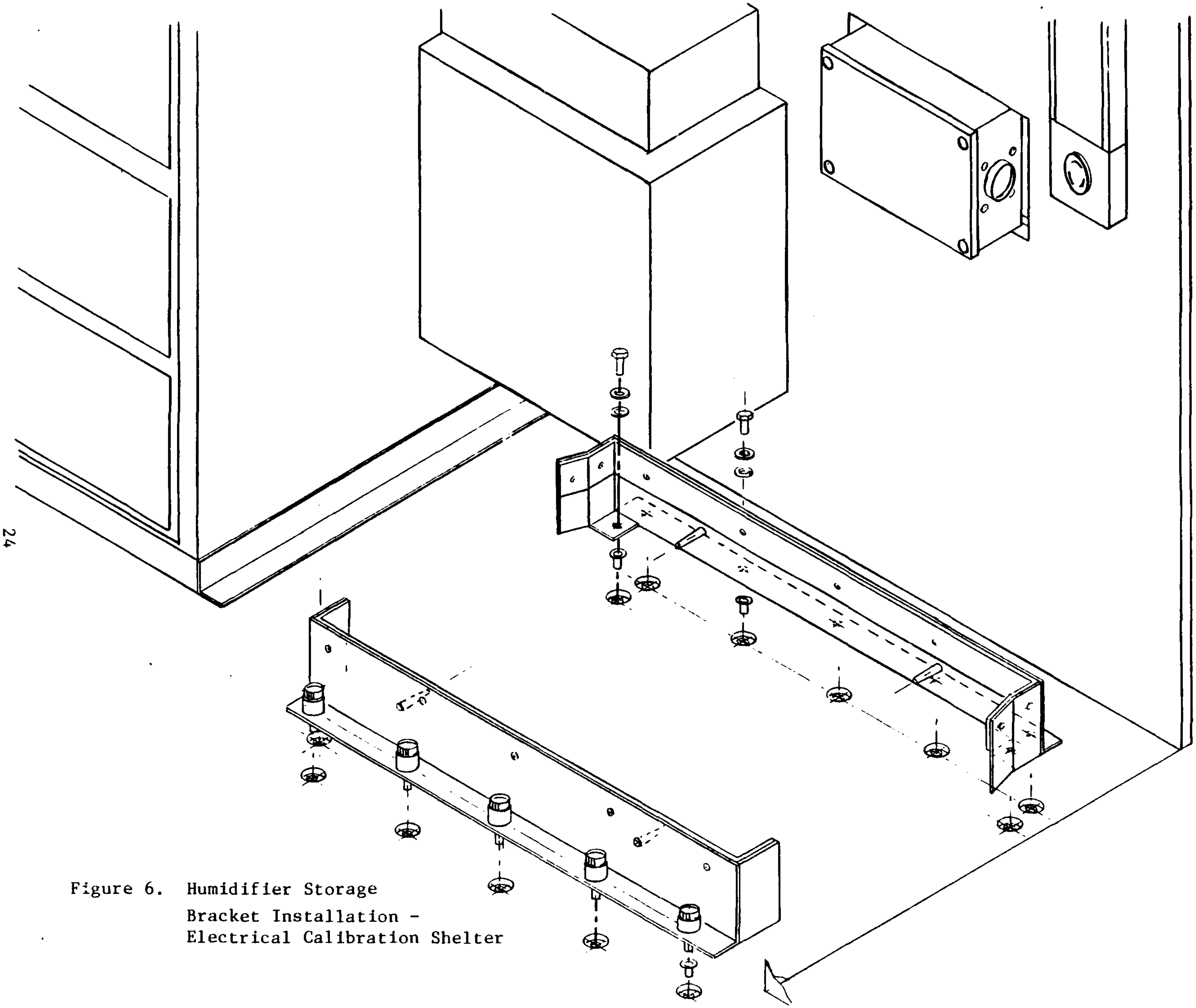

Figure 6. Humidifier Storage Bracket Installation - Electrical Calibration Shelter

Roll the humidifier into place against the rear bracket and insure the mounting pins engage the receptacles. Next, locate the front bracket in position by engaging the mounting pins and receptacles and squaring the bracket against the humidifier bottom panel. Locate the five 1/4" mounting holes and drill into the floor. Counterbore 1" Dia. holes through the finished flooring only. This will allow enough room for properly installing the rivnuts. Install the proper length rivnuts.

4.5 WST Support Brackets. Refer to Figure 7 during mounting installation. Figure 7 shows bracket installation in electrical calibration shelter only, however, mechanical shelter installation is similar. Install pivot bracket P/N 10510 by locating the bracket in the proper position shown and match drill the four 1/4" mounting holes into the floor. Counterbore 1" Dia holes through the finished flooring only. This will allow enough room for properly installing the rivnuts. Install the proper length rivnuts. Mount the pivot bracket.

Locate and install the pin bracket P/N 10743. Position bracket and match drill the two 1/4" mounting holes into the floor. Counterbore the 1/4" holes to 1" Dia., through the finished flooring only. Install the proper length rivnuts. Mount pin bracket with spacer P/N 10742 as shown.

Locate and install the floor lock bracket P/N 10749. Position bracket and match drill the two 1/4" mounting holes into the floor. Counterbore the 1/4" holes to 1" Dia., through the finished flooring only. Install the proper length rivnuts. Mount the floor lock bracket.

Insert WST support into pivot bracket. Swing WST support underneath work surface and check interface with floor mounted brackets. WST support mounted brackets that interface with floor brackets are slotted for horizontal adjustment. Spacers can be used for vertical adjustments. Install push pin fastener to ensure proper alignment of fastener brackets. Install WST and top proper into WST support and secure in place with 1" strap provided.

4.6 Electrical Wiring. Wiring harnesses W1 and W2 are bundled with tie wraps and routed through existing shelter raceway. A short section of harness W2 is exposed and therefore bundled with heat shrinkable tubing. Harnesses W3 through W6 are bundled with heat shrinkable tubing and routed external to shelter raceway exclusively. Harness W7 is bundled with tie wraps and routed internal to heat pump. (See Figures 8 and 9 for general harness routings.

Wire Harness W1 - Connects at the 100 amp AC main circuit breaker, neutral bus and ground/neutral bus in the existing panel board and at terminal board TB1 in the control panel. See wiring diagram drawing No. 10720 for individual wire connections. Remove panel board face plate and raceway cover from the panel board to HCS control panel. Connect wiring at panel board and place harness into raceway. Connect wiring at control panel terminal board.

Wire Harness W2 - Connects at terminal boards TB2 and TB3 in HCS control panel, at connector J9 of heat pump and at connector P1 in raceway underneath work surface. See wiring diagram drawing No. 10720 for individual wide connections. Remove cover on raceway located above work surface and raceway

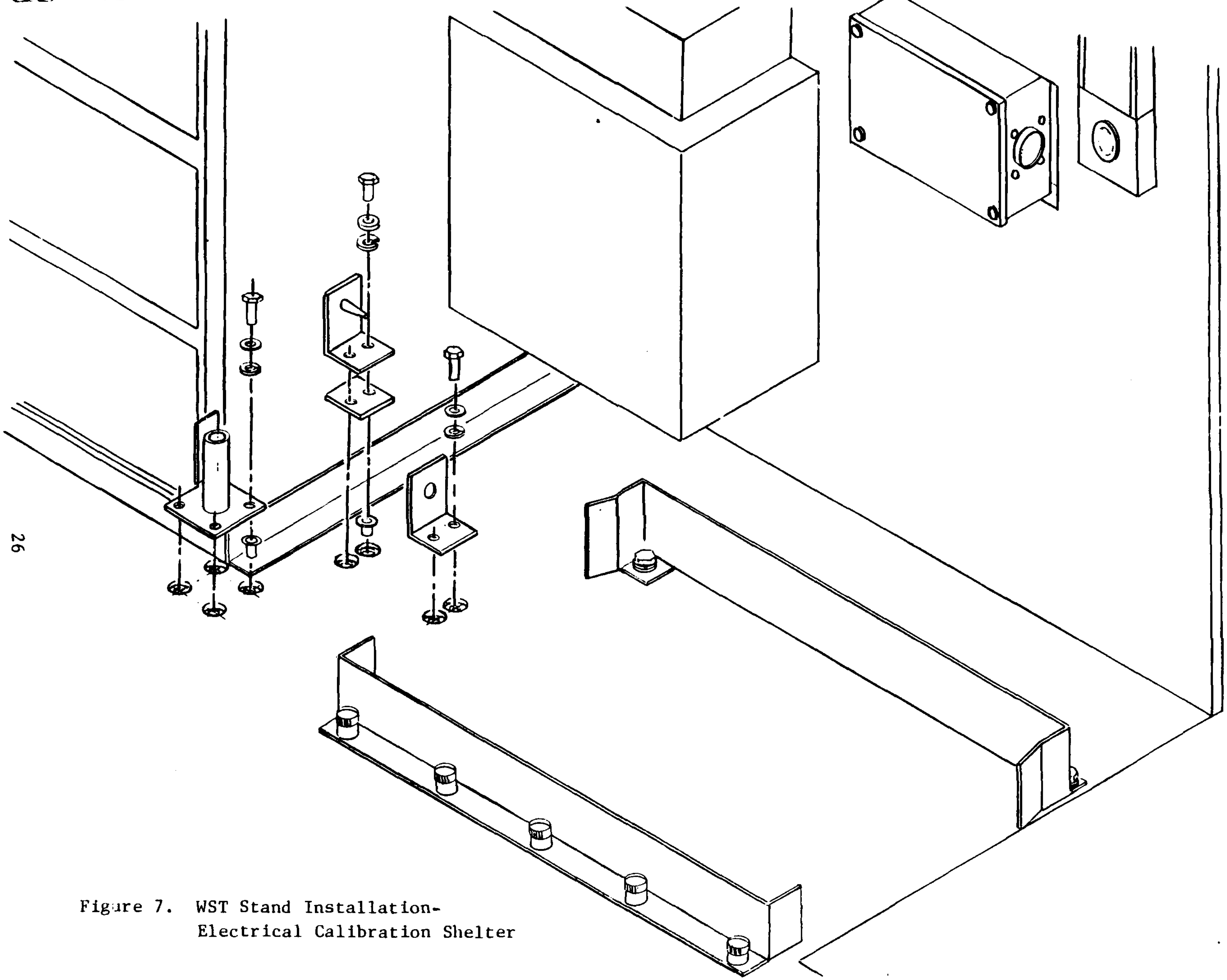

Figure 7. WST Stand Installation-
Electrical Calibration Shelter

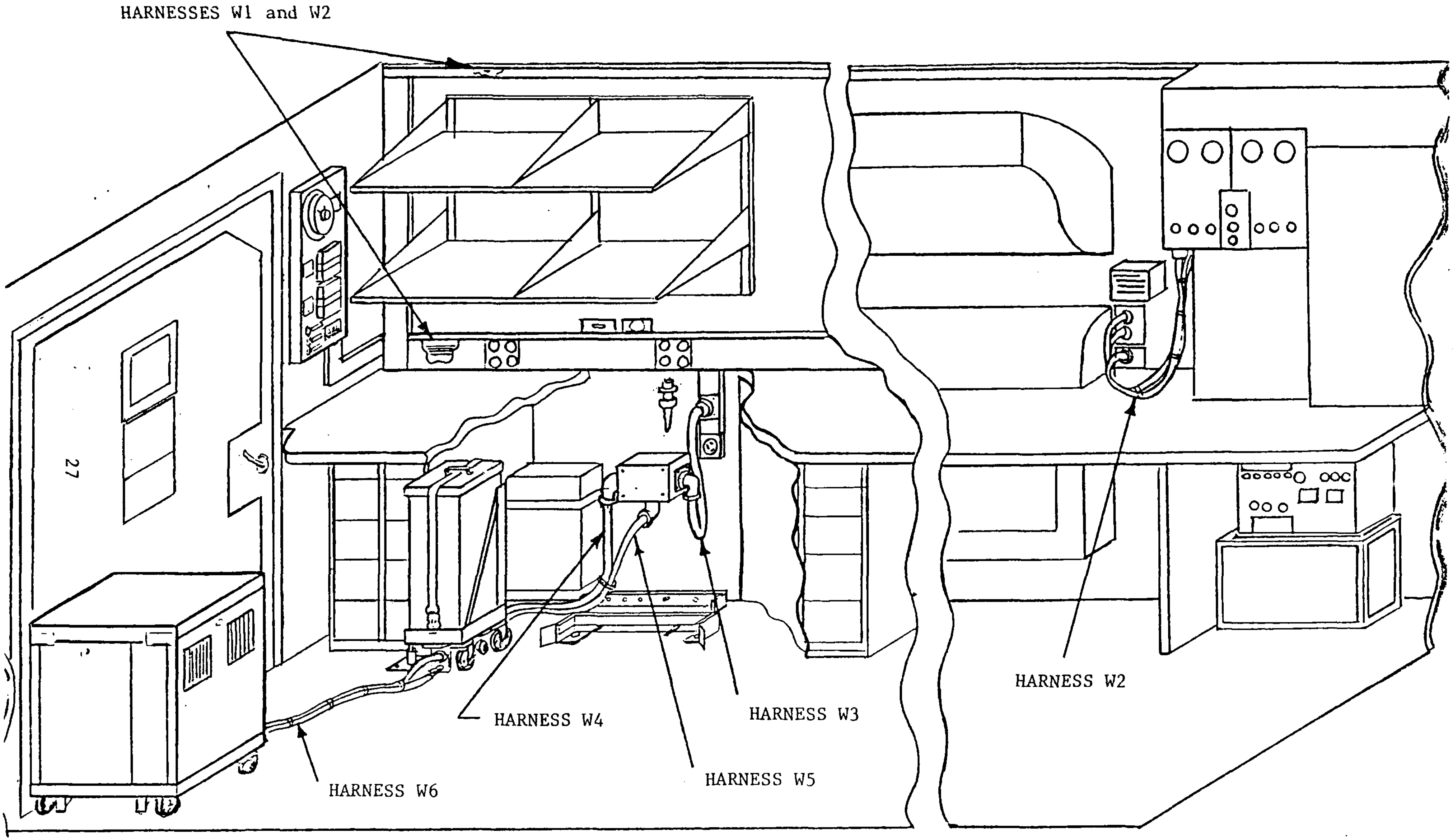

Figure 8. Wire Harness Routing - Electrical Calibration Shelter

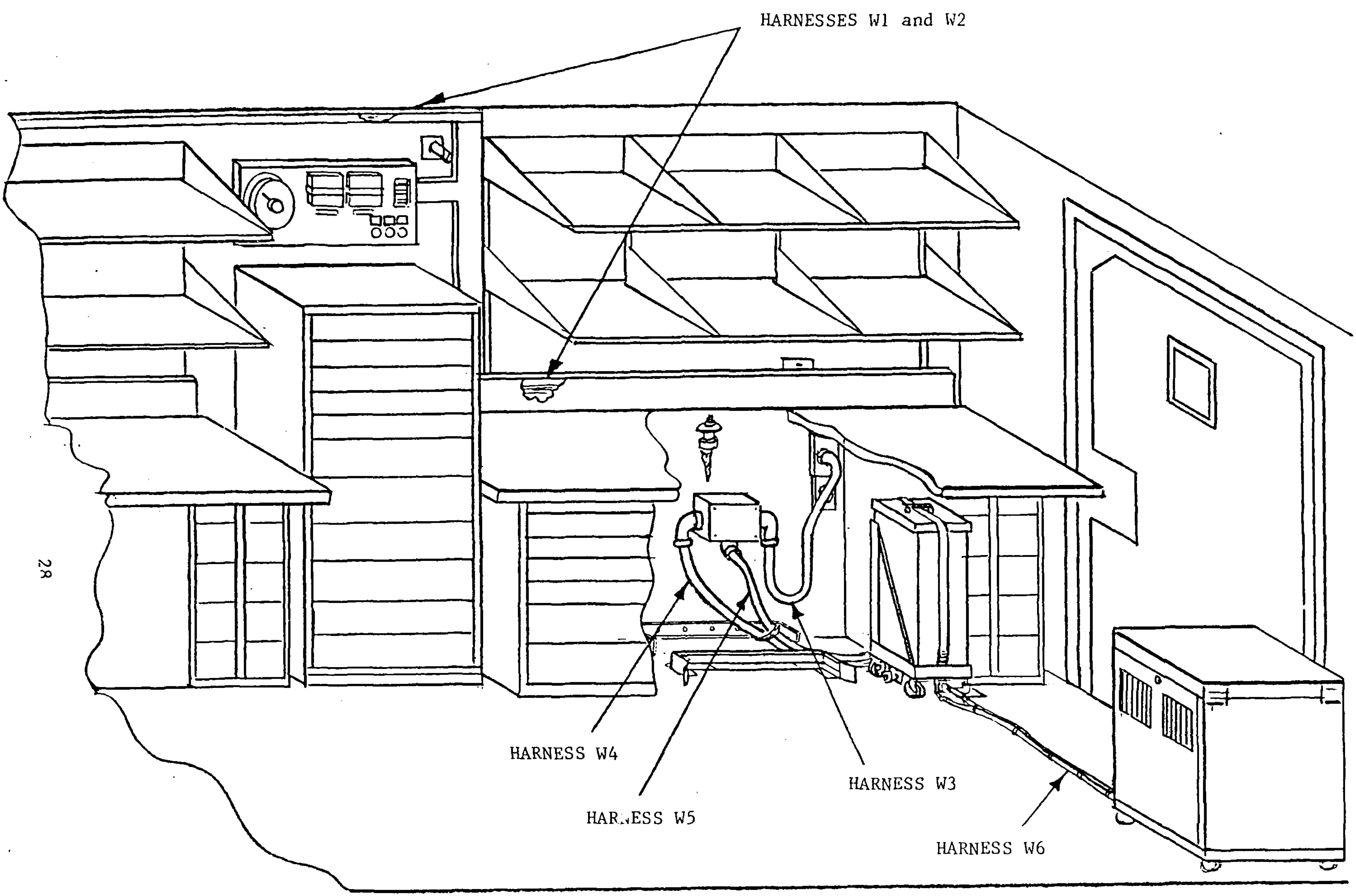

Figure 9. Wire Harness Routing - Mechanical Calibration Shelter

located beneath work surface to vacuum pump connection. It will be necessary to remove switch faceplates and move work surface itself to access covers. Install large hole for connector J1, per modification drawing Nos. 10749 and 10751, in raceway cover. Locate connector J1 in large hole and match drill the four smaller holes for connector mounting hardware. Place raceway cover aside.

Install hole in existing power converter box for routing of wire harness to heat pump. Locate 13/16" hole per drawing Nos. 10749 and 10751 and install.

Connect wiring at control panel and route main branch to underside of work surface. Mount J1 connector in raceway cover. Solder wires to J1 connector. Reinstall raceway cover. Next, route secondary branch to power converter box and through 1" hole previously installed. Run end of harness to feed through connector and extend beyond feed through approximately 5'. Install heat shrink over 5' extension and shrink to fit. Mount feed through connector. Solder wires to P9 connector and lay aside. Replace all raceway covers, face plates, etc. and secure work surface in proper position.

Wire Harness W7 - Connects at connector P9 of harness W2, at terminal board TB1 and relay K1 of heat pump. See wiring diagram drawing No. 10720 for individual wire connections. Install large hole in existing heat pump panel just below the cooling and heating power harness connectors. Center adapter plate P/N 10732 over hole installed above and match drill four mounting holes into heat pump panel. Install proper rivnuts into mounting holes. Install connector J9 into adapter plate. Install adapter plate assembly and connect wires to proper location in heat pump control panel.

Wire Harness W3 - Connect at J1 on shelter raceway and at J2 on power distribution box.

Wire Harness W4 - Connect at J3 on power distribution box and P5 beneath WST support.

Wire Harness W5 - Connect at J4 on power distribution box and J6 on WST support mounted junction box.

Wire Harness W6/Water Line Assembly - Remove side panel of humidifier and unwrap cord assembly from storage brackets. Connect P5 to J5.

4.6.1 Thermostat Replacement. Remove existing thermostat guard and thermostat from mounts. Mark wire positions and disconnect all wires from thermostat. Substitute modified thermostat. Reconnect existing wiring at thermostat. Two additional wires must be routed to the heat pump control panel from the substitute thermostat and one existing thermostat wire must be disconnected. See wiring diagram No. 10720 for wire connections and disconnections. Mount thermostat and guard.

4.7 System Checkout Procedures. With power provided to shelter perform the following procedures to verify proper HCS operation:

For Dehumidifier

- Switch HCS circuit breaker to "ON".

- Jumper thermostat terminals W1 and W2 with thermometer bulbs, remove Y1 thermostat bulb. Adjust humidity controller HC1 to call for dehumidification by turning differential to 4 and set point to 30.

- Set thermostat mode switch to "AUTO", fan switch to "ON" and system switch to "ON".

- Verify operation of dehumidifier by measuring approximate line currents as follows:

  L1 - 38 amps
  L2 - 30 amps
  L3 - 39 amps

  Should the shelter RH be extremely low, it may be necessary to bypass the controller by jumpering terminals 7 and 11 of control panel relay K1 to operate the dehumidifier. Slightly heated air should discharge from duct.

- Jumper thermostat terminal Y1 and verify dehumidifier operates in cooling mode only by measuring approximate line currents as follows:

  L1 - 12 amps
  L2 - 11 amps
  L3 - 13 amps

  Cool air should discharge from duct.

- Remove thermostat jumpers to Y1 and W1 and verify dehumidifier operates in low heat mode by measuring approximate line currents as follows:

  L1 - 15 amps
  L2 - 14 amps
  L3 - 16 amps

  Warm air should discharge from duct.

- Remove thermostat jumper to W2 and verify dehumidifier operates in high heat mode by measuring approximate line currents as follows:

  L1 - 31 amps
  L2 - 25 amps
  L3 - 25 amps

  Very warm air should discharge from duct. Replace thermostat bulbs in normal operating position and switch system to "OFF" position.

For Humidifier

- Roll humidifier out into operating position in shelter aisle.

- Switch HCS circuit breaker to "OFF" position. Disconnect the two aquastat wires to terminals 3 and 4 of humidifier terminal board TB2. Switch circuit breaker to "ON" position.

- Adjust humidity controller HC1 to call for humidification by turning differential to 4 and set point to 80.

- Verify operation of humidifier by measuring approximate line currents as follows:

  L1 - 10 amps
  L2 - 9 amps
  L3 - 9 amps

  The unit's internal blower should function. Should the shelter RH be extremely high, it may be necessary to bypass the controller by jumpering terminals 7 and 11 of control panel relay K2 to operate the humidifier.

4.8 Controller Calibration

4.8.1 General. Following HCS installation and equipment checkout it will be necessary to calibrate the humidity and alarm controllers (HC1 and AC1), and the humidity indicator. Use of an accurate psychrometer is required. The psychrometer should consist of two calibrated mercury filled thermometers, or equal, to measure dry bulb and wet bulb temperatures with graduations of .1°F and precision of ±.1°F. A clearly legible psychrometric chart is required for temperatures conversion to RH. Psychrometer should be located approximately 12" from controllers during calibration.

4.8.2 Humidity and Alarm Controllers. In order to calibrate the controllers the humidity in the shelter must be within the control range. The shelter RH should be relatively stable 30 minutes prior to calibration. System power must be "ON". Adjust the humidifier's aquastat to the coolest water setting to ensure that humidifier will not energize during calibration. Remove guard on the alarm controller. Adjust differential to "4". Adjust the set point until both the high humidity and low humidity alarm lamps are off simultaneously. If this does not occur, proceed as follows:

a. Adjust setpoint to point where the low humidity alarm lamp switches to the high humidity alarm lamp.

b. Remove the right plastic hole cover and using a small phillips head screwdriver, slightly turn the potentiometer clockwise.

c. Adjust the setpoint until both alarm lamps are off. If not, repeat step b. Verify that the differential is approximately 4% RH.

d. Replace the plastic hole cover.

Using the psychrometer determine shelter RH. With setpoint in dead zone, i.e., both alarm lamps off, determine if set point dial indicates $\pm 2\%$ of shelter RH. If it is, setpoint calibration is not required. If dial indication is in excess of $\pm 2\%$, adjust setpoint until it indicates the shelter RH measured by the psychrometer. Remove the left plastic hole cover and using a small phillips head screwdriver, slowly turn the potentiometer until both the alarm lamps are off. Replace the plastic hole cover. Follow same procedure for humidity controller calibration. Adjust the humidity controller and alarm controller setpoints and differentials to desired settings.

5.0 SPARE PARTS LIST

See Table 6 for HCS spare parts list.

Table 6. HCS Spare Parts List

Item	Quantity	Description	Manufacturer/ Supplier and (P/N)
For Humidifier:			
1	1	Heating Element	Dri-Steem (505080-001)
2	1	Contactor	Dri-Steem (407000-003)
3	1	Transformer	Dri-Steem (408965)
4	1	Fill Valve	Dri-Steem (505010)
5	1	Aquastat	Honeywell (L4006A1371)
6	2	Cover Gasket Front and Back	Dri-Steem (405100-003)
7	2	Clean out Gasket	Dri-Steem (308300-001)
8	2	Cover Gasket Sides	Dri-Steem (308400-002)
9	1	Fuse (2 Amp)	Gould Shawmut (TRM2)
10	1	Evaporating Chamber	Dri-Steem (165321-001)
11	1	Clean Out Plate Cover	Dri-Steem (308220)
12	1	Evaporating Chamber Cover	Dri-Steem (165470-001)
13	1	Probe Cap Wire Assembly	Dri-Steem (309750-003)
14	1	Probe	Dri-Steem (406050-001)
15	1	Blower	Dri-Steem (400090-002)
16	1	LW-310 Liquid Level Control Module	Dri-Steem (408510-001) Module
17	1	Drain Ball Valve	Dri-Steem (406060)
18	1	Strainer	Dri-Steem (300050)
19	1	Ground Lug	Dri-Steem (409250-017)
20	1	Power Block - 3 Pole	Dri-Steem (408300-002)
21	1	Terminal Strip	Dri-Steem (408250-003)
22	1	Terminal Strip Marker	Dri-Steem (408250-004)
23	1	Dispersion Tube w/hose Cuffs; Clamps	Dri-Steem (VV999474)
27	1	Wire Harness	VSE (10718)
28	1	Male Barbed Fitting	McMaster-Carr (5346K14)
29	1	Hose Clamp	McMaster-Carr (5321K14)
30	4	Nylon Bar	McMaster-Carr (8733K81)
31	1	Terminal Board	Kulka-Smith (39TB-9Z)
32	4	Caster	Rapistan (3120-HTC)
33	1	Power Block - 2 Pole	Dri-Steem (408300-001)
34	1	Pilot Light - Green	Dri-Steem (409520-002)
35	1	Linear-Limit Control	Dri-Steem (409597)
36	1	Aquastat - Well	Dri-Steem (700700)
37	1	VSE Front Door	Dri-Steem (MISC-020)
38	1	VSE Side Door	Dri-Steem (MISC-021)
39	1	VSE Cabinet	Dri-Steem (MISC-022)
40	1	Toggle Switch	Arrow-Hart (60F3455)
For Dehumidifier:			
1	2	Relay	Potter & Brumfield (KHS-17A11-24)
2	2	Relay Socket	Potter & Brumfield (27E166)

Table 6. HCS Spare Parts List (Continued)

Item	Quantity	Description	Manufacturer/ Supplier and (P/N)
For Dehumidifier:			
3	2	Relay Clip	Potter & Brumfield (20C297)
4	1	Thermostat	VSE (10178)
5	1	Wire Harness	VSE (10754)
For Water Storage Tank:			
1	1	Water Storage Tank	VSE (10513)
2	1	Tank Cover	VSE (10514)
3	2	Level Switch	Compac Engineering (15-650-PP)
4	2	Double End Shutoff Coupler	McMaster-Carr (5327K51)
5	2	Handle	Sessions & Son (5220)
6	1	Junction Box Assembly	VSE (10723)
7	1	Pump	March Manufacturing (AC-2CP-MD)
8	2	Tubing	McMaster-Carr (5549K13)
9	1	Push Pin	McMaster-Carr (90293A211)
10	3	Casters	McMaster-Carr (2406T34)
11	1	Tapered Pin	McMaster-Carr (92281A369)
12	1	Nylon Bar	McMaster-Carr (8733K81)
13	11	Nylon Sheet	McMaster-Carr (8681K33)
14	1	Male Barbed Fitting	McMaster-Carr (5346K24)
15	1	Female Barbed Fitting	McMaster-Carr (5346K42)
16	1	Elbow	J&B (116C)
17	3	Hose Clamp	McMaster-Carr (5321K14)
18	1	Connector	(MS3100F32)
19		Strap Assembly	VSE (10735)
20	1	Cushion Clamp	(MS21919WDE6)
21	2	Cushion Clamp	(MS21919WDE8)
For Control Panel:			
1	1	Control Panel Base	VSE (10730)
2	1	Control Panel	VSE (10729)
3	1	Raceway Fitting	VSE (10733)
4	1	Controller Guard	VSE (10725)
5	1	Terminal Board	Kulka-Smith (39TB-6Z)
6	1	Terminal Board	Kulka-Smith (37TB-16Z)
7	1	Humidity Indicator	Abbeon Cal (4703-600)
8	2	Humidity Controller	Johnson Controls (W50DG-1)
9	1	Circuit Breaker	Heinemann (AM3-829-102)
10	3	Flange Base Type 385 Bulb	Newark (37N1867)
11	3	Push-To-Test Subminiature Assembly	(MS25041-4)
12	2	Relay	Potter & Brumfield (KAS-17A11-24)

Table 6. HCS Spare Parts List (Continued)

Item	Quantity	Description	Manufacturer/ Supplier and (P/N)
For Control Panel:			
13	2	Relay Socket	Potter & Brumfield (27E166)
14	2	Relay Clip	Potter & Brumfield (20C297)
15	1	Control Panel Label	VSE (10734)
For Power Distribution Box:			
1	1	Electrical Box	Hoffman (A-806SC)
2	1	Box Panel	Hoffman (A-8PG)
3	1	Relay	Potter & Brumfield (KHS-17A11-24)
4	1	Relay Socket	Potter & Brumfield (27E166)
5	1	Relay Clip	Potter & Brumfield (20C297)
6	1	Terminal Board	Kulka-Smith (37TB-4Z)
7	1	Connector	MS3102F28-9P
8	1	Connector	MS3102F32-13S
9	1	Connector	MS3102F20-7S

APPENDIX A

COMMERCIAL LITERATURE

APPENDIX C

LETTER OF INTENT

DRI-STEEM
HUMIDIFIER COMPANY
BOX 128 • HOPKINS, MINNESOTA 55343
612/935-6986 • TELEX NO. 290675

September 25, 1987

VSE Corporation
2550 Huntington Avenue
Alexandria, VA 22303

Attn: Mark Baker

Dear Mark,

This is a letter stating DRI-STEEM Humidifier Company's intention to supply humidifiers to the Air Force through 1992, per the attached statement of work and specification.

Our price per unit based on a quantity of 34 units is $1920.00 each FOB Minneapolis, Minnesota. Our price per unit based on a quantity of 100 units is $1725.00 per unit FOB Minneapolis, Minnesota.

These prices are based on 1988 federal fiscal year dollars.

Respectfully submitted,

Chris Morton
OEM Sales
DRI-STEEM Humidifier Company

Attachment

CM/th

APPENDIX D

TEST PLAN FOR HUMIDITY CONTROL SYSTEM
FOR USE IN THE AIR FORCE F-16 MAINTENANCE SHELTER

TEST PLAN

FOR

HUMIDITY CONTROL SYSTEM FOR

USE IN THE AIR FORCE F-16 MAINTENANCE SHELTER

27 AUGUST 1987

CONTRACT NO. DAAK70-86-D-0023
TASK ORDER 0080

TEST PLAN
FOR
HUMIDITY CONTROL SYSTEM FOR
USE IN THE AIR FORCE F-16 MAINTENANCE SHELTER

CONTRACT NO. DAAK70-86-D-0023
TASK ORDER 0080

APPROVED BY:

Mark S. Baker
Engineer

Robert B. Sherfy
Senior Project Engineer

David A. Calderwood
Senior Project Manager

Lincoln. S. Hay
Environmental, Power and Physical
Security Group, Manager

L. R. McMillan
Quality Control, Manager

TEST PLAN
FOR
HUMIDITY CONTROL SYSTEM FOR
USE IN THE AIR FORCE F-16 MAINTENANCE SHELTER

Prepared For:

U.S. Army Belvoir Research, Development
and Engineering Center
Fort Belvoir, Virginia 22060-5606

27 August 1987

Prepared By:

VSE Corporation
2550 Huntington Avenue
Alexandria, Virginia 22303-1499

1.0 PURPOSE

The purpose of this test program is to determine the adequacy for use of the equipment recommendations set forth in the final scientific and technical report compiled under Contract No. DAAK70-86-D-0023, Task Order 0024, for humidity control in the F-16 maintenance (electrical and mechanical calibration) shelters. Testing will be performed on a complete humidity control system including a humidifier, dehumidifier (modified heat pump), humidity controls and alarm system.

2.0 APPLICABLE DOCUMENTS

Statement of Work and Services dated 24 June 1987, Task Order 0080, Contract No. DAAK70-86-D-0023.

Test Plan, compiled under Contract No. DAAK70-86-D-0023, Task Order 0024.

Final Scientific and Technical Report, Type III, compiled under Contract No. DAAK70-86-D-0023, Task Order 0024.

3.0 SYSTEM DESCRIPTION

The humidity control system proposed for the F-16 calibration shelters consists of a steam generating humidifier, a modified heat pump dehumidifier and separate controlling humidistats. Ancillary system equipment includes a humidity indicator for providing visual indication of ambient relative humidity and operation of extreme humidity alarm lights, and a water supply tank for the humidifier which provides water for up to eight hours of operation without operator attention. The supply tank is equipped with a float switch to activate an alarm light at low water level.

3.1 Humidification Equipment. The humidifier specified for the humidity control system is a modified commercial unit manufactured by Dri-Steem Humidifier Co. The humidifier is 29 1/2" high x 17" wide x 23" deep, with a 8.5 lb/hr capacity, weighs approximately 120 lb operating and requires input power of 3 kW. The unit possesses a 304 stainless steel vaporizing chamber with incoloy sheathed immersion heaters. An aquastat controller is provided which maintains the water in the vaporizing chamber in a preheated condition by cycling the heating element on and off. Water level is electrically sensed by three electrical probes of differing lengths which make or break electrical circuits through the water. The water level sensors actuate a solenoid operated fill valve as needed. A minimum water hardness (conductivity) is required for sensor operation. Generated steam rises from the vapor chamber, through a vapor hose, to a dispersion tube mounted down stream of a centrifugal blower. Forced air passing over the dispersion tube absorbs the vapor and distributes the high humidity air into the conditioned space.

The Dri-Steem humidifier is a specially packaged unit with the overall housing and blower distribution section custom fabricated to comply with an allowable size envelope. The vaporizing chamber along with the electronic controls and valves are the standard components of Dri-Steem's vaporstream model VPC-3.

3.2 Dehumidification Equipment. The dehumidification requirements of the F-16 maintenance shelter are provided by the existing shelter heat pump, currently fabricated by ARE Manufacturing Co. The heat pump model MHP 36K 208/60/3 is intended for heating and cooling the conditioned space, however the unit is equipped with auxiliary resistance heaters located after the cooling coil, which provide reheat capability and thus allow satisfactory dehumidification control during moderate temperatures. The heat pump electrical circuitry has been modified by the addition of two relays and necessary rewiring to the junction box and thermostat. Modification to the electrical circuitry is necessary to overcome the thermostat "dead band"; the temperature range between 72°F and 76°F where neither heating or cooling occur. Modifications enable the heat pump to operate in the cooling mode with simultaneous operation of the auxiliary resistance heaters. This operational mode allows shelter dehumidification to occur with only minor impact on shelter temperature.

3.3 Humidity Controls. The humidifier and dehumidifier will be actuated by Honeywell humidistats. Honeywell model H46C will operate the dehumidifier and Honeywell model H46D will operate the humidifier. An Abbeon Cal humidistat model 4703-602 is used to provide a visual indication of ambient relative humidity and to actuate extreme high and low humidity alarm lights. Each control contains a nylon element to sense 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 on the unit set point.

3.4 Alarm Panel. The alarm panel is required to annunciate extreme high or low shelter relative humidity conditions and low water level in the humidifier water storage tank. The panel consists of three red domed lights, General Instrument P/N 5100 824, mounted in a sheet metal bracket. The extreme RH alarm lights are activated by the Abbeon Cal humidistat. The low water level alarm light is activated by a Compac Engineering float switch P/N 15-650-PP. The alarm lights shall be wired into the humidifier control circuitry.

4.0 TEST LOCATION

All testing delineated in this test plan will be performed at the VSE Corporation prototype shop, 2550 Huntington Avenue, Alexandria, Virginia.

5.0 TEST EQUIPMENT

5.1 VSE Facilities and Hardware. The humidity control system shall be tested within an Army ISO rigid walled, nonexpandable shelter with external dimensions of 8' x 8' x 20'. This shelter is virtually identical to the F-16 calibration shelter. The heat pump dehumidifier shall be placed in the shelter entrance and sealed with cardboard and duct tape. The heat pump dehumidifier discharge shall be directed into the shelter using a fabricated sheet metal duct which will simulate the ducting in the actual application.

The water supply to the Dri-Steem humidifier shall consist of a seven gallon plastic tank mounted high in the shelter so as to provide supply water by gravity. Plastic tygon tubing shall connect the tank to the humidifier. The humidifier itself will rest on the floor of the shelter.

The Autoflo humidifier model L-1011-K procured under Task 0024 shall be used to provide additional humidification capacity. The L-1011-K has a capacity of 4.6 lb/hr.

A White-Westinghouse dehumidifier model ED132 with a capacity of 13 pints per day shall be used to provide additional dehumidification capacity.

5.2 VSE Instrumentation

5.2.1 Relative Humidity. The ambient shelter relative humidity shall be measured with a fabricated psychrometer. The psychrometer shall consist of two Miller & Weber precision mercury filled thermometers (one fitted with wicking), a water reservoir, a 55 cfm blower and a sheet metal housing. Dry bulb (db) and wet bulb (wb) temperature readings will be converted to relative humidity using an ASHRAE psychrometric chart no. 1.

5.2.2 Temperature. The humidifier and heat pump intake and discharge temperatures shall be measured with copper-constantan thermocouples connected to a Thermo Electric 18 channel thermocouple indicator.

5.2.3 Voltage. Voltage shall be measured with a Weston voltmeter model 341.

5.2.4 Current. Current shall be measured using a Fluke, Model 8021B digital multimeter with a model Y8100 induction probe.

5.2.5 Air Velocity. Air velocity shall be measured using a Sierra Instruments model 441 air velocity meter (hot wire anemometer).

5.2.6 Water Weight. Water weight shall be measured using an Accu-Weigh model 216TDX/L weight scale having 125 lb capacity and .05 lb resolution.

5.2.7 Time. Time measurements shall be made with a Seiko wrist watch indicating seconds, minutes and hours.

5.3 Calibration. The following VSE instrumentation will be calibrated with traceability to the National Bureau of Standards:

- Mercury filled thermometers
- Thermo Electric thermocouple indicator
- Weston voltmeter
- Fluke multimeter
- Air velocity meter

The Accu-Weight weight scale will be calibrated using a calibrated weight.

6.0 TESTING

6.1 General. The major area of concern regarding testing of the humidity control system is the response of the humidistats and humidity indicator. The ability of the system to maintain shelter humidity within a 45% $\pm$10% relative humidity range and the ability of the alarm system to accurately provide warning at extreme humidity levels is the primary purpose for this test program.

Humidity control testing shall consist of a fast response test and a slow response test. The humidistats and humidity indicator shall be located in a corner area of the shelter, away from the direct discharge of the humidifier or heat pump dehumidifer, which will simulate installation in the electrical calibration shelter. Capacity of the humidifier shall also be evaluated.

6.2 Test Preparation

6.2.1 Humidity Controller Calibration. The Honeywell model H46C and H46D as well as the Abbeon Cal model 4703-602 shall be calibrated prior to testing using the equipment and procedures delineated in Section 6.2 of the Test Plan dated 9 January 1987 and compiled under Contract No. DAAK70-86-D-0023, Task Order 0024.

6.2.2 Heat Pump Ventilation Airflow Calibration. The heat pump fresh air vent will be calibrated so that 120 cfm will be drawn into the evaporator compartment while the unit is operating in the cooling mode under wet coil condition. A 5" x 5 1/2" rectangular duct 24" long shall be installed on the fresh air intake to enable air flow measurement. An average air velocity will be determined by performing a nine point traverse of the duct using an air velocity meter and multiplying the average velocity by the duct cross sectional area. The heat pump fresh air vent opening will be reduced by use of duct tape until an air flow of approximately 120 cfm is achieved.

6.2.3 Aquastat Performance Verification. The Honeywell aquastat controller model L4006A provided with the humidifier shall be evaluated to ensure specified performance. Set the aquastat adjustable scale to 195°F. Immerse a thermocouple into the vaporization chamber and fill chamber with water. Supply 208V, 3 phase, 60Hz input power to unit. Determine time required to increase water temperature from initial water temperature to 190°F. Allow aquastat controller to cycle on/off for five cycles. Determine maximum and minimum water temperatures attained during the five cycles. Should the maximum temperature exceed 212°F, adjust aquastat set point correspondingly downward.

6.2.4 Humidifier Weight. Determine the dry and operating weight of the Dri-Steem humidifier. Weigh the humidifier in the dry condition using the weight scale. Fill the humidifier's vaporization with water and reweigh.

6.3 Humidifier Capacity.

Purpose of Test: The purpose of this test is to determine the moisture (steam) discharge capacity of the prototype Dri-Steem humidifier. It shall be determined if the manufacturers specified humidification rate is achieved.

Test Equipment:

- Dri-Steem humidifier
- Weight scale
- Voltmeter
- Ammeter
- Psychrometer
- Time clock

Test Procedure: Place humidifier in an indoor environment. Connect humidifier water inlet to water reservoir in such a way as to allow gravity feed of supply water. Connect humidifier to 208V, 3 phase, 60 Hz input power. Operate humidifier for a minimum of one hour to stabilize operation before starting test. Following the stabilization period weigh the water supply reservoir. Begin capacity test and continue humidifier operation undisturbed for one hour. Immediately following the one hour test period reweigh the water supply reservoir.

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 five readings:

- Ambient db and wb temperatures (psychrometer)
- Voltage
- Current

6.4 Controls Performance - Fast Response

Purpose of Test: The purpose of this test is to determine the speed of response of the humidity controls and humidity indicator. Control response will be determined for a sudden humidity increase and a sudden humidity decrease. This test may not accurately simulate humidity changes in the actual environment, but is intended to provide data on system capability.

Test Equipment:

- ISO Shelter
- Dehumidifier (heat pump)
- Humidifier (Dri-Steem)
- Humidity Controllers (Honeywell)
- Humidity Indicator (Abbeon Cal)
- Alarm Panel
- Psychrometer
- Auxiliary Dehumidifier (White-Westinghouse)
- Auxiliary Humidifier (Autoflo)
- ASHRAE Psychrometric chart No. 1
- Thermocouple Indicator (Thermo Electric)
- Thermocouples
- Time Clock (Seiko)

Test Procedure:

Preliminary - Install the auxiliary humidifier and dehumidifier in the ISO shelter with the complete humidification control system. Operate the Dri-Steem humidifier so that the water in the vaporization chamber is pre-heated. Set the system humidifier and heat pump dehumidifier controllers to 42% and 52% RH respectively. Set the humidity indicator to 40% and 54% RH for alarm actuation. Maintain shelter temperature between 72°F and 76°F during testing.

Part I - Humidification

Jumper the heat pump thermostat and disconnect the humidity controller so unit does not respond to temperature or humidity. Humidify the shelter space using the auxiliary humidifier to a relative humidity of 50% +10%, -0%. Maintain this relative humidity for at least 15 minutes prior to test. Jumper the heat pump humidity controller and energize the auxiliary dehumidifier thereby quickly reducing the shelter relative humidity. Determine the shelter RH and time when the Dri-Steem humidifier energizes. Record RH indicated by the humidity indicator. Immediately remove jumper from the heat pump humidity controller and de-energize the auxiliary dehumidifier. Note the minimum RH attained during the test. Determine the time required to raise the RH to 35% and ensure that the low humidity alarm light actuates if shelter RH dropped below 35%. Note the shelter RH when the Dri-Steem humidifier de-energizes. Monitor humidifier intake and discharge temperatures with thermocouples.

Part II - Dehumidification

Jumper the heat pump thermostat so unit does not respond to temperature and disconnect the Dri-Steem humidifier humidity controller. Dehumidify the shelter space using the auxiliary dehumidifier to 45% +0, -10% RH. Maintain this RH for at least 15 minutes. Jumper the Dri-Steem humidifier and energize the auxiliary humidifier thereby quickly raising the RH. Determine the shelter RH and time when the heat pump energizes. Record RH indicated by the humidity indicator. Immediately remove the jumper on the Dri-Steem humidifier and de-energize the auxiliary humidifier. Note maximum RH attained during the test. Determine time required to reduce the RH to 55% and ensure that the high humidity alarm light actuates if shelter RH rises above 55%. Note the shelter RH when the heat pump de-energizes. Monitor heat pump intake and discharge temperatures with thermocouples.

Recorded Data:

Using the psychrometer record:

- Shelter db and wb temperatures every 5 minutes during 15 minute stabilization periods.

- Shelter db and wb temperatures no less often than every two minutes throughout actual testing.

- Shelter db and wb temperatures and humidity indicator reading when the humidifier energizes during Part I and when the heat pump energizes during Part II.

Convert db and wb temperature readings to RH using the ASHRAE psychrometric chart no. 1. Record humidifier and heat pump intake and discharge temperatures whenever psychrometer readings are taken.

6.5 Control Performance - Slow Response

Purpose of Test: The purpose of this test is to determine the humidity controls response and overall system capability to maintain shelter environment within humidity range specified during both gradual increases and decreases in relative humidity which are most likely to occur in a natural environment.

Application Requirement: The humidity control system must maintain shelter RH within 45% $\pm$10% without actuation of extreme humidity alarm lights.

Test Equipment:

- ISO shelter
- Dehumidifier (heat pump)
- Humidifier (Dri-Steem)
- Humidity controllers (Honeywell)
- Humidity Indicator (Abbeon Cal)
- Alarm panel
- Psychrometer
- Auxiliary dehumidifier (White-Westinghouse)
- Auxiliary humidifier (Autoflo)
- ASHRAE Psychrometric chart No. 1
- Thermocouple Indicator (Thermo Electric)
- Thermocouples
- Time clock (Seiko)

Test Procedure:

Preliminary - Install the auxiliary humidifier and dehumidifier in the ISO shelter with the complete humidification control system. Operate the Dri-Steem humidifier temporarily to ensure that the water in the vaporization chamber is pre-heated. Set the system humidifier and heat pump dehumidifier controllers to 42% and 52% RH respectively. Set the humidity indicator to 40% and 54% RH for alarm actuation. The use of the auxiliary humidification and dehumidification equipment to gradually increase or decrease the shelter RH will depend upon the ambient RH. It is arbitrarily assumed that the ambient RH will be above 55% during the period this test is performed. Maintain shelter temperature between 72°F and 76°F during testing.

Part I - Humidification

Use the auxiliary dehumidifier to slowly decrease shelter RH so that a relative humidity reduction rate of 6% or less per hour will be achieved. Determine the shelter RH when the humidifier energizes. Record RH of humidity indicator. Determine shelter RH when the humidifier deenergizes. Record RH of humidity indicator. Ensure that the humidifier and heat pump dehumidifier do not operate simultaneously. Monitor humidifier intake and discharge temperatures with thermocouples.

Part II - Dehumidification

Establish a beginning RH of 45% or less and slowly increase shelter RH at a rate of 6% or less per hour. Shelter RH will probably be increased by allowing the natural migration of high humidity ambient air into the shelter. An auxiliary humidifier will be used if necessary. Determine the shelter RH when the dehumidifier energizes. Record RH of humidity indicator. Determine shelter RH when the dehumidifier deenergizes. Record RH of humidity indicator. Ensure that the humidifier and heat pump dehumidifier do not operate simultaneously. Monitor heat pump intake and discharge temperatures with thermocouples.

Recorded Data: Using the psychrometer record:

- Shelter db and wb temperatures every 5 minutes during 15 minute stabilization periods.

- Shelter db and wb temperatures no less often than every two minutes throughout actual testing.

- Shelter db and wb temperatures and humidity indicator reading when the humidifier energizes during Part I and when the heat pump energizes during Part II.

Convert db and wb temperature readings to RH using the ASHRAE psychrometric chart no. 1. Record humidifier and heat pump intake and discharge temperatures whenever psychrometer readings are taken.

SAMPLE DATA SHEET

HUMIDIFIER CAPACITY TEST

Time (min)	Voltage (volts)	Current (amps)	Ambient Temperatures db(^{o}F)	Ambient Temperatures wb(^{o}F)	Calculated Relative Humidity (%)	Power Watts	Remarks

Weight of Water Reservoir @ Test Initiation ____________

Weight of Water Reservoir @ Test Conclusion ____________

SAMPLE DATA SHEET

CONTROL PERFORMANCE - FAST RESPONSE

Time (min)	Shelter Temperatures db(^{o}F)	Shelter Temperatures wb(^{o}F)	Calculated Shelter RH (%)	Humidity Indicator RH (%)	Remarks

SAMPLE DATA SHEET

CONTROL PERFORMANCE - SLOW RESPONSE

Time (min)	Shelter Temperatures db(^{o}F)	Shelter Temperatures wb(^{o}F)	Calculated Shelter RH (%)	Humidity Indicator RH (%)	Remarks

APPENDIX E

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

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

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22 March 1988

Final Report for Period 03 November 1987 - 24 February 1988

Prepared for:

U.S. Army Belvoir Research, Development
and Engineering Center
Environmental Control Division
Fort Belvoir, VA 22060-5606

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

Testing Performed By:

VSE Corporation

Testing Initiated: 03 November 1987
Testing Completed: 24 February 1988

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1.0 REASON FOR TESTING - GENERAL

The reason for system testing described herein was to ascertain performance data with which to evaluate the system's capability to maintain the Air Force Aircraft Service Shelter within a relative humidity (RH) range of 45% ±10%. 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 A.

2.0 APPLICABLE DOCUMENTS

Statement of Work and Services dated 24 June 1987, Task Order 0080, Contract No. DAAK70-86-D-0023.

3.0 DESCRIPTION OF TEST SAMPLES

3.1 General. The Humidity Control System (HCS) is basically comprised of a humidifier, dehumidifier (modified heat pump), and humidity controls. An operating HCS was assembled in an 8'x8'x20' Army ISO shelter to determine the system's capability to maintain the shelter RH as desired. System power was provided by an Army 15 kW Diesel Generator.

3.2 Humidifier. The humidifier, Model No. VPC-3, Serial No. V694300, manufactured by the Dri Steem Humidifier Co., is a steam generation unit with a rated capacity of 8.5 lb per hour. The humidifier includes a stainless steel evaporating chamber with a 3 kW heating element. Evaporating chamber water level is sensed by a three probe conductivity sensor which controls a solenoid fill valve and provides for safety shutdown of heating element. The unit contains a 265 cfm blower which distributes steam, emitted from the steam distribution tube, throughout the conditioned space. The evaporating chamber, junction box and blower are housed in a custom fabricated steel cabinet. The unit is 208V, 3 phase, 50/60 Hz and weighs 137 lb operating. Overall dimensions are 18 1/4" W x 23" L x 29 1/2" H.

3.3 Dehumidifier. The dehumidifier is a modified heat pump Model No. MHP36K208/60/3, Serial No. MWM-119 manufactured by ARE Manufacturing Co., Inc. The unit is 208-230V, 3 phase, 50/60 Hz with 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 provide for 41,000 BTUH of electrical resistance heating. Unit volume is 72 1/2" H x 39 1/4" W x 15" D and weighs 450 lbs.

3.4 Thermostat. The ARE heat pump was tested 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. Setpoints 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. The thermostat was modified by the addition of two wires and breaking of one circuit path on the printed circuit board.

3.5 Humidity Controllers. The following humidity controllers were tested in the HCS:

3.5.1 Honeywell Humidity Controller. The Honeywell Models H46C and H46D contain a single pole, single throw snap switch which closes on a rise or fall in RH above or below the setpoint. Two controllers were necessary to operate the dehumidifier and humidifier. The H46C controls a dehumidifier and the H46D controls a humidifier. The controllers sense RH via a nylon element. Expansion or contraction of the hygroscopic nylon mechanically actuates the snap switch. The units are provided with a 20-80% or 10-60% RH adjustable dial and positive on/off settings for manual operation of the controlled equipment. The controllers possess a 5% RH differential, which closes the switch at the setpoint and will open the switch at the setpoint minus or plus the differential. The units are enclosed in a molded plastic case 4 21/32" L x 2 15/16" W x 1 3/8" D.

3.5.2 Johnson Controls Humidity Controller. The Johnson Model W50DG-1 contains two triacs (24 VAC electronic switches) which enable control of a humidifier and dehumidifier with a single unit. The triacs are for pilot duty only and must operate the humidifier and dehumidifier with 24VAC relays. The controller senses RH by way of a cellulose acetate butyrate element which actuates the triacs on changes in element resistance. The unit is provided with a 30-80% RH adjustable setpoint dial and a 4-20% RH adjustable differential dial. The setpoint always represents a point in the middle of the differential. The differential controls the zone range where the humidifier and dehumidifier are both off. Switching differentials for the individual humidifier and dehumidifier equipment are both fixed at 2% RH. The unit is enclosed in a steel base plate and cover. Overall dimensions are 5" L x 4 1/2" W x 17/18" D.

3.5.3 Abbeon Cal Humidity Indicator/Controller. 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 a 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

The humidifier, thermostat and humidity controller will remain at VSE Corporation until HCS shipment to Hanscom AFB, MA in July 1988. The GFE heat pump, and miscellaneous test equipment will remain 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 HCS humidifier provided by Dri Steem was tested for capacity and mineral accumulation. A simulated HCS was tested in an 8' x 8' x 20' ISO shelter to determine the system's ability to maintain shelter RH within the specified 45% ±10% range.

Results of the capacity test indicate the Dri Steem unit will discharge 7.3 lb/hr of steam. This measured capacity is adequate based on the maximum calculated system capacity requirement of 5.3 lb/hr.

Results of the mineral accumulation test revealed the worst mineral build-up around the nozzles of the steam distribution tube. The significant accumulations will require the steam distribution tube to become a maintenance item which will be addressed in the Operation, Maintenance and Installation Instruction. To facilitate maintenance, an access panel will be added to the humidifier.

Test data accumulated from the HCS shelter testing indicated that the nylon element Honeywell humidity controllers are not suitable for this application. Slow response of the controllers allowed the shelter RH to exceed specified limits. The Honeywell units were replaced with a Johnson Controls electronic humidity controller. With the electronic controller, and following system fine tuning, the HCS maintained shelter RH within the specified range of 45% ±10% for 100% of the test duration. The HCS maintained shelter RH within 45% ±5% for 90% of the test duration. The Abbeon Cal controller, intended to actuate extreme humidity alarm lamps, was too unresponsive. A second electronic controller should be used for alarm lamp actuation.

Based on the test results it is recommended that the Dri Steem humidifier be employed in the HCS. It is recommended that the steam distribution tube be cleaned periodically, with the maintenance interval to be dependent on supply water hardness and frequency of humidifier operation. It is further recommended that the Johnson Controls electronic humidity controller be employed in the HCS and that the prototype HCS's be installed in actual Air Force maintenance complex calibration shelters for field testing.

6.0 FACTUAL DATA - TESTING

6.1 Humidifier Capacity

6.1.1 Reason for Test. The humidifier capacity test was performed to ensure that the unit will emit steam at an adequate rate. Testing was also performed to verify proper operation of the aquastat (vapor chamber preheat switch) and to determine unit weight empty and during normal operation.

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

- Weight scale, Accu-Weight model 126TDX/L, 0-125 lb range with .05 lb resolution.

- Weight scale, Detecto Scales, I.D. No. 1493, 0-1000 lb range with .5 lb resolution.
- Digital volt meter, Fluke model 8021B, S/N 3430208, calibrated 6/18/87, recalibration required 6/18/88.
- AC current transfer, Fluke model 80I-600, 0-600 amp range.
- Temperature problem Fluke model 80T-150U, -58 to 302°F range.
- Sling psychrometer, Bacharach code 12-7012.
- Water reservoir, 10 gallon plastic tank.
- Wrist watch, Seiko.

6.1.3 Test Procedure. The humidifier was placed in an indoor ambient environment. The humidifier inlet was connected to a water reservoir in such a way as to allow gravity feed of supply water. The unit was energized while monitoring vapor chamber water temperature to verify aquastat operation. The aquastat was set to 180°F. Several cycles of the aquastat were observed. The water reservoir was then weighed at capacity test initiation. The unit humidistat connection terminals were jumpered to simulate a call for humidity. The humidifier operate undisturbed for 1 hour and 11 minutes. Immediately following the test period the water reservoir was reweighed. The humidifier was weighed with the vapor chamber both empty and full.

6.1.4 Test Results and Analyses. The humidifier emitted steam at a rate of 7.3 lb/hr. The aquastat cycled the vapor chamber water temperature between 193°F and 211°F.

The unit was energized approximately three hours prior to capacity testing to ensure a preheated vapor chamber. Since the Dri-Steem humidifier refill logic is cyclic, the capacity test began and ended immediately following a refill cycle.

The unit refilled three times during the test. A total of 8.6 lb of water were steamed into the air in 71 minutes.

Corrected for one hour (60 minutes):

$$\frac{8.6}{71} \times \frac{Y}{60} \qquad Y = 7.3$$

Humidifier's tested capacity is 7.3 lb/hr. The capacity is considered adequate for use in the HCS.

The addition of the aquastat greatly improves the unit response time. From cold start-up it requires approximately 22 minutes to bring water in the vapor chamber up to preheated temperature. From preheat temperature to steam emission requires approximately five minutes. However, observation of the HCS during performance testing, Section 6.2, reveals that steam emission will occur less than one minute following controller signal. While undergoing performance testing the humidifier cycled on and off frequently with the humidity controller. The controller cycling apparently maintained the vapor chamber water temperature higher than cycling with the aquastat.

The humidifier weighed 115 lb empty and 137 lb full. Test data sheets are provided in Appendix B.

6.2 <u>HCS Performance</u>

6.2.1 <u>Reason for Test</u>. This test was performed to determine the ability of the HCS to maintain shelter RH within the specified range under various outside ambient conditions.

6.2.2 <u>Description of Test Apparatus</u>. The following equipment and instrumentation were used to conduct the HCS performance test:

- o Army ISO shelter, rigid wall, nonexpandable with external dimensions of 8' x 8' x 20'.

- o Generator set, diesel engine driven, 15 kW, 208V, 3Ø, 60 Hz, trailer mounted, S/N KZ-00447.

- o Psychrometer assembly composed of the following components:

  - Mercury filled thermometer, Miller & Weber Inc., 30-90°F range, S/N 34835, calibrated 8/13/87, with woven wick for wet bulb temperature reading.

  - Mercury filled thermometer, Miller & Weber Inc., 30-90°F range, S/N 34813, calibrated 8/13/87.

  - Blower, Dayton Electric Mfg., model 4C548, 55 cfm.

  - Water reservoir, styrofoam cup.

  - Duct, sheet metal housing.

  - Purified water, Great Bear Spring Co.

  - Rubber stoppers.

- o Digital volt meter, Fluke model 8021B, S/N 3430208, calibrated 6/18/87, recalibration required 6/18/88.

- o AC current transformer, Fluke model 801-600, 0-600 amp range.

- o Two relays, double pole - double throw, Potter & Brumfield Model KUP-11A55-24.

- o Air velocity meter, Sierra Instruments Model 441, 0-6000 fpm range I.D. No. 2280, calibrated 6/18/87, recalibrated due 6/18/88.

- Water reservoir, 10 gallon plastic tank.
- Duct, sheet metal ceiling 5" x 20" x 170".
- Duct, sheet metal fresh air vent 5 1/8" x 5 1/4" x 24".
- Wrist watch, Seiko.
- Psychrometric chart, ASHRAE, psychrometric chart no. 1, sea level, normal temperature.

6.2.3 Test Set-up. The ISO shelter was void of internal equipment except for wall and floor mounted HCS hardware halfway along the shelter on one side. The test was performed in an Army ISO shelter located in the VSE equipment yard. One door of the ISO shelter was removed and the heat pump was set in the opening. Gaps between the heat pump and shelter were sealed with cardboard and duct tape. A sheet metal duct was installed down the length of the shelter ceiling to distribute heat pump discharge air. The thermostat was mounted just below the air intake. Cardboard was used to shield the thermostat from the air stream.

The humidifier was located at the opposite end of the shelter, simulating its location in both calibration shelters. The humidity controller and psychrometer were located on a 36" high table in the middle of the shelter. All testing was performed with the equipment in these general locations. During the final test runs the psychrometer was located approximately 12" from the controller's sensing element. See Figure 1 for HCS general arrangement. Virtually all testing was performed in the heating season where outside temperature varied from the low 20's to the upper 60's°F.

The heat pump control circuitry was modified and an operational checkout was performed. Heat pump operation was verified by observation and current measurements in all switch positions of thermostat and humidity controller.

The system capacity calculations are based on 120 cfm of ventilation air continuously entering the shelter. A test was performed to determine the position of the fresh air damper to allow infiltration of 120 cfm. The small elbow duct normally installed on the heat pump over the damper was not provided with the test unit. A 5 1/8" W x 5 1/2" H x 24" L duct was attached to the fresh air inlet and a 9-point traverse was performed with the air velocity meter. It was found the damper should be approximately 1/3 closed to achieve desired airflow. See Appendix C for heat pump checkout and ventilation air determination data sheets.

Assembled mercury thermometers, rubber stoppers, metal duct, water reservoir (styrofoam cup) and blower such that an air flow of approximately 600 fpm was induced over thermometer bulbs as measured by the air velocity meter. This served as the psychrometer assembly.

6.2.4 Test Procedure. The HCS was tested a total of 11 days for approximately 26 total hours of operation. Prior to each test run the

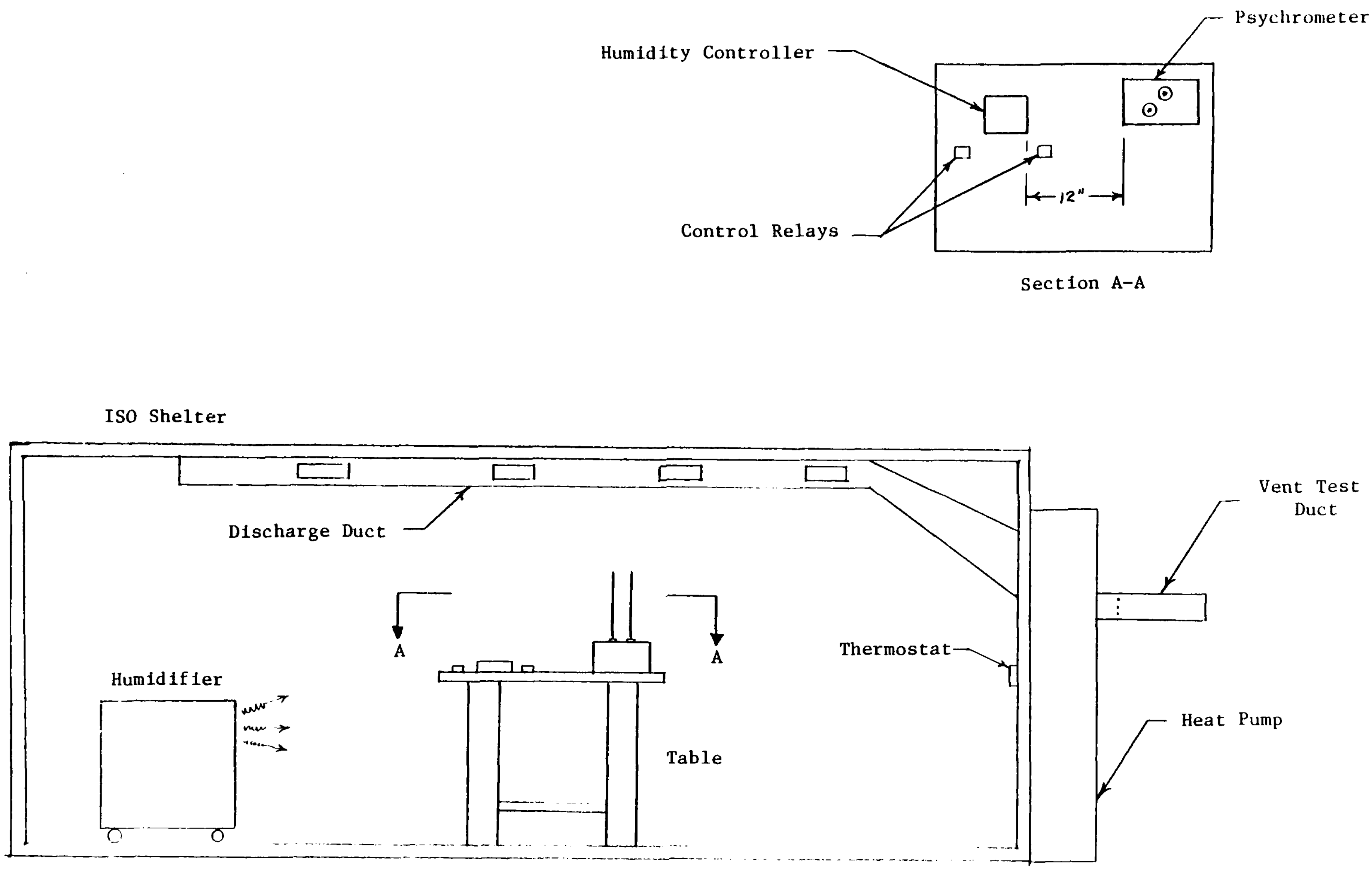


Figure 1. HCS Performance Test - General Arrangement

generator was set to 208V, 60 Hz. Data was recorded at one minute intervals. A set of data consisted of dry bulb and wet bulb temperatures, conversion of the two temperatures into shelter relative humidity, humidity indicator reading (if included in test) and notes as to what equipment was operating at the time. Determination of humidifier or dehumidifier operation was done by observation of the control relays. Determination of heat pump heating or cooling operation was done by listening for audible contactor operation and by feeling the temperature of discharge air. Each test involved a single operator shut inside the shelter to manually record data and make adjustments to controllers and equipment. The humidifier was tested at full capacity and at 2/3 capacity.

The first two test runs were performed with the Honeywell humidity controllers. All remaining testing was performed with the Johnson Controls humidity controllers and control relays required.

The final three test runs were performed with the humidity controller at identical setpoints with no other manipulations of the system.

6.2.5 Test Results and Analyses. Refer to Table 1 for summary of HCS performance testing. From results obtained early in the testing program, it became apparent that the task of controlling RH at 45% ±10% would be very difficult. The fact that the humidifier and dehumidifier/heat pump must be sized for extreme environmental conditions, which can be encountered anywhere in the world, dictate large equipment capacities. The HCS was tested under moderate environmental conditions between 20-70°F. When the equipment energized the shelter RH would change almost instantaneously. RH changes of 17% were recorded in as little as two minutes. Relative humidity is dependent on both water content of the air and air temperature. For example, this fact provided for a rapid RH drop when the heater energized, which required the humidifier to overcome in order to maintain the control range. Due to equipment sizing the response time of the controllers was crucial.

It became apparent test run No. 2 that the Honeywell nylon element humidity controllers originally selected for the HCS, would not provide satisfactory control due to slow response. Test run No. 2 was performed with the humidifier controller set at 42% and the dehumidifier controller set at 50-52% (Precise setpoint could not be determined due to dial graduations). These setpoints allowed the humidifier and dehumidifier to compete while the shelter RH varied from 33% to 60%. It was apparent that no adjustments to the controllers would allow satisfactory operation.

The Abbeon Cal humidity indicator/controller was determined to be too unresponsive for control of the extreme humidity alarm lamps as originally intended. Response to increases in shelter RH was poor and response to decreases in shelter RH was even worse. Differences between the indicator reading and the psychrometer were as much as 14% during testing.

The Johnson Controls electronic unit proved a much more responsive humidity controller. The controller was adjusted to a 42% setpoint and a 6% differential and was not changed over the final three test run Nos. 10, 11 and 12. The unit was able to maintain shelter RH within an extreme range of 37%

TABLE 1. HCS Performance Test Summary

Test Run No.	Date	Significant Events
1	11/18/87	HCS operates in dehumidification mode. Honeywell controllers maintain shelter RH between 36 and 54%. Abbeon Cal controller response proves very slow. Abbeon Cal unit responds faster to increases in RH than to decreases. Abbeon Cal unit wired to alarm lamps. Poor electrical path between indicator needle and setpoint prevents lamp from consistently lighting on contact.
2	11/19/87	HCS operates in humidification and dehumidification modes. Honeywell controllers maintain shelter RH between 33 and 60% while allowing humidifier and dehumidifier to compete. Honeywell and Abbeon Cal controllers response are judged to be too slow for HCS.
3	12/2/87	Initial test of Johnson electronic controller. Unit does not control shelter RH properly. It is determined that controller is not wired into HCS correctly.
4	12/17/87	Control relays added to circuit, Johnson controller is tested. Controller maintains shelter RH around 65%. Unit is recalibrated twice to eventually control around 34%. Unit exhibits superior response capability than the Honeywell units.
5	12/18/87	Electronic unit is recalibrated twice to control around 46% RH. Extreme span is 20%. Performance does not provide any system margin. Differential is at 4%, which forces humidifier and dehumidifier to compete. Extreme span is reduced to 14%.
6	12/22/87	Testing performed to evaluated continuous use of heat pump evaporator blower for better air mixing. Extreme span of 20% is reduced to 13%. HCS is able to maintain RH within 3% span when humidifier and heater are "in phase". Span increases to 13% when humidifier and heater are "out of phase".
7	1/7/88	All previous testing was done w/controller cover off. Unit was tested to determine impact with cover on. Extreme span increases to 15%.
8	1/22/88	Humidifier is rewired to 2/3 capacity. Humidifier operates continuously at 40°F outside temperature. Shelter RH rose to as high as 62%.

TABLE 1. HCS Performance Test Summary (Con't)

Test Run No.	Date	Significant Events
9	1/26/88	Testing is done to evaluate impact of 1) Bypassing humidifier blower thermal switch, 2) Removal of controller cover, 3) Location of psychrometer and 4) Ability of Johnson controller to actuate alarm lamps. At test initiation, humidifier blower is wired directly to power contactor - extreme span is 19%. Controller cover is removed - extreme span is 17%. Psychrometer is placed closer to controller - extreme span is 12%. Controller differential is increased to evaluate alarm lamp actuation performance. Relay switching for alarm lighting is fairly consistent. Unit appears suitable for alarm lamp control.
10	2/20/88	Various settings for controller differential and humidifier capacity were tested. Final controller adjustments with the setpoint at 42% and differential at 6%, maintain shelter RH between 37 and 51%. Humidifier was at full capacity. Outside temperature was 55°F.
11	2/23/88	Confidence test done to demonstrate RH control for multiple days. No adjustments were made to controller settings of 42% - setpoint and 6% - differential of test run #10. Shelter RH was maintained between an extreme span of 38 to 52%. Outside temperature was 63°F.
12	2/24/88	Confidence test done to demonstrate RH control for multiple days. No adjustments were made to controller settings of 42% - setpoint and 6% - differential of test run #10. Shelter RH was maintained between an extreme span of 37 to 49%. Outside temperature was 36°F.

to 52% (allowable range is 35% to 55%) without the equipment competing. Shelter RH was maintained within a 40% to 50% range approximately 90% of the time. Use of an identical Johnson Controls unit for alarm light operation should be adequate based on test data provided on test run No. 9. See Appendix D for HCS performance data sheets.

All testing with the electronic unit was accomplished during the humidification season. It is anticipated that in the dehumidification season, a slight adjustment of the controller's setpoint will be necessary.

Other system changes resulting from this test series are as follows:

- Continuous use of heat pump evaporator fan during HCS operation to provide better mixing of shelter air and thus improve system response.

- Replacement of electronic controller cover with a guard to allow better air circulation to sensor and thus improve system response.

- Elimination of humidifier blower thermostat to begin steam dissipation to shelter sooner and thus improve system response.

- Rewiring of humidifier heaters with the addition of a toggle switch to allow unit to operate a full or 2/3 capacity. This modification will provide greater system flexibility during moderate environmental conditions and thus better system control.

- Addition of relay in humidifier control circuitry to eliminate feedback and humidity controller relay chatter when the aquastat switch is "ON" during humidifier preheat.

It should be noted that a significant temperature gradient existed within the test shelter. The heat pump end tended to be cooler due to the poor thermal insulating value of the cardboard used to seal around the heat pump. The humidifier end tended to be warmer due to poor duct distribution of heat pump discharge air. Most of the air would discharge at the far end of the duct while relatively little air would discharge out openings along the duct sides. It is believed RH varied significantly along the test shelter length, though RH was measured in only one location. The actual calibration shelters will be better insulated and have better air distribution which should provide for more uniform RH.

6.3 Mineral Accumulation

6.3.1 Reason for Test. This test was performed to serve as an indication of how frequently the humidifier must be serviced. The test was also performed to ascertain where the worst mineral accumulations will occur.

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

- Water reservoir, 10 gallon plastic tank.
- Wire jumper.
- Wrist watch, Seiko.
- City water (mineral content believed to be moderate in Alexandria, VA)

6.3.3 Test Procedure. The humidifier was placed in an indoor ambient environment. The humidifier water inlet was connected to a water reservoir in such a way as to allow gravity feed of supply water. Terminals eight and nine of the humidifier terminal board were jumpered to allow for continuous operation. The water reservoir was partially filled once or twice a day for 11 days. The humidifier was started in the morning and operated continuously until the unit shut itself off on extreme low water. Approximately 10 gallons of water passed through the humidifier each day. The unit operated approximately 130 hours during this test.

6.3.4 Test Results and Analyses. The humidifier water handling equipment was disassembled to determine mineral accumulation. A small amount of a reddish brown substance had accumulated in the bottom of the vaporization chamber. The substance is believed to be rust particles introduced from the water supply piping. A significant mineral build-up occurred on the outside of the steam distribution tube around the nozzles. Moisture carryover with the generated steam tends to condense around the nozzles and deposit minerals. The humidifier manufacturer stated that this build-up is minimal with similar units. These mineral deposits will necessitate periodic maintenance for the steam distribution tube.

The build-up on the Air Force units is exacerbated because of deletion of the flush cycle and skimming features which are usually included in these type humidifiers. This allows concentration of minerals in the chamber, increasing mineral carryover. Also, the short distance between the boiling water and the distribution nozzles augments moisture carryover. The distance between the boiling water and distribution nozzles is necessitated by the specified overall dimensions for the humidifier. A maintenance schedule for the steam distribution tube should be included in the maintenance instructions. A photographic record of humidifier condition following testing is provided in Figures 2, 3 and 4. Mineral accumulation test data sheets are provided in Appendix E.

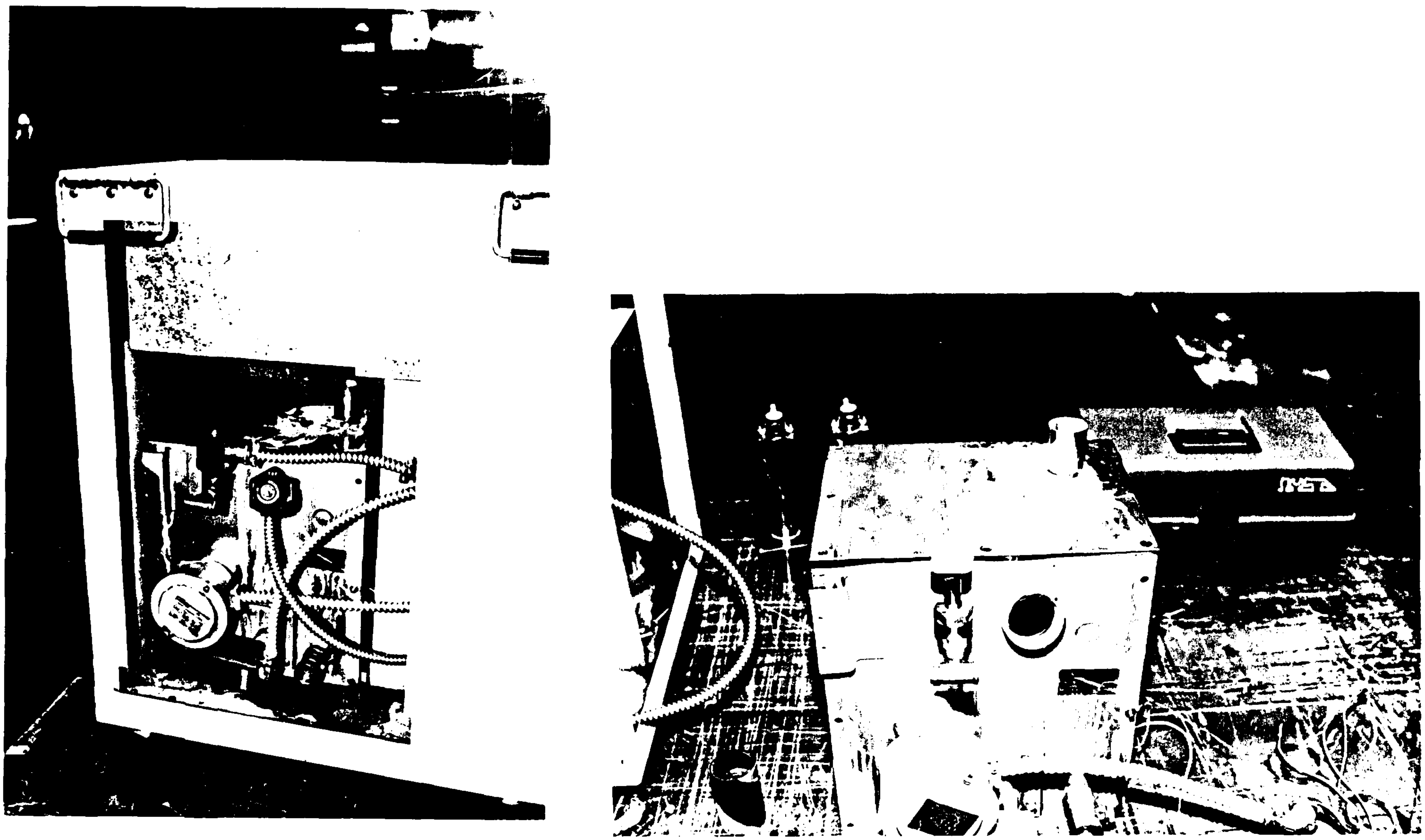


Figure 2. Vaporization Chamber - External

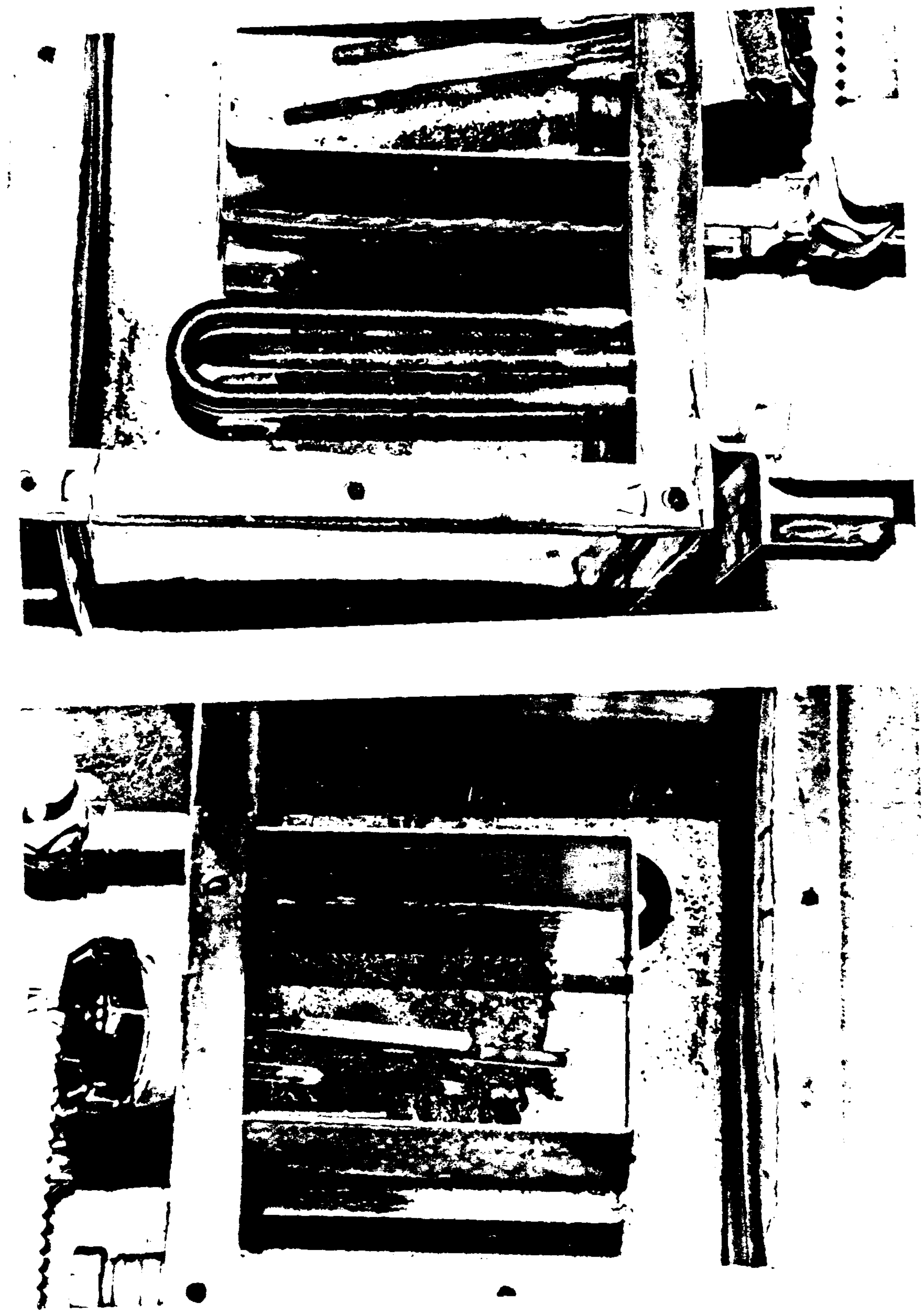


Figure 3. Vaporization Chamber - Internal

Left Tube	Right Tube
~127 hrs operation	~13 hrs operation

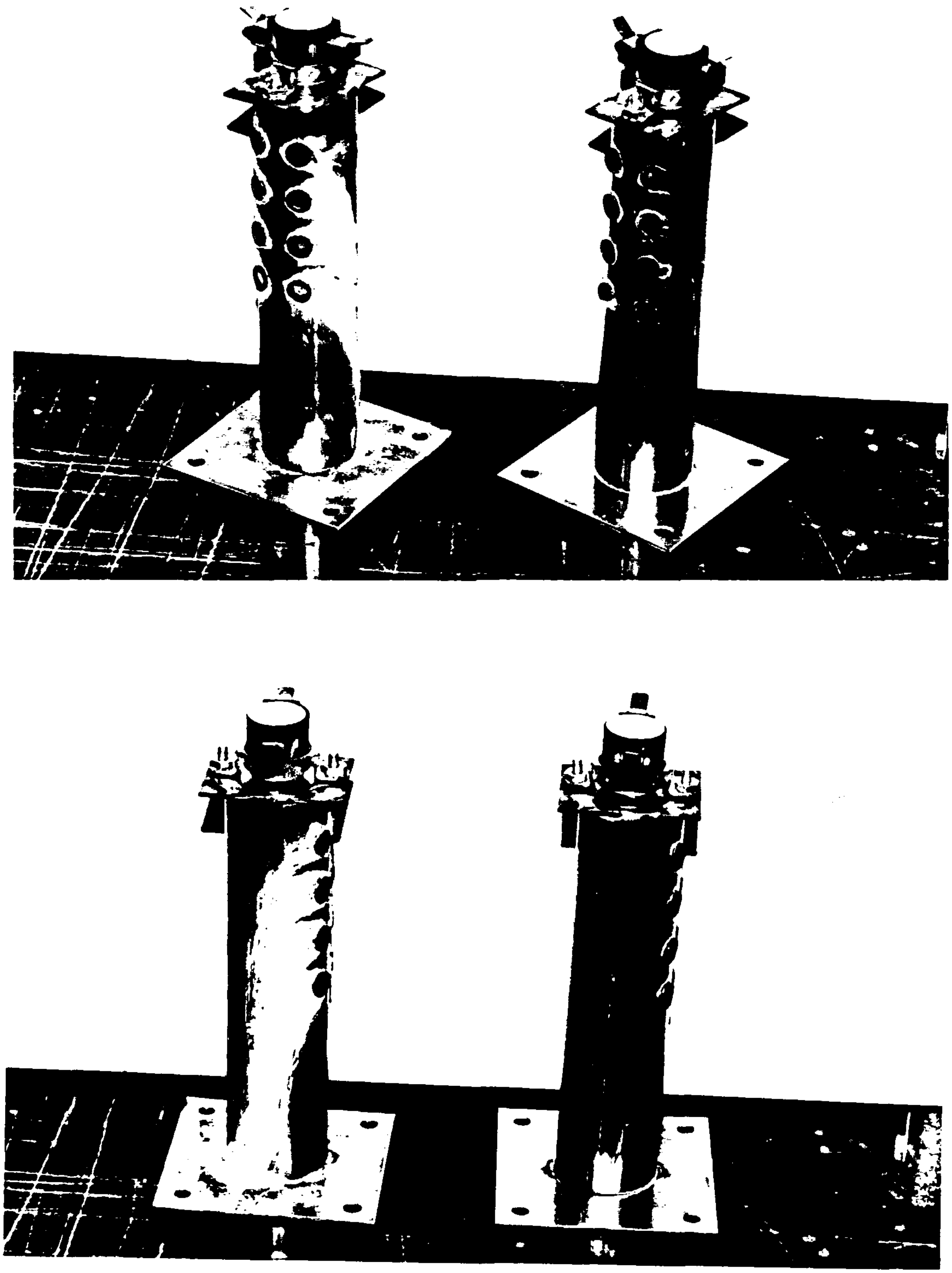
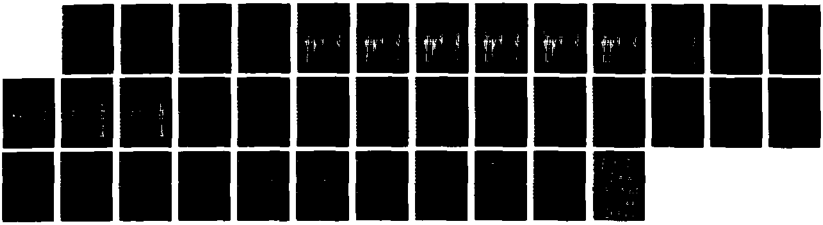
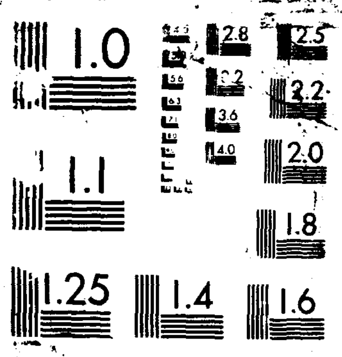


Figure 4. Steam Distribution Tube

AD-A198 879 HUMIDITY CONTROL IN THE US AIR FORCE AIRCRAFT SERVICE 2/2
SHELTER(U) VSE CORP ALEXANDRIA VA ARMY SYSTEMS DIV
M S BAKER ET AL. 30 JUN 88 VSE/ASD/0080-88/20RD
UNCLASSIFIED DAAK70-86-D-0023 F/G 13/1 NL




1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

APPENDIX A

APPROVED TEST PLAN

APPENDIX F

HCS STRUCTURAL ANALYSIS

Humidifier Structural Analysis

The humidifier was modeled as an integral sheet metal structure. It was subjected to inertial loads representing the distributed mass of its own structure and the masses of the fan, steam chamber and electrical panel at their respective mounting points.

The resulting six directional load distributions are presented in Figures 1 through 6. These are respectively:

- o Loading Case 1 - 4.5 G's downward (-y)
- o Loading Case 2 - 2 G's upward (+y)
- o Loading Case 3 - 3 G's longitudinal (-x)
- o Loading Case 4 - 3 G's longitudinal (+x)
- o Loading Case 5 - 3 G's lateral (-z)
- o Loading Case 6 - 3 G's lateral (+z)

The lateral and longitudinal axes of the humidifier were subjected to 3 G's because these directions can be arbitrary with respect to the inertial load.

Figures 7 thru 12, respectively represent the deflection outlines and the Von Mises stress profiles of the humidifier when subjected to loading cases 1 thru 6.

The maximum Von Mises stress for any loading case is below 20% of yield.

Humidifier Floor Mount

The total weight of the humidifier, full of water, is 137 lbs. Its center of gravity is 14 inches above its base mount. Its mounting brackets are 17 inches apart. The mounting pins on either bracket are on 13 inch centers.

Shear load on pins due to 2 G upward load:

$$F = (2)\ (137)$$

$$F = 274 \text{ LB}$$

Shear load on each of four pins:

$$F1 = F/4 = 68.5 \text{ LB}$$

Shear stress at stress area of pin threads:

$$A = .077 \text{ in}^2$$

$$\tau = F1/A$$

$$\tau = 68.5/.077$$

$$\tau = 8896.6 \text{ PSI}$$

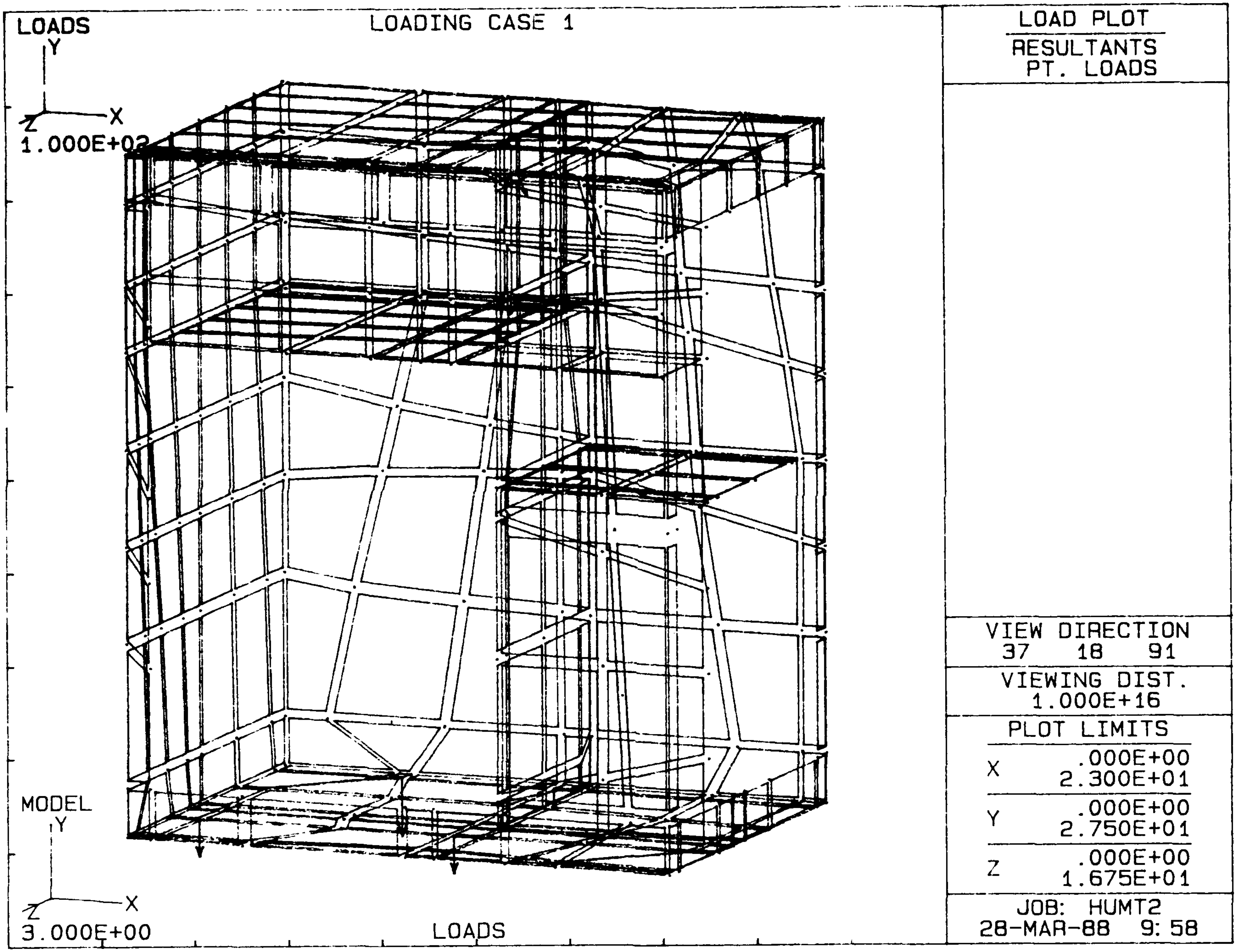


Figure 1. Loading Case 1

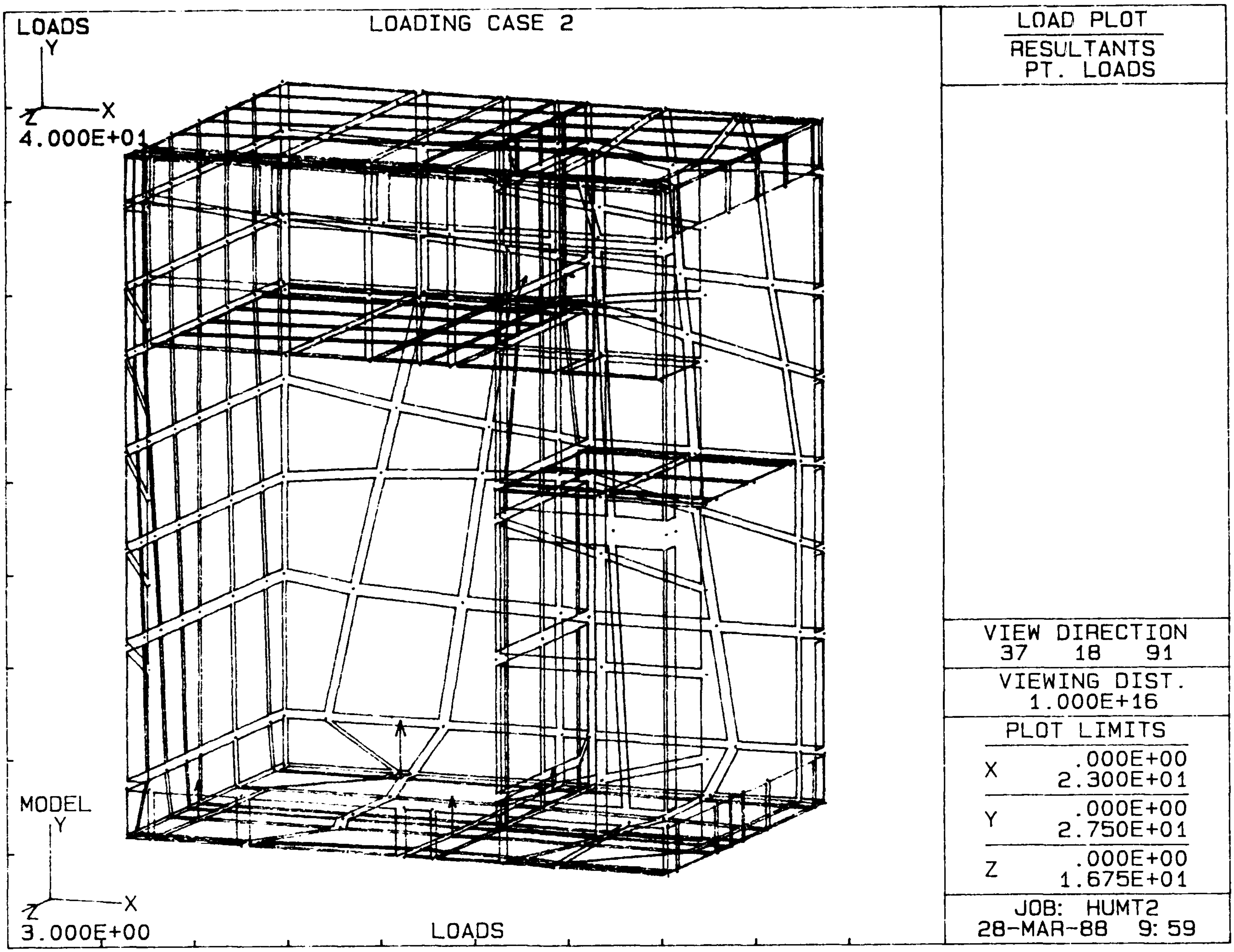


Figure 2. Loading Case 2

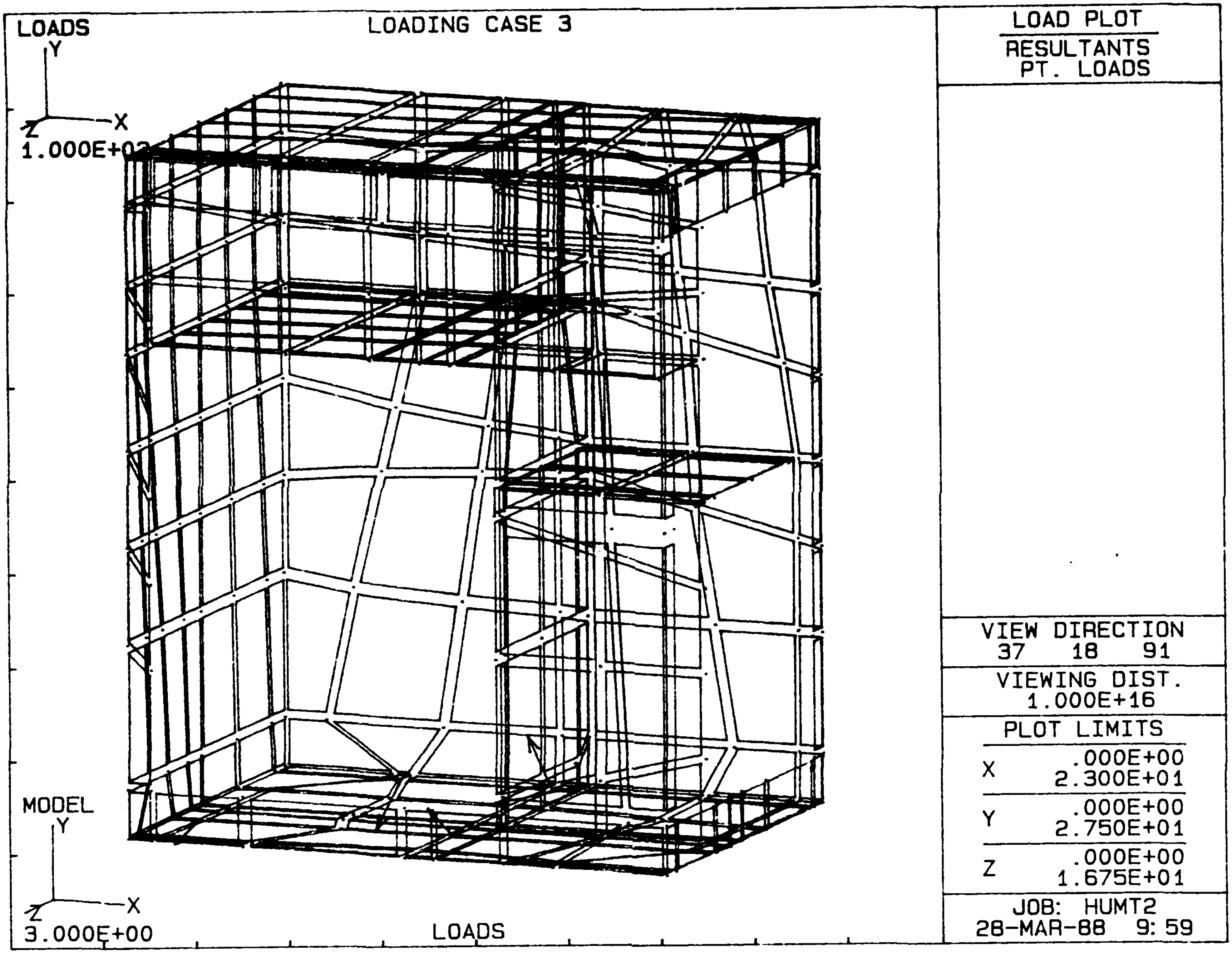


Figure 3. Loading Case 3

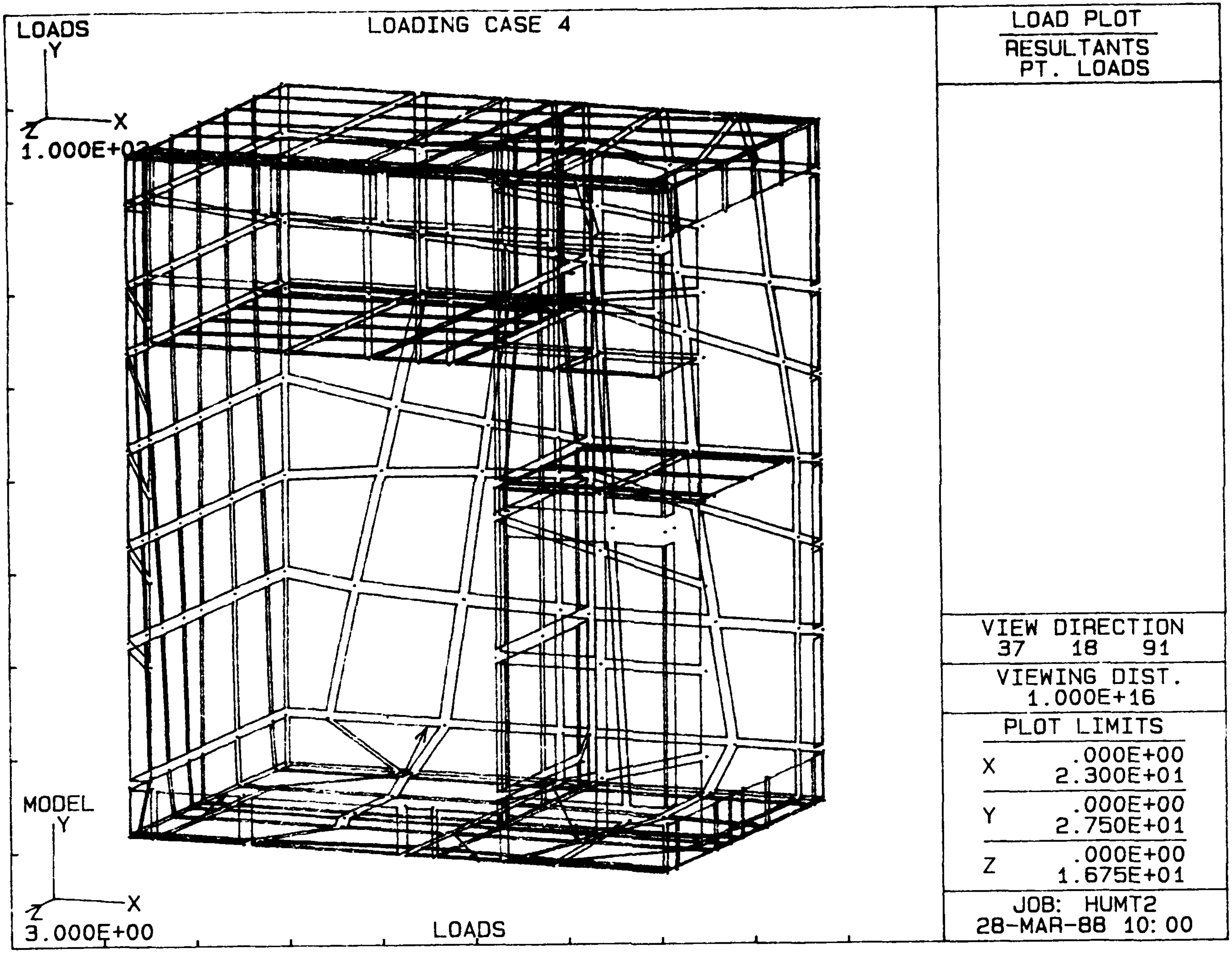


Figure 4. Loading Case 4

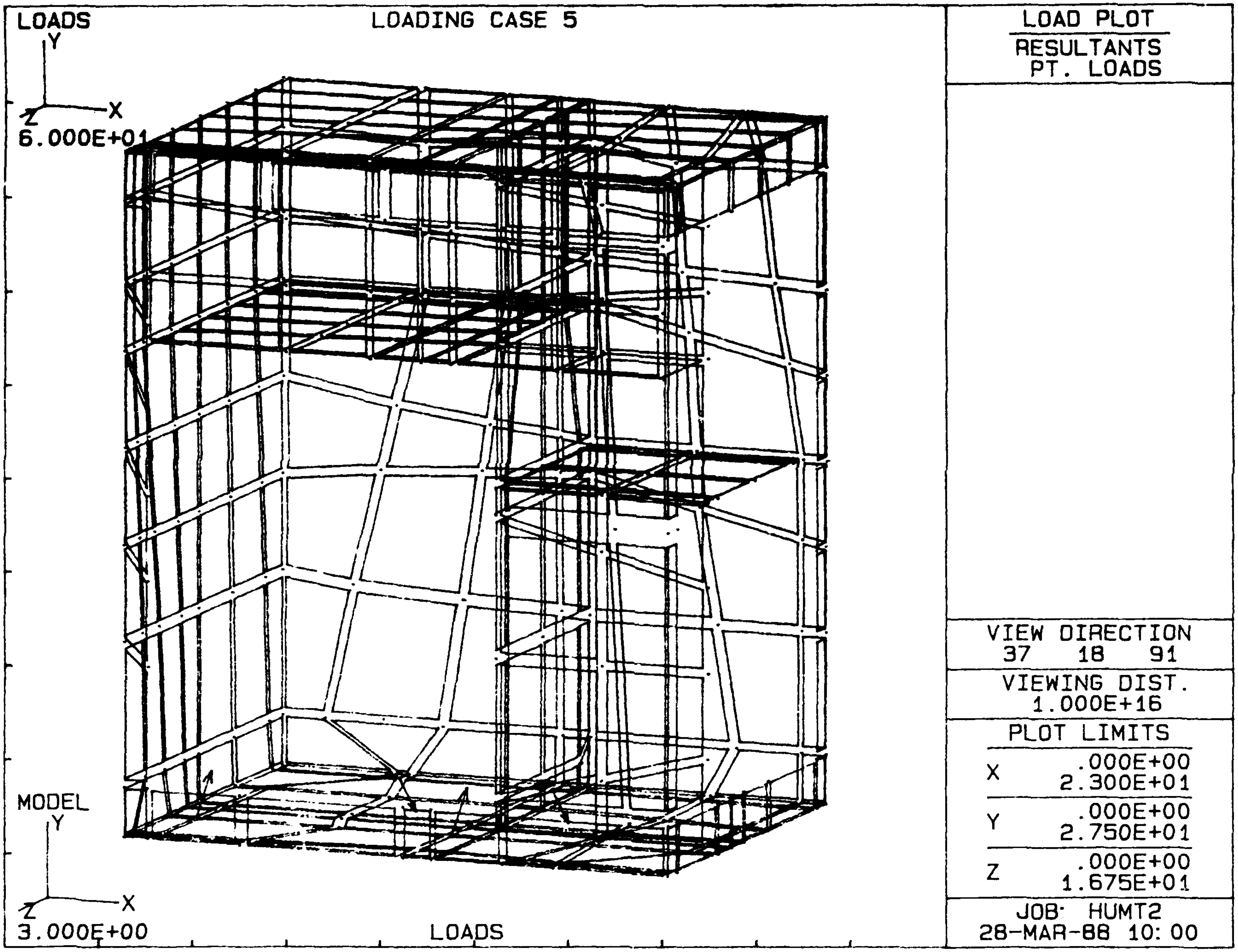


Figure 5. Loading Case 5

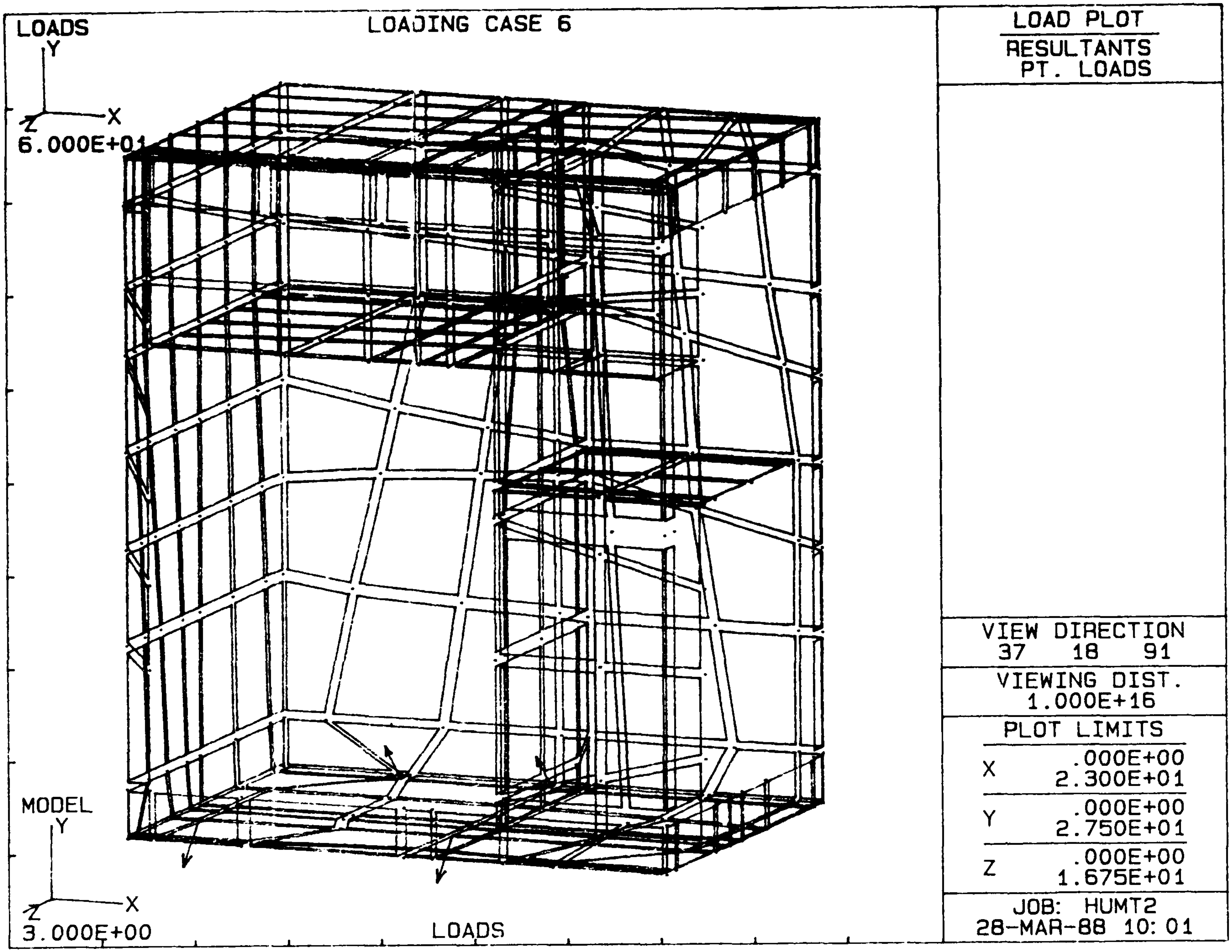


Figure 6. Loading Case 6

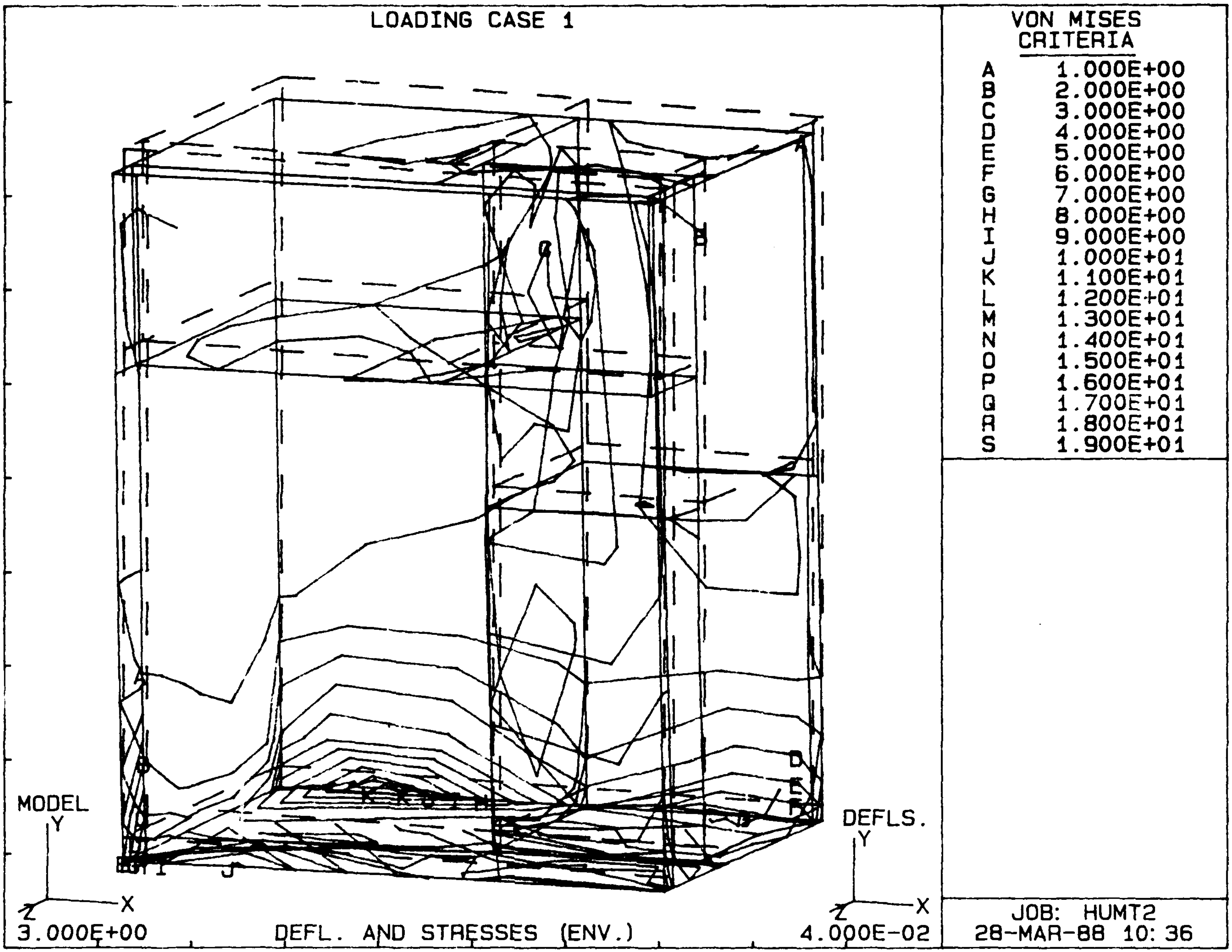


Figure 7. Loading Case 1

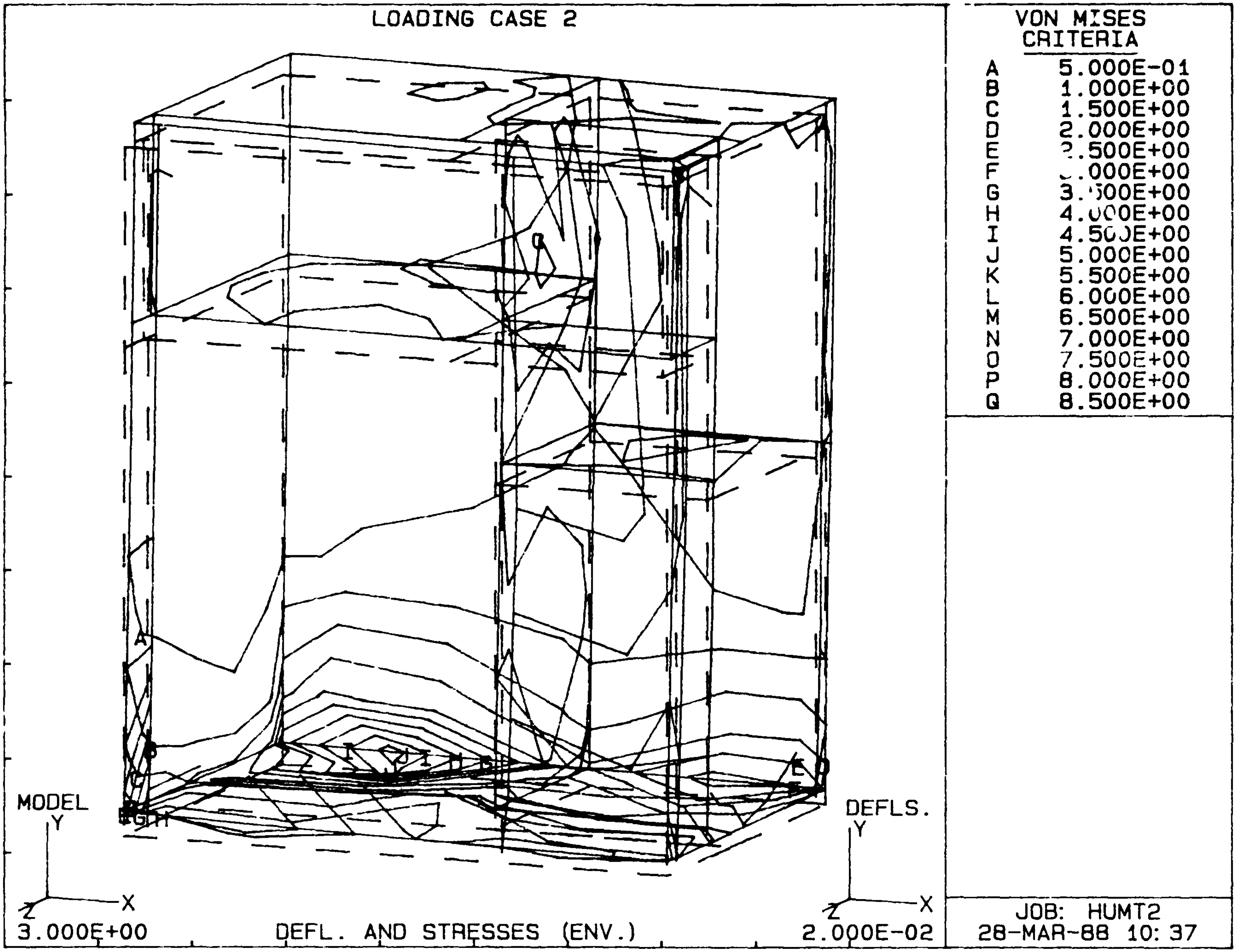


Figure 8. Loading Case 2

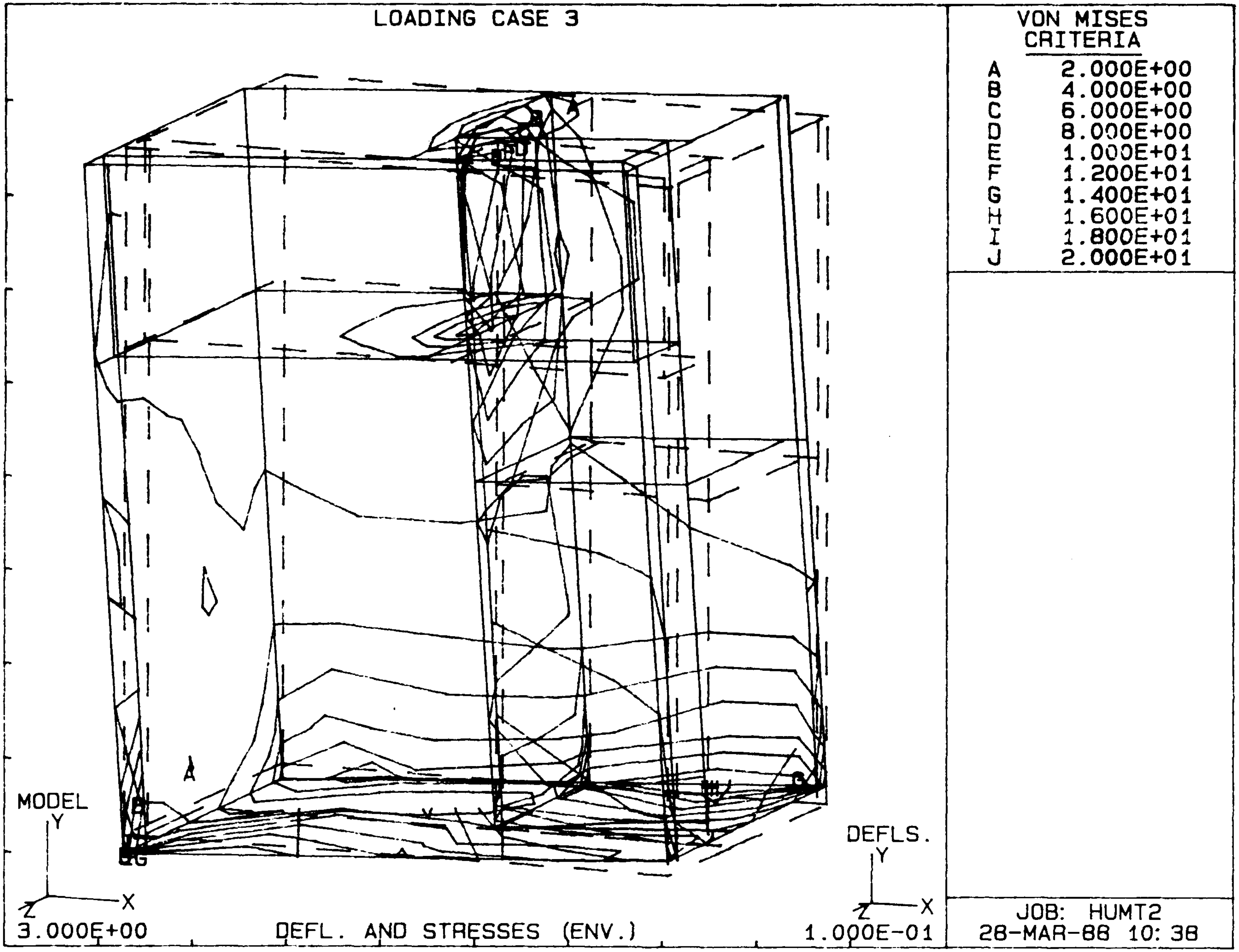


Figure 9. Loading Case 3

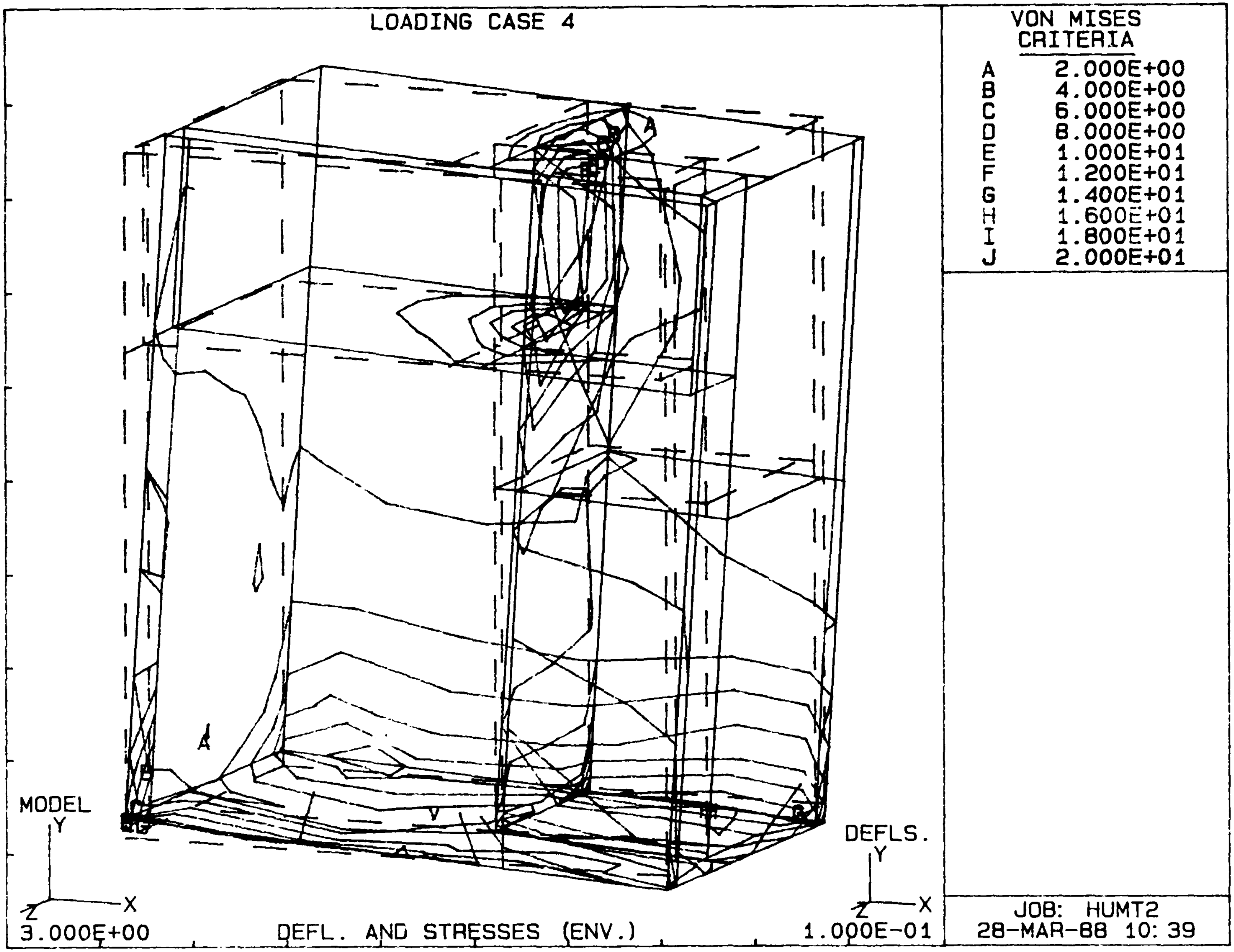


Figure 10. Loading Case 4

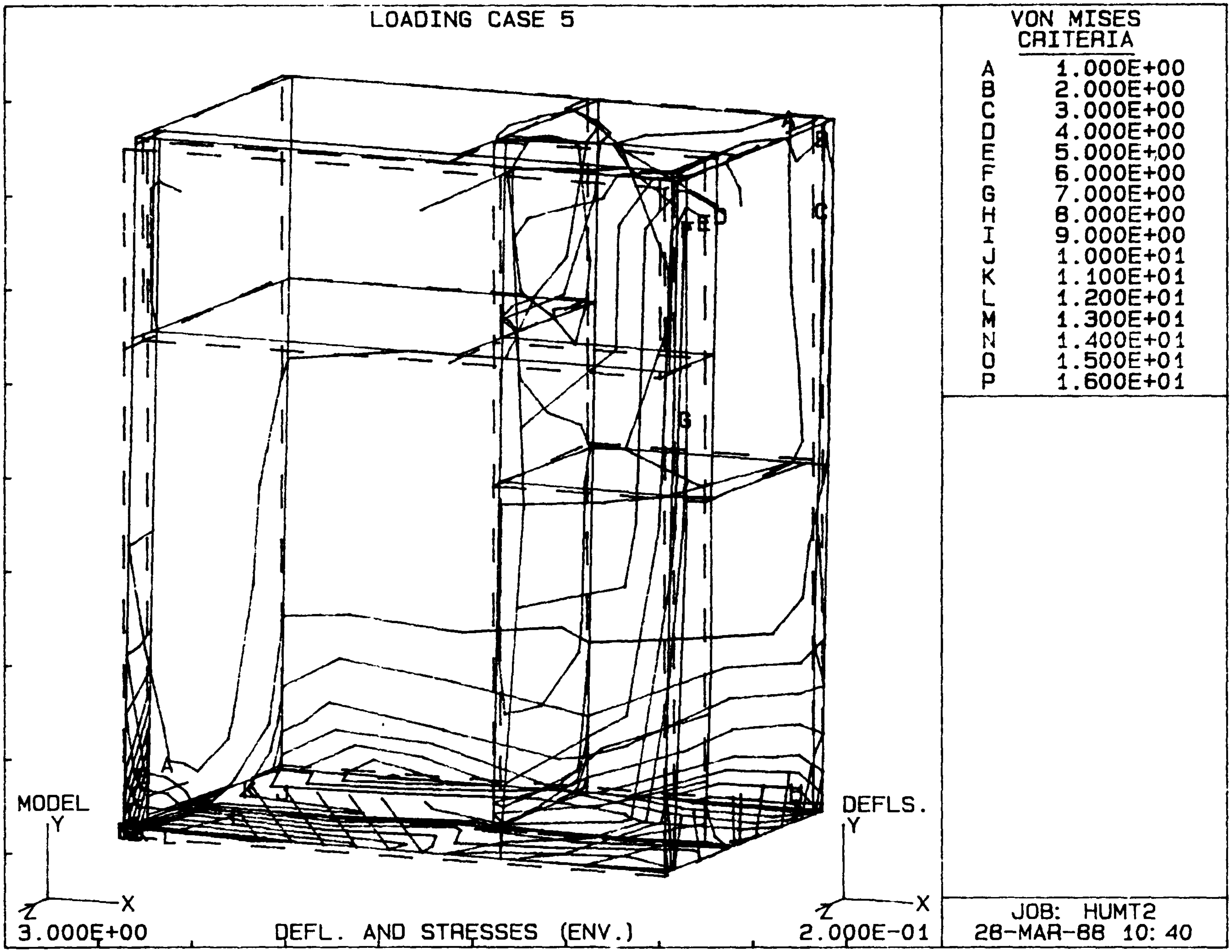


Figure 11. Loading Case 5

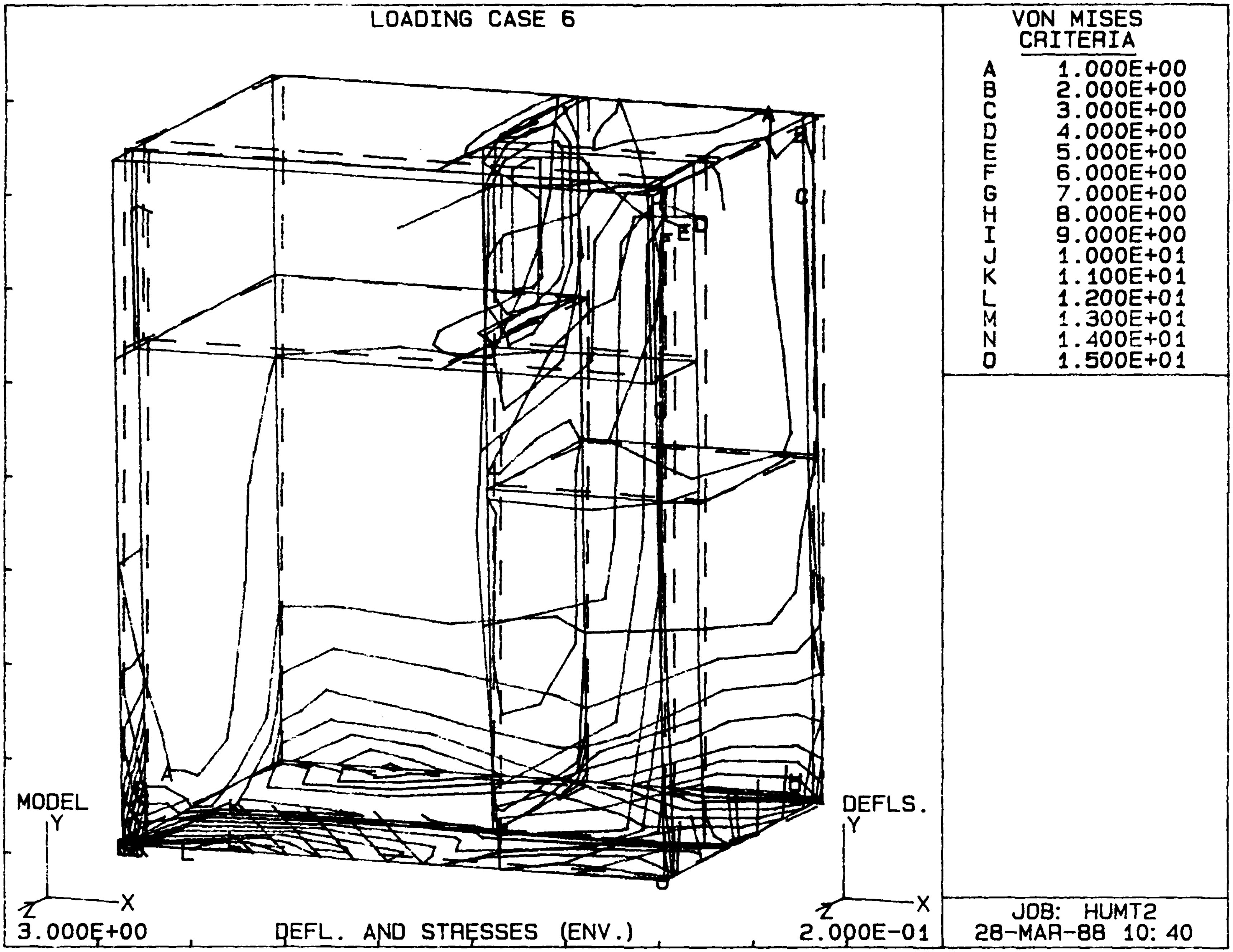


Figure 12. Loading Case 6

Shear load on pins due to 3 G lateral load:

Moment - $M = (3)(14)(137)$

$M = 5754$ IN LB

Per Pin $F1 = \frac{5754}{(2)(13)} = 221.3$ LB

The Shear Stress:

$$\tau = F1 = \frac{221.3}{.077}$$

$$\tau = 2874 \text{ PSI}$$

Thus the bracket pins have adequate strength.

Five (5) 1/4 inch bolts secure each bracket. Each has a stress area of .0317 in. sq. Assuming they are torqued to resist uplift, the shear they resist is due to the 3 G longitudinal inertial load (worst case).

$$\sigma = \frac{F1\,(2)}{(5)(A)} = \frac{(221.3)(2)}{(5)(.0317)}$$

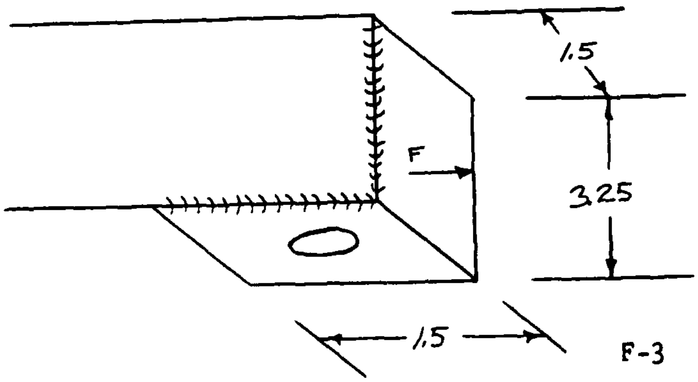
$$\sigma = 2792.4 \text{ PSI}$$

Two (2) #10 bolts secure each pin receptacle to the humidifier. Similarly:

$$\sigma = \frac{F1}{(2)(A)} = \frac{221.3}{(2)(.0174)}$$

$$\sigma = 6359.2 \text{ PSI}$$

It is intended that the pins transmit all inertial loads from the humidifier to the floor but dimensionally it is possible to load the ends of the brackets before loading the pins, therefore the welded corners of the bracket are designed to withstand the 3 G longitudinal inertial load.



To determine the weld stress, the moment of inertia of the weld will first be determined

The weld is a 1/8 inch filet. The weld centroid:

$$x = \frac{\sum_{i=1}^{N} A_i X_i}{\sum_{i=1}^{N} A_i}$$

$$x = \frac{(.707)(.125)(3.25)(.062)(.667) + (.707)(.125)(1.5)(.75)}{(.707)(.125)(3.25) + (.707)(.125)(1.5)}$$

$$x = .265 \text{ in}$$

The weld moments of inertia is then:

$$I = [(.707)(.125)]^{1/3}\ 1/12\ (3.25)+(.707)(.125)(3.25)(.265^2-[(.062)(.667)]^2)$$

$$+ 1/12\ (1.5)^3\ (.707)(.125) + (.707)(.125)(1.5)(.75^2-.265^2)$$

$$I = .10998 \text{ in}^4$$

The weld bending stress:

$$\sigma = \frac{MC}{I} = \frac{(442.6)(1.5)(.75-.265)}{.10998}$$

$$\sigma = 2927.7 \text{ PSI}$$

Water Tank Bracket, Strap and Floor Mount

The bracket weldment is a structurally sound unit. The strength of its strap and floor mount will be addressed here:

Floor Mount:

The distance from the center of gravity to the pins is as follows:

Bracket - 5.25"
Water Tank = 16.25"
Water - 16.25"

The Weights:

Bracket - 22 LB
Water Tank - 20 LB
Water - 63 LB

The overturning moment at 3 G's:

$$M = W_{BR}\, d_{BR} + W_{WT} + d_{WT} + W_W + d_W$$

$M = 3[(22)(5.25) + (20)(16.25) + (63)(16.25)$

$M = 4392.75$ IN LB

Worst case pin reaction due to the moment: (3.5 inch couple distance)

$R1 = \frac{4392.75}{(2)(3.5)} = 627.5$ LB

The stress area is .077 in^2

The shear stress in then:

$\tau = 8149.3$ PSI

Worst case pin reaction due to the longitudinal inertial load:

$R2 = 3/2\ (63 + 20 + 22)$

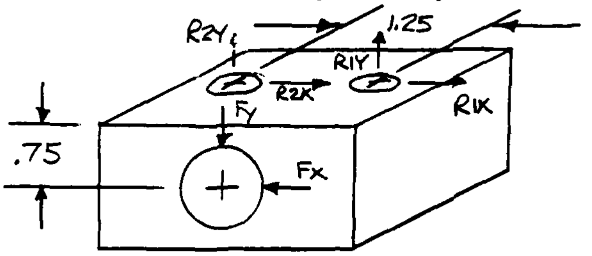
$R2 = 157.5$ LB

$\tau_2 = 2045.5$ PSI

Total Shear:

$\tau = (\tau_1^2 + \tau_2^2)^{1/2} = 8402.1$ PSI

Evaluating the pin receptacle block mounting.



Pin Load
Fx = 157.5 LB
Fy = 627.5 LB

$\Sigma Fx = 0$ R1x = R2x = 78.75 LB

$\Sigma Fy = 0$ R2y + R1y = Fy = 627.5 LB

$\Sigma M2 = 0$ R1y (1.25) = (Fx)(.75) + Fy (.625)

R1y = 408.25 LB

$\therefore$ R2y = 219.25 LB

The stress area of A 1/4" bolt - .0317 in^2

$\therefore$ The stress due to R1y

$\sigma = \frac{408.25}{.0317}$

$\sigma = 12878$ PSI (Low stress level for a machine screw)

The load on the water tank strap:

The worst case load would be due to the tank tipping out of its bracket due to a longitudinal load:

The moment due to 3 g's: (12 inch moment arm)

$$M = 3\,(W_W + W_{WT})(12)$$

$$M = (3)(83)(12)$$

$$M = 2988 \text{ IN LB}$$

The moment arm of the strap reaction is 24 inches:

$$R = \frac{M}{24} = 124.5 \text{ LB}$$

The strap has a 250 LB working load unit.

The Water Tank Floor mount is similar to the Humidifier floor mount. The humidifier weighs 137 LB while the water tank assembly weighs 105 LB thus its floor mount experience lower stress levels than the humidifier.

APPENDIX G

SIGNIFICANT TELEPHONE CONVERSATIONS

TELECON

JOB NO.: 0500.0080 TITLE: Humidity Control

DATE: 3/17/88 TIME: 2:00

CALLER: Mark Baker

CALLED: PERSON: Lt. Mark Reynolds

COMPANY: Tactical Shelter Systems Office

ADDRESS: Hanscom AFB

PHONE: 1 (617) 377-6429

SUBJECT: Disposition of HCS

PRECIS OF CALL: Lt. Reynolds confirmed Greg Wesley's earlier statement that the AF does not want the HCS installed in calibration shelters at Shaw AFB. Reynolds says that the origination of the HCS requirements provided Ft. Belvoir and VSE is unknown. The requirements provided are not suitable for the calibration shelters. Reynolds mentioned specifics below:

- RH need only be controlled between 20-70%
- the size of the equipment is too large
- The AF does not want to modify the heat pump
- Automatic control of the system is not required
- Estimated cost of system is way too expensive

Reynolds reiterated that VSE complete all work as planned with the exception of HCS installation at Shaw. The Lt. suggests that the HCS may be used in some other system.

DISTRIBUTION:

TELECON

JOB NO.: 0500.0080 TITLE: Humidity Control

DATE: 4/6/88 TIME: 1:30

CALLER: Mark Baker

CALLED: PERSON: Don Bannan

COMPANY: Medley Tool & Model Co.

ADDRESS:

PHONE:

SUBJECT: Miscellaneous questions on A.F. calibration shelters

PRECIS OF CALL: Originally planned to cut new opening in ECU front panel to feed thru additional wires to ECU controls. Don recommends against this due to sandwich of two 1/8" Al. plates and insulation in between which one would have to cut thru. He recommends installing additional connector on existing connector plate with ECU heating and cooling connectors.

Asked Don about existing layers (materials) which make up the floor. Don stated dwg he sent to me earlier was in error. Floor is ~~--~~ comprised of 1/8" Al plate with .105" linoleum layer overtop.

Asked Don about location of tile frame with respect to door edge in end wall. Don stated distance from door edge to edge of tile frame is 2.75". Don state he would send drawings of tile frame, ~~and~~ connector plate and front panel.

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TELECON

JOB NO.: 0500.0080 TITLE: Humidity Control System

DATE: 3/31/88 TIME: 2:30

CALLER: Mark Baker

CALLED: PERSON: Gordon Tolson

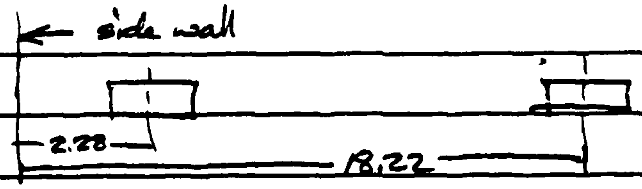
COMPANY: Gichner

ADDRESS: Dallastown PA

PHONE:

SUBJECT: Al Tube Locations in End Wall of Gichner 8'x8'x20' ISO shelters

PRECIS OF CALL: Queried Gordon as where the structural members are in the end wall of the ISO shelter, in vicinity of control panel mounting. Gordon stated that a 90.75" wide plate was part of the end wall. From the edge of this plate, the distances to the centerline of the Al tubes in the corner and at the door frame are 2.75" and 18.69" respectively. From the inside surface of side wall to centerlines of tubes are 2.28" and 18.22" respectively. 90.75" plate is wider than side wall to side wall distance.



DISTRIBUTION:

TELECON

JOB NO.: 0500.0080 TITLE: HCS

DATE: 1/27/88 TIME: 2:00

CALLER: Don Bannan, Medley Tool & Model Co.

CALLED: PERSON: Mark Baker

COMPANY: VSE

ADDRESS:

PHONE:

SUBJECT: Main Circuit Breaker in Elec. & Mech Calibration Shelters, Access to Raceway.

PRECIS OF CALL: Don identified 100 Main CB as a Square "D" P/N QIB3100. He believes it has exposed bolt-on screws on which VSE can tap onto with eyelet terminal lugs. He believes screws are No. 10. Don will send Drawings MFCDBMFEL 005 sheets 1-10 for further information. ME Don believes the work surface about the vacuum outlet may have to be removed to access raceway. Don offered to go to Shaw AFB with VSE to during equipment installation.

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TELECON

JOB NO.: 0500.0080 TITLE: Humidity Control

DATE: 12/1/87 TIME: 2:00

CALLER: M. Baker

CALLED: PERSON: Phil Rothsching

COMPANY: Medley Tool & Model

ADDRESS:

PHONE:

SUBJECT: Electrical Tie-ins of HCS into Existing Maintenance Shelter Wiring System

PRECIS OF CALL: HCS must be tied into existing load center (LC) downstream of Main Breaker. Phil stated that the AC CB receptacles in the LC were all full. He suggested that the HCS be piggy backed onto the ECU cooling CB. He has measured currents for fielded ECUs in cooling mode and they were between 15-18 amps. The existing ECU cooling CB is rated for 30 amps. The HCS draws 9-10 amps. We discussed alternatives such as tapping holes in the LC bus bars or connecting to downstream terminals of Main Breaker; in both cases a separate CB would be provided remote of the LC. Phil stated extra terminals were available on the neutral and ground buses in LC for 12 AWG wire. Phil will research the make and model of

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believes its Square D NQOB series

LC used and let me know.

Discussed how VSE could tie into the heat pump JB. I suggested following the route of the HP power cables, from the raceway, thru the power monitoring box, thru the open and into HP face plate. This involves knocking out holes in 1/8" P. monitor Box and in 1/8" or 3/16" HP face plate, and provide new MS connector, cable bulkhead fitting and small mounting plate (for MS connector). Phil stated this should be acceptable.

Discussed routing two additional wires from thermostat to HP JB. Phil stated there ~~too~~ should be no problem snaking two additional wires thru the grommet in the HP face plate. Phil stated Medley Tool has a drwg showing thermostat installation and wiring which he will send me. ~~Phil stated the~~

Phil also stated that NAVAIR drwg 1339AS 364 or 365 is a very complete drwg of LC details, if somehow I can get a copy of it.

TELECON

JOB NO.: 0500.0080 TITLE: Humidity Control

DATE: 12/9/87 TIME: 1:30

CALLER: Lt. Richard Simpson Hanscom AFB

CALLED: PERSON: Mark Baker

COMPANY:

ADDRESS:

PHONE:

SUBJECT: Action items for AF Resulting from 12/9/87 IPR at VSE corp.

PRECIS OF CALL: Richard stated that the Heat-Pump in the calibration shelters were most often run with the thermostat in the "AUTO" position with heating required @ 72°F and below, cooling required @ 76°F and above. This negates an earlier Telecon today where Richard stated the H-P thermostat was operated in "cool" position with cooling required @ 72°F and above, operated in "Heat" position with heating required @ 76°F and below.

Richard conveyed the Equipment Restraint criteria for aircraft transport per MIL-A-8421F. Richard stated that the humidity control system should be designed to withstand the following forces: Fore - 3g; Aft 1-½g; Lateral 1-½g; Up 2g.

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Richard stated that no downward force need be considered.

I asked about commercial equipment already existing in the shelters and how they are mounted. He stated most everything is strapped to equipment racks. Most commercial equipment is electronic in nature.

TELECON

JOB NO.: 05000080 TITLE: Humidity Control

DATE: 11/13 TIME: 3:30

CALLER: Don Bannan Medley Tool

CALLED: PERSON: Mark Baker

COMPANY:

ADDRESS:

PHONE:

SUBJECT: Miscellaneous Information on AF Shelters

PRECIS OF CALL: Don returned my call of 11/6 with the following information:

- Vacuum pump fitting in leg well is 4 1/2" from back wall in both mech. & elec. shelters.
- V.P. fitting measures 20" from the Stanley Bidmor cabinet in mech. shelter.
- The raceway used in the shelters is by Wire-Mold, plug mold G-4000, pg 99 of catalog.
- Raceway beneath work surface measures 1 3/4" in depth and 4 3/4" in width.
- Sound tile mounted on walls is 3/4" thick and can be removed with an exacto knife. Remaining glue should be scraped off w/ a paint scraper. Equipment mounted in

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tiles should be caulked around.
- The cabinet to cabinet opening (legwell) actually measures 37" in both shelters.

TELECON

JOB NO.: 0500.0080 TITLE: Humidity Control System

DATE: 11/6/97 TIME: 2:30

CALLER: M. Baker

CALLED: PERSON: Don Bannan

COMPANY: Medley Tool & Model Co.

ADDRESS:

PHONE: (215) 324-1150

SUBJECT: Miscellaneous Information on Installation of HCS in Elec. & Mech. calibration Shelters.

PRECIS OF CALL: Don promised to get locating dimensions on vacuum pump fitting in both shelters and double check leg well dimensions. He would also find out the type and size of raceway used in shelters. Don stated raceway was "snap-type".

Discussed floor mounting of equipment. Don feels we should have no problems with mounting water tank and humidifier (130 lb) to floor using steel 5/16" rivnuts into the 1/8" Al floor sheet.

Don informed me there is no room in the shelter's load center for an additional CB. He suggested piggy backing off the existing heat pump cooling CB, as long as the heat pump and humidifier are not used simultaneously. No problem w/ mounting on/off switch in raceway just above worksurface. Switch plate should cover entire

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width of raceway when installed. Don reiterated his concert w/ running the heat pump (in cooling) and humidifier simultaneously. F-16 systems in Las Vegas are having great difficulty in this regard. Heat pumps are running flat-out in a low humidity environment.

Sound absorbing material on shelter walls is 3/4" thick. Equipment mounted into SA. material or raceway that is removed and replaced should be re-caulked.

Medley Tool offered to review our design drawings on the HCS and make any comments.

TELECON

JOB NO.: 0500.0080 TITLE: Humidity Control

DATE: 10/21/87 TIME: 10:30

CALLER: Mark Baker

CALLED: PERSON: Lt. Richard Simpson

COMPANY: Air Force

ADDRESS: Hanscom AFB

PHONE: (617) 377-6429

SUBJECT: Water Storage Tank Design

PRECIS OF CALL: Richard and I discussed VSE's latest ideas regarding the water storage tank. I asked how the AF invisioned refilling the water tank. I asked whether or not the AF needed the flexibility of the tank being mounted on wheels such that the tank could be rolled over to a water source, filled, and never be lifted off the floor. Richard stated that this option is not necessary since operator's will be bringing refill water to the tank via 5 gallon containers. I explaned our latest design idea which would have the tank wheel mounted and rotating around a hinge type connection out from under the work surface. The ability to rotate will enable access to level switches and water pump mounted

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on the backside of tank, and allow access to tank top for refilling. Richard ~~ex~~ expressed a desire to keep the design simple but said if VSE feels a pivoting tank is necessary for access than the pivoting idea is OK with him.

I explained we will probably have a metal basket in which a plastic tank will sit. The metal basket will be provided for mounting handles. The basket and plastic tank assembly will in turn sit in pivoting mounting bracket. Richard felt this design was fine.

I explained that the water line and power cord to the humidifier would be detachable. The connections would be made beneath the storage tank with the water line and power cord being stored on brackets mounted on the side of the humidifier. This idea was ok with Richard.

The Lt. asked that a sketch of the water tank design be faxed to him as soon as possible.

TELECON

JOB NO.: 0080 TITLE: Humidity Control

DATE: ~~8~~ 7/1 TIME: ~10:00

CALLER: ~~[illegible]~~ Chris Morton Dri-Steem Special Products Division

CALLED: PERSON: Mark Baker Director of ?

COMPANY:

ADDRESS:

PHONE:

SUBJECT: Dri-Steem effort for VSE on A.F. Humidity control project

PRECIS OF CALL: Chris discussed various options/features Dri-Steem could employ to achieve our specifications. Chris suggested using a variation of the vaporstream (VPC-2) model humidifier. Less modifications would be necessary to the vaporstream than the vapormist which VSE originally tested. Chris mentioned installing a miniature pump in the water supply reservoir to reduce the non steaming period between humidifier refill cycles. Also the unit can be wired to maintain heater operation between cycles. Water reservoir of vaporstream is smaller thus requiring less initial warm up time. Chris stated he would send general arrangement drawings and information on chemical treatments for water. Chris has volunteered

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to attend the meeting at Medley Tool and Model Co. in Philadelphia. Chris stated that drawings would be provided to VSE by D.S. on a proprietary basis. The cost for prototypes was reaffirmed as $4 500 for two units.

- Delivery of prototypes will be 4-6 weeks ARO. Prices for production units were provided as follows:

No. of units –	50	500	1000
cost –	$1 615	1 470	1 420

Dri Steam Humidifier Co. has been in business for 20yrs and is the 3rd largest humidifier manufacturer in the world. Co. has 40-50 employees w/ sales of 4-5 million.